Basics of Communication Engineering. COMM.100
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Project Work 4: Transmission system 2

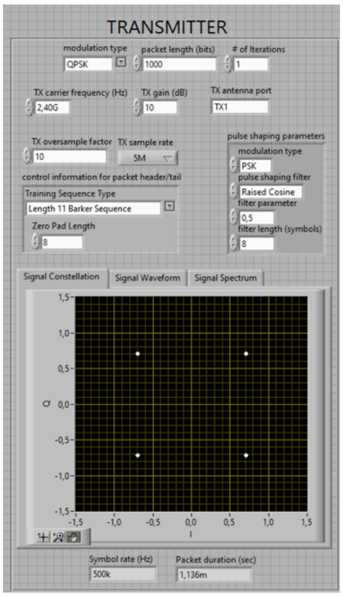
Noise in received signal.

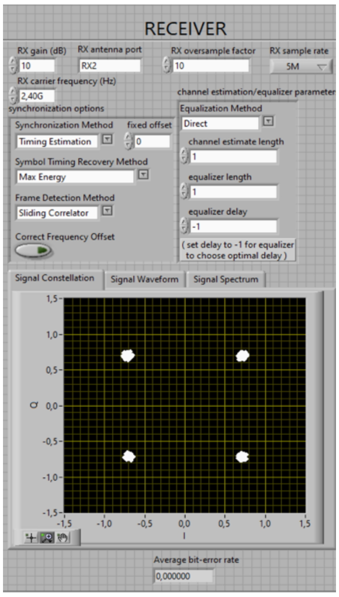
Task 4.1: <u>where is this noise stemming from in real life?</u>

In real life, noise can be originated from different sources in the device per se and in its operating environment. These can be **thermal noise** originated from the electronic components; **ADC or DAC noise** that appears during the conversion of digital and analog data; **radio frequency (RF) noise** in the front-end (amplifiers, mixers, filters…); **local oscillator noise** that comes from the mixing phase. Also, **timing imperfections**, **Electromagnetic Interference (EMI)**, **temperature variations or digital signal processing (DSP)** can introduce noise to the signal.

