Exercises. Lesson 3
Effects of noise in analog communications

Problem 3.1

A transmitter can perform either DSB or AM modulations. The post-detection signal-to-noise ratio has to be at least $20dB$ in order to meet the required quality specifications.
When DSB modulation is used, we get a maximum range of $15km$ with a transmission power of $1W$. The link attenuation (in dB) is proportional to the distance between transmitter and receiver.
Answer:

a. Calculate the power of the signal at the output on the transmitter when DSB modulation is used, and the desired range is $20km$.

b. Repeat a. when AM at 80% is used.

c. Calculate the envelope peak power values at the output of the transmitter under the conditions mentioned in a. and b., respectively.

DATA:

- $\frac{N_0}{2} = 2 \cdot 10^{-9} W/Hz$
- $W_x = 2\pi \cdot 5krad/s$
- $|x(t)|_{max} = 1V$
- $S_x = 0.5W$
- $\alpha_t[dB] = A \cdot d[km]$, with A a constant.

Problem 3.2

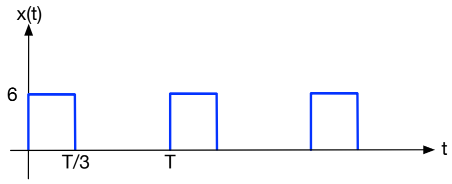
A normalized signal with $5kHz$ bandwidth and average power $0.5W$ is transmitted by an AM system. The transmitter power is $660W$. At the receiver side, located $40km$ away, we get a post-detection signal-to-noise ratio of $33dB$. We know that the noise power spectral density is $N_0/2 = 5 \cdot 10^{-13} W/Hz$, and that the propagation attenation is given by $A[dB] = 40 + 20 \cdot log(d[km])$. Answer:

a. Calculate the modulation index m.

b. Calculate the amount of power needed to transmit the carrier, and the amount of power devoted to the transmission of each sideband.

Problem 3.3

The signal $x(t)$ in the figure goes through a lowpass filter with bandwidth $10kHz$. We assume that the signal power is not affected, and that the DC component is removed.

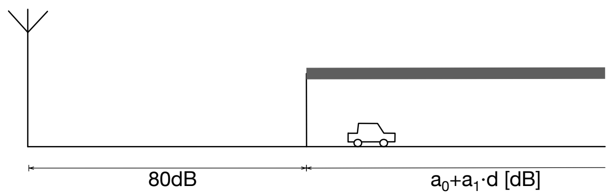


The resulting signal AM modulates a $125V$ carrier, with a modulation index of 0.7484. This signal is transmitted by a radio station. The transmission channel introduces 80 dB attenuation, and Gaussian white noise whose power spectral density is $N_0/2 = 10^{-11} W/Hz$.
A vehicle is tuned to this radio station, and it enters a tunnel where the propagation attenuation is no longer constant and varies according to:

$$A[dB] = a_0 + a_1 \cdot d$$

where:

- $a_0 = 10dB$
- $a_1 = \frac{1}{3} dB/m$
- d: Distance (m)



a. Calculate the average power of the modulated signal.

b. Calculate the demodulation signal-to-noise ratio at the tunnel entrance.

c. Calculate the distance where the signal will no longer be audible, if the demodulation threshold is $10dB$.

d. Repeat c. when the demodulator employed is an envelope detector, assuming that the pre-detection threshold is $13dB$.

Problem 3.4

A communication system is such that the signal arriving at the receiver side has a power $100dB$ below the emitted power at the transmitter side, and that the noise power spectral density is $N_0/2 = 5 \cdot 10^{-15} W/Hz$. A post-detection signal-to-noise ratio of $40dB$ is required for a correct reception.
The maximum voltage value of the message is $2V$, its mean power is $1W$, and its bandwidth, $10kHz$. A pre-detection threshold signal-to-noise ratio of $10dB$ is required. Calculate the minimum transmitted power when using each one of the following modulation systems:

a. DSB modulation.

b. AM modulation with $m = 0.5$ and envelope detection.

c. FM modulation without de-emphasis ($f_d = 10^5 Hz/V$).

