Lab 1. Modulations and receivers

Purpose: To get familiar with the principles of radio systems and radio receivers and to refresh the basic knowledge in modulations and frequency management.

1. Home task

1. Write down an expression of amplitude modulated signal if modulating signal is a sine wave. Express it as a sum of harmonic spectral components. Append timing diagrams and spectra of the modulating and modulated signals.

2. Draw the structure of the superheterodyne receiver. Assume it is supposed to receive AM signal. The modulating signal is $s(t)$. Carrier's frequensy is f_0, intermediate frequency — f_{IF}. Write down expressions of the signals in each point of the diagram.

2. MATLAB simulations

For the simulation use the following parameters:

- Baseband sampling frequency $f_s = 100$MHz.
- A modulating signal is a sequence of the symbols from the set $\{-1; 1\}$. Take the symbol rate equal to 25Mbaud, i.e., four samples per symbol. An additional pulse-shaping filter is not strictly required.
- For the simulation of moduation process, resample baseband signal to the sampling frequency $f_d = 4$GHz.

Perform the following experiments:

1. Crystal receiver

1. Create a modulating signal $s(t)$ and use it to modulate amplitude of the $f_0 = 140$MHz frequency harmonic wave.

2. Pass the signal through the channel, which attenuates it by 4dB.

3. Construct a crystal receiver. As a diode, you can use the absolute value calculating function. Assume that a diode adds to the signal white Gaussian noise with the standard deviation $\sigma_0 = 0.1$.

2. Tuned radio frequency receiver

1. Create a modulating signal $s(t)$ and use it to modulate amplitude of the $f_0 = 140\text{MHz}$ frequency harmonic wave.
2. Pass the signal through the channel, which attenuates it by 4dB.
3. Construct a tuned radio frequency receiver. As a diode, you can use the absolute value calculating function. Assume that a diode adds to the signal white Gaussian noise with the standard deviation $\sigma_0 = 0.1$. Add a bock that adjusts the level of the received signal to twice the level of modulating signal. Choose its correct position.

3. Superheterodyne receiver

1. Create a two modulating signals $s_1(t)$ and $s_2(t)$ and use them to modulate fequency of the $f_1 = 170\text{MHz}$ and $f_2 = 370\text{MHz}$ harmonic waves, respectively.
2. Pass the the sum of these signals through the channel, which attenuates it by 4dB.
3. Construct a superheterodyne receiver. As a diode, you can use the absolute value calculating function. Add a bock that adjusts the level of the received signal to twice the level of modulating signal. Choose its correct position. The receiver must contain a mixer. Intermediate frequency is $f_{IF} = 100\text{MHz}$.
4. Receive and demodulate both signals. Use for both signal demodulation the same local oscillator frequency f_{LO}.

4. Direct conversion receiver

1. Create a two modulating signals $s_1(t)$ and $s_2(t)$ and use them to modulate amplitude of the $f_1 = 170\text{MHz}$ and $f_2 = 370\text{MHz}$ harmonic waves, respectively.
2. Pass the the sum of these signals through the channel, which attenuates it by 4dB.
3. Construct a direct conversion receiver. Add a bock that adjusts the level of the received signal to twice the level of modulating signal. Choose its correct position.
4. Receive and demodulate both signals.

5. Introduce a small difference between the carrier frequency and local oscillator frequency. Try to demodulate the signal.

3. Task of increased complexity[1]

Formulation: Assume you have received FM modulated signal. You can use any of the used in this work. It is moved to QAM demodulator, thus obtaining Q- and I-channel signals. Perform any necessary operation with these signals to extract the original signal.

4. Report structure

1. Home task.
2. Block diagrams of all simulated receivers; timing diagrams and spectra of the signals in main points of the receiver.
3. Listings.
4. Conclusions, including answers for the following questions:
   - Compare receivers. Give a general description of the exercises you have solved. Try to analyze them.
   - Describe differences between crystal and tuned frequency receiver, their advantages and drawbacks.
   - Describe the process of mixing and the selection of carrier, image, local oscillator, and intermediate frequencies.
   - Propose possible usage of direct conversion receiver.
   - Assess the possibility of the AM signal demodulation if there is a small difference between the carrier frequency and local oscillator frequency.

[1] Necessary to get mark higher than 8 (eight)