VIT Vellore Institute of Technology (Deemed to be University under section 3 of the UGC Act, 1956)	**Final Assessment Test – Winter 2023-24 Semester - May 2024**	
	Course code : BECE 304 L	Slot:G2
	Course Title : Analog Communication Systems	Time: **Three Hours**
	Course Mode : **CBL**	Max. Marks: **100**
Emp Id: 11976	Faculty Name : Dr. G.Aarthi	School:SENSE
	Class Number(s): VL2023240501318, 1314,1304,1309,1312,1320,1306	Mobile No.: 9003043086

KEEPING MOBILE PHONE/SMART WATCH, EVEN IN 'OFF' POSITION IS TREATED AS EXAM MALPRACTICE

General Instructions if any:

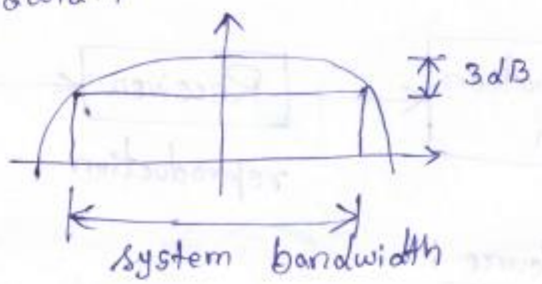
1. **"*fx* series" - non Programmable calculator are permitted : YES**
2. **Reference tables permitted : YES (if Yes, Please specify:** Scientific calculators and Bessel's table are permitted **)**

Answer <u>ALL Questions, Each Question carries Ten Marks.</u> (10 X 10 = 100 Marks)

Sl No	Question Text	Ma
1.	a. Define Signal Bandwidth and channel Bandwidth. b. Specify the frequency ranges allotted for AM and FM broadcast. c. Calculate the theoretical channel capacity if the SNR is 40dB and the channel bandwidth is 6MHz?	1

Signal bandwidth
↳ max freq present in the Signal

System bandwidth
↳



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(b) Frequency range of AM & FM.
[5 Marks]

AM Frequency Range = 535 - 1605 kHz

FM Frequency Range = 88 - 108 MHz.

(c) Calculate channel capacity: [5Marks]

SNR = 40 dB = 10,000.

Channel Bandwidth = 6 MHz.

$\therefore$ Channel Capacity $C = W \log_2 [1+SNR]$

$C = 6\times10^6 \log_2 [1+10{,}000]$

$C = 79.727$ Mbps.

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a. A Carrier wave of 10 MHz frequency and peak value of 10V is Amplitude modulated by a 5kHz sine-wave of 6V amplitude. Determine the Modulation Index and draw the one-sided spectrum of the Modulated wave.

b. Determine η & the percentage of the Total Power carried by the sidebands of the AM wave for Tone modulation when μ = 0.5 & when μ = 0.3.

Peak value of the modulating signal $= A_m = 6$ V

Peak value of the carrier signal $= A_c = 10$ V

Modulation index $= m = \dfrac{A_m}{A_c} = \dfrac{6}{10} = 0.6$

The AM signal may be represented as

$$x_c(t) = A_c\left[1 + m\cos\omega_m t\right]\cos\omega_c t$$

where, $A_c = 10\,\text{V}$, $m = 0.6$, $\omega_m = 2\pi f_m = 2\pi \times 5 \times 10^3$ rad/s and

(a) $\omega_m = 2\pi f_c = 2\pi \times 10 \times 10^6$ rad/s

$$x_c(t) = A_c\cos\omega_c t + mA_c(\cos\omega_c t.\cos\omega_m t)$$

$$= A_c\cos\omega_c t + \frac{1}{2}mA_c\cos(\omega_c + \omega_m)t + \frac{1}{2}mA_c\cos(\omega_c - \omega_m)t$$

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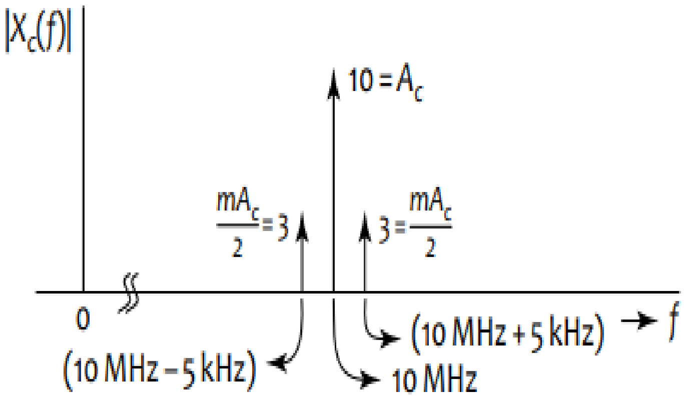


Power Efficiency of AM wave

$$\eta = \frac{\text{useful power}}{\text{total power}} = \frac{P_s}{P_c + P_s}:$$

For $\mu = 0.5$,

$$\eta = \frac{\mu^2}{2+\mu^2}100\% = \frac{(0.5)^2}{2+(0.5)^2}100\% = 11.11\%$$

Hence, only about 11% of the total power is in the sidebands. For $\mu = 0.3$,

$$\eta = \frac{(0.3)^2}{2+(0.3)^2}100\% = 4.3\%$$

(b) Hence, only 4.3% of the total power is in the sidebands that contain the message signal.

