# BAE 604 TELECOMMUNICATION ENGINEERING WK 1

FUNCTION OF COMMUNICATION SYSTEM – TRANSFER INFORMATION FROM ONE POINT TO ANOTHER VIA SOME COMMUNICATION LINK

## MODULATION

THE PROCESS OF IMPRESSING INFORMATION ON TO A HIGH FREQUENCY CARRIER FOR TRANSMISSION

SINE WAVE WITH HIGH FREQUENCY CARRIER

$$v = V_p \sin(\omega t + \phi)$$

$v$ = INSTANTANEOUS VALUE, $V_p$ = PEAK VALUE

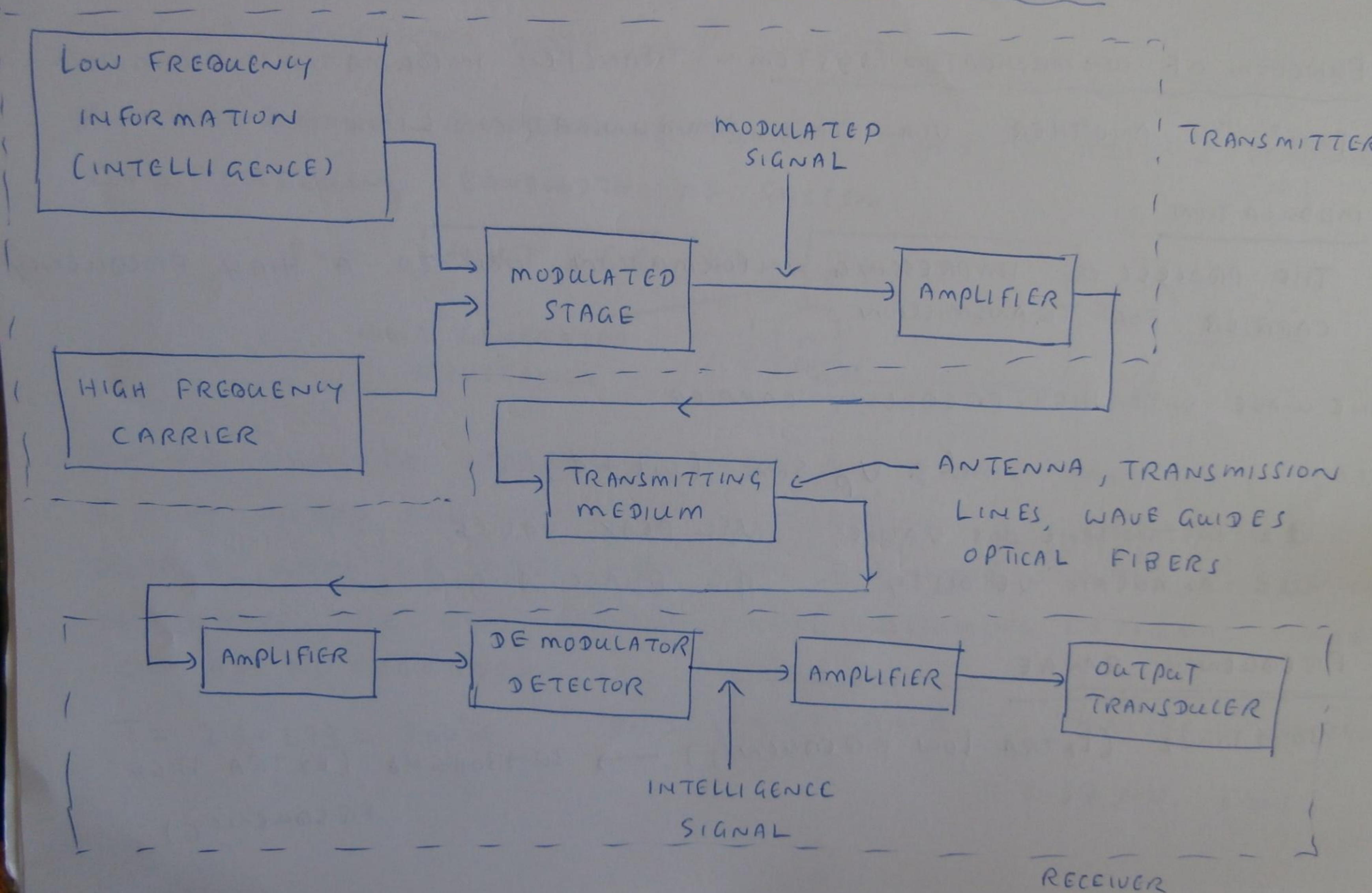
$\omega$ = ANGULAR VELOCITY $\phi$ = PHASE ANGLE

## FREQUENCY RANGE

30 → 300 Hz (EXTRA LOW FREQUENCY) ⟶ 30 → 300 GHz (EXTRA HIGH FREQUENCY)

COMMUNICATION SYSTEM BLOCK DIAGRAM





INTERNAL NOISE (THERMAL NOISE)

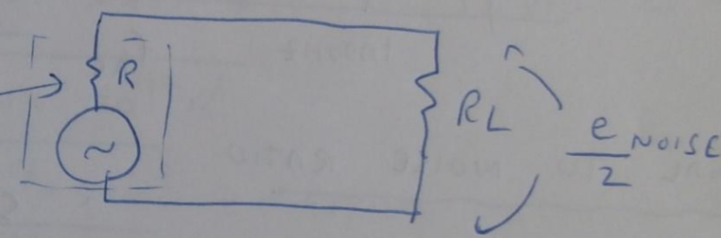
POWER OF GENERATED NOISE $P_n = KT\Delta f$

$K$ = BOLTZMANN'S CONSTANT ($1.38 \times 10^{-23}$ J/K), $T$ = RESISTOR TEMPERATURE (°K)

$\Delta f$ = FREQUENCY BANDWIDTH OF SYSTEM

$$e_n = \sqrt{4KT\Delta f R}$$

NOISE GENERATED RESISTANCE



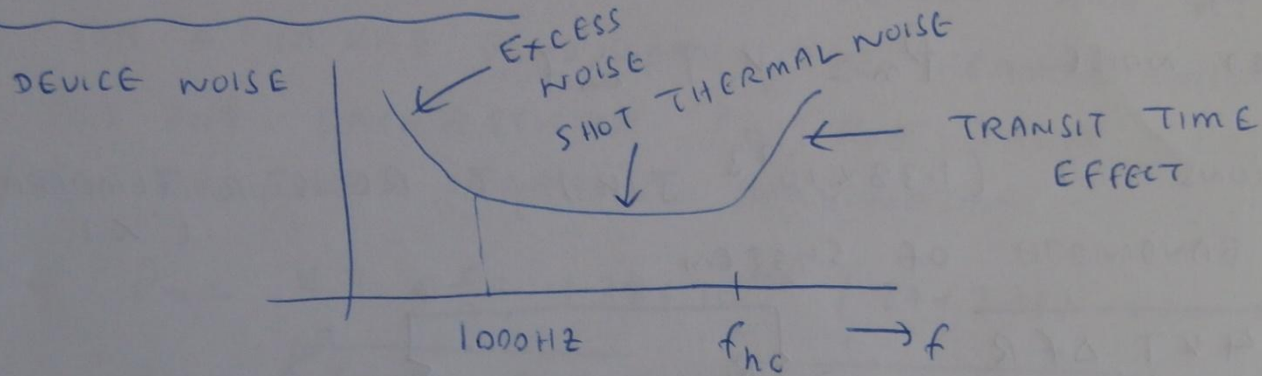

Pb — AN AMPLIFIER OPERATING OVER A 4 MHZ BANDWIDTH HAS A 100Ω INPUT RESISTANCE. IT IS OPERATING AT 27°C HAS A VOLTAGE GAIN OF 200, AND HAS AN INPUT SIGNAL OF 5 μV rms. DETERMINE THE rms OUTPUT SIGNAL. ASSUMING EXTERNAL NOISE CAN BE DISREGARDED.

