R&S®DDF5GTS High-Speed Scanning Direction Finder

System Manual

4073925502

System Manual

Version 05

ROHDE&SCHWARZ

This manual describes the following models:

- R&S®DDF5GTS, *High-Speed Scanning Direction Finder*, model 02, AC power supply (4073.9203.02), consisting of
  - R&S®EHT770, DF Converter, model 02, AC power supply (4074.9007.02) or model 08, AC power supply (4074.9007.08)
  - R&S®EBD770, Processing Unit, model 02, AC power supply (4074.5001.02)
- R&S®DDF5GTS, *High-Speed Scanning Direction Finder*, model 12, DC power supply (4073.9203.12), consisting of
  - R&S®EHT770, DF Converter, model 12, DC power supply (4074.9007.12) or model 18, AC power supply (4074.9007.18)
  - R&S®EBD770, Processing Unit, model 12, DC power supply (4074.5001.12)
- R&S®DDF5GTS, *High-Speed Scanning Direction Finder*, model 25, AC power supply (4073.9203.25), consisting of
  - R&S®EHT770, DF Converter, model 05, AC power supply (4074.9007.05) or model 28, AC power supply (4074.9007.28)
  - R&S®EBD770, Processing Unit, model 05, AC power supply (4074.5001.05)

The model variant of the individual R&S®DDF5GTS is always displayed on the four-line status display on the front panel (R&S®EBD770 only).

The firmware of the R&S DDF5GTS makes use of several valuable open source software packages. For detailed information see "R&S® Monitoring Receivers and Direction Finders Open Source Acknowledgment" on the Firmware & Utilities CD.
Rohde & Schwarz would like to thank the open source community for their valuable contribution to embedded computing.

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4073.9255.02 | Version 05 | R&S®DDF5GTS

The following abbreviations are used throughout this manual: R&S®DDF5GTS is abbreviated as R&S DDF5GTS. R&S®EHT770 is abbreviated as R&S EHT770. R&S®EBD770 is abbreviated as R&S EBD770.

Contents

1 Characteristics

1.1 Components of a Direction Finder (DF) System

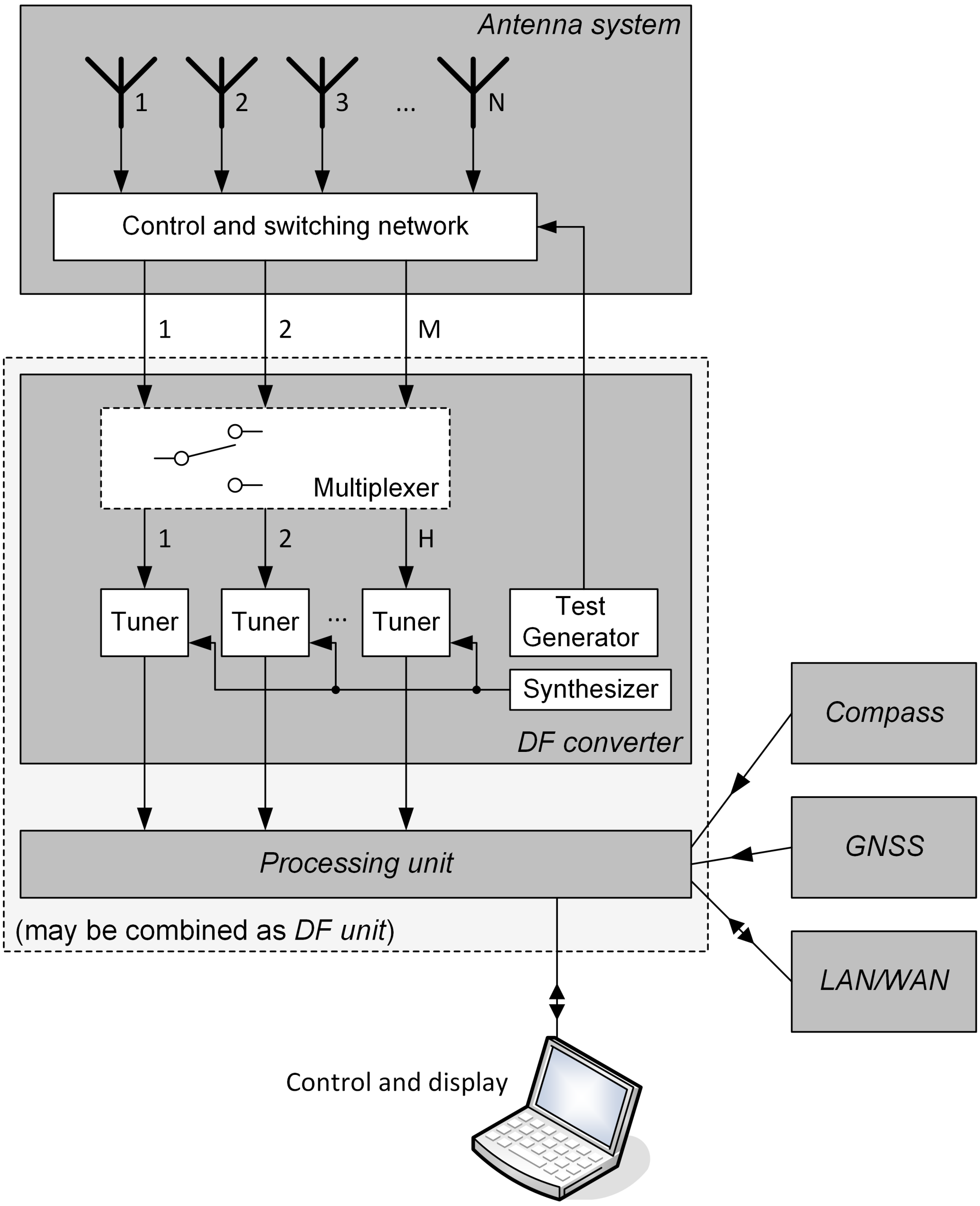


Figure 1-1: DF system components.

A direction finder (DF) system (Figure 1-1) consists of the following basic components:

- *antenna system*,

- *DF converter*,
- *processing unit*,
- *display unit*.

Depending on the configuration, systems for determining the direction finder's own coordinates/orientation (*GNSS*/*GPS*, *compass*), *remote-control* units (LAN, WAN), *antenna control* units etc., can be added.

The achievable DF speed mainly depends on the number `H` of Rx (receiving) sections, as this parameter determines the number of antenna outputs that can be measured in parallel.

If maximum DF speed is to be achieved, it must be possible to generate a bearing in a single time step, i.e. from one simultaneous set of samples (monopulse direction finding). For unambiguous direction finding over the total azimuth range, at least three antenna elements (`N = 3`) are required. If, for this minimum case, there are also three Rx sections (`H = 3`), as is with the R&S DDF5GTS, multiplexing of the measurement channels (antenna outputs) is not necessary.

Typical examples of monopulse DF antennas:

- Multimode antenna for amplitude comparison direction finders, e.g. Adcock antenna,
- Interferometer and rotating-field (phase) direction finder.

For high DF accuracy (e.g. 1°) and large frequency range (e.g. 1 MHz to 30 MHz or 20 MHz to 1000 MHz), five to nine aperture samples (antenna elements: `N = 5` to `N = 9`) are usually required. Since monopulse solutions would then be very complex, the samples are multiplexed to three antenna channels (antenna outputs: `M = 3`) within the antenna and the different three-element combinations processed sequentially in time.

Due to three-channel DF in the R&S DDF5GTS, an additional multiplexing in time of the three antenna outputs (`M = 3`) to fewer Rx channels is not necessary (`H = 3`).

The *DF converter* transposes the carrier-frequency antenna signals to a fixed IF (superheterodyne receiver, commonly from 20 MHz upwards). Alternatively, especially in use with lower frequency bands (MF/HF: 1 MHz to 30 MHz – only with HF option installed), a direct down converting is applied. Since this conversion must be performed with equal signal phase and amplitude in all Rx sections, the use of a common synthesizer is indispensable. Moreover, with most multichannel direction finders, the Rx sections are calibrated in order to ensure equal amplitude and phase. This is done with the aid of a test generator at defined intervals and prior to the actual DF operation.

The *processing unit* determines the bearing from the amplitudes and/or phases of the IF signal.

The R&S DDF5GTS consists of the two units R&S EHT770, the DF Converter, and R&S EBD770, the Processing Unit.

1.2 Use and Description

For information about use and description of the R&S DDF5GTS and a summary of the options offered refer to the product brochure, included in this CD "Documentation", see Figure 1-2.

1. On the menu "Documentation" select "Product Information"
2. On the menu "Product Information" select "DDF5GTS Product Brochure"

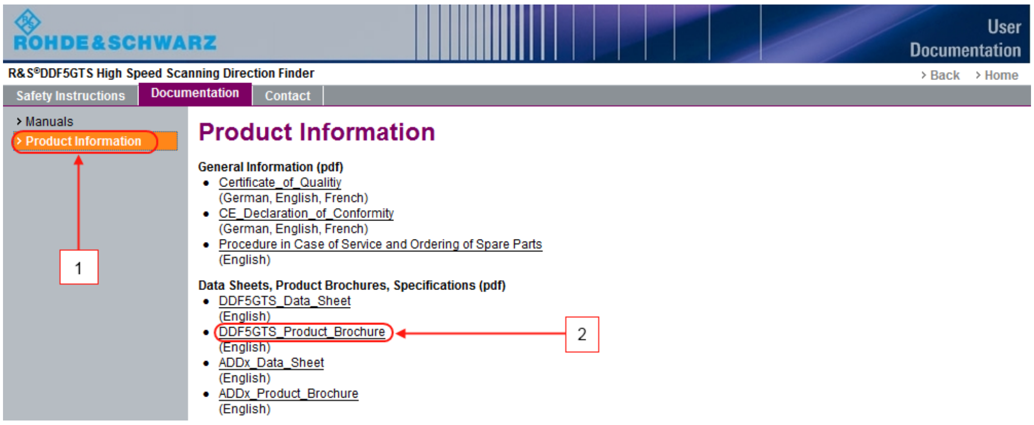


Figure 1-2: CD "Documentation": R&S DDF5GTS Product Brochure.

1.3 Application Examples

Find information about examples of application in [1.1].

1.4 Specifications

The specifications of the R&S DDF5GTS are given in the data sheet, included in this CD "Documentation", see Figure 1-3.

1. On the menu "Documentation" select "Product Information"
2. On the menu "Product Information" select "DDF5GTS Data Sheet"

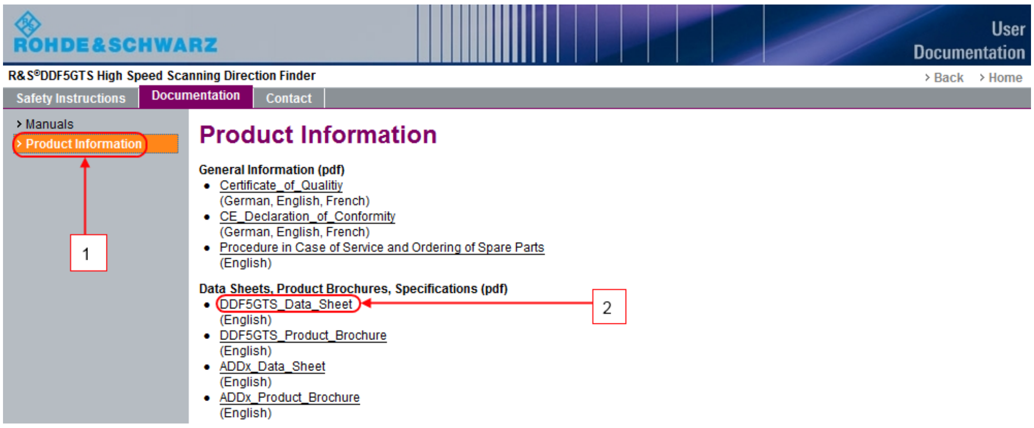


Figure 1-3: CD "Documentation": R&S DDF5GTS Data Sheet.

1.5 Equipment Supplied

1.5.1 R&S DDF5GTS AC Power Supply Models

AC power supply models		
Qu.	**Designation**	**Order number**
1	R&S DDF5GTS CD set, consisting of: ● *CD Documentation* ● *CD Firmware & Utilities*	4073.9278.00 ● 4073.9349.00 ● 4073.9355.00
1	AC power cable ● EURO: Schuko to IEC 60320 C13 straight ● U.S.A.: NEMA 5-20 to IEC 60320 C13	country-specific: ● 0025.2365.00 ● (on request)[1)]*
1	LAN cable	4055.6458.00
2	Time lag fuse (F1 and F2, see Chapter 3.3.2.1, "AC Power Supply Model", on page 96)	0020.7630.00
1	CD set RAMON (R&S DDF-CTL, cf [3.12]) (R&S RAMON COMINT/CESM Software)	3025.2729.02

1) *and others: Schuko to IEC 60320 C13 tilted, Japan, China, CH, Australia, UK, Brazil, South Africa.*

1.5.2 R&S DDF5GTS DC Power Supply Models

DC power supply models		
Qu.	**Designation**	**Order number**
1	R&S DDF5GTS CD set, consisting of: • *CD Documentation* • *CD Firmware & Utilities*	4073.9278.00 • 4073.9349.00 • 4073.9355.00
1	DC power cable	4074.4611.00
1	LAN cable	4055.6458.00
1	CD set RAMON (R&S DDF-CTL, cf [3.12]) (R&S RAMON COMINT/CESM Software)	3025.2729.02

1.5.3 R&S EHT770 AC Power Supply Model

AC power supply model		
Qu.	**Designation**	**Order number**
1	AC power cable • EURO: Schuko to IEC 60320 C13 straight • U.S.A.: NEMA 5-20 to IEC 60320 C13	country-specific: • 0025.2365.00 • (on request)[1)]*
2	Time lag fuse (F1 and F2, see Chapter 3.3.2.1)	0020.7630.00
1	*Molex* iPass x4 cable 74546-0401 W600	3588.5413.00
2	Molex iPass x8 cable 74546-0801 W601/602	3584.9250.00
1	RF cable set W100/W200, consisting of: • W100 (4075.0803.00) • W200 (4075.0810.00)	4075.0790.00
1	RF cable W300	4075.0826.00
1	RF cable W400	4075.0832.00
1	RF cable W500	4075.0849.00

[1)] *See footnote in 1.5.1.*

1.5.4 R&S EHT770 DC Power Supply Model

DC power supply model		
Qu.	**Designation**	**Order number**
1	DC power cable	4074.4611.00
1	Molex iPass x4 cable 74546-0401 W600	3588.5413.00
2	Molex iPass x8 cable 74546-0801 W601/602	3584.9250.00

DC power supply model		
Qu.	**Designation**	**Order number**
1	RF cable set W100/W200, consisting of: ● W100 (4075.0803.00) ● W200 (4075.0810.00)	4075.0790.00
1	RF cable W300	4075.0826.00
1	RF cable W400	4075.0832.00
1	RF cable W500	4075.0849.00

1.6 Ordering Information

1.6.1 Basic Unit

Basic unit		
Designation	**Type**	**Order number**
High-Speed Scanning Direction Finder, AC power supply *consisting of*	R&S DDF5GTS	4073.9203.02[1)]*
DF Converter, AC power supply	R&S EHT770	(4074.9007.08)
Processing Unit, AC power supply	R&S EBD770	(4074.5001.02)
High-Speed Scanning Direction Finder, DC power supply *consisting of*	R&S DDF5GTS	4073.9203.12[1)]*
DF Converter, DC power supply	R&S EHT770	(4074.9007.18)
Processing Unit, DC power supply	R&S EBD770	(4074.5001.12)

[1)] *The model variant (number's third section) affects*
- *first digit: the type of power supply (0: AC or 1: DC)*
- *second digit: modifications due to technical advance*

(Find information about model number on page 2. The model variant of the individual R&S DDF5GTS is always displayed on the four-line status display on the front panel [R&S EBD770 only].)

1.6.2 Hardware and Software (Firmware) Options

Hardware and software (firmware) options		
Designation (chapter)	**Type**	**Order number**
HF Frequency Extension (2.6.2)	R&S DDFGTS-HF	4074.1270.02
Time Synchronization (2.6.4)	R&S DDFGTS-TS	4074.0922.02

Hardware and software (firmware) options		
Designation (chapter)	**Type**	**Order number**
Internal GPS Module (2.6.9)	R&S DDF-IGT	4079.8009.04
Internal GNSS Module (2.6.9)	R&S DDFGTSIGT2	4079.8209.04
ITU Measurement Software (2.6.3)	R&S DDFGTS-IM	4074.0822.02
Documentation of Test Results (2.6.8)	R&S DDFGTS-DCV	4074.1187.02
Preclassifier[1)]*	R&S DDFGTS-CL	3025.2912.02
Enhanced Measurement Speed[2)]* (2.6.7)	R&S DDFGTS-EMS	4501.0604.02 4074.1587.02
EMS Identification[2)]* (2.6.7)	R&S DDFGTS-ID	4074.1229.02
DF Error Correction (2.6.6)	R&S DDFGTS-COR	4074.0974.02
Vector Matching (2.6.10)	R&S DDFGTS-VM	4074.1506.02
DDC Signal Extraction[3)]* (2.6.11)	R&S DDFGTSDDCE	4074.0716.02
Detection of Short-Time Signals[3)]* (2.6.12)	R&S DDFGTS-ST	4074.0739.02
High-Resolution Panorama[3)]* (2.6.13)	R&S DDFGTS-HRP	4074.0751.02
Signal Processing Board[3)]* (2.6.11, Note "Required Hardware")	R&S DDFGTS-SP	4074.1129.02
Service kit	R&S DDF-SK	4060.0454.02

1) *Option not described in this manual, but in the R&S DDF-CTL user manual [3.12], cf Chapter 1.5, Equipment Supplied.*

2) *R&S DDFGTS-EMS is export restricted and requires (or embraces) R&S DDFGTS-ID; contact Rohde & Schwarz for detailed information and proper ordering.*

3) *Options R&S DDFGTSDDCE, R&S DDFGTS-ST and R&S DDFGTS-HRP require option R&S DDFGTS-SP.*

1.6.3 DF Antennas and Antenna Accessories

Rx antennas		
Designation	**Type**	**Order number[1)]***
Active Rod Antenna	R&S HE010E	4097.6004.02

DF antennas		
Designation	**Type**	**Order number[1)]***
Super-Resolution HF DF Antenna	R&S ADD011SR	4078.0004.02
HF DF Antenna, mobile	R&S ADD119	4053.6509.02
Super-Resolution VHF DF Antenna	R&S ADD050SR	4071.7003.02

DF antennas		
Designation	**Type**	**Order number[1)]***
Super-Resolution VHF/UHF DF Antenna	R&S ADD153SR	4071.6007.02
Dual Polarized VHF/UHF DF Antenna	R&S ADD157	4069.4800.02
UHF DF Antenna for GSM, mobile	R&S ADD170	4055.7502.02
UHF DF Antenna ● stationary ● semi-mobile	R&S ADD070	 4043.4003.02 4043.4003.12
UHF DF Antenna, mobile	R&S ADD070M	4059.6000.02
Compact LF UHF DF Antenna	R&S ADD216	4068.3000.02
Broadband VHF/UHF DF Antenna	R&S ADD253	4071.4004.12
UHF/SHF Super-Resolution DF Antenna	R&S ADD078SR	4098.4005.02

Antenna accessories		
Designation	**Type**	**Order number**
Extended Lightning Protection	R&S ADD-LP	4069.6010.02
Antenna Cable Set HF for multichannel DF (8 kHz to 30 MHz, with option R&S DDFGTS-HF installed only)	R&S DDF1XZ[2)]*	4064.6286.xx[3)]*
Antenna Cable Set VHF/UHF for multichannel DF (8 kHz to 1.3 GHz)	R&S DDF5XZ[2)]*	4064.6728.xx[3)]*
Antenna Cable Set UHF for multichannel DF (8 kHz to 3 GHz)	R&S DDF7XZ[2)]*	4064.8043.xx[3)]*
Antenna Cable Set SHF for multichannel DF (500 kHz to 6 GHz)	R&S DDF3C-7[2)]*	4098.4757.xx[3)]*
Interconnection Cable Set	R&S DDF3CX[2)]*	4098.4763.10
External Power Supply with 10 m control cable	R&S IN061[2)]*	4041.9508.02

1) *With antenna part numbers, the second digit of the model variant (number's third section) tells the unit color; shown is '2' for*
- Rx antennas: RAL 7000 (squirrel gray)
- DF antennas: RAL 1015 (light ivory)

For additional colors available see antenna manual.

2) *For details on cable sets and on the R&S IN061, refer to Chapter 2.4.4, "Antenna Accessories", on page 41.*

3) *With cable set part numbers, the model variant affects the cable length. See Table 1-1 and Chapter 3.5.4 on page 121 for details.*

Table 1-1: Cable lengths.

Cable lengths		
Cable length[4]*	**Model variant**	**Availability**
1 m		R&S DDF3CX
5 m	05	R&S DDF1XZ, R&S DDF5XZ, R&S DDF7XZ, R&S DDF3C-7
10 m	10	R&S DDF5XZ, R&S DDF7XZ, R&S DDF3C-7
20 m	20	R&S DDF5XZ, R&S DDF7XZ, R&S DDF3C-7
30 m	30	R&S DDF1XZ, R&S DDF5XZ, R&S DDF7XZ, R&S DDF3C-7
40 m	40	R&S DDF5XZ, R&S DDF7XZ
50 m	50	R&S DDF5XZ, R&S DDF7XZ
80 m	80	R&S DDF5XZ[5]*
100 m	11	R&S DDF1XZ, R&S DDF5XZ[5]*
150 m	15	R&S DDF1XZ
250 m	25	R&S DDF1XZ

[4] *External power supply R&S IN061 required: when using*
- *R&S ADD119: from 100 m up,*
- *R&S ADD050SR: from 40 m up,*
- *any other Rohde & Schwarz antenna of Chapter 1.6.3: from 50 m up,*
- *any Rohde & Schwarz antenna of Chapter 1.6.3 in combination with R&S ADD050SR: from 25 m up.*

[5] *External power supply R&S IN061 included in delivery, see Chapter 2.4.4.*

1.6.4 External Accessories

External accessories		
Designation	**Type**	**Order number**
Antenna Compass[1]*	R&S GH150	4041.8501.02
GPS Navigator/GPS Receiver	R&S GINA[2]*	4055.6906.04
Vehicle Adapter	R&S AP502Z1	0515.1419.02
Mast Adapter	R&S ADD150A	4041.2655.02
Tripod with Adapter	R&S ADD1XTP	4063.4409.02
Mast Section	R&S KM051	4041.9008.02
Antenna Adapter	R&S ADD071Z	4043.7002.02
19" Rack Adapter • for stationary use • for mobile use	 • R&S ZZA-411 • R&S RMK-411	 • 1096.3283.00 • 4074.7504.02

1) *In "antenna" context often denoted as "electronic compass", see* *Chapter 2.5.2 on page 48**.*

2) ***G**PS-Based **I**nertial **NA**vigator, see* *Chapter 2.5.6 on page 76**.*

2 Preparation for Use

This section describes the basic steps to be taken when setting up the R&S DDF5GTS for the first time.

WARNING

Risk of injuries

To avoid injuries to yourself or others, always follow the instructions provided in the following sections. Furthermore, observe the safety instructions included in this documentation.

2.1 Unpacking and Checking

To remove the R&S DDF5GTS from its packaging and to check the equipment for completeness, proceed as follows:

1. Pull off the polyethylene protection pads from the rear feet.
2. Carefully remove the pads from the handles at the front.
3. Pull off the corrugated cardboard cover that protects the rear of the R&S DDF5GTS.
4. Carefully unthread the corrugated cardboard cover at the front that protects the handles and remove it.
5. Check the equipment for completeness using the delivery note and the accessory lists for the various items.
6. Check the R&S DDF5GTS for any damage. If there is damage, immediately contact the carrier who delivered it. Make sure not to discard the box and packing material.

Packing material

Retain the original packing material. If the R&S DDF5GTS needs to be transported or shipped later, you can use the material to prevent control elements and connectors from being damaged.

2.2 Setup

2.2.1 Bench Operation

Place the R&S DDF5GTS on a stable and level surface. Before folding out its feet at the bottom or stacking it on top of other devices, carefully read the safety instructions.

NOTICE

Equipment cooling

- Do not expose the R&S DDF5GTS to humidity.
- Leave at least 50 mm of empty space along both side panels in order to ensure proper equipment cooling.

There are no special requirements for desktop use. To facilitate access to the front panel elements, you should raise the front of the R&S DDF5GTS by folding out its standing feet.

WARNING

Safety Instructions

To avoid

- injuries to yourself or others,
- severe damage to the R&S DDF5GTS,

always follow the instructions provided in the following sections. Furthermore, observe the safety instructions

- Basic Safety Instructions,
- Safety Instructions for Instruments with Fold-Out Feet,
- Safety Instructions for Stacking Instruments.

2.2.2 Rack Mounting

The R&S DDF5GTS can be mounted in a 19" rack.

Stationary use

For stationary use a suitable rack adapter kit can be ordered as an external accessory (order number 1096.3283.00). To mount the R&S DDF5GTS correctly refer to the mounting instruction included in delivery.

Mobile use

For mobile use the rack mounting should be as stiff as possible because any dynamic loads being introduced may increase the overall load if there is insufficient device mounting stiffness. Therefore the rack adapter kit for stationary use is not recommended.

If the R&S DDF5GTS is to be operated at the specified high shock and vibration conditions it must be mounted with a special rack adapter kit for mobile use. It can be ordered as an external accessory (order number 4074.7504.02). To mount the R&S DDF5GTS correctly refer to the mounting instruction included in delivery.

2.2.3 Ambient Temperature

NOTICE

Ambient temperature

The R&S DDF5GTS should be used in an area where the ambient temperature does not exceed –10 °C to +55 °C. The R&S DDF5GTS is fan-cooled and must be installed with sufficient space along the sides to ensure a free flow of air. Make sure that there is sufficient space for hot air to escape from the R&S DDF5GTS. To ensure sufficient cooling do not attach telescopic rails to the sides of the unit.

2.2.4 EMI Protective Measures

In order to avoid electromagnetic interference (EMI), the R&S DDF5GTS may only be operated when it is closed and all shielding covers are in place. Use only appropriate shielded signal and control cables.

NOTICE

Signal and Control Cables

It is strongly recommended to only use the signal and control cables supplied by *Rohde & Schwarz* as external accessories (see Chapter 1.6.3, "DF Antennas and Antenna Accessories", on page 21). Correct contacting and shielding cannot be guaranteed with external products.

2.3 Cabling

2.3.1 Connecting to the Power Supply

Coverage

All information given in this chapter is valid for both the R&S EBD770 and the R&S EHT770 unless noted otherwise.

Connect the R&S DDF5GTS (R&S EBD770 and R&S EHT770) observing the following sections and instructions for use. The R&S DDF5GTS is suitable either for AC mains operation or for DC operation, depending on the model of the unit ordered (see Chapter 3.3, "Rear Panel Elements R&S EBD770", on page 91 and Chapter 3.4, "Rear Panel Elements R&S EHT770", on page 107).

2.3.1.1 Connecting to Mains (AC Power Supply Model)

NOTICE

Mains Voltage

Make sure that the available mains voltage is between 100 V and 240 V AC with mains frequencies ranging from 50 Hz to 400 Hz.

The R&S DDF5GTS AC power supply model is connected to the mains voltage by the plug X1 ***100...240 V AC*** (with mains filter) on the rear panel. The supply voltage must be between 100 V AC and 240 V AC with mains frequencies ranging from 50 Hz to 400 Hz. The R&S DDF5GTS AC power supply model is automatically adapted to the AC voltage supplied.

1. Make sure that the mains switch on the rear panel of the R&S DDF5GTS is set to 0 (OFF).
2. First, plug the AC power cable delivered with the R&S DDF5GTS to **X1**.
3. Next, connect the R&S DDF5GTS to the AC power source via the power cable.

The R&S DDF5GTS AC power supply model is protected by two fuses located in the fuse holder between the AC mains plug and the AC power switch (see Chapter 4.1.3, "Replacing the Fuses", on page 332).

2.3.1.2 Connecting to DC Source (DC Power Supply Model)

NOTICE

DC Supply Voltage and Polarity

- Make sure that the available supply voltage is between 12 V DC and 32 V DC.
- Observe the correct voltage polarity when connecting.
  Incorrect polarity may blow the fuse on the DC converter inside the R&S DDF5GTS or even damage the R&S DDF5GTS.

The R&S DDF5GTS DC power supply model is connected to an external 12 V to 32 V DC source (e.g. battery) via the connector X2 ***12...32 V DC*** on the rear panel.

Appropriate DC power cables are included in delivery of the R&S DDF5GTS DC power supply model.

Recommended connector (plug): *Neutrik* Speakon NL4FX (see Figure 2-1, 1). This is the correct counterpart to the Neutrik Speakon NL4MP (see Figure 2-1, 2) socket fitted in **X2**.

NOTICE

SELV

When using external DC sources for supplying the R&S DDF5GTS with DC low voltage (SELV), be sure to have the requirements on reinforced/double shielding according to

- DIN/EN/IEC 61010 (UL 3111, CSA C22.2 No. 1010.1) or
- DIN/EN/IEC 60950 (UL 1950, CSA C22.2 No. 950)

fulfilled.

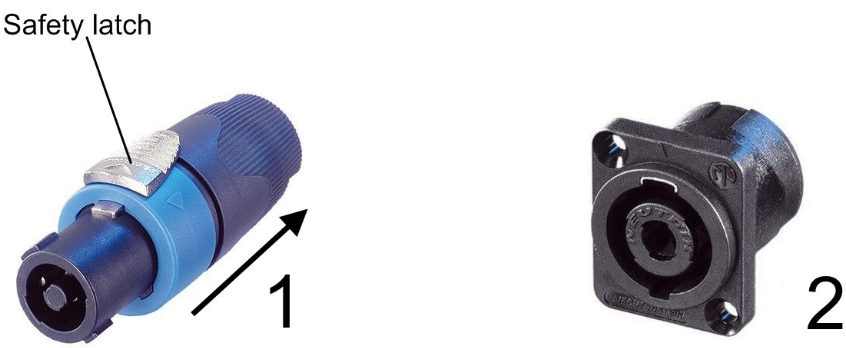


Figure 2-1: Neutrik Speakon connection elements.

1 = NL4FX plug (cable)
2 = NL4MP socket (DF unit, connector X2)

1. First, plug the DC power cable delivered with the R&S DDF5GTS to **X2**.
2. Next, connect the R&S DDF5GTS to the DC power source via the power cable, paying attention to correct polarity.

Connector X2 12...32 V DC
If MIL-SPEC regarding EMC must be fulfilled, you will need a double-screened connecting power cable.

Installing the connector:

1. Insert the Speakon NL4FX connector (Figure 2-1, 1) into socket **X2** (Neutrik Speakon NL4MP, Figure 2-1, 2) on the rear panel.
2. Turn the connector clockwise until it is locked in place and secured by the safety latch.

Removing the connector:

1. Press and shift back the safety latch of the Speakon NL4FX connector.
2. Turn the connector counter-clockwise and withdraw it.

NOTICE

DC Power Cable

- It is strongly recommended to use the delivered DC power cable (order number 4066.4016.00).
- If, however, there should be a need to assemble a user-specific power cable, the strict obedience to the correct polarity is of essential importance.
  In Figure 2-2 the connecting scheme of the Speakon NL4FX connector is shown, in Table 2-1 the correct assignment.
- For more detailed information about how to mount and assemble the plug, refer to the instructions of the manufacturer (e.g. on the manufacturer's website).

CAUTION

External Products

The use of different connectors is advised against in any case; reliable contacting and shielding cannot be guaranteed with external products.

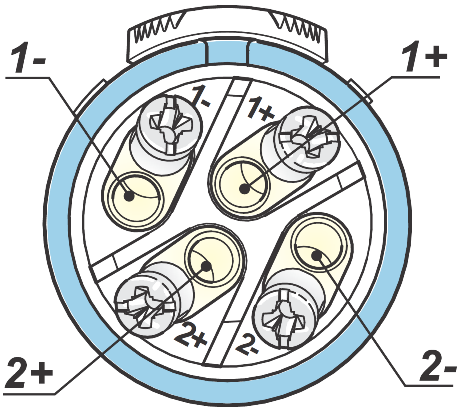


Figure 2-2: Neutrik Speakon NL4FX plug mechanical connecting scheme.

Table 2-1: Neutrik Speakon NL4FX plug contact assignment.

Contact name	1+	1–	2+	2–
Use	+	–	+	–

2.3.1.3 Grounding

The grounding bolt on the rear of the R&S DDF5GTS serves for earthing. For use as system earth, a rod, band or plate is recommended, also mind Note "Grounding". If the direction finder is located in a metallic enclosure (vehicle or shelter), the latter is to be grounded at a central point and connected with the unit.

The unit should be grounded also in stationary configurations even if a protected earthing is provided. For rackmount installations the rack as a whole should be grounded. Suitable diameters for the copper ground wire range from 16 mm^2. Country-specific regulations are to be observed.

CAUTION

Standards and procedures

Make sure you always comply with the local standards and procedures.

Particular attention should be paid to the grounding of the antenna to avoid damages by lightning strokes and overvoltages (see Chapter 2.4.5 on page 43).

2.3.1.4 Power on and off

The power supply unit **X1** or **X2**, respectively, is located in the bottom left corner of the rear panel.

NOTICE

STANDBY State (R&S EBD770 only)

You should definitely switch the R&S EBD770 to [Standby] state before you disconnect it from the AC or DC supply.

If you set the AC power switch to 0 ([Off]) or remove the AC or DC supply while the R&S EBD770 application is still running, you will lose the current settings. Moreover, you may experience loss of program data if the application is terminated improperly.

AC Power Supply Model

The AC power switch is located in the power supply unit to the right of the power supply plug and the fuse holder. To turn the power on or off, set the AC power switch to position I ([On]) or 0 ([Off]).

After power-on, the R&S EBD770 is in [Standby] or [Ready] state, depending on the state of the [On/Off] toggle key at the front panel of the R&S EBD770 (see 2.3.1.5) when it was last switched off. Note that (both R&S EBD770 and R&S EHT770) you can leave the AC power switch in its [On] position. Putting the AC power switch to position [Off] is only required if you have to remove the R&S DDF5GTS completely from the AC power supply.

DC Power Supply Model

DC power is always turned [On] when the DC power supply is connected.

2.3.1.5 STANDBY and READY

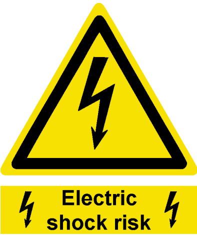
Limitation

Applies only to R&S EBD770.

The [On/Off] key is located in the bottom left corner of the front panel. It is used to switch the R&S EBD770 from [Standby] to [Ready] state and back (with the AC power supply model: provided that the AC power switch on the rear panel (2.3.1.4) is switched to position I: [On]).

In [Standby] state, the right, amber LED is on. The [Standby] power only supplies the power switch circuits. In this state it is safe to switch off the AC power and disconnect the R&S EBD770 from the AC or DC power supply.

The standby power consumption is below 1 W.



WARNING

Shock Hazard

The R&S EBD770 is still power-supplied while it is in [Standby] state.

After you have connected either AC power supply and switched on AC power, or DC power supply, respectively, to switch the R&S EBD770 from the [Standby] to the [Ready] state, press the [On/Off] key briefly.

In [Ready] state, the left, green LED is on. The R&S EBD770 is ready for operation. All modules are power-supplied and the instrument initiates its startup procedure. To switch the R&S EBD770 back from the [Ready] state to [Standby], just press again the [On/Off] key.

Premature Switching

- It is not recommended to switch, by again pressing the [On/Off] key, the R&S EBD770 back from the [Ready] state to [Standby] for the first approx. 4 s after having entered [Ready].
- To reactivate the R&S EBD770 (switch it back from the [Standby] to the [Ready] state) after having done so nevertheless, wait for about 4 s and then press the [On/Off] key for about 4 s more.

2.3.2 Connecting R&S EHT770 and R&S EBD770

The R&S DDF5GTS is a DF system consisting of two discrete units, the DF converter R&S EHT770 and the processing unit R&S EBD770. Thus, these both units have to be connected to each other.

A basic cabling scheme is displayed in Figure 2-3, also shown are the designations of the cables to be used for each individual connection (see Chapter 1.5, "Equipment Supplied", on page 18).

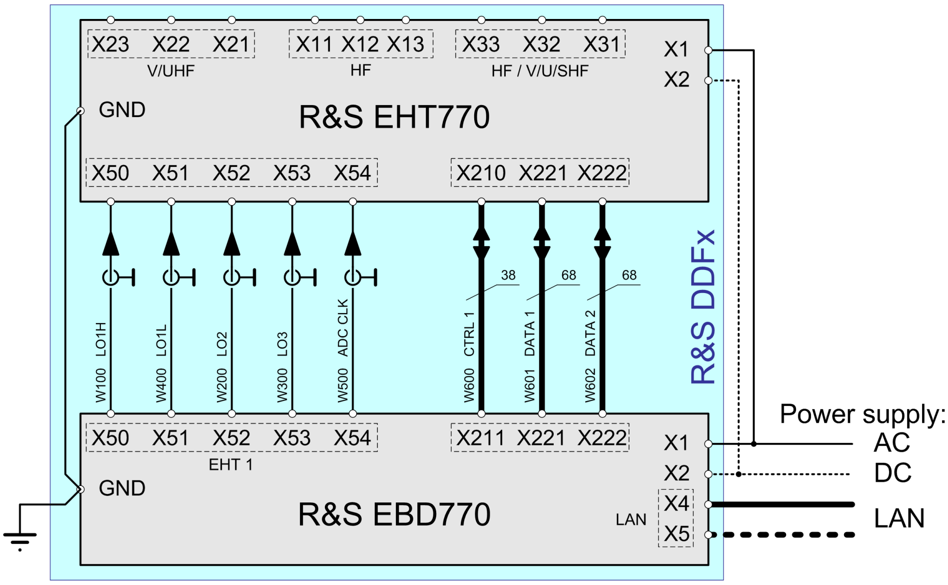
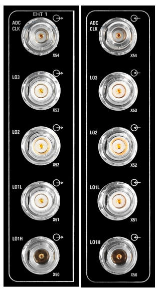
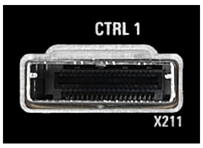
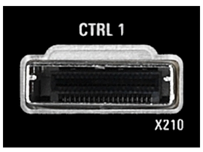


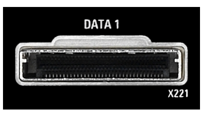
Figure 2-3: Connecting the R&S EHT770 to the R&S EBD770.

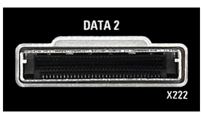
DDFx = DDF5GTS (AC or DC)
X1/X2 = only 1 mode of power supply: AC or DC
X4/X5 = use only 1 plug: X4 or X5
GND = see Note "Grounding"











Detailed information can be found in Chapter 3.3, "Rear Panel Elements R&S EBD770", on page 91 and Chapter 3.4, "Rear Panel Elements R&S EHT770", on page 107; connections between the units to be installed in the three-channel case are

- the 5 local oscillator cables (summarized as EHT 1 with the R&S EBD770, unlabeled with the R&S EHT770)
  - **X50** ***LO1H***, cable W100
  - **X51** ***LO1L***, cable W400
  - **X52** ***LO2***, cable W200
  - **X53** ***LO3***, cable W300
  - **X54** ***ADC CLK***, cable W500
- the 3 digital transmission cables
  - **X211** (R&S EBD770) to **X210** (R&S EHT770) ***CTRL 1***, cable 600
  - **X221** ***DATA 1***, cable 601
  - **X222** ***DATA 2***, cable 602
- a suitable connection between the grounding bolts of both units, see Note "Grounding".

NOTICE

Local Oscillator and Digital Transmission Cables

The local oscillator and digital transmission cables are part of the order with the R&S DDF5GTS (see Chapter 1.5, "Equipment Supplied", on page 18) and especially tailored for this purpose. Do not use other cables, because correct contacting and shielding cannot be guaranteed with external products.

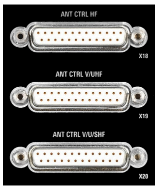
NOTICE

Grounding

To ensure correct operation concerning fulfilling of usual EMC regulations, proper earthing (grounding) has to be established:

- Connect the R&S EBD770 grounding bolt to ground by a grounding cable of at least 6 mm^2 of cross-sectional area.
- Connect the R&S EHT770 grounding bolt to the R&S EBD770 grounding bolt by a grounding cable of at least 6 mm^2 of cross-sectional area and maximum 50 cm of length.

2.3.3 Connecting to Antenna



For installing the antenna(s) follow the instructions given in Chapter 2.4, "Antennas", on page 37, Chapter 3.5, "Installation and Cabling of Antenna(s), Antenna Combinations and Related Equipment", on page 112 and in the individual antenna manuals.

For connecting the antenna(s) to the R&S DDF5GTS refer to Chapter 3.3, "Rear Panel Elements R&S EBD770", on page 91, Chapter 3.4, "Rear Panel Elements R&S EHT770", on page 107 and the information labels on the cables.

Example:

A HF/VHF/UHF/SHF antenna is connected to the R&S DDF5GTS:

- 3 signal channels to R&S EHT770 via
  - X31 ***HF / V/U/SHF, DF1***,
  - X32 ***HF / V/U/SHF, DF2*** and
  - X33 ***HF / V/U/SHF, DF3***
- 1 calibrating channel to R&S EBD770 via
  - X34 ***CAL U/SHF***
- 1 control line to R&S EBD770 via
  - X18 ***ANT CTRL HF***,
  - X19 ***ANT CTRL V/UHF*** or
  - X20 ***ANT CTRL V/U/SHF***

(the three control connectors are equivalent since each antenna identifies itself to the R&S DDF5GTS).

2.3.4 Connecting to LAN

You can connect a LAN cable to one of the LAN ports (**X4** ***LAN 1*** or **X5** ***LAN 2***) on the rear panel of the R&S EBD770.

NOTICE

LAN Cable

- It is strongly recommended to only use the LAN cable included in delivery with the R&S DDF5GTS.
- If using external products, strictly observe that the minimum quality standard required for the cable is Cat 6. Always use double-shielded cables.
- In order to comply with electro-magnetic compatibility guidelines (RTTE/R&TTE), only LAN cables shorter than 10 m may be used.

To establish a LAN connection, proceed as described below.

1. Refer to Chapter 4.2.2, "Changing the IP Address", on page 371 to learn how to set the unit's IP address.
2. Connect a LAN cable to one of the LAN ports (both ports are equivalent). The R&S EBD770 has an internal switch which automatically detects the type of LAN cable connected, so you can use any standard type of LAN cable to establish a network connection with the R&S DDF5GTS.

Dedicated vs. Non-Dedicated Network Connections

There are two methods to establish a LAN connection with the R&S DDF5GTS:

- A non-dedicated network (Ethernet) connection from the R&S DDF5GTS to an existing network. The R&S DDF5GTS is assigned an IP address and can coexist with a computer and with other hosts on the same network.
- A dedicated network connection between the R&S DDF5GTS and a single computer. The computer must be equipped with a network adapter and is directly connected to the R&S DDF5GTS. The use of hubs, switches or gateways is not required; however, data transfer is still made using the TCP/IP protocol.

The IP address is always displayed on the four-line status display on the front panel.

The two LAN ports on the rear panel of the R&S EBD770 are equivalent. Choose the one that is more convenient for your application.

NOTICE

Avoid Parallel Connections

Never use both LAN ports to connect the R&S DDF5GTS in parallel to the same network as this will result in connection errors.

2.4 Antennas

2.4.1 General

Due to multipath propagation (especially in metropolitan areas) not only the direct wave but also reflections arrive at the DF antenna. In Figure 2-4, Path 1 represents the direct wave from the transmitter to the DF vehicle, whereas Paths 2 to 4 are reflections of the emitted signal about the surrounding house walls.

The R&S ADDx multichannel DF antennas offer (due to their design) a higher immunity to such reflections than most other commercially available antennas, since they feature an exceptionally large number of antenna elements. Virtually all R&S ADDx DF antennas comprise 9 antenna elements for the HF/VHF/UHF range, or 8 for the UHF range. Commercially available DF antennas typically have only 5. The R&S ADDx (except the R&S ADD119) enable stable bearings even with a 50 percent share of reflections. If only 5 antenna elements are used, however, such conditions may result in substantial DF errors in certain frequency ranges.

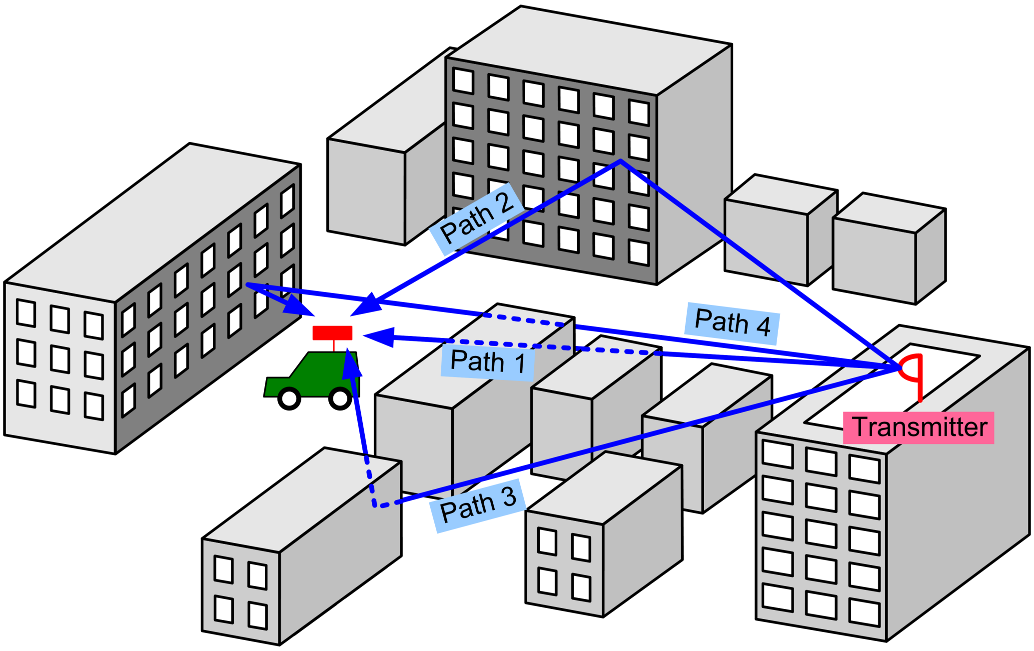
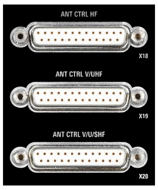
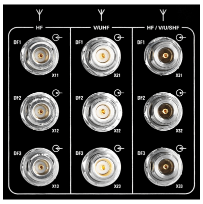


Figure 2-4: Multipath propagation of a transmitted signal in urban environment.

2.4.2 Antenna Types





Bearing evaluation in the direction finder R&S DDF5GTS occurs, depending on the connected antenna, according to a correlation process or the Watson-Watt process (named after the British physicist *Robert Alexander Watson-Watt*). Stating of the elevation angle is only possible with the correlation method, whereas Watson-Watt is based on a pure amplitude evaluation and thus cannot recognize slant of the incoming wave.

The antenna type is recognized by an individual antenna code transferred while booting the R&S DDF5GTS. The cables for the antenna control lines are connected to the R&S EBD770 via the antenna control sockets, with 3 interfaces available:

- **X18** ***ANT CTRL HF***
- **X19** ***ANT CTRL V/UHF***
- **X20** ***ANT CTRL V/U/SHF***

(all 3 equivalent), whereas the RF lines are connected to the R&S EHT770 RF inputs

- **X11** to **X13** ***HF*** (option R&S DDFGTS-HF installed)
- **X21** to **X23** ***V / U / SHF 1***
- **X31** to **X33** ***V / U / SHF 2***

and to the R&S EBD770 calibration outputs

- **X14** ***CAL HF*** (option R&S DDFGTS-HF installed)
- **X24** ***CAL V/UHF***
- **X34** ***CAL U/SHF***

A scope of the usable antennas is given in Table 2-2.

Table 2-2: Scope of the usable antennas with cable sets required.

Usable antennas				
DF antenna	**Cable set**	**Frequency range**		**Application**
R&S ADD011SR	R&S DDF1XZ	HF	300 kHz to 30 MHz	Stationary and semi-mobile
R&S ADD119				Mobile
R&S ADD050SR	R&S DDF5XZ	VHF/UHF	20 MHz to 450 MHz	Stationary and semi-mobile
R&S ADD153SR			20 MHz to 1.3 GHz	Mobile and stationary
R&S ADD157			20 MHz to 1.3 GHz (vert.) 40 MHz to 1.3 GHz (hor.)	
R&S ADD170	R&S DDF7XZ		800 MHz to 2 GHz	Mobile
R&S ADD070			1.3 GHz to 3 GHz	Stationary and semi-mobile
R&S ADD070M				Mobile
R&S ADD216			300 kHz to 3 GHz	
R&S ADD253			20 MHz to 3 GHz	
R&S ADD078SR	R&S DDF3C-7	UHF/SHF	500 kHz to 6 GHz	

More detailed information about all mentioned antennas can be seen from the antenna manual of the individual antenna.

2.4.3 Choosing the Antenna Site

Bearing range and bearing error (DF quality) strongly depend on the properties of the installation site for the DF antenna. The specified DF accuracy and sensitivity can only be obtained in an electromagnetically undisturbed environment free from shadows, reflections, interfering waves and electrosmog superimposed upon the signal to be borne.

For frequencies from 20 MHz upwards, the installation site therefore should meet the following basic requirements for environmental properties:

- Up to a distance of 50 m from the antenna no obstacles.
- From 50 m to 100 m only low obstacles.
- Up to a distance of 400 m no obstacles like pylons, tower buildings etc.

⚠ CAUTION

Operation near Transmitting Antennas

Operating the DF antenna in the direct vicinity of transmitting antennas may cause problems. Intermodulation products being formed in the antenna circuitry may over-drive the DF equipment.

For further information also consult the manuals of the individual antennas.

Basic requirements to a DF antenna site:

- The soil should have uniform conductivity and dielectric constant.
- Within a range of approximately 100 m around the antenna, the terrain should be homogenous.
- The ground should be level (roughness < 25 cm).
- The ground should not contain any buried metal structures (lines, pipes etc.).
- There should be a sufficient distance to any obstacles, see Table 2-3.

Table 2-3: Minimum distance of certain obstacles from a DF antenna site.

Obstacles and DF antenna site	
Min. distance	**"Obstacle"**
0 m	(DF antenna)
150 m	Flat buildings without metal components
300 m	Single-story buildings without metal components (e.g. steel reinforcements, roofs), bushes, scattered trees
400 m	Smaller buildings with metal roofs, telephone lines, low-voltage lines, metal fences (mind also plastic parts with metal filaments woven in!), automobiles, railroad tracks without over-head contact lines

Obstacles and DF antenna site	
Min. distance	**"Obstacle"**
800 m	Forests, single-story metal fronts, industrial zones with low buildings, private homes
900 m	Railroad tracks with overhead contact lines, lakes, rivers, creeks
1000 m	High-voltage overhead power lines with pylons ≤ 20 m in height
2000 m	High-voltage overhead power lines with pylons > 30 m in height, reservoirs (oil, gas) > 6 m in height

From a practical point of view, it will probably be difficult to find a perfect site, so trade-offs in relation to the requirements stated above are to be made. In a hilly terrain, for instance, ground homogeneity is of greater importance than a level surface. Power lines or industrial facilities near a DF antenna will have a negative effect in any case.

Where possible, you should follow these rules:

- Within an area of 200 m around the antenna, the terrain should not be slanting by more than 5 percent. Greater tolerances are permissible beyond this distance.
- Steep edges or clefts located within 800 m from the antenna should be avoided.
- From an elevation angle of 3°, no obstacles should be located around the DF antenna within "sight area".

Figure 2-5 [2.1] also gives an idea of minimum distances of some obstacles to the DF antenna. The range specifications shown are valid for the HF range; in VHF/UHF, shorter distances have to be considered.

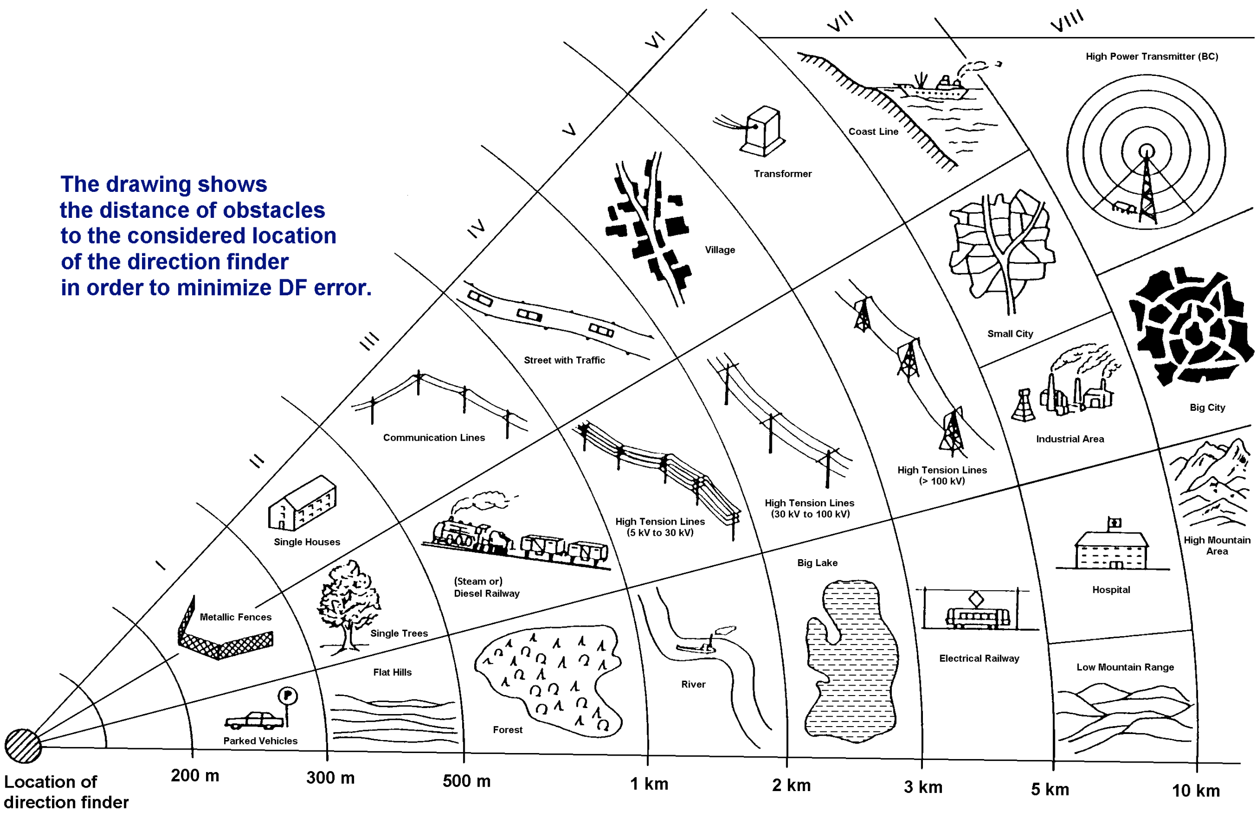


Figure 2-5: Minimum distance of obstacles.

2.4.4 Antenna Accessories

All antenna cable sets consist of the RF line(s) and a multipole control line for antenna switching purposes.

In the HF range (cable set R&S DDF1XZ, with option R&S DDFGTS-HF installed) as well as in VHF/UHF (cable set R&S DDF5XZ) and UHF ranges (cable set R&S DDF7XZ) three RF lines are provided. Due to the three direction finding channels available, no internal multiplexing or switching is to be performed.

Depending on the length of the cable set ordered, its appearance may differ considerably. Details on this are given in Chapter 3.5.4, "Cable Length", on page 121. Under some circumstances explained below, an external power supply (R&S IN061) is additionally needed or even included in delivery.

2.4.4.1 Interconnection Cable Set R&S DDF3CX

- The interconnection cable set R&S DDF3CX is used to interconnect the R&S ADD15x DF antennas (ADD153SR and ADD157) to R&S ADD78SR DF antenna and therefore is available in a fixed length of 1 m only.

2.4.4.2 HF Cable Set R&S DDF1XZ

- The HF cable set R&S DDF1XZ (with option R&S DDFGTS-HF installed) is available in lengths of 5 m, 30 m, 100 m, 150 m and 250 m.
- With the cable length of 250 m, the RF cables are divided in three individual components each.

2.4.4.3 VHF/UHF Cable Set R&S DDF5XZ

- The VHF/UHF cable set R&S DDF5XZ is available in lengths of 5 m, 10 m, 20 m, 30 m, 40 m, 50 m, 80 m and 100 m.
- With the cable lengths of 30 m, 40 m, 50 m, 80 m and 100 m, the RF cables are divided in three individual components each.
- With the cable lengths of 80 m and 100 m, the external power supply R&S IN061 is included in delivery.

2.4.4.4 UHF Cable Set R&S DDF7XZ

- The UHF cable set R&S DDF7XZ is available in lengths of 5 m, 10 m, 20 m, 30 m, 40 m and 50 m.
- With the cable lengths of 20 m, 40 m and 50 m, the RF cables are divided in three individual components each.

2.4.4.5 SHF Cable Set R&S DDF3C-7

- The SHF cable set R&S DDF3C-7 is available in lengths of 5 m, 10 m, 20 m and 30 m.
- With the cable lengths of 10 m, 20 m and 30 m, the RF cables are divided in three individual components each.

2.4.4.6 External power supply R&S IN061

For cable lengths exceeding a definite limit, the external power supply R&S IN061 is required to support the Antenna Control line (a 10 m control cable is included in delivery with the R&S IN061). These lengths are in detail:

- using an R&S ADD119: from 100 m upwards,
- using an R&S ADD050SR: from 40 m upwards,
- using any other *Rohde & Schwarz* antenna from Chapter 1.6.3: from 50 m upwards,
- using any *Rohde & Schwarz* antenna from Chapter 1.6.3 in combination with R&S ADD050SR: from 25 m upwards.

The R&S IN061 is needed in any case if more than 2 antennas are to be connected to the R&S DDF5GTS simultaneously.

Mind that the R&S IN061 is included in delivery with

- R&S DDF5XZ: lengths of 80 m and 100 m.

2.4.5 Grounding the Antenna

Concerning lightning-stroke immunity, ensure that a continuous low-ohmic connection exists between the antenna flange, masts, installation platform, power supply and ground soil and/or protective earth of the building (potential equalization).

CAUTION

Standards and procedures

Make sure you always comply with the local standards and procedures.

For sites at high risk of lightning stroke (high keraunic level, i.e. number of days with thunderstorms, and/or high masts), additional measures might be necessary:

- additional grounding of cables at regular intervals,
- passing cables in iron ducts,
- radial lightning rods below the DF antenna,
- massive grounding of cables where entering to the building,
- additional protective elements for the control lines.

Incorporation of gas conveyors in HF cables is not recommended since the extremely fast high-voltage spikes generated during ignition of the conveyors could possibly damage the protective circuits at the antenna outputs.

If the individual mast levels are insulated from one another, run an additional ground wire in parallel to the mast.

CAUTION

Lightning Protection

Always consider the complete system rather than just individual components (e.g. situated on exposed hilltops). For optimal protection, all subsystems, i.e. lightning rod, mast structure, building of operational center, grounding and power supply, have to be taken into account.

Make sure to have established the correct lightning protection at any time. For information about lightning protection of an individual antenna type, refer to the antenna manual.

Installation on Vehicles

For installation on vehicles by means of the R&S AP502Z1 adapter, a rotational symmetric ground connection between antenna and vehicle top must be provided.

2.4.6 Installation Examples

2.4.6.1 Stationary Installation

Always establish the correct lightning protection for the individual antenna(s) (cf Note "Lightning Protection" above), for information see the relevant antenna manual(s).

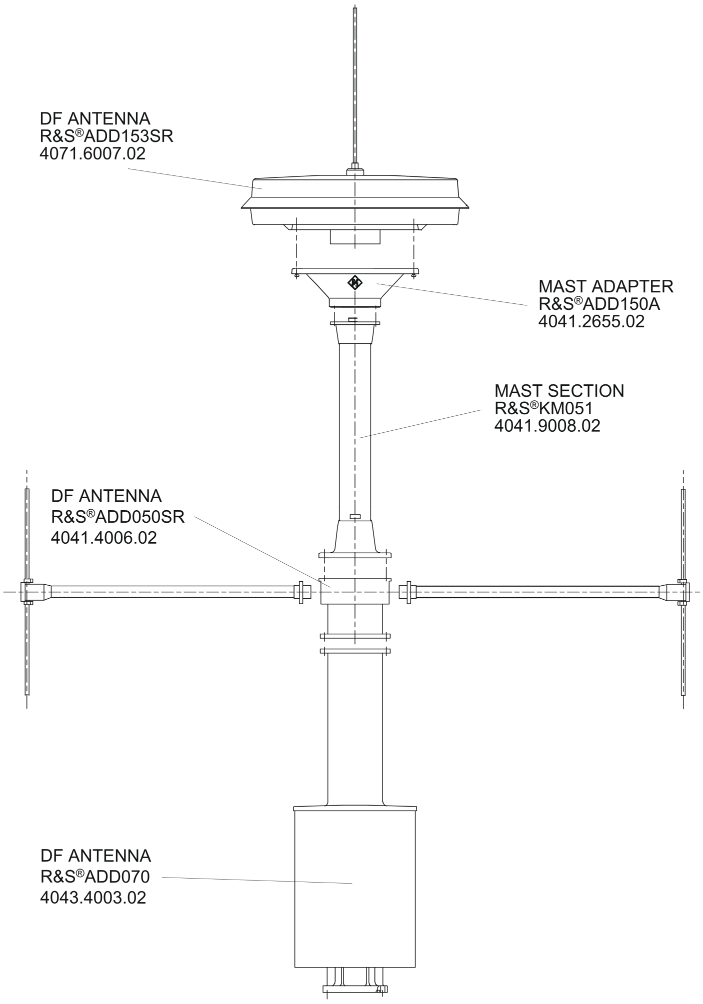


Figure 2-6: The single mast solution with adapters.

An example for a stationary installation is shown in Figure 2-6. The bottom end of R&S ADD070 is to be screwed to a tubular mast.

2.4.6.2 Vehicle Installation (DF Vehicle)

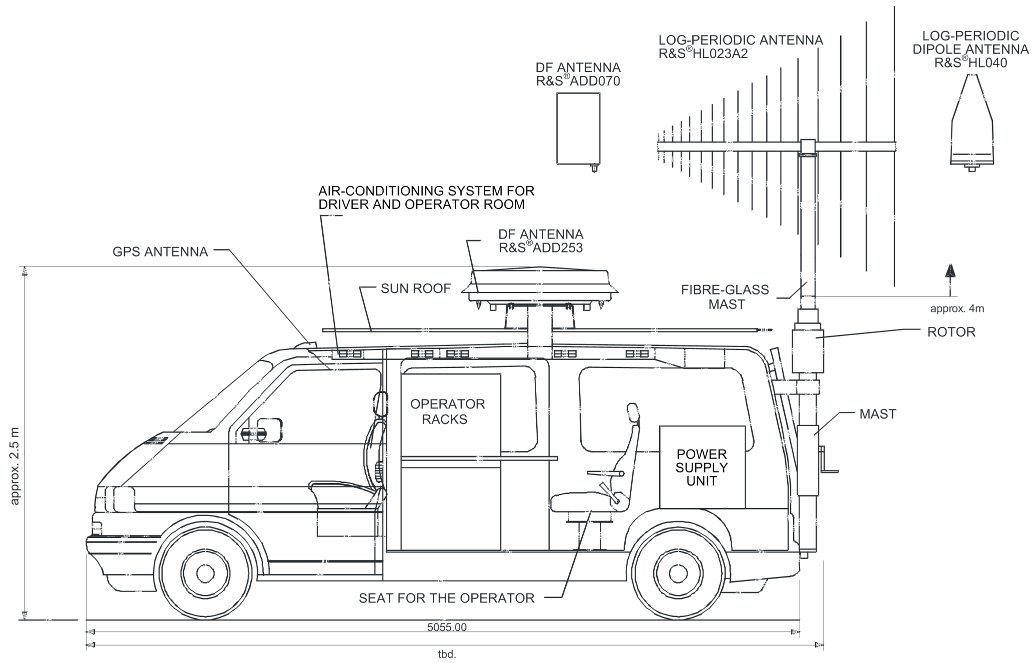


Figure 2-7: Mobile direction finding and radiomonitoring: example Volkswagen Caravelle.

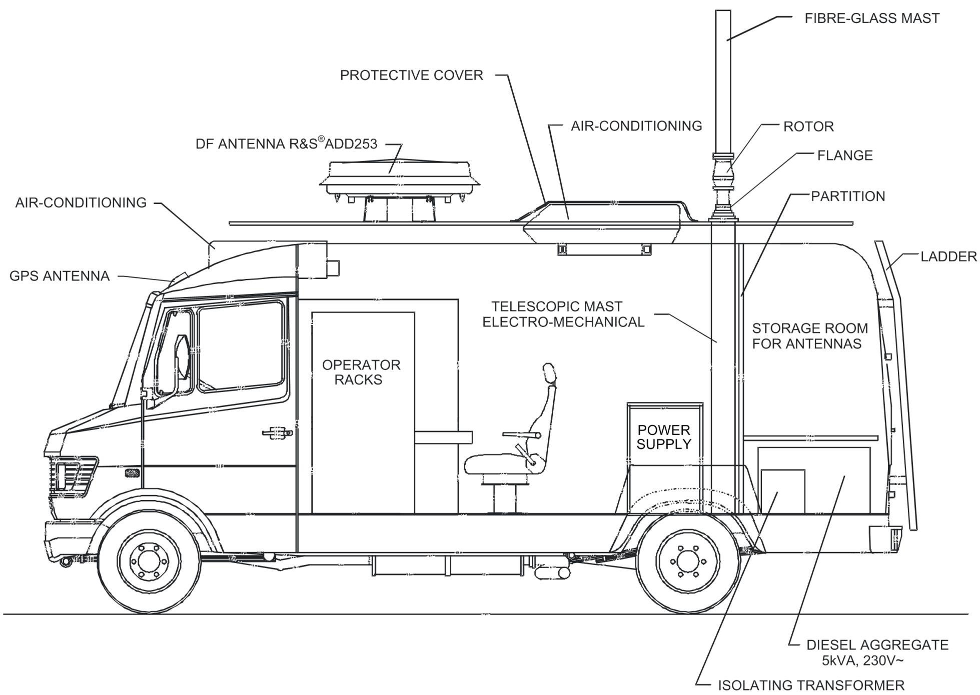


Figure 2-8: Mobile direction finding and radiomonitoring: example Mercedes 410D Four-wheel drive.

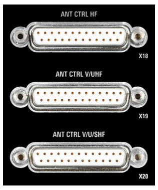
In Figure 2-7 and Figure 2-8 mounting examples onto a DF vehicle for mobile radiomonitoring and direction finding are illustrated. A typical peculiarity of this type of installation is the glass-fiber plastic mast.

In both cases, the R&S ADD253 antenna is mounted on the vehicle top. The more lightweight R&S ADD070 in case of operation is fixed to the mast, but shares this site eventually with other antennas being interchanged individually, depending on the task. When operating with the R&S ADD253, the mast is to be pulled in entirely and the antennas mounted thereon removed from the sight area of the R&S ADD253.

2.5 Compass and GNSS

2.5.1 Definition of Terms

2.5.1.1 Compass Types



- **Antenna compass**
  is a compass mounted directly to the DF antenna, normally a magnetic compass. It determines the orientation of the antenna itself, i.e. the deviation of its orientation from magnetic north. Before use, a calibration compensates for errors induced by local magnetic fields (called magnetic deviation). Local declination (① in Figure 2-11) should be compensated for by entering an appropriate correction value. Data transfer happens via the antenna control lines (all 3 equivalent)
  - X18 ***ANT CTRL HF***,
  - X19 ***ANT CTRL V/UHF*** and
  - X20 ***ANT CTRL V/U/SHF***.

  In an "antenna" context, the antenna compass is often called "electronic compass".

- **Vehicle compass**
  is a type of compass used in navigation applications. It commonly is integrated in all kinds of vehicles like as DF cars, aircraft, vessels etc., and normally is a *gyrostatic compass*, although in theory also a *magnetic compass* would be imaginable. But if, as in the usual case, operating as a gyroscope, magnetic influences do not affect it (but fast motions of the vehicle), and always true (not magnetic) north is shown.
  A third type of realization is the so-called *GPS compass*: Two antennas are mounted in a well-defined distance to each other, and the phase difference of the received signals of each antenna is used to determine the angle of the linking axis to the satellite, or even to north direction. Alternatively, in objects moving with sufficient speed, this information can be derived from only one antenna – provided that movement takes place in the vehicle axis direction, i.e. drift effects, e.g. with ships or aircraft, cannot be considered.
  Results usually come as digital data sent periodically via the dedicated compass connector X16 ***COMPASS*** (equivalent to X15 ***GPS***) or the LAN X4 ***LAN 1*** and X5 ***LAN 2***.

2.5.1.2 Nautical Angles (Ship Deviations)

The deviation of a ship, aircraft or other vehicle (and therewith the DF antenna mounted to it) from "original" position can be described as a distortion around the three rotational axes

- x: longitudinal
- y: transverse
- z: vertical

These directions of deviation (nautical angles) are called

- x-axis: **Roll** β
  The roll describes the rotation around the longitudinal axis, its letter here is β; positive direction is clockwise when seen from behind (or counter-clockwise from nose as in the figure).
- y-axis: **Pitch** α
  The pitch (or elevation) is the rotation around the transverse axis and is described by α; upward direction of nose (counter-clockwise when seen from right) is defined positive.
- z-axis: **Yaw** γ
  The yaw (or compass heading) can also be considered as a deviation from direction of heading (rotation around vertical axis), here described by the letter γ with positive direction being clockwise when seen from top (vehicle nose facing right of heading direction).

Commonly these expressions mean unwanted vibrations around the respective axis, but here just the value of deviation from "original" position (perfectly horizontal/vertical, nose faces to heading) is represented, see Figure 2-9 and Figure 2-10 for illustration.

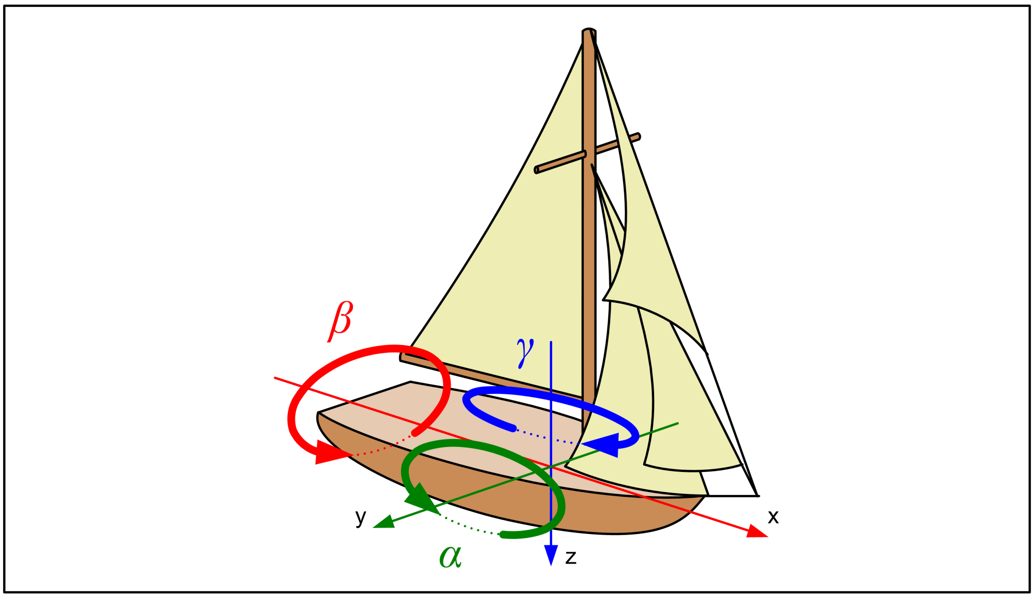


Figure 2-9: Axes of a ship and rotations around them (arrows show positive directions).

α = pitch (elevation)
β = roll
γ = yaw (heading)

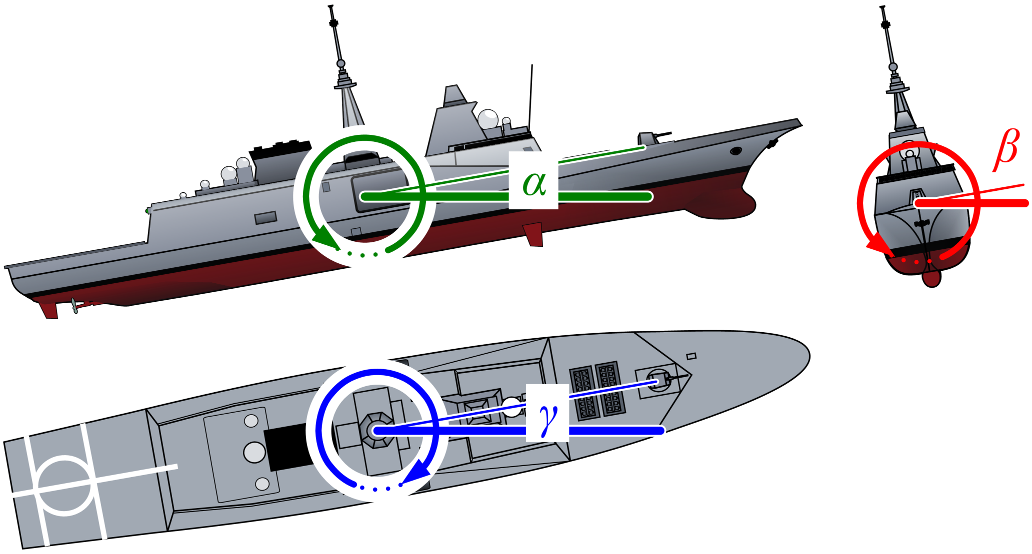


Figure 2-10: Deviations of a ship from ideal position (arrows show positive directions).

bold line = proper (correct) direction
regular line = deviation
top = view from right, α positive
right = view from nose, β positive
bottom = view from top, γ negative

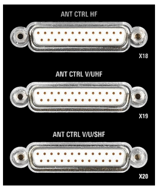
2.5.2 Antenna Compass R&S GH150

2.5.2.1 Uses

For "semi-stationary" applications with sites changing or even non-stationary, i.e. mobile operation in DF vehicles, use of the optional antenna compass (electronic compass) R&S GH150 is recommended. Correct orienting of the antenna to exact north direction will be simplified by this compass rather than using a handheld one. The compass (to a certain degree) is also suitable for computing magnetic north and – if a mechanical antenna orientation to north direction is not possible as in the mobile case – subsequently deciding and establishing the correction value in order to get a correct bearing result out of the raw DF value (versus the antenna north element in its random position). Of course, precision of later on corrected, i.e. final DF value is directly dependent on exactness of determination of this correction value.

2.5.2.2 Installation

The R&S GH150 may alternatively be installed in all antennas, except R&S ADD070 model 02[1)]*. It is fixed permanently to the antenna assembly in advance, after installation a calibration process is needed – which normally (i.e. if the compass is shipped with the antenna) is performed by the antenna manufacturer – to eliminate influence of magnetic deviation (local magnetic fields, see Chapter 2.5.5, "North Alignment", on page 65). In case of a later mounting of the compass to the antenna by the user, or for operation in a mutated magnetic environment, a recalibration is required (see 2.5.2.3). A 13-contact round connector (SJT type) establishes linking to the electrical interface prepared.



Data from the R&S GH150 comes in an internal data format and is transmitted to the R&S DDF5GTS via the control cable of the cable set (**X18**, **X19**, **X20**, see Chapter 2.5.1, "Definition of Terms"). All compass data is requested specifically by the R&S DDF5GTS – no periodic transmission of data is enabled.

For details refer to the R&S GH150 manual.

---

1) *Some antennas (not all usable with the R&S DDF5GTS) cannot be equipped with the R&S GH150: R&S ADD010, R&S ADD011, R&S ADD011SR and R&S ADD012.*

2.5.2.3 Calibration

Antennas delivered with a built-in antenna compass have been calibrated prior to shipping. An undisturbed magnetic environment (no iron objects except the antenna itself) is thereby used as a reference, and magnetic deviation is eliminated this way.

On-site post-calibration is recommended,

- if large iron objects affect, i.e. distort the magnetic field at the site, the most obvious situation in this context is mounting the antenna to an iron mast,
- on the occasion of equipping or re-equipping the DF vehicle, e.g. with additional antennas or other noteworthy iron superstructure.

For post-calibration a special calibration routine is provided for; it is described subsequently.

To perform calibration from an external client, an XML (XML) command [2.4]

- `CompassCmd`

is available (cf Chapter 3.17, "Control by Client Software", on page 243).

Installation in Host Platform

When performing the calibration, this is: compensation procedure, it is important that the compass be installed in the host platform, i.e. everything being rotated during operation (e.g. the entire DF vehicle) has also to be rotated for calibration.

You cannot perform a valid compensation by rotating only the compass!

The Eight-Point method allows you to perform an 8-point field calibration of the R&S GH150. During calibration, you will be asked to position the compass to certain headings. It is not important to position the compass exactly, just as long as it is pointing roughly the right way (i.e. ±15°). All that is required is that the compass reads eight data points in a rough circle, two points per quadrant. It is also permissible to start at any arbitrary heading, not necessarily, for example, with compass north orientation.

Once the calibration is complete, the control program (e.g. `DdfControl`) will display a Noise Score (first number, `X` in the sequence shown in Table 2-5) and a Magnetic Environment Count (second number, `Y`).

The Noise Score is an indication of the quality of the calibration procedure and will be a number in the range 0 to 9, 9 being the best and 0 the worst (Table 2-4). If the Noise Score is 7 or below, recalibration is recommended for optimum accuracy.

Table 2-4: Noise Score value interpretation.

Noise Score, X part	9	8	7	6	5	4	3	2	1	0	
Approximate Accuracy	0.5°	1°	2°	4°	8°	16°	32°	64°	128°	256°	(or better)

The Magnetic Environment Count gives an indication of the quality of the magnetic environment, with, again, 9 being the best and 0 the worst. If the value is less than 5, you should consider relocating and recalibrating the compass in a better environment (i.e. away from magnetic fields and material).

The Calibration Count (`Z` in Table 2-5) indicates the number of times the R&S GH150 has been calibrated, and will be a number between 0 and 255.

User calibration consists of entering the calibration mode and sequentially pointing the compass to eight different headings, approximately 45° apart, as directed by the prompt on the screen of the user monitor. Execution of each direction modification is then conveyed to the compass by serial commands.

It is not necessary to start at any particular heading. It is also not critical that these eight points be exactly 45° apart but try to be within ±15° of the desired heading. For optimum results, the installed compass should be on a stable platform (i.e. turntable) during this procedure. After installing the R&S GH150 in the host system, the calibration procedure should be done in a magnetically clean area.

To start the user calibration process proceed as shown in Table 2-5.

Command Syntax

- The CR stands for a carriage return character (ASCII D_{16}, or enter key).
- In all listings, there is an implied carriage return CR after all the messages. A prompt character > (ASCII $3E_{16}$) indicates that the message was accepted, and an exclamation character ! (ASCII 21_{16}) indicates that the message was not accepted.
- To accommodate a broad range of terminals and communications protocols, a line feed LF character (ASCII A_{16}) transmitted by the user will be accepted, but it will be ignored.
- The commands response uses small letters, not capital letters.
- The command =ce1 consists of an = character, two lower case characters c and e, the number character 1 and a concluding CR. Upper case characters should not be used.
- A particular XML command
  - CompassCmd

  is available to perform calibration, see above.

Table 2-5: Calibration process.

Calibration process			
User typing	**Meaning** ***Tell compass that ...***	**Compass response**	**Meaning (user action to be taken):** ***Turn the compass to ...***
=ce1<CR>	... calibration sequence starts.	> $000.0	... 0° (this can be any reference heading).
=ce1<CR>	... position 0° (reference) is taken.	> $045.0	...45° (this is approx. 45° clockwise from initial position).
=ce1<CR>	... position 45° is taken.	> $090.0	... 90° (this is approx. 90° clockwise from initial position).
=ce1<CR>	... position 90° is taken.	> $135.0	... 135° (this is approx. 135° clockwise from initial position).
=ce1<CR>	... position 135° is taken.	> $180.0	... 180° (this is approx. 180° clockwise from initial position).
=ce1<CR>	... position 180° is taken.	> $225.0	... 225° (this is approx. 225° clockwise from initial position).
=ce1<CR>	... position 225° is taken.	> $270.0	... 270° (this is approx. 270° clockwise from initial position).
=ce1<CR>	... position 270° is taken.	> $315.0	... 315° (this is approx. 315° clockwise from initial position).

Calibration process			
User typing	**Meaning** ***Tell compass that ...***	**Compass response**	**Meaning (user action to be taken):** ***Turn the compass to ...***
=ce1<CR>	... position 315° is taken.		X: Noise Score, Y: Magnetic Environment, Z: Calibration Count. Decide whether responded values signal a successful calibration.
		> > Field Calibration Complete. Noise Score: X, Y Calibration Count Z	

The calibration procedure can be aborted at any time by typing =cez.

Completeness of Calibration Process

A calibration process not cancelled intentionally must be performed completely and diligently. Otherwise – abandoning the calibration process without issuing the aborting command – a proper compass calibration previously existent might have been destroyed and compass values delivered after that might be invalid.

Some useful commands of the R&S GH150 compass command set are scoped in Table 2-6. For information about the complete command set refer to the R&S GH150 user manual.

Table 2-6: Useful commands.

Useful commands			
Compass command	**Meaning**	**Compass response**	**Description**
=ce1<CR>	Perform next calibration step	>	
?cs2<CR>	Query calibration status		X: Noise Score, Y: Magnetic Environment, Z: Calibration Count.
		> ?cs2,X,Y,Z<CR>	
=cez<CR>	Cancel calibration		
		> Calibration aborted	
?w<CR>	Query compass information		XXXXXXX: serial number, A: software version, B: hardware version, C: hardware type, YY/MM/DD: date of manufacturer calibration.
		> ?w XXXXXXX,A,B,C,YY/MM/DD	
zap<CR>	Warmboot compass		

2.5.3 NMEA 0183 Data Format

2.5.3.1 General

NMEA 0183 is a combined electrical and data specification for communication between marine electronic devices such as echo sounders, sonars, anemometers, gyrocompasses, autopilots, GNSS (e.g. GPS) receivers and many other types of instruments. It has been defined by, and is controlled by, the U.S.-based **N**ational **M**arine **E**lectronics **A**ssociation.

The NMEA 0183 standard uses a simple ASCII, serial communications protocol that defines how data is transmitted in a "message" from one "talker" to multiple "listeners" at a time. Through the use of intermediate expanders, a talker can have a unidirectional conversation with a nearly unlimited number of listeners, and, using multiplexers, multiple sensors can talk to a single computer port.

In NMEA 0183, these messages are called

- sentences.

At the application layer, the standard also defines the contents of each sentence type so that all listeners can parse sentences accurately.

Find more information in [2.5] and [2.6].

2.5.3.2 Data Link Layer

Data exchange in NMEA 0183 is performed in several formats differing slightly concerning baud rate, start and stop bits, parity bits etc. The format used here is shown in Table 2-7. It is set permanently and cannot be changed.

The baud rate in use will be determined automatically by the R&S DDF5GTS.

Table 2-7: NMEA 0183 data format.

Baud rate	Data bits	Start bits	Stop bits	Parity
4800 Bd	8	1	1	None
9600 Bd				
19200 Bd				

2.5.3.3 Application Layer

Each of the NMEA 0183 sentences is organized as follows (all data transmitted in MSByte first/MSB first):

- $ sign,
- *for standard sentence:*
  5 character ID, divided into
  – unit ID (2 characters): will be ignored by the R&S DDF5GTS,
  – kind-of-data ID (3 characters),

- *for proprietary sentence:*
  ID of varying length, divided into
  - 'P' for "proprietary" (1 character),
  - manufacturer code (3 characters),
  - type of sentence (within manufacturer's discretion, no fixed length),
- data fields individual to each sentence, separated from the ID and from each other by commas; count and meaning of data fields differ completely between each kind of sentence,
- (*optional* according to the standard, but *mandatory* with the R&S DDF5GTS) `*` sign, followed by a hexadecimal checksum (generated as XOR relation of all characters between, but not including, `$` and `*`.

Maximum length of a data sequence is 80 characters. Mind that a special length of decimal data fields is not stipulated, recognition happens only from the position within the sentence, and the decimal point itself renders evaluation of the field possible. If not needed, a field may even remain entirely empty, this is, two separating commas come consecutively.

As a representative, data format and an example are given for the DBT (**D**epth **B**elow **T**ransducer) sentence, explanation can be seen in Table 2-8.

Data format:

```
ID      1    2 3    4 5    6 7
|       |    | |    | |    | |
$uikdi,x.x,f,x.x,M,x.x,F*hh<CR><LF>
```

Example:

```
ID      1     2 3    4 5    6 7
|       |     | |    | |    | |
$SDDBT,22.3,f,6.8,M,3.7,F*3F<CR><LF>
```

Table 2-8: NMEA 0183 sentence architecture example.

NMEA 0183 sentence architecture				
	Item in			
No.	**data format**	**example**	**Type**	**Meaning**
ID	`$`	`$`		Start character
	`ui`	`SD`	Talker (kind of unit)	Sounder, Depth
	`kdi`	`DBT`	Message type (kind of data)	Depth Below Transducer
1	`x.x`	`22.3`	Data value	Depth [feet]
2	`f`	`f`	Unit	Feet
3	`x.x`	`6.8`	Data value	Depth [m]
4	`M`	`M`	Unit	Meters
5	`x.x`	`3.7`	Data value	Depth [fathoms]
6	`F`	`F`	Unit	Fathoms

NMEA 0183 sentence architecture				
	Item in			
No.	data format	example	Type	Meaning
7	*	*		Separation character
	hh	3F		Hexadecimal checksum
	<CR><LF>	<CR><LF>		Terminating sequence <CR><LF>

For detailed information about NMEA 0183 standard, refer to NMEA's website

- http://www.nmea.org/

or other surveys provided e.g. in the internet.

2.5.3.4 Paths within the R&S DDF5GTS

The R&S DDF5GTS accepts NMEA 0183 sentences via two paths:

- via the RS-232 plugs where the compass and GNSS receiver units are connected
- via UDP

Whereas with connected (especially GNSS) units the common frequency in use is one sentence a second, a maximum frequency of ten sentences a second is recommended for UDP.

UDP Packet Length with NMEA 0183 sentences

The length of a UDP packet to be received by the R&S DDF5GTS (containing one or even more NMEA 0183 sentences) is limited to 100 characters.

2.5.4 Gyrostatic Compass with NMEA 0183 Data Output

2.5.4.1 Uses

For mobile applications, connecting a gyrostatic compass is recommended. This type of compass (not assigned and mounted to an antenna, but existent as a standalone unit) is typically present in vehicles, ships or aircraft. Direction measuring is performed continuously, and so is output of result data, this is, no special querying of direction information needs to be done. Data provided accords to the NMEA 0183 standard (see Chapter 2.5.3).

2.5.4.2 Installation

The compass is connected to the **X16** ***COMPASS*** (or the equivalent **X15** ***GPS***) plug of the R&S DDF5GTS. Direction information is produced and transmitted using the NMEA 0183 sentence format (see Chapter 2.5.3).

2.5.4.3 Evaluated NMEA 0183 Sentences

General

The most important items evaluated are the heading items; preferably the heading indication against true north is used or, if not available, as an alternative the heading against magnetic north. Additionally, values for magnetic variation (also called declination, ① in Figure 2-11) and magnetic deviation (see Chapter 2.5.5.1, "Definition of Terms") are read. Other sentence components are only given here for completeness, detailed information can be found in relevant publications.

Description Completeness

Be aware that the NMEA 0183 sentences described subsequently are only the ones that are evaluated by the R&S DDF5GTS. Compasses are able to emit many more than these sentences; their description, if needed, may be looked up in relevant publications.

The description of the sentences mentioned, however, is given completely, even though not any individual item of a particular sentence might be used.

HCHDG

The first sentence type serviced by the compass and accepted by the R&S DDF5GTS is the HCHDG sentence. As explained in Chapter 2.5.3, the first 2 characters of the sentence identifier represent the ID of the sending unit, here HC stands for "Heading Compass", and the second 3 for the kind of sentence, here HDG for "Heading Deviation & Variation". Thus, this sentence comprises deviation and variation of the magnetic sensor.

Sentence format is (*data format*):

```
ID     1   2   3 4   5 6
|      |   |   | |   | |
$HCHDG,h.h,d.d,a,v.v,b*hh<CR><LF>
```

Example:

```
ID     1     2     3 4     5 6
|      |     |     | |     | |
$HCHDG,004.6,002.1,W,001.5,W*2B<CR><LF>
```

with the individual items explained in Table 2-9. Leading and trailing sentence parts not explained here can be looked-up in Chapter 2.5.3.

Table 2-9: HCHDG sentence architecture.

HCHDG				
	Item in			
No.	data format	example	T.	Meaning
ID	HC		T	Heading Compass
	HDG		M	Heading Deviation & Variation
1	h.h	004.6	D	Magnetic sensor heading [° (degrees)] (example: 4.6° meaning 4° 36')
2	d.d	002.1	D	Magnetic deviation (Chapter 2.5.5.1) [°] (example: 2.1° meaning 2° 6')
3	a	W	I	Direction of magnetic deviation: • E: east • W: west
4	v.v	001.5	D	Magnetic variation (declination: ① in Figure 2-11) [°] (example: 1.5° meaning 1° 30')
5	b	W	I	Direction of declination: • E: east • W: west

T. *Type of data: (cf also annotation of Table 2-14)*
- *T: talker (kind of unit)*
- *M: message type (kind of data)*
- *D: data value*
- *I: indicator*
- *U: unit*

HCHDM

The next sentence type is the HCHDM sentence. HDM stands for "Heading Magnetic" ("Magnetic" means that magnetic north is indicated in contrast to true north). Thus, this sentence comprises the (magnetic) north offset of the vehicle.

Sentence format is (*data format*):

```
ID      1   2 3
|       |   | |
$HCHDM,x.x,M*hh<CR><LF>
```

Example:

```
ID      1     2 3
|       |     | |
$HCHDM,003.1,M*2B<CR><LF>
```

with the individual items explained in Table 2-10. Leading and trailing sentence parts not explained here can be looked-up in Chapter 2.5.3.

Table 2-10: HCHDM sentence architecture.

HCHDM				
No.	Item in data format	Item in example	T.	Meaning
ID	HC		T	Heading Compass
	HDM		M	Heading Magnetic
1	x.x	003.1	D	Heading [°] against magnetic north (example: 3.1° meaning 3° 6')
2	M	M	I	Magnetic north (invariant)

HCHDT

The HCHDT sentence type describes, as indicated by the HDT ID, "Heading True" ("True" means that true north is indicated in contrast to magnetic north). Thus, this sentence comprises the (true) north offset of the vehicle.

Sentence format is (*data format*):

```
ID     1   2 3
|      |   | |
$HCHDT,x.x,T*hh<CR><LF>
```

Example:

```
ID     1     2 3
|      |     | |
$HCHDT,003.1,T*2B<CR><LF>
```

with the individual items explained in Table 2-11. Leading and trailing sentence parts not explained here can be looked-up in Chapter 2.5.3.

Table 2-11: HCHDT sentence architecture.

HCHDT				
No.	Item in data format	Item in example	T.	Meaning
ID	HC		T	Heading Compass
	HDT		M	Heading True
1	x.x	003.1	D	Heading [°] against true north (example: 3.1° meaning 3° 6')
2	T	T	I	True north (invariant)

HCOSD

A sentence type also accepted by the R&S DDF5GTS is the HCOSD sentence. OSD means "Own Ship Data".

Sentence format is (*data format*):

```
ID     1   2 3   4 5   6 7   8   9 10
|      |   | |   | |   | |   |   | |
$HCOSD,h.h,A,c.c,a,s.s,a,v.v,d.d,a*hh<CR><LF>
```

Example:

```
ID      1      2 3...9 10
|       |      | |   | |
$HCOSD,20.34,A,(...)*3F<CR><LF>
```

with the individual items explained in Table 2-12. Leading and trailing sentence parts not explained here can be looked-up in Chapter 2.5.3.

Table 2-12: HCOSD sentence architecture.

HCOSD				
	Item in			
No.	**data format**	**example**	**T.**	**Meaning**
ID	HC		T	Heading Compass
	OSD		M	Own Ship Data
1	h.h	20.34	D	Heading [°] against true north (example: 20.34° meaning 20° 20.4' = 20° 20' 24")
2	A	A	I	Validity: ● A: (active) data valid ● V: (void) data invalid
3	c.c		D	Vessel course [°] against true north 1)*
4	a		I	Course reference 1)*
5	s.s		D	Speed of vessel 1)*
6	a		I	Speed reference 1)*
7	v.v		D	Vessel set [°] against true north 1)*
8	d.d		D	Vessel drift (speed) 1)*
9	a		I	Speed units 1)*

1) *These items are not used (evaluated) by the R&S DDF5GTS, thus, indications are made only for completeness. For detailed information refer to relevant publications.*

HCVHW

The next sentence type is the HCVHW sentence. VHW stands for "Water speed and heading".

Sentence format is (*data format*):

```
ID      1   2 3    4 5    6 7    8 9
|       |   | |    | |    | |    | |
$HCVHW,t.t,T,m.m,M,n.n,N,k.k,K*hh<CR><LF>
```

Example:

```
ID      1      2 3      4 5     6 7     8 9
|       |      | |      | |     | |     | |
$HCVHW,133.47,T,131.43,M,12.56,N,23.26,K*5E<CR><LF>
```

with the individual items explained in Table 2-13. Leading and trailing sentence parts not explained here can be looked-up in Chapter 2.5.3.

Table 2-13: HCVHW sentence architecture.

HCVHW				
	Item in			
No.	data format	example	T.	Meaning
ID	HC		T	Heading Compass
	VHW		M	Water speed and heading
1	t.t	133.47	D	Heading [°] against true north (example: 133.47° meaning 133° 28.2' = 133° 28' 12")
2	T	T	I	True north (invariant)
3	m.m	131.43	D	Heading [°] against magnetic north (example: 131.43° meaning 131° 25.8' = 131° 25' 48")
4	M	M	I	Magnetic north (invariant)
5	n.n	12.56	D	Speed of vessel relative to the water [knots][1)*]
6	N	N	U	Knots[1)*]
7	k.k	23.26	D	Speed of vessel relative to the water [km/h][1)*]
8	K	K	U	Kilometers per hour[1)*]

1) *See footnote 1 of Table 2-12.*

PRSHRP

Another special sentence type accepted by the R&S DDF5GTS is the proprietary (private) PRSHRP sentence containing heading, roll and pitch angle (RP). Mind that proprietary sentences have a slightly differing architecture.

Sentence format is (*data format*):

```
ID      1 2   3   4   5   6   7   8 9 10        11 12 13   14
|       | |   |   |   |   |   |   | | |         |  |  |    |
$PRSHRP,S,h.h,r.r,p.p,k.k,t.t,u.u,B,D,hhmmss.sss,dd,mm,yyyy*hh<CR><LF>
```

Example:

```
ID      1 2       3       4     5     6    7     8 9 10          11 12 13   14
|       | |       |       |     |     |    |     | | |           |  |  |    |
$PRSHRP,1,127.883,-13.247,8.970,-5.31,0.87,11.34,A,A,152319.564,13,01,2015*2E<CR><LF>
```

with the individual items explained in Table 2-14. Leading and trailing sentence parts not explained here can be looked-up in Chapter 2.5.3. For nautical angles consult Chapter 2.5.1.2.

Table 2-14: PRSHRP sentence architecture.

PRSHRP				
	Item in			
No.	**data format**	**example**	**T.**	**Meaning**
ID	P		F	Proprietary (private identifier)
	RSH		C	Manufacturer code: *Rohde & Schwarz*
	RP		E	Roll, pitch (sentence identifier, defined by manufacturer)
1	S	1	I	Source*1)**: ● 0: unknown ● 1: single MINS, or (in dual systems) MINS1 ● 2: MINS2 (in dual systems only)
2	h.h	127.883	D	Heading (yaw) angle [°]*2)** (0° to [360–LSB]°, positive clockwise [0: true north]) (example: 127.883° meaning 127° 52.98' = 127° 52' 58.8")
3	r.r	-13.247	D	Roll angle [°]*2)** (–90° to +90°, positive for starboard down) (example: –13.247° meaning –13° 14.82' = –13° 14' 49.2")
4	p.p	8.970	D	Pitch (elevation) angle [°]*2)** (–90° to +90°, positive for bow up) (example: 8.970° meaning 8° 58.2' = 8° 58' 12.0")
5	k.k	-5.31	D	Heading (yaw) angular rate [°/s (degrees/second)]*2)** (–90 °/s to +90 °/s, positive: clockwise turn) (example: –5.31° meaning –5° 18.6' = –5° 18' 36.0")
6	t.t	0.87	D	Roll angular rate [°/s]*2)** (–90 °/s to +90 °/s, positive: when starboard moving down) (example: 0.87°/s meaning [0° 52.2']/s = [0° 52' 12.0"]/s)
7	u.u	11.34	D	Pitch (elevation) angular rate [°/s]*2)** (–90 °/s to +90 °/s, positive: when bow moving up) (example: 11.34°/s meaning [11° 20.4']/s = [11° 20' 24.0"]/s)
8	B	A	I	Status*3)**: ● V: (void) data invalid (accuracy insufficient) ● A: (active) navigation (specified accuracy reached) ● D: degraded (70 % of specified accuracy reached) ● S: simulation ● M: manual
9	D	A	I	Selection: ● A: (active) sentence selected in system ● V: (void) redundant sentence (not applicable for F125)
10	hhmmss.sss	152319.564	D	UTC timestamp (`hh` hour, `mm` minute, `ss.sss` second, seconds in fractional notation, resolution 1 ms) (example: 152319.564 meaning 15:23:19.564 [03:23:19.564 p.m.] UTC)
11	dd	13	D	UTC day (`dd` day) (example: 13th)
12	mm	01	D	UTC month (`mm` month) (example: 01 meaning January)
13	yyyy	2015	D	UTC year (`yyyy` year) (example: 2015; completely meaning January 13th, 2015)

T. *Type of data: (cf also annotation of Table 2-9)*
- *F: fixed entry*
- *C: manufacturer code*
- *E: manufacturer entry (within manufacturer's discretion)*
- *D: data value*
- *I: indicator*

1) *Not used.*

2) *The number of digits behind the decimal point can be variable. The standard resolution is 0.001° for angles, 0.01 °/s for rates.*

3) *Only 'V' for "data invalid" or any other for "data valid" evaluated.*

PANZHRP

Also supported by the R&S DDF5GTS is the proprietary (private) PANZHRP sentence. This sentence tallies with the PRSHRP sentence (Section "PRSHRP"), but contains no timestamp information. In order to avoid confusion, a complete sentence explanation is given subsequently.