3. a. A simple Diode Detector uses a load resistance of 400 kilo-ohms. Across this resistance, there is a 100pF Capacitor. If the maximum Modulation depth of the Input AM signal is 75%, what is the maximum frequency of the Modulating signal that can be detected without Diagonal clipping? 10

$$R_L C = 400 \times 10^3 \times 100 \times 10^{-12} = 4 \times 10^{-5} \text{ s}$$

$$R_L C \le \frac{1}{\omega_m}\left[\frac{\sqrt{1-m^2}}{m}\right]$$

$$4 \times 10^{-5} \le \frac{1}{6.28 f_m}\left[\frac{\sqrt{1-(0.75)^2}}{0.75}\right]$$

$$f_m \le \frac{10^5}{4 \times 6.28}\left[\frac{0.6614}{0.75}\right] = 3510 \text{ Hz}$$

$$\boxed{f_m \le 3510 \text{ Hz} \quad \therefore \text{ max. frequency} = 3510 \text{ Hz}}$$

b. An AM (Double Sideband plus full Carrier) signal waveform is as shown in Figure 1. Determine modulation index(m) and develop the expression for the modulated signal, the total power, carrier power and sideband power.

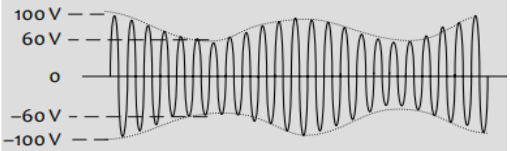


Figure 1

(i) $A_c[1+m]=100 \qquad \therefore 2A_c=160$

$A_c[1-m]=60$

$\therefore A_m=100-A_c=20 \quad \therefore m=\dfrac{A_m}{A_c}=0.25$

$$\text{(ii)}\ x_c(t)=A_c[1+mx(t)]\cos\omega_c t$$

$$=80[1+0.25\cos\omega_m t]\cos\omega_c t$$

$$\text{(iii)}\ P_c=\frac{1}{2}A_c^2=\frac{1}{2}\times 6400=3200 \text{ watts}$$

$$\therefore\ P_T=3200\left[1+\left(\frac{1}{4}\right)^2/2\right]=3200+\frac{3200}{32}=3300\text{ W}$$

$$\therefore\ \text{sideband power}=100\text{ W}$$

4. A DSB-SC signal is generated with a Balanced modulator and a Band pass filter. Consider the message signal m(t)= 10 sin (2π 1000 t) and the carrier signal c(t)= 50 sin (2π 5x 10^6 t). **10**

a) The output of the balanced modulator y(t).
b) The output of the Band pass filter $V_0(t)$
c) Suppose the DSB-SC signal $V_0(t)$ is applied to a coherent demodulator with a local oscillator signal c*(t)= 25 sin (31.4x 10^6 t+ π/4), find the scaled version of the message signal at the output of low pass filter.
d) Draw the spectrum of the DSB- SC and the demodulated output

$m(t) = 10 \sin(2\pi 1000 t)$ [10 Marks].

$c(t) = 50 \sin(2\pi \times 5 \times 10^6 t)$

(a) Output of the Balanced modulater:

In the balanced modulator, has two identical Amplitude modulator. The upper modulater (AM) use the message signal as it is. (u m(t)]. The lower modulater (AM), the message signal is ~~shi~~ phase shifted to 180° So the ~~the~~ message signal becomes $-m(t)$.

$\therefore$ The o/p of the balanced modulator,

$$y(t) = 2 \times 10 \times 50 \times \sin(2\pi \times 1000t) \cdot \cancel{\sin(2\pi \times 10^6 t)}$$
$$\sin(10\pi \times 10^6 t)$$

(b) The output of the Band pass filter:

$$V_0(t) = 2 \times 10 \times 50 \sin(2\pi \times 1000t) \cdot \sin(2\pi \times 10^6 t)$$

(c) Local oscillator Signal.

