1 Task description

1.1 Introduction

The task of the 2016 Engineering Competition preliminary round is to demodulate six baseband signals differing in amplitude and type of interference $rx(t/T_a)$ and to identify the signal content. Orthogonal Frequency Division Multiplexing (OFDM) is used to transmit information. Contestants must develop and implement receiver algorithms for demodulation.

Contestants will be evaluated on more than just their success in identifying the content of the signals in question (consist of an ASCII-coded text). They must also determine the amplitude of the disturbances with the greatest possible precision and additional points will be rewarded to the three teams that provide the most accurate measurements. Correct identification of signal content is therefore only part of the task. The competitor’s receiver algorithms will also be evaluated as part of the grading process.

1.2 Guidelines

You will need the standard version of Matlab. In case you don’t have access to it, please send us an e-mail.

The main part of the task is to develop and implement receiver algorithms for OFDM-Demodulation. This is why, while working on the task, you are not allowed to use extensive OFDM-Demodulators which you didn’t develop yourself, for example:

- the OFDM-Demodulator "comm.OFDMDemodulator" from the Communication System Toolbox in Matlab
- OFDM-Vector-Signal-Analyzer “R&S FS-K96” or "R&S FS-K96PC" from Rohde & Schwarz, etc.

Customary Signal processing algorithms like Fourier-Transformation (“fft”) or filtering methods (“conv”, “filter”), etc. included in Matlab may be used.

Your results must be sent in via email to **engineeringcompetition@rohde-schwarz.com**. It is important to use the “Results.mat” file format. Please see section “1.8. Result format” for more information

Please send us your solution after every solved signal. The last submission we receive within the deadline will be evaluated. This means you have the possibility to improve your previous results.

Also send us the program code of your developed and implemented OFDM-Demodulator after completing all the signals by email and be sure to meet the deadline.

Deadline for sending the solutions and the program codes is:

29th May 2016 at 23.59 pm

1.3 Transmitter model

The OFDM transmitter shown in **Fig. 1.1** is used to transmit text messages.

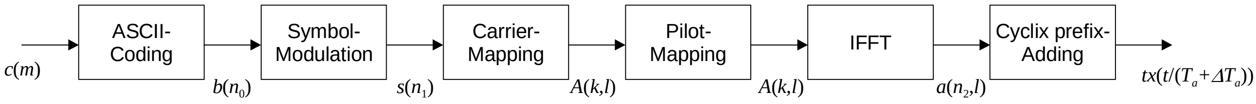


Fig. 1.1: Transmitter model.

The text signal $c(m)$ (whose chronologically oldest letter is transmitted with the smallest index m) is transformed into an ASCII-coded bit data stream $b(n_0)$ in the ASCII Coding block. A byte with eight bits results for each letter:

$$\{c(m)\} \to \{b(n_0 = 8m-7), b(n_0 = 8m-6), \ldots, b(n_0 = 8m)\}.$$

Eq. 1.1

The bits $b(n_0)$ of each byte are transmitted in decreasing order, i.e. most significant bit (MSB) $b(n_0 = 8m-7)$ first and least significant bit (LSB) $b(n_0 = 8m)$ last.

The bit data stream $b(n_0)$ is modulated into a symbol data stream $s(n_1)$ in the Symbol Modulation block. The transmitter can use BPSK, QPSK or 8PSK modulation. **Fig. 1.2** describes how bits $b(n_0)$ are assigned to symbols $s(n_1)$ for various types of modulation. With BPSK modulation, a bit from the signal $b(n_0)$ is transformed into a symbol of the signal $s(n_1)$. With QPSK modulation, two chronologically subsequent bits of the signal $b(n_0)$ are transformed into a symbol of the signal $s(n_1)$, while three chronologically subsequent bits are transformed into a symbol of the signal $s(n_1)$ when using 8PSK modulation. With BPSK modulation, the symbols $s(n_1)$ have the following value range:

$$s(n_1) \in \{e^{j \cdot 0 \cdot \pi}, e^{j \cdot 1 \cdot \pi}\}$$

Eq. 1.2

The range for QPSK is:

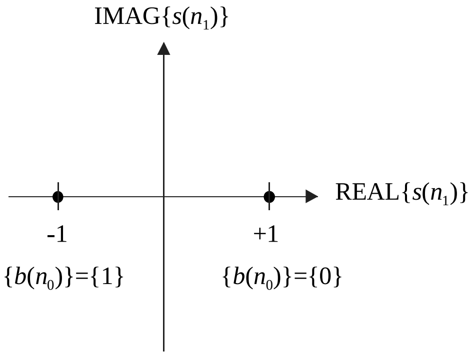
$$s(n_1) \in \{e^{j \cdot 1/4 \cdot \pi}, e^{j \cdot 3/4 \cdot \pi}, e^{j \cdot 5/4 \cdot \pi}, e^{j \cdot 7/4 \cdot \pi}\}$$

