# CHAPTER 7.4

## AMPLITUDE MODULATION

**Statement for Question 1 - 3**

An AM signal is represented by

$$x(t) = (20 + 4\sin 500\pi t)\cos(2\pi \times 10^5 t) \text{ V}$$

**1.** The modulation index is

(A) 20 (B) 4
(C) 0.2 (D) 10

**2.** The total signal power is

(A) 208 W (B) 204 W
(C) 408 W (D) 416 W

**3.** The total sideband power is

(A) 4 W (B) 8 W
(C) 16 W (D) 2 W

**Statement for Question 4 - 5 :**

An AM signal has the form $x(t) = [20 + 2\cos 3000\pi t + 10\cos 6000\pi t]\cos 2\pi f_c t$ where $f_c = 10^5$ Hz.

**4.** The modulation index is

(A) $\frac{201}{400}$ (B) $-\frac{201}{400}$
(C) $\frac{199}{400}$ (D) $-\frac{199}{400}$

**5.** The ratio of the sidebands power to the total power is

(A) $\frac{43}{226}$ (B) $\frac{26}{226}$
(C) $\frac{26}{226}$ (D) $\frac{43}{224}$

**6.** A 2 kW carrier is to be modulated to a 90% level. The total transmitted power would be

(A) 3.62 kW (B) 2.81 kW
(C) 1.4 kW (D) None of the above

**7.** An AM broadcast station operates at its maximum allowed total output of 50 kW with 80% modulation. The power in the intelligence part is

(A) 12.12 kW (B) 31.12 kW
(C) 6.42 kW (D) None of the above

**8.** The aerial current of an AM transmitter is 18 A when unmodulated but increases to 20 A when modulated.The modulation index is

(A) 0.68 (B) 0.73
(C) 0.89 (D) None fo the above

**9.** A modulating signal is amplified by a 80% efficiency amplifier before being combined with a 20 kW carrier to generate an AM signal. The required DC input power to the amplifier, for the system to operate at 100% modulation, would be

(A) 5 kW (B) 8.46 kW
(C) 12.5 kW (D) 6.25 kW

**10.** A 2 MHz carrier is amplitude modulated by a 500 Hz modulating signal to a depth of 70%. If the unmodulated carrier power is 2 kW, the power of the modulated signal is

(A) 2.23 kW (B) 2.36 kW
(C) 1.18 kW (D) 1.26 kW

**11.** A carrier is simultaneously modulated by two sine waves with modulation indices of 0.4 and 0.3. The resultant modulation index will be

(A) 1.0 (B) 0.7
(C) 0.5 (D) 0.35

**12.** In a DSB-SC system with 100% modulation, the power saving is

(A) 50% (B) 66%

(C) 75% (D) 100%

**13.** A 10 kW carrier is sinusoidally modulated by two carriers corresponding to a modulation index of 30% and 40% respectively. The total radiated power(is

(A) 11.25 kW (B) 12.5 kW

(C) 15 kW (D) 17 kW

**14.** In amplitude modulation, the modulation envelope has a peak value which is double the unmodulated carrier value. What is the value of the modulation index ?

(A) 25% (B) 50%

(C) 75% (D) 100%

**15.** If the modulation index of an AM wave is changed from 0 to 1, the transmitted power

(A) increases by 50% (B) increases by 75%

(C) increases by 100% (D) remains unaffected

**16.** A diode detector has a load of 1 kΩ shunted by a 10000 pF capacitor. The diode has a forward resistance of 1 Ω. The maximum permissible depth of modulation, so as to avoid diagonal clipping, with modulating signal frequency fo 10 kHz will be

(A) 0.847 (B) 0.628

(C) 0.734 (D) None of the above

**17.** An AM signal is detected using an envelop detector. The carrier frequency and modulating signal frequency are 1 MHz and 2 kHz respectively. An appropriate value for the time constant of the envelope detector is.

(A) 500 μ sec (B) 20 μ sec

(C) 0.2 μ sec (D) 1 μ sec

**18.** An AM voltage signal $s(t)$, with a carrier frequency of 1.15 GHz has a complex envelope $g(t) = A_C[1 + m(t)]$, where $A_c = 500$ V, and the modulation is a 1 kHz sinusoidal test tone described by $m(t) = 0.8\sin(2\pi \times 10^3 t)$ appears across a 50 Ω resistive load. What is the actual power dissipated in the load ?

(A) 165 kW (B) 82.5 kW

(C) 3.3 kW (D) 6.6 kW

**19.** A 1 MHz sinusoidal carrier is amplitude modulated by a symmetrical square wave of period 100 μ sec. Which of the following frequencies will NOT be present in the modulated signal?

