week 1

①

communication Fundamental

The function of a communication system is to 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.

- Allows propagation of the low frequency intelligence with a high frequency carrier.

mathematical representation of a sinewave with high frequency carrier

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

v = instantaneous value, V_p = peak value

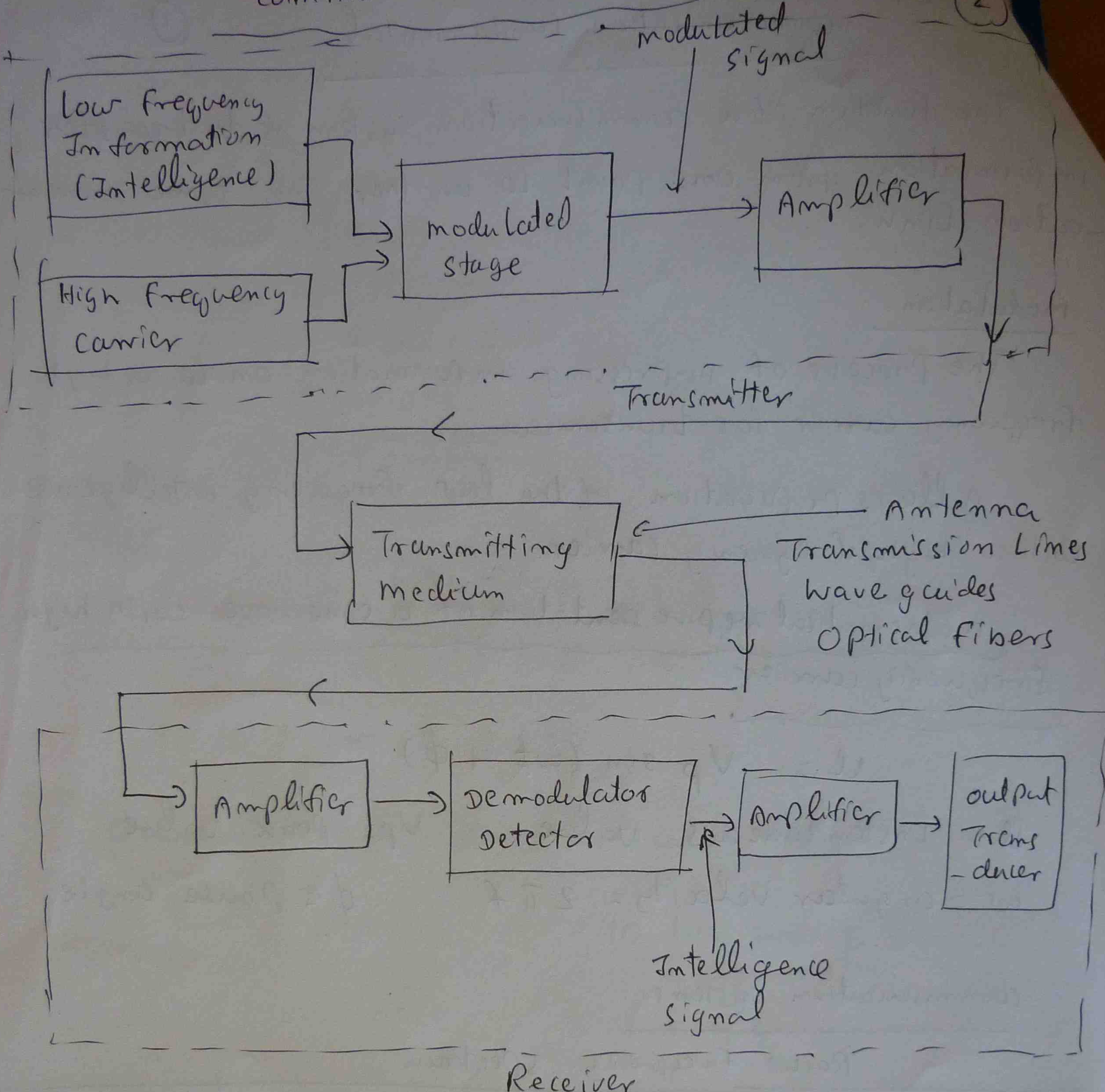
ω = angular velocity = $2\pi f$ $\quad$ ϕ = phase angle.

communication systems

Radio frequency spectrum

Frequency	Designation	Abbreviation
30 → 300 HZ	Extremely low frequency	ELF
300 → 3000 HZ	voice frequency	VF
3 → 30 KHZ	very low frequency	VLF
30 → 300 KHZ	Low frequency	LF
300 KHZ — 3 MHZ	medium frequency	MF
3 → 30 MHZ	High frequency	HF
30 → 300 MHZ	very High frequency	VHF
300 MHZ → 3 GHZ	ultra High Frequency	UHF
3 → 30 GHZ	super High frequency	SHF
30 → 300 GHZ	Extra High frequency	EHF

Communication System Block Diagram



Noise

- Any undesired voltages or currents that ultimately end up appearing in the receiver output

Noise introduced in the transmitting medium ⟶ External Noise

Noise introduced in the receiver ⟶ Internal noise.

External noise

man made noise, Atmospheric noise, space noise

Internal noise

Thermal noise

Power of generated noise

$$P_n = KT\Delta f$$

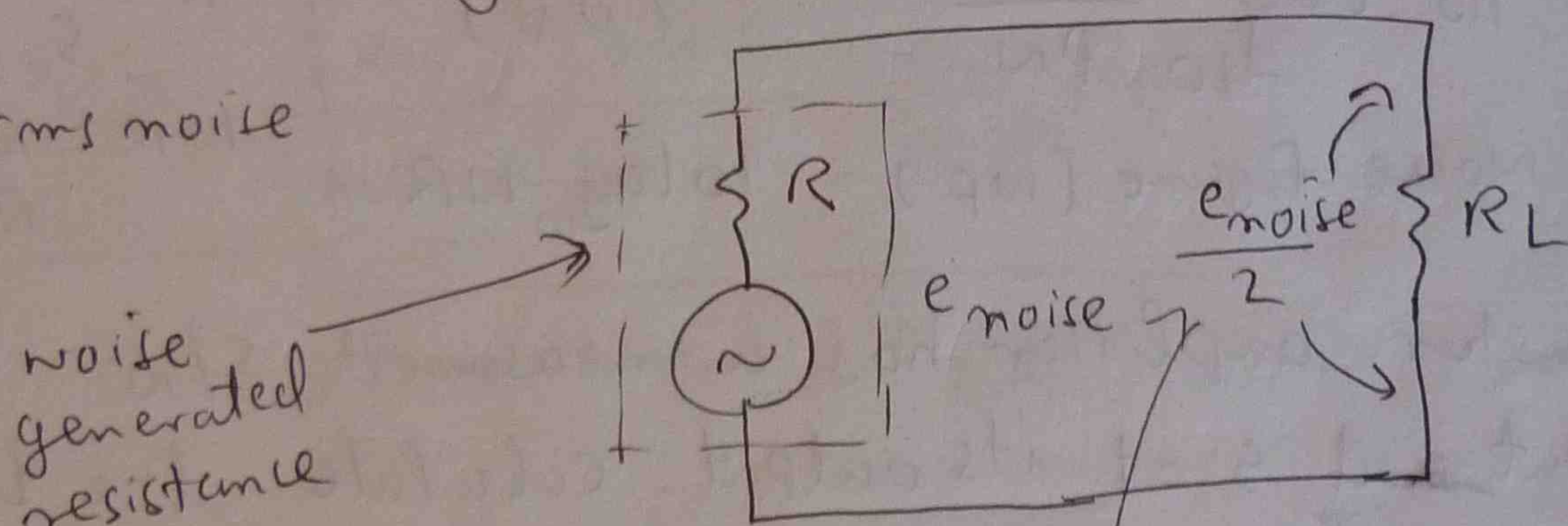
K = Boltzmann's constant (1.38×10^{-23} J/K)

T = Resistor temperature (°K)

Δf = Frequency band width of ~~with~~ the system.

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

e_n = rms noise



maximum noise power voltage when $R = R_L$

Ex 1-1

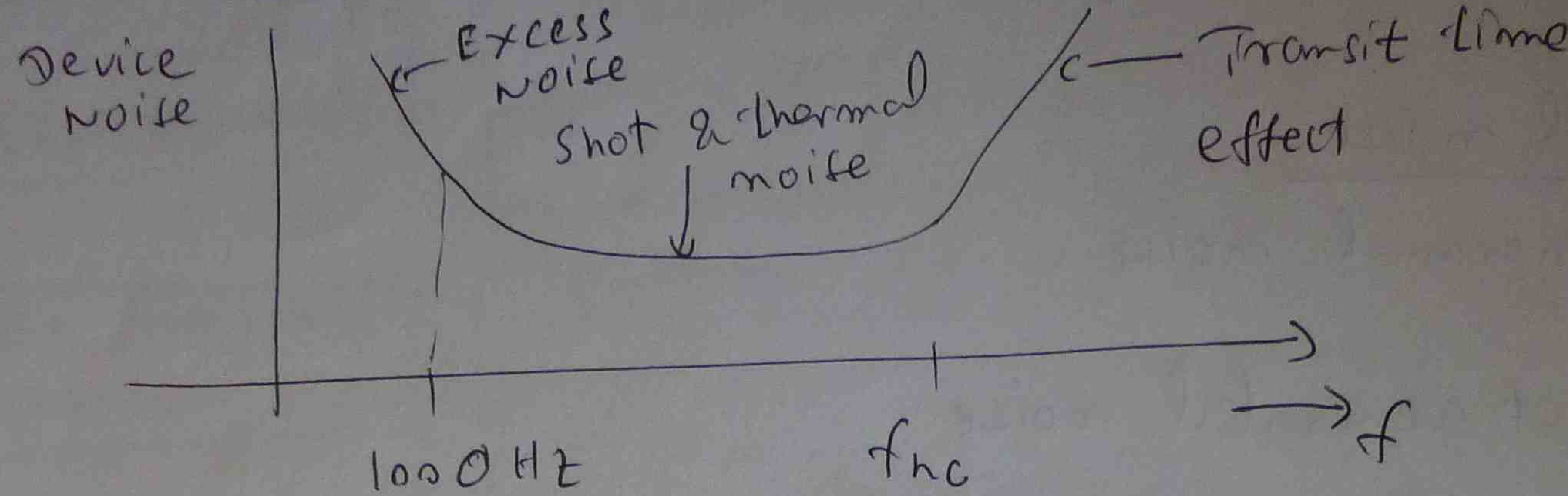
An amplifier operating over a 4 MHz band width has a 100Ω input resistance. It is operating at 27°C has a voltage gain of 200, and has an input signal of 5 μV rms. Determine the rms output signals (desired & noise) assuming external noise can be disregarded.

$T = 27 + 273 = 300$ K

$$e_n = \sqrt{4KT\Delta f R} = \sqrt{4 \times 1.38 \times 10^{-23} \times 300 \times 4 \times 100}$$
$$= 2.57 \text{ μV rms}$$

4

Frequency Noise effect



Noise designation & calculation

$$\text{Signal to noise ratio} = \frac{\text{Signal power}}{\text{Noise power}} = \frac{S}{N} = \frac{P_S}{P_N}$$

$$\frac{S}{N} = 10 \log_{10} \frac{P_S}{P_N} \quad (dB)$$

$$NR = \frac{S_i/N_i}{S_o/N_o}$$

NR = Noise Ratio

$$\text{Noise figure (NF)} = 10 \log_{10} NR$$

Ex 1-2

A transistor amplifier has a measured S/N of 10 at its input and 5 at its output. Calculate the transistor NF

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

Ex 1-3

Two resistors 5 kΩ and 20 kΩ are at 27°C. calculate 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) $P_n = KT\Delta f = 1.38\times10^{-23}\times(27+273)\times 10\ KHz$

$= 1.38\times10^{-23}\times 300\times 10\times 10^3$

$= 4.14\times10^{-17}\ W$

$e_n = \sqrt{4KT\Delta f R} = \sqrt{4\times 4.14\times10^{-17} R}$

For 5 kΩ $\quad e_n = \sqrt{4\times4.14\times10^{-17}\times 5\times10^3} = 0.91\ \mu V$

for 20 kΩ $\quad e_n = \sqrt{4\times4.14\times10^{-17}\times 20\times10^3} = 1.82\ \mu V$

(b) for series $\quad R = (5+20)\ k\Omega$

$e_n = \sqrt{4\times4.14\times10^{-17}(20+5)\times10^3} = 2.03\ \mu V$

(c) $R = \dfrac{5k\Omega\times 20k\Omega}{5k\Omega + 20k\Omega} = 4\ k\Omega$

$e_n = \sqrt{4\times4.14\times10^{-17}(4)\times10^3} = 0.81\ \mu V$

Reactance noise effect

$\Delta f_{eq} = \frac{\pi}{2} BW$

Noise due to amplifiers in cascade

$NR = NR_1 + \dfrac{NR_2 - 1}{PA_1} + \cdots + \dfrac{NR_n - 1}{PA_1\times PA_2 \cdots PA_{(n-1)}}$

Ex 1-4

A three stage amplifier has a 3 dB bandwidth of 200 KHz determined by an LC tuned circuit at its input. and operates at 22°C. The first stage has a power gain of 14 dB and a 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 output of this system

(b) The overall noise figure for the system

(c) The actual output noise voltage and power.

First stage	2nd	3rd
14 dB	20 dB	20 dB
NF = 3dB	NF = 8dB	NF = 8dB

$P_{Noise\ out} = P_{Noise\ in} \times P_G$

P_G: Antilog Total gain dB

$P_{Noise\ in}$: $KT\Delta f$

Δf: $\frac{\pi}{2}$ BW

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

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

$$= 1.28 \times 10^{-15} W$$

$$P_G = \text{Antilog}\ \frac{dB}{10}$$ (7)

Total power gain = 14 + 20 + 20 = 54 dB

$\therefore P_G = \text{Antilog}\ \frac{54dB}{10} = 2.51 \times 10^5$

$\therefore P_{noise\ out} = P_{noise\ in} \times P_G$

$= 2.51 \times 10^5 \times 1.28 \times 10^{-15} W$

$= 3.22 \times 10^{-10} W$

Noise voltage Input $e_{noise} = \sqrt{4KT\Delta f R}$

$= \sqrt{4 \times 1.38 \times 10^{-23} \times (273+22) \times 3.14 \times 10^5 \times 10 \times 10^3}$

$= 7.15 \mu V$

Noise voltage at output $\Rightarrow \sqrt{P_{noise\ out} \times R_{out}} = e_{noise\ out}$

$e_{noise\ out} = \sqrt{3.22 \times 10^{-10} \times 300} = 0.311\ mV$

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log

(h) overall Noise figure

$P_{G_1} = \text{Antilog}$ ~~PG = Noise~~ Gain 1 $= \text{Antilog}\ \frac{14}{10} = 25.1$

$P_{G_2} = P_{G_3} = \text{Antilog Gain } 2 = 3 = \text{Antilog}\ \frac{20}{10} = 100$

$Nf_1 = 3dB \rightarrow NR_1 = \text{Antilog}\ \frac{Nf_1}{10} = \text{Antilog}\ \frac{3}{10} = 2$

$Nf_2 = Nf_3 = 8dB \longrightarrow NR_2 = NR_3 = \text{Antilog}\ \frac{Nf_2\ |OR|\ Nf_3}{10}$

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

$$NR = NR_1 + \frac{NR_2 - 1}{Pa_1} + - - + \frac{NR_n - 1}{Pa_1\, Pa_2 - - Pa_{(n-1)}}$$

$$= NR_1 + \frac{NR_2 - 1}{Pa_1} + \frac{NR_{3-1}}{Pa_1\, Pa_2 - - Pa_{(3-1)}}$$

$$= NR_1 + \frac{NR_2 - 1}{Pa_1} + \frac{NR_2}{Pa_1\, Pa_2}$$

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

$$= \cancel{0.}\ 2.212$$

overall noise $NF = 10 \log NR$

$$= 10 \log \cancel{0.2}\ 2.212$$

$$= 3.45\ dB$$

$$NR = \frac{N_o}{N_i \times Pa_t}$$

Pnoise

$$2.212 = \frac{N_o}{1.23 \times 10^{-15} \times 2.51 \times 10^{5}} \Longrightarrow N_o = 7.11 \times 10^{-16}\ W$$

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

$$= 0.462\ mV$$

Information and bandwidth

Hartley's law

Information $\propto$ bandwidth $\times$ time of transmission

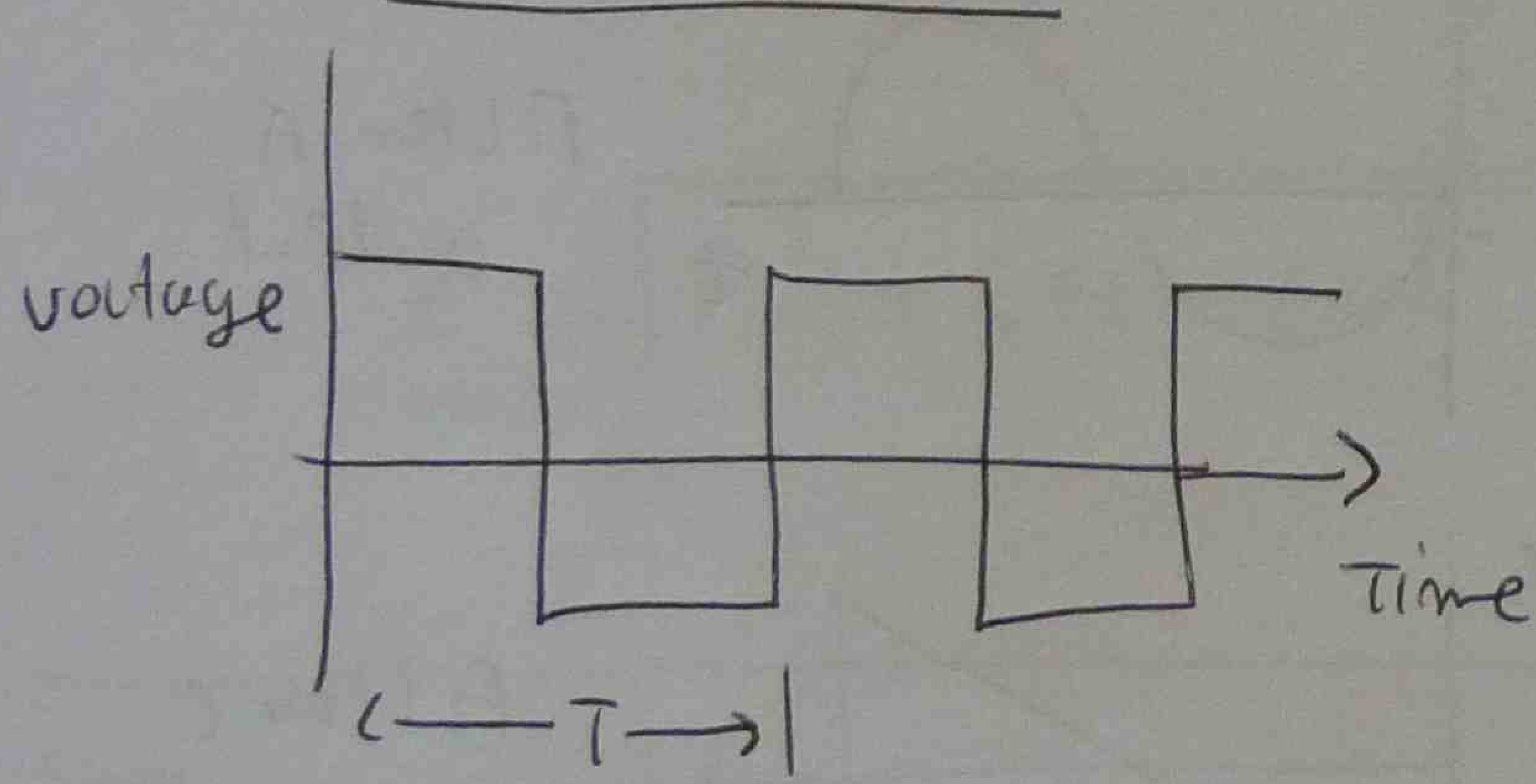
Non sinusoidal wave forms

Tv channel – a bandwidth 600 times the allowed Am bandwidth

Video signal – A pulse type waveform and a pulse waveform at one frequency requires a much larger bandwidth for transmission than a sinusoidal waveform of the same frequency.

Non sinusoidal repetitive wave forms $\longrightarrow$ Sinusoidal co-sinusoidal components.

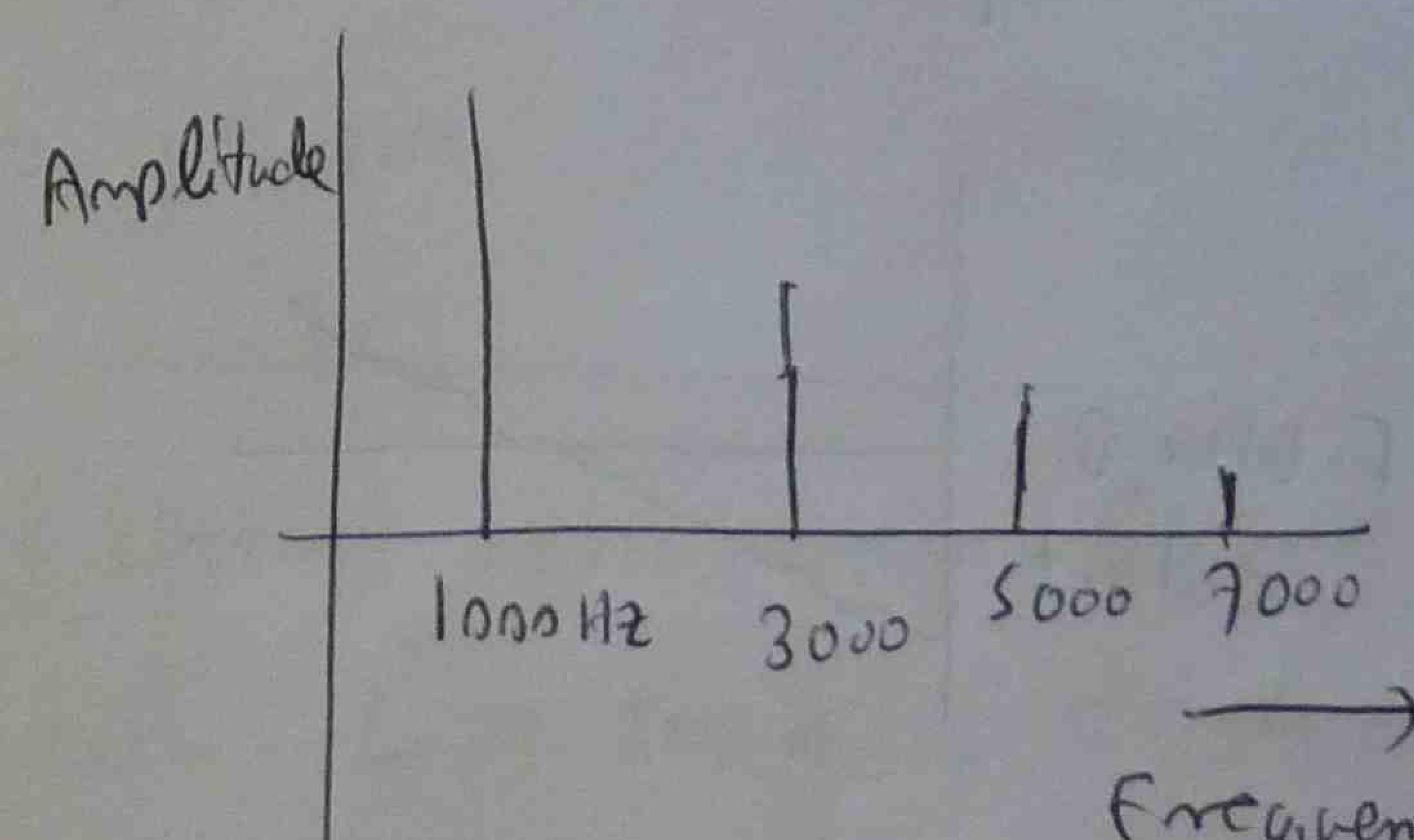
TIME DOMAIN



$f = \frac{1}{T} = 1000\ Hz$

1000 HZ Square wave

Frequency Domain



1000 Hz square wave signal spectrum

Filter (A)

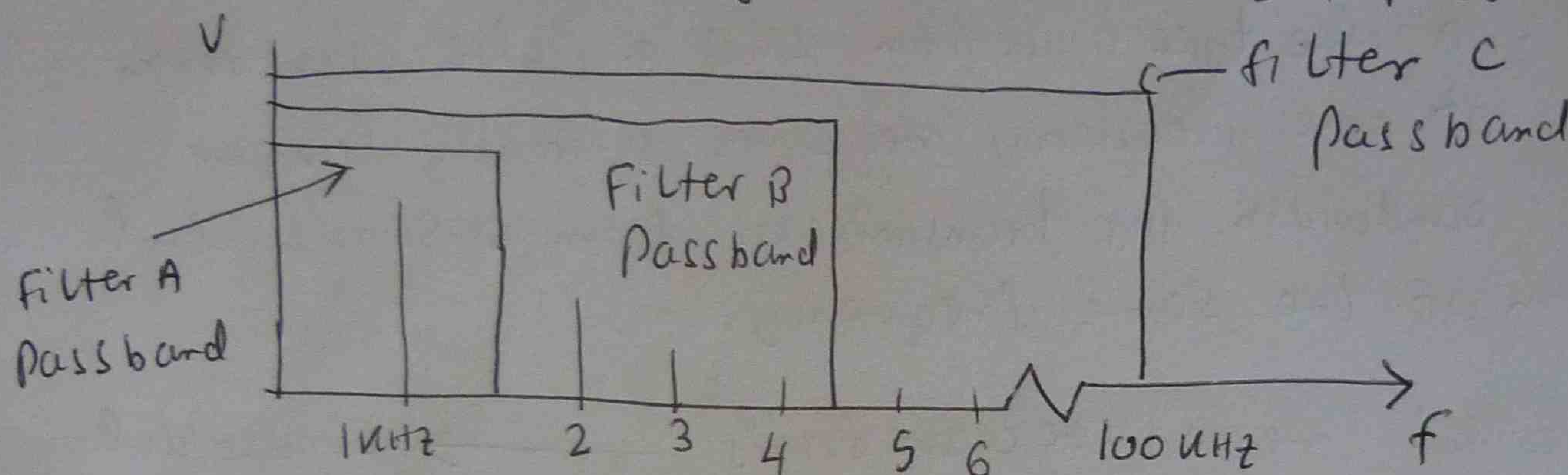
Fully passed away a sine wave at 1 KHz
No output at 2 KHz

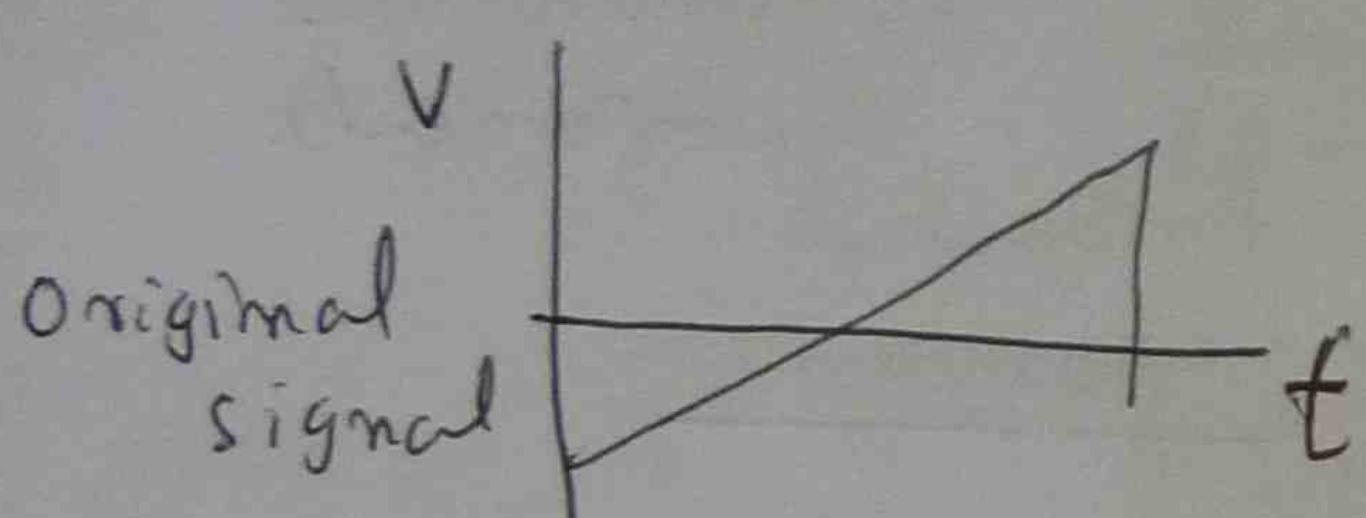
Filter (B)

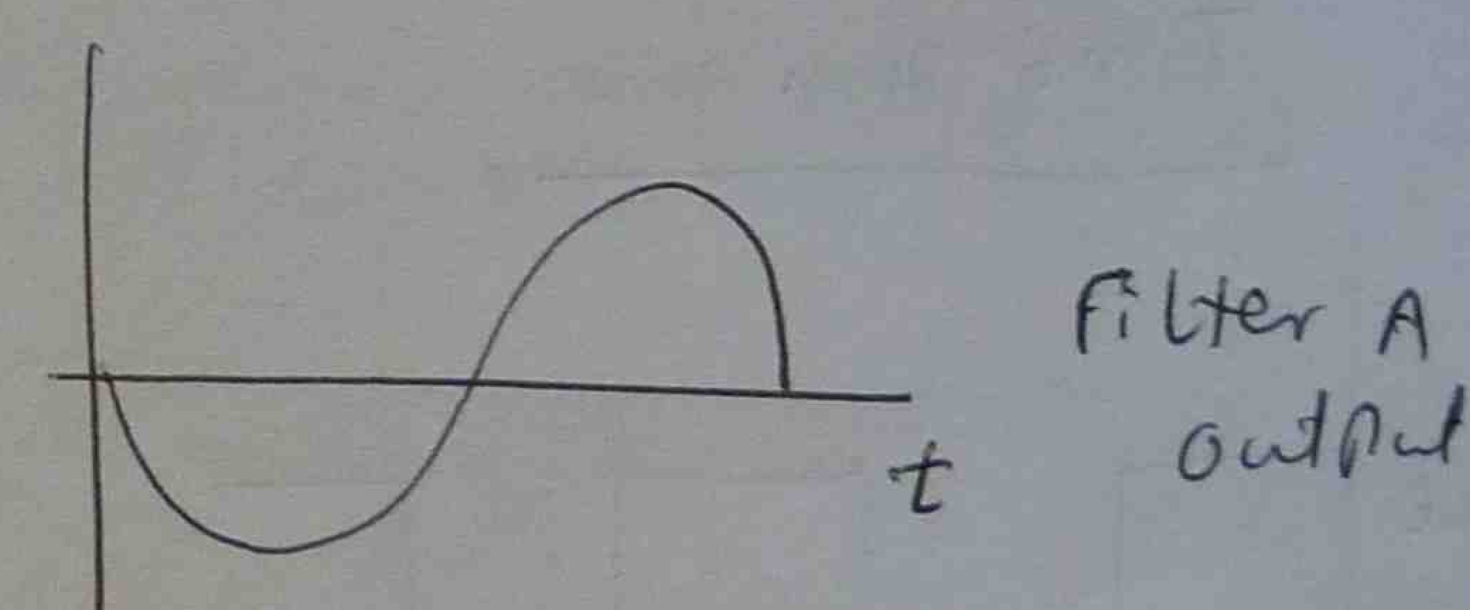
Passing sawtooth + First four harmonics.

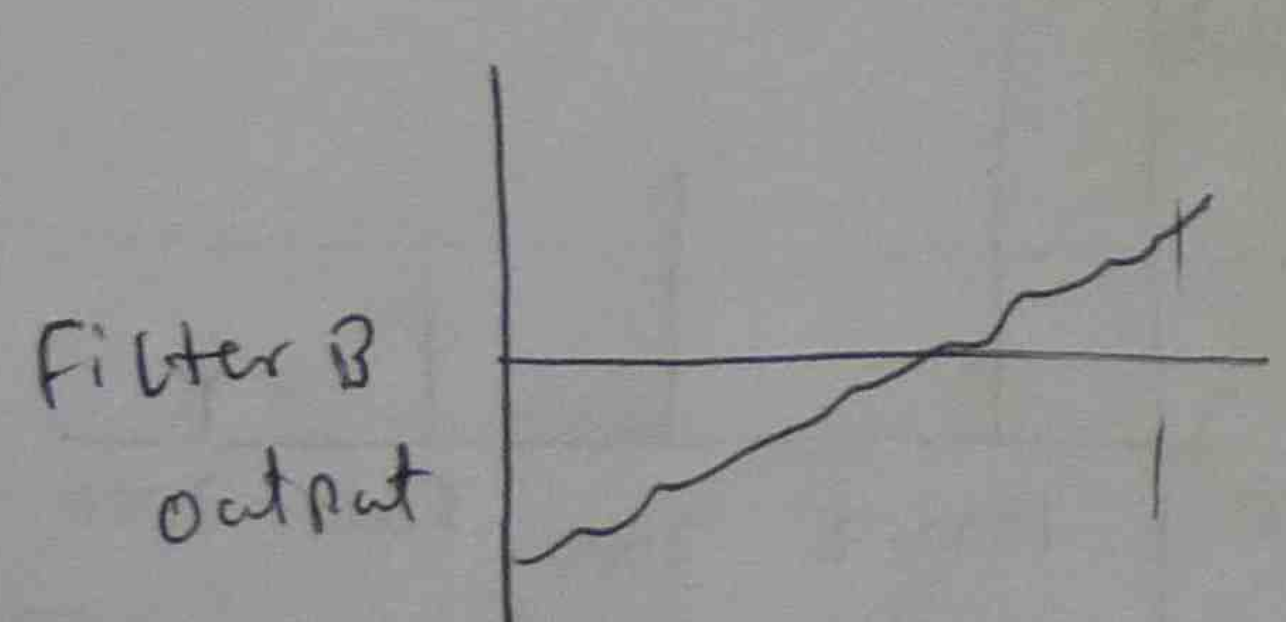
Filter (C)

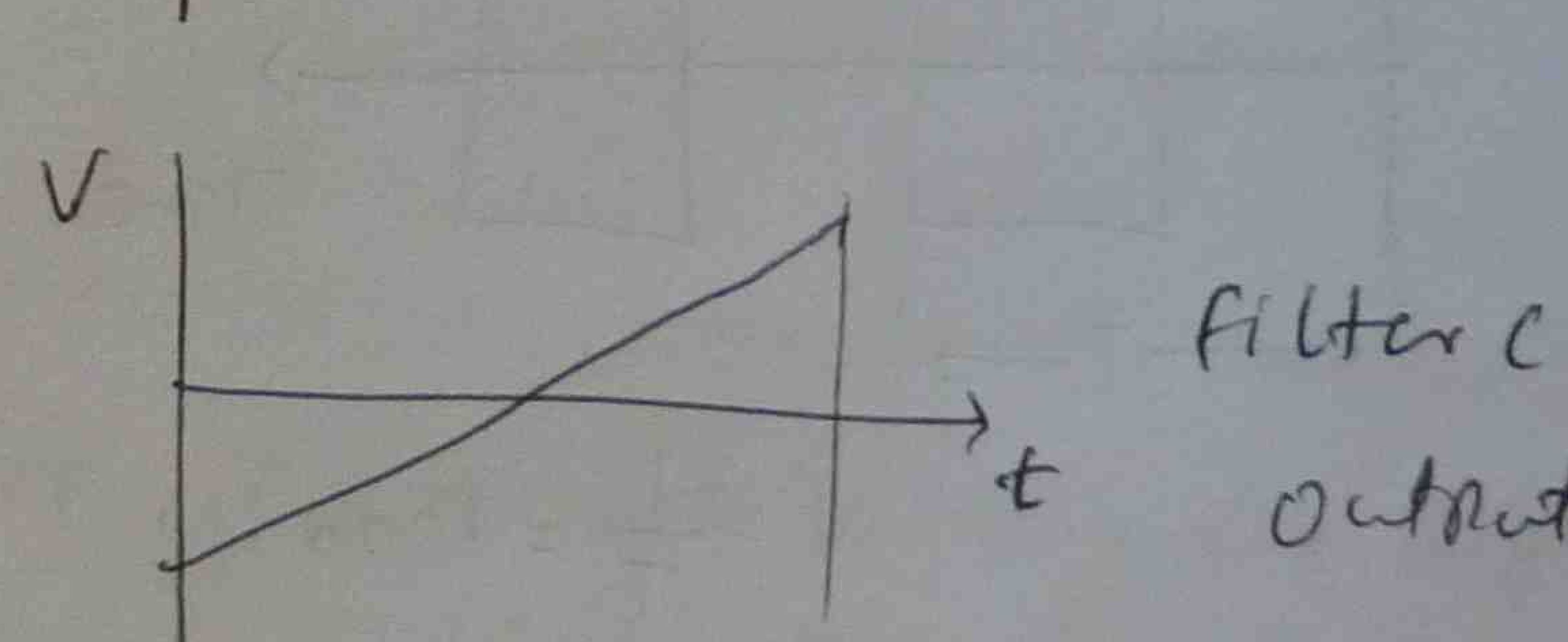
All of the significant harmonics to pass.