Eq. 1.3

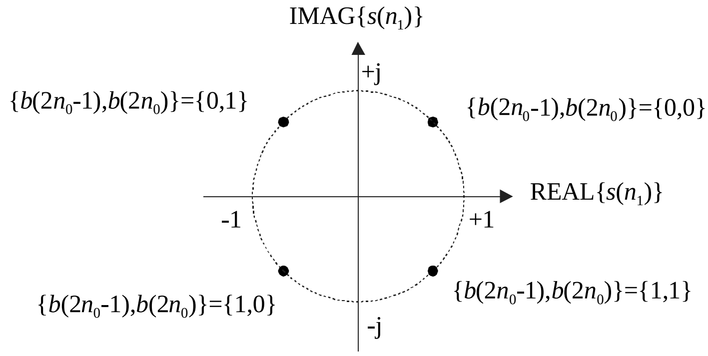
8PSK modulation has a range of:

$$s(n_1) \in \{e^{j \cdot 0/4 \cdot \pi}, e^{j \cdot 1/4 \cdot \pi}, e^{j \cdot 2/4 \cdot \pi}, e^{j \cdot 3/4 \cdot \pi}, e^{j \cdot 4/4 \cdot \pi}, e^{j \cdot 5/4 \cdot \pi}, e^{j \cdot 6/4 \cdot \pi}, e^{j \cdot 7/4 \cdot \pi}\}$$

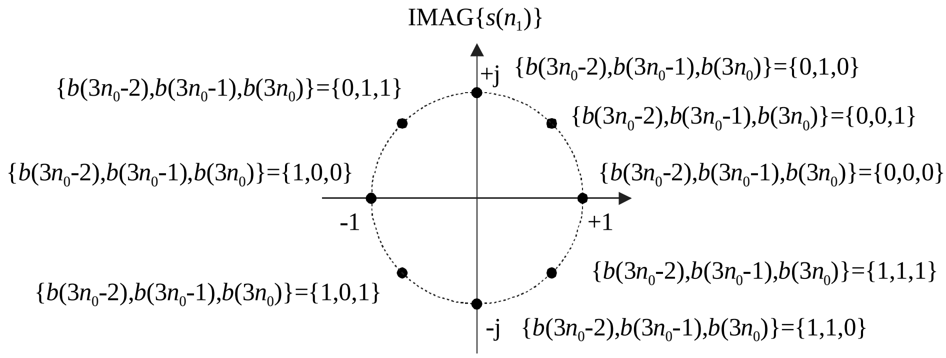
Eq. 1.4



BPSK-Modulation



QPSK-Modulation



8PSK-Modulation

Fig. 1.2: Transmitter modulation types.

In the Carrier Mapping block, the symbol data stream $s(n_1)$ is assigned to the OFDM symbols $A(k,l)$ in the frequency domain. The OFDM carrier number is represented by k