(A) 990 KHz (B) 1010 KHz

(C) 1020 KHz (D) 1030 KHz

**20.** For an AM signal, the bandwidth is 10 kHz and the highest frequency component present is 705 kHz. The carrier frequency used for this AM signal is

(A) 695 kHz (B) 700 kHz

(C) 705 kHz (D) 710 kHz

**21.** A message signal $m(t) = \text{sinc}\, t + \text{sinc}^2(t)$ modulates the carrier signal $(t) = A\cos 2\pi f_c t$. The bandwidth of the modulated signal is

(A) $2f_c$ (B) $\frac{1}{2}f_c$

(C) 2 (D) $\frac{1}{4}$

**22.** The signal $m(t) = \cos 2000\pi t + 2\cos 4000t$ is multiplied by the carrier $c(t) = 100\cos 2\pi f_c t$ where $f_c = 1$ MHz to produce the DSB signal. The expression for the upper side band (USB) signal is

(A) $100\cos(2\pi(f_c + 1000)t) + 200\cos(2\pi(f_c + 200)t)$

(B) $100\cos(2\pi(f_c - 1000)t) + 200\cos(2\pi(f_c - 2000)t)$

(C) $50\cos(2\pi(f_c + 1000)t) + 100\cos(2\pi(f_c + 2000)t)$

(D) $50\cos(2\pi(f_c - 1000)t) + 100\cos(2\pi(f_c - 100)t)$

**Statement for Question 23-26 :**

The Fourier transform $M(f)$ of a signal $m(t)$ is shown in figure. It is to be transmitted from a source to destination. It is known that the signal is normalized, meaning that $-1 \le m(t) \le 1$

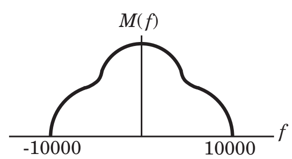


Fig.P7.4.23-26

**23.** If USSB is employed, the bandwidth of the modulated signal is

(A) 5 kHz (B) 20 kHz, 10 kHz

(C) 20 kHz (D) None of the above

**24.** If DSB is employed, the bandwidth of the modulated signal is

(A) 5 kHz (B) 10 kHz

(C) 20 kHz (D) None of the above

**25.** If an AM modulation scheme with $\alpha = 0.8$ is used, the bandwidth of the modulated signal is.

(A) 5 kHz (B) 10 kHz

(C) 20 kHz (D) None of the above

**26.** If an FM signal with $k_f = 60$ kHz is used, then the bandwidth of the modulated signal is

(A) 5 kHz (B) 10 kHz

(C) 20 kHz (D) None of the above

**27.** A DSB modulated signal $x(t) = Am(t)\cos 2\pi f_c t$ is mixed (multiplied) with a local carrier $x_L(t) = \cos(2\pi f_c t + \theta)$ and the output is passed through a LPF with a bandwidth equal to the bandwidth of the message $m(t)$. If the power of the signal at the output of the low pass filter is $p_{\text{out}}$ and the power of the modulated signal by $p_u$, the $\frac{p_{out}}{p_u}$ is

(A) $0.5\cos\theta$ (B) $\cos^2\theta$

(C) $0.5\cos^2\theta$ (D) $\frac{1}{2}\cos^2\theta$

**28.** A DSB-SC signal is to be generated with a carrier frequency $f_c = 1$ MHz using a non-linear device with the input-output characteristic $v_o = a_0 v_i + a_1 v_i^3$ where $a_0$ and $a_1$ are constants. The output of the non-linear device can be filtered by an appropriate band-pass filter. Let $v_i = A'_c\cos(2\pi f'_c t) + m(t)$ where $m(t)$ is the message signal. Then the value of $f'_c$(in MHz) is

(A) 1.0 (B) 0.333

(C) 0.5 (D) 3.0

**29.** A non-linear device with a transfer characteristic given by $i = (10 + 2v_i + 0.2v_i^2)$ mA is supplied with a carrier of 1 V amplitude and a sinusoidal signal of 0.5 V amplitude in series. If at the output the frequency component of AM signal is considered, the depth of modulation is

(A) 18 % (B) 10 %

(C) 20 % (D) 33.33 %

**Statement for Question 30-31**

Consider the system shown in figP7.4.30-31. The modulating signal $m(t)$ has zero mean and its maximum (absolute) value is $A_m = \max|m(t)|$. It has bandwidth $W_m$. The nonlinear device has a input-output characteristic $y(t) = ax(t) + bx^2(t)$.

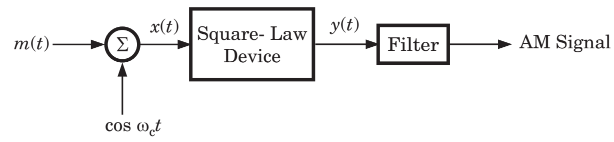


Fig.P7.4.30-31

**30.** The filter should be a

(A) LPP with bandwidth $W$

(B) LPF with bandwidth $2W$

(C) a BPF with center frequency $f_0$ and $BW = W$ such that $f_0 - W_m > f_0 - \frac{W}{2} > 2W_m$

(D) a BPF with center frequency $f_0$ and $BW = W$ such that $f_0 - W_m > f_0 - \frac{W}{2} > W_m$

**31.** The modulation index is

(A) $\frac{2b}{a}A_m$ (B) $\frac{2a}{b}A_m$

(C) $\frac{a}{b}A_m$ (D) $\frac{b}{a}A_m$

**32.** A message signal is periodic with period $T$, as shown in figure. This message signals is applied to an AM modulator with modulation index $\alpha = 0.4$. The modulation efficiency would be

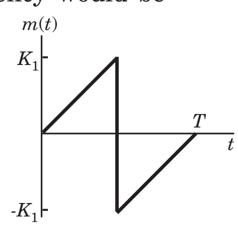


Fig.P7.4.32

(A) 51 % (B) 11.8 %

(C) 5.1 % (D) None of the above

**Statement for Question 33-36**

The figure 6.54-57 shows the positive portion of the envelope of the output of an AM modulator. The message signal is a waveform having zero DC value.