Inductor

$$Q = \frac{\text{Reactance}}{\text{Resistance}} = \frac{\omega L}{R}$$

Capacitor

$$Q = \frac{\text{Susceptance}}{\text{conductance}} = \frac{\omega C}{G}$$

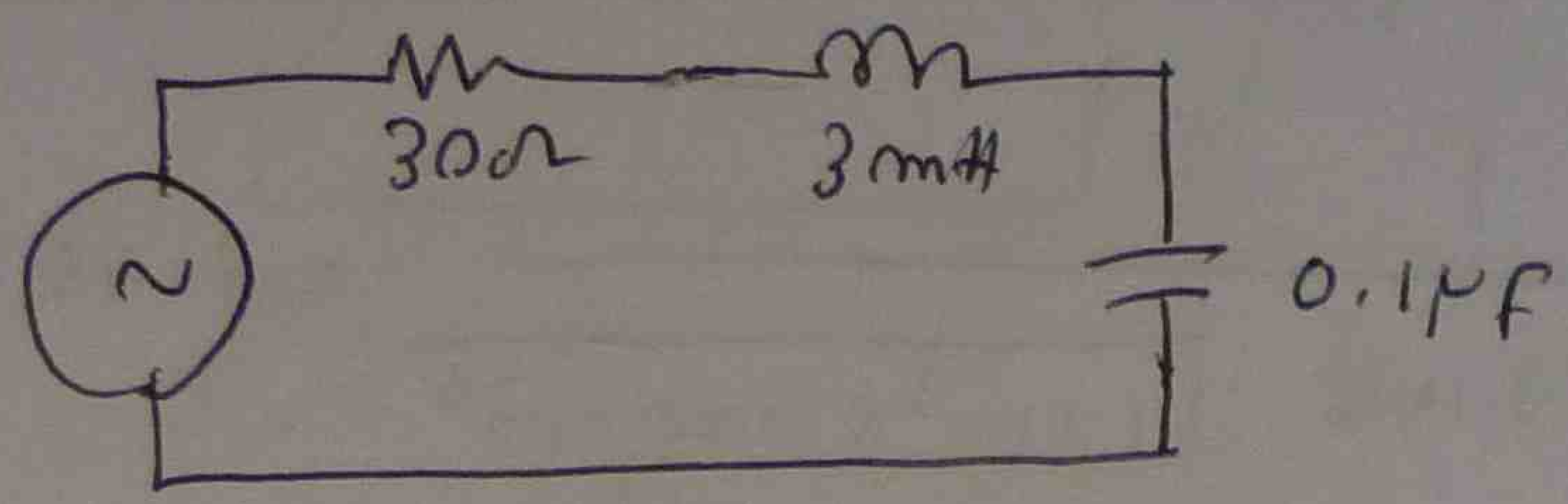
Resonance

$$X_L = X_C$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Ex

Determine the resonant frequency for the circuit shown in Fig 1.14 calculate its impedance when $f = 12\,KHz$



$$f_r = \frac{1}{2\pi\sqrt{3mH \times 0.1\mu F}}$$

$$= 9.19\ KHz$$

at 12 KHz

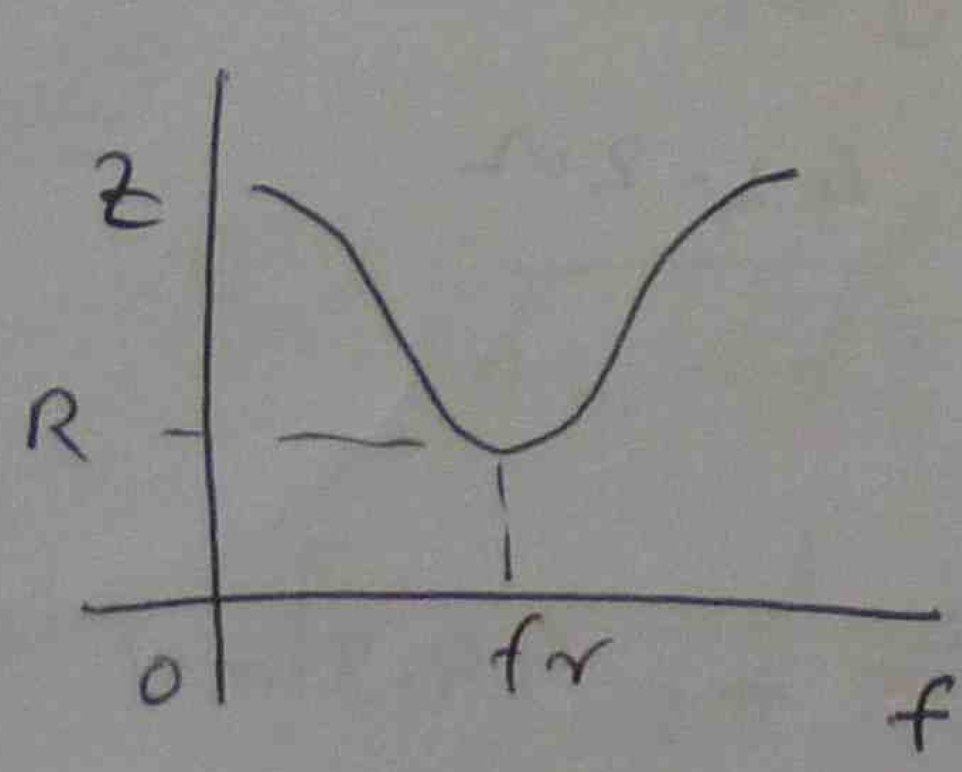
$$X_L = 2\pi f L = 2\pi \times 12\,KHz \times 3mH = 226\Omega$$

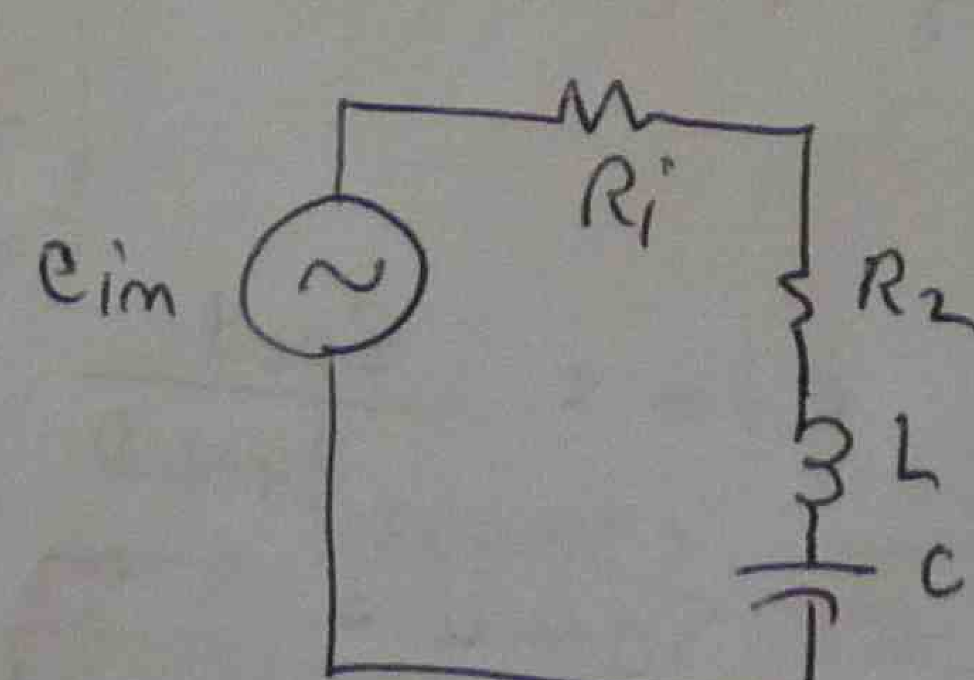
$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 12\,KHz \times 0.1\mu F} = 133\Omega$$

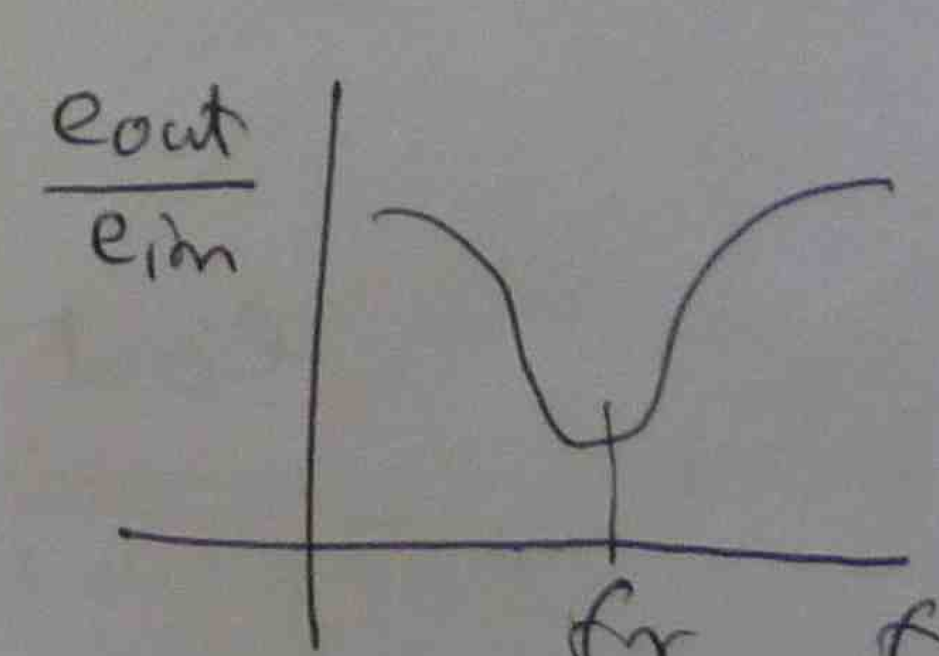
$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{30^2 + (226-133)^2}$$

$$= 97.7\Omega$$

Ex Determine f_r for the circuit shown in figure when $R_1 = 20\Omega$, $R_2 = 1\Omega$ $L = 1mH$, $C = 0.4\mu F$ $e_{in} = 50mV$. Calculate e_{out} at f_r and $12\,KHz$







(12)

$$e_{out} = e_{in} \times \frac{R_2}{R_1+R_2}$$

$$f_r = \frac{1}{2\pi\sqrt{LC}} \qquad Z_t = \sqrt{(R_1+R_2)^2 + (X_L - X_C)^2}$$

$$f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2 \times 3.1416 \sqrt{1\times10^{-3} \times 0.4 \times 10^{-6}}} = 7.96\ KHZ$$

At resonance

$$e_{out} = e_{in} \times \frac{R_2}{R_2+R_1}$$

$$= 50\,mV \times \frac{1\Omega}{1\Omega + 20\Omega} = 2.38\,mV$$

At $f = 12\ KHZ$

$$X_L = 2\pi f L = 2 \times 3.1416 \times 12\times10^{3} \times 1\times10^{-3}$$

$$= 75.4\Omega$$

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\times3.1416\times12\times10^{3}\times0.4\times10^{-6}}$$

$$= 33.2\Omega$$

$$Z_{total} = \sqrt{(R_1+R_2)^2 + (X_L - X_C)^2}$$

$$= \sqrt{(20+1)^2 + (75.4-33.2)^2}$$

$$= 47.1\Omega$$

$$Z_{out} = \sqrt{R_2^2 + (X_L - X_C)^2} = \sqrt{1^2 + (75.4-33.2)^2}$$

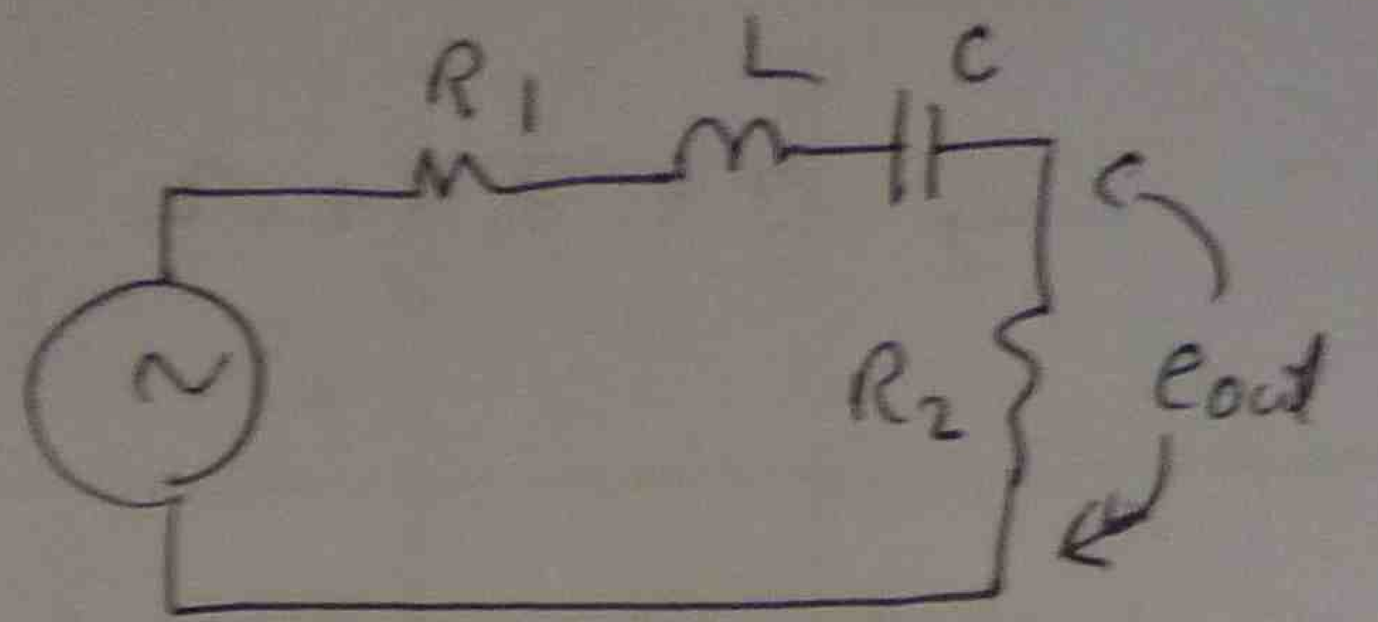
$$= 42.2\Omega$$

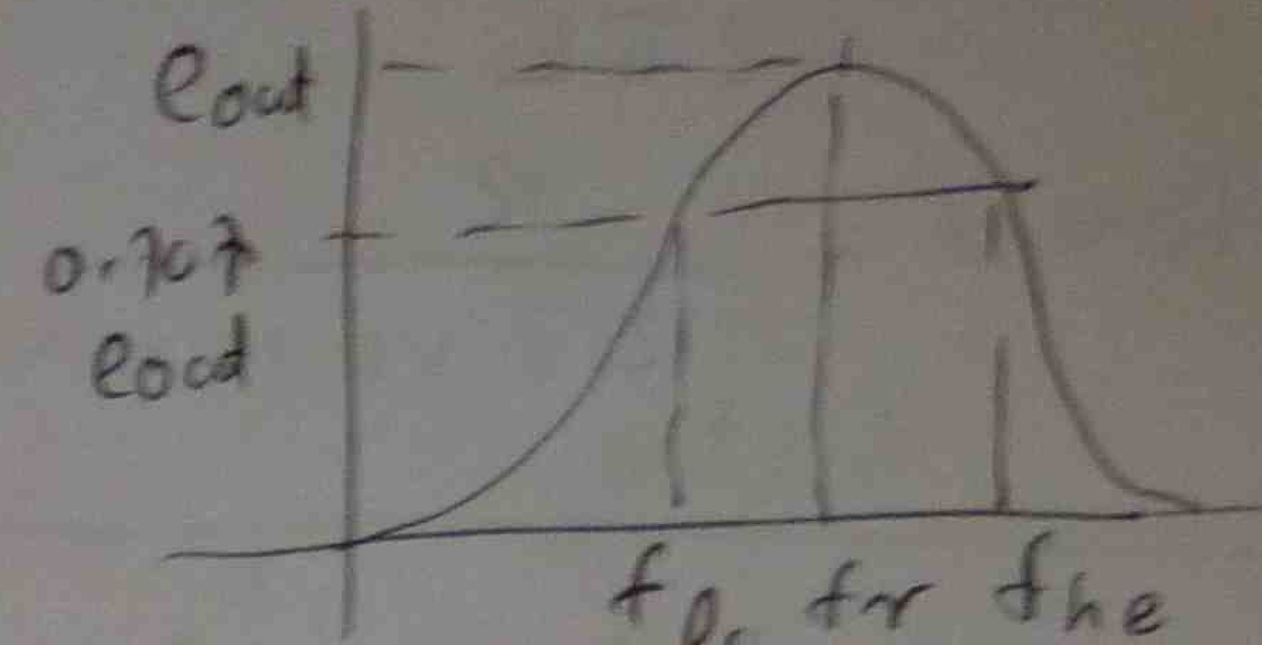
$$e_{out} = e_{in} \times \frac{Z_{out}}{Z_{total}}$$

$$= 50\,mV \times \frac{42.2}{47.1} = 44.8\,mV$$

(13)

LC Bandpass filter





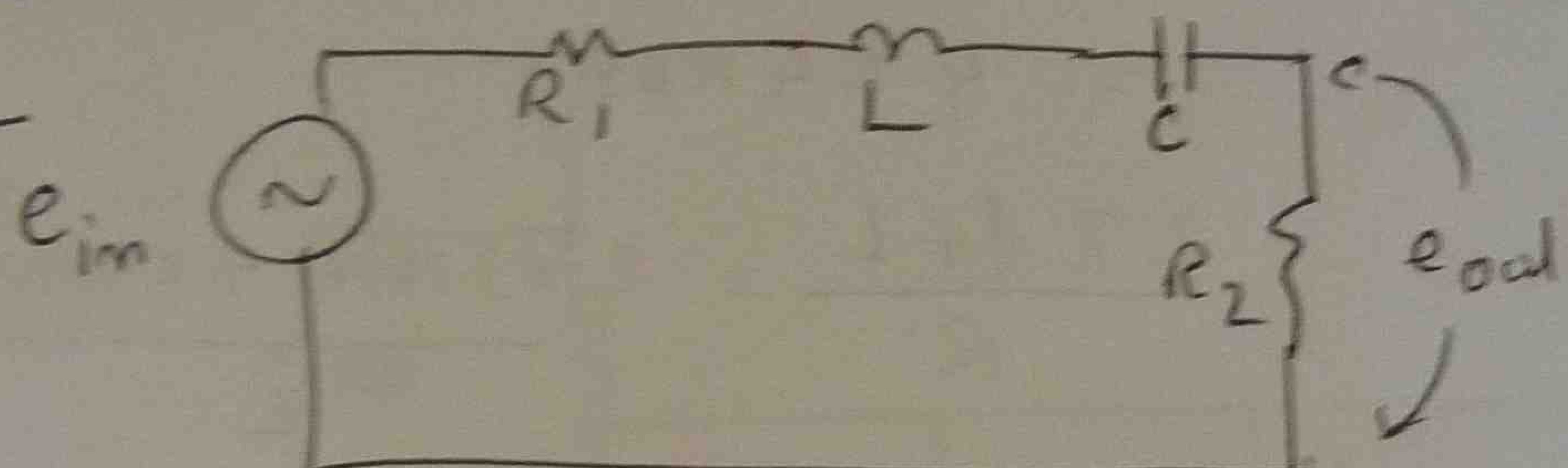
$$Bw = \frac{R}{2\pi L}$$

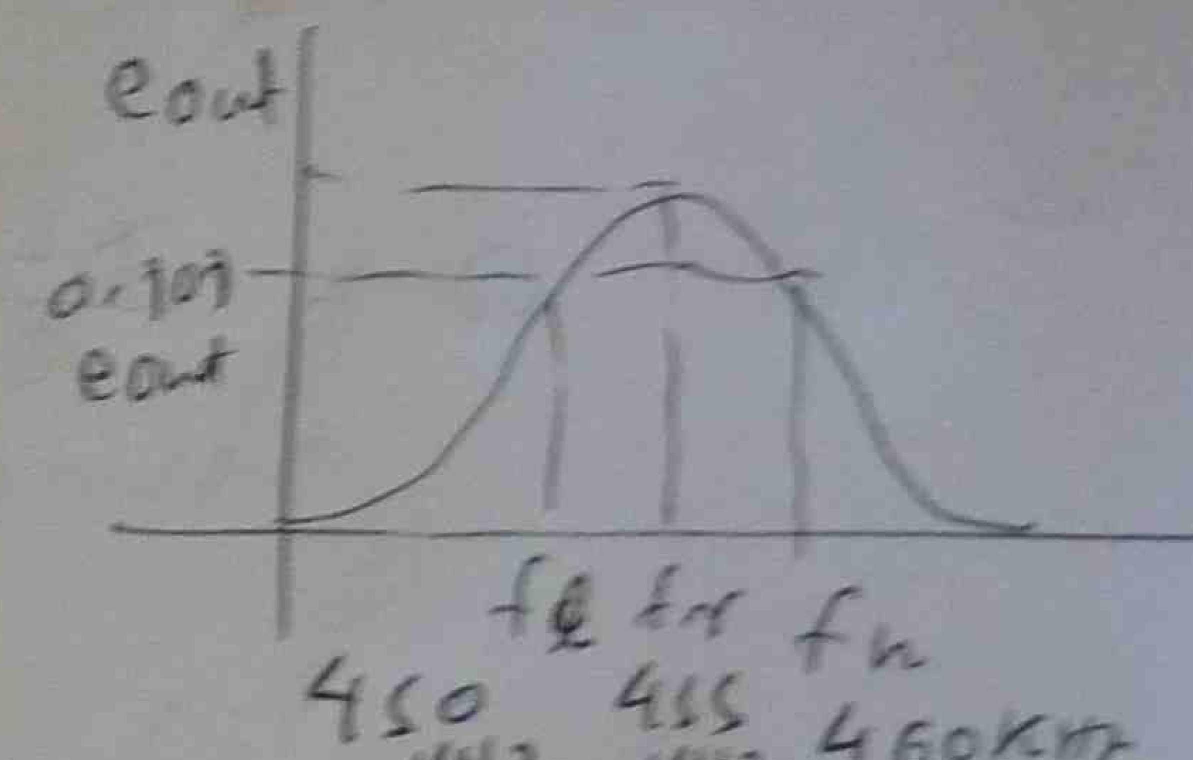
Bw = bandwidth (Hz)
R = total circuit resistance
L = circuit inductance

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

$$Q = \frac{\omega L}{R}$$

Ex





A filter circuit of the form ~~at~~ has a response as shown in fig. determine
(a) The bandwidth (b) The Q (c) The value of inductance if $C = 0.001\ \mu F$ (d) The total circuit resistance.

(a) $Bw = f_h - f_l = 460 - 450 = 10\ Hz$

(b) $Q = \dfrac{f_r}{Bw} = \dfrac{455\ kHz}{(460 - 450)} = 45.5$

$$Q = \frac{f_r}{f_h - f_l}$$

(c) $f_r = \dfrac{1}{2\pi\sqrt{LC}} \rightarrow 455\ kHz = \dfrac{1}{2\pi\sqrt{L \times 0.001 \times 10^{-6}}}$ $L = 0.12\ mH$

(d) $BW = \dfrac{R}{2\pi L}$

$10\,kHz = \dfrac{R}{2\pi \times 0.12\,mH} \rightarrow R = 7.52\,\Omega$

Ex 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) $f_r = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\times3.1416\sqrt{3\times10^{-3}\times0.47\times10^{-6}}}$

$= 4.24\,kHz$

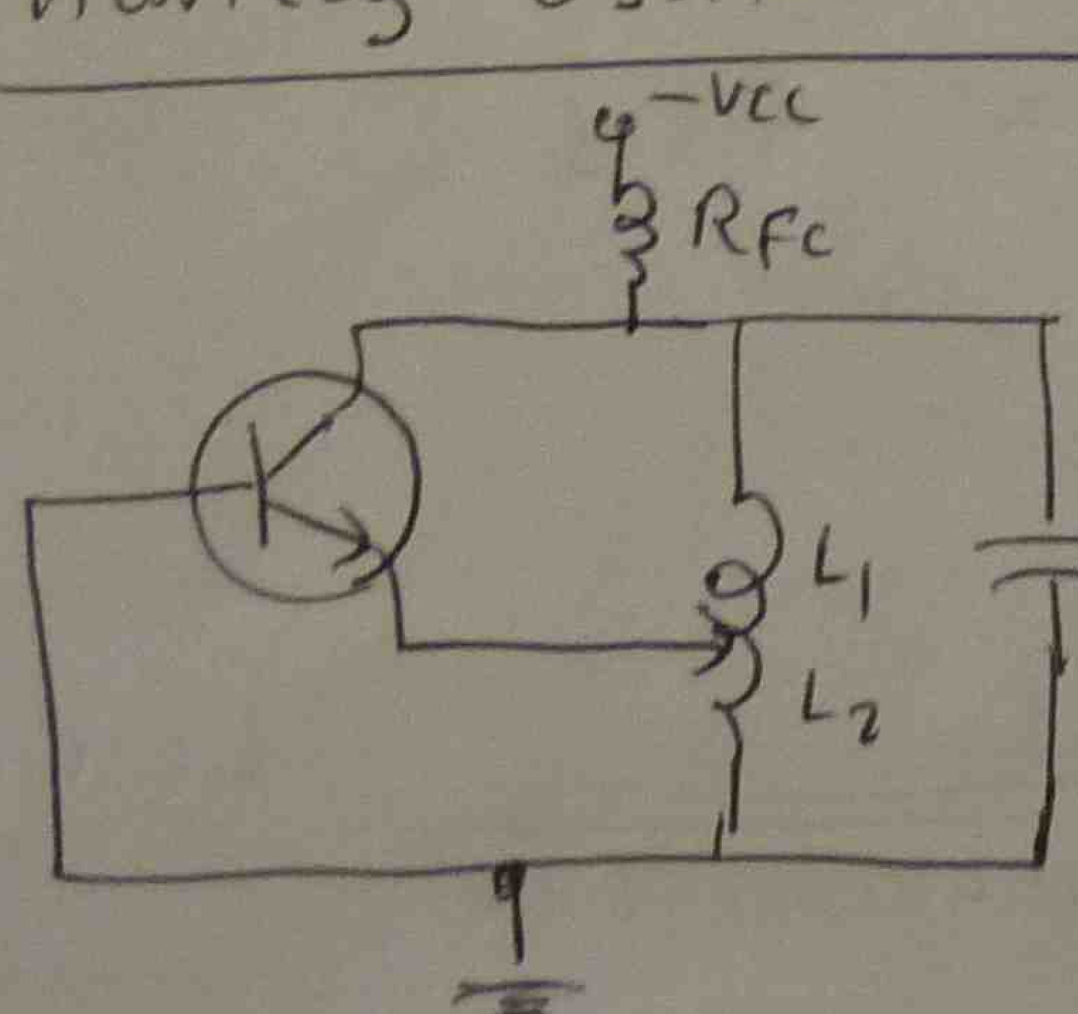
(b) $Q = \dfrac{X_L}{R} = \dfrac{2\pi f_r L}{R} = \dfrac{2\times3.1416\times4.24\times10^{3}\times3\times10^{-3}}{2}$

$= 39.9$

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

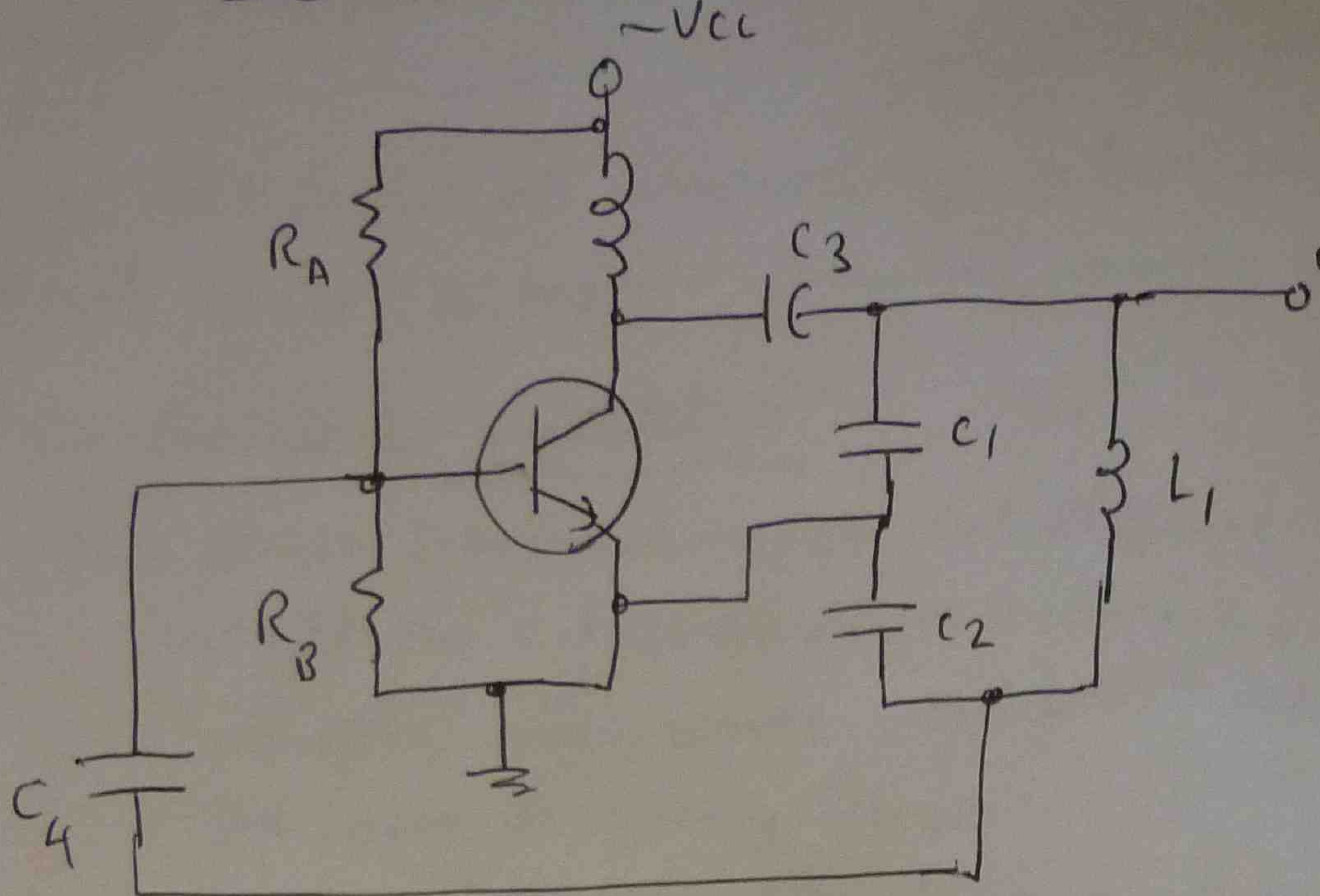
(d) $BW = \dfrac{R}{2\pi L} = \dfrac{2\,\Omega}{2\times3.1416\times3\times10^{-3}} = 106\,Hz$