Task 4.2: observe the noise in LabView

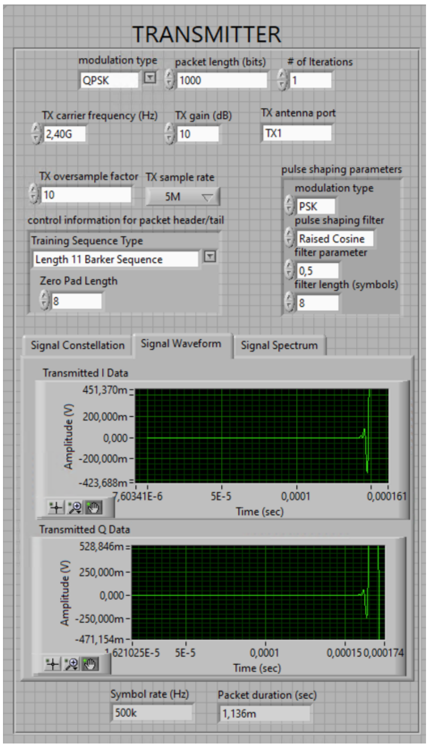
a) Signal Constellation figure

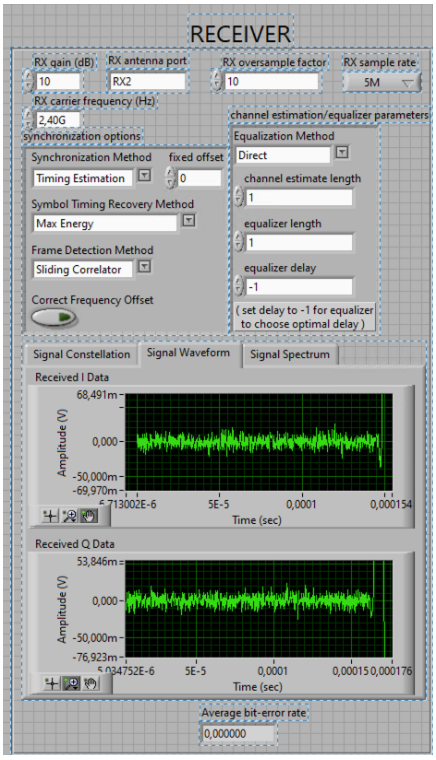




In constellation signal in the transmitter side, we see four dots because in QSPK we have four possible location for our constellation signals. QPSK actually have 500 symbols that can be placed in those four possible locations the transmitter. In the receiver side, the symbols are not in the ideal locations. Noise randomly deviates the symbols. This deviation grows proportionally to the amount of noise added to the signal.

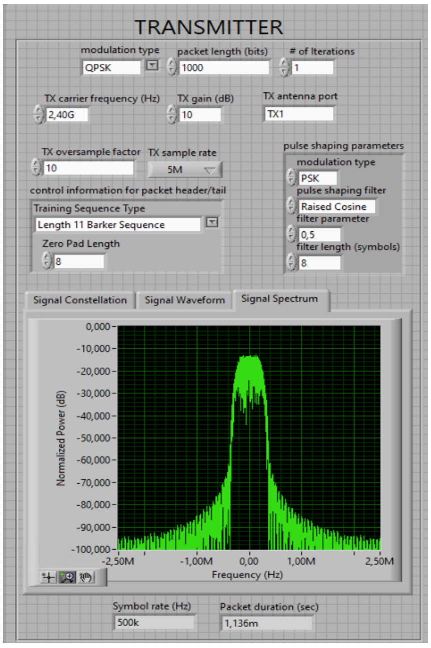
b) Signal Waveform figure

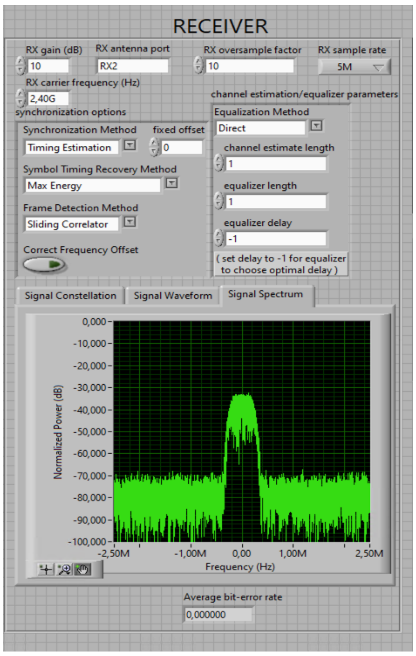




In signal waveform, we can observe noise from the edges of the figure. The reason for this lies in the fact that the signal is jumping up and down in the central part of the figure. For that reason, it is necessary to zoom up at the beginning and the end of the signal to see the noise.