Sentence format is (*data format*):

```
ID        1 2   3   4   5   6   7   8 9 10
|         | |   |   |   |   |   |   | | |
$PANZHRP,S,h.h,r.r,p.p,k.k,t.t,u.u,B,D*hh<CR><LF>
```

Example:

```
ID        1 2       3       4     5     6    7     8 9 10
|         | |       |       |     |     |    |     | | |
$PANZHRP,1,127.883,-13.247,8.970,-5.31,0.87,11.34,A,A*6F<CR><LF>
```

with the individual items explained in Table 2-15. Leading and trailing sentence parts not explained here can be looked-up in Chapter 2.5.3. For nautical angles consult Chapter 2.5.1.2.

Table 2-15: PANZHRP sentence architecture.

PANZHRP				
No.	Item in data format	Item in example	T.	Meaning
ID	P		F	Proprietary (private identifier)
	ANZ		C	Manufacturer code: *Anschütz*
	HRP		E	Heading, roll, pitch (sentence identifier, defined by manufacturer)
1	S	1	I	Source[1)] *: • 0: unknown • 1: single MINS, or (in dual systems) MINS1 • 2: MINS2 (in dual systems only)
2	h.h	127.883	D	Heading (yaw) angle [°][2)] * (0° to [360–LSB]°, positive clockwise [0: true north]) (example: 127.883° meaning 127° 52.98' = 127° 52' 58.8")
3	r.r	-13.247	D	Roll angle [°][2)] * (–90° to +90°, positive for starboard down) (example: –13.247° meaning –13° 14.82' = –13° 14' 49.2")

PANZHRP				
	Item in			
No.	data format	example	T.	Meaning
4	p.p	8.970	D	Pitch (elevation) angle [°][2)]* (–90° to +90°, positive for bow up) (example: 8.970° meaning 8° 58.2' = 8° 58' 12.0")
5	k.k	-5.31	D	Heading (yaw) angular rate [°/s (degrees/second)][2)]* (–90 °/s to +90 °/s, positive: clockwise turn) (example: –5.31° meaning –5° 18.6' = –5° 18' 36.0")
6	t.t	0.87	D	Roll angular rate [°/s][2)]* (–90 °/s to +90 °/s, positive: when starboard moving down) (example: 0.87°/s meaning [0° 52.2']/s = [0° 52' 12.0"]/s)
7	u.u	11.34	D	Pitch (elevation) angular rate [°/s][2)]* (–90 °/s to +90 °/s, positive: when bow moving up) (example: 11.34°/s meaning [11° 20.4']/s = [11° 20' 24.0"]/s)
8	B	A	I	Status[3)]*: • V: (void) data invalid (accuracy insufficient) • A: (active) navigation (specified accuracy reached) • D: degraded (70 % of specified accuracy reached) • S: simulation • M: manual
9	D	A	I	Selection: • A: (active) sentence selected in system • V: (void) redundant sentence (not applicable for F125)

1) 2) 3) See footnotes of Table 2-14.

PASHR

Also supported by the R&S DDF5GTS is the proprietary (private) PASHR sentence containing the heading, roll and pitch angles and heave (wave height).

Sentence format is (*data format*):

```
ID     1          2   3 4   5   6   7   8   9   10  11  12
|      |          |   | |   |   |   |   |   |   |   |   |
$PASHR,hhmmss.sss,H.H,T,R.R,P.P,a.a,r.r,p.p,h.h,Q1,Q2*hh<CR><LF>
```

Example:

```
ID     1          2      3 4        5    6     7     8     9     10 1112
|      |          |      | |        |    |     |     |     |     |  | |
$PASHR,152319.564,127.88,T,-13.24,8.97,-5.31,1.121,3.535,2.639,0,0*2E<CR><LF>
```

with the individual items explained in Table 2-16. Leading and trailing sentence parts not explained here can be looked-up in Chapter 2.5.3. For nautical angles consult Chapter 2.5.1.2.

Table 2-16: PASHR sentence architecture.

PASHR				
	Item in			
No.	**data format**	**example**	**T.**	**Meaning**
ID	P		F	Proprietary (private identifier)
	ASH		M	Manufacturer code: *Ashtech*
	R		E	Sentence identifier (defined by manufacturer)
1	hhmmss.sss	152319.564	D	UTC timestamp[1)]* (hh hour, mm minute, ss.sss second, seconds in fractional notation, resolution 1 ms) (example: 152319.564 meaning 15:23:19.564 [03:23:19.564 p.m.] UTC)
2	H.H	127.88	D	Heading (yaw) angle [°][2)]* (0° to [360–LSB]°, positive clockwise [0: true north]) (example: 127.88° meaning 127° 52.8' = 127° 52' 48") Undefined if not available, unusable if T missing or Q2=1
3	T	T	I	True north (invariant) Undefined if not available
4	R.R	-13.24	D	Roll angle [°][2)]* (–90° to +90°, positive for starboard down) (example: –13.24° meaning –13° 14.4' = –13° 14' 24") 0 if not available
5	P.P	8.97	D	Pitch (elevation) angle [°][2)]* (–90° to +90°, positive for bow up) (example: 8.970° meaning 8° 58.2' = 8° 58' 12") 0 if not available
6	a.a	-5.31	D	Heave [m][1)2)]*
7	r.r	1.121	D	Roll accuracy [°][1)2)]* (0° to 9.999°) (example: 1.121° meaning 1° 7.26' = 1° 7' 15.6")
8	p.p	3.535	D	Pitch (elevation) accuracy [°][1)2)]* (0° to 9.999°) (example: 3.535° meaning 3° 32.1' = 3° 32' 6")
9	h.h	2.639	D	Heading (yaw) accuracy [°][1)2)]* (0° to 9.999°) (example: 2.639° meaning 2° 38.34' = 2° 38' 20.4")
10	Q1	0	I	GPS position mode[1)]*: ● 0: GPS position not fixed ● 1: All GPS position fixes without RTK (Real Time Kinematic, see below) ● 2: RTK integer position fix
11	Q2	0	I	IMU (Inertial Measurement Unit) status: ● 0: IMU OK ● 1: IMU error 1 if not available

1) *Not used.*

2) *Number of digits behind the decimal point: the standard resolution is 0.01° for angles and heave, 0.001° for angle accuracies.*

Priority of Evaluated Sentences

If several NMEA 0183 sentences are sent to the R&S DDF5GTS simultaneously, the one with the highest priority will be evaluated, all other discarded. Priority can be seen from Table 2-17.

Table 2-17: Priority of evaluated NMEA 0183 sentences.

Priority	**High**						**Low**
Sentence	PASHR	PRSHRP[1)]* PANZHRP[1)]*	HCHDT	HCOSD	HCHDG	HCVHW	HCHDM

[1)] *Equal priority.*

2.5.5 North Alignment

2.5.5.1 Definition of Terms

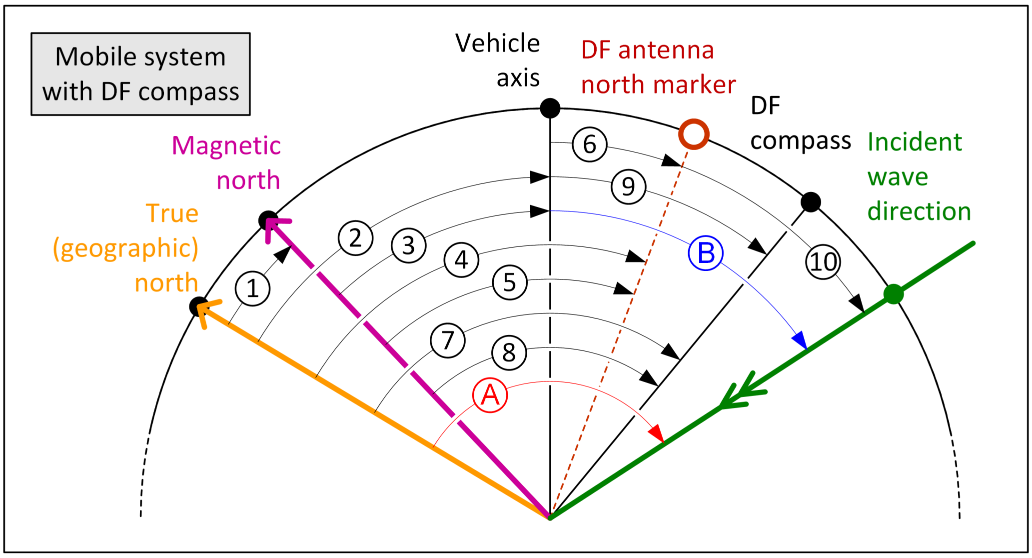


Figure 2-11: Terms to know for a correct antenna north alignment; DF case "Mobile system with DF compass" (universal case).

Ⓐ = DF value vs. true north
Ⓑ = DF value vs. vehicle axis
① = Declination
② = True heading
③ = Magnetic heading
④ = Antenna offset vs. true north
⑤ = Antenna offset vs. magnetic north (antenna compass value)
⑥ = Antenna (mechanical) offset vs. vehicle axis
⑦ = DF compass value vs. true north
⑧ = DF compass value vs. magnetic north
⑨ = DF compass offset vs. vehicle axis
⑩ = Uncorrected DF value (bearing angle vs. antenna north marker)

In Figure 2-11 the universal DF case "Mobile system with DF compass" is shown and all relevant terms for north alignment of a DF antenna are told. Suppose a DF vehicle with an antenna fitted and heading with its nose to upward direction of the figure. All possible deviations presentable in a figure are shown and additionally explained hereafter. Mind that, in contrast to habits in normal geometry, angle indications in the context of the four points of the compass and thus also in direction finding always are done in clockwise direction starting from north.

- **True (geographic) north**
  is the direction indicated by the true North Pole, i.e. the northern exit of the imaginary axis of the earth (rotating axis). It can only be determined directly by a DF system if a gyrostatic compass is available; if magnetic declination is known, it also can be derived from magnetic north.
- **Magnetic north**
  is the north direction given by the North Pole of the earth's magnetic field (physically a south pole). Since magnetic needles align themselves in the magnetic field, this north direction is indicated by any magnetic compass (in case of the earth's magnetic field not disturbed by external influences) – thus, availability of a magnetic compass (e.g. antenna compass) is necessary to obtain it. Depending on location, the deviation between both north directions (called declination, see ①) may vary from some degrees (either neglectible or correctable in advance) up to even 180° (especially in vicinity of the poles). Magnetic North and South Pole of the earth furthermore change temporally (but predictably).
- **Vehicle axis**
  is the axis of the DF vehicle, i.e. its temporary heading (direction of driving). Be aware that with non-earthbound vehicles, due to drift, heading of the vehicle nose might not coincide with direction of motion.
- **DF antenna north marker**
  is the orientation a DF antenna has at the moment. In mobile applications, in case of correct mounting of the antenna to the vehicle, this orientation normally coincides with the vehicle axis, whereas in stationary applications, orienting the antenna to correct north, commonly true north, should be aimed for.
  An antenna compass, if available, also is mounted in this direction – this is, a deviation between antenna north marker and antenna compass orientation is supposed negligible and not considered furthermore.
- **DF compass**
  is the compass value a DF compass (vehicle compass) indicates. This type of compass commonly is integrated in DF vehicles, ships, vessels etc., not necessarily exactly in direction of the vehicle axis and even less in north direction. It is usually, in the example given strictly, a gyrostatic compass.
- **Incident wave direction**
  is the direction a received wave is coming from, i.e. the direction to be found by the direction finder, also called Line of Bearing (LOB).

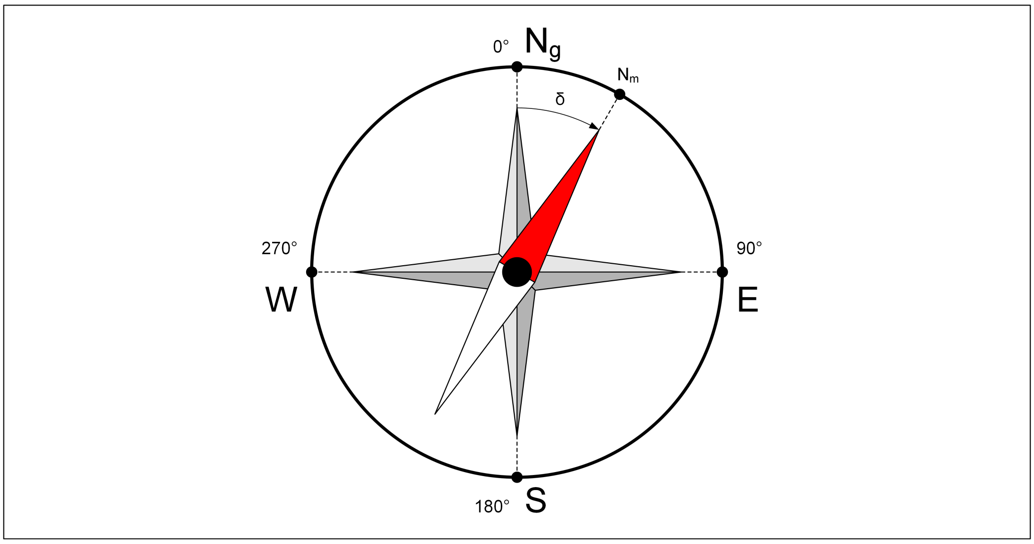


Figure 2-12: Magnetic declination.

N_g = Geographic (true) north
N_m = Magnetic north
δ = Declination
E = East
S = South
W = West

- ① **Declination**
  As explained above and additionally illuminated in Figure 2-12, declination gives the deviation from magnetic to true (geographic) north. Positive declinations show a position of magnetic north direction to the "right" (east) of true north direction. Declination often is also denoted as magnetic variation. It can, for a known location, be taken from relevant literature or maps or as well be determined by comparing the outputs of a gyrostatic and a magnetic compass (if available). This information is also supplied by common GNSS receivers.
- ② **True heading**
  means the heading of the vehicle indicated related to true north.
- ③ **Magnetic heading**
  means the heading of the vehicle indicated related to magnetic north.
- ④ **Antenna offset versus true north**
  gives the deviation (rotation) of the antenna north marker related to true north. In the stationary case, an antenna commonly will be oriented northward as precise as possible; in mobile direction finding, the antenna is rotated with the vehicle, thus, this deviation has always to be compensated supplementarily.
- ⑤ **Antenna offset versus magnetic north**
  gives the deviation (rotation) of the antenna north marker related to magnetic north, i.e. the compass value a connected (magnetic) antenna compass would issue.
- ⑥ **Antenna offset versus vehicle axis**
  gives the deviation (rotation) of the antenna north marker related to the vehicle axis. This is a merely geometric factor and commonly should be eliminated already when mounting the antenna to the vehicle; the correct north orientation of a

DF antenna is marked not only by a sticker, but also by shaping of the mounting equipment – this means, in the normal case it is not possible at all to mount the antenna elsewhise than in vehicle axis direction.

- ⑦ **DF compass value versus true north**
gives the indication of the DF compass if it is a gyrostatic compass (the normal case), i.e. the angle the compass is rotated around against true north.
- ⑧ **DF compass value versus magnetic north**
gives the indication of a magnetic DF compass (the exceptional case), i.e. the angle the compass is rotated around against magnetic north.
- ⑨ **DF compass offset versus vehicle axis**
again is a purely geometric error reflecting the degree of deviation of DF compass mounting from the exact vehicle axis. Compensating this angle mechanically in reality might be difficult due to situation in the vehicle interior.
- ⑩ **Uncorrected DF value (bearing angle versus antenna north marker)**
is the "raw" DF value: the direction of the incident wave as determined by the DF antenna related to its north marker and not corrected by any of the factors mentioned above.
- Ⓐ **DF value versus true north**
gives the direction of the incident wave, related to true north, the factor usually desired in stationary DF systems.
- Ⓑ **DF value versus vehicle axis**
gives the direction related to the vehicle axis, the factor usually demanded in mobile direction finding – this is, in the example of a car chase, the optimal heading to track.

Additional terms to be known are

- **Magnetic deviation**
summarizes all influences caused by the metal environment of the DF antenna, like masts, ship walls, other antennas nearby etc. induced to the magnetic field of the earth and thus deforming it from the ideal case. This deviation in the common case is invariant and thus can be measured in advance and compensated for subsequently.

Antenna Compass Values

In the following it is assumed that antenna compasses and other compasses mounted directly to a direction finder deliver angle values in relation to magnetic north. From this, a calibration of such a compass eliminates only the magnetic deviation (disturbance of the earth's magnetic field), but not magnetic declination (variation).

2.5.5.2 Aim of Calculation

The following scope summarizes the interesting factors for mobile and stationary direction finding and how to calculate them from values obtained in each DF case; detailed information and graphical diagrams are given in the subsequent chapters.

Magnetic and Geographic (True) North

Define diligently whether magnetic or geographic north is to be used as a reference:

- In mobile applications, the magnetic compass mounted directly to the antenna (antenna compass) is used mostly, it indicates magnetic north.
- Fixed (stationary) radiomonitoring stations, however, refer to geographic indications, i.e. maps, polar coordinates or long-path bearing (spherical calculations) – these always refer to true north.
- The deviation between both, called magnetic declination or magnetic variation, in Central Europe is just 1° or 2° and thus, depending on precision desired, might perhaps be ignored. But in other "temperate zones" of the earth, particularly in nordic countries or even in respectable parts of the U.S.A. and Canada, this angle difference increases considerably. Hence it can no longer be ignored and thus should be included when entering the static offsets.
  Detailed information about declination (e.g. maps) can be found in relevant publications.

Mobile Direction Finding

In mobile direction finding, several factors may be of interest:

DF Value versus True North Ⓐ

Ⓐ = ② + ⑥ + ⑩ .

Remember that for determining of true heading ② directly, a gyrostatic compass must exist as the DF compass in the system. If only a magnetic compass is available, magnetic heading ③ leads to the DF value versus magnetic north

Ⓧ = ③ + ⑥ + ⑩ .

Correct this value with the declination ① to obtain the value demanded:

Ⓐ = ① + Ⓧ = ① + ③ + ⑥ + ⑩ .

DF Value versus Vehicle Axis Ⓑ

Ⓑ = ⑥ + ⑩ = Ⓐ – ② .

This DF value is a relative value independent of the position of the vehicle relative to earth's surface, thus, the first part of the equation arises merely from the uncorrected DF value and the geometric position of the antenna on the vehicle. Hence no compass is needed at all.

True Heading ②

If only an antenna compass is available, first determine magnetic heading

③ = ⑤ – ⑥

and then true heading by considering the declination

② = ① + ③ = ① + ⑤ – ⑥ .

With a magnetic DF compass in the vehicle, determine magnetic heading as

③ = ⑧ – ⑨

and, again, correct it by the declination for true heading

② = ③ + ① = ⑧ – ⑨ + ① ,

or use a gyrostatic compass to obtain true heading directly

② = ⑦ – ⑨ .

Stationary Direction Finding

In stationary direction finding, calculations and factors of interest in principle are the same as in mobile applications. Because a vehicle axis does not exist in this case, no DF value related to it can be calculated anymore. Equate the former axis to the antenna north, remembering that also a DF compass in a stationary system does not exist

⑥ = 0 .

The antenna offset to true north ④ is just a geometric factor now and can be entered manually. Again, if only a magnetic antenna compass exists, calculate antenna offset to true north from that to magnetic north from

④ = ① + ⑧ .

The latter will be determined automatically if an antenna compass is connected. Without any compass available, enter mechanical offset to true north ④ manually.

For antennas with several antenna ranges (frequency ranges due to several circular arrays or UCAs [Uniform Circular Array] present) it might be necessary to specify a mechanical offset ④ for each individual range (no exact geometrical alignment of UCAs to each other existing). This can be performed by the DF error correction data; find more information in Chapter 3.8, "DF Error Correction", on page 150 and in [1.1].

DF Value versus True North Ⓐ

The bearing result (Line of Bearing, LOB) related to true north then arises from

Ⓐ = ④ + ⑩ = ① + ③ + ⑩ .

2.5.5.3 DF Value Correction in Different DF Cases

This chapter explains north correction for the relevant realistic DF cases, advancing from the general case to more special cases. The interesting angle factors are shown in diagrams for each case, factors that are not relevant any longer being presented anyway, but dashed, in order to make a diagram easier to derive from the previous one and thus for more clarity.

The procedure in the DF system is always

1. Calculate the uncorrected DF value (angle value of the incoming wave related to the antenna north marker) from the received antenna signals.

2. Correct the obtained DF value by a correction value, sometimes called "offset" or "antenna offset".
   This correction value in the end describes the real position of the antenna (antenna north marker rotated from real north). In stationary applications, the value is calculated once (or once again on request) in advance from all relevant influences and then stays unchanged, whereas in mobile direction finding, the vehicle position changes continually and hence must be determined continually by a compass and incorporated also.
3. Display the corrected DF value.

An additional correction of environment influences can be performed by the DF Error Correction (see Chapter 3.8, on page 150).

Mobile System with DF Compass

The "Mobile system with DF compass" case is the most general case, it is shown in Figure 2-11 (except that an antenna compass does not necessarily exist). The fixed correction factor for an exact Ⓐ indication consists of ⑥ and ⑨; one method to determine it is simply to measure it geometrically, another one is doing two consecutive bearings to a known transmitter (known direction α_{XMIT}):

1. Bearing with DF compass switched on: α_{ON}
2. Bearing with DF compass switched off (⑧ = 0 or ⑦ = 0, depending on compass type): α_{OFF}

$\alpha_{ON} - \alpha_{OFF} =$ ⑧ .

The sum of the mechanical offsets mentioned then results as

$\gamma = \alpha_{XMIT} - \alpha_{ON} -$ ⑧ $= \alpha_{XMIT} + \alpha_{OFF}$.

For being able to do measurements versus vehicle axis Ⓑ, the single ⑥ value is needed. Besides the geometrical method mentioned above, a way to obtain the unknown value is to determine the vehicle position by a usual compass and compare it to the antenna compass output.

Mobile System with Antenna Compass

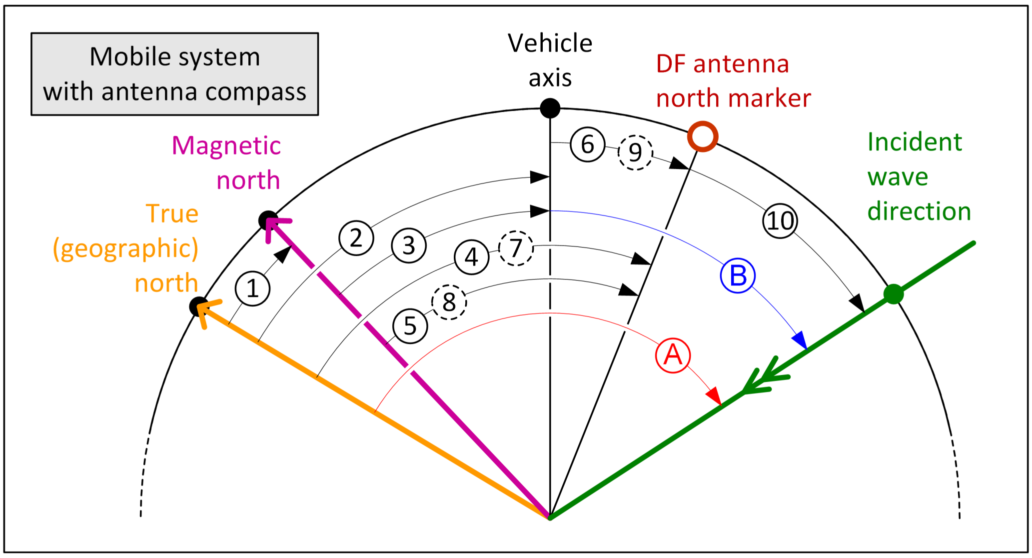


Figure 2-13: Mobile system with antenna compass.

In Figure 2-13 the "Mobile system with antenna compass" case is shown. In effect, there is no DF compass existing any longer, and the antenna compass (commonly a magnetic compass) takes on its task.

Stationary System with Antenna Compass

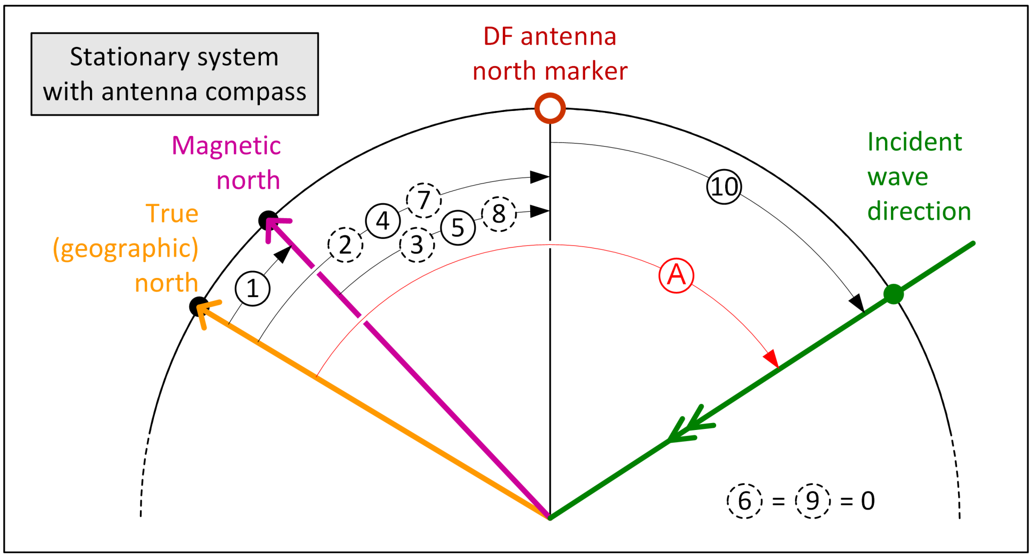


Figure 2-14: Stationary system with antenna compass.

The "Stationary system with antenna compass" case is given in Figure 2-14 – no vehicle axis is defined anymore and hence also no bearing versus this axis. The DF antenna, however, is oriented to another direction than exact north (indicated by the antenna compass), so a correction factor is to be regarded still.

Stationary System without Compass

System Oriented to True North

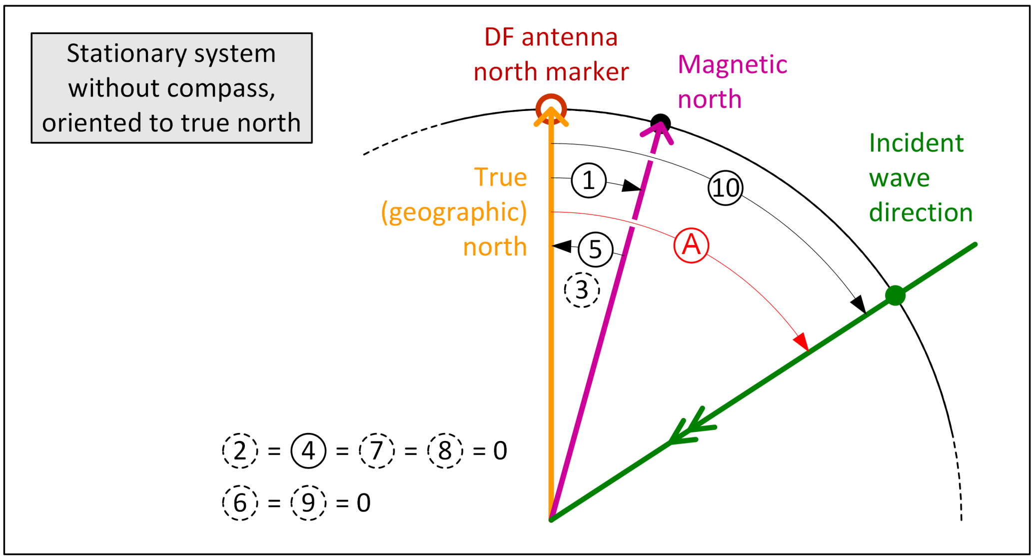


Figure 2-15: Stationary system without compass, system oriented to true north.

In Figure 2-15, the case "Stationary system without compass, system oriented to true north" can be seen. Due to orientation of the antenna to exactly the direction the bearing is to be related to, a correction factor is not needed.

System Oriented to Magnetic North

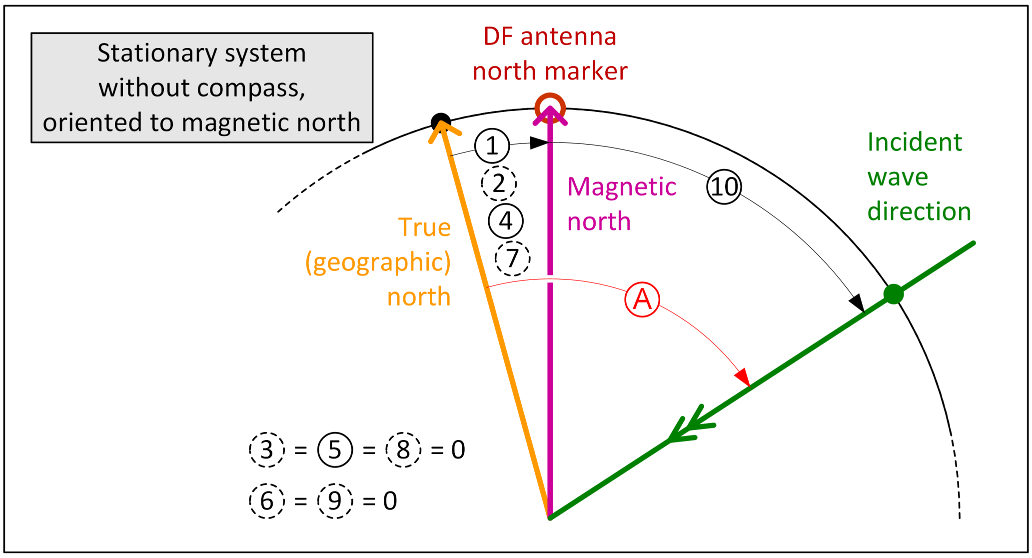


Figure 2-16: Stationary system without compass, system oriented to magnetic north.

If the antenna is adjusted to magnetic rather than to true north (Figure 2-16, e.g. if only a magnetic compass is available for orienting it), the case "Stationary system without compass, system oriented to magnetic north" arises. The only correction factor to be induced in this case is the magnetic declination.

2.5.5.4 The North Alignment Procedure

After having installed the direction finder, carry out a north alignment to obtain correct DF indication:

In stationary applications, for all antennas existing the angle between the so-called reference radiator (radiator 1 with *Rohde & Schwarz* antennas) and true north at the site has to be determined. Because antennas are fixed and thus never will be moved or rotated, the antenna compass is not used in this case.

When using the antenna compass (reasonably only in mobile applications), the declination (① in Figure 2-11) has to be determined. This is essential for a later referring to cartographic information.

A sticker provided with every *Rohde & Schwarz* DF antenna marks radiator 1 and thus shows aimed north direction. DF vehicles have been configured the way that radiator 1 is lined up with the vehicle axis in driving direction/vehicle nose. The boreholes in the antenna flange are coded mechanically, i.e. by shape, and thus allow no adjustment by rotating. The remaining angular deviation will be compensated electronically. The according procedure is explained in this chapter; it requires the user to be familiar with the operation of the R&S DDF5GTS.

Methods for Determining North in Stationary Applications

For finding north in stationary applications, the classical way is to make do with a handheld compass. Experienced operators, nevertheless, will prefer the DF system itself to determine north direction by using bearing results of signals from known transmitters. Their frequency is well-known, and emission of a sufficiently strong signal is taken for granted.

Two methods are possible:

- Taking bearings of a known transmitter situated not necessarily in the north direction,
- Directing a technical assistant into the true north direction (found in advance with a compass).

The calculation formula is in both cases

Correction value = True angle – Measured angle.

Of course, by applying the "modulo +360°" (adding or subtracting n·360°) the result is to be transformed into the range of 0° to 360°. (Bearing angles are always indicated as positive angles, so normally no sign is specified.)

Before starting the measurement, the previously active north offset in the MMI or R&S DDF5GTS has to be reset to 0°.

Known Transmitter Method

A transmitter in a known azimuth direction (not necessarily north) produces the incoming signal.

Two examples of correction value measurement are shown in Figure 2-17. In both examples, an antenna with 9 elements (radiators) is shown, and the transmitter producing the incoming wave is situated at 60° from north.

Example 1

In Figure 2-17, left, radiator 1 is currently rotated to 75° from north or, thus, 15° to the right of the incoming wave. For this reason, a bearing angle of 345° or –15° will be obtained, and by this the deducted correction value is to be calculated as 60° – (–15°) = 75°.

Example 2

In Figure 2-17, right, the reference radiator is situated at 25° from north or 35° at the left of the incoming wave. So the bearing angle obtained will be of 35°, the deducted correction value is calculated as 60° – 35° = 25°.

The DF indication obtained this way of course is in any case uncorrected and requires new calculation with the correction values to obtain the correct value.

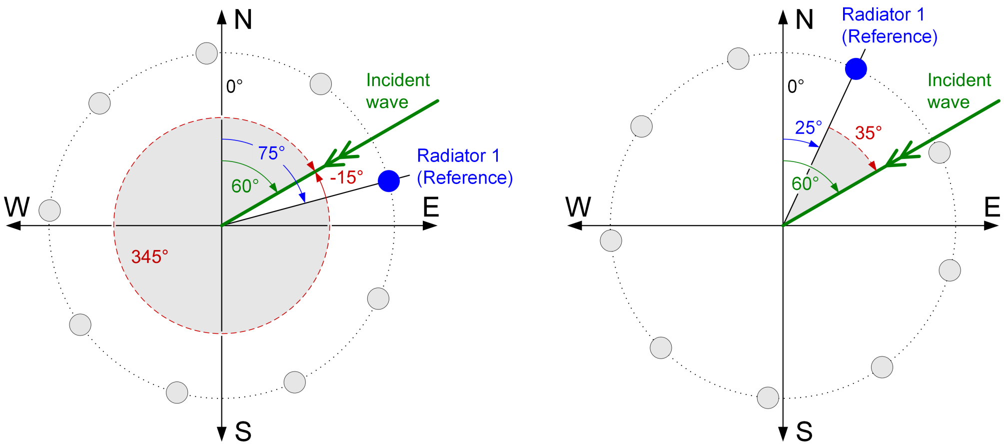


Figure 2-17: North alignment.

left = example 1: radiator 1 right of incoming test signal
right = example 2: radiator 1 left of incoming test signal
green = incident wave direction vs. north: desired bearing angle
red = bearing angle against reference radiator: obtained bearing angle
blue = reference radiator rotation against north: correction value

Technical Assistant Method

If an adequate terrain is available (i.e. without obstacles), a technical assistant is sent to a position in true north direction (which was determined beforehand with a compass). Distance should be at least 100 m from the observer (direction finder position). The assistant's position can be controlled and checked from the DF station for instance using a handheld transceiver – at least one transceiver is needed anyway since the assistant has to simulate the transmitter lying north. Again, to determine the offset between reference radiator and true north a bearing is taken. Due to the incoming wave now coming from true north, no additional calculation need be performed, but the bearing result itself shows the correction value to be applied. Mind that with this method correcting and hence bearing precision depend directly on the precision true north has been decided with.

2.5.6 GNSS Receiver

2.5.6.1 Uses

Bearing results once obtained are always supplied with a timing information (cf Chapter 3.6, "System Time", on page 124). This identifies the bearing data uniquely and facilitates an eventual post-evaluation later on; with the option R&S DDFGTS-TS (*Time Synchronization*, see Chapter 2.6.4) installed, this timing information becomes essential for being able to synchronize several R&S DDF5GTS units to each other.

Timing data can be derived from the internal realtime clock of the R&S DDF5GTS, or, more precisely, be delivered from a GNSS receiver:

- integrated, i.e. the option R&S DDF-IGT (*Internal GPS Module*), or R&S DDFGTSIGT2 (*Internal GNSS Module*), see Chapter 2.6.9 on page 86
- connected externally, e.g. the R&S GINA (**G**PS-Based **I**nertial **NA**vigator)

The GNSS receivers recommended so far are listed in Table 2-18.

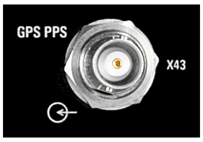
Table 2-18: Recommended GNSS receivers.

Recommended GNSS receivers		
Designation	**Type**	**Order number**
Internal GPS Module	R&S DDF-IGT	4079.8009.04
Internal GNSS Module	R&S DDFGTSIGT2	4079.8209.04
GPS Navigator	R&S GINA	4055.6906.04
GPS Receiver	R&S GPS129	3026.1010.02 (AC supply) 3026.1010.04 (DC supply)

2.5.6.2 Installation and Initialization

GNSS receivers are plugged to the **X15** ***GPS*** (or the equivalent **X16** ***COMPASS***) connector for controlling, they send their high-precision one-second pulse (PPS) to the **X43** ***GPS PPS*** BNC plug. The data format used is the NMEA 0183 sentence format (see Chapter 2.5.3, "NMEA 0183 Data Format", on page 53).

Initialization of the GNSS receiver is performed by the R&S DDF5GTS firmware. For additional information about initialization details, refer to the manual of the individual GNSS receiver you use. In case of use of the R&S GINA, also consult the manual of the *GARMIN* GPS 15L integrated therein.



NOTICE

Reprogramming of Initialization Parameters

Exercise extreme caution when doing modifications in initializing procedure. Especially the baud rate should not be changed without a convincing reason, in order not to disturb or destroy entirely data communications with the GNSS system.

2.5.6.3 Evaluated NMEA 0183 Sentences

GNSS receptions are performed by the receiver every 1 second, with a NMEA 0183 sentence set delivered with each reception event. This is the default value of, for example, the GARMIN GPS 15L receiver. A reprogramming of the repeat rate (and even more parameters) can be performed by the NMEA 0183 sentence PGRMC1 (Proprietary Garmin Additional Sensor Configuration Information), which in detail is described in [2.2] or [2.3]. Caution doing so is recommended strongly.

It is also possible to inhibit data of individual kinds of sentence completely. The PGRMO (Proprietary Garmin Output Sentence Enable/Disable, [2.2], [2.3]) sentence is used for that, information can be found in the R&S GINA manual.

GPRMC

The first message (sentence) type serviced by the GNSS receiver is the GPRMC sentence. As explained in Chapter 2.5.3, the first 2 characters of the sentence identifier represent the ID of the sending unit, here GP stands for "GPS", and the second 3 the kind of sentence, here RMC for "Recommended Minimum Navigation Information, Type C".

GPRMC is a sentence needed undispensably by the R&S DDF5GTS for determining position (latitude and longitude) and time (UTC). As can be seen from Table 2-19, also yielded are speed over ground, moving direction and magnetic variation (declination), if emitted by the corresponding GNSS receiver.

Sentence format is (*data format*):

```
ID     1         2 3       4 5        6 7   8   9      10  1112 13
|      |         | |       | |        | |   |   |      |   | |  |
$GPRMC,hhmmss.ss,v,llll.ll,a,yyyyy.yy,b,s.s,m.m,ddmmyy,x.x,c,m*hh<CR><LF>
```

Example:

```
ID     1         2 3         4 5          6 7    8     9    101112 13
|      |         | |         | |          | |    |     |     || |  |
$GPRMC,102548.93,A,4836.5375,N,12136.0099,W,2.69,79.65,230609,,,A*7D<CR><LF>
```

with the individual items explained in Table 2-19. Leading and trailing sentence parts not explained here can be looked-up in Chapter 2.5.3.

Table 2-19: GPRMC sentence architecture.

GPRMC				
No.	Item in data format	Item in example	T.	Meaning
ID	GP		T	GNSS
	RMC		M	Recommended Minimum Navigation Information, Type C
1	hhmmss.ss	102548.93	D	UTC timestamp (hh hour, mm minute, ss.ss second, seconds in fractional notation, resolution 1 ms) (example: 102548.93 meaning 10:25:48.93 [10:25:48.93 a.m.] UTC)
2	v	A	I	Validity: ● A: (active) data valid ● V: (void) data invalid
3	llll.ll	4836.5375	D	Latitude [°, ' (degrees, minutes)] (minutes in fractional notation) (example: 4836.5375° meaning 48° 36.5375' = 48° 36' 32.25")
4	a	N	I	Hemisphere of latitude: ● N: northern ● S: southern
5	yyyyy.yy	12136.0099	D	Longitude [°, '] (see on "latitude") (example: 12136.0099° meaning 121° 36.0099' = 121° 36' 0.594")
6	b	W	I	Hemisphere of longitude: ● E: eastern ● W: western
7	s.s	2.69	D	Speed over ground [knots] (example: 2.69 knots)
8	m.m	79.65	D	Moving direction [°] (example: 79.65° meaning 79° 39.0' = 79° 39' 0")
9	ddmmyy	230609	D	Date (dd day, mm month, yy year) (example: 230609 meaning June 23th, 2009)
10	x.x	-	D	Magnetic variation (declination) [°] (often empty due to GNSS)[1)] *
11	c	-	I	Direction of declination (often empty due to GNSS)[1)] *: ● E: east ● W: west
12	m	A	I	Mode of determination (aka "FAA mode") indicator[2)] *: ● A: autonomous mode ● D: differential mode ● E: estimated (dead-reckoning) mode ● M: manual input mode ● S: simulated mode ● N: data not valid

T. *Type of data:*
- *T: talker (kind of unit)*
- *M: message type (kind of data)*
- *D: data value*
- *I: indicator*
- *U: unit*

[1)] *Fields not used (evaluated), but declination calculated autonomously by the R&S DDF5GTS.*

[2)] *Field only existing with (applying to) NMEA revision 2.3 and later, otherwise absent.*

GPGGA

The other sentence type is the GPGGA sentence. The kind of sentence here is GGA for "Global Positioning System Fix Data".

In contrast to GPRMC, GPGGA is an optional information additionally telling the count of satellites in view and horizontal dilution (see Table 2-20).

Sentence format is (*data format*):

```
ID     1         2       3 4        5 6 7  8   9  10 11 12 13  14   15
|      |         |       | |        | | |  |   |   | |   | |   |    |
$GPGGA,hhmmss.ss,llll.ll,a,yyyyy.yy,b,q,nn,h.h,a.a,M,g.g,M,d.d,rrrr*hh<CR><LF>
```

Example:

```
ID     1         2         3 4          5 6 7  8   9  10 11... 15
|      |         |         | |          | | |  |   |   | |    |
$GPGGA,102548.93,4836.5375,N,12136.0099,W,1,04,3.2,200.2,M,,,,*1A<CR><LF>
```

with the individual items explained in Table 2-20. Leading and trailing sentence parts not explained here can be looked-up in Chapter 2.5.3.

Table 2-20: GPGGA sentence architecture.

GPGGA				
No.	**Item in data format**	**Item in example**	**T.**	**Meaning**
ID	GP		T	GNSS
	GGA		M	Global Positioning System Fix Data
1	`hhmmss.ss`	`102548.93`	D	UTC timestamp (see Table 2-19)
2	`llll.ll`	`4836.5375`	D	Latitude (see Table 2-19)
3	`a`	`N`	I	Hemisphere of latitude: N or S (see Table 2-19)
4	`yyyyy.yy`	`12136.0099`	D	Longitude (see Table 2-19)
5	`b`	`W`	I	Hemisphere of longitude: E or W (see Table 2-19)
6	`q`	`1`	I	GNSS quality: • 0: fix not available • 1: GPS fix • 2: DGPS fix
7	`nn`	`04`	D	Number of satellites in view: 0 to 12

GPGGA				
	Item in			
No.	**data format**	**example**	**T.**	**Meaning**
8	`h.h`	`3.2`	D	Horizontal dilution of precision (DOP)
9	`a.a`	`200.2`	D	Antenna altitude [m] above/below mean-sea-level (geoid)
10	`M`	`M`	U	Meters
11	`g.g`	–	D	Geoidal separation [m], the difference between the *WGS 84* earth ellipsoid and mean-sea-level (geoid), "–" means mean-sea-level below ellipsoid
12	`M`	–	U	Meters
13	`d.d`	–	D	Age of DGPS data [s] since last SC104 type 1 or 9 update (empty when DGPS is not used)
14	`rrrr`	–	I	DGPS reference station ID: 0000-1023

2.6 Options

2.6.1 Querying Installed Options

To see which options are installed in your R&S DDF5GTS, you can poll according information by the XML (XML) command [2.4]

- `Options`

A complete list of the signalization identifiers in use is shown in Table 2-21.

Table 2-21: Signalization of options.

Signalization of options		
Identifier	**Type**	**Designation (chapter)**
Orderable options (cf Chapter 1.6, "Ordering Information", on page 20)		
HF	R&S DDFGTS-HF	HF Frequency Extension (2.6.2)
TS	R&S DDFGTS-TS	Time Synchronization (2.6.4)
GPS	R&S DDF-IGT	Internal GPS Module (2.6.9)
	R&S DDFGTSIGT2	Internal GNSS Module (2.6.9)
IM*1)*	R&S DDFGTS-IM	ITU Measurement Software (2.6.3)
FW*2)*	R&S DDFGTS-EMS	Enhanced Measurement Speed (2.6.7)
ID*2)*	R&S DDFGTS-ID	EMS Identification (2.6.7)
COR	R&S DDFGTS-COR	DF Error Correction (2.6.6)
VM	R&S DDFGTS-VM	Vector Matching (2.6.10)

Signalization of options		
Identifier	**Type**	**Designation (chapter)**
DDCE	R&S DDFGTSDDCE	DDC Signal Extraction (2.6.11)
ST	R&S DDFGTS-ST	Detection of Short-Time Signals (2.6.12)
HRP	R&S DDFGTS-HRP	High-Resolution Panorama (2.6.13)
SP	R&S DDFGTS-SP	Signal Processing Board (2.6.11, Note "Required Hardware")
	Additional signalizations	
DC[3]*	–	DC supply
SR[4]*	(R&S DDFGTS-SR)	Super-Resolution (2.6.5)
PS[3]*	–	Panorama Scan
SL[1]*	–	Selective Calling
DF[3]*	–	Direction Finding
FE[3]*	–	Frequency Extension
WB[3]*	–	Wideband Direction Finding

1) *Selective Calling comes with R&S DDFGTS-IM, but is signalized separately.*

2) *R&S DDFGTS-EMS requires R&S DDFGTS-ID, both signalized separately.*

3) *Feature is standard for the R&S DDF5GTS, but option for other Rohde & Schwarz products, hence signalized here.*

4) *Former option, now standard, hence signalized here.*

For example, you obtain a series of the strings

```
COR   IM   TS   SR   HF   GPS
```

if you have the options

- R&S DDFGTS-COR, *DF Error Correction*
- R&S DDFGTS-IM, *ITU Measurement Software*
- R&S DDFGTS-TS, *Time Synchronization*
- R&S DDFGTS-SR, *Super-Resolution* (standard option, always installed, mind 2.6.5)
- R&S DDFGTS-HF, *HF Frequency Extension*
- R&S DDF-IGT, *Internal GPS Module*, or R&S DDFGTSIGT2, *Internal GNSS Module*

installed. Find information on complete structure of XML commands in Chapter 3.17.3, "Commands", on page 245.

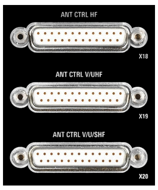
2.6.2 R&S DDFGTS-HF, HF Frequency Extension

Switching Relays

Switching between HF and the higher *frequency ranges* (VHF/UHF/SHF) as well as between the individual *connector groups* (**X11** to **X14**, **X21** to **X24**, **X31** to **X34**) is performed by relays. Mind that this does not only influence switching time, but that also the life cycle of these relays is finite (count of switching cycles, as with any other relay). When switching

- **connector groups**, a protecting mechanism against an actually incorrect operation (too fast switching) does exist (guard time, resulting in an increase of switching time by up to 100 ms);
- **frequency ranges**, no special guard time exists, thus switching of the relay every several ms would be possible in theory; it is up to the user to preferably avoid this situation.

In any case it is recommended, in order to prevent an untimely failure of the relay, to perform switching, e.g. by properly selecting scan and search ranges (Chapter 3.7, "DF Modes", on page 132), only as often as really needed.



The option R&S DDFGTS-HF, *HF Frequency Extension*, enlarges the frequency range covered downwards to 8 kHz (preferably Rx, since DF antennas provided by *Rohde & Schwarz* only start at 300 kHz).

The R&S DDFGTS-HF option enables three-channel direction finding in the MF (300 kHz to 3 MHz) and HF range (3 MHz to 30 MHz): the antenna (recommendably R&S ADD119) is connected to the HF inputs (**X11** ***HF DF1*** to **X14** ***HF CAL***) as described in Chapter 2.4.2, "Antenna Types", on page 38. (As a prerequisite, the antenna interface has to be compatible to the antenna control connector **X18** ***ANT CTRL HF*** [equivalent to **X19** ***ANT CTRL V/UHF*** and **X20** ***ANT CTRL V/U/SHF***].) A Watson-Watt DF evaluation (determining the elevation of the incoming signal is not possible on principle) is done after that.

The connectors **X11** to **X14** are only present when the option is installed.

2.6.3 R&S DDFGTS-IM, ITU Measurement Software

Owing to its performance, the R&S DDF5GTS meets all requirements for measurements in line with the ITU-R recommendations and the ITU Spectrum Monitoring Handbook [3.1]. If the R&S DDFGTS-IM option, *ITU Measurement Software*, is installed, the following measurements (find detailed explanations in Chapter 3.13, "ITU Measurements", on page 186) can be performed:

- Frequency and frequency offset in line with ITU-R SM.377 [3.3]
- Field strength in line with ITU-R SM.378 [3.2]
- Modulation in line with ITU-R SM.328 [3.4]
- Spectrum occupancy on the control PC in line with ITU-R SM.182 [3.7]/ SM.328 [3.4]

- Bandwidth in line with ITU-R SM.443 [3.6]
- Detection of mono and stereo transmissions in the case of FM broadcasting transmitters
- Decoding of selective-call methods and demodulation of pagers; find supported selective-call methods summarized in Table 2-22.
  For detailed information about the specific methods, refer to Chapter 3.15, "Selective Calling", on page 220 and to relevant publications.
- RDS (Radio Data System) analysis; the signal content (messages such as station name, frequency lists, traffic information etc.) is demodulated and decoded, see Chapter 3.12, "RDS", on page 180.

Table 2-22: Supported selective-call methods.

CCIR1	CCITT	DCS	EEA	EURO	VDEW	ZVEI2
CCIR7	CTCSS	DTMF	EIA	NATEL	ZVEI1	

2.6.4 R&S DDFGTS-TS, Time Synchronization

The measurement result of a direction finder usually comprises the parameters level, azimuth, elevation (depending on DF method and antenna used) and quality of bearing of the received signal. This gives the line of bearing (LOB), but does not permit to determine the exact emitter location. Besides other existing methods of poor precision like Single Station Location (SSL), location by crossing of at least two LOBs (triangulation) is the most common and recommendable one.

To locate a transmitter by triangulation, bearings are required of several direction finders. This is ensured for signals with normal transmission duration of a few hundred milliseconds and above.

With frequency-agile LPI signals such as hoppers and bursts, the duration of a single transmission is very short. Moreover, the frequency is not known, so that large frequency ranges have to be scanned. It may happen that only one direction finder is operating at the correct frequency at the moment of an emission. Locating the transmitter searched for is then impossible.

This means, previously location was only possible in Fixed Frequency Mode (FFM, DF at only one frequency, cf Chapter 3.7, "DF Modes", on page 132). For the detection of LPI signals, the direction finder has to be operated in wideband mode (so-called Scan Mode, meaning that several frequency channels are evaluated at a time). This requires the sweeps of the direction finders to run synchronously, so that measurement results are collected at exactly the same time.

Using the *Time Synchronization* R&S DDFGTS-TS option, the scan activities are synchronized, i.e. each direction finder measures exactly at the same frequency at the same time. A reliable bearing of any detected signal is taken by each direction finder, and the signal is located with maximum accuracy. Synchronization is highly accurate due to the use of GPS.

This option is therefore an important prerequisite for DF networks locating LPI signals.

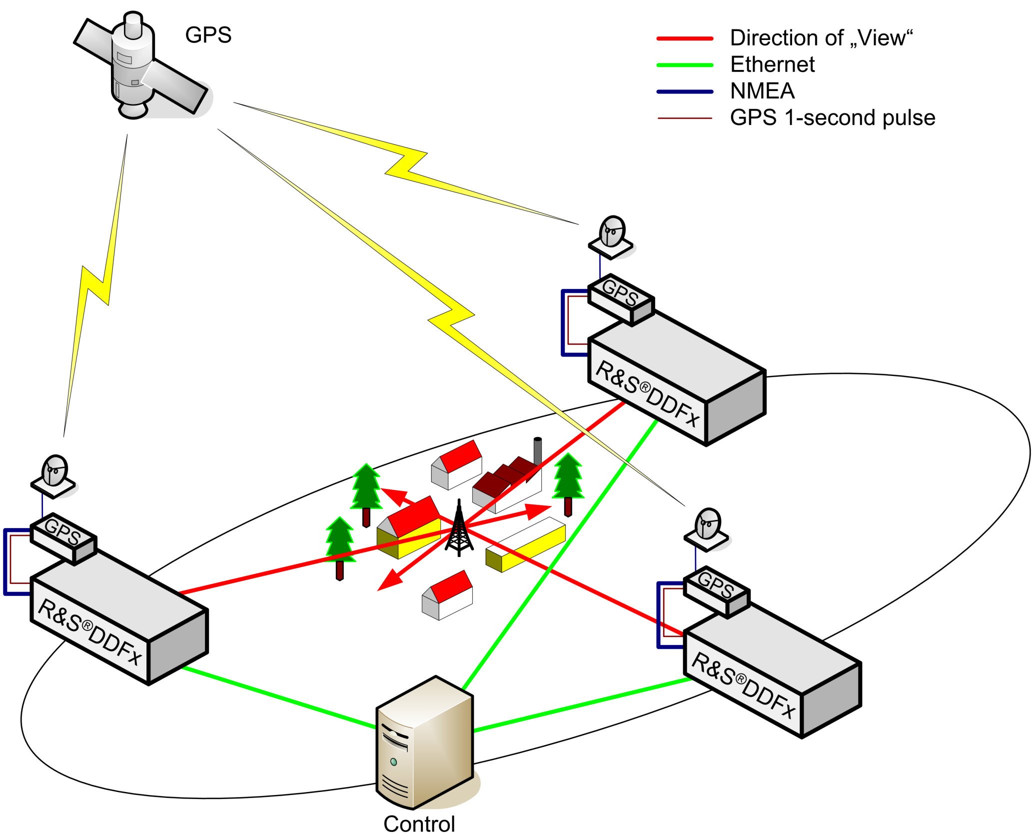


Figure 2-18: Triangulation with synchronous scan.

In Figure 2-18, a typical situation is shown: Three R&S DDF5GTS units positioned at different locations are used to locate a transmitter of unknown position. Each of them has a GPS receiver connected, delivering a high-precision (about 10^{-6} s) one-second pulse (synchronized to UTC full second) and an appropriate NMEA 0183 sentence (see Chapter 2.5.6, "GNSS Receiver"). A control server is linked via ethernet, it produces the correct start signal for the measurement. The directions of "view" of each R&S DDF5GTS intersect at the location of the emitter searched.

2.6.5 R&S DDFGTS-SR, Super-Resolution

Standard Option

The R&S DDFGTS-SR option, *Super-Resolution*, is a standard option, i.e. it is included in delivery with the R&S DDF5GTS (cannot be ordered separately any longer), but shows up if option equipping of the unit (see 2.6.1) is polled with the XML command

- `Options`

Classic DF methods assume just one single (predominant) wave existing in the frequency channel of interest. If this should not be the case but multiwave incidence be present, the result is not only that the individual waves cannot be separated, but also that indication of its azimuth angle(s) contains large defects (DF errors).

The R&S DDFGTS-SR option, *Super-Resolution*, reveals a way out of this situation. It performs a principal component analysis (PCA) of antenna data, thus being able to separate several waves inciding on one frequency at a time and determining the angle of incidence of each of them with the precision known from the single wave case. In use is the MuSiC algorithm (**Mu**ltiple **Si**gnal **C**lassification).

Find more detailed information about MuSiC and the option in Chapter 3.14, "Super-Resolution", on page 201.

2.6.6 R&S DDFGTS-COR, DF Error Correction

DF Error Correction performs compensation of some linear distortions caused by physical insufficiencies of the components involved in the DF process (not by the R&S DDF5GTS as such) with respect to high frequency effects, antenna shortcomings, cable attenuation and so on. Factors that can be influenced are

- Antenna factors
- Cable attenuation
- Azimuth correction
- Omniphase

Additionally some inputs can be done to the DF process within the

- Antenna reference coefficients
- Antenna parameters

Find a detailed description of this issue in Chapter 3.8, "DF Error Correction", on page 150 and in [1.1].

Correcting antenna factors, cable attenuation and omniphase values as well as specifying antenna reference coefficients and antenna parameters can all be done with the standard R&S DDF5GTS, whereas for correction of azimuth values installing the *DF Error Correction* option R&S DDFGTS-COR is needed.

2.6.7 R&S DDFGTS-EMS, Enhanced Measurement Speed, and R&S DDFGTS-ID, EMS Identification

With the option R&S DDFGTS-EMS, *Enhanced Measurement Speed*, purchased, you obtain access to the full measurement speed of the R&S DDF5GTS.

Export Limitations

Be aware that this option is subject to export limitations.

R&S DDFGTS-EMS exists in two configurations and can only be purchased together with R&S DDFGTS-ID, *EMS Identification*. R&S DDFGTS-EMS is an option universal to any R&S DDF5GTS unit, whereas R&S DDFGTS-ID is individually configured to a single R&S DDF5GTS unit (individual serial number). Thus, correct function is only available if both options are present.

More detailed information on proper ordering is available on request.

You recognize that you have access to the full speed if you issue the XML command

- `Options` (2.6.1)

and you then get a reply string containing

`FW ID`

i.e., the two options

- R&S DDFGTS-EMS, *Enhanced Measurement Speed*
- R&S DDFGTS-ID, *EMS Identification*

displayed.

2.6.8 R&S DDFGTS-DCV, Documentation of Test Results

The option R&S DDFGTS-DCV, *Documentation of Test Results*, comprises a documentation set of all measurement values determined during the end test of the R&S DDF5GTS.

2.6.9 R&S DDF-IGT, Internal GPS Module, and R&S DDFGTSIGT2, Internal GNSS Module

(Option with the R&S DDF5GTS)

The option R&S DDF-IGT, *Internal GPS Module*, or R&S DDFGTSIGT2, *Internal GNSS Module*, equips the R&S DDF5GTS by a complete built-in GPS or GNSS receiver. Find more detailed information about installing and operating the option in Chapter 3.9, "Internal GPS Module or Internal GNSS Module", on page 157.

2.6.10 R&S DDFGTS-VM, Vector Matching

Except when using the older Watson-Watt method (for crossed-loop antennas), the R&S DDF5GTS for direction finding deploys the correlation method; this means: the voltage values measured at the DF antenna are compared to corresponding expected values for all possible azimuth (0° to 360°) and elevation (0° to 90°) directions in fixed angle steps, the azimuth/elevation pair with the best coincidence (the maximum correlation value determined) is considered the direction of the incoming wave.

These comparative values are called the reference function, for conventional DF antennas this function (i.e. these values) can be calculated by the R&S DDF5GTS itself by, prior to bearing, emulating mathematically the antenna geometry for all azimuth and elevation directions in the desired angle steps. This process has to be performed for all frequencies (frequency ranges) where bearing should take place afterwards.

With antennas of an extraordinary geometry, or also for difficult conditions within the antenna surroundings, a plain calculation of the reference function as described might be impossible. In this case, the function has to be established by a precedent measuring process, the data found this way is then loaded to the R&S DDF5GTS (similar to an error correction file, see 2.6.6) and used for bearing – this strategy is called *vector matching*. This measuring process is normally not intended to be done by the user, but measured data is provided by the antenna manufacturer.

The option R&S DDFGTS-VM, *Vector Matching*, allows bringing this data to the R&S DDF5GTS, also cf Chapter 3.8.2.5, "Antenna Reference Coefficients", on page 152. Mind that reference data sets themselves are not part of the option.

You activate the vector matching DF method by the XML (XML) command [2.4]

- `MeasureSettingsFFM: eDfAlt=DFALT_VECTORMATCHING`

2.6.11 R&S DDFGTSDDCE, DDC Signal Extraction

Required Hardware

Mind that for this option, as also for the options R&S DDFGTS-ST, *Detection of Short-Time Signals* (2.6.12), and R&S DDFGTS-HRP, *High-Resolution Panorama* (2.6.13), you must, for proper operation, have some hardware requirements fulfilled that are listed below. (Contact *Rohde & Schwarz* if in doubt about hardware details.)

- The PCI of the *motherboard* (4074.3650.02) must be at least 08.02.
- The option R&S DDFGTS-SP, *Signal Processing Board*, must be installed. The part number of the board itself (not to be confused with the option's part number) must be 4066.3655.03, i.e. have a module number (third section of the part number) of 03, and the 4 GB SODIMM module (3586.0766.00) must be present.

You check whether the R&S DDFGTS-SP option is present with the XML command

- `Options`

and the board's hardware state (see above) with

- `ModuleInfo:zPartNumber=4066.3655.03,zName=SIGV:07`

(make sure that the part number ends in "03", i.e. has the form "xxxx.xxxx.03").

With the option R&S DDFGTSDDCE, *DDC Signal Extraction*, the R&S DDF5GTS becomes a multichannel receiver. The basic Rx channel is extended by 128 additional Rx channels, realized by DDCs (digital downconverters) the center frequencies of which can be directed anywhere all over the IF span currently set and the bandwidths selected individually, both independently of each other channel.

You also must have this option installed if you have found short-time detections with the *Short-Time Detector* (see 2.6.12) and now intend to generate a baseband signal from them by means of the *Short-Time Synthesizer*.

Find a detailed description of this issue in Chapter 3.16, "Signal Analysis", on page 226 and in the R&S CA120 (Multichannel Signal Analysis Software) manual [3.11].

2.6.12 R&S DDFGTS-ST, Detection of Short-Time Signals

Short-time signals (signals that appear only for a relatively short time, especially not in a persistent manner) are commonly invisible to traditional modes of monitoring and therefore impossible to be analyzed or even detected.

A chance to do so anyway is revealed by the option R&S DDFGTS-ST, *Detection of Short-Time Signals*: By means of the *Short-Time Signal Detector*, you can detect short-time signals within the putative noise and obtain information about spectral location (i.e. frequency and bandwidth) and duration in a burst emission list, and, with the *Short-Time Signal Synthesizer*, you moreover can (together with option R&S DDFGTSDDCE, *DDC Signal Extraction*, 2.6.11) generate baseband data of the detected signals to do further analyses of their contents.

For required hardware mind Note "Required Hardware" (2.6.11).

Find a detailed description of this issue in Chapter 3.16 and in [3.11].

2.6.13 R&S DDFGTS-HRP, High-Resolution Panorama

The *HRPan* (High-Resolution Panorama) offers a spectrum that is continuously calculated on the main IF data stream. The spectrum has a higher resolution (step size lower) compared to the IFPan (3.18.2.8, "IFPan") functionality.

To utilize *HRPan*, install option R&S DDFGTS-HRP, *High-Resolution Panorama*.

For required hardware mind Note "Required Hardware" (2.6.11).

Find a detailed description of this issue in Chapter 3.16 and in [3.11].

3 Operation

3.1 Front Panel Elements R&S EBD770

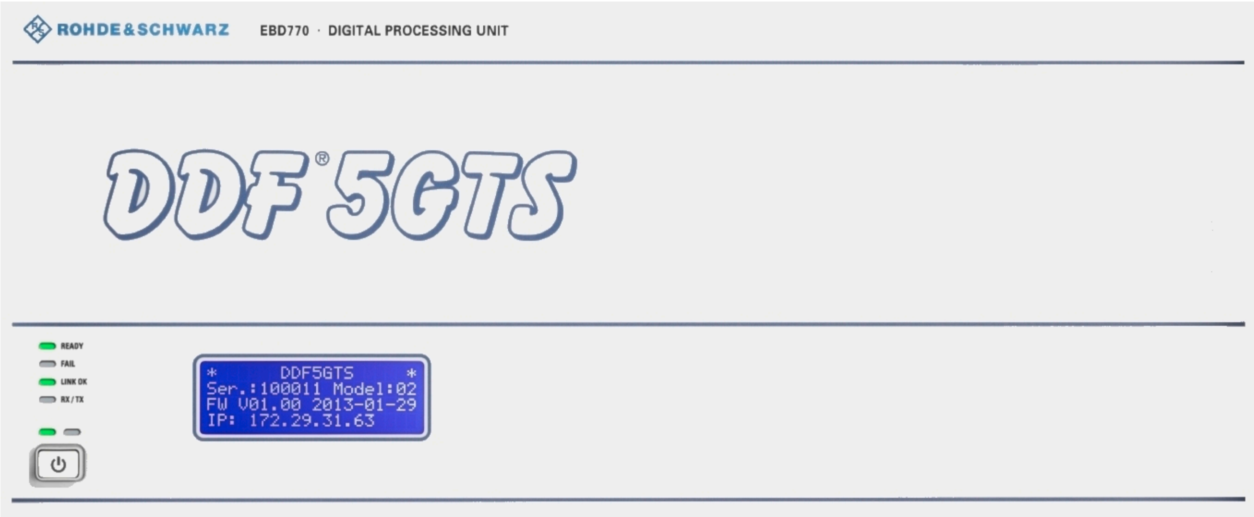


Figure 3-1: R&S EBD770 front panel.

In Figure 3-1 the R&S EBD770, Processing Unit, front panel is shown. Due to the fact that all operation is performed by remote control from a client, no operating elements are provided except the [On/Off] key, some status LEDs and the four-line status display.

Figure 3-2: Front panel LEDs and On/Off key (left), front panel display (right).

3.1.1 On/Off Key

The [On/Off] key (Figure 3-2, left) toggles between [Standby] and [Ready] state.

In [Standby] state, when the R&S EBD770 is shut down, the amber LED is on.

In [Ready] state, the R&S EBD770 operating state, the green LED is on.

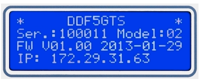
For more detailed information, refer to Chapter 2.3.1, "Connecting to the Power Supply", on page 28.

3.1.2 Status LEDs

The status LEDs (Figure 3-2, left) indicate the current status of the R&S EBD770:

- [Ready] (green): The R&S EBD770 is ready for use.
- [Fail] (red): Lights up if the built-in self test (BIT) has failed.
- [Link Ok] (green): Indicates the state of the network (LAN) interface.
- [Rx / Tx] (amber): Blinks when there is receive ("Rx") or transmit ("Tx") activity on the network (LAN).

3.1.3 Display



The R&S EBD770 front panel display (Figure 3-2, right) is lit in [Ready] state and indicates the current state of the unit:

- unit type: *R&S DDF5GTS*
- serial number: *100011*
- unit model: *02*
- firmware version and date: *version 1.00* of *January 29th, 2013*
- IP address: *172.29.31.63*

3.2 Front Panel Elements R&S EHT770

Figure 3-3: R&S EHT770 front panel.

In Figure 3-3 the R&S EHT770, DF Converter, front panel is shown. Due to the fact that all operation is performed by remote control from a client, no operating elements are provided.

For more detailed information about power supply, refer to Chapter 2.3.1, "Connecting to the Power Supply", on page 28.

3.3 Rear Panel Elements R&S EBD770

3.3.1 General

The R&S DDF5GTS can be ordered in two unit models, one for AC and one for DC power supply. Thus, the rear panels of both of its components, the R&S EBD770, Processing Unit, and the R&S EHT770, DF Converter (see Chapter 3.4 on page 107), have a different appearance depending on which model has been purchased. The two figures (3.3.1.1) show the rear panel of both models of the R&S EBD770, Figure 3-4 for the AC and Figure 3-5 for the DC model.

Be aware that in both figures the rear panel is shown with options installed.

This chapter 3.3 describes all inputs and outputs located on the rear panel of the R&S EBD770. A scope of all connectors is given in Table 3-1. Pinout of the types of D-Sub connectors used here is shown in Figure 3-6.

3.3.1.1 Rear Panel View R&S EBD770

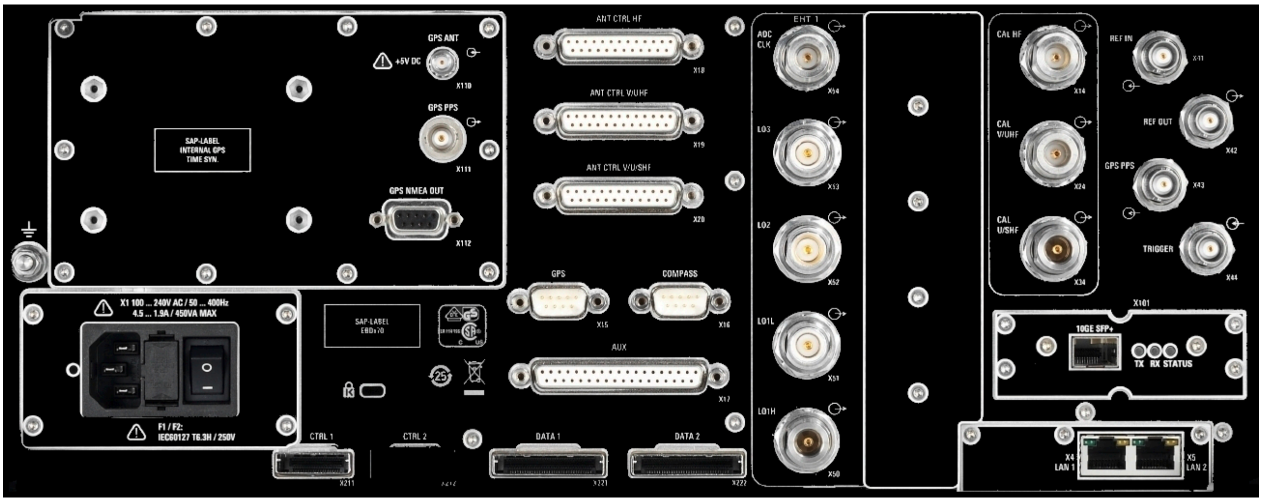


Figure 3-4: R&S EBD770 rear panel, AC power supply model.

X14 = if option R&S DDFGTS-HF (HF Frequency Extension, see Chapter 2.6.2) installed
X110 to X112 = if option R&S DDF-IGT (Internal GPS Module) or R&S DDFGTSIGT2 (Internal GNSS Module) installed, see Chapter 2.6.9

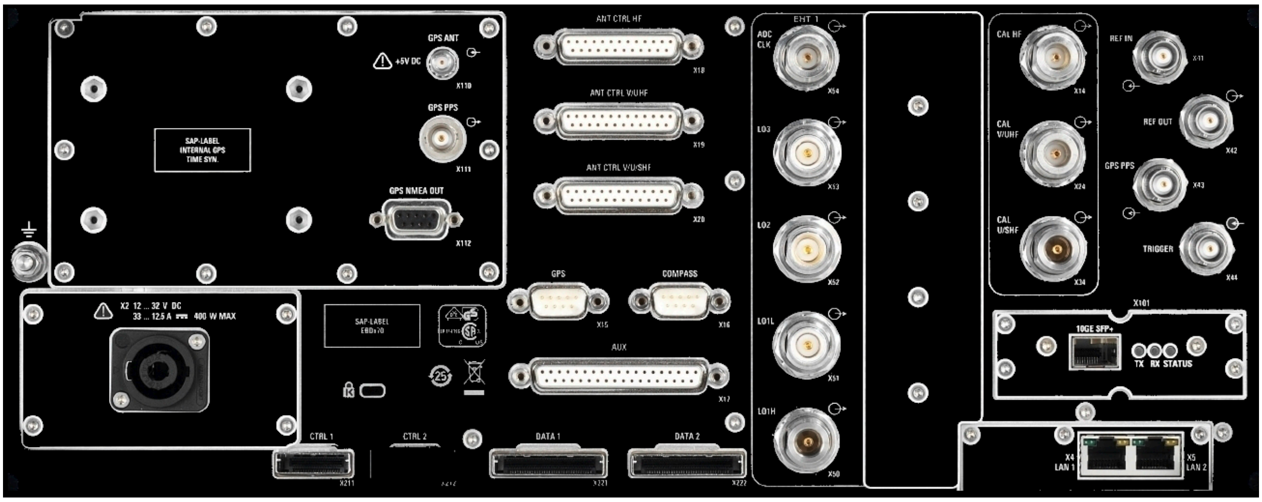


Figure 3-5: R&S EBD770 rear panel, DC power supply model.

X14 = if option R&S DDFGTS-HF installed
X110 to X112 = if option R&S DDF-IGT or R&S DDFGTSIGT2 installed

3.3.1.2 Overview

Cables to Use

Mind some limitations for the cables to be used to connect the R&S DDF5GTS to its peripheral equipment:

- **Power supply cables**: **X1** ***100...240 V AC*** or **X2** ***12...32 V DC***:
  Diligently observe the instructions given in Chapter 2.3.1, "Connecting to the Power Supply", on page 28.
- **Antenna cables** (**RF** and **control**):
  Only use the antenna cable sets provided by *Rohde & Schwarz* as external accessories; refer to Chapter 2.4.4, "Antenna Accessories", on page 41, Chapter 3.5, "Installation and Cabling of Antenna(s), Antenna Combinations and Related Equipment", on page 112 and Chapter 1.6.3, "DF Antennas and Antenna Accessories", on page 21.
- **Digital cables**:
  - **X15** ***GPS*** and **X16** ***COMPASS***:
    No limitations concerning length. Just observe cable attenuation with extraordinary lengths and, if in doubt, perform a measurement according to ETSI EN 301489-1.
  - **X17** ***AUX***:
    Maximum cable length permitted is 3 m. If longer cables have to be used, verify suitability by a measurement according to ETSI EN 301489-1.
- **Analog cables**: **X41** ***REF IN*** to **X44** ***TRIGGER***:
  Always use double-shielded cables. Observe cable attenuation when making use of exceptional lengths.
- **LAN cables**: **X4** and **X5**:
  Observe instructions given in Chapter 2.3.4, "Connecting to LAN", on page 36.
- **Local oscillator**: **X50** ***LO1H*** to **X54** ***ADC CLK*** and **digital transmission cables**: **X211** ***CTRL 1*** to **X222** ***DATA 2***:
  Part of the order with the R&S DDF5GTS (see Chapter 1.5, "Equipment Supplied", on page 18) and especially tailored for this purpose. Do not use other cables, because correct contacting and shielding cannot be guaranteed with external products.

Table 3-1: Connectors on rear panel of the R&S EBD770.

Rear panel R&S EBD770					
Group	**Conn.**	**Name**	**⇄**	**Notes**	
Mains	X1	***100...240 V AC***	I	AC power supply model only	IEC 60320 C14.
	X2	***12...32 V DC***		DC power supply model only	*Neutrik* Speakon NL4MP socket.
Antenna Control[1)]*	X18	***ANT CTRL HF***	I/O	Antenna control and supply voltage valid for • HF • VHF/UHF/SHF 1	D-Sub socket (female), 25 pins.
	X19	***ANT CTRL V/UHF***			

Rear panel R&S EBD770					
Group	**Conn.**	**Name**	**⇄**	**Notes**	
	X20	***ANT CTRL V/U/SHF***		• VHF/UHF/SHF 2	
Control misc.[2)]*	**X15**	***GPS***		GNSS control signal (from GNSS module) in	RS-232 (serial); D-Sub plug (male), 9 pins.
	X16	***COMPASS***		Compass control	
	X17	***AUX***			D-Sub socket (female), 37 pins.
Control	**X211**	***CTRL 1***		Digital transmission to R&S EHT770 control	*Molex* iPass x4 (or PCI x4) socket (female), 38 pins.
	X212	***CTRL 2***			
Data	**X221**	***DATA 1***		Digital transmission to R&S EHT770 data	Molex iPass x8 (or PCI x8) socket (female), 68 pins.
	X222	***DATA 2***			
LO and ADC	**X50**	***LO1H***	O	Local oscillator to R&S EHT770 1	Z = 50 Ω; N socket.
	X51	***LO1L***			
	X52	***LO2***		Local oscillator to R&S EHT770 2	
	X53	***LO3***		Local oscillator to R&S EHT770 3	
	X54	***ADC CLK***		ADC clock to R&S EHT770	
Calibration	Calibrating generator signal to antenna				
	X14	***CAL HF***	O	HF[3)]*: 8 kHz to 30 MHz	
	X24	***CAL V/UHF***		V/UHF: 20 MHz to 3 GHz	
	X34	***CAL U/SHF***		U/SHF: 20 MHz/8 kHz[4)]* to 6 GHz	
Reference misc.	**X41**	***REF IN***	I	Reference in	f = 10 MHz, U = 0.1 V to 1.0 V (RMS), 3 V (Vpp) max., Z = 600 Ω approx.; BNC socket.
	X42	***REF OUT***	O	Reference out	f = 10 MHz, P ≥ 0 dBm (sine), Z = 50 Ω; BNC socket.
	X43	***GPS PPS***	I	GPS reference signal (one-second pulse, PPS) in	f = 1 Hz, edge-triggered (rising edge) LVTTL (3.3 V max., tolerant to 5 V, pullup resistor 10 kΩ to 3.3 V); BNC socket.

Rear panel R&S EBD770					
Group	**Conn.**	**Name**	**⇄**	**Notes**	
	X44	***TRIGGER***		Configurable as source for Blanking signal, see Chapter 3.11.6.3, "Blanking", on page 175	BNC socket.
R&S DDF-IGT / R&S DDFGTSIGT2	**X110**	***GPS ANT***	I	GNSS antenna in	SMA socket.
	X111	***GPS PPS***	O	GPS reference signal (one-second pulse, PPS) out	BNC socket.
	X112	***GPS NMEA OUT***		GNSS control signal out	RS-232 (serial); D-Sub socket (female), 9 pins.
LAN[5]*	**X4**	***LAN 1***	I/O	LAN (Local Area Network) connector	RJ-45, 8 contacts.
	X5	***LAN 2***			
(GND)				Ground terminal	Standing bolt with M5 thread.
(Kensington)				Theft protection	*Kensington* Security Slot.

⇄ *Direction of signal: I: in, O: out.*

1) ***X18**, **X19** and **X20** equivalent.* 2) ***X15** and **X16** equivalent.* 5) ***X4** and **X5** equivalent.*

3) *Connector only present with option R&S DDFGTS-HF, HF Frequency Extension, installed.*

4) *With option R&S DDFGTS-HF installed.*

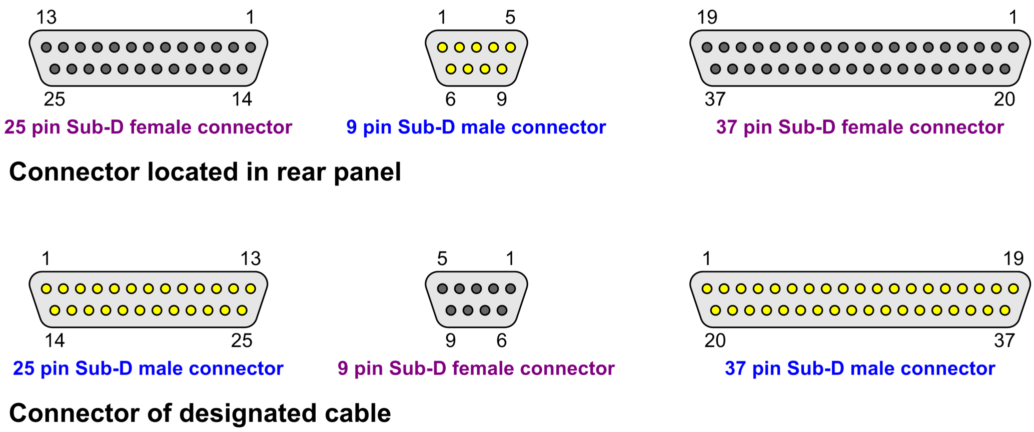


Figure 3-6: Pinout of D-Sub connectors.

yellow = pin
gray = socket
25 pin = X18 ANT CTRL HF
= X19 ANT CTRL V/UHF
= X20 ANT CTRL V/U/SHF
9 pin = X15 GPS
= X16 COMPASS

	= X112 GPS NMEA OUT
37 pin	= X17 AUX
Top	= connector located in R&S DDF5GTS rear panels, view to the rear panel from outside
Bottom	= connector of designated cable, view to the plug from outside
	= (exception X112: female in unit, male with cable)

NOTICE

Cable Types

- It is strongly recommended to only use the cables included in delivery with the R&S DDF5GTS (for power and LAN cables) or cables supplied by *Rohde & Schwarz* as external accessories (especially for cabling the DF antenna[s]). Correct contacting and shielding cannot be guaranteed with external products.
- If using external products anyway, strictly observe the following:
  - **LAN cable**: only use Cat 6,
  - all **signal and control cables**: always ensure proper shielding:
    signal cables: always double shielding,
    control cables: at least single, optimum double shielding.

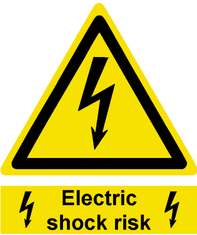
3.3.2 Mains

3.3.2.1 AC Power Supply Model

X1 *100...240 V AC*

The AC power-in assembly consists of (from left to right)

- Mains plug.
  The AC supply voltage is to be connected to this input (IEC 60320 C14).
- Fuse holder.
  The fuse holder houses two fuses (called F1 and F2) protecting the R&S EBD770 against illegal AC supply voltages. They may be replaced by the user if necessary; refer to Chapter 4.1.3, "Replacing the Fuses", on page 332 for details.
- Mains switch.
  The mains switch normally may remain in its **I** (ON) position. Setting it to 0 (OFF) is only recommended if the R&S DDF5GTS / R&S EBD770 has to be disconnected from AC power supply completely; see Chapter 2.3.1.4, "Power on and off", on page 31.



WARNING

Shock Hazard

Before you replace the fuse, make sure that the R&S EBD770 is

- switched off by the mains switch and
- disconnected from the power supply (plug removed from the AC power connector).

WARNING

Fuse Type

Be aware when replacing the fuse to always fit the correct type: IEC127-T6.3H/250 V (order number 0020.7630.00).

Fitting a different type of fuse may cause severe damage to the R&S EBD770, exceeding physical damage or even personal injury.

Mains Switch

The mains switch disconnects the R&S EBD770 completely from the power supply. It should only be operated when the unit is in [Standby] state (see Chapter 3.1.1, "On/Off Key", on page 89).

Switching off from [Ready] state may result in loss of configurations made or additional data settings.

NOTICE

Mains Voltage

Make sure that the available mains voltage is between 100 V and 240 V AC with mains frequencies ranging from 50 Hz to 400 Hz.

3.3.2.2 DC Power Supply Model

X2 12...32 V DC

The DC supply voltage is to be connected to this input (*Neutrik* Speakon NL4MP socket, cf Figure 2-1).

NOTICE

DC Supply Voltage and Polarity

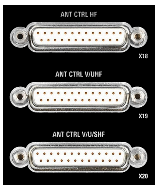
- Make sure that the available supply voltage is between 12 V and 32 V DC.
- Observe the correct voltage polarity when connecting.
  Incorrect polarity may blow the fuse on the DC converter inside the R&S EBD770 or even damage the R&S EBD770.

3.3.3 Antenna Control

Each antenna is to be installed with its

1. RF cables:
   - three channels RF from antenna to the R&S EHT770 (Chapter 3.4.6 on page 111),
   - a calibration signal from R&S EBD770 to antenna (3.3.10) and
2. a special control cable between R&S EBD770 and antenna.

The control cables can be linked to each of the available connectors described subsequently (the individual antenna type is signaled to the R&S DDF5GTS by the antenna itself), but the kind of antenna being present to each RF connector/connector group is to be configured via the client software.



X18 ***ANT CTRL HF*** **X19** ***ANT CTRL V/UHF*** **X20** ***ANT CTRL V/U/SHF***

are D-Sub sockets (female, 25 pins) for the control cables of the antennas installed to the R&S EHT770. Each antenna identifies itself to the R&S DDF5GTS, resulting in

- that all three control sockets **X18**, **X19** and **X20** are equivalent, but also
- that antennas having changed during operation have to be inquired by the special XML (XML) command [2.4]
  – `AntennaUsed`

Pin assignment of each socket is shown in Table 3-2 and pinout in Figure 3-6; the signals (also called antenna bits) are special to the R&S ADDx antennas, and their meaning, if needed, can be found in the antenna manuals.

Power Supply to Antennas by the R&S EBD770

Maximum number of antennas to be supplied by the R&S EBD770 via the Antenna Supply pins (pins 2, 4, 6, and 8, see Table 3-2) of the antenna control sockets is 2.

If more than 2 antennas are to be operated, a suitable external power supply has to be provided.

Table 3-2: Antenna control sockets X18, X19 and X20.

X18, X19 and X20 ANT CTRL									
Pin	**Name**	**Pin**	**Name**	**Pin**	**Name**	**Pin**	**Name**	**⇄**	**Range**
1	ANT0+	3	ANT1+	5	ANT2+	10	ANT3+	O	EIA-422 (RS-422) (±2 V Diff.)
12	ANT4+	9	ANT5+	15	ANT6+				
14	ANT0–	16	ANT1–	18	ANT2–	11	ANT3–		
13	ANT4–	22	ANT5–	17	ANT6–				
7	COM1+	20	COM1–					I/O	EIA-485 (RS-485) (±1.5 V Diff.)

X18, X19 and X20 ANT CTRL			
Pin	**Name**	**⇄**	**Notes**
2, 4, 6, 8	+18 V (1.5 A max.)	O	Antenna Supply
21, 23, 24, 25	GND	I/O	Ground
19	n.c.		

3.3.4 GPS

X15 *GPS*

The *GPS* link plug (D-Sub male, 9 pins) manages data exchange with an external GNSS receiver. It is a serial interface according to RS-232 standard (pin assignment in Table 3-3, for detailed information on each signal refer to relevant publications; pinout in Figure 3-6); data exchange is processed according to NMEA 0183 data format (see Chapter 2.5.3 on page 53). Additionally a GNSS receiver commonly supplies a high-precision one-second pulse, which is to be connected to the **X43** ***GPS PPS*** plug.

X15 is equivalent to **X16** ***COMPASS***.

Table 3-3: Control plugs X15 GPS and X16 COMPASS.

X15 GPS and X16 COMPASS								
Pin	**Name**	**Notes**	**⇄**	**Pin**	**Name**	**Notes**	**⇄**	**Range**
1	DCD[1]*	Data Carrier Detect	I	2	RXD	Receive Data	I	RS-232 (±3 V to ±15 V)
3	TXD	Transmit Data	O	4	DTR[1]*	Data Terminal Ready	O	
6	DSR[1]*	Data Set Ready	I	7	RTS	Request To Send		
8	CTS	Clear To Send						
5	GND	Ground	I/O	9	n.c.			

[1] *Internally connected to each other within the R&S EBD770.*

3.3.5 Compass

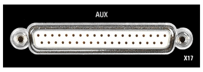
X16 *COMPASS*

The *COMPASS* link plug (D-Sub male, 9 pins) serves for connecting compasses *distant from* the antenna (commonly: available on the ship or vehicle). Like the GPS link **X15**, it is a serial interface according to RS-232 standard, thus, signal levels and pin assignment are the same and can be seen from Table 3-3, pinout from Figure 3-6. Again, data exchange is processed according to NMEA 0183 data format (see Chapter 2.5.3).

(Antenna compasses, i.e. compasses *mounted directly to* the antenna, are serviced via the antenna control lines **X18/X19/X20 *ANT CTRL***; signaling provided by the user normally is only required when recalibrating, whereas north correction is done internally.)

X16 is equivalent to **X15 *GPS***.

3.3.6 Auxiliary



X17 *AUX*

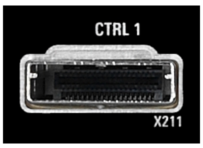
a D-Sub socket (female, 37 pins), combines several switching or indicator signals and further synchronization possibilities with an elaborate analog audio output. Details and pin assignment are given in Table 3-4, pinout in Figure 3-6.

Table 3-4: Auxiliary socket X17 AUX.

X17 AUX				
Pin	**Name**	**⇄**	**Range**	**Notes**
1	AF_SYM_RIGHT–	O	U = 0.4 V (±0.2 V) @ m = 0.5 f = 100 Hz to 12.5 kHz Ri = 600 Ω	Audio analog
2	AF_SYM_RIGHT+			
4	AF_LINE_MONO		U = 0.5 V (±0.3 V) @ m = 0.5 f = 10 Hz to 12.5 kHz R_i = 100 Ω	
5	AF_MUTE	I	LVTTL, active low	Audio Frequency Mute (comparable to PTT button)
6	EXT_RESET_IN			External reset of unit
7	DEVICE_SYNC_IN		LVTTL	Universal synchronization signal input (for future use)
8	GSM_STROBE			External synchronization signal for GSM, also usable for other measuring tasks
9	BLANKING		LVTTL, active low	Input for external controlling (suspending) of the DF (averaging) process; cf Chapter 3.11.6.3, "Blanking", on page 175

X17 AUX				
Pin	**Name**	**⇄**	**Range**	**Notes**
11	EXT_TRIG_IN1		LVTTL	Control inputs connected to FPGA (for higher clock rates) (for future use)
12	EXT_TRIG_IN2			
13	IN_A			Control inputs connected to PPC (for lower clock rates) (for future use)
14	IN_B			
18, 19	+5 V		+5 V @ 0.15 A	Supply voltage for low-power devices
20	AF_SYM_LEFT–		same as AF_SYM_RIGHT–, pin 1	Audio analog
21	AF_SYM_LEFT+			
22	AF_MONO		U = 5 V (Vpp) max. f = 10 Hz to 12.5 kHz R_i = 100 Ω	
23	AF_LINE_L		same as AF_LINE_MONO, pin 4	
24	AF_LINE_R			
25	DEVICE_SYNC_OUT		LVTTL	Universal synchronization signal output (for future use)
26	SIGNAL_VALID	O		Signal above threshold
27	FCHANGE			Frequency change duration indicator (synthesizer switching duration)
28	ANT_CTRL8			Control signals for antenna arrays (e.g. using a switch panel)
29	ANT_CTRL7			
30	ANT_CTRL6			
31	ANT_CTRL5			
32	ANT_CTRL4			
33	ANT_CTRL3			
34	ANT_CTRL2			
35	ANT_CTRL1			
3, 17, 36, 37	GND	I/O		Ground
10, 15, 16	n.c.			

3.3.7 Control



X211 *CTRL 1*   X212 *CTRL 2*

are *Molex* iPass x4 (or PCI x4) sockets (female, 38 pins) for controlling the R&S EHT770 by the R&S EBD770 (LVDS level); see pin assignment in Table 3-5, GND pins of both connectors in Table 3-6 and n.c. pins in Table 3-7. The underlying

PCI use of the connection has been modified for the R&S DDF5GTS, the original names are added in the table for information, however.

Be aware that, due to the fact that commonly ready-to-use cables are applied, no one-to-one wiring ("A"-to-"A" and "B"-to-"B" or "A"-to-"B" and "B"-to-"A") is established, but some "A"-pins are connected to the corresponding "B"-pins and some other to the "A"-pins (and vice versa); the opposite pin of each pin can be seen from the "Opp." column in the table, all "same-letter connections" are shown in bold.

The basic cabling scheme (including DATA, cf 3.3.8) can be seen from Figure 3-7.

PCI Standard

Meanings of signal lines of the Molex/PCI connectors have been changed and thus do not obey the usual PCI standard any longer. If correctly cabled as told in Figure 3-7, detailed knowledge of the individual signals will not be needed.

Be aware, however, that, for this reason, connecting the R&S EBD770 to common PCI interfaces via these plugs is not allowed.

Table 3-5: Control sockets X211 and X212 (GND and n.c. pins omitted, see separate tables).

Control sockets X211 and X212										
Pin	**(PCI name)**	**Opp.**	**Pin**	**(PCI name)**	**Opp.**	**Pin**	**(PCI name)**	**Opp.**	**⇄**	**Notes**
A2	PETp0	B2	A3	PETn0	B3	A5	PETp1	B5	I/O	(see Note "PCI Standard")
A6	PETn1	B6	A8	PETp2	B8	A9	PETn2	B9		
A11	PETp3	B11	A12	PETn3	B12	A14	CREFCLK+	**A14**		
A15	CREFCLK–	**A15**	A17	SB_RTN	**A17**	A18	CPRSNT#	**A18**		
A19	CPWRON	**A19**	B2	PERp0	A2	B3	PERn0	A3		
B5	PERp1	A5	B6	PERn1	A6	B8	PERp2	A8		
B9	PERn2	A9	B11	PERp3	A11	B12	PERn3	A12		
B18	CWAKE#	**B18**	B19	CPERST#	**B19**					

Table 3-6: GND pins in X211 and X212.

GND												
Pin	A1	A4	A7	A10	A13	A16	B1	B4	B7	B10	B13	**Name**	GND (I/O)
Opp.	B1	B4	B7	B10	B13	B16	A1	A4	A7	A10	A13		

Table 3-7: N.c. pins in X211 and X212.

Pin	B14	B15	B16	B17		**Name**	n.c.

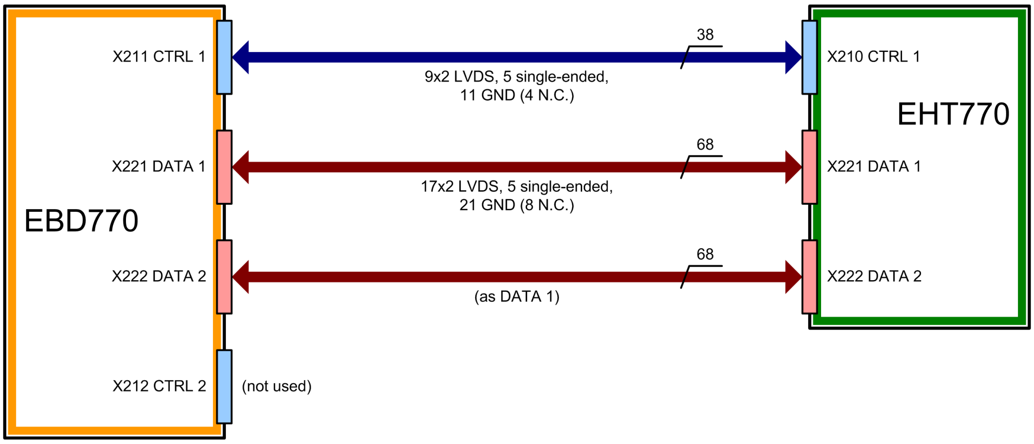
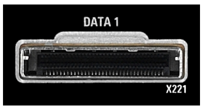
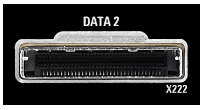


Figure 3-7: Basic cabling scheme (three-channel case) between R&S EBD770 and R&S EHT770.

3.3.8 Data





X221 DATA 1 X222 DATA 2

are two Molex iPass x8 (or PCI x8) sockets (female, 68 pins) for transferring data from the R&S EHT770 to the R&S EBD770 (LVDS level); see pin assignment of **X221** and of **X222** in Table 3-8, GND pins of both connectors in Table 3-9 and n.c. pins in Table 3-10. The underlying PCI use of the connection has been modified for the R&S DDF5GTS, the original names are added in the table for information, however.

See 3.3.7, "Control" for information about wiring (especially mind Note "PCI Standard" on page 102) and the "Opp." column of the table, and Figure 3-7 for the basic cabling scheme (including CTRL, cf 3.3.7).

Table 3-8: Data sockets X221 and X222 (GND and n.c. pins omitted, see separate tables).

Data sockets X221 and X222										
Pin	**(PCI name)**	**Opp.**	**Pin**	**(PCI name)**	**Opp.**	**Pin**	**(PCI name)**	**Opp.**	**⇄**	**Notes**
A2	PETp0	B2	A3	PETn0	B3	A5	PETp1	B5	I/O	(see Note "PCI Standard" on page 102)
A6	PETn1	B6	A8	PETp2	B8	A9	PETn2	B9		
A11	PETp3	B11	A12	PETn3	B12	A14	CREFCLK+	**A14**		
A15	CREFCLK–	**A15**	A19	SB_RTN	**A19**	A20	CPRSNT#	**A20**		
A21	CPWRON	**A21**	A23	PETp4	B23	A24	PETn4	B24		
A26	PETp5	B26	A27	PETn5	B27	A29	PETp6	B29		
A30	PETn6	B30	A32	PETp7	B32	A33	PETn7	B33		
B2	PERp0	A2	B3	PERn0	A3	B5	PERp1	A5		
B6	PERn1	A6	B8	PERp2	A8	B9	PERn2	A9		
B11	PERp3	A11	B12	PERn3	A12	B20	CWAKE#	**B20**		
B21	CPERST#	**B21**	B23	PERp4	A23	B24	PERn4	A24		

Data sockets X221 and X222										
Pin	**(PCI name)**	**Opp.**	**Pin**	**(PCI name)**	**Opp.**	**Pin**	**(PCI name)**	**Opp.**	**⇄**	**Notes**
B26	PERp5	A26	B27	PERn5	A27	B29	PERp6	A29		
B30	PERn6	A30	B32	PERp7	A32	B33	PERn7	A33		

Table 3-9: GND pins in X221 and X222.

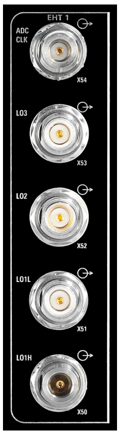
GND															
Pin	A1	A4	A7	A10	A13	A16	A22	A25	A28	A31	A34	B1	B4	B7	B10
Opp.	B1	B4	B7	B10	B13	**A16**	B22	B25	B28	B31	B34	A1	A4	A7	A10
Pin	B13	B22	B25	B28	B31	B34		**Name**		GND (I/O)					
Opp.	A13	A22	A25	A28	A31	A34									

Table 3-10: N.c. pins in X221 and X222.

Pin	A17	A18	B14	B15	B16	B17	B18	B19		**Name**	n.c.

3.3.9 Local Oscillator and ADC

3.3.9.1 EHT 1



X50 *LO1H* (out) **X51 *LO1L*** (out) **X52 *LO2*** (out) **X53 *LO3*** (out)
X54 *ADC CLK* (out)

X50 to **X53** are four reference frequency outputs. With regard to perfect synchronization, these signals are generated in the Wideband Synthesizer Board located in the R&S EBD770 and used in the mixer stages (local oscillators, LO) of the R&S EHT770 for frequency mixing. **X54** is a central clock signal for the A/D converter in the R&S EHT770 that digitizes the Rx signals from the antenna(s); synchronization considerations apply accordingly. All are N sockets.

3.3.10 Calibration

X14 *CAL HF* (out) **(with option R&S DDFGTS-HF installed)**

An antenna calibrating signal (comb spectrum or single CW tone) for the HF frequency range is generated by the internal calibrating generator and output here (N socket).

X24 *CAL V/UHF* (out)

Antenna calibrating signal (comb spectrum or single CW tone) for the VHF/UHF frequency range (N socket).

X34 *CAL U / SHF* (out)

Antenna calibrating signal (comb spectrum or single CW tone) for the UHF/SHF frequency range (N socket).

3.3.11 Reference Input/Output

X41 *REF IN*

is a BNC socket that an external clock signal (10 MHz, stability higher than 10^{-7}) can be connected to. If such a signal is provided and enabled by the XML command

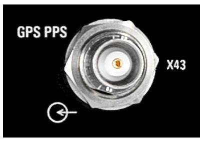
- `ReferenceMode`

all internal clocks are derived from it. This arrangement is intended for synchronizing exactly several devices (other direction finders, receivers, signal generators etc.) operated in a network, that is, synchronizing the internal OCXO frequencies. Thus, the correct signal to input here is, for example, the ***REF OUT*** signal of a "master" R&S DDF5GTS / R&S EBD770 controlling the present R&S DDF5GTS / R&S EBD770 as a slave.