Hartley Oscillator



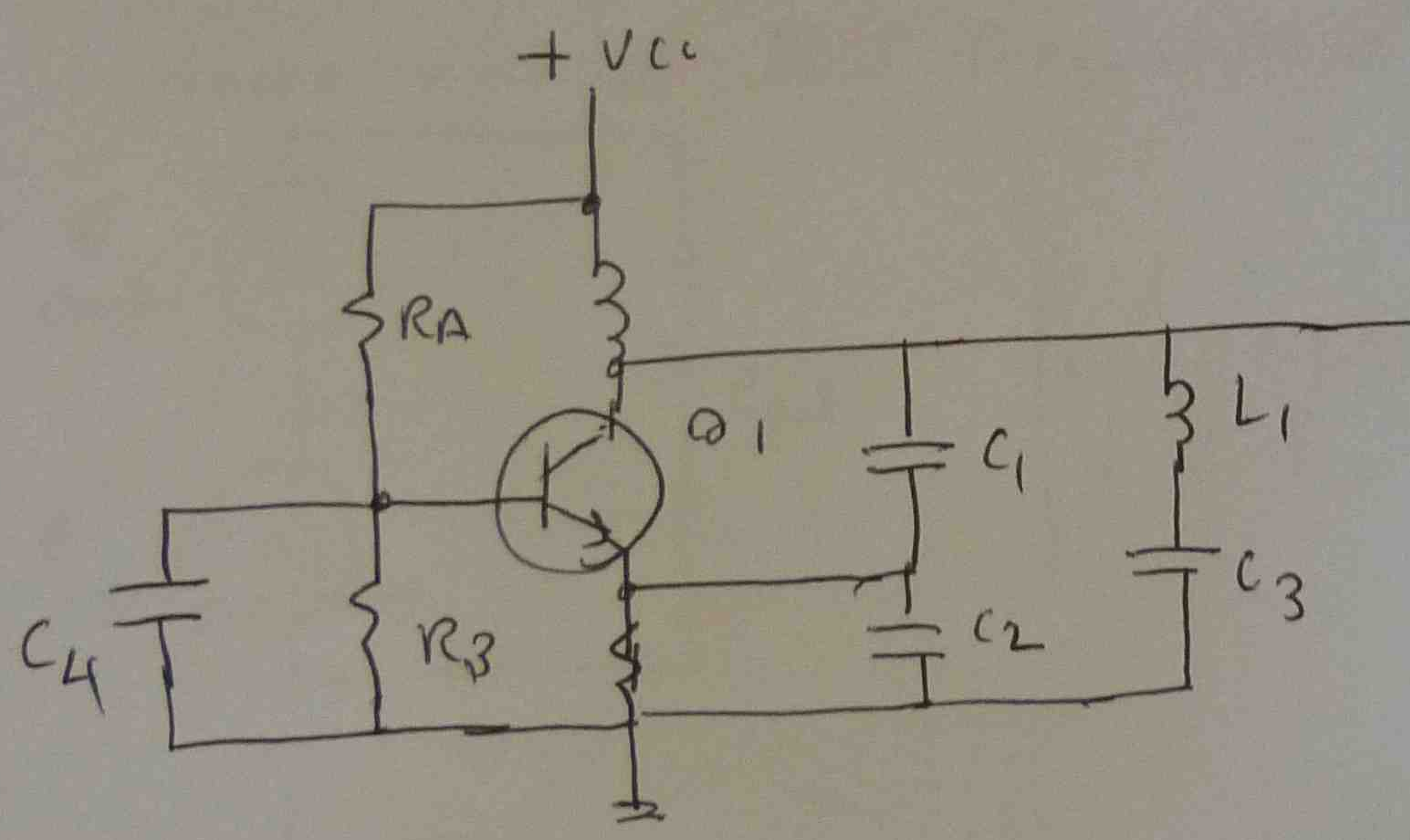
$f = \dfrac{1}{2\pi\sqrt{(L_1+L_2)C}}$

Colpitts oscillator



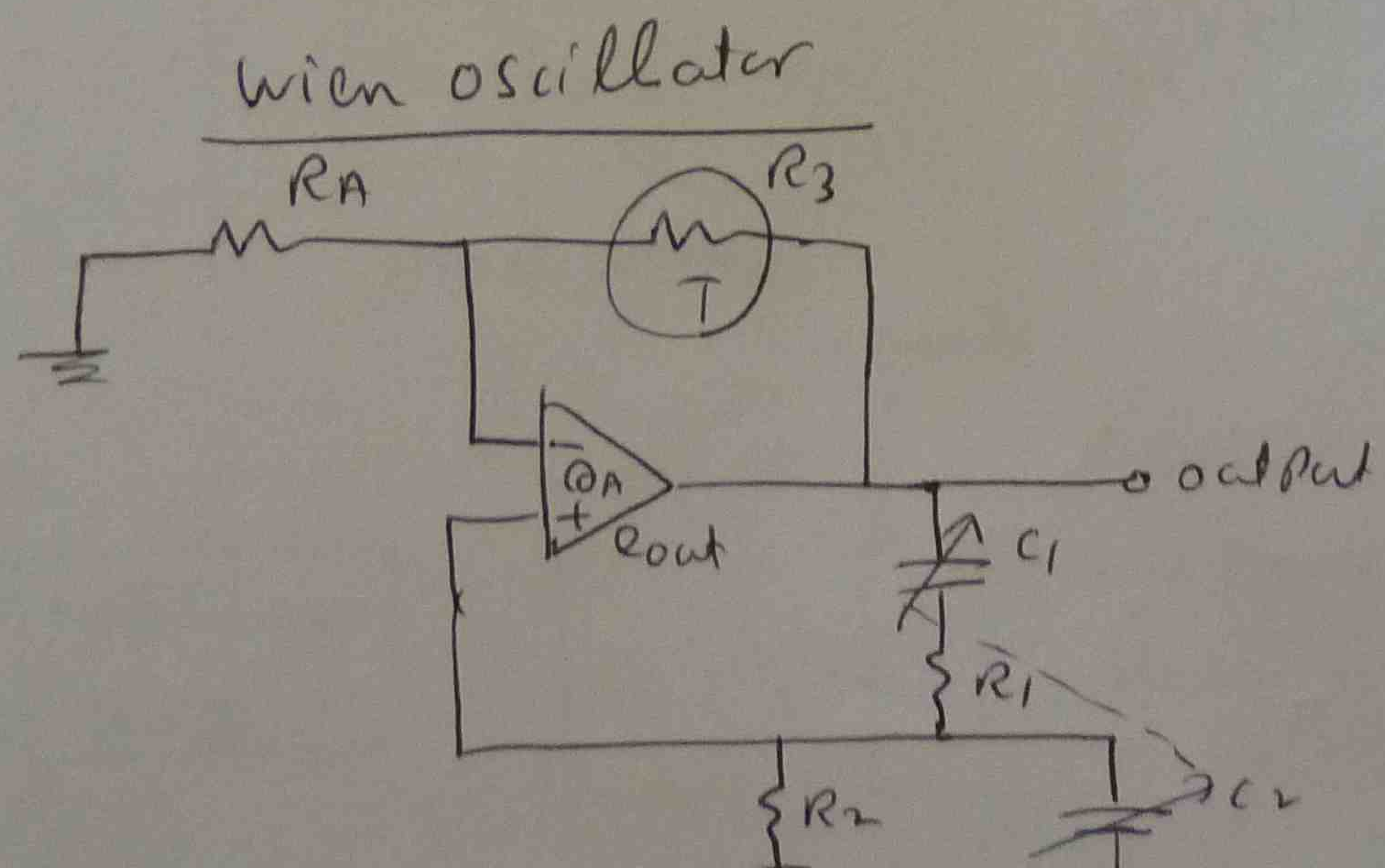
$$f = \frac{1}{2\pi\sqrt{(C_1 C_2/C_1+C_2)}}$$

Clapp oscillator



$$f = \frac{1}{2\pi\sqrt{L_1 C_3}}$$

wien oscillator



$$f = \frac{1}{18RC}$$

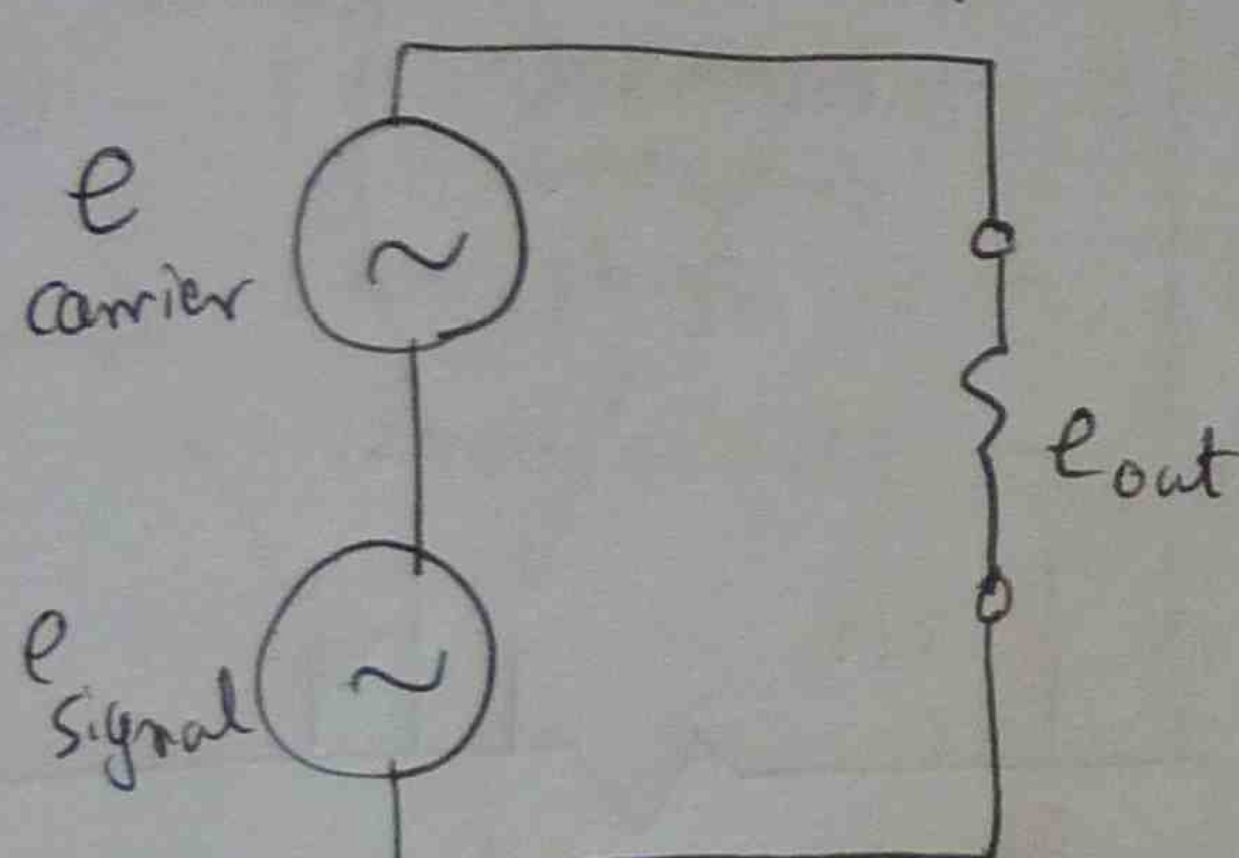
Amplitude modulation transmission

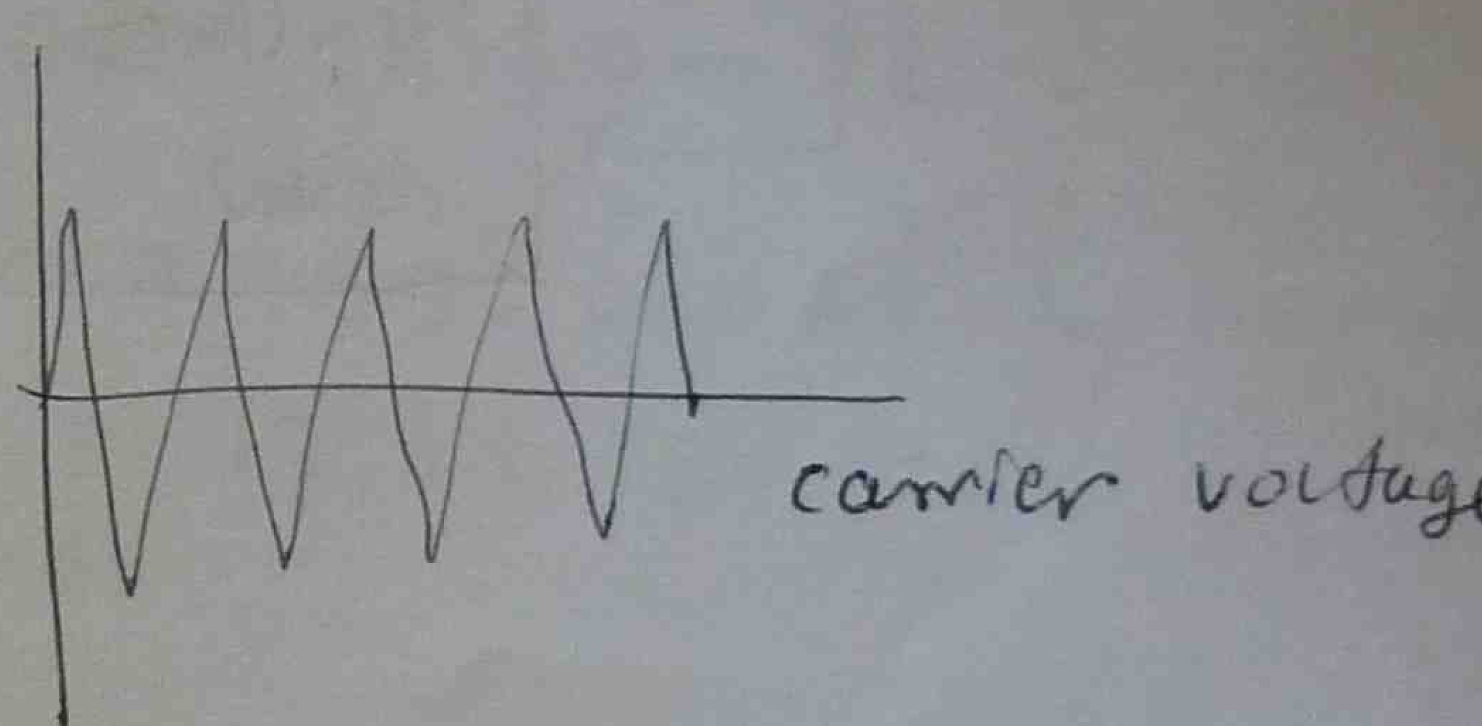
The process of impressing a low-frequency intelligence signal onto a higher frequency carrier signal.

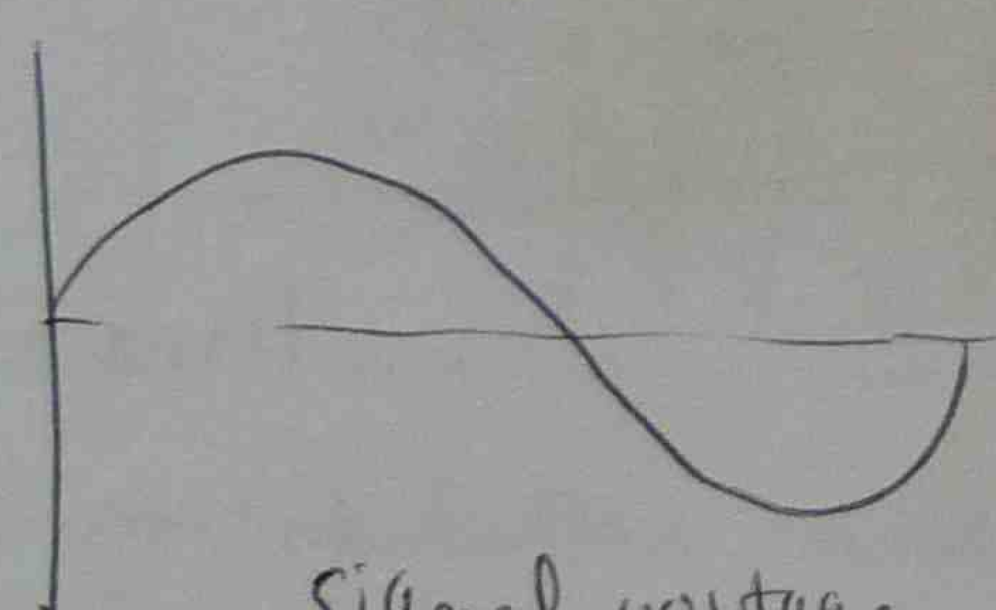
The reason for modulation

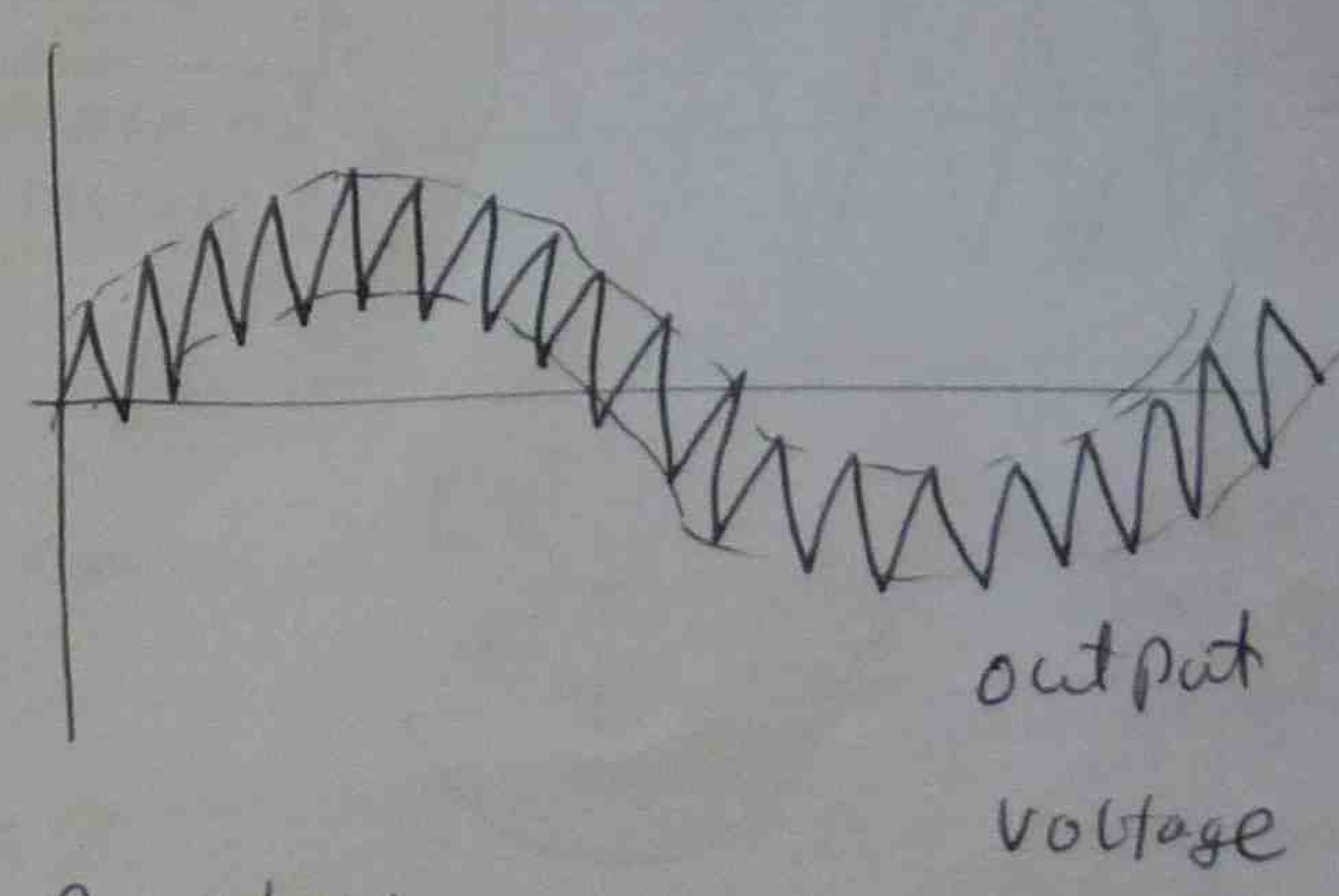
(a) Direct transmission of intelligence signals would result in catastrophic interference problems, since the resulting radio waves would all be at approximately the same frequency range

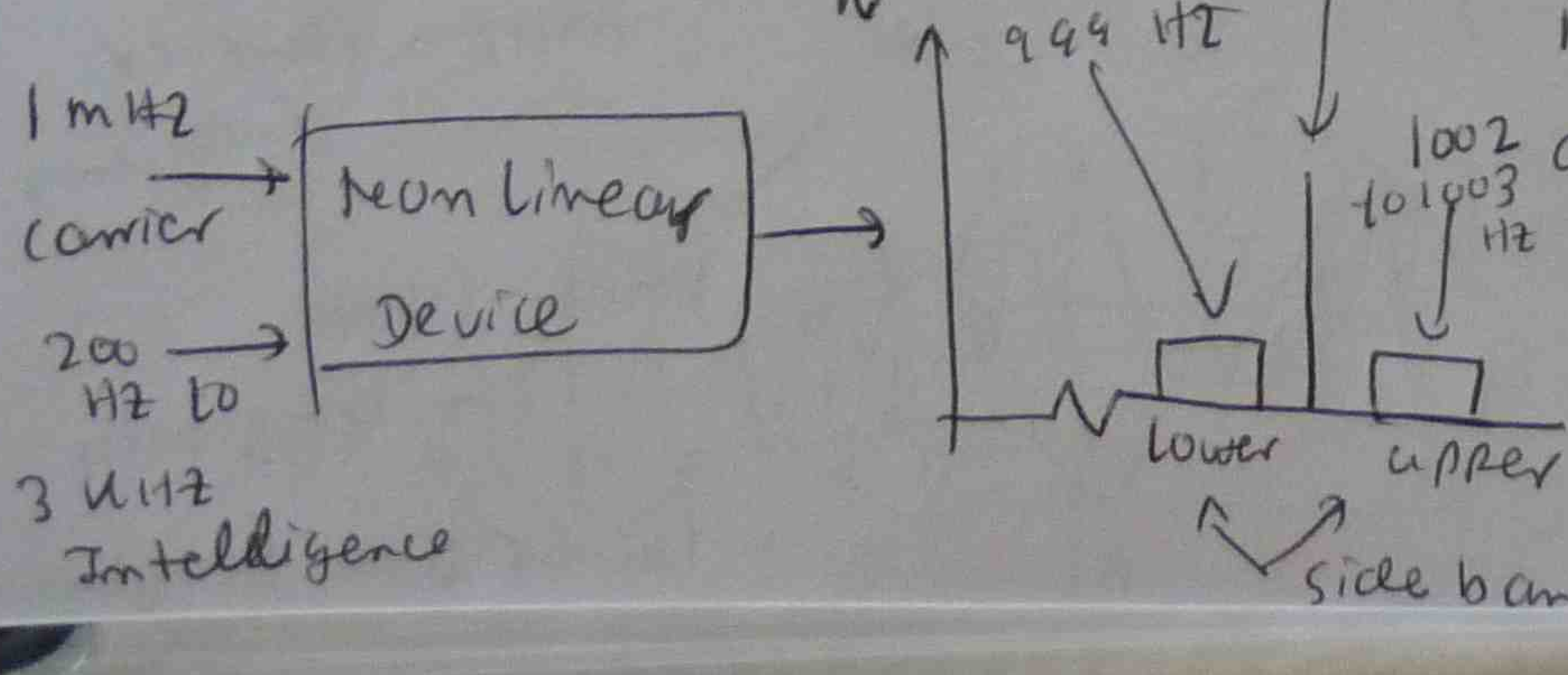
(b) most intelligible signals are at relatively low frequencies. Efficient transmission and reception of radio waves at low frequencies is not possible.





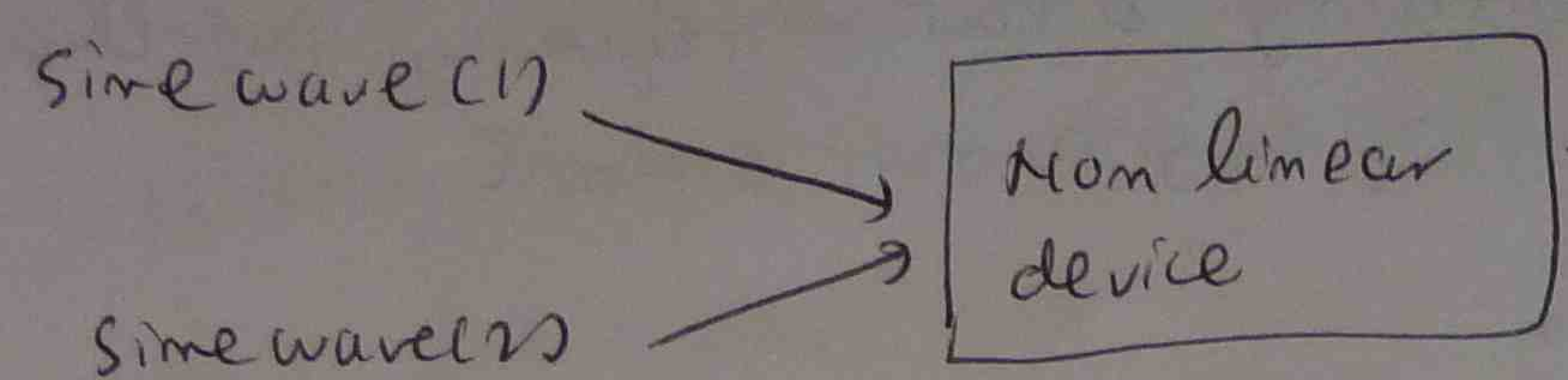




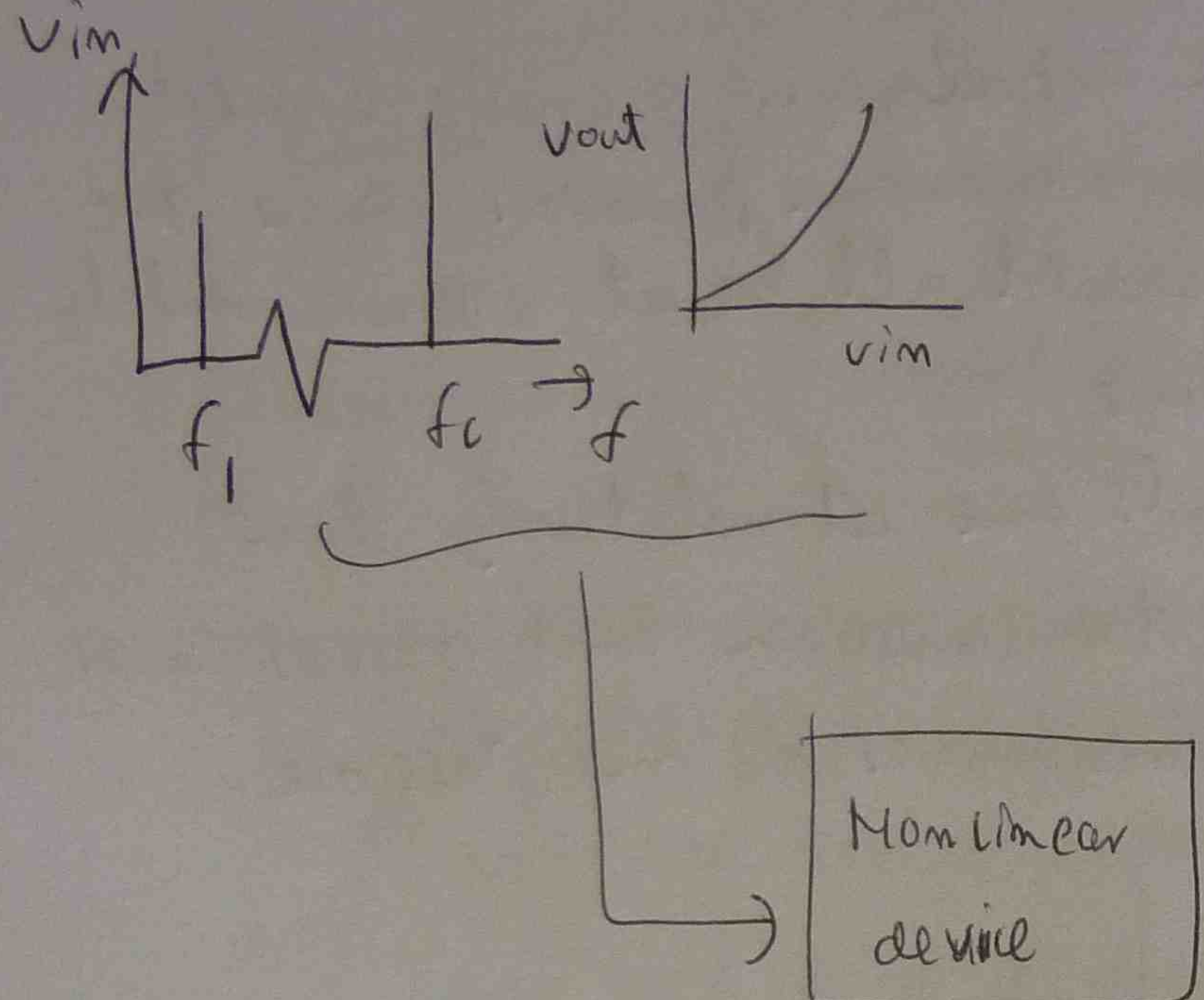


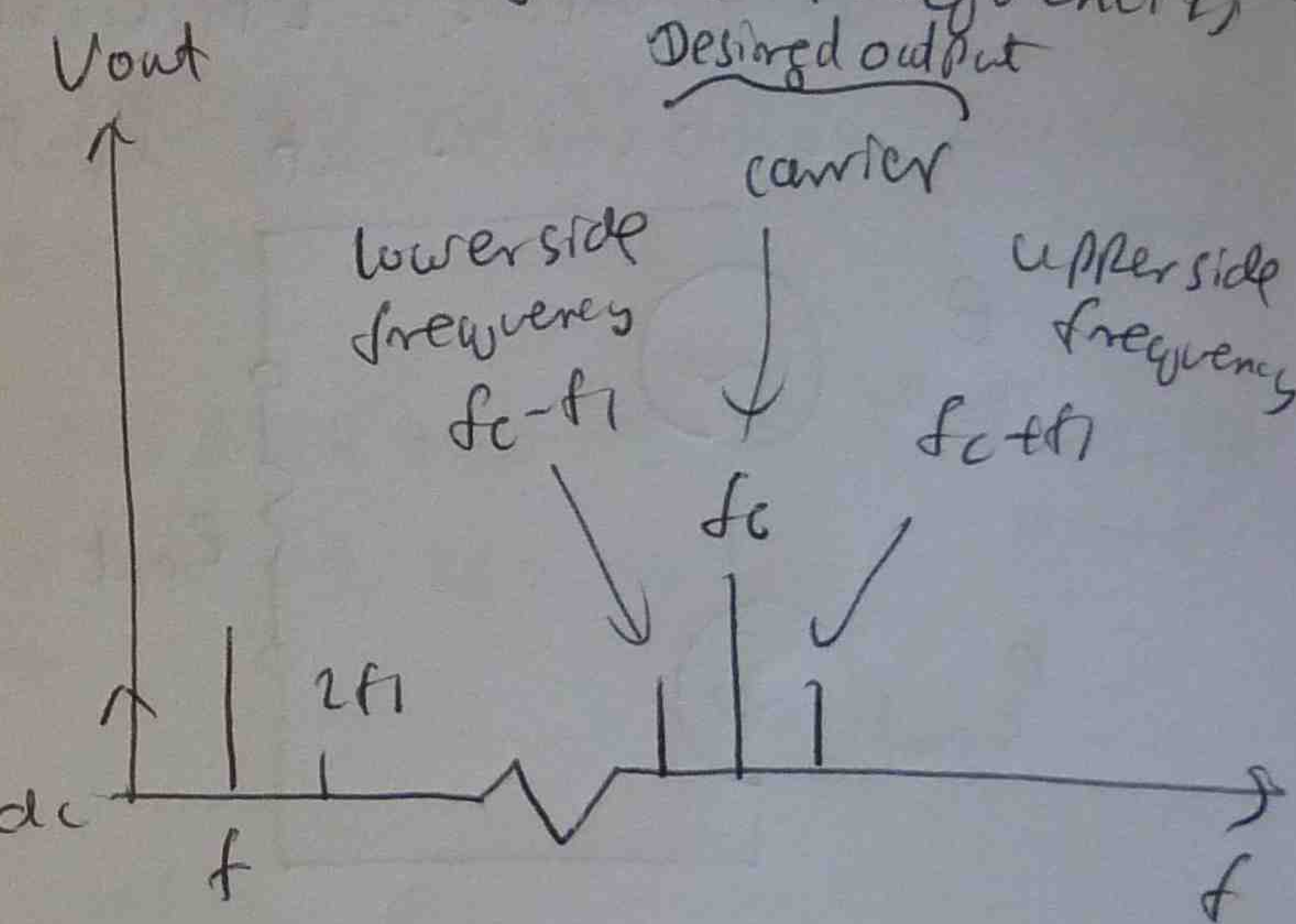
Result of combining signal and carrier voltage in linear network.

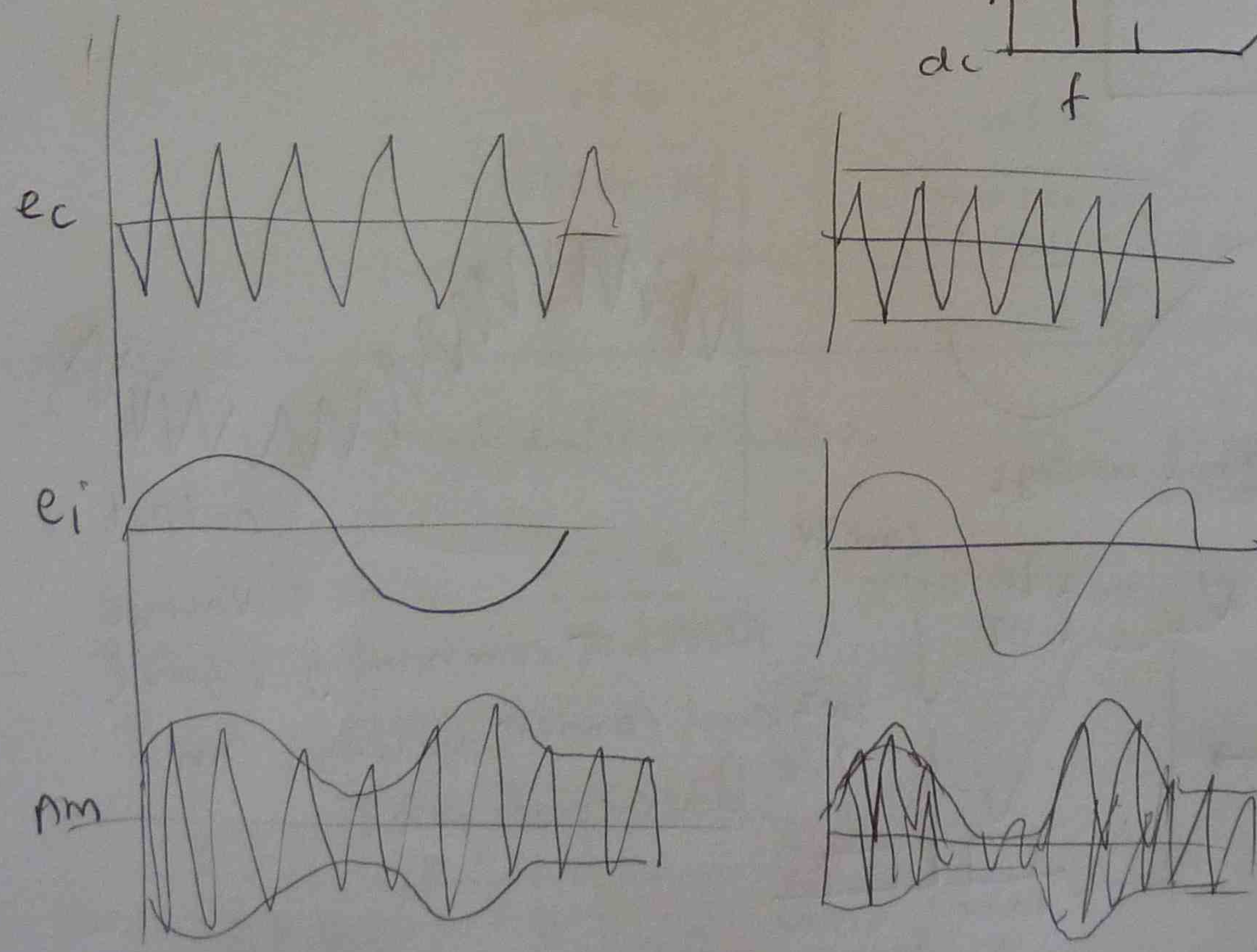
Non linear mixing



- DC level
- components at each of the two original frequencies
- components at the sum and difference frequencies of the signal frequencies
- Harmonics of two original frequencies







1MHz + 5kHz = 1.005 MHz upperside frequency

1MHz = carrier frequency

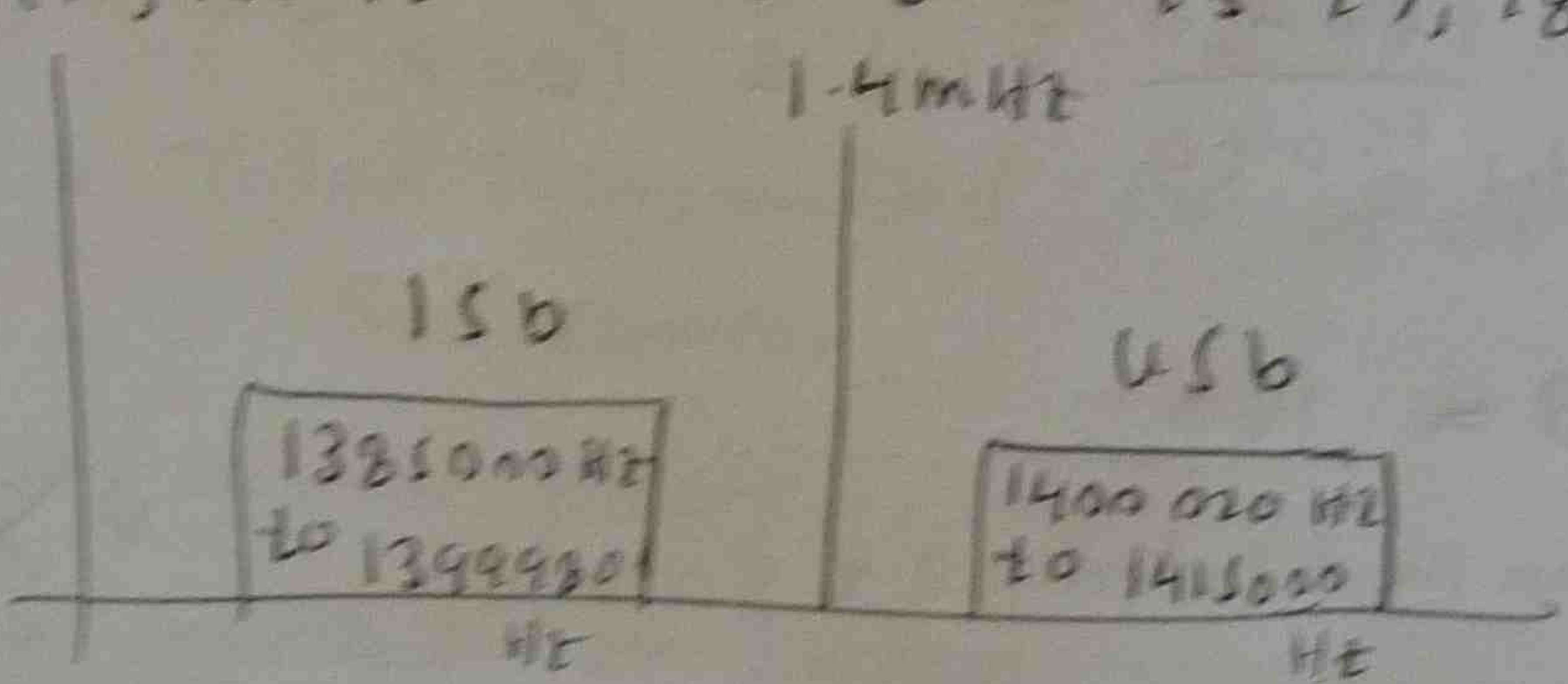
1MHz − 5kHz = 9.95 MHz lower side frequency

Ex 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 the upper and lower side bands.

