University of Waterloo
Department of Electrical and Computer Engineering

E&CE-318 – Communication Systems

Final Examination

Saturday, April 14, 2001
2:00 pm to 5:00pm

Instructor: X. Shen, 3B Electrical Engineering

Time allowed: 3 hours.
NO AIDS ALLOWED.
Attempt all 6 questions. **JUSTIFY ALL YOUR ANSWERS.**

The marking scheme is shown in the left margin and [60] constitutes full marks.

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[10] 1. A message signal $f(t)$ (with a bandwidth B) is transmitted using DSB-SC modulation; thus the transmitted waveform is given by $\phi(t) = f(t)\cos(\omega_c t)$. During transmission, the frequency and phase of the carrier signal are distorted, so that the received signal is $r(t) = f(t)\cos[(\omega_c + \Delta\omega_c)t + \psi]$. If the receiver local oscillator signal is $A_c \cos(\omega_c t)$:

[4] (a) Show the functional block diagram of the demodulator. Find an expression for the output of the demodulator.

[3] (b) If $\Delta\omega_c = 0$, find an expression for the total energy in the demodulator output, and plot the energy as a function of ψ for $\int_{-\infty}^{\infty} f^2(t)dt = 1$.

[3] (c) Let $\psi = 0$, and describe the effect of the erroneous frequency reference. Sketch a typical Fourier transform of the demodulator output for $|\Delta\omega_c| < B$. Assume a shape for $F(\omega) = \mathcal{F}\{f(t)\}$.

[10] 2. A nonlinear element with the input-output relation $v_o(t) = av_i^2(t) + bv_i(t)$ is used in a DSB-LC modulator, where $a > 0$ and $b > 0$. The message signal is $f(t)$ ($|f(t)| \leq 1$) with the Fourier transform $F(\omega)$ ($|F(\omega)| = 0$ for $|\omega| > 2\pi B_f$). The output must have a form of $A[1 + mf(t)]\cos(\omega_c t)$, where $\omega_c \gg 2\pi B_f$.

[4] (a) Draw a block diagram of the modulator with minimum configuration. Specify necessary parameters in the diagram.

[5] (b) Describe how the modulator works by using mathematical expressions.

[1] (c) Express m and A in terms of the parameters a and b.

[10] 3. The carrier $c(t) = 100\cos(2\pi 10^6 t)$ volts is frequency modulated by the sinusoid signal $f(t) = 2\cos(2000\pi t)$ volts. The frequency sensitivity of the modulator is $k_f = 3000$ Hz/volt.

[2] (a) Determine the modulation index β.

[2] (b) Determine the bandwidth of the FM signal using Carson's rule.

[2] (c) Determine the average power of the FM signal over a 1-ohm resistor.

[2] (d) If the amplitude of $f(t)$ is <u>decreased</u> by a factor of 2, how would your answers to parts (a)-(c) change?

[2] (e) If the frequency of $f(t)$ is <u>increased</u> by a factor of 2, how would your answers to parts (a)-(c) change?

[10] 4. A communication system operates in the presence of white noise with two-sided power spectral density $S_n(f) = 0.25 \times 10^{-14}$ watts/Hz, and with total path loss of 100 dB. The input bandwidth is 15 kHz. For a 15-kHz sinusoidal input and for a 40-dB output S/N ratio, calculate the total transmitted power if the modulation is

[4] (a) DSB-LC with $m = 0.5$ and with envelop detection.

[3] (b) SSB-SC with coherent demodulation.

[3] (c) FM with $\Delta f = 30$ kHz using frequency discriminator for demodulation.

[10] 5. A given preemphasis/deemphasis system is shown in Figure 1. The power spectral density of the additive noise is $S_n(f) = 2\exp(2\pi \times 10^{-4}|f|)$ μW/Hz. The frequency transfer function of the deemphasis filter is designed to yield a white output noise spectral density over the frequency range $0 < f < 7.5$ kHz.

[5] (a) What is the magnitude frequency transfer function $H(f)$ of the preemphasis filter required to yield no overall net signal distortion (assuming that the input signal has a bandwidth of 7.5 kHz)?

[5] (b) Calculate the SNR improvement (at the output of the system) obtained using this system over the frequency range $0 < f < 7.5$ kHz if $H(0) = 1$.

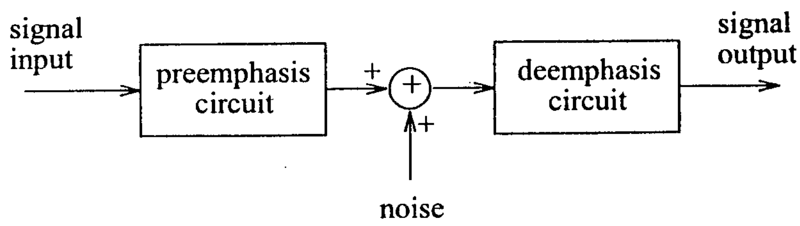

Figure 1

[10] 6. Consider a low-pass signal $g(t)$ having Fourier transform $G(f)$. It is to be sampled at the rate of $2f \leq 1/T_s$ Hz.

[5] (a) Draw a diagram to illustrate the magnitude spectrum of the ideally sampled process

$$g_\delta(t) = \sum_{n=-\infty}^{\infty} g(nT_s)\delta(t - nT_s).$$

What is $G_\delta(f)$ and how is $g(t)$ recovered from $g_\delta(t)$?

[5] (b) Draw a diagram to illustrate the magnitude spectrum of the flat-top sampled process

$$g_\Delta(t) = \sum_{n=-\infty}^{\infty} g(nT_s) rect(\frac{t - nT_s}{\tau})$$

for $\tau = T_s/2$, where

$$\text{rect}(\frac{t}{\tau}) = \begin{cases} 1, & |t| \leq \tau/2 \\ 0, & \text{otherwise} \end{cases}$$

What is $G_\Delta(f)$ and how is $g(t)$ recovered from $g_\Delta(t)$?