$$c^*(t) = 25 \sin(2\pi \times 5 \times 10^6 t)$$

∴ the output of coherent demodulator $y'(t)$ as

$$y'(t) = 1000 \sin(2\pi \times 1000t) \cdot \sin(2\pi \times 5 \times 10^6 t) \cdot 25 \sin(2\pi \times 5 \times 10^6 t).$$

$$y'(t) = 2500 \sin(2\pi \times 1000t) \sin^2(2\pi \times 5 \times 10^6 t)$$

$$= 2500 \sin(2\pi \times 1000t) \left(\frac{1 - \cos(20\pi \times 10^6 t)}{2}\right)$$

$$y'(t) = 1250 \sin(2\pi \times 1000t) - 2500 \sin(2\pi \times 1000t). \cos(20\pi \times 10^6 t).$$

$y'(t) \rightarrow$ LPF: then $y''(t)$ as:

$$\boxed{y''(t) = 1250 \sin(2\pi \times 1000t).}$$

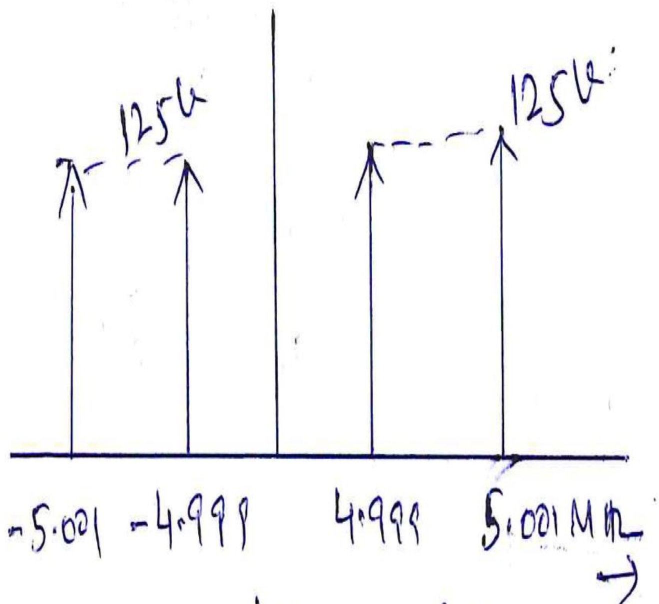
d) Draw the Spectrum of DSB-SC,

$f_c = 5\times10^6$ Hz ; 5 MHz

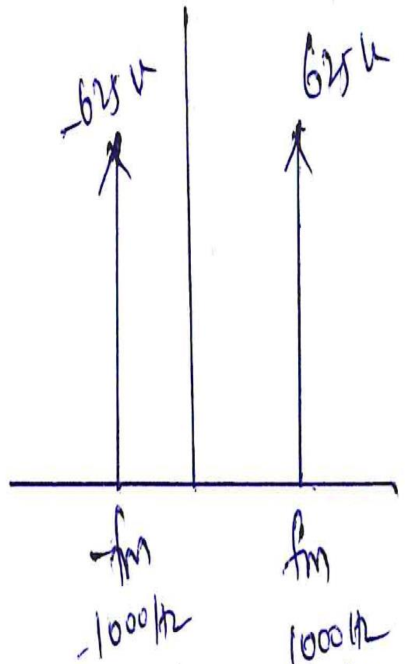
$f_m = 1000$ Hz

$f_c + f_m = 5.001$ MHz

$f_c - f_m = 4.999$ MHz.



DSB-SC Spectrum.



Demodulated Signal.

5. Consider a 2-stage SSB-modulator as shown in Figure 2. The input signal m(t) is in the range 2 kHz to 10 kHz. The two oscillator frequencies have values f_{c1}=400 kHz and f_{c2}=50 MHz. Determine **10**

a. Sidebands of DSBSC Modulated waves appearing at the outputs of the product modulators.
b. Sidebands of SSBSC Modulated waves appearing at the outputs of the two BPF's.(allows only USB)
c. Plot the spectrum of the signal at each point A, B, C and D for LSB and USB transmission.
d. Tabulate the passband and guardbands of the two BPF's.

