Integrated Circuits and Systems
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TSEK02 – Radio Electronics

Tutorial 4

System Design

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This project is not part of the examination in the course. Its sole purpose is an exercise to summarize the material of the course.

Scenario:

The city of Connectica has a very good high-speed fiber network and happy citizens. 10 km away, the small village of Nowajr is located in a valley surrounded by mountains which are at least 500 m higher than the tallest possible mast in the village. It has no internet connection.
The city council in Connectica has decided to provide Nowajr with internet service by connecting them to Connectica's high-speed fiber network.

Technical consultants have recommended a wireless link implementation at 16 GHz (the high part of the K_u band).

TSEK02 & Associates AB has been assigned to perform the concept work of the project. Your task is to recommend a link design (or a combination of links) to support this communication. The required speed from Connectica to Nowajr ("downlink") is 10 Mb/s and from Nowajr to Connectica ("uplink") is 0.1 Mb/s.
To avoid strong channel fading, it is suggested to design the system with 10 FDM channels.
The deployment costs are shared between the villages and low cost is important.

You are encouraged to use your own estimated values whenever is needed. However, some typical numbers are listed below to help you.

- Receiver sensitivity may be -100 dBm for a high-cost receiver and -70 dBm for a low-cost receiver.
- Generation of more than 1 W power significantly increases the cost of the transmitter.
- Assume efficiency of 25 % or less for the transmitter.
- Antenna gain can vary between 1.5 dBi to 30 dBi for different types of antennas. Higher gain generally leads to a more expensive antenna and less robust solution.
- Keep in-band intermodulation products below -45 dBc and out-of-band interferers below -65 dBc.
- If possible, keep the LO frequency as ratios of fixed numbers, making it possible to use a common frequency generator and simple frequency dividers and multipliers.
- Filter with fractional bandwidth below 5 % are difficult to implement and therefore expensive.
- Total amplifier gain can be increased by cascading multiple stages, however more than 50 dB gain at one frequency is not recommended due to risk for oscillations.
- Mixers can have gain or loss, here we just assume that the conversion gain is lossless.

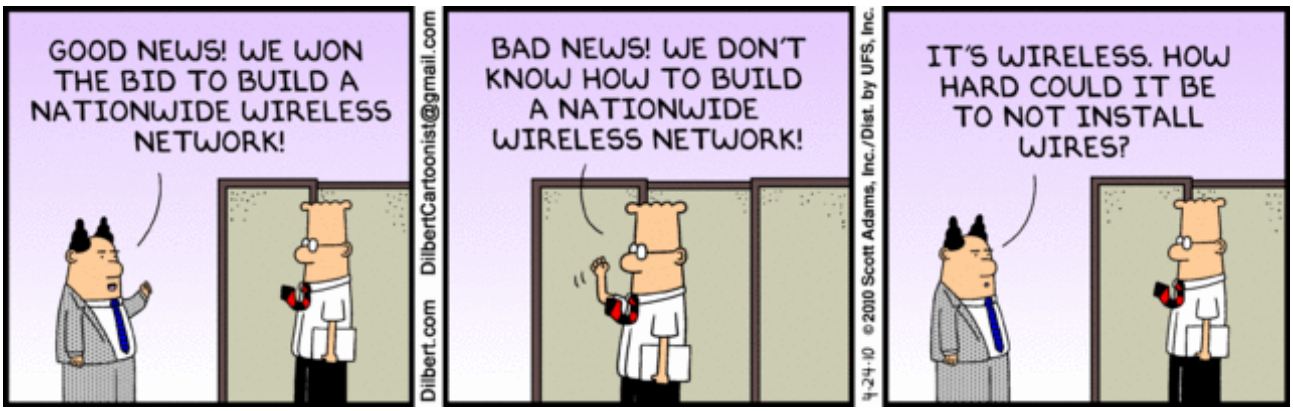
As you realize, this is a relatively big and complex project, which make group work necessary.

So we can start by working together, making an initial scheme of the link and divided the main task into different subtasks and assign them to groups with a number of students in each group.

At the second tutorial occasion, each group is expected to give a short oral presentation (on the whiteboard) of their results, and we can all discuss the pros and cons of the suggested solution.

