Tutorial-3: Communication Circuit Design

AM, SSC, FM, PLL

Question 1: A I.4-MHz carrier is modulated by a music signal that has frequency components from 20 Hz to 10 kHz. Determine the range of frequencies generated for the upper and lower side bands.

Solution

The upper sideband is equal to the sum of carrier and intelligence frequencies. Therefore, the upper sideband (usb) will include the frequencies from

$$1,400,000 \text{ Hz} + 20 \text{ Hz} = 1,400,020 \text{ Hz}$$

to

$$1,400,000 \text{ Hz} + 10,000 \text{ Hz} = 1,410,000 \text{ Hz}$$

The lower sideband (lsb) will include the frequencies from

$$1,400,000 \text{ Hz} - 10,000 \text{ Hz} = 1,390,000 \text{ Hz}$$

to

$$1,400,000 \text{ Hz} - 20 \text{ Hz} = 1,399,980 \text{ Hz}$$

This result is shown in Figure 6 with a frequency spectrum of the AM modulator's output.

Question 2: An unmodulated carrier is 560 V p-p. Calculate %*m* when its maximum p-p value reaches 700 V.

Solution

$$E_c = \frac{V_{p-p}}{2} = \frac{560}{2} = 280\,V$$

$$E_i = \frac{Max_{p-p} - V_{p-p}}{2} = \frac{700-560}{2} = 70\,V$$

(OR)

$$E_i = \frac{Max_{p-p}}{2} - E_c = \frac{700}{2} - 280 = 70V$$

$$\%m = \frac{E_i}{E_c} = \frac{70}{280} \times 100 = 25\,\%$$

Question 3: Determine the maximum sideband power if the carrier output is I kW. Also calculate the total maximum transmitted power.

Solution Since

$$E_{SF} = \frac{mE_c}{2}$$

it is obvious that the maximum sideband power occurs when $m = 1$ or 100 percent. At that percentage modulation, each side frequency is ½ the carrier amplitude. Since power is proportional to the square of voltage, each sideband has of the carrier power or ¼ X 1 kW, or 250 W. Therefore, the total sideband power is 250 W X 2 = 500 W and the total transmitted power is 1 kW + 500 W, or 1.5 kW.

Question 4: A 100-V carrier is modulated by a 1-kHz sine wave. Determine the side-frequency amplitudes when m = 0.75.

Solution

$$E_{SF} = \frac{mE_c}{2} = \frac{0.75 \times 100}{2} = 37.5\ V$$

Question 5: A 500-W carrier is to be modulated to a 90 percent level. Determine the total transmitted power.

Solution

$$P_t = P_c\left(1 + \frac{m^2}{2}\right)$$

$$P_t = 500\ \text{W}\left(1 + \frac{0.9^2}{2}\right) = 702.5\ \text{W}$$

Question 6: An AM broadcast station operates at its maximum allowed total output of 50 kW and at 95 percent modulation. How much of its transmitted power is intelligence (sidebands)?

Solution

$$P_t = P_c\left(1 + \frac{m^2}{2}\right)$$

$$50\ \text{kW} = P_c\left(1 + \frac{0.95^2}{2}\right)$$

$$P_c = \frac{50\ \text{kW}}{1 + (0.95^2/2)} = 34.5\ \text{kW}$$

Question 7: An AM transmitter has a 1-kW carrier and is modulated by three different sine waves having equal amplitudes. If $m_{eff} = 0.8$, calculate the individual values of m and the total transmitted power.

Solution

$$m_{eff} = \sqrt{m_1^2 + m_2^2 + m_3^2 + \cdots} \qquad => \quad 0.8 = \sqrt{m^2 + m^2 + m^2 + \cdots}$$

$$(0.8)^2 = 3m^2 \quad => \quad m = 0.462$$

$$P_t = P_c\left(1 + \frac{m_{eff}^2}{2}\right)$$
$$= 1k\left(1 + \frac{0.8^2}{2}\right) = 1.32kW$$

Question 8: A TRF receiver is to be designed with a single tuned circuit using a 10-µ H inductor.

a) Calculate the capacitance range of the variable capacitor required to tune from 550 to 1550 kHz.
b) The ideal 10-kHz BW is to occur at 1100 kHz. Determine the required Q.
c) Calculate the BW of this receiver at 550 kHz and 1550 kHz.

Solution

(a) At 550 kHz, calculate C using the following equation.

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

$$550 \text{ kHz} = \frac{1}{2\pi\sqrt{10\ \mu\text{H} \times C}}$$

$$C = 8.37 \text{ nF}$$

At 1550 kHz,

$$1550 \text{ kHz} = \frac{1}{2\pi\sqrt{10\ \mu\text{H} \times C}}$$

$$C = 1.06 \text{ nF}$$

Therefore, the required range of capacitance is from

1.06 to 8.37 nF

(b)

$$Q = \frac{f_r}{\text{BW}}$$
$$= \frac{1100 \text{ kHz}}{10 \text{ kHz}}$$
$$= 110$$

(c) At 1550 kHz,

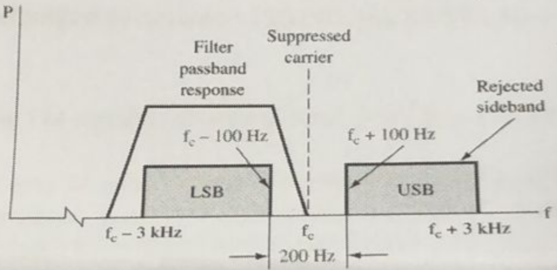
$$BW = \frac{f_r}{Q}$$
$$= \frac{1550 \text{ kHz}}{110}$$
$$= 14.1 \text{ kHz}$$

At 550 kHz,

$$BW = \frac{550 \text{ kHz}}{110} = 5 \text{ kHz}$$

Question 9: Calculate the required Q for the situation depicted in figure below for

a) A 1-MHz carrier and 80-dB sideband suppression.
b) A 1-MHz carrier and 80-dB sideband suppression.



