# TRANSMISSION AND RECEPTION OF RADIO SIGNALS



---

## 1. INTRODUCTION.

1.1 The whole of Radio depends upon the fact that a certain form of energy, called "electromagnetic radiation" can travel from one place to another, practically instantaneously, and even through a vacuum, or the near-vacuum of outer space.

Most people are familiar with the forms of electromagnetic radiation commonly recognised as light and heat. That these forms of energy radiation can travel through the near-vacuum of space is manifested by the facts that sunlight illuminates all objects on the earth's surface while the sun is shining, and the heating effect of the sun can be felt as one moves from shadow into sunlit areas.

Radio waves are merely another form of electromagnetic radiation along with light and heat. In order to understand what "electromagnetic radiation" is, the combination of two known phenomena should be considered:-

(i) The application of a voltage or e.m.f. to a capacitor causes it to "charge". This is a process whereby the space between the capacitor plates becomes electrically strained. This state of tension existing between the plates is called an electric filed, and is really stored energy that can be returned to the circuit when the capacitor is discharged.

(ii) The passage of current through an inductor sets up a magnetic field around the inductor. This magnetic field represents another form of stored energy, which can be returned to the circuit when the field collapses.

1.2 Previously it has been supposed that <u>all</u> the stored energy is an electric or magnetic field is returned to the circuit. In actual fact, however, not all this stored energy is returned to the circuit - some is lost - it escapes and flows or <u>RADIATES</u> away from the capacitor or inductor (like the ripples on the surface of a pond disturbed by a stone) and this energy can be picked up at a distant place by a suitable detecting device.

The amount of energy radiated from an A.C. circuit rises very rapidly as the frequency rises, being negligible at low frequencies.

Any changing magnetic line of force has an electrostatic line of force surrounding it at right angles, and vice versa. Therefore a radiated magnetic field is accompanied by an electric field, the combination being called "electromagnetic radiation".

2. RADIO WAVE RADIATION.

2.1 If we apply an alternating e.m.f. of suitable frequency to a capacitor or inductor a continuous series of electromagnetic waves will be produced. The continuous "build-up/decay/reversal" nature of the field will produce electromagnetic energy which will radiate away in the form of waves having the same frequency as that of the original alternating e.m.f. Radio Waves are electromagnetic waves that have a frequency of from about 10kc/s to 1000Gc/s.

2.2 Radio waves can be radiated in more efficient ways than from a capacitor or inductor. There have been developed special radiating devices which are known as AERIALS (or antennas). A properly designed aerial stores very little of the energy fed into it - it lets most of it escape, as radiation. Fig. 1 shows a transmitting radiator or aerial. This is a device specially designed to radiate electromagnetic energy. This aerial system combines the features of a capacitor and an inductor, in that the varying potentials between the aerial and earth create a varying electric field, while the currents in the aerial itself create a varying magnetic field, and the combination of these two simultaneously constitutes the radiation of electromagnetic waves.

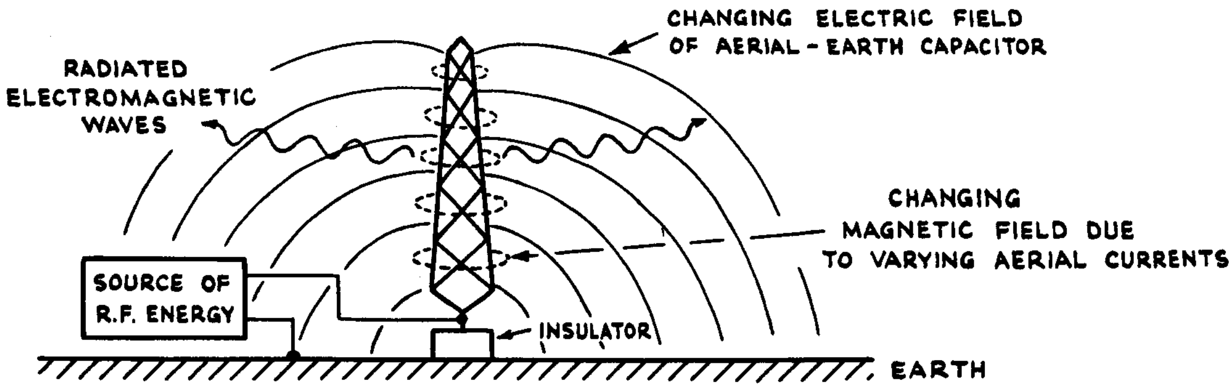



FIG. 1. TRANSMITTING ANTENNA RADIATING ELECTROMAGNETIC WAVES.

3. SENDING RADIO MESSAGES.

3.1 Transmission of messages by radio was first achieved by simply, interrupting the transmission of the radio frequency by means of morse key, thus sending telegraphic signals. Now the radio frequencies are used as a "carrier" for the messages. Two main requirements are needed in sending messages, one to impress or 'modulate' the radio waves with the message, and the other is to use a different radio frequency for each message, so as to separate the messages.

