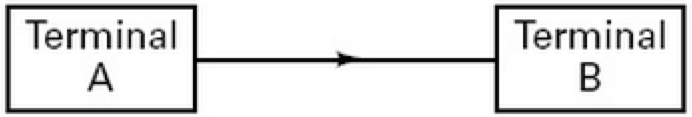
PRINCIPLES OF COMMUNICATION & AM MODULATION

EEN 462 – ANALOGUE COMMUNICATION

Friday, 12 September 2025

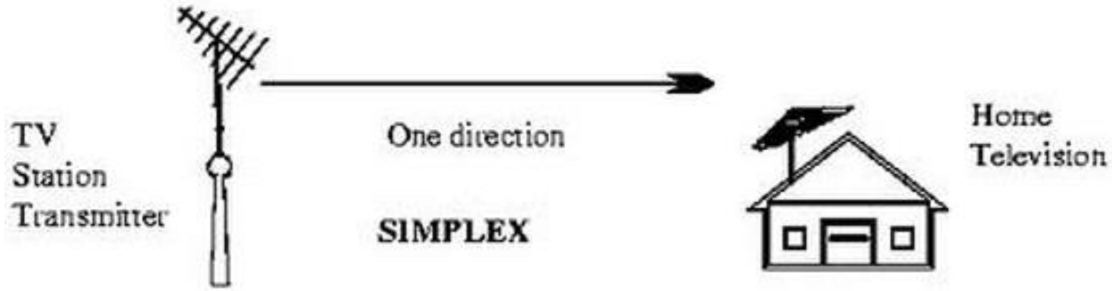
SIMPLEX COMMUNICATION

- Information is transmitted in one direction only



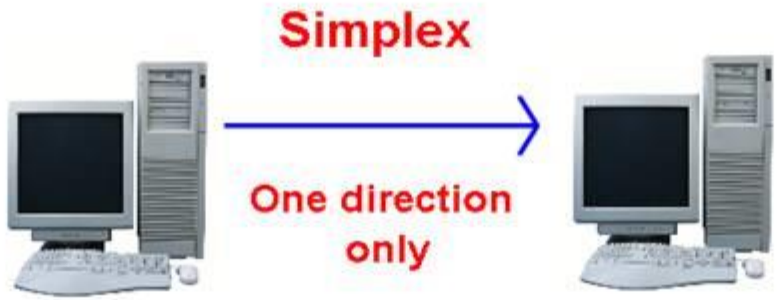
1. RADIO AND TV BROADCASTING

- The analogue TV can only receive the TV signals



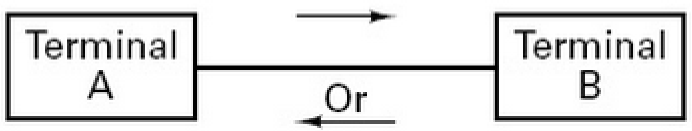
2. COMPUTER COMMUNICATION

- Data is transmitted from the sender to receiver only, eg: from a central computer to a dumb terminal.



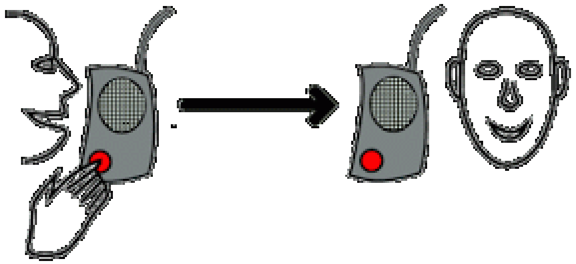
HALF DUPLEX

- Transmission in either direction but not simultaneously



<u>WALKIE TAKIES</u>

- Transmission in either direction but not simultaneously

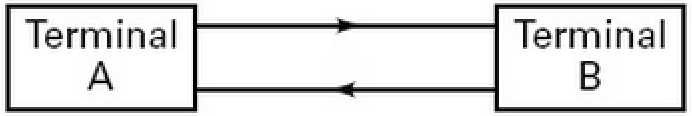


<u>COMPUTER COMMUNICATION</u>

- Transmission in either direction but not simultaneously

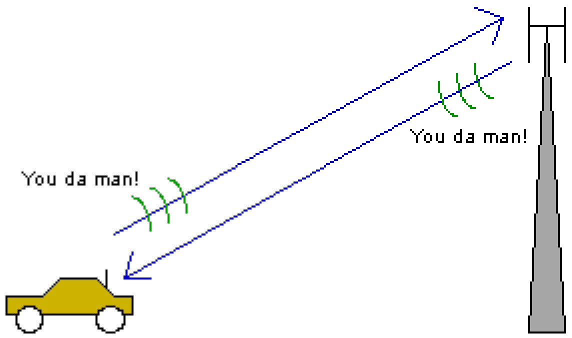
FULL DUPLEX COMMUNICATION

- Transmission in both directions simultaneously



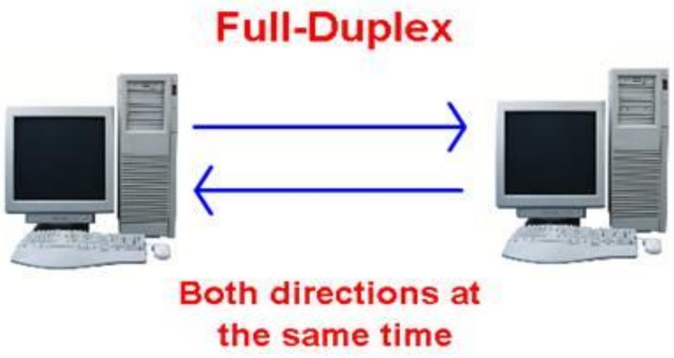
TELEPHONE COMMUNICATION

- Users of mobile phones communicate simultaneously.



COMPUTER COMMUNICATION

- Computers exchange data simultaneously.



CARRIERS IN MEDICINE

An asymptomatic carrier (healthy carrier or just carrier) is a person or other organism that has contracted an infectious disease, but who displays no symptoms. Although unaffected by the disease themselves, carriers can transmit it to others.

In humans, HIV goes through a long latency period, during which the host is asymptomatic. Many carriers are infected with persistent viruses such as EBV and Cytomegalovirus that only rarely progress to a disease state. Herpes simplex viral infection may also be asymptomatic and can be spread without the originally infected person realising they are infected.

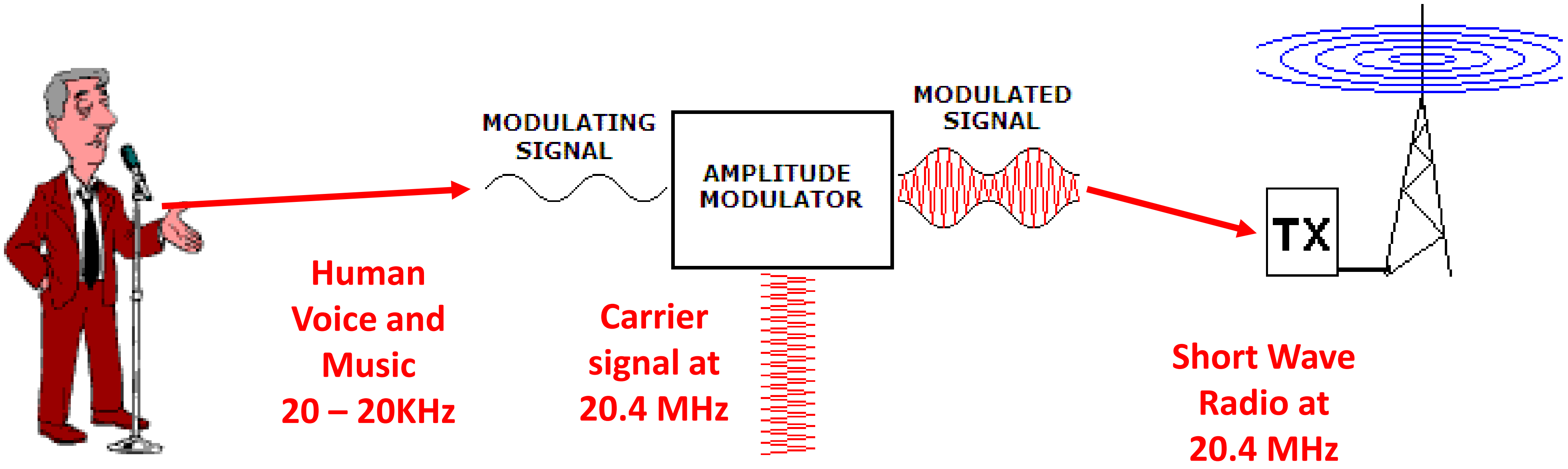
Mary Mallon, known as "Typhoid Mary", was an asymptomatic carrier of typhoid fever. She worked as a cook for several families in New York City at the beginning of the twentieth century and she also cooked for the soldiers. Several cases of typhoid fever in members of those families were traced to her by the Health Department. It appeared that she "carried" the infectious agent without becoming sick. There was at the time no way of eradicating the disease, and an attempt was made to restrict her from continuing to work as a cook to avoid spreading it to others

Typhoid Mary in a 1909 newspaper illustration

WHAT IS MODULATION? - RECAP

1. **Modulation is process of altering a carrier signal (a high-frequency periodic waveform)** by imposing the characteristics of information signal (a lower-frequency data stream).
2. **Modulation makes the information suitable for transmission over a specific channel**, such as radio waves, optical fibers, or coaxial cables.
3. **Modulation translates the baseband signal (e.g., audio, video, data) to a higher frequency band**, granting control over the signal's bandwidth and center frequency for efficient radiation from an antenna, which must be on the order of the wavelength to be effective.
4. **Key modulation types are Amplitude (AM), Frequency (FM), and Phase (PM) Modulation** named depending on how the alter the characteristics of the carrier.