You can also use this input if you have an even more precise 10 MHz reference at your disposal such as an external rubidium normal.

X42 *REF OUT*

(BNC socket) delivers a synchronizing signal (10 MHz, derived from the clock of the internal OCXO) to control exactly other devices (e.g. other R&S DDF5GTS / R&S EBD770 units) in a network. Connect this signal to the ***REF IN*** input of all "slave" devices (e.g. R&S DDF5GTS / R&S EBD770 units) to control.



X43 *GPS PPS* (in)

is a BNC socket where the GPS one-second pulse (PPS) is supplied to. This pulse is supplied by GNSS receivers and will be used for adding high-precision timing information to bearing results as well as for synchronizing several direction finders in a radiolocation network in order to ensure authentic bearing of short emissions and locating of their emitters. Control interface of a GNSS receiver is connected to **X15 *GPS*** (or to the equivalent **X16 *COMPASS***).

X44 *TRIGGER* (in)

is a BNC socket that can be configured as

- source for the Blanking signal, see Chapter 3.11.6.3, "Blanking", on page 175
- start signal input for initiating a DF measurement, e.g. for synchronized bearing

3.3.12 Internal GPS Module (Option R&S DDF-IGT) or Internal GNSS Module (R&S DDFGTSIGT2)

Find more detailed information about the options R&S DDF-IGT and R&S DDFGTSIGT2 in Chapter 2.6.9 on page 86.

X110 *GPS ANT* (in)

You connect the supplied antenna or another usual GNSS antenna to this socket (SMA socket, female).

NOTICE

Active or Passive Antenna

Pay attention whether the used antenna is an active (as is the supplied antenna) or a passive antenna, because in case of an active antenna a supply voltage of 5 V is fed into the antenna connector. A passive antenna does not need any supply voltage and might even be damaged if a voltage is fed anyway.

Set the appropriate antenna type (passive or active) before you connect your GNSS antenna. If using a passive antenna or also GNSS antenna splitters and having the active antenna type configured, irreversible damage of the antenna might occur.

X111 *GPS PPS* (out)

From this socket (BNC socket) a high-precision one-second pulse (PPS) is provided. With the cable set included in delivery with R&S DDF-IGT and R&S DDFGTSIGT2, this signal is to be connected to **X43 *GPS PPS***.

X112 *GPS NMEA OUT*

The NMEA 0183 sentences controlling GNSS handling in the R&S DDF5GTS are output via this connector (D-Sub female, 9 pins). It is to be linked to **X15 *GPS*** or also to **X16 *COMPASS***; both of them are equivalent. Find information about pin assignment in Table 3-3 and about pinout in Figure 3-6, for detailed information on each signal refer to relevant publications.

3.3.13 LAN

X4 *LAN 1*   X5 *LAN 2*

are the remote control sockets (type RJ-45, female, 8 contacts) obeying the known LAN standard. Pin assignment is shown in Table 3-11 and pinout in Figure 3-8, further information can be found in relevant publications.

Both connectors **X4** and **X5** are equivalent.

Table 3-11: LAN connectors X4 and X5.

X4 and X5 LAN				
Pin	**Name**	**⇄**	**Range**	**Notes**
1	TXD+	O	10/100/1000BASE-T pos.	Transmitted data
2	TXD–		10/100/1000BASE-T neg.	
3	RXD+	I	10/100/1000BASE-T pos.	Received data
6	RXD–		10/100/1000BASE-T neg.	

X4 and X5 LAN				
Pin	**Name**	**⇄**	**Range**	**Notes**
4, 5, 7, 8	n.c.			
(housing)	GND	I/O		

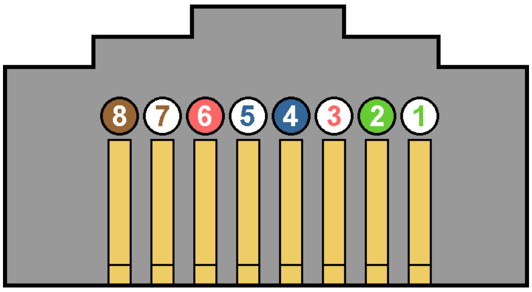


Figure 3-8: Pinout of X4 LAN 1 and X5 LAN 2 (view to the rear panel from outside).

3.3.14 Grounding Bolt

The ⏚ (grounding) bolt (standing bolt with M5 thread) serves for earthing the R&S EBD770 (see Chapter 2.3.1.3, "Grounding", on page 31).

3.3.15 Kensington Security Slot

In the Kensington Security Slot you can insert a *Kensington* lock or a similar anti-theft protection device.

3.4 Rear Panel Elements R&S EHT770

3.4.1 General

As told in Chapter 3.3 on page 91, the R&S DDF5GTS can be ordered in two unit models AC and DC, the rear panel appearance of both components, the R&S EBD770, Processing Unit, and the R&S EHT770, DF Converter, differs accordingly. The two figures (3.4.1.1) show the rear panel of both models of the R&S EHT770, Figure 3-9 for the AC and Figure 3-10 for the DC model.

Be aware that in both figures the rear panel is shown with options installed.

This chapter 3.4 describes all inputs and outputs located on the rear panel of the R&S EHT770. A scope of all connectors is given in Table 3-12.

3.4.1.1 Rear Panel View R&S EHT770

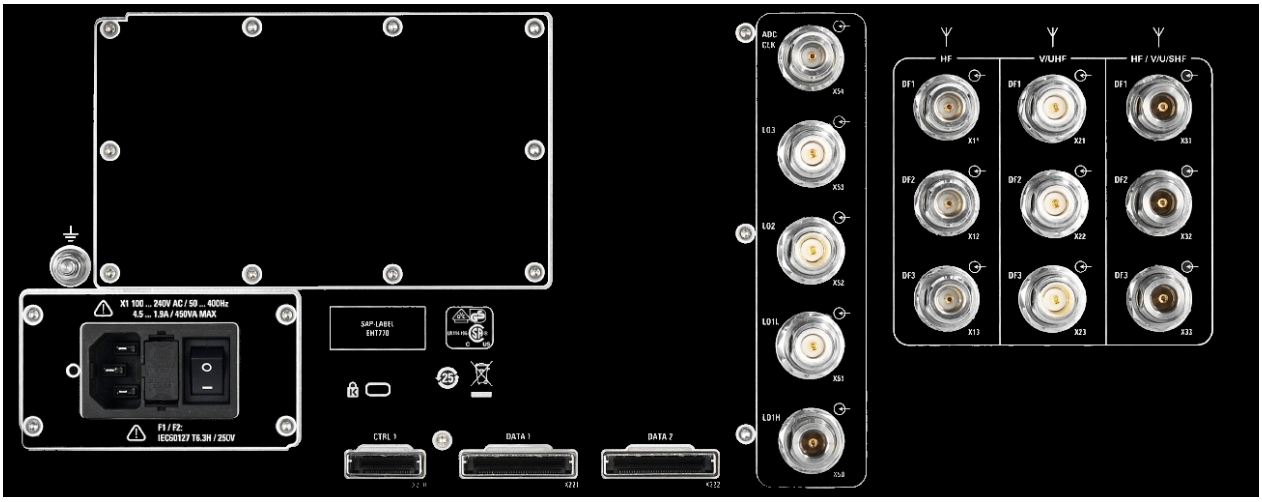


Figure 3-9: R&S EHT770 rear panel, AC power supply model.

X11 to X13 = if option R&S DDFGTS-HF (HF Frequency Extension, see Chapter 2.6.2) installed

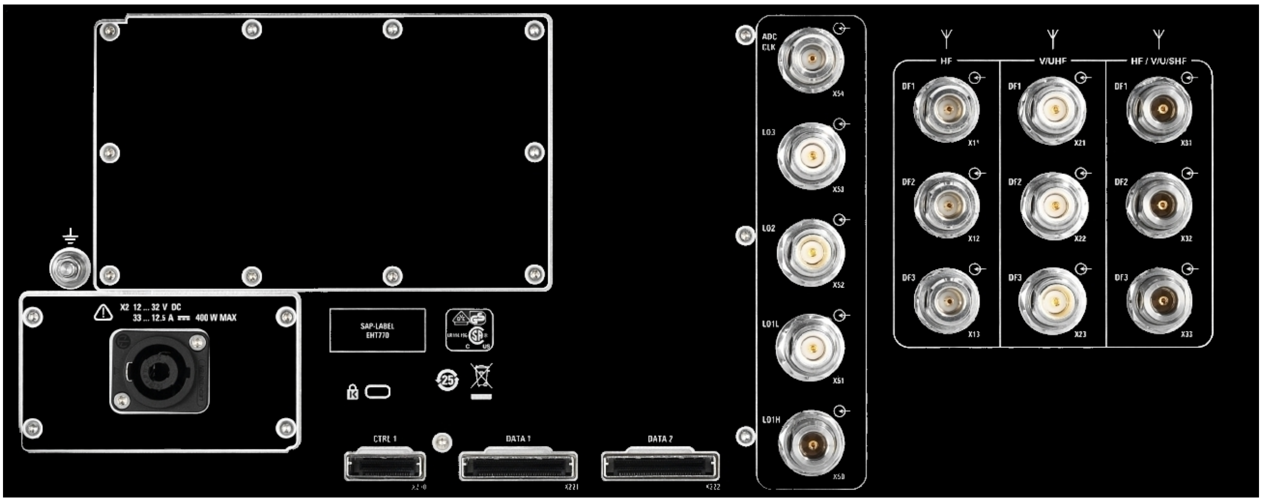


Figure 3-10: R&S EHT770 rear panel, DC power supply model.

X11 to X13 = if option R&S DDFGTS-HF installed

3.4.1.2 Overview

Cables to Use

Mind Note "Cables to Use" on page 93.

Table 3-12: Connectors on rear panel of the R&S EHT770.

Rear panel R&S EHT770						
Group	**Conn.**	**Name**	**⇄**	**Notes**		
Mains	**X1**	***100...240 V AC***	I	AC power supply model only		IEC 60320 C14.
	X2	***12...32 V DC***		DC power supply model only		*Neutrik* Speakon NL4MP socket.
Control	**X210**	***CTRL 1***	I/O	Digital transmission to R&S EBD770	control	*Molex* iPass x4 (or PCI x4) socket (female), 38 pins.
Data	**X221**	***DATA 1***			data	Molex iPass x8 (or PCI x8) socket (female), 68 pins.
	X222	***DATA 2***				
LO and ADC	**X50**	***LO1H***	I	Local oscillator to R&S EBD770	1	Z = 50 Ω; N socket.
	X51	***LO1L***				
	X52	***LO2***			2	
	X53	***LO3***			3	
	X54	***ADC CLK***		ADC clock to R&S EBD770		
HF	HF antenna[1]*: 8 kHz to 30 MHz					
	X11	***DF1***	I	Rx channel (radiator)	1	
	X12	***DF2***			2	
	X13	***DF3***			3	
V/UHF	VHF/UHF antenna: 20 MHz to 3 GHz					
	X21	***DF1***	I	Rx channel (radiator)	1	
	X22	***DF2***			2	
	X23	***DF3***			3	
HF / V/U/SHF	HF/VHF/UHF/SHF antenna: 20 MHz/8 kHz[2]* to 6 GHz					
	X31	***DF1***	I	Rx channel (radiator)	1	
	X32	***DF2***			2	
	X33	***DF3***			3	
(GND)				Ground terminal		Standing bolt with M5 thread.
(Kensington)				Theft protection		*Kensington* Security Slot.

⇄ *Direction of signal: I: in, O: out.*

1) *Connectors only present with option R&S DDFGTS-HF, HF Frequency Extension, installed.*

2) *With option R&S DDFGTS-HF installed.*

NOTICE

Cable Types

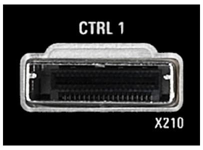
Mind Note "Cable Types" on page 96.

3.4.2 Mains

X1 ***100...240 V AC*** **X2** ***12...32 V DC***

Connecting the R&S EHT770 to the power supply is done exactly as with the R&S EBD770; therefore, all information about it can be seen from Chapter 3.3.2.

3.4.3 Control

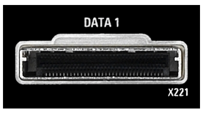


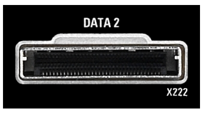
X210 ***CTRL 1***

is a *Molex* iPass x4 (or PCI x4) socket (female, 38 pins) for controlling the R&S EHT770 by the R&S EBD770 (LVDS level), i.e. the same connector as **X211** and **X212** in the R&S EBD770; thus, see pin assignment from Table 3-5, GND pins from Table 3-6 and n.c. pins from Table 3-7. The underlying PCI use of the connection has been modified for the R&S DDF5GTS, the original names are added in the table for information, however.

See Chapter 3.3.7 for information about wiring (especially mind Note "PCI Standard" on page 102) and the "Opp." column of the table.

3.4.4 Data



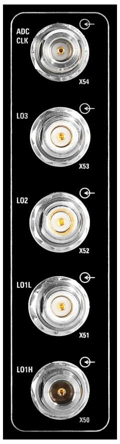


X221 ***DATA 1*** **X222** ***DATA 2***

are two Molex iPass x8 (or PCI x8) sockets (female, 68 pins) for transferring data from the R&S EHT770 to the R&S EBD770 (LVDS level), i.e. the same connectors as **X221** and **X222** in the R&S EBD770; thus, see pin assignment of **X221** and **X222** from Table 3-8, GND pins of both connectors from Table 3-9 and n.c. pins from Table 3-10. The underlying PCI use of the connection has been modified for the R&S DDF5GTS, the original names are added in the table for information, however.

See Chapter 3.3.7 for information about wiring (especially mind Note "PCI Standard") and the "Opp." column of the table.

3.4.5 Local Oscillator and ADC



X50 ***LO1H*** (in) **X51** ***LO1L*** (in) **X52** ***LO2*** (in) **X53** ***LO3*** (in) **X54** ***ADC CLK*** (in)

X50 to **X53** are the inputs for the local oscillator (LO) reference frequency signals, whereas **X54** receives the clock signal to the ADC that digitizes the Rx signals from the antenna(s). All are N sockets. The connectors correspond to **X50** to **X54** or **X60** to **X64**, respectively, of the R&S EBD770; find more information in Chapter 3.3.9.1, "EHT 1".

3.4.6 RF Input

3.4.6.1 General

Each antenna is to be installed with its RF cables (three due to three-channel DF). The calibration signal is supplied by the R&S EBD770, as is antenna control by the special control cable. Find information about calibration in Chapter 3.3.10, "Calibration" and about antenna control signals in Chapter 3.3.3, "Antenna Control".

Each one of the groups described in 3.4.6.2 to 3.4.6.4 (dedicated to distinct frequency ranges) has three sockets; each socket corresponds to one of the three DF channels, channel 1 of each group (i.e. **X11**, **X21** or **X31**, respectively) is the reference channel.

3.4.6.2 HF

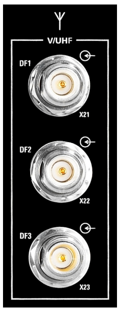
(with option R&S DDFGTS-HF installed)

X11 ***HF, DF1*** (in) **X12** ***HF, DF2*** (in) **X13** ***HF, DF3*** (in)

These three N sockets are the input for the RF signal of a connected HF antenna.

Digitized Rx data are transmitted to the R&S EBD770 via **X221** ***DATA 1*** and **X222** ***DATA 2*** (3.4.4); the control signals from the R&S EBD770 needed are provided via the **X210** ***CTRL 1*** control socket (3.4.3).

3.4.6.3 V/UHF

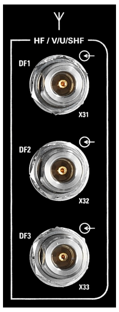


X21 *V/UHF, DF1* (in) **X22 *V/UHF, DF2*** (in) **X23 *V/UHF, DF3*** (in)

The three channels of a connected VHF/UHF antenna are input here (N sockets). Except for the covered frequency range, the inputs are equivalent to the **X11**, **X12** and **X13** inputs, see 3.4.6.1.

Again, digitized Rx data are transmitted to the R&S EBD770 via **X221 *DATA 1*** and **X222 *DATA 2*** (3.4.4); control signals from the R&S EBD770 needed are provided via the **X210 *CTRL 1*** control socket (3.4.3).

3.4.6.4 HF / V/U/SHF



X31 *HF / V/U/SHF, DF1* (in) **X32 *HF / V/U/SHF, DF2*** (in) **X33 *HF / V/U/SHF, DF3*** (in)

Antenna sockets for HF/VHF/UHF/SHF antenna, see 3.4.6.1 and 3.4.6.3.

3.4.7 Grounding Bolt

The ⏚ (grounding) bolt (standing bolt with M5 thread) serves for earthing the R&S EHT770 (see Chapter 2.3.1.3, "Grounding", on page 31).

3.4.8 Kensington Security Slot

In the Kensington Security Slot you can insert a *Kensington* lock or a similar anti-theft protection device.

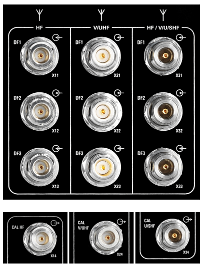
3.5 Installation and Cabling of Antenna(s), Antenna Combinations and Related Equipment

3.5.1 General

For details about correct cabling of antennas refer to Chapter 2.4.2, "Antenna Types", on page 38, Chapter 3.3, "Rear Panel Elements R&S EBD770", on page 91, Chapter 3.4, "Rear Panel Elements R&S EHT770", on page 107 and to the individual antenna manuals.

All RF cables have N connectors both on the DF unit side and on the antenna side: the central components of the three-component RF cables in case of cable lengths from about 20 meters upward are equipped with N sockets, the exterior or, with one-component RF cables, only component(s) with plugs. The control cable has a 25 pin D-Sub plug on the DF unit side and 22 pin SJT (VG96912) socket on the antenna side or, if needed, the power supply side. Linking between power supply and antenna is done with SJT connectors on both sides, plug on power supply and socket on antenna side. For details, see Table 3-13 and the R&S ADDx antenna manuals.

3.5.2 Configuring the Antenna Inputs



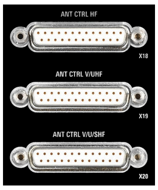
In addition to establishing the correct connections as told in the subsequent sections, you commonly have to configure the antenna inputs, i.e. tell the R&S DDF5GTS which of the three antenna inputs (groups of connectors)

- **X11** to **X13** ***HF*** and **X14** ***CAL HF*** (option R&S DDFGTS-HF installed)
- **X21** to **X23** ***V / U / SHF 1*** and **X24** ***CAL V/UHF***
- **X31** to **X33** ***V / U / SHF 2*** and **X34** ***CAL U/SHF***

is to be used in the individual frequency ranges (this is, also automatic switching of antenna input will be performed if required by an according change of the frequency range). Antennas identify themselves to the R&S DDF5GTS, so you normally have to do so if the desired operating frequency ranges deviate from the default ranges of the connected antennas.

Apply the XML (XML) commands [2.4]

- `AntennaControl` and `AntennaSetup`



for this issue. Remember in this context that the three antenna control connectors

- **X18** ***ANT CTRL HF*** **X19** ***ANT CTRL V/UHF*** **X20** ***ANT CTRL V/U/SHF***

are equivalent and can be used arbitrarily without configuring (see Chapter 3.3).

For each individual antenna connected, the command

- `AntennaSetup`

has to announce the relevant antenna parameters, such as frequency range the antenna is intended for, correction values for the nautical angles, input/output connectors for the antenna signals (RF and calibration). If, for the entire frequency range to cover, several antennas are in need or desired (and connected), then for the particular range currently active the appropriate antenna will be selected automatically this way. (In case of combined antennas, switching of subassemblies following the frequency ranges they are designed for is managed internally by the antenna itself and not subject to control of the user.)

Be aware that these settings for individual antennas can be overridden by the command

- `AntennaControl`

If you select *manual* antenna control mode, i.e. specify

- `AntennaControl`: `eAntennaControlMode=ANT_CTRL_MODE_MANUAL`

the settings available for individual antennas will be ignored and the parameters `eRFInput` and `eHFInput` of the `AntennaControl` command itself evaluated instead. No correction values, frequency range borders or other configurations of individual antennas stated elsewhere are active in this case, and there also is the risk to erroneously utilize wrong parameters; therefore use this setting only for temporary test purposes, but not for normal operation.

Thus, always have antenna control mode set to *automatic*:

- `AntennaControl`: `eAntennaControlMode=ANT_CTRL_MODE_AUTO`

3.5.3 Grouping and Cabling Example(s)

In all examples shown subsequently, for a better overview all connectors not relevant in this context are omitted.

3.5.3.1 Single HF Antenna

With option R&S DDFGTS-HF installed

In Figure 3-11 connecting of a single R&S ADD119 antenna covering the HF range (300 kHz to 30 MHz) is shown. Cabling is done with the antenna cable set R&S DDF1XZ (Chapter 2.4.4.2 on page 42), consisting of three RF cables guiding the signals from the three antenna channels to the R&S EHT770, another RF cable carrying the calibration signal from the R&S EBD770 to the antenna and the antenna control cable coming also from the R&S EBD770.

On the antenna side, two additional RF connectors are provided: X10 is switchable to each of the antenna components and thus can be used for universal DF purposes, whereas X20 makes up a link to the reference antenna only and therefore is suitable for monitoring purposes, i.e. a standard receiver can be connected.

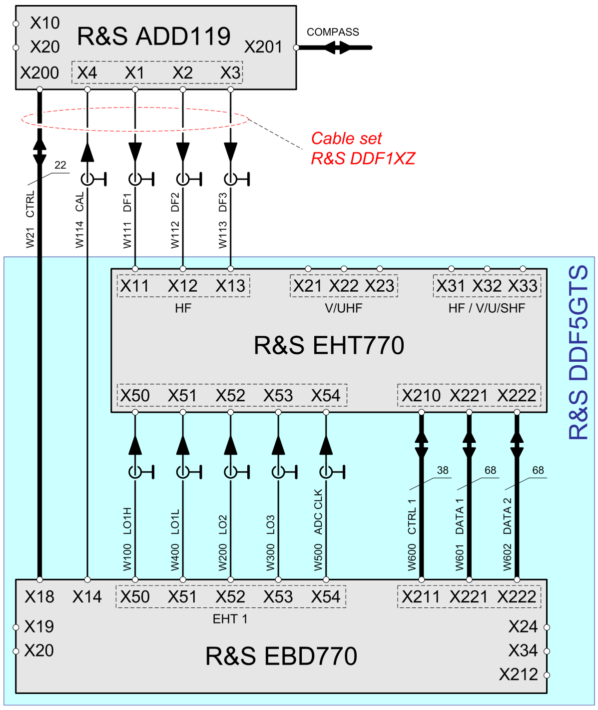


Figure 3-11: Direction Finder R&S DDF5GTS with antenna R&S ADD119.

3.5.3.2 Wideband Antenna Covering Large Parts of the Frequency Range

R&S ADD216 is an antenna usable with wide parts of the frequency range covered by the R&S DDF5GTS. Radiator arrays for the individual frequency sections are combined within the antenna, switching according to the current frequency (frequencies) in use is done internally. A frequency range of 300 kHz to 3 GHz can be operated this way with a single antenna. R&S ADD216 can preferably be employed on ships.

In Figure 3-12 the cabling scheme for an R&S ADD216 is given; be aware that due to the large frequency range merely the connectors **X31** to **X34** ***HF / V/U/SHF*** may be used.

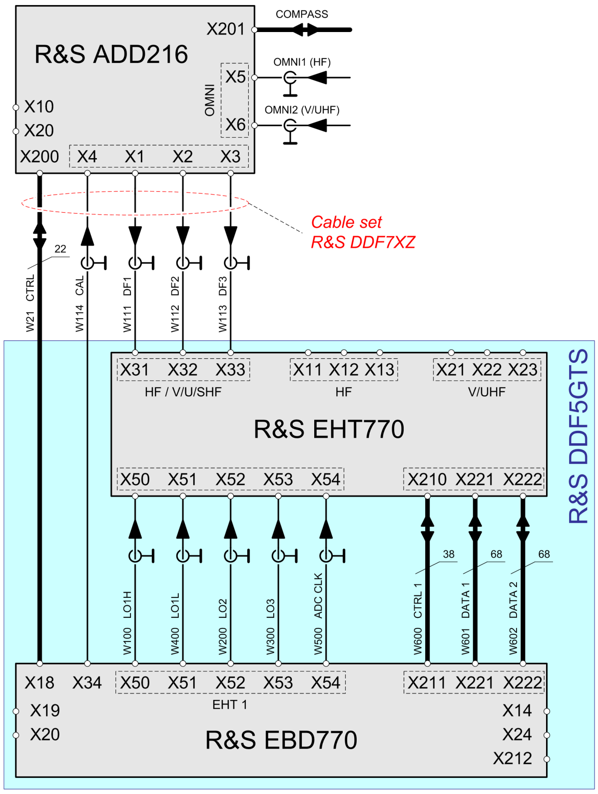


Figure 3-12: Direction Finder R&S DDF5GTS with antenna R&S ADD216.

3.5.3.3 Antenna Combination for VHF and UHF Range

R&S ADD153SR (9 antenna elements grouped in a circular array) covers the frequency range from 20 MHz to 1.3 GHz (VHF and lower range of UHF), whereas R&S ADD070 (8 antenna elements) is used for 1.3 GHz to 3 GHz (UHF, upper range); thus, combining both enables direction finding over the whole frequency range of the R&S DDF5GTS basic unit. For cabling, both the cable set R&S DDF5XZ (Chapter 2.4.4.3 on page 42) and also cable set R&S DDF7XZ (Chapter 2.4.4.4 on page 42) are needed, see Figure 3-13.

The same cabling scheme is valid if using R&S ADD157 or R&S ADD253 (replace cable set R&S DDF5XZ by R&S DDF7XZ) instead of R&S ADD153SR and R&S ADD070M or R&S ADD170 instead of R&S ADD070.

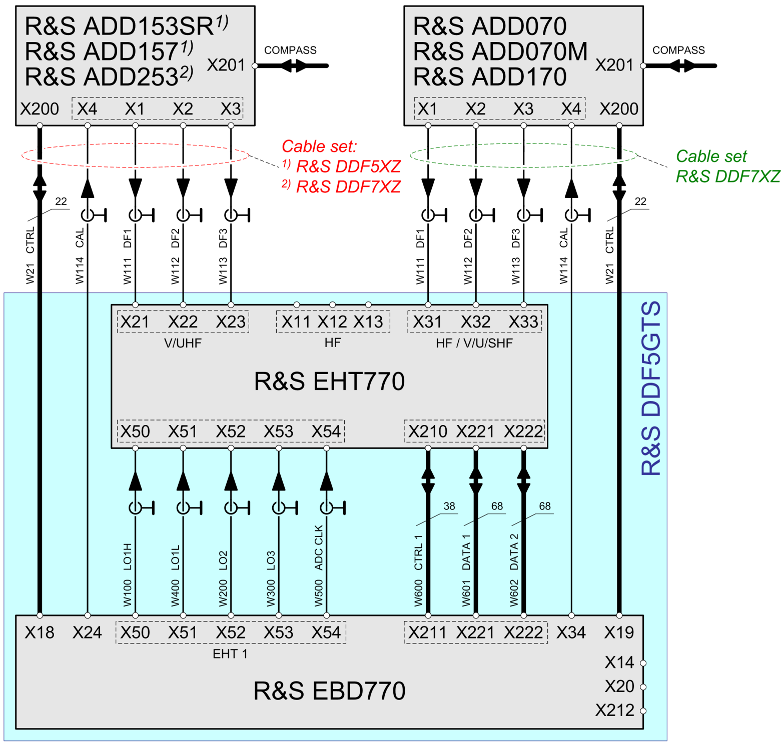


Figure 3-13: Direction Finder R&S DDF5GTS with antennas R&S ADD070/R&S ADD070M/ R&S ADD170 and R&S ADD153SR/R&S ADD157/R&S ADD253.

The situation if using R&S ADD078SR instead of R&S ADD070 is shown in Figure 3-14: the R&S ADD153SR need no longer be connected to the R&S DDF5GTS but can directly be plugged to the R&S ADD078SR.

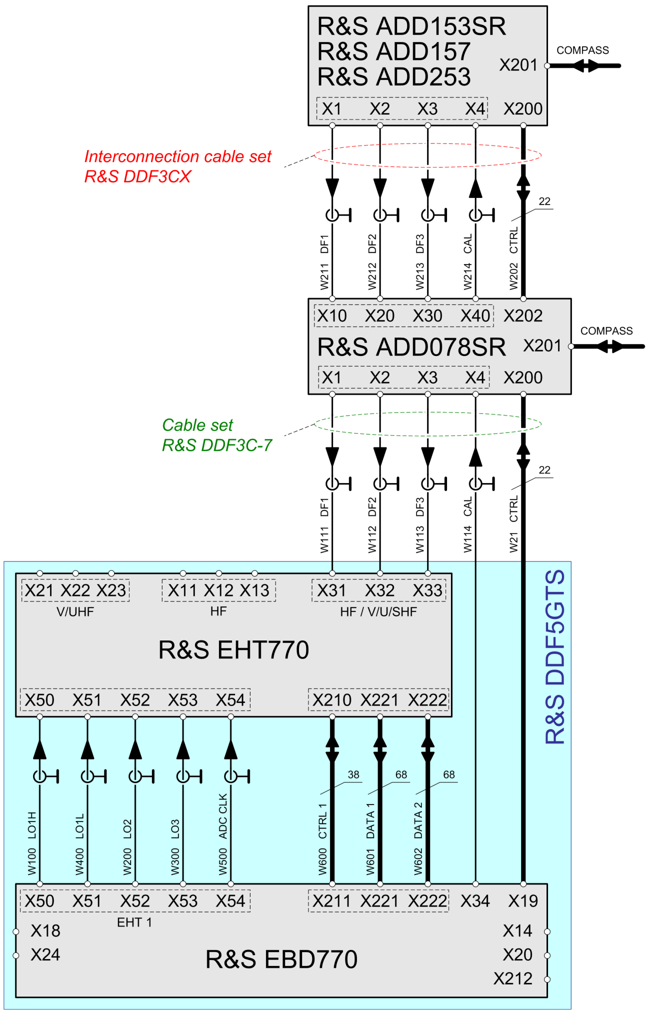


Figure 3-14: Direction Finder R&S DDF5GTS with antennas R&S ADD078SR and R&S ADD153SR/ R&S ADD157/R&S ADD253.

3.5.3.4 Antenna Combination due to Different Antenna Sensitivity

A combination consisting of R&S ADD050SR and R&S ADD153SR is illustrated in Figure 3-15. Although the latter covers the nominal frequency range of 20 MHz to 1.3 GHz (VHF and lower range of UHF), the former features a far better sensitivity in the range of 20 MHz to 450 MHz ("extended" VHF) and therefore is recommended to be used instead. (Correct switching is performed internally by the DF firmware.) In this combination both antennas are cascaded; the link to the R&S DDF5GTS is formed by the cable set R&S DDF5XZ (Chapter 2.4.4.3), whereas the connection between both antennas is built by the mast section R&S KM051.

The same cabling scheme is valid if using R&S ADD157 or R&S ADD253 instead of R&S ADD153SR.

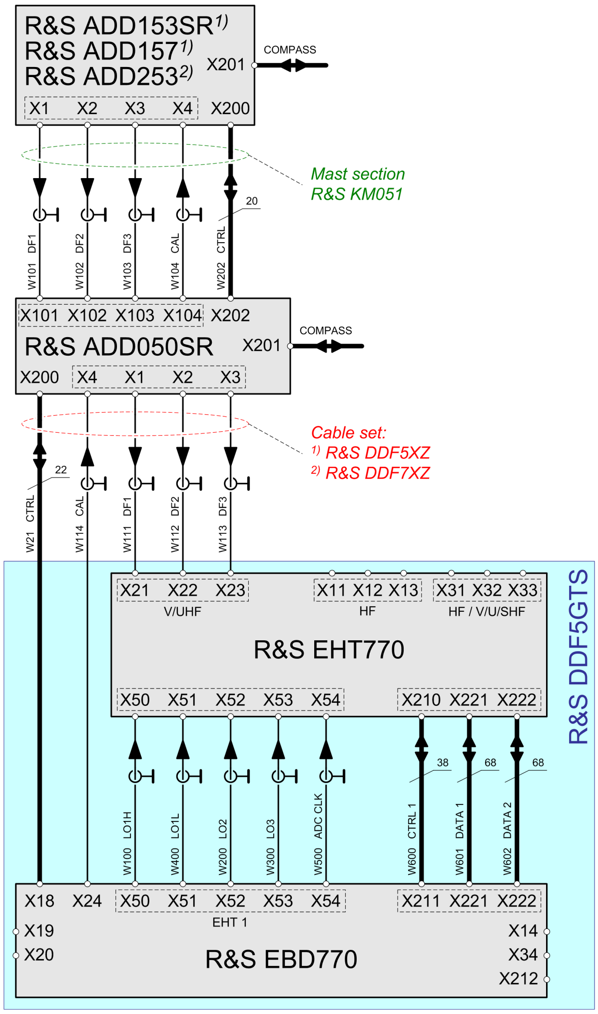


Figure 3-15: Direction Finder R&S DDF5GTS with antennas R&S ADD050SR and R&S ADD153SR/R&S ADD157/R&S ADD253.

3.5.3.5 Antenna Combination for VHF and UHF Range and due to Different Antenna Sensitivity

The union of the combinations of 3.5.3.3 and 3.5.3.4 is shown in Figure 3-16 (R&S ADD070, R&S ADD070M and R&S ADD170) and Figure 3-17 (R&S ADD078SR) for a better understanding of the cabling requirements.

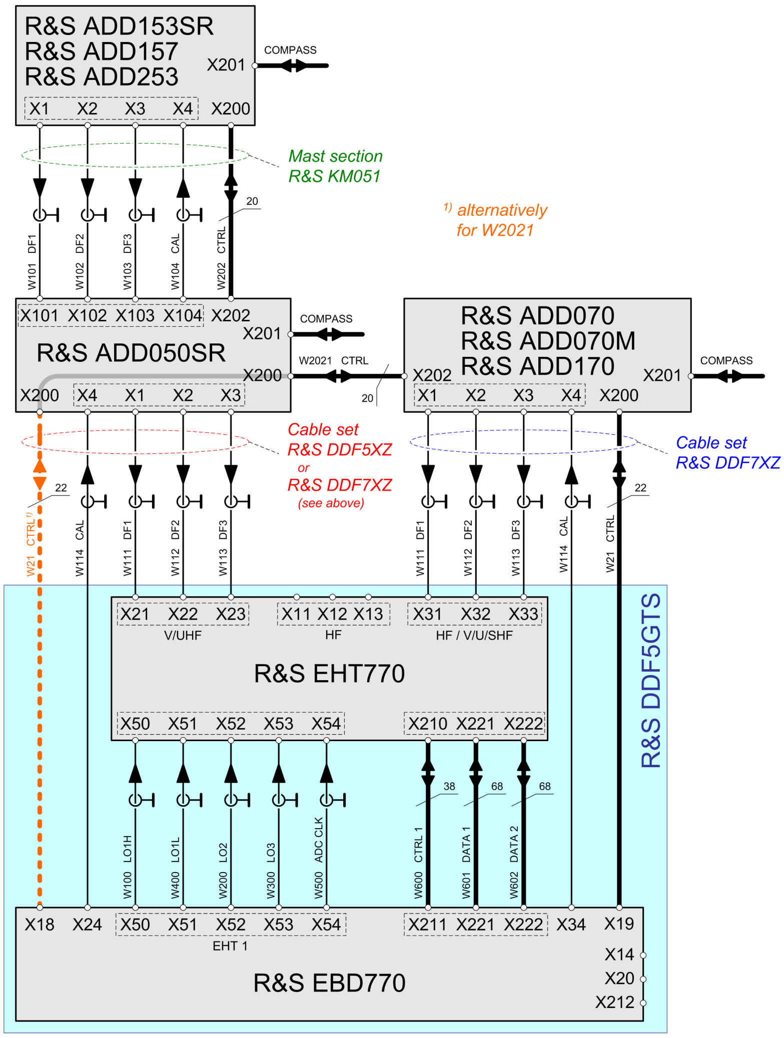


Figure 3-16: Direction Finder R&S DDF5GTS with antennas R&S ADD050SR, R&S ADD070/ R&S ADD070M/R&S ADD170 and R&S ADD153SR/R&S ADD157/R&S ADD253.

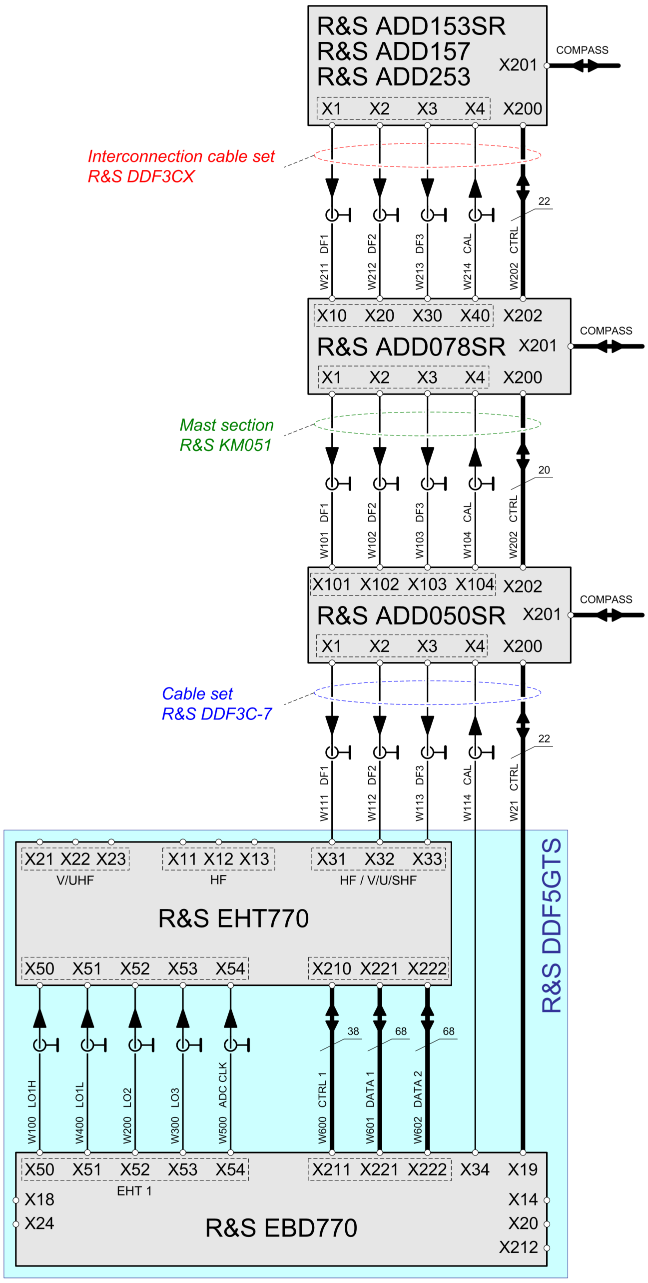


Figure 3-17: Direction Finder R&S DDF5GTS with antennas R&S ADD050SR, R&S ADD78SR and R&S ADD153SR/R&S ADD157/R&S ADD253.

3.5.4 Cable Length

Special attention is to be paid to the distance of the antenna from the R&S DDF5GTS and hence to the length of the cable set needed. Cable sets are available in lengths between 5 meters and 250 meters, the individual lengths depending on the particular type of set; all lengths, together with the cable set weights, are shown in Table 3-13.

(For ordering, the length is expressed in the last two digits of the *Rohde & Schwarz* part number, the so-called model number.)

Some peculiarities of the cable sets can be seen from Figure 3-18, Figure 3-19 and Figure 3-20:

- Depending on the antenna(s) used, larger lengths of the control cable require use of the additional power supply R&S IN061.
  The R&S IN061 is included in delivery with some models, i.e. lengths, of the cable sets; details are listed in Chapter 2.4.4, "Antenna Accessories", on page 41.
- Exceeding a special length threshold, the RF cables are divided in three individual components each, since dielectric losses due to higher cable lengths are to be minimized by using more voluminous cables.

Table 3-13: Lengths of cable sets.

Length in m	**5**	**10**	**20**	**30**	**40**	**50**	**80**	**100**	**150**	**250**
R&S DDF1XZ, 8 kHz to 30 MHz	1			1				1	1	3
Weight [kg]	5			30				98	147	421
R&S DDF5XZ, 8 kHz to 1.3 GHz	1	1	1	3	3	3	3, IN	3, IN		
Weight [kg]	5	10	20	54	72	89	287	396		
R&S DDF7XZ, 8 kHz to 3 GHz	1	1	3	3	3	3				
Weight [kg]	5	10	39	105	135	184				
R&S DDF3C-7, 500 kHz to 6 GHz	1	3	3	3						
Weight [kg]	5	12	24	36						

1 = *1-component RF cables* *3* = *3-component RF cables*

IN = *power supply R&S IN061 included in delivery*

No entry = *not available*

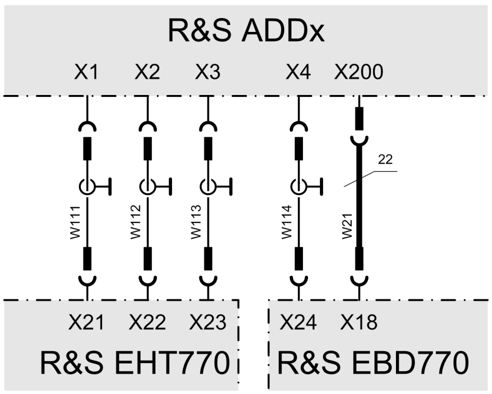


Figure 3-18: Schematic of cabling, small antenna distance.

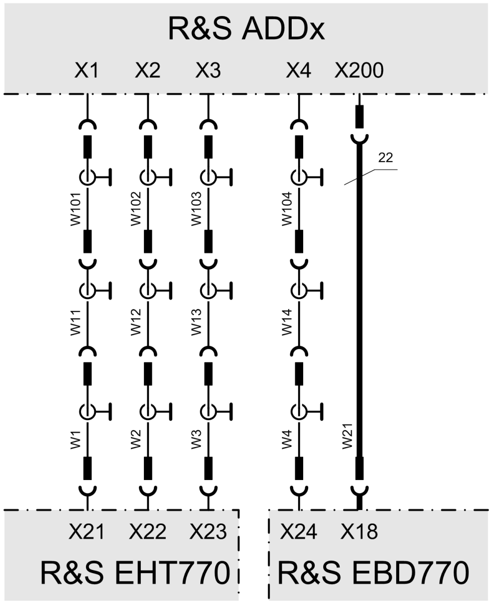


Figure 3-19: Schematic of cabling, medium antenna distance.

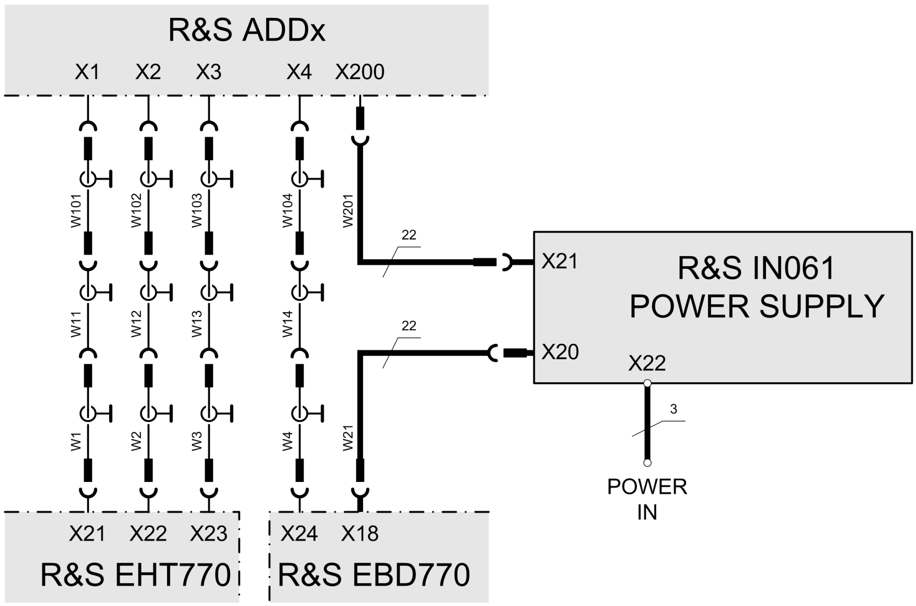


Figure 3-20: Schematic of cabling, large antenna distance.

3.6 System Time

3.6.1 General

The R&S DDF5GTS is controlled by an internal high-precision clock. This "central" clock provides *system time* that all other timing information, especially the timestamps delivered with every bearing, is derived from; additionally an internal battery-buffered realtime clock (RTC, lower precision) supports continuity of timing also while the unit is switched off. One of four origins for the initial setting of this system time has to be selected:

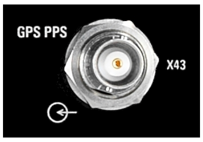
- Internal RTC, i.e. proceeded system time since last setting of the RTC (3.6.3), also default (power-up) setting
- Manual setting (3.6.4)
- GNSS: R&S DDF-IGT or R&S DDFGTSIGT2 (options, cf 2.6.9) or external GNSS receiver (3.6.5)
- External NTP server (3.6.6)

Nomenclature

In this chapter, the two existing clocks are distinguished as follows:

- **System clock**: high-precision clock delivering *system time*, i.e. all timing information for operation of the R&S DDF5GTS,
- **Realtime clock (RTC)**: battery-buffered clock of lower precision to maintain continuity of clock time in periods of power-down.

Depending on your special system configuration, you have to establish the necessary cabling connections (e.g. GPS pulse, RS-232) and to configure the related R&S DDF5GTS parameters accordingly. All configurations are performed by XML (XML) commands [2.4].



Another decision to be taken is whether clocking is to be started externally or internally, i.e. whether or not a synchronization is to be done to the one-second pulse (PPS) delivered by an external GNSS receiver from outside to **X43 *GPS PPS*.**

Find an overview on the complete timing architecture, including the XML commands to perform individual settings, in Figure 3-21.

Regardless of which origin timing data arises from, its current state (timestamp) always can be queried by the command (⑫ in the figure)

- `DateAndTime`

and location data by

- `LocationManual`

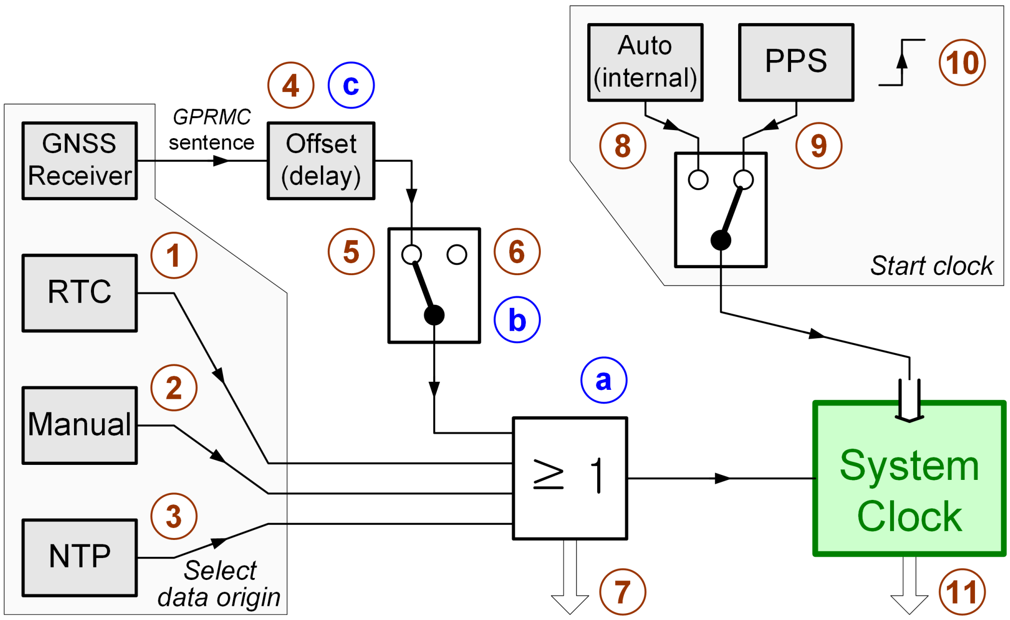
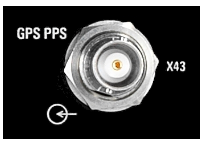


Figure 3-21: System timing architecture and XML commands.

① = (System power-up)
② = "DateAndTime" (setting of current system time)
= "LocationManual" (setting of current location)
③ = "NTP"
④ = "GPSSetup: eGpsTimeOffset=(Offset in ms)"
⑤ = "LocationAndTimeSource: eLocTimeSource=LOC_TIME_SRC_GPS"
⑥ = "LocationAndTimeSource: eLocTimeSource=LOC_TIME_SRC_MANUAL"
⑦ = "ClockSettings: eClock_Origin" (query of origin of last system clock setting)
⑧ = "ClockSettings: eClockStart=CLOCK_START_AUTO"
⑨ = "ClockSettings: eClockStart=CLOCK_START_EXTERNAL"
⑩ = "GPSSetup: eGpsEdge=EDGE_RAISING"
⑪ = "DateAndTime" (query of current system time)
= "LocationManual" (query of current location)
ⓐ = each input will be used
ⓑ = first GPRMC sentence after switching from ⑥ to ⑤ will be used
ⓒ = only with clock start Auto (internal) (⑧)

3.6.2 Synchronization



Normally a 10 MHz system reference that all other clockings and also the one of the system clock are derived from is generated internally. Remember that this reference can be synchronized to an external 10 MHz reference signal by the XML command

- `ReferenceMode`

this external signal is supplied at **X41** ***REF IN*** (see Chapter 3.3.11, "Reference Input/ Output", on page 105); an error message (message #**10**, case **c)**, see Chapter 4.1.8, "Troubleshooting (Error Messages)", on page 347) will appear if the external reference signal is not suitable (synchronizing PLL not locked). If the internal 10 MHz reference is used (e.g. no signal present at **X41**), but a GPS one-second pulse (PPS) fed to **X43** ***GPS PPS*** (usually coming from an external GNSS receiver), this internal reference will automatically tried to be synchronized (see Note "Precision of PPS Input") to the PPS signal. Find a graphical schematic in Figure 3-22.

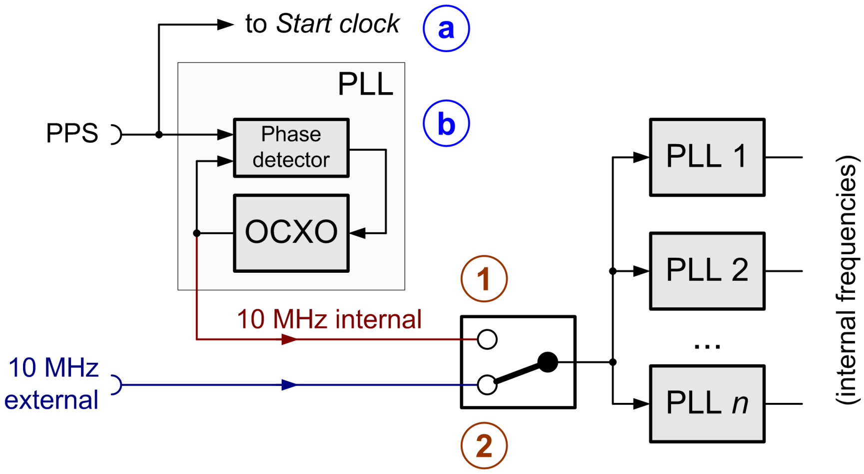


Figure 3-22: Synchronization of system time.

① = "ReferenceMode: eReferenceMode=REFERENCE_MODE_INTERNAL"
② = "ReferenceMode: eReferenceMode=REFERENCE_MODE_EXTERNAL"
ⓐ = see Figure 3-21 and Chapter 3.6.4.2, "Clock Start"
ⓑ = PLL only in use if PPS accuracy sufficient

Coupling of the internal reference signal to the PPS signal may take some minutes. After this period, a resynchronization of the system clock to the time signal delivered by the GNSS receiver will be performed. Starting of the system clock, however, is done using the internal synchronized reference signal because it is considered significantly more precise than the PPS signal coming from outside.

In any case a comparison is internally done whether the PPS signal is accurate enough, i.e. its jitter (in relation to the system reference, whether internal or external) is less than $2 \cdot 10^{-5}$ (20 µs). If this accuracy is found to be too poor, the PPS signal will not be used.

Since two externally supplied signals cannot be synchronized internally, in any case, if using an external reference together with a PPS signal, already have both signals synchronized to each other.

NOTICE

Precision of PPS Input

If accuracy of the supplied PPS signal is worse than 20 µs ($2 \cdot 10^{-5}$), it will not be used.

If using external references input to both **X41** ***REF IN*** and **X43** ***GPS PPS***, in any case supply signals synchronized to each other.

Status of synchronization can be queried by the XML command

- `ReferenceFrequency`: `eReferenceSynch`

see details from Table 3-14.

Table 3-14: Status of system time synchronization.

System time synchronization	
Parameter value	**Description: Synchronization of timing information to ...**
REFERENCE_SYNCH_INTERNAL	... internal reference
REFERENCE_SYNCH_EXTERNAL	... external reference (supplied at **X41 *REF IN***)
REFERENCE_SYNCH_PPS_UNLOCK	... internal reference synchronized to one-second pulse (PPS, supplied at **X43 *GPS PPS***), synchonization not yet completed (PLL not locked)
REFERENCE_SYNCH_PPS_LOCK	... ditto, synchonization completed (PLL locked)

3.6.3 Internal Realtime Clock

Upon system startup, system time will automatically be set by the RTC (see 3.6.1, ① in Figure 3-21). If a deviant setting (manual adjustment or time indication to come from GNSS or NTP) should be desired, it has to be done explicitly by the corresponding XML command; mind that any new time indication arriving, whether entered manually (3.6.4, ②) or read from outside (3.6.5, ⑤, and 3.6.6, ③), is also transferred to the RTC and overwrites its previous time information. The origin of the latest system clock setting can also be queried (⑦) by the command

- `ClockSettings: eClockOrigin`

Validity of this query starts from the last power-up, i.e. if no change has been made since then, the origin "power-up" (or "backup", i.e. RTC) is signalized:

- `ClockSettings: eClockOrigin=CLOCK_ORIGIN_BACKUP`

In the "Internal RTC" (power-up) case, system clock start by the external one-second pulse (3.6.1) is not possible, the system clock is always started internally (automatically) then; in other words, the default (power-up) value of `eClockStart` is `CLOCK_START_AUTO` (3.6.4). Also excluded is a manual (arbitrary) reloading of the system clock from the RTC.

3.6.4 Manual Setting

3.6.4.1 Timing Data

Selecting the "Manual" setting mode of the system time, an entirely arbitrary configuration of the timing information can be done. Thus, additionally a setting of every single parameter of date and time has to be performed. The tool for that is (② in Figure 3-21) the XML command

- `DateAndTime`

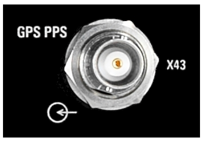
Date and time parameters to set are outlined in Table 3-15.

Table 3-15: Date and time parameters to set.

Date and time parameters				
Parameter	**Type**	**Value range**	**Example**	**Meaning**
Year	INT32	(4 digits)	2013	December 19th, 2013, 14:17:00 (02:17:00 p.m.) local Munich time (CET) (December 19th, 2013, 13:17:00 [01:17:00 p.m.] UTC)
Month	INT32	1 to 12	12	
Day	INT32	1 to 31	19	
Hour	INT32	0 to 23	14	
Minute	INT32	0 to 59	17	
Second	INT32	0 to 59	0	
TimezoneHours[1)]*	INT32	–12 to +12	1	Timezone CET: UTC+1
TimezoneMinutes[1)]*	INT32	–59 to +59	0	

[1)] *Positive values: east of UTC, negative values: west of UTC.*

3.6.4.2 Clock Start



With the XML command

- `ClockSettings`, parameter `eClockStart`

you decide whether the system clock will be started internally, this means: the date and time entries take effect immediately after the command has been processed:

- `ClockSettings`: `eClockStart=CLOCK_START_AUTO` (⑧),

or synchronized to the one-second pulse on **X43 *GPS PPS*** (see 3.6.1):

- `ClockSettings`: `eClockStart=CLOCK_START_EXTERNAL` (⑨).

Mind that in the latter case the system clock will not be started at all (remains halted) if the external pulse is missing. Mind also that the system clock is only started, but not synchronized continually. If wishing to resynchronize the system clock manually, intermediately set it to "Manual" (⑧, ②): XML commands

1. `ClockSettings`, `eClockStart=CLOCK_START_AUTO`
2. `DateAndTime`

and then back to "GPS" (3.6.5, ⑤):

- `LocationAndTimeSource`: `eLocTimeSource=LOC_TIME_SRC_GPS`

3.6.4.3 Location Data

Also, parameters concerning the location the R&S DDF5GTS is currently operated at have to be specified manually. This is done (②) with the XML command

- `LocationManual`

Location parameters to set are told in Table 3-16. The "Name of location" entry is a user defined string with arbitrary content. It is used only for user information, but not for internal distinguishing or storing of individual locations. If storing of several location data sets should be desired, it has to be established externally (within the client controlling the R&S DDF5GTS), an internal storage facility is not provided.

Table 3-16: Location parameters to set.

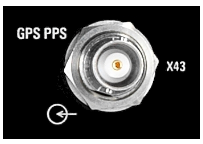
Location parameters				
Parameter		**Type**	**Example entry**	**Meaning**
Latitude	reference [N, S]	ENUM	`DIRECTION_NORTH`	Direction geographical latitude: north
	degrees [°]	INT32	48	48° 7.63848' = 48° 7' 38.3088" = 48.127308°
	minutes [' · 10^{-6}]	INT32	7638480	
Longitude	reference [E, W]	ENUM	`DIRECTION_EAST`	Direction geographical longitude: east
	degrees [°]	INT32	11	11° 36.73926' = 11° 36' 44.3556" = 11.612321°
	minutes [' · 10^{-6}]	INT32	36739260	
Altitude above MSL [cm]		INT32	54060	540.60 m
Geoidal separation valid		BOOLEAN	`true`	
Geoidal separation [cm][1)]*		INT32	4620	46.20 m
Name of location[2)]*		STRING	"Munich"	Munich

1) *Height difference between "above WGS 84 ellipsoid" and "above mean sea level":*
heightWGS84 = heightMSL + geoidalSeparation .

2) *Only for user information (no telling apart of several location data sets)*

3.6.5 Internal or External GNSS Receiver

(internal: R&S DDF-IGT or R&S DDFGTSIGT2 option installed)



If the option R&S DDF-IGT, *Internal GPS Module*, or R&S DDFGTSIGT2, *Internal GNSS Module* (see Chapter 2.6.9, on page 86), is installed or an external GNSS receiver connected to the R&S DDF5GTS, communication is done via **X15** ***GPS*** (or the equivalent **X16** ***COMPASS***) using NMEA 0183 sentences (Chapter 2.5.6.3 on page 77). Additionally a high precision one-second pulse (PPS) commonly is delivered by the receiver, it is input to the R&S DDF5GTS at **X43** ***GPS PPS***.

Data from the receiver (except the one-second pulse) comes in NMEA 0183 sentences, the most important of which are the GPRMC (GPS, "Recommended Minimum Navigation Information, Type C") and the GPGGA (GPS, "Global Positioning System Fix Data") sentence; find detailed information in Chapter 2.5.6.3.

Decide whether date and time and location data are to be taken from the data coming from the GNSS receiver by the XML command (⑤ in Figure 3-21)

- `LocationAndTimeSource: eLocTimeSource=LOC_TIME_SRC_GPS`

or not (but from the previously configured, see 3.6.3, 3.6.4 and 3.6.6) by (⑥)

- `LocationAndTimeSource: eLocTimeSource=LOC_TIME_SRC_MANUAL`

Be aware that, if "GPS" has been selected, only one (the subsequent) GPRMC sentence will be evaluated to determine timing and location information. This is done because precision of timing needed for aimed exactness of triangulation etc. will not be fulfilled by NMEA sentences, but instead by the internal timing reference (refer to 3.6.2). If wishing to evaluate another GPRMC, temporarily set the data source to "Manual" (⑥) and then back to "GPS" (⑤).

As with the "Manual" operation mode, starting the system clock can be internal or by the external one-second pulse on **X43 *GPS PPS***; all hints told in 3.6.4 also apply here.

If the system clock start is set to internal (ignoring the external one-second pulse, ⑧), an arbitrary offset, see Figure 3-23, can be specified indicating the moment at which the GPRMC sentence (or, if more sentences at a time than one are supplied by the GNSS receiver, the chain of GPRMC/GPGGA or GPGGA/GPRMC sentences, respectively) has been terminated, i.e. is available completely and ready to be evaluated. The offset is specified in relation to the one-second pulse, the system clock therefore started delayed by the offset and the offset value added directly to the UTC time specification coming with the GPRMC sentence in order to obtain a time marker as accurate as possible. Determine the timing situation representing your individual system (GNSS receiver) configuration by measuring with a usual oscilloscope.

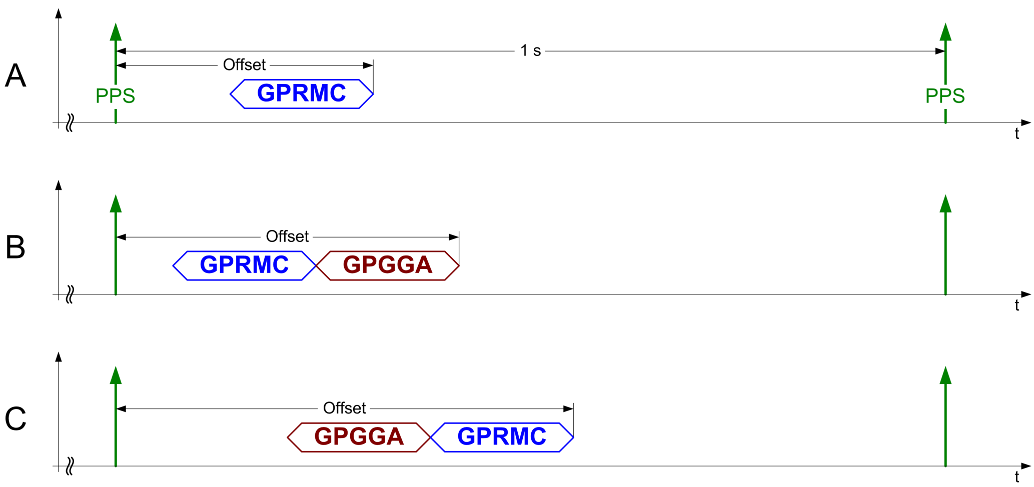


Figure 3-23: Timing offset with NMEA 0183 sentences.

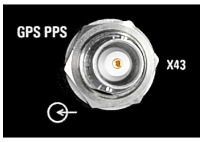
A = only GPRMC sentence
B = first GPRMC, then GPGGA sentence
C = first GPGGA, then GPRMC sentence

Programming of the offset is done with the XML command (④)

- `GPSSetup`

in the range of 0 ms to 999 ms. This command is also used for – in the case of external system clock start – selecting the rising (⑩) or the falling edge (⑪) of the one-second pulse for synchronizing.

3.6.6 External NTP Server



The fourth possible source of the system time is an external NTP (Network Time Protocol) server. If such a server is available in your system, you can perform a query of the timing information delivered by it via the XML command (③ in Figure 3-21)

- `NTP`

and use it as the current system time.

The IP address of the server to be queried is specified as a parameter to the command.

Again, the system clock can be started internally or by the external one-second pulse on **X43 *GPS PPS***; mind hints given in 3.6.4.

For best accuracy, the external server (e.g. *Meinberg* Lantime M300 or M900) should be connected (both optional) with its 10 MHz reference to **X41 *REF IN*** and with its GPS one-second pulse (PPS) to **X43 *GPS PPS***, and synchronization configured to external (3.6.4).

NOTICE

NTP Protocol

The XML command

- `NTP`

mentioned merely performs a single query of time information from the external NTP server. This is done just once per emitted command and the system time set according to it; a complete implementation of the NTP protocol is not provided this way and neither are any subsequent system clock adjustments.

If trying to reach an NTP server actually not present in the system, a communication error message ("Network Time Server not reached") will be issued by the R&S DDF5GTS, see subsequent note.

NOTICE

Error Message "Network Time Server not reached"

This message appears if an NTP server has been addressed, but could not be reached, e.g. because it is not (any longer) available in your system. Since the NTP function is stored nonvolatilely in the R&S DDF5GTS, this message might also occur after power-up – avoid it by reconnecting your NTP server or by switching off the server function by setting the server IP address to 0.0.0.0 via the XML `NTP` command.

3.6.6.1 Technical Details

When having issued an XML NTP command, an NTP packet will be generated and sent to the IP address (of the NTP server) specified in the command. Waiting period for a reply (timestamp) from the server is 5 s, if none is received, the complete process will be aborted.

Otherwise, the received packet is processed immediately: if the timestamp has not been detected within the first 500 ms of the full second (e.g. the period from 10.0 s to 10.5 s), another request is issued after an additional 100 ms period, and this repeated until an appropriate timestamp (within the first 500 ms) has been found. This timestamp is then accepted and applied to set the system clock.

Setting of the system clock depends on the synchronization setting to internal or external (3.6.4):

- internal: the system clock is set directly to the timestamp value,
- external: the value is rounded to the subsequent full second and the system clock started upon the next PPS pulse detected on **X43 *GPS PPS***.

3.7 DF Modes

3.7.1 General

The R&S DDF5GTS basically can be operated in five so-called DF modes, two of which allow merely Rx operation, whereas in the other modes DF can take place in distinct ways.

The Rx-only modes are

- **Rx Mode** (3.7.4)
- **Rx Panorama Scan Mode** (Rx PScan, 3.7.8)

and the DF modes in the proper sense

- **Fixed Frequency Mode** (FFM, 3.7.5)
- **Scan Mode** (3.7.6)
- **Search Mode** (3.7.7)

The modes are described in detail in the subsequent chapters; as a general rule, if more than one scan/search range (see below) are allowed to be assigned in the current mode, the overall count of DF channels is basically not limited to any maximum.

Output of the measuring results is done as mass data, Table 3-17 shows a scope which data traces carry data of the individual DF modes; architecture of the appropriate data records can be looked up in the dedicated chapters of Chapter 3.18, "Mass Data Output" / Chapter 3.18.2, "EB200 Protocol", on page 253.

Table 3-17: DF modes and data traces.

DF modes and data traces						
		DF mode				
Data trace	**See chapter**	**RxPScan**	**Rx**	**FFM**	**Search**	**Scan**
Audio	3.18.2.7		X	X		
IFPan	3.18.2.8		X	X		
CW	3.18.2.9		X			
IF	3.18.2.10		X	X		
Video	3.18.2.11		X	X		
VDPan	3.18.2.12		X	X		
PScan	3.18.2.13	X				
SelCall	3.18.2.14		X	X		
GPSCompass	3.18.2.15	(always issues data independent of DF mode)				
ANT_LEVEL	3.18.2.16			X		
DFPScan	3.18.2.17			X	X	X
SIGP	3.18.2.18			X	X	X
HRPan	3.18.2.19		X	X		
AMMOS IF	3.18.3.2		X	X		
AMMOS IF DDCE	3.18.3.3		X	X		
AMMOS Burst Emission List	3.18.3.4		X	X		

The individual DF mode is selected by the XML (XML) command [2.4]

- DfMode

3.7.2 Frontend Properties

3.7.2.1 RF Mode

The RF mode or preselection mode tells how to treat (amplify, attenuate) the very input signal arriving from the antenna input. Three modes can be selected with XML command

- RfMode

which of the modes to prefer depends on the current conditions of reception:

Normal

- Preselection filter active.

- RF path settings optimized for both good noise figure and good high-level signal characteristics (Rx bandwidth limited ahead of the amplifier).
- Recommended for standard Rx conditions.

Low Distortion

- Preselection filter active; low noise amplifier (LNA, in case of R&S EHT770 model 08/18) bypassed.
- Best linearity, but increases noise figure. RF path settings optimized for best large-signal immunity.
- Especially recommended for areas with plenty of strong signals.

Low Noise

- Preselection filter not active; LNA instead of the preselection filter active from 650 MHz up to improve noise figure at higher frequencies.
- RF path settings optimized for best noise figure, but amplifier is hit by full signal power of antenna input. This weakens large-signal immunity, especially concerning 2nd degree interferences.
- Strongly recommended for areas where no high-level signals exist in the input frequency range of 20 MHz to 6 GHz.
- *Restriction:* only with frontend 4093.1514.08 (R&S EHT770 model 08/18). Not for HF Frequency Extension (option R&S DDFGTS-HF).

3.7.2.2 Attenuation

HF

A symbolic block diagram of the attenuation chain within HF range is shown in Figure 3-24. It can be concluded that, despite of settings that might have been done by the XML commands told in the subsequent chapters, an adjustment of overall attenuation in steps of 1 dB cannot be achieved. The reason for that is that solely three distinct components controlling the attenuation value (an amplifier and two attenuators) can be activated or disabled, but no finer tuning performed.

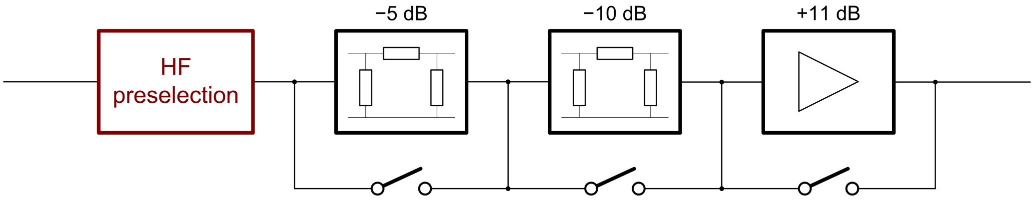


Figure 3-24: Symbolic block diagram of attenuation chain with HF range.

Find the possible combinations together with the value resulting for overall attenuation in Table 3-18. Mind with that that only approximate values can be given.

Table 3-18: Attenuations with HF range.

Attenuations HF				
Attenuation specified	**–5 dB**	**–10 dB**	**+11 dB**	**Total attenuation resulting**
0 dB			X	0 dB
1 dB to 5 dB	X		X	–5 dB
6 dB to 10 dB				–11 dB
11 dB to 15 dB	X			–16 dB
16 dB to 20 dB		X		–21 dB
21 dB to 40 dB	X	X		–26 dB

VHF/UHF

In VHF/UHF range attenuation values will correspond to values set by the command in steps of 1 dB.

3.7.3 Definitions

3.7.3.1 Quality

When discussing quality parameters in the context of DF, it is important to distinguish at least two terms:

- **DF quality** (bearing quality)
- **SR** (super-resolution) **quality**

DF Quality

The term and quantity of the DF quality are in use in context with general DF operation, no matter what DF process, as Watson-Watt, correlative interferometer, etc., be discussed. DF quality commonly is calculated by the DF algorithm itself at once with the actual DF result (angle of incidence) and output together with it; though the manner of calculation might be different due to the individual process. It is an elementarily important measure for a possible impact of interferences of all kinds (e.g. external interference signals or multiwave, i.e. multiple incidence of the DF signal itself due to reflection at metallic obstacles) onto the actual DF result – in other words: if DF quality is poor, errors with the DF angle determined might also result (but need not necessarily).

Commonly DF quality is denoted Q and indicated in percent ($0 < Q < 100$); other formats when issuing (like $0 < Q < 1$ or $0 < Q < 1000$, this is 1/10 percent, i.e. thousandth) are possibly to be regarded.

Applying a DF quality threshold (exclusion of signals with too low DF quality) for a DF measurement can improve confidence of the DF result.

Characteristic of DF quality, however, depends on multiple influences, like frequency, DF process, type/kind of DF antenna in use, its surroundings ([non-] existence of metallic items); thus a general recommendation for a numeric value of a suitable DF quality threshold cannot be made.

SR Quality

Compared to DF quality, SR quality does not mirror the impact of physical disturbance to the DF result, but describes probability of arising of uncertain signals, so-called "ghost signals", within the DF result found by SR (see Chapter 3.14, "Super-Resolution", on page 201), i.e. serves for being able to eliminate such signals. Ghost signals may emerge if certain conditions of the signal scenario are unfavourable for SR DF processing, for example:

- spatial and/or temporal correlation of signals disadvantageous
- sampling period for bearing too short
- wave estimator works inaccurate due to insufficient ratio of
  - signal to noise (SNR)
  - wanted to interfering signal

SR quality as well is determined by the DF algorithm itself, indicated in percent and may serve in threshold form for increasing confidence of the DF result.

In case of stationary DF systems operating under line-of-sight conditions, an SR DF result might be considered reliable if SR quality exceeds 95 % (typically).

Limitations

From this, both DF quality and SR quality serve as a valuable contribution for classification of confidence of a DF result. However, they should always be evaluated in connection with other observational criteria like signal (field) strength or bearing fluctuations (relating to level and angle).

3.7.3.2 Course of Bearing

- Channel
- Hop
- Scan/Search Range
- Sweep (DF Order)

Channel

A channel denotes a single frequency bin of a definite bandwidth. All channels of a hop (see below) have the same bandwidth and are processed at a time due to FFT calculation.

Hop

(For diverging usage of the term *hop* mind Note "Nomenclature" on page 228.)

A hop comprises a frequency range whose bandwidth matches the current Rx bandwidth of the R&S DDF5GTS (i.e. 100 kHz to 80 MHz). If a scan/search range (see below) is wider than this bandwidth, this is if it consists of several adjacent hops, its concluding hop might also be smaller in order to embrace the exact width of the scan range.

So, a hop is a frequency range of exactly the realtime bandwidth (frequency span) to be monitored at a time. It is situated symmetrically to the current center frequency, i.e. either the frequency the frequency synthesizer is tuned to (width with the R&S DDF5GTS 20 MHz or 80 MHz) or even digitally divided in smaller sections (Chapter 3.11.7, "Hopwise and Sweepwise Averaging", on page 176). The bandwidths permitted for the individual channels and therefore their count varies for each realtime bandwidth; detailed information about realtime and channel bandwidths and their combinations existing with the R&S DDF5GTS are given together with the XML commands.

Scan/Search Range

A scan range and a search range denote a contiguous frequency range that the user may arbitrarily define and that the R&S DDF5GTS is to observe (scan) for a certain time. A scan/search range may consist of just one hop or also of several ones; if the latter is the case and averaging has been commanded, always each individual hop will be averaged completely (dwelled on it until all averaging cycles have been processed) and only then changed over to the next hop (hopwise averaging, see Chapter 3.11.7). Again, just one or also several scan/search ranges may be defined at a time which, in the latter case, will be processed in sequence, see Figure 3-25. Each individual scan/search range is given by its start and stop frequency, however various ranges need not be set up in ascending order of frequency. They even may coincide entirely or partly (for example to operate with varying channel bandwidths).

Sweep (DF Order)

The sweep (sometimes also denoted as DF order) is, with Scan Mode (3.7.6) or Search Mode (3.7.7), the entirety of all scan/search ranges defined at a certain time. The ranges will, strictly cyclically, be processed in succession, in fact in the order they have been defined (generated/added). An arbitrary demand for processing that deviates from this regularity (for example to observe particular ranges more often than others) is not possible; especially handling need not be done with frequency strictly ascending. Thus, if an existing scan/search range is deleted and then reconstructed in an equal or modified form, its position of processing is shifted to the end of the chain (see Figure 3-25). This means, there is always only one sweep existing. It is defined

- (frequency domain) by the frequency range it covers (or only excerpts of it)
- (time domain) by its processing cycle (processing duration of complete sweep, i.e. until a definite state therein is reached next time)

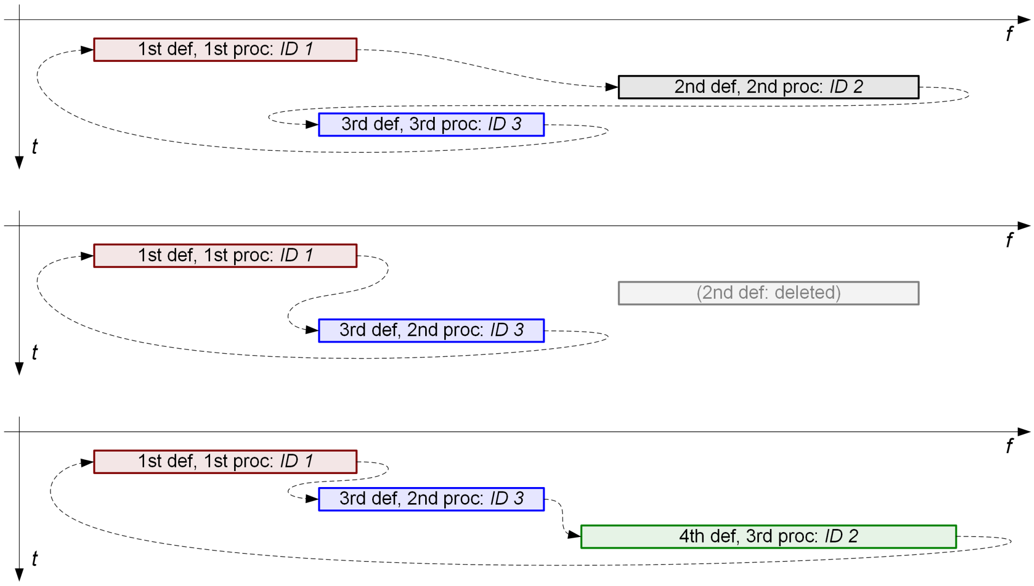


Figure 3-25: Scan/Search ranges in the sweep.

top = three ranges defined not in ascending order of frequency and partially overlapping (coinciding)
def = order of definition
proc = order of processing
center = 2nd range (ID 2) deleted
bottom = new range added: 4th that has been defined (now ID 2, but 3rd to be processed)

Each scan/search range of a sweep is identified uniquely by its ID whose number is assigned in ascending order. If ranges have been deleted in the past, their IDs will be reused for newly established ranges, but these IDs do not reveal anything about their order of processing.

3.7.4 Rx Mode

3.7.4.1 Operation

In Rx Mode the R&S DDF5GTS acts like a conventional receiver, i.e. operates on one single frequency. No bearing is possible, therefore no DF results are produced. Use this mode to

- demodulate the received signal
- output audio data in digital or, to make them audible, in analog form
- perform ITU measurements (only if option R&S DDFGTS-IM, *ITU Measurement Software*, installed, cf Chapters 2.6.3 on page 82 and 3.13 on page 186)
- carry out further signal analysis

The Rx Mode also serves as a standby mode. All settings and adjustments can be realized and scan/search ranges defined using a variety of XML commands.

The command to start a measurement in Rx Mode is

- `Initiate`

and the command to stop it

- `Abort`

But before doing so, you must give some indications about the antenna; see the subsequent sections.

3.7.4.2 DF Antenna as Rx Antenna

Situation

The main difference between a DF antenna and an Rx antenna is that the former has several antenna channels/elements (find more information in Chapter 3.11, "Averaging", on page 165) and the latter only one.

If not using a special Rx antenna (e.g. the R&S HE010E, active rod antenna, see Chapter 1.6, "Ordering Information", on page 20) with only one antenna channel, but the normal DF antenna for Rx operation, you are free to select any individual one of the DF antenna's elements. For example, you can choose the antenna element providing for the highest signal level this way. Depending on current Rx frequency and direction of signal arrival (angle of incidence), a significantly increased sensitivity of the monitoring path is offered.

This feature enables better monitoring capabilities on platforms where a separate monitoring antenna cannot be mounted and generally helps to reduce the system complexity.

Always keep in mind that, as DF operation uses all antenna elements at a time, selection of individual elements is confined to Rx Mode, hence is void if entering another DF mode.

Manual Element Selection

If you desire to choose a special antenna element manually (commonly the one with the largest level, see above), perform your selection with the XML command

- `AntennaElementSelection`

For example, if wishing to select antenna element 5, specify

- `AntennaElementSelection: iAntennaElement=5`

(For varying numbering of antenna elements, mind Note "Numbering System with Antenna Elements" on page 165.)

Be aware that automatic selection (see "Automatic Element Selection") must be disabled:

- `bAutomaticSelection=false`

otherwise the manual selection will be ignored.

If having left Rx Mode and later resuming it, and also when starting up the R&S DDF5GTS, enter your selected antenna element anew. If you do not, the default element (reference element: element 1; see 3.11) will be activated.

Automatic Element Selection

Alternatively, you may induce an automatic selection of the antenna element by

- `AntennaElementSelection`: `bAutomaticSelection=true`

The element with the highest Rx level will be selected in this case, letting you also decide whether determination of this level should happen just once or be repeated periodically:

- `AntennaElementSelection`: `bPeriodicSelection`

This selection will be resumed with a restart of Rx Mode if the mode has been left since.

With automatic selection mode, the levels of all elements of the antenna have to be measured in succession and then compared; this has to be done with as low impact onto the ordinary operation as possible, i.e. regular measuring and output of demodulated data has to be continued in the meantime.

A fresh measurement of the level will always be performed:

- when returning from any other DF mode to Rx Mode
- arbitrarily by the `AntennaElementSelectionTrigger` command
- when modifying some settings of Rx operation (see below)

If periodic selecting is in use, any of these measurement events starts the selecting cycle anew.

With Rx measuring mode *Periodic* (finite measuring period – not to be confused with periodic selecting), the level measuring period (measuring time: `iMeasureTime`, whether default or set) will be used unmodifiedly, whereas with measuring mode *Continuous* (unbroken measuring period) triple this period, but at least 10 ms, is in use.

As previously mentioned, an arbitrary measurement of the level may be performed by

- `AntennaElementSelectionTrigger`

As also mentioned above, modifying the following parameters (Rx settings) leads to a fresh level measurement:

- `DemodulationSettings`:
  - `iAfFrequency` (demodulation frequency)
  - `eAfBandwidth` (demodulation bandwidth)
  - `eLevelIndicator` (Rx measurements level detector characteristics: average/peak/fast/RMS)
- `RxSettings`:
  - `iMeasureTime` (Rx measuring time)
  - `eMeasureMode` (Rx measuring mode: continuous/periodic)
- `MeasureSettingsFFM`:

- – `iFrequency` (main tuner center frequency)
- – `eSpan` (realtime bandwidth [frequency span])
- – `eIFPanStep` (IF panorama channel spacing)
- – `eIFPanSelectivity` (IF panorama selectivity)

3.7.4.3 Special Rx Antenna

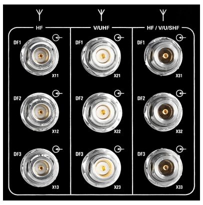
Defining the Antenna

In contrast to a DF antenna, which identifies itself to the R&S DDF5GTS, a peculiar Rx antenna has to be defined specifically. The XML command

- `AntennaRxDefine`

is intended for that. Besides the antenna name to identify the antenna later on, you have to tell the frequency range, polarization and some other parameters describing the antenna properties.

Selecting Antenna Input



If a special Rx antenna is in use, the next step to announce it to the R&S DDF5GTS is to select the antenna input it is connected to. The R&S DDF5GTS supports versatile cabling combinations of monitoring antennas (with or without DF antennas connected additionally). Any of the HF/VHF/UHF input ports (socket group and individual socket, mind Chapter 3.4, "Rear Panel Elements R&S EHT770", on page 107) currently free can be defined as a port for a separately connected Rx (monitoring) antenna. But be aware that the frequency range (HF or VHF/UHF) of the monitoring antenna(s) must match the type of the input path.

In many applications, an external antenna switching unit is not needed any longer, because all antennas are controlled by the R&S DDF5GTS itself.

The XML command

- `AntennaSetup`

is used for this purpose. Find an overview of possible combinations with Table 3-19.

Table 3-19: Antenna input selection.

Antenna input selection				
Connector selected if parameters set to[1]*				
`eHfRxPath/eRfRxPath =`		`RX_PATH_DF1`	`RX_PATH_DF2`	`RX_PATH_DF3`
`eHfInput =`	`HF_INPUT_HF1`	**X11**	**X12**	**X13**
	`HF_INPUT_HF2`	**X31**	**X32**	**X33**
`eRfInput =`	`RF_INPUT_VUSHF1`	**X21**	**X22**	**X23**
	`RF_INPUT_VUSHF2`	**X31**	**X32**	**X33**

1) *`eHfInput` and `eHfRxPath` defining an HF input, `eRfInput` and `eRfRxPath` a VHF/UHF/SHF input.*

As an example, if **X32** (member of the combined socket group **X31** to **X33** ***HF / V/U/ SHF***) is to be selected as an input for an HF monitoring antenna, specify

- `AntennaSetup`: `eHfInput=HF_INPUT_HF2 eHfRxPath=RX_PATH_DF2`

3.7.5 Fixed Frequency Mode

3.7.5.1 General

In the Fixed Frequency Mode or FFM the frequency synthesizer is strictly set to a single frequency, thus a switching of the synthesizer is not performed. Maximum bandwidth in FFM therefore is 20 MHz or 80 MHz with the R&S DDF5GTS. Settings in FFM need to be covered by exactly one FFM range.

Contrary to what the term "FFM" might suggest, DF can not just be done on one single frequency, but, due to the fact that all channels specified in the FFM range are evaluated at a time via FFT, on the complete frequency range of the hop (or part of it). In addition to DF, all functionalities mentioned with Rx Mode (3.7.4) are available to each frequency channel.

Use this mode also to perform an antenna element test (Chapter 4.1.7 on page 341).

When entering FFM, prior to measuring a calibration of the realtime range is performed. FFM can only be left prematurely when the current antenna cycle (Chapter 3.11.4, "Averaging Modes", on page 168) has been completed. Configuring of FFM is done by the XML command

- `MeasureSettingsFFM`

3.7.5.2 Selectivity

Spectral selectivity generally equates to channel spacing (channel bandwidth); DFT length ensues from realtime bandwidth (frequency span) and this spacing by

DFT length = realtime bandwidth / channel spacing

(only displayed [visible] portion of DFT length meant, complete length of applied FFT commonly larger).

Find an example of a count of 8 channels to be observed within the realtime bandwidth in Figure 3-26 (**top**). When utilizing a DFT, each set of samples is subjected to a windowing process, of course the length of the window in use has to match the length of the DFT.

If needed, selectivity can be enhanced by a factor (twice, **center** in the figure, or 4 times, **bottom**). Apparently the DFT length has to be prolongated by the same factor, as also is the window length; this furthermore means: renewal time for the next spectrum to be displayed is also longer as more sample values have to be gathered (awaited).

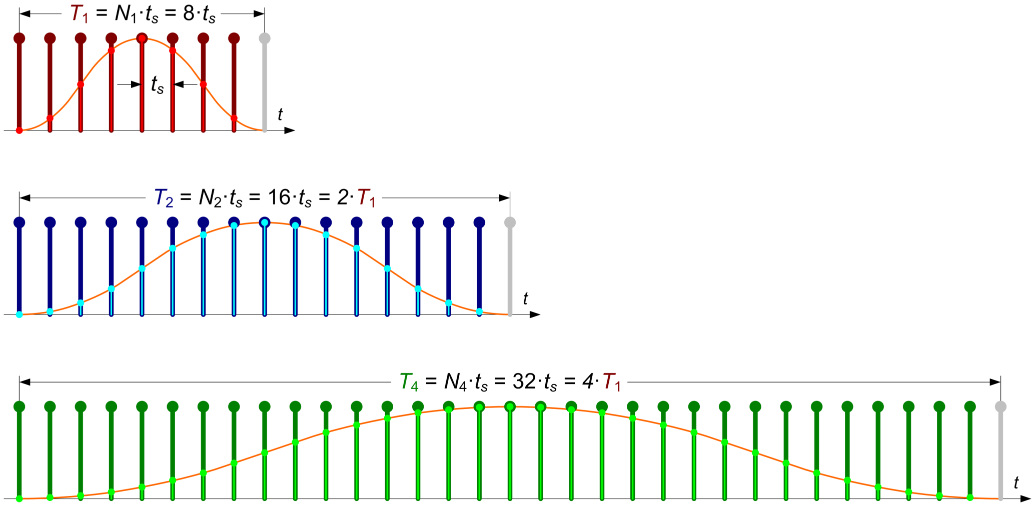


Figure 3-26: Selectivity: situation in time domain, example of 8 samples (channels) to display.

top = prolongation factor 1 (none), 8 samples in use (referred to as "Normal")
center = factor 2, 16 samples ("Narrow")
bottom = factor 4, 32 samples ("Sharp")
dark color = not-windowed values
orange = window function
bright color = windowed values
T_i (i = 1, 2, 4) = observation period
N_i = count of samples to include: $N_1 = 8$, $N_2 = 16$, $N_4 = 32$
t_s = sampling time interval

The effect in frequency domain can be seen in Figure 3-27: compared to the original situation (**top**, referred to as *Normal*), the selectivity f_{xi} is more accurate by 2 (**center**, *Narrow*) or 4 (**bottom**, *Sharp*), i.e. spectral bins half or fourth as wide, because the sampling frequency f_s remains the same in all three cases.

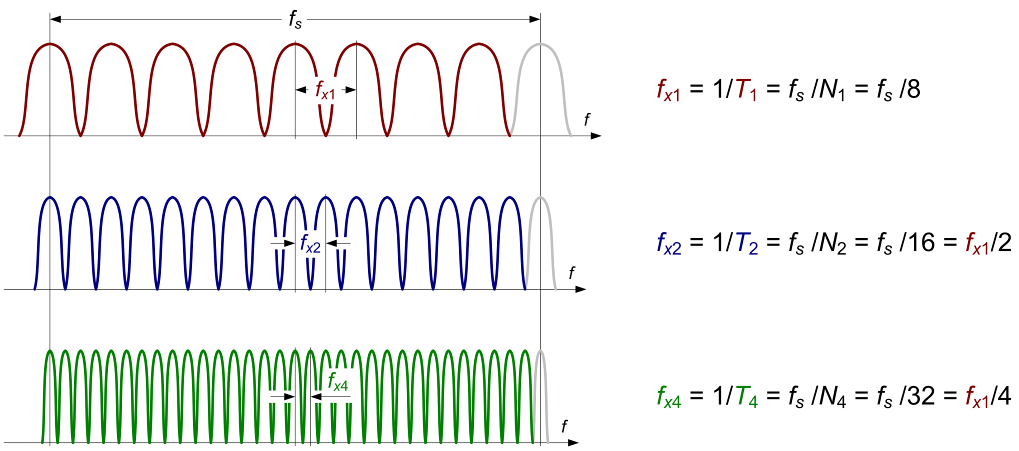


Figure 3-27: Selectivity: situation in frequency domain.

$f_s = 1 / t_s$ = sampling frequency
f_{xi} (i = 1, 2, 4) = spectral selectivity (width/distance of frequency bins)
all other explanations = see Figure 3-26

Remember that explanations in this section are just intended to give a basic understanding; if interested in more detailed information, refer to plenty of relevant literature available.

3.7.6 Scan Mode

3.7.6.1 General

Scan is the mode to cover frequency ranges larger than the ones with FFM (see 3.7.5). After having processed the current hop, the synthesizer is switched to the next one to handle. Be aware that if averaging is being performed, this switching is only done when the complete averaging block (all averaging cycles) is completed (hopwise averaging, see Chapter 3.11.6 on page 174).

You manage Scan Mode by defining scan ranges; a scan range comprises a start frequency, a stop frequency and the spacing of the desired channels to cover. From each of these scan ranges a hop list is internally derived describing all hops to take up. Scan Mode stays on each hop at least until a complete averaging process (block averaging time: time for all averaging cycles) has been performed, furthermore, an explicit scan (hop) dwell time longer than this period may be specified. If scan dwell time is a multiple of block averaging time, an averaging result is output after each averaging block; remainders resulting from this calculation too short for another averaging block will not be awaited and cut off.

Scan ranges can be added, removed or altered during operation; changes are adopted to the hop list immediately and are available with the subsequent sweep (exception: changes of the threshold with the subsequent hop). If no scan range is specified at all, Scan Mode is entered anyway, but no bearing is performed. Details about how to construct hop lists from a scan range are given in 3.7.6.2, "Converting Scan Ranges to Hop Lists". Furthermore, for scaling scan ranges, mind Note "Switching Relays" on page 82.

Similar to FFM, all hops in the hop list are to be calibrated when Scan Mode is entered before measuring can be started. This implies that if frequency parameters (for example channel spacing) have been modified during a running scanning process, the hop(s) concerned have to be calibrated anew. Again, a premature leaving of Scan Mode takes place only after completion of the current antenna cycle.

DF results are output using logical channel numbers, starting with "0" for the leftmost channel of the leftmost hop of the scan range (lowest frequency overall) with consecutive numbering up to the rightmost frequency of the rightmost channel (highest frequency). The next scan range again starts with "0" (distinct logical channel numbers for each scan range). The sweep time also issued as a result stretches from start of the first hop of the first scan range to the end of the last hop of the last scan range.

The count of scan ranges to be processed in Scan Mode is arbitrary in principle (but at least 1). In contrast, the sweep (DF order) can contain at most 1000 scan ranges and at most 5000 hops. The XML commands to control Scan Mode are

- `ScanRange`

- ScanRangeAdd
- ScanRangeDelete
- ScanRangeDeleteAll
- ScanRangeNext
- SweepTime

For particularities on handling of attenuation settings refer to 3.7.5.

3.7.6.2 Converting Scan Ranges to Hop Lists

Managing of Scan Mode is done by defining scan ranges; a scan range consists of a start frequency, a stop frequency and the spacing (bandwidth) of the desired channels to monitor. A scan range is to be converted to a hop list containing details of the hops that cover the original range.

Bandwidth of the hops of an individual scan range (same for all hops in the list emerging) equates to the realtime bandwidth (frequency span) currently set. You set the realtime bandwidth and the channel spacing (channel bandwidth) by appropriate XML commands, for example

- ScanRange

Find detailed information about what bandwidths and spacings are available and combinable together with the XML commands.

Even Case

In Figure 3-28 the so-called even case is shown, this is, dividing the realtime bandwidth into channels (of the channel bandwidth each) delivers an even number of channels. Mind that

1. any permissible combination of realtime bandwidth and channel bandwidth results in an integer number of channels; emerging of fractional parts is impossible,
2. at the moment this even case is the vastly more frequent case existing with the R&S DDF5GTS; only some occasional combinations can lead to the odd case (see "Odd Case").

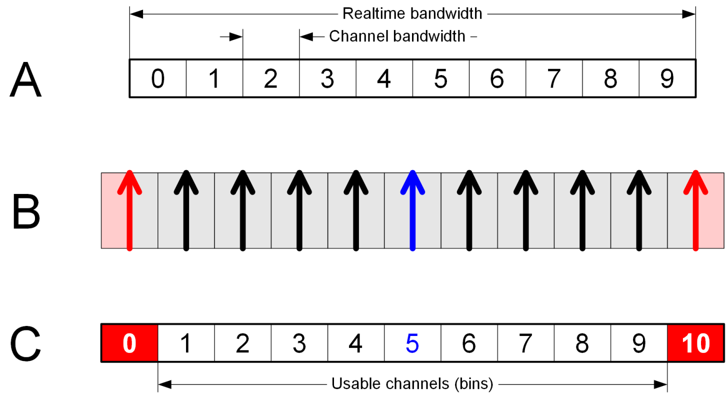


Figure 3-28: Dividing realtime bandwidth into channels, even case.

A	= hop in realtime bandwidth arithmetically divided into 10 channels
B	= frequency bins of FFT applied
blue	= hop center frequency
black	= other usable FFT bins
red	= not usable FFT bins
gray portion	= inside band
pink portion	= outside band
C	= combination of usable and unusable channels arising
white	= usable
red	= unusable

In the example the arithmetical number of channels that results is 10 (**A** in the figure); a "central" channel therefore does not exist, but the center of the hop is situated between two channels (channels 4 and 5 in the example). Simply applying an FFT evaluation (**B**) would lead to the effect that not the obtained channels would be hit by the FFT bins, but the borders (gaps) between them. From that, any channel placing in a hop has to obey the regularity that the central channel really has to represent the center of the hop, what, in the even case, results in that the two outside channels, if strictly being limited to the original hop width (realtime bandwidth), are only part of this width half (gray portion) and therefore cannot be used subsequently.

The logical step to take from that is illustrated in Figure 3-29: the two outside channels of each hop are discarded, only 9 channels are left to be employed. Of course, an uninterrupted coverage of the desired scan range (shown in green) has to be ascertained, what means that all hops are to be concatenated with an overlap of two channels each.

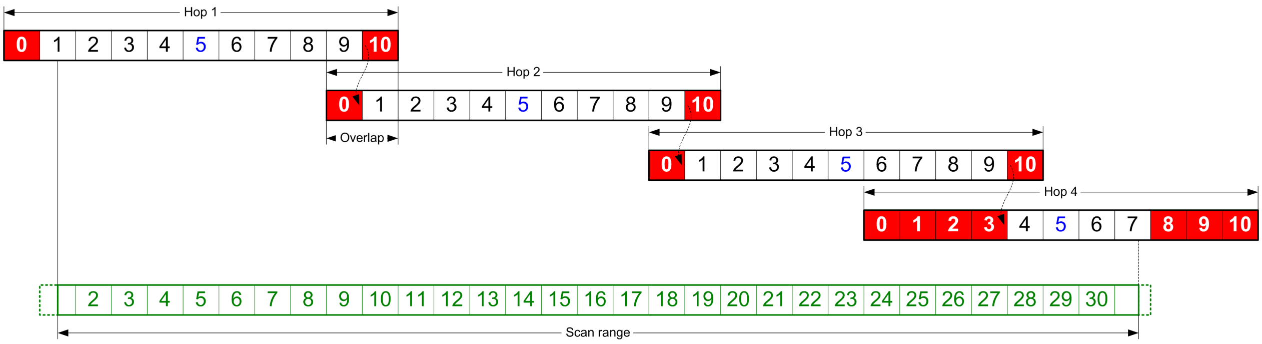


Figure 3-29: Combining a scan range from hops, even case.

top = hops needed
bottom = scan range to be covered

Also be aware in this context that the start frequency of a scan range can be specified entirely arbitrarily by the user; matching of the channels of the resulting hops will be performed correspondingly. Nor the starting frequency to specify has to be an integer multiple of the channel bandwidth neither a predefined arrangement of frequency channels possibly established in the frequency scenario (frequency band) to be observed is taken into account at all.

The concluding (last) hop to establish (hop 4 in the example) normally has a number of original channels to cover that is smaller than the one of the other hops (the channels remaining to have the complete scan range covered); it is always constructed the way that its resulting central channel is used as a valid channel. If the remaining number of channels not needed is even, they therefore are placed half left, half right of the used channels, if it is odd (as is in the example), the portion to the left is larger by 1.

The last channel (rightmost channel) of a scan range to be covered by hops is defined the one with its channel frequency (center frequency) within the scan range; in other words: a "remainder portion" of less than half a channel bandwidth will be discarded, of more than half included.

Odd Case

The so-called odd case (division result is odd, see "Even Case") can be seen in Figure 3-30 – remember that this case is by far less frequent than the even case. The central channel and also the FFT bin representing it are now really in the center of the hop, thus no invalid channels emerge and all can be used subsequently.