Problem 3.5

We want to transmit a signal with bandwidth $10kHz$ and normalized average power 0.5, by using an FM communication system. The post-detection signal-to-noise ratio has to be greater than $40dB$, but ensuring a minimum amount of output power consumption. The channel has $120kHz$ bandwidth and introduces white noise with power spectral density $N_0/2 = 0.5 \cdot 10^{-8} W/Hz$. This channel is characterized by an attenuation of $40dB$. Indicate the amount of power needed to trasmit the signal.

Problem 3.6

A radio transmission system uses a frequency modulator (FM) with modulator constant $f_d = 20kHz/V$, and carrier signal $c(t) = 5 \cdot cos(2\pi \cdot 5 \cdot 10^7 t)$. Answer:

a. Calculate the modulation index D and the approximate bandwidth when the modulating signal is $x_1(t) = cos(2\pi \cdot 500t)$.

b. Repeat a. when the modulating signal is $x_2(t) = cos(2\pi \cdot 10^4 t)$.

In order to improve the demodulation signal-to-noise ratio, a pre-emphasis and de-emphasis filters are introduced, with cut-off frequency $1430Hz$. The system is tested with the modulating signal $x(t) = x_1(t) + x_2(t)$.

c. Determine the improvement in demodulation signal-to-noise ratio.

Problem 3.7

A signal with bandwidth $5kHz$, whose maximum voltage value is $2V$ and with average power $0.5W$ is transmitted using FM through an AWGN channel. The channel has a noise power spectral density of $N_0/2 = 3 \cdot 10^{-14} W/Hz$. The receiver power is $50nW$. The maximum deviation of frequency is $20kHz$. Calculate the post-detection signal-to-noise ratio.

Problem 3.8

A signal with bandwidth $10kHz$ and normalized average power 0.5 is transmitted using FM through an AWGN channel. The channel has a noise power spectral density of $N_0/2 = 5 \cdot 10^{-10} W/Hz$ and attenuates the signal $40dB$. In order to meet the required quality specifications, a threshold γ_{th} of 100 is required for a pre-detection threshold signal-to-noise ratio of $10dB$.

a. Calculate the minimum possible power transmitted to the channel (S_T).

b. Find the demodulation (post-detection) signal-to-noise ratio.

In order to improve the demodulation signal-to-noise ratio, pre-emphasis and de-emphasis filters are introduced. The $3dB$ cutoff frequency of the de-emphasis filter, $B_{de} = 1kHz$.

c. Determine the improvement in dB of the demodulation (post-detection) signal-to-noise ratio.

Results for problem 8

1. $S_{T_{DBL}} = 7.96W$
2. $S_{T_{AM}} = 32.69W$
3. $PEP_{DBL} = 15.92W$, $PEP_{AM} = 80.25W$

Results for problem 9

1. $m = 0.8$
2. $P_p = 500W$, $P_{BL} = 80W$

Results for problem 10

1. $S_T = 10kW$
2. $\left(\frac{S}{N}\right)_D = 20.38dB$
3. $d = 11.94m$
4. $d' = 2.94m$

Results for problem 11

1. $S_T = 10kW$
2. $\gamma > \gamma_{th} \Rightarrow S_T = 170kW$
3. $\gamma < \gamma_{th} \Rightarrow S_T = S_{T_{th}} = 420W$

Results for problem 12

- $S_T = 416.66W$

Results for problem 13

1. $D_1 = 40$, $B_T = 41kHz$
2. $D_2 = 2$, $B_T = 80kHz$
3. $\Delta \left(\frac{S}{N}\right)_D = 12.14dB$

Results for problem 14

- $\left(\frac{S}{N}\right)_D = 30dB$

Results for problem 15

1. $S_{T_{min}} = 10dBW$
2. $\left(\frac{S}{N}\right)_D = 31.3dB$
3. $\Delta\left(\frac{S}{N}\right)_D = 15.23dB$