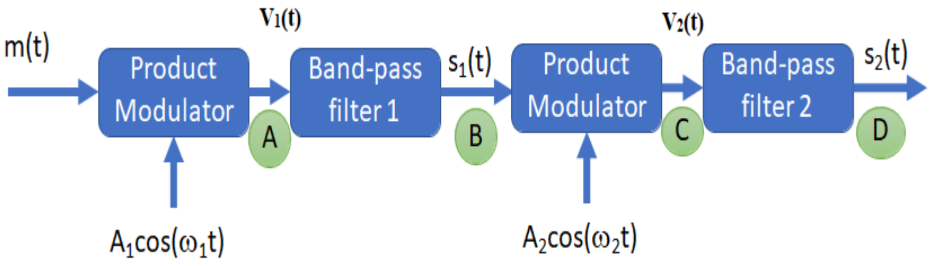
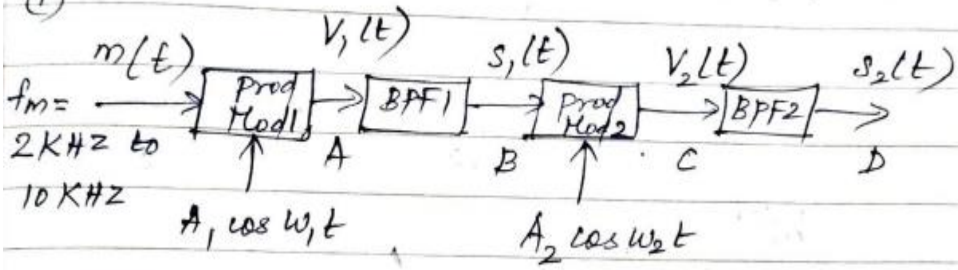


Figure 2.

(i)



$f_{c_1} = 400\,KHZ$ $\quad$ $f_{c_2} = 50\,MHZ$

a) The output of PM1 consists of two side bands.

$$LSB = f_{c_1} - f_m = 400\,KHZ - (2\,KHZ \text{ to } 10\,KHZ)$$

$$LSB = 398\,KHZ \text{ to } 390\,KHZ$$

$$USB = f_{c_1} + f_m = 400\,KHZ + (2\,KHZ \text{ to } 10\,KHZ)$$

$$USB = 402\,KHZ \text{ to } 410\,KHZ$$

b) output of BPF1 (Allows only USB)

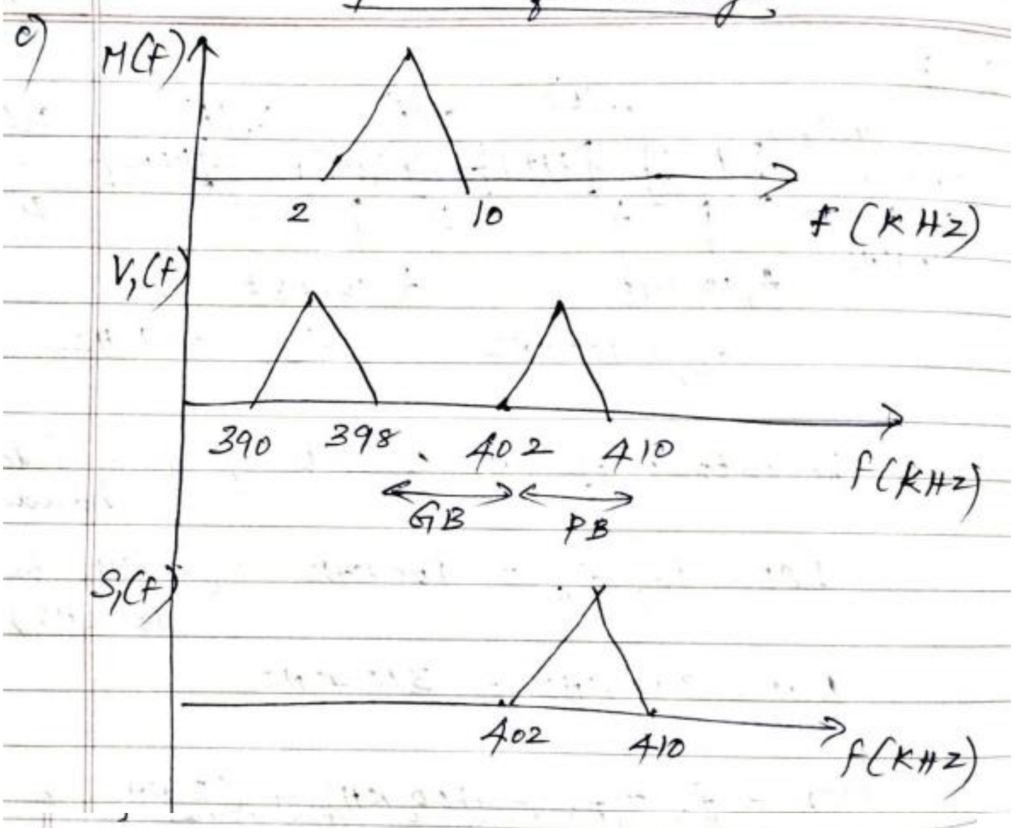
$$S_1(t) = 402\,KHZ \text{ to } 410\,KHZ$$

d) Passband of BPF1 = 402 KHZ to 410 KHZ

Guardband of BPF1 = 398 KHZ to 402 KHZ

Spectrum of Each stage

c)



a) The PM2 consists of two sidebands.