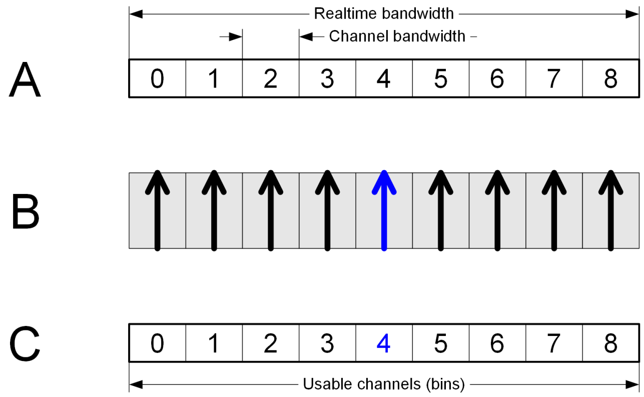


Figure 3-30: Dividing realtime bandwidth into channels, odd case.

A = hop in realtime bandwidth arithmetically divided into 9 channels
B = frequency bins of FFT applied;
blue = hop center frequency
black = other usable FFT bins
C = combination of usable and unusable (none in this case) channels arising

The hops to cover the scan range (Figure 3-31) now need not be overlapping, the concluding (last) hop is constructed the same way as in the even case.

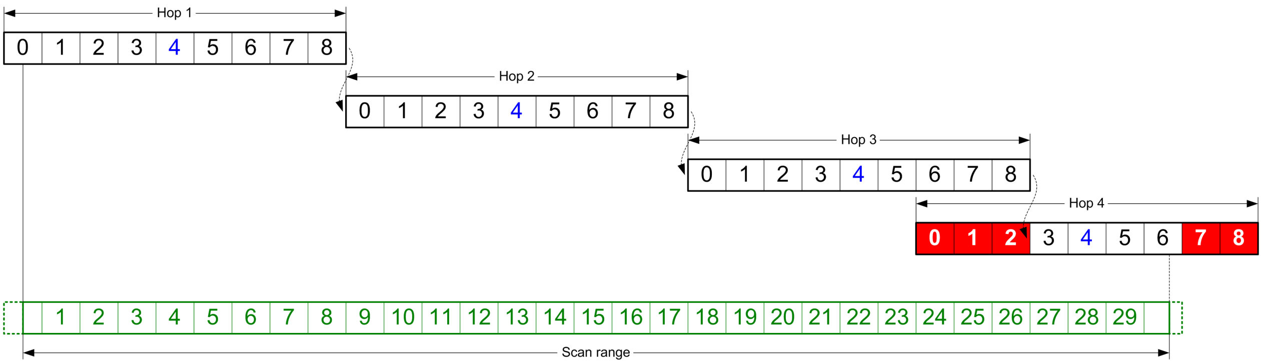


Figure 3-31: Combining a scan range from hops, odd case.

top = hops needed
bottom = scan range to be covered

3.7.7 Search Mode

Search Mode resembles up to a certain degree Scan Mode (3.7.6) in that frequency ranges, now called search ranges, are scanned. As the main difference, each frequency specified is processed successively, measuring on this individual frequency is performed for the *measuring time* (i.e. possibly using averaging) also told in the search range indications. If the level on this frequency has not been observed to be above the predefined threshold, the subsequent frequency will be called. Otherwise (considerable level found) a temporary FFM (see 3.7.5) will be entered, a calibration performed on the relevant frequency and then a bearing and a demodulation done with the settings given in the search range for the predefined *dwell time*.

Similar to the scan ranges of Scan Mode, the search ranges are specified in advance. (For scaling search ranges, also mind Note "Switching Relays" on page 82.) The fundamental difference is (see Figure 3-32) that in Scan Mode a scan range (width 80 MHz in the figure) is just split up into hops of the current realtime bandwidth (frequency span; 8 hops with 10 MHz width, 1 MHz channel spacing each) situated side by side, whereas in Search Mode an additional "frequency step" (13.33 MHz) can be specified allowing a wider difference of the emerging hops (but thus giving up complete coverage) than just adjacent to each other (resulting in 7 hops overall). Each frequency resulting from a frequency step will be used as center frequency of the next hop to search in; channel spacing (this is: also bandwidth of the central channel) can be told as before. Mind also that only the DF result of the center frequency is output (not of all channels).

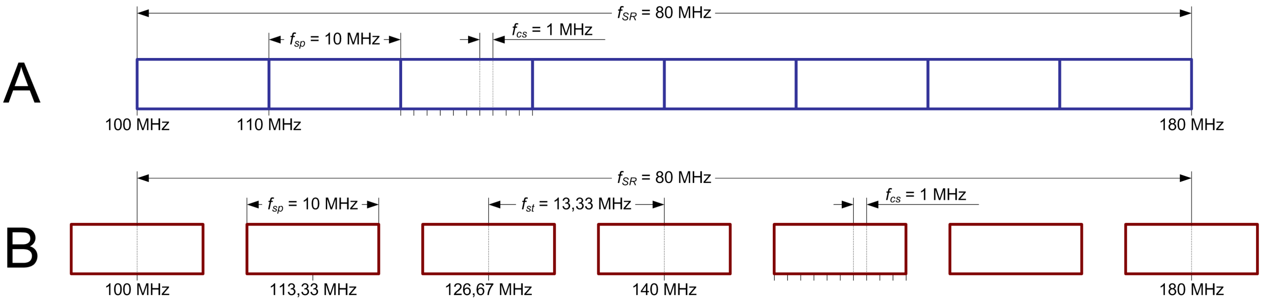


Figure 3-32: Hops in Scan Mode and Search Mode.

A = Scan Mode
B = Search Mode
f_{SR} = scan range/search range
f_{sp} = frequency span (realtime bandwidth)
f_{cs} = channel spacing
f_{st} = step frequency

While in the temporary FFM, modifications of the DF and demodulation settings are permitted, but they are not transferred to the primary search range settings and thus get lost when calling the next frequency.

You can arbitrarily stay in the temporary FFM for thorough investigations on an interesting signal found by issuing the XML command

- `Hold`

as well as you can leave the current frequency prematurely (if found to be not of interest) with the command

- `Continue`

Output of DF results is performed as with FFM.

Again, an arbitrary count (but at least 1) of DF orders can be processed. Control Search Mode by the XML commands

- `SearchRange`
- `SearchRangeAdd`
- `SearchRangeDelete`
- `SearchRangeDeleteAll`

- `SearchRangeNext`
- `SearchTimes`

With the last, the `SearchTimes` command you define

- the *measuring time*: the time the R&S DDF5GTS stays on a frequency while searching until it decides whether to enter temporary FFM or to go to the next frequency,
- the *minimum signal time*: the minimum signal duration needed to enter temporary FFM,
- the *dwell time*: the time the temporary FFM is to be held (unless having received a `Hold` or `Continue` command).

3.7.8 Rx Panorama Scan Mode

Rx Panorama Scan (Rx PScan) Mode is a mode similar to conventional Scan Mode (3.7.6), but without the DF feature of there, i.e. it is a pure Rx mode. Level panoramas (level spectra) can be caught and plotted with this mode in a very fast speed.

As known from Scan Mode, the range (or ranges) to scan is specified in a now so-called Rx PScan range, consisting of a start frequency, a stop frequency and a frequency step and permitted to exist just once. Modifications of entries to this range are allowed at any time and are adopted to the scanning process when starting the next sweep.

You perform measure settings in Rx PScan Mode by the XML command

- `MeasureSettingsPScan`

As with Rx Mode (3.7.4), if using a DF antenna (instead of a special Rx antenna), you can select an arbitrary antenna element; and if using an Rx antenna, you must announce it to the R&S DDF5GTS, as also the socket it is connected to. Find details with 3.7.4.2, "DF Antenna as Rx Antenna" and 3.7.4.3, "Special Rx Antenna".

3.8 DF Error Correction

Option

The functionality **Azimuth Correction** (3.8.2.3) is only available if the option

- R&S DDFGTS-COR, *DF Error Correction*,

and **Antenna Reference Coefficients** (3.8.2.5) only if the option

- R&S DDFGTS-VM, *Vector Matching*,

are installed.

3.8.1 General

DF Error Correction means eliminating some linear distortions caused by physical insufficiencies of the components involved in the DF process (not by the R&S DDF5GTS as such) with respect to high frequency effects, antenna shortcomings, cable attenuation and so on.

Correction data is used to compensate for these factors, which have their origins outside the device but affect the device's measurement results. Correction is performed by way of correction data sets, which are either known in advance (e.g. for a certain antenna) or collected in a prior measurement process and subsequently stored in the DF unit. They can then be applied to each subsequent bearing result.

The correlation DF method (the common case with the R&S DDF5GTS) works the way that the measured antenna voltages are compared to a reference function which is calculated anew with each frequency change. For antennas that do not permit such a calculation the easy way, the reference function is to be determined by a precedent measurement process instead; alternatively a delivery of antenna reference data by the manufacturer comes into question. For such cases, the R&S DDF5GTS also can manage data sets for reference functions.

The correction data is stored within the flash file system of the R&S DDF5GTS. More detailed information on correction data can be found in [1.1].

3.8.2 Factors of Influence

The R&S DDF5GTS can process the following correction data:

3.8.2.1 Antenna Factors

Antenna factors (k-factors) are required to convert an antenna's measured level into a field strength level. For all standard *Rohde & Schwarz* DF and Rx antennas compatible with the R&S DDF5GTS (see Chapter 2.4.2, "Antenna Types", on page 38), the correction data is provided as part of the firmware. In the case of a user defined antenna, you can generate the required antenna factors yourself and store them within the flash file system.

Data sets are formed as pairs of frequency points (in Hz) and associated field strength correction values (in dB(1/m)). Correction values between these points (for frequencies not explicitly specified) are calculated by a linear interpolation of the two adjacent points available. Thus, at least two points are required: one to mark the beginning of the frequency range to be corrected, and one to mark its end.

3.8.2.2 Cable Attenuation

Where higher frequencies and longer RF cables between the antenna and the R&S DDF5GTS are involved, there is an additional attenuation of the antenna level. This additional attenuation can be corrected to allow for a more precise field strength measurement.

Data comes in frequency[Hz]/attenuation[dB] value pairs and is interpolated linearly if necessary.

3.8.2.3 Azimuth Correction

(with option R&S DDFGTS-COR installed)

In the case of a mobile direction finder, the carrier vehicle's reflection characteristics near the DF antenna result in a more or less pronounced disturbance of the wave field. To a certain extent, this disturbance is of a systematic nature, and the vehicle's interference can largely be compensated for. The required correction data depends on the antenna, the frequency and the measured azimuth, i.e. for each frequency to be specified explicitly, a count of azimuth points has to be supplied. The whole azimuth range (360°) is then broken up into ranges of equal spacing defined by this count.

Now angle (°) values rather than attenuation (dB) values are required for correction. Similarly to the other correction values, a linear interpolation between the azimuth points of each frequency specified (and subsequently also between the values of each frequency sample) is performed to obtain the values in between.

Azimuth correction data is obtained by running a specific measurement procedure and deriving the desired data from the measurement result. The measurement procedure is described in 3.8.3, "Procedure for Azimuth Correction".

3.8.2.4 Omniphase Correction

With antennas working on the Watson-Watt principle, the carrier vehicle may cause an additional phase shift between the omni elements and the DF elements due to its reflection characteristics near the DF antenna. If the resulting phase difference exceeds ±90°, the DF value will be off by 180°. This kind of influence is of a systematic nature and can be corrected.

As explained in the case of azimuth correction, frequency samples have to be specified, but only a single correction value has to be determined for each sample (no division into azimuth segments required). As before, all other values are derived by linear interpolation.

3.8.2.5 Antenna Reference Coefficients

(with option R&S DDFGTS-VM installed)

Antenna reference coefficients are not correction data in the narrow sense (i.e. enabling a later correction of measured data), but provide reference function data for antennas that do not allow their easy calculation during the DF process. The data in this case has to be measured in advance or even be provided by the antenna manufacturer. (A reference function is always needed by the correlation DF method, which is the common case with the R&S DDF5GTS, see 3.8.1.)

3.8.2.6 Antenna Parameters

For reasons told in [1.1] and also to enter north offsets to distinct antenna ranges (UCAs, see Chapter 2.5.5, "North Alignment", on page 65), some antenna parameters can be entered manually.

Modifying Antenna Parameters

- Handle modification of antenna parameters with extreme care.
- Mind that especially altering the antenna diameter should exclusively be performed for R&S ADD011SR antennas.
  Pay attention that a diameter specified agrees exactly with the true geometrical diameter the antenna or UCA has been or will be erected.
  However, accept that antenna performance (e.g. affecting DF accuracy or DF sensitivity) might degrade if doing so.
- Cable sets indicated in Chapter 1.6, "Ordering Information", on page 20 are intended for the antenna diameter specified (might be too long if altered diameter is smaller). Determine your individually needed cable set (suitable length and required accuracy) and order it fitting to your particular project.
- Binding performance values cannot be told by *Rohde & Schwarz* in this case; the corresponding risk is transferred to the customer or system integrator.

3.8.3 Procedure for Azimuth Correction

(with option R&S DDFGTS-COR installed)

Some general rules for setting up a DF antenna are given in Chapter 2.4.3, "Choosing the Antenna Site", on page 39.

The following procedure is used to determine the most realistic (unadulterated) correction data (correction of the environmental influences is described in 3.8.2.3, "Azimuth Correction"):

- Positioning of the DF system (e.g. direction finder with antenna on a ship or vehicle) in an environment that is reasonably free of reflections.
- Installation of a signal generator at a sufficient distance.
- **Correction:** measurement of the environment over a sufficient count of azimuth angles and frequencies; storing of measured data in the predetermined format.
- Calculation of the correction data from the measured data and conversion to the format to be used.
- Introducing the data into the DF system (flash file system).
- **Verification:** repeating the measurements with the available correction data.

If an antenna is to be operated in several configurations, the measurement has to be performed separately for each configuration. Different configurations may involve

- Polarization
  – linear: vertical or horizontal,

  - circular: left-hand (counter-clockwise) or right-hand (clockwise),
- Preamplifier: active or passive,
- Operating mode: DF or Rx (receiving) antenna.

3.8.3.1 Positioning the DF system

When positioning the DF system make sure that

- it is subject to the operational conditions it will later be employed in (the DF system itself and the environment it is installed in, e.g. vehicle, aircraft or ship) and
- all other conditions interfering with the measurement procedure are eliminated as thoroughly as possible (port where the ship is located, nearby vehicles etc.).

To perform the measurement, provide for an environment that is reasonably free of reflections. In particular, there should be no disturbing metallic objects such as metal fences, tin roofs, vehicles, high-voltage power lines or street lights. Even deposits of metal in the ground floor can cause a distortion of the electromagnetic waves (mainly in the HF range).

A ship should always be measured at sea rather than in the port as other ships, masts or cranes located nearby will disturb the measurement. A vehicle should be measured on a large field free of reflections.

Apart from that, the DF system should be set up for calibration in the same way it would be set up for regular operation. A vehicle to be measured should be equipped just like the operational vehicle to be used later during regular operation, i.e. it should have the same roof superstructure, additional antennas or trailer(s), if any.

3.8.3.2 Establishing the Signal Generator

- The signal generator must be installed (relating to each frequency to be measured) at a minimum distance of several wavelengths in order to obtain a wave front inciding nearly planarly to the direction finder.
- The emission must be of good quality. In particular, there should be no reflections or multipath propagation such as would be created by nearby buildings.
- The output power must be high enough for disposing of a sufficient signal-to-noise ratio (SNR, at least 30 dB) at the direction finder.
- No external transmitters which are capable of influencing the measurement result must be operated nearby.

3.8.3.3 Measuring of the Environment

The measurement is done, over a full circle (360°) in the azimuth angle steps determined previously, by

- keeping the signal generator fixed and rotating the DF system together with its entire mounting environment **or**
- circumnavigating the fixed DF system with the signal generator (mounted on a vehicle, ship etc.) **or**

- moving the DF system (e.g. ship, aircraft etc.) around a fixed signal generator.

Rotating only DF System

Important: Detaching the DF system from its mounting environment (vehicle, ship) and rotating it while keeping the remaining components stationary does not yield the correct measurement result.

Correcting the bearing results at frequencies or azimuth angles for which no particular values were investigated when measuring is done automatically by the direction finder using data produced by interpolation from the adjacent measurement values. For this reason, the DF environment has to be measured for a sufficient count of azimuth angles and frequencies. In general, correction of the DF value during later operation will improve as the number of frequencies measured is increased. Determining the count itself depends on the extent to which the DF values are influenced by environmental factors (disturbing influences, i.e. deviation from an ideal environment), and on the desired precision of the bearings to be obtained.

Interpolation

Be aware that a correction is never performed for frequency values outside of the specified range, i.e. no extrapolation is done.

The azimuth angles have to be partitioned at equal distances (every 10° or every 5°). These angle predefinitions must strictly be complied with while measuring; the precision of the correction data obtained, and thus of the DF results obtained later on, depends crucially on how accurately these angles are maintained.

When selecting the frequencies, the entire frequency range (within which the correction is to be performed later on) of the DF system has to be covered. In frequency ranges where distortions of the DF values are to be expected or already known, a tighter frequency grid should be used than in ranges with a steadier behavior; additionally, as a general rule, with lower frequencies a more narrow frequency grid is recommended than with higher ones. Also, of particular importance is a sufficient number of frequency points near the border frequencies of the antenna as well as (with switched antennas) in the vicinity of their changeover points.

The maximum count of nodes that can be specified per antenna is 1000 (see 3.8.3.5).

Antenna Border Frequencies, Changeover Points (Switched Antennas), Intermediate Ranges

- **Antenna border frequencies:** As no extrapolation is ever done (see Note "Interpolation"), the outermost frequency points should be positioned at the borders of the antenna frequency range.
- **Changeover points:** Interpolation is always performed strictly linearly. With switched antennas, frequency points should therefore be placed as closely as possible to the changeover points – ideally at a distance of 1 Hz, approaching from either side (even values of the frequency, e.g. 1300 MHz, always belong to the lower range, whereas odd ones, e.g. 1300.000001 MHz, belong to the upper range).
- **Intermediate ranges:** For intermediate ranges (ranges where a correction is not desired between two ranges intended for correction), "neutral" correction values have to be specified, i.e. the correction value is to be set equal to the nominal value.

Information about the frequency range of a specific antenna and, in case of a switched antenna, about switching characteristics can be found in the corresponding antenna manual.

Automation of the measurement procedures (especially with going through the frequency ranges) can (should) be performed, it lessens amount of work as well as number of measuring errors remarkably.

3.8.3.4 Storing Data

The data measured as described in 3.8.3.3 has to be stored as a text file. From this file, the correction data (the data needed to perform the actual correction during operation) is generated by a dedicated software tool and subsequently stored within the flash file system of the R&S DDF5GTS.

For more detailed information, consult [1.1].

3.8.3.5 FAQ

When is correction data needed?

- If the accuracy of the bearings obtained is not sufficient.
- In the HF range (e.g. Watson-Watt direction finding), azimuth shifts of 180° may occur on principle. These shifts can be eliminated by omniphase correction (3.8.2.4).

From experience, no correction data is needed

- with frequencies above approx. 650 MHz, since environmental conditions have hardly any influence on the antenna at these frequencies,
- generally in fixed stations (e.g. antenna mast).

How often is a remeasurement needed?

- If the electromagnetic field within 3 to 10 times the wavelength has changed and thus the accuracy of the bearings has deteriorated.
- The flow of electric signals may also vary due to corrosion.

What kind of environmental conditions have an influence on the accuracy of the bearings?

- See Table 2-3 on page 39.

What kind of equipment is needed to determine the correction data?

- A signal generator (together with a transmitting antenna, amplifier etc.) suitable for the frequency range in question.
- If the DF system is mounted on a vehicle, an antenna turntable for the complete vehicle.

What azimuth steps (increments) are suitable?

- The direction of wave incidence must be varied in steps of 5° or 10°. This is mandatory.

What is the reference point for the measurement?

- This is invariably the vehicle axis (cf Chapter 2.5.5, "North Alignment", on page 65).

Is there a maximum count of nodes to be specified?

- The maximum count of nodes that can be specified per antenna is 1000 for the azimuth data, and 500 for all other data.

3.9 Internal GPS Module or Internal GNSS Module

Option

The functionality **Internal GPS Module** or **Internal GNSS Module** is only available if the option

- R&S DDF-IGT, *Internal GPS Module*, or
- R&S DDFGTSIGT2, *Internal GNSS Module*,

respectively, is installed.

3.9.1 Scope

Precision of bearing essentially depends on exact information about the location the direction finder is operated at and about current timing (cf Chapter 3.6, "System Time", on page 124). Today, this information is usually provided by common GNSS (e.g. GPS) receivers; obtained accuracy is some meters for the location and some microseconds or below for the timing. Additionally a continuous updating of the position is done automatically in mobile applications (whereas in stationary operation with the position/location once known, updating can be switched off and position presumed as fixed).

The option R&S DDF-IGT, *Internal GPS Module*, or R&S DDFGTSIGT2, *Internal GNSS Module*, equips the R&S DDF5GTS by a complete built-in GPS or GNSS receiver. As known from other off-the-shelf receivers, a connection to the GNSS satellites has to be established via a usual GNSS antenna, the data yielded by the receiver option consists of the NMEA 0183 sentences in use in this context (Chapter 2.5.6.3 on page 77) and the one-second pulse (PPS). An appropriate GNSS antenna is included in delivery with R&S DDF-IGT / R&S DDFGTSIGT2, but other standard GNSS antennas can be used as well.

R&S DDFGTSIGT2 is an enhancement of R&S DDF-IGT: whereas R&S DDF-IGT is a plain GPS module, R&S DDFGTSIGT2 supports the standards

- GPS (U.S.A.)
- GLONASS (Russia)
- Beidou (People's Republic of China)

Communication with the option is done via XML (XML) commands [2.4].

3.9.2 Installation

Once the option is installed in the R&S DDF5GTS (see Chapter 4.1.2, "Disassembling and Assembling the R&S DDF5GTS", on page 331), correct cabling is to be performed:

- Connect the supplied antenna or another usual GNSS antenna to **X110 *GPS ANT*** (SMA socket).
  Pay attention whether the used antenna is an active (as is the supplied antenna) or a passive antenna, because in case of an active antenna a supply voltage of 5 V is fed into the antenna connector. A passive antenna does not need any supply voltage and might even be damaged if a voltage is fed anyway. Distinction cannot be made by the antenna itself (no control possibility available), but by an internal parameter to set: use the XML command
  – `IGT` , parameter `eGpsAntType`

  to set the antenna type to
  – passive: `eGpsAntType=GPS_ANT_PASSIVE` or
  – active: `eGpsAntType=GPS_ANT_ACTIVE`

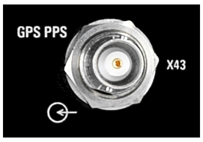
  or also to query the current status before operating the antenna.
  Also mind that the two GNSS antenna error messages provided
  – "GPS error; Antenna line open" and
  – "GPS error; Antenna line short"

  are issued only if the active antenna type is configured.

NOTICE

Active or Passive Antenna

Specify the appropriate antenna type (passive or active) before you connect your GNSS antenna. If using a passive antenna or also GNSS antenna splitters and having the active antenna type configured, irreversible damage of the antenna might occur.



- Connect **X111** ***GPS PPS*** (one-second pulse out) to **X43** ***GPS PPS*** (one-second pulse in) (BNC sockets).

- Connect **X112** ***GPS NMEA OUT*** (D-Sub socket) to **X15** ***GPS*** or the equivalent **X16** ***COMPASS*** (D-Sub plugs).

3.9.3 Satellite System (GNSS)

R&S DDF-IGT only operates with GPS satellite system; in contrast, with R&S DDFGTSIGT2 you may select your preferred system(s) out of GPS, GLONASS or Beidou. You do this by the XML command

- `IGTGnssState`

You must have at least one satellite system activated and at most two (not all three at a time); R&S DDFGTSIGT2 will always try to analyze the data of as many satellites as possible (as are in view), hence, with poor Rx conditions, it might be advantageous to evaluate information of two GNSS systems. However, for best accuracy of the mere absolute system time (timestamp, see Chapter 3.6, "System Time", in particular 3.6.5 on page 129), it is recommended to only have one GNSS system in use, preferably GPS.

3.9.4 Operation Modes

Operation of the Internal GPS Module/Internal GNSS Module is done in one of three modes:

- Free Run
- Averaging
- Fixed Location

Select the individual mode by the XML command

- `IGT`

3.9.4.1 Free Run

The "Free Run" mode is the usual mode of GNSS operation. The current position is updated continuously, thus, the position, if unknown, can be determined autonomously this way. This operation mode is recommendable especially for mobile scenarios, e.g. in a traveling vehicle, whereas for stationary applications the more accurate position indication of the "Fixed Location" mode (3.9.4.3) should be used.

3.9.4.2 Averaging

With the "Averaging" mode, a position not yet exactly known can (and must) be determined first. "Averaging" is a temporary mode, i.e. after having appointed position with the accuracy desired, it will be left and operation switched to "Fixed Location" (3.9.4.3).

Two parameters can be set to accomplish this goal: the accuracy of averaging and the minimal period for averaging; use the XML command

- `IGT`

for that. For example, averaging accuracy (parameter `iGpsAvgAccuracy`) might be set to 5 m and averaging minimal observation time (parameter `iGpsAvgMinObserveTime`) to 600 s, then the averaging process is terminated only if both conditions are met: accuracy is below the limit stated as well as averaging time has elapsed. Mind that, if one of these parameters is altered while averaging is in progress, the new value is valid immediately and might also (both conditions met from this moment on) lead to termination of the averaging process.

A third parameter (`iGpsAvgObserveTime`) describes the nominal averaging time and thus serves as a timeout, averaging will be aborted upon expiry even though the intended precision might not have been reached.

3.9.4.3 Fixed Location

In "Fixed Location" mode the location of the R&S DDF5GTS is assumed to be fixed (as is in stationary operation). This mode can be entered in two ways:

1. Enter position data (latitude, longitude and altitude) manually by the XML command
   - `IGTLocationFixed`

Data to enter is the same as for the command

- `LocationManual`

it can be seen from Table 3-16 on page 129. The "Name of location" entry is a user defined string with arbitrary content. It is used only for user information, not for internal distinguishing or storing of individual locations. If storing of several location data sets should be desired, it has to be established within the server controlling the R&S DDF5GTS, an internal storage facility is not provided.
After having entered the data, set operation mode to "Fixed" by the command

- `IGT`

This latter setting of the mode is only possible if the position data is available to the R&S DDF5GTS (has been set previously) and is considered appropriate (true, i.e. indication matches approximately location data of the site where operation currently takes place). If the difference is to large, location specification will be rejected, an error message

- "GPS error; Fixed position mismatch"

issued and the "Free Run" mode (3.9.4.1) entered.

2. Set mode to "Averaging" (3.9.4.2); after completion of the averaging process "Fixed Location" mode will be entered automatically.

3.9.5 Antenna Cable Length

The length of the cable of the GNSS antenna connected has to be specified as precisely as possible in order to increase exactness of the arrival of the one-second pulse (PPS).

Immediate length indications apply to a cable type with a signal propagation speed of 5 ns per meter of cable length (200.000 km/s). Due to later convertion of the specified length to a time delay, this length specification has to be modified in advance if cables with differing propagation properties are in use.

3.9.6 Reset

If wishing to delete the location data in the R&S DDF-IGT or R&S DDFGTSIGT2, execute a cold reset with the XML command

- `IGTReset: eGpsReset=GPS_RESET_COLD`

A factory startup will be performed this way. This measure might be advisable if the location of the R&S DDF5GTS has been changed considerably, i.e. it has been moved by a distance of hundreds of kilometers. Exceptional consumption of time to determine its location might be another reason.

Location information will be found in any case, however, even without executing a cold reset.

3.10 Synchronous Scan

Option

The functionality **Synchronous Scan** is only available if the option

- R&S DDFGTS-TS, *Time Synchronization*,

is installed.

3.10.1 Purpose

The option R&S DDFGTS-TS, *Time Synchronization*, enables a synchronous operation of several DF units (not necessarily of the same type), i.e. induces them to perform a scan in a common and synchronous manner (DF network). Each hop (see Chapter 3.7, "DF Modes", on page 132; for diverging usage of the term *hop* mind Note "Nomenclature" on page 228) will be processed (measured) at the same time by each of the DF units involved; thus the DF results obtained by this can be used for location of individual emitters.

A synoptic view of purpose and operation of synchronous scan is given in Chapter 2.6.4, "R&S DDFGTS-TS, Time Synchronization", on page 83.

3.10.2 Synchronous Operation

As known from conventional Scan Mode (described in Chapter 3.7.6, "Scan Mode", on page 144), operation is controlled by defining scan ranges, each of which contains a start frequency, a stop frequency and the channel spacing (frequency increment); a hop list is derived after that from each of these ranges, it describes the hops that each individual scan range is divided into.

For a successful synchronous operation you have to mind some important things:

- Before starting a synchronous scan operation, no other scan ranges (remaining from a former non-synchronous activity) may be defined. Clear all of these ranges on all DF units involved before setting up the ones for the synchronous operation.
- All scan ranges to cover must be established and commanded equally on each DF unit, resulting in that
- overall DF speed emerging is the speed of the slowest DF unit in the network (more precisely: related to each individual timing parameter separately).
- No scan range may contain internally an antenna switching point, synthesizer switching point or any other frequency singularity that could cause a delay in the measuring procedure. If wishing to cover a range that straddles such points, split the range into several single ranges that have the points in question merely at their very start. If in doubt, you can query these points directly from the individual DF units (see 3.10.4, "Strategy and Commands").

The XML (XML) commands [2.4] to issue are described in detail in 3.10.4.

3.10.3 Timing

Course of action over time is as follows:

- The order of executing scan ranges within a sweep (see Chapter 3.7) results from the order these ranges have been created in (command `ScanRangeAdd`) and can also not be modified by later on altering a range (command `ScanRange`).
- Timing in detail is (`n` scan ranges in the example, 1st scan range with m hops):

Set-up time 1st scan range	→ *Synthesizer switching time 1st hop*	⇛ *Measuring time 1st hop*	(1st hop measured completely)
`iTsTime ScanRange[1]`	`iTsTimeFreqChange[1]`	`iTsTimeMeas[1]`	
	→ *Synthesizer switching time 2nd hop*	⇛ *Measuring time 2nd hop*	(2nd hop measured completely)
	`iTsTimeFreqChange[1]`	`iTsTimeMeas[1]`	
	...		
	→ *Synthesizer switching time `m` th hop*	⇛ *Measuring time `m` th hop*	(`m` th hop and thus 1st scan range measured completely)
	`iTsTimeFreqChange[1]`	`iTsTimeMeas[1]`	
→ *Set-up time 2nd scan range*	...		(2nd scan range measured completely)
`iTsTime ScanRange[2]`			
...			
→ *Set-up time `n` th scan range*	...		(all `n` scan ranges measured completely)
`iTsTime ScanRange[n]`			

- Therefore time periods resulting in sum are
  – Time period for one scan range (synthesizer switching time and measuring time constant for all hops in a scan range):
    $T_{SR,i}$ = `iTsTimeScanRange[i]` + m · (`iTsTimeFreqChange[i]` + `iTsTimeMeas[i]`)
  – Sweep time (time period for all scan ranges):
    T_{SW} = sum of all $T_{SR,i}$
- The timestamp issued with each hop always refers to the instant of starting to measure the hop (beginning of each `iTsTimeMeas`, symbol ⇛).
- The timing raster ensuing is adjusted to the current sweep time; measuring will be done in this raster, relating to Unix epoch (January 1st, 1970, 00:00:00 [12:00:00 a.m.] UTC), without leap seconds.
  For example, the timestamp for the 1st hop being measured (symbol ⇛) is
  – T_{1st} = `a` · T_{SW} + `iTsTimeScanRange` + `iTsTimeFreqChange`

  with `a` being an unknown integer number (count of past sweeps).

3.10.4 Strategy and Commands

1. **Delete all former scan ranges:** XML command
   - `ScanRangeDeleteAll`

   All scan ranges defined so far will be deleted. No scan ranges may exist when synchronous operation is started.
2. **Enter synchronous operation:** XML command
   - `TriggerSettings`: `eTriggerMode=DFTRIGGERMODE_TIMESYNC`
3. **Query frequency switching points:** XML command
   - `FrequencySwitchPoints`

   Find out all frequency switching points of all DF units involved in the synchronous operation. Any single frequency returned with this querying process from any DF unit (this means: the union of all frequencies delivered) has to be considered for further commanding.
4. **Segment frequency range**
   Divide your overall frequency range in question into segments (scan ranges) the way that no frequency switching point is inside a scan range; a frequency switching point may only form the start frequency of a scan range.
5. **Establish scan ranges on DF units:** XML command
   - `ScanRangeAdd`

   Disclose erected scan ranges to all DF units. Perform this step in identical order for each DF unit, because order of establishing the scan ranges determines the order of later on executing them within the sweep.
6. **Query all relevant times:** XML command
   - `ScanRange`: `iTsTimeMeas`, `iTsTimeFreqChange`, `iTsTimeScanRange`

   For all scan ranges the relevant times, i.e. setup times, synthesizer switching times and measuring times have to be fetched from any DF unit involved.
7. **Search maximum values**
   For each individual timing indication the maximum value, comparing all DF units in the network, has to be figured out.
8. **Command maximum to DF units:** XML command
   - `ScanRange`: `iTsTimeMeas`, `iTsTimeFreqChange`, `iTsTimeScanRange`

   Due to the fact that only the slowest DF unit of all involved (regarding any specific timing indication) may decide maximum DF speed, all maximum values found in the previous step have to be set uniformly to all DF units.
9. **Start scan operation:** XML command
   - `DfMode`: `eOperationMode=DFMODE_SCAN`

3.11 Averaging

3.11.1 Antenna Configuring

Numbering System with Antenna Elements

Numbering of antenna elements may vary depending on context:

- For antennas with a "physically" existing reference element, antenna elements commonly (as in this manual) are numbered from 1 to *n* (*n* count of elements existing, see Figure 4-5 on page 344).
- For antennas without a physical (only virtually existing) reference element, numbering, however, might start from this element, i.e. the physical elements are counted from 2 to *n*+1.
- In software or firmware contexts (e.g. clients), numbering commonly is done from 0 to *n*–1.
- In manuals of individual antennas, even deviations from these guiding principles might be observed.

From this, always assure yourself that the perhaps differing numbering systems within your application match up.

In practice, the 3-antenna configuration basic to direction finding is enhanced by additional antenna elements so that the spacings between the antennas can be adapted optimally to the operating frequency range, and antenna spacings larger than $\lambda/2$ can be used to increase the accuracy of small-aperture DF systems. Frequently used antenna arrangements include the isosceles right triangle and the circular array (Figure 3-33, mind also Note "Numbering System with Antenna Elements").

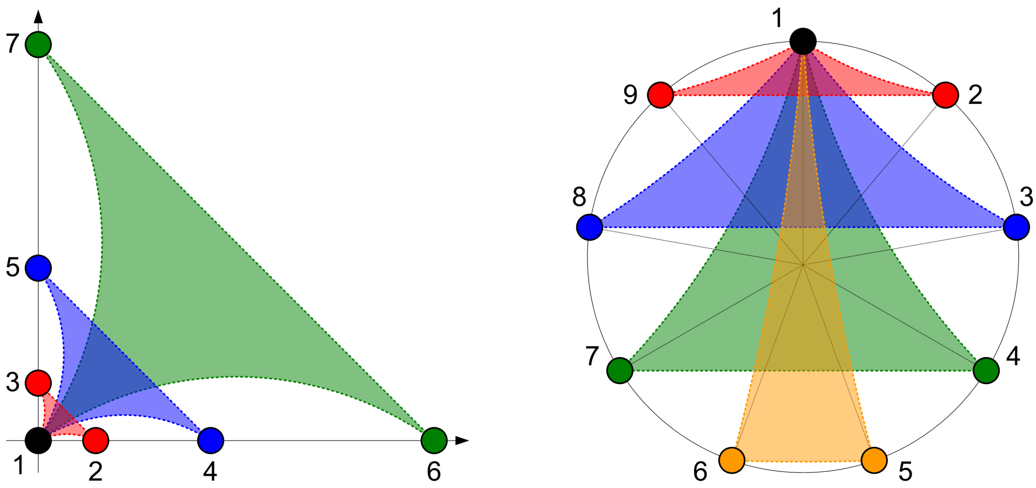


Figure 3-33: Multi-element arrays formed from several 3-element configurations.

left = linear array of 7 elements in isosceles right angle,
right = circular array of 9 elements.

All referencing described so far could be performed in principle in time domain as well as in frequency domain; in a multichannel direction finder as the R&S DDF5GTS the latter is the case, i.e. before continuing to process the data, a transformation of the primary time domain signal to frequency domain (FFT) is made.

Basically, the way the most obvious and easy to understand to achieve this referencing of antennas to each other would be to provide a separate Rx channel for each single antenna – what of course would not only be too expensive by the plain material to spend, but also by the effort to establish synchronism of all of these channels. For that reason, the solution preferred instead is to use fewer channels, and to switchserially in time (multiplex) the antenna elements to them. A solution using 3 Rx channels, as with the R&S DDF5GTS, together with a 9-element circular antenna is shown in Figure 3-34; for each DF step 4 sequential switchings have to be performed collecting 3 antenna element information items each (the reference antenna, antenna 1, is used in each step). This entire cycle is called an

- **antenna cycle**,

each single switching state an

- **antenna base**.

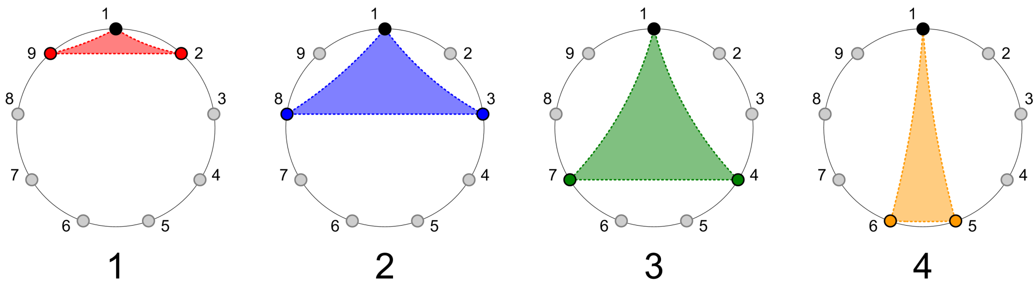


Figure 3-34: Switching procedure for an antenna with 9 elements connected to a 3-channel direction finder: 4 antenna bases with 3 antenna elements each.

Moreover, always diligently distinguish between the

- **antenna channel**,

describing the three antenna information items (streams) forming one three-element configuration basic to DF, and the

- **Rx channel**,

paraphrasing a tuner (hardware) path in the unit.

Because the count of antenna channels coincides with the count of Rx channels with the R&S DDF5GTS (both 3), no multiplexing has to be done.

A basic problem when switching the antenna elements serially in time to the Rx channels is that a signal to be measured has to be available ("on air") during the complete measuring period (antenna cycle), i.e. in all 4 antenna bases. If only one base is missing, i.e. the signal below detecting or measuring threshold, a bearing is not possible at all. There is no necessity, however, that a complete antenna cycle starts with the antenna base 1; the only mandatory thing is that 4 antenna bases are "active", i.e. their levels above threshold, in an uninterrupted succession (this means, a series of e.g. "4" – "1" – "2" – "3" is equivalent to the basic "1" – "2" – "3" – "4" series). For pulsed signals (not being active continuously), this means that the minimum signal duration must be as long as 4 plus 1, thus 5, antenna base periods in order to have 4 complete antenna bases certainly covered.

A bad, i.e. incorrect DF result commonly can be identified by the DF quality parameter showing a very poor value (considerably below 1 or 100 %); see also Chapter 3.7.3.1, "Quality", on page 135.

3.11.2 Processing Order

The normal order of processing the antenna voltages is as follows:

1. **Measuring and referencing**
   The antenna voltages (time signal) are measured at the antenna elements, input to the direction finder via the antenna cables, digitized in an A/D converter, transformed to frequency domain and then the particular antenna voltages (spectral values) related to the reference antenna voltage as described above.
2. **Level Calculating**
   From the antenna data (uncalibrated so far, since no phase information is needed for that), a level information is generated. This level is used to decide whether the signal is above or below the user-specified threshold ("active" or "inactive") at a particular time, and also for plotting the DF spectrum.
3. **Calibrating**
   In a special calibrating sequence (to be repeated in regular time intervals), calibration values have been generated (measured and interpolated if necessary) to compensate for differing antenna cable lengths and other irregularities (concerning the phase) between the available Rx channels. This calibration data is to be inserted to the antenna data in this step.
4. **Averaging**
   For a better distinguishing the signals to bear from the noise floor, and also to reduce the amount of incoming data, an averaging procedure is applied to both the level and the referenced antenna data. The characteristics of this averaging are described in the subsequent chapter. The standard deviation of the achieved DF result (azimuth angle) as a function of the amount of averaging can be calculated as

   $$\sigma_\alpha \approx \frac{k}{\sqrt{SNR \cdot n}}$$

   (σ_α standard deviation of azimuth angle, k constant of proportionality, *SNR* signal-to-noise ratio, n number of averaging cycles).

5. **Normalizing**
   Normalizing is done for eliminating some influences to the precision of the bearing result, like amplitude modulation, but is not necessary for a basic understanding.
6. **Bearing**
   From the antenna data modified to this degree, the bearing result is calculated: azimuth of the incoming wave and (not possible with Watson-Watt method) elevation.
7. **DF Error Correction**
   Correction data is applied to the bearing result (also called post-processing, cf Chapter 3.8, on page 150).

3.11.3 Level Calculation

A level can be calculated from each antenna element by omitting its phase component, i.e. if the complete complex value is available in polar (magnitude/phase) notation, using only the magnitude value, or, if in Cartesian (in-phase/quadrature) notation, summing up the square of both components and forming the square root of the sum. Two different level values are distinguished:

- The **reference level** is taken only from the reference antenna (antenna 1), whereas
- the **base level** is the averaged level of all antenna elements evaluated in a particular antenna base; e.g. 3 in case of a direction finder with the 3 Rx channels available.

Note that in the standard operation mode (no multiwave detection feature) only the reference level is calculated and used. The base level is, for example, needed in direction finding methods for multiwave resolution (e.g. the MuSiC algorithm); i.e. with super-resolution (Chapter 3.14 on page 201) active, this level will be determined, but even then not issued to the user.

The reference level (or base level, respectively) of a complete antenna cycle, again, is formed by averaging the level values of the individual antenna bases.

3.11.4 Averaging Modes

All averaging in the R&S DDF5GTS is done blockwise, i.e. any averaged data is output at the end of an averaging block. No intermediate issuing of data is possible.

- The decision how to perform the averaging, i.e. whether to include a particular value of an antenna base or not, is always derived from the **reference level** value (cf 3.11.3, "Level Calculation"); this is, the threshold to be specified by the user, and dividing the signal into "active", signal above threshold, and "inactive", signal below threshold, periods, is always set to this level signal.
- Averaging itself is applied to both level and antenna voltage signals in the same way.

- For plotting the DF spectrum, an additional averaging of the level signal always comprising all level data independent of this threshold (tallying with Continuous Mode, see below) is performed.

Nomenclature

In order not to confuse the different terms, these are summarized subsequently:

- **Antenna base**: single switching state of a multi-element antenna, combining as many antenna elements as Rx channels are available (3 in the case of the R&S DDF5GTS),
- **Antenna cycle**: all switching states needed to cover any of the available antenna elements (4 in the case of a 9-element antenna and the R&S DDF5GTS),
- **Averaging cycle**: one summing period in an averaging process, commonly done over all frequency channels of an antenna cycle,
- **Averaging block**: all summing periods in an averaging process, averaged value(s) is (are) output at its end.

An idea of the situation is given in Figure 3-35 for just 1 frequency channel and an averaging period (averaging block) of 17 averaging cycles; be aware that this is a demonstration showing the so-called averaging modes, but simplified in that

1. only averaging (more precisely: adding) of the level itself is shown (not of the antenna voltages – see above)
2. the level signal takes only two states: "2" for "above threshold" and "1" for "below threshold"; the value of the threshold itself is "1.5"
3. watching of the particular antenna bases of the frequency channel is omitted so far

Indicated is the sum (current and final) of the instantaneous values of the averaging cycles; of course, the averaged value would be taken from the final sum by dividing it by the count of averaging cycles performed, but this is not shown here.

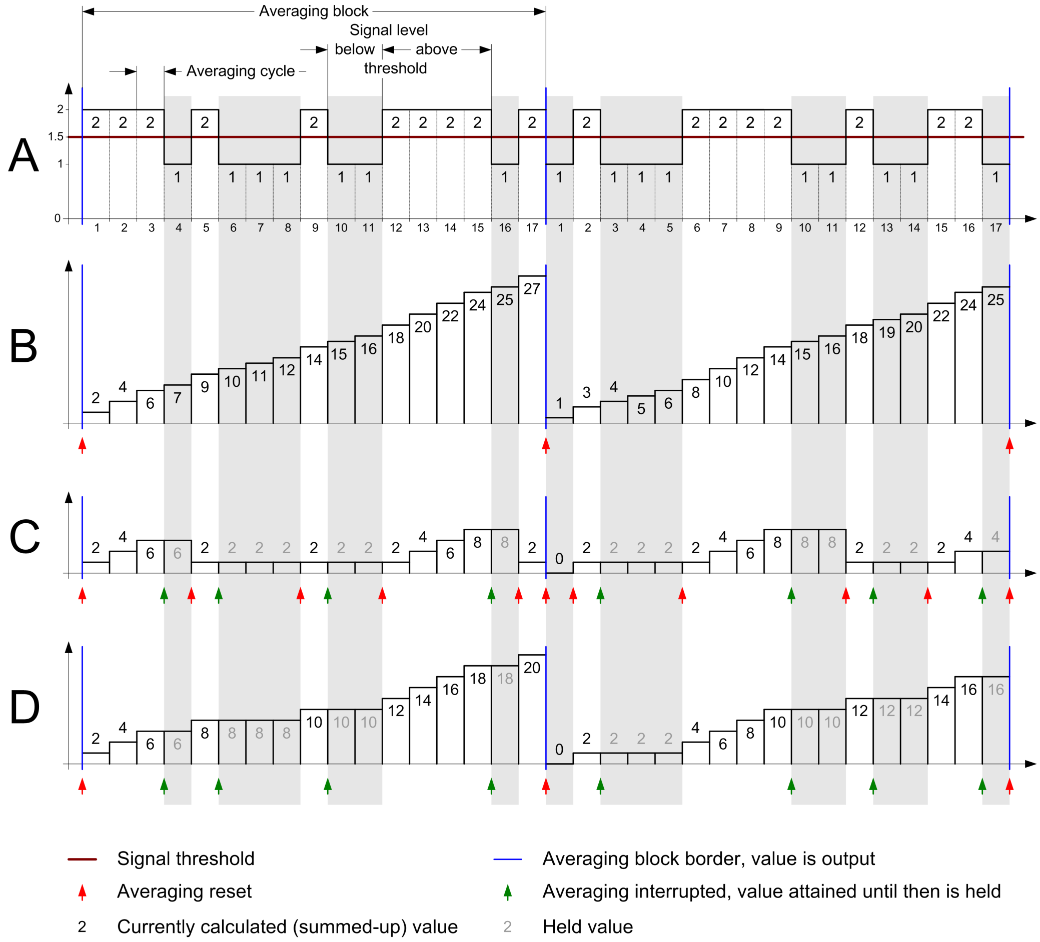


Figure 3-35: Averaging modes.

A = Original signal (not averaged)
B = Continuous Mode
C = Normal Mode
D = Gated Mode

In Figure 3-35, **A**, the original, not averaged, level signal is given, for simplicity reasons, as told above, only assuming two states, one above and one below the threshold level specified in advance by the user. This level is given the value of 1.5, the two states accordingly 2 and 1. Two averaging periods (averaging blocks) of equal length (17 averaging cycles) are considered.

Three averaging modes are defined:

- **Continuous Mode** (Figure 3-35, **B**)
  The averaged value is calculated from all instantaneous values regardless of the particular value being above or below the threshold, thus, the threshold is ignored entirely; what, of course, means nothing else than that a threshold does not exist at all. When having reached the end of the averaging block, the averaged value is formed from the final sum value reached and then output, and the averaging process (averaged value) reset.
  In the example 17 averaging cycles have been done, therefore a division by 17 has to be carried out.

Continuous Mode is commonly used for getting an overview of a signal scenario, especially for stationary signals.

- **Normal Mode** (Figure 3-35, **C**)
  The averaged value arises just from contiguous "active" periods of a signal. This means that, for a signal becoming "inactive" during an averaging cycle, averaging is interrupted and the value attained until then is held. If the signal becomes "active" a next time, averaging is restarted (the old value discarded). Thus, the value output at the end is the averaged value of the last "active" period of the signal within the averaging block.
  In the example, 1 averaging cycle in the first averaging block and 2 in the second have been done, thus division of the sum obtained by 1 or 2, respectively, has to take place.
  Normal Mode is useful for signals active in a half-duplex manner, i.e. two emitters (from different directions) working alternately on the same frequency.
- **Gated Mode** (Figure 3-35, **D**)
  The averaged value is taken from all "active" periods of the signal, i.e. excluding the "inactive" periods: this is the difference to Continuous Mode. The summed value therefore again is held during such "inactive" periods, but, with the start of a new "active" period, the averaging process is just continued, but the value not reset: this is the difference to Normal Mode.
  In the example, the average value is obtained from the final sum by division by 10 in the first block and by 8 in the second, due to 10 or 8 averaging cycles having been effective.
  Gated Mode should be applied for improving the signal-to-noise ratio: signal pauses are eliminated from averaging.

An example is shown in Figure 3-36: 1 averaging block consisting of 10 averaging cycles is given, 6 frequency channels are observed. The run of the level signal (current value also shown) together with the level threshold (value 50) yields the "above/below threshold" information. For all three averaging modes the averaged level value calculated following the rule, respectively, is indicated (upper line), and so are the averaging cycles contributing to this value (lower line). Be aware that this time not simply the sum, but the real averaged value is told.

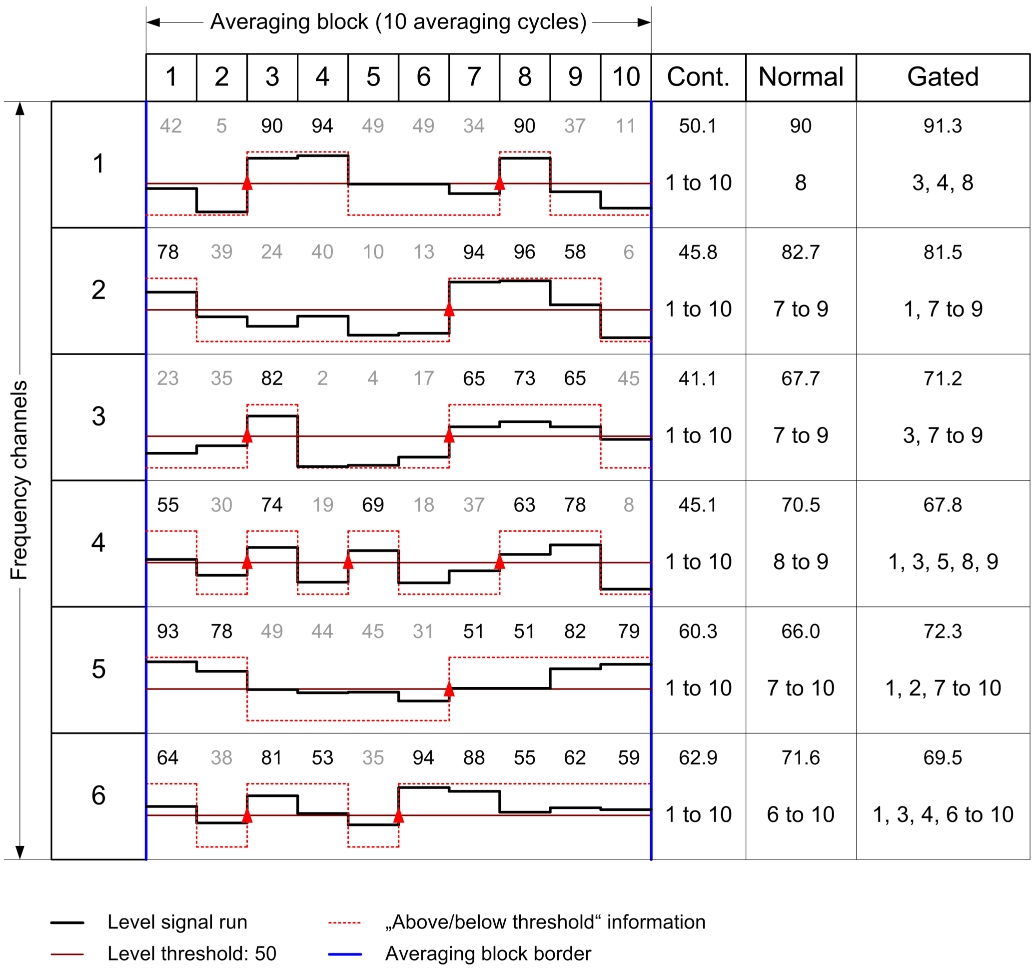


Figure 3-36: Averaging modes, example.

3.11.5 Antenna Bases

First, remember that each "antenna base" in the subsequent description in reality consists of multiple frequency channels, due to the time domain signal having been transformed to frequency domain for each base.

A correct bearing can only be performed (3.11.1) if, for an individual channel, all antenna bases are "active", i.e. their level is above the threshold. The R&S DDF5GTS forms 4 antenna bases in the case of a 9-element antenna, or also 2 for a 5-element antenna. If some bases are "missing", i.e. their level is below the threshold, the appropriate antenna cycle will be forwarded to the averaging process, however, but, depending which averaging mode (3.11.4) is to be applied, these bases might be excluded from averaging, and the values summed up to this moment are held.

In Figure 3-37 the case is shown for the three averaging modes in some special situations; assume that:

- 4 antenna bases are in use,
- 4 averaging cycles are performed,

- data output is always done after base 4 of the 4th antenna cycle,
- an "active" level signal equals to an "active" antenna base, accordingly for the "inactive" situation (pulsed inciding signal),
- only one frequency channel with its bases is considered.

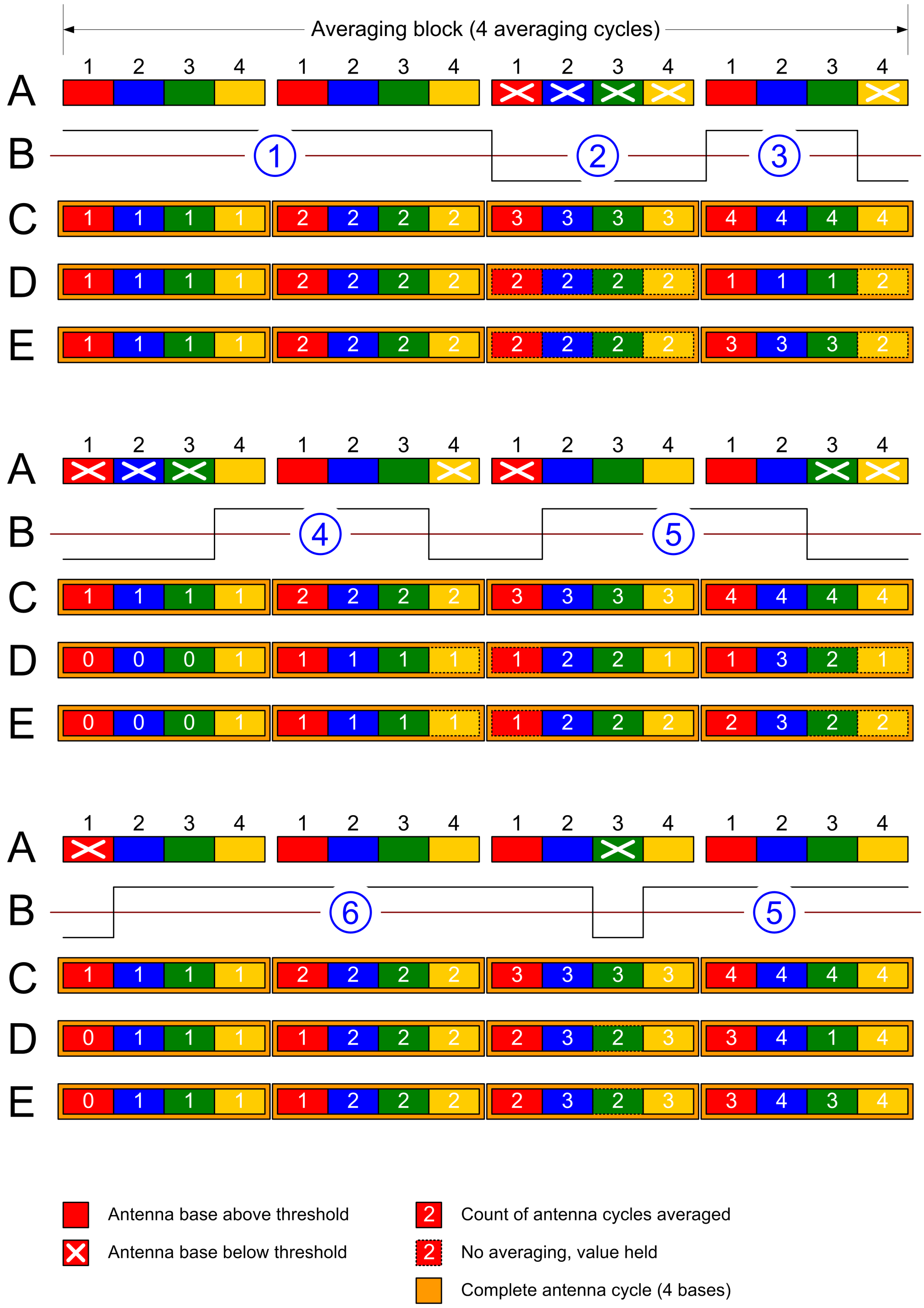


Figure 3-37: Use of antenna bases for averaging.

A = Antenna bases
B = Run of level signal
C = Averaging in Continuous Mode
D = Averaging in Normal Mode
E = Averaging in Gated Mode

- Item ① gives two coherent, complete (from base 1 to base 4) antenna base sets, thus being able to form two antenna cycles being usable for bearing/averaging without any problem in all three averaging modes.
- In item ②, 4 adjacent bases are below threshold, therefore, in Normal and Gated Mode, averaging is interrupted and the values summed so far are held. In Continuous Mode, averaging goes on: a threshold, therewith an "inactive" signal do not exist at all.
- Item ③ represents only 3 antenna bases being "active", not the complete 4: for these bases, in Normal Mode averaging is restarted, whereas in Gated Mode it is resumed. Note that from this moment on the number of averagings differs for the bases within an antenna cycle.
- Item ④ again shows a set of 4 bases being above threshold; now base 4 and not base 1 is the first found in chronological order.
- In item ⑤, more than 4 contiguous antenna bases are above threshold.
- Finally, item ⑥ delivers 9 bases above threshold, 8 of which form two complete antenna cycles.

3.11.6 Outside Influences

Some influences from outside also affect the averaging process. They are

- large external signal sources overdriving the antenna inputs (i.e. the ADCs), 3.11.6.1
- a special Blanking input allowing the user to arbitrarily include or not the current antenna signals to averaging and bearing, 3.11.6.3

3.11.6.1 Signaling

Occurrence of these influences is signaled by three bits within the *DFPScan* data trace (if selected: see Chapter 3.18.2.17, "DFPScan", on page 295):

- *Blanking* (Table 3-84, item `STATUS_BLANKOUT` [Bit 2], in Chapter 3.18.2.17) tells whether a Blanking signal has been observed anytime during the averaging block.
- *Overflow* (item `STATUS_OVERFLOW` [Bit 1]) indicates an anytime ADC overdrive.
- *Valid* (item `STATUS_VALID` [Bit 0]) is only reset if the Blanking signal was active during the complete averaging block, otherwise set.

Additionally the parameter *DF quality* (Chapter 3.18.2.17) is set to zero if one or more antenna bases were invalid (overdriven or blanked) during the entire block.

3.11.6.2 ADC Overdriven

If a very large transmission signal exists close to the antenna inputs, the ADCs will be overdriven; this situation is signaled internally and also (if selected) output within the *DFPScan* data trace (see 3.11.6.1). In this case, averaging of the ...

- ... level will be continued unalteredly to obtain the information whether a signal was present at all
- ... referenced antenna signals is interrupted because calculation of a DF value is not possible with distorted phase data

Thus, at the end of the averaging block, fewer averaging cycles have been completed successfully for the antenna bases concerned than originally intended.

To tell the reason for this issue, the Overflow bit is set if, during the block, an ADC overdrive has occurred no matter how long it lasted. The Valid flag will remain set due to the level signal existing, and, if bearing was possible anyway (each of the antenna bases contains a suitable value, i.e. at least one successful averaging process could take place with it), the DF quality shows a reasonable value; otherwise it is set to zero.

3.11.6.3 Blanking

Significance of Settings

- The blanking modes described in this section only apply to the DF branch (not to the Rx branch) of the R&S DDF5GTS, i.e. signaling told only appears in the
  – *DFPScan* data trace (Chapter 3.18.2.17)

  The signaling done in the
  – *IF* (Chapter 3.18.2.10 on page 275)
  – *Video* (Chapter 3.18.2.11 on page 279)
  – *AMMOS IF* (Chapter 3.18.3.2 on page 316)
  – *AMMOS IF DDCE* (Chapter 3.18.3.3 on page 320)

  traces is not affected by the modes (esp. cannot be switched off), thus always represents the status of the Blanking signal.
- The "hardware" settings (signal input and polarity) apply to both the Rx and the DF branch.

Blanking is a method to control averaging from outside by the same-named signal.

Blanking Modes

Three blanking modes exist:

- **Suspending:** with the Blanking signal active, both the level and the antenna signals are not used for averaging. The Blanking bit is set for the completed averaging block.
- **Status:** with the Blanking signal active, only the Blanking bit is set as told above, but averaging continued as usual.

- **Off:** the Blanking signal is ignored entirely, thus also the Blanking bit not set.

As known from the Overflow bit (3.11.6.1), the Blanking bit shows a Blanking event having occurred anytime during the block (except in mode Off), Valid bit and DF quality are used the same way as with ADC overdrive.

Signal Input

The Blanking signal can be input via two paths:

- X17 ***AUX***, pin 9 BLANKING
- X44 ***TRIGGER***

Polarity

Polarity of the Blanking signal can be configured to alternatively active high or active low.

Command

All selections are done by the XML (XML) command [2.4]

- `BlankingSettings`

3.11.7 Hopwise and Sweepwise Averaging

If you want to monitor a spectral range that is wider than the realtime bandwidth (frequency span) currently in use, this can only be achieved by dividing this range into sections of the realtime bandwidth each and dealing with each section in succession. Transient events occurring in a spectral range while another one is under examination will not be noticed this way and get lost. The maximum realtime bandwidth with the R&S DDF5GTS equates to the IF bandwidth (20 MHz or 80 MHz); more detailed information about available realtime bandwidths can be found together with the XML commands.

Thus, the following scheduling is done:

- **Sweep**
  A sweep comprises the whole spectral range to be monitored.
- **Hop**
  (For diverging usage of the term *hop* mind Note "Nomenclature" on page 228.)
  A hop is a section of the realtime bandwidth (frequency span) as mentioned. All hops of a sweep have an equal (band-)width and are averaged the same number of cycles.
- **Channel**
  A channel represents a single frequency bin of a defined bandwidth. All channels of a hop also have the same bandwidth and are processed all at a time due to FFT operation.

This situation is illustrated in Figure 3-38 for 5 hops forming a sweep; assume that no averaging is in process at the moment.

In this example, the flow through hops and sweeps is as with reading: from left to right through the hops within a sweep and then top down from sweep to sweep. In addition to the plain processing time for each hop, a certain amount of time has to be expended for switching the receiver synthesizer from one center frequency (frequency range) to another; this time has to be added and therefore it extends overall processing time.

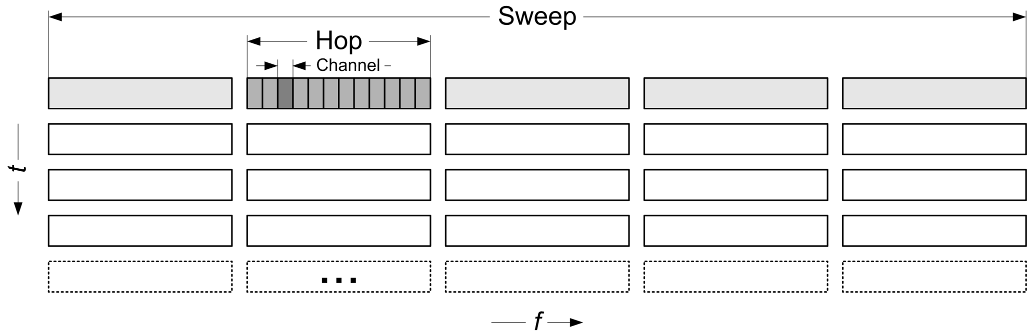


Figure 3-38: Spectral scheme of a direction finder.

From this fact, the conclusion results that two ways of averaging can be used in principle:

- **sweepwise averaging** and
- **hopwise averaging**.

3.11.7.1 Sweepwise Averaging

The one, maybe suggesting itself more, is the sweepwise averaging shown in Figure 3-39. You would, similarly to the structure of Figure 3-38, just switch from one hop to the next; the entire averaging cycle is completed when the last hop of a sweep has been processed, and the next cycle can be started. Data is output when all averaging cycles of the averaging block have been performed (t_a). The advantage of this method is that

- the repetition time t_r , i.e. the time elapsing from one covering of a special frequency (or channel) to the next, is not very long, because it does not depend on the count of averaging cycles desired,

but the disadvantages that

- the time period for an averaging block t_a is long and
- is additionally enlarged in that the synthesizer has to be switched after each single hop and thus adds its synthesizer switching time t_s several times a sweep (average cycle),
- the storage requirements are immense: the channel values of a complete sweep are to be kept.

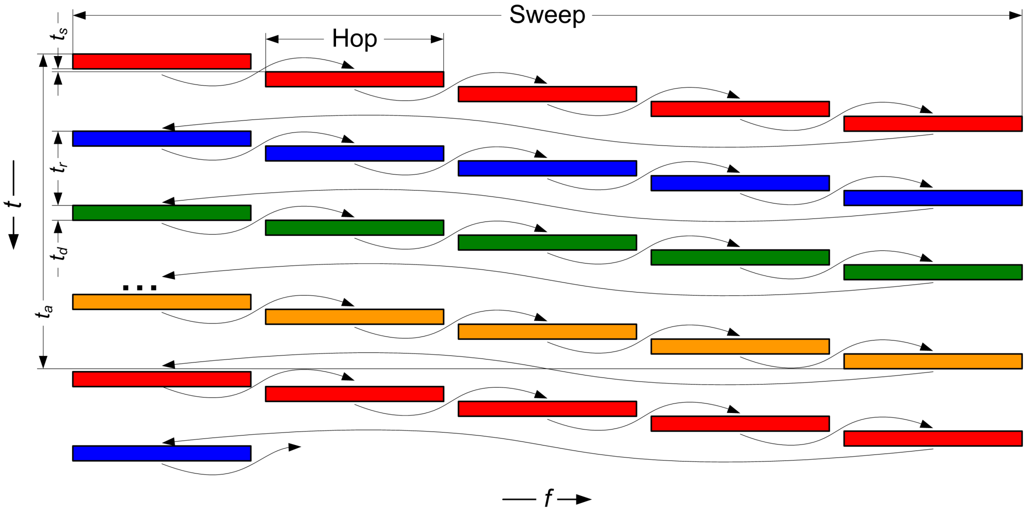


Figure 3-39: Sweepwise averaging.

t_r = repetition time of individual channel (in sweepwise averaging also averaging cycle time)
t_a = averaging block time
t_s = synthesizer switching time
t_d = hop dwell time

3.11.7.2 Hopwise Averaging

From that, in the R&S DDF5GTS solely the method of hopwise averaging given in Figure 3-40 is used. A complete averaging process (all cycles desired) is performed for the individual hop, and, moreover, an even longer dwell time for the hop may have been specified explicitly permitting additional averaging processes, only then the next hop is entered and averaging continued there. As can be easily seen, the main disadvantage is that

- the repetition time t_r increases substantially (with n averaging cycles, n times as long as with sweepwise averaging – but synthesizer switching time has to be subtracted); thus, short signals might remain unnoticed with a higher probability,

but

- results of an averaging process can be output after each hop (t_a decreases remarkably), thus relaxing data transmission,
- as already mentioned, the synthesizer has to be switched less often so that the amount of synthesizer switching time spans t_s is considerably less,
- memory has merely to store the data of one hop (not for an entire sweep).

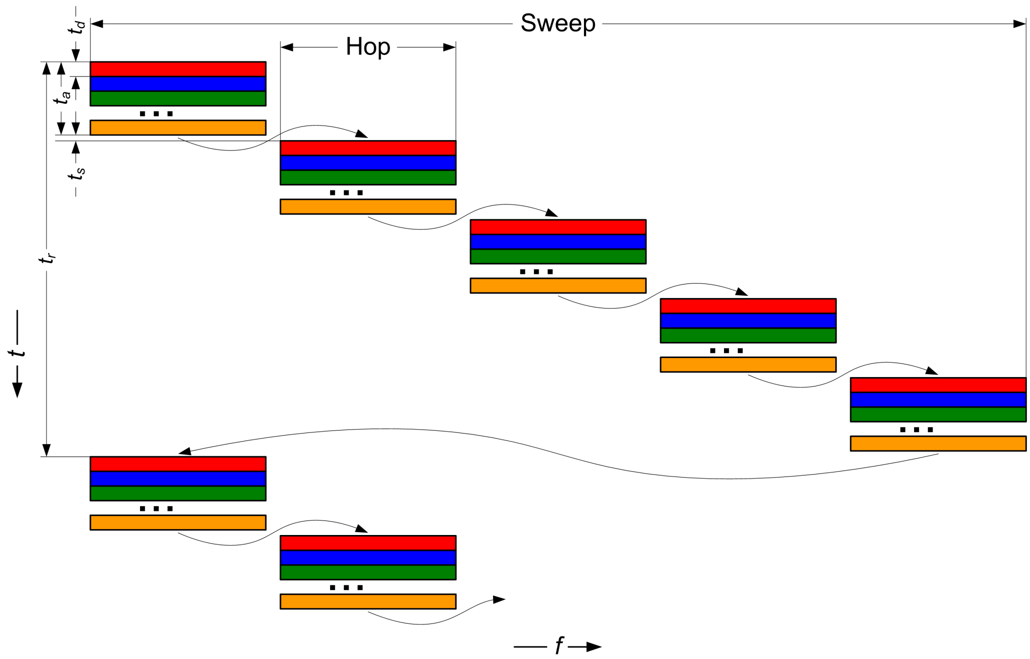


Figure 3-40: Hopwise averaging.

The minimum dwell time t_d , i.e. the period a hop has to be stayed on at least (if no differing, i.e. longer dwell time has been specified explicitly), is only determined by the needs for acquiring and processing antenna data and therewith independent of the averaging method.

3.11.8 Multi-user operation

Direction finding applying a multi-user scenario is also feasible: each user is served in turn based on a schedule managed from an outside controller (this operation mode not provided by the R&S DDF5GTS itself).

Be aware, however, that, if averaging in a way described above is desired, each user has to occupy a separate frequency range, as discrete averaging memory space for particular users is not available (memory is uniquely assigned to frequency ranges and cannot be distributed arbitrarily).

3.12 RDS

Option

The functionality **RDS decoding** is only available if the option

- R&S DDFGTS-IM, *ITU Measurement Software*,

is installed.

3.12.1 General

RDS (**R**adio **D**ata **S**ystem) is a transmission method for digital data via VHF/FM sound broadcast channels (frequency range 87.5 MHz to 108.0 MHz) which carry analog either stereophonic (pilot tone system) or monophonic programs. The main objective of RDS is to achieve improved functionality for FM receivers:

- Enhanced user-friendliness by displaying information like radio station name, program type, station characteristics (e.g. whether traffic information emitted or not),
- Automatic tuning to alternate frequency channels of the same station when moving (for portable or car radios),
- Optional emission of additional (text) information,
- Improved emergency warning by automatic switching to an appropriate station.

For a basic understanding of RDS, a scope of the most important key characteristics of RDS is given subsequently; for more detailed information refer to relevant publications, especially to the standard EN 62106 [3.8].

3.12.2 Modulation Characteristics

The binary data stream is amplitude-modulated to a subcarrier of 57 kHz; this subcarrier is, in case of a stereophonic emission, phase-locked to the third harmonic of the 19 kHz stereo pilot tone. During a monophonic emission (missing pilot tone), the subcarrier is 57 kHz, too. Together with the 15 kHz wide sum signal of the two stereo channels (coming in the baseband), their difference signal (mixed to a 38 kHz frequency position) and the pilot tone, this signal is frequency-modulated to the VHF carrier.

The data rate within RDS is obtained by dividing the subcarrier frequency by 48, i.e. it follows as 1187.5 bit/s.

3.12.3 Information Transmission

Transmission of RDS information is not performed in a rigid schedule of regularly repeated contents, but rather in an open, flexible way (also open to future requirements). Therefore, all data to broadcast is subdivided into categories of differing importance, the more relevant of which are emitted more often than the rarely needed; frequency of emission of a particular content may even be rated by the radio station itself. Only the most relevant data like station name, program type, traffic information data etc. is emitted very often or even with any data frame.

Data is transmitted in so-called (data) groups, 32 of which are existing, named (numbered) from 0 to 15 and additionally attached a "version" letter "A" or "B". An overview of the existing groups is shown in Table 3-20.

Table 3-20: (Data) Group types in RDS.

Group types	
Group type	**Description**
0 A, 0 B	Basic tuning and switching information only
1 A	Program Item Number and slow labeling codes only
1 B	Program Item Number
2 A, 2 B	Radiotext only
3 A	Applications Identification for ODA[1)]* only
4 A	Clock-time and date only
5 A, 5 B	Transparent Data Channels (32 channels) or ODA[1)]*
6 A, 6 B	In House applications or ODA[1)]*
7 A	Radio Paging or ODA[1)]*
8 A	Traffic Message Channel or ODA[1)]*
9 A	Emergency Warning System or ODA[1)]*
10 A	Program Type Name
13 A	Enhanced Radio Paging or ODA[1)]*
14 A, 14 B	Enhanced Other Networks information only
15 A	Defined in RBDS (Radio Broadcast Data System: U.S. variant) only
15 B	Fast switching information only
(all other)	ODA[1)]*

[1)] *Open Data Applications.*

Open Data Applications (ODA) are not explicitly specified in the standard. They are subject to a registration process and registered applications are listed in the ODA Directory of the EBU/RDS Forum, which references appropriate standards and normative specifications. These specifications may however be *public* (specification in the public domain) or *private* (specification not in the public domain). The terms public and private do not imply the degree of access to services provided by an application, for example a public service may include encryption.

The types of information defined in RDS are represented by the appropriate codes (see Table 3-21). Only the most important of these codes can be decoded by the R&S DDF5GTS, they are explained in detail subsequently.

Table 3-21: RDS codes (codes decodable by the R&S DDF5GTS shown in bold).

RDS codes			
Code	**Meaning**	**Code**	**Meaning**
AF	List of alternative frequencies	**PS**	Program service name
CT	Clock time and date	PTY	Program type
DI	Decoder identification	PTYI	Program type indicator (static/dynamic)
ECC	Extended country code	PTYN	Program type name
EON	Enhanced information on other networks	RP	Radio paging
EWS	Emergency warning systems	**RT**	Radiotext
IH	In-house application	**TA**	Traffic-announcement identification
MS	Music/speech switch	TDC	Transparent data channel
ODA	Open data application	TMC	Traffic message channel
PI	Program identification	**TP**	Traffic-program identification
PIN	Program-item number		

As told above, no fixed repetition rates for particular information types exist with RDS, but these rates may be determined by each individual station. In order to grant a satisfying functioning of the receivers listening, however, repetition rates are recommended for the most important information types (RDS codes), they are listed in Table 3-22. PI, PTY and TP codes are transmitted with each data frame and thus have the maximum repetition rate of 11.4/s. Proportions of transmission of particular groups resulting from these recommended rates are given in Table 3-23.

Table 3-22: Main information repetition rates.

Repetition rates			
Code	**Meaning**	**Group types containing this information**	**Appropriate repetition rate [1/s]**
PI	Program identification	all	11.4
PTY	Program type	all	11.4
TP	Traffic-program identification	all	11.4
PS	Program service name	0 A, 0 B	1
AF	List of alternative frequencies	0 A	4
TA	Traffic-announcement identification	0 A, 0 B, 14 B, 15 B	4
DI	Decoder identification	0 A, 0 B, 15 B	1
MS	Music/speech switch	0 A, 0 B, 15 B	4

Repetition rates			
Code	**Meaning**	**Group types containing this information**	**Appropriate repetition rate [1/s]**
RT	Radiotext	2 A, 2 B	0.2
EON	Enhanced information on other net-works	14 A	up to 2

Table 3-23: Transmission proportions resulting from repetition rate told.

Transmission proportions		
Group types	**Codes**	**Transmission proportion**
0 A, 0 B	PI, PS, PTY, TP, AF (0 A only), TA, DI, MS	40 %
1 A, 1 B	PI, PTY, TP, PIN	10 %
2 A, 2 B	PI, PTY, TP, RT	15 % [1)]*
14 A, 14 B	PI, PTY, TP, EON	10 %
Any other	Other applications	25 %

[1)] *Assuming that radio text messages are transmitted with 2 A groups.*

The R&S DDF5GTS decodes the following codes (see also Table 3-24):

- **PI**
  The PI code contains the program identification (not to be confused with the PS code, see below), consisting of a country code (16 different available), a coverage-area code (indicating what parts of a country are serviced by the program, 16 from "international" to "local") and a program reference number (256) distributed by each country to its radio stations like an address code.
- **TP**
  The TP code (1 bit) indicates whether a program carries traffic announcements or not.
- **TA**
  The TA code (1 bit) tells whether a traffic announcement is being broadcast at present. (The combination actually not possible TP = 0, TA = 1 shows that the program carries information about other stations giving traffic information [EON].)
- **MS**
  The MS code (1 bit) is set according to music or speech being broadcast at present.
- **PS**
  The PS code shows the alphanumeric name of the radio station, exactly 8 characters are admitted.
  Example:
  `BAYERN 3`
- **RT**

The RT code transmits arbitrary radio text to be shown on a display by the receiver. Maximum length of a text message is 64 or 32 characters, depending on which group type (*2 A* or *2 B*) is used.
Example:
`Bayern 3 - Klingt dreimal gut`

- **DI**
  The DI code (4 bit) comprises some information for the FM demodulator/decoder.

Table 3-24: Code meanings.

Code meanings			
		Bit = 0	**Bit = 1**
TP		Program without traffic announcements	Program with traffic announcements
TA		Current emission content not concerning traffic	Currently traffic announcement
MS		Speech	Music
DI	d_0	Mono	Stereo
	d_1	Conventional stereo (or, with $d_0=0$, mono)	Artificial-head stereo (not with $d_0=0$ [mono])
	d_2	Not-compressed FM	Compressed FM
	d_3	PTY (program type) static	PTY switched dynamically

3.12.4 Data Frames

Data transmission in RDS is performed in a continuous bitstream, i.e. no gaps of any kind are present. In Figure 3-41 the basic cycle, called a group, is shown; it is formed by four blocks consisting of 26 bits each, 16 of which contain the information, followed by 10 protection bits. As told above, transmission speed is 1187.5 bit/s, so that a frame duration of about 87.6 ms results.

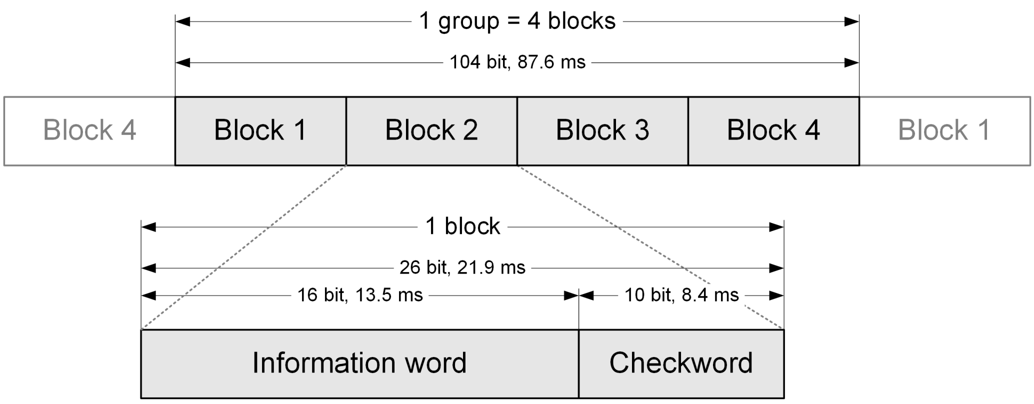


Figure 3-41: Data groups, blocks and basic timing in RDS.

In Figure 3-42 the basic distributing of the information is shown: due to 32 different group types (Table 3-20) being defined, each group must identify itself by its 4-bit type word and a 1-bit version sign, both coming in the information section of Block 2. Additionally the 16-bit PI (program identification) code (complete content of Block 1), the 1-bit TP (traffic program identification) code and the 4-bit PTY (program type) code are conveyed with each group regardless of its type. All remaining information space (the trailing 5 bits of information word 2 and the complete information words 3 and 4: 37 bits altogether) is occupied by contents varying from group to group and not described in detail here.

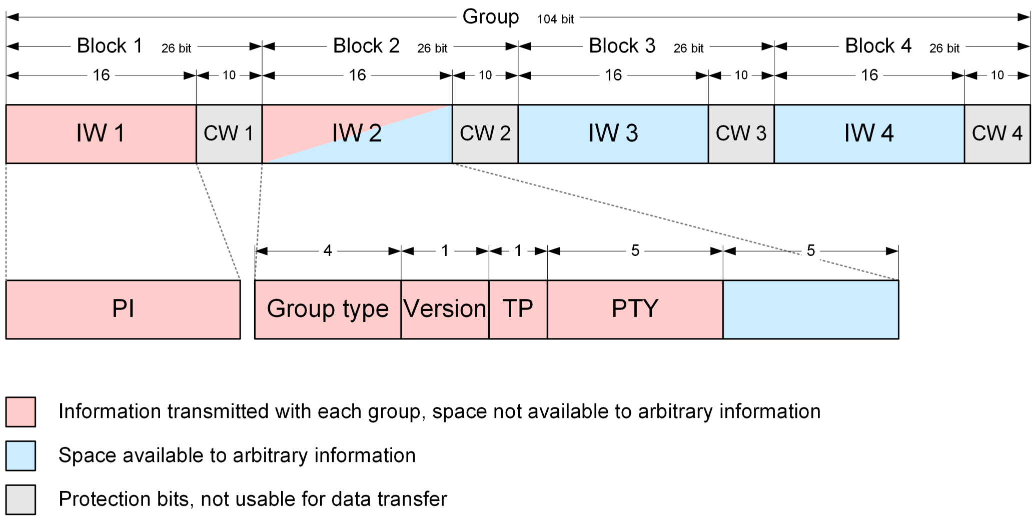


Figure 3-42: Message format and addressing.

IW = Information word
CW = Checkword
(all other abbreviations) = see Table 3-21

3.12.5 RDS in the R&S DDF5GTS

Setting or querying of RDS characteristics in the R&S DDF5GTS is exclusively performed by the appropriate XML (XML) command [2.4]

- `RDS`

i.e. no mass data output containing RDS information exists.

In addition to the genuine RDS codes already explained in 3.12.3, "Information Transmission", some indications related to, but not immediately part of RDS are returned:

- **Stereo pilot tone**
  A 19 kHz stereo pilot tone has been detected (Bit = 1) or not (Bit = 0), the latter indicating a mono transmission.
- ARI **carrier**
  A 57 kHz carrier (for RDS and formerly also for ARI information) is available (Bit = 1) or not (Bit = 0), what would reveal a radio station offering no RDS service.
- **RDS synchronized**
  This flag tells whether the R&S DDF5GTS has already established synchronization to the current RDS data stream and thus is able to decode it.
- **Group code statistics**

The frequency of the particular group codes 0 to 15, version A and B (see 3.12.3, "Information Transmission"), is counted while receiving RDS signals; the current status can be displayed and also reset.

3.13 ITU Measurements

Option

The functionality **ITU Measurements** is only available if the option

- R&S DDFGTS-IM, *ITU Measurement Software*,

is installed.

3.13.1 General

The option R&S DDFGTS-IM, *ITU Measurement Software*, offers some measurement feasibilities preferably useful for spectrum monitoring tasks. All measurings are in accordance with the corresponding recommendations of the ITU; offered are two measuring modes, four level detectors and a user-selectable measuring time.

All referenced documents where detailed information can be found are told in the subsequent chapters.

3.13.2 RF Level

Extensive information about all aspects of RF level measuring is given in the Spectrum Monitoring Handbook of the ITU [3.1].

3.13.2.1 Motivation

A parameter that can be measured directly (in contrast to field strength or power flux density) is the RF level (the level present at the RF input connectors, see Chapter 3.4.6, "RF Input", on page 111); the field strength (at the antenna itself) can be calculated hereof afterwards (3.13.3, "Field Strength").

Whereas RF level measurements of continuous (CW) emissions can be done easily either with a measurement receiver or a spectrum analyzer, certain considerations apply when the signal to be measured is modulated or even, as it is the case with digitally modulated signals, uses TDMA (Time Division Multiple Access) or is pulsed for another reason; this makes the RF level measurement more complicated.

In Figure 3-43 an example of a modulated signal is shown. Measuring can be done continuously, but attention has to be paid that, on the one hand, the measuring period is long enough to obtain a solid estimation of the "overall" level value (to have momentary level runs averaged out), and, on the other hand, the averaging period is not too long to sense changes in the signal level.

In addition, the figure shows some of the most commonly used definitions of "level" (see below).

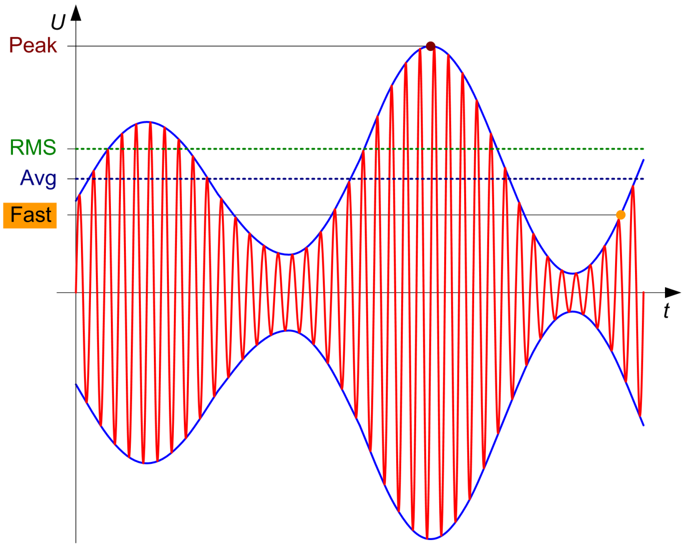


Figure 3-43: Modulated signal, parameters.

red = RF signal
blue = IF signal (envelope of RF)

In Figure 3-44 a pulsed signal is shown. It can easily be seen that in this case just measuring continuously or applying a definite measuring period arbitrarily in time (left) would deliver unwanted results because the pulsed signal is not covered perfectly, so the time period while the signal is inactive is part of this measuring period. Thus, level parameters that are measured by forming average values are also influenced by these "inactive"-period(s), and measurement will be incorrect. A reasonable indication of the emitted RF level or power is not possible this way (the item of interest typically is the level of solely the "active" sections). The right part of the figure, in contrast, gives the way out: the measuring period is adapted perfectly to the signal, normally issuing a correct result.

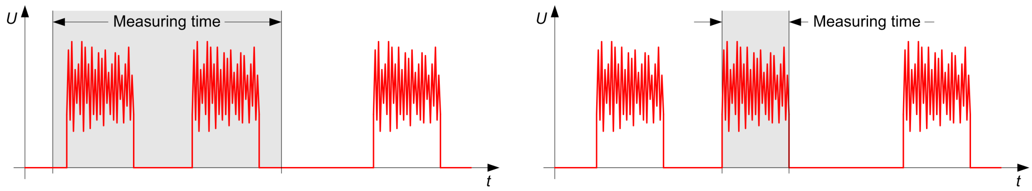


Figure 3-44: Measuring time.

left = not adapted to signal, incorrect measuring
right = adapted to signal, correct measuring

3.13.2.2 Detectors

Task

The standard task of a level "detector" is

- to observe the signal in question (that changes its amplitude value continuously) persistently and to regularly issue a single level value as a result (Section "Unbroken Measuring"), or
- to observe the signal for a certain time (the measuring time) and afterwards issue the value (Section "Finite Measuring Period").

As multiple ways exist to calculate this value, different detectors have been defined, the most important being in use are listed subsequently. In Figure 3-43 these detectors are also shown; be aware that in the R&S DDF5GTS implementation of the detectors has been done in the IF section, so the blue envelope curve has to be considered:

- **Peak detector:** out of all momentary amplitude values in the measuring time, the peak detector just extracts the highest.
- **Average detector:** this detector calculates the average value of all momentary (absolute) amplitudes.
- **RMS detector:** the RMS (root mean square) value is formed from the amplitudes, i.e. the average power (equivalent to the thermal power) is calculated. This is done by first squaring all values, then averaging them and finally extracting the square root of the mean value.
- **Fast detector:** fixes the current value, i.e. the value present at the moment of a readout query.

Unbroken Measuring

With unbroken measuring (as signified in Figure 3-43), all detectors are realized the way that a sliding averaging process takes place:

$$y(k+1) = \beta \cdot y(k) + (1-\beta) \cdot x(k)$$

$y(k+1)$ "new" averaged value,

$y(k)$ "old" averaged value,

$x(k)$ ongoing instantaneous value,

β weighting,

resulting in a step response of (see Figure 3-45, left)

$$y(k+1) = x\,e^{-\frac{1-\beta}{\beta}k}$$

for the falling edge (x start value, 1 in the figure) and (Figure 3-45, right)

$$y(k+1) = x\,(1 - e^{-\frac{1-\beta}{\beta}k})$$

for the rising edge (*x* final value, 1 in the figure).

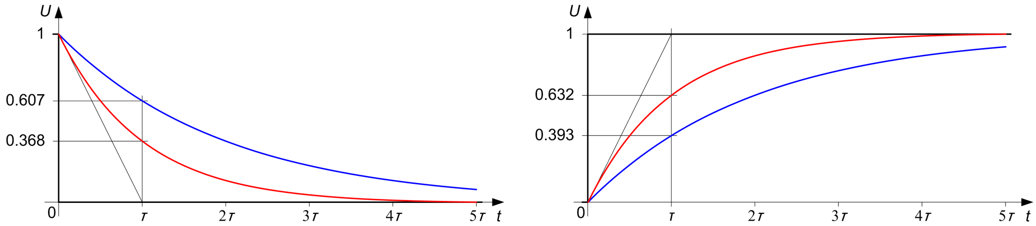


Figure 3-45: Detector step response.

left = negative step (falling edge)
right = positive step (rising edge)
red = averaging of unmodified value (peak and average detector)
blue = averaging of squared value (RMS detector)

In terms of rise and fall times, the Fast detector has none at all ($T_{rise,Fast}$ = $T_{fall,Fast}$ = 0), whereas the Peak detector, to be able to follow peaks newly detected, has no rise time ($T_{rise,Peak}$ = 0), but a definite, comparatively long fall time $T_{fall,Peak}$ for keeping the last peak value found for a certain period of time. The Average and the RMS detectors always have the same rise and fall times ($T_{rise,Avg}$ = $T_{fall,Avg}$ = $T_{rise,RMS}$ = $T_{fall,RMS}$); the different behavior of the RMS detector (see figure) stems from the fact that not the level itself but the power (square of level) is averaged (see above).

Finite Measuring Period

If a finite measuring period is to be applied (as shown in Figure 3-44), averaging performed by the detectors does not obey to a sliding manner any longer, but to a common linear mode; i.e. no exponential response results, but behavior is as follows:

- **Peak detector:** delivers the absolutely highest level value found during the period.
- **Average detector:** issues the strictly linear average value of the (absolute) input signal.
- **RMS detector:** determines the linearly calculated RMS average value.
- **Fast detector:** simply the last (momentary) value of the measuring period.

This finite measuring period or **Measuring Time** always becomes relevant when the detectors have been cleared intentionally and thus have to settle again. Detector clearing happens with

- a deliberate change of
  - Rx frequency,
  - Rx bandwidth,
  - demodulation mode,
  - detector type,
  - attenuator,
- the XML (XML) command [2.4] `Initiate` ,
- at regular intervals in Periodic Measuring Mode (see Section "Periodic Measuring Mode").

3.13.2.3 Measuring Modes

Continuous Measuring Mode

The mode of unbroken measuring (Section "Unbroken Measuring") is called **Continuous Measuring Mode** and can be selected by the XML command

- `RxSettings`

An explicit request for querying the detector can be made by the XML command

- `Initiate`

in addition, the detectors are cleared (see Section "Finite Measuring Period").

Periodic Measuring Mode

The mode with regular clearing of the detectors (Section "Finite Measuring Period") is called **Periodic Measuring Mode**. After each expiration of the measuring time active, the calculated value is output and the detector cleared.

3.13.2.4 Timing

Default Settings

For usual measuring tasks, rise and fall times (Section "Unbroken Measuring") correspond closely to the current Rx bandwidth. Therefore, for any bandwidth setting a default setting of these times has been defined delivering a measured value that can be expected to be correct. These values are given in Table 3-25; they are activated after power-up of the R&S DDF5GTS and after the XML command

- `Reset`

Table 3-25: Default rise and fall times.

Default rise and fall times	
Bandwidth [kHz]	**Time [µs]**
$T_{rise,Peak}$, $T_{rise,Fast}$, $T_{fall,Fast}$	
0.1, 0.15	500
0.3	250
0.6	125
1, 1.5, 2.1, 2.4, 2.7, 3.1, 4, 4.8, 6, ATC 8.333 [1)]*, 9, 12, 15	63
ATC 25 [1)]*, 30	32
50, 75	16
120, 150, 250	7
300, 500	4
800, 1000	2

Default rise and fall times	
Bandwidth [kHz]	**Time [µs]**
1250, 1500, 2000	1
5000, 8000, 10000, 12500, 15000, 20000, TV 5000	0
$T_{fall,Peak}$	
0.1, 0.15, 0.3, 0.6	2000000
1, 1.5, 2.1, 2.4, 2.7, 3.1, 4, 4.8, 6, ATC 8.333[1)]*, 9, 12, 15, ATC 25[1)]*, 30, 50, 75, 120, 150, 250, 300, 500, 800, 1000, 1250, 1500, 2000, 5000	1000000
8000, 10000, 12500, 15000, 20000, TV 5000	500000
$T_{rise,Avg}$, $T_{fall,Avg}$, $T_{rise,RMS}$, $T_{fall,RMS}$	
0.1, 0.15	200000
0.3, 0.6	100000
1, 1.5	50000
2.1, 2.4, 2.7, 3.1, 4, 4.8	25000
6	12000
ATC 8.333[1)]*, 9	6000
12	4000
15, ATC 25[1)]*, 30, 50, 75, 120, 150, 250, 300	3000
500, 800	2000
1000, 1250, 1500, 2000, 5000, 8000, 10000, 12500, 15000, 20000, TV 5000	1000

[1)] *Bandwidths with the prefix 'ATC' are specially designed for **A**ir **T**raffic **C**ontrol communications according to ETSI EN 300676-1.*

As with these rise and fall times in unbroken measuring, measuring time in finite-time measuring (Section "Finite Measuring Period") is also closely related to the currently set Rx bandwidth, and therefore, again, default values have been defined to be set with power-up or after the XML commands

- `Reset` or
- `RxSettings`

These values can be found in Table 3-26.

Table 3-26: Default measuring times.

Default measuring times	
Bandwidth [kHz]	**Time [µs]**
Average and RMS Detector: $T_{meas,Avg}$, $T_{meas,RMS}$	
0.1, 0.15	200000

Default measuring times	
Bandwidth [kHz]	**Time [µs]**
0.3, 0.6	100000
1, 1.5	50000
2.1, 2.4, 2.7, 3.1, 4, 4.8	25000
6	12000
ATC 8.333*1)* *, 9	6000
12	4000
15, ATC 25*1)* *, 30, 50, 75, 120, 150, 250, 300	3000
500, 800	2000
1000, 1250, 1500, 2000, 5000, 8000, 10000, 12500, 15000, 20000, TV 5000	1000
Peak Detector: $T_{meas,Peak}$	
0.1, 0.15	500000
0.3	400000
0.6	200000
1, 1.5	100000
2.1, 2.4, 2.7, 3.1, 4, 4.8	60000
6	30000
ATC 8.333*1)* *, 9	20000
12, 15	10000
ATC 25*1)* *, 30	5000
50, 75	4000
120, 150	2000
250, 300, 500, 800, 1000, 1250, 1500, 2000, 5000, 8000, 10000, 12500, 15000, 20000, TV 5000	1000
Fast Detector: $T_{meas,Fast}$	
0.1, 0.15	500
0.3	250
0.6	125
1, 1.5, 2.1, 2.4, 2.7, 3.1, 4, 4.8, 6, ATC 8.333*1)* *, 9, 12, 15	63
ATC 25*1)* *, 30	32
50, 75	16
120, 150, 250	7
300, 500	4

Default measuring times	
Bandwidth [kHz]	**Time [µs]**
800, 1000	2
1250, 1500, 2000	1
5000, 8000, 10000, 12500, 15000, 20000, TV 5000	0

1) *See footnote 1 of Table 3-25.*

Manual Setting

For more sophisticated measuring tasks, e.g. for pulsed digital signals or also pulse-shaped signals like ignition sparks (cf Figure 3-44), an automatically set (default) measuring time is not suitable. Time periods with the signal inactive could, for example, contribute to the averaging process and thus falsify the result. Therefore, a user-selectable measuring time is required for this purpose.

In this case (measuring time deviant from default), all transient (rise and fall) times (except the ones being 0 at any time, see Section "Unbroken Measuring") are set to the same value as the measuring time specified, and, of course, no timing depends on the current Rx bandwidth (see Section "Default Settings"). For a better overview, Table 3-27 summarizes the situation.

Table 3-27: Manual time settings.

Transient time			
Kind	**Value**	**Kind**	**Value**
$T_{rise,Fast}$ $T_{fall,Fast}$ $T_{rise,Peak}$	0	$T_{fall,Peak}$ $T_{rise,Avg}$, $T_{fall,Avg}$ $T_{rise,RMS}$, $T_{fall,RMS}$	Measuring time set

Manual setting of the measuring time is performed by the XML command

- `RxSettings`

3.13.3 Field Strength

The antenna field strength `Field_Strength` is not measured directly, but calculated from the RF level `RF_Level` (3.13.2) and the k-factor (antenna factor) `K_Factor` as

`Field_Strength = RF_Level + K_Factor`

for more detailed information about the k-factors see Chapter 3.8.2, "Factors of Influence", on page 151.