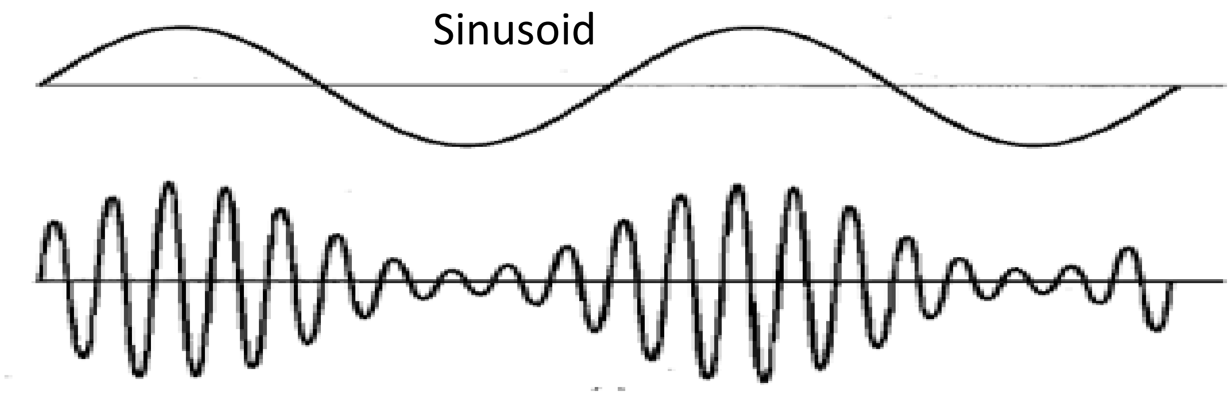
AM FROM PREVIOUS LESSON

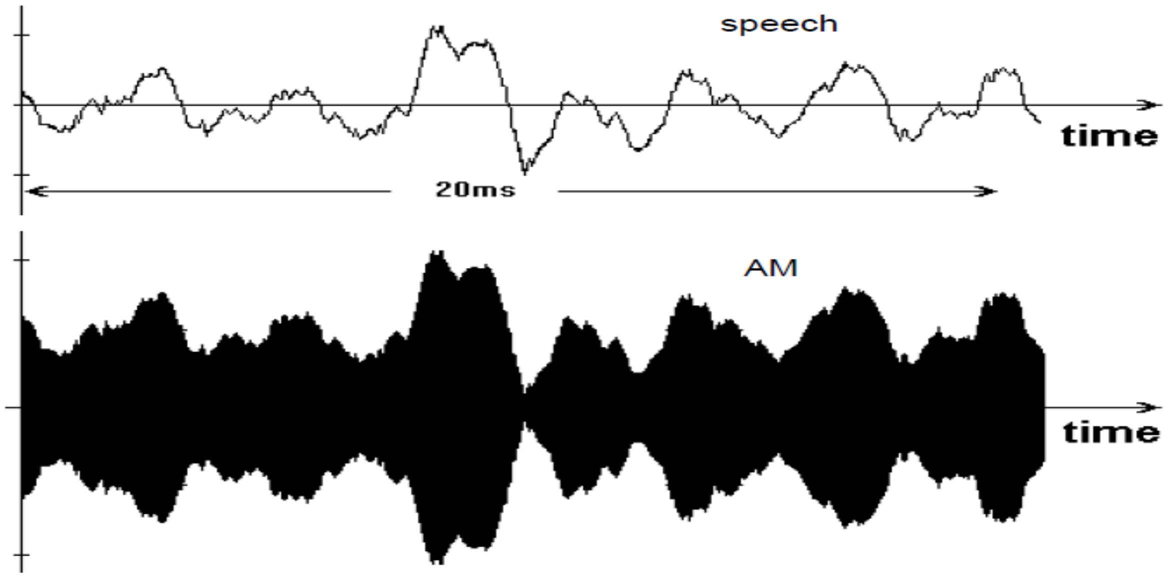


AMPLITUDE MODULATION OF A SPEECH SIGNAL

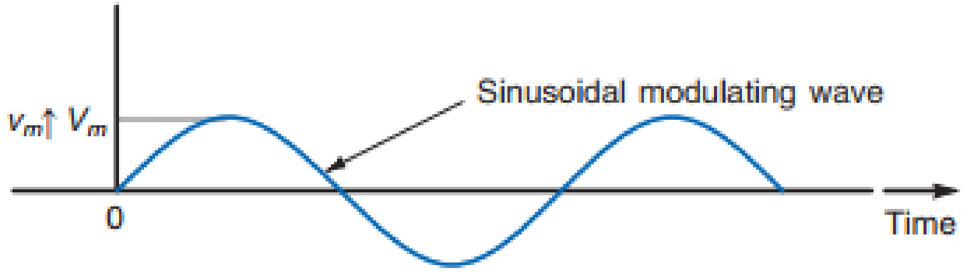
1. Human Speech is composed of many sinusoids and has peaks and pauses.

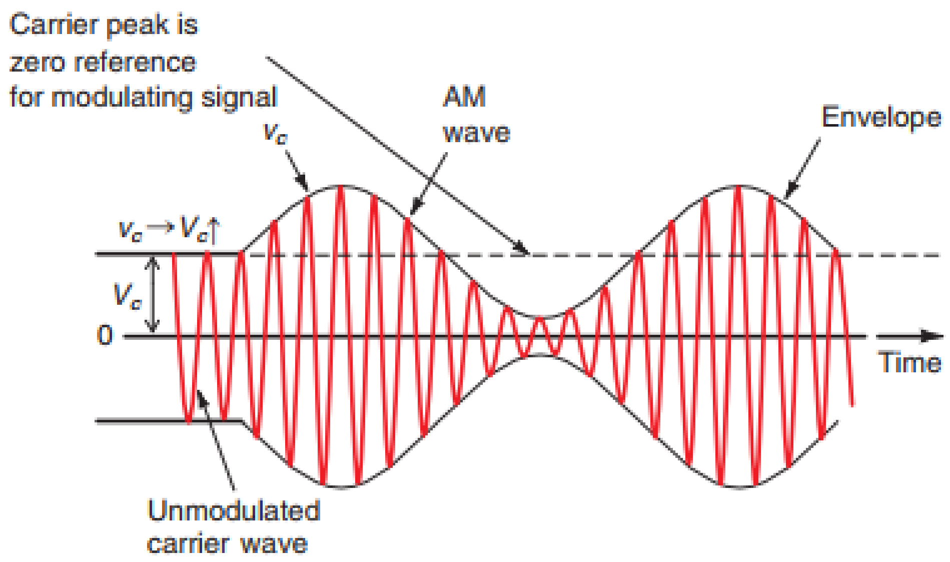
2. Care is taken to ensure that the signal is not over-modulated during the peaks.





ANALYSIS OF AM SIGNAL





Instantaneous value of the top and bottom peaks can be written as

$$v_1 = V_c + v_m = V_c + V_m Sin(2\pi f_m t)$$

We can therefore write the carrier modulated signal as

$$v_2 = v_1 sin(2\pi f_c t) = (V_c + V_m Sin(2\pi f_m t))Sin(2\pi f_c t)$$

$$= V_c Sin(2\pi f_c t) + V_m Sin(2\pi f_m t) Sin(2\pi f_c t)$$

AM MODULATION INDEX

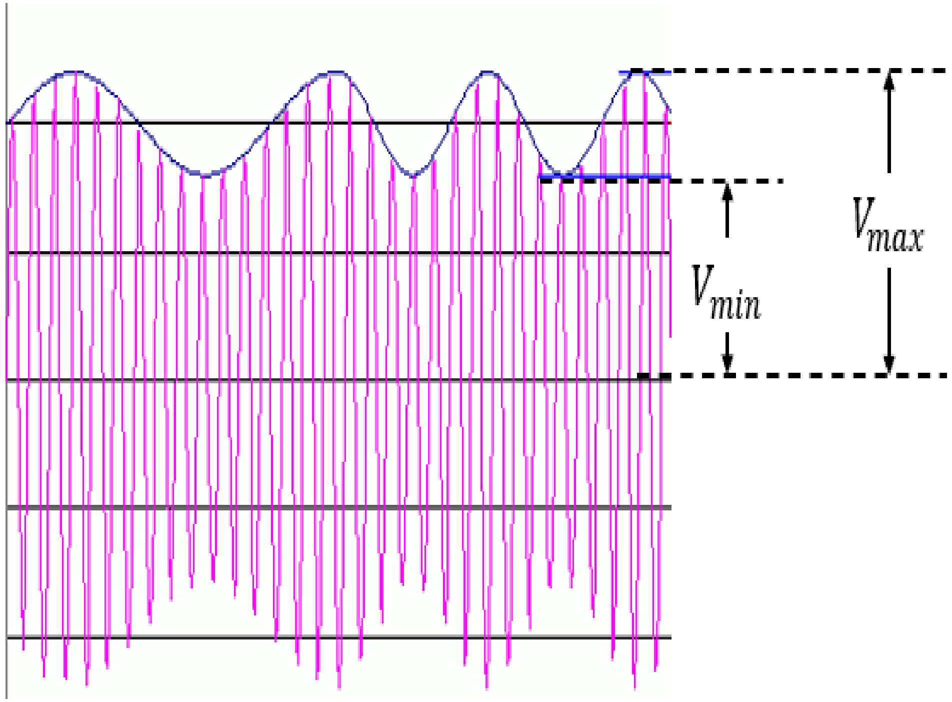
1. **Modulation index, m** is the ratio of the amplitude of the modulating signal to the amplitude of the carrier signal, and is given by:

$$m = \frac{V_m}{V_c}$$

2. **Modulation Index** can also be written as:

$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$$

3. **Percentage of modulation** is obtained my multiplying m with 100.