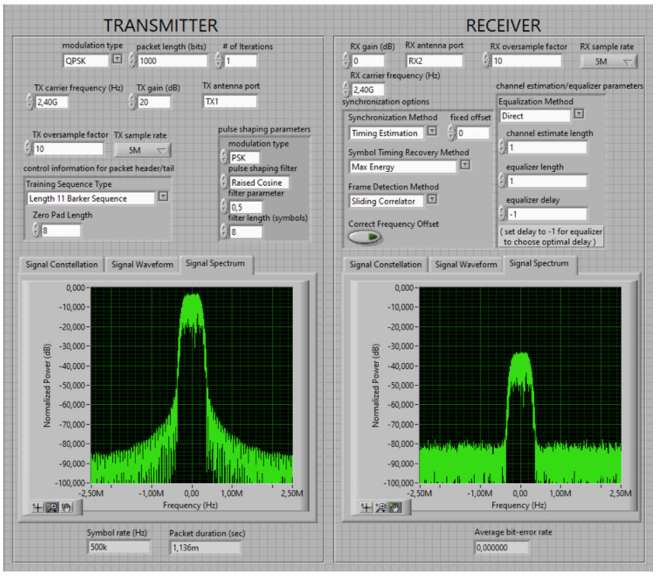
c) Singal Spectrum figure

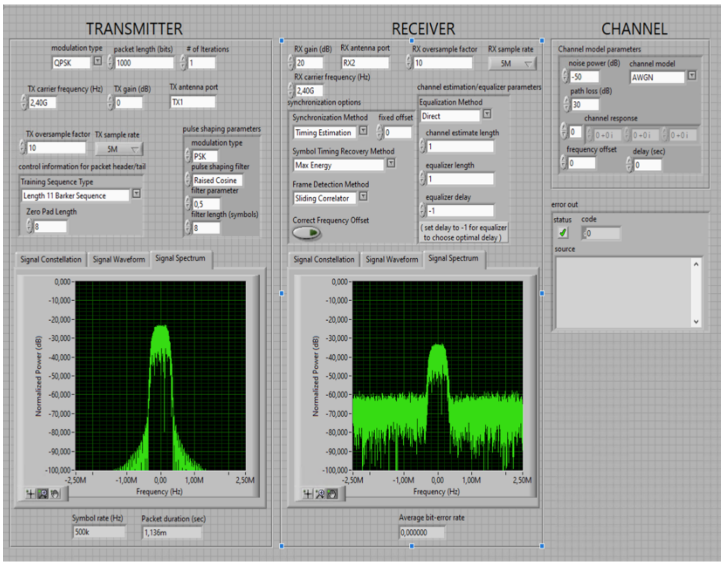




Here we can find th noise on the sides of th signals. On the transmitter side, the tails of the signal indicates the absence of noise. On the contrary, on the receiver side, we can see spikes on the flancs of the signals, close to -70 dB. This noise is equally distributed (White Gaussian Noise).

Task 4.3: Set the parameters of the *simulator.vi* program and save spectrum figures according to the instructions.





In the channel, noise is added to the signal creating a noisy signal. On the receiver, we have an amplifier which increases the inpute signal, affecting the signal-to-noise ration (SNR).

When we set the Transmitter gain to 20 dB and the Receiver to 0 dB, we are basically amplfying the signal before entering the channel. Consequently, the received signal is stronger, althought the noise level also increases to some extend. However, because the signal is amplified before noise is added, the increase in signal power outweights the increase in noise power. This leades to an overall inprovement in SNR.

Setting the the Transmitter gain to 0 dB and the Receiver to 20 dB, the latter will receive a weaker signal that needs to be boosted by 20 dB. However, the noise power is also amplyfied, surpasing the the increase in signal power. As a result, SNR decreases.

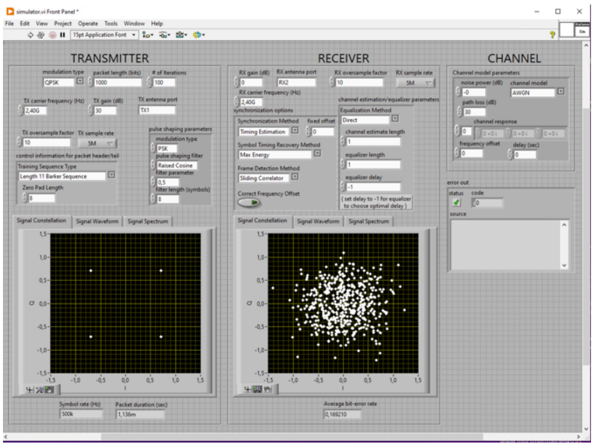
In conclusion, adjusting gains affects the balance between signal and noisy power differntly in the different escenarios explained before. Increasing trnasmitter gain normally leads to an improvemetn in SNR, whereas, increasing the Receiver gain decreases SNR because both, signal and noise, get amplified.

How SNR affects bit-error rate (BER)?