To radiate radio frequencies, the aerial is supplied by A.C. generated by an R.F. oscillator, and amplified by an R.F. amplifier.

The R.F. waves travel at the speed of all electromagnetic waves, light, etc. i.e. 186,000 miles per second, or 300 million ($3 \times 10^8$) metres per second.

The wavelength of the electromagnetic wave and its frequency are related by the formula:-

$$\text{Wavelength (metres)} \quad \lambda = \frac{3 \times 10^8}{\text{fc/s}}$$

$$\text{e.g. } \lambda \text{ (at 600kc/s)} = \frac{3 \times 10^8}{600 \times 10^3} = 500 \text{ metres.}$$

Fig. 2 illustrates the Electromagnetic Spectrum and shows the relative positions on the frequency scale of Radio waves, micro-waves, the visible, infra-red, ultra-violet rays, and x-rays, together with their wavelength in metres.

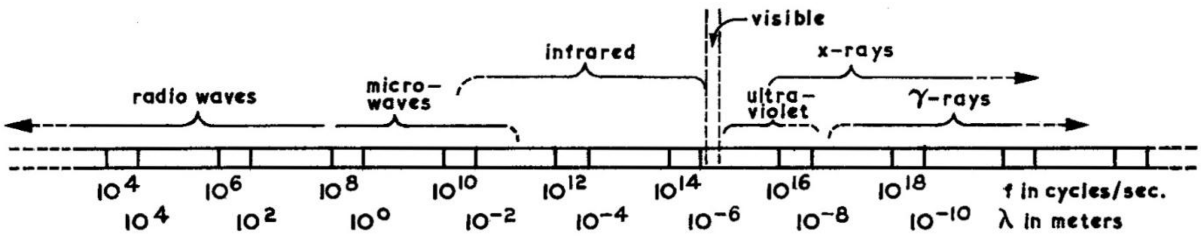



FIG. 2. ELECTROMAGNETIC SPECTRUM.

3.2 The radio frequencies used as "carriers" vary according to the function to be provided. "Broadcast" programmes use R.F. carriers of between 550kc/s to 1,600kc/s while some "short wave" programmes use 2Mc/s to 30Mc/s. This is in the High Frequencies (H.F.) range. Television programme video (picture) component is transmitted over a Very High Frequency (V.H.F.) carrier of between about 50Mc/s and 250Mc/s, and so on.

3.3 In the process of transmission of radio messages, the information to be transmitted, which may be speech, music, or telegraph signals, is amplified and then "mixed" with the constant output of an R.F. oscillator in a device called a "modulator" and the products of this mixture are again amplified and then directed to the transmitting aerial where they are propagated as radio frequency electromagnetic waves.

3.4 Introduction to Telecom. Engineering, Part 6, (Radio Services), describes the manner in which radio waves are propagated, in Para. 2.4; and the factors contributory to the attenuation of radio waves (called "fading") is discussed briefly in Paras. 2.5 and 2.6 and types of modulation used is explained in Para. 2.8 of the same paper.

Figure 3 shows a block diagram of a transmitting station from microphone to aerial.

