SUPERVISING DEPT.: E&D - PT&S – Bench testing – E/E Testing

MANAGING DEPT.: E&D - PT&S – Bench testing – E/E Testing

1

APPLICATION CRITERIA

To verify correct operation of system under test when subjected to 200 MHz thru 18 GHz electromagnetic field issuing from nearby RF sources.

Test aims at reproducing standard extreme electromagnetic field exposure conditions (test setup in anechoic chamber).

Change	Date	Description		
-	Sept. 92	Issue 1 –	New, issued in accordance with std. 7-G0020, supersedes para 10 of Std. 7.Z0890.	(LR)
-	May 97	Issue 2 –	Updated.	(LR)
-	Mar. 99	Issue 3 –	Revised and updated.	(SS)
-	June 01	Issue 4 –	“Data processing” form revised and helps updated.	(SS)
-	Nov. 03	Issue 5 –	Supervisor changed (was Durando).	(SS)
	May 06	Issue 6 –	Fully revised.	(SS)

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Build Level: A[ ] - B[ ] - C[ ] - D[ ] - E[ ]
Component Type:
Supplier:

Job:
Drawing Number:
Last Change:

2

REFERENCES

9.90110	Automotive electrical and electronic devices (CEL)
7-G0030	Significance of items under test (PGE)
ISO 11452-1	Road Vehicles – Component test methods for electrical disturbance from narrowband radiated electromagnetic energy – Part 1 General principles and terminology
ISO11452-2	Road Vehicles – Component test methods for electrical disturbance from narrowband radiated electromagnetic energy – Part 2 Absorber lined shielded enclosure

3

TEST EQUIPMENT

Test ambient and instrumentation to be used described below must be as per std. ISO 11452.

3.1

Shielded anechoic chamber

Chamber size to contain test table and E.M. generator antennas positioned 1 meter away from table and 1.5 m from shielded sidewalls. Internal clear dimensions to be: 6 m length, 4 m width and 3 m height.

3.2

Supply unit

Supply unit to provide voltage and max. current required for correct operation of device under test.

Use supply unit with adjustable voltage 0 to 24V, 40 Amp, with 45 Ah, 225 Amp battery.

3.3

Impedance stabilizer network (L.I.S.N.)

Electric circuit and impedance characteristic with changing frequency to be as per Help 1. Moreover, the following requirements shall be met:

- Electric characteristics LISN 5µH / 50Ω.
- Impedance across terminals P and B, with terminals A and B shorted, not to exceed 20% of nominal curve shown in Help 1 within 100 kHz thru 100MHz.
- Capacitance C to withstand continuous voltage to 1500 V min.
- Inductance L to withstand supply current of test specimen.

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3.4

Ground plane

High electrical conductivity sheet metal (e.g. copper, aluminum, brass, galvanized steel), 0.5 mm min. thickness, 2.5 x 1 m.

Ground plane height from floor to be 900 ± 100 mm.

Ground plane shall be connected to chamber shielding and to ground line of building thru copper braid welded to top.

Contact resistance between ground plane and shielded booth should not be greater than 2.5 mΩ.

3.5

Transmitter antennas

Shall generate 200 V/m EM fields at 1 meter from device under test throughout frequency band used.

Antenna input power shall be higher than max. RF power amplifier output.

Typical antennas for frequency band 200 MHz thru 18 GHz are: Log-periodic and horn-type.

3.6

Test specimen stimulating and monitoring system

Shall permit correct operation of test specimen in normal service conditions as per dwg or P.S.

Shall interface with sensors and actuators of system under test without significant changes to electrical characteristics (impedance).

Any dummy sensor/actuator shall not be sensitive to EM field levels generated inside chamber.

Device under test stimulation system not to E.M. interfere with device itself (pneumatic actuators with plastic hoses, plastic push-buttons, etc.).

Monitoring system to be connected to device using optic fibers or high-impedance loads.

Use stimulators and monitors as specified hereunder.

Example of admissible devices:

- Transmitter, stimulator signal, external, with electro-optic converter.
- Signal receiver/transmitter, shielded, self-supplied, with electro-optic converter (inside chamber).
- Injectors, simulator signals to sensor (transducers connected to system sensors).
- Optical fibers, between transmitter and receiver.
- Receiver, external, with opto-electric converter, to monitor test specimen operation.

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3.7
Radiofrequency generation and control system

For EM field generation at frequencies and levels required by test, as indicated hereunder.

3.7.1
RF signal generator

- Shall be able to generate sinusoidal signals within the chamber use frequency bans, modulated in width with variable modulation index (AM modulation) and in PM modulation, with variable duty cycle.
- Carrier frequency accuracy shall be ±1% and harmonics (or other spurious signals) shall be at least 25 dB lower than basic frequency. Amplitude shall be continuously variable or variable in steps not greater than 0.1 dB thru -100 dBm up to +10 dBm.

3.7.2
RF power amplifier

- Minimum frequency band: covering chamber application band.
- Generated power: adequate to obtain E.M. field level specified for transmitting antennas;
- Output signal harmonics: at least 12 dB lower than basic frequency, 6 dB for frequencies beyond 1 GHz.
- Other non-harmonic signals: minimum 20 dB lower than basic frequency for entire operating band.
- Input power to obtain maximum output power (sensitivity): 1 mW on 50 Ω (0 dBm).

3.7.3
RF wattmeter (2 channel)

- Minimum frequency band: covering RF amplifier application band.
- Reading accuracy: minimum ±1 dB throughout application frequency band.
- Input power: shall be compatible with power taken by means of directional couplers.

3.7.4
Directional couplers (for direct and reflected power)

- Minimum frequency band: covering RF amplifier application band.
- Reading accuracy: minimum ±1 dB throughout application frequency band.
- Input power: shall be compatible with RF amplifier max. output.

3.7.5
Control and change-over unit

- To control signal switches (from RF generators to RF amplifier input, and from directional couplers to RF wattmeter), power switches (on RF amplifier outputs toward antennas) and RF amplifiers, compatibly with frequency bands required for testing.

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Component Type:
Supplier:

Job:
Drawing Number:
Last Change:

3.7.6

Isotropic electric field meters

- Suitable for EM field intensities above 200 ± 1 V/m rms within chamber application frequency range, to incorporate internal supply batteries and optical fiber outputs for remote reading of electric field module (geometric average of rms on three Cartesian axes) thru digital or analog display.

For testing, use generators, amplifier and transmitting antennas and power meters compatibly with associated application frequency bands, using control and change-over unit to switch between connecting cables.

Note: *Equivalent equipment may be substituted but must be equal or superior in performance.*

Date:…………………………………………………………..

Exemption: NO [ ] YES [ ]

Test Engineer:…………………………………….………

Signature…………………………………………

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4

DESCRIPTION OF ITEM UNDER TEST

System:	
Drawing No.	
Code:	
ECU identification number:	
Supplier:	
Destination vehicle:	

Date:……………………………………………………..

Exemption: NO [ ] YES [ ]

Test Engineer:…………………………………….………

Signature…………………………………

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5

SIGNIFICANCE OF COMPONENTS UNDER TEST

COMPONENT WEIGHT AND CHARACTERISTICS FOR EVALUATING TEST SIGNIFICANCE					
Type of component	**% Significance (A)**	**Weight (B)**	**Component affecting test significance**	**Significant characteristics**	**Minimum build level**
Active		0.5	Electronic Control Unit	PCB, box if metallic, software release	B
Active		0.2	Wiring harness	Cable length and cross section	C/
Active		0.3	Sensors / Actuators	Impedance	C/

Significance of item under test (%) = Σ (A x B) =

Note: *For each component, evaluate % significance for the three distinct levels indicated in Standard 7-G0030, recording values in column A.*

Date:…………………………………………………..