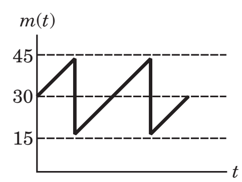


Fig.P7.4.33-36

**33.** The modulation index is

(A) 0.5 (B) 0.6

(C) 0.4 (D) 0.8

**34.** The modulation efficiency is

(A) 8.3 % (B) 14.28 %

(C) 7.69 % (D) None of the above

**35.** The carrier power is

(A) 60 W (B) 450 W

(C) 30 W (D) 900 W

**36.** The power in sidebands is

(A) 85 W (B) 42.5 W

(C) 56 W (D) 37.5 W

**37.** In a broadcast transmitter, the RF output is represented as

$e(t) = 50[1 + 0.89\cos 5000t + 0.30\sin 9000t]\cos(6\times 10^6 t)\text{V}$

What are the sidebands of the signals in radians ?

(A) $5\times 10^3$ and $9\times 10^3$

(B) $5.991\times 10^6$, $5.995\times 10^6$, $6.005\times 10^6$ and $6.009\times 10^6$

(C) $4\times 10^3$, $1.4\times 10^4$

(D) $1\times 10^6$, $1.1\times 10^7$, $3\times 10^6$, and $1.5\times 10^7$

**38.** An AM modulator has output

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

The modulation efficiency is

(A) 0.01 (B) 0.02

(C) 0.03 (D) 0.04

**39.** An AM modulator has output

$x(t) = A\cos 400\pi t + B\cos 380\pi t + B\cos 420\pi t$

The carrier power is 100 W and the efficiency is 40%. The value of $A$ and $B$ are

(A) 14.14, 8.16 (B) 50, 10

(C) 22.36, 13.46 (D) None of the above

**Statement for Question 40-41**

A single side band signal is generated by modulating signal of 900-kHz carrier by the signal $m(t) = \cos 200\pi t + 2\sin 2000\pi t$. The amplitude of the carrier is $A_c = 100$.

**40.** The signal $\hat{m}(t)$ is

(A) $-\sin(2\pi 1000t) - 2\cos(2000\pi t)$

(B) $-\sin(2\pi 1000t) + 2\cos(2000\pi t)$

(C) $\sin(2\pi 1000t) + 2\cos(1000t)$

(D) $\sin(2\pi 1000t) - 2\cos(2\pi 1000t)$

**41.** The lower sideband of the SSB AM signal is

(A) $-100\cos(2\pi(f_c - 1000)t) + 200\sin(2\pi(f_c - 1000)t)$

(B) $-100\cos(2\pi(f_c - 1000)t) - 200\sin(2\pi(f_c - 1000)t)$

(C) $100\cos(2\pi(f_c - 1000)t) - 200\sin(2\pi(f_c - 1000)t)$

(D) $100\cos(2\pi(f_c - 1000)t) + 200\sin(2\pi(f_c - 1000)t)$

**Statement for Question 42-43**

Consider the system shown in figure 6.69-70. The average value of $m(t)$ is zero and maximum value of $|m(t)|$ is $M$. The square-law device is defined by $y(t) = 4x(t) + 10x(t)$.

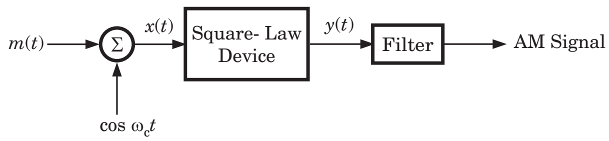


Fig. P7.4.42-43

**42.** The value of $M$, required to produce modulation index of 0.8, is

(A) 0.32 (B) 0.26

(C) 0.52 (D) 0.16

**43.** Let W be the bandwidth of message signal $m(t)$. AM signal would be recovered if

(A) $f_c > W$ (B) $f_c > 2W$

(C) $f_c \geq 3W$ (D) $f_c > 4W$

**44.** A super heterodyne receiver is designed to receive transmitted signals between 5 and 10 MHz. High-side tuning is to be used. The tuning range of the local oscillator for IF frequency 500 kHz would be

(A) 4.5 MHz - 9.5 MHz

(B) 5.5 MHz - 10.5 MHz

(C) 4.5 MHz - 10.5 MHz

(D) None of the above

**45.** A super heterodyne receiver uses an IF frequency of 455 kHz. The receiver is tuned to a transmitter having a carrier frequency of 2400 kHz. High-side tuning is to be used. The image frequency will be

(A) 2855 kHz (B) 3310 kHz

(C) 1845 kHz (D) 1490 kHz

**46.** In the circuit shown in fig.P7.4.46, the transformers are center tapped and the diodes are connected as shown in a bridge. Between the terminals 1 and 2 an a.c. voltage source of frequency 400 Hz is connected. Another a.c. voltage of 1.0 MHz is connected between 3 and 4. The output between 5 and 6 contains components at