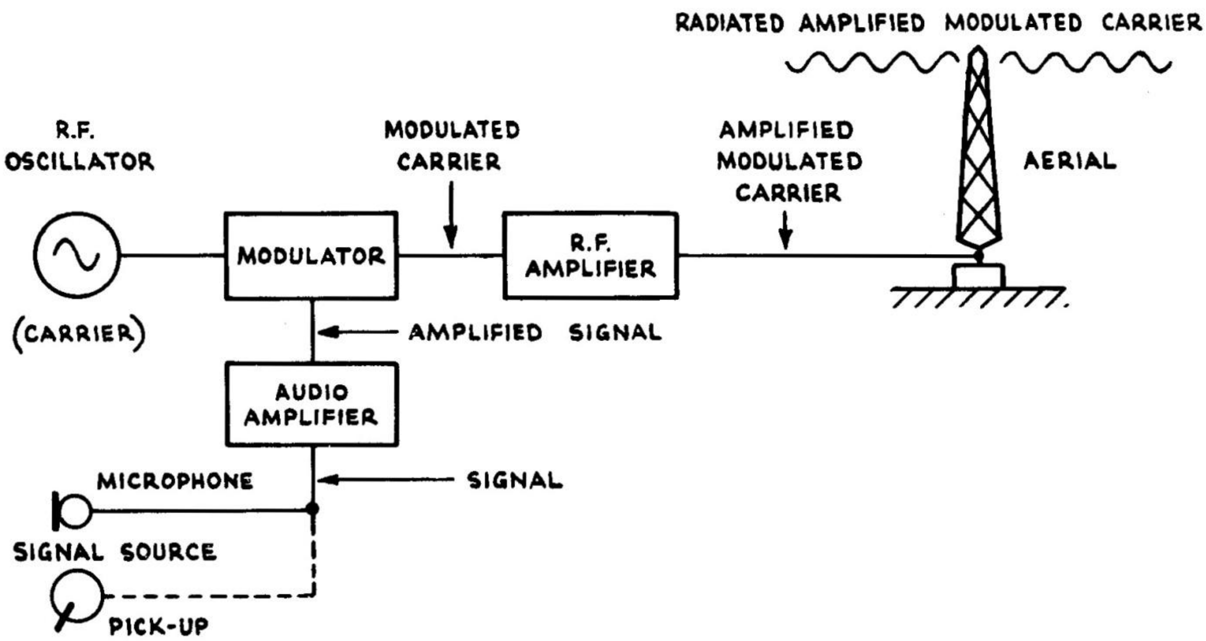



FIG. 3. TYPICAL RADIO TRANSMITTER BLOCK DIAGRAM.
(Microphone to Transmitter).

4. BASIC PRINCIPLE OF MODULATION.

4.1 For radio broadcasting purposes Amplitude Modulation (A.M.) is generally used, and also for the picture content (video component) of Television transmission. Frequency Modulation (F.M.) is used for the sound content (audio component) of T.V. These types of modulation, together with other types are described in a later part of the course.

In these notes, Amplitude Modulation only will be considered.

4.2 So that the function of an A.M. Modulator may readily be understood, it is assumed that a radio frequency of 1,000,000 cycles/sec. (1Mc/s) is to be used, and a tone of the voice frequency of 1,000 cycles (1kc/s) is the frequency to be transmitted. These two frequencies are connected to the modulator as shown in Fig. 4.

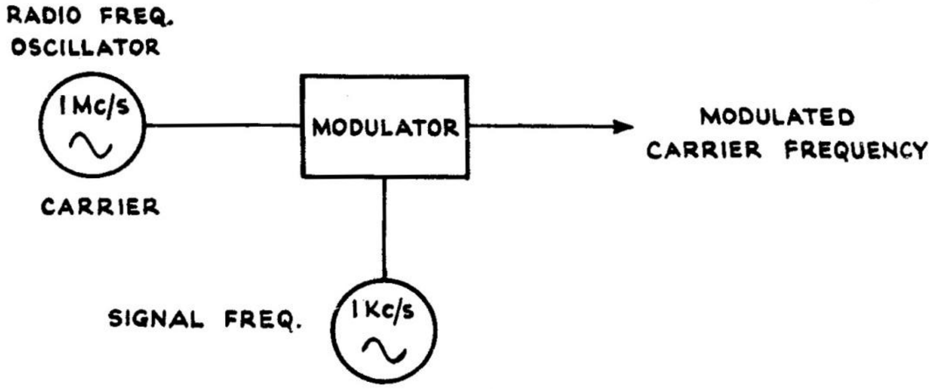



FIG. 4. CONNECTIONS TO MODULATOR.

4.3 When audio frequency and carrier frequency are combined in a modulator, the carrier is amplitude modulated by the audio frequency. As shown in Fig. 5.

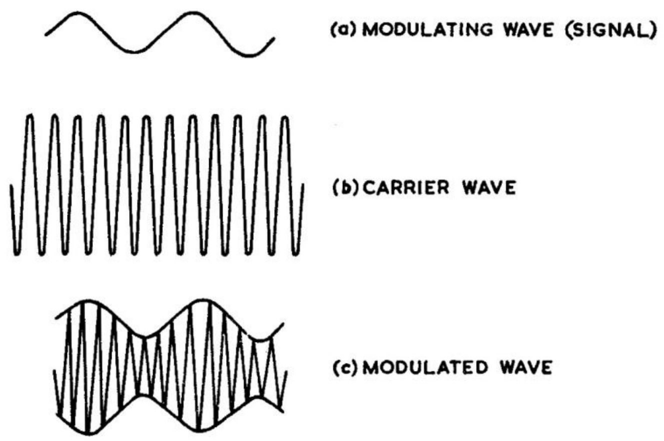



FIG. 5. CARRIER FREQUENCY MODULATED BY AN AUDIO FREQUENCY.

If as we have stated, a 1kc/s tone is used to control a 1Mc/s carrier, the maximum R.F. output will be obtained when the 1kc/s signal is at the peak of one half cycle, and the minimum will occur at the maximum of the next half cycle. This is the process of amplitude modulation, and the result of such modulation is the waveform as shown in Fig. 5c. This resultant signal is now entirely at radio frequency, but with its amplitude varying at the modulation rate (in this case 1kc/s).

It is likely to be considered that the only radio frequency present in such a signal is the original 1Mc/s, but such is not the case. Two new frequencies have appeared. These are the sum (1Mc/s + 1kc/s) and the difference (1Mc/s – 1kc/s) frequencies and thus the radio frequencies appearing after modulation are 1.001Mc/s and 0.999Mc/s. In general terms these frequencies are referred to respectively as the upper side frequency and the lower side frequency.

