Communication Systems: Homework #7

Due on Day 5, 1396 at 3pm

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Problem 1

A quadrature carrier multiplex modulator (a) and demodulator (b) system is shown in Figure 1. The system can be used to transmit two independent message signals $m_1(t)$ and $m_2(t)$ using one carrier frequency f_c. Assuming both messages having bandwidths of $W \ll f_c$:

(a) Assuming an ideal lossless channel, evaluate the signal at each stage of the system and show how the system operates.

(b) Assuming an ideal lossless channel, evaluate the system outputs when there is a phase error at the receiver oscillator. (This phenomenon is called cross talk between two output signals)

(c) Assume that the channel has a transfer function $H(f)$. What would be the condition on $H(f)$ to ensure proper demodulation process?

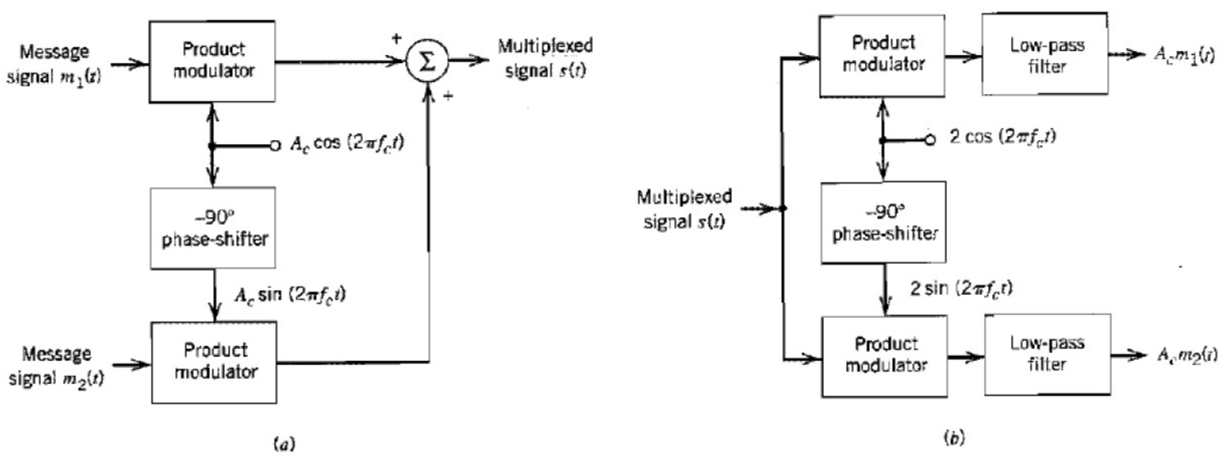

Figure 1: Problem 1

Problem 2

A receiver designer is given the task of designing a receiver for signals with carrier frequencies in the band from 10 MHz to 100 MHz and bandwidth of 5 kHz. To achieve good selectivity at reasonable cost, the designer wants to use a particular standard IF filter with a center frequency of 455 kHz. The designer first contemplates using a simple superhetrodyne receiver as discussed in the class.

1. If such a system is used, find

   (a) Find the range of frequencies that the local oscillator should generate.

Problem 2 continued on next page. . .

(b) How wide should the transition region of the RF filter be to eliminate the image frequency problem.

2. A better design that is used when high selectivity and wide RF frequency range is desired (such as spectrum analyzers) is shown below.

   (a) What should the frequency f_{LO2} be?
   (b) What should be the maximum transition region of the first IF filter be to reject all image frequencies of the second IF filter?
   (c) Compare the requirements for this filter with that of the IF filter in the super-hetrodyne receiver (Assume the index of difficulty in building a band-pass filter is the ratio of the center frequency of the filter to its pass-band bandwidth)
   (d) What range of frequencies the first local oscillator should be capable of generating?
   (e) What is the maximum width of the transition region of the RF filter?
   (f) Compare the difficulty of building the RF filter in this design with that of the regular superhetrodyne receiver.