All additional information can be found in the Spectrum Monitoring Handbook of the ITU [3.1] and the Recommendation ITU-R SM.378 [3.2].

3.13.4 Frequency Offset

The frequency offset is the offset of the frequency within the demodulation bandwidth containing most of the spectral energy to the frequency currently specified as the center frequency. Measuring is done in high precision; again, an averaging process is to be applied, i.e. detectors as explained above can be applied to the signal, the detector type used for this purpose is an average detector.

Default values for rise and fall times (fall time equals to rise time with an average detector) can be seen from Table 3-28, for measuring times from Table 3-29.

Table 3-28: Default rise and fall times.

Default rise and fall times	
Bandwidth [kHz]	**Time [µs]**
Frequency offset AM: $T_{rise,AMoffset}$, $T_{fall,AMoffset}$	
0.1, 0.15, 0.3, 0.6, 1, 1.5	100000
2.1, 2.4, 2.7, 3.1, 4, 4.8, 6, ATC 8.333[1)]*, 9	50000
12, 15, ATC 25[1)]*, 30, 50	20000
75, 120, 150	10000
250, 300	5000
500, 800	2000
1000, 1250, 1500, 2000, 5000, 8000, 10000, 12500, 15000, 20000, TV 5000	1000
Frequency offset FM and PM: $T_{rise,FMoffset}$, $T_{fall,FMoffset}$, $T_{rise,PMoffset}$, $T_{fall,PMoffset}$	
0.1, 0.15, 0.3, 0.6	200000
1, 1.5, 2.1, 2.4, 2.7, 3.1, 4, 4.8, 6, ATC 8.333[1)]*, 9, 12, 15, ATC 25[1)]*, 30, 50, 75	100000
120, 150	50000
250, 300	25000
500, 800	10000
1000, 1250, 1500, 2000, 5000, 8000, 10000, 12500, 15000, 20000, TV 5000	5000

[1)] *See footnote 1 of Table 3-25.*

Table 3-29: Default measuring times.

Default measuring times	
Bandwidth [kHz]	**Time [µs]**
Frequency offset AM: $T_{meas,AMoffset}$	
0.1, 0.15, 0.3, 0.6, 1, 1.5	100000
2.1, 2.4, 2.7, 3.1, 4, 4.8, 6, ATC 8.333[1)]*, 9	50000
12, 15, ATC 25[1)]*, 30, 50, 75	20000

Default measuring times	
Bandwidth [kHz]	**Time [µs]**
120, 150	10000
250, 300	5000
500, 800	2000
1000, 1250, 1500, 2000, 5000, 8000, 10000, 12500, 15000, 20000, TV 5000	1000
Frequency offset FM and PM: $T_{meas,FMoffset}$, $T_{meas,PMoffset}$	
0.1, 0.15, 0.3, 0.6	200000
1, 1.5, 2.1, 2.4, 2.7, 3.1, 4, 4.8, 6, ATC 8.333[1)]*, 9, 12, 15, ATC 25[1)]*, 30, 50, 75	100000
120, 150	50000
250, 300	25000
500, 800	10000
1000, 1250, 1500, 2000, 5000, 8000, 10000, 12500, 15000, 20000, TV 5000	5000

[1)] *See footnote 1 of Table 3-25.*

As with RF level measuring (3.13.2.4, "Timing"), the measuring times $T_{meas,Xoffset}$ (X Є (AM, FM, PM)) may be set manually; rise and fall times $T_{rise,Xoffset}$ and $T_{fall,Xoffset}$ equate to the measuring time in this case.

For detailed information, consult the Spectrum Monitoring Handbook of the ITU [3.1] and the Recommendations ITU-R SM.377 [3.3] and ITU-R SM.378 [3.2].

3.13.5 Modulation Parameters

3.13.5.1 Measuring procedure

For measuring of modulation parameters similar considerations apply as with RF level measuring (cf 3.13.2, "RF Level"), in detail, the measuring task is also to observe certain periods of time, thus, analogously the measuring procedure is used also here: output can be queried in an unbroken or a finite period observation mode, and detectors are in use for averaging the instantaneous values measured. These modulation detectors work as peak detectors only, i.e. in contrast to their fall times, their rise times $T_{AMdep,rise}$, $T_{FMdev,rise}$ and $T_{PMdev,rise}$ are always 0.

Again, default values both for the transient times (only fall times, due to the rise times being 0) and the measuring times dependent on the Rx bandwidth currently set have been defined:

- For AM modulation depth measuring, the fall times $T_{fall,AMdep}$ are equivalent to the RF level measuring fall times and can therefore be taken from the $T_{fall,peak}$ section of Table 3-25.

- For FM frequency deviation and PM phase deviation measuring, the fall times $T_{fall,FMdev}$ and $T_{fall,PMdev}$ equate to the fall times $T_{fall,FMoffset}$ and $T_{fall,PMoffset}$ of offset measuring, thus the *Frequency offset FM and PM* section of Table 3-28 can be used.
- The default measuring times $T_{meas,AMdep}$, $T_{meas,FMdev}$ and $T_{meas,PMdev}$ are the same as the default measuring times $T_{meas,Peak}$ for RF level measuring and can be seen from the *Peak detector* section of Table 3-26.

As explained above, the measuring time alternatively can be set by hand by the XML command

- `RxSettings`

all fall times equal to the measuring time in this case, whereas the rise times remain 0.

3.13.5.2 Amplitude Modulation (AM) Parameters

The situation with an amplitude-modulated (AM) signal is shown in Figure 3-46. The LF signal modulates the amplitude of the carrier, resulting in an amplitude envelope proportional to the original (modulating) signal.

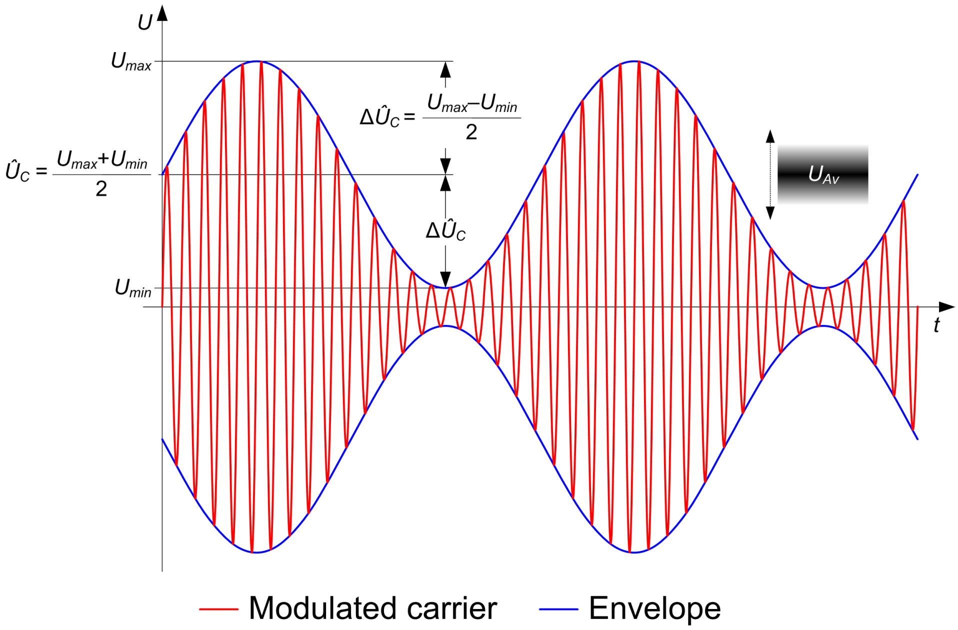


Figure 3-46: Amplitude-modulated signal, parameters.

The key parameter to measure in analog amplitude modulation is the modulation depth *m*; it can, as the most common definition in use, be derived from the maximum (U_{max}) and the minimum amplitude (U_{min}) by determining the average amplitude of the modulated carrier (the amplitude as it would be in the unmodulated case)

$$\hat{U}_C = \frac{U_{max} + U_{min}}{2}$$

Equation 3-1:

Modulation depth *m* is defined as the ratio of the amplitude of the envelope (thus, half the distance of U_{max} and U_{min})

$$\Delta\hat{U}_C = \frac{U_{max} - U_{min}}{2}$$

to the average carrier amplitude from Equation 3-1 as

$$m = \frac{\Delta\hat{U}_C}{\hat{U}_C} = \frac{U_{max} - U_{min}}{U_{max} + U_{min}}$$

Equation 3-2:

and commonly specified in %.

Shown in Figure 3-46 is modulation with a simple sinusoidal modulating signal: modulation resulting is strictly symmetric. If the envelope amplitude $\Delta\hat{U}_C$ would increase, U_{min} would reach the value of 0 (modulation of 100 %) or even become negative. This latter case is called overmodulation; it leads to strong distortions (no proper demodulation, i.e. recovery of the original modulating signal possible) and additionally to an increased consumption of bandwidth.

Alternatively, other definitions are in use for *m* which consider the average voltage U_{Av} (voltage averaged from all instantaneous values during the measuring period instead of calculated merely from U_{max} and U_{min}).

Using U_{max} and U_{Av} (as before, the envelope amplitude is related to the average carrier amplitude), one obtains

$$m_+ = \frac{U_{max} - U_{Av}}{U_{Av}}$$

Equation 3-3:

or, using U_{Av} and U_{min},

$$m_- = \frac{U_{Av} - U_{min}}{U_{Av}}$$

Equation 3-4:

In case of a sinusoidal modulating signal and no overmodulation, all definitions give the same result. If the signal contains non-symmetric modulation or even overmodulation, however, m_+ and m_- can still deliver reasonable measurement values, whereas *m* is no longer defined and would lead to largely erroneous results.

For detailed information about measuring of AM parameters, consult the Spectrum Monitoring Handbook of the ITU [3.1] and the Recommendation ITU-R SM.328 [3.4].

3.13.5.3 Angle Modulation Parameters

As can be seen from Figure 3-47, in angle modulation not the amplitude, but the instantaneous angle of the carrier is modulated by the LF signal. The amplitude is held constant (is not considered in the further process), thus, this kind of modulation is much less sensitive to amplitude distortions found in almost any transmission path.

A distinction is made, depending on whether the instantaneous phase (Figure 3-47, **A**) or the instantaneous frequency (which is nothing else but the derivative of the phase with respect to time, Figure 3-47, **B**) of the carrier is proportional to the original modulating signal, between phase modulation (PM) and frequency modulation (FM).

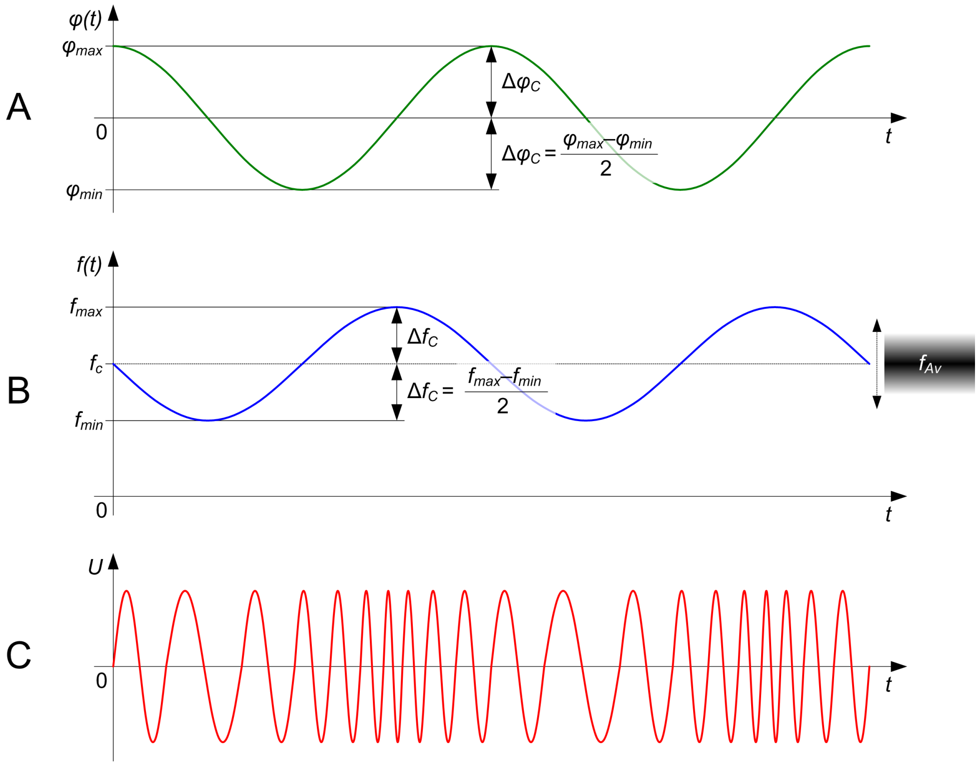


Figure 3-47: Angle-modulated signal, parameters.

A = Instantaneous phase
B = Instantaneous frequency
C = Modulated carrier

Additionally to the Spectrum Monitoring Handbook of the ITU [3.1] and the Recommendation ITU-R SM.328 [3.4], more detailed information about measuring of angle modulation parameters can be found in the Recommendation ITU-R SM.1268 [3.5].

FM Parameters

In FM, the more common case with analog modulation applications, the instantaneous frequency of the carrier is proportional to the modulating signal.

Therefore, an interesting parameter is the instantaneous frequency deviation and its extreme values (maximum f_{max} and minimum f_{min}) observed during a laid down measuring period. Similarly to Equation 3-1, the original frequency of the unmodulated carrier can be concluded from them as

$$f_C = \frac{f_{max} + f_{min}}{2}$$

or, as a more feasible approach, as the average value f_{Av} of all instantaneous values obtained during the entire measuring period.

From that, again three definitions of the frequency deviation Δf are possible:

$$\Delta f = f_{max} - f_C = f_C - f_{min}$$

Equation 3-5:

describes the more theoretical approach of a sinusoidal modulation (cf Equation 3-2),

$$\Delta f_+ = f_{max} - f_{Av}$$

Equation 3-6:

sets priorities to modulation in positive direction (higher frequencies of the carrier), cf Equation 3-3, and

$$\Delta f_- = f_{Av} - f_{min}$$

Equation 3-7:

in negative direction (lower carrier frequencies), cf Equation 3-4.

Frequency deviation measuring can be performed in any Rx operation mode of the R&S DDF5GTS, but not in mode **PM**.

PM Parameters

In phase modulation (PM), the instantaneous phase of the carrier is proportional to the modulating signal. This is a technique used more often with digital modulation (as Phase Shift Keying, PSK).

The characteristic parameters now are the instantaneous phase deviation and its extreme values (maximum φ_{max} and minimum φ_{min}); again, the value for the unmodulated carrier can be derived as

$$\varphi_C = \frac{\varphi_{max} + \varphi_{min}}{2}$$

or as the average value φ_{Av} of all instantaneous values obtained during the measuring period.

But, due to the fact that an absolute phase (not related to a reference) of an oscillation never can be told, this value for the unmodulated case is defined 0 and the maximum and minimum values considered symmetrical to it, i.e. for telling a phase deviation $\Delta\varphi$, indication of one of both (absolute value) will do. If both values differ due to calculation of φ_{Av}, the larger one will be used:

$$\Delta\varphi = \max(|\varphi_{max}|,|\varphi_{min}|) - \varphi_{Av} \overset{\varphi_{Av}\overset{!}{=}0}{=} \max(|\varphi_{max}|,|\varphi_{min}|)$$

Equation 3-8:

Phase deviation measuring can exclusively be performed if the R&S DDF5GTS is in the Rx operation mode **PM**.

3.13.6 Bandwidth

For the bandwidth occupied by a signal, different definitions are in use, two of which can be handled by the R&S DDF5GTS:

- the x dB bandwidth and
- the β % bandwidth.

For more detailed information, consult the Recommendations ITU-R SM.328 [3.4], ITU-R SM.443 [3.6] and the ITU Spectrum Monitoring Handbook [3.1].

Selecting the kind of bandwidth definition to be used and specifying the parameters (x [dB] for the x dB bandwidth and β [%] for the β % bandwidth, respectively) is done by the dedicated XML command

- `ITU`

3.13.6.1 The x dB Bandwidth

The x dB bandwidth has been defined in ITU-R SM.328 [3.4] as

- "The width of a frequency band such that beyond its lower and upper limits any discrete spectrum component or continuous spectral power density is at least *x* dB lower than a predetermined 0 dB reference level."

The situation is explained in Figure 3-48.

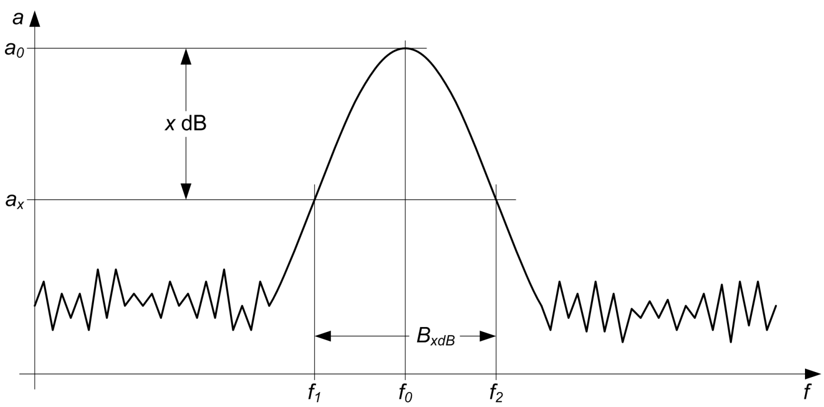


Figure 3-48: The x dB bandwidth.

3.13.6.2 The β % Bandwidth

The β % bandwidth has been defined in the ITU Spectrum Monitoring Handbook [3.1] as

- "The width of a frequency band such that, below the lower and above the upper frequency limits, the mean powers emitted are each equal to a specified percentage β/2 of the total mean power of a given emission."

This means: β (commonly specified in %) of the power of an observed frequency span is out of band (-width) ($\beta/2$ to the left, $\beta/2$ to the right of the interesting band, respectively), $1-\beta$ in band. The situation can be seen in Figure 3-49.

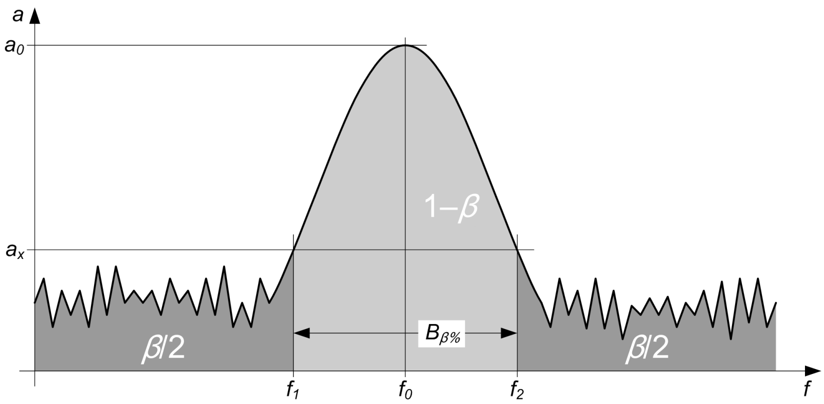


Figure 3-49: The β % bandwidth.

3.14 Super-Resolution

(Included in delivery as a standard option with the R&S DDF5GTS, see Chapter 2.6.5, "R&S DDFGTS-SR, Super-Resolution", on page 84)

3.14.1 Motivation

Classic DF methods assume just one single (predominant) wave existing in the frequency channel of interest. If this should not be the case but multiwave incidence as shown in Figure 3-50 be present, the result is not only that the individual waves cannot be separated, but also that, even if one of the waves should be the dominating one, indication of its azimuth angle(s) contains large defects (DF errors).

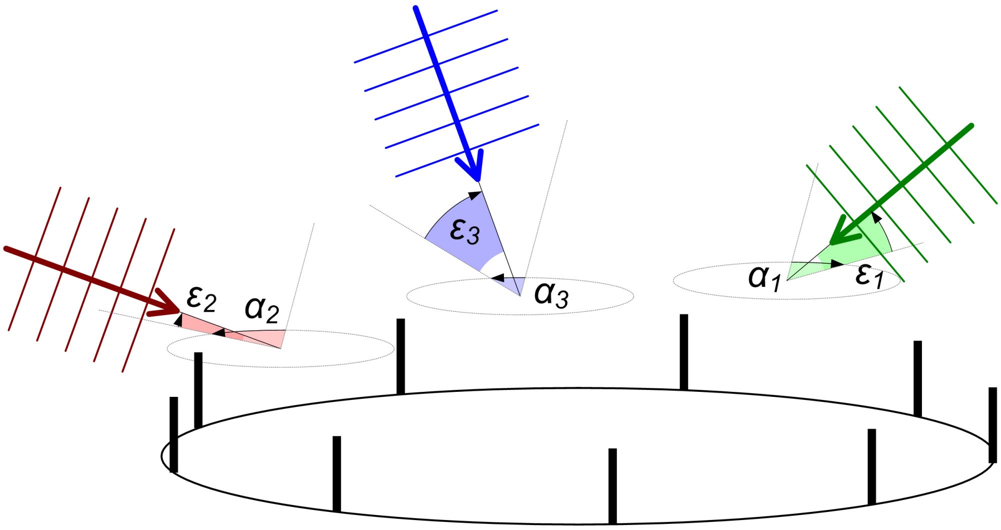


Figure 3-50: Several waves inciding to a circular array.

α_i = azimuth angle
ε_i = elevation angle

Reasons for multiwave incidence might be:

- In the HF range propagation conditions are subject to continual change. Sometimes emissions reach coverages much larger than originally intended and thus are received also in regions where another station is operated on the same frequency.
- In urban areas, an emission does not only follow the immediate path to the receiver (direct line of propagation) but is also reflected by buildings or vehicles und thus incides several times coming from different directions (see Chapter 2.4, "Antennas", on page 37).
- Especially in the HF range a wave is reflected by the ionosphere , therefore, in addition to the immediate wave (ground wave), one or even more sky waves must be taken into account.
- Damaged electronic devices might produce electromagnetic disturbances lying on the frequency of an emitter.
- In single frequency networks (SFN) being in use e.g. with digital audio (DAB) and video (DVB) broadcasting, several emitters at distinct locations transmit the same signal on the same frequency in order to improve transmission quality.
- With the transmission method CDMA (Code Division Multiple Access), known for example from the mobile communications standard UMTS (Universal Mobile Telecommunications System), many stations transmit on the same frequency at the same time, the individual signals being distinguishable to their receivers by their spreading codes superseding the actual information.
- Sometimes particular signals are disturbed deliberately by emitting an interfering signal on the same frequency.

Several waves commonly come from different directions (of azimuth, shown as α_1 to α_3 in Figure 3-50, and of elevation, shown as ε_1 to ε_3). Not shown are possible differences in polarization (linear, circular).

Two approaches exist with *classic* DF methods (designed for single wave incidence) to solve this problem:

- If the disturbing wave portion is of lower power than the wave portion in use, the DF error can be minimized by an appropriate dimensioning of the DF equipment, especially by selecting a sufficiently large antenna base (Chapter 3.11, "Averaging", on page 165).
- If, in contrast, the disturbing wave portion is larger, multichannel direction finders of high frequency resolution capability sometimes can exploit spectral differences of signals not correlated to each other to find out their directions.

A more systematic solution of the problem is offered by the so-called *super-resolution* (SR) methods that allow determination both of the count of inciding waves and of their directions of incidence

- model-based with the Maximum Likelihood method or
- by principal component analysis (PCA) of antenna data.

The super-resolution method uses the latter approach.

Of essential relevance in this context are temporal coherence (autocorrelation) and spatial coherence (cross-correlation) existing within the resulting wave field present to the antenna. Whether signals can be separated by an individual super-resolution method or not and, if yes, how efficiently, depends on these items to a large degree.

3.14.2 History and Existing Methods

A short survey about existing super-resolution methods together with a (partial) estimation of their quality is given in Table 3-30, without detailed explanation of the individual methods. If wishing to get more information, refer to relevant publications.

Table 3-30: Systematics of super-resolution methods.

Sensor array processing[1)]*						
Beamforming		**Maximum Likelihood**	**Subspace**			
			Signal		**Noise**	
Conventional	**Adaptive**		**Search based**	**Algebraic**	**Search based**	**Algebraic**
Fourier Correlation Vector matching	Capon (Cat. 1) Linear Predictor	ML estimator (Cat. 3)	Minimum variance AR method (Cat. 2) Subspace fitting	ESPRIT (Cat. 2) GEESE	Pisarenko (Cat. 2) MuSiC (Cat. 2)	Root MuSiC (Cat. 2)
High resolution methods						

1)	*Categories indicating performance of method: 1 least, 3 most powerful.*
AR	***A**uto**R**egressive*
ESPRIT	***E**stimation of **S**ignal **P**arameters via **R**otational **I**nvariance **T**echniques*
GEESE	***GE**neralized **E**igenvalues Utilizing **S**ignal Subspace **E**igenvectors*
MuSiC	***Mu**ltiple **Si**gnal **C**lassification*

One example for multiwave resolution by elimination of inciding waves is beamforming shown in Figure 3-51. It generalizes the archaic method of (manually) rotating a crossed-loop antenna thereby trying to separate acoustically one wave from the other (one). Beamforming achieves this goal by an adaptive antenna; weighting of each of its individual elements is done the way that a local minimum in the overall antenna diagram is created in the direction of each wave present at the moment. This principle is in use in communications systems to extinguish disturbing waves; in DF systems the directions of incidence may be determined this way. Weighting $\mathbf{W} = (W_1, W_2, \ldots , W_N)$ of the beamformer is selected hereto the way that output power becomes minimal under certain supplementary conditions.

Find more information about beamforming in relevant publications.

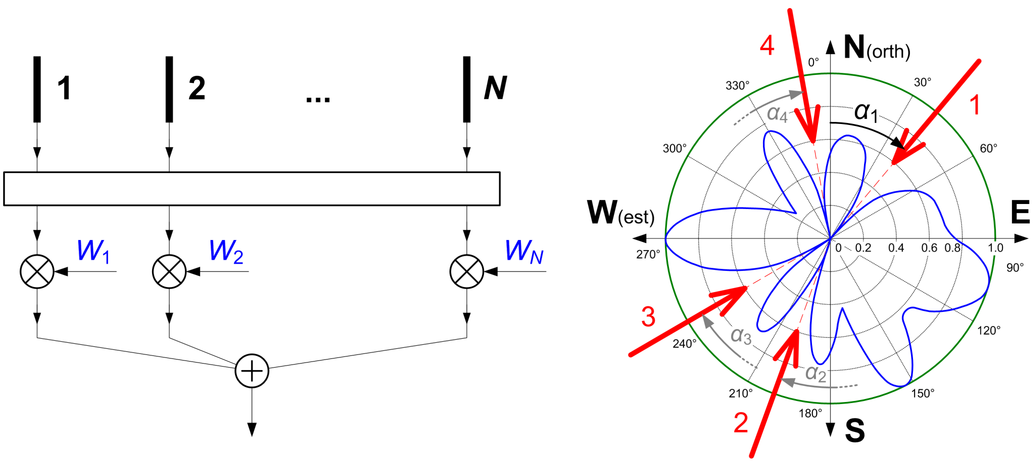


Figure 3-51: Beamforming.

left	= weighting of antenna element output levels and adding to overall antenna diagram
right	= antenna diagram obtained with M = 4 waves inciding, minima at each of the azimuth angles
1 to N	= antenna elements (N and W not to be confused with north and west direction)
W_1 to W_N	= weighting factors
1 to 4	= inciding waves: α_1 = 40°, α_2 = 200°, α_3 = 240° and α_4 = 350° in the example
α_i	= azimuth angle of wave i

3.14.3 Multiple Wave Incidence

Find the scenario with DF in case of a single wave inciding in Figure 3-52, in the example from the direction of 30° vs. north (mind that, in contrast to common mathematics, geographic angles are always determined clockwise from north). Shown are the angle of incidence, α, and the phase fronts, called isophase lines, being vertical to this direction of incidence. Amplitude level of the arriving wave is constantly 1 and shown in colors, mind the color chart besides delivering a dark red for this value. If wishing to determine the angle of incidence (the purpose of DF), the isophase lines have to be detected by the antenna (its elements not necessarily having to be placed exactly on the line itself as shown in the right part of the figure; see the antenna elements of an imaginary 9-element antenna implied in the left part) and the direction desired be derived thereof.

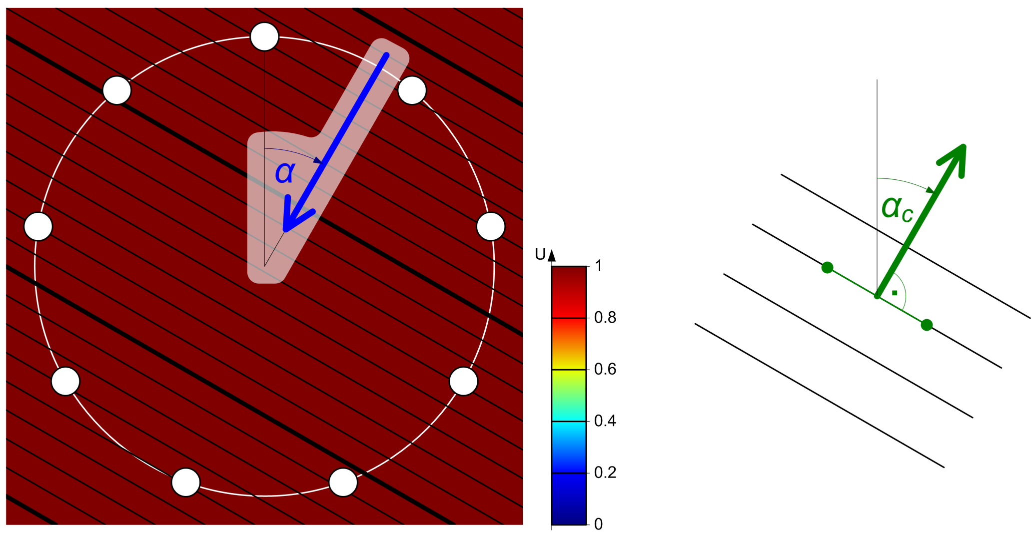


Figure 3-52: One wave inciding to circular array.

left = inciding wave (amplitude shown in color, mind color chart)
blue = azimuth direction of inciding wave: α = 30° vs. north, normalized signal amplitude 1
black = isophase lines
right = determining azimuth from isophase lines
α_c = azimuth angle calculated correctly (shown as direction to [not from] emitter)

If two waves instead of one incide in the same frequency channel as shown in Figure 3-53, one as in the first example and a second one from –60° (vertical to it) and of half its amplitude, it can be observed that the isophase lines do not form straight lines any longer, but degenerate to shapes of a character not easy to describe mathematically. The right part of the figure illustrates the attempt to determine the direction of incidence nevertheless: a considerable DF error now arises, especially in the small aperture case (antenna elements in distances to each other of less than half the wavelength); a decreasing, but not an elimination, of the DF error can be achieved by enlarging antenna aperture – what is not always desired. In addition, the amplitude of the resulting wave field is not constant any longer, but forms "strips" of wave crests and troughs running in a direction not trivial to predict.

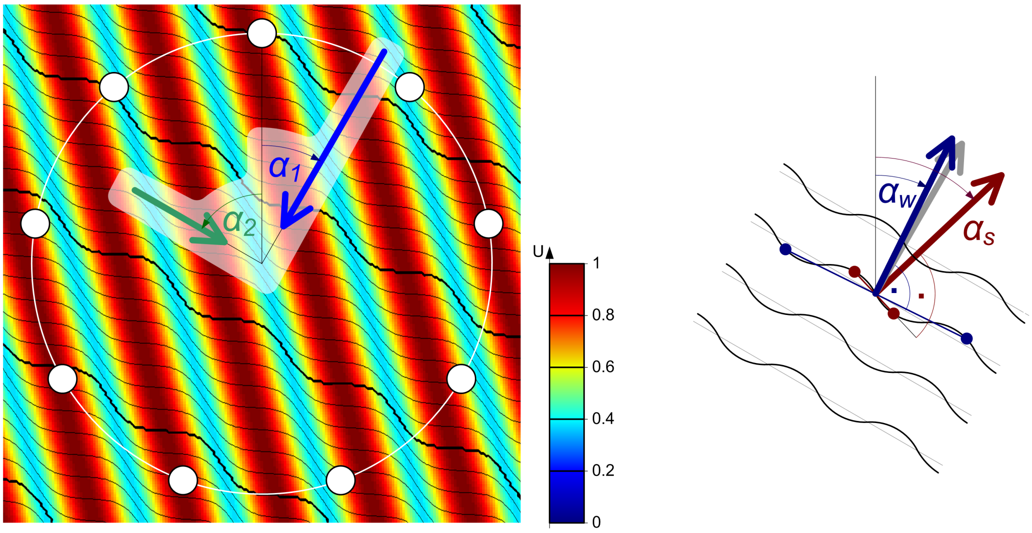


Figure 3-53: Two waves inciding to circular array.

left = inciding waves
blue = azimuth direction of inciding main wave: α_1 = 30° vs. north, normalized signal amplitude 1
green = inciding secondary wave: α_2 = –60° = 300°, amplitude 0.5
right = determining azimuth from isophase lines
red = small aperture case: largely distorted isophase line
α_s = azimuth angle calculated erroneously (large DF error due to concluding from distorted line portion)
blue = wide aperture case
α_w = angle with smaller DF error due to using larger line portion
gray = correct azimuth angle (of main wave)

As a third and last example, Figure 3-54 tells the situation of three waves inciding: the isophase lines now have a no more comprehensible shape, nor do the amplitudes of the wave field. A conclusion of the direction of incidence by means of the isophase lines is not reasonable any longer and thus no longer shown in the figure.

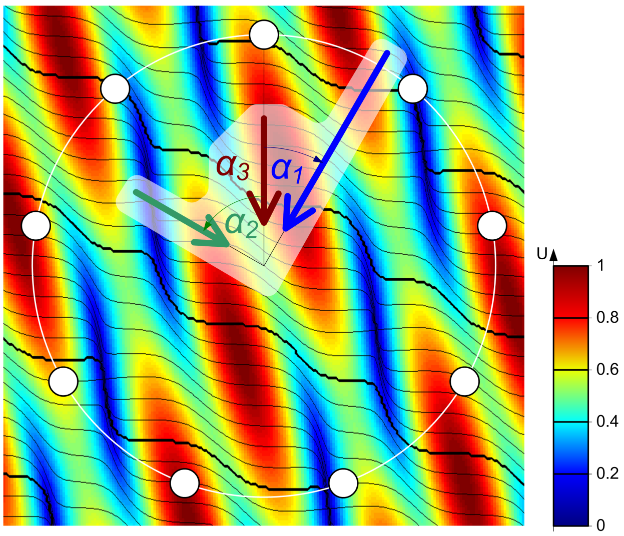


Figure 3-54: Three waves inciding to circular array.

blue = azimuth direction of inciding main wave: α_1 = 30° vs. north, normalized signal amplitude 1
green = inciding secondary wave: α_2 = –60° = 300°, amplitude 0.5
red = additional secondary wave: α_3 = 0°, amplitude 0.5

3.14.4 Theory of Super-Resolution

Purpose of Chapter

The subsequent chapter tries to give the reader an impression of the functional principle of super-resolution methods. For this purpose, an antenna with three antenna elements is assumed as an example, resulting in a vector space with just three dimensions. Consecutively, count of inciding waves described is limited to 1 (the common single wave situation) and 2 (an example multiwave scenario).

The general case to consider would be an antenna with *N* antenna elements (opening a vector space, see below, of *N* dimensions) being able to detect *M* directions of wave incidence with always

$M < N$.

In no case a completeness of whatever kind is intended, this is also the reason why formulas and equations, especially trading with elusive matrix operations, is dispensed with to the greatest extent. If interested in a more profound or detailed manner of notation, refer to relevant publications.

3.14.4.1 Antenna Geometry

Assume an antenna array of, as told above, 3 (in the general case: *N*) antenna elements, and furthermore assume a wave field created by just one inciding wave. This wave might incide under an arbitrary angle combined of the azimuth angle (commonly denoted as α) and the elevation angle (ε); the sum angle in the following will be called φ.

This situation commonly is condensed to the formula (bold letters tell vectors)

$\mathbf{x}_0(t) = s(t)\,\mathbf{a}(\varphi)$

with

$\mathbf{x}_0(t)$	measured antenna element output value,
$s(t)$	envelope of the signal: shape, i.e. amplitude, modulation,
$\mathbf{a}(\varphi)$	directional vector: containing all characteristics of the antenna elements as directional pattern (magnitude and phase), position of the individual element.

If this angle φ is being varied to "all" possible values or, in reality, to a representative number of them, φ_1 to φ_M (this might be done by theoretically calculating or also by measuring), the so-called direction vector $\mathbf{a}(\varphi)$ will describe a curve in the 3-dimensional (generally: *N*-dimensional) vector space called the group manifold (see Figure 3-55, left). You could grasp this curve as a reference function describing the "electromagnetic geometry" of the antenna array.

3.14.4.2 One Wave without Noise

A wave field caused by whatever electromagnetic excitation (more precisely: the antenna element outputs raised by this wave field) can generally be described as a point, or vector, in an *N*-dimensional (in this example: 3-dimensional) vector space moving with time (Figure 3-55, center, dark red curve). With the wave field mentioned resulting from just one inciding wave, the point will follow a straight line (light red curve).

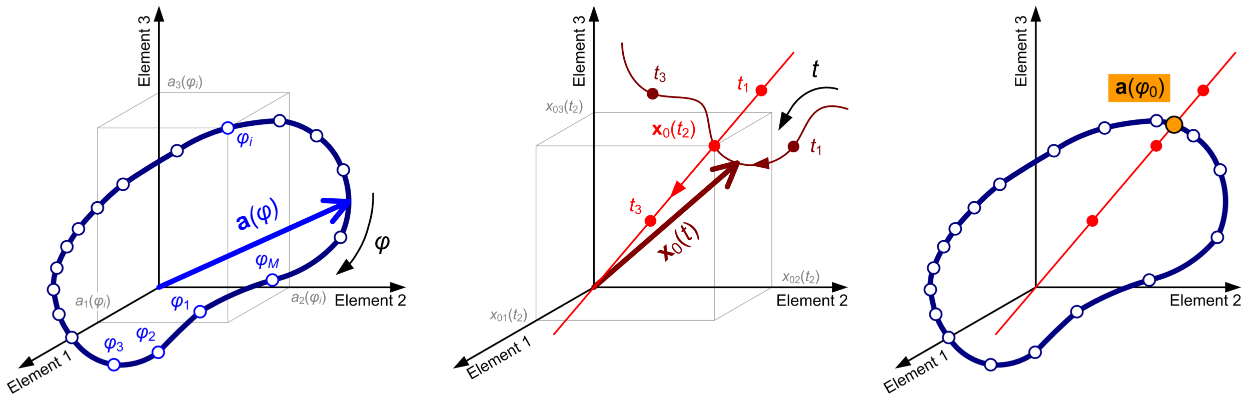


Figure 3-55: General DF task, example with 3-element antenna (N = 3, resulting in a 3-dimensional vector space) and single inciding wave (M = 1).

left	= antenna characteristics: antenna vector drawing group manifold
center	= incoming wave characteristics exciting antenna elements: signal vector drawing line over time
right	= signal vector intersects group manifold at azimuth angle wanted
light blue	= antenna vector a(φ)
dark blue	= group manifold
φ_1 to φ_M	= assumed angles to calculate or measure antenna element output
dark red	= signal vector $x_0(t)$, multiwave case
light red	= $x_0(t)$, single wave case: straight line (1-dimensional vector space)
$a(\varphi_0)$	= signal vector wanted
φ_0	= azimuth angle wanted

If thererafter a wave incides from an initially unknown direction, with the group manifold known and the antenna element outputs observed (measured), the straight line will intersect the group manifold at the angle of incidence wanted, here called φ_0 (Figure 3-55, right). The equation resulting from that is

$$\mathbf{x}_0(t) = s(t)\,\mathbf{a}(\varphi_0)$$

with

$\mathbf{x}_0(t)$	has been measured
φ_0	angle of incidence in question

3.14.4.3 Two Waves without Noise

Now the scenario is extended to a wave field induced by exactly two incoming waves that moreover are not fully correlated: with advancing time the signal vector will span a plane (i.e. 2-dimensional) in the 3-dimensional vector space, called the signal plane (Figure 3-56, left). The two wave directions in question now emerge by the two intersection points of the group manifold with this plane (Figure 3-56, right). The equation now is (cf 3.14.4.2)

$\mathbf{x}_0(t) = s_1(t)\ \mathbf{a}(\varphi_1) + s_2(t)\ \mathbf{a}(\varphi_2)$.

Again,

$\mathbf{x}_0(t)$	has been measured

and, now,

φ_1, φ_2	are the angles of incidence in question

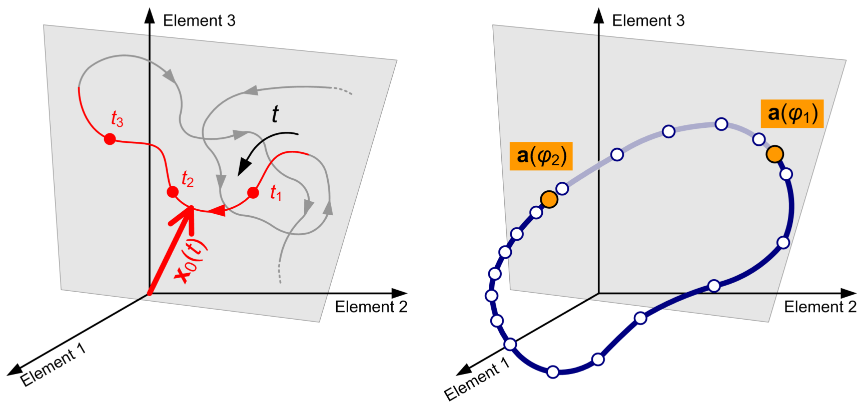


Figure 3-56: Two inciding waves (M = 2), not correlated to each other.

left = incoming wave characteristics exciting antenna elements: signal plane
right = signal plane intersects group manifold at two azimuth angles wanted
red = signal vector $x_0(t)$, two inciding waves
gray = signal plane (2-dimensional vector space) spanned by signal vector over time

3.14.4.4 Adding Noise

It could be seen so far that the count of inciding waves *M* (1 or 2 in the treated example) always was assumed less than the count of antenna elements *N* (here 3). Now be aware that additional noise always exists in communications systems, here within the Rx paths (*N* or 3 paths, respectively). Noise always is present in all paths available, in other words, if, corresponding to the signal vector, defining a noise vector, this noise vector will move in all *N* dimensions. See this scenario in Figure 3-57: the 2-dimensional signal vector already known (left) and a noise signal represented by a noise vector moving through all 3 dimensions (center).

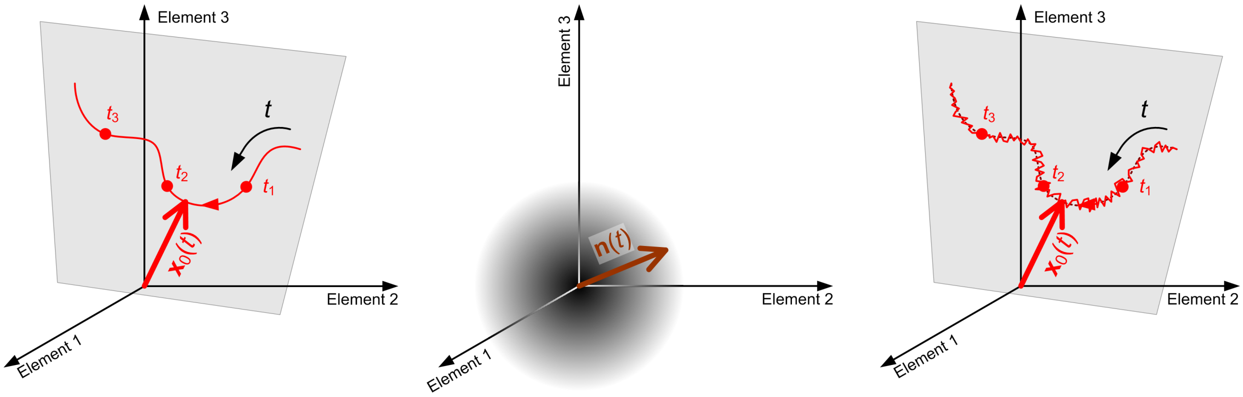


Figure 3-57: Adding noise to signal vector.

left = signal vector $x_0(t)$ moving in signal plane (2 dimensions)
center = noise vector n(t) moving in all 3 dimensions (uncorrelated noise, thus shown as a sphere)
right = signal vector with noise added leaving signal plane into 3rd dimension

Adding the noise signal to the original signal results in that (Figure 3-57, right) the signal vector data points do not remain in the 2-dimensional plane any longer, but now occupy all three dimensions available. Find the situation comprised in the equation (cf 3.14.4.2 and 3.14.4.3)

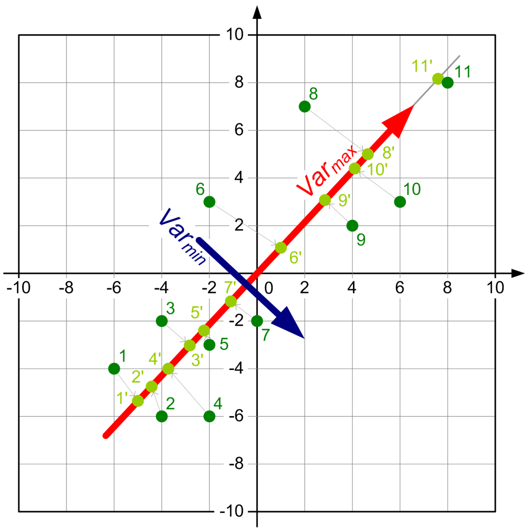
$\mathbf{x}_0(t) = s_1(t)\ \mathbf{a}(\varphi_1) + s_2(t)\ \mathbf{a}(\varphi_2) + \mathbf{n}(t)$.

Searching the directions of incidence nevertheless with the help of the points of intersection would lead to DF errors (bad or even completely wrong angle of incidence) and a limited resolution (separation of individual waves). The super-resolution methods (subspace methods) shortly explained subsequently aim to separate the noise space from the signal space, thus optimizing exactness of bearing and resolution.

3.14.4.5 Principal Component Analysis

When having sampled antenna element output values (consisting of signal and noise portions), the question arising immediately is how the signal space can be separated from the noise space. Watching Figure 3-58 it can be seen intuitively that the signal space will be opened by the vector directions in *N*-dimensional vector space that show the largest values in variance. The example in the figure assumes a now only two-dimensional antenna array (two antenna elements) with one wave inciding forming the one dimension, and the other dimension given by noise contribution. The antenna element output samples given (vector **X**) are considered to be real; also depicted is the resulting covariance matrix **R**.

It can easily be supposed that the red arrow line called Var_{max} tells the direction of the signal space and the blue one called Var_{min} of the noise space. (Remember that the spread of the samples is caused by noise influence, i.e. if no noise would be present all samples would be situated on the red arrow line itself, as shown in the figure in light green.)



Samples:

$$\mathbf{X} = \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} = \begin{array}{c} \begin{array}{ccccccccccc} 1 & & & & 5 & & & & & 10 & \end{array} \\ \begin{bmatrix} -6 & -4 & -4 & -2 & -2 & -2 & 0 & 2 & 4 & 6 & 8 \\ -4 & -6 & -2 & -6 & -3 & 3 & -2 & 7 & 2 & 3 & 8 \end{bmatrix} \end{array}$$

Covariance matrix:

$$\mathbf{R} = \begin{bmatrix} 17.2 & 15.6 \\ 15.6 & 21.8 \end{bmatrix}$$

Figure 3-58: Directions of maximal and minimal variance for example set of real samples (N = 2, M = 1).

green = samples (with noise)
light green = samples (imagined without noise)
red = (direction of) maximal variance
blue = minimal variance

In the general case the signal space occupies *M* dimensions (just 1 in the figure), whereas the noise space is regarded to fill the remaining *N*–*M* dimensions (also 1); it is orthogonal to the signal space. The directions where the variance has its extremes are called the principal axes. Signals transformed to these principal axes are always uncorrelated.

It has been shown (Karhunen-Loeve transformation) that the principal axes of a data value set are given by the eigenvectors of the covariance matrix; the variances (in the directions of the principal axes) are told by the corresponding eigenvalues.

From all told so far it can be concluded inevitably that the count of inciding waves (*M*) always has to be less than the count of antenna elements (*N*) to obtain a noise space at all.

3.14.5 MuSiC

3.14.5.1 Standard Course of Action

The MuSiC algorithm (**Mu**ltiple **Si**gnal **C**lassification, *Ralph Otto Schmidt* 1982, [3.9]) improves the approach of only using one noise eigenvector by incorporating all noise eigenvectors. This is especially useful for the case frequent in practice that the count of waves is considerably less than the count of antenna elements.

The basic idea of MuSiC arises from the fact that the directional vectors of the waves present are orthogonal to the noise subspace. It uses the quadratic mean of all projections of directional vectors onto the noise eigenvectors. Essentially, the algorithm (see also Figure 3-59) consists of the following steps:

1. Capture data
   Calculate covariance matrix
   Calculate eigenvalues and eigenvectors of covariance matrix
2. Determine count of waves by comparing size of eigenvalues (use a threshold, see 3.14.5.2)
3. Extract signal space and noise space by assigning noise eigenvalues to corresponding eigenvectors
4. Determine intersections of group manifold to signal space: angles yielded are solutions wanted
5. Calculate level and SR quality of each signal found.

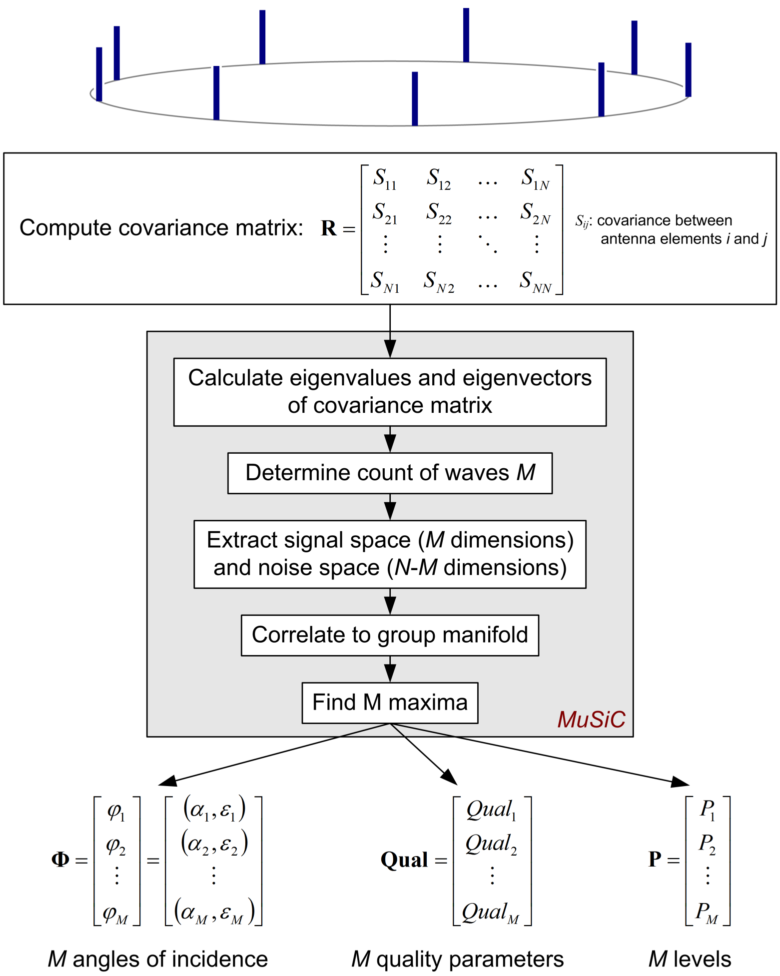


Figure 3-59: MuSiC algorithm.

3.14.5.2 Wave Estimator

General

For correct splitting up the eigenvectors gained by the principal axes transformation (cf 3.14.4.5) into both subspaces, knowledge of the count of signals present in the wave field is necessary. Commonly this count is not known a priori (so that splitting up could be done immediately), but must be estimated from the measured data.

Wave estimating takes over this task; a schematic representation is given in Figure 3-60.

The example in the figure shows a scenario of *M* = 5 waves (maximum count of waves separable by the R&S DDF5GTS) and an antenna with *N* = 9 elements, thus enabling

- a signal space with *M* = 5 dimensions (eigenvalues λ_5 to λ_9) and
- a noise space with *N*–*M* = 4 dimensions (eigenvalues λ_1 to λ_4).

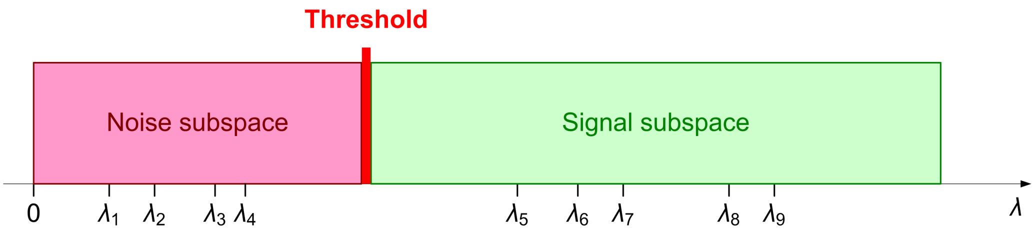


Figure 3-60: Wave estimating with MuSiC, N = 9 antenna elements, M = 5 waves estimated to be present.

λ, λ_i = eigenvalues (i = 1 to N) (not to be confused with wavelength λ)

Wave estimating can be performed automatically (Section "Automatic Estimating") or, in more difficult situations, also manually by the user (Section "Manual Estimating"). It evaluates the eigenvalue spectrum and states a separating threshold thereof for distinction between the signal space and the noise space.

Use the XML (XML) command [2.4]

- `MeasureSettingsFFM`, parameter `iSrEmitterEstimation`

to select automatic estimating:

- `MeasureSettingsFFM`: `iSrEmitterEstimation=0`

or manual estimating, at the same time announcing the count of waves found to be present:

- `MeasureSettingsFFM`: `iSrEmitterEstimation=M`

(*M* being the count of waves; *M* = 1 to 5).

For deciding whether to rely on the result of the automatic wave estimator or rather to estimate the current scenario manually, the eigenvalues themselves always are displayed to the user. Some examples for 3 waves, 2 waves and 1 wave present are given in Figure 3-61; in contrast, Figure 3-62 shows eigenvalues for no wave at all, i.e. only noise, but no signal existent.

Mind in this context that all subsequent eigenvalue diagrams (Figures 3-61 to 3-64) are intended to give an understanding of the principal method of super-resolution and MuSiC, but not necessarily are affiliated with the output format of the related trace data (Chapter 3.18.2.17, "DFPScan", on page 295). Data output comes in a linear, normalized form in ascending order of the eigenvalue size, whereas the example eigenvalue diagrams use a logarithmic scaling, also normalized to an assumed maximum value of 1 and minimum of 0 and displayed descendingly. Merely Figure 3-62 shows, for a better vividness, a logarithmic representation both normalized only to the maximum (left) and to the maximum and minimum value (right) of the noise eigenvalues.

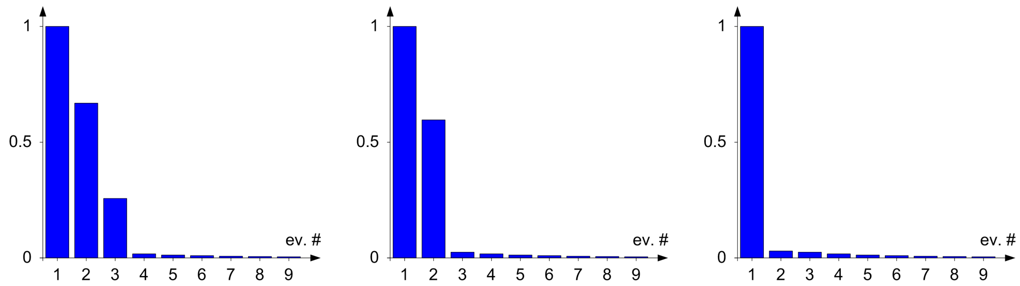


Figure 3-61: Display of the eigenvalues, different count of waves present.

left = 3 waves
center = 2 waves
right = 1 wave
ev. = eigenvalue

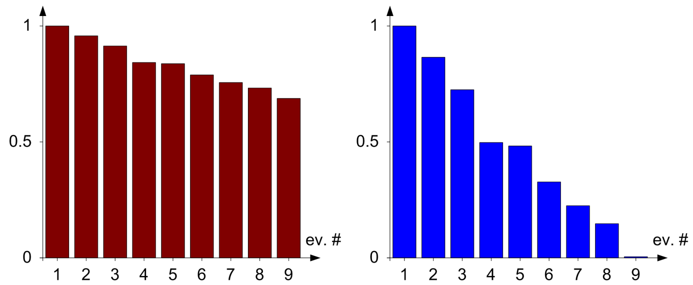


Figure 3-62: Display of the eigenvalues, no wave present (only noise found).

left = representation: logarithmic, normalized to maximum value
right = normalized to maximum and minimum value

Quality of wave estimating (SR quality) depends on the Rx scenario and is affected (among other things) by

- count of sampled measured values
- current signal-to-noise ratio
- degree of temporal and spatial correlation of the signals to each other
- diameter to wavelength ratio (d/λ) of the antenna used.

Automatic Estimating

Criteria in use for automatic estimating are (not described in detail here) AIC (Akaike Information Criterion) or MDL (Minimum Description Length Criterion). MDL is the criterion used with the R&S DDF5GTS.

In difficult situations like

- some of the signals too weak to be unambiguously separated from noise,
- too few samples available to evaluate or
- signal-to-interferer ratio of the signals involved too poor,

manual estimation (see Section "Manual Estimating") might be considered necessary. The decision has to be taken by the user by visually observing the eigenvalue situation (displayed eigenvalues). Be aware that the eigenvalues in the display always are graded by their size.

SR quality (reliability) reached by automatic wave estimation can be monitored with the *DFPScan* data trace. See Table 3-88 on page 303, item `SignalCountEstimation`.

Manual Estimating

In Figure 3-63, a scenario of 4 waves present each is shown. In the left diagram, (too) few samples have been evaluated, thus an insufficient averaging has taken place; it can be seen that the fourth (fourth largest) eigenvalue (of the signal space) cannot be distinguished from all other (belonging to the noise space). Bringing in more samples as done with the diagram on the right, this eigenvalue of the fourth wave stands out much more obvious and reveals it being originated by an additional wave rather than just by noise.

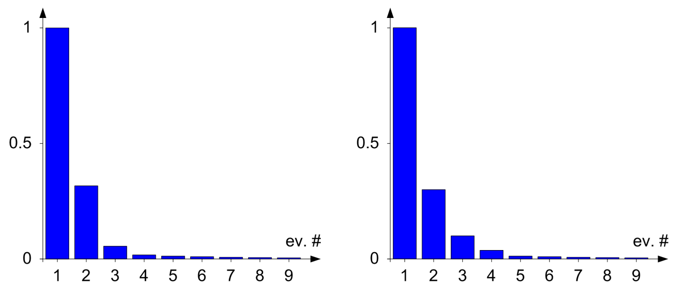


Figure 3-63: Display of the eigenvalues, 4 waves present, different count of samples.

left = few samples, insufficient averaging
right = sufficient samples and averaging

With Figure 3-64 (left), a similar situation is shown: the third and the fourth eigenvalue optically seem to feature the same size, but if investigating the numeral value it will be found that the difference is more than one decade, i.e. a manual evaluation of eigenvalues (assigning the value to the signal space rather than to the noise space) more probably will lead to success.

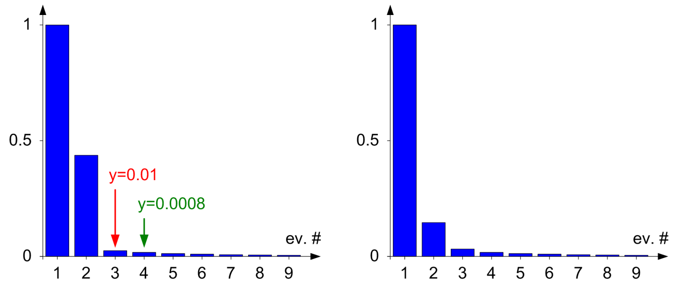


Figure 3-64: Display of the eigenvalues, difficult situations.

left = 3 waves present, 3rd too weak to recognize (4th ev. is noise)
right = 3 waves present, insufficient averaging, 3rd wave appearing doubtful

Similarly, the right diagram tells a scenario with few samples known to have been used, thus not easy to decide whether the third eigenvalue belonging to a third wave or just to noise.

Designing a robust estimating algorithm is not trivial; nevertheless it can be said:

Selectivity and resolution of the angular spectrum with MuSiC rise with the count of dimensions of the noise space. Thus, with conditions unclear, prefer to estimate the signal space too large (assign noise eigenvectors to the signal space) rather than disturbing orthogonality between the noise space and the signal space (see 3.14.4.5). In Figure 3-66 both situation of assigning an eigenvector incorrectly (noise ev. to signal space and signal ev. to noise space) are illustrated. It can easily be seen that in the right diagram not only separation of two adjacent waves fails, but also angles of incidence of signals found are wrong.

3.14.6 Performance

3.14.6.1 Operational Constraints

In addition to the constraints caused by local Rx situation itself, like adequate signal-to-noise ratio and a correctly dimensioned antenna, the mathematical principles fundamental to MuSiC involve a number of collateral marginal conditions. A good knowledge of the mathematical background of the method is essential with regard to reach objectives like

- correct estimation of the count of waves present
- high selectivity in frequency
- high resolution in angle(s) of incidence

In this way, incorrect hypotheses with the wave estimator (3.14.5.2) result in a too large or too small noise subspace, what could lead to a violation of the orthogonality condition between the noise space and the signal subspace and ultimately yield an entirely different angle spectrum.

For optimal performance, MuSiC requires that

- the antenna elements in use are uncorrelated, this is, the group manifold shows no ambiguities (collinear group)
- an uncorrelated noise process is superimposed to the antenna voltages
- data signals can be considered stationary during the observation period
- the count of data (samples) gathered to estimate the correlation matrix is sufficient
- the data signals are not completely coherent
- the noise subspace has at least one dimension
- the count of signals present in the Rx wave field could be estimated with sufficient precision.

Find some sketches of performance of MuSiC in Figure 3-65, also depicted are results obtained by conventional beamforming.

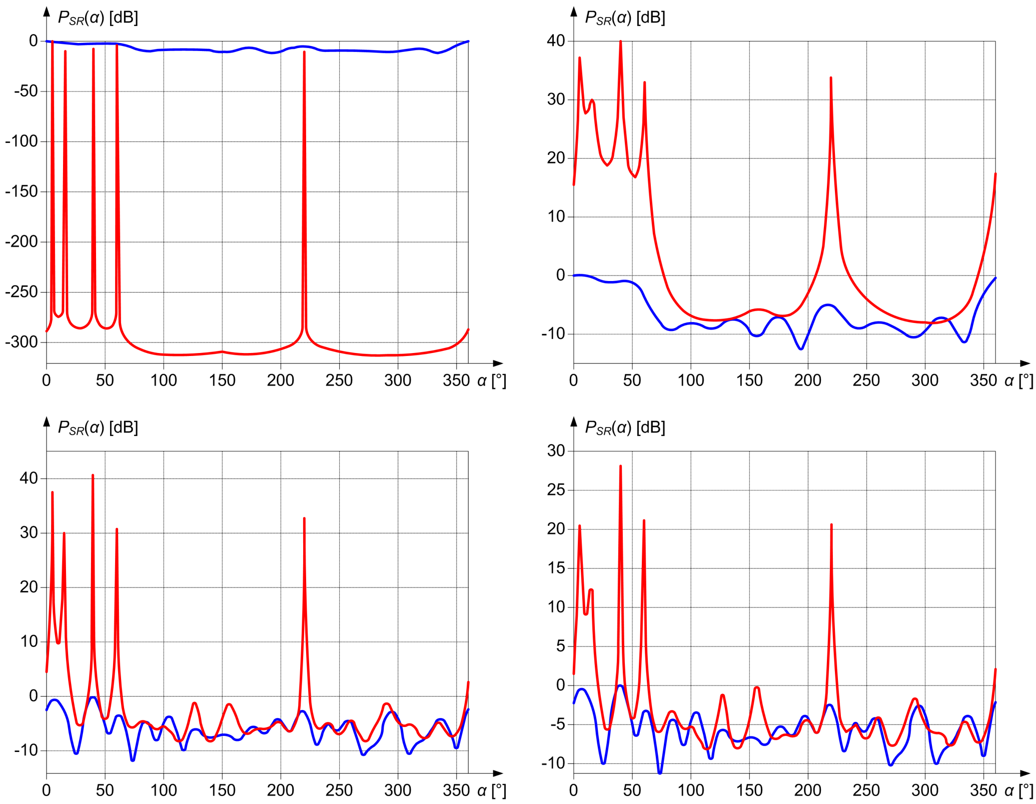


Figure 3-65: Performance of MuSiC algorithm, N = 9 antenna elements, M = 5 waves.

red	= MuSiC
blue	= conventional beamforming
$P_{SR}(\alpha)$	= super-resolution pseudospectrum
Wave 1	= α_1 = 5°, s_1 = 1
Wave 2	= α_2 = 15°, s_2 = 0.8
Wave 3	= α_3 = 40°, s_3 = 1
Wave 4	= α_4 = 60°, s_4 = 0.7
Wave 5	= α_5 = 220°, s_5 = 0.5
top left	= d/λ = 1.4, SNR = 20 dB, covariance matrix known exactly

top right = covariance matrix estimated
bottom left = d/λ = 3.0
bottom right = SNR = 10 dB

3.14.6.2 Possible Parameterization Errors

As told above, when selecting manual eigenvalue estimating, a diligent configuring of the input parameters is indispensable in order not to obtain incorrect results. The most frequent mistakes to make are

- to observe the signal not long enough, i.e. to evaluate too few samples
- to assign eigenvectors found to the wrong subspace (signal or noise)

If in doubt whether to assign an eigenvector to signal space or noise space, prefer to consider it a signal eigenvector. Both variants of wrong or more specifically doubtful assigning an eigenvector are told in Figure 3-66; it is evident that the results displayed in the right diagram do not show what is present in reality.

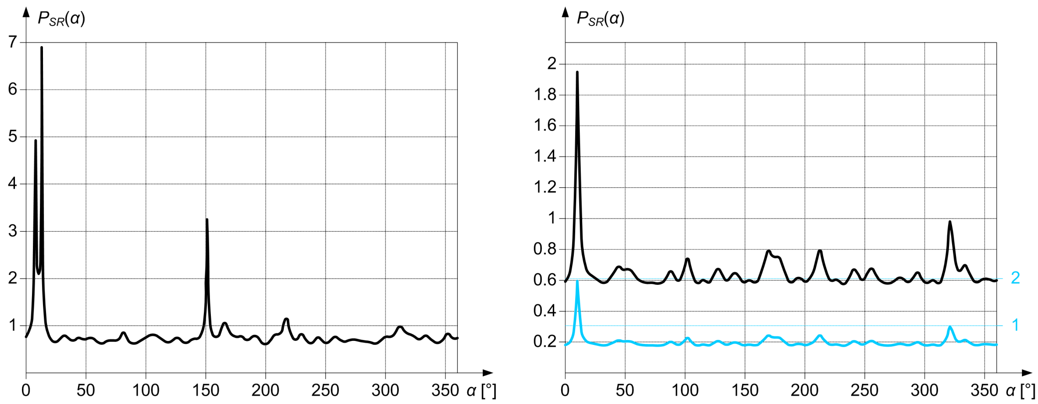


Figure 3-66: Manual estimation of eigenvalues, doubtful assigning an eigenvector.

left = noise eigenvector incorrectly assigned to signal space
right = signal eigenvector incorrectly assigned to noise space
light blue = same curve, adapted to scale of left diagram
Wave 1 = α_1 = 7°, s_1 = 0 dBm
Wave 2 = α_2 = 12°, s_2 = 0 dBm
Wave 3 = α_3 = 150°, s_3 = –10 dBm
Wave 4 = α_4 = 220°, s_4 = –16 dBm

If including too few samples, the results obtained are not entirely wrong, but precision will decrease dramatically. Find two examples for that situation in Figure 3-67, the one for an SNR of 0 dB, the other one for 10 dB. It can be seen that (①) resolution in angles is not satisfactory (signals from angles lying close together cannot be separated), other angles (②) are determined with too poor precision or, due to the related signal peak not ascending clearly enough, a signal (③) might be not identified at all.

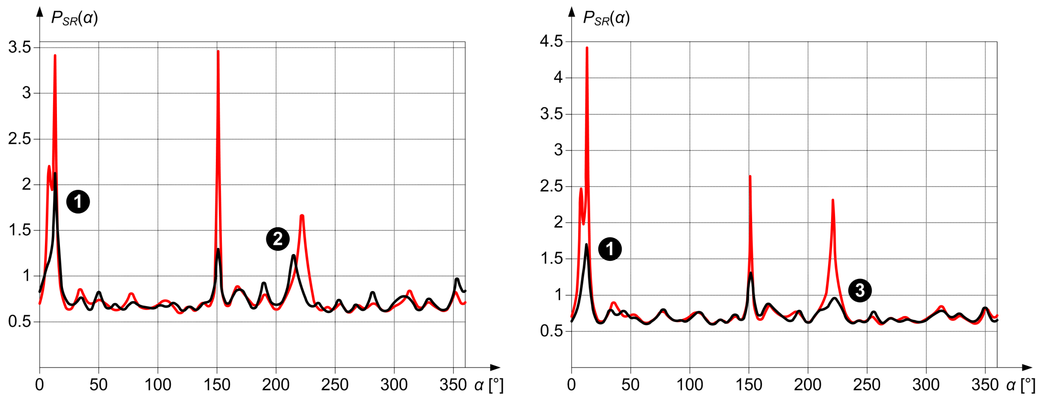


Figure 3-67: Manual estimation of eigenvalues, different count of samples.

left = SNR 0 dB
right = SNR 10 dB
red = sufficient count of samples
black = too few samples

3.14.7 Super-Resolution in the R&S DDF5GTS

This section summarizes all features of the super-resolution functionality in the R&S DDF5GTS.

- Wideband super-resolution: query the count of possible frequency channels in parallel by the XML command
  - `DeviceInfo`: `eDEVICE_INFO=DEV_INFO_SR_CHANNELCOUNT_MIN_MAX`
- Maximal throughput 1000 channels/s
- Maximum count of waves separable: 5 waves with an antenna having 8 elements or more (as are many *Rohde & Schwarz* DF antennas, see Chapter 2.4.2, "Antenna Types", on page 38)
- Wave estimator alternatively automatic or manual
- Regular display of eigenvalues to facilitate verification or even manual correction of values found automatically

You activate the super-resolution DF method by the XML command

- `MeasureSettingsFFM`: `eDfAlt=DFALT_SUPERRESOLUTION`

As told with 3.14.6.2, always be aware to cover a sufficient amount of samples, this is, to specify a long enough averaging period. The R&S DDF5GTS will set an appropriate period automatically if the period currently specified has been selected too short. Thus, if having altered channel spacing or realtime bandwidth, always pay attention to the averaging period to have been specified correctly.

Super-resolution can only be operated in Continuous Mode (see Chapter 3.11.4, "Averaging Modes", on page 168); Normal Mode and Gated Mode cannot be selected.

Find more information on operating the super-resolution method in the user manual of the R&S DDF-CTL, *DDF-Control* [3.12].

3.15 Selective Calling

Option

The functionality **Selective Calling** is only available if the option

- R&S DDFGTS-IM, *ITU Measurement Software*,

is installed.

3.15.1 General

Selective calling is used to address a subset of radios operating on the same channel. In principle, depending on method, both a single station or a group of stations can be called by a special code word/number. All stations decode the code word received but only those that are set to respond to the transmitted tone sequence will open their squelch, while others will remain muted.

The methods the R&S DDF5GTS is able to detect can be split up into four groups:

- **Five-tone methods**, also known as SELCAL-5T: A sequence of 5 tones selected from a tone table containing up to 16 tones is emitted in the normal audio band prior to the actual message. Most of the methods covered by the R&S DDF5GTS belong to this type; the differences are mainly with tone frequency and tone duration.
- **Touch-tone**: On push-button telephones, dialing is done in a so-called multifrequency manner, i.e. when a key is pressed, 2 tones out of a table of 8 tones are sent to select the partner station.
- **Continuous Tone**: The transmitter emits a continuous tone together with the message (i.e. the tone is present during the whole message). The tone frequency lies below the band where messaging (e.g. speaking) itself is done. Only receivers that state agreement with their own tone frequency (the frequency they have been programmed to in advance) open their squelch.
- **Digital Coded Squelch**: Not an analog tone as with Continuous Tone, but a continuous digital code number is emitted to select the receiver to address. Again, the frequency to transmit this signal is below the used band.

In Table 3-31, the methods recognizable by the R&S DDF5GTS are listed and attributed to these categories.

Table 3-31: SelCal methods.

SelCal methods		
Method	**Explanation of name**	**Type**
CCIR1	**C**omité **C**onsultatif **I**nternational des **R**adiocommunications (International Consultative Committee on Radio)	Five-tone
CCIR7 (same as CCIR2)	**C**omité **C**onsultatif **I**nternational des **R**adiocommunications (International Consultative Committee on Radio)	Five-tone

SelCal methods		
Method	**Explanation of name**	**Type**
CCITT	**C**omité **C**onsultatif **I**nternational **T**éléphonique et **T**élégraphique (International Telegraph and Telephone Consultative Committee)	
EEA	**E**lectronic **E**ngineering **A**ssociation (United Kingdom)	
EIA	**E**lectronics **I**ndustries **A**ssociation (United States)	
EURO	**EURO**signal, six-tone sequential high power AM paging for CEPT countries (**C**onférence **E**uropéenne des Administrations des **P**ostes et des **T**élécommuni-cations / European Conference of Postal and Telecommunications Administrations)	
NATEL	Scandinavian **NA**tional **TEL**ephone	
VDEW	German institution "**V**ereinigung **D**eutscher **E**lektrizitäts**W**erke e.V." (Union of German Power Companies)	
ZVEI1	German institution "**Z**entral**V**erband **E**lektrotechnik und Elektronik**I**ndustrie e.V." (Central Association of Electrical and Electronic Industries)	
ZVEI2		
DTMF	**D**ual-**T**one **M**ulti-**F**requency Signaling	Touch-tone
CTCSS	**C**ontinuous **T**one **C**oded **S**ubaudio **S**quelch or **C**ontinuous **T**one **C**oded **S**quelch **S**ystem	Continuous Tone
DCS (or DCSS)	**D**igital **C**oded **S**quelch (or **D**igitally **C**oded **S**quelch **S**ignaling)	Digital Coded Squelch

3.15.2 Five-Tone Methods (SelCal-5T)

SelCal (selective calling) is used in radio communications systems to select (address) particular receivers by emitting a number code representing the specific address of the desired receiver. An activated (selected) receiver will then open its squelch and thus make audible the following announcements; other receivers will remain muted.

SelCal is an analog system, i.e. the address codes consisting of 5 digits (6 with EURO method) are represented by a sequence of five tones (the SelCal code). These tones are taken from a pool (tone set) of up to 16 tone frequencies so that 16 digits can be reproduced, commonly digits 0 to 9 form the address itself, whereas the 6 "hexadecimal" extensions A to F are used for signaling purposes. The tone frequencies are audio tones (in the audible frequency range), their duration depends on the standard chosen, but the most common tone duration is 70 ms. The number encoded in a SelCal burst is used to address one or also more receivers.

Since a receiver normally merely decides the tone frequency of each individual tone, but cannot detect the tone duration, two consecutive tones of the same frequency (in case of a repeated digit in the original code) are to be avoided. A repeat digit is established instead: the second appearance of a digit will not be given by the tone of the digit, but by the repeat tone (but the third again by the digit tone), so that, for example, a "12334" sequence would be converted to "123R4" ("R" being the repeat tone), or a "12222" sequence to "12R2R".

Disadvantages of analog signaling are the long time consumed by a single signaling (alarming) process (several seconds, followed by the voice message itself, and even more if the signaling is to be repeated for security) and the lack of any protection against tapping or even generation of malicious false alarms.

Some common SelCal standards are shown in Table 3-32.

Table 3-32: Tone frequencies and timing for some common SelCal methods.

Tone frequencies and timing										
	Tone frequency [Hz]									
	ZVEI		**CCIR**							
Digit	**-1**	**-2**	**-1**	**-7 (2)**	**VDEW**	**CCITT**	**EEA**	**EIA**	**EURO[2]***	**NATEL**
0	2400	2200	1981		2280	400	1981	600	979.8	1633
1	1060	970	1124		370	697	1124	741	903.1	631
2	1160	1060	1197		450	770	1197	882	832.5	697
3	1270	1160	1275		550	852	1275	1023	767.4	770
4	1400	1270	1358		675	941	1358	1164	707.4	852
5	1530	1400	1446		825	1209	1446	1305	652.0	941
6	1670	1530	1540		1010	1335	1540	1446	601.0	1040
7	1830	1670	1640		1240	1477	1640	1587	554.0	1209
8	2000	1830	1747		1520	1633	1747	1728	510.7	1336
9	2200	2000	1860		1860	1800	1860	1869	470.8	1477
A	2800[1]*	2600[1]*	2400[1]*		2000[1]*	1900	1055[1]*	2151	1062.9	1633
B	810	2800	930		2100	2000	930	2433		600
C	970	810	2247		2200	2100	2247	2010[1]*		1995[1]*
D	885	885	991		2300	2200	991	2292		2205
E	2600	2400	2110		2400	2300	2110	459		1805
F							2400			
Tone duration [ms]	70		100	70	100	100	40	33	100	70

1) *Repeat tone.*

2) *Tone sequence of 6 tones.*

3.15.3 Touch-Tone

DTMF (Dual-Tone Multi-Frequency Signaling) is used for push-button telephone tone dialing. The intention to use phones to access computers led to the addition of

- the number sign (**#**) key and

- the asterisk or "star" (*) key as well as
- a group of keys for menu selection: **A**, **B**, **C** and **D**.

(Today the lettered keys were dropped from most phones, and it was many years before these keys became widely used for VSCs [**V**ertical **S**ervice **C**odes] – such as "*67" in the U.S. and Canada to suppress caller ID.) For this reason, the DTMF keypad is laid out in a 4×4 matrix, with each row representing a low frequency, and each column representing a high frequency (Table 3-33). Pressing a single key (e.g. **1**) will send a sinusoidal tone for each of the two frequencies (e.g. 697 Hz and 1209 Hz). The original keypads had levers inside, so each button activated two contacts. The multiple tones are the reason for calling the system multifrequency. These tones are then decoded by the switching center to determine which key was pressed.

Table 3-33: Keypad frequencies.

Keypad frequencies				
	1209 Hz	**1336 Hz**	**1477 Hz**	**1633 Hz**
697 Hz	1	2	3	A
770 Hz	4	5	6	B
852 Hz	7	8	9	C
941 Hz	*	0	#	D

3.15.4 Continuous Tone

In CTCSS (Continuous Tone Coded Subaudio Squelch / Continuous Tone Coded Squelch System), together with the message and thus lasting as long as the message itself a control tone is conveyed. These tones have their frequency at the lower end of the audible frequency spectrum, i.e. standard radio receivers suppress such deep tones; they normally sound only a frequency range between 300 Hz and 3 kHz (speech frequency). In Table 3-34 the frequency values are shown; most of them are standardized by the EIA (Electronics Industries Alliance, until 1997 Electronics Industries Association, in the U.S.) / TIA (Telecommunications Industry Association). In a given area, only frequencies from one of the groups should be used. Frequency values correlate to each other in a way that no CTCSS frequency can arise from two others. For more detailed information, consult the EIA Standard RS-220-A.

Table 3-34: CTCSS frequencies [Hz].

CTCSS frequencies									
Group A									
67.0	77.0	88.5	100.0	107.2	114.8	123.0	131.8	141.3	151.4
162.2	173.8	186.2	203.5	218.1	233.6	250.3			
Group B									
71.9	82.5	94.8	103.5	110.9	118.8	127.3	136.5	146.2	156.7
167.9	179.9	192.8	210.7	225.7	241.8				
Group C									

CTCSS frequencies									
74.4	79.7	85.4	91.5						
Not standardized by EIA/TIA									
69.3	97.4	159.8	165.5	171.3	177.3	183.5	189.9	196.6	199.5
206.5	229.1	254.1							

With CTCSS, a single frequency channel can be shared by several users; but operation is limited to the Rx end of the transmission path. Receivers for whom the message is not intended can be excluded from obtaining it in order not to be disturbed by unwanted messages. More precisely: a receiver, by activating CTCSS, excludes itself, thus, if not equipped with CTCSS or if having it switched off, it hears all messages running on the channel.

Protection of whatever kind against tapping is not provided this way (message encryption is not part of the method).

Additionally, if currently excluded from a special channel by CTCSS, no conclusion, however, can be drawn whether this channel is occupied at the moment or not. Therefore, a separate indicator is needed for that; if activity on the channel is told to take place, no other transmission is permitted on it.

Be aware that, with individual manufacturers of radio equipment, deviating denominations may exist.

Due to the fact that no special (digital) address codes are defined, the R&S DDF5GTS issues the frequency values themselves (in 1/10 Hz, i.e. 10 times the frequency).

3.15.5 Digital Coded Squelch

The functional principle of DCS (Digital Coded Squelch) is similar (or equal) to CTCSS (3.15.4, "Continuous Tone"), but realization is completely different.

Instead of the analog continuous tone as with CTCSS, here a continuous digital code stream is transmitted with the message. The codes commonly in use are listed in Table 3-35; deviations due to individual manufacturers may occur.

Table 3-35: DCS codes.

DCS codes														
023	025	026	031	032	036	043	047	051	053	054	065	071	072	073
074	114	115	116	122	125	131	132	134	143	156	145	152	155	162
165	172	174	205	212	223	225	226	243	244	252	245	246	251	255
261	263	265	266	271	274	306	311	315	325	346	331	332	343	351
356	364	365	371	411	412	413	423	431	432	454	445	446	452	455
462	464	465	466	503	506	516	523	526	532	546	565	606	612	624
627	631	632	654	662	664	703	712	723	731	754	732	734	743	

The code stream to transmit is composed as follows:

- The original DCS code is interpreted as an octal value (in none of the codes the digits "8" and "9" exist), the corresponding dual code (9 bit) is formed.
- The 9-bit code is reversed (LSB first).
- The fixed bit sequence 0 0 1 is appended, yielding a total of 12 bits.
- A Golay (23,12) coding is applied, its 11 check bits result in an overall code word length of 23.

The structure together with an example is shown in Table 3-36.

Table 3-36: DCS code word structure and example.

	1 … 9	10 … 12	13 … 23
Structure	9 data bits	3 fixed bits	11 check bits
Example	156 (bit-reversed)	always	Golay code
	0 1 1 1 0 1 1 0 0	0 0 1	X X X X X X X X X X X

The code stream itself (uninterupted repetition of the 23-bit word) at a fixed rate of 134.4 bit/s is added to the message to be transmitted. The lowest frequency arising depends on the number of contiguous same-value bits in the stream. The maximum number of 6 for that emerges with codes 023 to 036 and leads to a lowest-frequency value of 11.17 Hz.

Again, individual manufacturers of radio equipment may use deviating denominations.

For further details about DCS, consult the standard MPT 1381 of the Ministry of Postal service and Telecommunications (UK). Golay coding will be explained in relevant publications.

3.16 Signal Analysis

Conditions

All signal analysis features only operate if

- the R&S DDF5GTS is in the DF mode (Chapter 3.7 on page 132)
  - Rx
    (XML (XML) command [2.4] `DfMode: eOperationMode=DFMODE_RX`) or
  - FFM
    (`eOperationMode=DFMODE_FFM`)
  - Scan (only Short-Time Signal Analysis, cf 3.16.2)
    (`eOperationMode=DFMODE_SCAN`)
- the signal to analyze is provided to the "***DF1***" connectors, i.e. **X11**, **X21** or **X31** (depending on the selected frequency range); find more information in Chapter 3.4, "Rear Panel Elements R&S EHT770", on page 107

Nomenclature

- In this Chapter 3.16, the terms **short-time** and **short-time signal** (analysis, detector, synthesizer) are often abbreviated as **ST**.

3.16.1 DDC Signal Extraction

Option

The functionality **DDC Signal Extraction** is only available if the option

- R&S DDFGTSDDCE, *DDC Signal Extraction*

is installed.

With DDC signal extraction, the R&S DDF5GTS becomes a multi-channel receiver. The basic Rx channel is extended by 128 additional Rx channels, realized by DDCs (digital downconverters) the center frequencies of which can be directed anywhere all over the IF span currently set and the bandwidths selected individually, both independently of each other channel.

The maximum bandwidth each channel can be configured to is 300 kHz; the main Rx IF signal span must be configured to at least 100 kHz. Find minimum and maximum bandwidth values that can be selected for each span together with the sample rate of the IF signal in Table 3-37.

Table 3-37: DDC output bandwidths (minimum and maximum), sample rate of IF signal and permitted maximum delay time for each IF span.

DDC data											
Span [MHz[1)]*]		**80**	**40**	**20**	**10**	**5**	**2**	**1**	**500 k**	**200 k**	**100 k**
Bandwidth	**min. [Hz]**	100									
	max. [kHz]	300								150	50
Sample rate [MHz[1)]*]		102.4	51.2	25.6	12.8	6.4	3.2	1.6	800 k	400 k	200 k
Delay time	**[s]**	8	16	32		64	128	256	512	1024	2048
	[min:s]	0:08	0:16	0:32		1:04	2:08	4:16	8:32	17:04	34:08

[1)] *Unless noted otherwise ("k" for kHz).*

When DDC signal extraction is activated, the original IF signal, prior to extraction, can be delayed by a configurable latency, i.e. the IF is written to a buffer memory and extraction of signals is done on the stored data. This approach allows a combined workflow of having detected signals in the current IF spectrum of the receiver by the *Short-Time Detector* and setting up DDCs to examine them in more detail with the *Short-Time Synthesizer* (3.16.2). The DDC result output will, due to this delay of the IF signal, contain the exact moment of detections. Find permitted delay times in Table 3-37, too.

Each DDC delivers I/Q data with additional information such as sample rate, center frequency, timestamp, level etc. Output is performed as mass data at the LAN interface; the I/Q data of all activated DDCs is multiplexed into one data trace: the *AMMOS IF DDCE* trace (Chapter 3.18.3.3 on page 320). You can choose between two bit resolutions (32 bit and 16 bit) for the result I/Q data samples of all DDC channels; bandwidth on LAN interfaces is saved if using a lower bit resolution, but also the dynamic range of the output data will be worse. A partial compensation of this drawback can be achieved by activating block rescaling (gain control mechanism to better exploit the available bits) by the XML command:

- `DDCEControl: eGainControl`

An individual DDC can exist at a fixed frequency independent of the R&S DDF5GTS Rx frequency or be coupled to it (maintain a constant distance to it), i.e. this determines whether the DDC frequency follows the Rx frequency when tuning is altered, or not. Mind in any case that a DDC ceases delivering data if its frequency temporarily gets outside of the frequency span selected, but resumes output when returning inside.

The sample rate that data is output with for each bandwidth configured is shown in Tables 3-38/3-39.

Table 3-38: Bandwidth and sample rate of IF data (part 1).

Bandwidth [kHz[1)]*]	100 Hz	150 Hz	300 Hz	600 Hz	1	1.5	2.1	2.4	2.7	3.1	4
Sample rate [kHz[1)]*]	781.25 Hz				1.5625		3.125		6.25		

Table 3-39: Bandwidth and sample rate of IF data (part 2).

Bandwidth [kHz]	4.8	6	9	12	15	30	50	120	150	250	300
Sample rate [kHz]	6.25	12.5		25		50	100	200		400	

1) *Unless noted otherwise.*

Mind that R&S DDFGTSDDCE offers no ability to demodulate DDC channels inside the R&S DDF5GTS. Instead these channels are destined for operators doing further processing outside of the R&S DDF5GTS, such as with the R&S CA120 (Multichannel Signal Analysis Software) [3.11].

Configuration of an individual DDC instance is performed by the XML command

- `DDCEConfig`

whereas configurations for all DDCs in total are accomplished by the command

- `DDCEControl`

3.16.2 Short-Time Signals

3.16.2.1 General

Nomenclature

In signal-analysis contexts, an individual appearance of a short-time signal is often denoted as **hop**. Mind that this expression in scanning DF means something different: the dwell time of the DF receiver on a special Rx frequency (see Chapter 3.11.7, "Hop-wise and Sweepwise Averaging", on page 176). Appearances of signals all over this manual, but especially in this Chapter 3.16.2, are called **emission**.

Short-time signals (signals that appear only for a relatively short time, especially not in a persistent manner, frequently also called bursts) are commonly invisible to traditional modes of monitoring and therefore impossible to be analyzed or even detected. Figure 3-68 shows this situation in a symbolic representation:

- The immediate (unaveraged) *spectral* reproduction of the selected frequency span (**top** in the figure) shows only noise, sometimes short signals "flash", not offering the opportunity to be fixed and then investigated. Only two continuous signals are able to exceed the level threshold and thus also appear in the spectrum.
- In the *"waterfall"* diagram (**bottom**, left), i.e. the spectrogram telling the history of the spectrum over time, several runs of the spectrum are averaged to result in one waterfall line, so that such signals can be found with their spectral location (f_x) and width (i.e. bandwidth: f_{st}), their location (start time t_x) and duration (t_D) in time and their mean level; the spectral and time properties can be seen directly (enlargement at **bottom**, right) whereas the level is paraphrased by a color chart (not

shown in detail in this example figure). Expectedly, the continuous signals can be discerned as vertical lines (or bars).

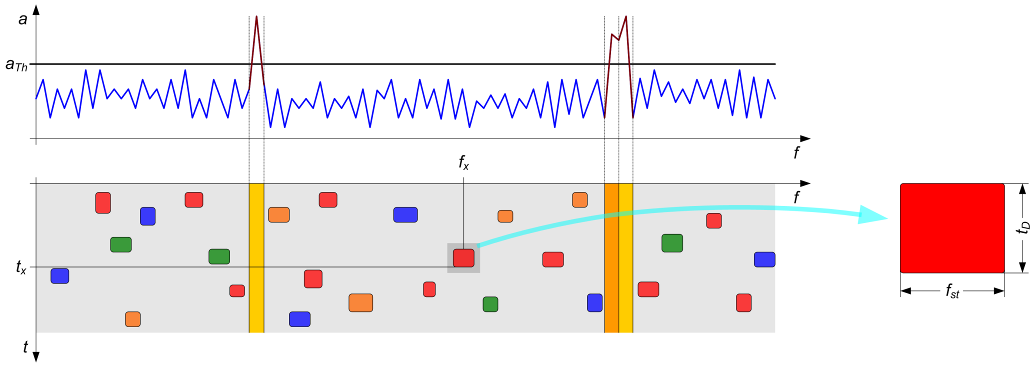


Figure 3-68: Short-time signals in spectrum.

top	= monitored spectrum: no visible signals in putative noise (shown in blue) due to short duration of appearance, except continuous signals (shown in red)
a_{Th}	= level threshold for detection
bottom	= waterfall display (color of signal describing signal level)
rectangular spots	= appearances (mind Note "Nomenclature") of non-continuous signals
vertical bars	= continuous signals
t_x, f_x	= start time and spectral location of signal in question
f_{st}	= spectral step size
t_D	= duration of signal

If a more detailed analysis of such signals is desired, the complete Rx signal interesting (i.e. time and spectral section to investigate, also called a *snapshot*) has primarily to be stored, then the signals in question detected by the *Short-Time Signal Detector* (3.16.2.3) and lastly the detected time and spectral sections recalled from the stored data (to make them available to a further analysis). This latter step is performed by the *Short-Time Signal Synthesizer* (3.16.2.4): it uses DDC instances to cut out the corresponding I/Q-samples. Relating the selected short-time signals to the extracted data samples is done via a special ID called *Burst Emission ID*; find more information about that in Chapter 3.18.3.3, "AMMOS IF DDCE", on page 320 and Chapter 3.18.3.4, "AMMOS Burst Emission List", on page 324.

Be aware that in advance an appropriate setting of the signal threshold is to be done to avoid including mere noise signals into consideration.

The actual analysis of the extracted data is not performed by the R&S DDF5GTS, but exclusively by external applications, e.g. the R&S CA120 (Multichannel Signal Analysis Software) [3.11].

3.16.2.2 Mapping of DF Bins to ST Bins

Segmentation (mapping) of a hop within a scan range to usable channels (bins) for DF in essence is independent of segmentation for ST. With symmetric hops (odd count of channels, the common case) however the center frequency of the hop always coincides with the Rx frequency, whereas with asymmetric hops (even count, the rare case) the Rx frequency is shifted against the center of the hop by half a DF channel. Find information on segmentation for DF in Chapter 3.7.6.2, "Converting Scan Ranges to Hop Lists", on page 145, notably on differing between symmetric and asymmetric hops.

Two numerical examples for the symmetric case can be found in Figure 3-69: on the left, the case is depicted for 7, on the right for 9 usable DF channels. Covering of the hop by ST bins has always to be complete, but the count to expend depends on their width, hence in both cases the count might be equal or different. Thus the frequency range covered for ST analysis may be slightly wider than the nominal width of the hop; maximum enlargement is one ST bin on either side.

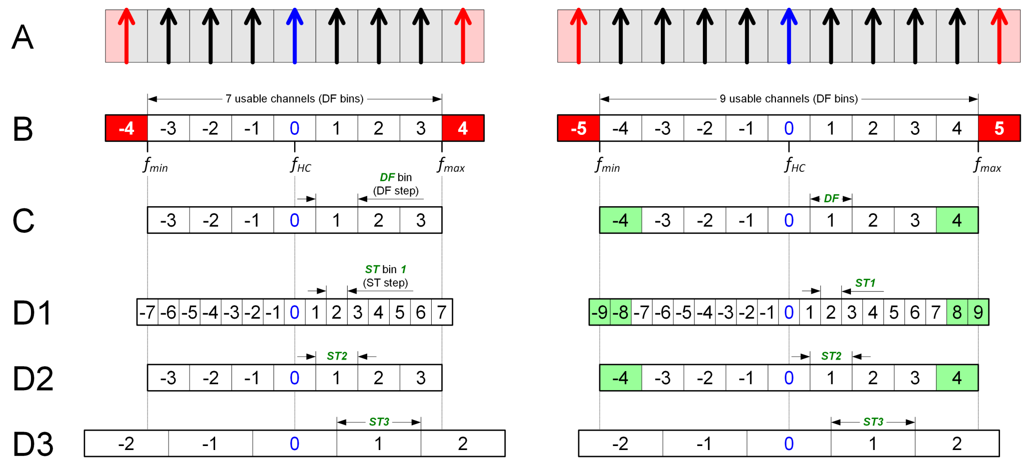


Figure 3-69: Mapping of symmetric hop (common case).

left = 7 (usable) DF channels: –3 to 3
right = 9 DF channels: –4 to 4
A = frequency bins of FFT applied
B = usable and unusable channels (white: usable, red: unusable)
f_{min}, f_{max} = lower and upper frequency border of hop
f_{HC} = center frequency of hop
C = resulting (usable) channels for DF
D = channels to monitor for ST analysis
D1 = ST bin half as large as DF bin: ST1 = DF/2
D2 = ST bin as large as DF bin: ST2 = DF
D3 = ST bin twice as large as DF bin: ST3 = 2 * DF
green = ST bins additionally needed for complete coverage

Two scenarios for the far more rare asymmetric case are shown in Figure 3-70: on the left for 6, on the right for 8 usable DF channels. Shift of the central channel can easily be seen, but also that, due to covering by ST bins needed, again a symmetric situation may emerge.

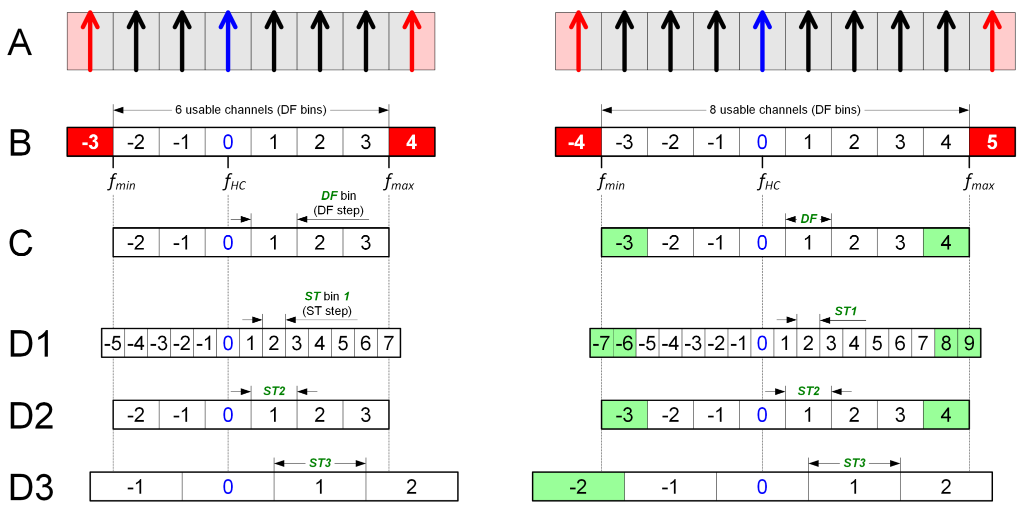


Figure 3-70: Mapping of asymmetric hop (exceptional case).

left = 6 (usable) DF channels: –2 to 3
right = 8 DF channels: –3 to 4
all other explanations = see Figure 3-69

3.16.2.3 Short-Time Signal Detector

Option

The functionality **Short-Time Signal Detector** is only available if the option

- R&S DDFGTS-ST, *Detection of Short-Time Signals*

is installed.

Motivation

The *Short-Time Signal Detector* (ST Detector) analyzes the spectrum for short-time signals (cf 3.16.2.1). For each detected signal the ST Detector determines the signal start time, duration, center frequency (frequency offset towards "snapshot" center frequency) and level (average power). The bandwidth is only estimated coarsely, i.e. the value issued in the data stream is the spectral width of the snapshot itself, and modulation analysis is currently not supported (fields in the data stream, see below, will be 0).

Output is done via the *AMMOS Burst Emission List* data stream (trace), cf Chapter 3.18.3.4, the trace tag in use is *STDet* (see Table 3-54 on page 258). The ST Detector works in a gap-free manner, that is, if correctly configured no signals will get lost.

Spectral Considerations

The Rx signal spans of the R&S DDF5GTS that can be set are queried by the XML command

- `DeviceInfo: eDEVICE_INFO=DEV_INFO_ST_SPAN_LIST` and, together with the permitted step sizes (minimum and maximum) for each, are told in Table 3-40; you configure the entire detector with

- `ShortTimeDetector`

Table 3-40: Minimum and maximum spectral step size.