AM IN FREQUENCY DOMAIN

From above, AM signal can be written as

$$v_{AM} = V_c\, sin(2\pi f_c t) + V_m sin(2\pi f_m t) Sin(2\pi f_c t)$$

Using the trigonometric identity

$$sin(A) sin(B) = \frac{1}{2} cos(A - B) - \frac{1}{2} cos(A + B)$$

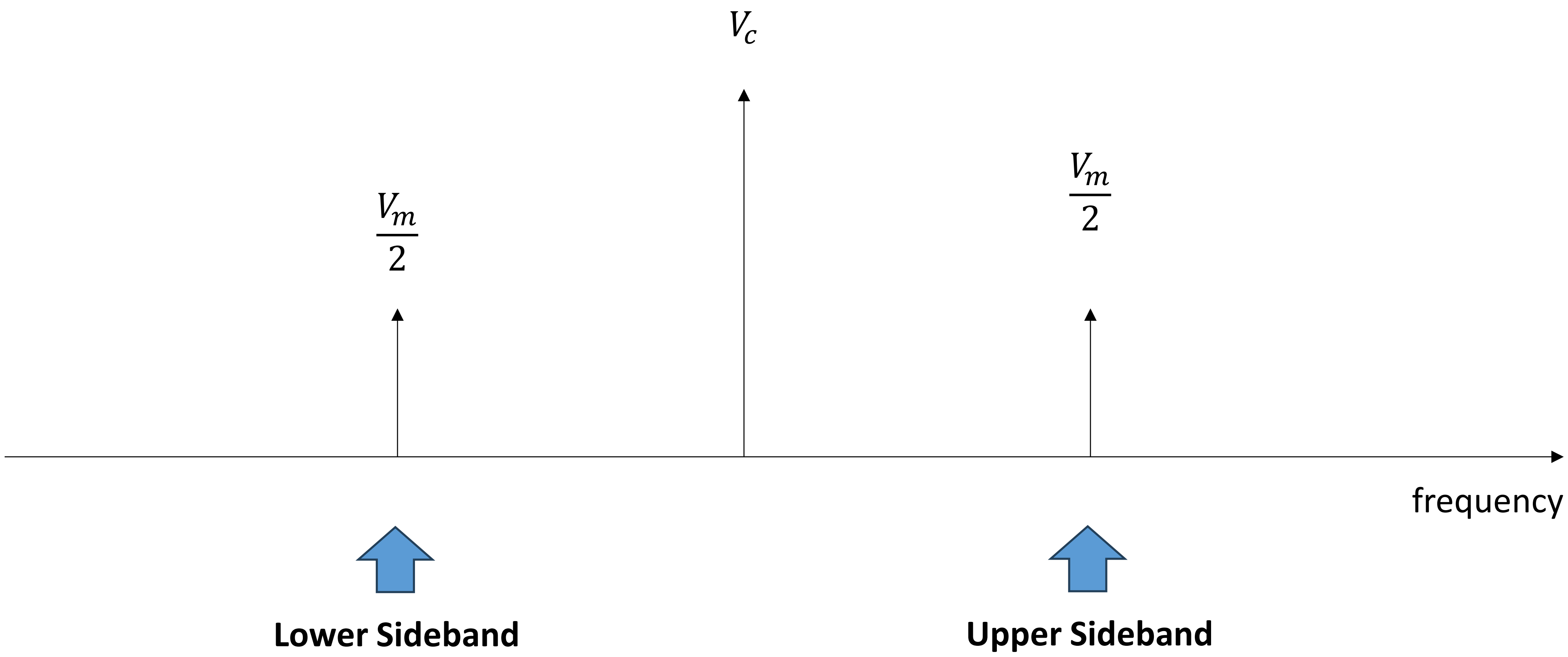
We get

$$v_{AM} = V_c\, sin(2\pi f_c t) + \frac{1}{2} V_m sin(2\pi(f_c - f_m)t) + \frac{1}{2} V_m sin(2\pi(f_c + f_m)t)$$

Lower Sideband

Upper Sideband

AM FREQUENCY SPECTRUM



CLASS EXERCISE 1

1. A standard AM radio station is licensed to transmit modulating frequencies up to 5 kHz. If the AM station is transmitting on a frequency of 980 kHz, compute the following:
   - **(a)** The maximum and minimum upper and lower sideband frequencies.
   - **(b)** The total bandwidth occupied by the AM station.

SOLUTION

(a) The maximum and minimum upper and lower sidebands are:

f_{USB} = 980 + 5 = 985 kHz

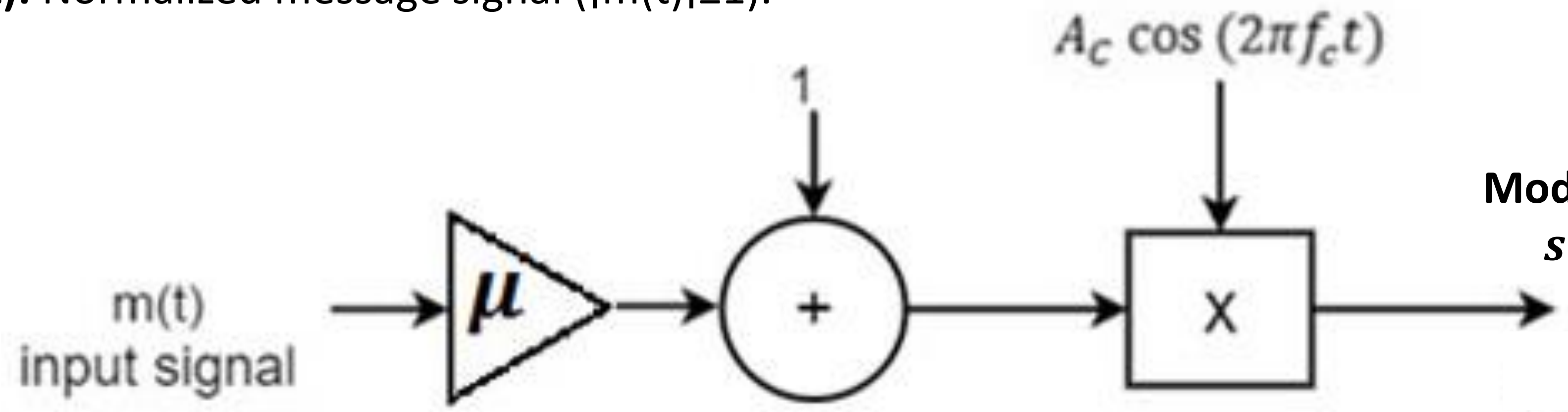
f_{LSB} = 980 - 5 = 975 kHz

(b) The total bandwidth BW is:

BW = 975 – 985 = 10 KHz

BLOCK DIAGRAM OF AM MODULATOR

A_c: Carrier amplitude.
μ: Modulation index (0<μ≤1).
m(t): Normalized message signal (|m(t)|≤1).



Modulated signal:

$$s(t) = A_c(1 + \mu\, m(t))\cos(2\pi f_c t)$$

$$s(t) = A_c \cos(2\pi f_c t) + \frac{\mu A_c}{2} \cos(2\pi(f_c + f_m)t) + \frac{\mu A_c}{2} \cos(2\pi(f_c - f_m)t)$$

EXPRESSION FOR POWER OF AM SIGNALS

Consider AM signal is given by

$$v_{AM} = V_c \, sin(2\pi f_c t) + \frac{1}{2} V_m sin(2\pi(f_c - f_m)t) + \frac{1}{2} V_m sin(2\pi(f_c + f_m)t)$$

We can write peak values as RMS values as follows

$$v_{AM} = \frac{V_c}{\sqrt{2}} sin(2\pi f_c t) + \frac{V_m}{2\sqrt{2}} sin(2\pi(f_c - f_m)t) + \frac{V_m}{2\sqrt{2}} sin(2\pi(f_c + f_m)t)$$

Power is given by $P = \frac{V_{RMS}^2}{R}$

We can write the power of the AM signal as:

$$P_T = \frac{\left(\frac{V_c}{\sqrt{2}}\right)^2}{R} + \frac{\left(\frac{V_m}{2\sqrt{2}}\right)^2}{R} + \frac{\left(\frac{V_m}{2\sqrt{2}}\right)^2}{R}$$

$$= \frac{V_c^2}{2R} + \frac{V_m^2}{8R} + \frac{V_m^2}{8R}$$

EXPRESSION POWER OF AM SIGNAL IN TERMS OF MODULATION INDEX

The previous expression can be written in terms of the modulation index since $V_m = mV_c$ as:

$$P_T = \frac{V_c^2}{2R} + \frac{V_m^2}{8R} + \frac{V_m^2}{8R} = \frac{V_c^2}{2R} + \frac{m^2V_c^2}{8R} + \frac{m^2V_c^2}{8R}$$

$$P_T = \frac{V_c^2}{2R}\left(1 + \frac{m^2}{4} + \frac{m^2}{4}\right) = \frac{V_c^2}{2R}\left(1 + \frac{m^2}{2}\right)$$

If the carrier power is P_c, we can write the equation as:

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

We can infer the following:

(a) If the modulation index, m = 0, then $P_T = P_c$

(b) If the modulation index, m = 1, then $P_T = 1.5P_c$

CLASS EXERCISE 2

1. A KBC AM transmitter has a carrier power of 30 W. The percentage of modulation is 50%. Calculate
   a) total power
   b) power in one sideband.