Solution

(a)
$$Q = \frac{f_c(\log^{-1} \text{dB}/20)^{1/2}}{4\Delta f}$$
$$= \frac{1 \text{ MHz}(\log^{-1} 80/20)^{1/2}}{4 \times 200 \text{ Hz}} = \frac{1 \times 10^6(10^4)^{1/2}}{800}$$
$$= \frac{1 \times 10^8}{8 \times 10^2} = 125{,}000$$

(b)
$$Q = \frac{100 \text{ kHz}(\log^{-1} 80/20)^{1/2}}{4 \times 200 \text{ Hz}}$$
$$= \frac{10^7}{8 \times 10^2} = 12{,}500$$

Question 10: A 25-mV sinusoid at a frequency of 400 Hz is applied to a capacitor microphone FM generator. If the deviation constant for the capacitor microphone FM generator is 750 Hz/10 mV, determine

a) The frequency deviation generated by an input level of 25 mV
b) The rate at which the carrier frequency is being deviated.

Solution

(a) positive frequency deviation $= 25\text{ mV} \times \dfrac{750\text{ Hz}}{10\text{ mV}} = 1875\text{ Hz}$ or 1.875 kHz

negative frequency deviation $= -25\text{ mV} \times \dfrac{750\text{ Hz}}{10\text{ mV}} = -1875\text{ Hz}$ or -1.875 kHz

The total deviation is written as ± 2.25 kHz for the given input signal level.

(b) The input frequency (f_i) is 400 Hz; therefore, by Equation (1)

$$f_{out} = f_c + ke_i \qquad (1)$$

The carrier will deviate ± 1.875 kHz at a rate of 400 Hz.

Question 11: An FM signal has a center frequency of 100 MHz but is swinging between 100.001 MHz and 99.999 MHz at a rate of 100 times per second. Determine:

a) The intelligence frequency f_i.
b) The intelligence amplitude.
c) What happened to the intelligence amplitude if the frequency deviation changed to between 100.002 and 99.998 MHz

Solution

a) Because the FM signal is changing frequency at a 100-Hz rate, $f_i = 100$ Hz.
b) There is no way of determining the actual amplitude of the intelligence signal. Every FM system has a different proportionality constant between the intelligence amplitude and the amount of deviation it causes.
c) The frequency deviation has now been doubled, which means that the intelligence amplitude is now double whatever it originally was.

Question 12: Determine the bandwidth required to transmit an FM signal with fi = 10 kHz and a maximum deviation $\delta = 20$ kHz.

Solution

$$m_f = \frac{\delta}{f_i} = \frac{20\text{ kHz}}{10\text{ kHz}} = 2 \qquad (4)$$

From Table 2 with $m_f = 2$, the following significant components are obtained:

$$J_0, J_1, J_2, J_3, J_4$$

This means that besides the carrier, J_1 will exist ± 10 kHz around the carrier, J_2 at ± 20 kHz, J_3 at ± 30 kHz, and J_4 at ± 40 kHz. Therefore, the total required bandwidth is $2 \times 40\text{ kHz} = 80\text{ kHz}$.

Question 13:

a) Determine the permissible range in maximum modulation index for commercial FM that has 30-Hz to 15-kHz modulating frequencies.

b) Repeat for a narrowband system that allows a maximum deviation of 1-kHz and 100-Hz to 2-kHz modulating frequencies.

c) Determine the deviation ratio for the system in part (b).

Solution

(a) The maximum deviation in broadcast FM is 75 kHz.

$$m_f = \frac{\delta}{f_i} = \frac{75\text{ kHz}}{30\text{ Hz}} = 2500$$

For $f_i = 15$ kHz:

$$m_f = \frac{75\text{ kHz}}{15\text{ kHz}} = 5$$

(b)

$$m_f = \frac{\delta}{f_i} = \frac{1\text{ kHz}}{100\text{ Hz}} = 10$$

For $f_i = 2$ kHz:

$$m_f = \frac{1\text{ kHz}}{2\text{ kHz}} = 0.5$$

(c)

$$\text{DR} = \frac{f_{\text{dev(max)}}}{f_{i(\text{max})}} = \frac{1\text{ kHz}}{2\text{ kHz}} = 0.5$$

Question 14: Determine the worst-case output S/N for a broadcast FM program that has a maximum intelligence frequency of 5 kHz. The input S/N is 2.

Solution

The input $S/N = 2$ means that the worst-case deviation is about $\frac{1}{2}$ rad (see the preceding paragraphs). Therefore,

$$\delta = \phi \times f_i \tag{9}$$
$$= 0.5 \times 5\text{ kHz} = 2.5\text{ kHz}$$

Because full volume in broadcast FM corresponds to a 75-kHz deviation, this 2.5-kHz worst-case noise deviation means that the output S/N is

$$\frac{75\text{ kHz}}{2.5\text{ kHz}} = 30$$

Question 15: A PLL is set up so that its VCO free-runs at 10 MHz. The VCO does not change frequency until the input is within 50 kHz of 10 MHz. After that condition, the VCO follows the input to ±200 kHz of 10 MHz before the VCO starts to free-run again. Determine the lock and capture ranges of the PLL.

Lab Material

Each student is required to compl…

Lab-1, Week-…

Lab-2 …

Solution

The capture occurred at 50 kHz from the free-running VCO frequency. Assume symmetrical operation, which implies a capture range of 50 kHz X 2 = 100 kHz. Once captured, the VCO follows the input to a 200-kHz deviation, implying a lock range of 200 kHz X 2 = 400 kHz