<table>
<tr><th colspan="9">Minimum and maximum spectral step size</th></tr>
<tr><td colspan="2">Span [MHz]</td><td>80</td><td>40</td><td>20</td><td>10</td><td>5</td><td>2</td><td>1</td></tr>
<tr><td rowspan="2">Step size [kHz[1)]*]</td><td>min.</td><td>25</td><td>12.5</td><td>6.25</td><td>3.125</td><td>1.5625</td><td>781.25 Hz</td><td>390.625 Hz</td></tr>
<tr><td>max.</td><td>100</td><td>50</td><td>25</td><td>12.5</td><td>6.25</td><td>3.125</td><td>1.5625</td></tr>
</table>

1) *Unless noted otherwise.*

Mind in this context that the Rx span can be set (altered) independently of this step size by XML command

- `MeasureSettingsFFM`

If a combination of Rx span and step size arises this way that is not permitted for the ST Detector, data output will be stopped (disabled). The easiest way to avoid this situation is to configure automatic mode for step size setting:

- `ShortTimeDetector: eStepAuto=STATE_ON`

Find default values of step size for this case in Table 3-41.

Table 3-41: Default spectral step sizes and reasonable minimum time durations.

<table>
<tr><th colspan="10">Default step sizes and reasonable minimum time durations</th></tr>
<tr><td colspan="3">Span [MHz]</td><td>80</td><td>40</td><td>20</td><td>10</td><td>5</td><td>2</td><td>1</td></tr>
<tr><td colspan="3">Default step size [kHz[1)]*]</td><td>50</td><td>25</td><td>12.5</td><td>6.25</td><td>3.125</td><td>1.5625</td><td>781.25 Hz</td></tr>
<tr><td rowspan="9">Minimum time duration for step size</td><td>100</td><td rowspan="7">kHz</td><td>0.05 ms</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>50</td><td colspan="2">0.1 ms</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>25</td><td colspan="3">0.2 ms</td><td></td><td></td><td>n/a</td><td></td></tr>
<tr><td>12.5</td><td></td><td colspan="3">0.4 ms</td><td></td><td></td></tr>
<tr><td>6.25</td><td></td><td></td><td colspan="3">0.8 ms</td><td></td></tr>
<tr><td>3.125</td><td></td><td></td><td></td><td colspan="3">1.6 ms</td></tr>
<tr><td>1.5625</td><td></td><td>n/a</td><td></td><td></td><td colspan="3">3.2 ms</td></tr>
<tr><td>781.25</td><td rowspan="2">Hz</td><td></td><td></td><td></td><td></td><td></td><td colspan="2">6.4 ms</td></tr>
<tr><td>390.625</td><td></td><td></td><td></td><td></td><td></td><td></td><td>12.8 ms</td></tr>
</table>

1) *Unless noted otherwise.*

Time Domain

Another parameter to be specified is the minimum and maximum duration for the signals to be searched for (signals shorter than minimum or longer than maximum duration will be ignored; valid values range from 50 μs to 500 ms). The spectral averaging of the ST Detector will automatically be set to a value that approximates these durations as closely as possible. This approximation will succeed more likely if the minimum signal duration is selected longer than the *minimum time duration* values told in Table 3-41; remember that empty table cells represent non-permissible combinations of Rx span and ST Detector step size (cf Table 3-40).

Set minimum and maximum duration the way that the signals of your interest be well included, for example by allowing a "safety" margin of about 20 %; capture ratio will be improved this way. Example: if in search of a signal appearing for 1 ms at a known frequency, specify 1 ms – 20 % = 0.8 ms for minimum and 1 ms + 20 % = 1.2 ms for maximum duration.

The level threshold for detection must also be set; this is, only signals that exceed the noise level estimated internally by the value of this threshold will be considered. In other words, the ratio of the peak level of the detected signal and the noise level is calculated and compared to the threshold to decide. Alternatively, an automatic setting of the threshold can be selected.

Noise level is estimated by applying an averaging process to the noise portions of the IF data stream; this means, estimation is done excluding signals present in the data (averaging is never applied to the short-time signals existing). The appropriate averaging time can be configured in the range of 1 μs to 10 s.

Limitations

It cannot be ruled out that signals be recognized as short-time signals that in reality are part of (more or less) continuously present signals. FM, DAB, DVB (-T), TETRA might be examples for this kind of signals. The ST Detector takes precautions to discern such signals from actual short-time signals: if an "accidental" short-time signal has been detected, output of all emissions at (and close to) its frequency, i.e. within and in the vicinity of its bandwidth, will be suppressed from then on.

The suppressed frequency region is always a multiple of the ST Detector's step size (cf Table 3-40/Table 3-41). Hence, if desiring to minimize this region, preferably select the smallest possible step size.

By its very nature, the suppression has to be kept active beyond the moment the continuously present signal disappears. It will typically end after a period of time in the range of the configured maximum burst duration has elapsed, and emissions will then be signalized again. Similarly, if the ST Detector is already active and such a signal appears newly, suppression will only start after the same amount of time; from that, false emission reports cannot be inhibited until this moment.

3.16.2.4 Short-Time Signal Synthesizer

Option

The functionality **Short-Time Signal Synthesizer** is only available if the options

- option R&S DDFGTSDDCE, *DDC Signal Extraction*
- option R&S DDFGTS-ST, *Detection of Short-Time Signals*

are installed.

After having detected (localized in time and spectrum, see 3.16.2.3) your signals of interest, you may want to subject them to a further analysis, for example determine modulation or coding parameters. For this purpose, each individual signal has to be isolated from all other, i.e. I/Q samples generated of the signal converted to baseband.

This is done by the *Short-Time Signal Synthesizer* (ST Synthesizer): it extracts the short-time signals from the original signal that meanwhile has been stored by the R&S DDF5GTS. This extraction is accomplished by instructing DDC instances (see 3.16.1, "DDC Signal Extraction") to create (synthesize) the I/Q signal data for the correct moment and suitable duration of time (point and amount in time such that the detected signal is well included in the extracted IF signal band). To that end, the information (detections) of the ST Detector (3.16.2.3) has to be evaluated.

Each DDC to dedicate to this task is to bind to the ST Synthesizer with XML command

- `DDCEConfig`: `eState=DDCE_STATE_STIF`

for all DDCs configured this way you can set the bandwidth (i.e. that the ST Synthesizer is to apply to extract the I/Q samples) to either 30 kHz or 300 kHz; the selected value then is common to all individual DDCs (instances of the synthesizer); individual bandwidth settings or other configurations to particular DDCs are not possible with the ST Synthesizer. Use the command

- `ShortTimeSynthesizer`

to set this bandwidth, as also to enable or disable the ST Synthesizer in general.

Some configurations for all DDCs in total are accomplished by the command

- `DDCEControl`

Again, data is output with an AMMOS data trace, this time the trace *AMMOS IF DDCE*, find details in Chapter 3.18.3.3; the trace tag is *DDCE* (see Table 3-54 on page 258).

3.16.2.5 Operational Restrictions and Conditions

Find subsequently the preconditions for a correct working of especially the *ST Synthesizer* (3.16.2.4):

- At least one DDC (instance of R&S DDFGTSDDCE, Section 3.16.1) must be connected to the ST Synthesizer, i.e. be set to (XML command)
  - `DDCEConfig`: `eState=DDCE_STATE_STIF`

- Signal synthesis will always use the configured DDC bandwidth:
  – 30 kHz:
    `ShortTimeSynthesizer: eBandwidth=STS_BW_30000`
  – 300 kHz:
    `eBandwidth=STS_BW_300000`
- The IF signal forwarded to short-time signal extraction must be delayed by at least 1 s:
  – `DDCEControl: iSignalDelay=1` (or more)
- The length of the I/Q samples to issue (16 bit or 32 bit) has to be specified:
  – 16 bit I, 16 bit Q:
    `DDCEControl: eRemoteMode=DDCE_REMOTE_MODE_SHORT`
  – 32 bit I, 32 bit Q:
    `eRemoteMode=DDCE_REMOTE_MODE_LONG`
- The ST Detector must be configured
  – `ShortTimeDetector`

  before starting the ST Synthesizer (see below).
- Output via data trace must have been enabled (see Chapter 3.18.4, "Remote Commands Controlling Data Traces", on page 326)
  – `TraceEnable: eTraceTag=TRACETAG_DDCE`

  before starting the ST Synthesizer:
  – `ShortTimeSynthesizer: eState=STATE_ON`

In a more general view:

1. **set up** the ST Detector (see above) and the ST Synthesizer:
   - `ShortTimeSynthesizer`
2. **start** the ST Synthesizer (see above)
3. **start** the ST Detector:
   - `ShortTimeDetector: eState=STATE_ON`

3.16.2.6 Special Considerations for Scan Mode

Basics

The *ST Detector* and the *ST Synthesizer* basically work the same way with Scan Mode (Chapter 3.7.6, "Scan Mode", on page 144) as with Rx Mode and FFM (Chapter 3.7.4/3.7.5), but observe some characteristics that are described subsequently.

In Scan Mode, particular scan ranges (frequency ranges) arbitrarily defined by the user are processed that in turn, if they are wider than the realtime bandwidth (frequency span), are divided into several individual hops of this width (Chapter 3.7.6.2, "Converting Scan Ranges to Hop Lists", on page 145). Therefore, as staying on a particular

Rx frequency is only for a definite time (duration of the hop), ST analysis also can only take place during this period. Thus, two change events are to be regarded:

- Scan range
  When switching scan range, other configuration parameters become valid; *exception:* bandwidth for the ST synthesizer, which you have to configure throughout all scan ranges.
- Hop
  Switching the hop (Rx frequency of the R&S DDF5GTS) causes several consequences for the ST analysis:
  – All pending detections (waiting for the end of the emission at the time of hop switching) are aborted.
  – The noise threshold (level threshold above that an emission is judged as such) is determined (trained, see Section "Block Averaging Time and Training Time") anew.
  – New emissions on the Rx frequency now valid are searched for.
  – If emissions have been found (detections completed), they are transferred to the *Burst Emission List* and output.
  – For these emissions base band signals (I/Q samples) are extracted by the ST synthesizer.

That implies that a signal of a duration exceeding the dwell time cannot be recognized because either its start or its end is outside the period of observation. Thus, specify maximal length of signals to be found correspondingly (notably shorter than dwell time).

Configuring

In Scan Mode, you configure the ST detector separately for each scan range and store the different configurations in parameter sets. You in total may create 64 individual parameter sets P_n (count/ID n = 1 to 64), besides there is a parameter set P_0 (ID 0) for Rx Mode and FFM. Since as many as 1000 scan ranges may exist at a time, you also may use parameter sets repeatedly (for several scan ranges); do selection by using the ID of the set. If you specify –1, ST analysis for the scan range in question is disabled: thus, no separate enabling is needed, but, on the other hand, always ST detection und ST synthesis are switched on or off together, you cannot enable only the ST detector. The situation is depicted with Figure 3-71; Table 3-42 summarizes switching on and off and the parameter sets to use for Rx Mode or FFM, respectively, and Scan Mode.

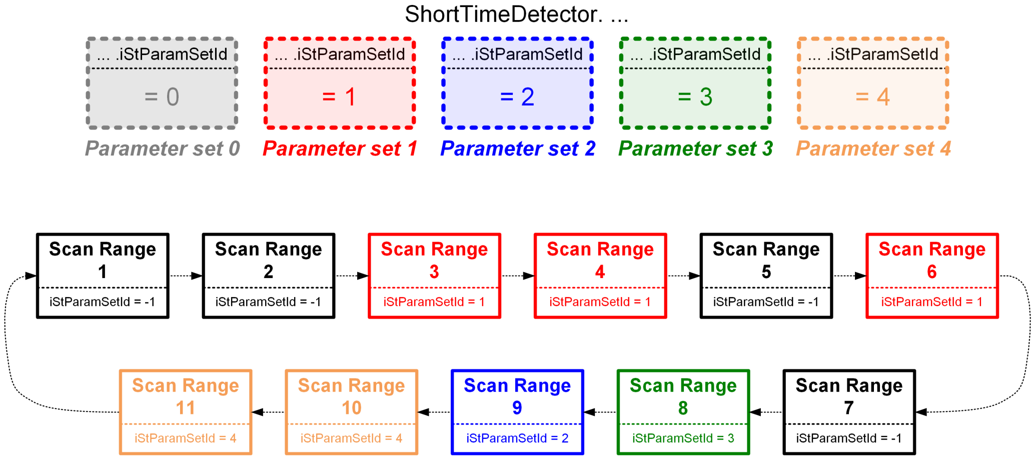


Figure 3-71: Short-time analysis parameter sets and scan ranges.

top = parameter sets
gray = parameter set P_0: not used in Scan Mode (Rx Mode and FFM only)
colored = parameter sets P_1 to P_4
bottom = Scan Mode example (see also Figure 3-25)
black = scan ranges not using ST analysis
colored = scan ranges using ST analysis with parameter set told by parameter set ID 1 to 4

Table 3-42: Enabling ST analysis and parameter sets in use with Rx/FFM and Scan Mode.

Enabling ST analysis and parameter sets in use						
DF mode	**ShortTime ... .eState = STATE_ ...**[1)]*		**PS**[2)]* **specified**	**Short-time**		**PS**[2)]* **in use**
	Detector	**Synthesizer**		**detection**	**synthesizing**	
Rx, FFM	OFF	OFF	(does not apply)	no	no	(none)
	ON	OFF		yes	no	*P_0*
	ON	ON		yes	yes	*P_0*
Scan	(does not apply)		PS = –1	no	no	(none)
			PS = n (n > 0)	yes	yes	*P_n*

1) *Parameter* `ShortTimeDetector.eState`, `ShortTimeSynthesizer.eState`; *Value* `STATE_OFF`, `STATE_ON`.

2) *Parameter set: n = 1, ..., 64.*

If you try to specify an incorrect parameter set (PS), it will be rejected and an error message issued.

Realtime Bandwidth (Frequency Span)

Mind at this that all scan ranges that use ST analysis show a concordant realtime bandwidth (frequency span) (independent of parameter set in use). If you add new scan ranges with a deviating span, ST analysis will not be performed for these scan ranges.

The parameter set of a scan range thus remains valid as long as the range is active. If, according to schedule, switching to the next scan range occurs, the parameters of the new scan range, because scan mechanism is superior to ST mechanism, become valid, previous ST analysis is aborted and the *Burst Emission List* is filled with the newly detected bursts (see Section "Basics"). An automatic adaption of scan dwell time (parameter `BlockAveragingTime`) to maximal length of signals to be searched for (parameter `iMaxTime`) is not done, so this length may not exceed dwell time but should be notably shorter than it.

Hence, the single ST parameter set known from Rx/FFM and defined by

- `ShortTimeDetector`

turns into an array of 65 parameter sets for 65 configurations max.; the parameter

- `ShortTimeDetector:iStParamSetId` (0, ..., 64)

facilitates distinguishing. With this, the parameter set told by `iStParamSetId` = 0 applies for Rx and FFM (you thus cannot use it with Scan Mode), and the sets `iStParamSetId` = 1 to 64 are intended for Scan Mode.

The counterpart on the scan range definition side via the command

- `ScanRange`

is also called

- `ScanRange:iStParamSetId` (1, ..., 64)

the parameter set to be used for the respective scan range is given by it. `iStParamSetId` = –1 disables ST analysis (detection und synthesis) for the current scan range.

- `ShortTimeSynthesizer:eState`

is not in use with Scan Mode so that ST synthesizer is always enabled together with ST analysis; this is, you cannot disable ST synthesizer selectively.

Remember that

- `ShortTimeSynthesizer: eBandwidth`

is a global parameter. You have to define it before starting scan and it is valid throughout the scan and even when scan is left. Hence you cannot configure Scan Mode with ST operation that comprises two or more scan ranges owning diverging values for `eBandwidth`.

Signal delay

- `DDCEControl:iSignalDelay`

in Scan Mode is fixed to 1 s; the value selected for Rx Mode and FFM, however, stays set and retakes effect when Scan Mode is left again.

Additionally, automatic mode for spectral step size (see 3.16.2.3)

- `ShortTimeDetector`: `eStepAuto=STATE_ON`

is not supported with Scan Mode; rather, you always have to set step size explicitly.

Moreover, all scan ranges to be used with ST operation have to show a coinciding real-time bandwidth (frequency span):

- `ScanRange:eSpan`

Strategy

From this it is recommended, to add scan ranges and ST parameter sets safely to a scenario, to observe the following sequence:

1. Delete all scan ranges.
   This step indeed delivers the most robust definition of the scenario, but all previously existing scan ranges get lost this way. If this should not be desired, it is recommended instead to perform steps 2 and 3 in Rx Mode or FFM as no verification/alignment to scan settings that are already existing is done.
2. Define all ST parameter sets for
   - `ShortTimeDetector:iStParamSetId` > 0
3. Define all scan ranges.

To modify safely settings of a structure

- `ShortTimeDetector`

(even with Scan Mode running), proceed as follows:

1. For all scan ranges connected to this structure, set
   - `ShortTimeDetector:iStParamSetId` = –1
2. Modify the structure
   - `ShortTimeDetector`

   or the global parameter
   - `ScanRange:eSpan`
3. For all modified structures, return
   - `ShortTimeDetector:iStParamSetId`

   to the previous ID.

If desiring to add a new scan range with ST analysis active, ensure that its realtime bandwidth (frequency span) (parameter `eSpan`) coincides with the one of all other scan ranges also using ST analysis; if this is not the case, ST analysis fails to work for this scan range.

Sequence

Even though Scan Mode runs strictly periodically (at the end of the entire sweep, cycle starts anew; aborting can only be effected by the user), internally the next sweep will be initialized afresh anyway. This entails that, at the end of the sweep, all bearings have been terminated but commonly not all ST syntheses; rather, IF data from past hops remain in the IF delay buffer in order to be processed by ST synthesis. If scan continues periodically, you will not notice this process (additional time for execution has to be expended) from outside; if, in contrast, it is terminated, ST synthesis is halted at the same time, and the remaining values (commonly about 1 s) will not be synthesized, but vanish.

Block Averaging Time and Training Time

With each new Rx frequency (hop) ST analysis starts anew, requiring a notable portion of available time for determining the noise level. This determining (training) has to take place during active measurement, hence time remaining for the actual burst recognition decreases. Some typical training times are given in Table 3-43 (see also Table 3-40).

Table 3-43: Typical training times of ST detector.

Typical training times				
	Training time at step [kHz[1)]*]			
Span [MHz]	**largest step**	**time**	**smallest step**	**time**
80	100	80 µs	25	320 µs
40	50	160 µs	12.5	640 µs
20	25	320 µs	6.25	1.28 ms
10	12.5	640 µs	3.125	2.56 ms
5	6.25	1.28 ms	1.5625	5.12 ms
2	3.125	2.56 ms	781.25 Hz	10.24 ms
1	1.5625	5.12 ms	390.625 Hz	20.48 ms

1) *Unless noted otherwise.*

Therefore, for a successful short-time burst recognition, block averaging time t_{BM} should fulfill the following condition (t_T training time, t_{maxD} maximal duration of the signals to be searched for):

$$t_{BM} = t_T + 2\ t_{maxD}$$

On behalf of an adequate probability of detection, you should even use a notably longer block averaging time.

3.16.3 High-Resolution Panorama

Option

The functionality **High-Resolution Panorama** is only available if the option

- R&S DDFGTS-HRP, *High-Resolution Panorama*

is installed.

The *HRPan* (High-Resolution Panorama) offers a spectrum that is continuously calculated on the main IF data stream. The spectrum has a higher resolution (step size lower) compared to the *IFPan* functionality (see Chapter 3.18.2.8 on page 268).

Enable *HRPan* by the XML command (data mode, i.e. length of issued data, is unalterably set to 16 bit)

- `HRPan`: `eMode=HRPAN_16BIT`

Maximum and minimum frequency step sizes achievable for each IF span can be queried by

- `DeviceInfo`: `eDEVICE_INFO=DEV_INFO_HRP_SPAN_LIST`

and are shown in Tables 3-44/3-45 and, in comparison to the ones of *IFPan*, in Figure 3-72 (also see Figure 3-76 on page 268). Table and figure also give the value preferred in case of automatic selection (default value):

- `HRPan`: `eStepAuto=STATE_ON`

Table 3-44: Minimum, maximum and automatically selected frequency step sizes (part 1).

Span [MHz]		80	40	20	10	5
Step size [Hz[1)] *]	min.	195.32	97.66	48.83	24.42	12.21
	max.	12.5 k	6.25 k	3.125 k	1.5625 k	781.25
	auto	1.5625 k	781.25	390.63	195.32	97.66

Table 3-45: Minimum, maximum and automatically selected frequency step sizes (part 2).

Span [MHz[1)] *]		2	1	500 k	200 k	100 k
Step size [Hz]	min.	6.11	3.06	1.53	0.77	0.39
	max.	390.63	195.32	97.66	48.83	24.42
	auto	48.83	24.41	12.21	6.104	3.052

[1)] *Unless noted otherwise ("k" for kHz).*

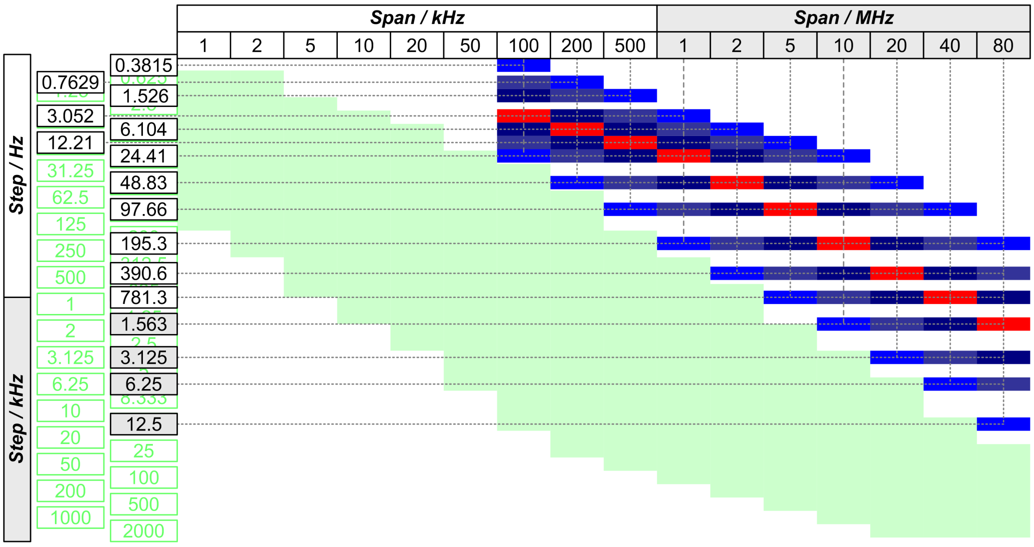


Figure 3-72: Combinations of frequency steps and spans with HRPan.

blue = step sizes possible for frequency span
red = default (automatic) step size
light green = possible step sizes with IFPan for comparison

A complete list of permitted combinations of step sizes and IF spans can be seen with Table 3-47.

After having activated *HRPan*, output of the first averaged spectrum may be delayed for several reasons: basic signal latency and internal memory management. Some typical values of this time delay can be seen from Table 3-46.

Table 3-46: Typical HRPan latencies (setup times).

Span [MHz[1)]*]	80	40	20	10	5	2	1	500 k	200 k	100 k
Latency [s]	0.5		1		2	5	10	20	40	80

[1)] *Unless noted otherwise ("k" for kHz).*

Spectrum data may be averaged for smoothing the display (elimination of instantaneous events and thus mitigation of noise). The averaging period may be specified:

- `HRPan: iAvgTime`

and the receiver will calculate one single spectrum by averaging all internally calculated spectra during this period. Mind that exact adhering to this time designation commonly is not achievable, rather the R&S DDF5GTS will use a value as close as possible to the configured one; you can query it with

- `HRPan: iAvgTimeCurrent`

However, the determined value can strongly deviate from the requested one, depending on the IF data span and *HRPan* step size currently set. A good approximation of the requested value is achieved within the limits told by *min. time* and *max. time* given in Table 3-47. (Non-empty cells show the IF span/step size combinations supported, empty ones non-permissible choices.)

Table 3-47: Average times.

<table>
<tr><th colspan="11">Average times</th></tr>
<tr><th>Span [MHz 1) *]</th><th>80</th><th>40</th><th>20</th><th>10</th><th>5</th><th>2</th><th>1</th><th>500 k</th><th>200 k</th><th>100 k</th></tr>
<tr><td>Time — max. [s]</td><td colspan="2">2.5</td><td>5</td><td colspan="7">10</td></tr>
<tr><td colspan="11">Time — min. [ms 1) *] with step size [Hz 1) *]</td></tr>
<tr><td>12.5 k</td><td>20.24</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6.25 k</td><td>20.64</td><td>20.24</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3.125 k</td><td>20.81</td><td>20.64</td><td>20.48</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1.5625 k</td><td>21.14</td><td>20.81</td><td colspan="2">20.48</td><td></td><td></td><td></td><td></td><td>n/a</td><td></td></tr>
<tr><td>781.25</td><td>21.86</td><td>21.14</td><td colspan="3">20.48</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>390.63</td><td>23.41</td><td>21.84</td><td colspan="4">20.48</td><td></td><td></td><td></td><td></td></tr>
<tr><td>195.32</td><td>163.84</td><td>81.92</td><td>40.96</td><td colspan="4">20.48</td><td></td><td></td><td></td></tr>
<tr><td>97.66</td><td></td><td>163.84</td><td>81.92</td><td>40.96</td><td colspan="4">20.48</td><td></td><td></td></tr>
<tr><td>48.83</td><td></td><td></td><td colspan="7">40.96</td><td></td></tr>
<tr><td>24.42</td><td></td><td></td><td></td><td>163.84</td><td colspan="6">81.92</td></tr>
<tr><td>12.21</td><td></td><td></td><td></td><td></td><td colspan="6">163.84</td></tr>
<tr><td>6.11</td><td></td><td></td><td></td><td></td><td></td><td colspan="5">327.68</td></tr>
<tr><td>3.06</td><td></td><td></td><td>n/a</td><td></td><td></td><td></td><td colspan="4">655.36</td></tr>
<tr><td>1.53</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">1.31072 s</td></tr>
<tr><td>0.77</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">2.62144 s</td></tr>
<tr><td>0.39</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>5.24288 s</td></tr>
</table>

1) *Unless noted otherwise ("k" for kHz).*

Output of High-Resolution Panorama data is performed as mass data with the *HRPan* data trace (Chapter 3.18.2.19, "HRPan", on page 309); use the trace tag *HRPan* (see Table 3-54 on page 258).

3.17 Control by Client Software

3.17.1 General

Complete operation of the R&S DDF5GTS is done via remote control from a client software – no local, i.e. front panel operating elements are provided except an [On/Off] key, some status LEDs and the four-line status display. Details about these elements are given in Chapter 3.1, "Front Panel Elements R&S EBD770", on page 89. Hence, all usable functions are performed by remote XML (XML) commands; establishing the connection needed and basic operation are described in this chapter, whereas details about the individual commands can be found in [2.4].

For creating a correct remote interface, mind the following requirements.

3.17.2 Connecting to Network

3.17.2.1 Establishing

The R&S DDF5GTS must be connected to a network environment via one of the remote control sockets **X4** ***LAN 1*** and **X5** ***LAN 2*** of the R&S EBD770. Both sockets are equivalent.

3.17.2.2 Verifying

The `ping` command is a simple way to check whether the controller is able to establish a connection to the R&S DDF5GTS. Just open a DOS command window, enter the command

- `ping <IP address>`

and observe whether an answer from the unit (or a timeout message) appears. The command sequences for a successful and a failed ping command are shown in subsequent examples 1 a and 1 b.

Example 1 a

Command sequence: successful `ping` command (valid connection available):

```
C:\DDF5GTS>ping 172.29.31.73

Pinging 172.29.31.73 with 32 bytes of data:

Reply from 172.29.31.73: bytes=32 time<1ms TTL=255
Reply from 172.29.31.73: bytes=32 time<1ms TTL=255
Reply from 172.29.31.73: bytes=32 time<1ms TTL=255
Reply from 172.29.31.73: bytes=32 time<1ms TTL=255

Ping statistics for 172.29.31.73:
  Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
```

```
Approximate round trip times in milli-seconds:
  Minimum = 0ms, Maximum = 3ms, Average = 0ms

C:\DDF5GTS>
```

Example 1 b

Command sequence: failed `ping` command (no valid connection available):

```
C:\DDF5GTS>ping 172.29.31.73

Pinging 172.29.31.73 with 32 bytes of data:

Request timed out.
Request timed out.
Request timed out.
Request timed out.

Ping statistics for 172.29.31.73:

  Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

C:\DDF5GTS>
```

Implementation of the interface is a TCP/IP socket connection.

The R&S DDF5GTS embodies the socket server, it waits for a TCP/IP connection from a client software via port 5563 (port 5555 + 8, see Note "IP Addresses and Port Numbers" on page 372).

3.17.3 Commands

The format of the commands is XML. A complete list of all commands together with more detailed information for any individual command can be looked-up in [2.4].

The interface is to be regarded as a synchronous interface, this is, any command sent to the unit will be responded after processing. Thus, after having emitted a command from the client, its processing has to be awaited. Only after this is confirmed by the correct response, the next command may be sent.

3.17.3.1 Command ID

Each command comprises a command ID (for reasons of compatibility to comparable applications; in the example 2 a and 2 b shown in 3.17.3.4 it is `"123"`). This ID may be altered by the user (client) arbitrarily; the R&S DDF5GTS will use this (possibly altered) ID in its command response for unambiguous identification.

3.17.3.2 Command Types

Emitted commands are tagged by the keyword Request, whereas the reply from the R&S DDF5GTS to a command is marked by Reply. Two types of commands exist:

- set commands alter parameter values within the R&S DDF5GTS, create or delete items of all kinds, in other words: change the current status of the unit.
- get commands just query portions of the status the unit is in at the moment.

3.17.3.3 Command Parameters

Commands and also the replies to them have parameters (keyword Param, in [2.4] denoted as "members") with them. Parameters come in five different types (so-called *i/o types*):

- id: the parameter addresses the item the command will apply to; it must always be specified and will always be replied. Commands with missing id parameters will be rejected.
- in: the parameter carries a value that a unit parameter is to be set to. If it has been omitted in the command, the unit parameter will not be altered (keep its previous value). An in parameter will not be replied.
- auto: the parameter also carries a value for a unit parameter, but, if it has been omitted, the unit parameter will be set to its default value. An auto parameter will always be replied.
- out: the parameter carries the current value of a unit parameter in the answer (<Reply>) from the R&S DDF5GTS; it only can exist in this answer. If an out parameter is tried to be sent in the user command (<Request>) anyway, it will be ignored.
- i/o: the parameter acts like in with set commands and like out with get commands: thus, it will only be replied with a get command.

3.17.3.4 Correct Command

Example 2 a

Query current DF mode (operating mode): XML command (keyword Request, type get)

- DfMode

to be sent to the R&S DDF5GTS:

```
<Request type="get" id="123">
  <Command name="DfMode">
  </Command>
</Request>
```

Example 2 b

Answer to query of example 2 a: XML response (keyword `Reply`) to command

- `DfMode`

emitted by the R&S DDF5GTS:

```
<Reply type="get" id="123">
  <Command name="DfMode">
    <Param name="eOperationMode">DFMODE_FFM</Param>
  </Command>
</Reply>
```

3.17.3.5 Incorrect Command

Example 3 a

If a command of incorrect form has been sent

```
<Request type="get" id="123">
  <Command nickname="DfMode">
  </Command>
</Request>
```

Example 3 b

the R&S DDF5GTS answers as follows, the command ID (see 3.17.3.1) in the reply in this case being always set to "0"

```
<Reply id="0" type="set">
  <Command name="CouldNotParseCommandError">
  </Command>
</Reply>
```

3.17.3.6 Unknown Command or Parameter Value

Example 4 a

If the form of the command is correct, but the command itself (command name) unknown

```
<Request type="get" id="123">
  <Command name="SaySomethingStupid">
  </Command>
</Request>
```

Example 4 b

the answer of the R&S DDF5GTS will be as follows, with the reply ID being the one of the original command (for `returnCode` and `returnMessage` see subsequent item, word wrap inserted ex post for better readability)

```
<Reply id="123" type="get">
  <Command name="SaySomethingStupid"
       returnCode="10516"
       returnMessage="Unknown command received">
  </Command>
</Reply>
```

If a synchronous error is detected while processing a command, the reply to the command contains an error number and an error message. These can be found in the attributes `returnCode` (numeric values for internal use only, but '0' without an error found) and `returnMessage` in the command tag of the reply. See examples 5 a and 5 b.

Example 5 a

Query of antenna properties of an antenna with an unknown antenna type "ADD999": XML command

- `AntennaProperties`

to be sent to the R&S DDF5GTS:

```
<Request id="3" type="get">
  <Command name="AntennaProperties">
    <Param name="zAntennaName">ADD999</Param>
  </Command>
</Request>
```

Example 5 b

Answer to query of example 5 a: XML response to command

- `AntennaProperties`

emitted by the R&S DDF5GTS (word wrap inserted ex post for better readability):

```
<Reply id="3" type="get">
  <Command name="AntennaProperties"
       returnCode="10520"
       returnMessage="No antenna found with the name "ADD999"">
    <Param name="zAntennaName">foo</Param>
  </Command>
</Reply>
```

3.17.3.7 Packet Structure

Not the plain ASCII string (7 bit with terminating zero) of the XML command (or response) is used for data exchange, but each command (response) is surrounded by a packet structure (see Table 3-48): two "magic words" (each an invariant bit sequence) and the count of bytes to be sent are amended.

Table 3-48: Packet structure of a packed XML command.

Packed XML command				
	Byte	**Format**	**Parameter**	**Description**
	0 to 3	INT32	MagicWordStart	`B1C2D3E4`$_{16}$ (invariant)
	4 to 7	INT32	Length	Length `n` [byte] of XML command (including terminating `\0`)
`n`	8 to (8 + `n` – 1)	INT8		XML command (as 7-bit ASCII with terminating zero)
	(8 + `n`) to (8 + `n` + 3)	INT32	MagicWordEnd	`E4D3C2B1`$_{16}$ (invariant)

All data of the packeted format is sent (like any data with the R&S DDF5GTS) in network byte order (big endian, i.e. when reading addresses in ascending order, sequence will be from MSB to LSB – in other words, MSB first transmitting).

For any further information about remote control, especially about the individual commands available, refer to [2.4].

3.18 Mass Data Output

3.18.1 General

The mass data output of the R&S DDF5GTS is used to transfer large data amounts (scan result data, measurement data, spectrum data, audio data and I/Q data) to an external client via the network, hereby avoiding the need to query these data individually by commands.

3.18.1.1 Data Streaming via TCP

In contrast to UDP (supported by the R&S DDF5GTS only for NMEA sentences, see Chapter 2.5.3, "NMEA 0183 Data Format", on page 53, but not for mass data streaming), the TCP protocol monitors the course of data transmission and, if data packets have got lost, is capable to resend them. However, this also means that TCP has to add overhead to the protocol, which though lowers throughput. Another peculiarity is that TCP is a data stream rather than a packet-oriented protocol: there will be no certain starting or end point of the data transmission. Thus, with TCP, the connection must first be initiated by the client.

3.18.1.2 System Topology

The R&S DDF5GTS acts as a data server which is configured from a client via the TCP/IP control path with XML (XML) commands [2.4]. The data path can be connected to the same client (also emitting the commands, Figure 3-73) or to a different client (Figure 3-74).

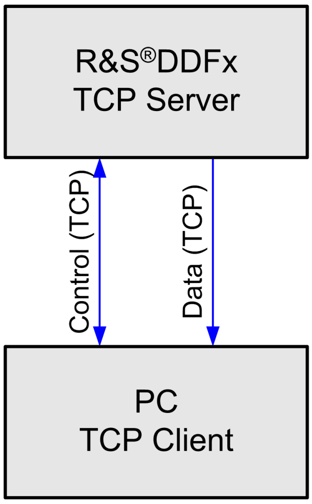


Figure 3-73: System topology, only one client existing, same client for commands and mass data.

DDFx = DDF550
= DDF5GTS
= DDF1GTX

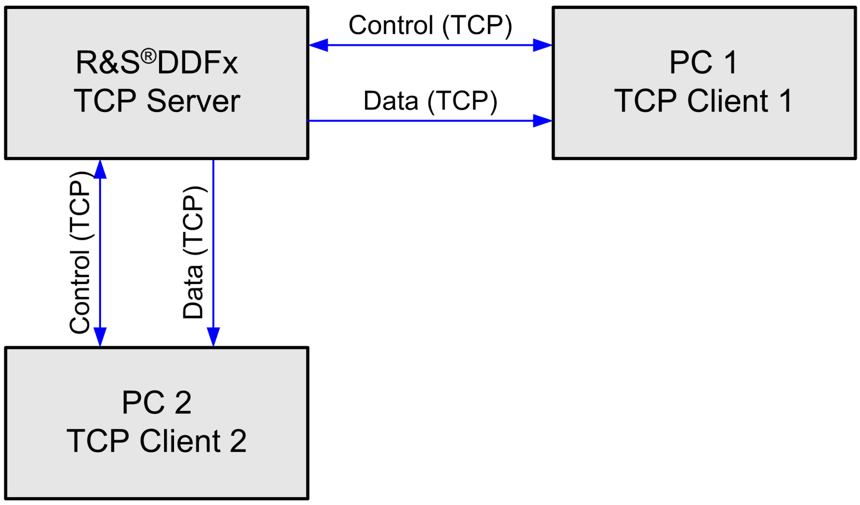


Figure 3-74: System topology, more than one client existing, same or different clients for commands and mass data.

DDFx = DDF550
= DDF5GTS
= DDF1GTX

3.18.1.3 Addressing

The *TCP path* concept is intended for distribution of data. A TCP path contains the destination IP address, a port number specific to the path and additional configuration data. One host also can serve several TCP paths (different port numbers with possibly different configurations). TCP port numbers used with the R&S DDF5GTS are calculated from the Telnet port number (see Figure 4-21 and Note "IP Addresses and Port Numbers" on page 372) by adding an offset of 10; thus the default TCP port results as

5555 + 10 = 5565

If a client tries to connect a data socket before a configuration is available, the connection is set up anyway, but no data will be sent until a configuration available. In reverse, it is possible to configure data for a data socket that has not yet been connected. In this case, this data is kept in the database until a matching socket is established. This situation may occur if a client has temporarily turned unavailable. The socket may be closed after the usual timeout has elapsed and then be reestablished when the client appears again.

This process must be managed by the client, since the R&S DDF5GTS always works as the server; the server has to ensure that the data stream for a new connection always starts with the header information.

3.18.1.4 Receive Buffer Size

Size of the receive buffer on the client side is especially important with non-realtime operating systems like Windows or Linux receiving data that emerges in realtime, like I/Q data streams. This buffer size depends on the peculiarities of the expected data traffic and has to be set before the client connects to the R&S DDF5GTS.

3.18.1.5 Transmit Buffer Size

TCP guarantees error-free transmission of data. In systems as in the present case where data is generated in realtime it might occur that data temporarily is not taken off by the client. Correctness of data (absence of errors) can only be ensured in this case by retransmission; i.e. if an acknowledgment from the receiver has not been detected by the transmitter after a certain timeout has elapsed, the data will be retransmitted. The suitable length of this timeout depends on the underlying network structure; it may vary from some milliseconds up to some seconds (e.g. with wide area networks).

Of course, all data to retransmit must be held within the transmitter. So, in reality, the timeout length is conditioned by the length of the transmitter queue, this is, the size of the transmit buffer: if the buffer overflows, data gets lost. Therefore, to improve the reliability of a particular trace TCP connection (see 3.18.1.3), the size of its transmit buffer can be individually increased.

When a new connection is to be established, a default value is preset (approx. 1.9 Mbyte); after having successfully set up the connection, you may set a longer transmission queue by the XML command

- `TraceTcpTxBuffer`

But be aware that all trace TCP connections share one pool of memory for their transmission queues – this is: if one connection claims more buffer volume, less volume is left for the others; thus, attempting to claim more than the volume still available in the pool is rejected, as is establishing a new connection if not enough volume is at disposal for it (given by the default value).

Query the complete and also the remaining pool size by the command

- `TraceTcpTxBufferPool`

In other words, if a client would connect and thereafter claim all of the remaining pool size, no future client would be able to connect anymore until this client releases again.

3.18.1.6 Configuration

In order to receive mass data from the R&S DDF5GTS, three steps are to be taken:

1. Establish a TCP/IP socket connection to the R&S DDF5GTS on the mass data port, port number 5565 (port 5555 + 10, see Note "IP Addresses and Port Numbers").
2. Establish a command connection or convince yourself to have already done so (see Chapter 3.17, "Control by Client Software", on page 243 for hints how to setup a valid command interface).
3. Send one or more XML commands
   - `TraceEnable`

   to enable one or more trace tags (see Table 3-54) and therewith tell the R&S DDF5GTS what kind of mass data should be emitted via the connection established in step 1 (EB200 protocol only, cf Chapter 3.18.2; for AMMOS protocol see Chapter 3.18.3).

As soon as step 3 is performed, the R&S DDF5GTS will occupy a trace slot for this connection. At maximum 10 trace slots can be occupied at a time, if trying to occupy more, an asynchronous error message will be issued on the error data sink (more information in Chapter 4.1.8, "Troubleshooting (Error Messages)", on page 347):

```
2012-05-02 12:48:02 [ -223] ERR-RT : "Too much data" No more trace slots free
```

For releasing a trace slot, it is not sufficient to disable all trace tags on this slot by the

- `TraceDisable`

command, rather the trace is to be deleted via

- `TraceDelete`

– in this case, the trace will be deleted completely even if still trace tags are enabled on its connection.

For special actions to be taken to obtain mass data via particular trace tags, refer to Table 3-54 on page 258 and the chapter of the individual tag (EB200 protocol only, cf Chapter 3.18.2; for AMMOS protocol see Chapter 3.18.3).

3.18.1.7 Survey of Connection

Since TCP/IP sockets survey the connection anyway, no separate protocol is needed: the availability is detected by the TCP/IP protocol. To activate the "keep-alive mechanism", the client must send at least 1 byte to the R&S DDF5GTS (server); this byte will be ignored, but data traffic generates a first valid sequence number and then starts the keep-alive probing.

3.18.1.8 Supported Protocols

The R&S DDF5GTS supports two mass data protocols:

- EB200 protocol (Chapter 3.18.2)
- AMMOS protocol (Chapter 3.18.3 on page 312)

3.18.2 EB200 Protocol

3.18.2.1 General

This chapter describes the mass data protocol named EB200 protocol (also used in other *Rohde & Schwarz* products, namely the R&S EB200 [Miniport Receiver]). The various data types therein are identified by means of "trace tags" and are provided with length information. Host applications can filter out and process specific data and thus need not implement the complete protocol specification.

Differing Types Existing in Parallel

Due to technological advance, two differing types (formats) of the EB200 protocol exist in parallel in the R&S DDF5GTS, called the

- **conventional** and the
- **advanced** type.

Both are explained in detail subsequently; which one of both is in use in an individual context is also told together with the description.

Timestamps

For notation of timestamps mind Note "Conditions" on page 313.

3.18.2.2 EB200 Format

For a better overview, the hierarchy structure of the EB200 format is depicted in Figure 3-75. Shown is an example of a *DFPScan* trace with all data subsets selected (see Chapter 3.18.2.17 on page 295), all "reserved" items are generally omitted. Descriptions of the mentioned terms can be found in the subsequent chapters.

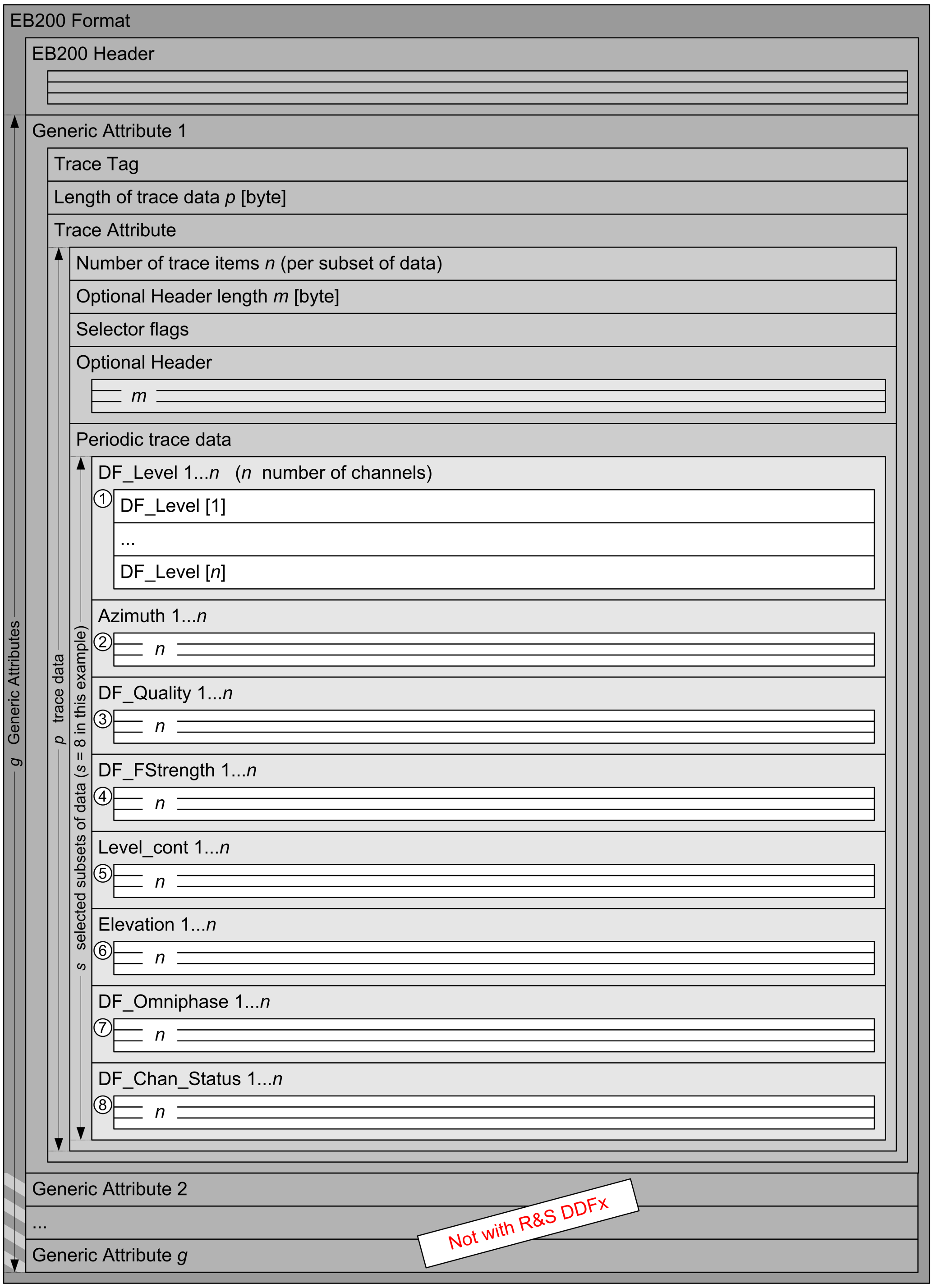


Figure 3-75: Hierarchy structure of the EB200 format, example DFPScan trace (all "reserved" items omitted).

DDFx = DDF550
= DDF5GTS
= DDF1GTX

Each EB200 packet (see Table 3-49) consists of

- **Header**
  The header clearly identifies a data item of the protocol.
- **Data units**
  One or, in the general case, several data units follow the header. They can be distinguished by dedicated trace tags and are denoted as Generic Attributes.

Be aware that the R&S DDF5GTS will only send EB200 packets that contain exactly one Generic Attribute.

Network Order (Endianness)
Generally all data is transferred in network byte order, i.e. in big-endian order.

Table 3-49: Description of the EB200 format.

EB200 format		
	Parameter	**Description**
	EB200 Header	Marks the beginning of each EB200 packet, see 3.18.2.3
g[1)]*	GenericAttribute[1]	Data elements, each containing a complete data set (g number of *GenericAttributes*); type of data is announced by trace tags (see 3.18.2.4) In the R&S DDF5GTS, only one *GenericAttribute* is sent: g = 1
	GenericAttribute[2]	
	...	
	GenericAttribute[g]	

1) *g (in cases where it may exceed 1) is not told explicitly, but data reading is continued due to DataSize parameter in Table 3-50.*

3.18.2.3 EB200 Header

Description

The header (Table 3-50) marks the beginning of each EB200 packet.

Table 3-50: Description of the EB200 header (16 bytes = 128 bits).

EB200 header			
	Data type	**Parameter**	**Description**
	UINT32	MagicNumber	Constant value that never changes (used for frame synchronization): $000EB200_{16}$ (also valid for R&S DDF5GTS)
	UINT16	VersionMinor	Version of the EB200 format, lower, i.e. least significant part: see Table 3-51 for version on hand
	UINT16	VersionMajor	Ditto, upper, i.e. most significant part: 02_{16} for version on hand
	UINT16	SeqNumLow[1)]*	Sequence number, lower, i.e. least significant part. Starts at a certain value and is incremented by 1 for every new EB200 packet. When the highest value is reached, a wraparound takes place

EB200 header			
	Data type	**Parameter**	**Description**
	UINT16	SeqNumHigh[1)]*	ditto, higher, i.e. most significant part
	UINT32	DataSize[1)]*	Size [byte] of the complete EB200 packet (not only EB200 Header!)

1) *Mind Table 3-51.*

Version History

Table 3-51 tells the version history, i.e. summarizes what changes within the EB200 protocol have been made within new versions (or from what version number on parameters told in the subsequent sections are valid).

Mind in this context that changes with upward compatibility ensured, e.g. simple additions of parameters (tags) or modifications of existing ones, cause an increment of parameter `VersionMinor`, whereas larger structural changes negating compatibility increment `VersionMajor` (this case happening rarely).

Table 3-51: Version history (VersionMinor only).

Version history			
V.	**Data Trace**	**Parameter**	**Modification**
25	IF, Video		
		AGC	added
26	IF, Video		
		RxAttenuation	replaces parameter AGC
	Audio, IF, Video		
		DemodulationString	added
30	(not in the R&S DDF5GTS)[1)]*		
31	(EB200 header)	DataSize	added
40	(various)	Timestamps	added
50	GenericAttribute TraceAttribute		advanced attribute type supported
53	IFPan, VDPan, PScan, DFPScan, SIGP		
		StepFreqNumer(ator) StepFreqDenom(inator)	added: fractional step frequency
54	Audio, IFPan, CW, IF, Video, VDPan, GPSCompass		
		SignalSource	added
55	IFPan, VDPan		
		MeasureMode	added

<table>
<tr><td colspan="4">Version history</td></tr>
<tr><td>V.</td><td>Data Trace</td><td>Parameter</td><td>Modification</td></tr>
<tr><td>60</td><td>(EB200 header)</td><td>Seq(uence)Num(ber)-
• Low
• High</td><td>formed from ancient <code>SequenceNumber</code> and two previously reserved bytes: 32-bit (instead of 16-bit) numbering helps to identify phantom datagrams by simply detecting an increase of sequence number.</td></tr>
<tr><td>61</td><td>GPSCompass</td><td>GPSExtensionHeader</td><td>added (34 bytes)</td></tr>
<tr><td>62</td><td colspan="3">(not in the R&S DDF5GTS)[1)]*</td></tr>
<tr><td rowspan="5">63</td><td colspan="3">IFPan, VDPan</td></tr>
<tr><td></td><td>Selectivity</td><td>added</td></tr>
<tr><td>PScan</td><td>AvgType</td><td>added</td></tr>
<tr><td rowspan="2">GPSCompass</td><td>AntennaRollExact</td><td rowspan="2">added</td></tr>
<tr><td>AntennaElev(ation)Exact</td></tr>
<tr><td>64</td><td>PScan</td><td>PScanTraceHeader</td><td>extended to support new feature segmented <code>PScan</code>.</td></tr>
</table>

V. VersionMinor number: indicated in hexadecimal notation. Mind that missing numbers result from course of development and do not concern the user.

1) Used in other Rohde & Schwarz products.

3.18.2.4 Generic Attribute

This section describes the general structure of every subsequent data trace (as Generic Attribute). Be aware that (see Note "Differing Types Existing in Parallel and Table 3-51) two types of this attribute exist in parallel, called the **conventional** (Table 3-52) and the **advanced** attribute type (Table 3-53), the latter of which delivering more data (data packets longer by 20 bytes).

Table 3-52: Description of the Generic Attribute, conventional attribute type.

<table>
<tr><td colspan="4">Generic Attribute conventional</td></tr>
<tr><td></td><td>Data type</td><td>Parameter</td><td>Description</td></tr>
<tr><td></td><td>UINT16</td><td>Trace tag</td><td>Type of contents of Generic Attribute (Table 3-54)</td></tr>
<tr><td></td><td>UINT16</td><td>Length</td><td>Length <code>p</code> [byte] of the <code>TraceData</code> section</td></tr>
<tr><td rowspan="4"><code>p</code></td><td rowspan="4">UINT8</td><td>TraceData[1]</td><td rowspan="4">Exactly 1 Trace Attribute (useful data, see 3.18.2.5)</td></tr>
<tr><td>TraceData[2]</td></tr>
<tr><td>...</td></tr>
<tr><td>TraceData[<code>p</code>]</td></tr>
</table>

Table 3-53: Description of the Generic Attribute, advanced attribute type.

*Generic Attribute advanced[1)]**			
	Data type	**Parameter**	**Description**
	UINT16	Trace tag	Type of contents of Generic Attribute (Table 3-54)
	UINT16	(reserved)	Reserved for future extensions
	UINT32	Length	Length `p` [byte] of the `TraceData` section
4	UINT32	(reserved)	Reserved for future extensions
`p`	UINT8	TraceData[1]	Exactly 1 Trace Attribute (useful data, see 3.18.2.5)
		TraceData[2]	
		...	
		TraceData[`p`]	

[1)] *Mind Table 3-51.*

There is a

- common structure (called Trace Attribute)

for all kinds of data traces currently defined (*Audio*, *IFPan*, *CW*, *IF*, *Video*, *VDPan*, *PScan*, *SelCall*, *GPSCompass*, *ANT_LEVEL*, *DFPScan*, *SIGP* and *HRPan* in the R&S DDF5GTS). The kind of the individual data traces is identified by

- *trace tags*

see Table 3-54 (tags denoted as "not for R&S DDF5GTS" are used in other *Rohde & Schwarz* products). The structure(s) is described in the following chapters, starting with 3.18.2.5. (This structure is represented by the element `TraceData` of the Generic Attribute.)

As also can be seen in Table 3-54, the **conventional** type of Generic Attribute and Trace Attribute is used with trace tags having a value less than 5000, whereas tags higher than 5000 use the **advanced** type.

Table 3-54: Description of trace tags.

Trace tags				
Symbolic name	**Data type**	**Format**	**Dc. value**	**Attribu. type**
FScan	(not for R&S DDF5GTS)[1)]*	EB200	101	conventional
MScan			201	
(reserved)			301	
Audio	Digital audio signal		401	
IFPan	Spectrum of the IF signal		501	
CW	Measurement data (triggered manually or periodically)		801	
IF	IF signal (I/Q data, unregulated)		901	

Trace tags				
Symbolic name	**Data type**	**Format**	**Dc. value**	**Attribu. type**
Video	Video data		1001	
VDPan	Video panorama data		1101	
PScan	Panorama scan level data		1201	
SelCall	SelCal analysis data		1301	
DFPan	(not for R&S DDF5GTS)[1)]*		1401	
PIFPan			1601	
GPSCompass	GPS and compass data		1801	
ANT_LEVEL	Antenna level data (from antenna element test)		1901	
PDW	(not for R&S DDF5GTS)[1)]*		5201	advanced
DFPScan[2)]*	DF data		5301	
SIGP[2)]*	Antenna data		5501	
HRPan[2)]*	High-resolution spectrum of the IF signal		5601	
AIF[3)]*	AMMOS IF data	AMMOS	Not relevant with AMMOS data formats	
DDCE[3)]*	AMMOS DDC data			
STDet[3)]*	AMMOS Burst Emission List data			

1) *Used in other Rohde & Schwarz products.*

2) *Mind Table 3-51.*

3) *For internal reasons, the AMMOS trace tags also are given names. However, no signalization via trace tags is done within the data trace itself, the type of current data is rather determined from the Frame-Type item of the AMMOS Frame Header (see Table 3-94 on page 314).*

3.18.2.5 Trace Attribute

The Trace Attribute describes the structure common to all kinds of trace data. As with the Generic Attribute (3.18.2.4), it comes in the two types (see also Table 3-54 and Table 3-51) **conventional** (Table 3-55) and **advanced** (Table 3-56). It basically is divided into an

- *optional header* section and a
- *periodic trace data* section

(with the length of each section amended).

Output of the *optional header* section, as implied by its name, can be queried or excluded optionally (see Note "Selector Flag Use in the R&S DDF5GTS"); it contains data concerning all of the *periodic trace data* in common.

The *periodic trace data* section contains the real trace data, it comes channel by channel, measurement by measurement etc., respectively.

Special attention should be paid to the

- *selector flags*

item: with these flags it is possible to select (i.e. extract) a special subset of each individual data trace – for each subset desired the client sets the corresponding flag by the XML (XML) command [2.4]

- `TraceFlagEnable`

for disabling a subset the flag is reset by

- `TraceFlagDisable`

(see Note "Selector Flag Use in the R&S DDF5GTS"). This might, if not the complete data is needed, be useful to speed up the repetition rate of data output.

But mind that the selector flags are common to all kinds of data traces, so careful setting of these flags is indispensable. In particular, in the R&S DDF5GTS a data trace, when having been enabled, will be issued with all allowed selector flags set (complete data trace; exception: *DF_OMNIPHASE* flag with *DFPScan* data trace, 3.18.2.17) by default – even though some of these flags might have been reset manually before (in connection with another data trace). For a general understanding of the flags, Table 3-57 gives a scope of all flags defined so far. As can be seen, one of the flags (the most significant one) indicates whether an optional header is to be issued or not.

Be aware that, although some data traces (in the R&S DDF5GTS: *DFPScan* and *SIGP*, 3.18.2.18) use the advanced type of the Trace Attribute, no selector flags of the `SelectorFlagsHigh` data field are in use.

Selector Flag Use in the R&S DDF5GTS

The R&S DDF5GTS issues complete data traces by default:

- *optional header* included and
- all allowed *selector flags* set,

i.e. for any individual data trace after enabling all possible selector flags (exception: *DF_OMNIPHASE* flag with *DFPScan* data trace) are set including the *OPTIONAL_HEADER* flag – in other words, with each kind of trace the *selector flags* item has its maximum value (but differing from one kind of trace to another, for example $\texttt{800CF800}_{16}$ with the *DFPScan* item). Disable flags of subsets not desired by the XML commands told; but be aware that some of these flags might become set again when activating an additional data trace.

If using super-resolution (Section "Super-Resolution Case" on page 302), do not suppress the optional header because the special super-resolution (SR) selector flags are part of it and are needed to correctly interpret the data delivered.

If a specific data trace facilitates more than one subsets of data, the length *n* of the periodic trace data section (`NumberOfTraceItems`) is always specified per subset (i.e. not for the overall section), thus telling e.g. the count of channels observed.

Table 3-55: Description of the Trace Attribute, conventional attribute type.

Trace Attribute conventional				
		Data type	**Parameter**	**Description**
		INT16	NumberOfTraceItems	Length `n` [items] of the `PeriodicTraceData` section per subset of data
		UINT8	(reserved)	Reserved for future extensions
		UINT8	OptionalHeaderLength	Length `m` [byte] of the `OptionalHeader` section: • > 0: optional header included • 0: no optional header included
		UINT32	SelectorFlags	Bit field for exact specification of data; see Table 3-57
	`m`	UINT8	OptionalHeader[1] OptionalHeader[2] ... OptionalHeader[`m`]	Header (optional to specify), individual to each type of trace
`s`	`n`	$TTTT_1x_1$ 1)*	*Selected subset 1:* PeriodicTraceData[1] PeriodicTraceData[2] ... PeriodicTraceData[`n`]	Individual trace data: • Content depending on kind of data trace (`Tag` in the Generic Attribute, see 3.18.2.4) and *selector flags* set • Start address depending on length of `OptionalHeader` • One or more subsets of data (`n` items each) possible depending on kind of data trace
	`n`	$TTTT_2x_2$ 1)*	*Selected subset 2*	
	`n`	$TTTT_ix_i$ 1)*	...	
	`n`	$TTTT_sx_s$ 1)*	*Selected subset `s`*	

1) *Item type* $TTTT_i$ *and length* x_i *varying from one subset to next;* x_i *= 8,* x_i *= 16 or* x_i *= 32 possible.*

Table 3-56: Description of the Trace Attribute, advanced attribute type.

Trace Attribute advanced 1)*				
		Data type	**Parameter**	**Description**
		UINT32	NumberOfTraceItems	Length `n` [items] of the `PeriodicTraceData` section per subset of data
		UINT32	(reserved)	Reserved for future extensions
		UINT32	OptionalHeaderLength	Length `m` [byte] of the `OptionalHeader` section: • > 0: optional header included • 0: no optional header included
		UINT32	SelectorFlagsLow	Bit field for exact specification of data, lower, i.e. least significant part; see Table 3-57
		UINT32	SelectorFlagsHigh	ditto, higher, i.e. most significant part
	4	UINT32	(reserved)	Reserved for future extensions

Trace Attribute advanced[1)]*				
		Data type	**Parameter**	**Description**
	m	UINT8	OptionalHeader[1]	Header (optional to specify), individual to each type of trace
			OptionalHeader[2]	
			...	
			OptionalHeader[m]	
s	n	$TTTT_1x_1$[2)]*	*Selected subset 1:*	Individual trace data: • Content depending on kind of data trace (`Tag` in the Generic Attribute, see 3.18.2.4, "Generic Attribute") and *selector flags* set • Start address depending on length of `OptionalHeader` • One or more subsets of data (`n` items each) possible depending on kind of data trace
			PeriodicTraceData[1]	
			PeriodicTraceData[2]	
			...	
			PeriodicTraceData[n]	
	n	$TTTT_2x_2$[2)]*	*Selected subset 2*	
	n	$TTTT_ix_i$[2)]*	...	
	n	$TTTT_sx_s$[2)]*	*Selected subset s*	

1) *Mind Table 3-51.*

2) *See footnote 1 of Table 3-55.*

Upward Compatibility

To access the actual trace data (start of *periodic trace data* section), always reference the value of `OptionalHeaderLength`. Upward compatibility is ensured this way even for "MinorVersion" (cf Table 3-50) modifications. Never try to conclude the section start from the *selector flags* indication; the flags are dealt with here for a general understanding, but might cause failures when applied to the individual traces.

Table 3-57: Description of selector flags (with "advanced" case only SelectorFlagsLow data field concerned until further notice).

Selector flags					
Flag name	**Used with trace**	**Hex. pos.**[1)]*	**Byte**	**Kind of all recorded data**	
				Type	**Unit**
LEVEL	IFPan, CW, VDPan, PScan, HRPan	1	0	INT16	1/10 dBµV
OFFSET	CW	2	0	INT32	Hz
FSTRENGTH	CW	4	0	INT16	1/10 dB(µV/m)
AM	CW	8	0	INT16	1/10 %
AM_POS	CW	10_{16}	1	INT16	1/10 %

Selector flags					
Flag name	**Used with trace**	**Hex. pos.**[1)]*	**Byte**	**Kind of all recorded data**	
				Type	**Unit**
AM_NEG		20₁₆		INT16	
FM		40₁₆		INT32	Hz
FM_POS		80₁₆		INT32	Hz
FM_NEG		100₁₆	2	INT32	Hz
PM		200₁₆	2	INT16	1/100 rad
BANDWIDTH		400₁₆	2	INT32	Hz
DF_LEVEL	DFPScan	800₁₆	2	INT16	1/10 dBµV
AZIMUTH	DFPScan	1000₁₆	3	INT16	1/10 °
DF_QUALITY	DFPScan	2000₁₆	3	INT16	1/10 %
DF_FSTRENGTH	DFPScan	4000₁₆	3	INT16	1/10 dB(µV/m)
DF_LEVEL_CONT	DFPScan	8000₁₆	3	INT16	1/10 dBµV
CHANNEL	(not in the R&S DDF5GTS)[2)]*	10000₁₆	4		
FREQ_LOW	(not in the R&S DDF5GTS)[2)]*	20000₁₆	4		
ELEVATION	DFPScan	40000₁₆	4	INT16	1/10 °
DF_CHANNEL_ STATUS	DFPScan	80000₁₆	4	INT16	(bit field)
DF_OMNIPHASE	DFPScan	100000₁₆	5	UINT16	1/10 °
FREQ_HIGH	(not in the R&S DDF5GTS)[2)]*	200000₁₆	5		
...					
BASECOUNTER	(do not use)[2)]*	1000000₁₆	6		
...					
SWAP	(not in the R&S DDF5GTS)[2)]*	20000000₁₆	7		
SIGNAL_GREA TER_SQUELCH	(not in the R&S DDF5GTS)[2)]*	40000000₁₆	7		
OPTIONAL_ HEADER	Audio, IFPan, CW, IF, Video, VDPan, PScan, SelCall, GPSCompass, ANT_LEVEL, DFPScan, SIGP, HRPan	80000000₁₆	7	(misc.)	(bit field)

1) *Hexadecimal position in bit field*
- `SelectorFlags` *in conventional Trace Attribute type (Table 3-55)*
- `SelectorFlagsHigh:SelectorFlagsLow` *in advanced Trace Attribute type (Table 3-56)*

2) *Used in other Rohde & Schwarz products: keep flag reset (0) at all times.*

3.18.2.6 Invalid and Illegal Values

When the R&S DDF5GTS issues mass data, some constants are predefined indicating that a value is either *invalid* or *illegal*. The difference between these both terms is:

- *invalid*: the corresponding measurement is switched to off
- *illegal*: the measurement is not possible due to an inappropriate setting of parameters. With the R&S DDF5GTS, DF quality will be set to zero value if not enough measured values are available.

Find a scope of all indicated values in Table 3-58.

Table 3-58: Values indicated for parameters if invalid or illegal.

Parameter	Value if		Parameter	Value if	
	invalid	illegal		invalid	illegal
LEVEL	2000_{10}	1999_{10}	ANTFACTOR	$7FFF_{16}$	$7FFE_{16}$
OFFSET	10000000_{10}	9999999_{10}	AZIMUTH	$7FFF_{16}$	$7FFE_{16}$
AM	$7FFF_{16}$	$7FFE_{16}$	QUALITY	$7FFF_{16}$	$7FFE_{16}$
FM	$7FFFFFFF_{16}$	$7FFFFFFE_{16}$	ELEVATION	$7FFF_{16}$	$7FFE_{16}$
PM	$7FFF_{16}$	$7FFE_{16}$	LEVELCONT	$7FFF_{16}$	$7FFE_{16}$
BAND	$7FFFFFFF_{16}$	$7FFFFFFE_{16}$	OMNIPHASE	$7FFF_{16}$	$7FFE_{16}$
FSTRENGTH	$7FFF_{16}$	$7FFE_{16}$			

3.18.2.7 Audio

The *Audio* data trace contains audio, thus baseband data, i.e. demodulated LF data: a data stream of real values ready to be entered to a conventional sound card to make them audible (compare the *IF* data trace, 3.18.2.10).

Conditions

The *Audio* data trace only issues data if [2.4]

- the R&S DDF5GTS is in the DF mode (Chapter 3.7 on page 132)
  - Rx: XML (XML) command
    `DfMode: eOperationMode=DFMODE_RX` or
  - FFM:
    `eOperationMode=DFMODE_FFM`,
- the Audio mode is not "Off": XML command
  - `AudioMode: eAudioMode` is not `AUDIO_MODE_OFF`,

  and also
- squelch operation (noise suppression in case of missing signal) is either
  - switched off:
    `DemodulationSettings: bUseAfThreshold=false`,
    i.e. all signals are demodulated regardless of their level, or
  - switched on:
    `bUseAfThreshold=true`
    and the current signal exceeds the preselected demodulation threshold:
    `DemodulationSettings`: set in dBµV with `iAfThreshold`.

The current Rx frequency will then be demodulated and output via the trace.

The *Audio* data trace can contain data in a variety of modes (see Table 3-59). These modes differ in the parameters sampling rate, quantization (number of bits per sample) and channels (1 for mono or 2 for stereo). The number of bytes (1 for 8 bits or 2 for 16 bits) in each sample multiplied by the number of channels yields the number of bytes per frame, the data rate is the sampling rate multiplied by this number.

If squelch operation, i.e. noise suppression in case of missing signal, has been chosen and the signal is currently below threshold, no useful audio data is available. Then no audio data is output at all (see Note "Conditions" in this chapter). Transition of the signal from "high" (above threshold) to "low" level (below threshold) will be reported by a single *Audio* data attribute with the Audio mode parameter (`AudioMode`) set to 0. In all other cases (audio modes 1 to 12, the "PCM modes"), a frame contains 1, 2 or 4 bytes, as explained above.

Table 3-59: Audio modes.

Audio modes							
Mode	**Sampling rate**	**Sample length**		**Channels**	**Data rate**	**Frame length**	
	[kHz]	**[bit]**	**[byte]**		**[kbyte/s]**	**[bit]**	**[byte]**
0	No further audio data output after this data attribute (thus, no Mode parameter as well) until useful data is present again (see above)						
1	32	16	2	2	128	32	4
2	32	16	2	1	64	16	2
3	32	8	1	2	64	16	2

Audio modes							
Mode	**Sampling rate**	**Sample length**		**Channels**	**Data rate**	**Frame length**	
	[kHz]	**[bit]**	**[byte]**		**[kbyte/s]**	**[bit]**	**[byte]**
4	32	8	1	1	32	8	1
5	16	16	2	2	64	32	4
6	16	16	2	1	32	16	2
7	16	8	1	2	32	16	2
8	16	8	1	1	16	8	1
9	8	16	2	2	32	32	4
10	8	16	2	1	16	16	2
11	8	8	1	2	16	16	2
12	8	8	1	1	8	8	1

No subset of data can be selected or suppressed, i.e. the selector flags (Table 3-57) for audio data only contain

- *OPTIONAL_HEADER*

Flag is always set on enabling trace: `SelectorFlags` = `80000000`$_{16}$; to reset and set use XML commands

- `TraceFlagDisable`
- `TraceFlagEnable`

Data is sent depending on the selector flags set; the order corresponds to the significance (upward) of these flags. The number of values of the data section (i.e. the number of values corresponding to one selector flag, not the overall sum) is defined in the `NumberOfTraceItems` item of the Trace Attribute (see Table 3-55).

The Optional Header (here called *Audio trace header*) is described in detail in Table 3-60.

Table 3-60: Description of the Audio trace header (42 bytes = 336 bits).

Audio trace header			
	Data type	**Parameter**	**Description**
	INT16	AudioMode	See Table 3-59
	INT16	FrameLength	Frame length [byte]
	UINT32	Freq_low	Rx frequency [Hz] (as a 64-bit value, lower, i.e. least significant part)
	UINT32	Bandwidth	Demodulation bandwidth [Hz]
	UINT16	Demodulation	Demodulation mode: • 0: FM • 1: AM • 2: Pulse • 3: PM • 4: I/Q • 5: ISB • 6: CW • 7: USB • 8: LSB • 9: TV

Audio trace header

	Data type	**Parameter**	**Description**
8	UINT8	DemodulationString[1][1)]*	Demodulation mode as a string (left-aligned with the remaining characters being filled by 'NUL'):
		DemodulationString[2]	• "FM": FM • "AM": AM • "PULS": Pulse • "PM": PM • "IQ": I/Q • "ISB": ISB • "CW": CW • "USB": USB • "LSB": LSB • "TV": TV
		...	
		DemodulationString[8]	
	UINT32	Freq_high	Rx frequency [Hz · 2^{32}] (as a 64-bit value, upper, i.e. most significant part)
6	UINT8	(reserved)	6 bytes reserved for 64-bit alignment
	UINT64	OutputTimestamp	Timestamp [ns] at data output; value expressed as elapsed time since Unix epoch, without leap seconds
	INT16	SignalSource[1)]*	Signal source: • 0: antenna • 1: replay of recording

[1)] *Mind Table 3-51 on page 256.*

An example of a complete *Audio* data trace (called *Audio attribute*), as a Trace Attribute (conventional type), i.e. including length, selector flags (only *OPTIONAL_HEADER*) and optional header indications, is shown in Table 3-61 (cf also Table 3-55).

Table 3-61: Example of a complete Audio attribute.

Audio attribute

	Data type	**Parameter**	**Description**
	INT16	NumberOfFrames	Length `n` [items] of the `AudioData` section (corresponds to the `NumberOfTraceItems`)
	INT8	(reserved)	Not used
	UINT8	OptionalHeaderLength	Length `m` [byte] of `OptionalHeader` section: • 42: optional header included • 0: no optional header included
	UINT32	SelectorFlags	Bit field, see description of selector flags, Table 3-57: 80000000_{16} for optional header in the R&S DDF5GTS
`m`	UINT8	OptionalHeader	*Audio trace header* as described in Table 3-60
`n`	UINTx	AudioData[1]	Audio data `n` frames, `x` = frame length [bit] (8, 16 or 32, see Table 3-59)
		AudioData[2]	
		...	
		AudioData[n]	

The *Audio* data packets are transmitted internally in a cycle of 30 ms. The size of each packet depends on the audio mode (see Table 3-59); any packet can merely contain one or more complete frames. To change the audio mode, use the XML command

- AudioMode

3.18.2.8 IFPan

The *IFPan* (IF panorama) data trace contains IF panorama data (in the FFM the IF panorama shows signals centered around the current Rx frequency).

If in need of an even higher frequency resolution than available with *IFPan*, install the option R&S DDFGTS-HRP, *High-Resolution Panorama* (see 3.18.2.19, "HRPan").

Conditions

The *IFPan* data trace only issues data if [2.4]

- the R&S DDF5GTS is in the DF mode (Chapter 3.7 on page 132)
  - Rx: XML (XML) command
    `DfMode: eOperationMode=DFMODE_RX` or
  - FFM:
    `eOperationMode=DFMODE_FFM`.

Due to evaluation of spectral situation with FFT and to limited FFT lengths (bin count) not any spectral resolution (fine step size) possibly desired can be selected. Find an overview of possible frequency steps for each frequency span in Figure 3-76 (also see Figure 3-72 on page 242).

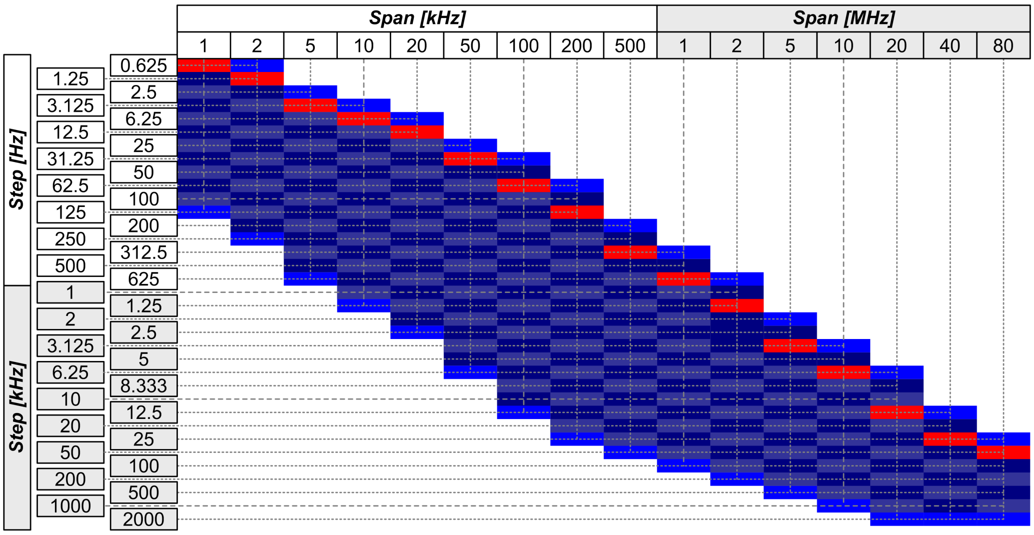


Figure 3-76: Combinations of frequency steps and spans with IFPan.

blue = valid step size for given frequency span
red = default (automatic) step size

The only subset of data to be selected or suppressed is the level data, i.e. the selector flags (Table 3-57) for IF panorama data only contain

- *LEVEL*
- *OPTIONAL_HEADER*

Flags are always set on enabling trace: `SelectorFlags` = 80000001_{16}; to reset and set use XML commands

- `TraceFlagDisable`
- `TraceFlagEnable`

Data is sent depending on the selector flags set; the order corresponds to the significance (upward) of these flags. The number of values of the data section (i.e. the number of values corresponding to one selector flag, not the overall sum) is defined in the `NumberOfTraceItems` item of the Trace Attribute (see Table 3-55).

The Optional Header (here called *IFPan trace header*) is described in detail in Table 3-62.

Table 3-62: Description of the IFPan trace header (62 bytes = 496 bits).

IFPan trace header			
	Data type	**Parameter**	**Description**
	UINT32	Freq_low	IF panorama center frequency [Hz] (as a 64-bit value, lower, i.e. least significant part)
	UINT32	FreqSpan	Frequency span [Hz]
	INT16	(reserved)	Not used
	INT16	AvgType	Averaging mode: • 0: MINimum • 1: MAXimum • 2: AVERage | SCALar • 3: CLRWRITE | OFF
	INT32	MeasureTime	Measuring time [µs]
	UINT32	Freq_high	IF panorama center frequency [Hz · 2^{32}] (as a 64-bit value, upper, i.e. most significant part)
	INT32	DemodFreqChannel	Index: points to the channel of the demodulation frequency
	UINT64	DemodFreq	Demodulation frequency [Hz]
	UINT64	OutputTimestamp	Timestamp [ns] at data output; value expressed as elapsed time since Unix epoch, without leap seconds
	UINT32	StepFreqNumer *1)**	Numerator value of fractional step frequency [Hz] *2)**
	UINT32	StepFreqDenom *1)**	Denominator value of fractional step frequency [Hz] *2)**
	INT16	SignalSource *1)**	Signal source: • 0: antenna • 1: replay of recording
	INT16	MeasureMode *1)**	Measuring mode (see Chapter 3.13.2.3, "Measuring Modes", on page 190): • 0: Continuous • 1: Periodic
	UINT64	MeasureTimestamp	Timestamp [ns] at measurement; value expressed as elapsed time since Unix epoch, without leap seconds
	INT16	Selectivity *1)**	FFT selectivity • 0: Auto • 1: Normal (prolongation factor 1, i.e. none) • 2: Narrow (factor 2) • 3: Sharp (factor 4)

1) *Mind [Table 3-51 on page 256](#).*

2) *The parameters `StepFreqNumer(ator)`, `StepFreqDenom(inator)` and `FreqOfFirstStep` facilitate an exact calculation of the frequency of each level sample even with non-integer `StepFreq` (e.g. 8⅓ kHz):*

$f_{sample} = f_{1st\ step} + n_{sample} \cdot \mathtt{StepFreqNumer} / \mathtt{StepFreqDenom}$

(f_{sample} frequency of spectral sample in question, $f_{1st\ step}$ frequency of 1st spectral sample of current span, n_{sample} ordinal number of sample in question).

An example of a complete *IFPan* data trace (called *IFPan attribute*), as a Trace Attribute (conventional type), i.e. including length, selector flags (*LEVEL* and *OPTIONAL_HEADER*) and optional header indications, is shown in Table 3-63 (cf also Table 3-55).

Table 3-63: Example of a complete IFPan attribute.

IFPan attribute			
	Data type	**Parameter**	**Description**
	INT16	NumberOfTraceValues	Length `n` [channels] of the `Level` section (corresponds to the `NumberOfTraceItems`)
	INT8	(reserved)	Not used
	UINT8	OptionalHeaderLength	Length `m` [byte] of `OptionalHeader` section: ● 60: optional header included ● 0: no optional header included
	UINT32	SelectorFlags	Bit field, see description of selector flags, Table 3-57: `80000001`$_{16}$ for optional header and level in the R&S DDF5GTS
`m`	UINT8	OptionalHeader	*IFPan trace header* as described in Table 3-62
`n`	INT16	Level[1]	Level [1/10 dBµV] of the `i`-th channel (1 ≤ `i` ≤ `n`)
		Level[2]	
		...	
		Level[`n`]	

3.18.2.9 CW

The *CW* data trace contains data delivered by measurements; triggering might have happened manually or periodically.

Conditions

The *CW* data trace only issues data if [2.4]

- the R&S DDF5GTS is in the DF mode (Chapter 3.7 on page 132)
  – Rx: XML (XML) command
    `DfMode: eOperationMode=DFMODE_RX`.

The *CW* trace data is needed especially if the *ITU Measurement Software* option (R&S DDFGTS-IM, see Chapter 2.6.3, on page 82) is installed. If this is not the case, better use the *DFPScan* trace (3.18.2.17) instead.

The subsets of data to be selected or suppressed with `CW` depend on whether the R&S DDFGTS-IM option is installed or not and whether the ITU measurements have been enabled or disabled: XML command

- `ITU`

If disabled (`ITU`: `bEnableMeasurement=FALSE`, whether option installed or not), there are level, frequency offset and optional header, i.e. the selector flags (Table 3-57) for CW data contain

- *LEVEL*
- *OFFSET*
- *OPTIONAL_HEADER*

Flags are always set on enabling trace: `SelectorFlags` = 80000003_{16}; to reset and set use XML commands

- `TraceFlagDisable`
- `TraceFlagEnable`

If enabled (`ITU`: `bEnableMeasurement=TRUE`, option must be installed), there are level, frequency offset, field strength, all modulation (AM, FM and PM) flags, bandwidth and optional header, i.e. the selector flags contain

- *LEVEL*
- *OFFSET*
- *FSTRENGTH*
- *AM*
- *AM_POS*
- *AM_NEG*
- *FM*
- *FM_POS*
- *FM_NEG*
- *PM*
- *BANDWIDTH*
- *OPTIONAL_HEADER*

(always set on enabling trace: `SelectorFlags` = $800007FF_{16}$; use XML command to reset).

(If the option is not installed, it is not possible to enable the ITU measurements.)

In **Periodic Measuring Mode** (Chapter 3.13.2.3, "Measuring Modes", on page 190): XML command

- `RxSettings`: `eMeasureMode=MEASUREMODECP_PER` for "Periodic"

data is output periodically corresponding to the parameter `iMeasureTime` of the `RxSettings` command. In **Continuous Measuring Mode**:

- `eMeasureMode=MEASUREMODECP_CONT` for "Continuous"

in contrast, data sets will be output only after the XML command

- `Initiate`

has been issued.

Data is sent depending on the selector flags set; the order corresponds to the significance (upward) of these flags. The number of values of each data section (i.e. the number of values corresponding to one selector flag, not the overall sum) is defined in the `NumberOfTraceItems` item of the Trace Attribute (see Table 3-55).

The Optional Header (here called *CW trace header*) is described in detail in Table 3-64.

Table 3-64: Description of the CW trace header (18 bytes = 144 bits).

CW trace header			
	Data type	**Parameter**	**Description**
	UINT32	Freq_low	Rx (receiving) frequency [Hz] (as a 64-bit value, lower, i.e. least significant part)
	UINT32	Freq_high	Rx frequency [Hz · 2^{32}] (as a 64-bit value, upper, i.e. most significant part)
	UINT64	OutputTimestamp	Timestamp [ns] at data output; value expressed as elapsed time since Unix epoch, without leap seconds
	INT16	SignalSource[1)]*	Signal source: ● 0: antenna ● 1: replay of recording

1) *Mind Table 3-51 on page 256.*

An example of a complete *CW* data trace (called *CW attribute*), as a TraceAttribute (conventional type), i.e. including length, selector flags (*LEVEL*, *OFFSET* and *OPTIONAL_HEADER* or, see above, additionally *FSTRENGTH*, *AM*, *AM_POS*, *AM_NEG*, *FM*, *FM_POS*, *FM_NEG*, *PM* and *BANDWIDTH*) and optional header indications, is shown in Table 3-65 (cf also Table 3-55).

Table 3-65: Example of a complete CW attribute.

CW attribute			
	Data type	**Parameter**	**Description**
	INT16	NumberOfFrames	Length `n` [items] of each of the data sections of the `CWData` section: a) ITU measurements disabled, option installed or not (Table 3-66): ● `Level` ● `Offset` b) option installed, ITU measurements enabled (Table 3-67): ● `Level` ● `AM_pos` ● `FM_neg` ● `Offset` ● `AM_neg` ● `PM` ● `FStrength` ● `FM` ● `Bandwidth` ● `AM` ● `FM_pos` (corresponds to the `NumberOfTraceItems`)
	INT8	(reserved)	Not used
	UINT8	OptionalHeaderLength	Length `m` [byte] of `OptionalHeader` section: ● 18: optional header included ● 0: no optional header included
	UINT32	SelectorFlags	Bit field, see description of selector flags, Table 3-57: value depends on ITU measurements enabled or not: $800007FF_{16}$ or 80000003_{16} in the R&S DDF5GTS

CW attribute			
	Data type	**Parameter**	**Description**
m	UINT8	OptionalHeader	*CW trace header* as described in Table 3-64
r	INT16	CWData[1]	CW data: • r = 2 * n (Table 3-66) • r = 11 * n (Table 3-67)
		CWData[2]	
		...	
		CWData[r]	

The contents of the `CWData` section depend on whether the R&S DDFGTS-IM option is installed and (if yes) whether the ITU measurements are disabled or enabled. A detailed breakdown of the data issued by the *CW* data trace is given in

- Table 3-66: option installed or not, measurements disabled, and
- Table 3-67: option installed, measurements enabled.

Refer to Chapter 3.13 on page 186 for more detailed information on ITU measurements.

Table 3-66: Example of a complete CW data stream, option R&S DDFGTS-IM installed or not, ITU measurements disabled.

CW data			
	Data type	**Parameter**	**Kind of data**
n	INT16	Level[1]	Level
		Level[2]	
		...	
		Level[n]	
n	INT32	Offset[1]	Frequency offset
		Offset[2]	
		...	
		Offset[n]	

Table 3-67: Example of a complete CW data stream, option R&S DDFGTS-IM installed, ITU measurements enabled.

CW data			
	Data type	**Parameter**	**Kind of data**
n	INT16	Level[1]	Level
		Level[2]	
		...	
		Level[n]	
n	INT32	Offset[1]	Frequency offset

CW data			
	Data type	**Parameter**	**Kind of data**
		Offset[2]	
		...	
		Offset[n]	
n	INT16	FStrength[1]	Field strength
		FStrength[2]	
		...	
		FStrength[n]	
n	INT16	AM[1]	Amplitude swing, average
		AM[2]	
		...	
		AM[n]	
n	INT16	AM_pos[1]	Amplitude swing, positive
		AM_pos[2]	
		...	
		AM_pos[n]	
n	INT16	AM_neg[1]	Amplitude swing, negative
		AM_neg[2]	
		...	
		AM_neg[n]	
n	INT32	FM[1]	Frequency deviation, average
		FM[2]	
		...	
		FM[n]	
n	INT32	FM_pos[1]	Frequency deviation, positive
		FM_pos[2]	
		...	
		FM_pos[n]	
n	INT32	FM_neg[1]	Frequency deviation, negative
		FM_neg[2]	
		...	
		FM_neg[n]	
n	INT16	PM[1]	Phase swing

CW data			
	Data type	**Parameter**	**Kind of data**
		PM[2]	
		...	
		PM[n]	
n	INT32	Bandwidth[1]	Bandwidth
		Bandwidth[2]	
		...	
		Bandwidth[n]	

3.18.2.10 IF

The *IF* data trace contains demodulated, but unregulated I/Q data, i.e. a data stream of complex value pairs (compare the *Audio* data trace, 3.18.2.7).

Denomination

For compatibility reasons, data output by the *IF* data trace is named IF **data**, although it is in reality the demodulated I (real part) and Q (imaginary part) data.

The I/Q data is represented as fixed point data, as the case may be using 16 bit or 32 bit. The principle of fixed point data representation is given in Figure 3-77:

A decimal number consists of its sign (1 bit in digital representation), the integer part (n bits), the decimal point (0 bits) and the fractional part (m bits), requiring an overall count of $k = 1 + n + m$ bits. The decimal point need not be incorporated in the digital representation at all so long as it is certain how many bits contain the integer and how many the fractional part, i.e. between which two positions the point could be imagined. Of course, if only positive (or only negative) numbers are of interest, the sign bit also could be omitted ($k = n + m$). The most common case, however, and also the case used here is the representation with only sign and fractional, but no integer part, thus always $n = 0$ and therefore $k = 1 + m$ (the leading zero left to the decimal point is not pictured as well). Due to two's complement representation, a binary number range of -2^m to $+2^m-1$ can be covered, resulting in a fractional number range of -1 to $+1 - 2^{-m}$. The granularity (dynamic range) calculates as $m \cdot 6$ dB. The figure shows the general case and the 16-bit and the 32-bit cases used here.

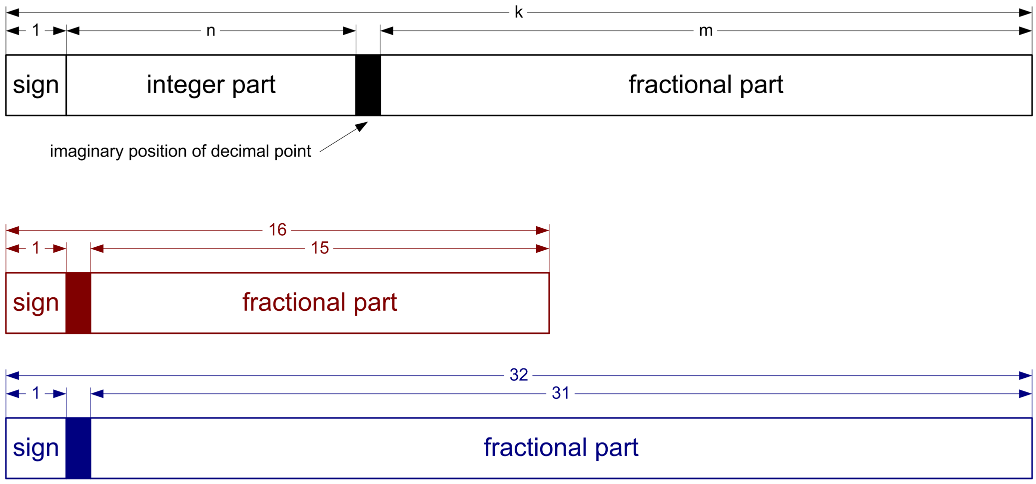


Figure 3-77: Fixed point representation of a number.

black = General case with integer and fractional part
red = 16-bit case with only fractional part
blue = 32-bit case with only fractional part

Conditions

The *IF* data trace only issues data if [2.4]

- the R&S DDF5GTS is in the DF mode (Chapter 3.7 on page 132)
  - Rx: XML (XML) command
    `DfMode: eOperationMode=DFMODE_RX` or
  - FFM:
    `eOperationMode=DFMODE_FFM`, and also
- output of **IF data** has been enabled: XML command
  - `IfMode: eIfMode=IF_16BIT` or `eIfMode=IF_32BIT` instead of `eIfMode=IF_OFF`.

No subset of data can be selected or suppressed, i.e. the selector flags (Table 3-57) for IF data can only contain

- *OPTIONAL_HEADER*

Flag is always set on enabling trace: `SelectorFlags` = 80000000_{16}; to reset and set use XML commands

- `TraceFlagDisable`
- `TraceFlagEnable`

Data is sent depending on the selector flags set; the order corresponds to the significance (upward) of these flags. The number of pairs of values of the data section (i.e. the number of values corresponding to one selector flag, not the overall sum) is defined in the `NumberOfTraceItems` item of the Trace Attribute (see Table 3-55).

The Optional Header (here called *IF trace header*) is described in detail in Table 3-68.

Table 3-68: Description of the IF trace header (58 bytes = 464 bits).

IF trace header			
	Data type	**Parameter**	**Description**
	INT16	IFMode	See XML command `IfMode`: • 0: IF_OFF • 1: IF_16BIT • 2: IF_32BIT
	INT16	FrameLength	Length [bytes] of **IF data** pair (I and Q): • `eIfMode`=IF_16BIT: 4 • `eIfMode`=IF_32BIT: 8
	UINT32	SampleRate	Sampling rate [Hz]
	UINT32	Freq_low	Rx frequency [Hz] (as a 64-bit value, lower, i.e. least significant part)
	UINT32	Bandwidth	Demodulation bandwidth [Hz]
	UINT16	Demodulation	Demodulation mode: • 0: FM • 1: AM • 2: Pulse • 3: PM • 4: I/Q • 5: ISB • 6: CW • 7: USB • 8: LSB • 9: TV
	INT16	RxAttenuation[1)]*	Overall attenuation from antenna input (depending on HF option equipping) • **X11** to **X13** ***HF***, • **X21** to **X23** ***V / UHF*** • **X31** to **X33** ***HF / V/U/SHF*** to level of **IF data**[2)]*
	INT16	Flags	• Bit 0: SignalValid: – 0: current signal not valid due to different reasons – 1: current signal valid • Bit 1: Blanking (cf Chapter 3.11.6.3, "Blanking", on page 175): – 0: not active – 1: active[3)]* • Bit 15: AntennaFactorValid: – 0: no antenna factors (k-factors) known for current antenna, thus no field strength calculable from level of received signal – 1: antenna factors known, field strength will be calculated Mind Note "Significance of Settings" on page 175
	INT16	K_Factor	k-factor for field strength calculation [1/10 dB(1/m)][4)]*
8	UINT8	DemodulationString[1][1)]*	Demodulation mode as a string (left-aligned with the remaining characters being filled by 'NUL'): • "FM": FM • "AM": AM • "PULS": Pulse • "PM": PM • "IQ": I/Q • "ISB": ISB • "CW": CW • "USB": USB • "LSB": LSB • "TV": TV
		DemodulationString[2]	
		...	
		DemodulationString[8]	
	UINT64	SampleCount	Number of 1st sample; can be used to calculate timestamp of each sample
	UINT32	Freq_high	Rx frequency [Hz · 2^{32}] (as a 64-bit value, upper, i.e. most significant part)

IF trace header			
	Data type	**Parameter**	**Description**
4	UINT8	(reserved)	4 bytes reserved for 64-bit alignment
	UINT64	StartTimestamp	Timestamp [ns] at start of data sampling; value expressed as elapsed time since Unix epoch, without leap seconds
	INT16	SignalSource *1)**	Signal source: ● 0: antenna ● 1: replay of recording

1) *Mind* *Table 3-51 on page 256**.*

2) *The averaged RMS level of the* ***IF data*** `Level_IFData` *is calculated from the I and Q samples* `I_sample` *and* `Q_sample` *by*

$$Level\_IFData = 10 \cdot \log_{10} \frac{1}{n} \sum_{i=1}^{n} \left(I\_sample[i]^2 + Q\_sample[i]^2 \right)$$

The power level at the antenna `Level_Antenna` *can be derived from the* ***IF data*** *level* `Level_IFData` *with the parameter* `RxAttenuation`*:*

`Level_Antenna = Level_IFData + RxAttenuation.`

3) *Blanking will stay on for at least 320 ms irrespectively of how long it was asserted.*

4) *The field strength [dB(µV/m)] affecting the antenna* `FieldStrength` *can be derived from the power level [dBµV] at the antenna* `Level_Antenna` *(see footnote 2) with the k-factor [dB(1/m)]* `K_Factor` *(mind that the value is delivered in 1/10 dB(1/m)):*

`FieldStrength = Level_Antenna + K_Factor.`

An example of a complete *IF* data trace (called *IF attribute*), as a Trace Attribute (conventional type), i.e. including length, selector flags (only *OPTIONAL_HEADER*) and optional header indications, is shown in Table 3-69 (cf also Table 3-55).

Table 3-69: Example of a complete IF attribute with 16-bit case (IFMode set to IF_16BIT).

IF attribute 16 bit			
	Data type	**Parameter**	**Description**
	INT16	NumberOfTraceValues	Length `n` [pairs] of the `I_sample/Q_sample` section (corresponds to the `NumberOfTraceItems`)
	INT8	(reserved)	Not used
	UINT8	OptionalHeaderLength	Length `m` [byte] of `OptionalHeader` section: ● 58: optional header included ● 0: no optional header included
	UINT32	SelectorFlags	Bit field, see description of selector flags, Table 3-57: 80000000_{16} for optional header in the R&S DDF5GTS
`m`	UINT8	OptionalHeader	*IF trace header* as described in Table 3-68
2`n`	INT16 *1)**	I_sample[1]	**IF data** pairs: `n` pairs in fixed point notation (see above)
		Q_sample[1]	
		I_sample[2]	

IF attribute 16 bit			
	Data type	**Parameter**	**Description**
		Q_sample[2]	
		...	
		I_sample[n]	
		Q_sample[n]	

1) *INT32 with 32-bit case (`IFMode` set to IF_32BIT).*

3.18.2.11 Video

The *Video* data trace contains so-called video data, i.e. the current demodulated signal is output in amplitude (AM) and frequency demodulation (FM). Data comes in pairs of AM and FM samples, and all demodulation parameters always correspond to the values the R&S DDF5GTS is set to at the moment.

If desiring to see the spectral representation of the data instead, select the *VDPan* data trace (3.18.2.12).

Conditions

The *Video* data trace only issues data if [2.4]

- the R&S DDF5GTS is in the DF mode (Chapter 3.7 on page 132)
  - Rx: XML (XML) command
    `DfMode`: `eOperationMode=DFMODE_RX` or
  - FFM:
    `eOperationMode=DFMODE_FFM`.
- the Video mode is not "Off": XML command
  - `VideoPan`: `eVideoMode` is not `VIDEO_OFF`,

  and also
- the display variant is not "Off" or "IFPan":
  - `VideoPan`: `eDisplayVariants` is not `DISPLAY_VARIANTS_OFF` and
    `eDisplayVariants` is not `DISPLAY_VARIANTS_IF_PAN`,
    thus
    `eDisplayVariants=DISPLAY_VARIANTS_VIDEO_PAN_x`.

No subset of data can be selected or suppressed, i.e. the selector flags (Table 3-57) for video data only contain

- *OPTIONAL_HEADER*

Flag is always set on enabling trace: `SelectorFlags` = 80000000_{16}; to reset and set use XML commands

- `TraceFlagDisable`

- `TraceFlagEnable`

Data is sent depending on the selector flags set; the order corresponds to the significance (upward) of these flags. The number of pairs of values of the data section (i.e. the number of values corresponding to one selector flag, not the overall sum) is defined in the `NumberOfTraceItems` item of the Trace Attribute (see Table 3-55).

The Optional Header (here called *Video trace header*) is described in detail in Table 3-70.

Table 3-70: Description of the Video trace header (58 bytes = 464 bits).