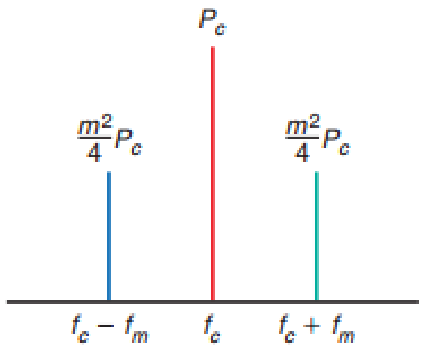
MODEL ANS

(a) If the carrier power is P_c, we can write the equation as:

$$P_T = P_c\left(1 + \frac{m^2}{2}\right) = 30 \text{ X } (1 + \frac{0.5^2}{2}) = 30 \text{ X } 1.125 = 33.75 \text{ W.}$$

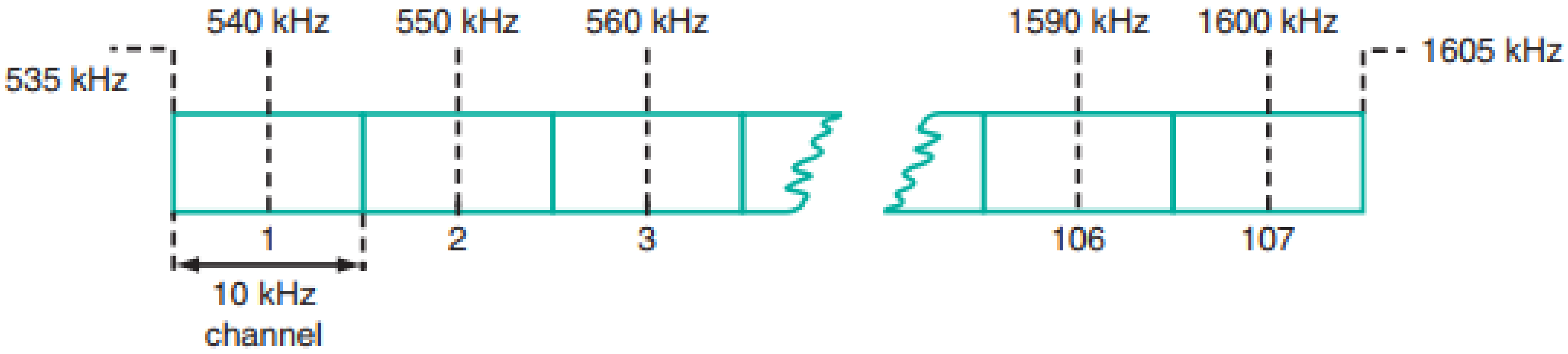
(b) Power in one sideband is given by

$$P_{LSB} = P_c\left(\frac{m^2}{4}\right) = 30 \text{ X } (0.25/4) = 1.875\text{W}$$



FREQUENCY PLAN FOR AM BROADCAST

1. AM broadcast stations are spaced every 10 kHz across the spectrum from **540 to 1600 kHz.**
2. The sidebands from the first AM broadcast frequency extend down to 535 kHz and up to 545 kHz, forming a 10-kHz channel for the signal.



REAL-WORLD MEASUREMENT OF POWER

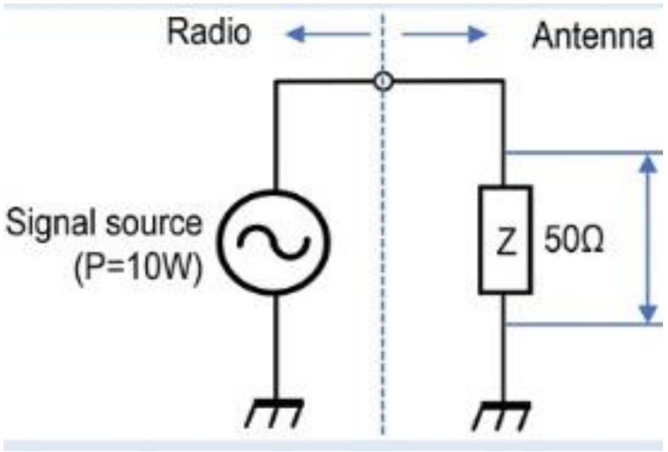
1. In the real world it is difficult to measure the RMS power and use the expression P = $V^2/2$ to calculate the power.
2. However, it is easy to use RF ammeter measure the current and use the expression

$$P_T = I_T R$$

where

R is the impedance of the antenna

$$I_T = I_c\sqrt{(1 + m^2/2)}$$



CLASS EXERCISE 3

1. An antenna has an impedance of 20 Ohms. An unmodulated AM signal produces a current of 5A. If the modulation index is 0.5, calculate:
   a) Carrier power
   b) Total power
   c) Power in one sideband.

MODEL ANS

(a) Carrier power, $P_c = I^2R = 25 \times 20 = 500W$

(b) Total power, $P_T = I_T^2R$

where

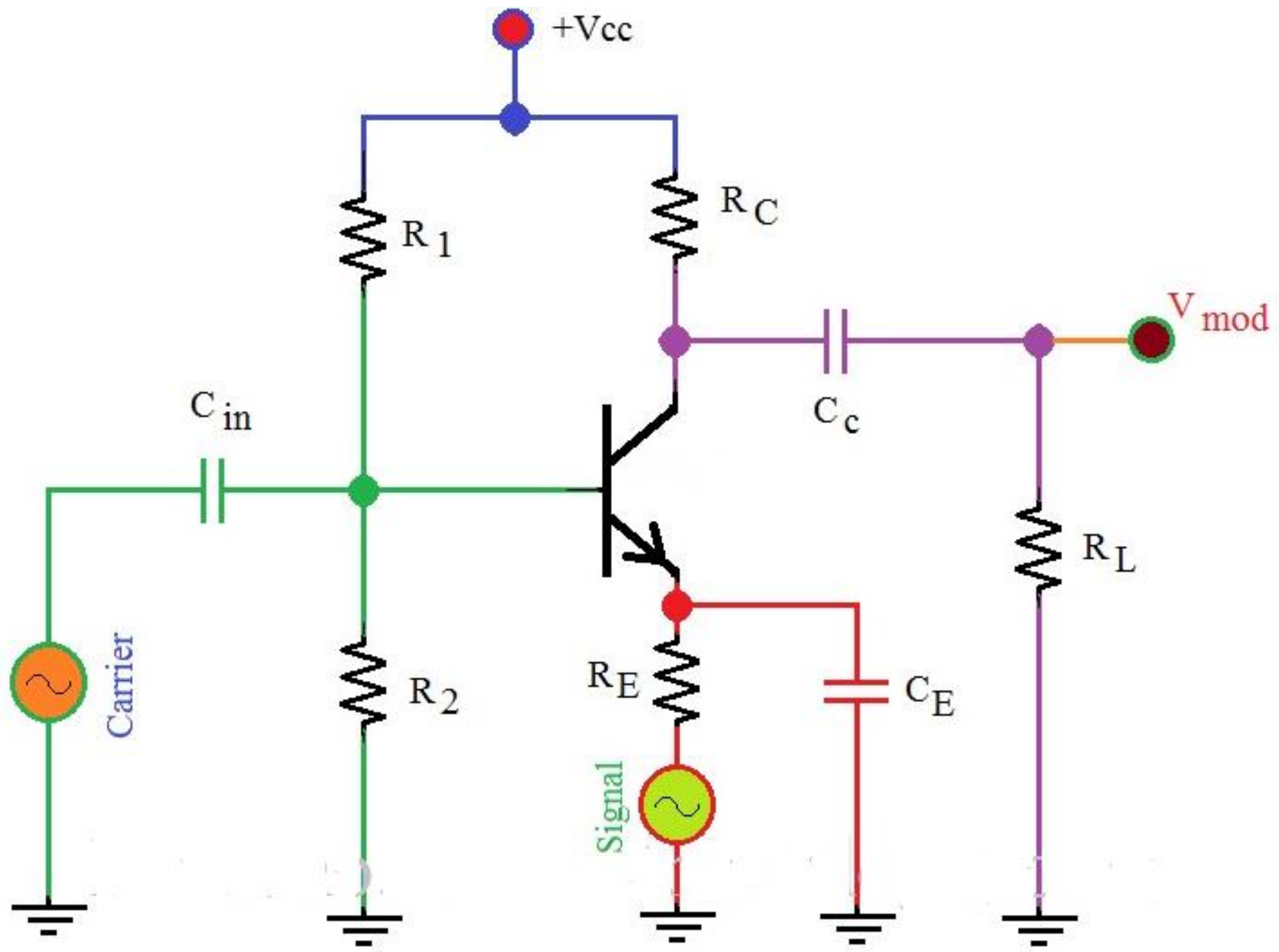
$$I_T = I_c\sqrt{\left(1 + \frac{m^2}{2}\right)} = 5\sqrt{\left(1 + \frac{0.25}{2}\right)} = 5\sqrt{1.125} = 5.3A$$