Here $f_m = f_{USB} = (402 \text{ to } 410)$ KHZ

$f_{c_2} = 50$ MHZ.

$$LSB = f_{c_2} - f_m$$

$$= 50\,MHZ - (0.402 \text{ to } 0.410)\,MHZ$$

$$= 49.598\,MHZ - 49.59\,MHZ$$

$$USB = f_{c_2} + f_m$$

$$= 50\,MHZ + (0.402 \text{ to } 0.410)\,MHZ$$

$$= 50.402\,MHz - 50.410\,MHZ$$

b) output of BPF2 (Allows only USB)

$$S_2(t) = 50.402\,MHZ - 50.410\,MHZ$$

<table>
<tr><td></td><td>$USB = f_{c_2} + f_m$
$= 50 MHZ + (0.402 \text{ to } 0.410) MHZ$
$= 50.402 MHZ - 50.410 MHZ$
b) output of BPF2 (Allows only USB)
$S_2(t) = 50.402 MHZ - 50.410 MHZ$
d) passband of BPF2 = (50.402 to 50.410) MHZ
~~passband of~~
Guardband of BPF2 = (49.598 to 50.402) MHZ</td><td></td></tr>
<tr><td>6.</td><td>Figure 3, shows wideband frequency modulator (WBFM). The narrow band FM signal initially generated has a carrier frequency of 200 kHz and a frequency deviation of 25 Hz. The oscillator frequency $f_0 = 10.8\ MHz$. Choose the appropriate multiplier n_1 and n_2 such that WBFM signal is to have carrier frequency 96 MHz and the frequency deviation is 76.8 kHz.

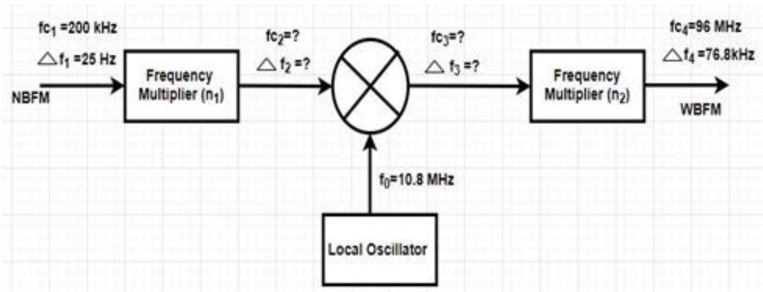


Figure 3.</td><td>10</td></tr>
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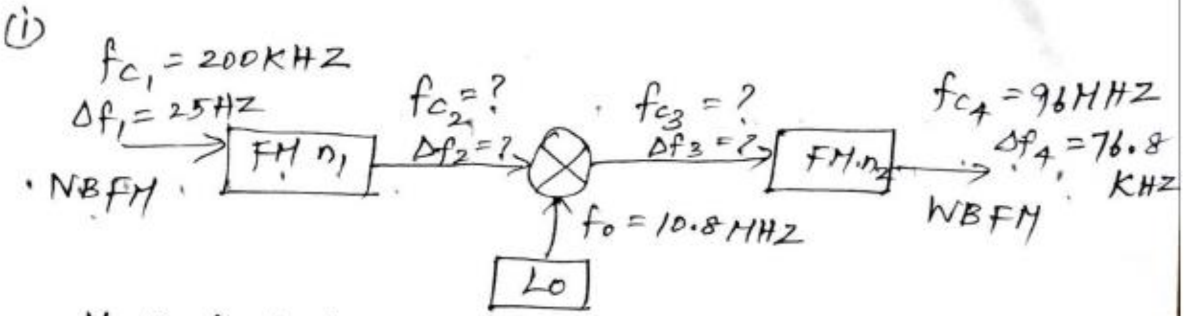
(i)