Test Engineer:…………………………………..………

Exemption: NO [ ] YES [ ]

Signature…………………………………

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6

TEST PREPARATION

6.1

obtain the technical documents (i.e. specifications, drawings, P.S., etc.) needed for testing, including: [ ]

- classification of system under test as per P.S.9.90110
- operating conditions of system under test and of stimulating system (when required)
- monitored parameters and their tolerances
- malfunction definition
- connection diagram of system during test.

6.2

Identify DUT and fill in "Description of item under test" form. [ ]

6.3

Find test target in technical documentation and enter in related table (Reading of sensitivity profile with CW / AM / GSM signal) of form "Data processing" at "EM field level (V/m) item. [ ]

6.4

Test set-up preparation (Help 3)

6.4.1

Power Supply and LISN

6.4.1.1

Prepare harness so that each DUT power line is supplied through a 5 µH/50 Ω, network simulator (LISN) as a function of how DUT is installed on vehicle: [ ]

- **REMOTE GROUND**: use 2 LISNs (one for power supply and the other for ground return) if DUT on vehicle is grounded by a wiring harness longer than 200 mm.

- **LOCAL GROUND**: use only one LISN (on supply only) if DUT on vehicle is grounded by a wiring harness shorter than 200 mm.

LISN is directly placed on ground plane with casing also connected to ground reference.

Also negative power supply pole must be connected to ground plane upstream of LISN.

LISN to be closed with 50 Ω load.

LISN connection diagram is described at Help 2.

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6.4.2

Wiring harness position

6.4.2.1

Place wiring harness on a dielectric, low relative permissibility material support ($\varepsilon_r \leq 1.4$) at 50 ± 5 mm above ground plane, as per conditions below: [ ]

- wiring parallel to ground plate edge must be 100 ± 10 mm from the latter
- wiring parallel to ground plane edge to be 1500 ± 75 mm long.
- total wiring length from DUT to load simulator shall not exceed 2 m.
- type of cable is defined by the specific type of application.
- measures to be adopted when using a different wiring on vehicle:
  - if wiring used it that installed on vehicle and supply lines (positive and negative) do not permit connection to impedance stabilization network (L.I.S.N.) keeping at least 1500±75 mm of harness parallel to front edge of metal surface, lines shall be extended using two cables parallel and close to one another 50±5 mm away from ground plane.
  - any branches (wiring harness sections connecting sensors/actuators to main wiring) that, due to their reduced length, do not allow placing them beyond 1.5 m from section of wiring exposed to EM field) shall be placed at right angles (90°±15°) as to wiring harness longitudinal axis.

6.4.3

Position of load, sensor and actuator simulator

6.4.3.1

Preferably place load simulator directly on ground plane, then, if load simulator has a metallic case, connect case to ground plane. [ ]

Note: *alternatively, load simulator can be placed adjacent to round plane (with case connected to it) or out of the anechoic chamber, routing wiring connecting it to DUT through an RF interface connected to round plane. When load simulator is placed on round plane, load simulator supply lines must be connected to LISN.*

6.4.3.2

Connect DUT sensors and actuators to wiring, preferably the same ones as per vehicle installation drawing. [ ]

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Component Type: Drawing Number:
Supplier: Last Change:

6.4.4
Antenna position

6.4.4.1
Position antennas as per conditions below: [ ]

- antenna phase center height is 100 ± 10 mm above ground plane
- no antenna radiant part to be at:
  - less then 250 mm from floor
  - less than 500 mm from absorbing material walls
  - less than 1500 mm from chamber walls or roof
- distance between wiring and antenna must be 1000 ± 10 mm. Distance is measured:
  - from antenna phase center in case of biconical antenna (intermediate point)
  - from closest point to antenna in case of Log-periodic antenna (antenna tip)
  - from closest point to antenna in case of Horn-type antenna (antenna opening).

- **Frequency range 220 MHz – 1 GHz:** for frequencies within 220 MHz - 1 GHz range, antenna phase center is in front of center of 1500 mm long longitudinal wiring.
- **Frequency range > 1 GHz:** for frequencies greater than 1 GHz, antenna phase center is 750 mm offset parallel to wiring harness and directly oriented toward DUT when it will be connected to wiring.

Test is performed with change procedure described by Std. ISO 11452-1 and ISO 11452-2.

Procedure is performed in two phases:

- field calibration (without DUT but with wiring, stimulation and monitoring devices, LISN present).
- sensitivity procedure on DUT.

Procedure is based on use of direct power as a reference parameter.

6.5
Test apparatus calibration

Calibration consists in acquisition of power curve of antenna (Pdirect) necessary to generate in selected point an electric field of known constant intensity throughout the frequency band to be used for test.
As electric field is tied to antenna output thru a quadratic relationship, during test this reference curve permits monitoring electric field which would occur in no-load condition (without system under test) at the point of calibration, by controlling direct power.
According to change procedure and without modulation (CW), calibration must be performed as per Std. ISO 11452-1 and ISO 11452-2, with horizontal and vertical polarization.

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Component Type:
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Drawing Number:
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6.5.1

Position field sensor as below (help 4): [ ]

- with phase center 150 ± 10 mm above ground plane, 100 ± 10 mm from ground plane edge and 1000 ± 10 mm from antenna
- **Range 220 MHz** to **1 GHz** at center of 150 mm long wiring parallel to ground plane edge.
- **Range 1 GHz** to **2.5 GHz** aligned with DUT position.

6.5.2

For each frequency point defined by table 1 below, apply to antenna sufficient power to read a range with required level on RMS meter. [ ]

Table 1 – Frequency step
To be used both for calibration and during linear scanning test shown in table below.

	Range [MHz]	Step [MHz]
B1	220 – 400	2.5
B2	400 - 800	5
B3	800 - 1000	5
B4	1000 - 1700	10
B5	1700-2000	5
B6	2000-2500	10

6.5.3

Detect and store reading of direct power to antenna and related RF signal to be set on generator for each frequency point. [ ]

6.6

Test setup position

6.6.1

Place DUT on ground plane, on a low relative permissivity dielectric support ($\varepsilon_r \leq 1.4$) at 50 ± 5 mm on round plane, trying to orient DUT connectors toward transmitting antenna and keeping this side parallel to front edge of metallic plane (side turned toward transmitting antenna) at a minimum distance of 200 ± 10 mm from it. [ ]

6.6.2

Connect DUT, as a function of how it is installed, on vehicle (REMOTE or LOCAL GROUND), as shown in help 2. [ ]

Note: *DUT casing must not be connected to round plane unless on-vehicle configuration is simulated. In this case, ground connection to be as short as possible or as required on vehicle.*

Date:……………………………………………………….. Exemption: NO [ ] YES [ ]

Test Engineer:……………………………………..……… Signature…………………………………

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7

TEST PROCEDURE

Operations/reading to be performed at ambient temperature 23 ± 5 °C with 45 to 70 %. R.H.