$$k \in \{-N_{FFT}/2, -N_{FFT}/2+1, \ldots, +N_{FFT}/2-2, +N_{FFT}/2-1\}$$

Eq. 1.5

The value l represents the OFDM symbol number

$$l \in \{0,1,2,\ldots\}$$

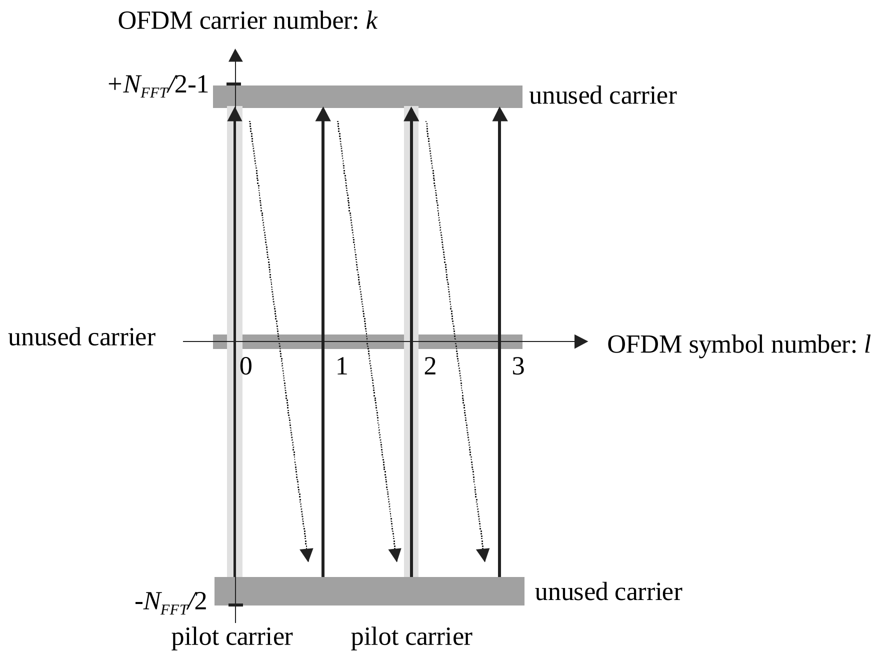
Eq. 1.6

The value N_{FFT} is the length of the inverse Fourier transform used by the transmitter. The transmitter can use the lengths N_{FFT} summarized in **Table 1.1**.

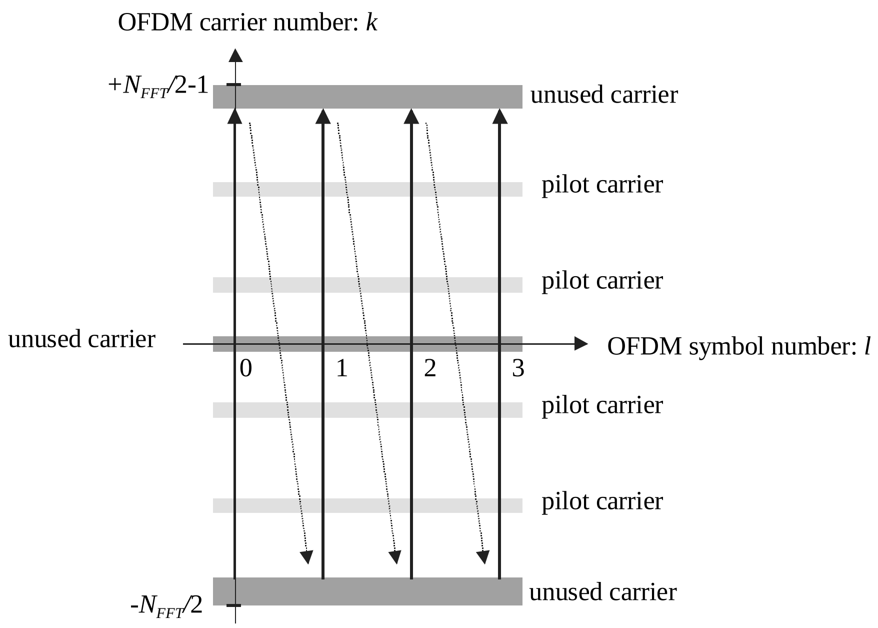
Inverse Fourier transform lengths N_{FFT}
32
64
128

Table 1.1: Inversion Fourier transform lengths used by transmitter.

The assignment sequence shown in **Fig. 1.3** is used, i.e. older symbols $s(n_1^{'})$ are transmitted with smaller OFDM carrier indexes and $k^{'} \leq k^{''}$ smaller OFDM symbol indexes $l^{'} \leq l^{''}$ than chronologically newer symbols $s(n_1^{'} < n_1^{''})$.



Pilot mapping method A



Pilot mapping method B

Fig. 1.3: Assignment of data symbols $s(n_1)$ and pilot symbol for OFDM carrier indexes k and OFDM symbol indexes l.

The OFDM carrier number $k_{DC} = 0$ (DC carrier) is not used for data or pilot-symbol transmissions. Some OFDM carriers k_{guard} are not available to transmission data and pilot symbols on the edges of the transmission band (guard carrier). In each case, they are assigned in such a way that there is an equal number of usable OFDM carriers to left and right of the OFDM carrier index $k = 0$. **Table 1.2** summarizes the OFDM carriers, which are not used to transmit data and pilot symbols.

Length N_{FFT} of inverse Fourier transform	**Indexes of unused OFDM carriers k_{DC} and k_{guard}**
32	–16, –15, –14, 0, +14, +15
64	–32, –31, –30, –29, 0, +29, +30, +31
128	–64, –63, –62, –61, –60, 0, +60, +61, +62, +63

Table 1.2: Indexes of unused OFDM carriers k_{DC} and k_{guard}.

No power is transmitted via the DC and guard carriers k_{DC} and k_{guard}.

At special positions (k_{pilot}, l_{pilot}) of the OFDM symbol in the frequency domain $A(k,l)$, pilot symbols are transmitted for receiver synchronization purposes (see **Fig**. **1.3**). Two different pilot assignment methods (A and B) are used to transmit pilot symbols.

