Ex 4-12:

In a SSB system, the message signal is a single tone, of frequency 3 kHz, and peak amplitude 14 volt, the receiver input impedance is 50 Ω, the equivalent noise spectral density at the input is 10^{-14} watt/Hz (two sided) and the path losses is 30 dB. If the input noise power is considered in the entire signal bandwidth, find:

1- SNR at receiver input.

2- SNR at receiver output.

Solution:

1) $P_t = \overline{f^2(t)} = \frac{A_m^2}{2R} = \frac{14^2}{2\times 50} = 1.96\, watt \cong 2.92\, dB$

$$S_i = 2.92 - 30 = -27.1\, dB \equiv 1.95 * 10^{-3}\, watt$$

$$N_i = \frac{2}{2\pi}\int_0^{2\pi*3*10^3} S_n(\omega)d\omega = \frac{1}{\pi}\int_0^{6\pi*10^3} 10^{-14} d\omega = 6 * 10^{-11}\, watt$$

$$SNR_i = \frac{S_i}{N_i} = \frac{1.95 * 10^{-3}}{6 * 10^{-11}} = 3.25 * 10^7$$

$$\equiv 75.11\, dB$$

2) In SSB (synchronous detector)

$$\frac{S_o}{N_o} = \frac{S_i}{N_i} \quad \Longrightarrow \therefore \; SNR_o = 75.11\, dB$$

Problem Sheet for Amplitude Modulation

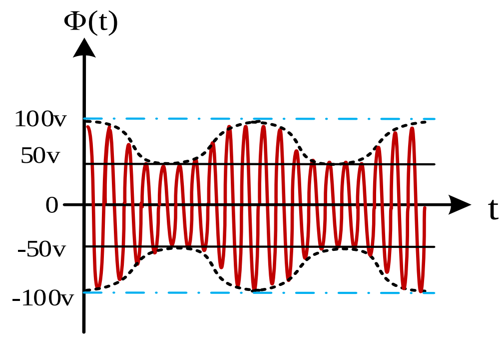
Q1: For the sinusoidaly modulated DSB/LC waveform shown in Fig. below.

a- Find the modulation index.

b- Sketch a line spectrum.

c- Calculated the ratio of average power in the sidebands to that in the carrier.

d- Determine the amplitude of the additional carrier, which must be added to obtain a modulation index of 10%



Ans: (a) 0.33

(b)0.055.

(d) 17s v.

Q2: A given AM (DSB – LC) transmitter develops an unmodulated power output of 1 kW. Across 50Ω resistive load. When a sinusoidal test tone with a peak amplitude of $5v$ is applied to the input of the modulator, it is found that the spectral line for each sideband in the magnitude spectrum for the output is 40% of the carrier line. Determine the following quantities in the output signal:

a-The modulation index.

b-The peak amplitude of the lower sideband.

c-The ratio of total sideband power to carrier power.

d-The total output power.

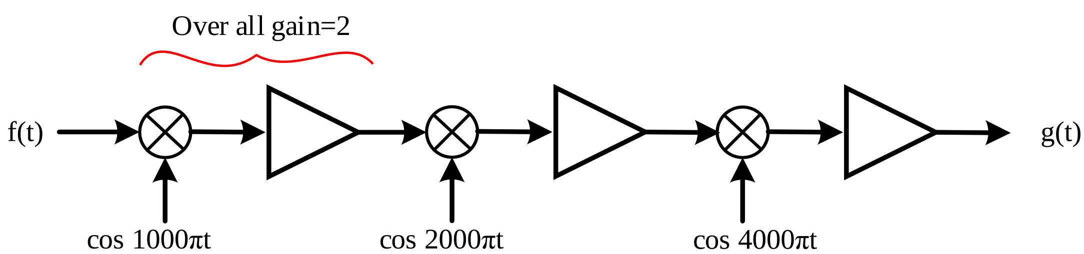
e-The total average power in thr output if the peak amplitude of the modulation sinusoid is reduced to 4 volt.

Q3: The modulating signal $f(t) = 2\cos 100\,\pi t + cos\ 400\pi t$ is applied at the input of a DSB/ SC modulator operating at a carrier frequency of 1 kHz. Sketch the spectral density of $f(t)$ and the resulting AM-DSB/SC waveform identifying the upper and lower sidebands.