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 = 13 99,980 Hz
} lower side band



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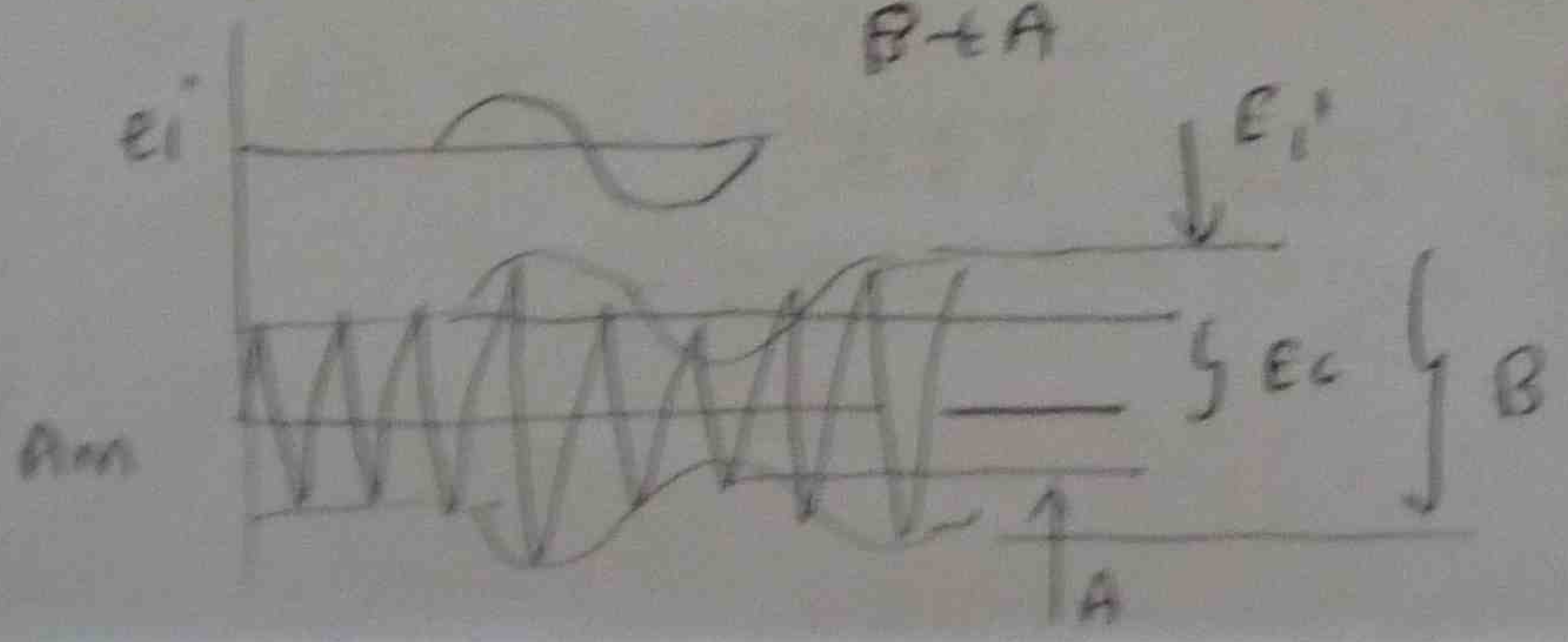
m = modulation index $\quad m = \frac{E_l}{E_c}$

B = maximum peak carrier frequency

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

A = minimum peak carrier frequency



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

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

Ex determine %m for the following conditions if the unmodulated carrier is 80V Peak to Peak (P-P)

	maximum P-P carrier (V)	minimum P-P carrier (V)
(a)	100	60
(b)	125	35
(c)	160	0
(d)	180	0
(e)	135	35

B < 2x unmodulated = 100 < 80x2

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

(b) $\%m = \frac{125-35}{125-35} \times 100 = 56.25\%$

B < 2x unmodulated

125 < 80x2

(c) $\%m = \frac{160-0}{160+0} \times 100 = 100\%$

B = 2x unmodulated

(d) ~~%m~~ B = 180

2x unmodulated = 2 x 80 = 160 ∴ B > 2x unmodula

Overmodulated

(e) B = 135

2x unmodulated = 2x80 = 160 HZ

$\%m = \frac{135-35}{135+35} \times 100 = 58.8\%$

$$e = \underbrace{E_c \sin w_c t}_{\text{① carrier}} + \underbrace{\frac{m E_c}{2} \cos(w_c - w_i)t}_{\text{② lower sideband}} - \underbrace{\frac{m E_c}{2} \cos(w_c + w_i)t}_{\text{③ upper sideband}}$$

where

Peak amplitude $= A = E_c + e_i$

$e_i = E_i \sin w_i t$

$E_i = m E_c$

$E_{SF} = \frac{m E_c}{2}$

m = modulation index

E_{SF} = side frequency amplitude

E_c = carrier amplitude

High percentage modulation

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

P_t = Total transmitted power of side bands and carrier

P_c = carrier power

m = modulation index

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

I_t = Total transmitted current

I_c = carrier current

m = modulation index

Ex

A 500W carrier is to be modulated to a 90% level. determine the total transmitted power.

$m = 0.9$, $P_c = 500W$

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

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

Ex

An Am broad cast station operates at its maximum allowed total output of 50kW and at 95% modulation. How much of its transmitted power is intelligence (side bands)?

To find $P_i = P_t - P_c$

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

Given $P_t = 50kW$, $m = 0.95$

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

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

$$= 34.5kW$$

$$\therefore P_i = P_t - P_c = 50 - 34.5$$

$$= 15.5kW$$

22

Ex The antenna current of an AM transmitter is 12A when unmodulated but increases to 13A when modulated. Calculate %m

$I_t = 13\text{ A}$ (modulated)

$I_c = 12\text{ A}$ (unmodulated)

$m = ?$

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

$$13 = 12\sqrt{1 + \frac{m^2}{2}}$$

$$\left(\frac{13}{12}\right)^2 = 1 + \frac{m^2}{2}$$

$$\therefore m^2 = 2\left[\left(\frac{13}{12}\right)^2 - 1\right]$$

$$m = \sqrt{2\left[\left(\frac{13}{12}\right)^2 - 1\right]} = 0.59$$

$$\%m = 0.59 \times 100 = 59\%$$

Ex A transmitter with a 10kW carrier transmits 11.2kW when modulated with a single sine wave. Calculate the modulation index. If the carrier is simultaneously modulated with another sine wave at 50% modulation, calculate the total transmitted power.

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

$$11.2\text{kW} = 10\text{kW}\left(1 + \frac{m^2}{2}\right)$$

$$\therefore m = 0.49$$

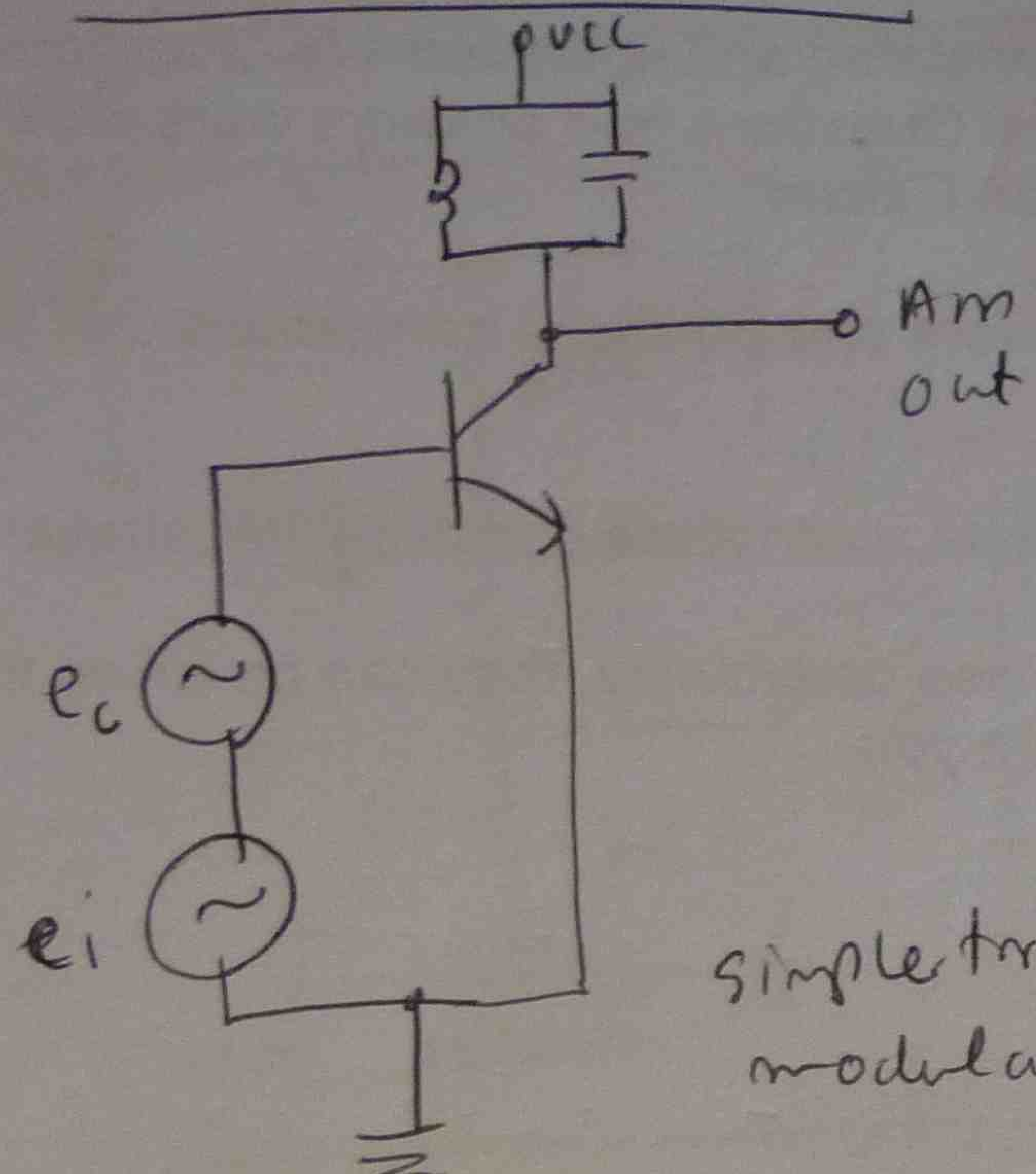
$\boxed{\text{simultaneously transmit}}$

effective modulation $m_{eff} = \sqrt{m_1^2 + m_2^2 + \cdots}$

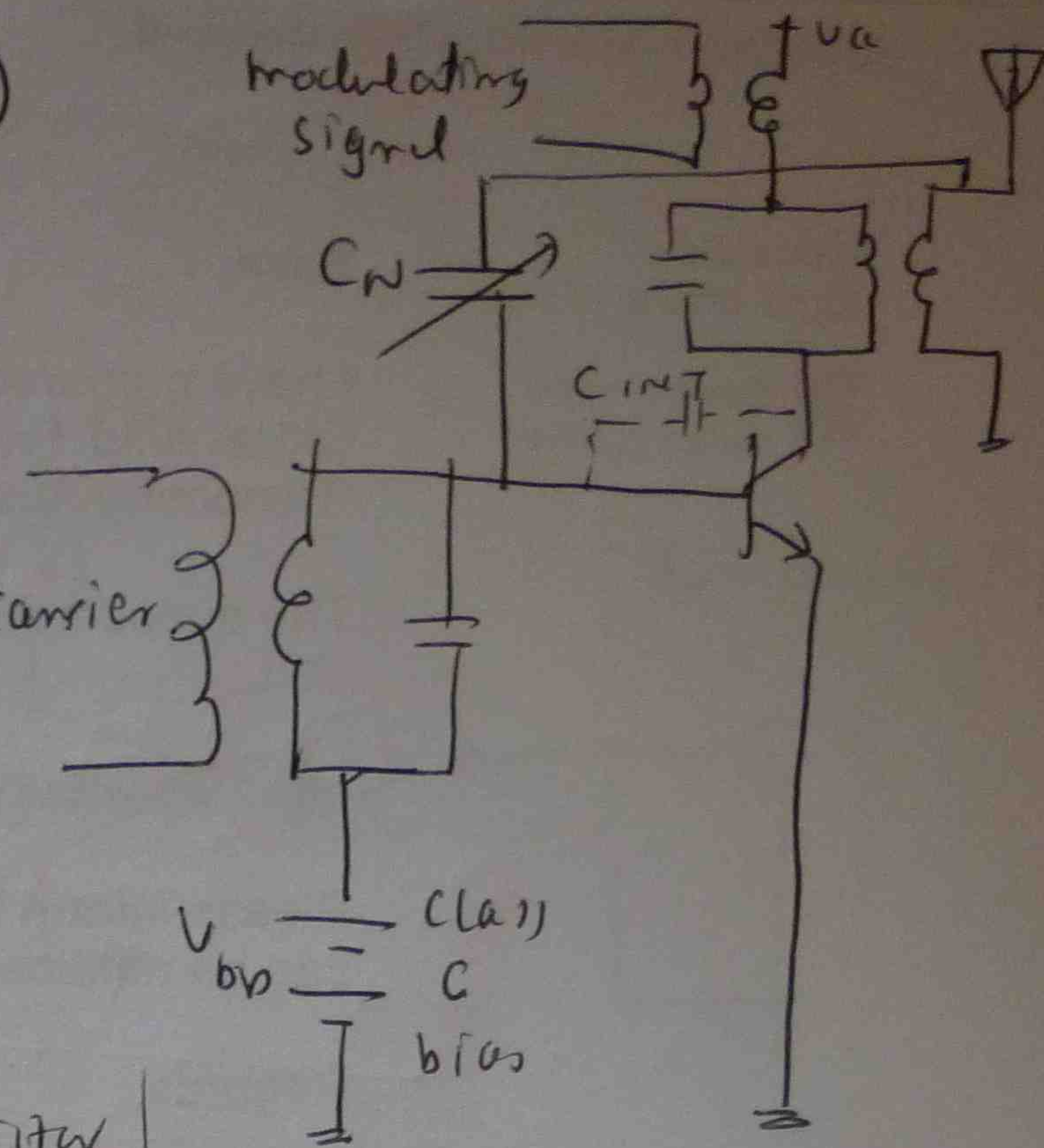
$$m_{eff} = \sqrt{0.49^2 + 0.5^2} = 0.7$$