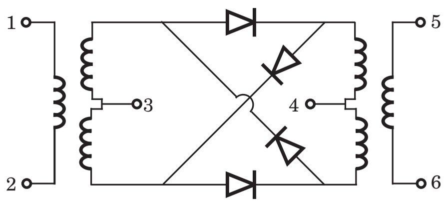


Fig.P7.4.46

(A) 400 Hz, 1.0 MHz, 1000.4 kHz, 999.6 kHz

(B) 400 Hz, 1000.4 kHz, 999.6 kHz

(C) 1 MHz, 1000.4 kHz, 999.6 kHz

(D) 1000.4 kHz, 999.6 kHz

**47.** A superheterodyne receiver is to operate in the frequency range 550 kHz-1650 kHz, with the intermediate frequency of 450 kHz. Let $R = \frac{C_{max}}{C_{min}}$ denote the required capacitance ratio of the local oscillator and $I$ denote the image frequency (in kHz) of the incoming signal. If the receiver is tuned to 700 kHz, then

(A) $R = 4.41$, $I = 1600$ (B) $R = 2.10$, $I = 1150$

(C) $R = 3$, $I = 1600$ (D) $R = 9.0$, $I = 1150$

**48.** Consider a system shown in Figure . Let $X(f)$ and $Y(f)$ denote the Fourier transforms of $x(t)$ and $y(t)$ respectively. The ideal HPF has the cutoff frequency 10 kHz. The positive frequencies where $Y(f)$ has spectral peaks are

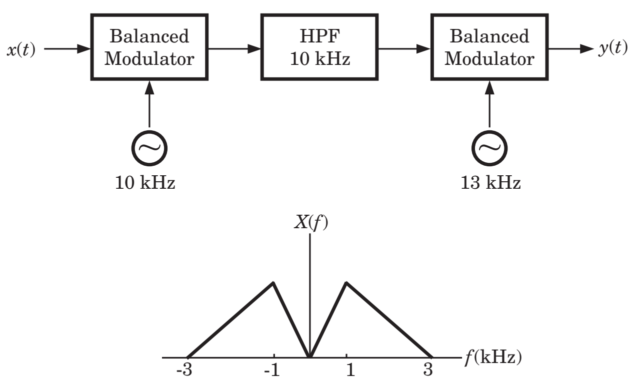


Fig.P7.4.48

(A) 1 kHz and 24 kHz

(B) 2 kHz and 24 kHz

(C) 1 kHz and 14 kHz

(D) 2 kHz and 14 kHz

**49.** In fig.P7.4.49

$$m(t) = \frac{2\sin 2\pi t}{t}, s(t) = \cos 200\pi t \text{ and } n(t) = \frac{\sin 199\pi t}{t}$$

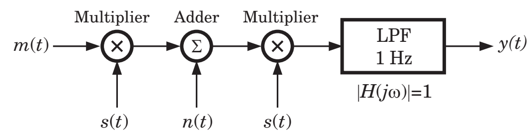


Fig.P7.4.49

The output $y(t)$ will be

(A) $\frac{\sin 2\pi t}{t}$

(B) $\frac{\sin 2\pi t}{t} + \frac{\sin \pi t}{t}\cos 3\pi t$

(C) $\frac{\sin 2\pi t}{t} + \frac{\sin 0.5\pi t}{t}\cos 1.5\pi t$

(D) $\frac{\sin 2\pi t}{t} + \frac{\sin \pi t}{t}\cos 0.75\pi t$

**50.** 12 signals each band-limited to 5 kHz are to be transmitted over a single channel by frequency division multiplexing. If AM -SSNB modulation guard band of 1 kHz is used, then the bandwidth of the multiplexed signal will be

(A) 51 kHz (B) 61 kHz

(C) 71 kHz (D) 81 kHz

**51.** Let $x(t)$ be a signal band-limited to 1 kHz. Amplitude modulation is performed to produce signal $g(t) = x(t)\sin 2000\pi t$. A proposed demodulation technique is illustrated in figure 6.83. The ideal low pass filter has cutoff frequency 1 kHz and pass band gain 2. The $y(t)$ would be

(A) $2y(t)$ (B) $y(t)$

(C) $\frac{1}{2}y(t)$ (D) 0

**52.** Suppose we wish to transmit the signal $x(t) = \sin 200\pi t + 2\sin 400\pi t$ using a modulation that create the signal $g(t) = x(t)\sin 400\pi t$. If the product $g(t)\sin 400\pi t$ is passed through an ideal LPF with cutoff frequency $400\pi$ and pass band gain of 2, the signal obtained at the output of the LPF is

(A) $\sin 200\pi t$ (B) $\frac{1}{2}\sin 200\pi t$

(C) $2\sin 200\pi t$ (D) 0

**53.** In a AM signal the received signal power is $10^{-10}$ W with a maximum modulating signal of 5 kHz. The noise spectral density at the receiver input is $10^{-18}$ W/Hz. If the noise power is restricted to the message signal bandwidth only, the signals-to-noise ratio at the input to the receiver is

