Mid-Semester Examination

Communication Systems (EE 308), Autumn'19

Sept. 16, 2019; Total: 30 marks; Time: 2 hours

- *You are allowed to use ONE A4 sheet with handwritten notes on ONE side.*
- *You are allowed to use any result discussed in class without proof. For all other results, a proof needs to be provided.*

QUESTION 1 (1.5 + 1 + 1.5 = 4 MARKS)

An AM signal has the form:

$$u(t) = [20 + 2\cos(3000\pi t) + 10\cos(6000\pi t)]\cos(2\pi f_c t),$$

where $f_c = 10^5$ Hz.

(a) Determine and sketch the spectrum of $u(t)$.

(b) Determine the power in each of the frequency components of $u(t)$.

(c) Determine the power in the sidebands, the total power, and the ratio of the sidebands power to the total power.

QUESTION 2 (3 MARKS)

In a DSB system, the carrier is $c(t) = A\cos(2\pi f_c t)$ and the message signal is given by $m(t) = \text{sinc}(t) + \text{sinc}^2(t)$. Find the Fourier transform and the bandwidth of the modulated signal.

QUESTION 3 (2.5 MARKS)

Suppose the message signal, $m(t)$, is strictly band-limited with bandwidth B. The modulated signal is given by:

$$s(t) = A_c\cos(2\pi f_c t + km^2(t)),$$

where $A_c > 0$, $k > 0$ are constants and $f_c >> B$. Find the best estimate you can, of the bandwidth of the signal $s(t)$. State the assumptions you made.

QUESTION 4 (2 MARKS)

A superheterodyne FM receiver operates in the frequency range of $88 - 108$ MHz. We require that the image frequency, f'_c, fall outside of the $88 - 108$ MHz region for every carrier frequency f_c. Determine the minimum required f_{IF} and the range of variations in the local oscillator frequency f_{LO}.

QUESTION 5 (3.5 MARKS)

The rectangular RF pulse:

$$x(t) = \begin{cases} A\cos(2\pi f_c t), & 0 \leq t \leq T, \\ 0, & \text{elsewhere,} \end{cases}$$

is applied to a linear filter with impulse response:

$$h(t) = x(T - t).$$

Assume that the frequency f_c equals a large integer multiple of $\frac{1}{T}$. Determine the output of the filter (frequency-domain expression).

QUESTION 6 (2.5 MARKS)

A narrowband FM signal modulator is available, which takes as input a message signal with bandwidth 15 kHz and generates a narrowband FM signal with carrier frequency 100 kHz and frequency deviation 1.5 kHz. Design an Armstrong FM modulator, which uses the above narrowband FM signal to generate a wideband FM signal with carrier frequency $f_c = 104$ MHz and frequency deviation 75 kHz.

QUESTION 7 (1 + 3 = 4 MARKS)

The input signal to a square-law modulator is:

$$v_1(t) = A_c \cos(2\pi f_c t) + m(t),$$

where $m(t)$ is a message signal and $A_c \cos(2\pi f_c t)$ is the carrier wave. The input-output relation is:

$$v_2(t) = a_1 v_1(t) + a_2 v_1^2(t),$$

where a_1 and a_2 are constants.

(a) Find the output signal $v_2(t)$.

(b) Suppose $v_2(t)$ is input to a filter. Find the frequency response of the filter such that the output of the filter is an AM signal with f_c as the carrier frequency. Determine the AM signal that is generated. What is its amplitude sensitivity? Justify your answer.

QUESTION 8 (3.5 MARKS)

The FM signal:

$$s(t) = A_c \cos\left[2\pi f_c t + 2\pi k_f \int_0^t m(\tau) d\tau\right]$$

is applied to the system shown in Fig. 1 consisting of a high-pass RC filter and an envelope detector. Assume that (a) the resistance R is small compared with the reactance of the capacitor C for all significant frequency components of $s(t)$ and (b) the envelope detector does not load the filter. Determine the resulting signal at the envelope detector output, assuming that $k_f|m(t)| < f_c$ for all t.

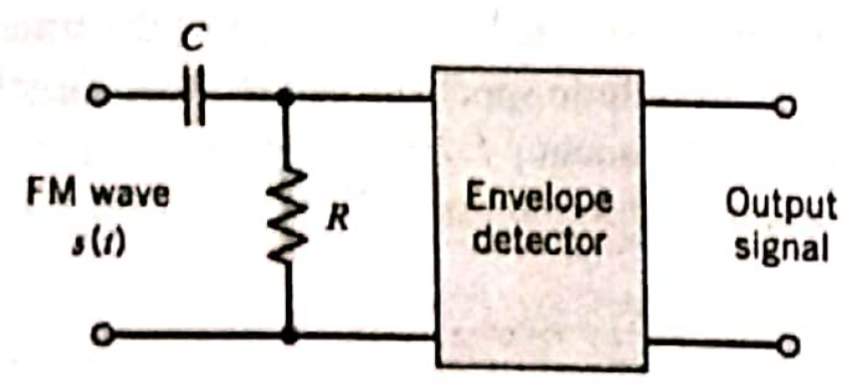

Fig. 1. The figure for Question 8.

QUESTION 9 (2.5 + 2.5 = 5 MARKS)

A VSB modulation system is shown in Fig. 2. The bandwidth of the message signal $m(t)$ is W and the transfer function of the bandpass filter is shown in the figure.

(a) Determine the complex envelope, $\tilde{h}(t)$, of $h(t)$, where $h(t)$ represents the impulse response of the bandpass filter.

(b) Derive an expression for the modulated signal $u(t)$ and simplify it.

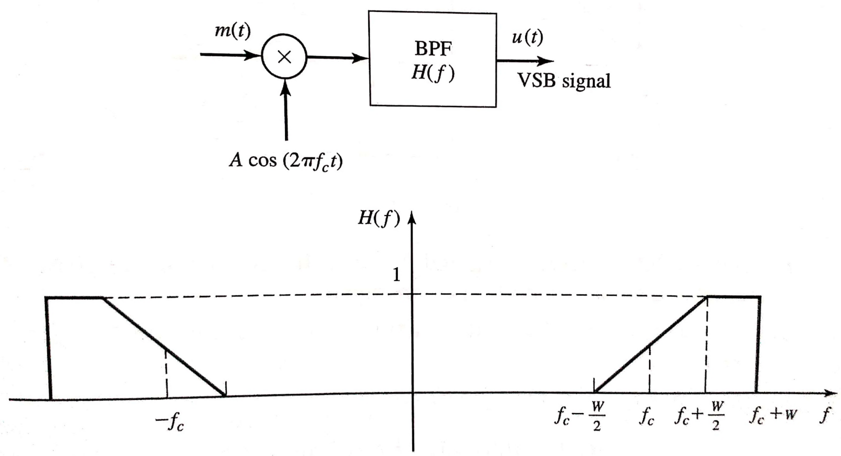

Fig. 2. The figure for Question 9.