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

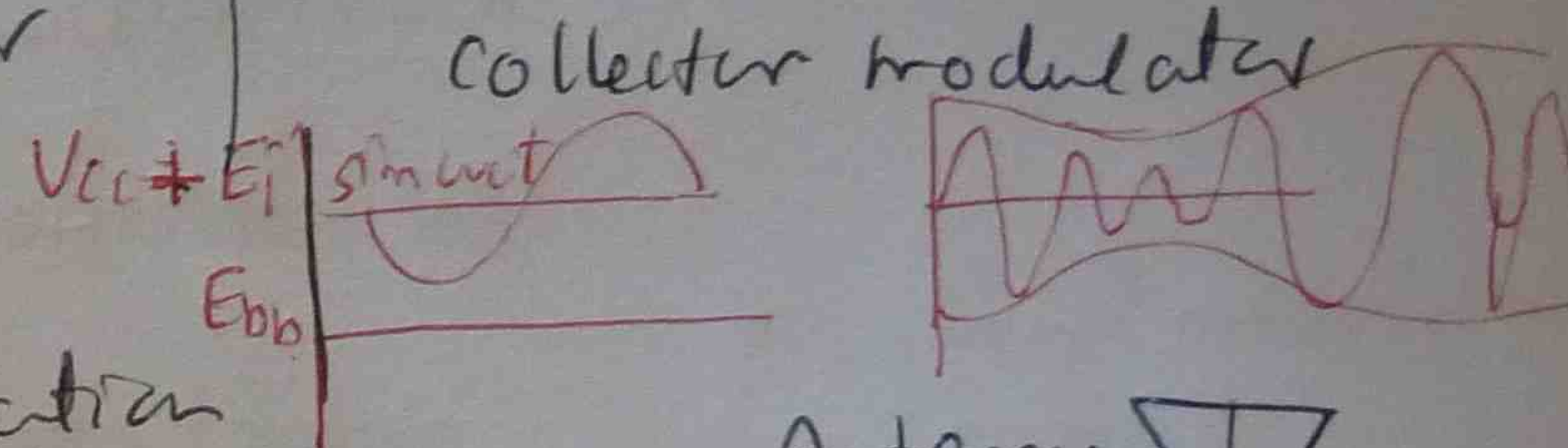
AM Generation



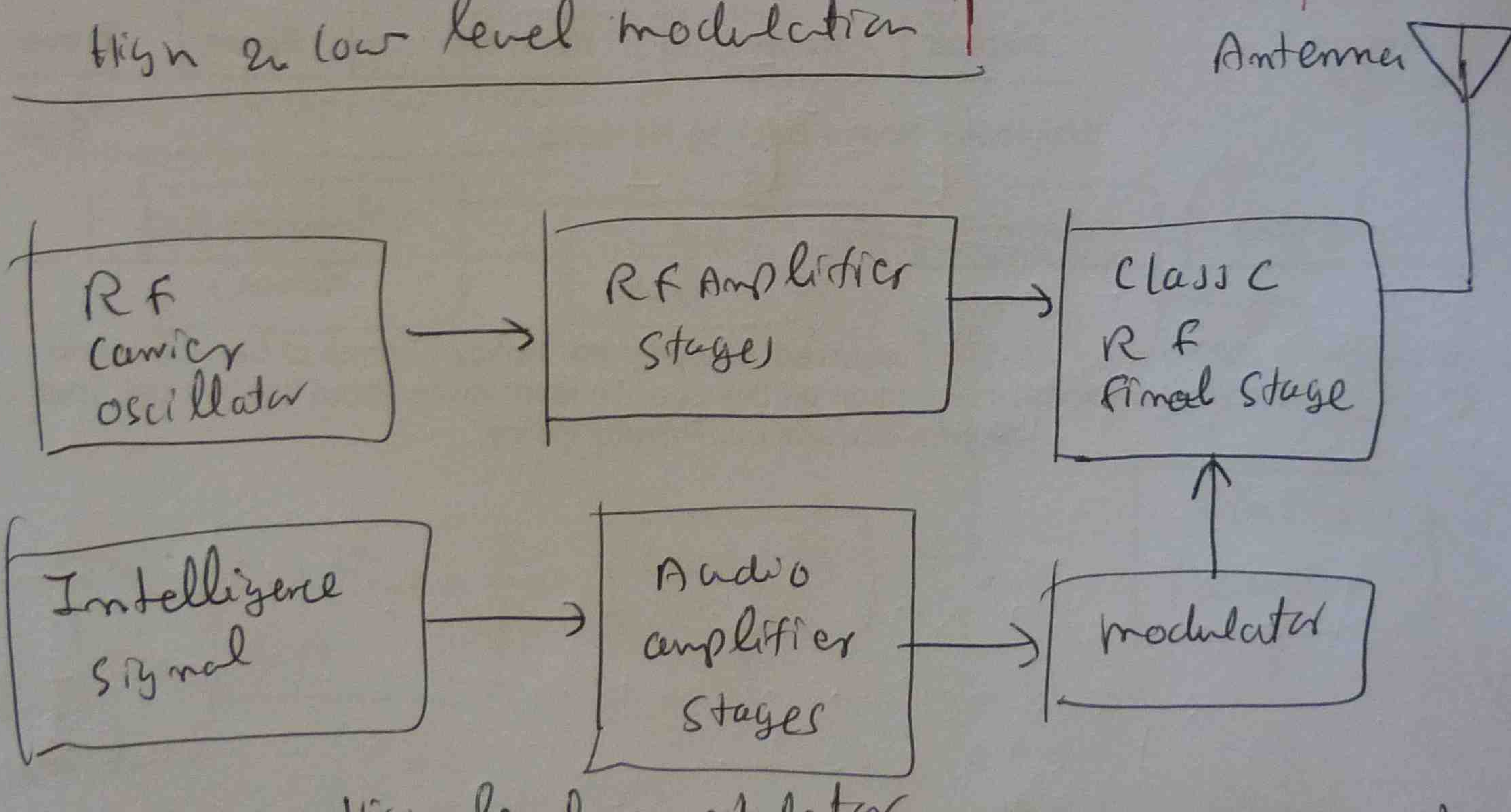
simple transistor modulator



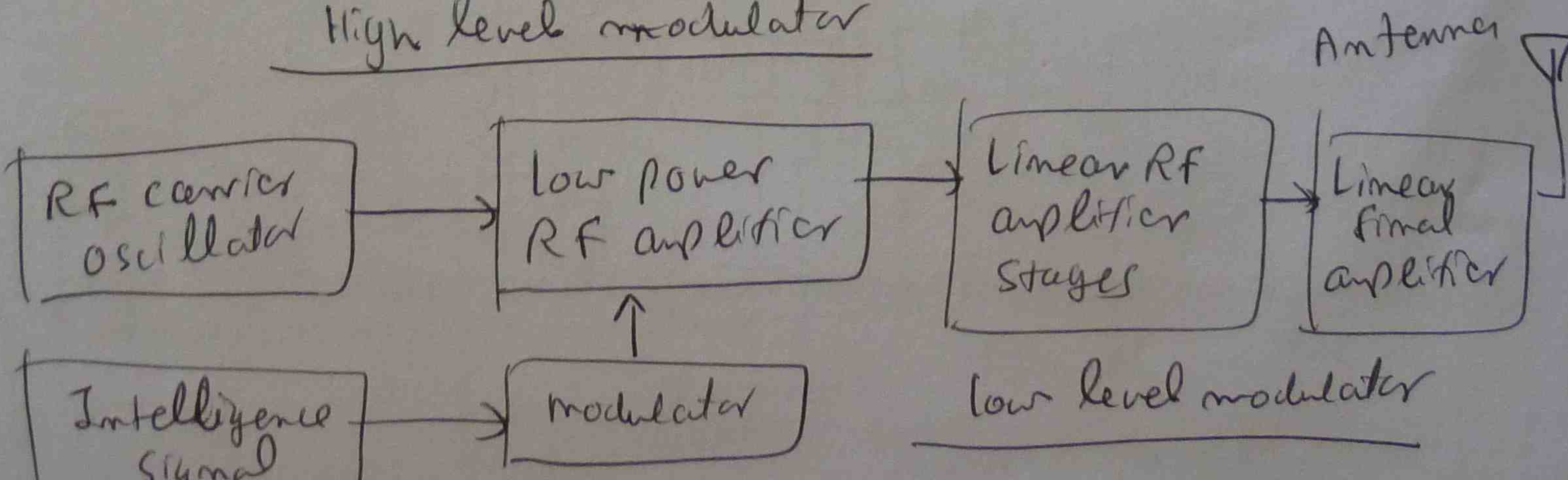
Collector modulator



High & low level modulation

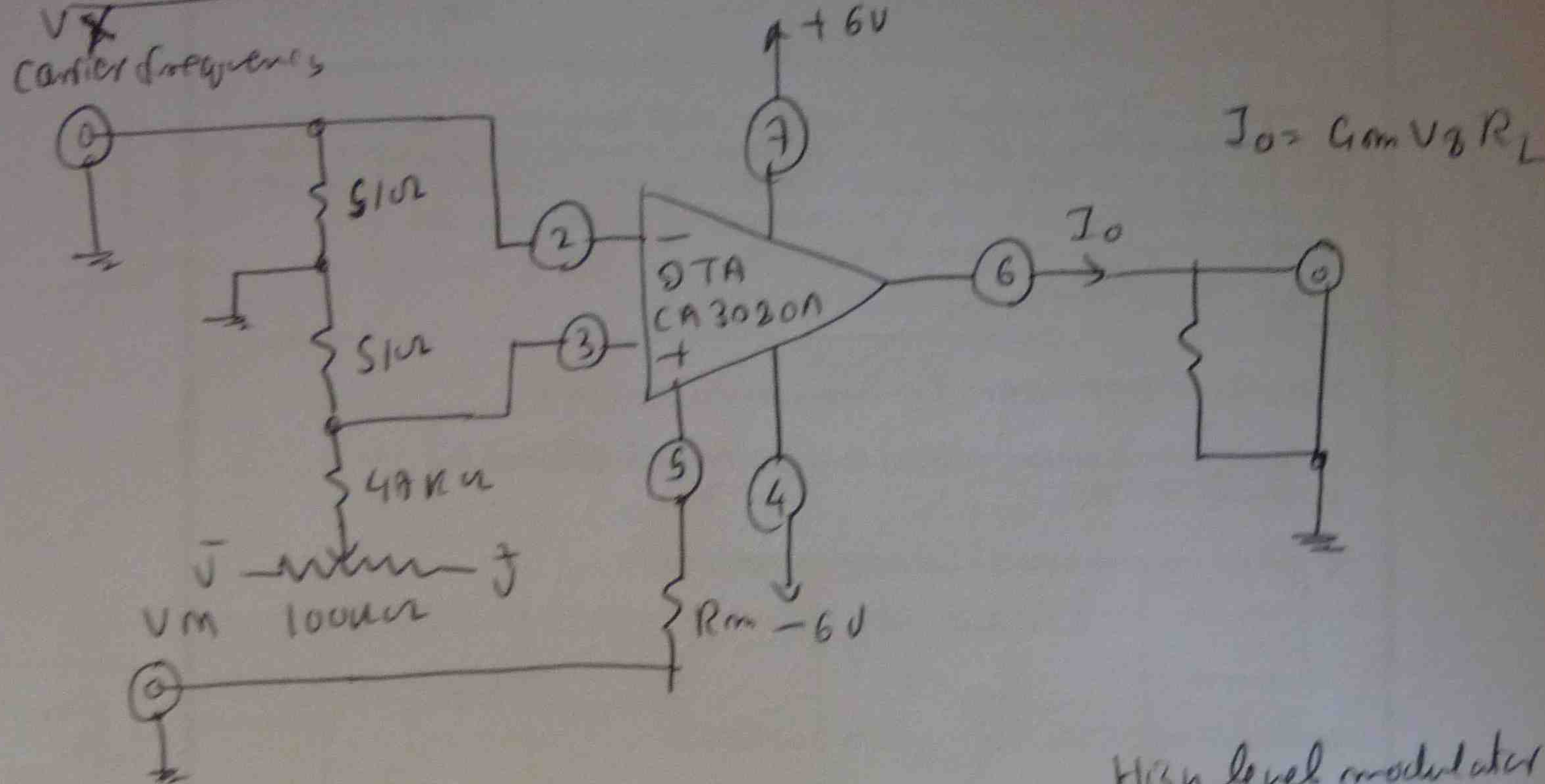


High level modulator

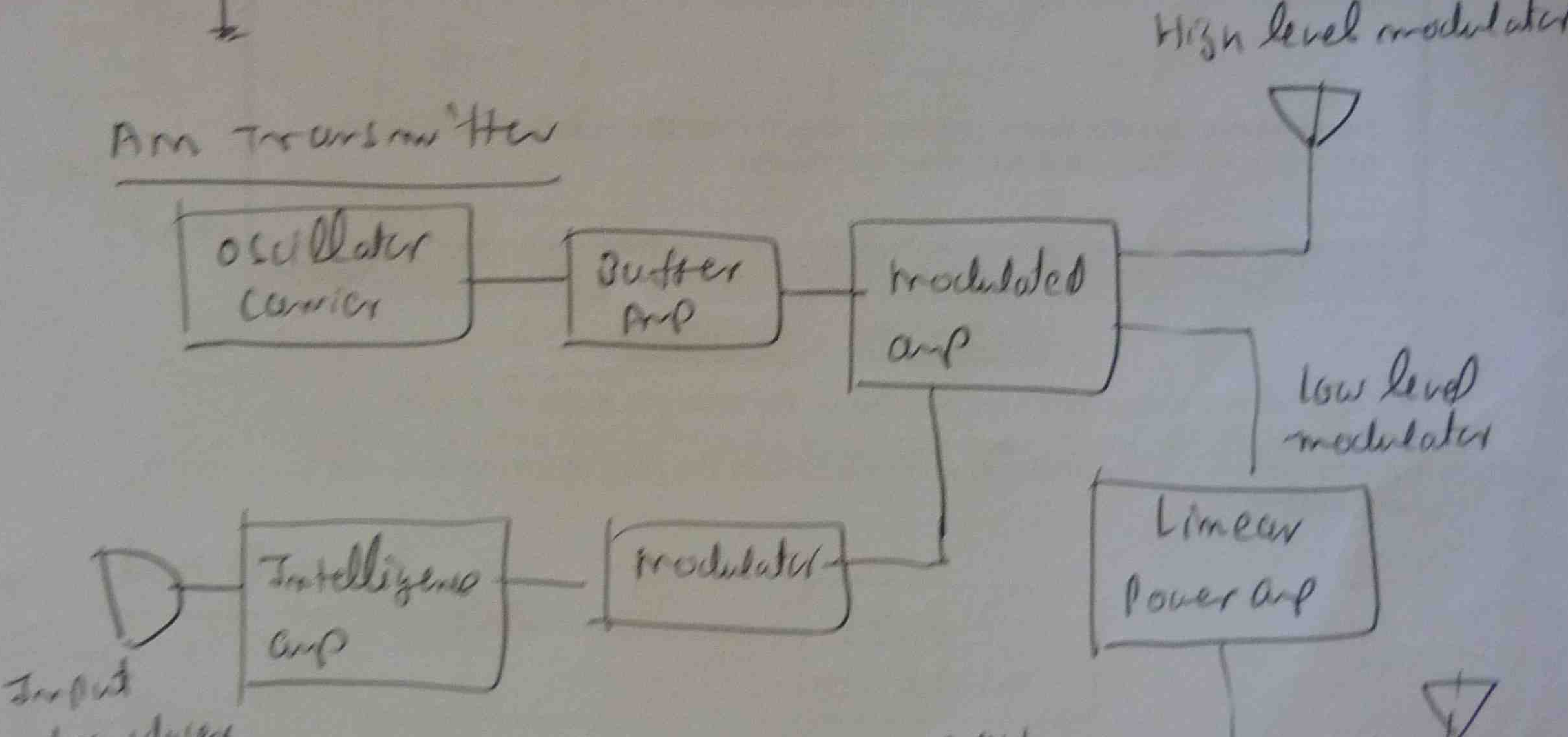


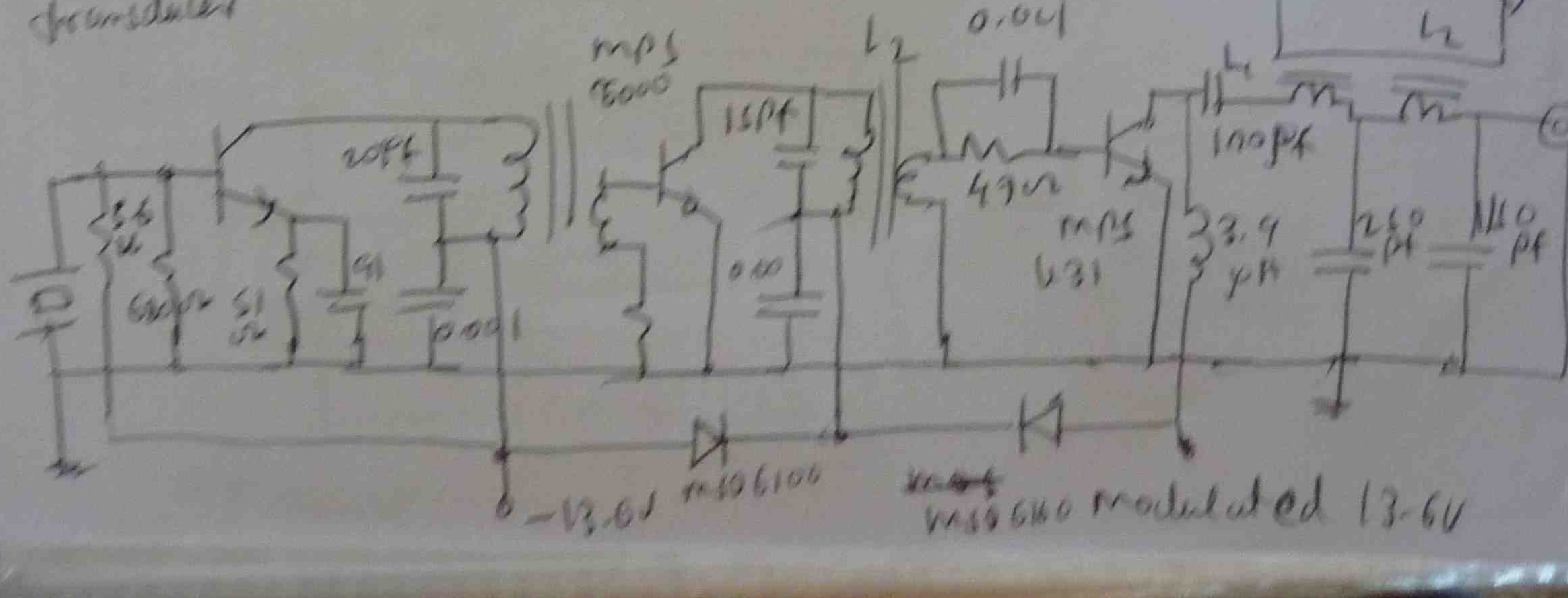
low level modulator

Amplitude modulator

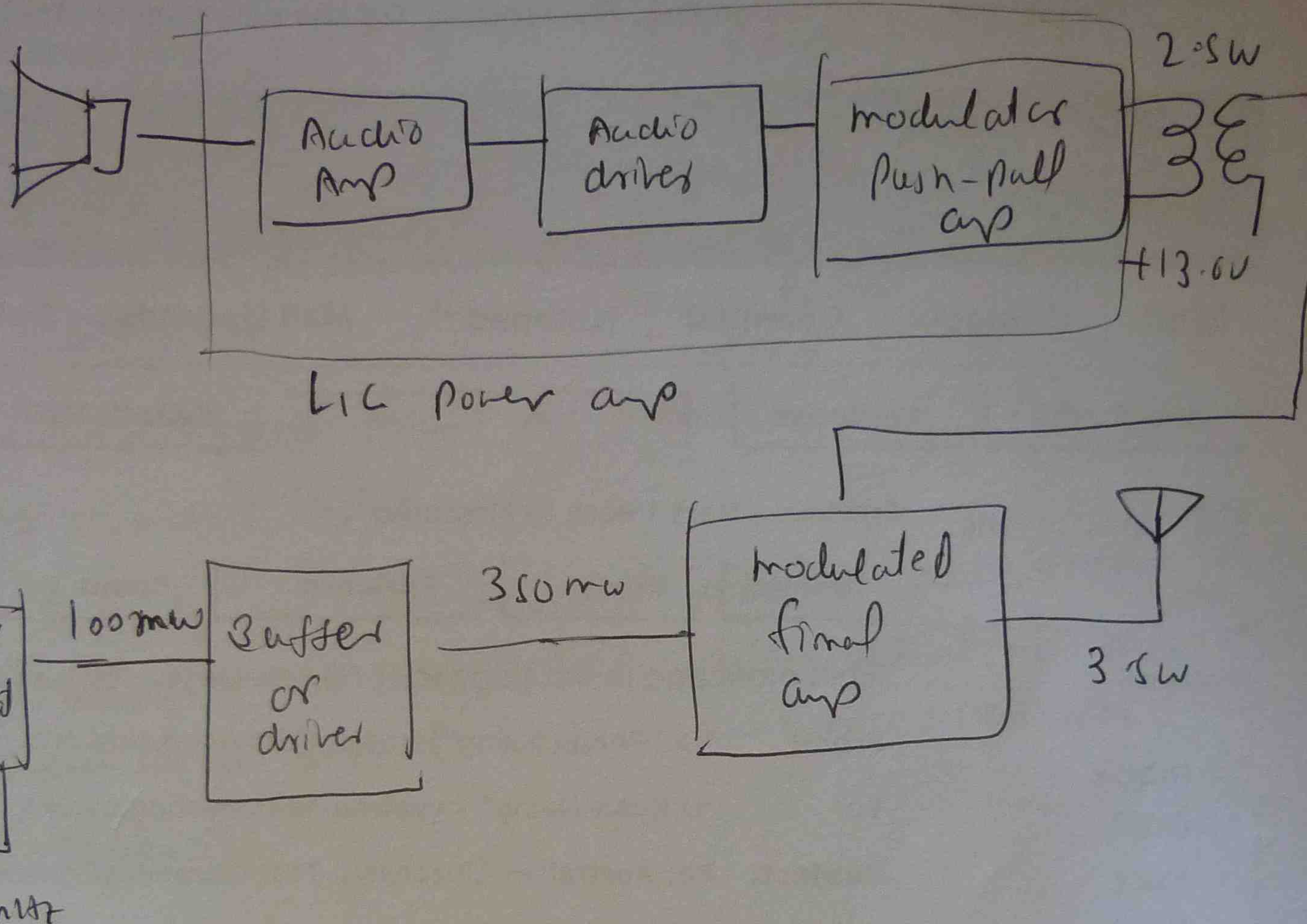


Am Transmitter



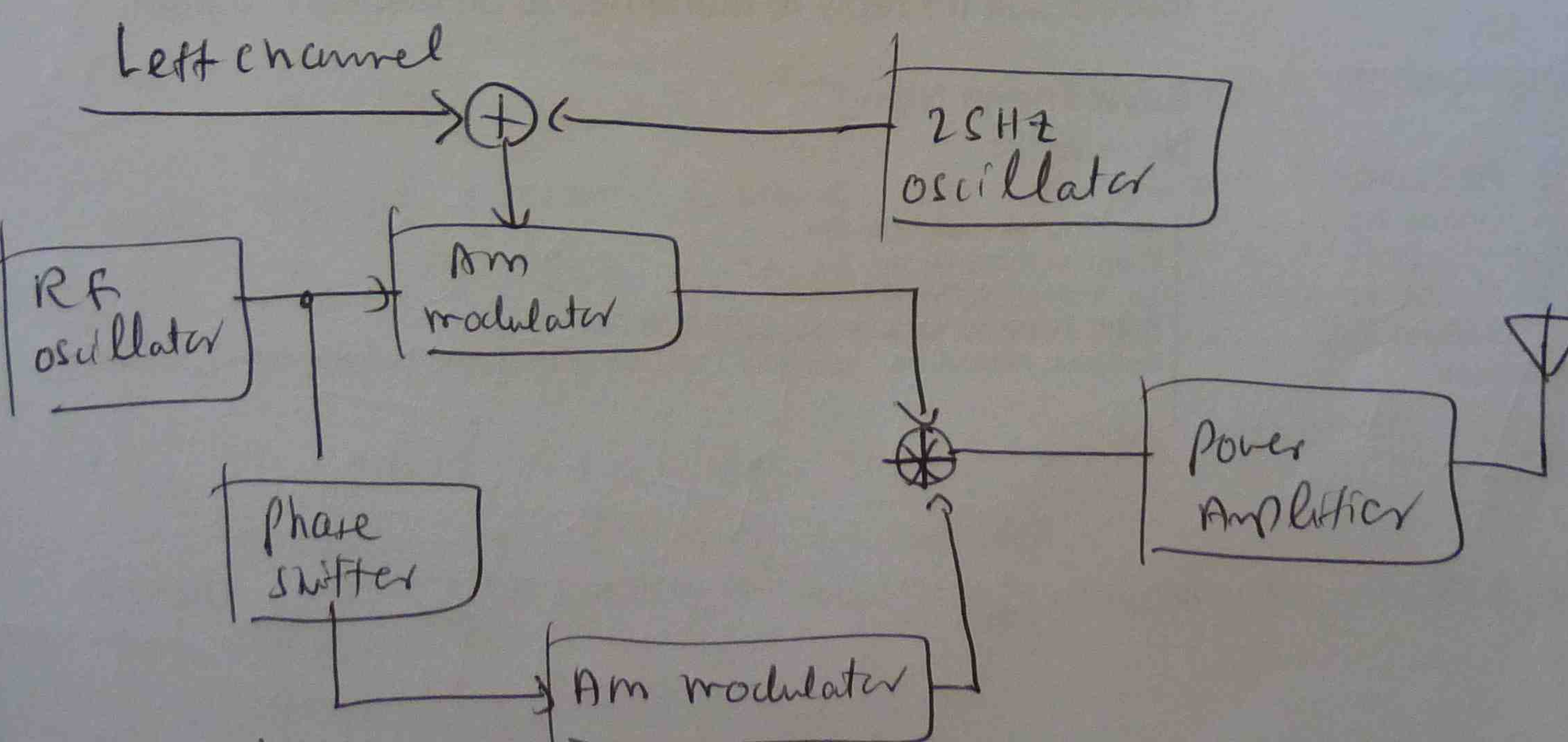


Transmitter



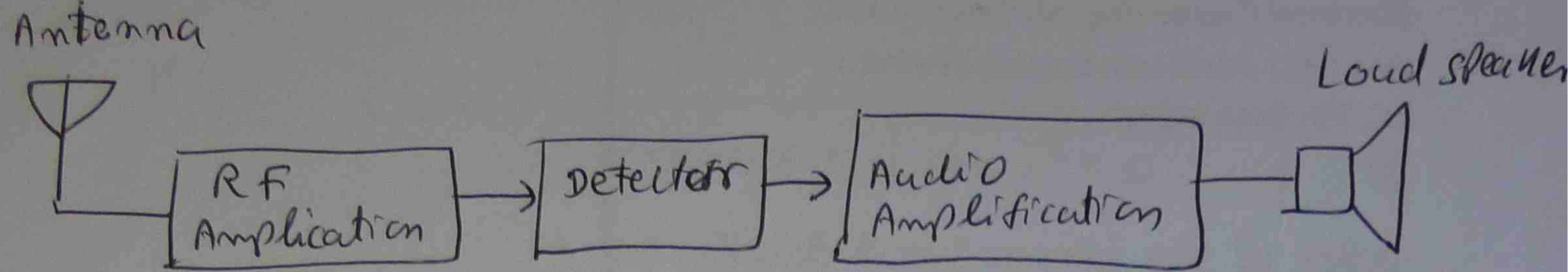
Stereo broadcasting

Reproduction of music with two separate channels



Week 4

Amplitude modulation reception



main characteristics of receiver

- sensitivity → Ability to drive the output transducer to an acceptable level.
- Selectivity.

→ The input signal must be greater than the noise at the receiver's input.

→ Selectivity may be defined as the extent to which a receiver is capable of differentiating between the desired signal and disturbances at other frequencies

TRF selectivity

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

Ex

A TRF receiver is to be designed with a ~~signal~~ single tuned circuit using a 10 μH 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.

at 550kHz

(a) $C = ?$

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

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

$$C = 8.37\ nf$$

at 1550kHz

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

$$C = 1.06\ nf$$

Range of capacitance $1.06\ nf \rightarrow 8.37\ nF$

(b) $$Q = \frac{f_r}{BW} = \frac{1100\times10^3}{10\times10^3} = 110$$

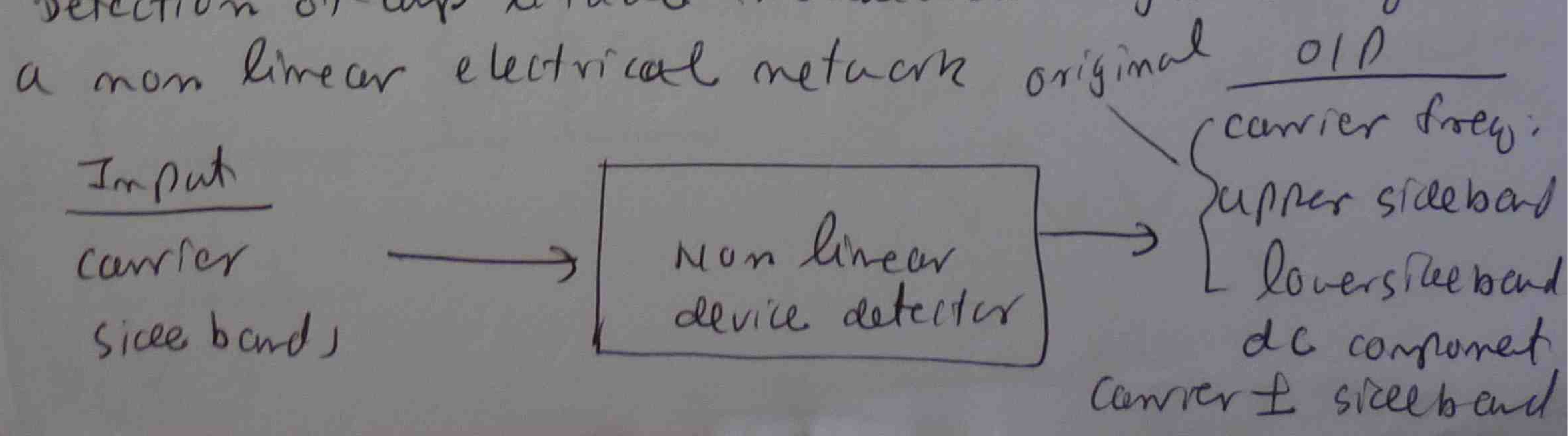
(c) at 1550kHz $$BW = \frac{f_r}{Q} = \frac{1550\times10^3}{110} = 14.1\ kHz$$

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

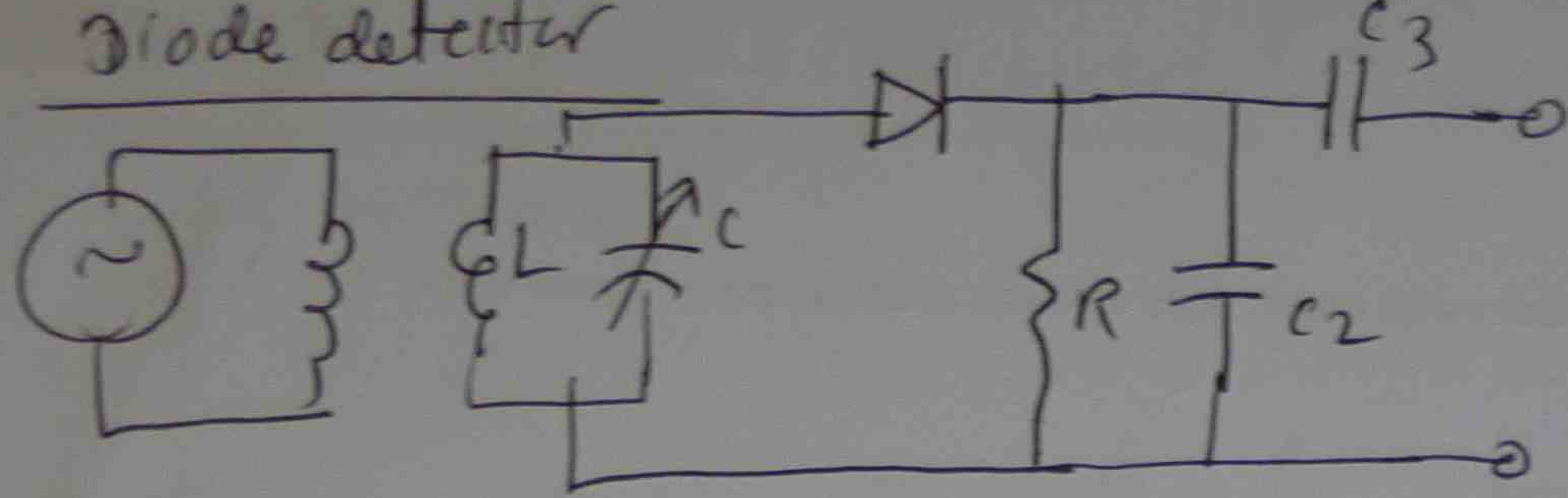
Am Detection

The carrier and sidebands of the Am signals are separated in frequency by an amount equal to the intelligence frequency.

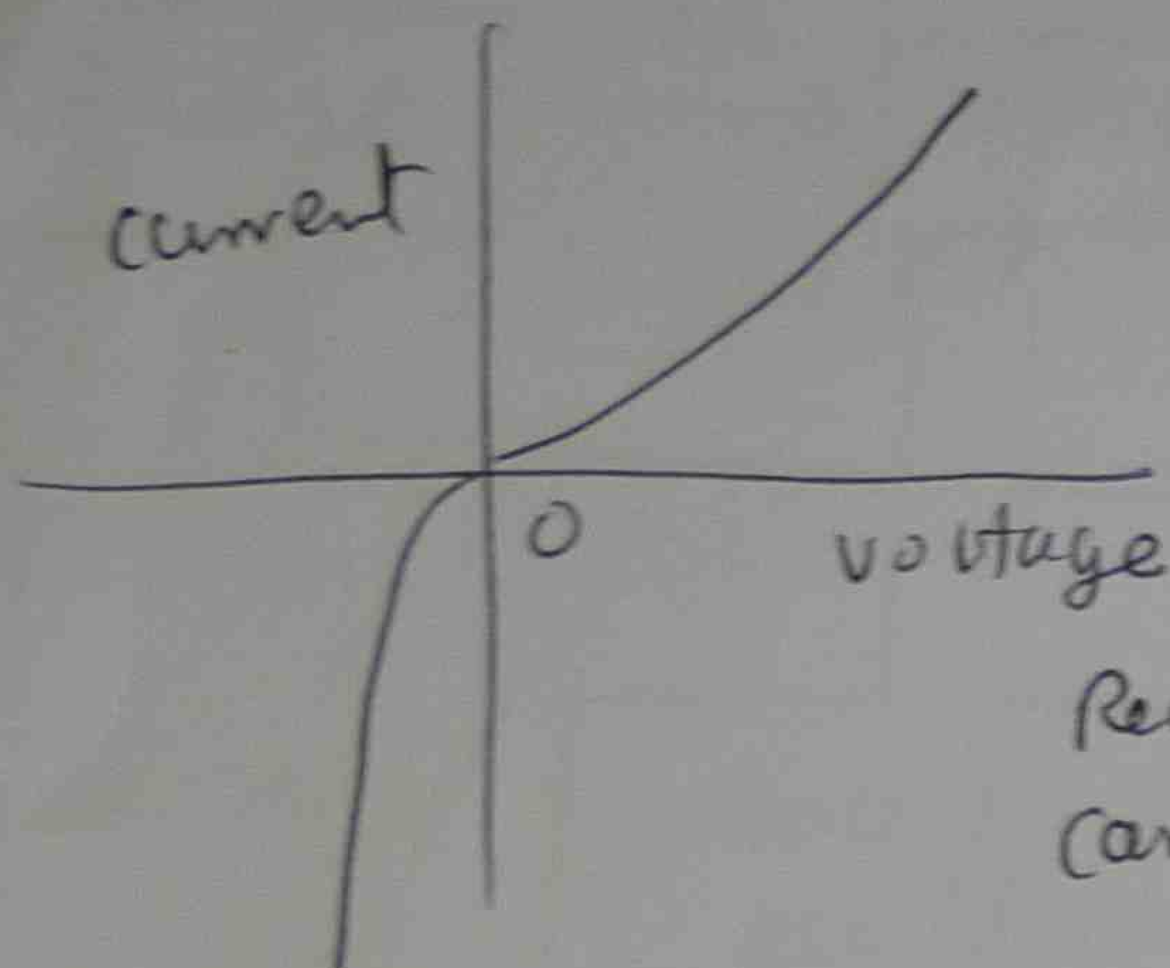
Detection of amplitude modulated signals requires a non linear electrical network

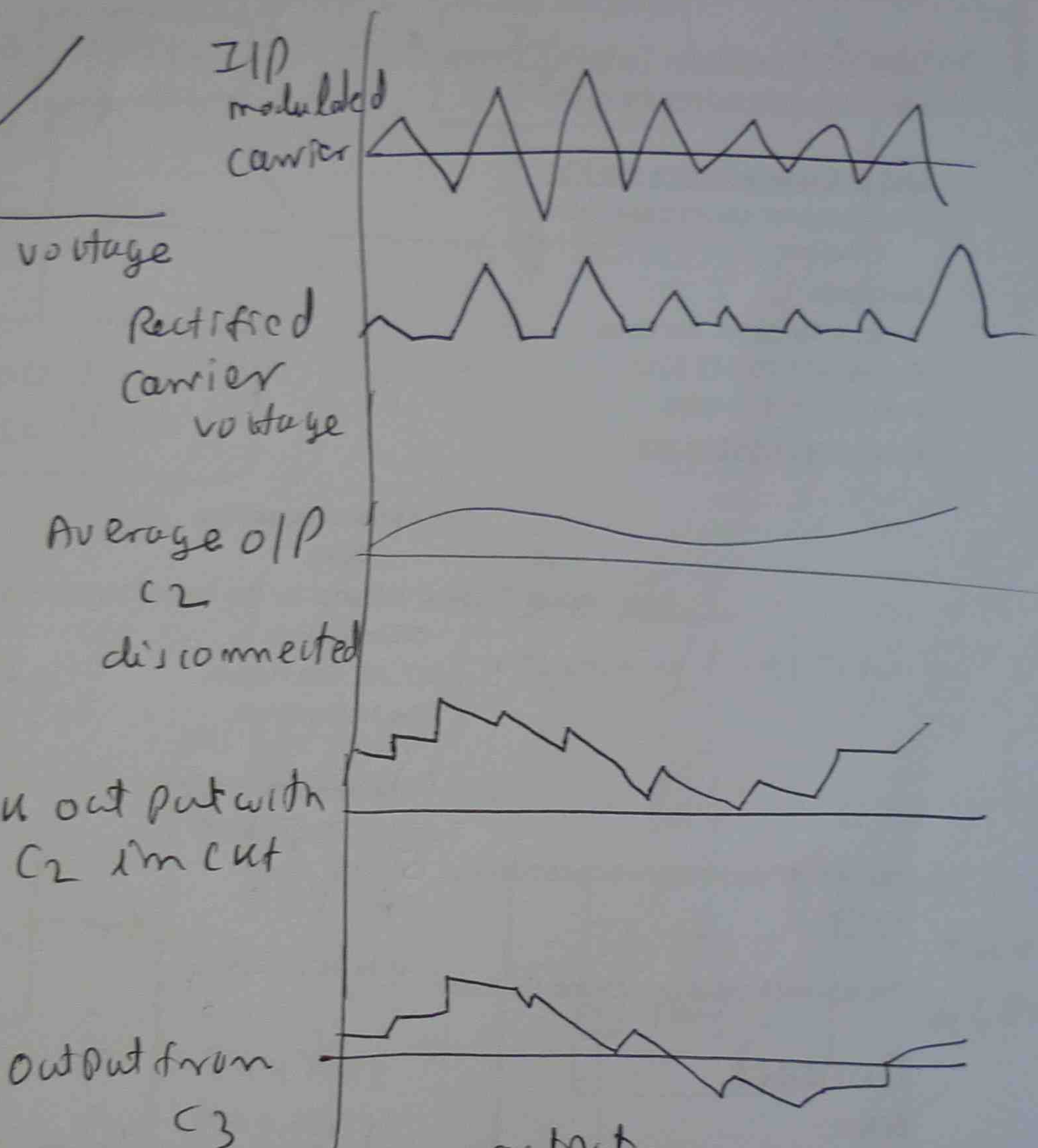


Diode detector

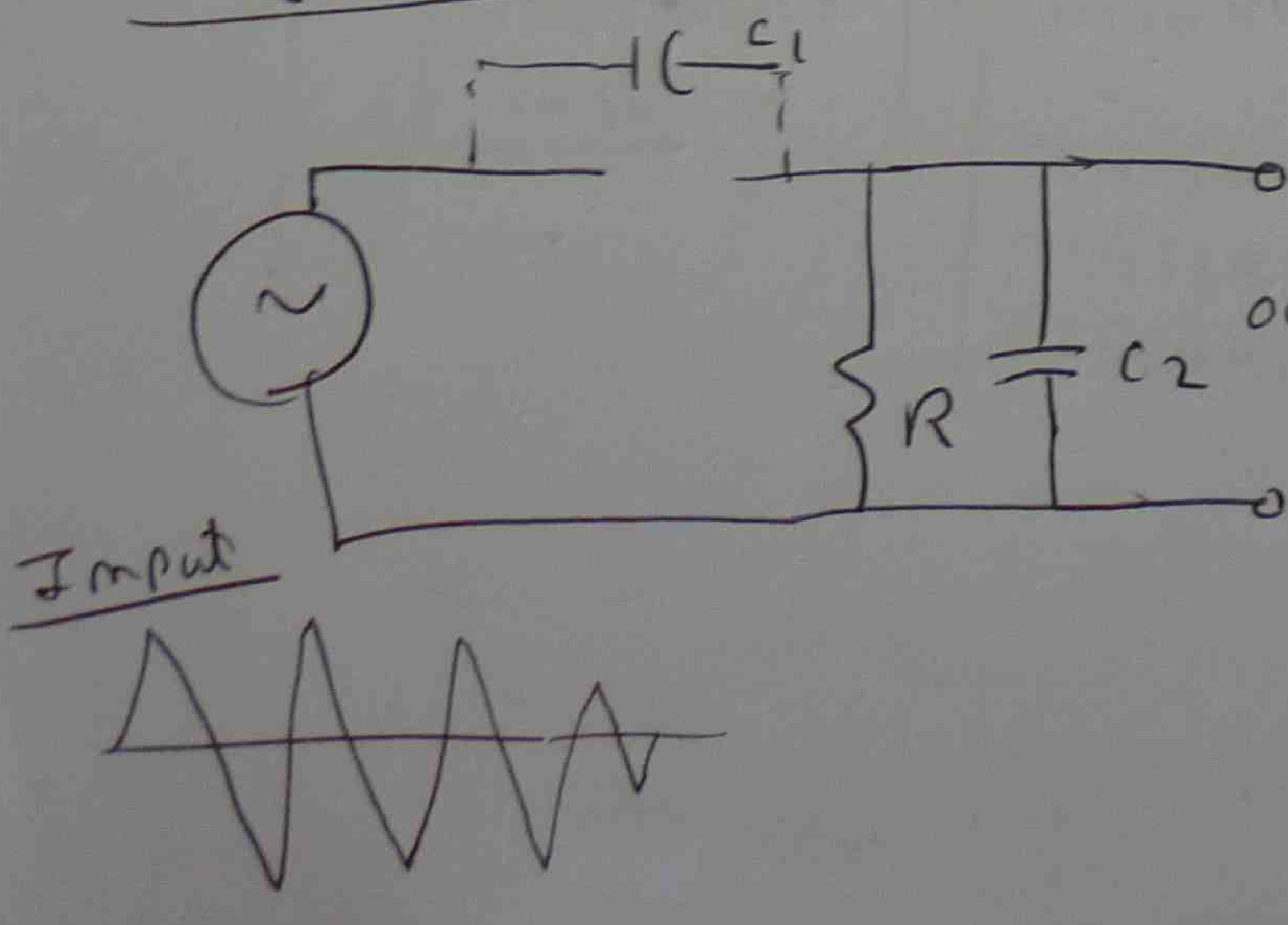


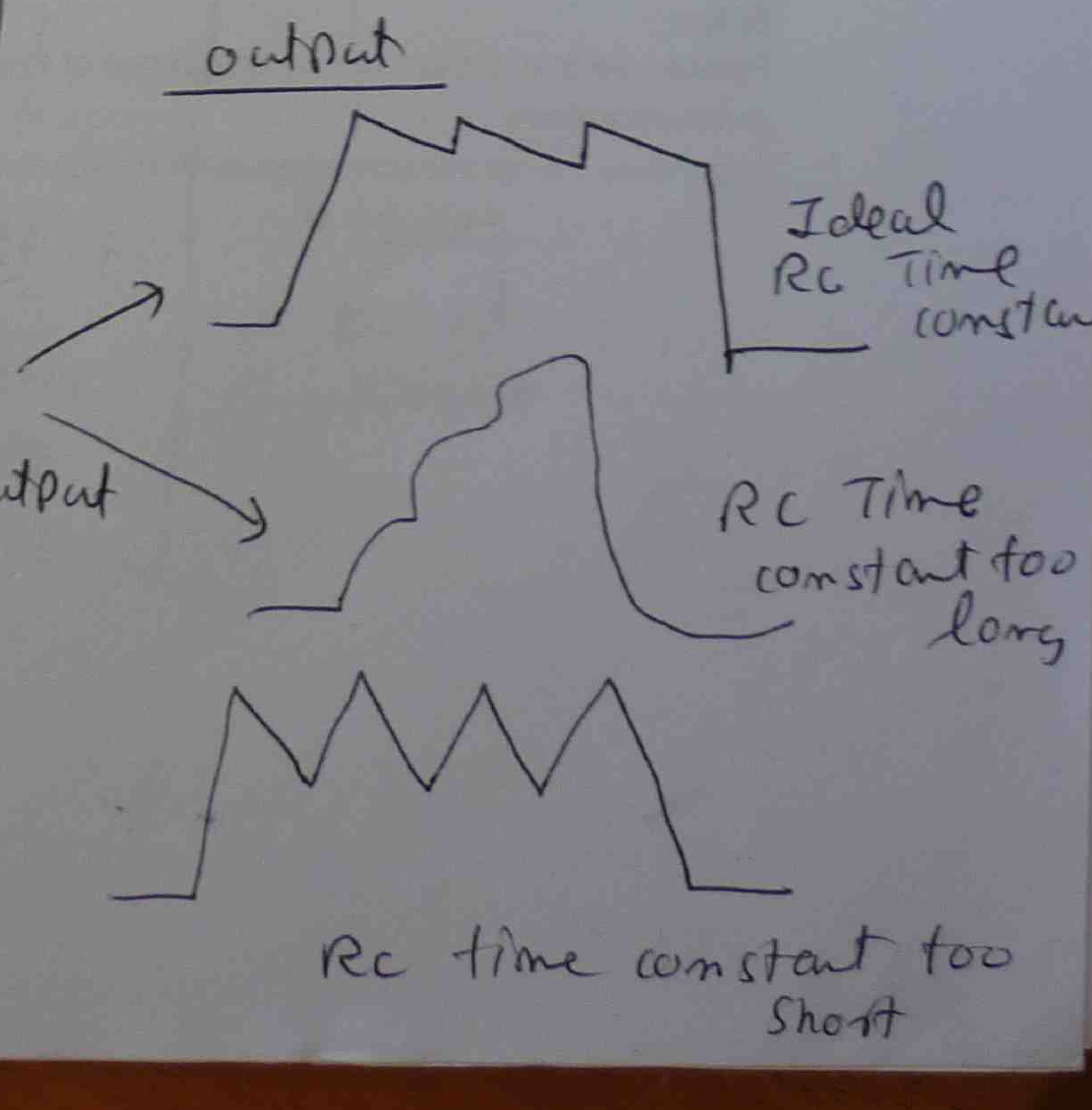
C2 & R removes carrier frequency.



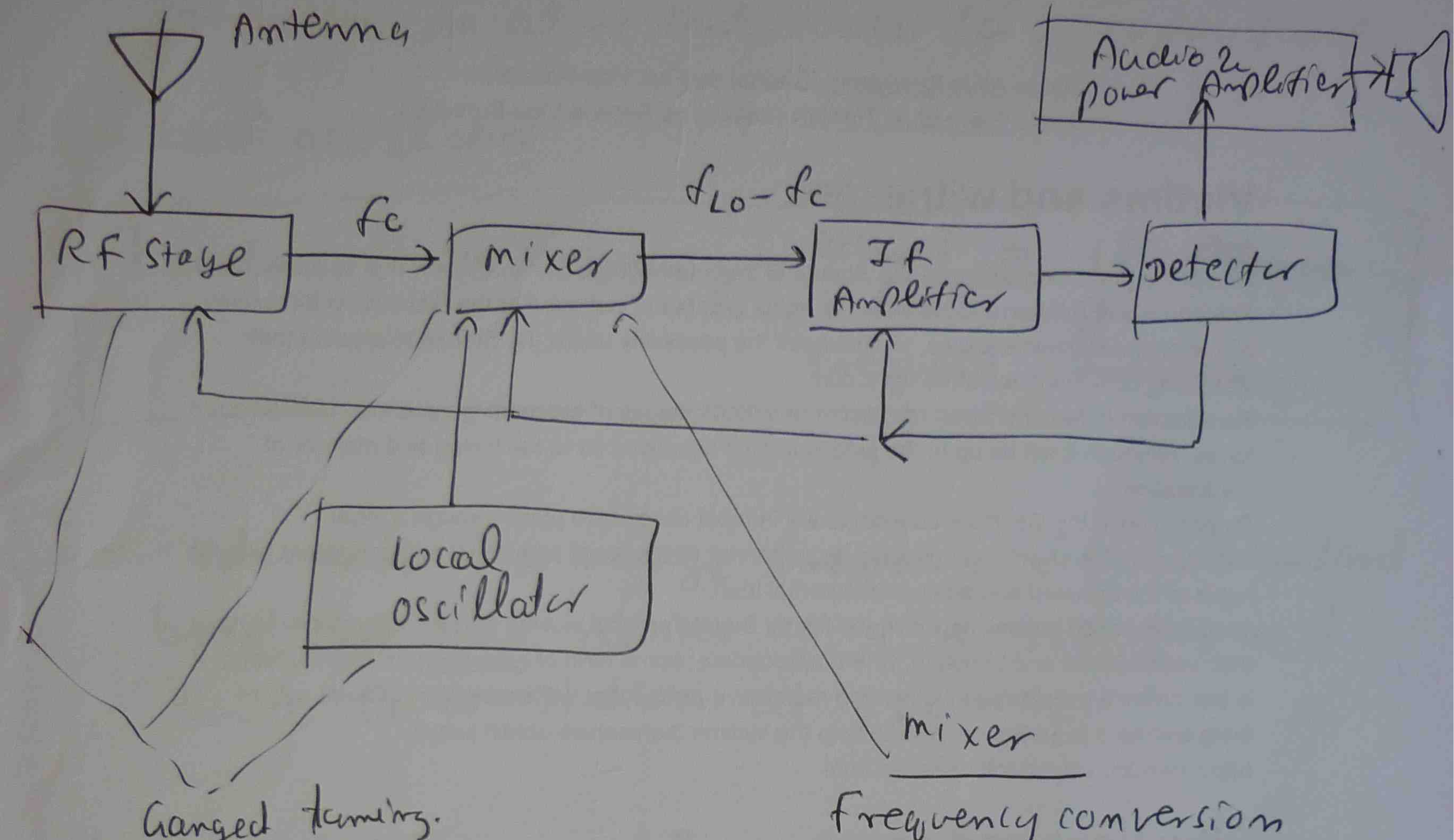


Diagional clipping

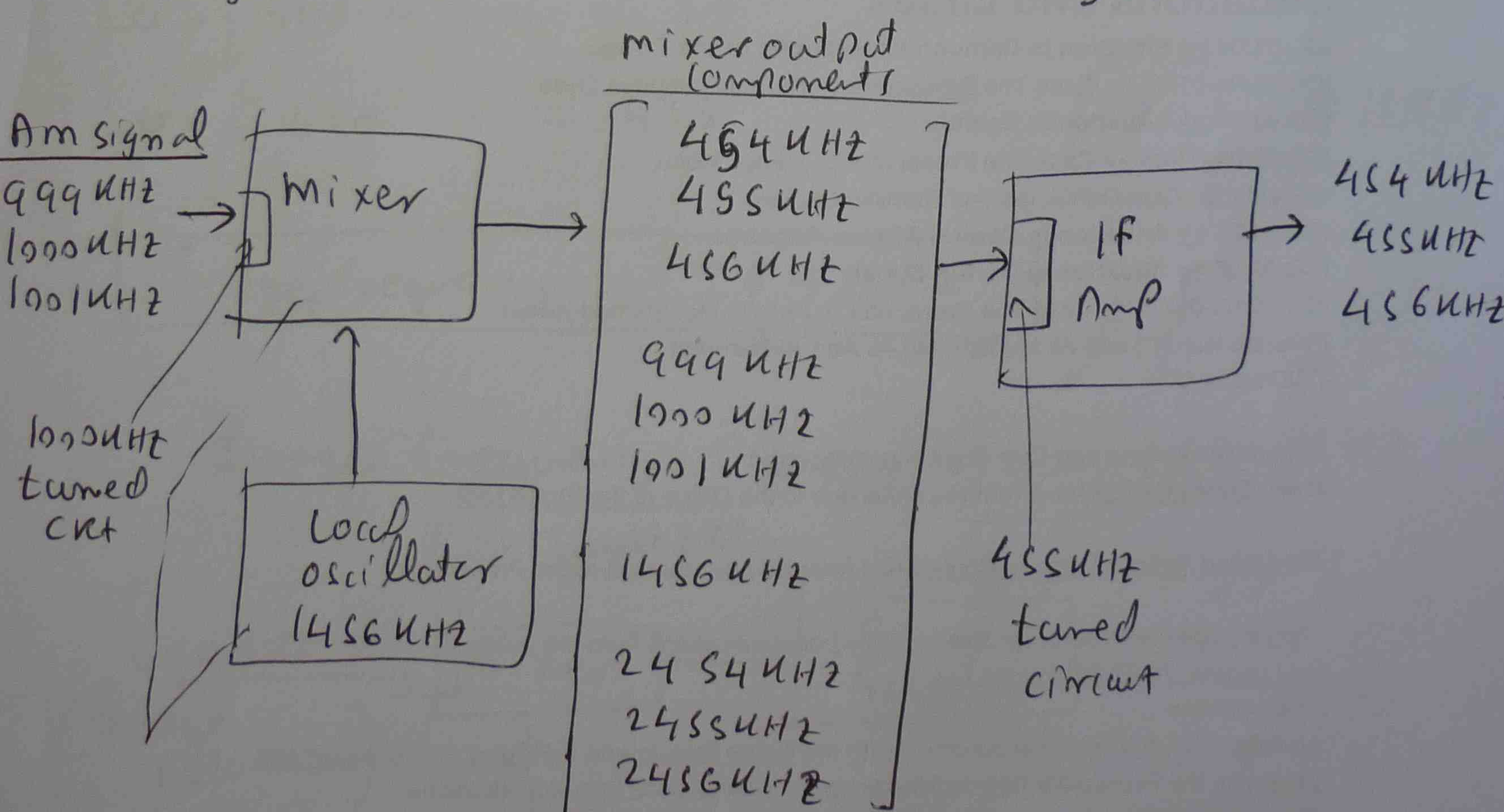




Superheterodyne Receivers



frequency conversion



Tuned ckt adjustment

reduction in either inductance (or) capacitance

LO – Local oscillator

$$\boxed{\text{Local oscillator frequency} - \text{desired station's frequency} = \text{IF frequency} \neq \cancel{\text{Image freq}}:}$$

