MTE - 2 - REPEAT

Question 1

(a) Briefly explain TWO(2) methods of FM generation and give ONE(1) example circuit for each of the method mentioned.

Direct method	Indirect method
• Frequency of the carrier is varies (deviated) directly by the modulating signal.	• Frequency-up conversion → to up-convert the frequency of the modulated carrier after modulation has been performed.
• The instantaneous frequency deviation is directly proportional to the amplitude of the modulating signal.	• Two ways: Heterodyne method and Multiplication method
• Example circuit: FM Reactance modulator, Varactor diode modulator, Linear integrated-circuit direct FM modulator	• Example: Armstrong modulator

(b) Modulation is performed in a transmission by a circuit called a modulator. Justify FOUR(4) reasons why modulation is needed in a communication system.

- To generate a modulated signal suited and compatible to the characteristics of the transmission channel.
- For ease radiation and reduction of antenna size.
- Reduction of noise and interference
- Channel assignment
- Increase transmission speed

(c) In an Frequency Modulation (FM) system a carrier signal $V_c(t) = 20\cos(3\times10^{8}\pi t)$ Volts is modulated by the message signal $V_m(t) = 10\sin(62\,500\,\pi t)$ Volts and the carrier frequency varies within 5.5% of its unmodulated value. Determine

(i) Modulation index, mf

① $2\pi f_c = 3\times10^6\pi$

$f_c = 1.5\ MHz$

$\Delta f = 5.5\% \times 1.5\ MHz$, $\Delta f = KV_m\ (Hz)$

$= \left(\frac{5.5}{100}\right)\times 1.5\ MHz$

$= 82.5\ kHz$

② $f_m = \frac{62500\pi}{2\pi} = 31.25\ kHz$ ③ $\frac{\Delta f}{f_m} = 2.64$

(ii) Bandwidth required using Carson's rule.

$B_{fm} = 2(\Delta f + f_m)$

$= 2(82.5\ kHz + 31.25\ kHz)$

$= 227.5\ kHz$

Question 2

(a) A telecommunication technician is given a task to access the output power levels of a conventional AM transmitter with respect to a different kind of modulation modes with the same intelligibility received. Given that the antenna transmits a 13.2 kW of total power at 75% modulation, determine:

DSBFC

(i) The total power, P_T delivers through the antenna

$P_T = P_c + \frac{m^2}{4}P_c + \frac{m^2}{4}P_c$

$= 13.2\ kW + \frac{(0.75)^2}{4}(13.2\ kW) + \frac{(0.75)^2}{4}(13.2\ kW)$

$= 16.9\ kW$

(ii) The total power using Double-Sided Band Suppressed Carrier (DSBSC)

$P_T = \frac{m^2}{4}P_c + \frac{m^2}{4}P_c$

$= \frac{0.75^2}{4}(13.2\ kW) + \frac{0.75^2}{4}(13.2\ kW)$

$= 3.71\ kW$

(1) SSBFC, $P_T = P_c + \frac{m^2}{4} P_c$ (2) SSBSC $P_T = \frac{m^2}{4} P_T$

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(iii) The percentage of power saving of Single-Side Band Full Carrier (SSBFC) compared to Double-Side Band Full Carrier (DSBFC).

$P_T = P_c + \frac{m^2}{4} P_c = 13.27\,kW + \frac{0.75^2}{4}(13.27\,kW) = 15.06\,kW$

Power saving of SSBFC compare to DSBFC

$\% P = \frac{16.97\,kW - 15.06\,kW}{16.97\,kW} \times 100\% = 10.39\%$

(b) An AM modulated wave with the output wave changes of $\pm 7.5\,V_p$ is represented by the following equation:

$V_{am}(t) = \underset{E_c}{20} \sin(2\pi 500 \times 10^3 t) - 3.75 \cos(2\pi 510 \times 10^3)t + 3.75 \cos(2\pi 490 \times 10^3)t$

$\frac{mE_c}{2}$

Determine

(i) Modulation index, m and percent of modulation

$E_{usf} = E_{lsf} = \frac{E_m}{2} = \frac{mE_c}{2} = 3.75$

$\frac{m\,20\,V_p}{2} = 3.75\,V_p$

$m = 0.375$

$\%m = 37.5\%$

(ii) The peak amplitude of the modulated carrier, upper and lower side of frequency voltages.