$T = 27 + 273 = 300$ °K

$$e_n = \sqrt{4KT\Delta f R} = \sqrt{4 \times 1.38 \times 10^{-23} \times 300 \times 4 \times 100}$$

$= 2.57$ μV rms.

## FREQUENCY NOISE EFFECT




## SIGNAL TO NOISE RATIO

$$\text{SIGNAL TO NOISE RATIO} = \frac{\text{SIGNAL POWER}}{\text{NOISE POWER}} = \frac{S}{N} = \frac{P_S}{P_N} = 10 \log_{10} \frac{P_S}{P_N} \text{ (dB)}$$

**Pb** A TRANSISTOR AMPLIFIER HAS A MEASURED S/N OF 10 AT IT'S INPUT AND 5 AT IT'S OUTPUT. CALCULATE THE TRANSISTOR NOISE RATIO.

$$NR = 10 \log \frac{S_i/N_i}{S_o/N_o} = 10 \log \frac{10}{5} = 10 \log 2 = 3 \text{ dB}$$

**Pb** TWO RESISTORS $5\,k\Omega$ AND $20\,k\Omega$ ARE AT 27°C. CALCULATE S FOR A 10 KHZ BANDWIDTH, THE THERMAL NOISE POWER AND VOLTAGE (a) FOR EACH RESISTOR (b) FOR THEIR SERIES COMBINATION (c) FOR THEIR PARALLEL COMBINATION

(a) $P_n = kT\Delta f = 1.38 \times 10^{-23}(27+273) \times 10 = 4.14 \times 10^{-17}\,W$

$e_n = \sqrt{4kT\Delta f R} = \sqrt{4 \times 4.14 \times 10^{-17} R}$

FOR $5\,k\Omega \rightarrow$ $e_n = \sqrt{4 \times 4.14 \times 10^{-17} \times 5 \times 10^{3}} = 0.91\,\mu V$

FOR $20\,k\Omega \rightarrow$ $e_n = \sqrt{4 \times 4.14 \times 10^{-17} \times 20 \times 10^{3}} = 1.82\,\mu V$

(b) FOR SERIES $R = (20+5)\,k\Omega$

$e_n = \sqrt{4 \times 4.14 \times 10^{-17}(20+5) \times 10^{3}} = 2.03\,\mu V$

(c) $R = \dfrac{5 \times 20}{5+20} = 4\,k\Omega$ $e_n = \sqrt{4 \times 4.14 \times 10^{-17} \times 4 \times 10^{3}}$

$= 0.81\,\mu V$

## NOISE DUE TO AMPLIFIERS IN CASCADE

$$NR = NR_1 + \frac{NR_2 - 1}{PG_1} + \cdots + \frac{NR_n - 1}{PG_1 \times PG_2 \times \cdots PG_{(n-1)}}$$

PD A THREE STAGE AMPLIFIER HAS A 3dB BANDWIDTH OF 200 KHZ. DETERMINED BY AN LC TUNED CIRCUIT AT IT'S INPUT. AND OPERATES AT 22°C. THE FIRST STAGE HAS A POWER GAIN OF 14dB AND NF OF 3dB. THE SECOND AND THIRD STAGES ARE IDENTICAL. WITH POWER GAINS OF 20dB AND NF = 8dB. THE OUTPUT LOAD IS 300 Ω. THE INPUT NOISE IS GENERATED BY A 10 kΩ RESISTOR. CALCULATE

(a) THE NOISE VOLTAGE AND POWER AT THE INPUT AND THE OUT PUT OF THIS SYSTEM

(b) OVER ALL NOISE FIGURE

(c) ACTUAL OUT PUT NOISE AND POWER

| FIRST STAGE | 2nd STAGE | 3rd STAGE |
|---|---|---|
| 14dB, NF = 3dB | 20dB | 20dB |
| | NF = 8dB | NF = 8dB |

$$P_{NOISE\ OUT} = P_{NOISE\ IN} \times P_G$$

$P_{NOISE\ IN}$ ← $kT\Delta f$, where $\Delta f$ ← $\frac{\pi}{2}$ BW

$P_G$ ← ANTI LOG TOTAL GAIN dB

$\Delta f = \frac{\pi}{2} BW = \frac{3.14}{2} \times 200 \times 10^3 = 3.14 \times 10^5$ Hz

$P_{NOISE} = KT\Delta f = 1.38 \times 10^{-23} \times (273+22) \times 3.14 \times 10^5 = 1.28 \times 10^{-15}$ W

$PG = \text{ANTI LOG } \frac{dB}{10}$

TOTAL POWER GAIN = 14+20+20 = 54 dB

$PG = \text{ANTI LOG } \frac{54}{10} dB = 2.51 \times 10^5$

$P_{NOISE\ OUT} = P_{NOISE\ IN} \times PG = 2.51 \times 10^5 \times 1.28 \times 10^{-15}$ W $= 3.22 \times 10^{-10}$ W

NOISE VOLTAGE $e_{NOISE} = \sqrt{4KT\Delta f R} = \sqrt{4 \times 1.38 \times 10^{-23} (273+22) \times 3.14 \times 10^5 \times 10 \times 10^3}$

$= 7.15\ \mu V$

NOISE VOLTAGE AT OUT PUT $= \sqrt{P_{NOISE\ OUT} \times R_{OUT}} = e_{noise\ out}$

$e_{NOISE\ OUT} = \sqrt{3.22 \times 10^{-16} \times 300} = 0.311$ mV

(b)

OVER ALL NOISE FIGURE $PG_1$ = ANTILOG GAIN 1 = ANTILOG $\frac{14}{10}$ = 25.1

$PG_2 = PG_3$ = ANTILOG GAIN 2 = 3 = ANTILOG $\frac{20}{10}$ = 100

$NF_1$ = 3dB → $NR_1$ = ANTILOG $\frac{NF_1}{10}$ = ANTILOG $\frac{3}{10}$ = 2

$NF_2 = NF_3 = 8dB \longrightarrow NR_2 = NR_3 = \text{ANTILOG } \frac{NF_2 \text{ (or) } NF_3}{10}$ 8

$= \text{ANTILOG } \frac{8}{10} = 6.31$

$$NR = NR_1 + \frac{NR_2 - 1}{PG_1} + \text{---} + \frac{NR_n - 1}{PG_1 \, PG_2 \text{ --- } PG_{(n-1)}}$$

$$= NR_1 + \frac{NR_2 - 1}{PG_1} + \text{---} \frac{NR_3 - 1}{PG_1 \, PG_2 \; PG_{(3-1)}}$$

$$= NR_1 + \frac{NR_2 - 1}{PG_1} + \text{---} \frac{NR_2}{PG_1 \, PG_2}$$

$$= 2 + \frac{6.31 - 1}{25.1} + \frac{6.31 - 1}{25.1 \times 100}$$

$$= 2.212$$

OVER ALL NOISE $NF = 10 \log NR = 10 \log 2.212 = 3.45 dB$

$$NR = \frac{N_O}{N_i \times PG} \implies 2.212 = \frac{N_O}{1.28 \times 10^{-15} \times 2.51 \times 10^5} \implies N_O = 7.11 \times 10^{-16} W$$

$$e_n = \sqrt{N_O \times R_{out}} = \sqrt{7.11 \times 10^{-16} \times 300} = 0.462 mV$$