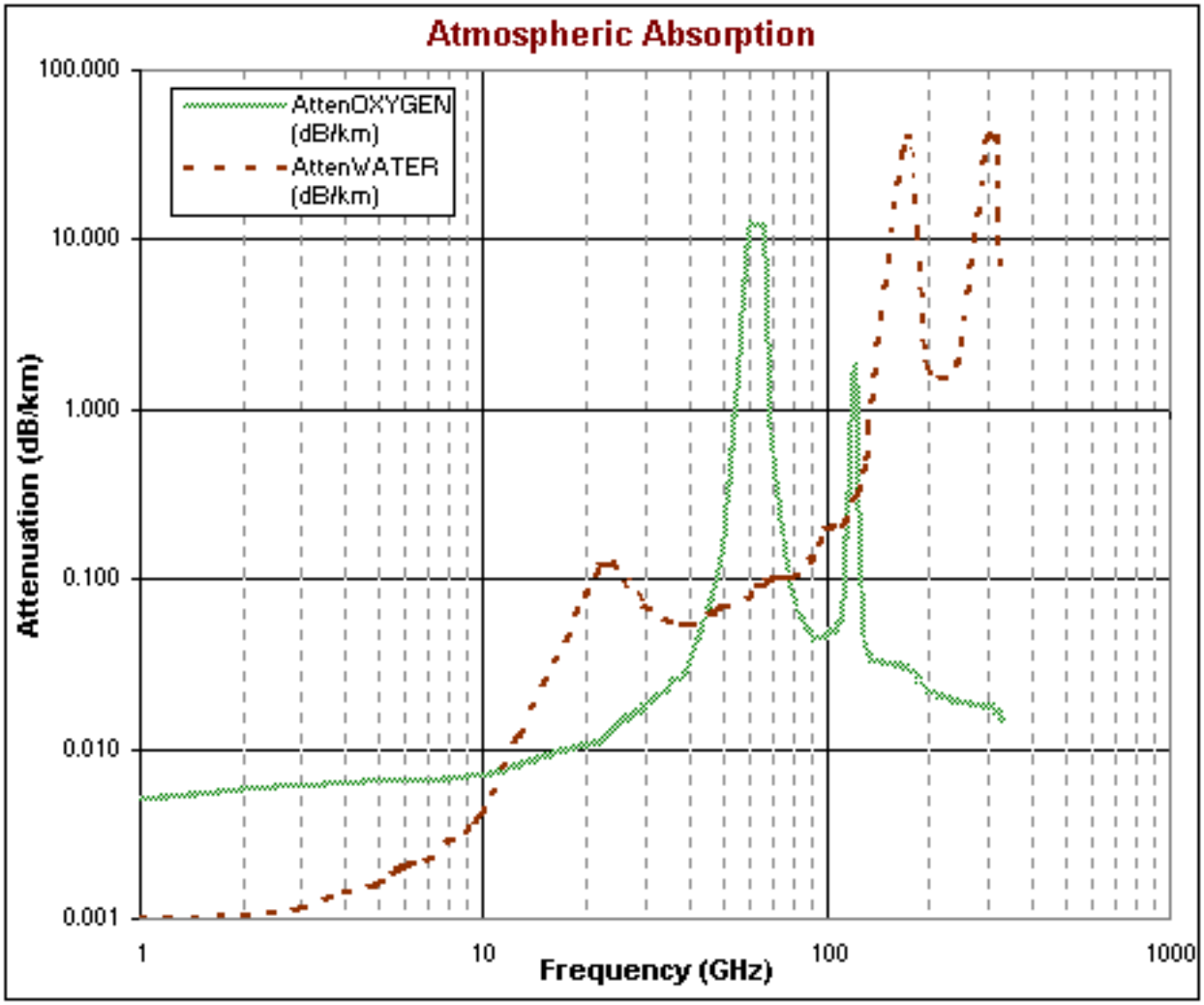
The presented material should include:

- a block diagram of the design,
- relevant numbers (frequency, gain, NF, IP3, etc.),
- a description of the design procedure,
- potential improvements, e.g. by estimating the impact of updating some of the typical numbers that are given above.