In this example, the modulating signal was assumed to be a pure tone but the modulating signal can just as well be a band of frequencies making up speech (approximately 300c/s to 3kc/s) content or music (approximately 100c/s to 10kc/s or higher) content. In these cases, the side frequencies are grouped into the upper side band and the lower side band.

4.4 Fig. 6 shows the products of amplitude modulation of a 1 megacycle R.F. carrier frequency modulated by an audio frequency of 100c/s to 10kc/s.

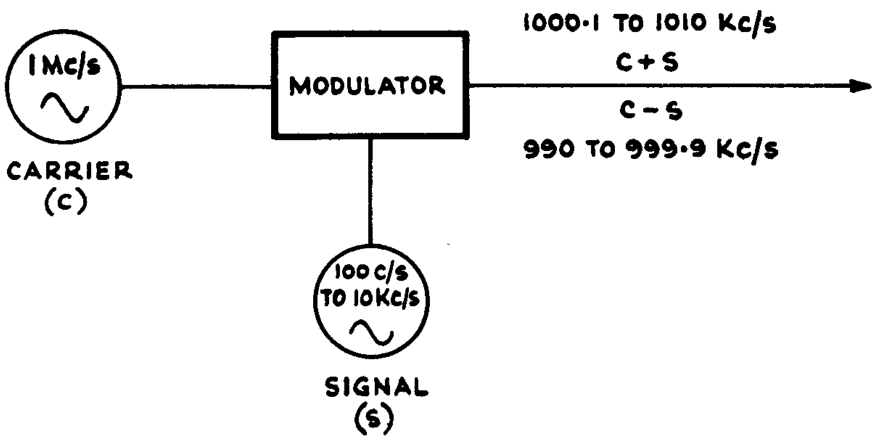



FIG. 6. PRODUCTS OF MODULATION.

The sum frequencies are:-

1Mc/s + 100c/s = 1,000,000c/s + 100c/s = 1,000,1kcs
and 1Mc/s + 10kc/s = 1,000,000c/s + 10,000c/s = 1,010kc/s

The difference frequencies are:-

1Mc/s – 10kc/s = 1,000,000c/s – 10,000c/s = 990,1kcs
and 1Mc/s - 10c/s = 1,000,000c/s - 100c/s = 999.9kc/s

Hence the upper and lower sidebands are:-

1,000.1kc/s to 1,010kc/s and 990kc/s to 999.9kc/s

The difference between the lowest modulated frequency, 990kc/s the highest, 1010kc/s is the bandwidth of the particular station, in this case 20kc/s. The radio frequencies allotted to transmitting stations are spaced so that there is no overlapping of sideband frequencies.

## 5. RECEIVING RADIO MESSAGES.

5.1 In order to receive a particular radio message an aerial is used to "intercept" the radio waves emanating from the transmitting antenna, and to pass the small amount of energy from these to the receiver. The next step is to select, the desired signal from the number present in the aerial.

5.2 Selection of Radio Signals. To select a particular radio signal from the jumble of e.m.fs. supplied by the aerial system the aerial signals are fed into a tuned circuit.

The capacitor and inductor of the tuned circuit are arranged to be resonant at the frequency of the desired signal so that the e.m.fs. developed across it are those of the signal concerned. If it is desired to receive signals from any one of a number of transmitting stations the tuned circuit is arranged to have its resonant frequency adjustable over the required band of frequencies. This can be done by making either the inductor or the capacitor a variable unit and thus it is possible to SELECT the frequency required as shown in Fig. 7.

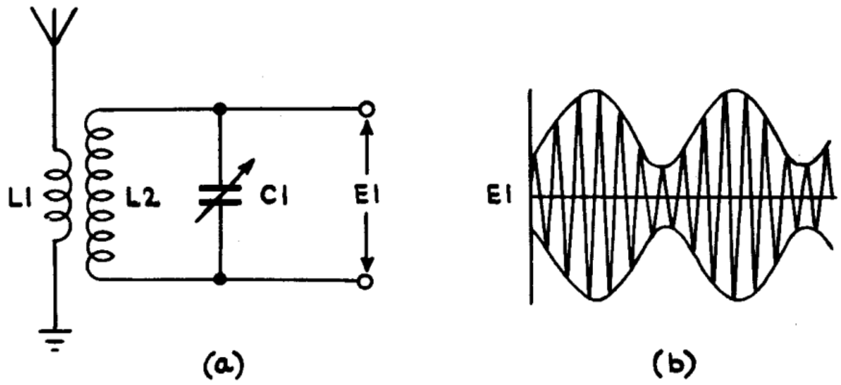



FIG. 7. TYPICAL SELECTION CIRCUIT OF RADIO RECEIVER AND ASSOCIATED WAVE SHAPE.