With method A, pilot symbols are transmitted for odd OFDM pilot symbol indexes $l_{pilot} = 2 \cdot x, x = 0,1,2,...$ to all OFDM pilot carrier indexes $k_{pilot} = k \neq k_{DC}$ and $k_{pilot} = k \neq k_{guard}$.

With method B, pilot symbols are transmitted in all OFDM pilot symbol indexes $l_{pilot} = l$ using special OFDM pilot carrier indexes k_{pilot}. The OFDM pilot carrier indexes k_{pilot} used to transmit pilot symbols are summarized in **Table 1.3** for method B.

FFT length N_{FFT}	**OFDM pilot carrier indexes k_{pilot}**
32	–13, –4, +4, +13
64	–28, –20, –12, –4, +4, +12, +20, +28
128	–59, –52, –44, –36, –28, –20, –12, –4, +4, +12, +20, +28, +36, +44, +52, +59

Table 1.3: OFDM pilot carrier indexes k_{pilot} used in pilot assignment method B.

The positions (k_{pilot}, l_{pilot}) in the OFDM symbol within the frequency domain $A(k,l)$ are occupied by pilot symbols and not used for data transmission.

The Pilot Mapping block is used to insert the pilot symbols

$$A(k_{pilot}, l_{pilot}) = 1$$

Eq. 1.7

in the OFDM symbol within the frequency domain $A(k,l)$ at the positions (k_{pilot}, l_{pilot}).

For demonstration, **Fig. 1.4** shows the transmission of the text message "Test" with QPSK modulation, pilot symbol assignment method B and an inverse Fourier transform length of $N_{FFT} = 64$.

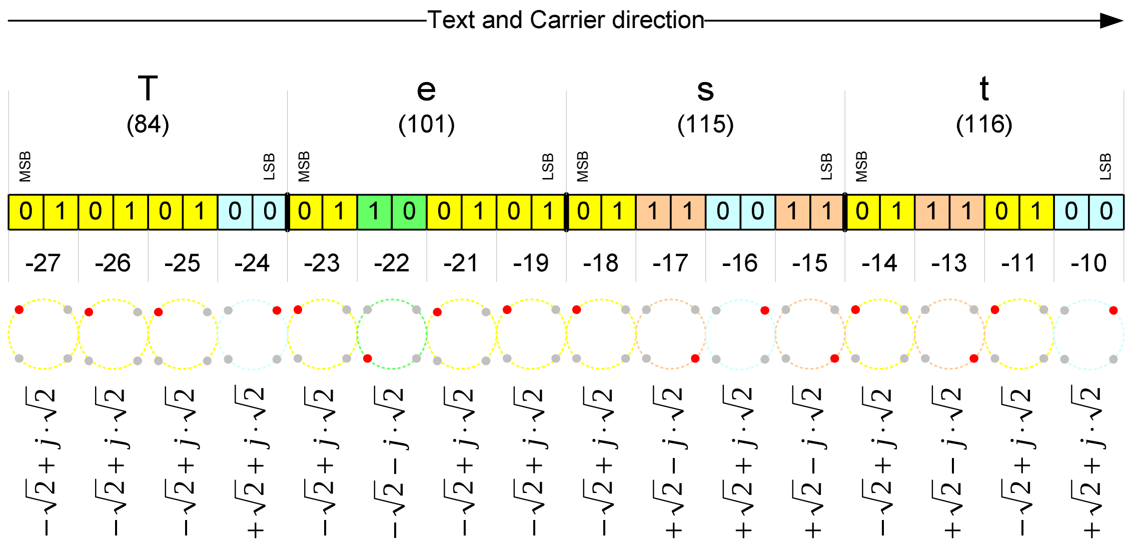


Fig. 1.4: Example using QPSK modulation.

The transmission of the first letter (T) begins with the first OFDM symbol (only a single OFDM symbol is used due to the shortness of the text string) and the most negative OFDM carrier number of this symbol. As the OFDM carriers –32, –31, –30 and –29 are not occupied (guard carrier), the first usable OFDM carrier is –28. When using pilot mapping method B, however, carrier –28 is occupied by the pilot signal and must be skipped. This also applies to carriers –20 and –12.

The text message sent may not fill up all of the OFDM carriers in the most recently transmitted OFDM symbol. In this case, the text message is filled with as many space characters as there is room for whole ASCII characters (eight bits) and the remaining OFDM carriers (less than eight) are set to a null symbol $0 + j \cdot 0$.