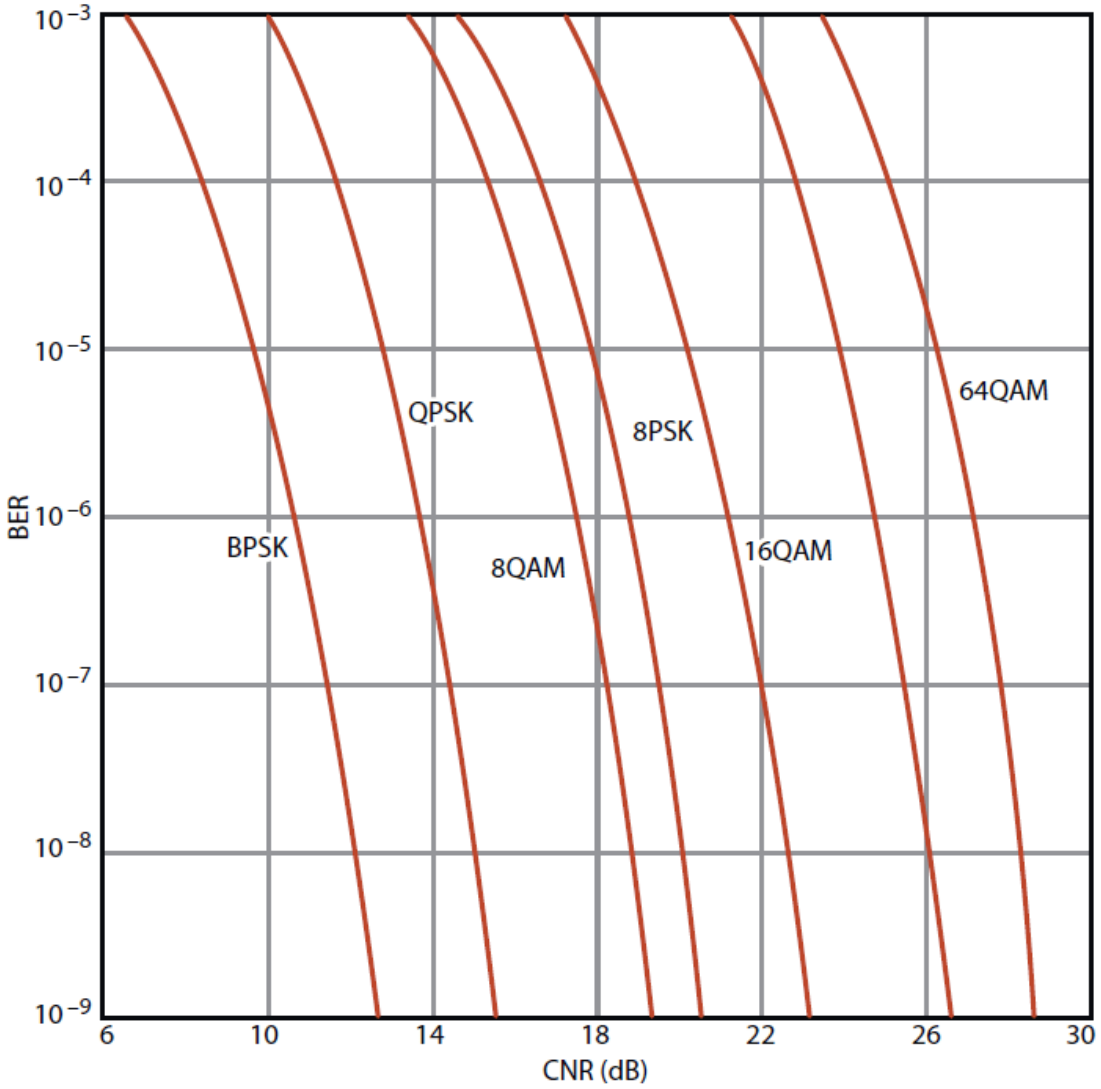


Background material:

Most of the material you need to develop solutions can be found in the lecture material and in more detail in the course book (Razavi). In this section, some more material is given that can be use for you. And you can of course find even more background material on the internet!



Electromagnetic waves are absorbed in the atmosphere according to wavelength. Two compounds are responsible for the majority of signal absorption: oxygen (O_2) and water vapor (H_2O). The actual amount of water vapor and oxygen in the atmosphere normally declines with an increase in altitude because of the decrease in pressure, so these graphs apply from sea level to around 1 km altitude.



7. This is a comparison of several popular modulation methods and their spectral efficiency expressed in terms of BER versus CNR. Note that for a given BER, a greater CNR is needed for the higher QAM levels.

$CNR = E_b/N_0$

FDM systems (from Frenzel, Principles of Electronic Communication System, 4th ed, 2014).

Figure 10-2 The transmitting end of an FDM system.

