1. Suppose that a nonlinear device is available for which the output current \( i_0 \) and the input voltage \( v_i \) are related by \( i_0 = a_1 v_i + a_3 v_i^3 \), where \( a_1 \) and \( a_3 \) are constants. Explain how these devices may be used to provide

(a) a double-sideband suppressed carrier signal,
(b) a full AM signal.

2. Consider the AM signal

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

produced by a sinusoidal modulating signal of frequency \( f_m \). Assume that the modulation factor \( \mu = 2 \), and the carrier frequency \( f_c \) is much greater than \( f_m \). The AM signal \( s(t) \) is applied to an ideal envelope detector, producing the output \( v(t) \).

(a) Determine the Fourier series representation of \( v(t) \).
(b) What is the ratio of the second-harmonic amplitude to the fundamental amplitude in \( v(t) \)?

3. Consider a message signal \( m(t) \) with spectrum \( M(f) \) given by

\[ M(f) = \begin{cases} 
1 - \frac{|f|}{W} & |f| \leq W \\
0 & \text{otherwise.}
\end{cases} \]

where \( W = 1 \) KHz. This signal is applied to a product modulator, together with a carrier wave \( A_c \cos(2\pi f_c t) \), producing the DSB-SC signal \( s(t) \). The modulated signal is next applied to a coherent detector. Assuming perfect synchronism between the carrier waves in the modulator and detector, determine the spectrum of the detector output when

(a) the carrier frequency \( f_c = 1.25 \) KHz,
(b) the carrier frequency \( f_c = .75 \) KHz.

What is the lowest carrier frequency for which each component of the modulated signal \( s(t) \) is uniquely determined by \( m(t) \)?

4. The local oscillator used for the demodulation of an SSB signal has a frequency error \( \Delta f \) measured with respect to the carrier frequency \( f_c \) used to generate \( s(t) \). Otherwise, there is perfect synchronism between this oscillator in the receiver and the oscillator supplying the carrier in the transmitter. Evaluate the demodulated signal for the following two situations:

(a) The SSB signal \( s(t) \) consists of the upper sideband only.
(b) The SSB signal \( s(t) \) consists of the lower sideband only.
5. The figure below shows the block diagram of a system for generating SSB modulated waves. The message signal \( m(t) \) is limited to the band \( f_a \leq |f| \leq f_b \). The auxiliary carrier applied to the first pair of product modulators has a frequency \( f_0 \), which lies at the center of this band, i.e., \( f_0 = \frac{f_a + f_b}{2} \). The low-pass filters in the in-phase and quadrature channels are identical, each with a cut-off frequency equal to \( \frac{f_b - f_a}{2} \). Sketch the spectra at the various points in the diagram and hence show that

(a) For the lower sideband, the contributions of the in-phase and quadrature phase channels are of opposite polarity and by adding them at the modulator output, the lower sideband is suppressed.

(b) For the upper sideband, the contributions of the in-phase and quadrature phase channels are of same polarity and by adding them at the modulator output, the upper sideband is transmitted. How would you modify the modulator in this figure so that only the lower sideband is transmitted.