The IFFT block carries out the inverse Fourier transform and we receive the OFDM symbol in the time domain:

$$a(n_2,l)=\sum_{k=-\frac{N_{FFT}}{2}}^{+\frac{N_{FFT}}{2}-1} A(k,l)\cdot e^{j\frac{2\pi}{N_{FFT}}\cdot k\cdot n_2}, n_2=-N_{FFT}/2,-N_{FFT}/2+1,\ldots,+N_{FFT}/2-1\,.$$

Eq. 1.8

The spectral spacing of the adjacent OFDM carriers is the same for all lengths N_{FFT} of the inverse Fourier transform, i.e. the signal bandwidth of the transmitter doubles approximately when the length N_{FFT} of the inverse Fourier transform is doubled.

As shown in **Fig. 1.5**, the cyclic prefix (CP) is inserted by repeating a part of the data stream $a(n_2,l)$ in the Cyclic Prefix Adding block.

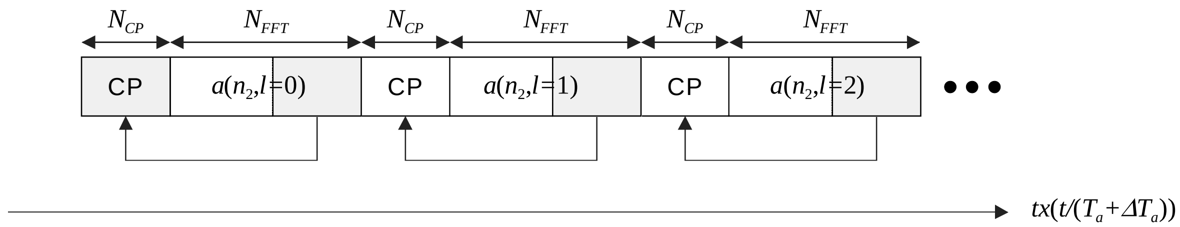


Fig. 1.5: Cyclic prefix (CP) enhancement.

The length N_{CP} of the cyclic prefix is equal to one quarter of the length N_{NFFT} of the inverse Fourier transform:

$$N_{CP}=\frac{1}{4}N_{FFT}\,.$$

Eq. 1.9

The signal $tx(t/(T_a+\Delta T_a))$ is the unimpaired baseband signal of the transmitter, sampled with at a rate of $1/(T_a+\Delta T_a)$. The sampling period $T_a+\Delta T_a$ is related to the sampling period T_{a2} of the signal $a(n_2,l)$ according to Eq. 1.10.

$$T_a+\Delta T_a=\frac{N_{FFT}}{N_{FFT}+N_{CP}}T_{a2}$$

Eq. 1.10

1.4 Channel model

The transmitter signal is impaired in various ways by the transmission channel. The interference is modeled in the baseband. **Fig. 1.6** depicts a model of the transmission channel. The baseband signal of transmitter $tx(t/(T_a + \Delta T_a))$ is complex.

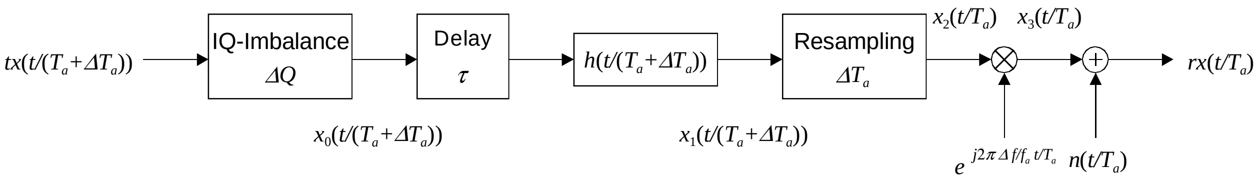


Fig. 1.6: Transmission channel model.

There is initially crosstalk between the real and imaginary parts of the signal $tx(t/(T_a + \Delta T_a))$:

$$x_0(t/(T_a + \Delta T_a)) = \mathrm{REAL}\{tx(t/(T_a + \Delta T_a))\} + j \cdot (1 + \Delta Q_Q + j \cdot \Delta Q_I) \cdot \mathrm{IMAG}\{tx(t/(T_a + \Delta T_a))\}.$$

Eq. 1.11

The crosstalk is designated IQ imbalance $\Delta Q = \Delta Q_Q + j \cdot \Delta Q_I$. The IQ imbalance ΔQ is small: $|\Delta Q| << 1$.