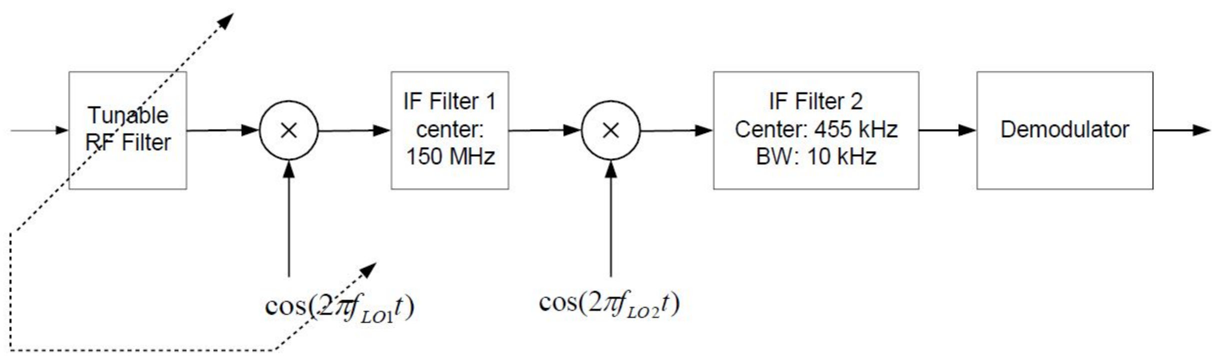

Figure 2: Problem 2

Problem 3

Suppose a commercial AM superhet receiver has been designed such that the image frequency always falls above the broadcast band. Find the minimum value of f_{IF}, the corresponding range of f_{LO} and the bounds on B_{RF}.

Problem 4

In a broadcast communication system, the transmitter power is $50KW$, the channel attenuation is $70dB$, and the noise PSD is $10^{-10}W/Hz$. The message signal has a bandwidth of $W = 10kHz$.

(a) Find the SNR at the input of the receiver.

(b) Find the output SNR if the modulation is DSB.

(c) Find the output SNR if the modulation is SSB.

(d) Find the output SNR if the modulation is AM with $= 0.85$ and normalized message power of 0.2.

Problem 5

Let $y(t) = 2n(t)cos(\omega_c t + \theta)$ where $n(t)$ is a bandpass noise centered at f_c. Show that $y(t)$ has a low pass and a bandpass component. Find the mean value and variance of each component in terms of the properties of $n(t)$.

Problem 6

Write a Matlab program that generates a sine wave of unity amplitude and frequency 10 KHz for a sufficient duration of time. Modulate this signal with a carrier frequency of 4MHz and using AM modulation with $\mu = 0.6$. Pass this signal through a channel that has a $20dB$ loss. In the receiver, add White Gaussian Noise of variable variance to the received signal. Use envelope detection at the receiver and detect the message signal.

(a) Change the power of AWGN [1] such that the input SNR varies between 30 dB and 3 dB in steps of 1dB. For each value of this SNR, calculate the output SNR and plot $(\frac{S}{N})_O$ versus $(\frac{S}{N})_I$ for these values. Do you see a linear curve? Explain the behavior of the system using your knowledge of the detection operation.

(b) Repeat the above step for $\mu = 0.6, 0.8, 1$ and for each case plot $(\frac{S}{N})_O$ versus $(\frac{S}{N})_I$.

(c) What is the impact of μ? Explain?

Problem 7

Write a Matlab program that generates a sine wave of unity amplitude and frequency 10 KHz for a sufficient duration of time. Modulate this signal with a carrier frequency of 4MHz and using FM modulation with $\beta = 10$. Pass this signal through a channel that has a $20dB$ loss. In the receiver, add White Gaussian Noise of variable variance to the received signal. Use a typical FM receiver (differentiator followed by envelope detection) at the receiver and detect the message signal.

[1] Additive White Guassian Noise

Problem 7 continued on next page. . .

(a) Change the power of AWGN such that the input SNR varies between 30 dB and 3 dB in steps of 1dB. For each value of this SNR, calculate the output SNR and plot $(\frac{S}{N})_O$ versus $(\frac{S}{N})_I$ for these values. Do you see a linear curve? Explain the behavior of the system using your knowledge of the detection operation.

(b) Repeat the above step for $\beta = 2, 5, 15, 20$ and for each case plot $(\frac{S}{N})_O$ versus $(\frac{S}{N})_I$.

(c) What is the impact of β? Explain?

(d) For the case of $\beta = 10$ and $(\frac{S}{N})_I = 15dB$, plot the power spectral density of the signal at the output of the demodulator (desired signal plus noise) and observe if its shape matches the analytical results obtained in class.

(e) Repeat part (d) when $(\frac{S}{N})_I = 3dB$ and state your conclusion.