(A) 43 dB (B) 66 dB

(C) 56 dB (D) 33 dB

**Statement for Question 54-55**

Consider the following Amplitude Modulated (AM) signal, where $f_m < B$

$$x_{AM}(t) = 10(1 + 0.5 \sin 2\pi f_m t) \cos 2\pi f_c t.$$

**54.** The average side-band power for the AM signal given above is

(A) 25 (B) 12.5

(C) 6.25 (D) 3.125

**55.** The AM signal gets added to a noise with Power Spectra Density $S_n(f)$ given in the figure below. The ration of average sideband power to mean noise power would be

(A) $\frac{25}{8N_0B}$ (B) $\frac{25}{4N_0B}$

(C) $\frac{25}{2N_0B}$ (D) $\frac{25}{N_0B}$

**Statement for Question 56-57**

A certain communication channel is characterized by 80 dB attenuation and noise power-spectral density of $10^{-10}$W/Hz. The transmitter power is 40 kW and the message signal has a bandwidth of 10 kHz.

**56.** In the case of conventional AM modulation, the predetecion SNR is

(A) $10^8$ (B) $2 \times 10^8$

(C) $10^2$ (D) $2 \times 10^2$

**57.** In case of SSB, the predetecion SNR is

(A) $2 \times 10^2$ (B) $4 \times 10^2$

(C) $2 \times 10^3$ (D) $4 \times 10^3$

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# SOLUTION

**1.** (C) $u(t) = (20 + 4 \sin 500\pi t) \cos(2\pi \times 10^5 t)$ V

$= 20(1 + 0.2 \sin 500\pi t) \cos(2\pi \times 10^5 t)$ V, $\alpha = 0.2$

**2.** (B) $P_c = \frac{20^2}{2} = 200$ W, $P_t = P_c\left(1 + \frac{(0.2)^2}{2}\right) = 204$ W

**3.** (A) $P_{sb} = P_t - P_c = 204 - 200 = 4$ W

**4.** (B) $x(t)$

$= [20 + 2\cos(2\pi 1500 t) + 10\cos(2\pi 3000 t)]\cos(2\pi f_c t)$

$= 20\left(1 + \frac{1}{10}\cos(2\pi 1500 t) + \frac{1}{2}\cos(2\pi 3000 t)\cos(2\pi f_c t)\right)$

This is the form of a conventional AM signal with message signal

$m(t) = \frac{1}{10}\cos(2\pi 1500 t) + \frac{1}{2}\cos(2\pi 3000 t)$

$= \cos^2(2\pi 1500 t) + \frac{1}{10}\cos(2\pi 1500 t) - \frac{1}{2}$

The minimum of $g(z) = z^2 + \frac{1}{10}z - \frac{1}{2}$ is achieved for $z = -\frac{1}{20}$ and it is $\min(g(z)) = -\frac{201}{400}$. Since $z = -\frac{1}{20}$ is in the range of cos $(2\pi 1500 t)$, we conclude that the minimum value of $m(t)$ is $-\frac{201}{400}$. Hence, the modulation index is $\alpha = -\frac{201}{400}$

**5.** (B) $x(t) = 20\cos(2\pi f_c t) + \cos(2\pi(f_c - 1500)t)$

$+ \cos(2\pi(f_c - 1500)t)$

$= 5\cos(2\pi(f_c 3000)t) + 5\cos(2\pi(f_c + 3000)t)$

The power in the sidebands is

$P_{\text{sidebands}} = \frac{1}{2} + \frac{1}{2} + \frac{25}{2} + \frac{25}{2} = 26$

The total power is $P_{\text{total}} = P_{\text{carrier}} + P_{\text{sidebands}} = 200 + 26 = 226$

The ratio of the sidebands power to the total power is

$\frac{P_{\text{sidebands}}}{P_{\text{total}}} = \frac{26}{226}$

**6.** (B) $P_t = P_c\left(1 + \frac{\alpha^2}{2}\right) = 2000\left(1 + \frac{0.9^2}{2}\right) = 2810$ W

**7.** (A) $P_t = P_c\left(1 + \frac{\alpha^2}{2}\right)$ or $50 \times 10^3 = P_c\left(1 + \frac{0.8^2}{2}\right)$

$P_c = 37.88$ kW, $P_i = (P_t - P_c) = (50 - 37.88) = 12.12$ kW

**8.** (A) $I_t = I_c\left(1+\frac{\alpha^2}{2}\right)^{\frac{1}{2}}$ or $20 = 18\left(1+\frac{\alpha^2}{2}\right)^{\frac{1}{2}}$ or $\alpha = 0.68$

**9.** (C) $P_t = 20000\left(1+\frac{1}{2}\right)$, $P_t = 30$ kW,

$P_i = 30 - 20 = 10$ kW

The DC input power $= \frac{10}{0.8} = 12.5$ kW.

**10.** (A) $P_c$=2 kW, $\alpha = 70\% = 0.7$

$P_t = P_c\left(1+\frac{\alpha^2}{2}\right)^{\frac{1}{2}} = 2\left(1+\frac{0.7^2}{2}\right) = 2.23$ kW

**11.** (C) $\alpha^2 = \alpha_1^a + \alpha_2^2 = 0.3^2 + 0.4^2 = 0.5^2$ or $\alpha = 0.5$

**12.** (B) In previous solution $P_c = \frac{2}{3}P$. If carrier is suppressed then $\frac{2}{3}P$ or 66% power will be saved.