7.1

Test setup activation

7.1.1

Supply DUT as specified on drawing or P.S. [ ]

7.1.2

Apply signals needed for system operation to all relevant electrical inputs or physical sensors by means of specific stimulation system. [ ]

7.1.3

Set DUT to static (no change in stimulation signals) or dynamic (sequence of given changes in stimulation signals to deliberately alter system status or behavior) operation specified on drawing or P.S. to test for correct operation. [ ]

7.1.4

Acquire characteristic parameters of signals supplied by actuators to be used as reference during testing by means of monitoring system. [ ]

7.2

Sensitivity profile

Plot sensitivity profile of system under test for each system operating condition, as per frequency range and conditions specified in P.S. 9.90110 with antenna polarized both vertically and horizontally.

Tests with modulated signals to be performed as per pick preservation principle (Help 5), described by Std. ISO 11452-1 defining that following shall match:

- peak level of non-modulated signal acquired during calibration and whose RMS value corresponds to required immunity level
- peak level of modulated signal generated during test.

Repeat procedure below for each frequency point:

7.2.1

Select proper setup of monitoring and change-over system compatibly with frequency of EM field to be generated. [ ]

7.2.2

Set required frequency on RF signal generator (see table 1 of "Preliminary operations" form). [ ]

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7.2.3

Ad just power of generator output signal so that antenna direct input power P_{CW} meets equation below: [ ]

$$P_{CW} = P_{CAL}\left(\frac{E}{E_r}\right)^2$$

where E corresponds to required field value, Er to field value used as a reference during calibration and P_{CAL} to direct power recorded during calibration.

7.2.4

Apply to RF signal the modulation characteristics required for field (CW, AM, GSM, etc.). [ ]

For AM modulation, direct power of modulated signal must comply with pick preservation principle, i.e.:

$$P_{MOD} = P_{CW}\frac{2+m^2}{2(1+m)^2}$$

where P_{MOD} is modulated signal power (AM), P_{CW} is non-modulated signal power and m is modulation depth.

7.2.5

Check for correct operation of test specimen in the condition in question by comparing parameters of signals supplied by sensors to reference signals. [ ]

7.2.6

In case of wrong device operation, decrease direct power P_{CW} and repeat operations from para 7.2.3 to para 7.2.5, till DUT restarts its regular operation. Then, increase power till failure is found again and note related field level of non-modulated signal E. [ ]

7.2.7

Enter field level E in related frequencies vs. EM field table of "Data processing" form and describe fault in a fault detection card. [ ]

7.2.8

Repeat operations from para 7.2.2 to para 7.2.7 till completing all test frequency ranges (range B1, B2 ….). [ ]

7.2.9

With field levels detected in test frequency range, build related sensitivity profile graph. [ ]

Note*: In CATNET ambient, sensitivity graph, within test frequency, is automatically built.*

Date:………………………………………………….. Exemption: NO [ ] YES [ ]

Test Engineer:……………………………………..……… Signature…………………………………

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8

DATA PROCESSING

Items below to be included in test report:

- description of the functions monitored.
- type of modulation
- malfunction criteria
- monitoring techniques and instrument
- photos of the three DUT positions
- tables below duly filled out for each band, polarization and modulation, as well as related graphs showing electric field level for each frequency at which malfunction takes place.

8.1

<u>Sensitivity profile</u>

data.xls

Date:…………………………………………………..

Exemption: NO [ ] YES [ ]

Test Engineer:……………………………….………

Signature…………………………………

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9

POST-TESTING PROCEDURE

9.1

Disconnect instrumentation (sensors, actuators, etc.) not integral to system from system under test. [ ]

9.2

Dismantle test setup, remove DUT and related wiring. [ ]

9.3

Archive DUT for at least 10 years so that it can easily be traced. [ ]

Note: *At the end of storage period, component must be demolished.*

Date:…………………………………………………….. Exemption: NO [ ] YES [ ]

Test Engineer:……………………………….……… Signature…………………………………

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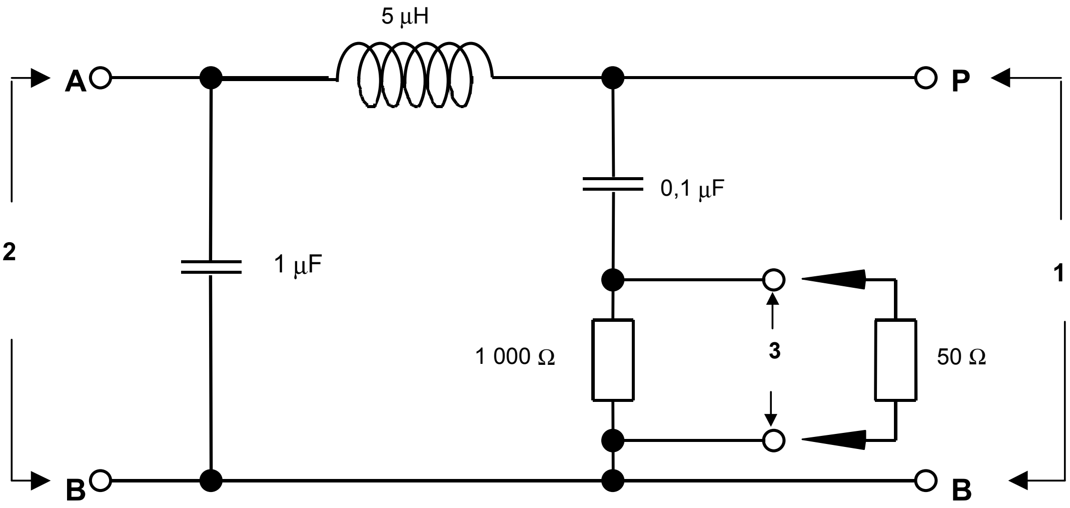
10

HELP

Help 1

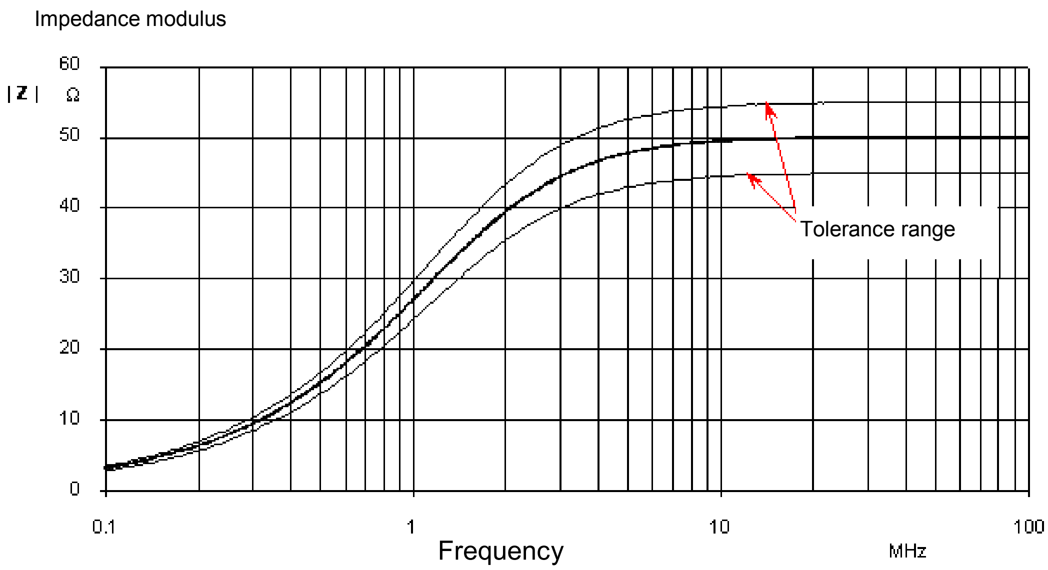
LISN described by Std. ISO11452-2 is used for simulation of vehicle wiring impedance.
Diagram is shown below:



1 DUT port
2 Power supply port
3 Test port

Impedance of LISN $|Z_{PB}|$ within 0.1-100 MHz range is shown in fig. below. Tolerance is ±20%.