$E_c = 20\,V_p$

$E_{usf} = E_{lsf} = 3.75\,V_p$

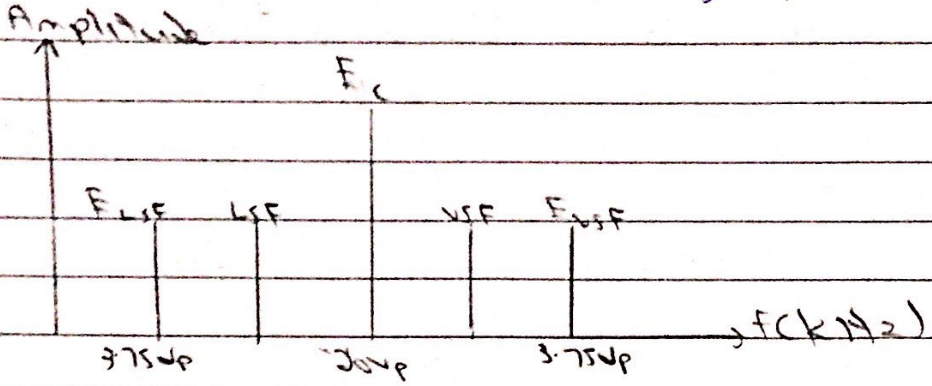
(iii) The maximum and minimum amplitude of the envelope

$E_m = mE_c = 0.375 \times 20 = 7.5\,V_p$

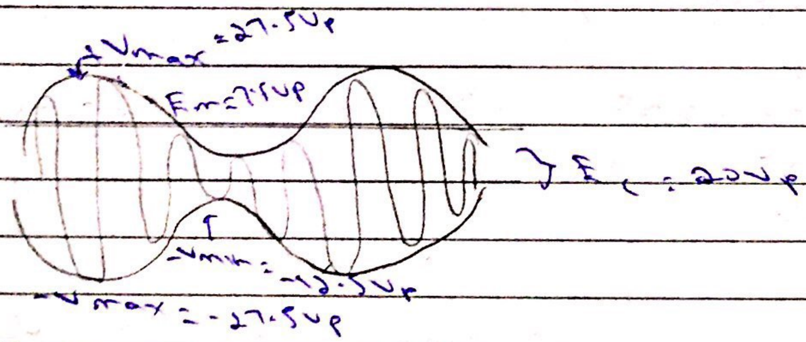
$V_{max} = E_c + E_m = 20\,V_p + 7.5\,V_p = 27.5\,V_p$

$V_{min} = E_c - E_m = 20\,V_p - 7.5\,V_p = 12.5\,V_p$

(iv) Draw and label the frequency spectrum



(v) Sketch and label the AM modulated envelope



Question 2

a) Write an expression for a AM voltage wave with the following values:

- Unmodulated carrier = 20 Vp
- Modulation coefficient = 0.4
- Modulating signal frequency = 5 kHz
- Carrier frequency = 200 kHz

$$V_{am}(t) = E_c \sin(2\pi f_c t) - \frac{mE_c}{2}\cos[2\pi(f_c+f_m)t] + \frac{mE_c}{2}\cos[2\pi(f_c-f_m)t]$$

$$= 20\sin(2\pi 200kt) - \frac{0.4(20)}{2}\cos[2\pi(200k+5k)t] + \frac{(0.4)(20)}{2}\cos[2\pi(200k-5k)t]$$

$$= 20\sin(400\pi kt) - 4\cos(410\pi kt) + 4\cos(390\pi kt)$$ #

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(b) Given an FM modulated waveform $V_{FM}(t) = 4\cos[(8.6\times10^5)\pi t + 2\sin(27\times10^3)\pi t]$ is transmitted through an antenna with a load resistance $R_L = 15\,\Omega$. By referring to the Bessel Function Table in Appendix 1, answer the following questions:

(i) Determine the carrier frequency, f_c, modulating frequency, f_m and modulation index, m_f.

① $2\pi f_c = 8.6\times10^5\pi$

$f_c = 430\text{ kHz}$

② $2\pi f_m = 27\times10^3\pi$

$f_m = 13.5\text{ kHz}$

③ $m_f = 2$

(ii) Determine the relative amplitude of the carrier and side frequencies.

From Bessel Function Table,

$m_f = 2,\ n = 4$

$V_n = J_n V_c$

$V_0 = J_0 V_c = 0.22 \times 4V = 0.88V$

$V_1 = J_1 V_c = 0.58 \times 4V = 2.32V$

$V_2 = J_2 V_c = 0.35 \times 4V = 1.4V$

$V_3 = J_3 V_c = 0.13 \times 4V = 0.52V$

$V_4 = J_4 V_c = 0.03 \times 4V = 0.12V$

(iii) Determine the total power in modulated carrier, P_t.

$$P_t = \frac{V_c^2}{2R} + \frac{2(V_1)^2}{2R} + \frac{2(V_2)^2}{2R} + \frac{2(V_3)^2}{2R} + \frac{2(V_4)^2}{2R}$$

$$= \frac{0.88^2}{2(15)} + \frac{2(2.32)^2}{2(15)} + \frac{2(1.4)^2}{2(15)} + \frac{2(0.52)^2}{2(15)} + \frac{2(0.12)^2}{2(15)}$$

$$= \frac{16.0288}{30}$$

$= 0.534\text{ W}$

(iv) Produce the power spectrum of the modulated output wave with their respective power amplitudes.