Multiplication Factor $n_1 n_2$

$$\frac{\Delta f_4}{\Delta f_1} = \frac{76.8 \times 10^3}{25} = 3072$$

Factorize 3072,

i,e $n_1 = 64$, & $n_2 = 48$

To compute f_{c_2} & Δf_2

$$f_{c_2} = n_1 f_{c_1} = 64 \times 200 \text{ KHZ} = 12.8 \text{ MHZ}$$

$$\Delta f_2 = n_1 \times \Delta f_1 = 64 \times 25 = 1600 \text{ HZ}$$

To compute f_{c_3} & Δf_3

$$f_{c_3} = |f_{c_2} \pm f_0| = |12.8 \pm 10.8| \text{ MHZ}$$

$$= \boxed{2 \text{ MHZ}} \text{ (or) } 23.6 \text{ MHZ}$$

↳ Required

$$\Delta f_3 = \Delta f_2 = 1600 \text{ HZ}$$

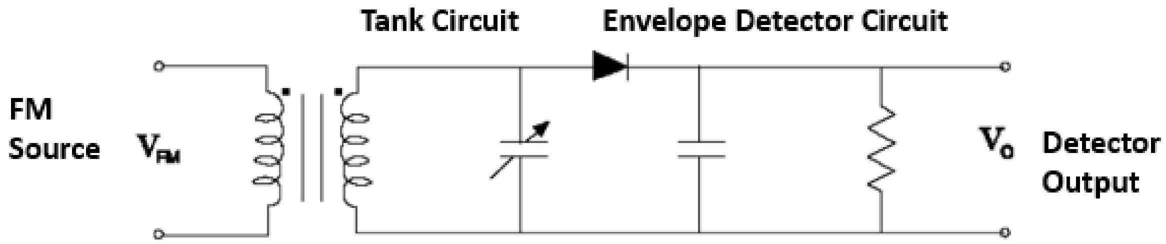
To compute f_{c_4} & Δf_4

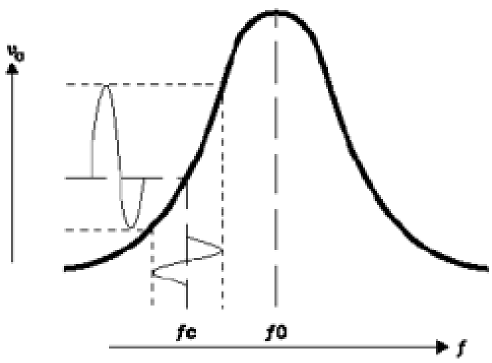
$$f_{c_4} = n_2 \times f_{c_3} = 48 \times 2 \text{ MHZ} = 96 \text{ MHZ}$$

$$\Delta f_4 = n_2 \times \Delta f_3 = 48 \times 1600 = 76.8 \text{ KHZ}$$

$$\therefore \boxed{n_1 = 64 \text{ \& } n_2 = 48}$$

7.	With suitable figures and mathematical derivation, clearly explain the working principle of slope detector and balanced slope detector for demodulation of FM wave. Also state its advantages and disadvantages. **Slope Detector**	10





Voltage versus Frequency Curve

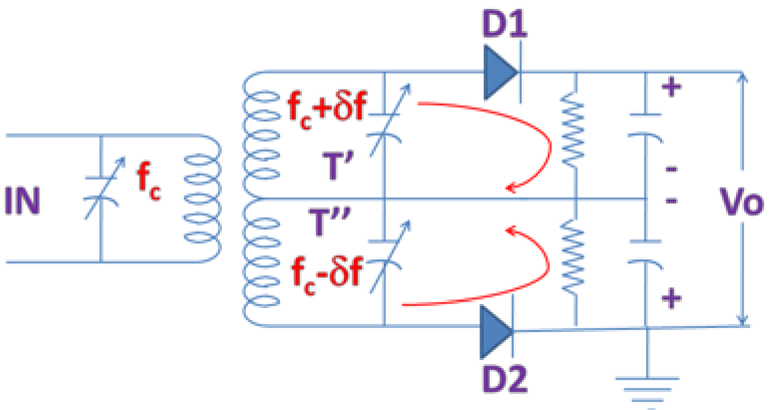
Advantages

- Simple - can be used to provide FM demodulation when only an AM **detector** is present.
- Enables FM to be detected without any additional circuitry.

Limitations

- **It is inefficient, as it is linear in very limited frequency range.**
- **It reacts to all amplitude changes.**
- **It is relatively difficult to tune, as tuned circuit must be tuned to different frequency than carrier frequency.**

Balanced Slope Detector



Advantages

- This circuit is more efficient than simple **slope detector**.
- It has better linearity than the simple **slope detector**

Limitations

- **Even more difficult to tune, as there are three different frequencies to be tuned.**
- **Amplitude limiting still not provided.**
- **Linearity, although better than single slope detector, is still not good enough.**

8. a. Draw a diagram of a tuned radio-frequency (TRF) radio receiver and explain the working of the receiver. 10

: a.

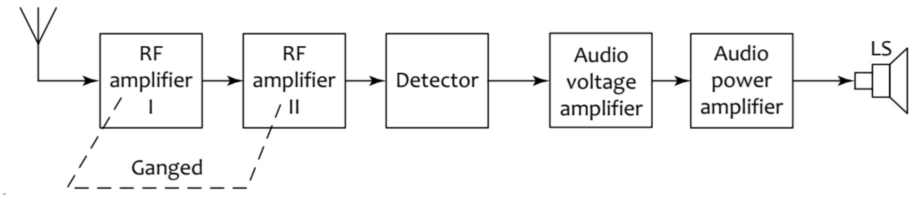


Fig: Tuned radio frequency receiver

The TRF receiver is a simple "logical" receiver with simplicity and high sensitivity. In TRF receivers typically two or three RF amplifiers, all tuned to the same frequency, are employed to select and amplify the frequency of interest and simultaneously reject all others. After the signal is amplified to a suitable level, it is demodulated (detected) and fed to the loudspeaker after being passed through the appropriate audio amplifying stages. Such receivers are simple to design and work well at medium wave broadcast frequencies (535 to 1640 kHz), but they present difficulties at higher frequencies. This is mainly because of the risks of instability associated with high gain multistage amplifier. Another limitation faced by the TRF receiver is a variation in bandwidth over the
tuning range.