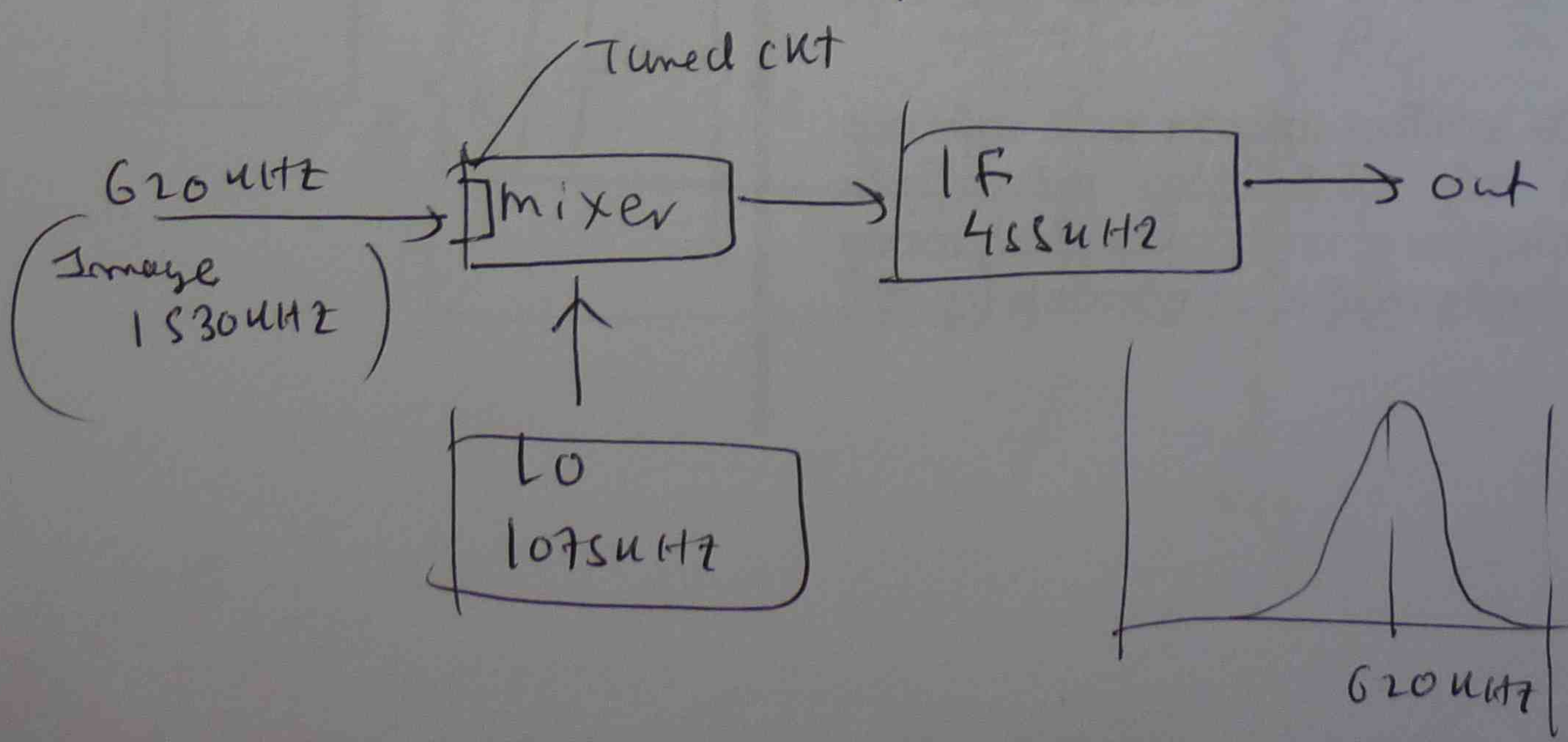
Ex determine the image frequency for a standard broadcast band receiver using a 455 KHZ and tuned to a station at 620 KHZ

LO – station freq: = IF

LO – 620 = 455 ⟶ ∴ LO = 1075 KHZ

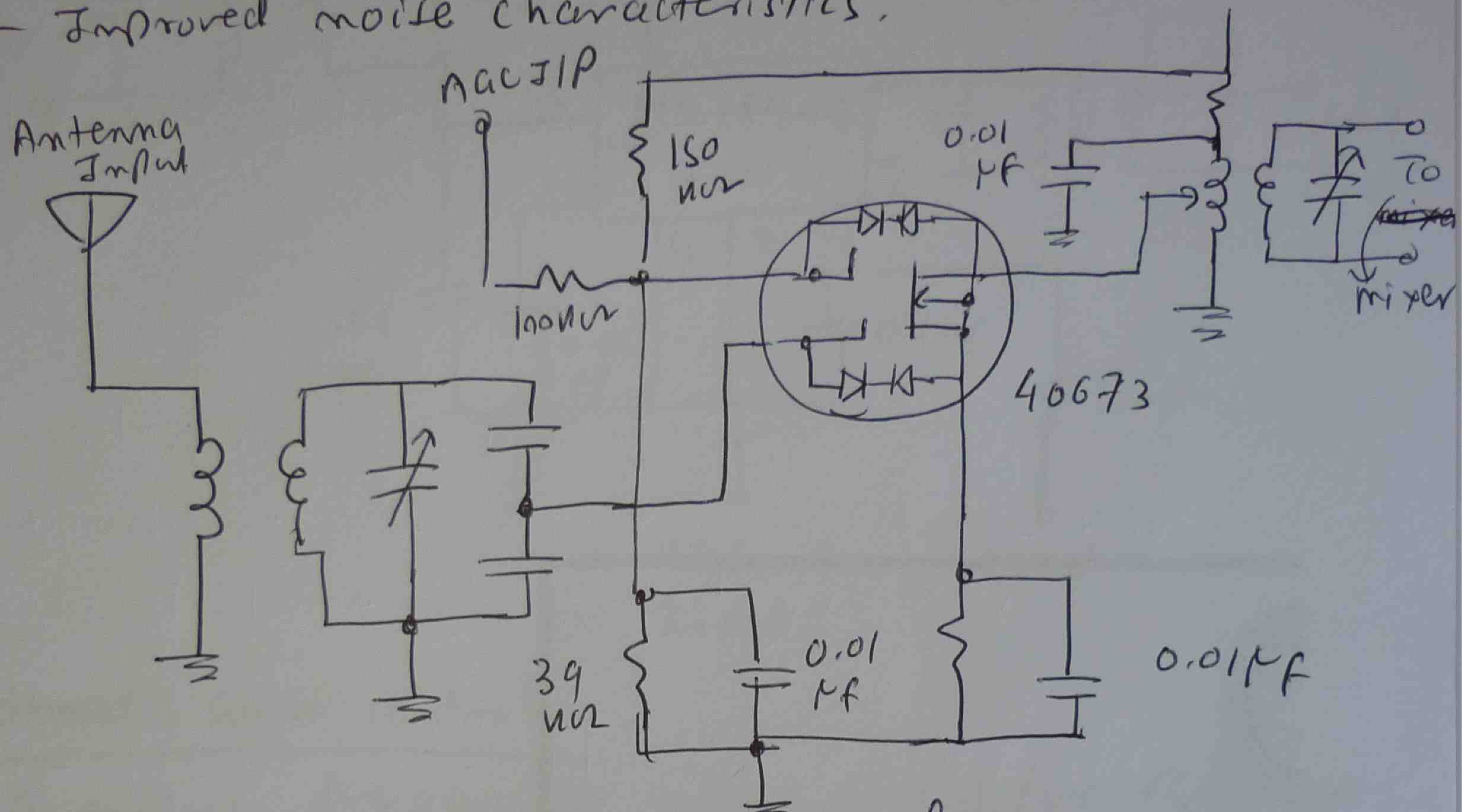
$$\boxed{\text{Image frequency} = IF + LO}$$

∴ Image frequency = 455 + 1075 = 1530 MHZ



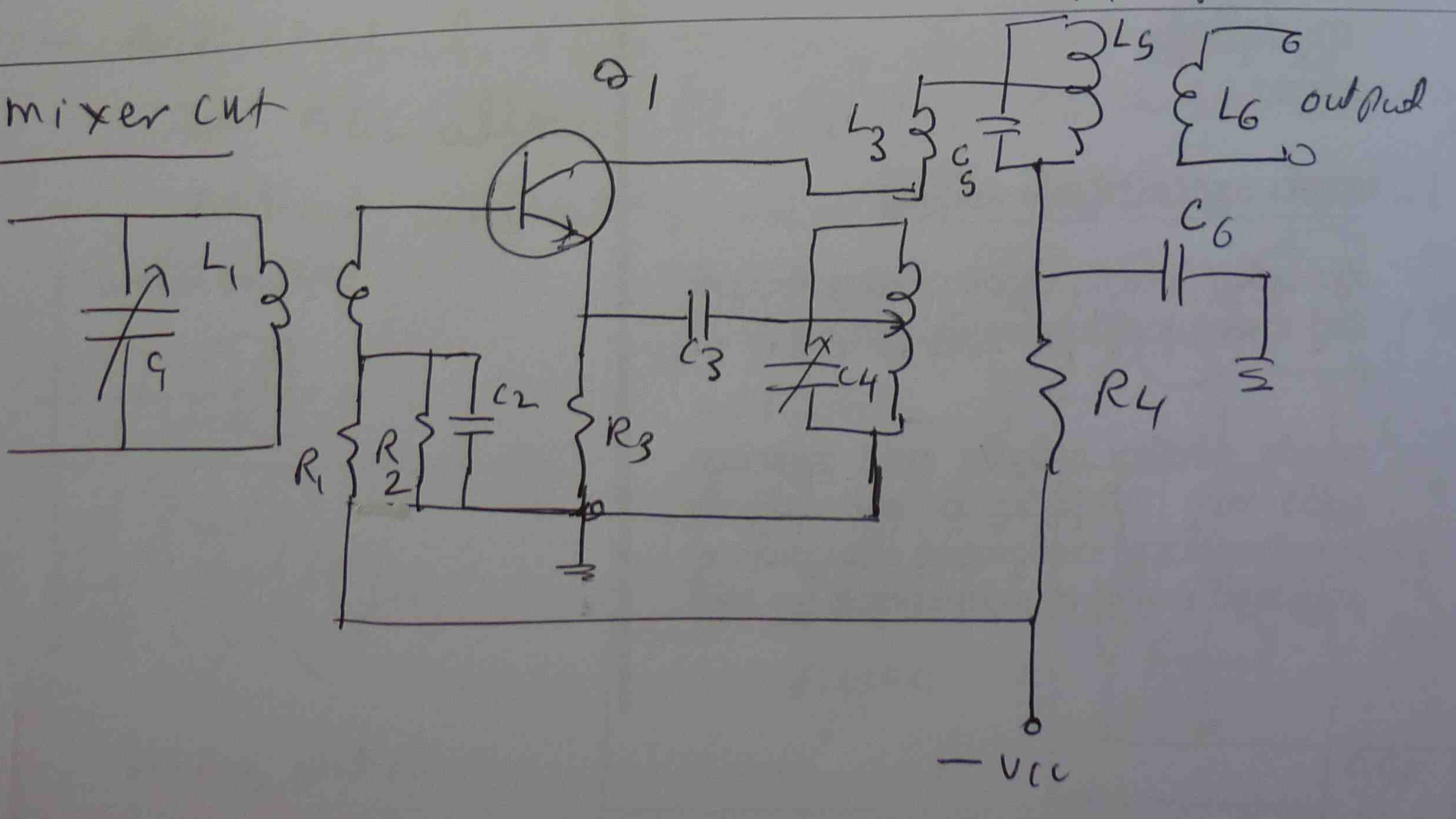
RF Amplifier

- Improved image frequency rejection
- more gain and better sensitivity
- Improved noise characteristics.

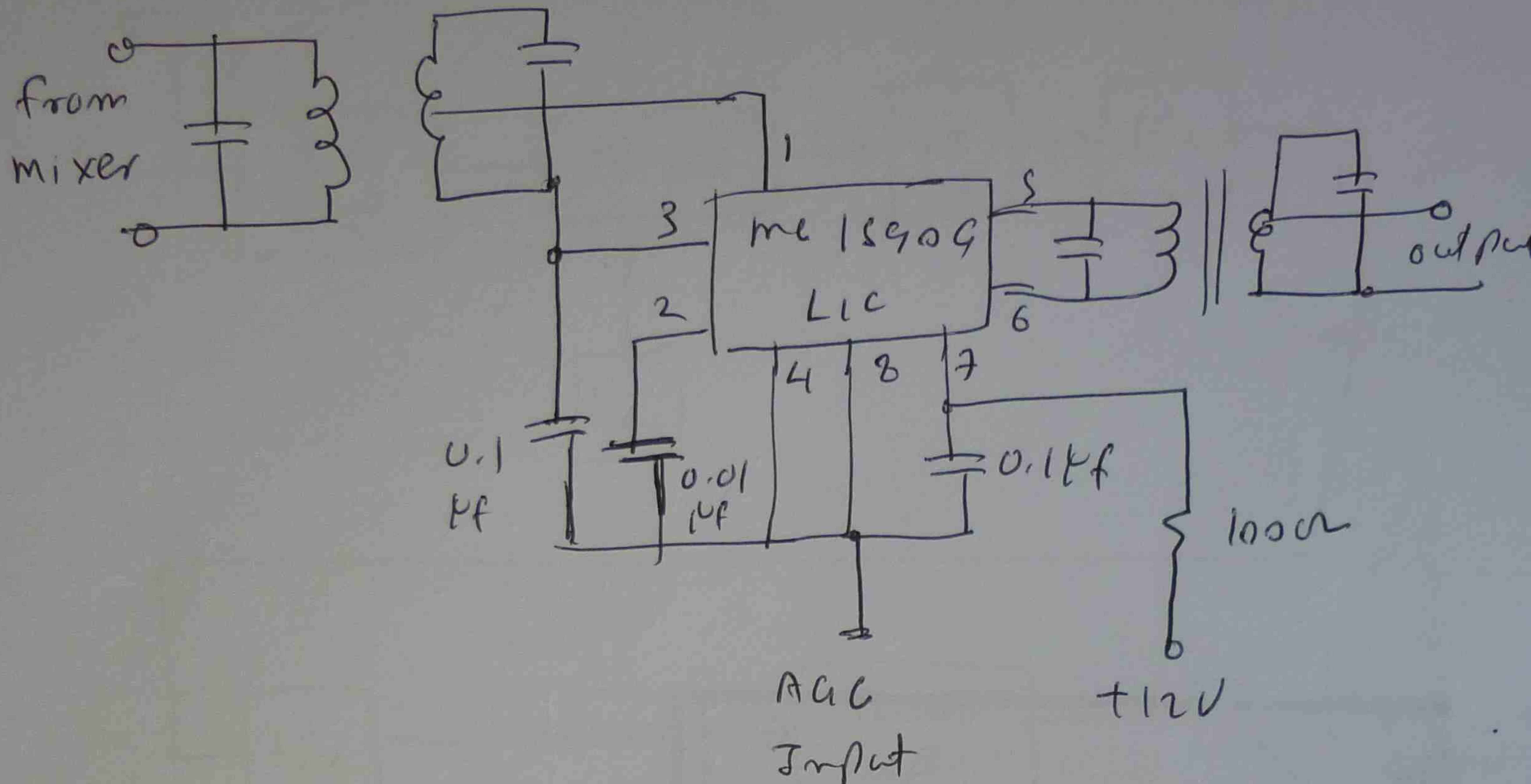


Dual Gate MOSFET RF Amplifier

mixer ckt



IF Amplifier

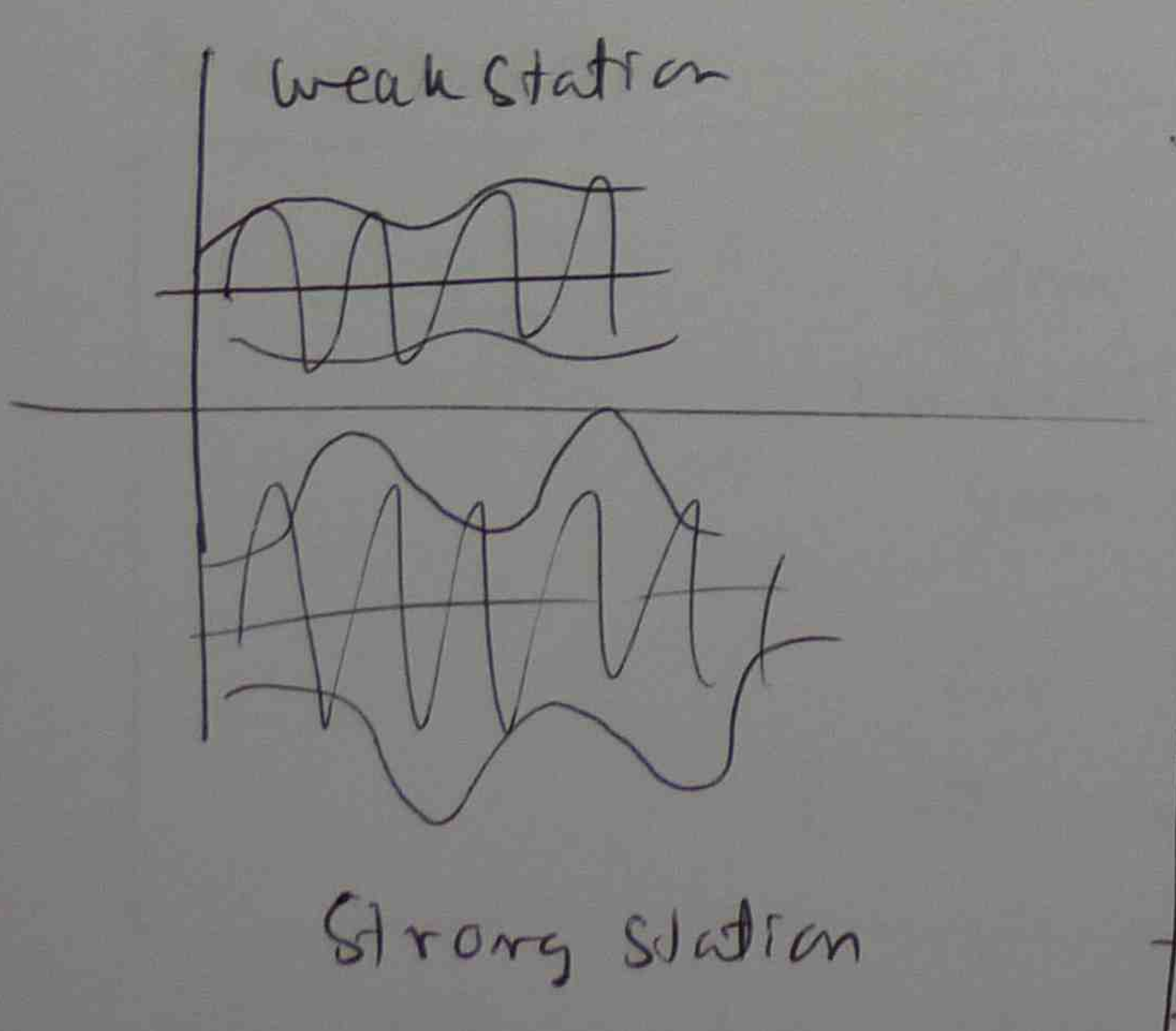


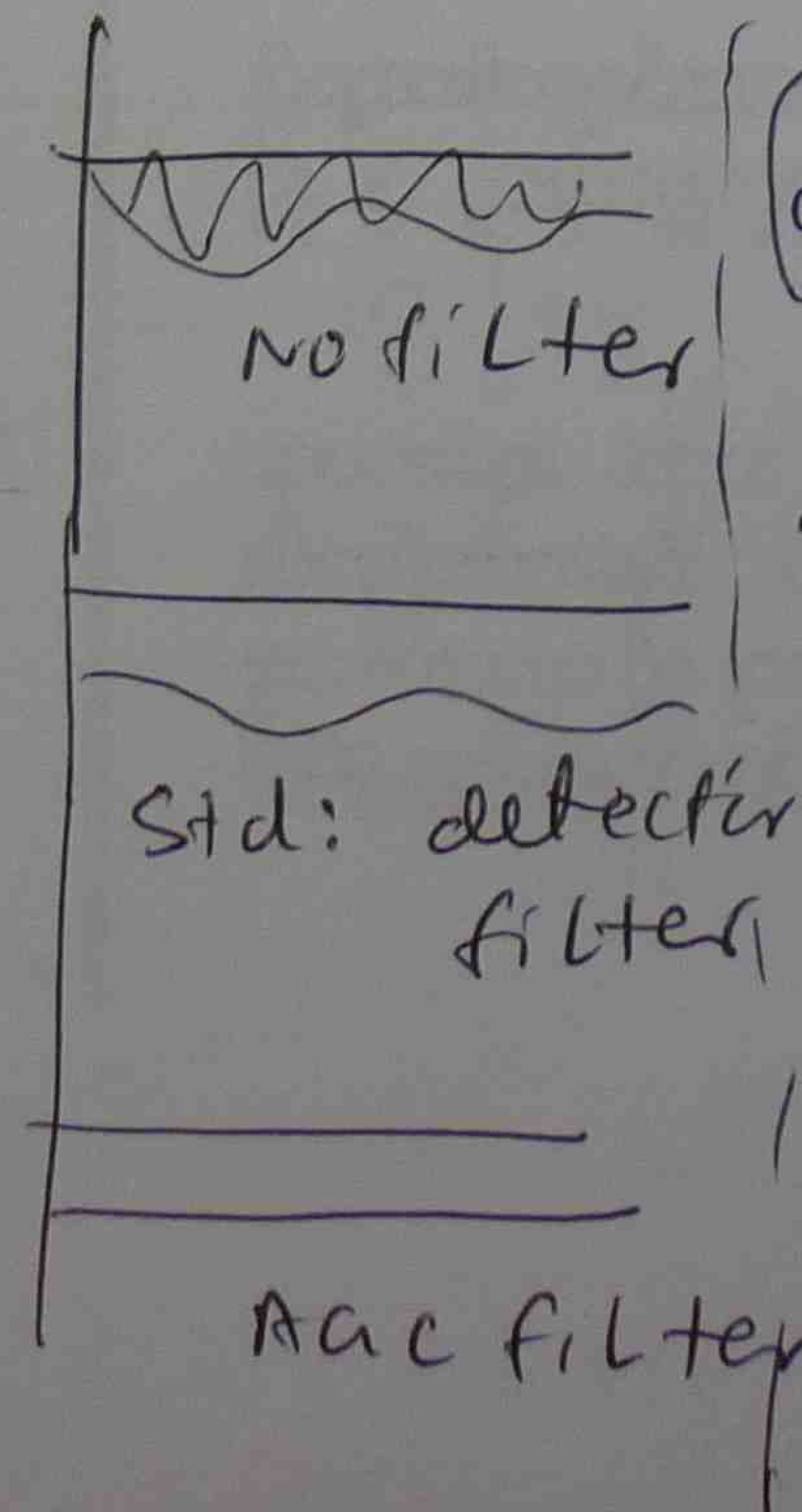
Automatic Gain control

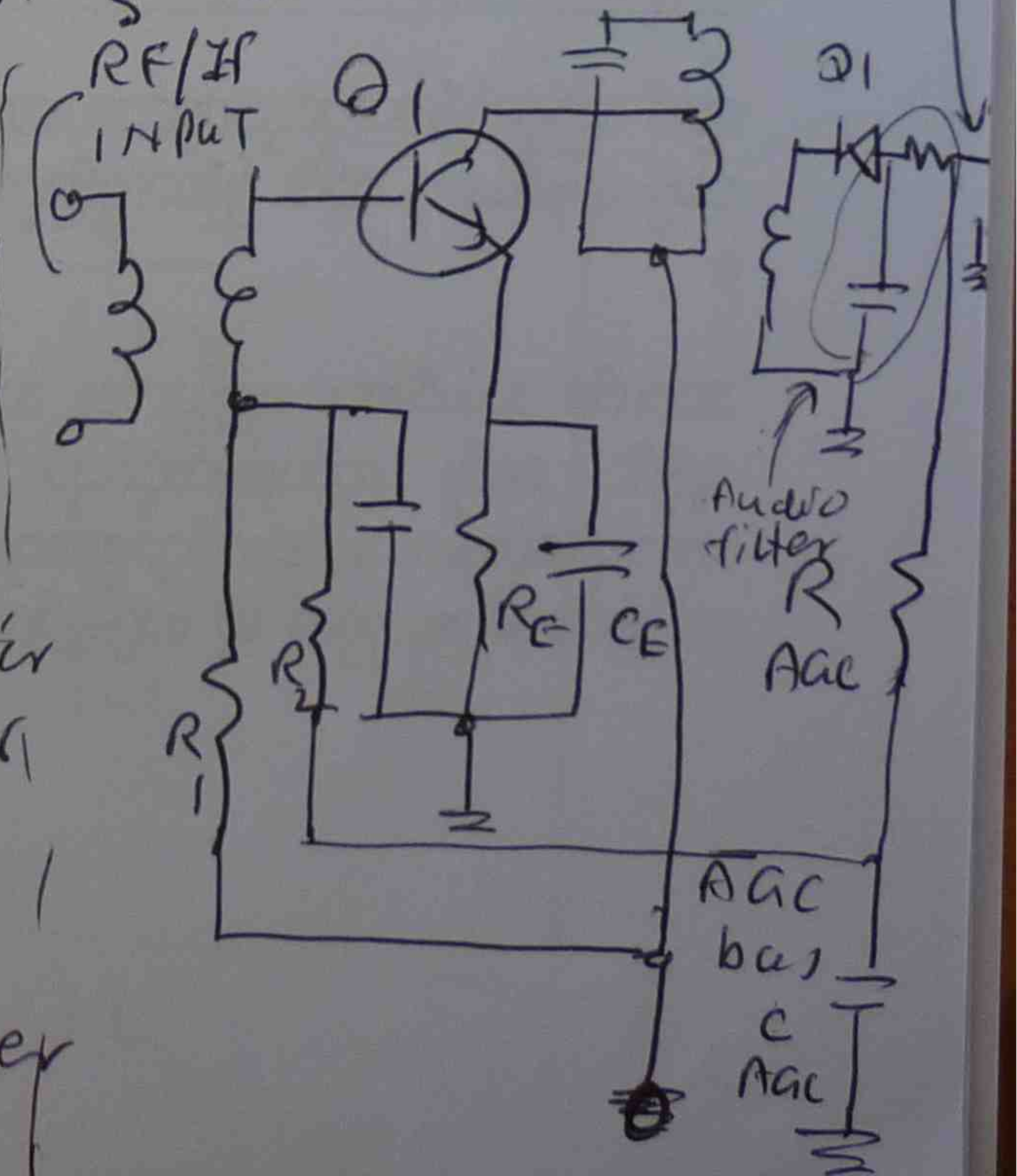
To control the gain of mixer and/or RF stages.

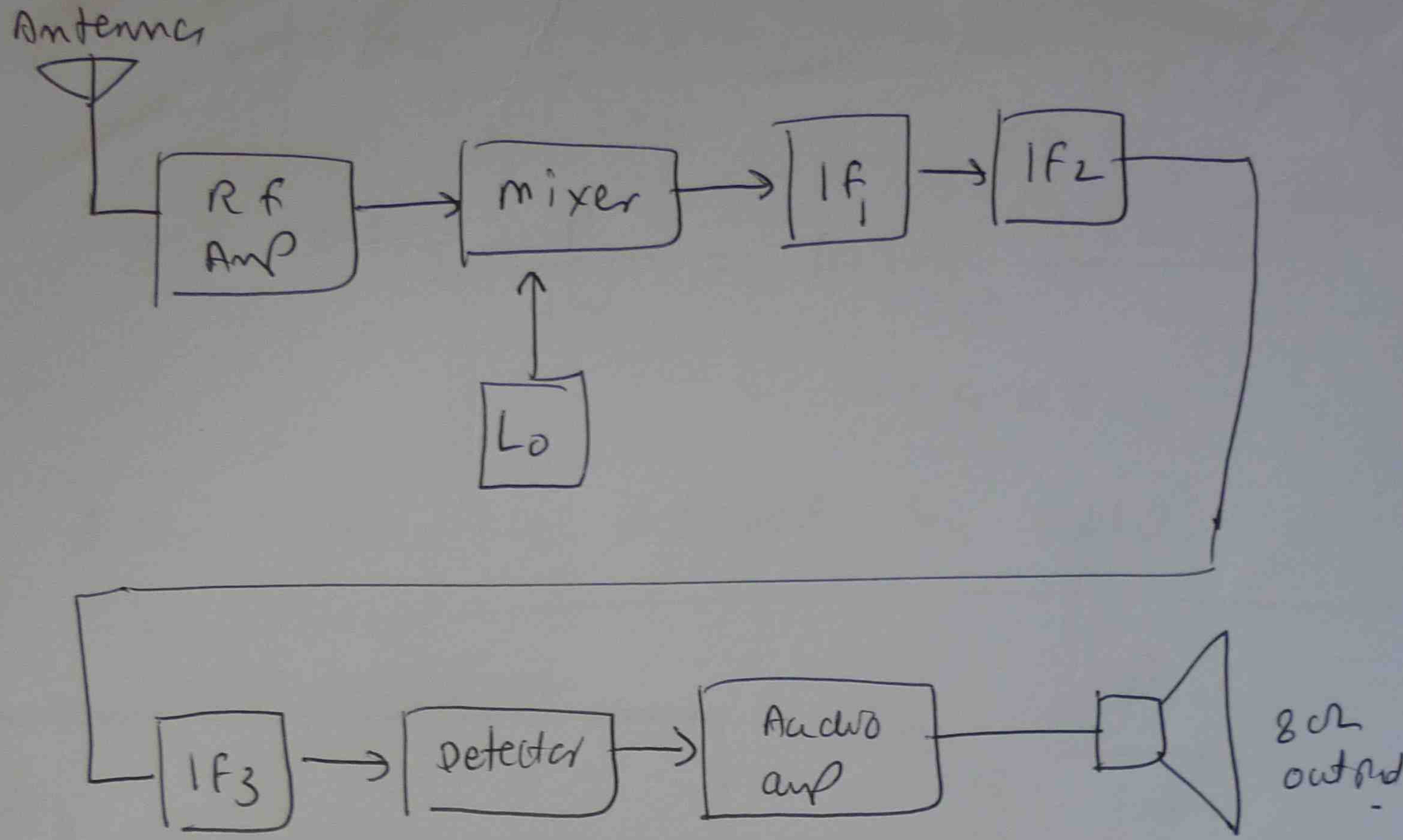
- Not to miss the weak station signal
- Received signal is changing due to weather.

~~To~~ AGC allows to listen to a station pulling out without constantly monitoring volume control









Receiver block diagram

Ex
consider the radio receiver given in above figure. The antenna receives an $8\,\mu V$ signal into it's 50Ω impedance, calculate the input power in watts, dBm, and dBw. calculate the power driven into the speaker.

$$P = \frac{V^2}{R}$$

$$\text{dBm} = 10 \log_{10} \frac{P}{1\cdot mW}$$

1 miliwatt gain

$$\text{dB} = 10 \log_{10} \frac{P}{1W}$$

1 watt gain

$$P = \frac{V^2}{R} = \frac{(8\times10^{-6})^2}{50\Omega} = 1.28\times10^{-12}\,W$$

(33)

$$dBm = 10 \log_{10} \frac{1.28 \times 10^{-12}}{1 \times 10^{-3}} = -89\,dBm$$

$$dBw = 10 \log_{10} \frac{P}{1w} = 10 \log_{10} \frac{1.28 \times 10^{-12}}{1}$$

$$= -119\,dBw$$

dBm & dBw are different by 30dB.

$$\therefore \boxed{\text{difference between dBm and dBW} = 10 \log_{10} \frac{P_{out}}{1mw}}$$

$$30 = 10 \log_{10} \frac{P_{out}}{1 \times 10^{-3}}$$

$$\cancel{10^{3}} \quad 3 = \log_{10} \frac{P_{out}}{10^{-3}}$$

$$10^{3} = \frac{P_{out}}{10^{-3}}$$

$$\therefore P_{out} = 10^{3} \times 10^{-3} = 1 \text{ watt}$$

$$\boxed{4, 5, 6, 8, 9, 11, 12}$$

week (5)   (34)

Single side banded communications

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.

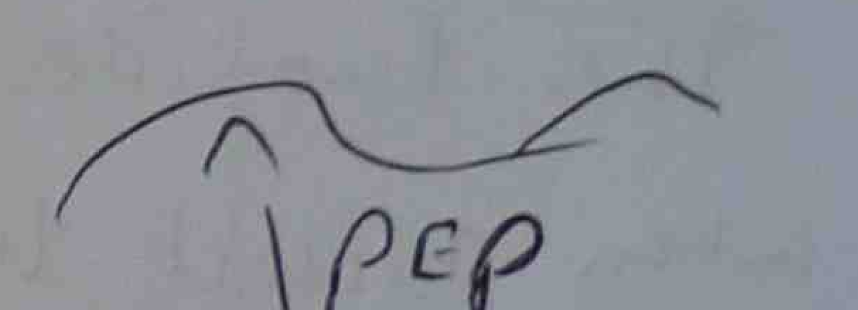
(3) A frequency equal to the sum of the carrier and the modulating frequencies.

(2) & (3) are side band frequencies

After the carrier and one of the side bands were eliminated, the other side band could be used to transmit the intelligence.

2/3 of power in carrier

SSB → voice communication.



$$\text{Peak Envelope Power} = \frac{(\text{maximum Envelope voltage})^2}{2}$$

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 sidebands. (Twin-sideband suppressed carrier (or) independent side band transmission)

Advantage of SSB

— more effective utilization of the available spectrum.