Substituting $P_T = I_T^2R$ = $5.3^2 \times 20$ = 561.8 W

(c) Power in one sideband is given by

$P_{LSB} = \frac{1}{2}(P_T - P_c) = \frac{1}{2}(561.8 - 500)$ = 30.9W

SIMPLE TRANSISTOR AMPLITUTE MODULATOR

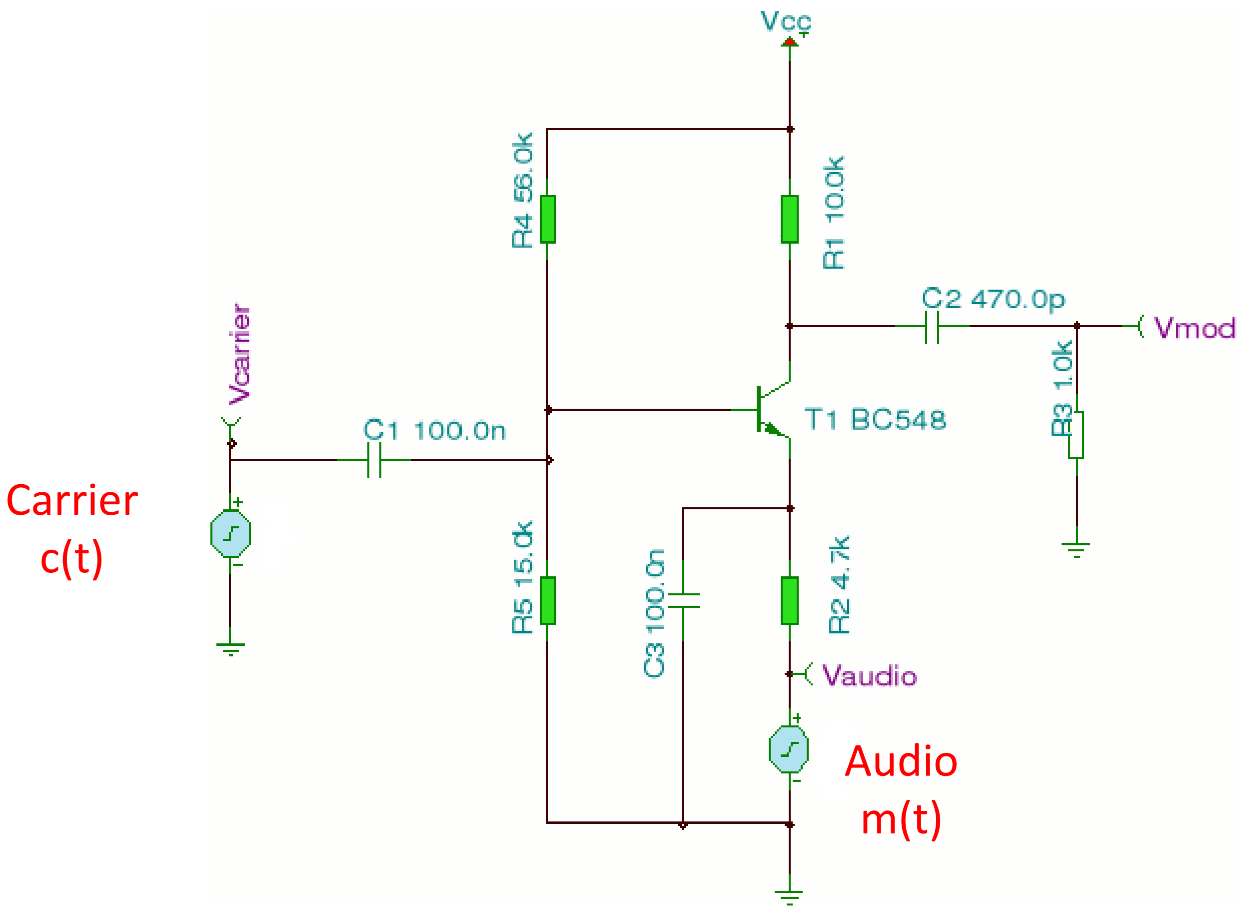


1. The carrier c(t) is applied at the input of the amplifier.
2. The modulating signal m(t) is applied in the emitter resistance circuit.
3. Since the modulating signal is a part of the biasing circuit, it produces low frequency which variations in the emitter circuit which generates the signal:

$$s'(t) = Ac(t)\,(1+km(t))$$

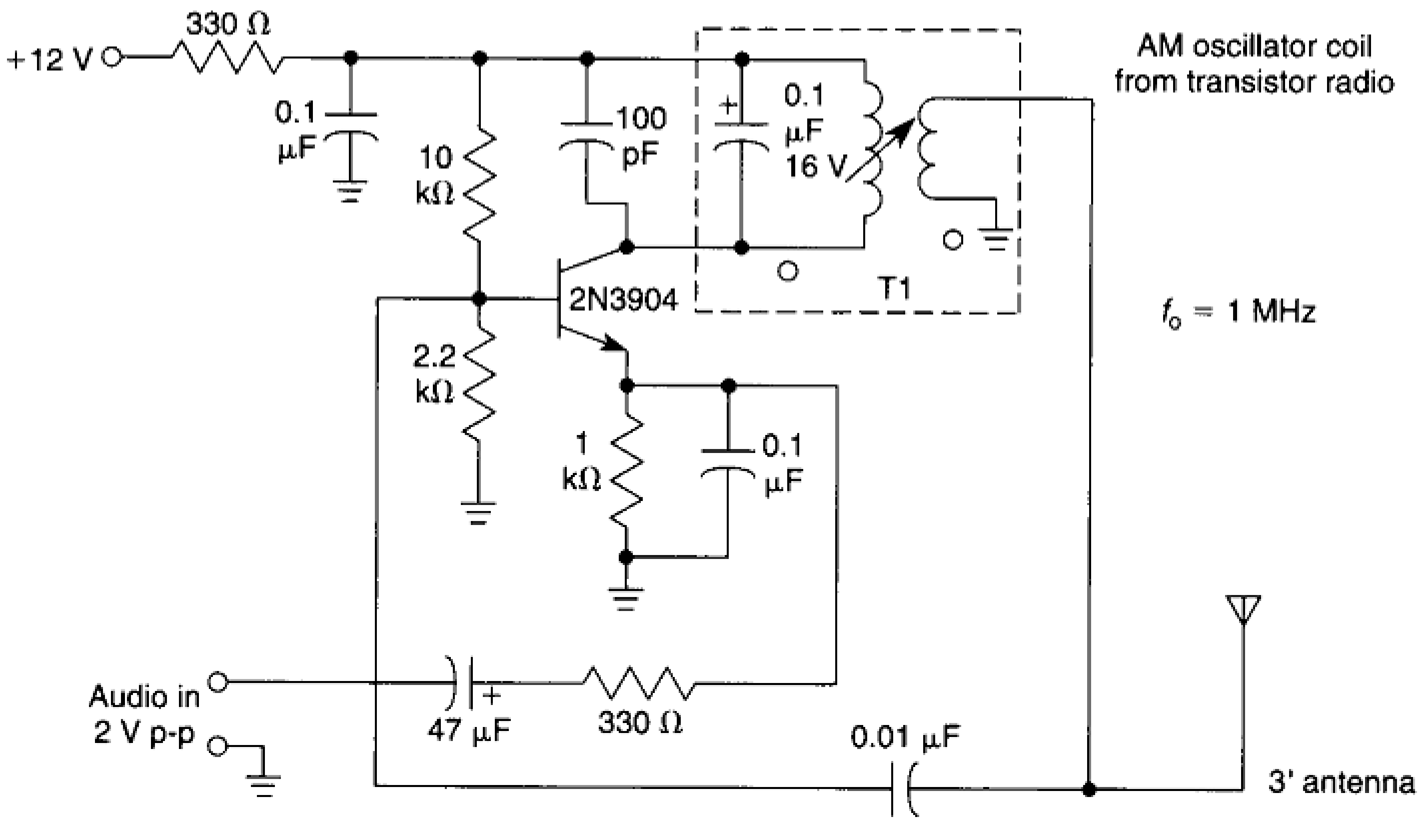
where A is the amplifier gain.

PRACTICAL AMPLITUDE MODULATOR CIRCUIT (1)



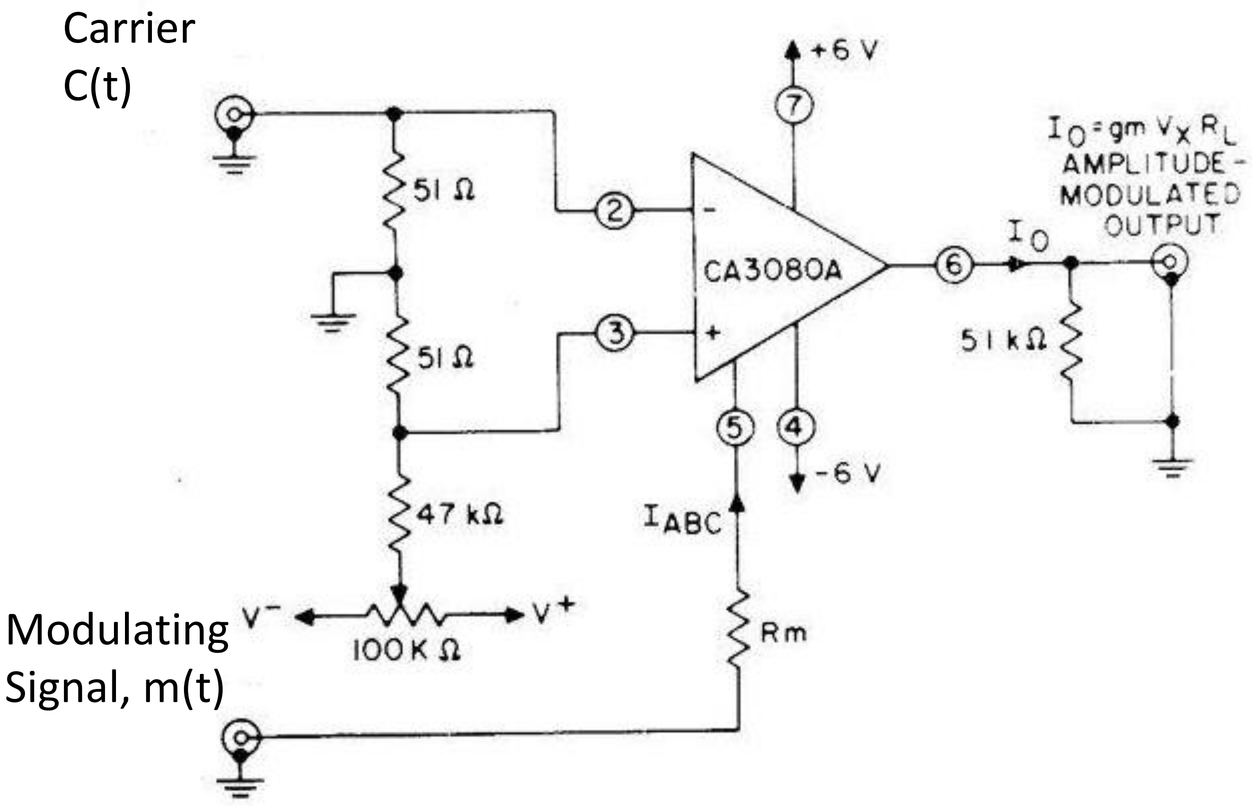
1. Two signal generators are used in this circuit, one representing a high frequency (200kHz) RF carrier, c(t), the other signal generator is used to inject a 1KHz audio signal m(t).
2. The two signals are mixed and amplified by the transistor and an amplitude modulated signal appears at the collector of the transistor.
3. The DC component is removed by C2 .
4. The RF output now appears across the load resistor R3.