Q4: The spectral density of the input $f(t)$ to the system shown in fig. below is band – limited to 100Hz.

a- Sketch the spectral density of the output for an assumed input spectral density.

b- Write an expression for the output spectral density in terms of the input spectral density if the sequence of sinusoidal generators and mixers extended indefinitely:

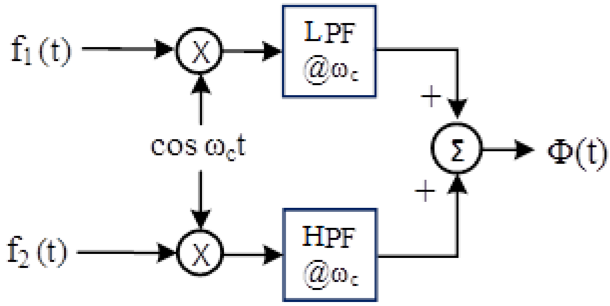


Ans: $G(\omega) = \sum_{n_{odd}=-\infty}^{\infty} F(\omega - 1000\pi n)$

Q5: The system shown in fig. below can be used for sending two messages on one carrier.

(a) If $f_1(t) = cos\omega_1 t$ and $f_2(t) = cos\omega_2 t$ derive an expression for $\phi(t)$.

(b) Devise block diagram for suitable demodulator for $\phi(t)$.



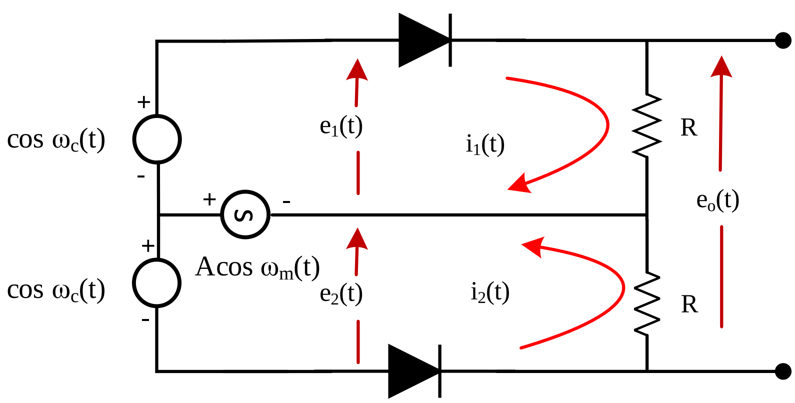
Ans: $\phi(t) = \frac{1}{2}\cos(\omega_{c1} - \omega_1)\,t + \frac{1}{2}\cos(\omega_c - \omega_2)$

Q6: When the input to a given system audio is $(4\cos 800\,\pi t + cos\ 2000\pi t)mv$, the measured frequency component at 600 kHz is 1mv. Represent the amplifier output – input characteristic by $e_o = a_1 e_i + a_2 e_i^2$ and calculate the numerical values of a_1 and a_2 from the data given.

Ans: $a_1 = 1000$; $a_2 = 250\ v^{-1}$.

Q7: The balanced modulator in fig. below is to be investigated for the possible generation of AM – DSB signal with $m \leq 1$ each diode has the characteristic:

$$i(t) = a_1 e(t) + a_2 e^2\,(t)$$



(a) Determine the maximum allowable value of A.

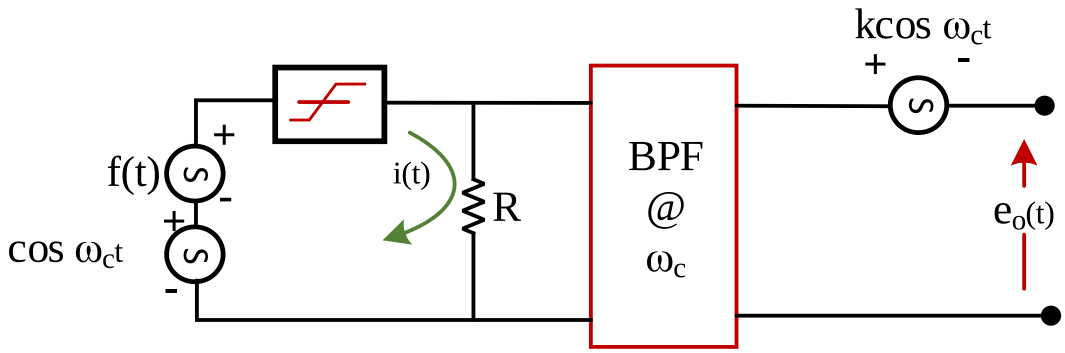
(b) Determine the maximum and minimum bandwidth of an ideal BPF required on the output if one of the diodes is open – circuited.