Impedance is measured between terminals P and B with 50 Ω load placed on test port "3" and terminals A and B shorted.



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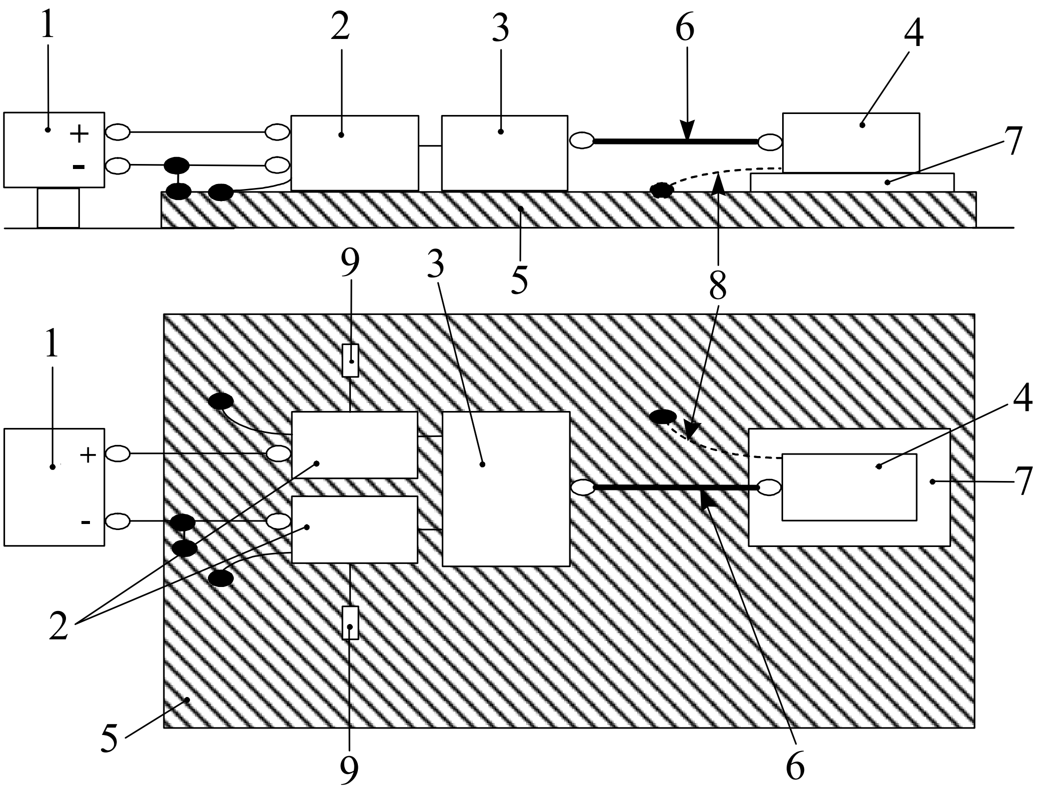
Help 2

DUT connection, power supply and LISN diagrams

REMOTE GROUND - DUT grounded on vehicle by wiring longer than 200 mm



Legend

1 Power source
2 LISN
3 Load simulator
4 DUT / EUT
5 Ground plane
6 Wiring (containing both power supply line and ground return line)
7 Insulating support
8 DUT casing (possibly connected to ground plane, if required by test plan)
9 50 Ω load

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Component Type:
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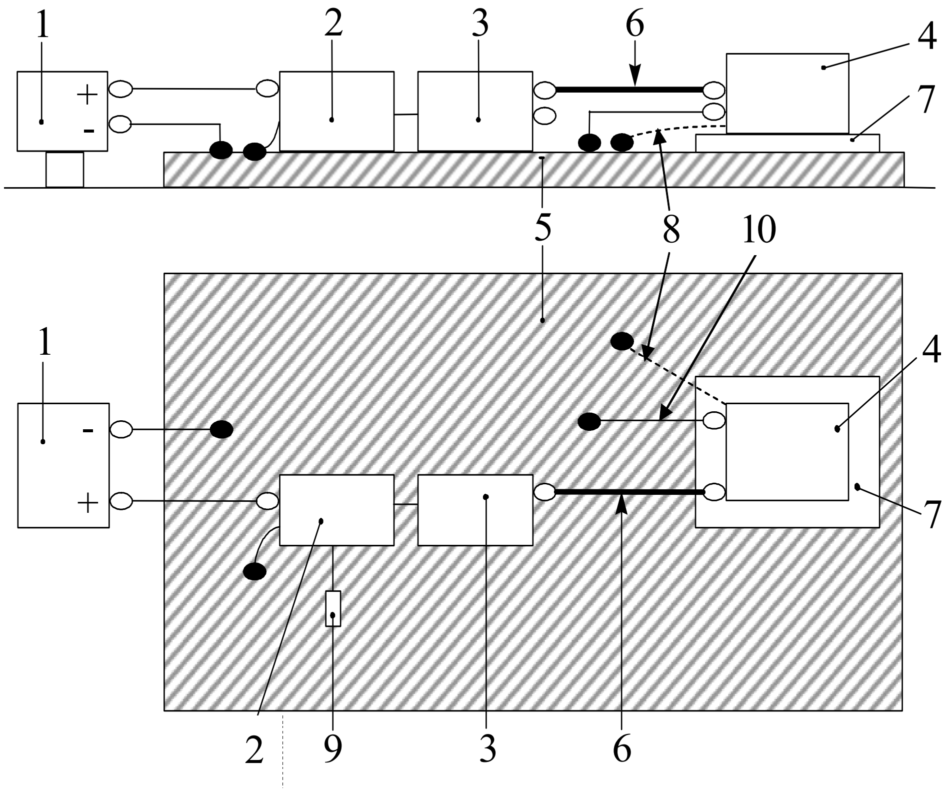
REMOTE GROUND - DUT grounded on vehicle by wiring shorter than 200 mm



Legend

1	Power source
2	LISN
3	Load simulator
4	DUT / EUT
5	Ground plane
6	Wiring (not including ground return line)
7	Insulating support
8	DUT casing (possibly connected to ground plane, if required by test plan)
9	50 Ω load
10	Return supply line (max. length 200 mm)