PRACTICAL AMPLITUDE MODULATOR FOR WIRELESS MICROPHONE



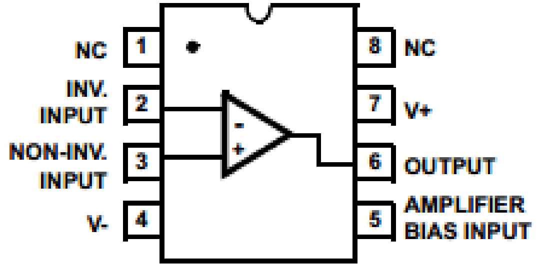
1. Use a winding coli with a turn ratio of 10:1 and inductance of 50-150 µH.

PRACTICAL OP-AMP AMPLITUDE MODULATOR



1. Uses controlled variation of amplifier bias current IABC in CA3080A variable Op-amp to obtain effective gain control of the carrier c(t).

2. Variations in modulating signal m(t) changes the Op-amp bias current through Rm yielding s'(t) = c(t)(1+km(t))



AM DEMODULATION

EEN 462- ANALOGUE COMMUNICATIONS

Friday, 12 September 2025

METHODS OF DEMODULATION

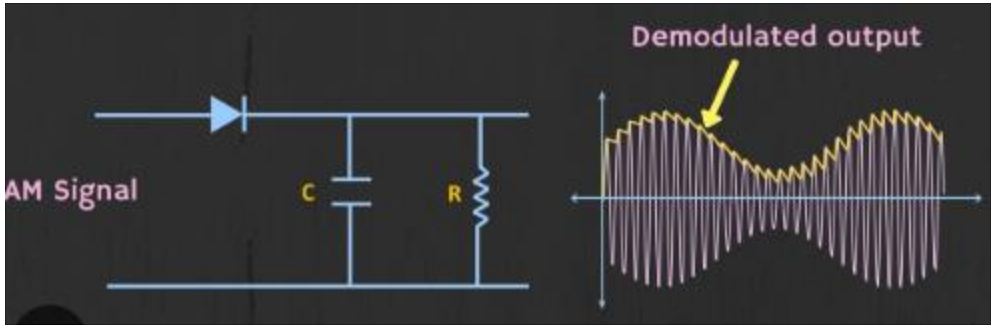
There are two different ways to demodulate an AM signal and recover the transmitted waveform, i.e

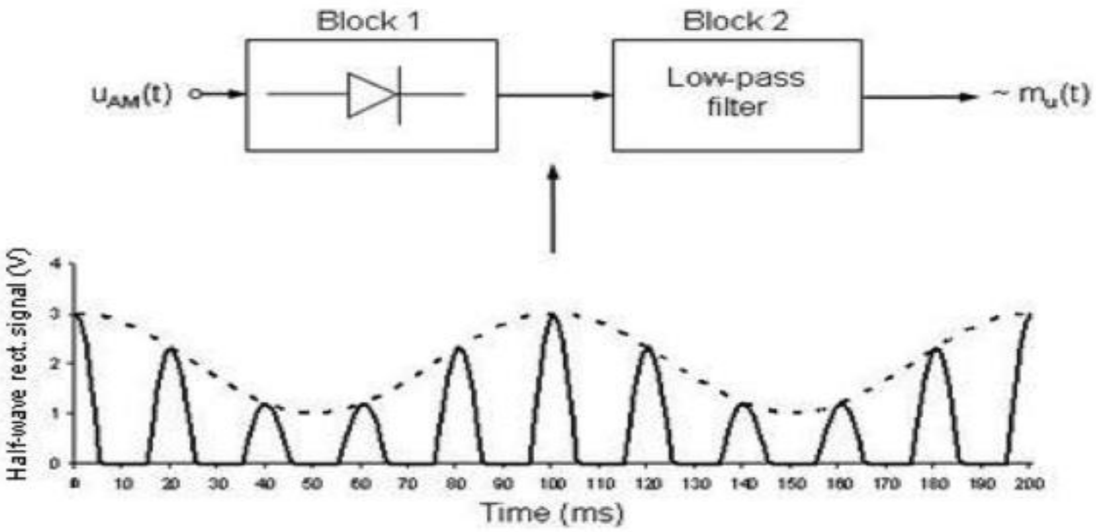
a) Envelope detector

b) Product detector

ENVELOPE DETECTOR

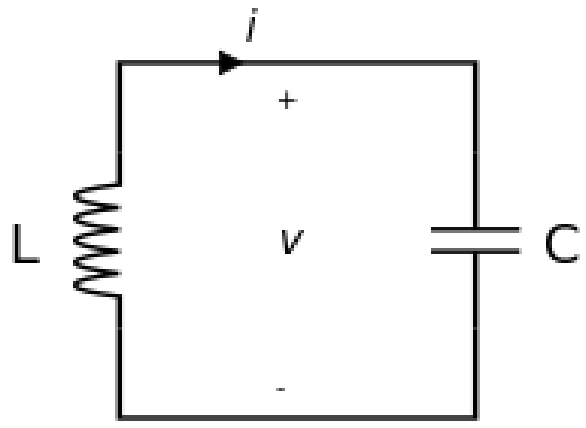
1. **Envelope detector is a simple circuit used to demodulate amplitude modulated (AM) signals** and extract the original baseband information.
2. **Its operation relies on a nonlinear component**, typically a diode, which rectifies the incoming AM signal, allowing current to flow primarily in one direction and thus capturing the peaks of the high-frequency carrier wave.
3. **The rectified signal is then passed through a low-pass filter (usually an RC circuit),** which smooths the output by averaging the signal and filtering out the high-frequency carrier component.





TUNED CIRCUIT (RECAP)

1. Tuned circuit also called a resonant circuit or tank circuit, consists of an inductor, L, and a capacitor, C.
2. The circuit can act as an electrical resonator, an electrical analogue of a tuning fork, storing energy oscillating at the circuit's resonant frequency.
3. Tuned circuit is used in the envelope detector to pick out (tune to) a signal at a particular frequency from RF signal coming from an antenna.



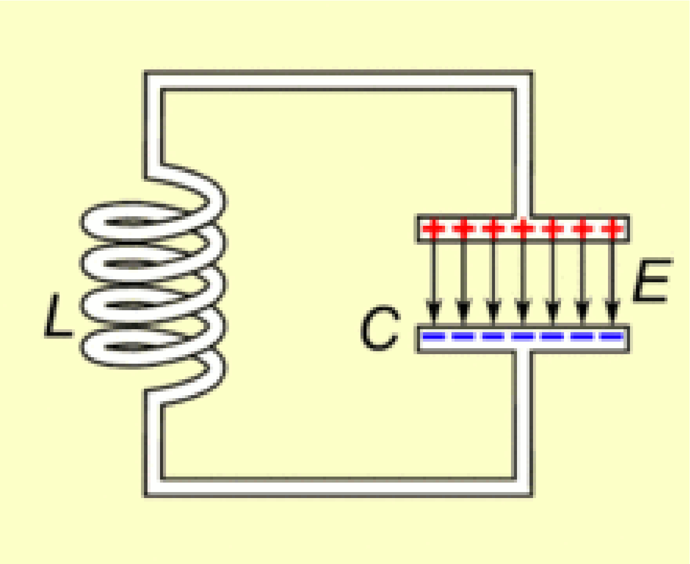
$$Resonant\ frequency, \omega_0 = \frac{1}{\sqrt{LC}}$$