5.2 Detection or Demodulation of Radio Signals.

In order to derive the speech or music content from the modulated R.F. signal it is necessary to separate this component from its R.F. carrier. This process is known as DEMODULATION or DETECTION. The detector stage by means of a diode allows only part of the signal to pass and to attenuate (or suppress) the other part. The "one-way" action of the diode allows only one series of half cycles to pass through it, i.e. the positive half cycles. The negative half-cycles are blocked. The detector stage (basically) is shown as a simple diode in Fig. 8a and the resulting wave shape is shown across the local resistor $R_L$ in Fig. 8b.

The wave shape of Fig. 8b consists of half cycle R.F. pulses which vary in amplitude according to the modulating information.

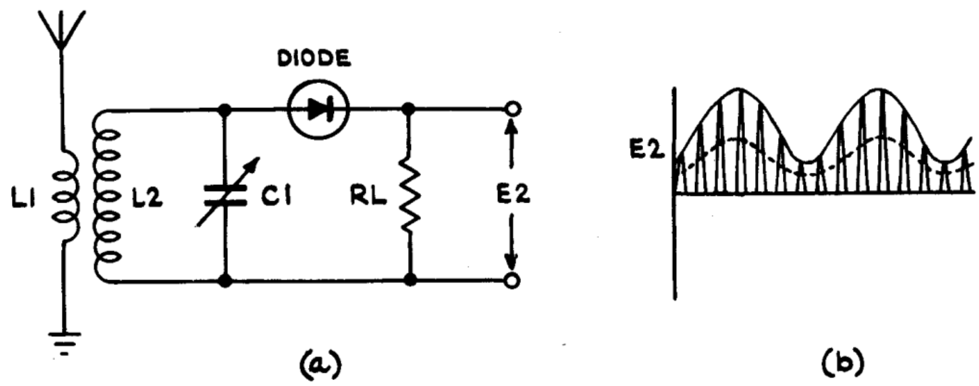



FIG. 8. DETECTOR STAGE & ASSOCIATED WAVE SHAPE.

A small capacitor, C2 is placed across the load resistor, as in Fig. 9a, to bypass the R.F. component of the signal to earth, leaving a signal pulsating at the modulation frequency (Fig. 9b), which is then amplified to the required strength.

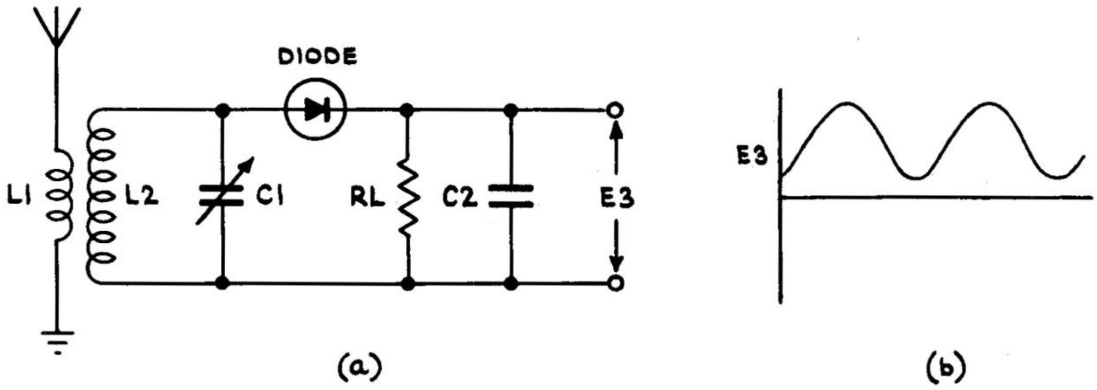



FIG. 9. SIMPLE RECEIVER CIRCUIT AND ASSOCIATED WAVE SHAPE.

6. MICROPHONES.

6.1 A microphone is a device used to convert the air pressure changes (that characterise the sounds of speech or music) into electrical signals suitable for electronic amplification.

6.2 Perhaps the most common types of microphones in general use are:-

(i) Carbon granule type. (See Tel. 1, Paper 2 Section 2).

(ii) Moving coil type.

(iii) Crystal type.

These are what are known as pressure operated microphones – there is another type known as a Velocity microphone which will be discussed at a later part of the course.

6.3 Moving Coil Microphone. This is one of the most useful types. While the output is low it has small size and weight, good performance and reasonably robust construction. This type of microphone is in effect a miniature moving coil loudspeaker. Its construction is shown in Fig. 10 and its operation is as follows:

A small conical or domed diaphragm is employed to move (under air pressure, from the sound waves) a coil attached firmly to the butt of the diaphragm. This coil is arranged so as to be able to move within the area of a magnetic field provided by a permanent magnet. As the coil is moved to and fro across a magnetic field e.m.fs. are induced into it (by Faraday's Law), and, if the coil circuit is closed currents will flow. In other words, a cone vibrated by sound wave causes an attached coil to move within a magnetic filed and thereby produce an alternating e.m.f. across its end.

Sound waves are converted into signal voltages, which, can be amplified and applied to appropriate circuitry, allowing for, e.g., either public address, or transmission over lines, as required.