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Component Type: Drawing Number:
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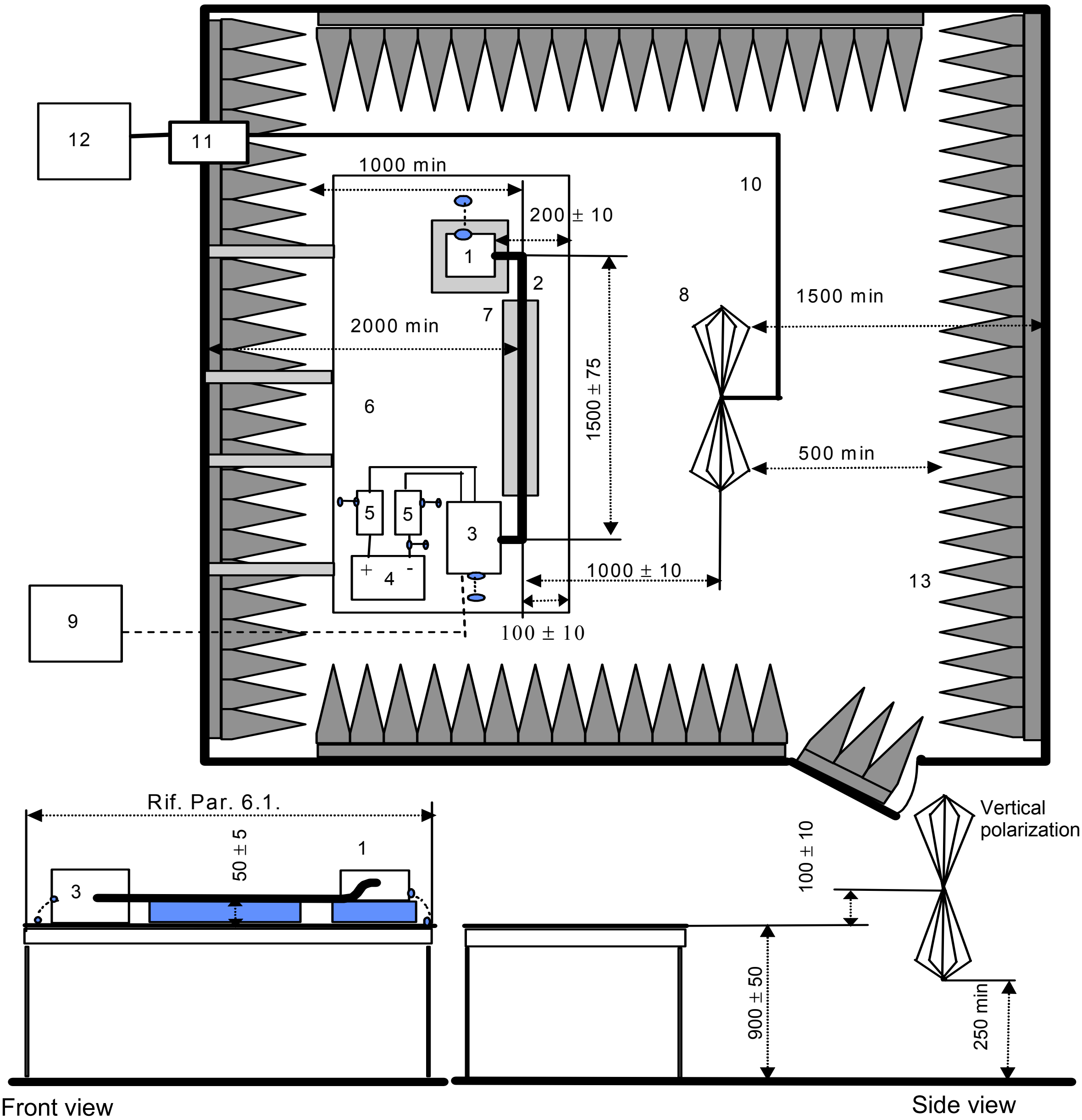
Help 3

220 MHz - 1 GHz test setup (Biconical antenna)

View from top (horizontal polarization) Dimensions in mm



Legend

1	DUT (locally grounded if required by test plan)	8	Biconical antenna
2	Test wiring	9	Monitoring and stimulation system
3	Load simulator (location and connections as per para 6.4)	10	Coaxial shielded cable (50 Ω)
4	Power source	11	Bulkhead connector
5	Artificial network (LISN)	12	RF signal generator and amplifier
6	Ground plane (connected to shielded chamber)	13	RF sound-deadening material
7	Low permissibility support (εr≤ 1.4)		

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Build Level: A[ ] - B[ ] - C[ ] - D[ ] - E[ ] Job:

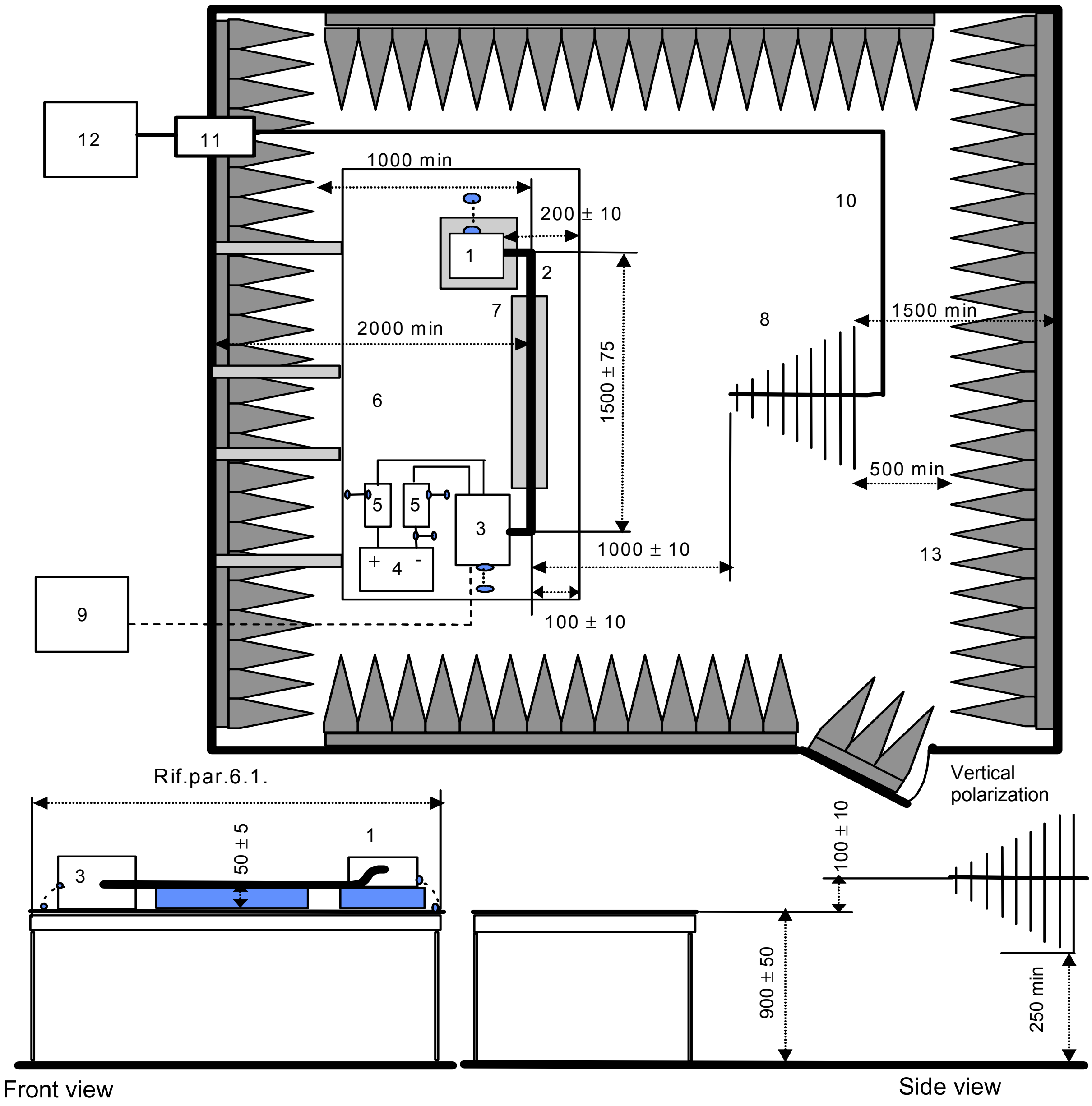
Component Type: Drawing Number:

Supplier: Last Change:

220 MHz - 1 GHz test setup (Log-periodic antenna)

View from top (horizontal polarization)