or

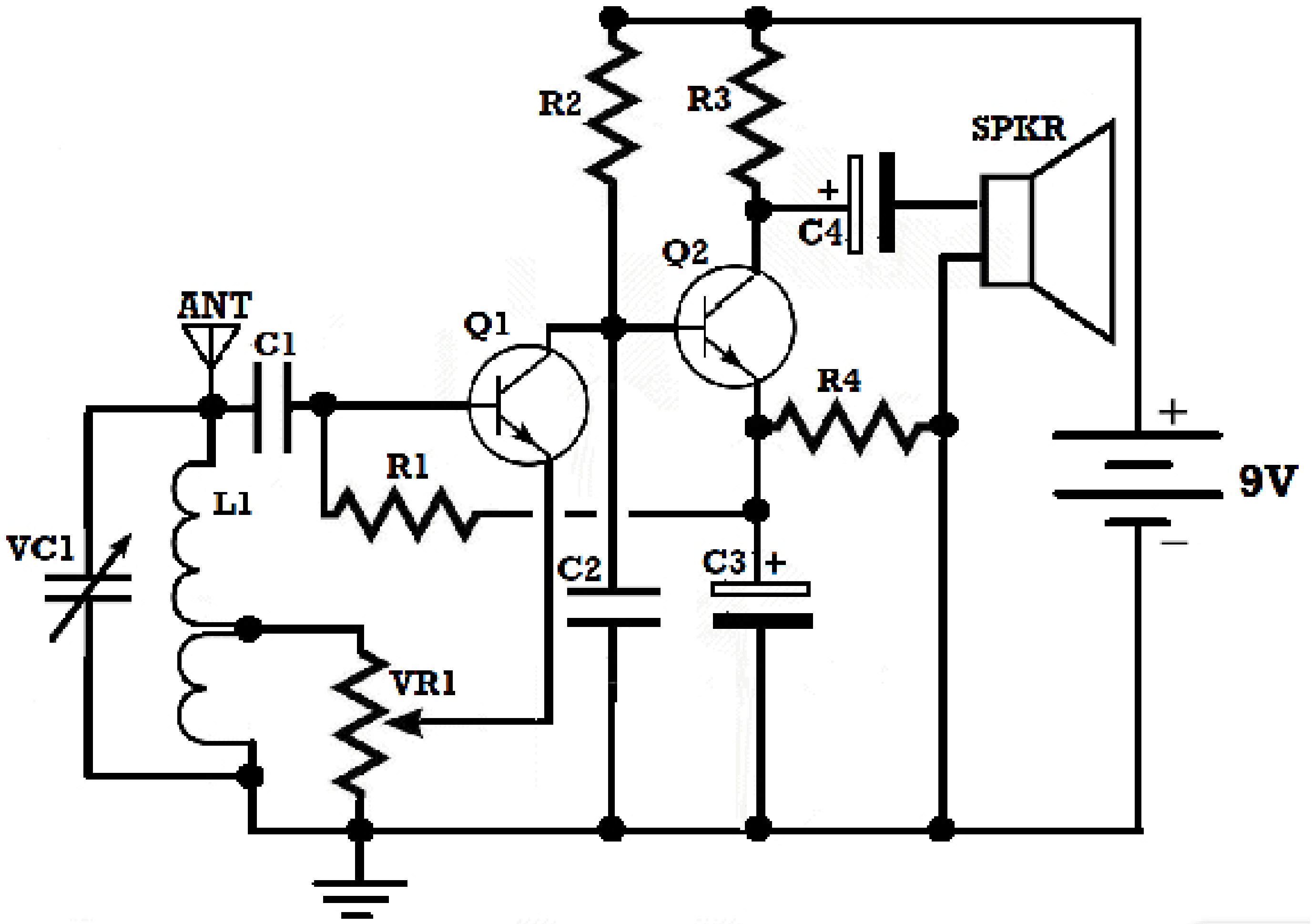
$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

PRINCIPLE OF OPERATION (RECAP)

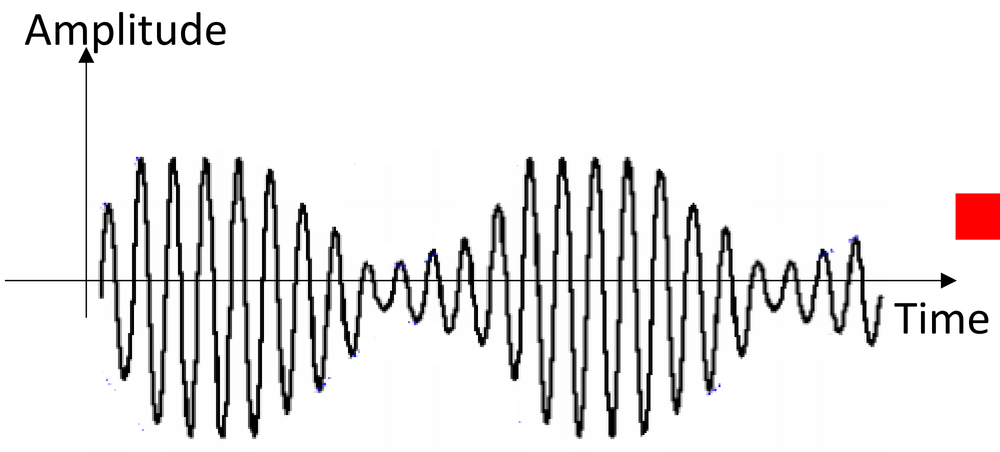
1. A charged capacitor is connected across an inductor, charge will start to flow through the inductor, building up a magnetic field around it and reducing the voltage on the capacitor.
2. Eventually all the charge on the capacitor will be gone and the voltage across it will reach zero.
3. Current continues, because inductors resist changes in current. The energy to keep it flowing is extracted from the magnetic field, which also begins to decline.
4. The energy oscillates back and forth between the capacitor and the inductor until (if not replenished by power from an external circuit) the internal resistance makes the oscillations die out.

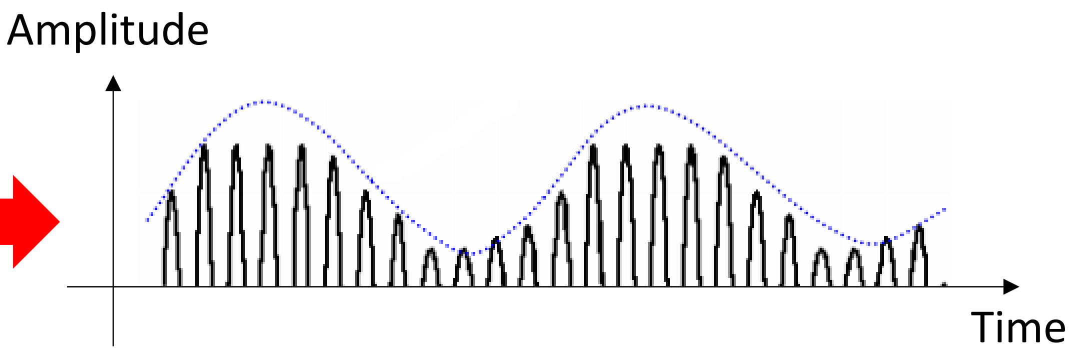


EXAMPLE OF TANK CIRCUIT IN SIMPLE AM RECEIVER



THE ENVELOPE DETECTOR (1)



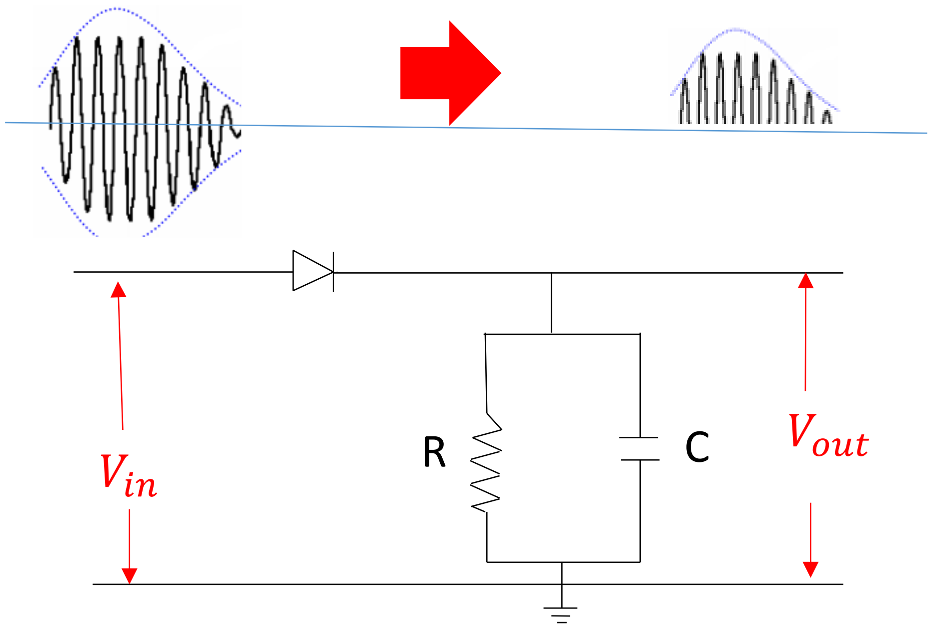


1. The modulating signal rides on carrier amplitude and thus forms the envelope of the transmitted signal.

2. **The envelope detector** recovers the transmitted signal riding on the carrier by extracting the envelope of the received signal.

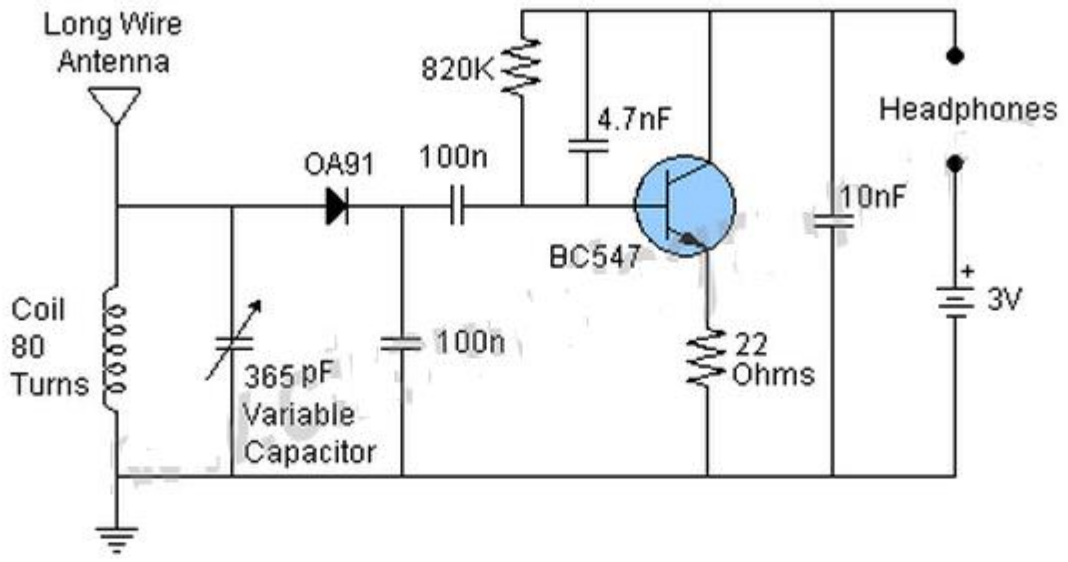
THE ENVELOPE DETECTOR

1. The peak envelope detector is one of the most commonly used AM detectors
2. It consists of a diode and an RC circuit.
3. It is cheap and easy to build which is the main reasons of popularity of AM in early radios.