— Less subject to the effect of selective fading

Am transmission

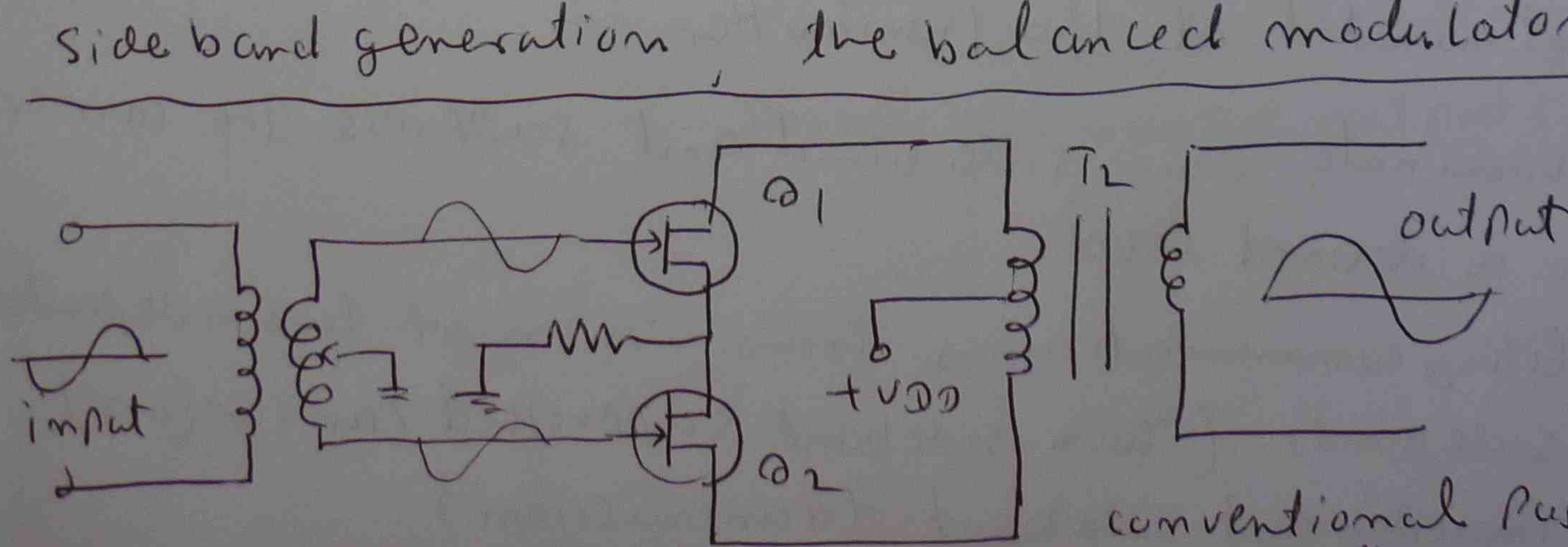
If the upper side band frequency strikes the inosphere and is refracted back to earth at a different angle from that of the carrier and lower side band frequencies, distortion is introduced at the receiver. Under extremely bad conditions, complete signal cancellation may result, which means a complete loss of intelligence.

The two side bands should be identical in phase so that when passed through a non linear device (diode detector) the difference between side bands and carrier is identical.

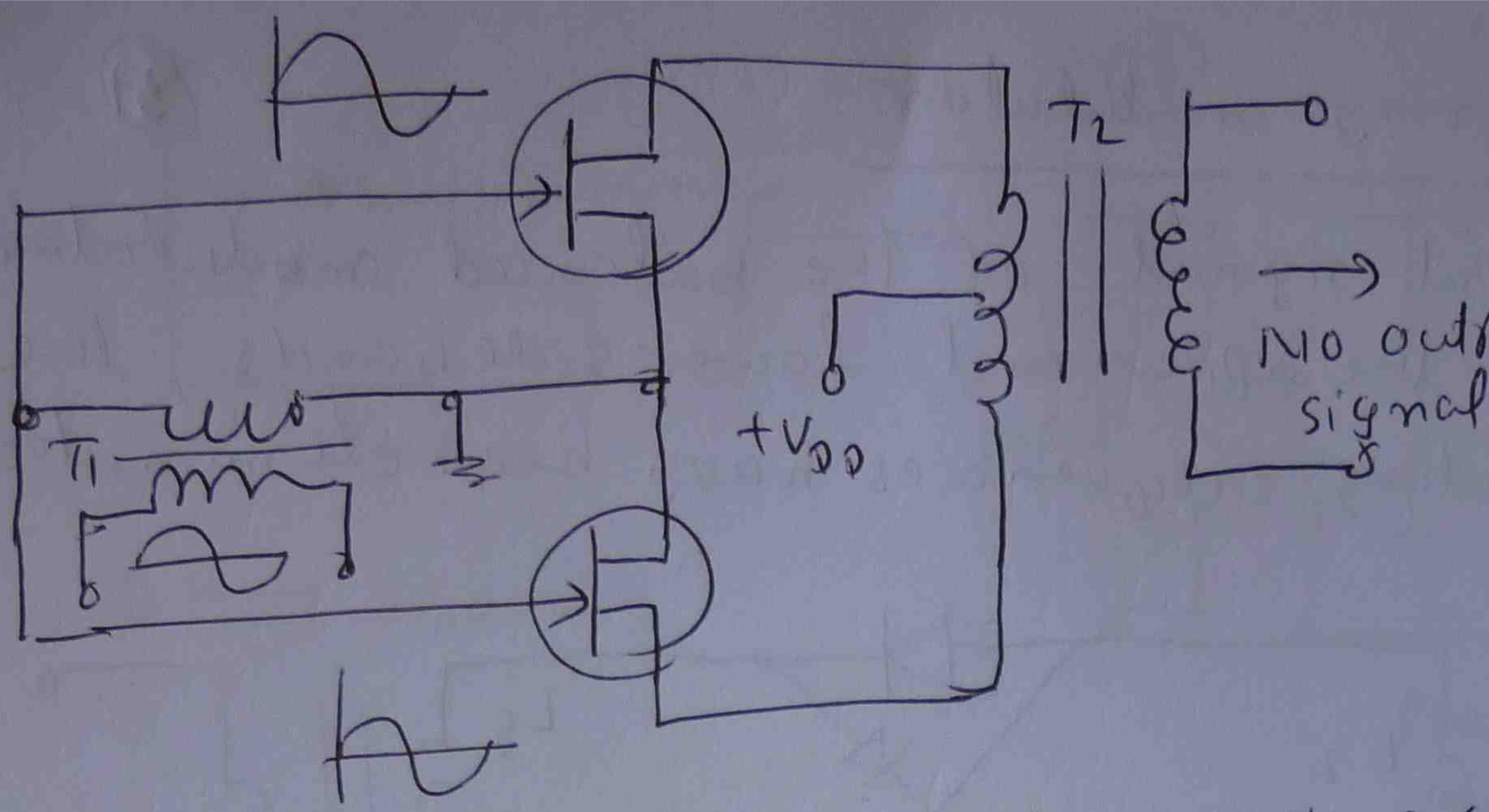
SSB has noise reduction over Am due to bandwidth reduction.

low SSB transmission = 100W Am transmission.

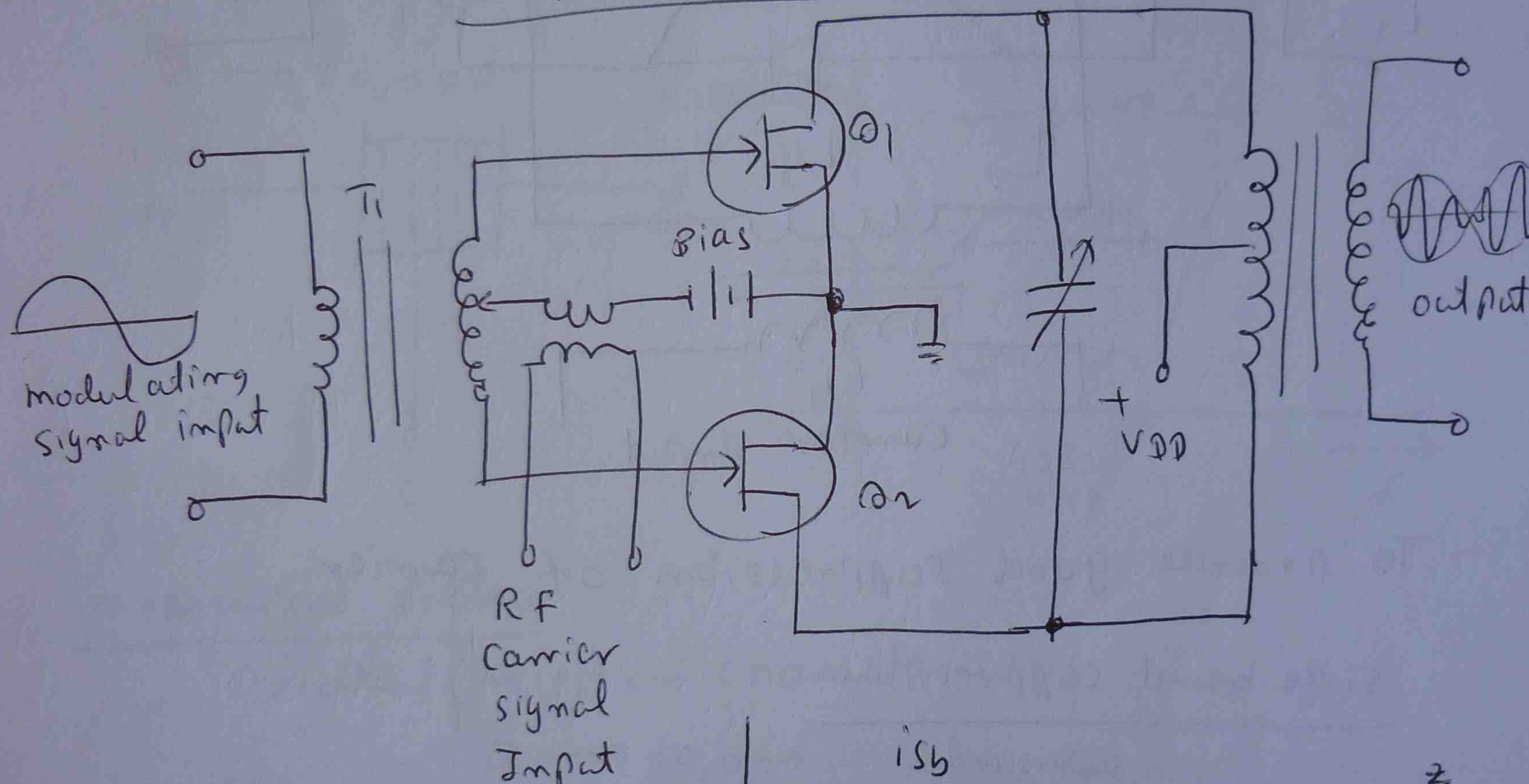
Side band generation, the balanced modulator

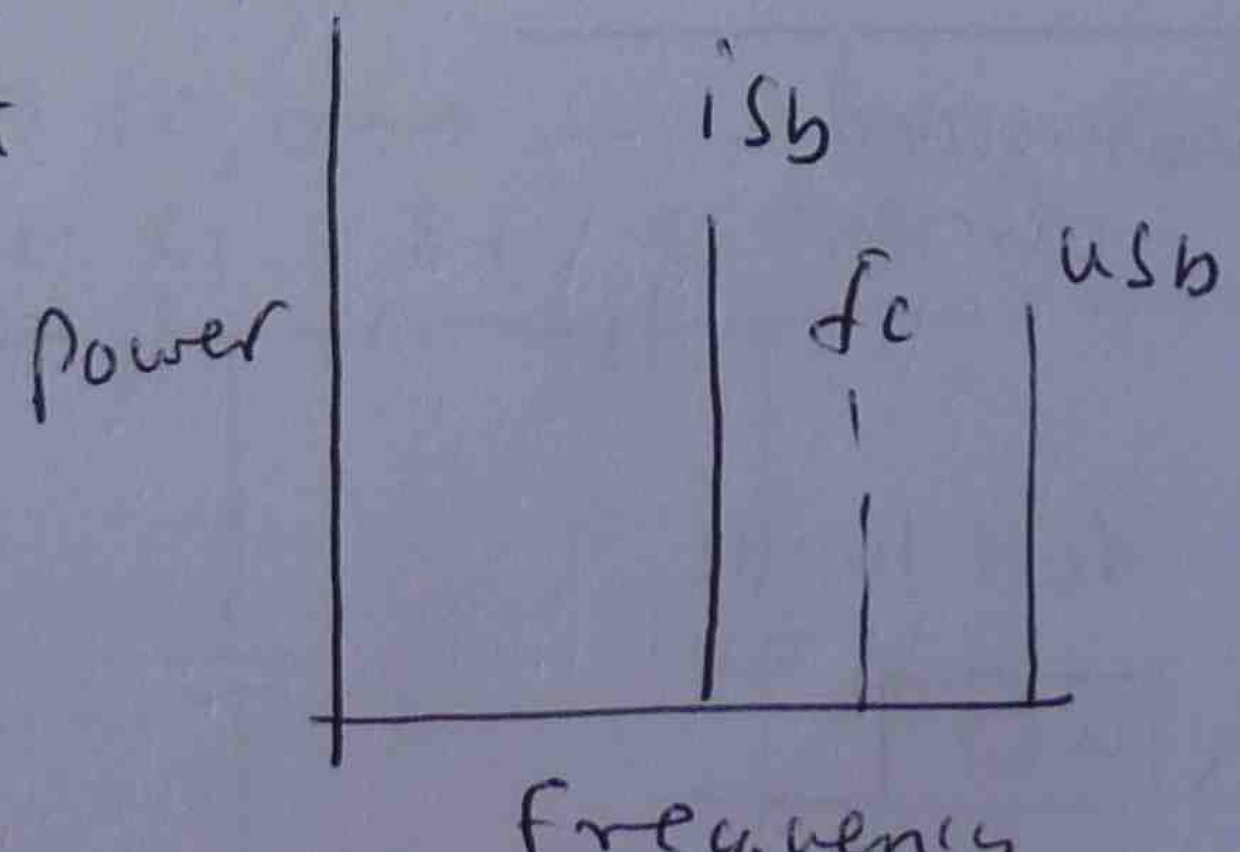


conventional Push pull



Push pull amplifier with signal applied in phase

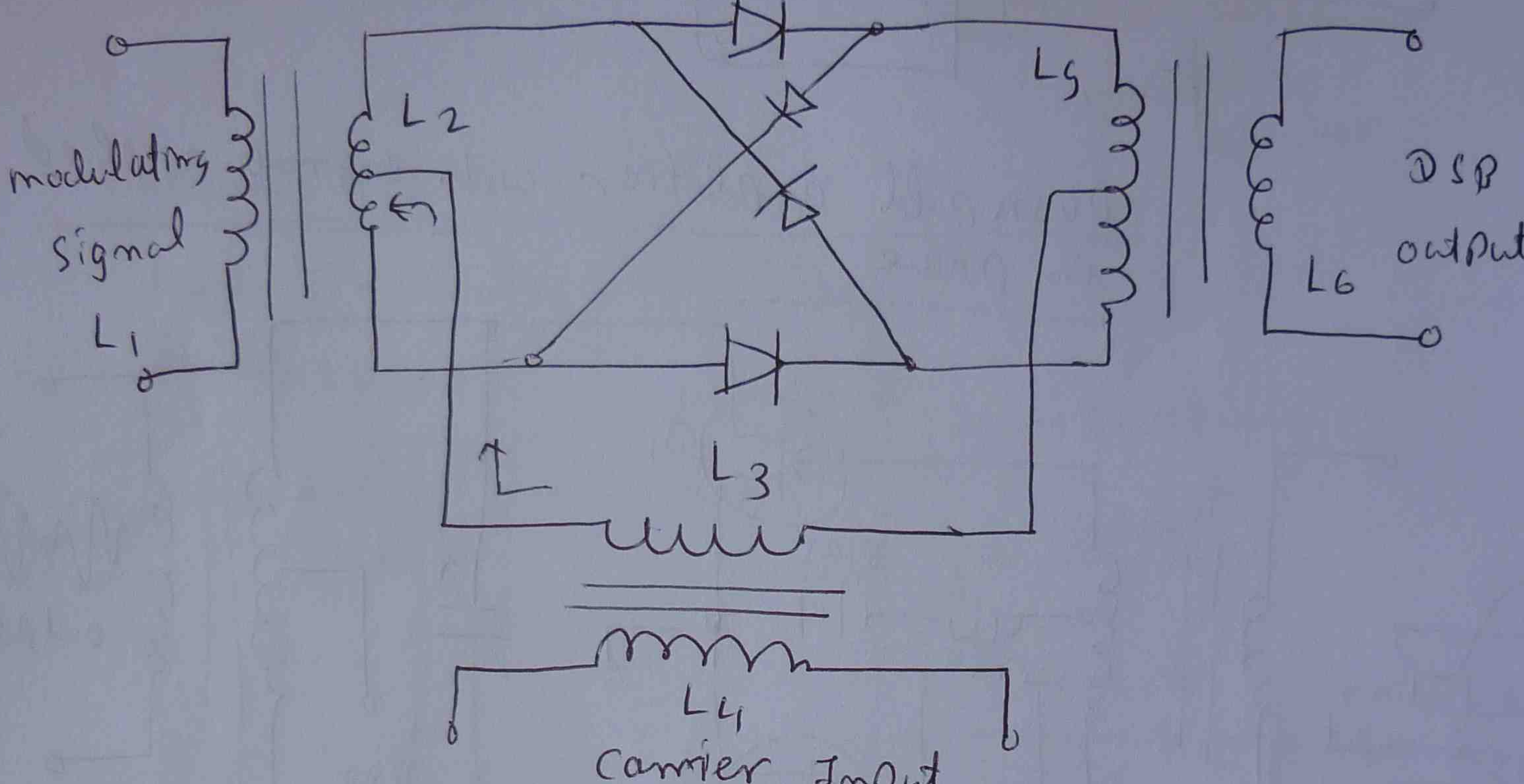




Double side banded output signal

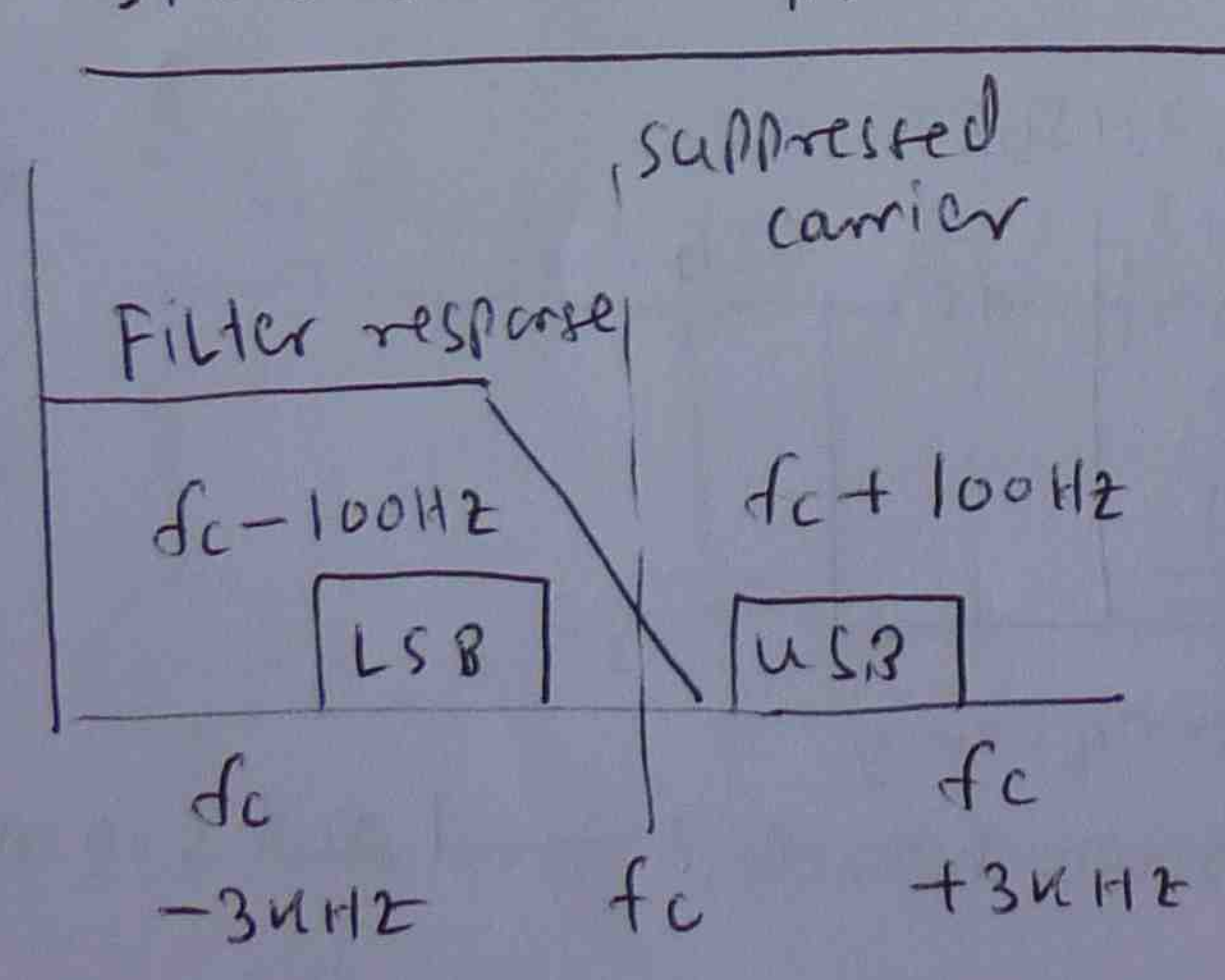
Balanced ring modulator

The output signal of the balanced modulator consists of the upper and lower side bands, the carrier and modulating frequencies have been eliminated.



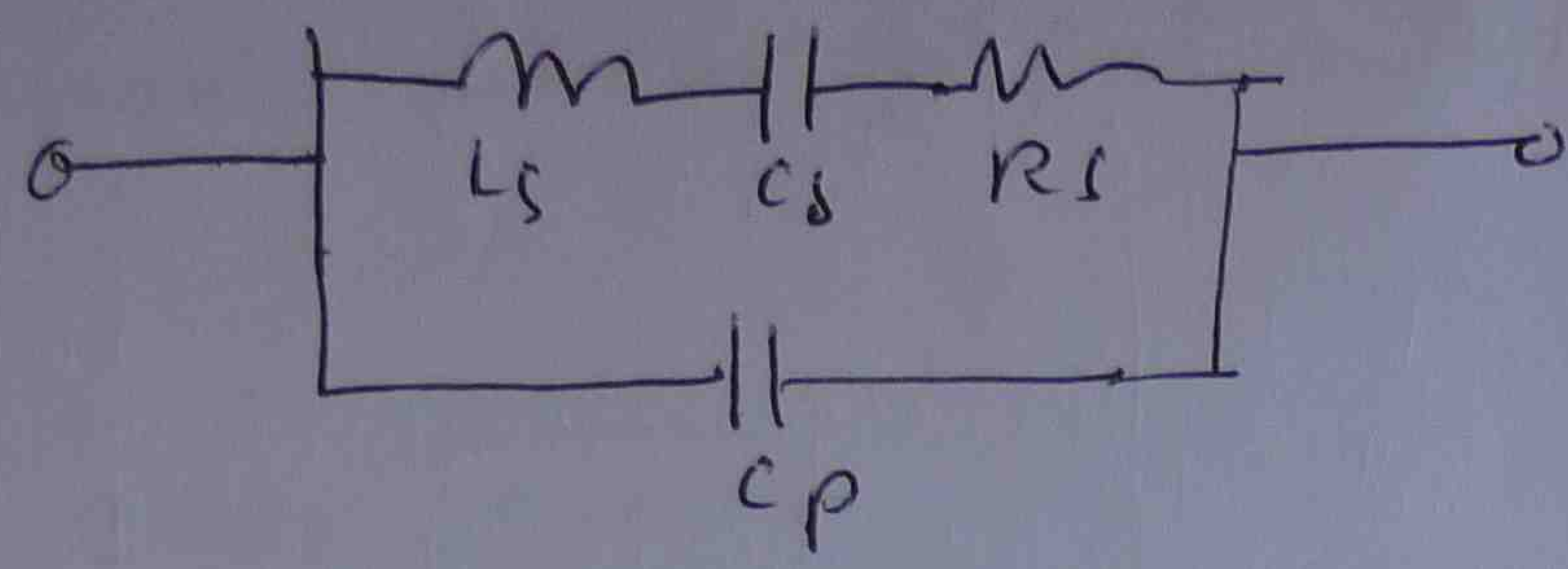
- To provide good suppression of carrier

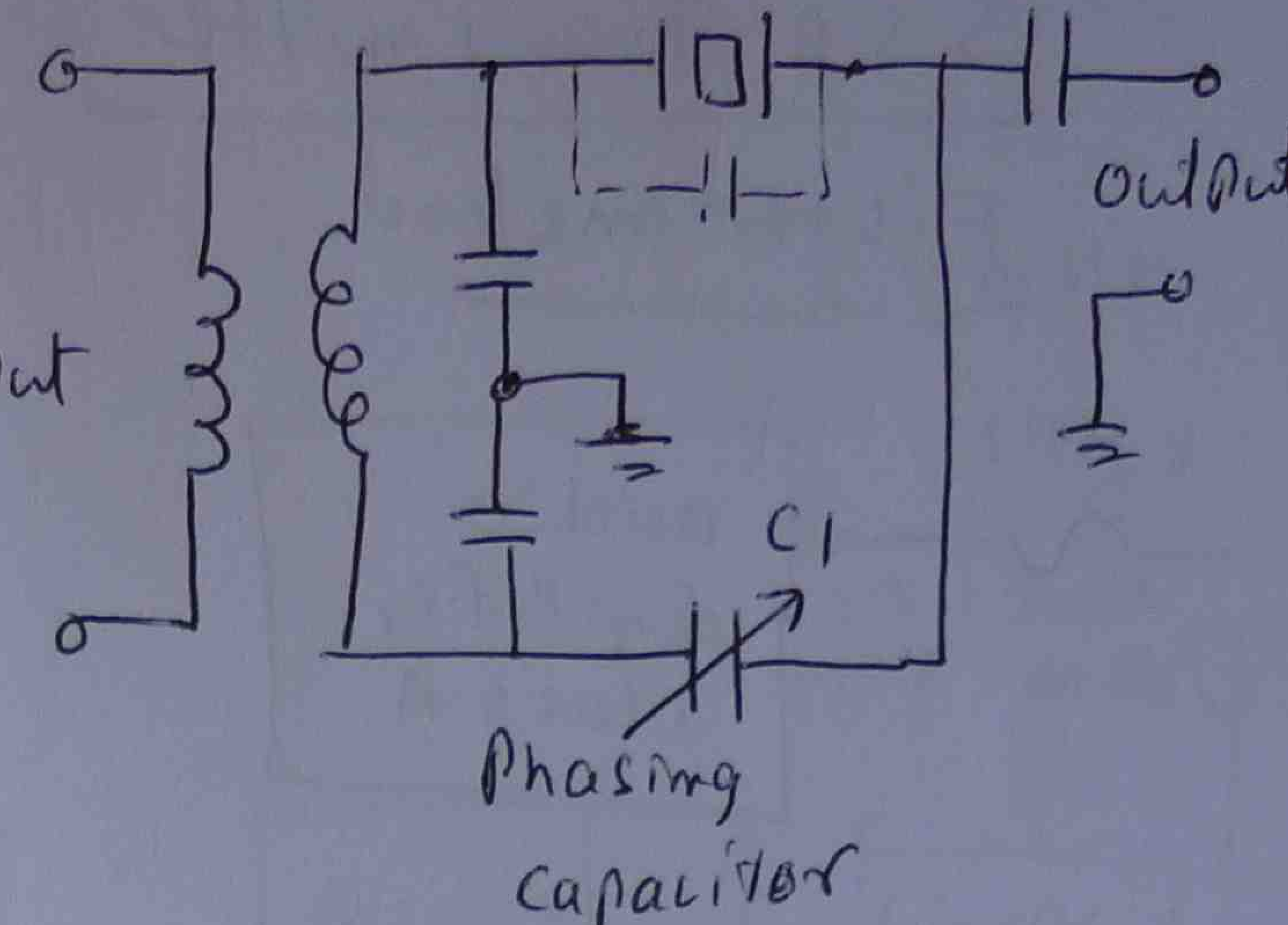
side band suppression



Crystal filter

The crystal filter is commonly used in single-side band system to attenuate the unwanted side band. Crystal is a series resonant circuit with very high Q.