# INFORMATION AND BANDWIDTH

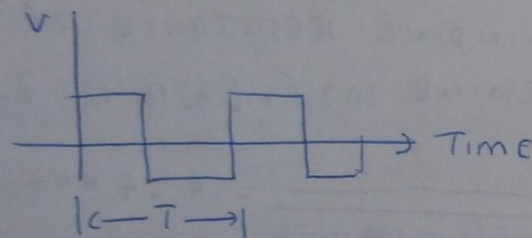
## HARTLEY'S LAW

INFORMATION $\propto$ BANDWIDTH $\propto$ TIME OF TRANSMISSION

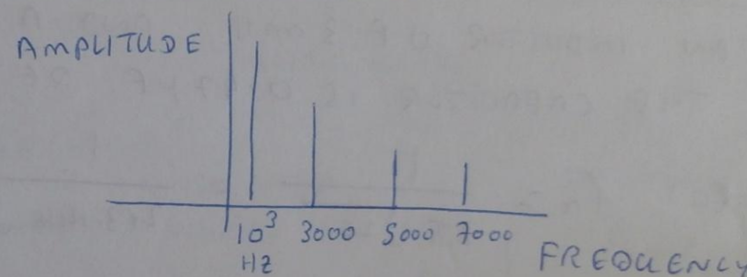
TV CHANNEL - BANDWIDTH = 600 x AM BANDWIDTH

VIDEO SIGNAL - PULSE WAVEFORM

## TIME DOMAIN



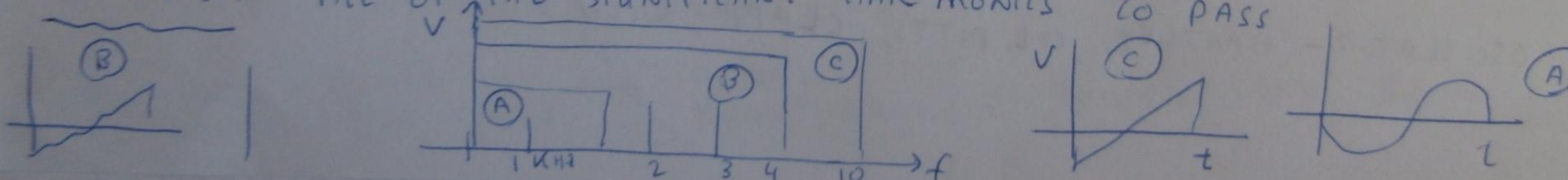

## FREQUENCY DOMAIN



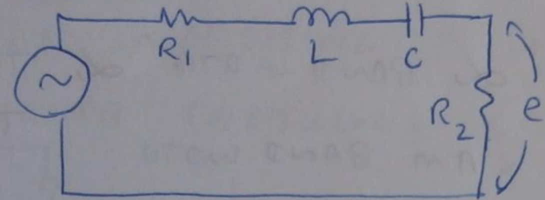

**FILTER (A)** FULLY PASSED AWAY, A SINE WAVE AT 1 KHZ, NO OUTPUT AT 2 KHZ

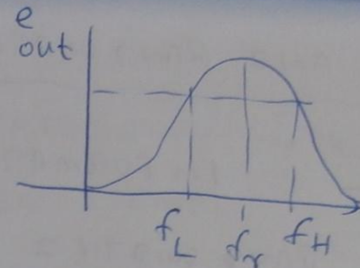
**FILTER (B)** PASSING SAWTOOTH + FIRST FOUR HARMONICS

**FILTER (C)** ALL OF THE SIGNIFICANT HARMONICS TO PASS



# LC BY PASS FILTER




$$BW = \frac{R}{2\pi L}$$

$$Q = \frac{f_r}{BW}$$

BW - BAND WIDTH (HZ), R = TOTAL CIRCUIT RESISTANCE $Q = \frac{\omega L}{R}$

**PD** A PARALLEL LC TANK CIRCUIT IS MADE UP OF AN INDUCTOR OF 3 mH, AND A WINDING RESISTANCE OF 2Ω THE CAPACITOR IS 0.47 μF. DETERMINE (a) $f_r$ (b) Q (c) $Z_{max}$ (d) BW

(a) $f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\times 3.1416\sqrt{3\times10^{-3}\times 0.47\times10^{-6}}} = 4.24\ kHz$

(b) $Q = \frac{X_L}{R} = \frac{2\pi f_r L}{R} = \frac{2\times 3.1416\times 4.24\times10^{3}\times 3\times10^{-3}}{2} = 39.9$

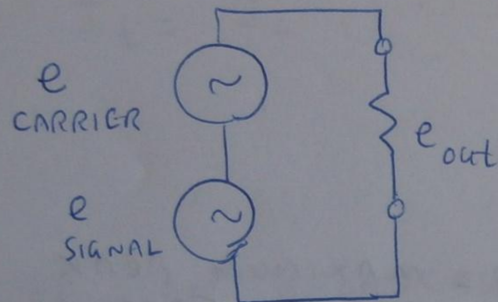
(c) $Z_{max} = Q^2\times R = (39.9)^2\times 2 = 3.19\ k\Omega$

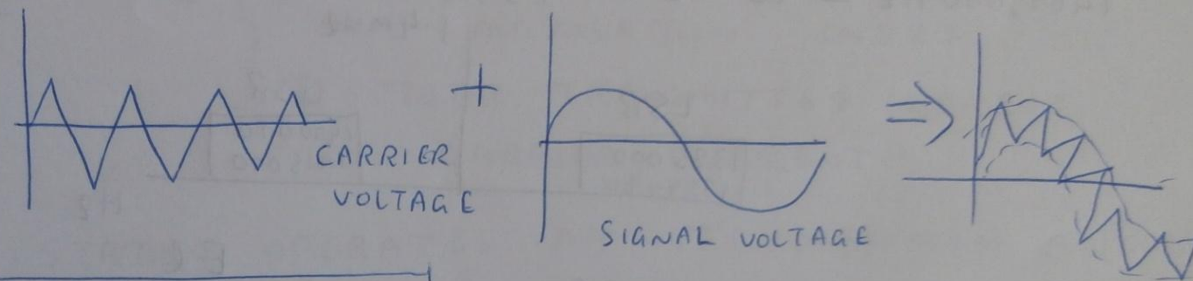
(d) $BW = \frac{R}{2\pi L} = \frac{2\Omega}{2\times 3.1416\times 3\times10^{-3}} = 106\ HZ$

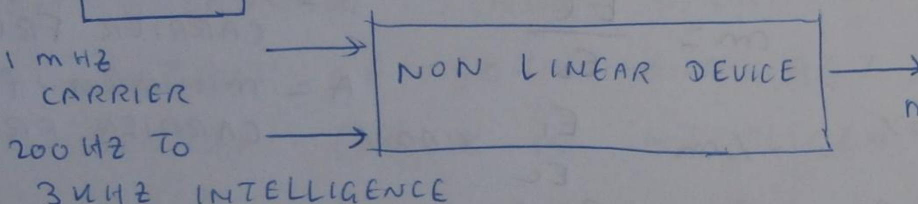
OSCILLATOR - HARTLEY, COL PITTS, CLAPP, WIEN

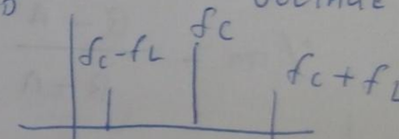
# AMPLITUDE MODULATION

THE PROCESS OF IMPRESSING A LOW FREQUENCY INTELLIGENCE SIGNAL ON TO A HIGHER FREQUENCY CARRIER SIGNAL.