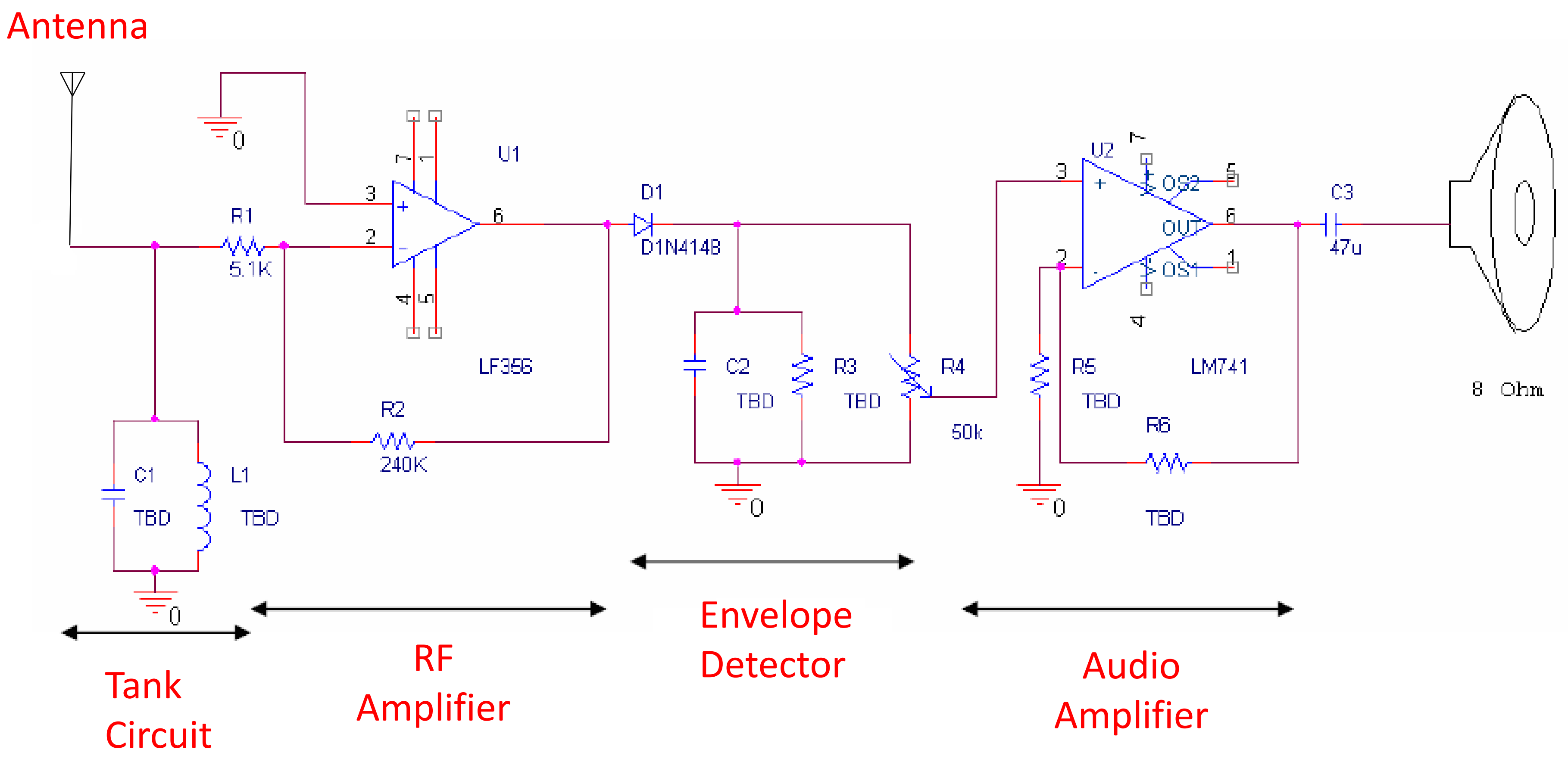


SINGLE TRANSISTOR ENVELOPE RECEIVER

1. The 80 turns coil and 365pF variable capacitor form a tank circuit
2. The germanium diode and the 100nF capacitor form the envelope detector
3. The general purpose BC547 transistor together with the biasing components form the audio amplifier.
4. The coil is equal to 80 turns of 26 s.w.g. Enameled copper wire wound on an empty card board toilet roll or an off cut piece of plastic waste pipe

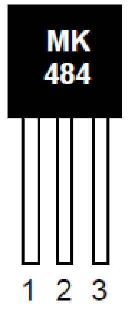


OP-AMP AM ENVELOPE RECEIVER CIRCUIT



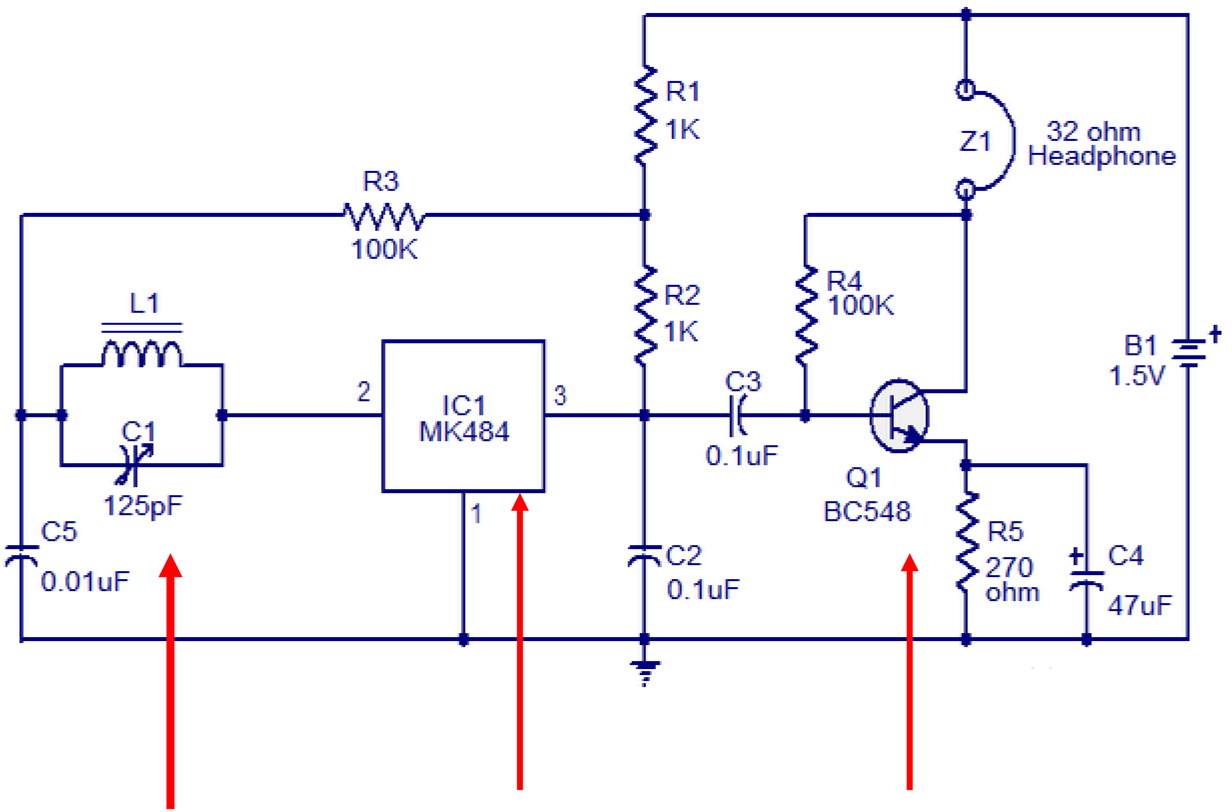
INTEGRATED CIRCUIT RADIO RECEIVER – MK484

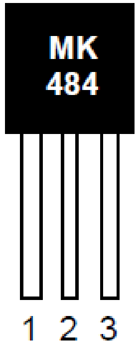
1. The MK484 is a monolithic integrated circuit designed for use as a one chip AM radio receiver solution.
2. Using MK484 high sensitivity and high-quality AM radio is possible with very few external components.
3. The MK484 has an input impedance of 4MΩ and operates over a frequency range of 150KHz - 3MHz.



Pin No.	Symbol	Description
1	Vss	Gnd
2	I/P	Input
3	O/P	Output

PRACTICAL AM RECEIVER CIRCUIT USING MK484





Series tuned LC filter

MK484 Envelope detector

Transistor Amplifier

REVIEW QUESTIONS

1. With the aid of a block diagram, describe the operation of an envelope Amplitude Modulation (AM) receiver.
2. Why is it necessary to have a tank circuit in AM receivers?