b. A TRF receiver is to be tuned over the range 550 to 1550 kHz with a 25-uH inductor. Calculate the required capacitance range.

b. The resonant frequency

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

$$C = \frac{1}{4\pi^2 f_r^2 L}$$

$$C_{min} = \frac{1}{4\pi^2 f_{r_{max}}^2 L} = \frac{1}{4\pi^2 (25\times10^{-6})(1550\,k)^2}$$

$$= 421.7\ pF$$

$$C_{Max} = \frac{1}{4\pi^2 f_{r_{min}}^2 L} = \frac{1}{4\pi^2 (25\times10^{-6})(550\,k)^2}$$

$$= 3349.5\ pF$$

c. $$Q = \frac{f_r}{B.W} = \frac{1000\,KHz}{10\,KHz} = 100$$

c. Determine the tuned circuit's necessary Q if a 10-kHz bandwidth is desired at 1000 kHz

9. A receiving antenna that has noise temperature 450K is connected to an amplifier that has noise figure 3dB and gain 10dB by a UHF cable that suffers a loss of 0.2dB per m and has noise figure 2dB. The cable is 5m long. (a) What is the overall system noise factor and (noise) temperature of the system? (b) What is the noise factor and temperature of the system if a low noise preamplifier of gain 6dB and F = 1.25 is placed right after the antenna (preceding the connecting cable). **10**

(a) Antennas have no gain or loss. They just pick up signal. So the gain of the antenna $G_1 = 1$. If the antenna is not particularly selective it will pick up extraneous background of signals that will be manifested as a noise temperature, which in this case $T_1 = 450$K and is the same as noise factor $F_1 = 1 + 450/300 = 2.5$.

The cable has thermal properties that manifest themselves as a noise. A noise figure of 2dB corresponds to noise factor $F_2 = 1.585$ [note: $F = \log^{-1}(2/10)$] which corresponds to noise temperature $T_2 = (1.585 - 1) \times 300 = 175$K.

The cable has a loss of 5m × (-0.2dB/m) = -1dB, which corresponds to gain factor $G_2 = 0.79$.

It is usually in order to determine noise factor F, noise temperature T_e, and gain (loss) of each part of a system.

The amplifier has noise factor $F_3 = 2.0$ (same as noise figure 3dB) (same as noise temperature 300K) and gain $G_3 = 10$.

Listing these in the order indicated:

$T_1 = 450,\ F_1 = 2.5,\quad G_1 = 1.0$
$T_2 = 175,\ F_2 = 1.585,\quad G_2 = 0.79$
$T_3 = 300,\ F_3 = 2.0,\quad G_3 = 10$

The overall noise factor is then $$F = 2.5 + \frac{(1.585-1)}{1.0} + \frac{(2.0-1)}{1.0\times 0.79} = \underline{4.35}$$

which is the same as $T_e = (4.35 - 1) \times 300 = \underline{1005\text{K}}$

It is usually simpler to find T_e (rather than F), i.e.

$$T_e = 450 + \frac{175}{1} + \frac{300}{1.0\times 0.79} = \underline{1005\text{K}}$$

(b) For preamplifier of gain $G = 4.0$ (same as 6dB) and noise factor $F = 1.25$ ($T_e = 75^o$) inserted at the antenna the system becomes a cascade of <u>four</u> stages, with listings

$T_1 = 450,\ F_1 = 2.5,\quad G_1 = 1.0$
$T_2 = 75,\ F_2 = 1.25\quad G_2 = 4.0$
$T_3 = 175,\ F_3 = 1.585,\quad G_3 = 0.79$
$T_4 = 300,\ F_4 = 2.0,\quad G_4 = 10$

for which $$T_e = 450 + \frac{75}{1} + \frac{175}{1\times 4} + \frac{300}{1.0\times 4\times 0.79} = \underline{662\text{K}}$$

= a much lower noise temperature (or noise factor) than before

(OR)

9.	Table 1, shows the specification of three amplifiers.

Table 1.Specifications of cascaded amplifiers

Amplifier Number	F	Te	Gain (dB)
1		360 K	15
2	8 dB		26
3	12 dB		26

i) Find the noise figure of the cascaded amplifiers.
ii) If the amplifiers 2 and 3 are interchanged then compute its noise figure.
iii) Find the effective temperature (T_e) of part (i) and (ii).
iv) Assuming the configuration of part (a), find the required output noise power. Assume the system bandwidth is 50 kHz.