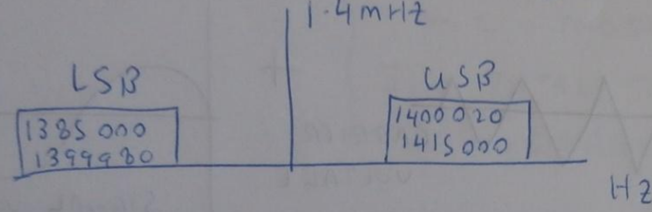

pb A 1.4 MHZ CARRIER IS MODULATED BY A MUSIC SIGNAL THAT HAS FREQUENCY COMPONENTS FROM 20 HZ TO 15 KHZ. DETERMINE THE RANGE OF FREQUENCIES GENERATED FOR UPPER AND LOWER SIDEBANDS

CARRIER + (SIGNAL LOWER RANGE ⟶ SIGNAL HIGHEST RANGE = UPPER SIDE BAND

CARRIER − (SIGNAL LOWER RANGE ⟶ SIGNAL HIGHEST RANGE = LOWER SIDE BAND

1400,000 HZ + 20 HZ = 1400 020 HZ
1400,000 HZ + 15000 HZ = 1415 000 HZ } UPPER SIDE BAND

1400,000 HZ − 15000 HZ = 1385 000 HZ
1400,000 HZ − 20 HZ = 1399 980 HZ } LOWER SIDE BAND




m = MODULATION INDEX

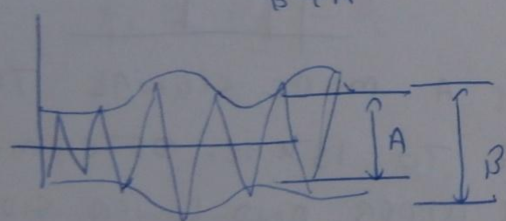
$$m = \frac{E_l}{E_c}$$

B = MAXIMUM PEAK CARRIER FREQUENCY
A = MINIMUM PEAK CARRIER FREQUENCY

$$\%m = \frac{B-A}{B+A} \times 100\%$$

$$\%m = \frac{E_i}{E_c} \times 100\%$$

$$\%m = \frac{B-A}{B+A} \times 100\%$$




Pb MAXIMUM P-P CARRIER 100V
MINIMUM P-P CARRIER 60V
FIND %m

$$\%m = \frac{B-A}{B+A} \times 100 = \frac{100-60}{100+60} \times 100 = 25\%$$

$A = E_c + E_i$, m = MODULATION INDEX
$E_i = m E_c$, $E_c$ = CARRIER AMPLITUDE

$$e = E_c \sin \omega_c t + \frac{m E_c}{2} \cos(\omega_c - \omega_i)t - \frac{m E_c}{2} \cos(\omega_c + \omega_i)t$$

(1) CARRIER (2) LOWER SIDE BAND (3) UPPER SIDE BAND

# HIGH PERCENTAGE MODULATION

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

$$I_t = I_c\sqrt{1+\frac{m^2}{2}}$$

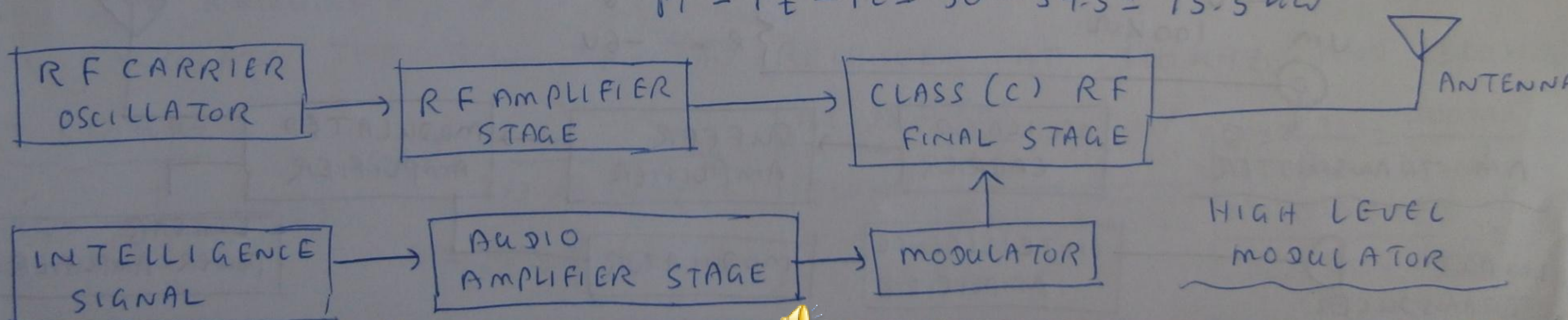
- $P_t$ = TRANSMITTED POWER OF SIDE BAND & CARRIER
- $P_c$ = CARRIER POWER
- $m$ = MODULATION INDEX
- $I_t$ = TOTAL TRANSMITTED CURRENT
- $I_c$ = CARRIER CURRENT

**Pb** AN BROADCAST STATION OPERATES AT IT'S MAXIMUM ALLOWED TOTAL OUTPUT OF 50KW AND 95% MODULATION. HOW MUCH OF IT'S TRANSMITTED POWER IS INTELLIGENCE?

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

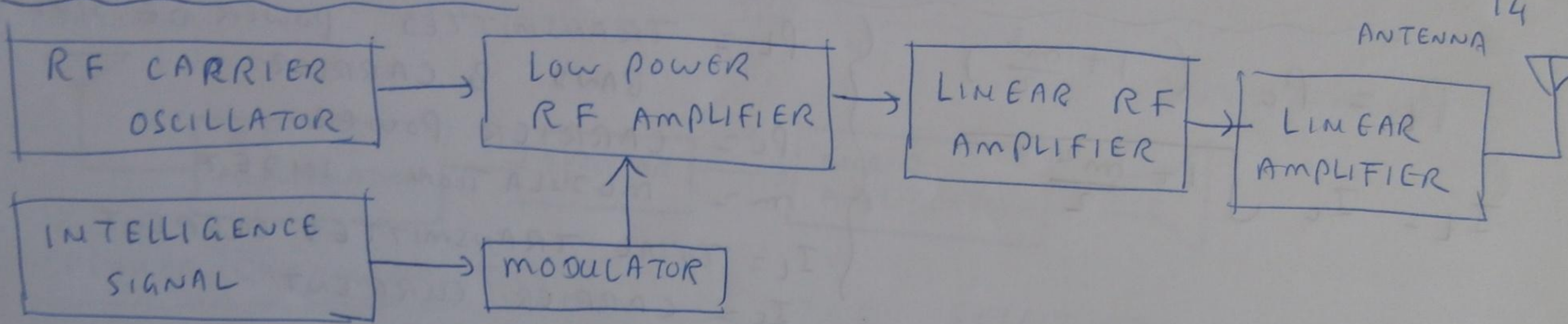
$50 = P_c\left(1+\frac{0.95^2}{2}\right) \Rightarrow P_c = 34.5kw$