**13.** (A) $P_t = P_c\left(1+\frac{\alpha_1^2}{2}+\frac{\alpha_2^2}{2}\right) = 10\left(1+\frac{0.3^2}{2}+\frac{0.4^2}{2}\right)$

$= 11.25$ kW

**14.** (D) $x(t) = A_c(1+\alpha\cos 2\pi f_m t)\cos 2\pi f_c t$

Here $A_c(1+\alpha) = 2A_c$, Thus $\alpha = 1$, therefor modulation index is 1 or 100% modulation.

**15.** (A) If modulation index $\alpha$ is 0, then

$$P_{t1} = \frac{A_c^2}{2}\left(1+\frac{0^2}{2}\right) = \frac{A_c^2}{2}$$

If modulation index is 1 then

$$P_{t2} = \frac{A_c^2}{2}\left(1+\frac{1^2}{2}\right) = \frac{3}{4}A_c^2, \qquad \frac{P_{t2}}{P_{t1}} = \frac{3}{2}$$

Thus $P_{t2} = 1.5P_{t1}$ and $P_{t2}$ is increases by 50%

**16.** (A) $f_m = 10$ kHz, $R = 1000\,\Omega$, $C = 10000$ pF

Hence $2\pi f_m RC = 2\pi \times 10^4 \times 10^3 \times 10^{-8} = 0.628$

$\alpha_{max} = (1+(0.628)^2)^{-\frac{1}{2}} = 0.847$

**17.** (B) $\frac{1}{f_c} \le RC \le \frac{1}{BW_m}$, Here $f_c = 1$ MHz

Signal Bandwidth $BW_m = 2f_m = 2\times 2\times 10^3 = 4$ kHz

Thus $\frac{1}{10^6} \le RC \le \frac{1}{4\times 10^3}$ or $10^{-6} \le RC \le 250\,\mu s$

Thus appropriate value is 20 $\mu$ sec

**18.** (A) $P_t = \frac{A_c^2}{2}\left[1+\frac{\alpha^2|m(t)|^2}{2}\right]$

Here modulation index $\alpha = 1$. Thus

$$P_t = \frac{500^2}{2}\left[1+\frac{0.8^2}{2}\right] = 165 \text{ kW}$$

**19.** (C) $c(t) = \sin 2\pi f_c t$, $f_c = 1000$ kHz, $x(t) = c(t)m(t)$

Expressing square wave as modulating signal $m(t)$

$$m(t) = \frac{4}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{2n-1}\cos[2\pi f_m(2n-1)]$$

The modulated output

$$x(t) = \left[\frac{4}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{2n-1}\cos[2\pi f_m(2n-1)]\right]\sin(2\pi 1000\times 10^3 t)$$

So frequency component $(10^6 \pm f_m(2n-1)$ will be present where $n = 1, 2, 3, \ldots$.

For $f_m = 10$ kHz and $n = 1$ & 2 frequency present is 990, 970, 1030 kHz. Thus 1020 kHz will be absent.

**20.** (B) $f_c + f_m = 705$ kHz,

$BW = 2f_m = 10$ kHz or $f_m = 5$ kHz

$f_c = 705 - 5 = 700$ kHz

**21.** (C) $x(t) = m(t)\,c(t) = A(\text{sinc}(t) + \text{sinc}^2(t)\cos(2\pi f_c t)$

Taking the Fourier transform of both sides, we obtain

$$X(f) = \frac{A}{2}[\Pi(f) + \Lambda(f)] * (\delta(f-f_c) + \delta(f+f_c))$$

$$= \frac{A}{2}[\Pi(f-f_c) + \Lambda(f-f_c) + \Pi(f+f_c) + \Lambda(f-f_c)]$$

Since $\Pi(f-f_c) \ne 0$ for $|f-f_c| < \frac{1}{2}$, whereas $\Lambda(f-f_c) \ne 0$ for $|f-f_c| < 1$. Hence, the bandwidth of the bandpass filter is 2.

**22.** (C) $x(t) = m(t)\,c(t)$

$= 100[\cos(2\pi 1000t) + 2\cos(2\pi 2000t)]\cos(2\pi f_c t)$

$= 100\cos(2\pi 1000t)\cos(2\pi f_c t) + 200\cos(2\pi 2000t)\cos(2\pi f_c t)$

$= \frac{100}{2}[\cos(2\pi(f_c+1000)t) + \cos(2\pi(f_c-1000)t)]$

$+ \frac{200}{2}[\cos(2\pi(f_c+2000)t) + \cos(2\pi(f_c-2000)t)]$

Thus, the upper sideband (USB) signal is

$x_u(t) = 50\cos[2\pi(f_c+1000)t] + 100(2\pi(f_c+2000)t)$

**23.** (B) When USSB is employed the bandwidth of the modulated signal is the same with the bandwidth of the message signal. Hence $W_{USSB} = W = 10^4$ Hz

**37.** (B) Sidebands are $(6 \times 10^6 \pm 5000)$ and $(6 \times 10^6 \pm 9000)$

Thus $6.005 \times 10^6$, $5.995 \times 10^6$, $5.991 \times 10^6$ or $5.991 \times 10^6$, $6.005 \times 10^6$ and $6.009 \times 10^6$

