**Association of Professional Engineers of Ontario**

Annual Examinations - 2003
98-Elec-A3

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.

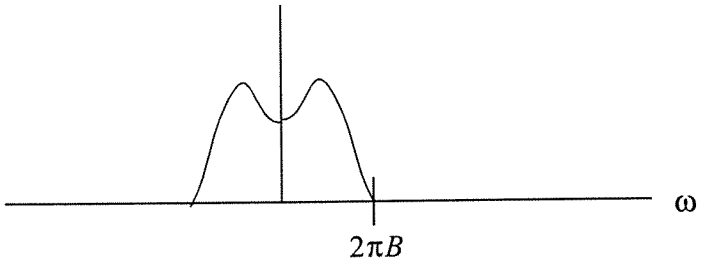
2) "Closed-Book" - no aids other than a calculator (Casio FX-991 or Sharp EL-540) are permitted.

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)** The SSB signal $x(t) = m(t)\cos(\omega_c t) - m_h(t)\sin(\omega_c t)$ is transmitted on a channel.

a) If the message signal $m(t)$ has the spectrum given in the following Figure and $m_h(t)$ is the Hibert transform of $m(t)$, determine the spectrum of the signals $m_h(t)$ and $x(t)$.




b) Assume that a coherent receiver is utilized and that the local reference signal is equal to $\cos(\omega_c t + \theta)$. Give the output of the demodulator.

c) Determine the average power of the signal $x(t)$ in terms of the power of the signal $m(t)$, $P_m$.

d) Suppose we use the carrier re-insertion method to demodulate. We add the signal $A\cos(\omega_c t)$ to $x(t)$ and then input to an invelope detector. Give the output of the envelope detector and then give an approximate value for large $A$.

**2)** A linear system has an impulse response given by $h(t) = e^{-at}$ for $t \geq 0$ and 0 for $t < 0$ (where $a > 0$). If the input is given by $x(t) = A$ for $0 < t < T$ and 0 elsewhere, determine the output $y(t)$. Plot the result and label the plot with all the parameters.

**3)** An FM signal has the form $s(t) = A_c\cos(\omega_c t + \phi(t))$, where $A_c = 5$ $\phi(t) = a\cos(\omega_1 t) + b\cos(\omega_2 t)$, $a = 1$, $b = 2$, $\omega_1 = 2\pi \times 2000$ rad/sec, and $\omega_2 = 2\omega_1$

a) Determine the message signal $m(t)$, assuming that the frequency deviation constant is 5 KHz/volt.

b) What is the average power of the FM signal $s(t)$?

c) Determine the peak frequency deviation of the FM signal.

d) Determine the bandwidth of the FM signal.

e) Give the block diagram of a suitable demodulator.

**4)** A voice signal $m(t)$ is to be digitized using a PCM encoding scheme. The bandwidth of the signal is 8 KHz, and the signal is to be quantized using a uniform quantization scheme for each of two ranges of the signal. Let $m_p$ be the peak value of $|m(t)|$, and let $m_s$ be a sample of $m(t)$. If $|m_s| < \frac{m_p}{2}$ then the quantization error should be less than 0.1% of the peak, $m_p$, and if $\frac{m_p}{2} \le |m_s| \le m_p$ then the quantization error should be less than 0.4% of the peak.

a) Determine a quantization scheme by listing all the threshold values; that is, specify the characteristics of the quantizer by giving the quantizer characteristics - the output quantized level versus the input analog voltage level.

b) What is the number of bits per sample if a binary encoding scheme is used.

c) Determine the bit rate for the digitized voice signal.

**5)** A discrete time system is described by the following transfer function

$$H(z) = \frac{1 + 2z^{-1}}{1 - \frac{1}{4}z^{-2}}$$

a) Give a block diagram to implement the system using delay elements, multipliers, and adders. Use the smallest possible number of delay elements (all of the same delay).

b) Find the impulse response of the system.

c) Give a difference equation, in terms of the input and output, to describe the system.

d) Is the system stable?

**6)** An AM signal has a carrier frequency equal to 2 MHz and a baseband message signal bandwidth equal to 15 KHz. It is desirable to demodulate the signal by first converting the signal to an intermediate frequency at 500 KHz and then using envelope detection.

a) Give two possible values for the frequency of the local oscillator to achieve this conversion.

b) Suppose that the above AM signal is in a large frequency band with many other signals (non-overlapping in spectrum). For each of the above cases give the block diagrams to demodulate the signal assuming an envelope detector operating at the carrier frequency of 500 KHz, and the widest possible receiver front-end filter.