$P_i = P_t - P_c = 50 - 34.5 = 15.5\,kw$

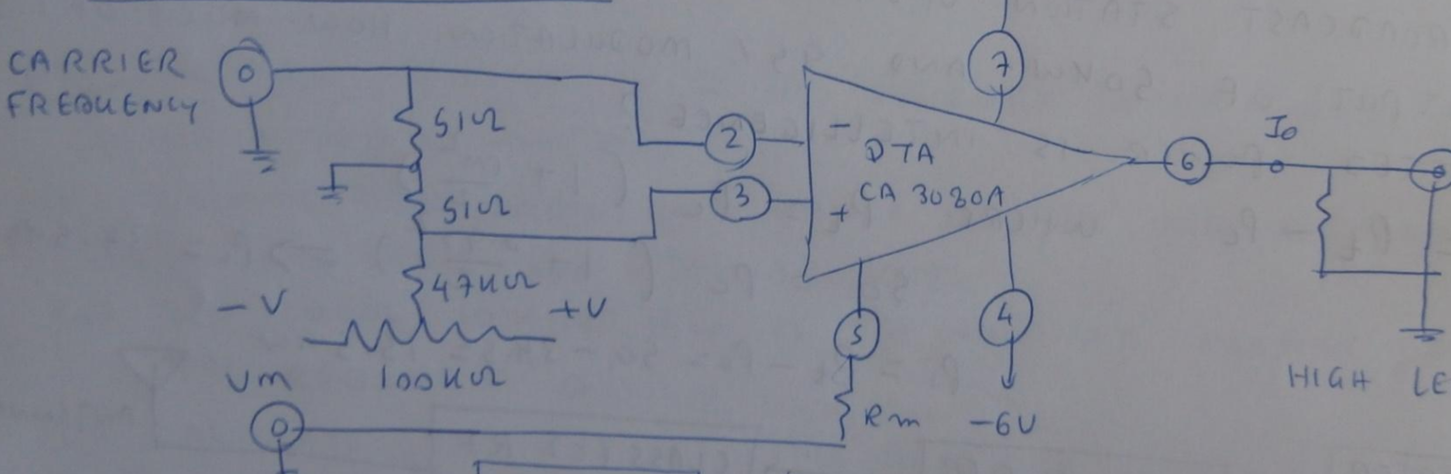



HIGH LEVEL MODULATOR

## LOW LEVEL MODULATOR

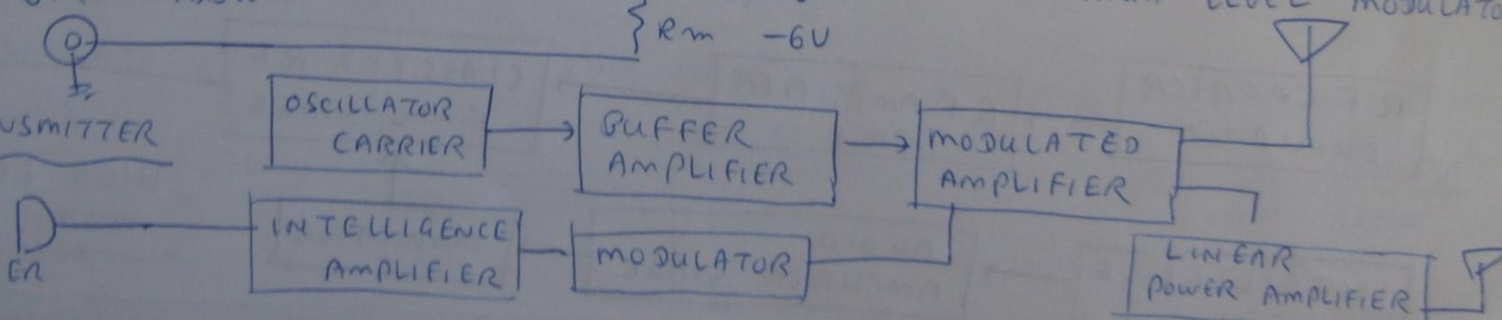



## AMPLITUDE MODULATOR



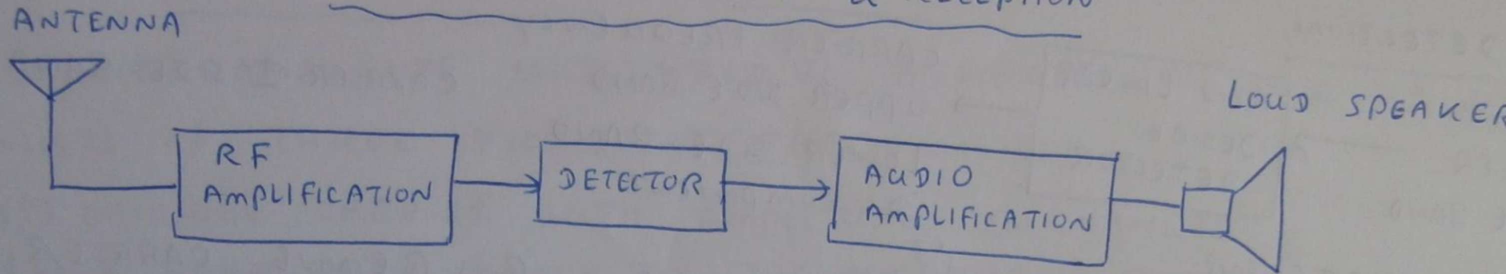

## HIGH LEVEL MODULATOR

## AM TRANSMITTER



# AMPLITUDE MODULATION & RECEPTION






## SPEAKER CHARACTERISTICS

SENSISTIVITY, SELECTIVITY

TRF SELECTIVITY

$$Q = \frac{f}{BW}$$

**PB** A TRF RECEIVER IS TO BE DESIGNED WITH A SINGLE TUNED CIRCUIT USING A 10 $\mu$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 B.W OF THIS RECEIVER AT 550 KHZ AND 1550 KHZ

AT 550 KHZ

$$f_r = \frac{1}{2\pi\sqrt{LC}} \Rightarrow 550\times10^3 = \frac{1}{2\times3.1416\sqrt{10\times10^{-6}\times C}}$$

C = 8.37 mF

AT 1550 KHZ

$$1550\times10^3 = \frac{1}{2\times3.1416\sqrt{10\times10^{-6}\times C}}$$

C = 1.06 mF

$$Q = \frac{f_r}{BW} = \frac{1100\times10^3}{10\times10^3} = 11$$

AT 1550 KHZ

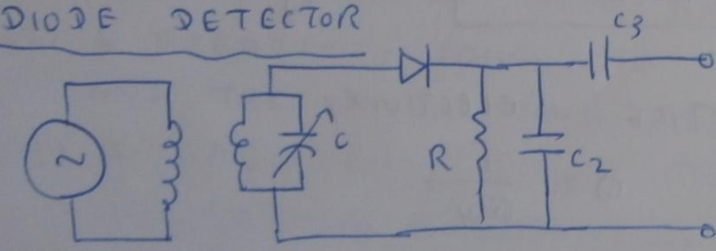
$$BW = \frac{f_r}{Q} = \frac{1550\times10^3}{110} = 14.1 \text{ KHZ}$$