**38.** (B) $x(t)$ can be written as

$x(t) = (40 + 8\cos 40\pi t)\cos 400\pi t$

modulation index $\alpha = \frac{8}{40} = 0.2$

$P_c = \frac{1}{2}(40)^2 = 800$ W

The components at 180 Hz and 220 Hz are side band

$P_{sb} = \frac{1}{2}(4)^2 + \frac{1}{2}(4)^2 = 16$ W,

$$E_{eff} = \frac{P_{sb}}{P_c + P_{sb}} = \frac{16}{800 + 16}$$

**39.** (A) Carrier power $P_c = \frac{A^2}{2} = 100$ W, $A = 14.14$

$$E_{eff} = \frac{P_{sb}}{P_c + P_{sb}} = \frac{40}{100} \quad \text{or} \quad \frac{P_{sb}}{100 + P_{sb}} = 0.4$$

$P_{sb} = 66.67$ W, $\quad P_{sb} = \frac{1}{2}B^2 + \frac{1}{2}B^2 = 66.67 \quad$ or $B = 8.161$

**40.** (D) The Hilbert transform of $\cos(2\pi 1000t)$ is $\sin(2\pi 1000t)$, whereas the Hilbert transform of $\sin(2\pi 1000t)$ is $\cos(2\pi 1000t)$

Thus $\hat{m}(t) = \sin(2\pi 1000t) - \cos(2\pi 1000t)$

**41.** (D) The expression for the LSSB AM signal is.

$x_l(t) = A_c m(t)\cos(2\pi f_c t) + A_c m(t)\sin(2\pi f_c t)$

Substituting

$A_c = 100$, $m(t) = \cos(2\pi 1000t) + 2\sin(2\pi 1000t)$

and $\hat{m}(t) = \sin(2\pi 1000t) - 2\cos(2\pi 1000t)$

we obtain

$x_l(t) = 100[\cos(2\pi 1000t) + 2\sin(2\pi 1000t)\cos(2\pi f_c t)]$

$+100[\sin(2\pi 1000t) - 2\cos(2\pi 1000t)\sin(2\pi f_c t)]$

$= 100[\cos(2\pi 1000t)\cos(2\pi f_c t) + \sin(2\pi 1000t)\sin(2\pi f_c t)]$

$+200[\cos(2\pi f_c t)\sin(2\pi 1000t) - \sin(2\pi f_c t)\cos(2\pi 1000t)]$

$= 100\cos(2\pi(f_c - 1000)t) - 200\sin(2\pi(f_c - 1000)t)$

**42.** (D) $y(t) = 4(m(t) + \cos\omega_c t) + 10(m(t) + \cos\omega_c t)^2$

$= 4m(t) + 4\cos\omega_c t + 10m^2(t) + 20m(t)\cos\omega_c t + 5 + 5\cos 2\omega_c t$

$= 5 + 4m(t) + 10m^2(t) + 4[1 + 5m(t)]\cos\omega_c t + 5\cos 2\omega_c t$

The AM signal is, $\quad x_c(t) = 4[1 + 5m(t)]\cos\omega_c t$

$m(t) = Mm_n(t)$

$x_c(t) = 4[1 + 5Mm_n(t)]\cos\omega_c t$

$5M = 0.8 \quad$ or $\quad M = 0.16$

**43.** (C) The filter characteristic is shown in fig.S7.4.43

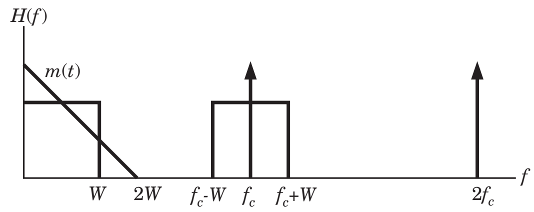


Fig.S7.4.43

$f_c - W > 2W$ or $f_c > 3W$,

$f_c + W < 2f$ or $f_c > W$

Therefore $f_c > 3W$

**44.** (B) Since High-side tuning is used

$f_{LO} = f_m + f_{IF} = 500$ kHz,

$f_{LOL} = 5 + 0.5 = 5.5$ MHz,

$f_{LOU} = 10 + 0.5 = 10.5$ MHz

**45.** (B) $f_{\text{image}} = f_L + 2f_{IF} = 2400 = 3310$ kHz

**46.** (D) The given circuit is a ring modulator. The output is DSB-SC signal. So it will contain $m(t)\cos(n\omega_c t)$ where $n = 1, 2, 3......$ Therefore there will be only (1 MHz ± 400 Hz) frequency component.

**47.** (A) $f_{\max} = 1650 + 450 = 2100$ kHz

$f_{\min} = 550 + 450 = 1000$ kHz. $\quad$ or $\quad f = \frac{1}{2\pi\sqrt{LC}}$

frequency is minimum, capacitance will be maximum

$R = \frac{C_{\max}}{C_{\min}} = \frac{f_{\max}^2}{f_{\min}^2} = (2.1)^2 \quad$ or $R = 4.41$

$f_i = f_c + 2f_{IF} = 700 + 2(455) = 1600$ kHz

**48.** (B) Since $X(f)$ has spectral peak at 1 kHz so at the output of first modulator spectral peak will be at $(10 + 1)$ kHz and $(10 - 1)$ kHz. After passing the HPF frequency component of 11 kHz will remain. The output of 2nd modulator will be $(13 \pm 11)$ kHz. So $Y(f)$ has spectral peak at 2 kHz and 24 kHz.