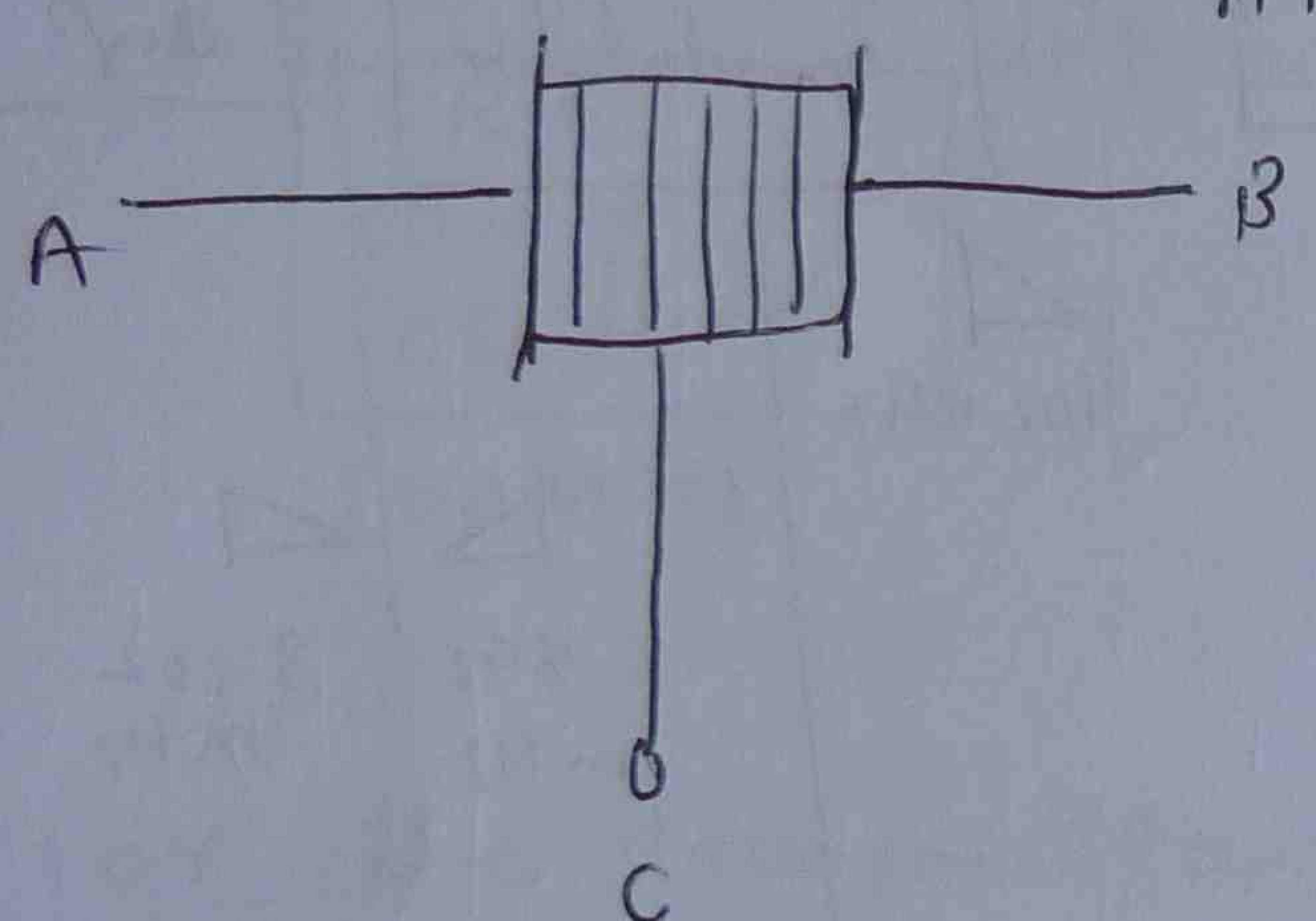


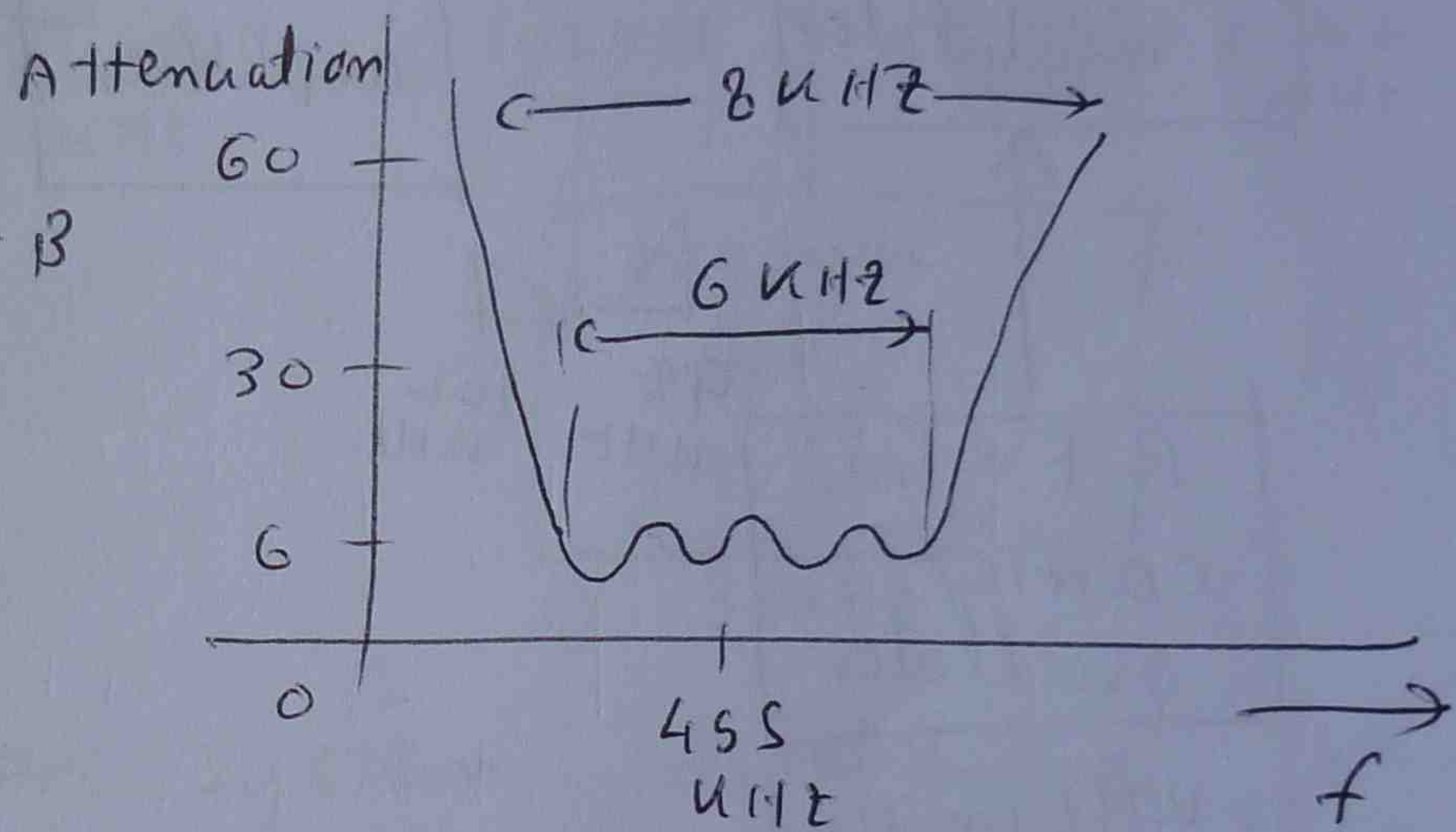
Q → 50,000

Ceramic Filter

Lead zirconate - titanate

Q → 20,000

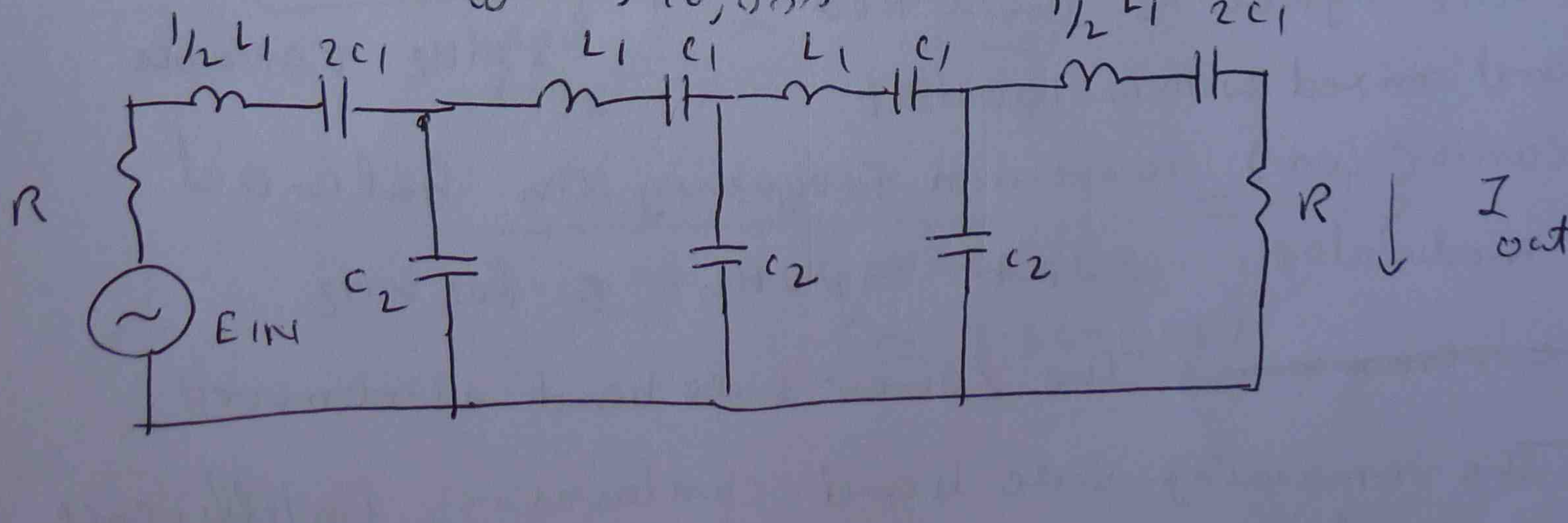




mechanical filter

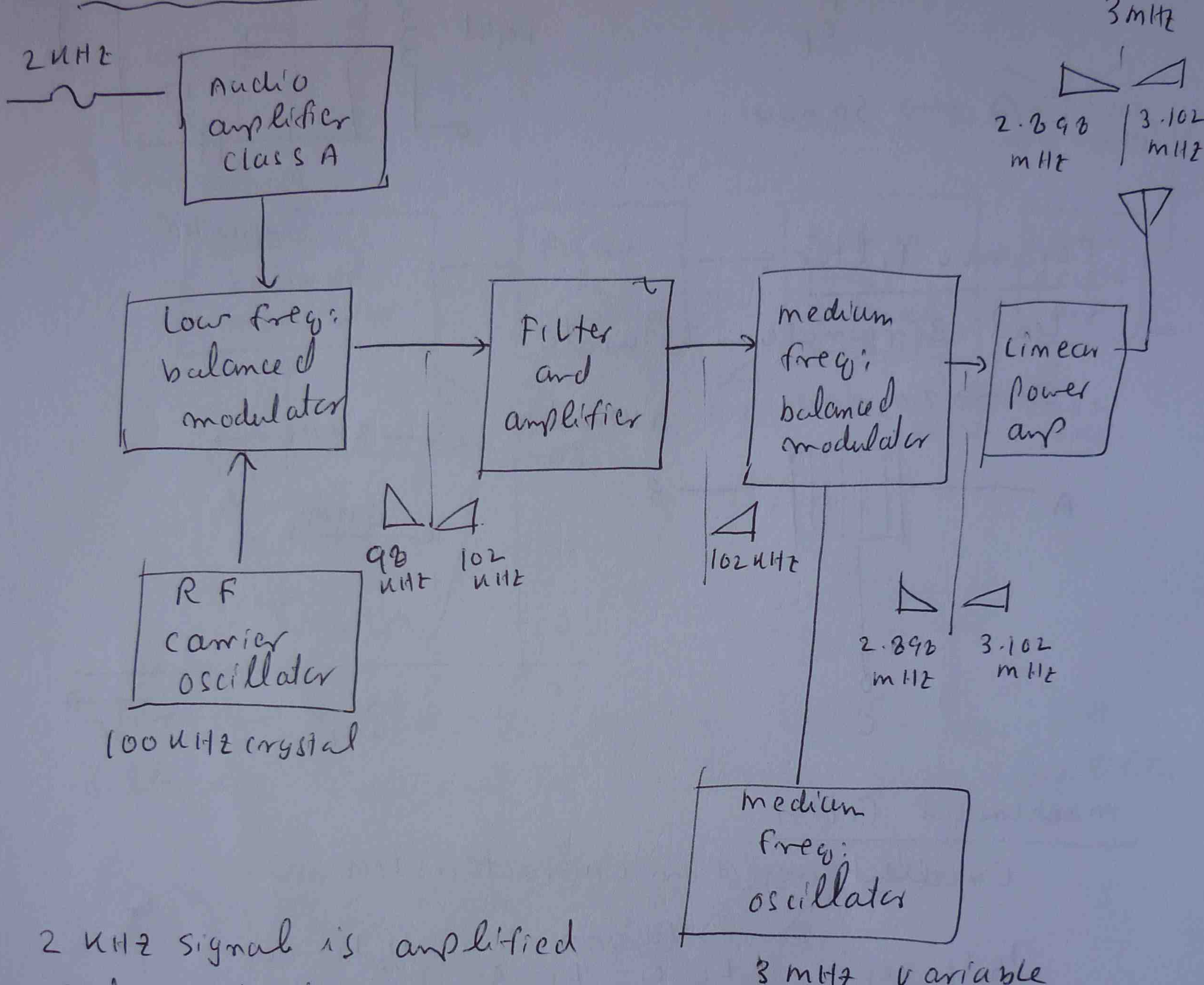
Excellent rejection characteristics

Q → 10,000



SSB Transmitter

Filter method

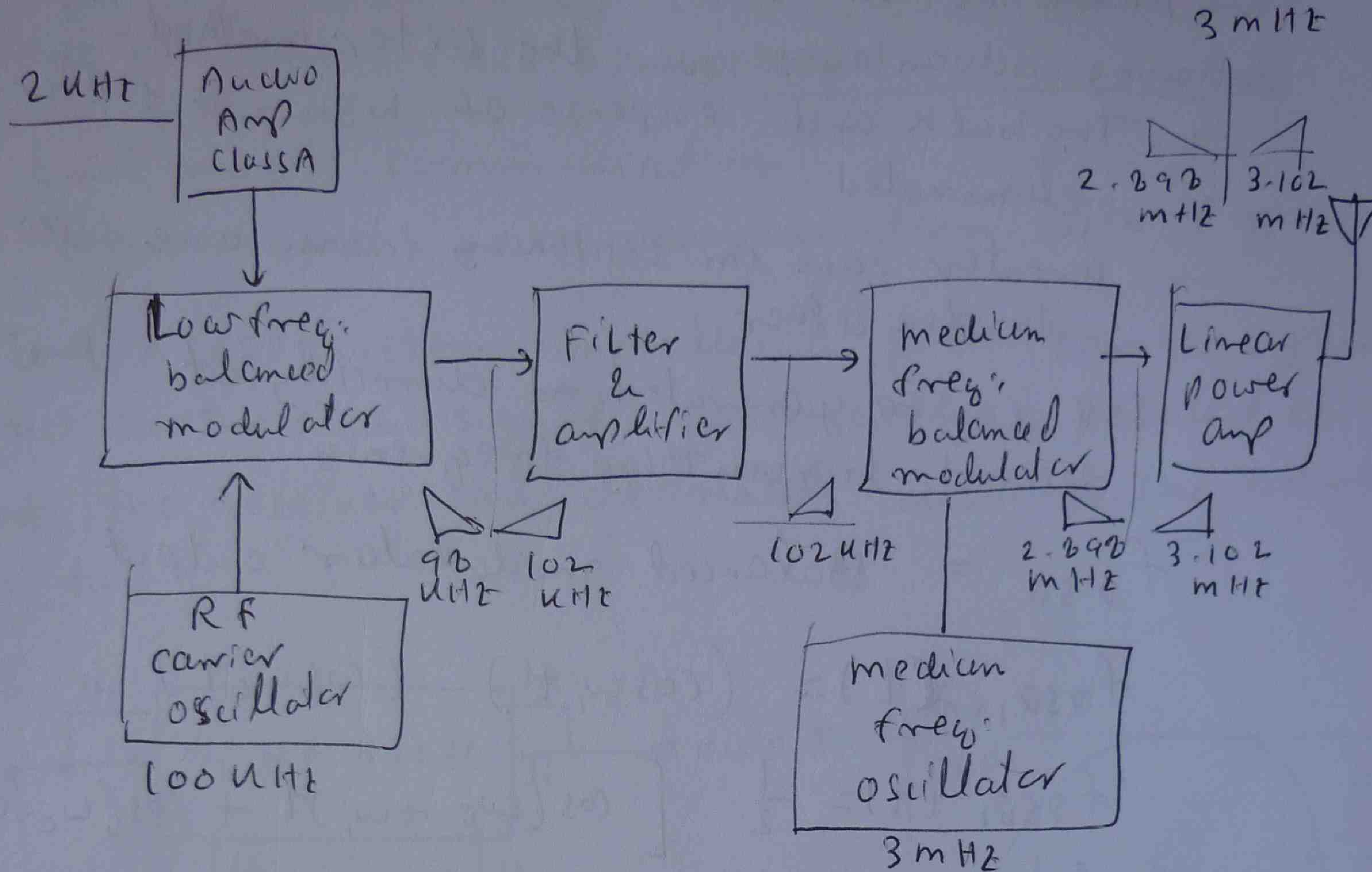


2 kHz signal is amplified and mixed with a 100 kHz carrier (or) conversion frequency in balanced modulator. output 98 kHz & 102 kHz.

~~The remaining~~ The lower side band is removed.

The remaining side band containing intelligence is too low in frequency to transmit efficiently, it must be mixed again with a new conversion frequency to raise it to the desired transmitter frequency. 3 mHz oscillator is applied. Produce 3.102 mHz / 2.898 mHz tunable linear out put amplifier.

Pb



For the transmitter system, determine the filter Q required in the linear power amplifier.

$$Q = \frac{\text{medium osillator freq:}}{\text{upper side band freq:} - \text{lower side band freq:}}$$

$$= \frac{3 \text{ mHz}}{3.1 \text{ mHz} - 2.9 \text{ mHz}} = 15$$

($\simeq$ 2.898 mHz)

Phase method

The phase method of SSB generation offers the following advantages over the filter method.

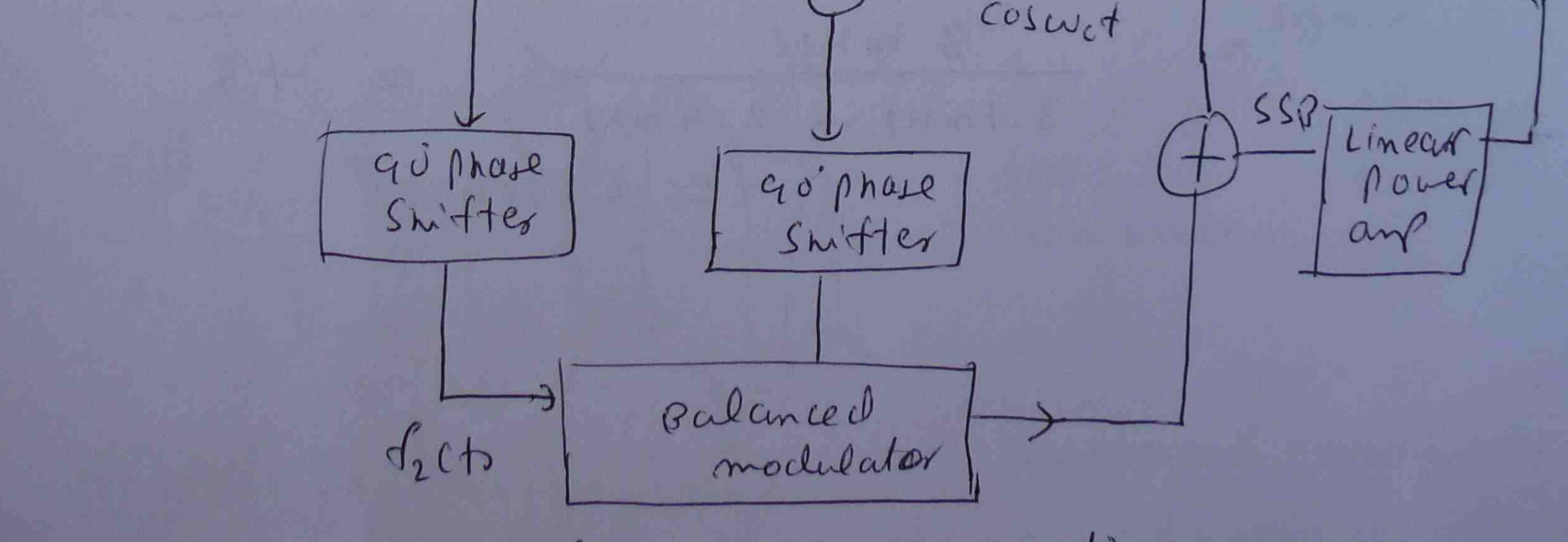
- The bulk and expense of high-Q filter is eliminated
- Greater ease in switching from one sideband to the other
- SSB can be generated ~~at~~ directly at the desired transmitting frequency.

$$f_{DSB} = \text{Balanced modulator output}$$

$$f_{DSB_1}(t) = (\cos \omega_i t)(\cos \omega_c t)$$

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

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



Phase SSB generation

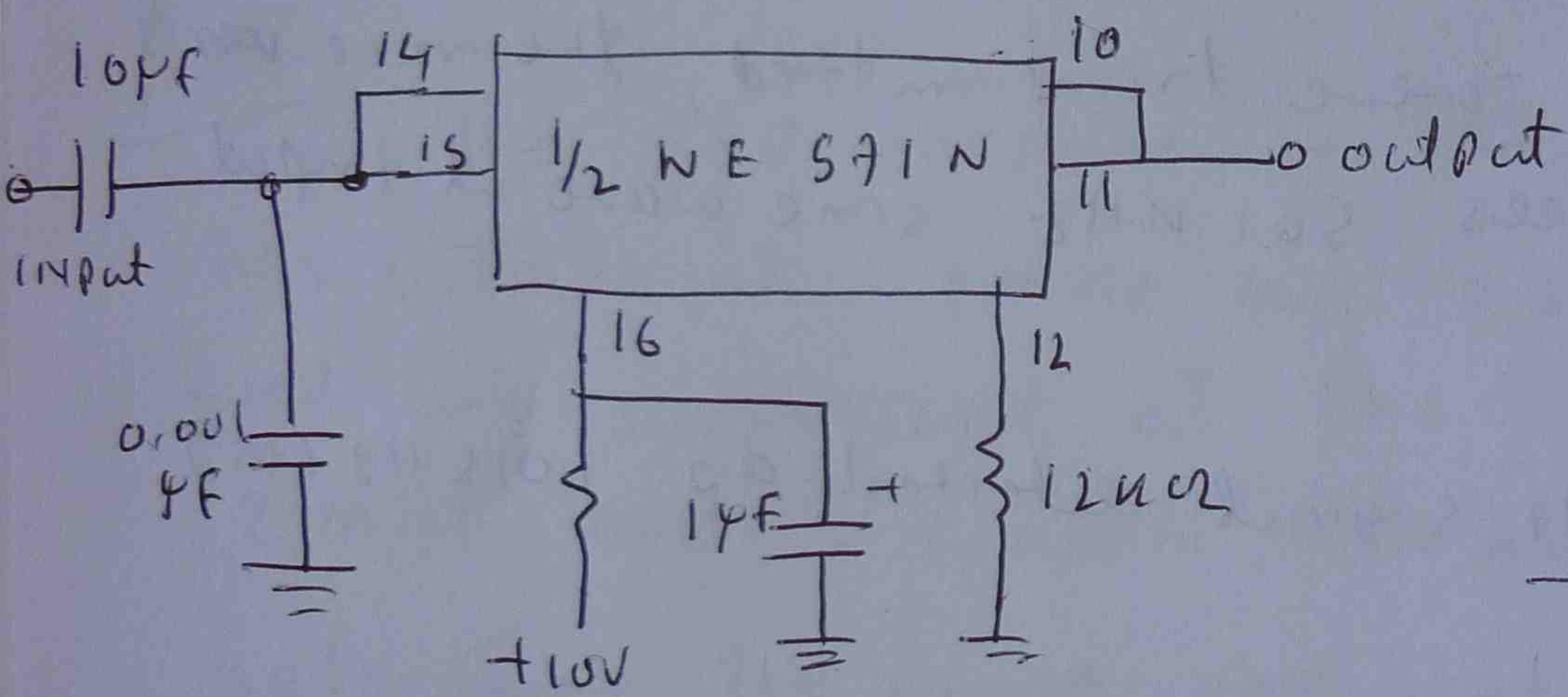
ACSSB system

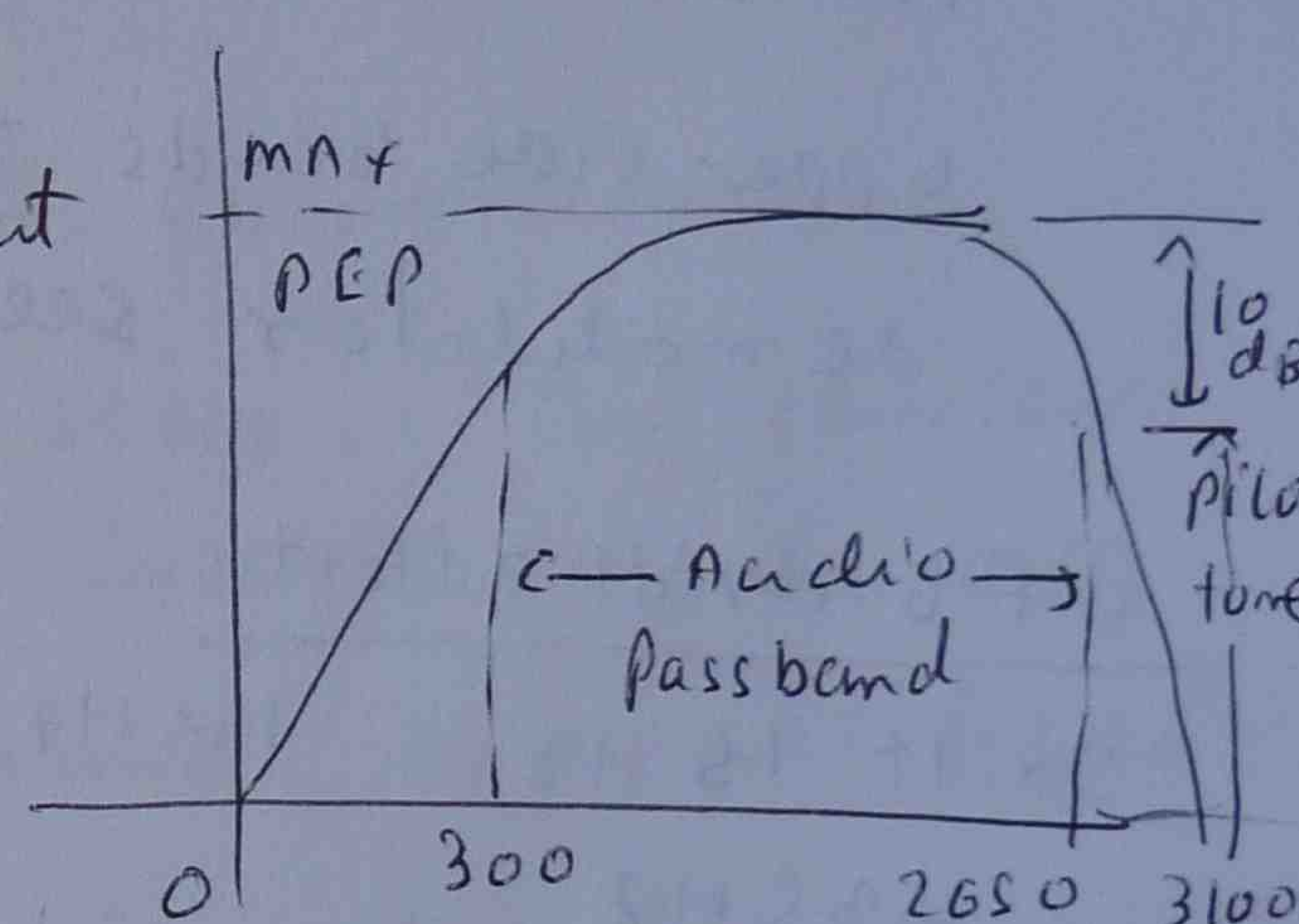
Amplitude compandoring (compression - expandor) Single side band (ACSSB) system

Land mobile communication

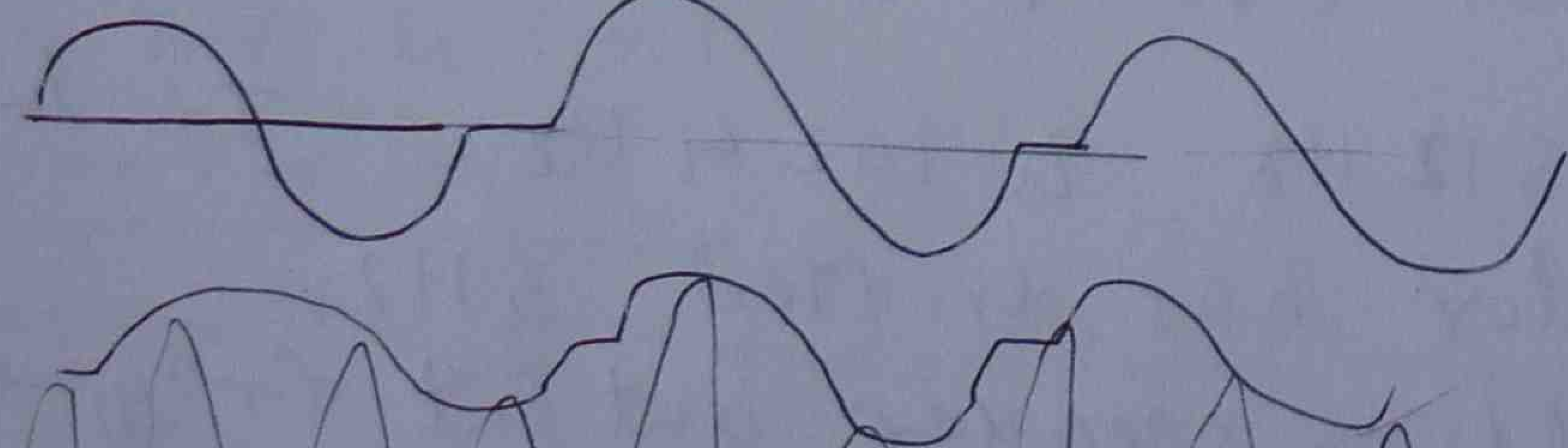
Narrow band voice communication with FM

The ACSSB system includes a pilot carrier signal added to the audio signal sufficiently separated so that the receiver can ultimately distinguishe between the two

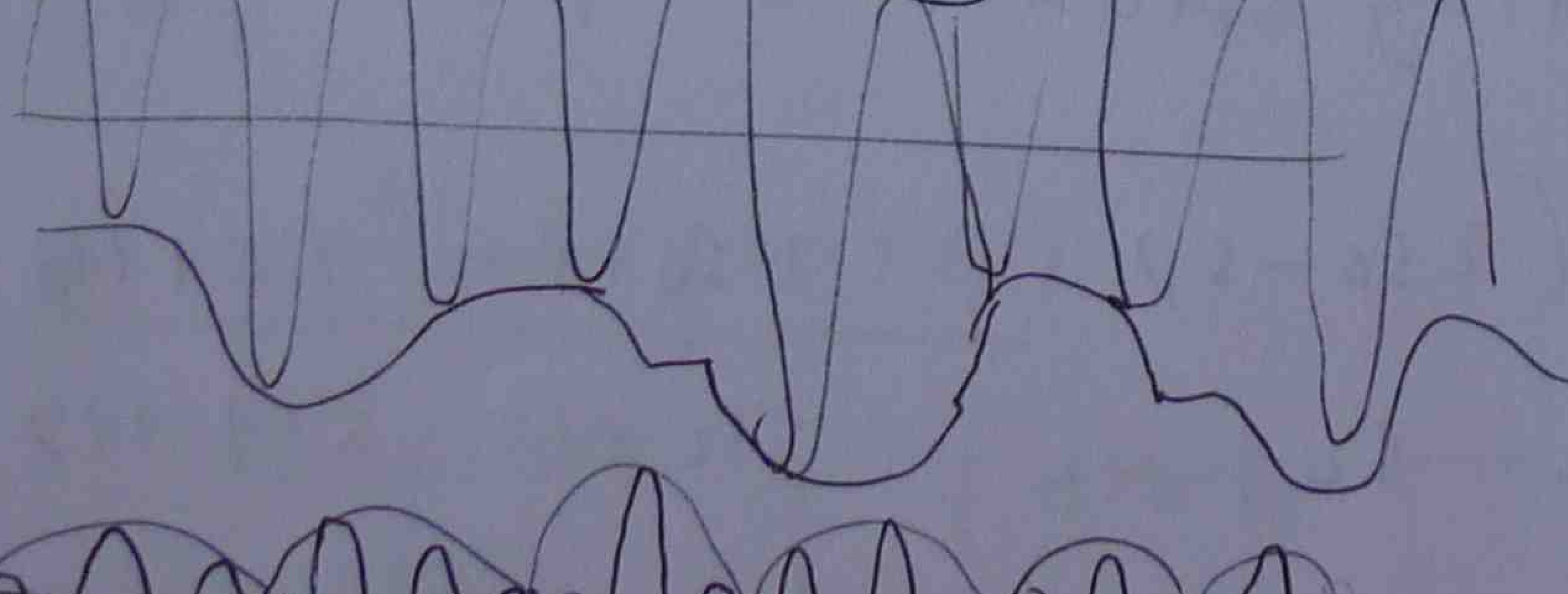




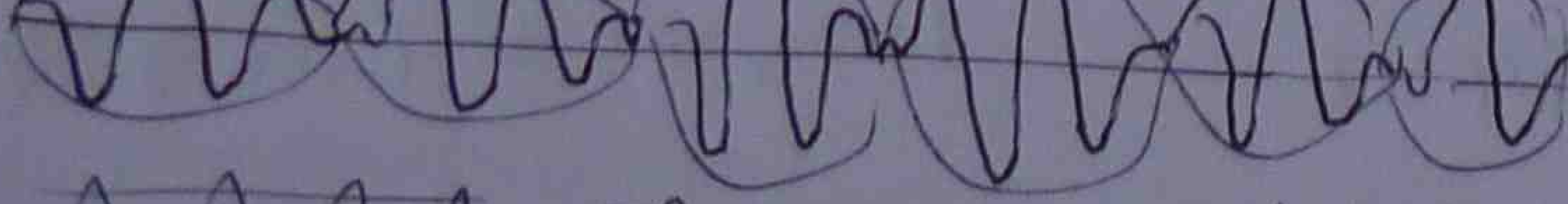
SSB demodulation



(a) Intelligence signal



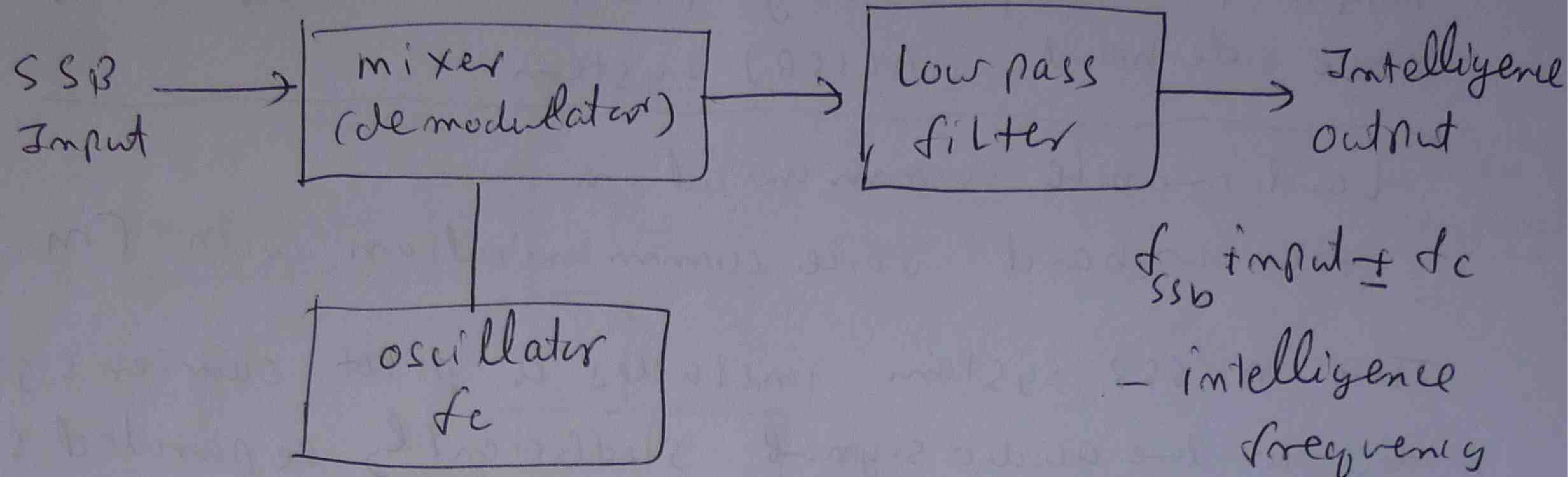
(b) AM wave



(c) suppressed carrier wave

(d) SSB suppressed carrier

mixer SSB Demodulator



500KHZ carrier frequency has been modulated by 1KHZ sine wave.

upper side bands were transmitted, the receiver's demodulator sees 501 KHZ sine wave at input.

BFO drift effect

Drift 15 HZ, 1KHZ signal detected as 1015 HZ (or) 985 HZ

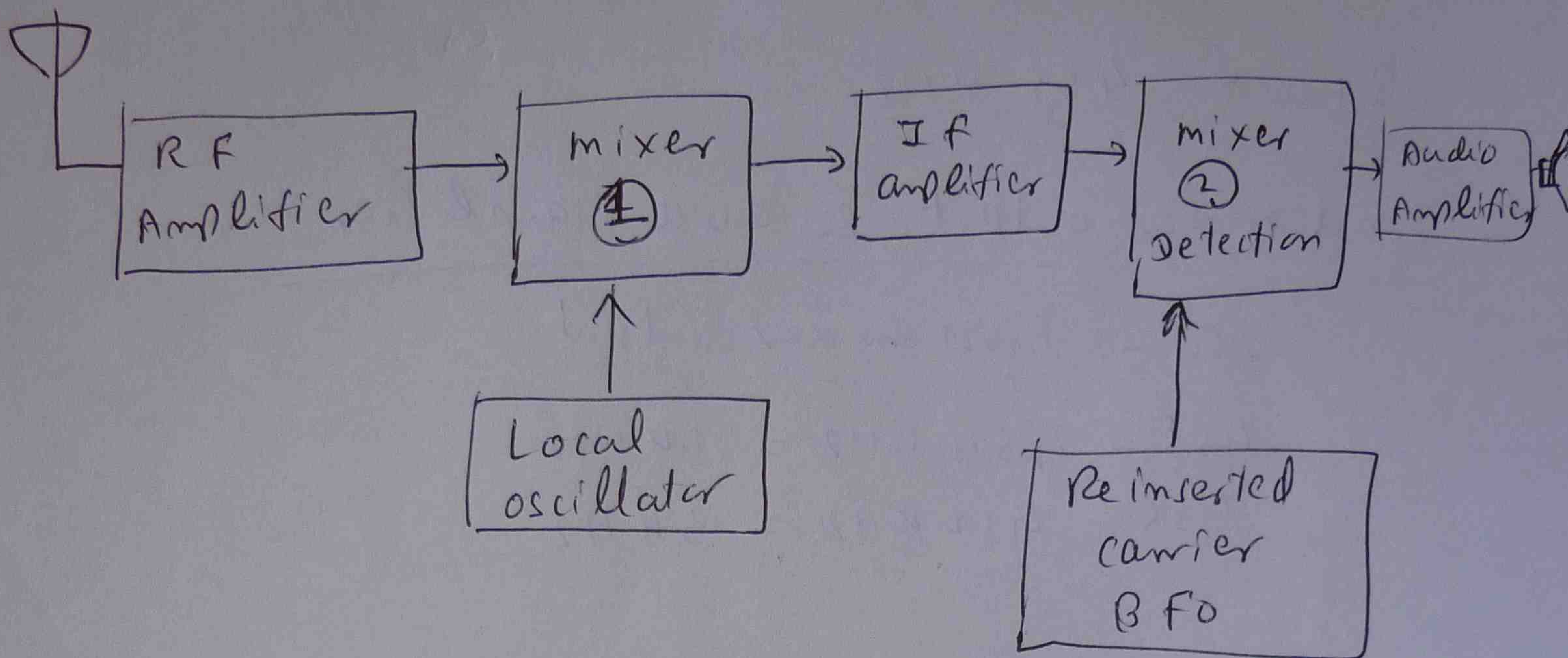
Pb At one instant of time, an SSB music transmission consists of 256 HZ sine wave & 2nd & 4th harmonics 512 HZ & 1024 HZ. If the receiver's demodulator has drifted 5 HZ, determine the resulting speaker output frequencies

256 HZ ⟶ 251 HZ (256 – 5), 256 + 5 = 261 HZ

512 HZ ⟶ (512 – 5) = 507 HZ, 512 + 5 = 517 HZ

1024 HZ – (1024 – 5) = 1019 HZ, 1024 + 5 = 1029 HZ

SSB Receiver



Pb The SSB receiver at 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 KHz IF frequency.

I RF Amp & first mixer input

Transmitter freq + two outputs → 2000 + 1 KHz = 2001 KHz
2000 + 3 KHz = 2003 KHz

II Local oscillator (mixer)

Transmitter freq + IF freq → 2000 + 455 = 2455 KHz
↑ BFO

III First mixer output

Local oscillator (mixer) − (RF amp & first mixer)