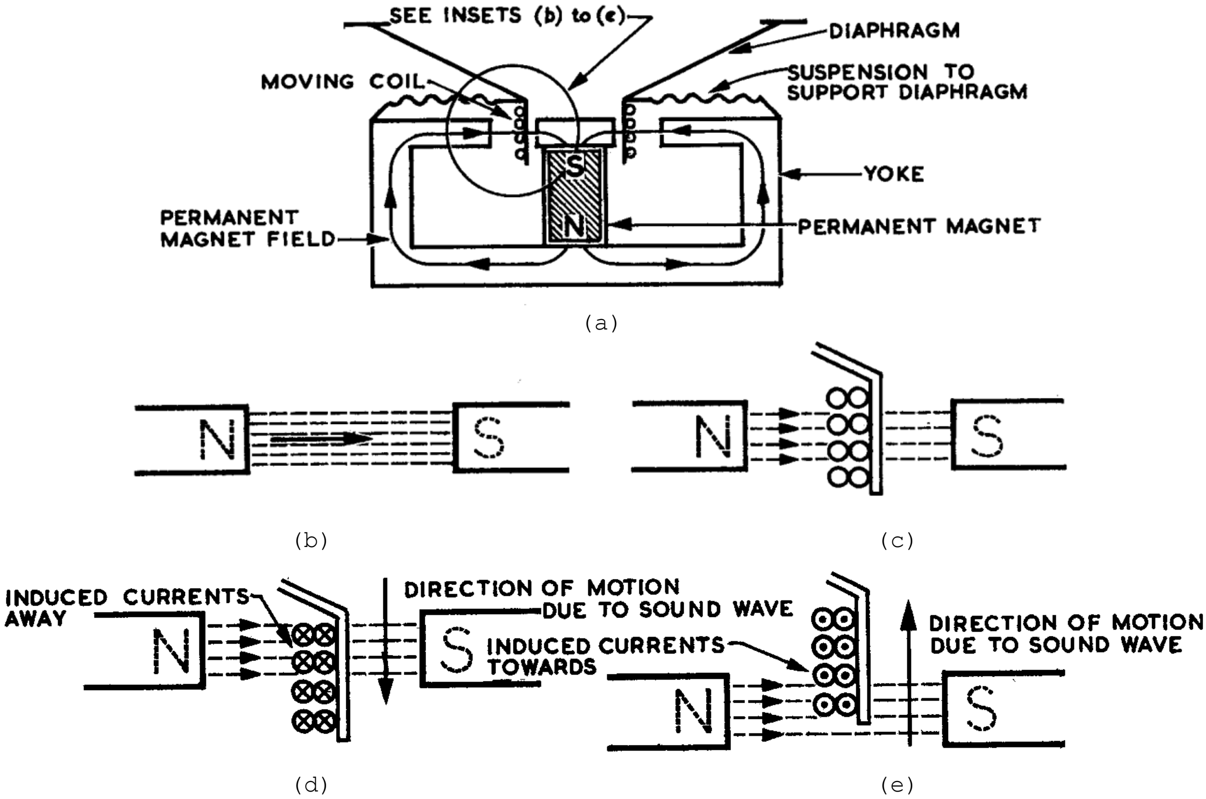



FIG. 10. MOVING COIL MICROPHONE.

Fig. 10a shows the basic construction of a moving coil microphone.

Fig. 10b shows an enlarged view of the field across the L.H. airgap, and Fig. 10c shows a portion of the diaphragm, the coil side and the yoke with its induced polarities.

Fig. 10d assumes that the diaphragm is driven by sound waves in toward the yoke, and the resulting current direction which is induced in the coil side – in this case downwards through the paper.

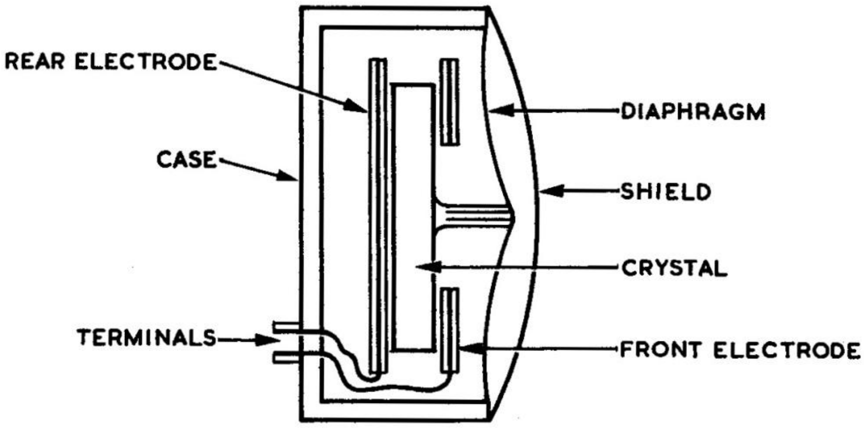
Fig. 10e assumes the diaphragm is moving away from the yoke, and the resultant induced current direction is upwards through the paper, in the same coil side, thus alternating motion of the diaphragm produces alternating e.m.fs in the coil.

