EE 308: Communication Systems (Section 1 – Autumn 2018)
Tutorial Problem Set 2: Amplitude and Angle Modulation[1]

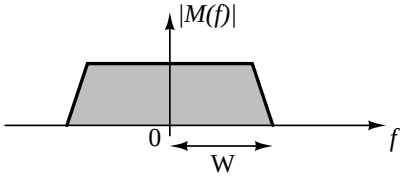
mt = cos200pit

1. The output signal from an AM modulator is $u(t) = 5\cos 1800\pi t + 20\cos 2000\pi t + 5\cos 2200\pi t$.
   (a) Determine the modulating signal $m(t)$ and the carrier signal $c(t)$. carrier:20cos 1800
   (b) Determine the modulation index. 0.5
   (c) Determine the ratio of the power in the sidebands to the power in the carrier. 1:16

2. A DSB-SC AM signal is modulated by the signal $m(t) = 2\cos 2000\pi t + \cos 6000\pi t$. The modulated signal is $u(t) = 100m(t)\cos 2\pi f_c t$, where $f_c = 1MHz$. Text
   (a) Determine and sketch the spectrum of the AM signal.
   (b) Determine the average power in the frequency components.

3. Consider a baseband message signal $m(t)$ with bandwidth W. It is DSB amplutde modulated with carrier frequency f_c. In DSB modulation, *spectral overlap* is said to occur if the spectrum centred around f_c has some overlap with the spectrum centred around $-f_c$.
   (a) What condition must the modulated wave satisfy if we are to avoid spectral overlap. 2fc<w
   (b) A coherent detector for the demodulation of DSB-SC fails to operate satisfactorily if the modulator experiences spectral overlap. Explain the reason for this failure.

4. The message signal $m(t)$ has low-pass bandwidth W, and carrier frequency $f_c \gg W$. The Hilbert transform of $m(t)$ is $\hat{m}(t)$ and its magnitude spectrum is shown below.



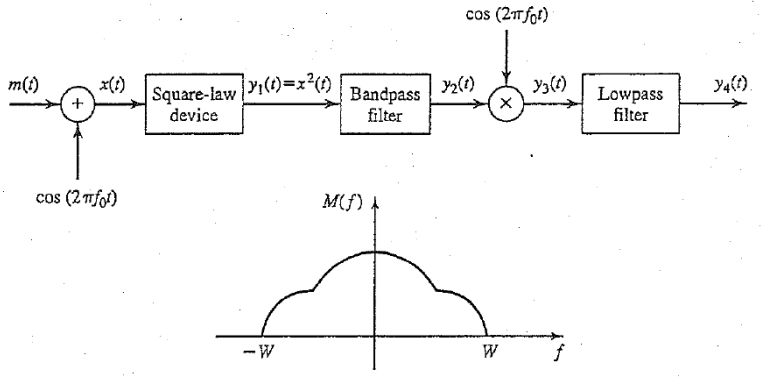
   Draw the magnitude spectrum for
   (a) $m(t) + j\hat{m}(t)$ only-ve side left 2times the mag
   (b) $m(t) - \hat{m}(t)$ (note that intentionally j has not been used in this expression).
   (c) $jm(t) + \hat{m}(t)$
   (d) $[m(t) + j\hat{m}(t)]\cos 2\pi f_c t$ Text
   (e) $[m(t) + j\hat{m}(t)]\, e^{j2\pi f_c t}$ Text
   (f) $\mathrm{Re}\big([m(t) - j\hat{m}(t)]\, e^{j2\pi f_c t}\big)$ Text

5. Consider a nonlinear device in which the output current i_0 can be expressed in terms of input voltage v_i as $i_o = a_1 v_i + a_3 v_i^3$, where a_1 and a_3 are constants. Show how such a device can be used for amplitude modulation.

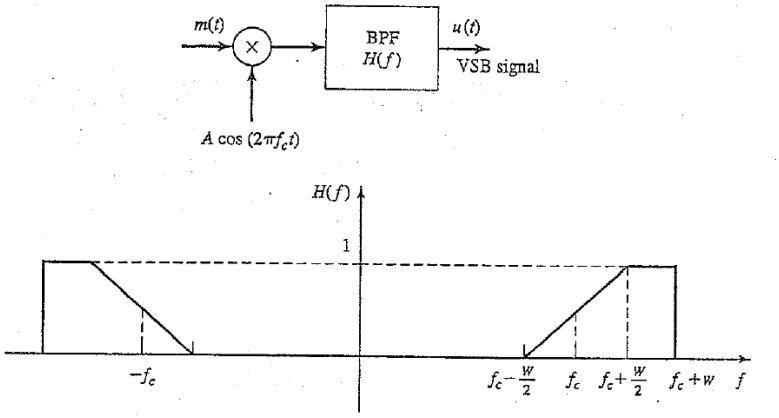
6. An SSB AM signal is generated by modulating an 800 kHz carrier by the signal $m(t) = \cos 200\pi t + 2\sin 200\pi t$. The amplitude of the carrier is $A_c = 100$.
   (a) Determine the signal $\hat{m}(t)$.
   (b) Determine the (time domain) expression for the lower sideband of the SSB AM signal.
   (c) Show the magnitude spectrum of the lower sideband SSB signal.

[1] Most problems have been taken from "Communication Systems Engineering" by John G. Proakis and Masoud Salehi.

7. The spectrum of message signal $m(t)$ is shown in the figure below. The signal is passed through the system shown in the same figure. The bandpass filter has a bandwidth of $2W$ centered at f_0, the lowpass filter has a bandwidth W, and $f_0 \gg W$. Sketch the spectra of the signals $x(t), y_1(t), y_2(t), y_3(t)$ and $y_4(t)$. The spectral magnitudes need not be very precise, but mark the frequencies accurately.



8. A vestigial sideband modulation system is shown in the figure below. The bandwidth of the message signal $m(t)$ is W and the transfer function of the bandpass filter is shown in the figure below.



   (a) Determine $h_l(t)$ the lowpass equivalent of $h(t)$, where $h(t)$ represents the impulse response of the bandpass filter.
   (b) Derive an expression for the modulated signal $u(t)$.

9. An angle modulated signal has the form $u(t) = 100\cos[2\pi f_c t + 4\sin 2000\pi t]$, where $f_c = 10\,\text{MHz}$.
   (a) Determine the average transmitted power.
   (b) Determine the peak phase-deviation.
   (c) Determine the peak frequency-deviation.
   (d) Will you categorize this signal as FM signal or a PM signal? Explain.

10. An angle-modulated signal has the form $u(t) = 100\cos[2\pi f_c t + 4\sin 2\pi f_m t]$ where $f_c = 10\,\text{MHz}$ and $f_m = 1000\,\text{Hz}$.
   (a) Assuming that this is an FM signal, determine the modulation index and the transmitted signal bandwidth.
   (b) Repeat (a) if f_m is doubled.
   (c) Assuming that this is a PM signal. Determine the modulation index and the transmitted signal bandwidth.
   (d) Repeat (c) if f_m is doubled.

11. Find the smallest value of the modulation index in an FM system that guarantees that all the modulated signal power is contained in the sidebands and no power is transmitted at the carrier frequency.