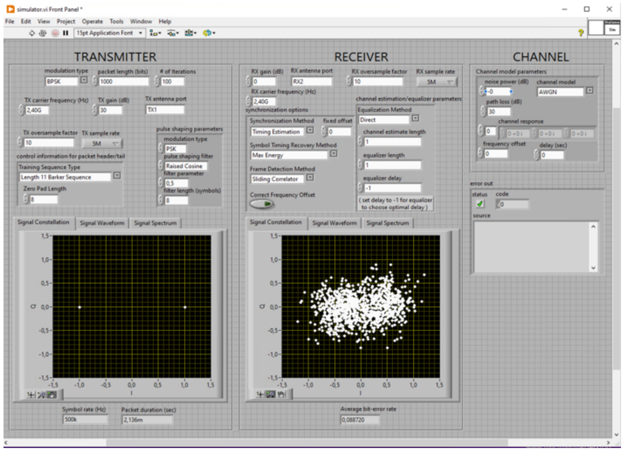
Task 4.4: Use the *simulator.vi* and fill in the average bit-error rates to the table below. **Save also figure of the received signal constellation** for **all** SNR values and for **both** modulation methods (12 figures in total).

SNR = 0 dB

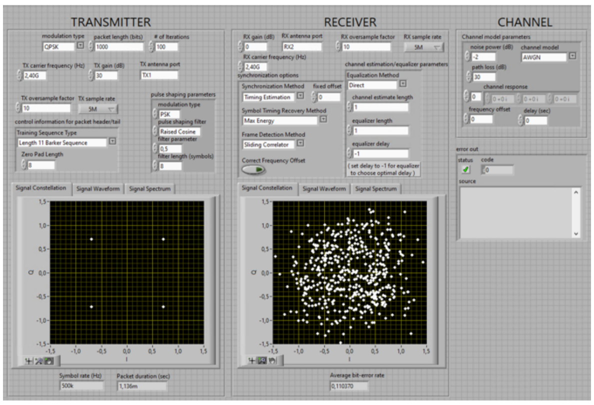
QPSK

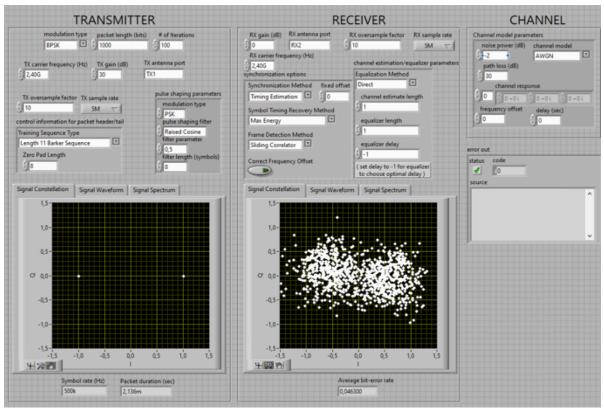