## AM DETECTION

INPUT: CARRIER, SIDE BAND → NON LINEAR DEVICE DETECTOR → OUTPUT:
- CARRIER FREQUENCY
- UPPER SIDE BAND
- LOWER SIDE BAND
- DC COMPONENT

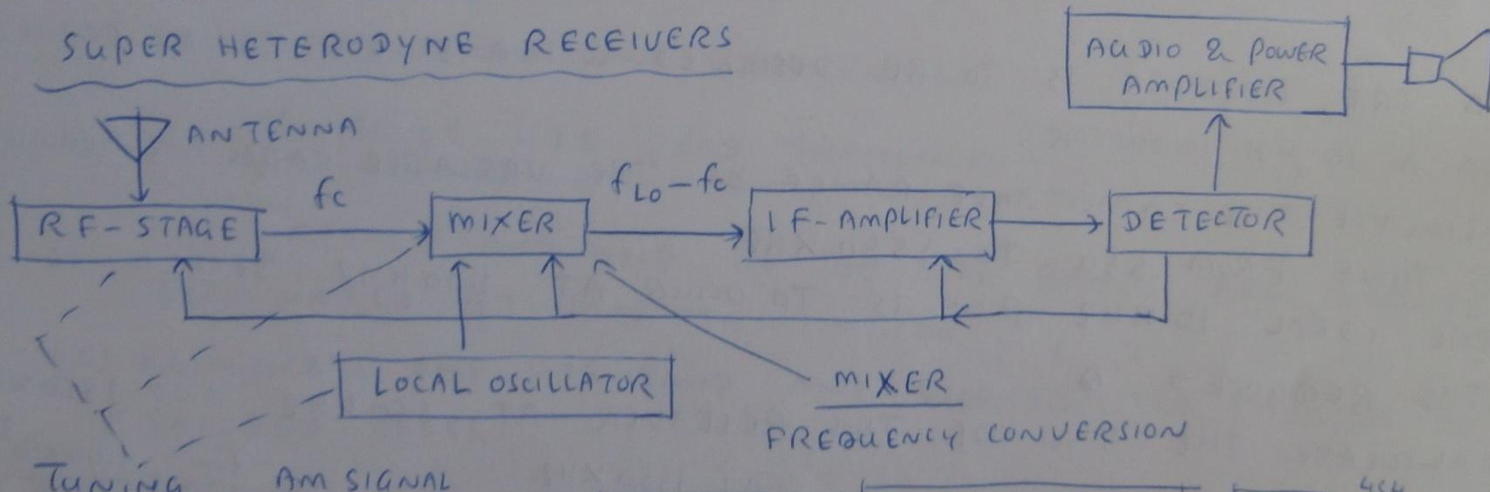
CARRIER ± SIDE BAND

## DIODE DETECTOR

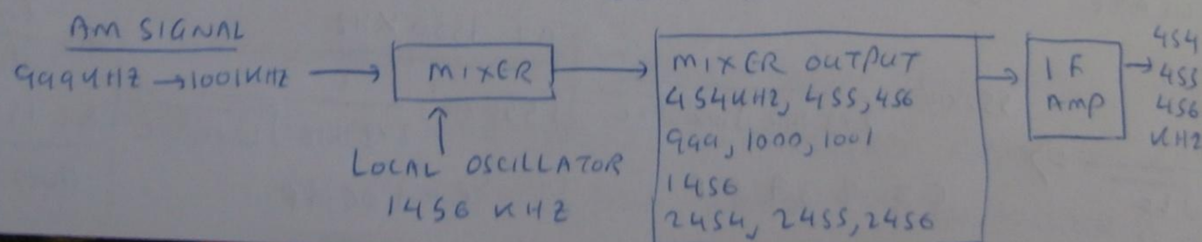



C2 AND R REMOVE CARRIER FREQUENCY

## SUPER HETERODYNE RECEIVERS




FREQUENCY CONVERSION



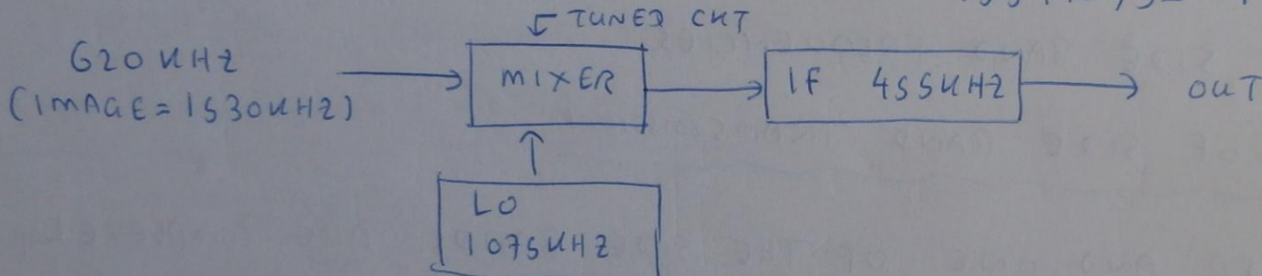
LOCAL OSCILLATOR FREQUENCY − DESIRED STATION'S FREQUENCY = IF - FREQUENCY

**pb** DETERMINE THE IMAGE FREQUENCY FOR A STANDARD BROADCAST BAND RECEIVER USING A 455 KHZ AND TUNED TO A STATION AT 620 KHZ.

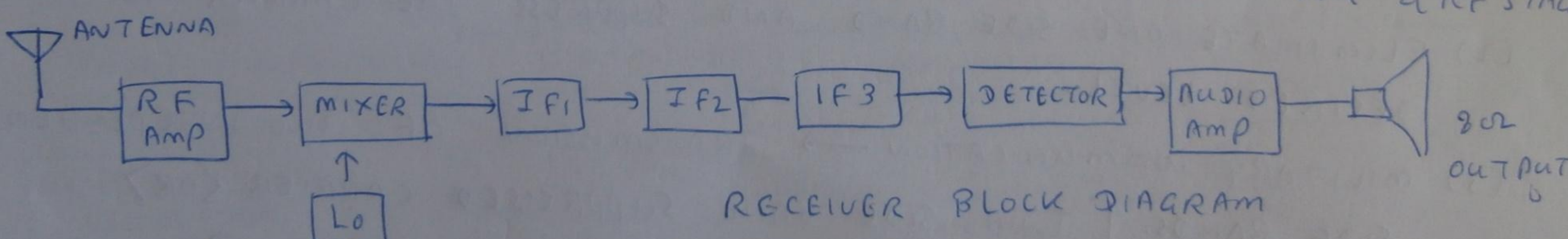
LO − STATION FREQUENCY = IF

LO − 620 = 455 → LO = 620 + 455 = 1075 KHZ

IMAGE FREQUENCY = IF + LO = 455 + 1075 = 1530 KHZ




AUTOMATIC GAIN CONTROL → TO CONTROL THE GAIN OF MIXER & RF STAGES




RECEIVER BLOCK DIAGRAM

## SINGLE SIDE BANDED COMMUNICATION

A CARRIER AMPLITUDE MODULATED BY A SINGLE SINE WAVE OF VOLTAGE CONSISTS OF THREE DIFFERENT FREQUENCIES

(1) ORIGINAL CARRIER WITH AMPLITUDE UNCHANGED

(2) A FREQUENCY EQUAL TO THE DIFFERENCE BETWEEN THE CARRIER AND THE MODULATING FREQUENCIES.