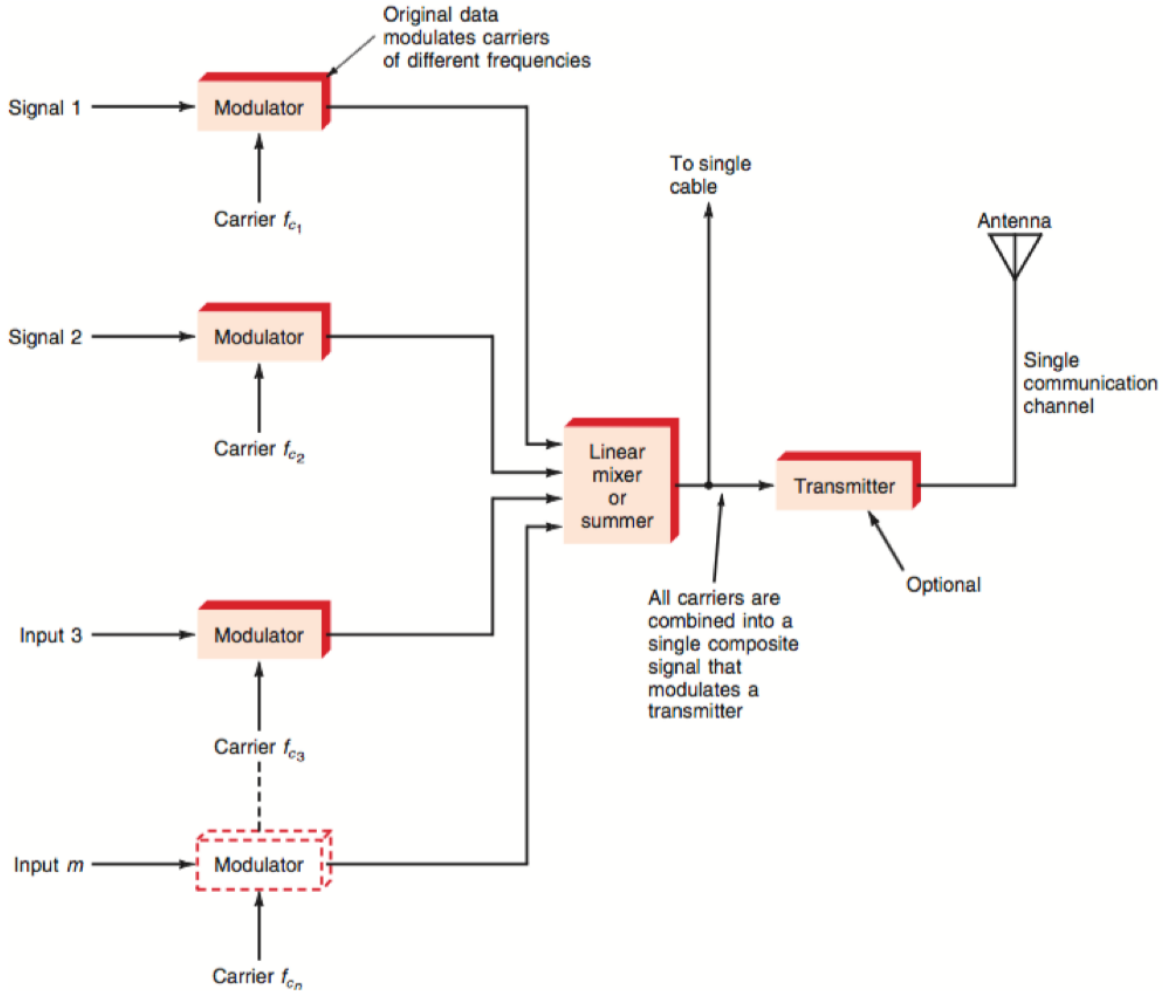


Figure 10-3 Spectrum of an FDM signal. The bandwidth of a single channel is divided into smaller channels.

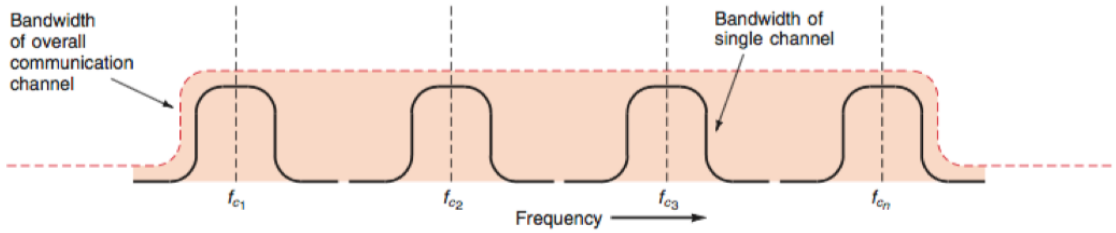


Figure 10-4 The receiving end of an FDM system.