The signal $x_0(t/(T_a + \Delta T_a))$ experiences latency of $\tau/(T_a + \Delta T_a)$ and is convolved with the complex channel impulse response $h(t/(T_a + \Delta T_a))$:

$$x_1(t/(T_a + \Delta T_a)) = \sum_{\xi=0}^{L-1} h(\xi) \cdot x_0(t/(T_a + \Delta T_a) - \tau/(T_a + \Delta T_a) - \xi).$$

Eq. 1.12

The Fourier transform of the channel impulse response $h(t/(T_a + \Delta T_a))$ is equal to the channel transfer function $H(f/f_a)$. The signal latency $\tau/(T_a + \Delta T_a)$ can alternatively be modeled using a channel impulse response $\tilde{h}(t/(T_a + \Delta T_a))$. The latency $\tau/(T_a + \Delta T_a)$ and the channel impulse response $h(t/(T_a + \Delta T_a))$ are chronologically independent.

The transmitter uses sampling rate $T_a + \Delta T_a$, while the receiver works with sampling rate T_a. The sampling rate difference ΔT_a between the transmitter and receiver is small: $\Delta T_a << T_a$. The value

$$\frac{\Delta f_a}{f_a} = \frac{-\Delta T_a}{T_a + \Delta T_a}$$

Eq. 1.13

is designated as the sampling frequency offset.

A frequency difference between the carrier frequencies of the transmitter and the receiver are modeled using the carrier frequency offset $\Delta f / f_a$:

$$x_3(t/T_a) = e^{j\cdot 2\pi\cdot \Delta f / f_a \cdot t/T_a} \cdot x_2(t/T_a) .$$

Eq. 1.14

The carrier frequency offset $\Delta f / f_a$ between the transmitter and the receiver is small: $\Delta f / f_a << 1$.

Ultimately, the signal $x_2(t/T_a)$ is overlaid with an additive complex interferer $n(t/T_a) = n_I(t/T_a) + j\cdot n_Q(t/T_a)$:

$$rx(t/T_a) = x_3(t/T_a) + n(t/T_a) .$$

Eq. 1.15

The interferers $n_I(t/T_a)$ and $n_Q(t/T_a)$ are both stationary, zero-mean, white and have a Gaussian probability density function.

The signal-to-interference ratio

$$SNR = \frac{\sum_k \sum_l |A(k,l)|^2}{\sum_k \sum_l |N(k,l)|^2}$$

Eq. 1.16

is defined in the frequency domain as the power ratio of the deviation

$$N(k,l) = A(k,l) - \hat{A}(k,l)$$

Eq. 1.17

of the impaired $\hat{A}(k,l)$ and unimpaired $A(k,l)$ OFDM symbols in the frequency range. The impaired OFDM symbols in the frequency domain $\hat{A}(k,l)$ are those OFDM symbols in the frequency domain for which the receiver compensated carrier frequency offset $\Delta f / f_a$, sampling frequency offset $\Delta f_a / f_a$, channel transfer function $H(f/f_a)$ and the IQ imbalance ΔQ .

1.5 Tasks

Please answer the following questions regarding the signals below.

Note: In the absence of specific questions regarding interference with special signals, you can ignore the influence of interferers on the special signals in question. This does not apply to latency $\tau/(T_a + \Delta T_a)$ in all cases.

1.5.1 Signal 1

This signal was modulated using an inverse Fourier transform length of $N_{FFT} = 64$ and pilot assignment method A.

1. Which type of modulation mod (BPSK, QPSK, 8PSK) was used to transmit the message? (2 points)

2. Which message $c(m)$ was transmitted? (2 points)
3. Is there a hint to the current location of Dr. Gauss? (2 points)

1.5.2 Signal 2

This signal was modulated using an inverse Fourier transform length of $N_{FFT} = 64$ and pilot assignment method A.

1. Calculate an estimate $|\hat{H}(f/f_a)|$ of the magnitude $|H(f/f_a)|$ of the channel transfer function $H(f/f_a)$ for $f/f_a = [-1/2 : 1/N_{FFT} : 1/2 - 1/N_{FFT}]$. (2 points)

   Note: You do not need to estimate the sampling rate of the channel transfer function magnitude for $f/f_a = k_{DC}$ and $f/f_a = k_{guard}$.
2. Which type of modulation mod (BPSK, QPSK, 8PSK) was used to transmit the message? (2 points)
3. Calculate an estimate $S\hat{N}R$ of the signal-to-interference ratio. (2 points)
4. Which message was $c(m)$ transmitted? (2 points)
5. Is there a hint to the current location of Dr. Gauss? (2 points)

1.5.3 Signal 3

This signal was modulated using an inverse Fourier transform length of $N_{FFT} = 64$ and pilot assignment method B.