(3) A FREQUENCY EQUAL TO THE SUM OF THE CARRIER AND MODULATING FREQUENCIES

(2) & (3) ARE SIDE BAND FREQUENCIES

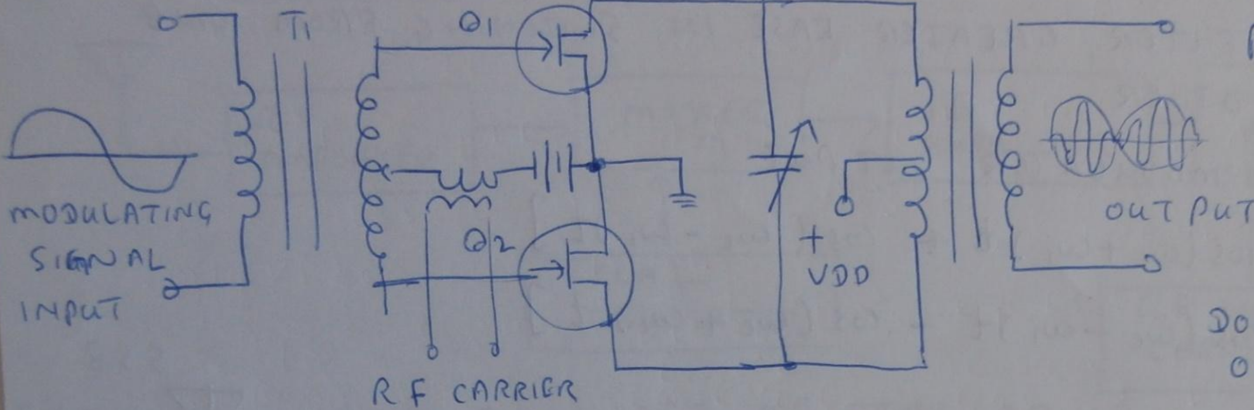
## TYPES OF SIDE BAND TRANSMISSION

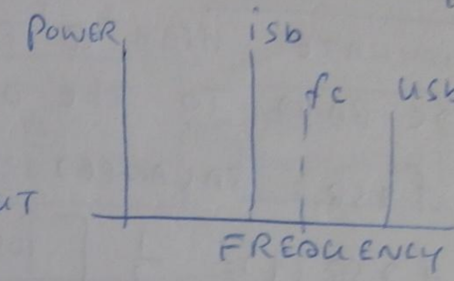
(1) THE CARRIER AND ONE OF THE SIDE BANDS ARE COMPLETELY ELIMINATED AT THE TRANSMITTER

(2) ELIMINATE ONE SIDE BAND AND SUPPRESS THE CARRIER TO A DESIRED LEVEL.

(3) MILITARY COMMUNICATION ⟶ TRANSMISSION OF TWO INDEPENDENT SIDE BANDS. [TWIN SIDE BAND SUPPRESSED CARRIER <OR> INDEPENDENT SIDE BAND TRANSMISSION]