BPSK

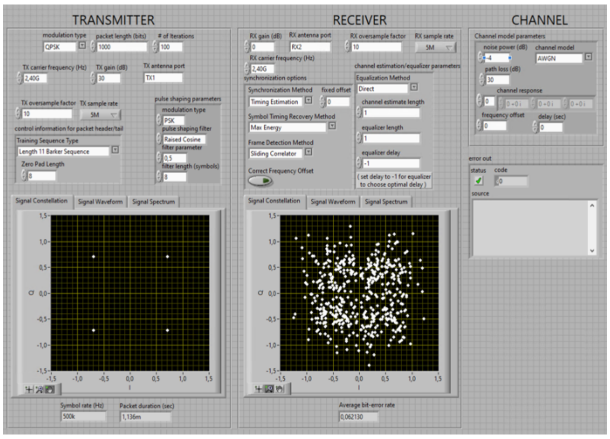


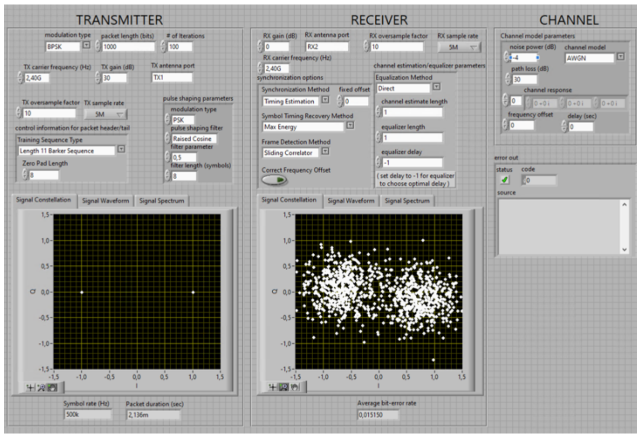
SNR = 2 dB



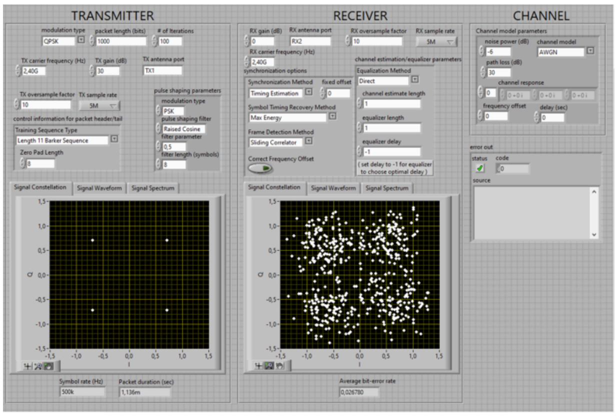


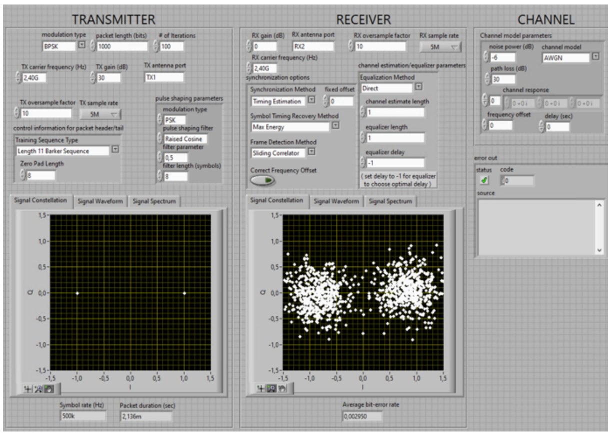
SNR = 4 dB



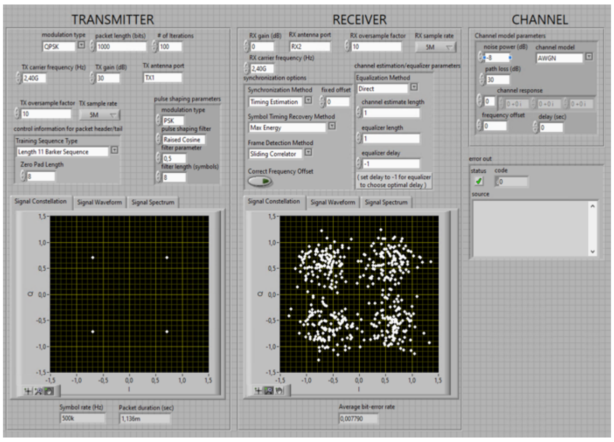


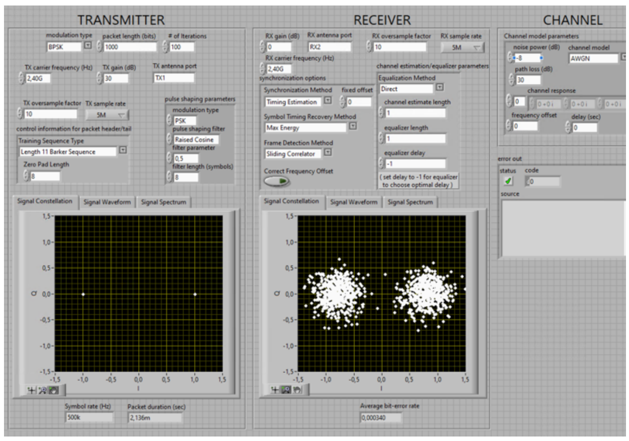
SNR = 6 dB



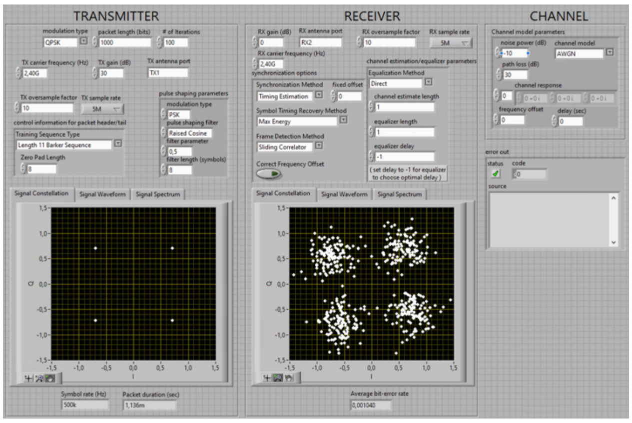