**49.** (C) $m(t)s(t) = y_1(t)$

$$= \frac{2\sin(2\pi t)\cos(200\pi t)}{t} = \frac{\sin(202\pi t) - \sin(198\pi t)}{t}$$

$$y_1(t) + n(t) = y_2(t) = \frac{\sin 202\pi t - \sin 198\pi t}{t} + \frac{\sin 198\pi t}{t}$$

$y_2(t)s(t) = y(t)$

$$= \frac{[\sin 202\pi t - \sin 198\pi t + \sin 199\pi t]\cos 200\pi t}{t}$$

$= \frac{1}{2}[\sin(402\pi t) + \sin(2\pi t) - \{\sin(398\pi t) - \sin(2\pi t)\}$

$+ \sin(399\pi t) - \sin(\pi t)]$

After filtering

$$y(t) = \frac{\sin(2\pi t) + \sin(2\pi t) - \sin(\pi t)}{2t}$$

$$= \frac{\sin(2\pi t) + 2\sin(0.5t)\cos(1.5\pi t)}{2t}$$

$$= \frac{\sin 2\pi t}{2t} + \frac{\sin 0.5\pi t}{t}\cos 1.5\pi t$$

**50.** (D) The total signal bandwidth = $5 \times 12 = 60$ kHz
There would be 11 guard band between 12 signal. So guard band width = 11 kHz
Total band width = 60 + 11 = 71 kHz

**51.** (D) $x_1(t) = g(t)\cos(2000\pi t)$

$= x(t)\sin(2000\pi t)\cos(2000\pi t) = \frac{1}{2}x(t)\sin(4000\pi t)$

$$X_1(j\omega) = \frac{1}{4j}X(j(\omega - 4000\pi)) - X(j(\omega + 4000\pi))$$

This implies that $X_1(j\omega)$ is zero for $|\omega| \leq 2000\pi$ because $\omega < 2\pi f_m = 2\pi 1000$. When $x_1(t)$ is passed through a LPF with cutoff frequency $2000\pi$, the output will be zero.

**52.** (A) $y(t) = g(t)\sin(400\pi t) = x(t)\sin^2(400\pi t)$

$= (\sin(200\pi t) + 2\sin(400\pi t)\frac{(1 - \cos)(800\pi t)}{2}$

$= \frac{1}{2}[\sin(200\pi t) - \sin(200\pi t)\cos(800\pi t) + 2\sin(400\pi t)$

$-\sin(400\pi t)\cos(800\pi t)$

$= \frac{1}{2}\sin(200\pi t) - \frac{1}{4}[\sin(1000\pi t) - \sin(6000\pi t)]$

$+ \sin(400\pi t) - \frac{1}{4}[\sin(1200\pi t) - \sin(400\pi t)]$

If this signal is passed through LPF with frequency $400\pi$ and gain 2, the output will be $\sin(200\pi t)$

**53.** (A) Message signal BW $f_m = 5$ kHz
Noise power density is $10^{-18}$ W/Hz
Total noise power is $10^{-18} \times 5 \times 10^3 = 5 \times 10^{-15}$ W
Input signal-to-noise ratio

$$\text{SNR} = \frac{10^{-10}}{5 \times 10^{-15}} = 2 \times 10^4 \text{ or } 43 \text{ dB}$$

**54.** (C) Average side band power is

$$\frac{A_c^2\alpha^2}{4} = \frac{10^2(0.5)^2}{4} = 6.25 \text{ W}$$

**55.** (D) Noise power = Area rendered by the spectrum $= N_0 B$
Ratio of average sideband power to mean noise

$$\text{Power} = \frac{6.25}{N_0 B} = \frac{25}{4N_0 B}$$

**56.** (C) Since the channel attenuation is 80 db, then

$$10\log\frac{P_T}{P_R} = 80$$

or $P_R = 10^{-8}P_T = 10^{-8} \times 40 \times 10^3 = 4 \times 10^{-4}$ Watts
If the noise limiting filter has bandwidth B, then the pre-detection noise power is

$$P_n = 2\int_{f_c - \frac{B}{2}}^{f_c + \frac{B}{2}} \frac{N_0}{2}\,df = N_0 B = 2 \times 10^{-10} \text{ B Watts}$$

In the case of DSB or conventional AM modulation, $B = 2W = 2 \times 10^4$ Hz, whereas in SSB modulation $B = W = 10^4$. Thus, the pre-detection signal to noise ratio in DSB and conventional AM is

$$\text{SNR}_{\text{DSB,AM}} = \frac{P_R}{P_n} = \frac{4 \times 10^{-4}}{2 \times 10^{-10} \times 2 \times 10^4} = 10^2$$

**57.** (A) In SSB modulation $B = W = 10^4$

$$\text{SNR}_{\text{SSB}} = \frac{4 \times 10^{-4}}{2 \times 10^{-10} \times 10^4} = 2 \times 10^2$$

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