# PUSH PULL AMPLIFIER WITH SIGNAL APPLIED IN PHASE



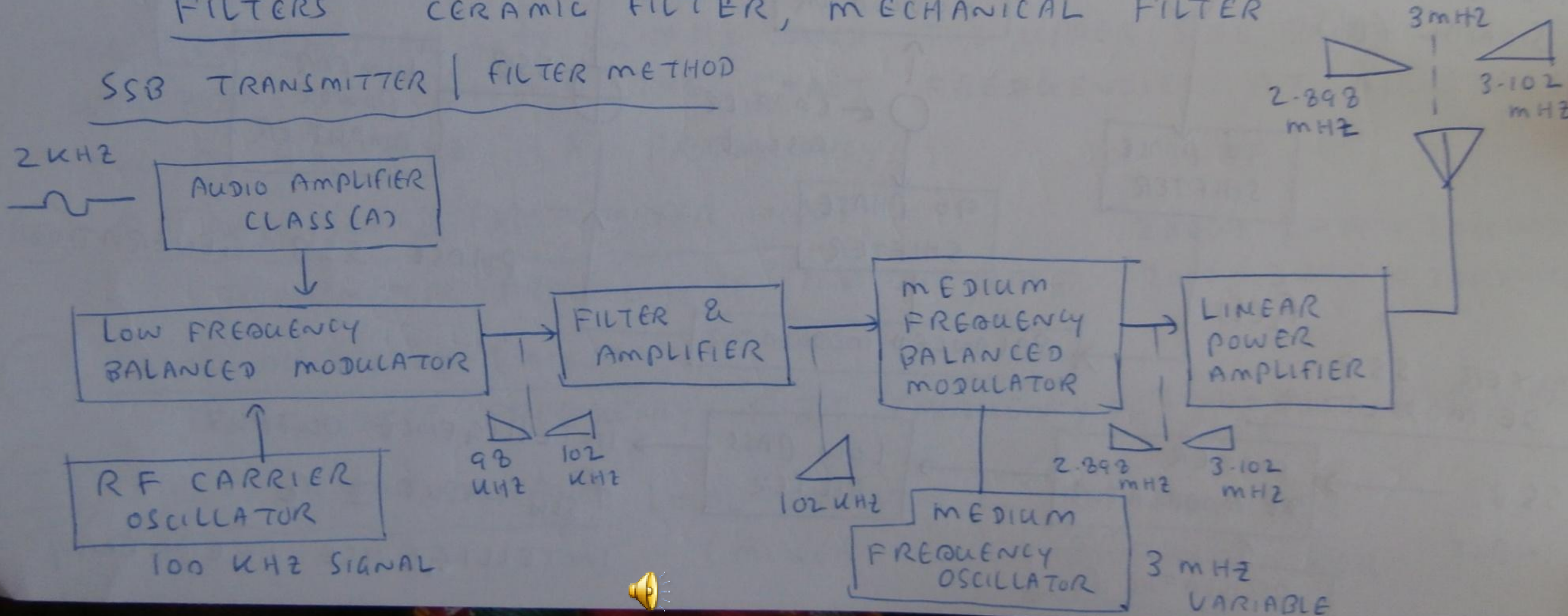




DOUBLE SIDE BANDED OUTPUT SIGNAL

BALANCED RING MODULATOR

**FILTERS** CERAMIC FILTER, MECHANICAL FILTER

## SSB TRANSMITTER | FILTER METHOD



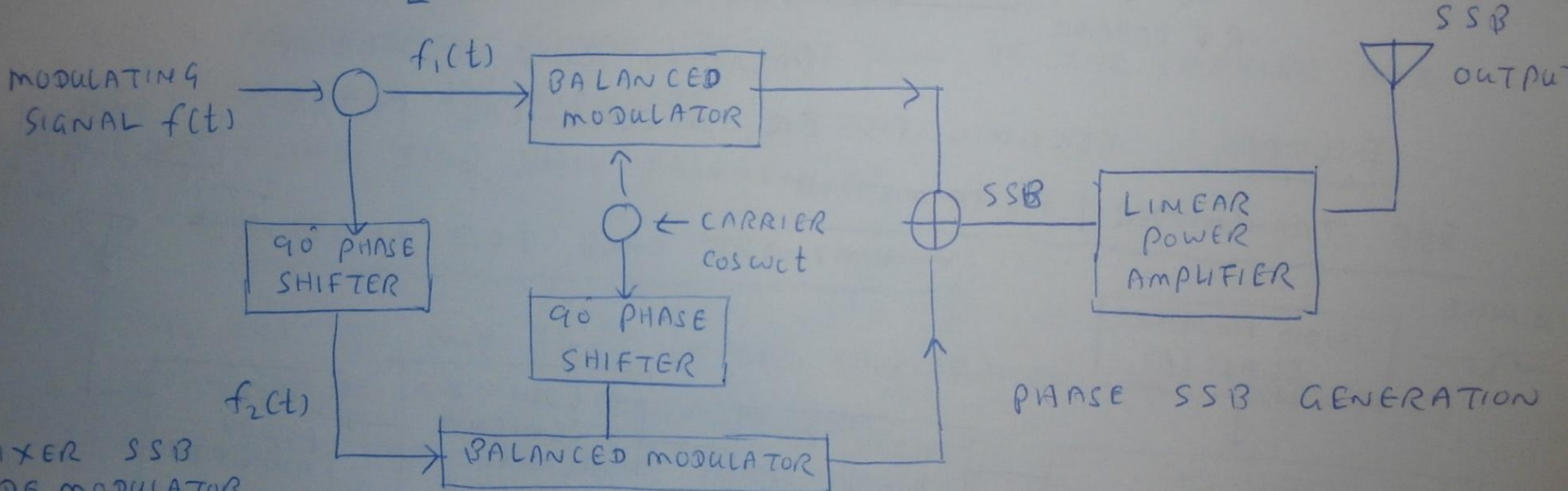
## PHASE METHOD

- ELIMINATE HIGH 'Q' FILTER, GREATER EASE IN SWITCHING FROM ONE SIDE BAND TO THE OTHER

$f_{DSB}$ = BALANCED MODULATOR OUTPUT

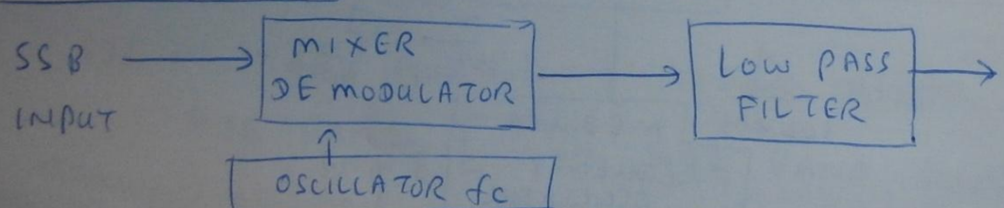
$$f_{DSB_1}(t) = \frac{1}{2}\left[\cos(\omega_c+\omega_i)t + \cos(\omega_c-\omega_i)t\right]$$

$$f_{DSB_2}(t) = \frac{1}{2}\left[\cos(\omega_c-\omega_i)t - \cos(\omega_c+\omega_i)t\right]$$




PHASE SSB GENERATION

## MIXER SSB DE MODULATOR

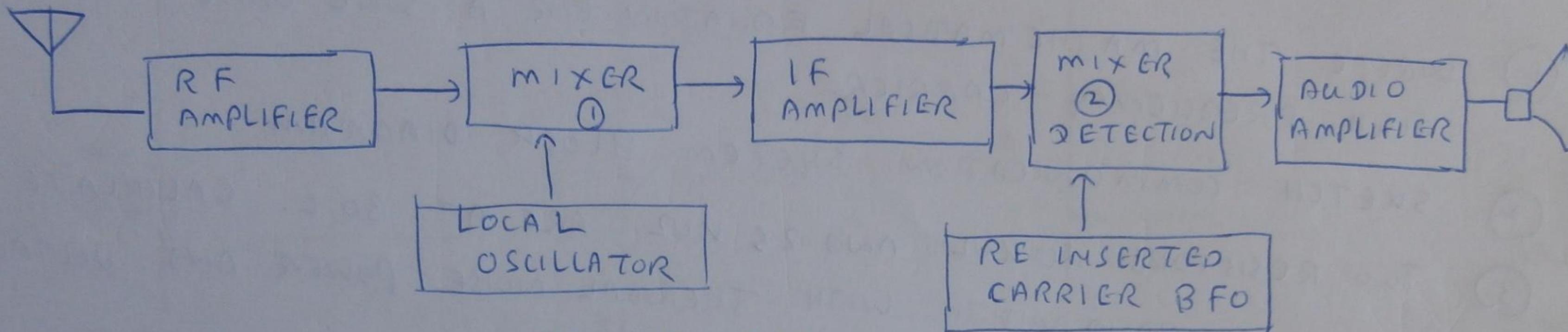



$f_{SSB}$ INPUT $\pm$ $f_c$

INTELLIGENCE FREQUENCY

# SSB RECEIVER






**Pb** THE SSB RECEIVER OF THE ABOVE DIAGRAM HAS OUTPUTS AT 1 KHZ AND 3 KHZ. THE CARRIER USED AND SUPPRESSED AT THE TRANSMITTER WAS 2 MHZ AND THE UPPER SIDE BAND WAS UTILIZED. DETERMINE THE EXACT FREQUENCIES AT ALL STAGES FOR A 455 MHZ IF FREQUENCY.

(I) RF AMPLIFIER & FIRST MIXER INPUT

TRANSMITTER FREQUENCY + TWO OUTPUTS = 2000 + 1 KHZ = 2001 KHZ; 2000 + 3 KHZ = 2003 KHZ

(II) LOCAL OSCILLATOR (MIXER)

TRANSMITTER FREQUENCY + IF FREQUENCY = 2000 + 455 = 2455 KHZ

(III) FIRST MIXER OUTPUT: LOCAL OSCILLATOR (MIXER) − RF AMPLIFIER & FIRST MIXER

# EXERCISE



1. WRITE THE MATHEMATICAL EQUATION FOR A SINE WAVE WITH HIGH FREQUENCY CARRIER.
2. SKETCH COMMUNICATION SYSTEM BLOCK DIAGRAM.
3. TWO RESISTORS 10 kΩ AND 25 kΩ ARE AT 30°C. CALCULATE 25 kHz BANDWIDTH WITH THERMAL NOISE POWER AND VOLTAGE FOR EACH RESISTOR.
4. EXPLAIN VIDEO FILTER CLASS A, B AND C.
5. CALCULATE % MODULATION FOR MAXIMUM P-P CARRIER VOLTAGE 200V
   MINIMUM P-P CARRIER VOLTAGE 80V
6. SKETCH THE BLOCK DIAGRAM OF HIGH LEVEL MODULATOR
7. SKETCH THE BLOCK DIAGRAM OF SUPER HETERODYNE RECEIVER
8. EXPLAIN THE TYPES OF SIDE BAND TRANSMISSION.
9. SKETCH THE CIRCUIT OF PUSH PULL AMPLIFIER WITH SIGNAL APPLIED IN PHASE
10. EXPLAIN PHASE METHOD WITH DIAGRAM & EQUATIONS.