Dimensions in mm



Legend

1	DUT (locally grounded if required by test plan)	8	Log-Periodic antenna
2	Test wiring	9	Monitoring and stimulation system
3	Load simulator (location and connections as per para 6.4)	10	Coaxial shielded cable (50 Ω)
4	Power source	11	Bulkhead connector
5	Artificial network (LISN)	12	RF signal generator and amplifier
6	Ground plane (connected to shielded chamber)	13	RF sound-deadening material
7	Low permissibility support ($\varepsilon r \leq 1.4$)		

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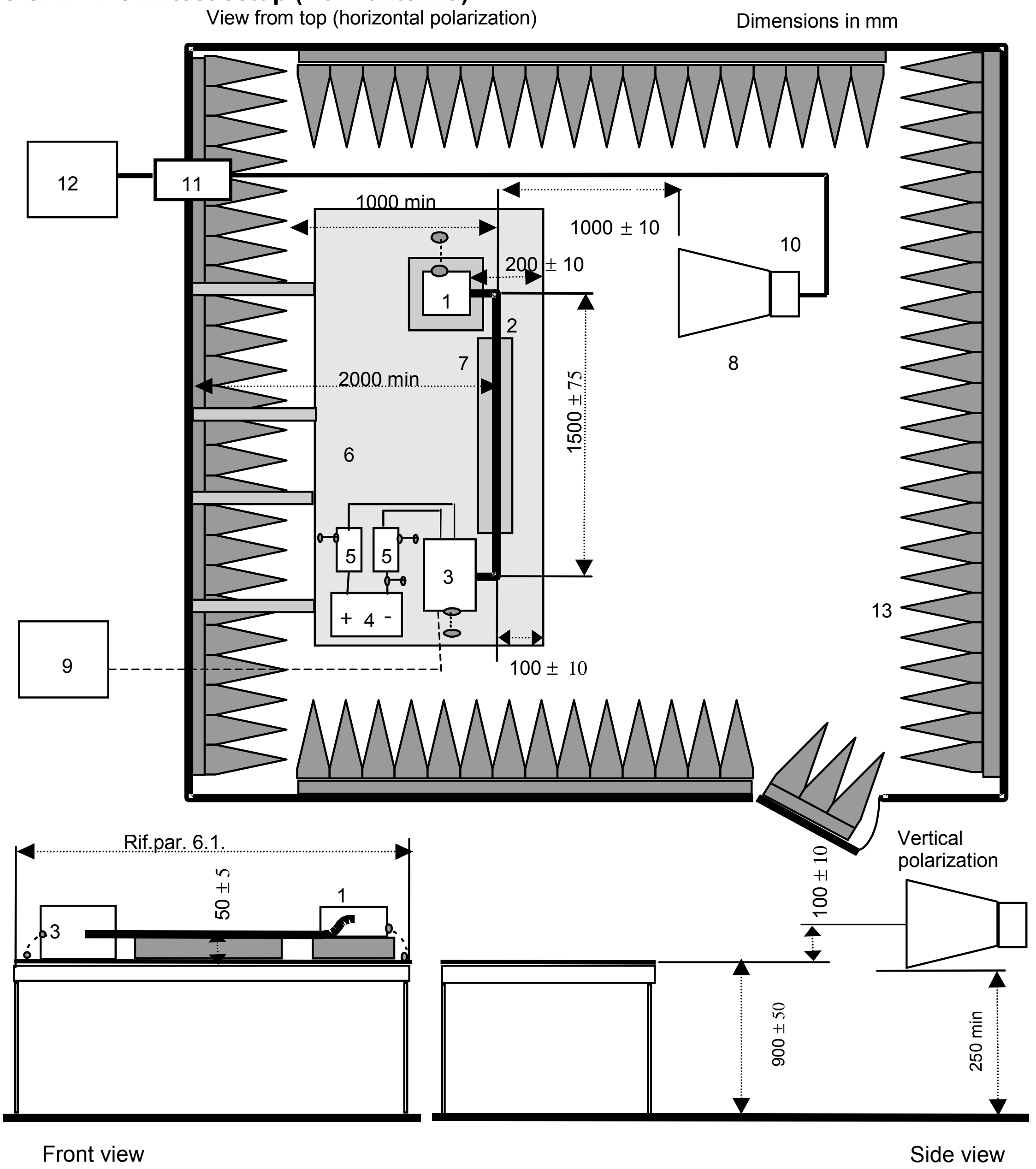
Build Level: A[ ] - B[ ] - C[ ] - D[ ] - E[ ]
Component Type:
Supplier:

Job:
Drawing Number:
Last Change:

1-2.5 GHz - 1 GHz test setup (Horn antenna)



Legend

1	DUT (locally grounded if required by test plan)	8	Horn antenna
2	Test wiring	9	Monitoring and stimulation system
3	Load simulator (location and connections as per para 6.4)	10	Coaxial shielded cable (50 Ω)
4	Power source	11	Bulkhead connector
5	Artificial network (LISN)	12	RF signal generator and amplifier
6	Ground plane (connected to shielded chamber)	13	RF sound-deadening material
7	Low permissibility support ($\varepsilon r \leq 1.4$)		

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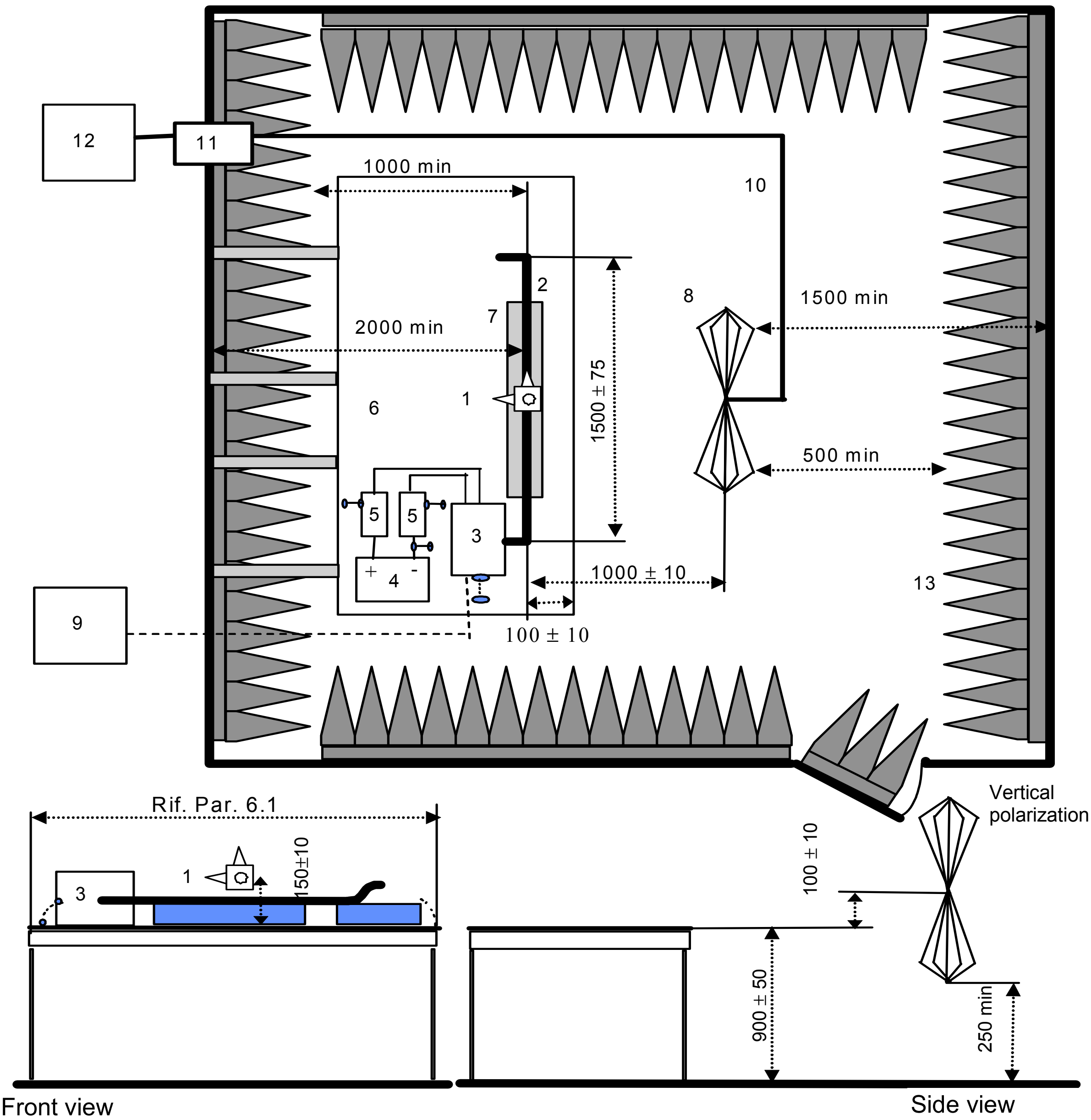
Build Level: A[ ] - B[ ] - C[ ] - D[ ] - E[ ]
Job:
Component Type:
Drawing Number:
Supplier:
Last Change:

Help 4

220 MHz - 1 GHz calibration setup (Biconical antenna)

View from top (horizontal polarization)

Dimensions in mm



Legend

1	Electric field probe	8	Biconical antenna
2	Test wiring	9	Monitoring and stimulation system
3	Load simulator (location and connections as per para 6.4)	10	Coaxial shielded cable (50 Ω)
4	Power source	11	Bulkhead connector
5	Artificial network (LISN)	12	RF signal generator and amplifier
6	Ground plane (connected to shielded chamber)	13	RF sound-deadening material
7	Low permissibility support (εr≤ 1.4)		

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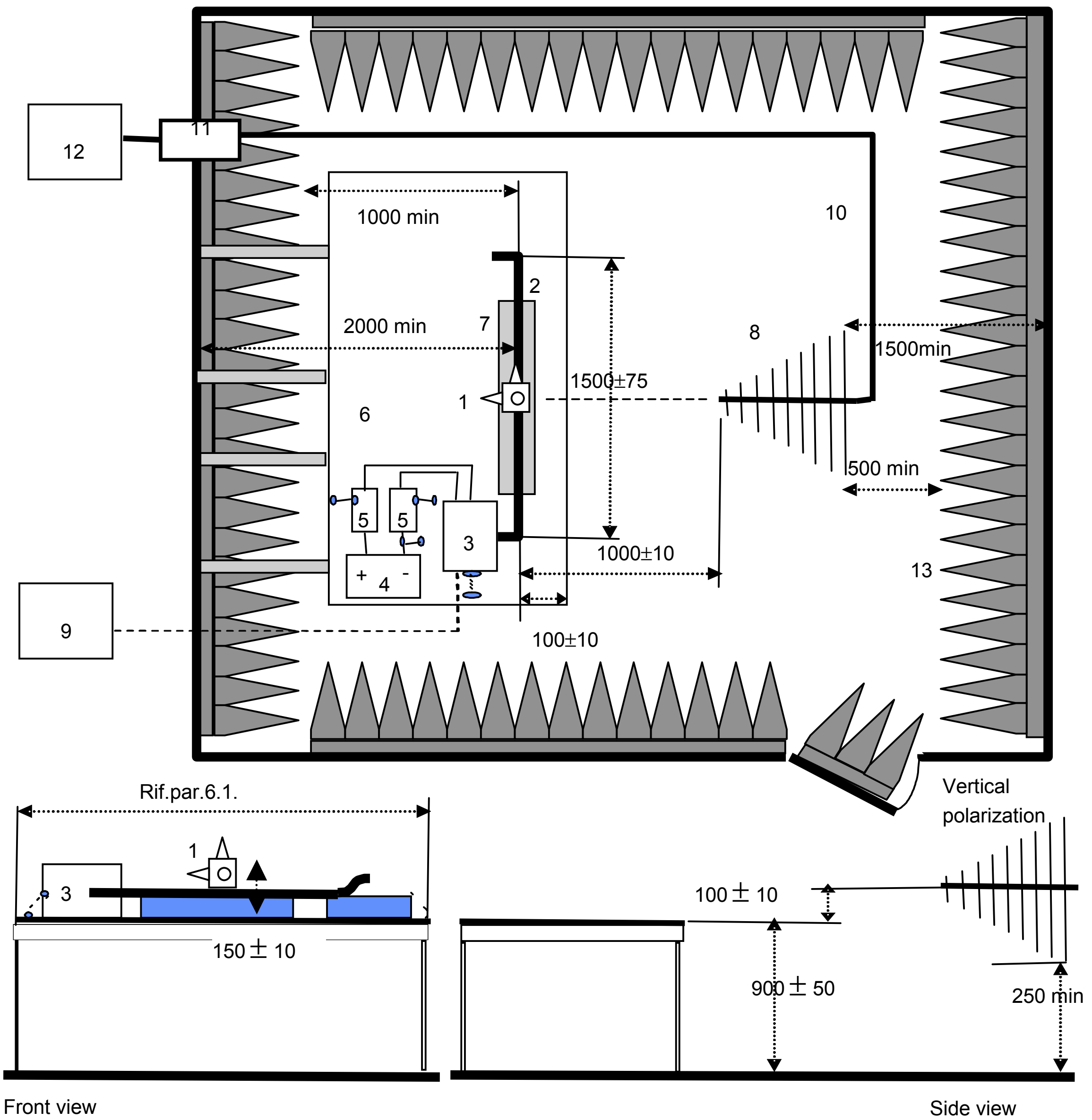
Build Level: A[ ] - B[ ] - C[ ] - D[ ] - E[ ]
Job:
Component Type:
Drawing Number:
Supplier:
Last Change:

220 MHz - 1 GHz calibration setup (Log-periodic antenna)

View from top (horizontal polarization)   Dimensions in mm



Legend

1	Electric field probe	8	Log-periodic antenna
2	Test wiring	9	Monitoring and stimulation system
3	Load simulator (location and connections as per para xx xx)	10	Coaxial shielded cable (50 Ω)
4	Power source	11	Bulkhead connector
5	Artificial network (LISN)	12	RF signal generator and amplifier
6	Ground plane (connected to shielded chamber)	13	RF sound-deadening material
7	Low permissibility support (εr≤ 1.4)		