Ampl

$G_1 = 15\,dB$
$= 31.62$
$T_e = 360\,K$

Amp2

$G_2 = 26\,dB$
$= 398.10$
$F_2 = 8\,dB$
$= 6.30$

Amp3

$G_3 = 26\,dB$
$= 398.10$
$F_3 = 12\,dB$
$= 15.84$

$T_e = [F_1 - 1]T_0$

$360 = [F_1 - 1]\,290$

$F_1 - 1 = \frac{360}{290} = 1.24$

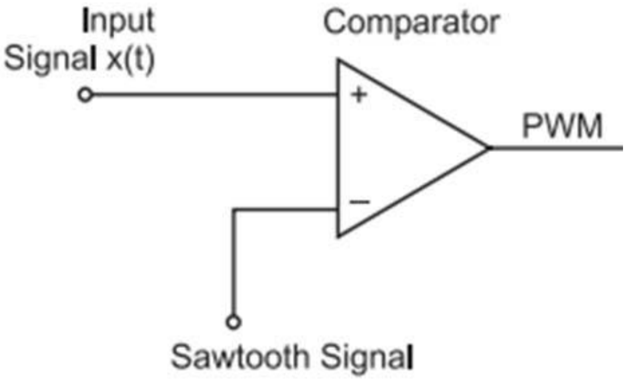
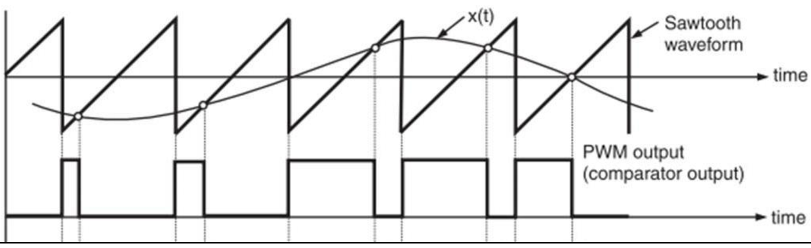
$F_1 = 2.24 = 3.50\,dB$

(a)

$F_{cascade} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2}$

$= 2.408$

$= 3.816\,dB$

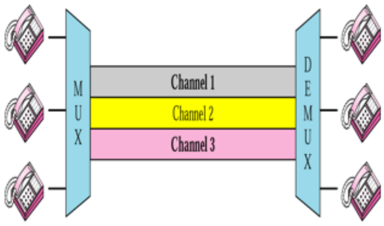
	(b) If amplifiers 2 and 3 are interchanged, $F_{cascade} = 2.74$ (c) a) $T_e = [F_{cas} - 1] T_o$ $= [2.408 - 1] 290$ $T_e = 408.32\ k$ b) $T_e = [2.741 - 1] 290$ $T_e = 504.89\ k$ d) output Noise power of part-a, $B = 50\ KHZ$ $P_{no2} = F_{cas}\, G_{eq}\, K\, T_o\, B$ $= 2.408 \times 31.62 \times 398.10 \times 398.10 \times 1.38 \times 10^{-23} \times 290 \times 50 \times 10^3$ $P_{no2} = 2.414 \times 10^{-09}\ W$	
10.	Explain the generation and detection of pulse width modulation signal with neat diagram. Draw the various stages of waveforms during detection.   	10
	(OR)	

10. (i) (i)With a neat sketch explain the transmitter and receiver of FDM. **10**

(ii)Compare the advantages and disadvantages of FDM and TDM schemes.

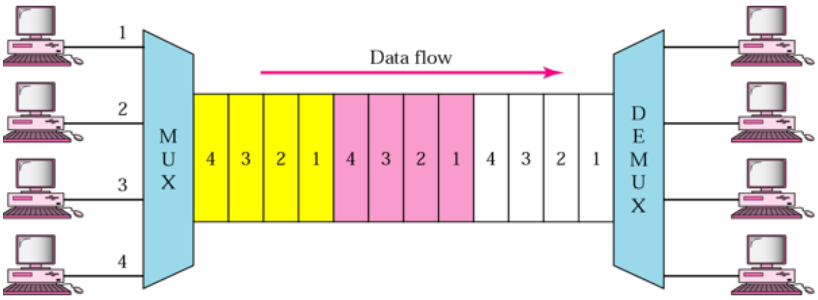
Frequency-division Multiplexing (FDM)

- In FDM signals generated by each device modulate different carrier frequencies. These modulated signals are combined into a single composite signal that can be transported by the link.



FDM is an analog multiplexing technique that combines signals.

TDM



TDM is a digital multiplexing technique to combine data.