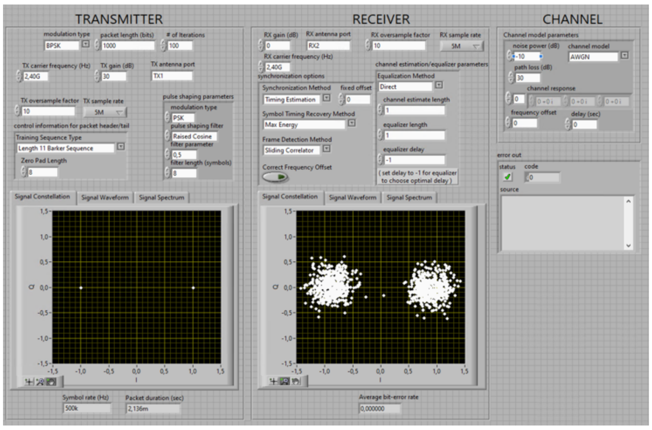
SNR = 8 dB





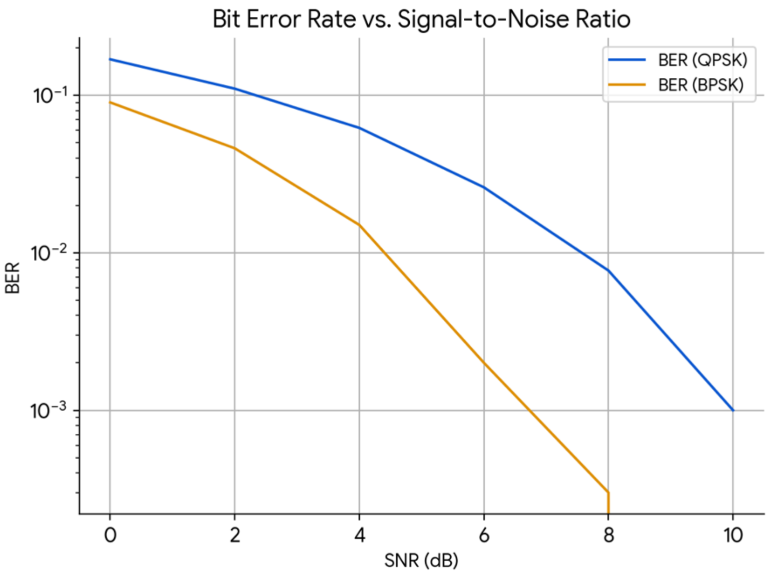
SNR = 10 dB





SNR	BER (QPSK)	BER (BPSK)
0 dB	0.169	0.09
2 dB	0.11	0.046
6 d4	0.062	0.015
6 dB	0.026	0.002
8 dB	0.0077	0.0003
10 dB	0.001	0

Task 4.5: Draw a graph of the values in the table of Task 4.4. The graph should have SNR on the horizontal axis and BER on the vertical axis.



