ECC-201: Principles of Communication Systems

Autumn Semester 2025-26 **Tutorial Sheet:2**

1. An AM (DSB-FC) signal can be represented as

$$s(t) = A_c[1 + \mu\, m_n(t)] \cos(2\pi f_c t)$$

where $m_n(t)$ is the message signal $m(t)$ normalized such that the minimum value of $m_n(t)$ is -1 and the parameter μ is known as the *modulation index.*

   (a) Determine the maximum value of μ that allows demodulation using envelope detector.

   (b) An AM modulator has output

$$s(t) = 40\cos(400\pi t) + 4\cos(360\pi t) + 4\cos(440\pi t).$$

   Determine the modulation index and power efficiency.

2. Consider the DSB-SC signal $s(t) = A_c m(t)\cos(2\pi f_c t)$, where $f_c >> f_m$ and $m(t) = \cos(2\pi f_m t + \phi)$.

   (a) Determine and sketch the spectrum of the upper sideband and lower sideband signals (sketch the real and imaginary parts of the spectrum separately).

   (b) Determine the time-domain expressions for the LSB and USB signals.

   (c) Determine the time-domain expressions for the complex envelope of the LSB and USB signals.

3. A particular version of *AM stereo* uses quadrature multiplexing. Specifically, the carrier $A_c\cos(2\pi f_c t)$ is used to modulate the sum signal

$$m_1(t) = V_0 + m_l(t) + m_r(t)$$

where V_0 is a DC offset included for the purpose of transmitting the carrier component, $m_l(t)$ is the left-hand audio signal, and $m_r(t)$ is the right-hand audio signal. The quadrature carrier $A_c\sin(2\pi f_c t)$ is used to modulate the difference signal

$$m_2(t) = m_l(t) - m_r(t).$$

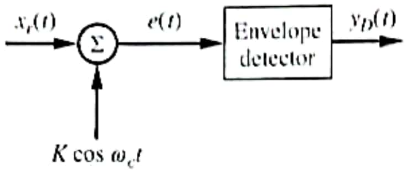
   (a) Show that an envelope detector may be used to recover $m_r(t)+m_l(t)$ from the multiplexed signal. How would you minimize the signal distortion produced by the envelope detector?

   (b) How the carrier signal can be extracted from the multiplexed signal?

   (c) Show that a coherent detector can recover the difference $m_r(t) - m_l(t)$.

   (d) How the desired $m_l(t)$ and $m_r(t)$ can be finally obtained?

4. The following figure shows the *carrier re-insertion* method for SSB demodulation.



Determine the condition on K such that the envelope detector output $y_D(t) \approx \frac{1}{2}A_c m(t) + K$.

5. The figure shows the circuit diagram of a square-law modulator. The signal applied to the nonlinear device is relatively weak, such that it can be represented by a square law:

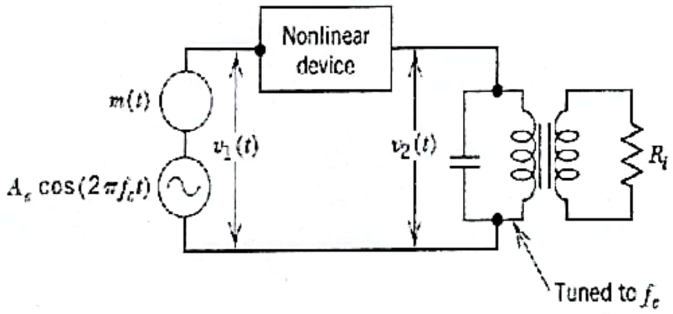
$$v_2(t) = av_1(t) + bv_1^2(t)$$

where a and b are constants, $v_1(t)$ is the input voltage, and $v_2(t)$ is the output voltage. The input voltage is defined by $v_1(t) = m(t) + A_c \cos(2\pi f_c t)t$

(a) Evaluate the output voltage $v_2(t)$.

(b) Specify the frequency response that the tuned circuit in Fig. 2 must satisfy in order to generate an AM signal with f_c as the carrier frequency.

(c) What is the amplitude sensitivity of this AM signal?

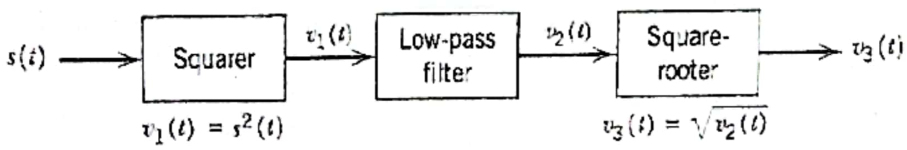


The circuit diagram of a square-law modulator.

6. The AM signal:

$$s(t) = A_c[1 + k_a m(t)] \cos 2\pi f_c t$$

is applied to the system shown in Fig. 3. Assuming that $|k_a m(t)| < 1$ for all t and the message signal $m(t)$ is limited to the interval $-B \leq f \leq B$, and that the carrier frequency $fc > 2B$, show that $m(t)$ can be obtained from the square-rooter output $v_3(t)$.



Non-linear modulator.