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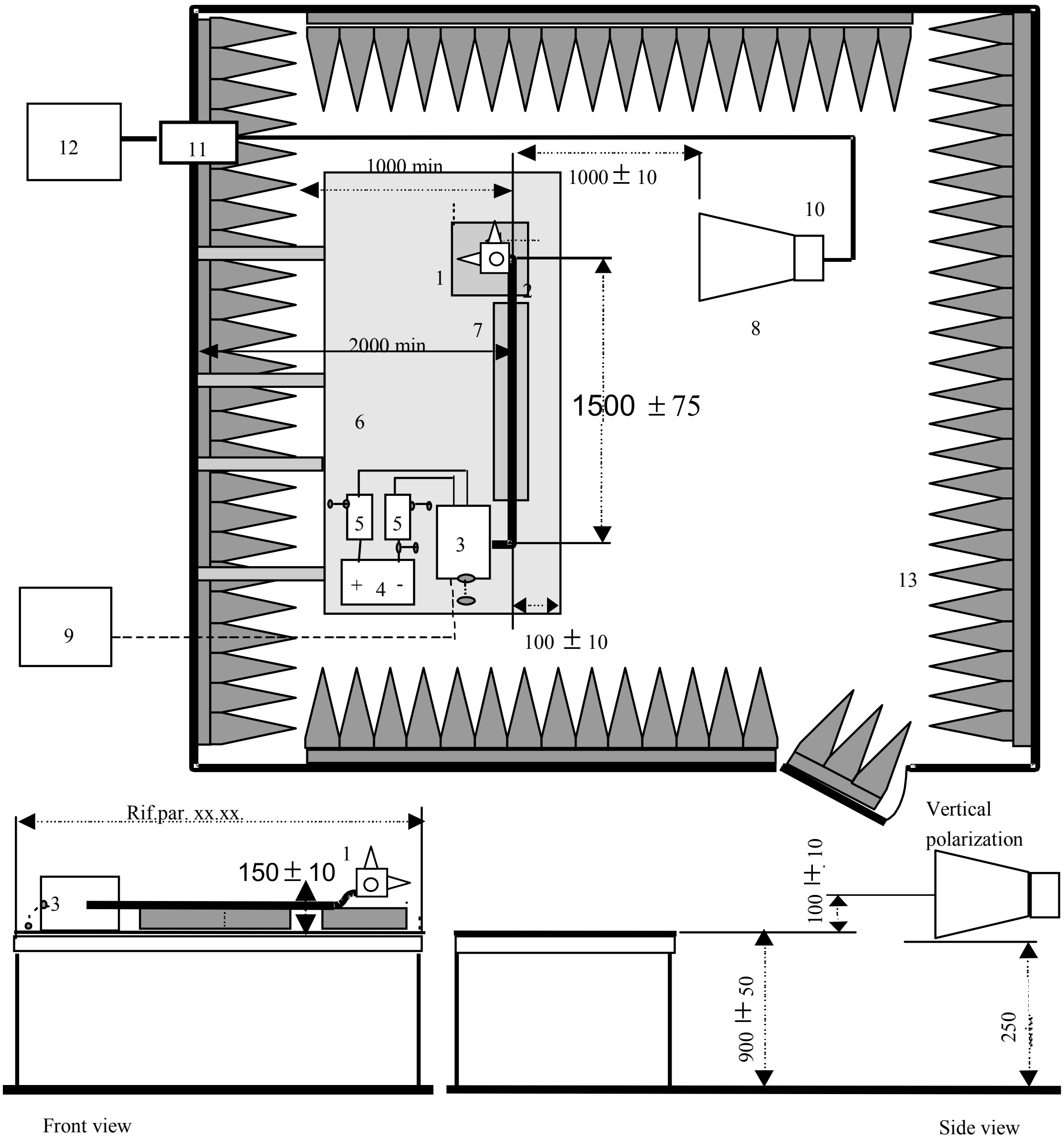
Build Level: A[ ] - B[ ] - C[ ] - D[ ] - E[ ]
Component Type:
Supplier:

Job:
Drawing Number:
Last Change:

1 - 2.5 GHz - 1 GHz calibration setup (Horn antenna)

View from top (horizontal polarization)

Dimensions in mm



Legend

1	Electric field probe	8	Horn antenna
2	Test wiring	9	Monitoring and stimulation system
3	Load simulator (location and connections as per para xx xx)	10	Coaxial shielded cable (50 Ω)
4	Power source	11	Bulkhead connector
5	Artificial network (LISN)	12	RF signal generator and amplifier
6	Ground plane (connected to shielded chamber)	13	RF sound-deadening material
7	Low permissibility support (εr≤ 1.4)		

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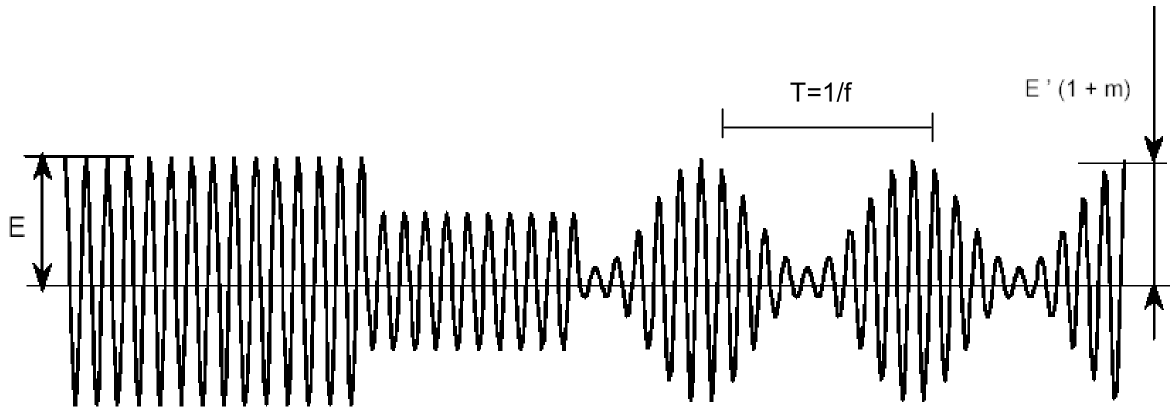
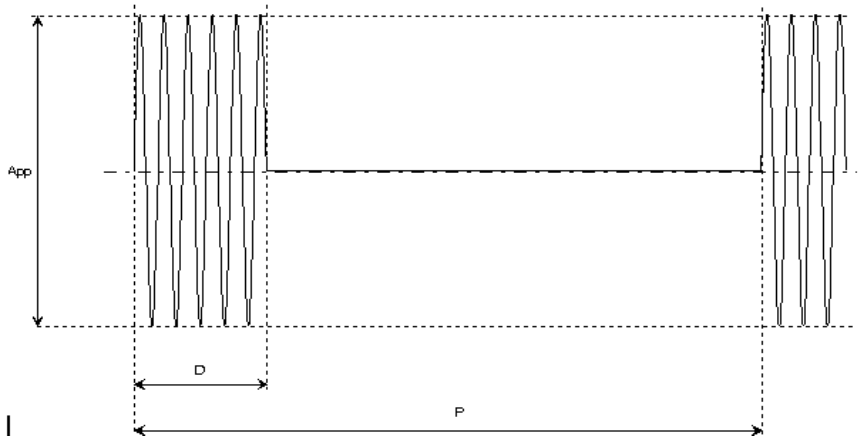
Build Level: A[ ] - B[ ] - C[ ] - D[ ] - E[ ]
Job:
Component Type:
Drawing Number:
Supplier:
Last Change:

Help 5

CHARACTERISTICS OF TEST SIGNAL TO BE GENERATED
AM MODULATION



GSM MODULATION



E = peak level of non-modulated signal used during calibration and of AM signal used during test

m = modulation index ((1+m)*E' = E) [0.8 = 80%]

E' = width of non-modulated signal on which AM modulation is applied
(E' = E/(1+m))

f = modulating signal frequency (f = 1/T)

T =modulating signal period (T = 1/f)

D = Burst time [577 µs]

P = burst repetition period [4600 µs]

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