Task 4.6: Analyze the results of the Tasks 4.4 and 4.5 by answering to the following questions.

a) How the amount of noise affects bit-error rate?

In theory, higher noise levels lead to higher bit-error rate. Noise corrupts the signal making it difficult to distinguish different bit values. When noise increases, the probability to bit misinterpretation increases. Namely, we get more errors.

b) What can you conclude by comparing the BER results of BPSK to the BER results of QPSK?

When more noise power is added to the channel, it is possible to see the BER is higher in QPSK than in BPSK. This indicates tha QPSK is more sensitive to noise

c) Why do you get less bit errors with the other modulation type although the signal power and noise power (i.e. SNR) are the same for both modulation types?

This is due to the fact that at lower SNR levels the multiple phase angles of QPSK increases the probability of error because noise becomes more prominent. On the other hand, BPSK has simpler modulation scheme that reduces the complexity when detecting errors.

At higher SNR levels, the performance of both modulations increases. However, this improvement is faster in QPSK than in BPSK. This is mainly due to the fact that QPSK enjoys four phase angles that help to distinguish noise in an easier way.

In conclusion, at lower SNR, BPSK outperforms QPSK because of its simplicity. Therefore, BPSK has better resilience against noise since it has less bit errors.

d) So, if one modulation type gives you less bit errors than the other modulation type (SNR being the same), why would you ever want to use the modulation type that causes more bit errors? [Hint: Remember the conclusions of Task 3.3 in PW3.]

This is mainly because QPSK has higher data rate measured in bits per seconds. In other words, QPSK carries twice the data rate of BPSK for the same bandwidth. So, data thoughput can be maximized. Futhermore, QPSK can enconde more bits per symbol, gaining on spectral efficientcy.

Link budget of the transmission system

Task 4.7: In the following table, some values are given related to our transmission system. Look al- so at Figures 2 and 3 to understand the overall arrangement. First, find out the attenuations of the coaxial cable and the attenuator by following the instructions given after the table. After that, cal- culate the *received signal power* in the output of the Drive Amplifier. Give your answer in dBm unit.

Attenuation of the coaxial cable = **0.624 dB**

mathematical explanation:

100 m cable attenuates at 2.5 GHz. By the data sheet, this attenuation = **62.4 dB**

So, the attenuation of 1m is calculated following this:

$\text{Attenuation}_{1m} = \frac{Attenuation\ 100m}{100m}$

Let's calculate:

$\text{Attenuation}_{1m} = \frac{62.4\ dB}{100m}$ = **0.624 dB/m**

Attenuation of the 30-dB attenuator = **29.08 dB**

The received signal power = **-31.07 dBm**

Mathematical explanation:

$P_{received} = P_{transmitted} + G_{total} – A_{total}$

Where:

- $P_{received}$ is the received signal power
- $P_{transmitted}$ is the transmitted signal power
- G_{total} is the total gain in the system
- A_{total} is the total attenuation in the system

Given values:

- $P_{transmitted}$ = -50 dBm
- Transmitted Amplifier gain: G_{TA} = 20 dB
- Attenuation of the coaxial cable: A_{cable} = 0.624 dB
- Attenuation of the 30-dB attenuator: $A_{attenuator}$ = 29.08 dB
- Low Noise Amplifier gain: G_{LNA} = 14 dB
- Drive Amplifier gain: G_{DA} = 20 dB
- Other attenuations: A_{other} = 2 dB

$G_{total} = G_{TA} + G_{LNA} + G_{DA} - A_{other}$
G_{total} = 20 dB + 14 dB + 20 dB -2dB = 52 dB

$A_{total} = A_{cable} + A_{attenuator}$
A_{total} = 0.624 dB + 29.08 dB = 29.07 dB

$P_{received} = P_{transmitted} + G_{total} – A_{total}$
$P_{received}$ = -50 dBm + 52 dB – 29.07 dB = **-31.07 dBm**