3-rd practical exercise
Binary Shift Keying Signal Generation with Noise

The purpose of the work is to create signal models for each modulation type to be used in next work for receiving these signals with noise via optimal correlation receiver. Additional purpose of the work is learning to generate AWGN noise without the use of built-in function.

The report should be prepared and sent to email address: elans.grabs@rtu.lv. The report must include the following:

1. The objective of practical exercise;
2. The full source code of simulation programs (3 programs);
3. The plots obtained during simulation (for each modulation, with and without noise).

The tasks to be solved:
1. Choose a random sequence of “1” and “0” binary symbols and display this signal as 1-st subplot;
2. Generate BASK signal (without noise) and display this signal as 2-nd subplot;
3. Introduce additive white Gaussian noise (no *awgn( )* function allowed) to this signal with 15 dB SNR ratio, plot the result
4. Repeat steps 1 to 3 for BFSK modulation type;
5. Repeat steps 1 to 3 for BPSK modulation type.
6. Make some (visual based) conclusions on noise immunity of these modulation types.

The guidelines for practical exercise

1. There are multiple parameters needed for generation of signal. They are summarized in table below:

T	Symbol duration	1 s
f0	Carrier frequency	10 Hz
sB	Binary data vector	[…] (arbitrary sequence of “0” and “1”)
N	Length of binary data vector	N = length(sB);
SNR	Signal-to-Noise Ratio	100 dB (initial value)

Use subplot( ) and stairs( ) functions to display sB data as follows:
```
subplot(211), stairs(0:T:N*T,[sB sB(end)])
```

Note: in order to show completely the last symbol, You must specify the next symbol value. Consider, that the next symbol after the last is the same as last.

2. The next step is generating carrier signal for 1 symbol duration
- For this, You need to specify time interval as follows: $0 \le t \le T - \Delta T$ with some step $\Delta t = T/200$, where 200 is the number of carrier signal samples per symbol.
- Generate carrier signal as:

$$s_0(t) = \sin{(2\pi f_0 t)}$$

3. Generate BASK signal by calculating multiplication with carrier signal. You have to use Kroneker multiplication, to vectorize this operation for all symbols at the same time. Example of Kroneker function:

```
a = [1 2 3 4]; b = [1 1 1 1]; kron(a,b)
```

The result is multiplication of each a vector element by entire b vector:

```
ans =
      1    1    1    1      2    2    2    2      3    3    3    3      4    4    4    4
```

4. Add noise to modulated signal. Generate noise by using function randn( ), which generates random numbers with Gaussian distribution. For this to work, You must specify two parameters:
- Distribution mean value: $\mu = 0$ (for AWGN)
- Distribution standard deviation: σ

The standard deviation can be calculated from noise power density: $\sigma^2 = N_0/2$, which can be obtained from SNR ratio as follows:

$$\frac{E_b}{N_0} = 10^{\frac{SNR}{10}}$$

$$N_0 = \frac{E_b}{10^{\frac{SNR}{10}}}$$

For this, You need to calculate the energy of a carrier signal:

$$E_b = \sum_{i=1}^{N} s_0[i]^2$$

After variance has been calculated, the random normal process can be generated as follows:

```
sqrt(N0/2) * randn(1,N*200);
```

5. For plotting the obtained signal, You need to create vector of time values matching this new signal: $0 \le t_{MOD} \le NT - \Delta T$ with some step $\Delta t = T/200$, where 200 is the number of carrier signal samples per symbol, and N is the number of symbols. Use subplot(212) command to add extra plot in the same window.

6. For other modulation types

Important: Please, make a copy of existing file before any modifications!

1. BFSK modulation type can be considered a superposition of two BASK signals. Each these BASK modulations has its own carrier frequency f_1 or f_2, which must be calculated based on orthogonality condition:

$$\Delta f = |f_1 - f_2| = \frac{k}{2T}$$

   where k – integer number

   $f_1 = f_0 - \Delta f/2$

   $f_2 = f_0 + \Delta f/2$
2. Furthermore, You specify two carrier signals:

$$s_1(t) = \sin(2\pi f_1 t)$$
$$s_2(t) = \sin(2\pi f_2 t)$$
3. And generate BFSK signal as a sum of two BASK signals:

$$s_{BFSK}(t) = d(t) \otimes s_1(t) + \bar{d}(t) \otimes s_2(t)$$

   where $\otimes$ denotes Kroneker multiplication;

   $d(t)$ is binary data vector (sB in Matlab code)

   $\bar{d}(t)$ is inverse binary data vector (inversion in Matlab is calculated via ~ operator, i.e. ~SB).

4. For BPSK modulation, You can use BASK program, and convert sB signal into NRZ form before Kroneker multiplication.