Video trace header			
	Data type	**Parameter**	**Description**
	INT16	VideoMode	Video mode: • 0: OFF • 1: SHORT (16 bit) • 2: LONG (32 bit)
	INT16	FrameLength	Frame length [byte]
	UINT32	SampleRate	Sampling rate [Hz]
	UINT32	Freq_low	Rx frequency [Hz] (as a 64-bit value, lower, i.e. least significant part)
	UINT32	Bandwidth	Demodulation bandwidth [Hz]
	UINT16	Demodulation	Demodulation mode: • 0: FM • 1: AM • 2: Pulse • 3: PM • 4: I/Q • 5: ISB • 6: CW • 7: USB • 8: LSB • 9: TV
	INT16	RxAttenuation[1)]*	Overall attenuation from antenna input (depending on HF option equipping) • **X11** to **X13** ***HF***, • **X21** to **X23** ***V / UHF*** • **X31** to **X33** ***HF / V/U/SHF***. to level of **IF data**[2)]*

	INT16	Flags	• Bit 0: SignalValid:
			  – 0: current signal not valid due to different reasons
			  – 1: current signal valid
			• Bit 1: Blanking (cf Chapter 3.11.6.3, "Blanking", on page 175):
			  – 0: not active
			  – 1: active[3)]*
			Mind Note "Significance of Settings" on page 175

2	UINT8	(reserved)	2 bytes reserved for 64-bit alignment
8	UINT8	DemodulationString[1][1)]* DemodulationString[2] ... DemodulationString[8]	Demodulation mode as a string (left-aligned with the remaining characters being filled by 'NUL'): • "FM": FM • "AM": AM • "PULS": Pulse • "PM": PM • "IQ": I/Q • "ISB": ISB • "CW": CW • "USB": USB • "LSB": LSB • "TV": TV
	UINT64	SampleCount	Number of 1st sample

Video trace header			
	Data type	**Parameter**	**Description**
	UINT32	Freq_high	Rx frequency [Hz · 2^{32}] (as a 64-bit value, upper, i.e. most significant part)
4	UINT8	(reserved)	4 bytes reserved for 64-bit alignment
	UINT64	StartTimestamp	Timestamp [ns] at start of data sampling; value expressed as elapsed time since Unix epoch, without leap seconds
	INT16	SignalSource[1)]*	Signal source: ● 0: antenna ● 1: replay of recording

1) *Mind Table 3-51 on page 256.*

2) *See footnote 2 and 4 of Table 3-68.*

3) *Blanking will stay on for at least 320 ms irrespectively of how long it was asserted.*

An example of a complete *Video* data trace (called *Video attribute*), as a Trace Attribute (conventional type), i.e. including length, selector flags and optional header indications, is shown in Table 3-71 (cf also Table 3-55).

Table 3-71: Example of a complete Video attribute.

<table>
<tr><th colspan="4">Video attribute</th></tr>
<tr><th></th><th>Data type</th><th>Parameter</th><th>Description</th></tr>
<tr><td></td><td>INT16</td><td>NumberOfTraceValues</td><td>Length <code>n</code> [pairs] of the <code>AM_sample/FM_sample</code> section (corresponds to the <code>NumberOfTraceItems</code>)</td></tr>
<tr><td></td><td>INT8</td><td>(reserved)</td><td>Not used</td></tr>
<tr><td></td><td>UINT8</td><td>OptionalHeaderLength</td><td>Length <code>m</code> [byte] of <code>OptionalHeader</code> section:
● 58: optional header included
● 0: no optional header included</td></tr>
<tr><td></td><td>UINT32</td><td>SelectorFlags</td><td>Bit field, see description of selector flags, Table 3-57:
80000000_{16} for optional header in the R&S DDF5GTS</td></tr>
<tr><td><code>m</code></td><td>UINT8</td><td>OptionalHeader</td><td>Video trace header as described in Table 3-70</td></tr>
<tr><td rowspan="7">2<code>n</code></td><td rowspan="7">INT16[1)]*</td><td>AM_sample[1]</td><td rowspan="7">Video data pairs: <code>n</code> pairs in fixed point notation (see above)</td></tr>
<tr><td>FM_sample[1]</td></tr>
<tr><td>AM_sample[2]</td></tr>
<tr><td>FM_sample[2]</td></tr>
<tr><td>...</td></tr>
<tr><td>AM_sample[<code>n</code>]</td></tr>
<tr><td>FM_sample[<code>n</code>]</td></tr>
</table>

1) *INT32 with 32-bit case (`VideoMode` set to LONG).*

3.18.2.12 VDPan

The *VDPan* (Video panorama) data trace contains so-called video data, i.e. the spectrum of the signal currently demodulated is output in amplitude (AM) or frequency demodulation (FM). The selection between AM and FM samples is done by the XML (XML) command [2.4]

- `VideoPan`, parameter `eDisplayVariants`,

and all demodulation parameters always correspond to the values the R&S DDF5GTS is set to at the moment.

If desiring to see the time signal of the data instead, select the *Video* data trace (3.18.2.11).

Conditions

The *VDPan* data trace only issues data if

- the R&S DDF5GTS is in the DF mode (Chapter 3.7 on page 132)
  – Rx: XML command
  `DfMode`: `eOperationMode=DFMODE_RX` or
  – FFM:
  `eOperationMode=DFMODE_FFM`,

  and also
- the Video mode is not "Off":
  – `VideoPan`: `eVideoMode` is not `VIDEO_OFF`.

The only subset of data to be selected or suppressed is the level data, i.e. the selector flags (Table 3-57) for video panorama data only contain

- *LEVEL*
- *OPTIONAL_HEADER*

Flags are always set on enabling trace: `SelectorFlags` = `80000001`$_{16}$; to reset and set use XML commands

- `TraceFlagDisable`
- `TraceFlagEnable`

Data is sent depending on the selector flags set; the order corresponds to the significance (upward) of these flags. The number of values of the data section (i.e. the number of values corresponding to one selector flag, not the overall sum) is defined in the `NumberOfTraceItems` item of the Trace Attribute (see Table 3-55).

The Optional Header (here called *VDPan trace header*) is described in detail in Table 3-72.

Table 3-72: Description of the VDPan trace header (62 bytes = 496 bits).

VDPan trace header			
	Data type	**Parameter**	**Description**
	UINT32	Freq_low	IF panorama center frequency [Hz] (as a 64-bit value, lower, i.e. least significant part)
	UINT32	FreqSpan	Frequency span [Hz]
	INT16	(reserved)	Not used
	INT16	DisplayVariant	Averaging mode: • 2: AM | LEFT • 3: FM | RIGHt • 4: IQ • 5: AMSquare • 6: FMSquare • 7: IQSquare
	INT32	(reserved)	Not used
	UINT32	Freq_high	IF panorama center frequency [Hz · 2^{32}] (as a 64-bit value, upper, i.e. most significant part)
	INT32	(reserved)	Not used
	UINT32	DemodFreq_low	Demodulation frequency [Hz] (as a 64-bit value, lower, i.e. least significant part)
	UINT32	DemodFreq_high	Demodulation frequency [Hz · 2^{32}] (as a 64-bit value, upper, i.e. most significant part)
	UINT64	OutputTimestamp	Timestamp [ns] at data output; value expressed as elapsed time since Unix epoch, without leap seconds
	UINT32	StepFreqNumer[1)*]	Numerator value of fractional step frequency [Hz][2)*]
	UINT32	StepFreqDenom[1)*]	Denominator value of fractional step frequency [Hz][2)*]
	INT16	SignalSource[1)*]	Signal source: • 0: antenna • 1: replay of recording
	INT16	MeasureMode[1)*]	Measuring mode (see Chapter 3.13.2.3, "Measuring Modes", on page 190): • 0: Continuous • 1: Periodic
	UINT64	MeasureTimestamp	Timestamp [ns] at measurement; value expressed as elapsed time since Unix epoch, without leap seconds
	INT16	Selectivity[1)*]	FFT selectivity • 0: Auto • 1: Normal (prolongation factor 1, i.e. none) • 2: Narrow (factor 2) • 3: Sharp (factor 4)

1) *Mind Table 3-51 on page 256.*

2) *See footnote 2 of Table 3-62 on page 269.*

An example of a complete *VDPan* data trace (called *VDPan attribute*), as a Trace Attribute (conventional type), i.e. including length, selector flags and optional header indications, is shown in Table 3-73 (cf also Table 3-55).

Table 3-73: Example of a complete VDPan attribute.

VDPan attribute			
	Data type	**Parameter**	**Description**
	UINT16	NumberOfTraceValues	Length `n` [channels] of the `Level` section (corresponds to the `NumberOfTraceItems`)
	INT8	(reserved)	Not used
	UINT8	OptionalHeaderLength	Length `m` [byte] of `OptionalHeader` section: ● 60: optional header included ● 0: no optional header included
	UINT32	SelectorFlags	Bit field, see description of selector flags, Table 3-57: `80000001`$_{16}$ for optional header and level in the R&S DDF5GTS
`m`	UINT8	OptionalHeader	*VDPan trace header* as described in Table 3-72
`n`	INT16	Level[1]	Level [1/10 dB] of the `i`-th channel (1 ≤ `i` ≤ `n`)[1)]*
		Level[2]	
		...	
		Level[`n`]	

1) *The supplied level values [1/10 dB] refer to Full Scale of the internally controlled video signal. To transfer these values into the range of –160 dB to 0 dB Full Scale, subtract 120 dB (the value of 1200) from the values supplied.*

3.18.2.13 PScan

The *PScan* (panorama scan) data trace contains panorama scan level data.

Conditions

The *PScan* data trace only issues data if [2.4]

- the R&S DDF5GTS is in the DF mode (Chapter 3.7 on page 132)
  – Rx PScan: XML (XML) command `DfMode: eOperationMode=DFMODE_RXPSCAN`.

The only subset of data to be selected or suppressed is the level data (a selection whether all data or only data exceeding the squelch level is to be output, as in other *Rohde & Schwarz* products, cannot be done), i.e. the selector flags (Table 3-57) for panorama data contain

- *LEVEL*
- *OPTIONAL_HEADER*

Flags are always set on enabling trace: `SelectorFlags` = `80000001`$_{16}$; to reset and set use XML commands

- `TraceFlagDisable`

- `TraceFlagEnable`

Data is sent depending on the selector flags set; the order corresponds to the significance (upward) of these flags. The number of values of the data section (i.e. the number of values corresponding to one selector flag, not the overall sum) is defined in the `NumberOfTraceItems` item of the Trace Attribute (see Table 3-55).

The Optional Header (here called *PScan trace header*) is described in detail in Table 3-74.

Table 3-74: Description of the PScan trace header (52 bytes = 416 bits).

PScan trace header			
	Data type	**Parameter**	**Description**
	UINT32	StartFreq_low	Start frequency [Hz] (as a 64-bit value, lower, i.e. least significant part)
	UINT32	StopFreq_low	Stop frequency [Hz] (as a 64-bit value, lower, i.e. least significant part)
	UINT32	StepFreq	Step frequency [Hz]
	UINT32	StartFreq_high	Start frequency [Hz · 2^{32}] (as a 64-bit value, upper, i.e. most significant part)
	UINT32	StopFreq_high	Stop frequency [Hz · 2^{32}] (as a 64-bit value, upper, i.e. most significant part)
4	UINT8	(reserved)	4 bytes reserved for 64-bit alignment
	UINT64	OutputTimestamp	Timestamp [ns] at data output; value expressed as elapsed time since Unix epoch, without leap seconds
	UINT32	StepFreqNumer[1)]*	Numerator value of fractional step frequency [Hz][2)]*
	UINT32	StepFreqDenom[1)]*	Denominator value of fractional step frequency [Hz][2)]*
	UINT64	FreqOfFirstStep	Frequency of first step in this protocol [Hz][2)]*
	INT16	AvgType[1)]*	Averaging mode: • 0: MINimum • 1: MAXimum • 2: AVERage | SCALar • 3: CLRWRITE | OFF
	INT16	SetIndex[1)]*	Index of segmented PScan set • > 0: index number • 0: common (non-segmented) PScan

[1)] *Mind Table 3-51 on page 256.*

[2)] *See footnote 2 of Table 3-62 on page 269.*

An example of a complete *PScan* data trace (called *PScan attribute*), as a Trace Attribute (conventional type), i.e. including length, selector flags (*LEVEL* and *OPTIONAL_HEADER*) and optional header indications, is shown in Table 3-75 (cf also Table 3-55).

Table 3-75: Example of a complete PScan attribute.

PScan attribute			
	Data type	**Parameter**	**Description**
	INT16	NumberOfFrames	Length `n` [items] of the `Level` section (corresponds to the `NumberOfTraceItems`)
	INT8	(reserved)	Not used
	UINT8	OptionalHeaderLength	Length `m` [byte] of `OptionalHeader` section: • 52: optional header included • 0: no optional header included
	UINT32	SelectorFlags	Bit field, see description of selector flags, Table 3-57: `80000001`$_{16}$ for optional header and level in the R&S DDF5GTS
`m`	UINT8	OptionalHeader	*PScan trace header* as described in Table 3-74
`n`	UINT16	Level[1]	Level [1/10 dBµV] of the `i`-th channel (1 ≤ `i` ≤ `n`)
		Level[2]	
		...	
		Level[`n`]	

3.18.2.14 SelCall

The *SelCall* data trace outputs data obtained from an analysis of SelCal (selective calling) signals.

Conditions

The *SelCall* data trace only issues data if [2.4]

- the option R&S DDFGTS-IM, *ITU Measurement Software*, is installed,
- the SelCal decoder is enabled: XML (XML) command
  – `SelCall: bDecoderEnabled=true`,
- the R&S DDF5GTS is in the DF mode (Chapter 3.7 on page 132)
  – Rx: XML command
    `DfMode: eOperationMode=DFMODE_RX` or
  – FFM:
    `eOperationMode=DFMODE_FFM` and
- a pilot tone signal has been received.

The *SelCall* trace data is needed especially if the *ITU Measurement Software* option (R&S DDFGTS-IM, see Chapter 2.6.3 on page 82) is installed. This option can be used to decode selective-call methods and to demodulate pagers. The following selective-call methods are supported:

- CCIR1
- CCIR7
- CCITT
- CTCSS
- DCS
- DTMF
- EEA
- EIA
- EURO
- NATEL
- VDEW
- ZVEI1
- ZVEI2

For detailed information about the specific methods, refer to Chapter 3.15, "Selective Calling", on page 220 and to relevant publications.

No subset of data can be selected or suppressed, i.e. the selector flags (Table 3-57) for SelCal data can only contain

- *OPTIONAL_HEADER*

Flag is always set on enabling trace: `SelectorFlags` = `80000000`$_{16}$; to reset and set use XML commands

- `TraceFlagDisable`
- `TraceFlagEnable`

Data is sent depending on the selector flags set; the order corresponds to the significance (upward) of these flags. The number of values of the data section (i.e. the number of values corresponding to one selector flag, not the overall sum) is defined in the `NumberOfTraceItems` item of the Trace Attribute (see Table 3-55).

The Optional Header (here called *SelCall trace header*) is described in detail in Table 3-76.

Table 3-76: Description of the SelCall trace header (48 bytes = 384 bits).

SelCall trace header			
	Data type	**Parameter**	**Description**
	UINT32	Freq_low	Rx frequency [Hz] (as a 64-bit value, lower, i.e. least significant part)
	UINT32	Bandwidth	Demodulation bandwidth [Hz]
	UINT16	Demodulation	Demodulation mode: • 0: FM • 1: AM • 2: Pulse • 3: PM • 4: I/Q • 5: ISB • 6: CW • 7: USB • 8: LSB • 9: TV
8	UINT8	DemodulationString[1]	Demodulation mode as a string (left-aligned with the remaining characters being filled by 'NUL'): • "FM": FM • "AM": AM • "PULS": Pulse • "PM": PM • "IQ": I/Q • "ISB": ISB • "CW": CW • "USB": USB • "LSB": LSB • "TV": TV
		DemodulationString[2]	
		...	
		DemodulationString[8]	
	UINT16	SelCallMode	Detected SelCal mode: • 0: CCIR7 • 1: CCIR1 • 2: CCITT • 3: EEA • 4: EIA • 5: EURO • 6: NATEL • 7: VDEW • 8: ZVEI1 • 9: ZVEI2 • 10: DTMF • 11: CTCSS • 12: DCS
10	UINT8	SelCallModeString[1]	Detected SelCal mode as a string (left-aligned with the remaining characters being filled by 'NUL'):

SelCall trace header			
	Data type	**Parameter**	**Description**
		SelCallModeString[2] ... SelCallModeString[10]	• "CCIR7": CCIR7 • "CCIR1": CCIR1 • "CCITT": CCITT • "EEA": EEA • "EIA": EIA • "EURO": EURO • "NATEL": NATEL • "VDEW": VDEW • "ZVEI1": ZVEI1 • "ZVEI2": ZVEI2 • "DTMF": DTMF • "CTCSS": CTCSS • "DCS": DCS
	UINT32	Freq_high	Rx frequency [Hz · 2^{32}] (as a 64-bit value, upper, i.e. most significant part)
6	UINT8	(reserved)	6 bytes reserved for 64-bit alignment
	UINT64	OutputTimestamp	Timestamp [ns] at data output; value expressed as elapsed time since Unix epoch, without leap seconds

An example of a complete *SelCall* data trace (called *SelCall attribute*), as a Trace Attribute (conventional type), i.e. including length, selector flags (only *OPTIONAL_HEADER*) and optional header indications, is shown in Table 3-77, a code sequence example can be seen in Table 3-78 (cf also Table 3-55).

Table 3-77: Example of a complete SelCall attribute.

SelCall attribute			
	Data type	**Parameter**	**Description**
	INT16	NumberOfCodes	Length `n` [items] of the `SelCallCodes` section (corresponds to the `NumberOfTraceItems`)
	INT8	(reserved)	Not used
	UINT8	OptionalHeaderLength	Length `m` [byte] of `OptionalHeader` section: • 48: optional header included • 0: no optional header included
	UINT32	SelectorFlags	Bit field, see description of selector flags, Table 3-57: `80000000`$_{16}$ for optional header in the R&S DDF5GTS
`m`	UINT8	OptionalHeader	*SelCall trace header* as described in Table 3-76
`n`	UINT32	SelCallCodes[1] SelCallCodes[2] ... SelCallCodes[`n`]	SelCall codes (`n` codes)

Table 3-78: Code sequence example for number 0 89 / 41 29 - 0.

	SelCallCodes[`i`]							
NumberOfCodes	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]
8	0	8	9	4	1	2	9	0

In the case of CTCSS (see Chapter 3.15), codes are coded as CTCSS frequencies in 1/10 Hz; e.g. 151.4 Hz would be coded as "1514".

See also the description of the XML command

- `SelCall`

Additionally, the R&S DDFGTS-IM option is capable to analyze Radio Data System (RDS) signals. The signal content (messages such as station name, frequency lists, traffic information etc.) is demodulated and decoded. More detailed information can be taken from Chapter 3.12, "RDS", on page 180.

Note that the RDS information does not come as mass data but only on individual queries with the appropriate XML command

- `RDS`

3.18.2.15 GPSCompass

The *GPSCompass* data trace contains GPS and compass data. Find more information about nautical angles in Chapter 2.5.1.2, "Nautical Angles (Ship Deviations)", on page 47.

Conditions

The *GPSCompass* data trace always issues data.

Some of the data delivered by the *GPSCompass* data trace is also issued with the *DFPScan* (DF panorama) data trace (3.18.2.17), but this additional GPS trace is useful if GPS and compass data is needed while receiving but not direction finding.

No subset of data can be selected or suppressed, i.e. the selector flags (Table 3-57) for GPS and compass data only contain

- *OPTIONAL_HEADER*

Flag is always set on enabling trace: `SelectorFlags` = `80000000`$_{16}$; to reset and set use XML (XML) commands [2.4]

- `TraceFlagDisable`
- `TraceFlagEnable`

The Optional Header (here called *GPSCompass trace header*) is described in detail in Table 3-79.

Table 3-79: Description of the GPSCompass trace header (8 bytes = 64 bits).

GPSCompass trace header			
	Data type	**Parameter**	**Description**
	UINT64	OutputTimestamp	Timestamp [ns] at data output; value expressed as elapsed time since Unix epoch, without leap seconds

An example of a complete *GPSCompass* data trace (called *GPSCompass attribute*), as a Trace Attribute (conventional type), i.e. including length, selector flags (only *OPTIONAL_HEADER*) and optional header indications, is shown in Table 3-80 (cf also

Table 3-55). Note that in this case there is just 1 data subset with a fixed number of bytes (96).

Table 3-80: Example of a complete GPSCompass attribute.

GPSCompass attribute			
	Data type	**Parameter**	**Description**
	INT16	NumberOfTraceValues	Number of GPS data sections: always 1
	INT8	(reserved)	Not used
	UINT8	OptionalHeaderLength	Length `m` [byte] of `OptionalHeader` section: • 8: optional header included • 0: no optional header included
	UINT32	SelectorFlags	Bit field, see description of selector flags, Table 3-57: `80000000`$_{16}$ for optional header in the R&S DDF5GTS
`m`	UINT8	OptionalHeader	*GPSCompass trace header* as described in Table 3-79
GPS data (96 bytes = 768 bits)			
	UINT16	CompassHeading	Heading [1/10 °] of a connected compass (antenna yaw, see Chapter 2.5.1.2) vs. CompassHeadingType (see below) (0 to 3599)
	INT16	CompHeadType	Heading type of the connected compass: • –1: UNDEFINED: no compass value available • 0: UNKNOWN: heading unknown • 1: COMPASS: heading value uncorrected • 2: MAGNETIC: heading value related to magnetic north (magnetic heading) • 3: TRUE: heading value related to true (geographic) north (true heading) • 4: BAD: heading value bad because movement too slow (only for GPS compass, see Chapter 2.5.1, "Definition of Terms", on page 46) • 5: GPS: heading value derived from movement related to GPS • 6: GPS_SLOW: heading value derived from movement related to GPS, but speed too low (< 1 m/s)
	Start GPSHeader (24 bytes = 192 bits)		
	INT16	GPSValid	Denotes whether GPS data (from `CompassHeading`) to be considered valid: • 0: not valid • 1: valid
	INT16	NoOfSatInView	Number of satellites in view: • 0 to 12: number of satellites • –1: GPS_UNDEFINED (no GPGGA sentence received, see Chapter 2.5.6.3, "Evaluated NMEA 0183 Sentences", on page 77)
	INT16	LatRef	Direction of geographical latitude: • 'N': N • 'S': S
	INT16	LatDeg	Latitude degrees [°]
	FLOAT (32)	LatMin	Latitude minutes [']

GPSCompass attribute			
	Data type	**Parameter**	**Description**
	INT16	LonRef	Direction of geographical longitude: ● 'E': E ● 'W': W
	INT16	LonDeg	Longitude degrees [°]
	FLOAT (32)	LonMin	Longitude minutes [']
	FLOAT (32)	Dilution	Mean dilution of precision (DOP) of location: ● 1: ideal ● 1 to 2: excellent ● 2 to 5: good ● 5 to 10: moderate ● 10 to 20: fair ● more than 20: poor
	End GPSHeader		
	INT16	AntValid[1)]*	Denotes whether antenna data (`AntElev` and `AntRoll`) to be considered valid: ● 0: not valid ● 1: valid
	INT16	AntTiltOver[2)]*	Denotes whether antenna tilt over: ● 0: not tilt over ● 1: tilt over
	INT16	AntElev[1)]*	Antenna elevation (pitch) [°] seen over the length axis vs. perfect horizontal/vertical position (see Chapter 2.5.1.2 and also `AntElevExact`)
	INT16	AntRoll[1)]*	Antenna roll [°] around the length axis vs. perfect vertical position (see Chapter 2.5.1.2 and also `AntRollExact`)
	INT16	SignalSource[3)]*	Signal source: ● 0: antenna ● 1: replay of recording
	INT16	AngularRatesValid[1)]*	Denotes whether angular rates (`HeadingAngularRate` to `RollAngularRate`) to be considered valid: ● 0: not valid ● 1: valid
	INT16	HeadingAngularRate[1)]*	Heading (yaw) angular rate [1/100 °/s]
	INT16	ElevAngularRate[1)]*	Elevation (pitch) angular rate [1/100 °/s]
	INT16	RollAngularRate[1)]*	Roll angular rate [1/100 °/s]
	*Start GPSExtensionHeader (34 bytes = 272 bits)[3)]**		
	INT16	GeoidalSepValid	Denotes whether geoidal separation to be considered valid: ● 0: not valid ● 1: valid
	INT32	GeoidalSeparation	Geoidal separation [cm][4)]*
	INT32	Altitude	Height above mean sea level [cm]
	INT16	SpeedOverGround	Speed over ground [1/10 m/s]
	INT16	TrackMadeGood	Track made good over ground [1/10 °]

GPSCompass attribute			
	Data type	**Parameter**	**Description**
	FLOAT (32)	PDOP	Positional dilution of precision ● > 0: position dilution ● –1.0: invalid
	FLOAT (32)	VDOP	Vertical dilution of precision ● > 0: vertical dilution ● –1.0: invalid
	UINT64	GPSTimestamp	Timestamp [ns] of GPS position at data output; value expressed as elapsed time since Unix epoch, without leap seconds
	INT32	(reserved)	Reserved for future use
		End GPSExtensionHeader	
	UINT64	CompassTimestamp[1)]*	Timestamp [ns] of compass data at data output; value expressed as elapsed time since Unix epoch, without leap seconds
	INT16	MagDeclinSource	Magnetic declination source: ● 0: none, no magnetic declination ● 1: manual ● 2: GPS
	INT16	MagneticDeclination	Magnetic declination [1/10 °] ● > 0: magnetic declination ● –1: invalid
	INT16	AntRollExact[3)]*	Antenna roll [1/10 °] (see `AntRoll`)
	INT16	AntElevExact[3)]*	Antenna elevation (pitch) [1/10 °] (see `AntElev`)

1) *Data are commonly valid if NMEA 0183 sentences PRSHRP or PANZHRP are available (`CompassTimestamp` only with PRSHRP) (see Chapter 2.5.4, "Gyrostatic Compass with NMEA 0183 Data Output", on page 55).*

2) *Not used with the R&S DDF5GTS, always filled by zero values at present.*

3) *Mind Table 3-51 on page 256.*

4) *See footnote 1 of Table 3-16 on page 129.*

3.18.2.16 ANT_LEVEL

The *ANT_LEVEL* data trace contains antenna level data arising from an antenna element test or an antenna cable test (find more details in Chapter 4.1.7 on page 341).

The count of channels per hop

- channels/hop = `MeasureSettingsFFM:eSpan` / `eDfPanStep`

is limited to 3200 with antenna element test or antenna cable test activated. Attempts to do inconsistent settings will be rejected with an error message.

Conditions

The *ANT_LEVEL* data trace only issues data if [2.4]

- the R&S DDF5GTS is in the DF mode (Chapter 3.7 on page 132)
  - FFM: XML (XML) command
    `DfMode: eOperationMode=DFMODE_FFM,`
- the antenna element test or the antenna cable test is activated:
  - for executing the antenna element test with antennas with no test radiator integrated:
    `AntennaLevelSwitch: eAntLevelSwitch=ANTLEVEL_ON_EMITTER_OFF`
  - with antennas with integrated test radiator:
    `eAntLevelSwitch=ANTLEVEL_ON_EMITTER_ON`
  - for executing the antenna cable test:
    `eAntLevelSwitch=ANTLEVEL_ON_CABLE`

No subset of data can be selected or suppressed, i.e. the selector flags (Table 3-57) for antenna level data only contain

- *OPTIONAL_HEADER*

Flag is always set on enabling trace: `SelectorFlags` = 80000000_{16}; to reset and set use XML commands

- `TraceFlagDisable`
- `TraceFlagEnable`

Data is sent depending on the selector flags set; the order corresponds to the significance (upward) of these flags. The number of values of the data section (i.e. the number of values corresponding to one selector flag, not the overall sum) is defined in the `NumberOfTraceItems` item of the Trace Attribute (see Table 3-55).

The Optional Header (here called *ANT_LEVEL trace header*) is described in detail in Table 3-81.

Table 3-81: Description of the ANT_LEVEL trace header (56 bytes = 448 bits).

ANT_LEVEL trace header			
	Data type	**Parameter**	**Description (see also [2.4])**
	UINT64	OutputTimestamp	Timestamp [ns] at data output; value expressed as elapsed time since Unix epoch, without leap seconds
	UINT64	Frequency	Frequency [Hz] of central channel
	INT32	K_Factor	k-factor for field strength calculation [1/10 dB(1/m)] of central channel[1)*]; if `eAntLevelSwitch` • ≠ `ANTLEVEL_ON_CABLE`: k-factor • = `ANTLEVEL_ON_CABLE`: ILLEGAL_ANTFACTOR
24	UINT8	AntennaString[1] AntennaString[2] ...	Antenna name as a string (left-aligned with the remaining characters being filled by 'NUL')

ANT_LEVEL trace header			
	Data type	**Parameter**	**Description (see also [2.4])**
		AntennaString[24]	
	INT32	DFStatus	DF status: boolean information for each measurement (see Table 3-84)
	INT16	CalGenLevel	Calibration generator level [1/10 dBμV]; if `eAntLevelSwitch` • ≠ `ANTLEVEL_ON_EMITTER_OFF`: level • = `ANTLEVEL_ON_EMITTER_OFF`: ILLEGAL_LEVEL
	INT16	AntLevelSwitch	Antenna level switch: • `ANTLEVEL_OFF`: normal DF or Rx operation • `ANTLEVEL_ON_EMITTER_OFF`: antenna element test operation without antenna test radiator • `ANTLEVEL_ON_EMITTER_ON`: ditto, with test radiator • `ANTLEVEL_ON_CABLE`: antenna cable test operation
	INT16	JobID	Job ID (lower 16 bits of ID of the request having defined the current DF order)
	INT16	(reserved)	Not used

[1)] *See footnotes 2 and 4 of Table 3-68 on page 277.*

An example of a complete *ANT_LEVEL* data trace (called *ANT_LEVEL attribute*), as a Trace Attribute (conventional type), i.e. including length, selector flags (only *OPTIONAL_HEADER*) and optional header indications, is shown in Table 3-82 (cf also Table 3-55).

Table 3-82: Example of a complete ANT_LEVEL attribute with all selector flags set.

ANT_LEVEL attribute			
	Data type	**Parameter**	**Description**
	UINT16	NumberOfTraceValues	Length `n` [items] (number of antenna elements) of each of the data sections (corresponds to the `NumberOfTraceItems`)
	UINT8	(reserved)	Not used
	UINT8	OptionalHeaderLength	Length `m` [byte] of `OptionalHeader` section: • 56: optional header included • 0: no optional header included
	UINT32	SelectorFlags	Bit field, see description of selector flags, Table 3-57: 80000000_{16} for optional header and level in the R&S DDF5GTS
`m`	UINT8	OptionalHeader	*ANT_LEVEL trace header* as described in Table 3-81
`n`	INT16	Ant_Level[1] Ant_Level[2] ... Ant_Level[`n`]	• Antenna element test: antenna level [1/10 dBμV] for all `n` antenna elements • Antenna cable test: level of each antenna channel (DF path: 3 in the case of the R&S DDF5GTS) (for order of issuing refer to Chapter 4.1.7 on page 341)

3.18.2.17 DFPScan

A *DFPScan* (DF panorama) data trace is issued as the result of each averaging block.

The *DFPScan* data trace exists in two variants:

- Standard (normal DF, Section "Standard Case")
- Super-resolution (Section "Super-Resolution Case")

Distinction which variant an individual data set belongs to is done by the `STATUS_DFMETHOD` item of the DF status bit field (Table 3-84).

Standard Case

The *DFPScan* data trace (standard case) contains DF panorama data (in the FFM the DF panorama shows signals centered around the current frequency).

Conditions

The *DFPScan* data trace (standard case) only issues data if [2.4]

- the R&S DDF5GTS is in the DF mode (Chapter 3.7 on page 132)
  – FFM: XML (XML) command
    `DfMode`: `eOperationMode=DFMODE_FFM`,
  – Search:
    `eOperationMode=DFMODE_SEARCH` or
  – Scan:
    `eOperationMode=DFMODE_SCAN`,
- valid DF settings have been specified and
- the antenna element test is not activated:
  – `AntennaLevelSwitch`: `eAntLevelSwitch=ANTLEVEL_OFF`.

The subsets of data to be selected or suppressed are the various level data, azimuth, elevation, DF quality and a DF channel status, i.e. the selector flags (Table 3-57) for DF panorama data contain

- *DF_LEVEL*
- *AZIMUTH*
- *DF_QUALITY*
- *DF_FSTRENGTH*
- *DF_LEVEL_CONT*
- *ELEVATION*
- *DF_CHANNEL_STATUS*
- *DF_OMNIPHASE*
- *OPTIONAL_HEADER*

Flags are always set on enabling trace, except the *DF_OMNIPHASE* flag: `SelectorFlags` = `810CF800`$_{16}$; to reset and set use XML commands

- `TraceFlagDisable`
- `TraceFlagEnable`

Mind that the *DF_OMNIPHASE* flag never will be set by default, also not with a Watson-Watt antenna connected, always use the command to activate it.

Data is sent depending on the selector flags set; the order corresponds to the significance (upward) of these flags. The number of values of each data section (i.e. the number of values corresponding to one selector flag, not the overall sum) is defined in the `NumberOfTraceItems` item of the Trace Attribute (see Table 3-56).

The Optional Header (here called *DFPScan trace header*) is described in detail in Table 3-83, for details about GPS data also refer to Chapter 2.5.6, "GNSS Receiver", on page 76.

Table 3-83: Description of the DFPScan trace header (80 bytes = 640 bits).

DFPScan trace header			
	Data type	**Parameter**	**Description**
	INT32	ScanRangeID	Scan range identification number
	INT32	ChansInScanRange	Number of channels in current scan range [1 to (5000 · 9601)]
	UINT64	Frequency	Frequency [Hz] of 1st channel in current scan range
	INT32	LogChannel	Logical channel number in current scan range of 1st channel in current packet [0 to (5000 · 9601) – 1]
	INT32	StepFreqNumer[1)]*	Numerator value of channel raster [Hz][2)]*
	INT32	StepFreqDenom[1)]*	Denominator value of channel raster [Hz][2)]*
	INT32	Span	Frequency span (realtime bandwidth) [Hz]
	FLOAT (32)	Bandwidth	Channel bandwidth [Hz]
	INT32	MeasureTime	Averaging time [µs] per hop
	UINT16	MeasureCount_low	Count of measurements (antenna cycles) within averaging time (as a 32-bit value, lower, i.e. least significant part): ● > 0: count ● –1: undefined
	INT16	Threshold	Averaging level threshold [dBµV]
	INT16	CompassHeading	Heading [1/10 °] of a connected compass (antenna yaw, see 3.18.2.15) vs. `CompassHeadingType` (see below) [0 to 3599]
	INT16	CompHeadType	Heading type of the connected compass: ● –1: UNDEFINED: no compass value available ● 0: UNKNOWN: heading unknown ● 1: COMPASS: heading value uncorrected ● 2: MAGNETIC: heading value related to magnetic north (magnetic heading) ● 3: TRUE: heading value related to true (geographic) north (true heading) ● 4: BAD: heading value bad because movement too slow (only for GPS compass, see Chapter 2.5.1, "Definition of Terms", on page 46)
	INT32	DFStatus	DF status: boolean information for each measurement (see Table 3-84)
	UINT64	SweepTime	Time [ns] required for one sweep
	UINT64	MeasureTimestamp	Timestamp [ns] at measurement; value expressed as elapsed time since Unix epoch, without leap seconds
	UINT16	JobID	Job ID (lower 16 bits of ID of the request having defined the current DF order)

DFPScan trace header			
	Data type	**Parameter**	**Description**
	INT16	SRSelectorflags	Selector flags for super-resolution data (only with super-resolution, see Table 3-87 on page 303)
	UINT8	SRWaveCount	Number `w` of waves issued per channel: • = 0: no super-resolution in use • > 0: count of waves detected (only with super-resolution)
	UINT8	NoOfEigenvalues	Number `e` of eigenvalues (only relevant with super-resolution; to be ignored otherwise)
	INT16	MeasureCount_high	Count of measurements (antenna cycles) within averaging time (as a 32-bit value, upper, i.e. most significant part) (see `MeasureCount_low`)
	INT32	HopCount	Count of measurements (block averaging results, i.e. count of *DFPScan* traces issued in total) within hop dwell time (cf Chapter 3.7.6, "Scan Mode", on page 144): • > 0: count • –1: undefined

[1] *Mind Table 3-51 on page 256.*

[2] *See footnote 2 of Table 3-62 on page 269.*

Find details of item DF status in Table 3-84.

Table 3-84: DF status.

DF status		
Bit	**Name**	**Description**
31 (MSB) to 28	(reserved)	Reserved for future extensions
27 to 24	STATUS_DFMODE	DF mode: • 2 (0010_2): FFM: Fixed Frequency Mode • 3 (0011_2): SCAN: Scan • 4 (0100_2): SEARCH: Search • 5 (0101_2): GSM: GSM • 15 (1111_2): CAL: calibration
23 to 22	(reserved)	Reserved for future extensions
21	STATUS_FSTRCOR	Antenna factor (k-factor) correction data: • 0: not applied • 1: applied
20	STATUS_AZIMCOR	Azimuth correction data: • 0: not applied • 1: applied
19 to 16	STATUS_AVGMODE	Averaging mode: • 0 (0000_2): Continuous Mode • 1 (0001_2): Gated Mode • 2 (0010_2): Normal Mode

DF status		
Bit	**Name**	**Description**
15 to 12	STATUS_DFMETHOD	DF method: • 0 (0000_2): (reserved) • 1 (0001_2): WW: Watson-Watt • 2 (0010_2): CORR: correlation • 3 (0011_2): SR: super-resolution • 4 (0100_2): VM: vector matching
11	(reserved)	Reserved for future extensions
10	STATUS_PREAMP	Antenna preamplifier: • 0: OFF: off • 1: ON: on
9 to 8	STATUS_ANTPOL	Polarisation: • 0 (00_2): VERT: linear vertical • 1 (01_2): HOR: linear horizontal • 2 (10_2): LEFT: circular left-hand (counter-clockwise) • 3 (11_2): RIGHT: circular right-hand (clockwise)
7 to 6	(reserved)	Reserved for future extensions
5	SimulatedDFResults	Simulated DFResults (azimuth, elevation, omniphase, DF level, DF level [continuous])
4	SWEEP_END	Last hop in sweep (sent in each mode, therefore continuously set in FFM): • 0: another than last • 1: last If a hop dwell time (cf Chapter 3.7.6) setting leads to more than one *DFPScan* data trace, this flag is only set with the terminating trace.
3	STATUS_CALIBRATION_OLD	Calibration outdated: • 0: valid • 1: outdated If active, last calibration longer ago than specified calibration interval (only if no automatic calibration active)
2	STATUS_BLANKOUT	Status of the Blanking source, i.e. user controllable validation of bearings (see Chapter 3.11.6.3, "Blanking", on page 175): • 0: not active • 1: active[1)]* Mind Note "Significance of Settings" on page 175
1	STATUS_OVERFLOW	Overflow of ADC input signal of at least one antenna base (Chapter 3.11.6): • 0: no data overflow • 1: data overflow
0 (LSB)	STATUS_VALID	Bearing result valid (Chapter 3.11.6): • 0: bearing not valid due to internal reasons, do not use result • 1: bearing valid

1) *Blanking immediately follows the asserted signal (will not stay on for at least 320 ms).*

An example of a complete *DFPScan* data trace (called *DFPScan attribute*), as a Trace Attribute (advanced type), i.e. including length, selector flags and optional header indications, and with all selector flags set (*DF_LEVEL*, *AZIMUTH*, *DF_QUALITY*, *DF_FSTRENGTH*, *DF_LEVEL_CONT*, *ELEVATION*, *DF_CHANNEL_STATUS*, *DF_OMNIPHASE* and *OPTIONAL_HEADER*) is shown in Table 3-85 (cf also Table 3-56).

The eight data subsets (thus, the selector flags defined in the R&S DDF5GTS except the optional header flag) are in detail:

- **DF level** (selector flag name *DF_LEVEL*): A level information describing the averaged value of a data block. The mode of averaging can be preselected from the so-called Continuous Mode, Normal Mode and Gated Mode (Chapter 3.11.3, "Level Calculation", on page 168 and Chapter 3.11.4, "Averaging Modes", on page 168). In
  – Normal and Gated Mode

  a threshold is in effect excluding all level values below it from averaging, whereas in
  – Continuous Mode

  all values are used for the average result (no threshold existing).
- **Azimuth** (*AZIMUTH*): The horizontal angle of incidence (the DF result), i.e. the direction of the incoming signal in degrees related to north direction.
- **DF quality** (*DF_QUALITY*): A measure for the reliability of the DF result, following from the DF process itself and given in percent.
- **DF field strength** (*DF_FSTRENGTH*): The level of the incoming wave "on air", i.e. before reaching the antenna. This value is concluded from the level of the received signal, but considering the frequency response of the antenna (the so-called k-factors).
- **DF level (continuous)** (*DF_LEVEL_CONT*): Also a level information, but independent of the selected averaging mode, so it delivers always the result as it would be in Continuous Mode (if Continuous Mode is selected, DF Level [continuous] and DF level are the same). This level data is used for plotting the DF spectrum.
- **Elevation** (*ELEVATION*): The vertical angle of incidence (the other part of the DF result), i.e. the signal direction in degrees related to horizontal incidence.
- **DF omniphase** (*DF_OMNIPHASE*): Additional phase information for eliminating the 180° phase ambiguity with Watson-Watt DF evaluation.
- **DF channel status** (*DF_CHANNEL_STATUS*): see Table 3-86.

Table 3-85: Example of a complete DFPScan attribute with all selector flags set, standard case.

DFPScan attribute, standard case			
	Data type	**Parameter**	**Description**
	UINT32	NumberOfTraceValues	Length `n` [items] (number of channels) of each of the data subsets: • `DF_Level` • `DF_Level_Cont` • `Azimuth` • `Elevation` • `DF_Quality` • `DF_Omniphase` • `DF_FStrength` • `DF_Chan_Status`

DFPScan attribute, standard case			
	Data type	**Parameter**	**Description**
			(corresponds to the `NumberOfTraceItems`)
	UINT32	(reserved)	Not used
	UINT32	OptionalHeaderLength	Length `m` [byte] of `OptionalHeader` section: ● 76: optional header included ● 0: no optional header included
	UINT32	SelectorFlagsLow	Bit field, lower, i.e. least significant part; see description of selector flags, Table 3-57: `800CF800`$_{16}$ (as told above) in the R&S DDF5GTS
	UINT32	SelectorFlagsHigh	Ditto, higher, i.e. most significant part: `0` in the R&S DDF5GTS
4	UINT32	(reserved)	Not used
`m`	UINT8	OptionalHeader	*DFPScan trace header* as described in Table 3-83
`n`	INT16	DF_Level[1] DF_Level[2] ... DF_Level[`n`]	DF level [1/10 dBµV] of the `i`-th channel (1 ≤ `i` ≤ `n`)
`n`	INT16	Azimuth[1] Azimuth[2] ... Azimuth[`n`]	Azimuth [1/10 °] of the `i`-th channel (1 ≤ `i` ≤ `n`)
`n`	INT16	DF_Quality[1] DF_Quality[2] ... DF_Quality[`n`]	DF quality [1/10 %] of the `i`-th channel (1 ≤ `i` ≤ `n`): ● > 0: DF data and quality valid ● = 0: all DF data for current frequency channel invalid
`n`	INT16	DF_Fstrength[1] DF_Fstrength[2] ... DF_Fstrength[`n`]	DF field strength [1/10 dB(µV/m)] of the `i`-th channel (1 ≤ `i` ≤ `n`)
`n`	INT16	DF_Level_Cont[1] DF_Level_Cont[2] ... DF_Level_Cont[`n`]	DF level (continuous) [1/10 dBµV] of the `i`-th channel (1 ≤ `i` ≤ `n`)
`n`	INT16	Elevation[1] Elevation[2] ...	Elevation [1/10 °] of the `i`-th channel (1 ≤ `i` ≤ `n`)

DFPScan attribute, standard case			
	Data type	**Parameter**	**Description**
		Elevation[n]	
n	UINT16	DF_Chan_Status[1] DF_Chan_Status[2] ... DF_Chan_Status[n]	DF channel status (Table 3-86) of the i-th channel (1 ≤ i ≤ n)
n	INT16	DF_Omniphase[1] DF_Omniphase[2] ... DF_Omniphase[n]	DF omniphase [1/10 °] of the i-th channel (1 ≤ i ≤ n)

Details of item DF channel status can be seen in Table 3-86.

The *DFPScan* attribute will be extended in the super-resolution (SR) case, see Section "Super-Resolution Case", especially Table 3-89.

Table 3-86: DF channel status.

DF channel status		
Bit	**Name**	**Description**
15 (MSB) to 11	(not used)	
10 to 9	AngleCorrStatus	Angle correction status for this wave (not applicable with super-resolution): • 0 (00_2): disabled (angle value $7FFE_{16}$, illegal, cf Table 3-58) • 1 (01_2): invalid (angle value $7FFF_{16}$, invalid) • 2 (10_2): undefined region • 3 (11_2): valid
	(same as Bit 10 to 9 of SR wave status [Table 3-88, only with super-resolution])	
8 to 7	FieldstrCorrStatus	Field strength correction status for this wave (sum level with super-resolution): • 0 (00_2): disabled (field strength value $7FFE_{16}$, illegal, cf Table 3-58) • 1 (01_2): invalid (field strength value $7FFF_{16}$, invalid) • 2 (10_2): antenna factors valid • 3 (11_2): antenna factors and cable attenuation valid
	(same as Bit 8 to 7 of SR wave status [Table 3-88, only with super-resolution])	
6 to 5	SigCountEstimation	Reliability of count of waves (quality criterion for automatic estimation of count of waves) • 0 (00_2): estimation reliable • 1 (01_2): estimation doubtful (inappropriate measurement settings) • 2 (10_2): noise only (no wave detected in current channel) • 3 (11_2): no estimation performed, but count specified by command (cf Chapter 3.14.5.2, "Wave Estimator", on page 213)

DF channel status		
Bit	**Name**	**Description**
	(same as Bit 1 to 0 of SR wave status [Table 3-88, only with super-resolution])	
4	ChannelValid	Channel valid (all antenna bases active, DF result could be calculated): ● 0: not valid ● 1: valid
3	(not used)	
2	OverThresLevValid	DF level valid (at least 1 averaging cycle has been done for DF level): ● 0: not valid ● 1: valid
1	SquelchOffLevValid	DF level (continuous) valid (at least 1 averaging cycle has been done for DF level [continuous]): ● 0: not valid ● 1: valid
0 (LSB)	FirstChannel	(Marker for internal synchronization)

Super-Resolution Case

The *DFPScan* data trace undergoes some modifications (enlargements, cf Section "Standard Case") in the super-resolution (SR) case that are described subsequently.

A broad outline of the super-resolution method can be seen from Chapter 3.14, "Super-Resolution", on page 201.

Conditions

The *DFPScan* data trace (super-resolution case) only issues data if [2.4]

- super-resolution mode is activated: XML command `MeasureSettingsFFM: eDfAlt=DFALT_SUPERRESOLUTION`
- the R&S DDF5GTS is in the DF mode (Chapter 3.7 on page 132)
  - FFM: `DfMode: eDFMODE=DFMODE_FFM` and
- valid DF settings (see Chapter 3.14.7, "Super-Resolution in the R&S DDF5GTS", on page 219) have been specified.

The additional subsets of data to be selected or suppressed are the SR eigenvalues, level, azimuth, elevation, DF quality and field strength, i.e. the SR selector flags (Table 3-87) for DF panorama (SR case) data contain

- *SR_EIGENVALUE*
- *SR_LEVEL*
- *SR_AZIMUTH*
- *SR_QUALITY*
- *SR_FSTRENGTH*
- *SR_ELEVATION*
- *SR_WAVESTATUS*

SR data is sent depending on the special SR selector flags set; the order corresponds to the significance (upward) of these flags. The number of values of each data section (i.e. the number of values corresponding to one selector flag, not the overall sum) is defined by the `NumberOfTraceItems` item (`n`) of the Trace Attribute (see Table 3-56), multiplied by the `NumberOfEigenvalues` item (`e`) or the `SRWaveCount` item (`w`) of the *DFPScan* trace header (see Table 3-83): `e · n` or `w · n`, respectively.

The SR selector flags come with the *DFPScan* trace header (Table 3-83), thus, in SR case this header may not be suppressed by the user.

Table 3-87: Super-resolution (SR) selector flags.

SR selector flags				
Bit	**Name**	**Value**	**Data type**	**Unit**
15 (MSB) to 7	(not used)			
6	SR_WAVESTATUS	40_{16}	INT16	see table Table 3-88
5	SR_ELEVATION	20_{16}	INT16	1/10 °
4	SR_FSTRENGTH	10_{16}	INT16	1/10 dB(µV/m)
3	SR_QUALITY	8	INT16	1/10 %
2	SR_AZIMUTH	4	INT16	1/10 °
1	SR_LEVEL	2	INT16	1/10 dBµV
0 (LSB)	SR_EIGENVALUE	1	FLOAT (32)	value range 0.0 to 1.0 (non-dimensional)

The individual bits of the SR wave status are explained in Table 3-88.

Table 3-88: SR wave status.

SR wave status		
Bit	**Name**	**Description**
15 (MSB) to 11	(not used)	
10 to 9	AngleCorrStatus	Angle correction status for this wave: ● 0 (00_2): disabled (angle value $7FFE_{16}$, illegal, cf Table 3-58) ● 1 (01_2): invalid (angle value $7FFF_{16}$, invalid) ● 2 (10_2): undefined region ● 3 (11_2): valid
8 to 7	FieldstrCorrStatus	Field strength correction status for this wave: ● 0 (00_2): disabled (field strength value $7FFE_{16}$, illegal, cf Table 3-58) ● 1 (01_2): invalid (field strength value $7FFF_{16}$, invalid) ● 2 (10_2): antenna factors valid ● 3 (11_2): antenna factors and cable attenuation valid
6 to 3	(not used)	

SR wave status		
Bit	**Name**	**Description**
2	FewSamples	Too few samples • 0: enough samples • 1: too few samples
1 to 0 (LSB)	SigCountEstimation	Reliability of count of waves: • 0 (00_2): estimation reliable • 1 (01_2): estimation doubtful • 2 (10_2): noise only • 3 (11_2): no estimation performed, but count specified by command (cf Chapter 3.14.5.2, "Wave Estimator", on page 213)

An example of a complete *DFPScan* data trace (called *DFPScanAttribute*) in SR case, as a Trace Attribute (advanced type), with all SR selector flags set (*SR_EIGENVALUE*, *SR_LEVEL*, *SR_AZIMUTH*, *SR_QUALITY*, *SR_FSTRENGTH*, *SR_ELEVATION* and *SR_WAVESTATUS*) is shown in Table 3-89.

The seven additional data subsets (thus, the SR selector flags defined in the R&S DDF5GTS) are in detail:

- **SR eigenvalue** (selector flag name *SR_EIGENVALUE*): The eigenvalues of a SR procedure.
- **SR level** (*SR_LEVEL*): A level information describing the averaged value of each wave found, thus the count of values equates to number of waves, as do value counts of all remaining (subsequent) items. The mode of averaging is always Continuous Mode (see Section "Standard Case").
- **SR azimuth** (*SR_AZIMUTH*): see *azimuth* ("Standard Case").
- **SR quality** (*SR_QUALITY*): see *DF quality* ("Standard Case"). SR quality will be > 0 for all waves found and = 0 else.
- **SR field strength** (*SR_FSTRENGTH*): see *DF field strength* ("Standard Case").
- **SR elevation** (*SR_ELEVATION*): see *elevation* ("Standard Case").
- **SR wave status** (*SR_WAVESTATUS*): see Table 3-88.

Table 3-89: Example of a complete DFPScan attribute with all selector flags and all SR selector flags set, SR case.

DFPScan attribute, SR case			
	Data type	**Parameter**	**Description**
		DFPScanAttribute	*DFPScan attribute, standard case*, as described in Table 3-85
`e · n`	FLOAT (32)	SR_Eigenvalue[1,1]	Size (see below) of the `j`-th SR eigenvalue (1 ≤ `j` ≤ `e`) in the `i`-th channel (1 ≤ `i` ≤ `n`) Eigenvalues 1 to `e` of each individual channel (`i`) appear in ascending order of size
		SR_Eigenvalue[2,1]	
		...	
		SR_Eigenvalue[`e`,1]	
		SR_Eigenvalue[1,2]	
		SR_Eigenvalue[2,2]	

DFPScan attribute, SR case			
	Data type	**Parameter**	**Description**
		...	
		SR_Eigenvalue[e,n]	
w · n	INT16	SR_Level[1,1]	SR level [1/10 dBµV] of the j-th wave (1 ≤ j ≤ w) in the i-th channel (1 ≤ i ≤ n) (order valid for all subsequent subsets)
		SR_Level[2,1]	
		...	
		SR_Level[w,1]	
		SR_Level[1,2]	
		SR_Level[2,2]	
		...	
		SR_Level[w,n]	
w · n	INT16	SR_Azimuth[1,1]	SR azimuth [1/10 °] of the j-th wave (1 ≤ j ≤ w) in the i-th channel (1 ≤ i ≤ n) (order same as with subset SR_Level)
		SR_Azimuth[2,1]	
		...	
		SR_Azimuth[w,n]	
w · n	INT16	SR_Quality[1,1]	SR DF quality [1/10 %] of the j-th wave (1 ≤ j ≤ w) in the i-th channel (1 ≤ i ≤ n) (order same as with subset SR_Level)
		SR_Quality[2,1]	
		...	
		SR_Quality[w,n]	
w · n	INT16	SR_Fstrength[1,1]	SR field strength [1/10 dB(µV/m)] of the j-th wave (1 ≤ j ≤ w) in the i-th channel (1 ≤ i ≤ n) (order same as with subset SR_Level)
		SR_Fstrength[2,1]	
		...	
		SR_Fstrength[w,n]	
w · n	INT16	SR_Elevation[1,1]	SR elevation [1/10 °] of the j-th wave (1 ≤ j ≤ w) in the i-th channel (1 ≤ i ≤ n) (order same as with subset SR_Level)
		SR_Elevation[2,1]	
		...	
		SR_Elevation[w,n]	
w · n	UINT16	SR_Wavestatus[1,1]	SR wave status (see table Table 3-88) of the j-th wave (1 ≤ j ≤ w) in the i-th channel (1 ≤ i ≤ n) (order same as with subset SR_Level)
		SR_Wavestatus[2,1]	
		...	
		SR_Wavestatus[w,n]	

The output format of the eigenvalues (called "size" in the table) is the linear and normalized form, i.e. each eigenvalue emerging from the MuSiC algorithm (Chapter 3.14.5, "MuSiC") is divided by the count of antenna elements (9 or 8 in case of *Rohde & Schwarz* super-resolution antennas) before output. This way the maximum value obtainable in theory is 1. For a better handling of the eigenvalues, especially if a manual evaluation of the count of waves should be preferred (see Chapter 3.14.5.2), it might be recommendable to use a logarithmic representation. Logarithmation has to be done by the downstream user interface, the R&S DDF5GTS itself does not offer logarithmic form of output (even though diagrams in Chapter 3.14.5.2 use this form for more clearness).

The DF channel status bit field is also enlarged, see Table 3-86.

3.18.2.18 SIGP

The *SIGP* data trace contains ready-to-use antenna data (i.e. antenna voltages related to reference path, calibrated and averaged, in I [real part] and Q [imaginary part] component pairs). This so-called raw data is intended to be stored and then processed later on.

Conditions

The *SIGP* data trace only issues data if [2.4]

- the R&S DDF5GTS is in the DF mode (Chapter 3.7 on page 132)
  - FFM: XML (XML) command
    `DfMode`: `eOperationMode=DFMODE_FFM`,
  - Search:
    `eOperationMode=DFMODE_SEARCH` or
  - Scan:
    `eOperationMode=DFMODE_SCAN`,
- valid DF settings have been specified and
- the antenna element test is not activated:
  - `AntennaLevelSwitch`: `eAntLevelSwitch=ANTLEVEL_OFF`.

No subset of data can be selected or suppressed, i.e. the selector flags (Table 3-57) for raw data only contain

- *OPTIONAL_HEADER*

Flag is always set on enabling trace: `SelectorFlags` = 80000000_{16}; to reset and set use XML commands

- `TraceFlagDisable`
- `TraceFlagEnable`

Data is sent depending on the selector flags set; the order corresponds to the significance (upward) of these flags. The number of pairs of values of the data section (i.e. the number of values corresponding to one selector flag, not the overall sum) is defined in the `NumberOfTraceItems` item of the Trace Attribute (see Table 3-55).

The Optional Header (here called *SIGP trace header*) is described in detail in Table 3-90.

Table 3-90: Description of the SIGP trace header (144 bytes = 1152 bits).

SIGP trace header			
	Data type	**Parameter**	**Description**
	UINT32	(reserved)	Not used: always 100
	UINT16	DatatypeVersMinor	Version of trace format (concerning data type specified), lower, i.e. least significant part: `0` for version on hand
	UINT16	DatatypeVersMajor	Ditto, upper, i.e. most significant part: `1` for version on hand
	UINT64	MeasureTimestamp	Timestamp [ns] at measurement; value expressed as elapsed time since Unix epoch, without leap seconds
	UINT64	Frequency	Frequency [Hz] of 1st channel in current scan range
	INT32	StepFreqNumer*1)**	Numerator value of fractional step frequency [Hz]*2)**
	INT32	StepFreqDenom*1)**	Denominator value of fractional step frequency [Hz]*2)**
	INT32	Span	Frequency span (realtime bandwidth) [Hz]
	INT32	ScanRangeID	Scan range identification number
	INT32	ChansInScanRange	Number of channels in current scan range [1 to (5000 · 9601)]
	INT32	LogChannel	Logical channel number in current scan range of 1st channel in current packet [0 to (5000 · 9601) – 1]
	UINT16	JobID	Job ID (lower 16 bits of ID of the request having defined the current DF order)
	INT16	AntennaRange	Index of used antenna range (see [1.1]) (1 to 8)
24	INT8	AntennaString[1] AntennaString[2] ... AntennaString[24]	Antenna name as a string (left-aligned with the remaining characters being filled by 'NUL')
	INT8	NumberOfAntElem	Number of antenna elements within circular array
	INT8	AddAntElem	Additional (central) antenna element existing: ● 0: no central element: omnidirectional antenna ● 1: central (reference) element: cardioid antenna
	INT16	AntOffset	Antenna offset vs. true north [1/10 °]
	FLOAT (32)	RefA	Antenna specific factor A*3)**
	FLOAT (32)	RefB	Antenna specific factor B*3)**
	INT32	Diameter	Antenna diameter [mm]
	INT16	CompassHeading	Heading [1/10 °] of a connected compass (antenna yaw, see Chapter 2.5.1.2, "Nautical Angles (Ship Deviations)", on page 47) vs. CompassHeadingType (see below) (0 to 3599)

SIGP trace header			
	Data type	**Parameter**	**Description**
	INT16	CompHeadType	Heading type of the connected compass: • –1: UNDEFINED: no compass value available • 0: UNKNOWN: heading unknown • 1: COMPASS: heading value uncorrected • 2: MAGNETIC: heading value related to magnetic north (magnetic heading) • 3: TRUE: heading value related to true (geographic) north (true heading) • 4: BAD: heading value bad because movement too slow (only for GPS compass, see Chapter 2.5.1, "Definition of Terms", on page 46) • 5: GPS: heading value derived from movement related to GPS • 6: GPSLOW: heading value derived from movement related to GPS, but speed too low (< 1 m/s)
	INT16	AntRollExact[4)]*	Antenna roll [1/10 °] around the length axis vs. perfect vertical position (see Chapter 2.5.1.2)
	INT16	AntElevExact[4)]*	Antenna elevation (pitch) [1/10 °] seen over the length axis vs. perfect horizontal/vertical position (see Chapter 2.5.1.2)
	INT32	DFStatus	DF status: boolean information for each measurement (see Table 3-84)
	UINT64	SweepTime	Time [ns] required for one sweep
	FLOAT (32)	Bandwidth	Channel bandwidth [Hz]
	INT32	MeasureTime	Averaging time [µs] per hop
	INT16	MeasureCount	Count of measurements (antenna cycles) within averaging time: • > 0: count • –1: undefined
	INT16	Threshold	Averaging level threshold [dBµV]
	INT32	BasesOverThres	Count of antenna bases above threshold during averaging
	INT16	ThresholdLevel	Averaged level [dBµV] of data block
	INT16	ContinuousLevel	Averaged level [dBµV] of data block, independent of averaging mode
	INT16	Azimuth	Azimuth [1/10 °] (0 to 3599)
	INT16	Elevation	Elevation [1/10 °] (–900 to 900, "illegal" with Watson-Watt)
	INT16	Quality	DF quality [1/10 %] (0 to 1000)
	INT16	Omniphase	Omniphase [1/10 °] (Watson-Watt only)
	INT16	FieldStrength	DF field strength [1/10 dB(µV/m)]
	INT16	(reserved)	Not used

[1)] *Mind Table 3-51 on page 256.*

[2)] *See footnote 2 of Table 3-62 on page 269.*

3) *The parameters* `RefA` *and* `RefB` *are needed for calculating the pattern (characteristic) of a cardioid antenna:*

S(φ) = `RefA` *+* `RefB` *· cos φ*

4) *See footnote 1 of Table 3-80 on page 290.*

An example of a complete *SIGP* data trace (called *SIGP attribute*), as a Trace Attribute (advanced type), i.e. including length, selector flags and optional header indications, is shown in Table 3-91 (cf also Table 3-55).

Table 3-91: Example of a complete SIGP attribute.

<table>
<tr><td colspan="4">SIGP attribute</td></tr>
<tr><td></td><td>Data type</td><td>Parameter</td><td>Description</td></tr>
<tr><td></td><td>INT16</td><td>NumberOfTraceValues</td><td>Length <code>n</code> [pairs] of the <code>I_sample/Q_sample</code> section (corresponds to the <code>NumberOfTraceItems</code>)</td></tr>
<tr><td></td><td>INT8</td><td>(reserved)</td><td>Not used</td></tr>
<tr><td></td><td>UINT8</td><td>OptionalHeaderLength</td><td>Length <code>m</code> [byte] of <code>OptionalHeader</code> section:
● 144: optional header included
● 0: no optional header included</td></tr>
<tr><td></td><td>UINT32</td><td>SelectorFlags</td><td>Bit field, see description of selector flags, Table 3-57:
<code>80000000</code>$_{16}$ for optional header in the R&S DDF5GTS</td></tr>
<tr><td><code>m</code></td><td>UINT8</td><td>OptionalHeader</td><td>SIGP trace header as described in Table 3-90</td></tr>
<tr><td rowspan="7">2<code>n</code></td><td rowspan="7">FLOAT (32)</td><td>I_sample[1]</td><td rowspan="7">SigP data pairs: antenna voltages related to reference path, calibrated and averaged, I (real part) and Q (imaginary part) component

<code>n</code> pairs in float notation</td></tr>
<tr><td>Q_sample[1]</td></tr>
<tr><td>I_sample[2]</td></tr>
<tr><td>Q_sample[2]</td></tr>
<tr><td>...</td></tr>
<tr><td>I_sample[<code>n</code>]</td></tr>
<tr><td>Q_sample[<code>n</code>]</td></tr>
</table>

3.18.2.19 HRPan

The *HRPan* (High-Resolution Panorama) offers a spectrum that is continuously calculated on the main IF data stream. The spectrum has a higher resolution (step size lower) compared to the *IFPan* (3.18.2.8) functionality.

Conditions

The *HRPan* data trace only issues data if [2.4]

- the option R&S DDFGTS-HRP, *High-Resolution Panorama*, is installed and
- the R&S DDF5GTS is in the DF mode (Chapter 3.7 on page 132)
  – Rx: XML (XML) command
    `DfMode`: `eDFMODE=DFMODE_RX` or
  – FFM:
    `eDFMODE=DFMODE_FFM`.
- the signal to analyze is provided to the "***DF1***" connectors, i.e. **X11**, **X21** or **X31** (depending on the selected frequency range); find more information in Chapter 3.4, "Rear Panel Elements R&S EHT770", on page 107
- realtime bandwidth (frequency span) is set to at least 20 MHz (one out of 80 MHz, 40 MHz or 20 MHz).

The only subset of data to be selected or suppressed is the level data, i.e. the selector flags (Table 3-57) for HR panorama data only contain

- *LEVEL*
- *OPTIONAL_HEADER*

Flags are always set on enabling trace: `SelectorFlags` = `80000001`$_{16}$; to reset and set use XML commands

- `TraceFlagDisable`
- `TraceFlagEnable`

Data is sent depending on the selector flags set; the order corresponds to the significance (upward) of these flags. The number of values of the data section (i.e. the number of values corresponding to one selector flag, not the overall sum) is defined in the `NumberOfTraceItems` item of the Trace Attribute (see Table 3-55).

The Optional Header (here called *HRPan trace header*) is described in detail in Table 3-92.

Table 3-92: Description of the HRPan trace header (36 bytes = 288 bits).

HRPan trace header			
	Data type	**Parameter**	**Description**
	UINT32	Freq_low	IF panorama center frequency [Hz] (as a 64-bit value, lower, i.e. least significant part)
	UINT32	Freq_high	IF panorama center frequency [Hz · 2^{32}] (as a 64-bit value, upper, i.e. most significant part)
	UINT32	FreqSpan	Frequency span [Hz]: ChannelCount · bandwidth of single channel
	UINT32	ChannelCount	Number of channels in entire spectrum

HRPan trace header			
	Data type	**Parameter**	**Description**
	UINT32	ChannelOffset	Number of first channel delivered (0 to ChannelCount – 1) The number of the central channel (situated at IF panorama center frequency) calculates as • ChannelCount/2 (for even ChannelCount) • (ChannelCount–1)/2 (for odd ChannelCount) Depending on frequency span and HRPan frequency step, a spectrum may be divided into segments and distributed to multiple EB200 datagrams (HRPan trace tag). ChannelOffset allows to indentify current segment.
	UINT32	StartTimestamp_low	Timestamp [ns] of 1st input sample in use to calculate current spectrum; value expressed as elapsed time since Unix epoch, without leap seconds (as a 64-bit value, lower, i.e. least significant part)
	UINT32	StartTimestamp_high	Timestamp [ns · 2^{32}] as above (as a 64-bit value, upper, i.e. most significant part)
	INT16	K_Factor	k-factor for field strength calculation [1/10 dB(1/m)][1)]*
	UINT16	StatusWord	• Bit 0: Fragmentation: – 0: entire spectrum in datagram – 1: part of spectrum in datagram; entire spectrum spread over several datagrams • Bit 1: SignalInvalid: – 0: current signal valid – 1: current signal not valid due to different reasons • Bit 2: Blanking: – 0: not active, i.e. level H if active low or L if active high at Blanking source (**X17** ***AUX***, pin 9 BLANKING, or **X44** ***TRIGGER*** on rear panel R&S DDF5GTS) – 1: active, i.e. level L if active low or H if active high[2)]* • Bit 3 to 6: Averaging mode: – 0_{10}, 1_{10}: reserved – 2_{10}: AVERage | SCALar – 3_{10} to 15_{10}: reserved • Bit 7 to 15: reserved
	UINT32	AvgTime	Time period [ns] of input signal used for calculating a spectrum

1) *See footnote 4 of Table 3-68 on page 277.*

2) *Blanking will stay on for at least 320 ms irrespectively of how long it was asserted.*

An example of a complete *HRPan* data trace (called *HRPan attribute*), as a Trace Attribute (advanced type), i.e. including length, selector flags (*LEVEL* and *OPTIONAL_HEADER*) and optional header indications, is shown in Table 3-93 (cf also Table 3-55).

Table 3-93: Example of a complete HRPan attribute.

HRPan attribute			
	Data type	**Parameter**	**Description**
	UINT32	NumberOfLevelValues	Length `n` [channels] of the `Level` section (corresponds to the `NumberOfTraceItems`)
	UINT32	(reserved)	Not used
	UINT32	OptionalHeaderLength	Length `m` [byte] of `OptionalHeader` section: • 36: optional header included • 0: no optional header included
	UINT32	SelectorFlagsLow	Bit field, lower, i.e. least significant part; see description of selector flags, Table 3-57: `800CF800`$_{16}$ (as told above) in the R&S DDF5GTS
	UINT32	SelectorFlagsHigh	Ditto, higher, i.e. most significant part: `0` in the R&S DDF5GTS
4	UINT32	(reserved)	Not used
`m`	UINT8	OptionalHeader	*HRPan trace header* as described in Table 3-92
`n`	INT16	Level[1]	Level [1/10 dBµV] of the `i`-th channel (`ChannelOffset` ≤ `i` ≤ `ChannelOffset+NumberOfLevelValues-1`) If the entire spectrum contains an odd number of usable bins (`ChannelCount`), `n` might still be an even number (last fragment of the spectrum being conveyed), and thus `ChannelOffset+NumberOfLevelValues-1` exceed `ChannelCount`. In this case, ignore (discard) the last `Level` value.
		Level[2]	
		...	
		Level[`n`]	

3.18.3 AMMOS Protocol

Nomenclature

- In this Chapter 3.18.3, a **word** always means a data unit of 32 bit of length.
- All **length** indications are given in words, i.e. 32-bit units, unless noted otherwise.
- On behalf of an easier readability, the term *R&S®AMMOS®* is abbreviated to *AMMOS* throughout the chapter.
- **Data streams** within the AMMOS context are denoted as *datastreams*.

Conditions

- Some AMMOS data traces only apply with **options** installed (find more detailed information with Chapter 3.16, "Signal Analysis", on page 226).
- Always watch out that **timestamps** with AMMOS may appear in µs (microseconds) or also in ns (nanoseconds), depending on kind of timestamp/type of data frame (even two different units within the same frame possible), in contrast to every timestamp told in ns indications with EB200 protocol (Chapter 3.18.2 on page 253).
  All timestamps (regardless whether EB200 or AMMOS, i.e. whether in ns or in µs) are told in *Unix time* (also known as *POSIX time* or *epoch time*), this is, as a difference to (elapsed time since) so-called *Unix epoch*: Thursday, January 1st, 1970, 00:00:00 (midnight/12:00:00 a.m.) UTC, without leap seconds.
- **Counting of frames**: with EB200, the *sequence number* (Table 3-50) is applied to (incremented with) each EB200 datagram irrespective of its trace tag (frame type), whereas with AMMOS, each frame type uses its own *frame counter* (Table 3-94).

3.18.3.1 AMMOS Data Formats

The AMMOS datastream format is a format different from the EB200 format (Chapter 3.18.2). It comprises specially structured data applied with R&S AMMOS® systems; some of the data traces of the R&S DDF5GTS use this format, so a short overview of it will be given in the subsequent chapters. If in need of precise information about format details, you can find it in the AMMOS datastreams manual [3.10]. Also described there are the remaining AMMOS datastream formats which are not in use with the R&S DDF5GTS and therefore not explained here.

AMMOS data traces do not obey the EB200 Protocol format (e.g. do not contain Generic Attribute, 3.18.2.4, Trace Attribute, 3.18.2.5 etc.), even though they also are activated/deactivated by the XML (XML) commands [2.4] (see Chapter 3.18.4, "Remote Commands Controlling Data Traces", on page 326)

- `TraceEnable`
- `TraceDisable`

Generic Frame Format

All datastreams of the AMMOS type have a frame based structure using the same format (Figure 3-78), consisting of a global

- **Frame Header**

coupled with a data-type specific

- **Frame Body** (i.e. the frame payload).

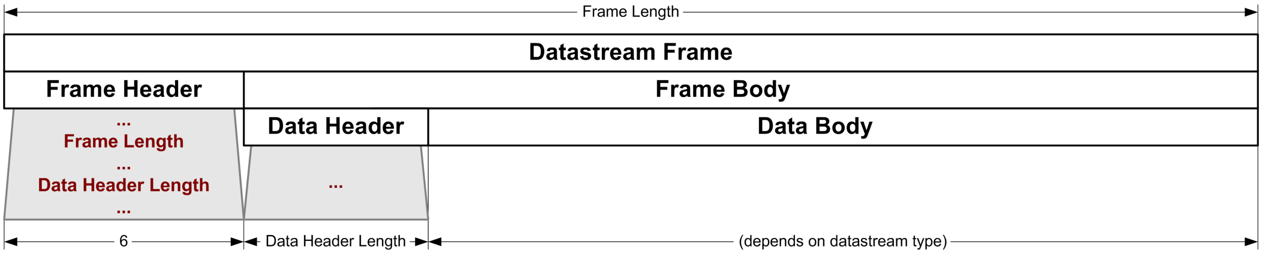


Figure 3-78: AMMOS data frame format.

The *Header* and the *Body* of the frame consist of a number of exclusively 32-bit words (no other data item lengths, i.e. data types, exist, except that sometimes two 16-bit items might be merged to one 32-bit word). The *Frame Header* (Table 3-94) has a pre-defined structure and size (currently 6 words). The size and structure of the *Frame Body* are determined by the payload type, this is, the type of the AMMOS format regarded. The overall size of the entire frame depends on this factor.

Frame Header

Table 3-94: AMMOS Frame Header (6 words = 24 bytes = 192 bits).

Frame Header			
	Type	**Parameter**	**Description**
1.	UINT32	MagicNumber	Constant value that never changes (used for frame synchronization): `FB746572`$_{16}$
2.	UINT32	FrameLength	Total frame length [words] (including all headers, starting from `MagicNumber`)
3.	UINT32	FrameCount	Frame counter, i.e. number of current frame: is set when configurating the associated item (that generates the frame type in question), increments with each frame of same frame type and serves for sequencing and detection of lost frames (in case of network congestion)
4.	UINT32	FrameType	Type of frame: identifies data type contained in this frame and thus determines structure of frame body as told in subsequent sections
5.	UINT32	DataHeaderLength	Length of Data Header (with some frame types – not with the R&S DDF5GTS – that contain no data header: void)
6.	UINT32	(reserved)	Not used: always 0

Frame Body

Commonly the Frame Body furthermore falls into a *Data Header* and a *Data Body*; with some format types (not with the R&S DDF5GTS), however, no Data Header exists at all and thus the according entry `DataHeaderLength` in the Frame Header is void.

In addition to possible length indications of other elements, the length of the overall frame including all of its elements is always told in the frame header.

The AMMOS data formats utilized by the R&S DDF5GTS so far are the

- *IF* data frame format
- *IF DDCE* data frame format

- *Burst Emission List* data frame format

An overview of these formats can be seen in the subsequent sections "AMMOS IF Format" to "AMMOS Burst Emission List Format", a more detailed description, also enumerating the individual elements, of the traces in 3.18.3.2 to 3.18.3.4. If ENUM values or header file names to extract programming contents out of them should be required, again refer to [3.10].

AMMOS IF Format

Figure 3-79 shows the generic *AMMOS IF* data frame format. The *Data Header* may appear in two lengths: 14 (conventional type) or 19 (extended type), the Data Header itself tells the count of *Datablocks* the *Data Body* falls into (called *n* in the figure). Each individual Datablock consists of a *Datablock Header* and the data itself in the *Datablock Body*, the length of which (uniform within the entire frame) also is told in the Data Header.

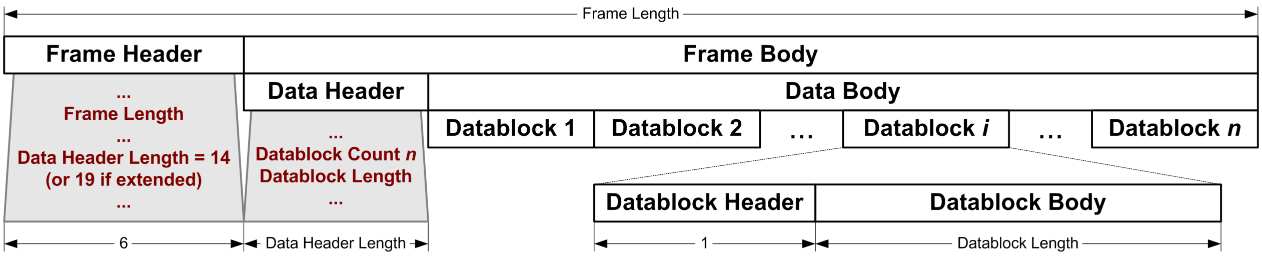


Figure 3-79: AMMOS IF data frame format.

With the R&S DDF5GTS the subsequent limitations apply: Data Header always of extended type (length 19), only one Datablock (*n* = 1), Datablock Body length constantly 240.

The complete depiction of the *AMMOS IF* datastream format is given in 3.18.3.2.

AMMOS IF DDCE Format

For the *AMMOS IF DDCE* format (Figure 3-80), the *Frame Length* is 256 and the *Data Header* length 9.

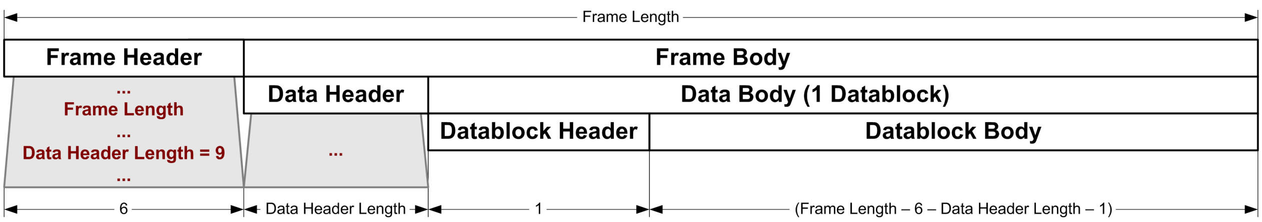


Figure 3-80: AMMOS IF DDCE data frame format.

The *Data Body* consists of only one *Datablock* formed of a *Datablock Header* (length fixed as 1) and a *Datablock Body* that contains the actual IF samples.

The Datablock Body is defined as an array the size of which is not indicated explicitly, but ensues to

Frame Length – 6 – *Data Header Length* – 1 = 240 (this size should be ≥ 1). The actual data samples have to be extracted from the array; their structure and size depend on the current IF DDCE datastream type (16 bit or 32 bit of length possible).

Find more detailed information about signal extraction with DDCs in Chapter 3.16, "Signal Analysis", on page 226, and the complete depiction of the *AMMOS IF DDCE* datastream format in 3.18.3.3.

AMMOS Burst Emission List Format

The *AMMOS Burst Emission List* format (Figure 3-81) also has a length of the *Data Header* of 9.

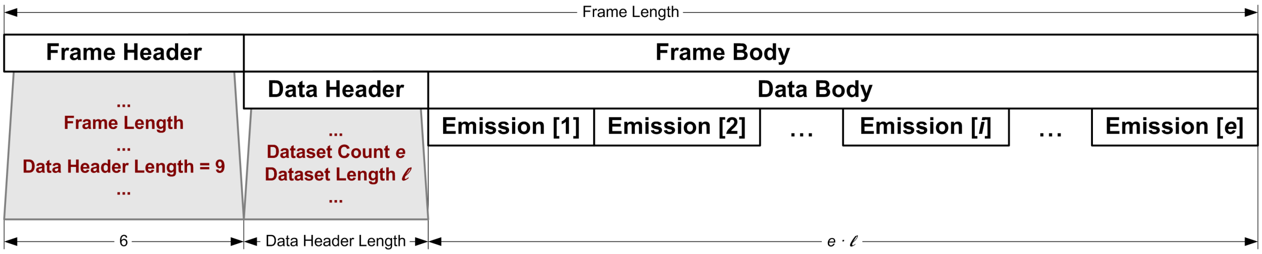


Figure 3-81: AMMOS Burst Emission List data frame format.

The *Data Body* is made up of the data of several emissions (number given by Dataset Count in the *Data Header*, *e* in the figure), each of which itself has a length indicated by Dataset Length ℓ; thus the length of the entire Data Body calculates as $e \cdot \ell$.

The complete definition of this format can be seen from 3.18.3.4; again, find more basic information in Chapter 3.16.

3.18.3.2 AMMOS IF

The *AMMOS IF* data trace can be considered an alternative form of the *IF* data trace (Chapter 3.18.2.10 on page 275). It delivers specially structured data used with R&S AMMOS® systems.

Frame

The basic *AMMOS IF* data structure has been told in Section "AMMOS IF Format" (3.18.3.1, "AMMOS Data Formats"). With the R&S DDF5GTS, one sole frame contains baseband I/Q samples of the main Rx path and also meta information, such as sampling rate and Rx frequency; data comes in words uniformly 32 bit wide (Bit 31 MSB). A word can represent one single I or Q data sample (32 bits, cf Table 3-100) or be composed of a pair of I and Q sample (16 bits each, cf Table 3-101). This is: here in the end a frame (Table 3-95) always contains exactly one data packet (*Datablock*), preceded by the headers

- *Frame Header*
- *Data Header*
- *Datablock Header*

Table 3-95: Structure of AMMOS IF data frame.

AMMOS IF frame	
Length [words]	**Name of Block**
6	Frame Header (Table 3-96)
19	Data Header, extended type (Table 3-97)
1	Datablock Header (Table 3-99)
`r`	Datablock (Tables 3-100 and 3-101)

Find additional information about conditions for issuing of data and about data formats in Chapter 3.18.2.10.

Be aware that the Data Header (Table 3-97) is of the extended type (length 19, conventional type not in use with the R&S DDF5GTS), and the Datablock Header (Table 3-99) consists of just one word used as a status word (bit field).

Frame Header

Table 3-96: Frame Header for AMMOS IF data (6 words = 24 bytes = 192 bits).

Frame Header			
	Type	**Parameter**	**Description**
1.	UINT32	MagicNumber	Constant value that never changes (used for frame synchronization): `FB746572`$_{16}$
2.	UINT32	FrameLength	Total frame length [words] (including all headers, starting from `MagicNumber`)
3.	UINT32	FrameCount	Number of current frame (cf also Table 3-94)
4.	UINT32	FrameType	Type of Datablock • 1: length of I/Q samples 32 bit (Table 3-100) • 2: length of I/Q samples 16 bit (Table 3-101)
5.	UINT32	DataHeaderLength	Length of Data Header (Table 3-97): constantly 19 (only extended header type with the R&S DDF5GTS)
6.	UINT32	(reserved)	Not used: always 0

Data Header

Table 3-97: Data Header, extended type (19 words = 76 bytes = 608 bits).

Data Header			
	Type	**Parameter**	**Description**
1.	UINT32	(DatablockCount)*1)* *	Number of Datablocks in this *AMMOS IF* frame: always 1
2.	UINT32	DatablockLength	Length `r` [words] of Datablock: • `r = 2 * n` (Table 3-100) • `r = n` (Table 3-101)
		OutputTimestamp	Timestamp [µs] at data output; value expressed as elapsed time since Unix epoch, without leap seconds (as a 64-bit value) Mind Note "Conditions" on page 313

Data Header			
	Type	**Parameter**	**Description**
3. 4.	UINT32 UINT32	Low High	
5.	UINT32	DataHeadStatWord	Data Header status word (see Table 3-98)
6. 7.	UINT32 UINT32	(SignalSourceID)[1)] * (SignalSourceState)[1)] *	Not used: always 0
8. 9.	UINT32 UINT32	Freq_low[2)] * Freq_high[2)] *	Rx frequency [Hz] (as a 64-bit value)[3)] *
10.	UINT32	Bandwidth[2)] *	Demodulation bandwidth [Hz][3)] *
11.	UINT32	SampleRate[2)] *	Sampling rate [Hz][3)] *
12.	UINT32	(Interpolation)[1)] *	Interpolation factor: always 1
13.	UINT32	(Decimation)[1)] *	Decimation factor: always 1
14.	INT32	RxAttenuation[2)] *	Overall attenuation from antenna input (depending on HF option equipping) • X11 to **X13** ***HF***, • X21 to **X23** ***V / UHF*** • X31 to **X33** ***HF / V/U/SHF*** to level of **IF data**[1)] *
15. 16.	UINT32 UINT32	StartTimestamp[2)] * Low High	Timestamp [ns] at start of data sampling; value expressed as elapsed time since Unix epoch, without leap seconds (as a 64-bit value) Mind Note "Conditions" on page 313
17. 18.	UINT32 UINT32	SampleCount[2)] * Low High	Number of 1st sample in this frame; can be used to calculate timestamp of each sample[5)] *
19.	INT32	KFactor[2)] *	k-factor for field strength calculation [1/10 dB(1/m)][4)] * • > 0: k-factor • 80000000_{16}: no k-factor defined

1) *Data field part of original R&S AMMOS® data frame, not used in the R&S DDF5GTS*

2) *Corresponds to same-named field in IF data trace (3.18.2.10)*

3) *Value typically will not change from frame to frame, but due to signal processing path reconfigured*

4) *See footnotes 2 and 4 of Table 3-68 on page 277.*

5) *Timestamp `ts` of a sample is calculated by*

$ts = StartTimestamp + SampleCounter / SampleRate$

or, considering decimation/interpolation factors different from 1 and delivering the result in ns, by

$ts = StartTimestamp + SampleCounter / SampleRate \cdot Decimation \cdot Interpolation \cdot 10^9$

Table 3-98: Data Header status word (1 word = 4 bytes = 32 bits).

Data Header status word		
Bit	**Name**	**Description**
31 (MSB)	Change	*Change* flag (indicates whether any data field of Data Header (Table 3-97) [excluded timestamp] has changed compared to previous frame or time leap happened; will be cleared again in subsequent frame): • 0: no data field differing, no time leap • 1: at least one differing data field or time leap
30	dB_FS	*dB full scale* flag (indicates whether IF data has to be taken as dB full scale due to missing additional level information): • 0: `RxAttenuation` (Table 3-97) can be used to calculate absolute level • 1: no level calculation possible, all data in this frame considered dB full scale Always 0 with the R&S DDF5GTS
29 to 8	(reserved)	Reserved for future extensions: always 0
7 to 0 (LSB)	UserDefFlags	User flags for individual signaling; not in use with the R&S DDF5GTS: always 0

Datablock Header

Table 3-99: Datablock Header (status word: 1 word = 4 bytes = 32 bits).

Datablock Header		
Bit	**Name**	**Description**
31 (MSB) to 8	(reserved)	Reserved for future extensions: always 0
7 to 2	UserDefFlags	User flags for individual signaling; not in use with the R&S DDF5GTS: always 0
1	Blanking	*Blanking* flag: indicates whether data of block possibly disturbed due to external influence, e.g. transmitter close to antenna; told by Blanking source (cf Chapter 3.11.6.3, "Blanking", on page 175): • 0: not active • 1: active[1)]* Mind Note "Significance of Settings" on page 175
0 (LSB)	Invalid	*Invalid* flag[2)]* (indicates whether at least one data value is distorted or at least one header field does not show correct situation of Datablock): • 0: data correct • 1: data within this block may be corrupt

1) *Blanking will stay on for at least 320 ms irrespectively of how long it was asserted.*

2) *A typical situation for the Invalid flag activated is a switchover to new parameters. The flag will only be released after all parameters applied and the system settled again.*

Datablock

Table 3-100: Datablock Body, length of I/Q samples 32 bit.

Datablock Body 32 bit			
	Data type	**Parameter**	**Description**
r	INT32	I_sample[1]	IF data pairs as 32-bit signed fractionals (1 sample/word, Bit 31 MSB) Block length `r = 2 * n` (`r` words, `n` pairs)
		Q_sample[1]	
		I_sample[2]	
		Q_sample[2]	
		...	
		I_sample[n]	
		Q_sample[n]	

Table 3-101: Datablock Body, length of I/Q samples 16 bit.

Datablock Body 16 bit				
		Parameter		
	Data type	**Bit 31 to 16**	**Bit 15 to 0**	**Description**
r	INT32	Q_sample[1]	I_sample[1]	IF data pairs as 16-bit signed fractionals (1 pair/word, Bit 31 and Bit 15 MSB, respectively) Block length `r = n` (`r` or `n` words/pairs)
		Q_sample[2]	I_sample[2]	
		...		
		Q_sample[n]	I_sample[n]	

3.18.3.3 AMMOS IF DDCE

Frame

The basic *AMMOS IF DDCE* data structure has been told in Section "AMMOS IF DDCE Format" (3.18.3.1, "AMMOS Data Formats"). The Frame Body again contains just one data packet (each DDC instance creates an individual data trace), it in turn falls into a Data Header and a Data Body. Now, the Data Body consists of in any case one Datablock built of Datablock Header (length 1) and Datablock Body (length fixed to 240 words). See the IF DDCE frame resumed in Table 3-102; again it makes up a data packet, preceded by the headers

- *Frame Header*
- *Data Header*
- *Datablock Header*

Table 3-102: AMMOS IF DDCE data frame (256 words = 1024 bytes = 8192 bits).

AMMOS IF DDCE frame	
Length [words]	**Name of Block**
6	Frame Header (Table 3-103)
9	Data Header (Table 3-104)
1	Datablock Header (Table 3-105)
240	Datablock (Tables 3-106 and 3-107)

Find additional information about conditions for issuing of data in Chapter 3.16, "Signal Analysis", on page 226.

The Datablock Header (Table 3-105) consists of just one word used as a status word (bit field).

Frame Header

Table 3-103: Frame Header (6 words = 24 bytes = 192 bits).

Frame Header			
	Type	**Parameter**	**Description**
1.	UINT32	MagicNumber	Constant value that never changes (used for frame synchronization): `FB746572`$_{16}$
2.	UINT32	FrameLength	Total frame length [words] (including all headers, starting from `MagicNumber`): constantly 256
3.	UINT32	FrameCount	Number of current frame (cf also Table 3-94)
4.	UINT32	FrameType	Type of Datablock ● 60_{16}: length of I/Q samples 32 bit (Table 3-106) ● 61_{16}: length of I/Q samples 16 bit (Table 3-107)
5.	UINT32	DataHeaderLength	Length of Data Header (Table 3-104): constantly 9
6.	UINT32	(reserved)	Not used: always 0

Data Header

Table 3-104: Data Header (9 words = 36 bytes = 288 bits).

Data Header			
	Type	**Parameter**	**Description**
1.	UINT32	SignalSourceID	• Bit 31 to 30: Signal Source Group ID: – 0: R&S DDFGTSDDCE – 1: R&S DDFGTS-ST • Bit 29 to 18: reserved: always 0 For statically allocated instances (R&S DDFGTSDDCE): • Bit 17 to 8: reserved: always 0 • Bit 7 to 0: channel number (0 to 127) For burst emission synthesis (R&S DDFGTS-ST): • Bit 17 to 0: burst emission ID (0 to 262143), corresponds to item 1 of Data Body of Burst Emission List (Table 3-111)
2.	INT32	AntennaVoltageRef	Correction factors[1)]* (as INTs each): • Bit 31 to 16: K_Factor – k-factor [1/10 dB(1/m)] for field strength calculation[2)]* – 8000_{16}: no k-factor defined • Bit 15 to 0: RxAttenuation: overall attenuation [1/10 dB] from antenna input to level of **IF data**[2)]*
3.	UINT32	(reserved)	Not used: always 0
 4. 5.	 UINT32 UINT32	OutputTimestamp Low High	Timestamp [µs] at output of 1st sample (1st value of Datablock Body) in frame; value expressed as elapsed time since Unix epoch, without leap seconds (as a 64-bit value) Timestamp accuracy achieved by DDCE: ±80 µs (vs. real signal time) Mind Note "Conditions" on page 313
6. 7.	UINT32 UINT32	Freq_low Freq_high	Rx frequency [Hz] (as a 64-bit value): frequency the narrowband signal has been extracted by the current DDC instance, thus not necessarily the frequency the R&S DDF5GTS is tuned to[1)]*
8.	FLOAT[3)]*	Bandwidth	Usable bandwidth [Hz][1)]*
9.	FLOAT[3)]*	SampleRate	Sample rate [Hz][1)]*

[1)] *Value typically will not change from frame to frame, but due to signal processing path reconfigured.*

[2)] *See footnotes 2 and 4 of Table 3-68 on page 277.*

[3)] *32-bit floating point format (IEEE 754/854).*

Datablock Header

Table 3-105: Datablock Header (status word: 1 word = 4 bytes = 32 bits).

Datablock Header		
Bit	**Name**	**Description**
31 (MSB)	Change	*Change* flag (indicates whether any data field of Data Header (Table 3-104) [excluded timestamp] has changed compared to previous frame of same Signal Source Group ID [item 1 of Data Header]; will be cleared again in subsequent frame): • 0: no data field differing • 1: at least one differing data field
30	dB_FS	*dB full scale* flag (indicates whether IF data has to be taken as dB full scale due to missing additional level information): • 0: `RxAttenuation` (Table 3-104) can be used to calculate absolute level • 1: no level calculation possible, all data in this frame considered dB full scale Always 0 with the R&S DDF5GTS
29 to 10	(reserved)	Reserved for future extensions: always 0
9	Blanking	*Blanking* flag: indicates whether data of block possibly disturbed due to external influence, e.g. transmitter close to antenna; told by Blanking source (cf Chapter 3.11.6.3, "Blanking", on page 175): • 0: not active • 1: active[1)]* Mind Note "Significance of Settings" on page 175
8	Invalid	*Invalid* flag[1)]* (indicates whether at least one data value is distorted or at least one header field does not show correct situation of Datablock): • 0: data correct • 1: data within this block may be corrupt
7 to 1	UserDefFlags	User flags for individual signaling between baseband data processing components; must be 0 if not used.
0 (LSB)	STSynth EndFrame	Short-time synthesis end frame flag: only valid if `Signal Source Group ID` (Table 3-104) is 1; in this case • 0: more frames to come • 1: current frame is last frame of a signal synthesis for a particular emission

[1)] *See footnote 2 of Table 3-99 on page 319.*

Datablock

Table 3-106: Datablock Body, length of I/Q samples 32 bit (240 words = 960 bytes = 7680 bits).

Datablock Body 32 bit			
	Data type	**Parameter**	**Description**
240	INT32	I_sample[1] Q_sample[1] I_sample[2] Q_sample[2]	IF data pairs as 32-bit signed fractionals (1 sample/word, Bit 31 MSB) Block length always 240 words (120 pairs)

Datablock Body 32 bit			
	Data type	Parameter	Description
		...	
		I_sample[120]	
		Q_sample[120]	

Table 3-107: Datablock Body, length of I/Q samples 16 bit (240 words = 960 bytes = 7680 bits).

Datablock Body 16 bit				
		Parameter		
	Data type	Bit 31 to 16	Bit 15 to 0	Description
240	INT32	Q_sample[1]	I_sample[1]	IF data pairs as 16-bit signed fractionals (1 pair/word, Bit 31 and Bit 15 MSB, respectively) Block length 240 words/pairs
		Q_sample[2]	I_sample[2]	
		...		
		Q_sample[240]	I_sample[240]	

3.18.3.4 AMMOS Burst Emission List

Frame

The basic *AMMOS Burst Emission List* data structure has been told in Section "AMMOS Burst Emission List Format" (3.18.3.1, "AMMOS Data Formats"). As the contents of this data trace are properties (characteristics) of detected emissions, the count of these properties is always the same, but not the count of emissions; this means, the Data Body in this case is formed of several datasets (each representing one emission) of constant length (the emission properties). Both counts, i.e. the Dataset Count *e* (varying) and the Dataset Length ℓ (constantly 9 at the moment) are told in the Data Header, thus a separate Datablock Header is not needed here. Therefore the overall structure (Table 3-108) now is

- *Frame Header*
- *Data Header*
- *Data Body*, made up of several "emission" elements

Table 3-108: AMMOS Burst Emission List data frame.

AMMOS Burst Emission List frame	
Length [words]	Name of Block
6	Frame Header (Table 3-109)
9	Data Header (Table 3-110)
$e \cdot \ell$	Data Body (Table 3-111)

Find additional information about conditions for issuing of data in Chapter 3.16, "Signal Analysis", on page 226.

Frame Header

Table 3-109: Frame Header (6 words = 24 bytes = 192 bits).

Frame Header			
	Type	**Parameter**	**Description**
1.	UINT32	MagicNumber	Constant value that never changes (used for frame synchronization): `FB746572`$_{16}$
2.	UINT32	FrameLength	Total frame length [words] (including all headers, starting from `MagicNumber`)
3.	UINT32	FrameCount	Number of current frame (cf also Table 3-94)
4.	UINT32	FrameType	Type of Datablock: always 150_{16}
5.	UINT32	DataHeaderLength	Length of Data Header (Table 3-110): constantly 9
6.	UINT32	(reserved)	Not used: always 0

Data Header

Table 3-110: Data Header (9 words = 36 bytes = 288 bits).

Data Header			
	Type	**Parameter**	**Description**
 1. 2.	 UINT32 UINT32	SnapshotCentFreq Low High	Snapshot center frequency [Hz] (as a 64-bit value)
3.	UINT32	Bandwidth	Snapshot bandwidth [Hz]
 4. 5.	 UINT32 UINT32	EmissionTimestamp Low High	Timestamp [µs] of emergence of 1st emission (1st sample) reported in this frame; value expressed as elapsed time since Unix epoch, without leap seconds (as a 64-bit value) Mind Note "Conditions" on page 313
6.	UINT32	SnapshotLength	Snapshot duration [ms] of the signal segment in which this emission list was intercepted
7.	UINT32	Statusword	**Status word** (bit-coded): ● Bit 31 to 1: reserved (must be 0) ● Bit 0: Snapshot end flag – 1: end of emission of current signal segment – 0: emission interception not yet concluded for current signal segment

Data Header			
	Type	**Parameter**	**Description**
8.	UINT32	DatasetCount	Dataset count `e`: Number of emission entries (Data Body elements, Table 3-111) in this frame ● > 0: dataset count ● 0: no emission detected during observed time period (defined by timestamp and snapshot duration); no Data Body will be delivered
9.	UINT32	DatasetLength	Dataset length ℓ [words] of each emission entry (data body element) in this frame: constantly 9

Data Body

Table 3-111: Data Body element (ℓ = 9 words = 36 bytes = 288 bits).

Data Body			
	Type	**Parameter**	**Description**
1.	UINT32	EmissionID	Burst emission ID, i.e. emission identifier (0 to 262143); corresponds to item 1, bit 17 to 0 of data header of IF DDCE (Table 3-104)
2.	UINT32	StartTimeOffset	Start time [µs] of this emission (1st sample) relative to `EmissionTimestamp`
3.	UINT32	Duration	Duration [µs] of this emission
4.	INT32	CentFreqOffset	Frequency offset [Hz] of this emission, relative to snapshot center frequency
5.	UINT32	Bandwidth	Bandwidth [Hz] of this emission; value is only coarse estimation (spectral width of snapshot itself)
6.	FLOAT32	Magnitude	Average power [dBm] measured for this emission
7.	UINT32	ModulationType[1)]*	Modulation type determined: ● 0: unknown ● 1: FSK2 ● 2: AM ● 3: PSK2A ● 4: PSK2B ● 5: PSK4A ● 6: PSK4B ● 7: PSK8A
8.	FLOAT32	ModParam1[1)]*	Modulation specific parameter 1 (determined): for digital emissions: symbol rate [symbols/s], else meaningless
9.	FLOAT32	ModParam2[1)]*	Modulation specific parameter 2 (determined): for FSK emissions: frequency shift [Hz], else meaningless

1) *Always 0: modulation analysis currently not supported*

3.18.4 Remote Commands Controlling Data Traces

Enabling and disabling of the mass data output is controlled by the XML (XML) commands [2.4]

- TraceEnable (3.18.4.2)
- TraceDisable (3.18.4.3)
- TraceDelete (3.18.4.4)
- TraceDeleteInactive (3.18.4.5)

3.18.4.1 Parameters

The parameters of the XML commands

- TraceEnable
- TraceDisable
- TraceDelete

are shown in Table 3-112. The eTraceTag parameter is an ENUM parameter; it can only assume the values shown in Table 3-113. The command

- TraceDeleteInactive

has no parameters.

Table 3-112: Parameters for the Trace commands.