1. Calculate an estimate $|\hat{H}(f/f_a)|$ of the magnitude $|H(f/f_a)|$ of the channel transfer function $H(f/f_a)$ for $f/f_a = [-1/2 : 1/N_{FFT} : 1/2 - 1/N_{FFT}]$. (2 points)

   Note: You do not need to estimate a sampling rate of the channel transfer function magnitude for $f/f_a = k_{DC}$ and $f/f_a = k_{guard}$.
2. Which type of modulation mod (BPSK, QPSK, 8PSK) was used to transmit the message? (2 points)
3. Calculate an estimate $S\hat{N}R$ of the signal-to-interference ratio. (2 points)
4. Which message $c(m)$ was transmitted? (2 points)
5. Is there a hint to the current location of Dr. Gauss? (2 points)

1.5.4 Signal 4

This signal was modulated using an inverse Fourier transform length of $N_{FFT} = 64$ and pilot assignment method A.

1. Calculate a normalized estimate $\Delta\hat{f}/f_a$ of the carrier frequency offset. The normalization value is the sampling rate f_a of the signal. (2 points)
2. Calculate an estimate $|\hat{H}(f/f_a)|$ of the magnitude $|H(f/f_a)|$ of the channel transfer function $H(f/f_a)$ for $f/f_a = [-1/2 : 1/N_{FFT} : 1/2 - 1/N_{FFT}]$. (2 points)

   Note: You do not need to estimate the sampling rate of the channel transfer function magnitude for $f/f_a = k_{DC}$ and $f/f_a = k_{guard}$.
3. Which type of modulation mod (BPSK, QPSK, 8PSK) was used to transmit the message? (2 points)
4. Calculate an estimate $\hat{SNR}$ of the signal-to-interference ratio. (2 points)
5. Which message $c(m)$ was transmitted? (2 points)
6. Is there a hint to the current location of Dr. Gauss? (2 points)

1.5.5 Signal 5

This signal was modulated using an inverse Fourier transform length of $N_{FFT} = 64$ and pilot assignment method B.

1. Calculate a normalized estimate $\Delta\hat{f}/f_a$ of the carrier frequency offset. The normalization value is the sampling rate f_a of the signal. (2 points)
2. Calculate a normalized estimate $\Delta\hat{f}_a/f_a$ of the sampling frequency offset. The normalization value is the sampling rate f_a of the signal. (2 points)
3. Calculate an estimate $|\hat{H}(f/f_a)|$ of the magnitude $|H(f/f_a)|$ of the channel transfer function $H(f/f_a)$ for $f/f_a = [-1/2 : 1/N_{FFT} : 1/2 - 1/N_{FFT}]$. (2 points)

   Note: You do not need to estimate the sampling rate of the channel transfer function magnitude for $f/f_a = k_{DC}$ and $f/f_a = k_{guard}$.
4. Which type of modulation mod (BPSK, QPSK, 8PSK) was used to transmit the message? (2 points)
5. Calculate an estimate $\hat{SNR}$ of the signal-to-interference ratio. (2 points)
6. Which message $c(m)$ was transmitted? (2 points)
7. Is there a hint to the current location of Dr. Gauss? (2 points)

1.5.6 Signal 6

Pilot assignment method B was used to modulate this signal. The inverse Fourier transform length $N_{FFT} \in \{32,64,128\}$ used is unknown. The sampling period $T_a + \Delta T_a$ of the transmitter is equal to the period required for an inverse Fourier transform length N_{FFT} of $N_{FFT} = 128$.

1. What inverse Fourier transform length N_{FFT} did the transmitter use? (2 points)
2. Calculate a normalized estimate $\Delta\hat{f}/f_a$ of the carrier frequency offset. The normalization value is the sampling rate f_a of the signal. (2 points)
3. Calculate a normalized estimate $\Delta\hat{f}_a/f_a$ of the sampling frequency offset. The normalization value is the sampling rate f_a of the signal. (2 points)
4. Calculate an estimate $|\hat{H}(f/f_a)|$ of the magnitude $|H(f/f_a)|$ of the channel transfer function $H(f/f_a)$ for $f/f_a = [-1/2 : 1/N_{FFT} : 1/2 - 1/N_{FFT}]$. (2 points)

   Note: You do not need to estimate the sampling rate of the channel transfer function magnitude for $f/f_a = k_{DC}$ and $f/f_a = k_{guard}$.
5. Calculate an estimate $\Delta\hat{Q}$ of the IQ imbalance. (2 points)
6. Which type of modulation mod (BPSK, QPSK, 8PSK) was used to transmit the message? (2 points)
7. Calculate an estimate $S\hat{N}R$ of the signal-to-interference ratio. (2 points)
8. Which message $c(m)$ was transmitted? (2 points)
9. Is there a hint to the current location of Dr. Gauss? (2 points)