A transformer is usually fitted in the case to raise the output e.m.f. and provide impedance matching to the amplifier input. The impedance of a moving coil microphone is 50 ohms.

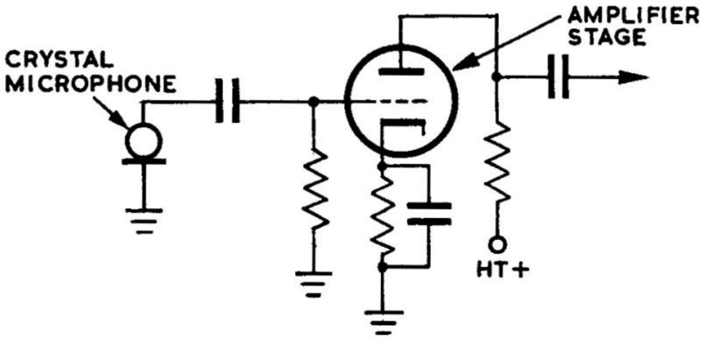
6.4 Crystal Microphones operate on an entirely different principle, in that, while still being "pressure" operated, and employ a phenomenon based on "Piezo – electric activity".

Piezo – electric activity is the term applied to quartz crystals and certain synthetic crystalline substances (notably Rochelle Salts e.g. Sodium Potassium Tartrate) that exhibit unusual peculiarities, i.e. mechanical distortion or deformation of the crystal produces electric charges between the faces of the crystal. This phenomenon is reversible – that is potentials applied to opposite faces produce mechanical deformation or distortion of the crystal.

To use the principle for a microphone, sound waves impressed upon such a crystal alternatively compress or relax it. The repetitive variations in pressure produce e.m.fs. – compression would be of one polarity and relaxation of the other; hence a crystal subjected to sound wave pressures gives rise to an alternating e.m.f. across its faces. The e.m.fs. are collected by electrodes, and amplified, as required.




(a) Construction.




(b) Associated Circuitry.

FIG. 11. TYPICAL CRYSTAL MICROPHONE.

The construction and associated circuitry are shown in Fig. 11. The crystal microphone is a high impedance device which gives a relatively large output and therefore may be directly connected to the input of an amplifier.

7. LOUDSPEAKERS.

7.1 A loudspeaker is a device which produces sound waves from electrical signals and to faithfully reproduce the sound waves the loudspeaker must have a wide frequency response and be able to handle large signals without distortion. Many different applications varying from pocket radios to elaborate public address loudspeaker systems, require sizes ranging anywhere between 1½″ to 15″ cone diameters. The loudspeaker achieves its function of converting electrical signals to sound waves by virtue of the interaction of two magnetic fields. Its operation being the reverse of that of the moving coil microphone, in fact, in many small internal communications systems the one unit is used as both microphone and loudspeaker alternatively.

7.2 Moving Coil Permanent Magnet Loudspeaker Construction and Operation. The construction of a moving coil loudspeaker is shown in Fig. 12. Instead of fitting a permanent magnet in the centre, as shown in Fig. 12a an alternate arrangement is to use a "ring" magnet, as shown in Fig. 12b. There is no difference in the operation of these two types.

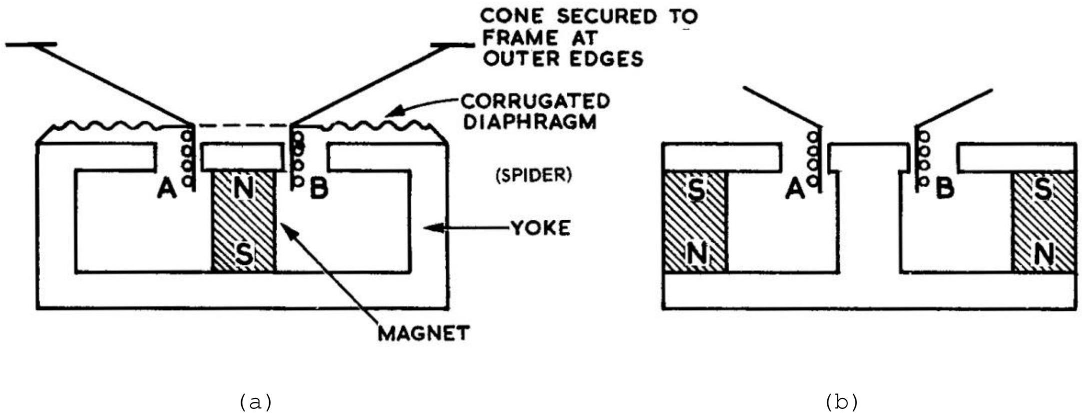



FIG. 12. MOVING COIL PERMAG LOUDSPEAKER CONSTRUCTION.