Name	Type	Description	Example
eTraceTag[1)]*	ENUM, see Table 3-113	Kind of data output affected	TRACETAG_AUDIO
zIP	string	IP address of client host	10.11.12.13
iPort	INT32	Local port on client host	12345

1) *TraceEnable and TraceDisable only.*

Table 3-113: Values of the eTraceTag.

eTraceTag			
Trace tag	**Kind of data**	**Format**	**Chapter**
TRACETAG_AUDIO	Audio	EB200	3.18.2.7, "Audio", on page 264
TRACETAG_IFPAN	IFPan		3.18.2.8, "IFPan", on page 268
TRACETAG_CWAVE	CW		3.18.2.9, "CW", on page 270
TRACETAG_IF	I/Q		3.18.2.10, "IF", on page 275
TRACETAG_VIDEO	Video		3.18.2.11, "Video", on page 279
TRACETAG_VIDEOPAN	VDPan		3.18.2.12, "VDPan", on page 282
TRACETAG_PSCAN	PScan		3.18.2.13, "PScan", on page 284
TRACETAG_SEL_CALL	SelCall		3.18.2.14, "SelCall", on page 286
TRACETAG_GPS_COMPASS	GPSCompass		3.18.2.15, "GPSCompass", on page 289
TRACETAG_ANT_LEVEL	ANT_LEVEL		3.18.2.16, "ANT_LEVEL", on page 292
TRACETAG_DF	DFPScan		3.18.2.17, "DFPScan", on page 295

eTraceTag			
Trace tag	**Kind of data**	**Format**	**Chapter**
TRACETAG_SIGP	SIGP		3.18.2.18, "SIGP", on page 306
TRACETAG_HRPAN	HRPan		3.18.2.19, "HRPan", on page 309
TRACETAG_PDW	(not in the R&S DDF5GTS)[1)*]		
TRACETAG_DET			
TRACETAG_AMMOS_IF	I/Q	AMMOS	3.18.3.2, "AMMOS IF", on page 316
TRACETAG_DDCE	IF DDCE		3.18.3.3, "AMMOS IF DDCE", on page 320
TRACETAG_STD	Burst Emission List		3.18.3.4, "AMMOS Burst Emission List", on page 324

[1)] *Used in other Rohde & Schwarz products.*

3.18.4.2 TraceEnable

The XML command `TraceEnable` will enable data output for an already connected data trace (for configuration of a trace connection see Chapter 3.18.1.6, "Configuration", on page 252). It can be used as a set command only. Selection of the kind of data to be issued is done by the input parameter

- `eTraceTag`

Proceed as follows to enable the trace data output:

1. Send the command shown in example 1.
   The input parameters are described in Table 3-112.
2. Answer shown in example 2.

   In the answer appearing, the parameters specified are confirmed (or rejected with
   - `eTraceTag = TRACETAG_ILLEGAL_VALUE`

   if invalid).

Example 1: Command

```
<Request type="set" id="123">
  <Command name="TraceEnable">
    <Param name="eTraceTag">TRACETAG_GPS_COMPASS</Param>
    <Param name="zIP">10.11.12.13</Param>
    <Param name="iPort">12345</Param>
  </Command>
</Request>
```

Example 2: Answer

```
<Reply type="set" id="123">
  <Command name="TraceEnable">
```

```
    <Param name="eTraceTag">TRACETAG_GPS_COMPASS</Param>
    <Param name="zIP">10.11.12.13</Param>
    <Param name="iPort">12345</Param>
  </Command>
</Reply>
```

3.18.4.3 TraceDisable

The XML command `TraceDisable` will disable a running data output on a data trace. It can be used as a set command only.

Proceed as follows to disable the trace data output:

1. Send the command shown in example 3.
   The input parameters are described in Table 3-112. Note that, since any kind of data trace can be switched off individually, the parameter
   - `eTraceTag`

   is still relevant here.
2. Answer shown in example 4.

   In the answer appearing, the parameters specified are confirmed.

Example 3: Command

```
<Request type="set" id="123">
  <Command name="TraceDisable">
    <Param name="eTraceTag">TRACETAG_GPS_COMPASS</Param>
    <Param name="zIP">10.11.12.13</Param>
    <Param name="iPort">12345</Param>
  </Command>
</Request>
```

Example 4: Answer

```
<Reply type="set" id="123">
  <Command name="TraceDisable">
    <Param name="eTraceTag">TRACETAG_GPS_COMPASS</Param>
    <Param name="zIP">10.11.12.13</Param>
    <Param name="iPort">12345</Param>
  </Command>
</Reply>
```

3.18.4.4 TraceDelete

The XML command `TraceDelete` will delete an entire trace connection (all tags). Due to backward compatibility reasons, a trace is not deleted when the TCP connection is being closed.

3.18.4.5 TraceDeleteInactive

The XML command `TraceDeleteInactive` will delete all inactive traces (i.e. all traces without an active TCP connection). Due to backward compatibility reasons, a trace is not deleted when the TCP connection is being closed, see 3.18.4.4.

4 Service

4.1 Maintenance

4.1.1 General

4.1.1.1 Cleaning

Clean the outside of the R&S DDF5GTS using a soft, lint-free dust cloth.

NOTICE

Damage caused by cleaning agents

Never use cleaning agents such as solvents (thinners, acetone, etc.), acids, bases, or other substances. They can damage the R&S DDF5GTS, for example the front panel labeling or plastic parts.

4.1.1.2 Storing and Packing

The R&S DDF5GTS can be stored at the temperature range quoted in its specifications. When it is stored for a longer period of time protect it against dust.

For transportation always use the original packing, particularly the protective caps at the front and rear. If the original packing is no longer available, use a sturdy cardboard box of suitable size and carefully wrap the R&S DDF5GTS to protect it against mechanical damage.

4.1.2 Disassembling and Assembling the R&S DDF5GTS

Authorized Service Staff

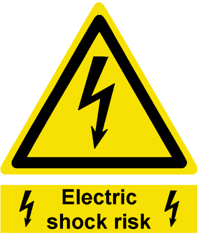
All work requiring disassembly and reassembly of the R&S DDF5GTS is exclusively to be done by authorized service staff.

This also applies to replacement of the lithium back-up battery located on the Processor Board.

4.1.3 Replacing the Fuses

Information given in this chapter is valid for both the R&S EBD770 and the R&S EHT770.

4.1.3.1 Fuses in AC Power Supply Model



The R&S DDF5GTS (R&S EBD770 and R&S EHT770) is protected against too high supply voltage by two fuses (called F1 and F2, type IEC127-T6.3H/250 V) located in the fuse holder beside the AC power switch on the rear panels (Chapter 3.3.2.1, "AC Power Supply Model", on page 96).

WARNING

Shock Hazard

Before you replace the fuse, make sure that the R&S DDF5GTS is

- switched off by the mains switch and
- disconnected from the power supply (plug removed from the AC power connector).

WARNING

Fuse Type

Be aware when replacing the fuse to always fit the correct type: IEC127-T6.3H/250 V (order number 0020.7630.00).

Fitting a different type of fuse may cause severe damage to the R&S DDF5GTS, exceeding physical damage or even personal injury.

To replace the fuses, follow the procedure described below.

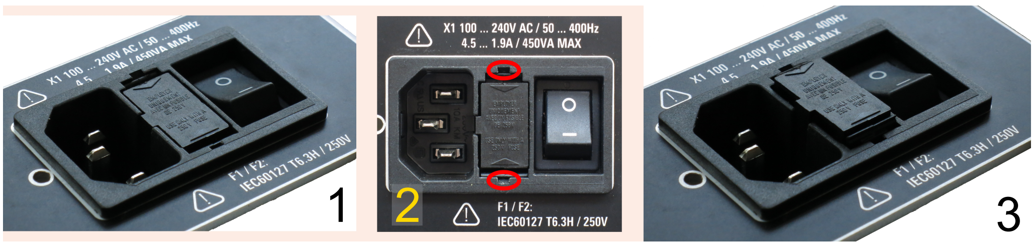


Figure 4-1: Replacing the fuses: removing fuse holder.

1 = fuse holder mounted
2 = fuse holder top view, holes to unlock marked red
3 = fuse holder ejected

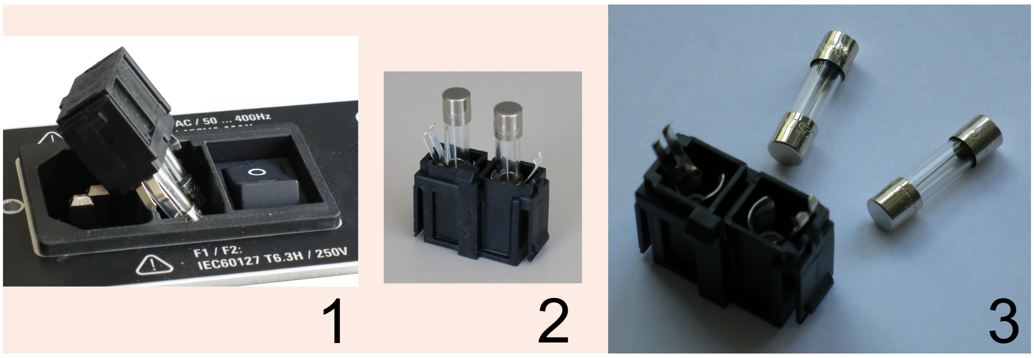


Figure 4-2: Replacing the fuses: removing and remounting fuses.

1 = removed fuse holder
2 = fuse holder with its two fuses
3 = fuse holder with fuses dismounted

1. The fuse holder (Figure 4-1, 1) is held in its housing by two flat springs at its narrow side. Unlock them one after another by introducing a sharp tool into the particular hole (marked red in Figure 4-1, 2) and pressing it towards the fuse holder.
2. When both springs are unlocked, the fuse holder will be ejected by itself (Figure 4-1, 3). Lever it out further with a pocket screw driver or the like if necessary and remove it (Figure 4-2, 1 and 2).
3. The two fuses can be removed easily (Figure 4-2, 3).
4. In place of the damaged fuse(s) insert (a) new one(s) in the same position and fix it (them) by pressing it (them) in smoothly.
5. Remount the assembled fuse holder to its housing, thereby observing the correct orientation. Remounting it in the wrong (turned round) orientation is not possible. Pay attention that none of the fuses falls out of its retainer; if this should happen, first refit it before remounting the fuse holder.
6. Press the fuse holder back to its housing until it finishes to the surface. A clicking sound indicates the plastic springs snapping in.

4.1.3.2 Fuses in DC Power Supply Model

Since, using low supply voltage, fuse contacts would cause the risk of inadmissibly high transfer resistance, it is not possible in the DC case to achieve overvoltage protection by replaceable fuses. A protection exists anyway, consisting of protector diodes dissipating too high supply voltage to a certain degree and of an additional fuse situated within the unit. This fuse is not to be replaced by the user though, but only by authorized service staff. Thus, with the R&S DDF5GTS DC model, pay special attention not to feed a supply voltage outside of the permitted range (see electrical specifications in the R&S DDF5GTS data sheet).

⚠ WARNING

DC Supply Voltage and Polarity

The R&S DDF5GTS DC power supply model is intended to be utilized in cars and vehicles with a car battery voltage of 12 V or 24 V.

If operated in other environment with different voltage sources, pay enhanced attention to

- voltage being in the permitted range (see electrical specifications in the R&S DDF5GTS data sheet)

and, in any case, to

- correct polarity.

4.1.4 Alignment of the 10 MHz Reference Oscillator

In order to ensure accurate receiver frequencies, the internal 10 MHz reference oscillator (OCXO, inside the R&S EBD770) must be trimmed once a year:

- Connect a frequency counter with a tolerance of $1 \cdot 10^{-8}$ (or less) to **X42** ***REF OUT*** at the rear panel of the R&S EBD770.
- Switch to internal reference; this can be done either via the GUI (see the R&S DDF5GTS operating manual) or via the (XML) command [2.4]
  - `ReferenceMode`
- The warm-up time of the devices before start of calibration is at least 5 minutes.
- Trim the frequency to 10 MHz ± 0.1 Hz at room temperature.

Environmental Influence on Oscillator Precision

Always observe diligently the above-mentioned environmental indications:

- precision of the frequency counter,
- long enough warm-up time,
- accurate trimming to the correct value.

Disregarding correctness of even one of these parameters would result in wrong calibration of an essential part of the R&S DDF5GTS and thus to a future unsatisfactory function of the whole unit or the entire system containing it.

4.1.4.1 OCXO Calibration via GUI

See R&S DDF5GTS Operating Manual.

4.1.4.2 OCXO Calibration via Remote Command

The alignment can be carried out via the XML command

- `OCXO`

The parameters are described in Table 4-1.

Table 4-1: Parameters for the OCXO command.

OCXO parameters				
Name	**Type**	**Description**	**Direction**	**Example**
iCalValue	INT32	Calibration value (D/A converter value)	SET, GET	2048
iCalYear	INT32	Calibration date, year		2012
iCalMonth	INT32	Calibration date, month		5
iCalDay	INT32	Calibration date, day		24
bStore	BOOLEAN	Store calibration value and date permanently? • TRUE: yes • FALSE: no	SET	TRUE

Example 1

Query on the current calibration value and date:

Command to the R&S DDF5GTS:

```
<Request type="get" id="123">
  <Command name="OCXO">
  </Command>
</Request>
```

Answer from the R&S DDF5GTS:

```
<Reply type="get" id="123">
  <Command name="OCXO">
    <Param name="iCalValue">2048</Param>
    <Param name="iCalYear">2012</Param>
    <Param name="iCalMonth">5</Param>
    <Param name="iCalDay">24</Param>
  </Command>
</Reply>
```

Example 2

Change the values, do not store altered values:

Command to the R&S DDF5GTS:

```
<Request type="set" id="123">
  <Command name="OCXO">
    <Param name="iCalValue">2048</Param>
    <Param name="iCalYear">2012</Param>
    <Param name="iCalMonth">5</Param>
    <Param name="iCalDay">24</Param>
```

```
    <Param name="bStore">false</Param>
  </Command>
</Request>
```

Answer from the R&S DDF5GTS:

```
<Reply type="set" id="123">
  <Command name="OCXO">
  </Command>
</Reply>
```

Example 3

Store calibration value and date of calibration:

Command to the R&S DDF5GTS:

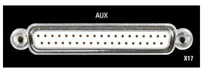
```
<Request type="set" id="123">
  <Command name="OCXO">
    <Param name="iCalValue">2048</Param>
    <Param name="iCalYear">2012</Param>
    <Param name="iCalMonth">5</Param>
    <Param name="iCalDay">24</Param>
    <Param name="bStore">true</Param>
  </Command>
</Request>
```

Answer from the R&S DDF5GTS:

```
<Reply type="set" id="123">
  <Command name="OCXO">
  </Command>
</Reply>
```

The trimmed value is stored non-volatilely in the synthesizer module and is not affected from reset or factory reset.

4.1.5 Reset



A reset is carried out when line "EXT_RST_IN" (pin 6 of connector **X17** ***AUX***) at the rear panel is briefly grounded (for example, via pin 3 of connector **X17**) while the R&S DDF5GTS is switched [on] (see Chapter 2.3.1.4, "Power on and off", on page 31). The data for the configuration of the LAN interface is stored in an EEPROM. It is not affected by power failures and cannot be changed by a reset.

Resetting the main processor by the XML (XML) command [2.4]

- `Reset`

is described in Section "Starting the Update", on page 367.

4.1.6 Built-in Self Tests

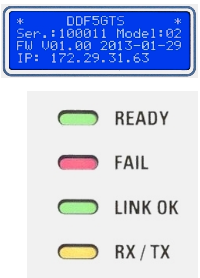
The R&S DDF5GTS has an extensive self test feature (BIT) incorporated, consisting of

- tests monitoring normal operation (based on a range of test points spread over the internal modules and being continuously observed) and issuing error messages if necessary,
- the possibility to invoke special diagnosis tests interrupting operation in order to inspect the signal paths.

4.1.6.1 Test Levels

Power-On Self Test

- *Monitoring the booting process*



The power-on self test is processed while the firmware is being booted. The booting procedure is monitored and some messages concerning the progress are displayed on the four-line status display on the front panel. If failures occur, the red [Fail] LED lights up in any case, but booting is tried to be continued. If booting of the PPC could be performed successfully, all test points described in Section "Continuous Monitoring (CM)" should normally be possible to inspect, allowing conclusions onto the reason for the failure this way. If booting had to be stopped, normal operation of the unit is not possible in consequence. Reasons for that mostly are situated in the hardware field, thus, measures to take cannot be recommended generally. Try to find out evident causes for the abortion making use of the display messages, eliminate them if possible and retry booting; otherwise initiate a repair.

Continuous Monitoring (CM)

- *Continuous processing during normal operation*
- *Monitoring the correct operation of the unit by continuous inspecting of a selection of test points*

Continuous Monitoring (CM) is continuously processed during normal operation. If the operation parameter of a defined test point has been detected to have left its intended range, the red [Fail] LED lights up and a message (4.1.8) is displayed in the GUI.

Test parameters are in detail:

- Speed of the cooling fans,
- Temperature of some sensors throughout internal space,
- DC/DC converter (used for internal voltage generation, not to be confused with DC power supply) output voltages,
- Supply voltages of each board,
- Voltage of internal lithium battery cell,
- VCO voltages,
- Internal overvoltage sensors,
- (Pre-) Amplifier currents,

- Some clock or other frequencies,
- Local oscillator (LO) levels,
- "PLL locked" signal,
- Multi-Gigabit Transceivers (MGT) (fast serial lines for data transfers) between the FPGAs.

All of these test points/parameters can also be inquired selectively by the XML (XML) command [2.4]

- `TestPoints;`

if unsure about which hardware module to examine, specify `ALL` (also the default value) for obtaining information about all test points on all modules, instead of a decided `zModuleName`.

Dependencies between these factors are observed, from that, in case of identification of multiple faults in parameters arranged hierarchically only the higher-ranking fault will be signaled.

An example of an error message is shown in Table 4-2.

Table 4-2: Test point output in case of tolerance limit exceeded.

Name		value			Explanation
assembly (short)	test point	measured	tolerance limit		
			lower	upper	
H1	TPREAMP_N	2346	:400	1200	Preselection HF

Short Self Test

- *Initiation by a special XML command (4.1.6.2), interrupting normal operation*
- *Signal path test for the frequency currently set*
- *Calibration test*

A short and a long self test can be initiated by the user via a special XML command (4.1.6.2). Both tests inspect the signal path through the analog modules from the Wideband Frontend to the ADC Multi-Board (beginning of digital subsequent processing). Normal operation will be interrupted meanwhile.

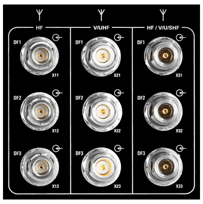
The analog signal path (selection filters) varies with the frequency range used. From this, the most significant difference between both kinds of test is that the short self test does the signal path inspection only for the path used for the current setting of the Rx frequency, whereas the long self test (Section "Long Self Test") does so for all signal paths testable with the current configuration.

As explained in Chapter 2.6.2, "R&S DDFGTS-HF, HF Frequency Extension", on page 82, the entire RF frequency range of the R&S DDF5GTS is covered by the individual ranges HF (option R&S DDFGTS-HF), VHF/UHF and SHF. Due to the three Rx channel architecture in all frequency ranges, short and long test can take place in the same manner in each range (Section "Multichannel Self Test").

Multichannel Self Test

In Figure 4-3, the signal flow for a multichannel self test (HF with option R&S DDFGTS-HF and VHF/UHF) is shown: As the signal source, the calibration generator is used here; its output (comb spectrum or single CW tone) is sent to the DF antenna connected via the calibrating signal socket:

- **X14** ***CAL HF*** (option R&S DDFGTS-HF installed),
- **X24** ***CAL V/UHF*** or
- **X34** ***CAL U/SHF***.



In the star point of the DF antenna the signal is distributed to the three signal paths, these are delivered back to the unit and entered via the RF connectors:

- (option R&S DDFGTS-HF installed)
  X11 ***HF, DF1***,
  X12 ***HF, DF2***,
  X13 ***HF, DF3*** or
- **X21** ***V/UHF, DF1***,
  X22 ***V/UHF, DF2***,
  X23 ***V/UHF, DF3*** or
- **X31** ***HF / V/U/SHF, DF1***,
  X32 ***HF / V/U/SHF, DF2, 2***,
  X33 ***HF / V/U/SHF, DF3***,

respectively. Each of the three antenna signals is forwarded to its own frontend. Again, the digitalized levels measured are compared to the reference values stored in the calibration generator, and they also are made available to the GUI.

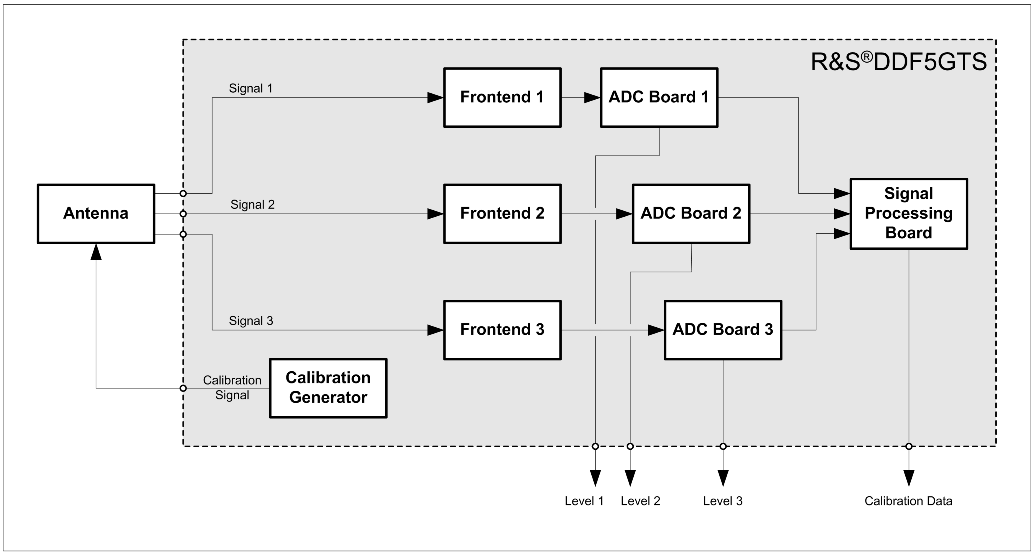


Figure 4-3: Signal flow in multichannel test.

Note that this testing method requires a suitable DF antenna to be connected to the R&S DDF5GTS during the test. The selected antenna must be compatible to the switching process and, in addition, be capable of treating the frequency range to be tested. (The frequency characteristic of the RF switch inside the antenna is optimized to the frequency range the antenna is intended for, thus it cannot be used outside this range.) Alternatively, a dummy antenna may be connected being able to test the entire frequency range (see performance specifications in the R&S DDF5GTS data sheet) making use of a wideband power divider.

This method does not test the DF antenna itself (e.g. the antenna elements) because distribution of the signal is done in the star point (not via a test radiator) and, by this, the antenna elements are not part of the signal path.

In the VHF/UHF range, also a calibration test of the DF antenna (including the antenna RF lines) is performed. For this purpose, three times a calibration with 11 spectral lines (comb frequencies) surrounding the current frequency is done: absolute level values and level and phase differences from DF channel 2–1 (2 referenced to 1) to channel 3–1 and also between the three calibration sequences are evaluated.

Long Self Test

- *Initiation by a special* XML *command (4.1.6.2), interrupting normal operation*
- *Query of peripherals*
- *Check of the Serial Peripheral Interface (SPI) bus*
- *Signal path test for all frequencies currently applicable*
- *Calibration test*

Prior to the main component of the long self test described below, scanning (querying) of the peripherals currently connected is repeated (as done when booting the unit), thus testing again the relevant external interfaces.

The serial bus connecting all internal boards (SPI bus) is tested as the next step.

In the long self test, in contrast to the short test, the signal paths for all frequencies covered by the connected DF antenna(s) are inspected. Currently, the overall count of signal paths in parallel is 11, the relevant one to be selected from according to the current frequency. The procedure is to test each of these paths near the lower border, near the center and near the upper border of the covered frequency range. If applicable, both available IF bandwidths (20 MHz and 80 MHz) are used subsequently. Additionally, all existing settings of the internal attenuators are checked.

All other proceedings have been described in Section "Short Self Test". Again, in the VHF/UHF range, a calibration test is done on each applied frequency using the 11 spectral lines mentioned.

Test during Calibration

- *Execution during calibration process*
- *Monitoring of the level of the calibration generator signal output*

Additionally, during each calibration process (calibration measurement and subsequent readjusting of the corresponding correction values) the levels of the calibrating signal are surveyed:

- Level of calibrating signal of all comb lines: > 30 dBµV,
- Level of CW calibrating signal: > 50 dBµV,
- Level difference between DF channels 1 and 2 or 1 and 3, respectively: < 10 dB.

4.1.6.2 Initiating (Command)

For initiating a self test (short self test or long self test), you use the XML (XML) command [2.4]

- `Selftest`

with the options

- short (`eSelfTestType=SELFTEST_SHORT`) and
- long (`eSelfTestType=SELFTEST_LONG`).

Failures possibly occurred will be issued as described in 4.1.8.

4.1.7 Antenna Element Test and Antenna Cable Test

4.1.7.1 General

- *Initiation by a special user command, interrupting normal operation*
- *Testing of the individual antenna elements and antenna cables*

Signal Emission

When performing antenna element tests, always be sure, in order not to disturb normal radiocommunication, to emit signals only on frequencies you have a permission for.

Two methods for testing the individual elements of a DF antenna and also a test of the cables are possible:

- **DF antenna with no test radiator integrated:**
  A test of the individual antenna elements (radiators) cannot be performed using the calibrating signal from the calibration line, because distribution of the signals is done at the star point of the antenna.
  Thus, the signal of a known transmitter is used as the exciting signal. This method is commonly employed if no test radiator is integrated with the DF antenna, but can also be practiced otherwise.
  If the sensitivity of the entire antenna or the individual elements is not independent of the direction of wave incidence, the emitter is to be made surround the antenna (or the antenna is to be rotated), and later-on evaluation of measured levels has to consider these dependencies.
- **DF antenna with integrated test radiator:**
  If the DF antenna offers a test radiator, the calibrating signal from the calibration generator is sent to it. Be aware to only have frequencies in use that do not carry strong external signals at the moment.
- **Antenna cable test:**
  As told with the case "with test radiator", the calibrating signal is sent to the antenna, but now the calibration switch is set to calibration. Hence the signal is not carried to the test radiator to be emitted, but immediately returned to the R&S DDF5GTS via the antenna signal lines.

The antenna element/cable test only works in DF mode FFM (cf Chapter 3.7 on page 132).

4.1.7.2 Antenna Geometry

In Figure 4-4, an example of a nine-element DF antenna with a test radiator is given: in antenna element test mode, the test radiator is supplied via the antenna star point with the calibration signal coming from the R&S DDF5GTS, emits it to the nine antenna elements under test (not all emission paths shown for clarity), each of which receives the signal and, via the internal antenna wiring, delivers it back to the star point and via the RF lines to the unit. Correct switching, if necessary, is provided by the antenna control lines.

When testing the antenna cables instead of the antenna elements, the calibration switch inside the antenna star point leads the calibration signal directly back to the R&S DDF5GTS (not via test radiator and antenna elements).

Be aware that, due to geometrical limitations, the test radiator is not necessarily positioned in the exact center of the antenna or might be partially shadowed, hence no high-precision measurements, but just functional tests are intended to be possible.

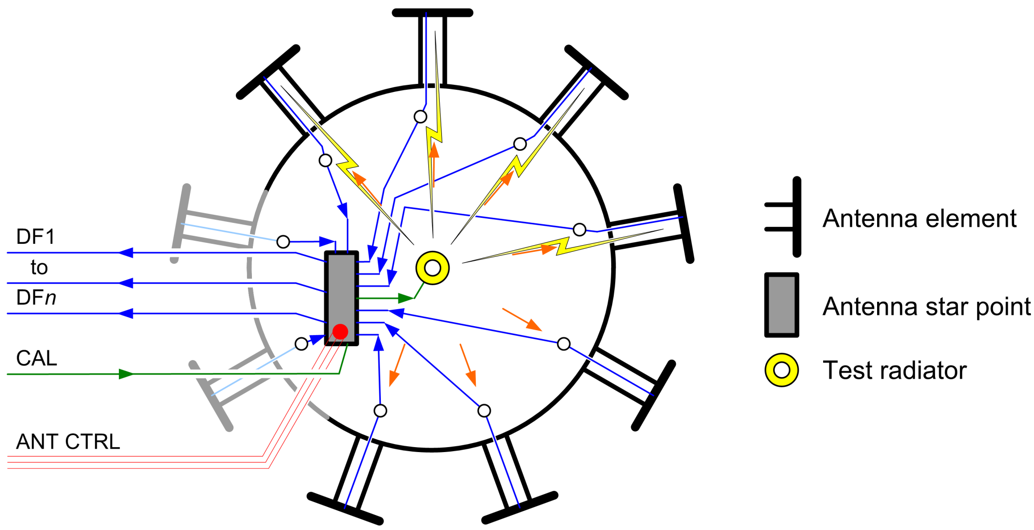


Figure 4-4: Multi-element DF antenna with test radiator.

n = count of antenna signal lines
R&S DDF550 = 3 lines: n = 3
R&S DDF5GTS = 3 lines: n = 3
R&S DDF1GTX = 10 lines (max.): n = 10

With antennas that cover a wider frequency range by switching between several distinct individual antenna arrays, always solely the array will be tested that is in use together with the currently activated Rx frequency (or calibrating frequency, if using a test radiator). If intending to test a special part of the antenna, therefore always make sure to have the appropriate frequency selected.

4.1.7.3 Invoking

Inquire whether the particular antenna to be tested is equipped with an antenna test radiator or not by the XML (XML) command [2.4]

- `AntennaProperties` , parameter `bTestElementAvailable`

The parameter will have the value `true` if a test radiator exists and `false` otherwise.

The antenna element/cable test itself is executed on request by the XML command

- `AntennaLevelSwitch` , parameter `eAntLevelSwitch`

In case of an antenna without a built-in test radiator, select

- `AntennaLevelSwitch`: `eAntLevelSwitch=ANTLEVEL_ON_EMITTER_OFF`

or, for such a radiator existing with the antenna,

- `AntennaLevelSwitch`: `eAntLevelSwitch=ANTLEVEL_ON_EMITTER_ON`

or, for executing the antenna cable test,

- `AntennaLevelSwitch`: `eAntLevelSwitch=ANTLEVEL_ON_CABLE`

In all cases, normal operation will be interrupted meanwhile, this is, the R&S DDF5GTS stops issuing *DFPScan* mass data (Chapter 3.18.2.17 on page 295) and starts sending *ANT_LEVEL* diagnosis data (Chapter 3.18.2.16 on page 292) instead.

You terminate the antenna element/cable test by

- `AntennaLevelSwitch`: `eAntLevelSwitch=ANTLEVEL_OFF`

the R&S DDF5GTS will cease issuing of *ANT_LEVEL* diagnosis data then and resume sending of normal *DFPScan* mass data.

4.1.7.4 Order of Data Issuing

The order of issuing the individual antenna element level values follows the labeling order of these elements themselves; mind also Note "Numbering System with Antenna Elements" on page 165. Find this order (seen from top) in Figure 4-5 for

- **Correlation antennas with 9 elements (A):**
  Element 1 is the one pointing to the direction of the antenna north marker (not necessarily to real north direction, cf Chapter 2.5.5, "North Alignment", on page 65), the remaining elements (2 to 9) are numbered clockwise from there.
- **Correlation antennas with 8 (B) or 6 elements (C):**
  Element 1 is the virtual so-called "omni" antenna (not physically existing, but calculated from the averaged values of the other antennas), imagined in the antenna center, element 2 the north element (see above), the remaining elements (3 to 8 or 6, respectively), again, following clockwise.
- **Watson-Watt antennas with 2 two-element pairs (D):**
  A Watson-Watt or "Adcock" antenna (named after the British engineer *Frank Adcock*) consists of two pairs of elements, the one (pair 2) of which is oriented from

antenna north to south and the other one (pair 3) from east to west. Again, a virtual omni antenna (element 1) is imagined in the center.

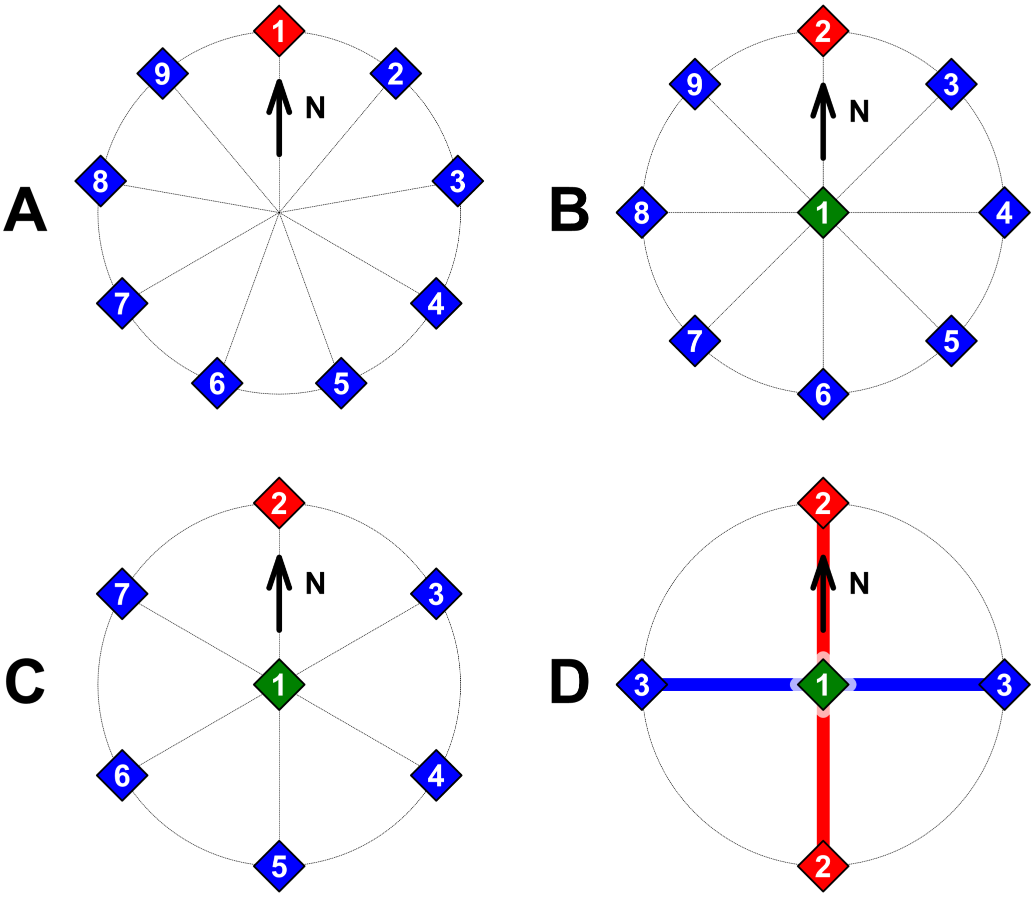


Figure 4-5: Labeling of antenna elements (view from top).

A = correlation antenna with 9 antenna elements: "1" to "9"
B = 8 elements: "2" to "9"
C = 6 elements: "2" to "7"
D = Watson-Watt antenna: crossed-loop ("Adcock") antenna of element pairs: 2 pairs: "2" and "3"
N = direction of antenna north marker
red = element pointing to antenna north marker (or N – S oriented element pair)
blue = all other elements (or E – W oriented pair)
green = virtual "omni" element (not physically existent): "1"

With antenna cable test selected, the basic order of issuing is the same, but, due to only 3 antenna channels (3 antenna lines) (find more information on this in Chapter 3.11, "Averaging", on page 165) and commonly more than 3 antenna elements present, the level indications of the individual antenna bases are averaged over the antenna cycle. From that, the values of each antenna base (e.g., for **A** in the figure, elements 2, 3, 4 and 5 or 9, 8, 7 and 6, respectively) issued with the *ANT_LEVEL* data trace are the same. Find an example on this in Table 4-3.

Table 4-3: ANT_LEVEL issuing example for a 9-element DF antenna (A in the figure).

Position of issuing Ant_Level[*i*] (*i* = 1, ..., 9)	Level indication of element *i* in case of test of antenna ... elements	cables
[1]	1	1
[2]	2	Ø(2,3,4,5)
[3]	3	Ø(2,3,4,5)
[4]	4	Ø(2,3,4,5)
[5]	5	Ø(2,3,4,5)
[6]	6	Ø(6,7,8,9)
[7]	7	Ø(6,7,8,9)
[8]	8	Ø(6,7,8,9)
[9]	9	Ø(6,7,8,9)

4.1.7.5 Order of Incidence

Be aware in this context that this issuing order has nothing to do with the order of chronological (or spatial) incidence of an incoming wave to the individual elements. As can easily be understood from Figure 4-6, such an order of issuing the values (3 – 2 – 4 – 1 – 5 – 9 – 6 – 8 – 7 in the example shown) would depend on the current angle of wave incidence *α* and therefore not be unambiguous.

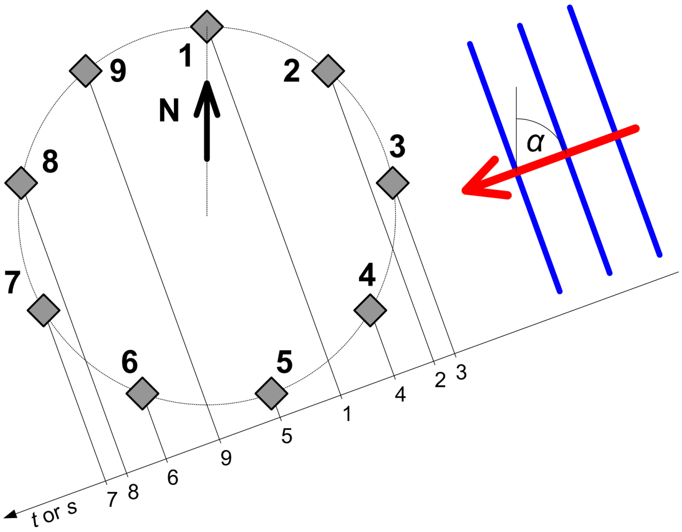
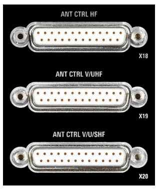


Figure 4-6: Wave inciding to correlation antenna.

α = angle of wave incidence vs. antenna north

4.1.7.6 Antenna Bits

For diagnostic or test reasons, you may modify the antenna control signals (cf Chapter 3.3.3, "Antenna Control", on page 98), also called antenna bits, of



X18 ***ANT CTRL HF*** **X19** ***ANT CTRL V/UHF*** **X20** ***ANT CTRL V/U/SHF***

i.e. the signals ANT0+/ANT0– to ANT6+/ANT6–. Pin assignment of each socket is shown in Table 3-2 and pinout in Figure 3-6; the signals theirselves are special to the R&S ADDx antennas, find their meaning, if needed, in the antenna manuals.

Use the XML command

- `AntennaBitsControl`

for this, but be aware that it is only recommended for testing signal flow in the R&S DDF5GTS, but particularly advised against to arbitrarily do so with an antenna connected. The antenna control signals (antenna bits) control the DF antenna (correct configuration for the individual frequency ranges, polarizations or other physical conditions); this is done automatically by the R&S DDF5GTS and intended in no case to be affected by the user.

The command contains an antenna bits mask (parameter `iAntennaBitsMask`) and the actual bits to set or reset the antenna control signals themselves (parameter `iAntennaBits`). Only antenna signals the corresponding mask bits of which are opened (set to 1) are concerned (set [= 1] or reset [= 0]), all others remain unchanged. Additionally, you may select whether the bits to set should be valid in any case or a distinction be made between normal DF operation and calibration mode. This distinction is, separately for both parameters, activated by bit 31 (MSB): if set to

- **0:** bit 7 to bit 0 apply at any time
- **1:** bit 7 to bit 0 apply only for normal DF operation, bit 15 to bit 8 for calibration

You use these parameters for setting the bits or also to read back what you have set/reset lately; mind, however, that the pins of the socket are mere output pins, hence do not try to apply an external input signal to the socket and then to read it back with the command; neither can you determine the current antenna state this way.

Assignment of the parameter bits to the socket pins is shown in Table 4-4 (bit 7 to bit 0 only, applies for bit 15 to bit 8 accordingly).

Table 4-4: Assignment of command parameter bits to signal pins.

Assignment of command parameter bits to signal pins								
Bit in parameter	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Signal name	used internally	ANT6+/–	ANT5+/–	ANT4+/–	ANT3+/–	ANT2+/–	ANT1+/–	ANT0+/–
Pin no.		15/17	9/22	12/13	10/11	5/18	3/16	1/14

The command always applies to all three antenna control sockets at a time, selection of an individual socket is not possible. If you wish to terminate manually influencing the antenna bits, reset the antenna bits mask entirely and issue the command anew.

4.1.8 Troubleshooting (Error Messages)

4.1.8.1 Error Data Sink

All events in the R&S DDF5GTS are logged via the error data sink.

For linking yourself to the error data sink, establish a TCP socket connection to port 5564 (port 5555 + 9, unless the base port number is different from 5555, see Note "IP Addresses and Port Numbers" on page 372). From this moment, asynchronous error messages are received via this interface (directly in plain ASCII). Each message occupies an extra line.

The error data sink supports multiple TCP clients. As long as no client at all is connected, emerging messages will be buffered and then output to the first client having established a connection. Further clients connected later on, anyway, will not receive these buffered messages any longer, but only new messages appearing from the moment their TCP connection has been established.

4.1.8.2 Message Format

The message format is

```
date time [number] level-type : text
```

with

`date`	Date in the format YYYY-MM-DD (year-month-day)
`time`	Time (UTC) in the format HH-MM-SS (hour-minute-second)
`number`	12-digit number (message number) of the event (blanks added to the left if necessary)
`level`	3-character code of message level (see Table 4-5)
`type`	2-character code of message type (see Table 4-5)
`text`	Plain text (message text)

Examples (word wrap inserted ex post for better readability):

```
2011-03-31 10:19:59 [       10000] INF-RT : logger: connected to 10.8.13.63

2013-03-06 10:02:04 [       10520] ERR-CH : command <AntennaProperties> -
    No antenna found with the name "ADD999"
```

4.1.8.3 Levels and Types

The possible levels and types of messages that are output via the error data sink are listed in Table 4-5.

Table 4-5: Levels and types of built-in self test messages.

Level		*Type*			
Meaning	**Code**	**Meaning**	**Code**	**Meaning**	**Code**
Info	INF	Command History	CH	Long Test	LT
Warning	WRN	Runtime	RT	Boot	BO
Error	ERR	Short Test	ST	Continuous Monitoring	CM
Debug[1)]*	DBG				

[1)] *For internal use only.*

4.1.8.4 Messages

The R&S DDF5GTS, as mentioned in 4.1.6, transmits information about all errors detected during Continuous Monitoring (CM) or a self test invoked specifically to the GUI (client) in error messages.

A list of most relevant messages together with an explanation of each is given subsequently. Shown (see the example) are the message number and the message text; as told in 4.1.8.2, arising messages also contain information about date and time they have been generated and their level and type.

Message Significance

- Decisive for the identity of an individual message is the message number, it is considered dedicated to it; thus use it, if desired, for automatic error classification. The text of a message, in contrast, might be subject to change in future firmware versions.
- The list of messages given in this chapter does not cover all error messages issued by the R&S DDF5GTS, i.e. additional messages (with deviant numbers) not originally intended for the user might be observed.

Example

`10,"Component failure;Fan defective"`

If an error message arises, first determine the kind of message (represented by the leading error number and additionally written in plain text – in the example shown error number `10` and message kind `Component Failure`), and then try to find the error location and source by the message content (`Fan defective` in the example). If the fault signalized seems to be evident (e.g. `Temperature too high`), eliminate the cause and try again, otherwise check the test points (4.1.6.1) in the environment of the location told. In most cases, if there is a hardware failure, contacting *Rohde & Schwarz* for initiating a repair might be inevitable.

Word Wraps and Blanks

- Word wraps in the successive descriptions of the error messages have been inserted belatedly for a better readability. The original error messages are output in plain ASCII without any word wrap.
- The count of blanks shown in the description may differ from the count in the original message.

Message 1

`"Device dependent error;Backup lithium battery low"`

Level:	**WRN** (Warning)
Type:	• CM (Continuous Monitoring)
Meaning:	Voltage of lithium backup battery low, loss of data imminent
Cause:	Battery exhausted (test point has responded)
Measure:	Contact *Rohde & Schwarz* to have battery replaced

Message 10

a) `"Component failure;`*`[hardware_assembly]`*` defective"`

b) `"Component failure;Check external reference"`

c) `"Component failure;Reference unlocked"`

Level:	**ERR** (Error): Hardware fault
Type:	• CM (Continuous Monitoring)
Meaning:	**a)** fault in assembly *`hardware_assembly`*: • `ADC board`: ADC Multi-Board 1 or 2 • `DC converter`: DC/DC converter used for internal voltage generation (available both with AC and DC power supply), not to be confused with DC power supply • `DDF CalGen`: Calibration Generator and Distribution Board • `Fan`: one of the cooling fans moves too slow or too fast • `Motherboard`: Motherboard • `Preselector`: VHF/UHF Wideband Frontend Board 1 or 2 • `Preselector HF`: HF Frontend Board • `Processor`: Processor Board or Ethernet Switchboard • `SIGV board`: Signal Processing Board 1 or 2 • `Synthesizer`: Wideband Synthesizer Board
	b) no external reference available
	c) signal on external reference input detected, but reference PLL not yet locked

Cause:	Test point (see 4.1.6, "Built-in Self Tests") has responded In case of **a)**, `Fan defective`: fan speed not correct, damage of assemblies due to overtemperature imminent In case of **b)** cabling possibly wrong
Measure:	Switch off the R&S DDF5GTS immediately (especially in case of `Fan defective`) Check correct cabling (in case of **b)**), otherwise contact *Rohde & Schwarz* and tell test point ID to get further information

Message 200

`"Temperature too high;`*`[hardware_assembly]`*` defective"`

Level:	**ERR** (Error): Hardware fault
Type:	• CM (Continuous Monitoring)
Meaning:	Fault in assembly *`hardware_assembly`*: temperature too high (cf message 10): • `ADC board` • `Motherboard` • `Processor` • `DC converter` • `Preselector` • `SIGV board` • `DDF CalGen` • `Preselector HF` • `Synthesizer`
Cause:	Test point (see 4.1.6) has responded
Measure:	Switch off the R&S DDF5GTS immediately Check whether environment temperature specifications (see environmental specifications in the R&S DDF5GTS data sheet) have been obeyed, otherwise contact *Rohde & Schwarz* and tell test point ID to get further information

Message 201

`"Temperature too low;`*`[hardware_assembly]`*` defective"`

Level:	**ERR** (Error): Hardware fault
Type:	• CM (Continuous Monitoring)
Meaning:	Fault in assembly *`hardware_assembly`*: temperature too low (cf message 10): • `ADC board` • `Motherboard` • `Processor` • `DC converter` • `Preselector` • `SIGV board` • `DDF CalGen` • `Preselector HF` • `Synthesizer`
Cause:	Test point (see 4.1.6) has responded
Measure:	Switch off the R&S DDF5GTS immediately Check whether environment temperature specifications (see environmental specifications in the R&S DDF5GTS data sheet) have been obeyed, otherwise contact *Rohde & Schwarz* and tell test point ID to get further information

Message 11213

`"Missing hardware for signal analysis options:`
`SIGV optional board"`

Level:	**ERR** (Error)
Type:	• RT (runtime)

Meaning:	With signal analysis options ● R&S DDFGTSDDCE, *DDC Signal Extraction* ● R&S DDFGTS-ST, *Detection of Short-Time Signals*, and/or ● R&S DDFGTS-HRP, *High-Resolution Panorama* installed, the hardware option R&S DDFGTS-SP, *Signal Processing Board*, needed for their proper operation is missing
Cause:	Hardware option told not present
Measure:	Install option

Message 11214

```
"Missing hardware for signal analysis options:
wrong version of SIGV optional board [ob]"
```

Level:	**ERR** (Error)
Type:	● RT (runtime)
Meaning:	With signal analysis options (see message 11213) installed, the hardware version, i.e. ● module number `#ob` of the signal processing board (SIGV board) in option R&S DDFGTS-SP, *Signal Processing Board* is wrong (too old)
Cause:	Hardware option told present, but obsolete
Measure:	Install option in correct version

Message 11215

```
"Missing hardware for signal analysis options:
FlexCable between ADC1 and ADC2"
```

Level:	**ERR** (Error)
Type:	● RT (runtime)
Meaning:	With signal analysis options (see message 11213) installed, the Flex cable between ADC board 1 and ADC board 2 is missing
Cause:	Flex cable between the ADC boards told is missing
Measure:	Install Flex cable

Message 11300

```
"Test failed:
  antenna path [ap],
  could not set signal"
```

Level:	**ERR** (Error)
Type:	● ST (short test) ● LT (long test)
Meaning:	Due to an internal problem, the ● antenna path `#ap` (`ap` = 1 to 3) could not be switched over

Cause:	Cabling possibly wrong
Measure:	Check cabling; test will be continued with next frequency range possible

Message 11301

```
"Test skipped:
  f=[f] MHz,
  antenna path,
  no antenna found"
```

Level:	**INF** (Info): Intended test not possible
Type:	• ST (short test) • LT (long test)
Meaning:	An antenna for the • frequency `f` MHz could not be found on any antenna path
Cause:	Cabling possibly wrong or no antenna present at all for frequency range in question
Measure:	Check cabling or supply suitable antenna; test will be continued with next frequency range possible

Message 11302

```
"Test started:
  f=[f] MHz,
  antenna path [ap],
  antenna [antenna_name]"
```

Level:	**INF** (Info): Status message
Type:	• ST (short test) (for HF only if option R&S DDFGTS-HF installed, see Chapter 2.6.2 on page 82) • LT (long test)
Meaning:	A test measurement at the • frequency `f` MHz on • antenna path #`ap` with the • antenna `antenna_name` has been started

Message 11304

```
"Test failed:
  att=[a] dB,
  noise=[n] dBuV,
  level=[L] dBuV,
  src=[s] dBuV,
  expected=[e] dBuV,
  unexpected signal conditions"
```

Level:	**ERR** (Error): Test failed
Type:	• ST (short test) (for HF only if option R&S DDFGTS-HF installed, see message 11302) • LT (long test)
Meaning:	The test measurement with • attenuation setting *a* dB has failed for a reason not told explicitly Parameters measured have been: • Receiver noise (calibration generator switched off): *n* dBµV, • Level received: *L* dBµV, • Level emitted by calibration generator: *s* dBµV, • Level expected: *e* dBµV
Measure:	Switch off the R&S DDF5GTS immediately Contact *Rohde & Schwarz* and tell message ID to get further information

Message 11305

```
"Test failed:
  att=[a] dB,
  noise=[n] dBuV,
  level=[L] dBuV,
  src=[s] dBuV,
  expected=[e] dBuV,
  signal out of expected range -30 to +16 dB"
```

Level:	**ERR** (Error): Test failed
Type:	• ST (short test) (for HF only if option R&S DDFGTS-HF installed, see message 11302) • LT (long test)
Meaning:	The test measurement (see detailed specification from message 11304) has failed because the • received level *L* dBµV differs too largely from the • level value expected *e* dBµV
Cause:	Cabling of the path not correct Fault in frontend assembly Fault in attenuator
Measure:	Switch off the R&S DDF5GTS immediately Check correct cabling, otherwise contact *Rohde & Schwarz* and tell message ID to get further information

Message 11306

```
"Test failed:
  att=[a] dB,
  noise=[n] dBuV,
  level=[L] dBuV,
  src=[s] dBuV,
  expected=[e] dBuV,
  signal overdriven"
```

Level:	**ERR** (Error): Test failed
Type:	• ST (short test) (for HF only if option R&S DDFGTS-HF installed, see message 11302) • LT (long test)
Meaning:	The test measurement (see detailed specification from message 11304) has failed because • level *L* dBµV emitted by the calibration generator has been too large (overdriven)
Cause:	Frequency low, cabling lines between antenna and R&S DDF5GTS extremely short, level emitted by the calibration generator too high
Measure:	Switch off the R&S DDF5GTS immediately Contact *Rohde & Schwarz* and tell message ID to get further information

Message 11307

```
"Test failed:
  att=[a] dB,
  noise=[n] dBuV,
  level=[L] dBuV,
  src=[s] dBuV,
  expected=[e] dBuV,
  snr < 12 dB"
```

Level:	**ERR** (Error): Test failed
Type:	• ST (short test) (for HF only if option R&S DDFGTS-HF installed, see message 11302) • LT (long test)
Meaning:	The test measurement (see detailed specification from message 11304) has failed because • level *L* dBµV emitted by the calibration generator has been too low, i.e. signal-to-noise ratio • *L* dBµV – *n* dBµV has been too low
Cause:	Frequency high, cabling lines between antenna and R&S DDF5GTS extremely long, level emitted by the calibration generator too low
Measure:	Switch off the R&S DDF5GTS immediately Check correct cabling, otherwise contact *Rohde & Schwarz* and tell message ID to get further information

Message 11308

```
"Test started:
  f=[f] MHz,
  calibration,
  antenna [antenna_name]"
```

Level:	**INF** (Info): Status message
Type:	• ST (short test) (for HF only if option R&S DDFGTS-HF installed, see message 11302) • LT (long test)
Meaning:	A calibration at the • frequency *f* MHz with the • antenna *antenna_name* has been started

Message 11309

```
"Test failed:
  u_ref=[uref] dBuV,
  u21=[u2] dB,
  u31=[u3] dB,
  level divergence between antenna paths > [dvg] dB"
```

Level:	**ERR** (Error): Test failed
Type:	• ST (short test) (for HF only if option R&S DDFGTS-HF installed, see message 11302) • LT (long test)
Meaning:	The test has failed because deviation of the levels of the paths is too large, i.e. exceeds • *dvg* dB: • uref = *uref* dBµV • u1/u2 = *u2* dB • u1/u3 = *u3* dB
Cause:	Cabling of one of the paths not correct Fault in an assembly
Measure:	Switch off the R&S DDF5GTS immediately Check correct cabling, otherwise contact *Rohde & Schwarz* and tell message ID to get further information

Message 11310

```
"Test failed:
  u_ref=[uref] dBuV,
  std_u21=[su2],
  std_u31=[su3],
  level deviation (3 measurements) > [ldev] dB"
```

Level:	**ERR** (Error): Test failed
Type:	• ST (short test) (for HF only if option R&S DDFGTS-HF installed, see message 11302) • LT (long test)
Meaning:	The test has failed because deviation (value of standard deviation) of the levels of each measurement step is too large, i.e. exceeds • *ldev* dB: • uref = *uref* dBµV • std_u21 = *su2* • std_u31 = *su3*

Cause:	Cabling of one of the paths not correct Fault in an assembly
Measure:	Switch off the R&S DDF5GTS immediately Check correct cabling, otherwise contact *Rohde & Schwarz* and tell message ID to get further information

Message 11311

```
"Test failed:
  u_ref=[uref] dBuV,
  std_phi21=[sp2],
  std_phi31=[sp3],
  phase deviation (3 measurements) > [pdev] deg"
```

Level:	**ERR** (Error): Test failed
Type:	• ST (short test) (for HF only if option R&S DDFGTS-HF installed, see message 11302) • LT (long test)
Meaning:	The test has failed because deviation of the propagation times (value of standard deviation of phase difference) of each measurement step is too large, i.e. exceeds • *pdev* degrees: • uref = *uref* dBμV • std_phi21 = *sp2* • std_phi31 = *sp3*
Cause:	Cabling of one of the paths not correct Fault in an assembly
Measure:	Switch off the R&S DDF5GTS immediately Check correct cabling, otherwise contact *Rohde & Schwarz* and tell message ID to get further information

Message 11312

```
"Test failed:
  f=[f] MHz,
  calibration,
  invalid,
  unexpected error"
```

Level:	**ERR** (Error): Test failed
Type:	• ST (short test) (for HF only if option R&S DDFGTS-HF installed, see message 11302) • LT (long test)
Meaning:	The calibration test for • frequency *f* MHz has failed for unknown reason
Cause:	(Internal fault)

Messages 11313, 11319

```
"Selftest ([fban]) failed:
  antenna path [ap] probably defective,
  check connector"
```

Level:	**ERR** (Error): Test failed
Type:	• ST (short test) • LT (long test)
Meaning:	All tests of • frequency band *fban* for • antenna path #*ap* have failed
Cause:	Cabling of the path not correct Fault in the antenna
Measure:	Switch off the R&S DDF5GTS immediately Check correct cabling, otherwise contact *Rohde & Schwarz* and tell message ID to get further information

Messages 11314, 11320

```
"Selftest ([fban]) failed:
  attenuation [a] dB
  of antenna path [ap] probably defective"
```

Level:	**ERR** (Error): Test failed
Type:	• ST (short test) • LT (long test)
Meaning:	All tests of • frequency band *fban* for • attenuation setting *a* dB of • antenna path #*ap* have failed
Cause:	Fault in the internal attenuator
Measure:	Switch off the R&S DDF5GTS immediately Contact *Rohde & Schwarz* and tell message ID to get further information

Messages 11315, 11321

```
"Selftest ([fban]) failed:
  frontend path [fp]
  (frequency range [f1] MHz to [f2] MHz,
  attenuation range [a1] dB to [a2] dB)
  of antenna path [ap] probably defective"
```

Level:	**ERR** (Error): Test failed
Type:	• ST (short test) (for HF only if option R&S DDFGTS-HF installed, see message 11302) • LT (long test)

Meaning:	All tests of • frequency band `fban` for • frontend path[1)]* #`fp` (`fp` = 0 to 10) • (frequency range `f1` MHz to `f2` MHz and • attenuation range `a1` dB to `a2` dB) of • antenna path #`ap` have failed
Cause:	Fault in the frontend path assembly
Measure:	Switch off the R&S DDF5GTS immediately Check correct cabling, otherwise contact *Rohde & Schwarz* and tell message ID to get further information

1) *The "frontend path" issued means in reality the entire analog signal path (from antenna input to ADC) active at the moment.*

Messages 11316, 11322

```
"Selftest ([fban]) failed:
  path for bandwidth [b] MHz
  of antenna path [ap] probably defective"
```

Level:	**ERR** (Error): Test failed
Type:	• ST (short test) • LT (long test)
Meaning:	All tests of • frequency band `fban` for • bandwidth `b` MHz (80 MHz or 20 MHz) in • antenna path #`ap` have failed
Cause:	Fault in the frontend path assembly
Measure:	Switch off the R&S DDF5GTS immediately Check correct cabling, otherwise contact *Rohde & Schwarz* and tell message ID to get further information

Messages 11317, 11323

```
"Selftest ([fban]) result:
  [i] of [n] tests failed"
```

Level:	**ERR** (Error): Summary message
Type:	• ST (short test) • LT (long test)
Meaning:	Tests in • frequency band `fban`: • `i` tests of • `n` performed have failed

Messages 11318, 11324

```
"Selftest ([fban]) result:
  all [n] tests passed"
```

Level:	**INF** (Info): Summary message
Type:	• ST (short test) • LT (long test)
Meaning:	Tests in • frequency band *fban* : • all *n* tests have been accomplished successfully

Message 11325

```
"Test passed:
  f=[f] MHz,
  calibration,
  antenna [antenna_name]"
```

Level:	**INF** (Info): Test passed
Type:	• ST (short test) (for HF only if option R&S DDFGTS-HF installed, see message 11302) • LT (long test)
Meaning:	The calibration test for • frequency *f* MHz with the • antenna *antenna_name* has been accomplished successfully

Message 11326

```
"Test failed:
  f=[f] MHz,
  calibration,
  antenna [antenna_name]"
```

Level:	**INF** (Info) / **ERR** (Error): Summary message (Test failed)
Type:	• ST (short test) (for HF only if option R&S DDFGTS-HF installed, see message 11302) • LT (long test)
Meaning:	The calibration test for • frequency *f* MHz with the • antenna *antenna_name* has failed: summary of preceded calibration fail messages

Message 11327

```
"Test passed:
  f=[f] MHz,
  antenna path [ap],
  antenna [antenna_name]"
```

Level:	**INF** (Info): Summary message
Type:	• ST (short test) (for HF only if option R&S DDFGTS-HF installed) • LT (long test)
Meaning:	A test measurement at the • frequency `f` MHz on • antenna path #`ap` with the • antenna `antenna_name` has been accomplished successfully

Message 11328

```
"Test failed:
  f=[f] MHz,
  antenna path [ap],
  antenna [antenna_name]"
```

Level:	**INF** (Info) / **ERR** (Error): Summary message (Test failed)
Type:	• ST (short test) (for HF only if option R&S DDFGTS-HF installed, see message 11302) • LT (long test)
Meaning:	A test measurement at the • frequency `f` MHz on • antenna path #`ap` with the • antenna `antenna_name` has failed: summary of preceded fail messages (11313 to 11317 [HF] or 11319 to 11323 [VHF/UHF])

Message 11329

```
"Test skipped:
  f=[f] MHz,
  calibration,
  no antenna found"
```

Level:	**INF** (Info): Intended test not possible
Type:	• ST (short test) • LT (long test)
Meaning:	An antenna for the • frequency `f` MHz on could not be found
Cause:	Cabling possibly wrong or no antenna present at all for frequency range in question
Measure:	Check cabling or supply suitable antenna; test will be continued with next frequency range possible

4.2 Firmware Update and Changing of IP Address

4.2.1 Firmware Update

4.2.1.1 General

The R&S DDF5GTS firmware (the software for the PPC and DSP processors and for the FPGA) can be replaced by a firmware update. The firmware is updated via the device's LAN interface (connector **X4** ***LAN1*** or **X5** ***LAN2*** on the R&S EBD770 rear panel). A firmware update via the LAN interface requires the "Update32" tool, which runs under Windows NT, Windows 2000, Windows XP and Windows 7.

The following updates can be done with the "Update32" tool:

- updating the "bootprog" (only by service personnel)
- updating the firmware of the R&S DDF5GTS.

NOTICE

Updating the "Bootprog"

Updating the "bootprog" (which is equivalent to the BIOS in a standard PC) should only be done by service personnel. The "bootprog" version is shown in the display after system power-up.

Although the update of a device will run automatically after it is started, the person who supervises this process should keep in mind the following aspects:

- While updating a device, the flash memory of the system will be deleted (except for a small part, i.e. the "bootprog"). This is the most time-consuming step in the update procedure (it may take up to 4 minutes).
- The new firmware will be downloaded afterwards. Usually this does not take much time (about 1 minute for the R&S DDF5GTS). Progress is visualized by the progress bar of the "Update32" tool.
- Switching off the device's power supply (refer to Chapter 2.3.1.4, "Power on and off", on page 31) during the update procedure is not recommended, but will not harm the device as it will not affect the "bootprog".
  If a power failure or reset occurs during the update procedure, the remaining "bootprog", although the old firmware may already have been deleted, will still allow a correct update of the firmware.

4.2.1.2 Preparations

System Requirements

For a firmware update you need

- an *IBM*-compatible PC running Windows NT, Windows 2000, Windows XP or Windows 7 with LAN interface,
- a standard LAN cable with RJ-45 connectors,
- WinPcap.

Installing Update32 Tool

If the "Update32" tool is not already installed on your PC use the installation on the CD Firmware & Utilities (see "setup.exe" in the folder Update32).

The "Update32" tool for Windows requires a WinPcap installation. Since this is included in the setup of the "Update32" tool, installing the latest version of the tool will also install the latest version of WinPcap (note the disclaimer and the information in WinPcap's "About" box).

Connecting the Device

Proceed as follows to connect the device:

Use the LAN cable to connect

- the Ethernet port of your PC directly
  or
- the hub or network

to LAN interface **X4 *LAN 1*** or **X5 *LAN 2*** on the rear panel of the R&S EBD770.

Network Adapters

If you have more than one network adapter in your computer, the "Update32" tool will take the first as the default adapter and try to use it for the update. To change the network adapter to be used, select "Network Adapter" in the "Config" menu of the "Update32" tool.

Checking the Device Firmware Version Number

For gleaning number and date of the firmware version currently installed, several methods can be applied:

1. Number and date are always shown on the front panel display.
2. An appropriate GUI command is available (refer to the R&S DDF5GTS Operating Manual).
3. Use the XML (XML) command [2.4]
   - `SoftwareVersion`

   this "low-level" procedure is described below.

Proceed as follows to display the version number:

1. Send the command shown in example 1.
   The `id` tag may have any value.
2. Answer shown in example 2.

   In the answer appearing, you find the software versions of all relevant CPLDs, FPGAs etc. In the example given, the MAIN module (1st structure of the answer string) has the current version B01.41; it dates from May 02, 2012, the current build is 24575.

Example 1: Command

```
<Request type="get" id="35">
  <Command name="SoftwareVersion"/>
</Request>
```

Example 2: Answer

```
<Reply id="35" type="get">
  <Command name="SoftwareVersion">
    <Array name="asSwVersion">
      <Struct name="sSwVersion">
        <Param name="zModuleName">MAIN</Param>
        <Param name="zSwVersion">B01.41 2012-05-02 build:24575</Param>
      </Struct>
      <Struct name="sSwVersion">
        <Param name="zModuleName">IF</Param>
        <Param name="zSwVersion">V01.00 2012-05-02</Param>
      </Struct>
      <Struct name="sSwVersion">
        <Param name="zModuleName">FPGA</Param>
        <Param name="zSwVersion">V02.31 2011-06-07</Param>
      </Struct>
      <Struct name="sSwVersion">
        <Param name="zModuleName">MB_CPLD</Param>
        <Param name="zSwVersion">V02.01</Param>
      </Struct>
      <Struct name="sSwVersion">
        <Param name="zModuleName">BOOTPROG</Param>
        <Param name="zSwVersion">V01.18 2010-11-30</Param>
      </Struct>
      <Struct name="sSwVersion">
        <Param name="zModuleName">BBFRONTEND_1_CPLD</Param>
        <Param name="zSwVersion">V01.04</Param>
      </Struct>
      <Struct name="sSwVersion">
        <Param name="zModuleName">BBFRONTEND_2_CPLD</Param>
        <Param name="zSwVersion">V01.04</Param>
      </Struct>
```

```
    <Struct name="sSwVersion">
      <Param name="zModuleName">SYNTHESIZER_CPLD</Param>
      <Param name="zSwVersion">V01.06</Param>
    </Struct>
    <Struct name="sSwVersion">
      <Param name="zModuleName">CALGEN_CPLD</Param>
      <Param name="zSwVersion">V01.02</Param>
    </Struct>
    <Struct name="sSwVersion">
      <Param name="zModuleName">ADC_BOARD1_FPGA</Param>
      <Param name="zSwVersion">V02.05 2012-02-06</Param>
    </Struct>
    <Struct name="sSwVersion">
      <Param name="zModuleName">ADC_BOARD1_CPLD</Param>
      <Param name="zSwVersion">V02.01</Param>
    </Struct>
    <Struct name="sSwVersion">
      <Param name="zModuleName">ADC_BOARD2_FPGA</Param>
      <Param name="zSwVersion">V02.05 2012-02-06</Param>
    </Struct>
    <Struct name="sSwVersion">
      <Param name="zModuleName">ADC_BOARD2_CPLD</Param>
      <Param name="zSwVersion">V02.01</Param>
    </Struct>
    <Struct name="sSwVersion">
      <Param name="zModuleName">SIGV_BOARD1_FPGA</Param>
      <Param name="zSwVersion">V01.10 2012-03-08</Param>
    </Struct>
    <Struct name="sSwVersion">
      <Param name="zModuleName">SIGV_BOARD1_CPLD</Param>
      <Param name="zSwVersion">V01.10</Param>
    </Struct>
    <Struct name="sSwVersion">
      <Param name="zModuleName">SIGV_BOARD2_FPGA</Param>
      <Param name="zSwVersion"></Param>
    </Struct>
    <Struct name="sSwVersion">
      <Param name="zModuleName">SIGV_BOARD2_CPLD</Param>
      <Param name="zSwVersion"></Param>
    </Struct>
    <Struct name="sSwVersion">
      <Param name="zModuleName">GUI</Param>
      <Param name="zSwVersion"></Param>
    </Struct>
    <Struct name="sSwVersion">
      <Param name="zModuleName">FPC</Param>
      <Param name="zSwVersion"></Param>
    </Struct>
  </Array>
```

```
  </Command>
</Reply>
```

4.2.1.3 Update Procedure Using the Update32 Tool

The "Update32" tool can update the firmware of the R&S DDF5GTS.

First Steps

Make sure the power supply of the R&S DDF5GTS to be updated is switched off; you will have to switch it on later in this procedure. Also make sure the unit and the PC you use for running the "Update32" tool are connected to a switch by LAN cables as shown in Figure 4-7.

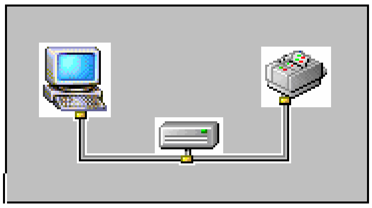


Figure 4-7: Connection between device and PC.

Change to the folder containing the "Update32" tool and start the tool by double-clicking file `upd32.exe`. You can also double-click the program icon on your desktop.

The tool opens with the start screen shown in Figure 4-8.

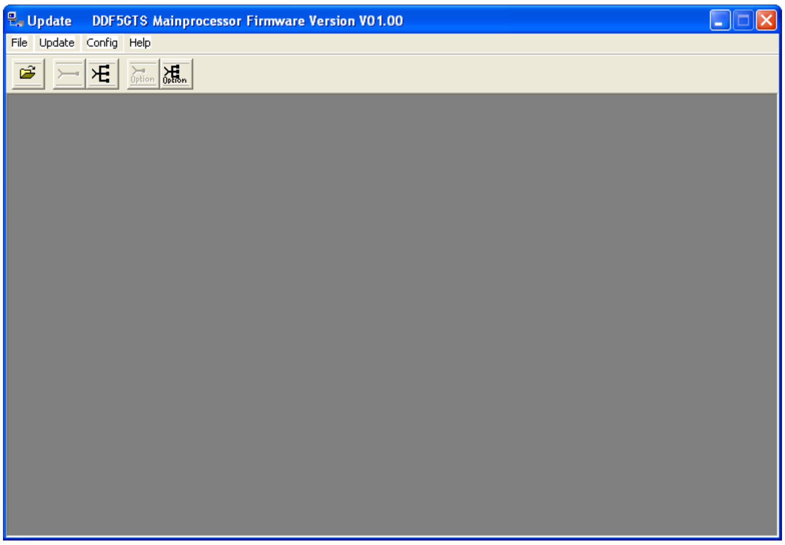


Figure 4-8: Firmware update, Start screen of the "Update32" tool.

Selecting the Network Adapter

Be sure to have configured the correct setting of the network adapter in your computer (otherwise a working communication cannot be established). To do so, use the "Network adapter" item of the "Config" drop-down menu (Figure 4-9) or the [F6] key. The

"Select a Network Adapter" dialog (Figure 4-10) will pop up and let you choose the correct one from a menu of all adapters located in your PC.

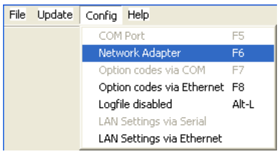


Figure 4-9: Firmware update, "Config" menu.

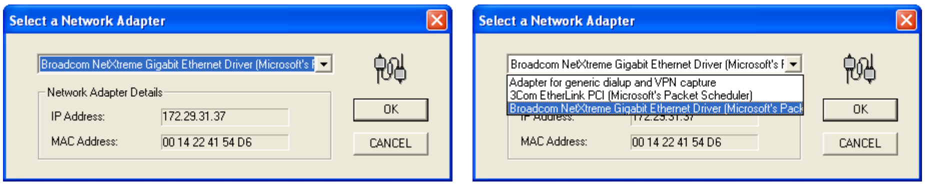


Figure 4-10: Firmware update, "Select a Network Adapter" dialog.

Selecting the Configuration File

If you use the "Update32" tool to update also other devices, a distinction is to be made between all types of devices existing. This is done by a configuration file for each type; it tells which firmware to load to each device and gives information about the checksum, software size etc. The configuration file is part of the firmware delivered with the R&S DDF5GTS.

Thus, to update a device, the correct update configuration file has to be selected. Open the corresponding dialog by clicking the button or use the "File" drop-down menu, item "Config File" (Figure 4-11), or the [F2] function key.

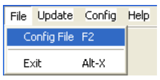


Figure 4-11: Firmware update, "File" menu.

The dialog of Figure 4-12 opens, in the "Look in:" drop-down menu you locate the folder containing the desired configuration file. Configuration files found will be displayed in the upper part of the dialog; next, select the appropriate item and click the "ACCEPT" button.

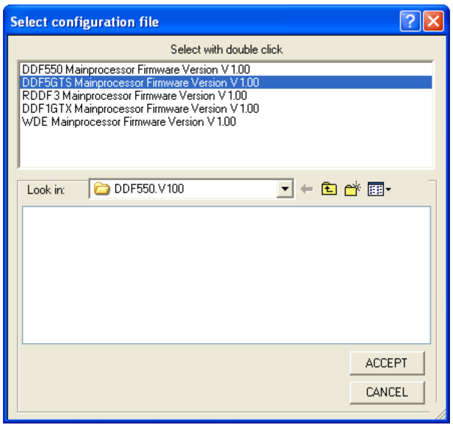
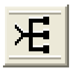


Figure 4-12: Firmware update, "Select configuration file" dialog.

Starting the Update



To start the update, click the button, use the "Update" drop-down menu, item "via Ethernet" (Figure 4-13), or the [F4] function key; the "Switch on target(s)" dialog (Figure 4-14) is displayed. If other devices than the one intended to be updated are reached via the connection, they are displayed here (Figure 4-14 shows a situation where this is not the case).

Figure 4-13: Firmware update, "Update" menu.

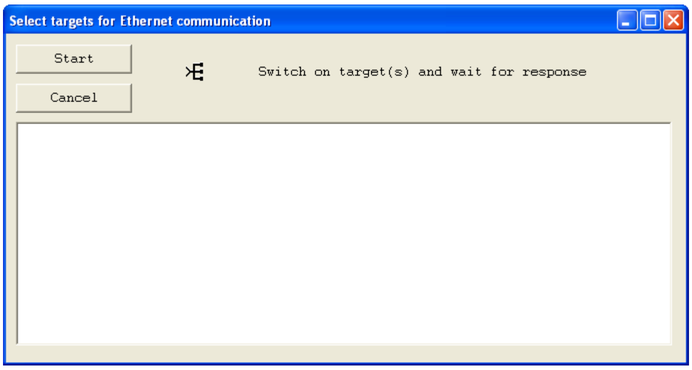


Figure 4-14: Firmware update, "Select targets for Ethernet communication/Switch on target(s)" dialog.

Now switch on the power supply of the device ("target") to be updated. After a short period a new entry will be shown in the list of target devices (Figure 4-15, the example now shows – in contrast to Figure 4-14 – a second device being present).

Instead of switching the device off and on again, you can also reset the main processor by the XML (XML) command [2.4]

- `Reset`

You can choose between a warm and a cold reset:

- A **warm reset** forces the reboot of the main processor, closes all communications interfaces, but does not set the device parameters back to factory defaults; this type of reset is useful for starting the firmware update procedure.
- A **cold reset** will do the same as the warm reboot and additionally reset all device parameters to their factory settings.

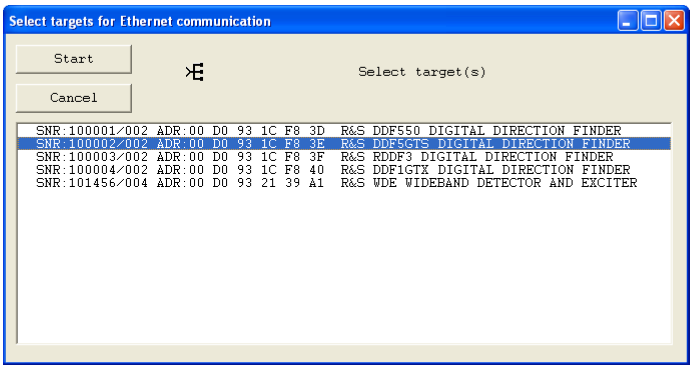


Figure 4-15: Firmware update, "Select targets for Ethernet communication/Select target(s)" dialog.

Select the appropriate target device (the R&S DDF5GTS as shown in Figure 4-15) and click the "Start" button to start the update process.

Several Devices

If more than one device is switched on while the "Update32" tool is running, they will be listed as targets. You can then select the target device to be updated.

NOTICE

Correct Target Device

Be sure to have selected the correct target device before operating the "Start" button. If unsure, compare the displayed serial number [SNR:] to the one fixed to the device to be updated.

Loading the firmware to another device than the one intended will result in unpredictable behaviour.

Observing the Update Procedure

After having started the update you see the dialog shown in Figure 4-16. If all is working well the program tells you that the flash memory is being erased. A short period later the next protocol line appearing indicates that the program code is being loaded (Figure 4-17). This may take some minutes, finally the checksum is calculated, this process also being displayed by a protocol line (Figure 4-18).

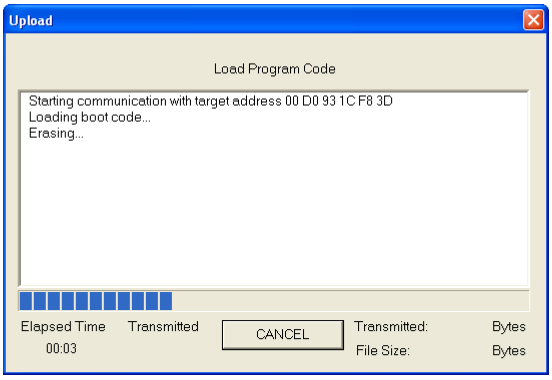


Figure 4-16: Firmware update, "Upload" dialog, "Erasing".

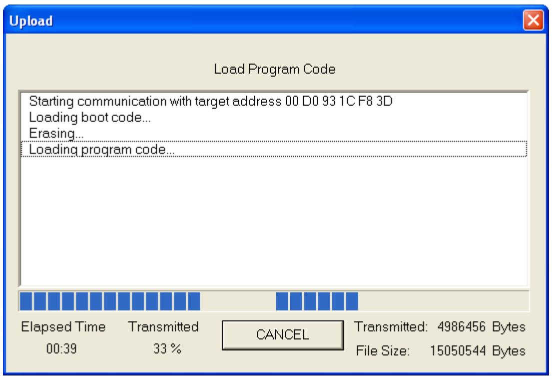


Figure 4-17: Firmware update, "Upload" dialog, "Loading program code".

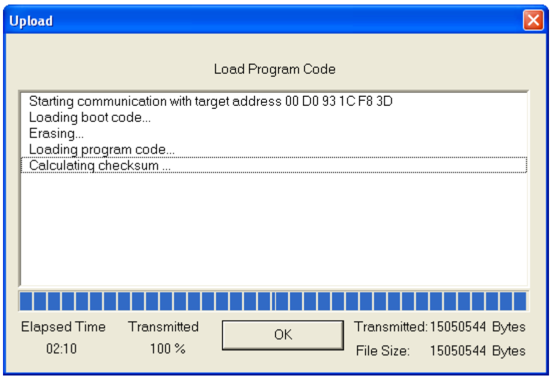


Figure 4-18: Firmware update, "Upload" dialog, "Calculating checksum".

Completing the Update

After the update procedure has been finished (Figure 4-19), close the dialog by clicking the "OK" button.

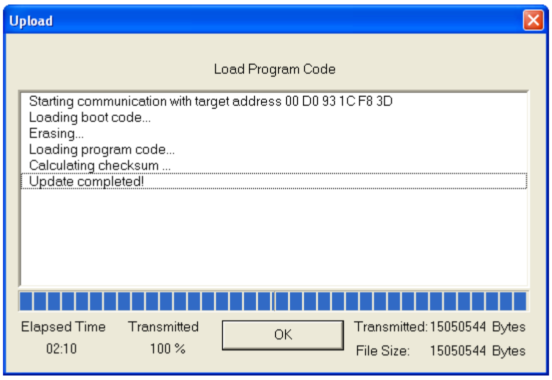


Figure 4-19: Firmware update, "Upload" dialog, "Update completed!".

To check whether the update has succeeded, switch off the power supply of the device. Switch it on again and check if the system starts regularly: the [Ready] LED has to light up after a short while (about 1 minute).

4.2.1.4 Troubleshooting

Timeout during the Update Procedure

If this problem occurs, simply switch off the device and restart the update procedure.

Update Messages

The "Update32" tool displays the following messages:

- `Starting communication with target address [address]`
- `Loading boot code...`
- `Erasing...`
- `Loading program code...`
- `Calculating checksum...`
- `Update completed!`

Front Panel Indications

The constantly lighted [Rx / Tx] LED on the front panel of the R&S EBD770 shows that an update is in progress. After completion of the update this LED is switched off, and the [Fail] LED is switched on. If no problem is detected, the R&S DDF5GTS application starts automatically and switches off the [Fail] LED. If a problem is detected, the [Fail] LED indicates the error code (Table 4-6) by blinking as often as the code is.

Table 4-6: Firmware update error codes.

Error codes		
Code	**Definition**	**Remark**
0	ERROR_NO_ERROR	No error
1	ERROR_CPLD_NOT_PROGRAMMED	Internal
2	ERROR_EEPROM_NO_IDENT_BLOCK	Internal
3	ERROR_EEPROM_NO_SERIAL_NUMBER	Internal
4	ERROR_EEPROM_NO_ETH_ADDR	Internal
5	ERROR_WRONG_LOCATED	Internal
6	ERROR_NO_APPLICATION	There is no application in the Flash EEPROM.

4.2.2 Changing the IP Address

You can change the device's IP address using the "Update32" tool. For instructions on how to run the "Update32" tool and select the IP configuration file see Chapter 4.2.1.3, "Update Procedure Using the Update32 Tool". Again, be sure that the device to be configured is switched off.

4.2.2.1 Starting the Procedure

To start the procedure for changing the IP address, select "LAN Settings via Ethernet" from the "Config" menu (Figure 4-20). The "Switch on target(s)" dialog (Figure 4-14) pops up and displays all devices found in the network.

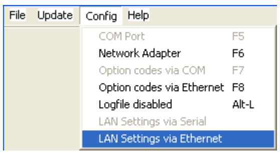


Figure 4-20: Changing IP address, "Config" menu.

4.2.2.2 Selecting the Target Device

Switch on the device of which you want to change the IP address. After a short period a new entry will be shown in the list of target devices. Select the appropriate target device as shown in Figure 4-15 and press the "Start" button.

NOTICE

Correct Target Device

Be sure to have selected the correct target device before operating the "Start" button. If unsure, compare the displayed serial number [SNR:] to the one fixed to the device to be updated.

Changing the IP address of another device than the one intended will result in unpredictable behaviour.

4.2.2.3 Changing the Address

Make the desired changes in the "LAN settings" window (Figure 4-21). If you have a DHCP server in your network you want to use, tick the "Use DHCP" check box.

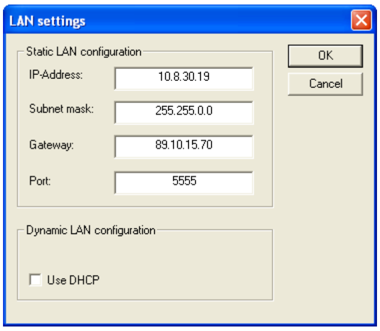


Figure 4-21: Changing IP address, "LAN settings" dialog.

NOTICE

IP Addresses and Port Numbers

- IPv4 vs. IPv6
  Only *IPv4* addresses (Version 4, i.e. consisting of 4 bytes) are handled by the R&S DDF5GTS, but no *IPv6* addresses (Version 6, i.e. consisting of 16 bytes and commonly written in hexadecimal digits).
- Interrelation between Port Numbers
  The port number entered to the "Port" field is basic to all other port numbers existing in the R&S DDF5GTS context, i.e. mentioned in this manual (these numbers are defined by their offset to this base). If changing the number of the "Port" field by a specific offset, be aware that all other port numbers also will be modified by this offset.
- Changing Port Number(s)
  It is strongly advised against to change the port number(s) without a convincing reason. Be aware that for connecting a client software to the R&S DDF5GTS, you need to know the port number(s), but the only way to determine it (if number of current unit is unknown) is this one by the "Update32" tool.

After a successful change of the IP address, you will be asked if you want to update the program code as well (Figure 4-22). If you want to do so, select "Yes", otherwise select "No".

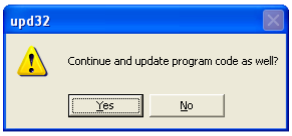


Figure 4-22: Changing IP Address, "upd32/Continue and update program code" dialog.

Annex

A Additional Information

A.1 XML Commands

Detailed information about all XML (XML) commands are included in this CD "Documentation", see Figure A-1 and 2.4.

1. On the menu "Documentation" select "Manuals"
2. On the menu "Manuals" select "Remote Commands"

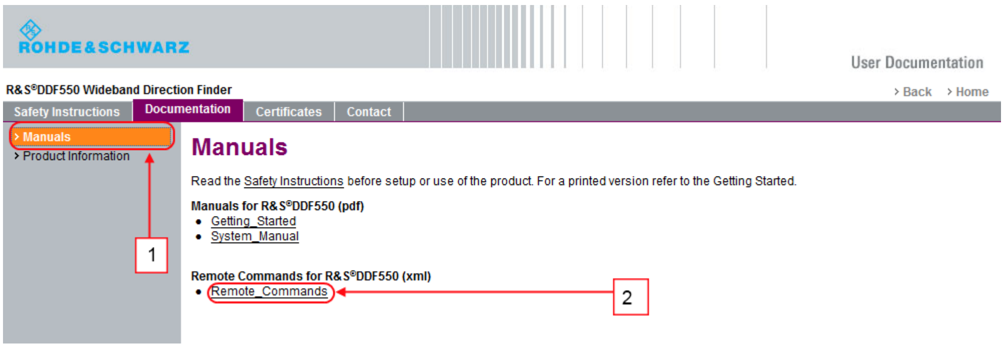


Figure A-1: CD "Documentation": remote commands.

A.2 DF Error Correction

More detailed information on correction data (DF Error Correction) can be found on the

- CD "Firmware & Utilities" in
- subfolder "\Utilities\Antenna Error Correction"

and its subfolders, especially in the

- **Antenna Error Correction Manual** [1.1].

B References

[1.1] *R&S DDF Antenna Error Correction*, *Rohde & Schwarz* manual (see Annex A.2, "DF Error Correction")

[2.1] *R. Grabau, K. Pfaff: Funkpeiltechnik*, Franckh'sche Verlagshandlung, W. Keller & Co., Stuttgart 1989, p. 396

[2.2] *Garmin 15H and 15L Technical Specifications*, Garmin International, Inc., Olathe 2004, p. 13

[2.3] *Garmin Proprietary NMEA 0183 Sentences Technical Specifications*, Garmin International, Inc., Olathe 2008, p. 2 to 3

[2.4] *R&S DDF XML Command Interface*, XML (XML) file (see Annex A.1, "XML Commands")

[2.5] *NMEA 0183 Standard*, Versions 2.00 (January 1992) to 4.10 (May 2012), National Marine Electronics Association (NMEA)

[2.6] IEC 61162, Part 1: *Single talker and multiple listeners*; Part 2: ditto, *high-speed transmission*, IEC

[3.1] *Spectrum Monitoring Handbook*, Edition 2010, ITU-R, Geneva 2011

[3.2] *Field-Strength Measurements at Monitoring Stations*, Recommendation SM.378-6 (last issue 1995), ITU-R

[3.3] *Accuracy of Frequency Measurements at Stations for International Monitoring*, Recommendation SM.377-3 (last issue 1994), ITU-R

[3.4] *Spectra and Bandwidth of Emissions*, Recommendation SM.328-10 (last issue 1999), ITU-R

[3.5] *Method of Measuring the Maximum Frequency Deviation of FM Broadcast Emissions at Monitoring Stations*, Recommendation SM.1268-1 (last issue 1999), ITU-R

[3.6] *Bandwidth Measurement at Monitoring Stations*, Recommendation SM.443-2 (last issue 1995), ITU-R

[3.7] *Automatic Monitoring of Occupancy of the Radio-Frequency Spectrum*, Recommendation SM.182-4 (last issue 1992), ITU-R

[3.8] *Specification of the Radio Data System (RDS) for VHF/FM sound broadcasting in the frequency range from 87,5 MHz to 108,0 MHz*, IEC 62106:2009

[3.9] *Ralph O. Schmidt: Multiple Emitter Location and Signal Parameter Estimation*, IEEE Transactions on Antennas and Propagation, Vol. AP-34, No. 3, March 1986, pp. 276 to 280

[3.10] *AMMOS Datastreams*, *Rohde & Schwarz* reference document

[3.11] *R&S CA120, Multichannel Signal Analysis*, *Rohde & Schwarz* manual

[3.12] *R&S DDF-CTL, DDF1GTX/550/5GTS-Control User Manual*, *Rohde & Schwarz* manual

Glossary: Abbreviations

Symbols

': Angular Minute (1/60 °); see also min (minute of time)

": Inch (2.54 cm) | Angular Second (1/60 ' = 1/3600 °); see also s (second of time)

°: Degree

°C: ° Celsius

α: Azimuth angle | other angles

ε: Elevation angle

λ: Wavelength | Eigenvalue

µs: Microsecond (10^{-6} s)

µV: Microvolt (10^{-6} V)

φ: (Phase) Angle

Ω: Ohm

A

A: Ampere

a.m.: (*Latin*) Ante Meridiem (before Midday)

A/D: Analog to Digital

AC: Alternating Current

ADC: A/D Converter

AM: Amplitude Modulation

AMMOS: Automatic Modular Monitoring of Signals

ARI: (*German*) Autofahrer-Rundfunk-Information(ssystem) (Car Drivers' Radio Information [System])

ASCII: American Standard Code for Information Interchange

ATC: Air Traffic Control

B

BASE-T: Baseband/Twisted Pair (several different standards for Ethernet over Twisted Pair)

Bd: Baud

Beidou: (*Chinese*) Great Bear (constellation)

BIOS: Basic Input Output System

bit: Binary Digit (also used as a unit)

BIT: Built-in Test

BNC: Bayonet *Neill Concelman* (or Bayonet Nut Connector or British Naval Connector)

byte: 8 bit

C

Cat: Category for LAN cable

CCIR: (*French*) Comité Consultatif International des Radiocommunications (International Consultative Committee on Radio) (now ITU-R)

CCITT: (*French*) Comité Consultatif International Téléphonique et Télégraphique (International Telegraph and Telephone Consultative Committee) (now ITU-T)

CD: Compact Disc

CDMA: Code Division Multiple Access

CEPT: (*French*) Conférence Européenne des Administrations des Postes et des Télécommunications (European Conference of Postal and Telecommunications Administrations)

CESM: Counter Electronic Support Measures

CET: Central European Time

CH: (*Latin*) Confoederatio Helvetica (Swiss confederacy): Switzerland

cm: Centimeter (10^{-2} m)

CM: Continuous Monitoring

COMINT: Communications Intelligence

CPLD: Complex Programmable Logic Device

CR: Carriage Return

CSA: Canadian Standards Association

CW: Continuous Wave

D

d: Diameter

D-Sub: D Subminiature ("D" due to shape of connector)

DAB: Digital Audio Broadcasting

dB: Decibel (general unit for logarithmic ratio)

dB(1/m): dB referenced to 1/m (unit for antenna factor [k-factor])

dB(µV/m): dB referenced to 1 µV/m (unit for field strength)

dBm: (also: **dB(mW)**) dB referenced to 1 mW (unit for power)

dBµV: (also: **dB(µV)**) dB referenced to 1 µV (unit for voltage)

DC: Direct Current

DDC: Digital Downconverter

DF: Direction Finder/Finding

DFT: Discrete Fourier Transformation

DGPS: Differential GPS

DHCP: Dynamic Host Configuration Protocol

DIN: (*German*) Deutsches Institut für Normung (German Institute for Standardization)

DOP: Dilution of Precision

DOS: Disk Operating System, also shortened form of MS-DOS

DSP: Digital Signal Processor/Processing

DVB: Digital Video Broadcasting

E

E: East

EBU: European Broadcasting Union

EEPROM: Electrically Erasable Programmable Read-Only Memory

EIA-422: Electronic Industries Alliance

EIA-485: (see EIA-422)

EMC: Electromagnetic Compatibility

EMI: Electromagnetic Interference

EN: (*German*) Europäische Norm (European standard) (or Euronorm)

ETSI: European Telecommunications Standards Institute

F

f: Frequency

FAA: Federal Aviation Administration

FAQ: Frequently Asked Questions

FFM: Fixed Frequency Mode

FFT: Fast Fourier Transformation

FM: Frequency Modulation

FPGA: Field-Programmable Gate Array

G

GHz: Gigahertz (10^9 Hz)

GLONASS: (*Russian* ГЛОНАСС) Глобáльная навигациóнная спýтниковая систéма / "Globalnaja nawigazionnaja sputnikowaja sistema" (Global Navigation Satellite System)

GND: Ground

GNSS: Global Navigation Satellite System

GPS: Global Positioning System

GSM: Global System for Mobile Communications (formerly [*French*] Groupe Spécial Mobile [study group four mobile communications])

GUI: Graphical User Interface

H

h: Hour(s) | Height

H: Logic Level High (1) | High Breaking Capacity

HF: High Frequency (f = 3 MHz to 30 MHz, λ = 10 m to 100 m)

HU: Height Unit (1 HU = 1¾" = 44,45 mm)

Hz: Hertz

I

I: In(put) | In-Phase

I/Q: In-Phase (I) and Quadrature (Q)

IBM: *International Business Machines Corporation*

ID: Identifier

IEC: International Electrotechnical Commission

IEC 60320: Standard IEC 60320 "*Appliance couplers for household and similar general purposes*", C13, C19 (female), C14, C20 (male)

IF: Intermediate Frequency

IMU: Inertial Measurement Unit

IP: Intercept Point | Internet Protocol

ISB: Independent Sideband

ITU: International Telecommunication Union

ITU-R: ITU, Radiocommunication Sector (formerly CCIR)

ITU-R SM: ITU-R, Spectrum Management

ITU-T: ITU, Telecommunication Standardization Sector (formerly CCITT)

K

k-factor: (*German*) Korrekturfaktor (correction factor): antenna factor

kHz: Kilohertz (10^3 Hz)

km: Kilometer (10^3 m)

L

L: Logic Level Low (0)

LAN: Local Area Network

LED: Light Emitting Diode

LF: Line Feed | Low Frequency (f = 30 kHz to 300 kHz, λ = 1 km to 10 km)

LO: Local Oscillator

LOB: Line of Bearing

LPI: Low Probability of Intercept

LSB: Least Significant Bit | Lower Sideband

LVDS: Low Voltage Differential Signaling

LVTTL: Low Voltage TTL (Transistor-Transistor Logic)

M

m: Meter | Modulation Factor (Modulation Depth)

M: Metric Thread (e.g. M5: thread 5 mm)

Mbyte: Megabyte (10^6 byte; exactly: 2^{20} byte = 1048576 byte)

MF: Medium Frequency (f = 300 kHz to 3 MHz, λ = 100 m to 1 km)

MGT: Multi-Gigabit Transceiver

MHz: Megahertz (10^6 Hz)

MIL-SPEC: Military Specification (defense specification)

min: Minute (time); see also ' (angular minute)

MINS: Marine Inertial Navigation System

mm: Millimeter (10^{-3} m); **mm²**: square millimeter

MMI: Man-Machine Interface

ms: Millisecond (10^{-3} s)

MS-DOS: *Microsoft* Disk Operating System

MSB: Most Significant Bit

MSByte: Most Significant Byte

MSL: Mean Sea Level

MuSiC: Multiple Signal Classification

mW: Milliwatt (10^{-3} W)

N

N: Newton | North | N Connector (after inventor *Paul Neill*)

n.c.: No Connection

NEMA: National Electrical Manufacturers Association

NMEA: National Marine Electronics Association

NMEA 0183: NMEA combined electrical and data specification for communication between marine electronic devices

ns: Nanosecond (10^{-9} s)

NTP: Network Time Protocol

O

O: Out(put)

Ø: Arithmetic mean | diameter

OCXO: Oven Controlled Xtal (crystal) Oscillator

P

P: Power

p.m.: (*Latin*) Post Meridiem (after Midday)

PC: Personal Computer

PCI: Peripheral Component Interconnect

PCM: Pulse Code Modulation

PLL: Phase Locked Loop

PM: Phase Modulation

PowerPC: Performance Optimization with Enhanced RISC – Performance Computing

pp: Peak to Peak

PPC: PowerPC

PPS: Pulses per Second

PSK: Phase Shift Keying

PTT: Push to Talk

Q

Q: Quadrature

R

rad: Radian

RAL: (*German*) Reichs-Ausschuss für Lieferbedingungen und Gütesicherung (imperial commission for delivery terms and quality assurance): color matching system

RDS: Radio Data System

RF: Radio Frequency

Ri: Internal Resistance

RISC: Reduced Instruction Set Computer

RJ-45: Registered Jack

RMS: Root Mean Square (quadratic mean)

RS-232: Radio Sector (or Recommended Standard)

RS-422: (see RS-232)

RS-485: (see RS-232)

RTC: Realtime Clock

RTK: Real Time Kinematic

RTTE: Radio and Telecommunications Terminal Equipment (also R&TTE)

Rx: Receive

S

s: Second (time); see also " (angular second)

S: South

Schuko: (*German*) Schutzkontakt (protective contact)

SELV: Safety Extra Low Voltage

SFN: Single Frequency Network

SHF: Super High Frequency (f = 3 GHz to 30 GHz, λ = 1 cm to 10 cm)

SJT: Standard Scoop-Proof Junior Tri-Lock Connector (*Amphenol*)

SMA: Subminiature-A

SNR: Serial Number | Signal-to-Noise Ratio

SPI: Serial Peripheral Interface

SR: Super-resolution

SSL: Secure Sockets Layer | Single Station Location

ST: Short-Time, Short-Time Signal

T

t: Time

T: Time (period) | Time Lag | *Torx* Size (e.g. T20: Torx size 20)

TCP: Transmission Control Protocol

TCP/IP: TCP/ Internet Protocol

TDMA: Time Division Multiple Access

Telnet: Teletype Network

TETRA: Terrestrial Trunked Radio

TMC: Traffic Message Channel

TV: Television

Tx: Transmit

U

U: Voltage

U.S.: United States (of America)

U.S.A.: United States of America

UCA: Uniform Circular Array

UDP: User Datagram Protocol

UHF: Ultra High Frequency (f = 300 MHz to 3 GHz, λ = 10 cm to 1 m)

UK: United Kingdom

UL: *Underwriters Laboratories Inc.*

UMTS: Universal Mobile Telecommunications System

Unix: (or *UNIX*, formerly UNICS) Uniplexed Information and Computing Service

Unix epoch: Thursday, January 1st, 1970, 00:00:00 (midnight/12:00:00 a.m.) UTC: start point in Unix time (or POSIX time or epoch time: time-counting system widely used in Unix-like and many other operating systems)

USB: Upper Sideband

UTC: Universal Time Coordinated (or Universal Time Code or Universal Time Convention)

V

V: Volt

VCO: Voltage Controlled Oscillator

VG: (*German*) Verteidigungs-Geräte (defense devices)

VHF: Very High Frequency (f = 30 MHz to 300 MHz, λ = 1 m to 10 m)

W

W: Watt | West

WAN: Wide Area Network

WGS 84: World Geodetic System 1984

WinPcap: *Windows* Packet Capture Library

X

XML: Extensible Markup Language (cf Annex A.1, "XML Commands", on page 374)

XOR: Exclusive Or

Z

Z: Impedance

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