Association of Professional Engineers of Ontario

Annual Examinations
07-Elec-A3, May 2015

Signals and Communications

3 hours duration

Notes:

1) If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumption made.

2) "Closed-Book" - no aids other than a standard non-programmable (no text storage) calculator are permitted.

3) Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.

4) All questions are of equal value.

1) Consider the pulse $p(t) = \frac{t}{a}$, for $|t| \le a$, where $a = 0.5$ ms, and $p(t) = 0$ elsewhere. Let

$$x = \sum_{k=-\infty}^{\infty} p(t-ka)$$

a) Determine the Fourier series of $x(t)$ in terms of real basis functions.

b) Determine the Fourier series in terms of complex basis functions.

c) Determine the power spectral density of the signal $x(t)$.

d) If the signal $x(t)$ is input to a filter with impulse response $h(t) = \frac{\sin\left(\frac{2\pi t}{a}\right)}{\frac{2\pi t}{a}}$ determine the output of the filter in the time domain.

2) A discrete time linear system is described by the following difference equation:

$$y(n) = a_1 y(n-1) + a_2 y(n-2) + x(n) + x(n-1)$$

where $x(n)$ is the input, $y(n)$ is the output and $a_1 = a_2 = \frac{1}{4}$.

a) Give the transfer function for the system.

b) Find the impulse response of the system.

c) Give a block diagram for the filter implementation that minimizes the number of delay elements.

3) An AM signal has a modulation index $a = 0.9$ and an average power equal to 3W. The message is a sinusoidal signal (assume to be a cosine). The carrier frequency is 10 MHz and the message bandwidth is equal to 20 KHz.

a) Give an expression for the AM signal in the time domain, and plot it.

b) Plot the spectrum of the AM signal.

c) Plot the envelope of the AM signal. Give all the parameters.

d) Give the block diagram for an envelope detector that will demodulate the AM signal.

e) Give the block diagram for a coherent detector that will demodulate the AM signal.

f) Which of the above detectors is preferred and why? Be specific as to which one is better and why we sometimes use the other one.

4) A PCM system with uniform quantization is used to transmit a speech signal. The bandwidth of the signal is equal to 6 KHz. At the receiver we require an SNR in the reconstructed signal equal to 40 dB.

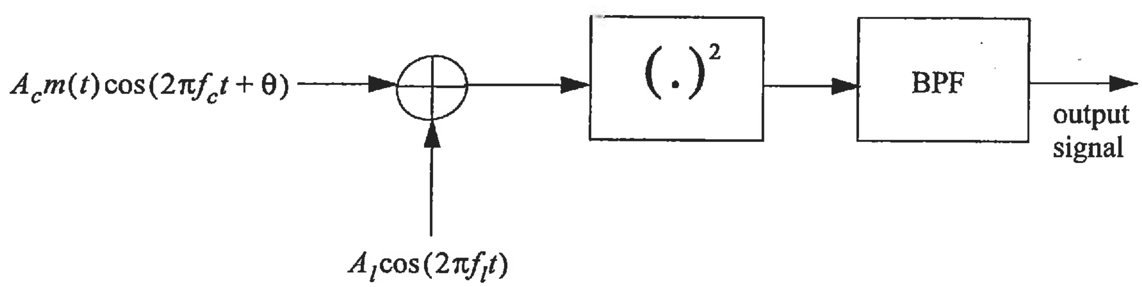
a) What is the minimum sampling rate for the speech signal?

b) In the signal quantization what is the smallest number of possible levels?

c) What is the bit rate of the PCM signal, using the number of quantization levels in b) and the sampling rate in a)?

d) Explain the reason for using non-uniform quantizers.

5) A frequency downconverter is implemented using a square-law device as follows:



The band-pass filter has a center frequency $f_i = |f_c - f_l|$ (also known as the intermediate frequency, IF). Assume that the message bandwidth of the input signal $m(t)$ is equal to B Hz.

a) Determine the smallest possible IF frequency so that there is no distortion in the output signal.

b) For a given IF frequency what is the smallest bandwidth of the band-pass filter (BPF) so that there is no distortion in the output signal?

c) For a given IF frequency what is the largest bandwidth of the BPF so that there is no distortion in the output signal?

6) An FM modulation signal has a carrier frequency equal to 10 MHz and a bandwidth equal to 60 KHz. The bandwidth of the message signal is equal to 10 KHz.

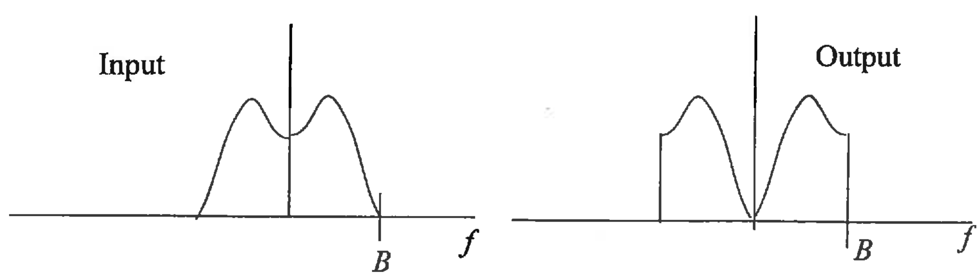
a) Suppose we input the FM signal to a x2 frequency multiplier. Determine the bandwidth of the output signal.

b) Give the block diagram of a system that converts the above FM signal to one of the same bandwidth as in a) and a carrier frequency equal to 15 MHz.

c) Give the block diagram of a system to demodulate the FM signal.

d) Suppose we input an FM signal with carrier frequency ω_c into a square-law device. Can we demodulate the original signal from the output of the square-law device? Or is it distorted beyond recovery? If distorted say why, if not give the block diagram of a system to demodulate the signal and obtain the original message signal, i.e. take the square-law output signal and recover the original message signal.

7) A speech scrambler transforms low frequency to high frequency components and vice versa so that a baseband signal of bandwidth B is transformed to another baseband signal of the same bandwidth and a component at the frequency f is transformed into a component at the frequency $B-f$, where B is the bandwidth of the signal. An example is shown in the following figure.



a) Give the block diagram of a linear system to accomplish this scrambling.

b) Give a block diagram to descramble the signal.