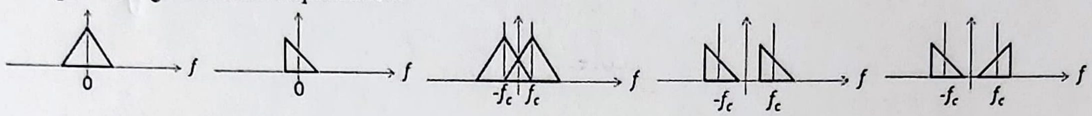
EE364000 Communication System I, Midterm Exam

Nov. 23, 2020

Note: You have to give your solution as clear and detailed as possible. If there's anything not clear in your solution, you'll only receive partial credits!!

Short Quiz (20 %):

1. (a) (5 %) If a filter has a unit gain and linear phase function as $H(f)=\exp(-j2\pi f\alpha)$, what happens to the input signal?
   (b) (5 %) For the following 5 amplitude spectra, please identify which is a transmittable bandpass signal and give a brief explanation.



(i) (ii) (iii) (iv) (v)

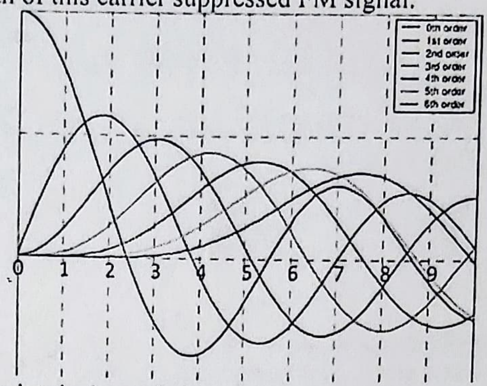
   (c) (5 %) For a wideband FM signal, if we use an ideal band-pass filter that has a bandwidth, B_T, equivalent to Carson's rule, can we get an undistorted signal after FM demodulation? Why?
   (d) (5 %) For a conventional AM signal: $s(t) = A_c[1 + k_a m(t)]\cos(2\pi f_c t)$, we need to limit $|k_a m(t)|$ to be less than 1 if we use an envelope detector to detect it. This constraint can be removed by Costas receiver. Why?

2. (20 %) For a linear time invariant system with an impulse response $h(t)$. Assume the input $x(t) = \exp(j2\pi ft)$,
   (a) (5 %) please find the output $y(t)$ in terms of the frequency response, $H(f)$, of the system and input $x(t) = \exp(j2\pi ft)$.
   (b) (15 %) Now we wish to measure the amplitude spectrum, $|H(f)|$, and phase spectrum, $\beta(f)$, of the system, where $H(f)=|H(f)|\exp[j\beta(f)]$. From (a), if you have the following equipment in hands: frequency tunable sinusoidal wave generator and oscilloscope. Please design a measuring system that can measure $|H(f)|$ and $\beta(f)$ and explain how it works.

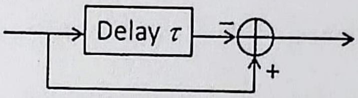
3. (30 %) A signal's power is defined as $P_s = \lim_{T\to\infty}\left\{\frac{1}{2T}\int_{-T}^{T}|s(t)|^2\,dt\right\}$
   (a) (7 %) Assume an AM signal: $s(t)=A_c(a_0+m(t))\cdot\cos(2\pi f_c t)$, where $m(t)=A_m\cos(2\pi f_m t)$ is the baseband signal with amplitude A_m and frequency f_m, and A_c and f_c are the carrier's amplitude and frequency, respectively. If no over-modulation for all time t, what is the maximum power, P_s, carried by this AM signal?
   (b) (5 %) If the carrier amplitude, A_c, is 2 Volt and the message $m(t)$ is with a frequency at $f_m = 10$ KHz and a power of 2 Watt. Assume the total signal power, P_s, is 22 Watt. What is the voltage value of a_0? Here we assume all the resistors are 1 Ω.
   (c) (3 %) Following (b), is this an over-modulated signal? Why?
   (d) (3 %) Same as (a), but the signal is now in frequency modulation format, the signal can be written as $s(t)=A_c\cos(2\pi f_c t+2\pi k_f\int_0^t m(t)dt)=A_c\sum_{-\infty}^{\infty}J_n(\beta)\cos[2\pi(f_c+nf_m)t]$, where k_f is the frequency sensitivity and β is the phase deviation. Express this signal's spectrum in frequency domain.
   (e) (4 %) Following (d), from this signal's frequency components, please find its signal power, P_s.

(f) (4 %) An interesting behavior of FM is that, there exist some specific frequency deviations, Δf, that the carrier component is totally suppressed, i.e., no carrier component. According to the following plot of the nth order Bessel function of the first kind, find the smallest frequency deviation, Δf, in terms of f_m, that there is no carrier component in the transmitted signal $s(t)$.

(g) (4 %) Following (b) and (f), $f_m = 10$ KHz, by using $|J_n(\beta)| > 0.01$ as a criterion, please estimate the transmission bandwidth of this carrier suppressed FM signal.



4. (20 %) For a tapped-delay-line circuit shown below:
   (a) (4 %) Please find its impulse response $h(t)$.
   (b) (4 %) Please find its frequency response $H(f)$.
   (c) (6 %) Under what condition can this circuit be approximated as a differentiator? You need to describe the details.
   (d) (6 %) Use this circuit to design an FM demodulator.



5. (20 %) A square-law modulator, as shown in Fig. P.5(a), has the response governed by a square law: $y(t) = a_1x(t) + a_2x^2(t)$, where $y(t)$ and $x(t)$ are output and input respectively, and a_1 and a_2 are constants. Assume the message $m(t)$ is with bandwidth W and the modulator input, $x(t)$, is defined as shown in Fig. P.5(b),

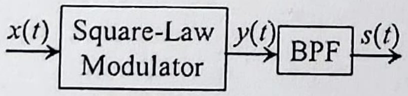


Fig. P.5(a)

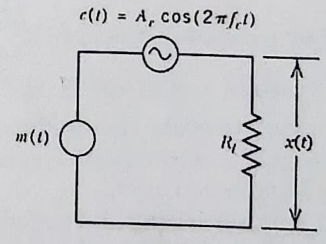


Fig. P.5 (b)

(a) (3 %) From Fig. P5.(b), please express $x(t)$ by $m(t)$ and $c(t)$.
(b) (7 %) Evaluate the output $y(t)$.
(c) (5 %) Obviously, the answer you obtained in (a) has many spurious signals. To select the desired AM signal, we need to apply a BPF after the nonlinear modulator. Assume the bandwidth of the message $m(t)$ is W and $W << f_c$. Please specify a proper specification of the BPF that will be used.
(d) (5 %) After the BPF, please calculate the amplitude sensitivity of this AM signal.