Ans: (a) $\frac{a_1}{2a_2}$ (b) $B_{max} = 2(f_c - 2f_m)$; $B_{min} = 2f_m$.

Q8: The model of a possible DSB/ SC modulator is shown in fig below. Determine the required value of the constant k if the bandpass filter has unity gain at $+\,\omega_c$.

Ans: $k = a_1 R$

Nonlinear element $i(t) = a_1 e(t) + a_2 e^2(t)$



Q9: Determine the power in the sidebands as a percentage of the total power of a modulated signal in the case of a carrier – amplitude – modulated by two sinusoidal signals of different frequencies, with individual modulation depths of 0.3 and 0.4.

Ans: 11.1%

Q10: Determine the saving, in signal power, in the case of 50% modulated AM signal, if the carrier is suppressed before transmission.

Ans: 88.9%

Q11: An AM modulation waveform signal:

$$\phi(t) = (1 + 0.5\cos 2000\pi t + 0.5\cos 4000\pi t)\cos 20000\pi t$$

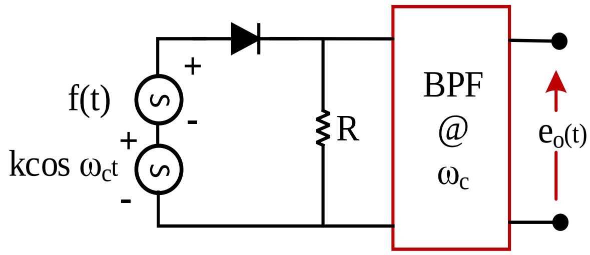
(a) Sketch the amplitude spectrum of $\phi(t)$.

(b) Find total power, sideband power and power efficiency.

(c) Find the average power containing of each sideband.

(d) What is the modulation index?

Q12: The system shown in fig. besides can be used to generate AM signal even if the diode is not operated as an ideal switch.



In this case the nonlinearities in the diode characteristics may be approximated with the power series of the form:

$$i(t) = a_1 e(t) + a_2 e^2(t) + \cdots \quad , i(t)R \ll e(t)$$

Retaining only first two terms, let $(t) = cos\omega_m t$, and if $a1 = 0.01$, $a2 = 0.001$. Determine the modulation index of the resulting DSB signal when all terms except the near the carrier frequency are shifted out.

Ans: m=0.2

Q13: A DSB/ SC and an SSB/ SC transmissions are ach sent at $1\ MHz$ in the presence of noise. The modulating signal in each case is band – limited to3 kHz. The received signal power in each case is $1\ mw$ and the received noise is assumed to white with a (two – sided) power spectral density of $10^{-3}\ \mu w/Hz$. The receiver consists of a bandpass filter (BPF) whose bandwidth matches synchronous detector.

a- Compare the SNR_s at detector input.

b- Compare the SNR_s at detector output.

Q14: The DSB–LC signal $\phi(t) = 3\cos 10000\pi t + \cos 1000\pi t\ \cos 10000\pi t$ Volt is present with additive band-limited white noise whose two-sided power spectral density is $1\ \mu w/Hz$ up to $10\ kHz$ and zero at higher frequencies. The signal – plus – noise is passed through an ideal BPF with a bandwidth of $100\ Hz$ centered at $5500\ Hz$. Assume all resistance level are one ohm.

a- Compute the average SNR at the input of BPF.

b- If the desired output signal is that portion of input signal with spectral components within the passband of the filter, what is the average S/N ratio at the output of the filter?

c- Assume that the desired output signal is the amplitude of the signal in item (b) above. Compute S/N of the synch. Detector with an output bandwidth of $50Hz$ that can make this measurement.

$Ans: (a)\ 23.8\ dB \quad (b)\ 28dB \quad (c)\ 31dB.$

Q15: A certain station uses DSB – SC with an average transmitter power of P watts. If SSB – SC were used instead, what must be the average transmitted power for:

a) The same received signal strength.

b) The same received S/ N ratio.

Assume the synchronous Detection with the same local oscillator Signal strength for both cases.

Q16: A FDM system uses SSB – SC modulation and AM main carrier modulation. There are forty (40) equal amplitude voice input channels; each bandlimited to 3.3 kHz. A 0.7 kHz guard band has allowed between channels and below the first channels.

(a) Determine the final transmission BW.

(b) Compute the degradation in signal- to- noise of input No. 40 when compared to input No.1, assuming that PSD of noise (two – sided) is $f^2\ \mu w/Hz$.

Ans: 160 kHz, 36 dB.