1.6 Evaluation

The following results

- Estimate $|\hat{H}(f/f_a)|$ of the magnitude $|H(f/f_a)|$ of the channel transfer function $H(f/f_a)$
- Normalized estimate $\Delta\hat{f}/f_a$ of the carrier frequency offset $\Delta f/f_a$
- Normalized estimate $\Delta\hat{f}_a/f_a$ of the sampling frequency offset $\Delta f_a/f_a$
- Estimate $\Delta\hat{Q}$ of the IQ imbalance ΔQ
- Estimate $S\hat{N}R$ of the signal-to-interference ratio SNR

are estimated values $\hat{p}_i$, for which exist no 100% correct result. For this reason, estimates $\hat{p}_i$ shall be considered correct and receive the points indicated if the relative deviation

$$\frac{|p_i - \hat{p}_i|}{|p_i|}$$

Eq. 1.18

of the estimated value $\hat{p}_i$ is less than 1% of the parameter p_i used in the transmission channel.

The estimate $|\hat{H}(f/f_a)|$ of the magnitude $|H(f/f_a)|$ of the channel transfer function $H(f/f_a)$ is a special case. The relative deviation of the magnitude of the channel transfer function will be calculated as follows:

$$\frac{\sum_{f/f_a}\left(|H(f/f_a)| - |\hat{H}(f/f_a)|\right)^2}{\sum_{f/f_a}|H(f/f_a)|^2}.$$

Eq. 1.19

Moreover, the groups with the three smallest relative deviations per estimate $\hat{p}_i$ will receive additional points. **Table 1.4** explains how these additional points will be distributed.

Relative deviation	Additional points
Smallest relative deviation	3
Second smallest relative deviation	2
Third smallest relative deviation	1

Table 1.4: Distribution of additional points.

1.7 Signal format

The six signals to be demodulated are baseband signals, which have been sampled at a rate of $f_a = 1/T_a$. The complex signals $rx(t/T_a)$ are available with real and imaginary parts

$$rx(t/T_a) = \mathrm{REAL}\{rx(t/T_a)\} + j \cdot \mathrm{IMAG}\{rx(t/T_a)\}$$

Eq. 1.20

in floating point format as vectors of the "Signal" variables in the following Matlab files: Signal1.mat, Signal2.mat, ..., Signal6.mat. Signal(1) is the chronologically oldest sampling value of the signal, while Signal(end) is the chronologically newest sampling value.

1.8 Result format

Your results of the demodulation task **must** be sent in via email to **engineeringcompetition@rohde-schwarz.com**. It is important to use the “Results.mat” file format.

Table 1.5 describes the fields of the Matlab "Results structure. The "TemplateResults.mat" file contains a template of the Matlab "Results" structure. You should use the "CheckResultFormat(Results)" Matlab function provided to verify the format of your Matlab "Results" structure prior to submission.

Fieldname	Format	Number format	Value range	Description
Name	Vector [1xLength]	char		Student group name
Address	Vector [1xLength]	char		Student group address
Phone	Vector [1xLength]	char		Student group phone number
Email	Vector [1xLength]	char		Student group email
Date	Vector [1xLength]	char		Date of results: day.month.year (i.e. 31.08.2016)
ModulationType	Vector [1xLength]	char	'BPSK', 'QPSK', '8PSK'	Transmitter modulation type mod used.
MagChannelTransferFunktion	Vector [1xLength]	real valued		Estimate $\left\|\hat{H}(f/f_a)\right\|$ of the magnitude $\left\|H(f/f_a)\right\|$ of the channel transfer function $H(f/f_a)$.
SNR	Scalar	real valued		Estimate $\hat{SNR}$ of the signal to noise ratio in a linear format.
SignalContent	Vector [1xLength]	char		Signal content $c(m)$ in character format.
City	Vector [1xLength]	char		Solution word (a city) which can be derived from text in field “SignalContent”
NormalizedCarrierFrequencyOffset_fa	Scalar	real valued		Normalized estimate $\Delta\hat{f}/f_a$ of the carrier frequency offset. Normalization value is the sampling rate f_a of the signal.
NormalizedSamplingFrequencyOffset_fa	Scalar	real valued		Normalized estimate $\Delta\hat{f}_a/f_a$ of the sampling frequency offset. Normalization value is the sampling rate f_a of the signal.
IQImbalance_fa	Scalar	complex valued		Estimate $\Delta\hat{Q}$ of the IQ-Imbalance.
FFTSize	Scalar	real valued	32, 64, 128	Inverse Fourier transform size N_{FFT} used by the transmitter.

Table 1.5: Preround results format for fields in the matlab structure.