In each case a permanent magnet field is concentrated across the circular airgap. The moving coil, wound on its former, which in turn is fixed to the base of the cone is situated in this airgap. A flexible diaphragm (or spider) locates the coil accurately and allows movement only along the gap. When current flows through the moving coil such that it is upwards through the paper in coil side A (Fig. 12) the conductors (and hence the former and cone) are moved away towards the top of the page (Faraday's Right hand Electron rule for Motors). Similarly when the direction of voice coil current is reversed the movement of the speaker cone is reversed. Thus an alternating current applied to the voice coil will cause the cone to move in and out, producing compressions and rarefactions of the air in front of the cone, and this results in the production of sound waves. The impedance of the moving coil loudspeaker is low and an output transformer is used to match the output of the amplifier to the coil of the loudspeaker.

8. AERIALS.

8.1 The purpose of a transmitting aerial is to radiate into space, in the desired direction or directions, as much of the energy it receives from the radio transmitter as possible, as shown in para 2.2, or, in the case of receiving aerials, to collect as much of the desired energy as possible, and deliver it to a radio receiver.

8.2 The simple aerial is a straight wire, and, ideally should be half a wavelength long, and since the wire will have capacitance to earth and inductance, these constants tend to "tune" the aerial, and are used in the design of the aerial. A single vertical wire will radiate in all directions, and sometimes this effect is modified in the design to give "directivity" to the signal. This is important in communications as it helps to concentrate the energy radiated in the direction required and also reduces interference by other signals.

8.3 Types of Aerials. The vertical type of aerial is shown in Fig. 13. This type is seen at most M.F. broadcast transmitters where the mast acts as the radiator, being insulated from the ground. The guy wires supporting the mast are also insulated. The height of the mast is related to the wavelength to be transmitted.

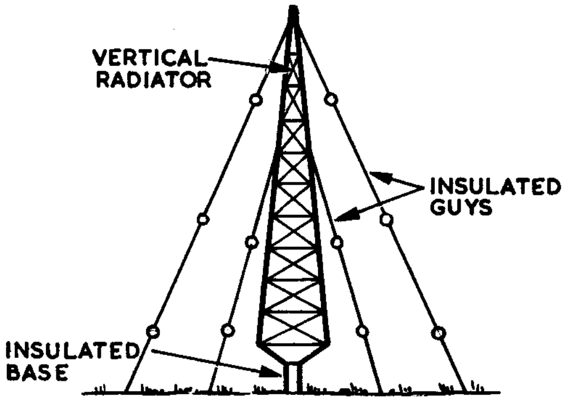
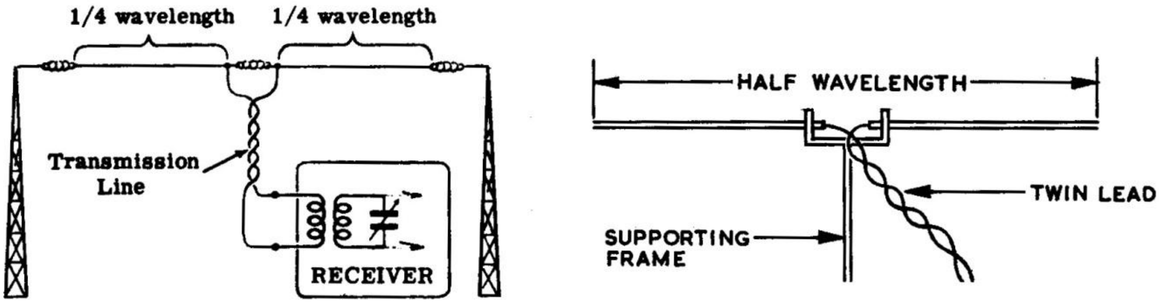



FIG. 13. VERTICAL MAST USED AS A RADIATOR.

The dipole type is shown in Figs. 14a and 14b, and consists of a wire suspended horizontally, and divide at the centre.

The transmission line consists of a pair of wires which are connected one to each half of the aerial at the centre.

Very high frequency aerials, being short in physical length, use light metal tubes in place of the wires and are supported by a single mast (Fig. 14b).




(a) Wire Type.

(b) Bar Type.

FIG. 14. DIPOLE AERIALS.

8.4 For best results aerials such as the dipole types should be high above the ground. In the case of transmitting aerials the nature of the surrounding country and even the type of soil affects the distance the transmitting aerials cover.

8.5 Receiving Aerials should be in the same plane as that of the transmitter whose signal is desired, e.g. horizontal plane or vertical plane.

Horizontal aerials such as the dipole type also should be parallel to the transmitting aerial.

Where reception conditions are good, and receivers sensitive, the efficiency of the aerial is not particularly important, but where fading, interference etc., are experienced, the aerial efficiency becomes a large factor in the good reception of radio signals.

8.6 It will be seen that to produce electromagnetic radiation a single wire separated from other conductors is used, whereas, to prevent radiation, as in a transmission line, two conductors are placed close together, where the charges on the one tend to cancel those of the other.

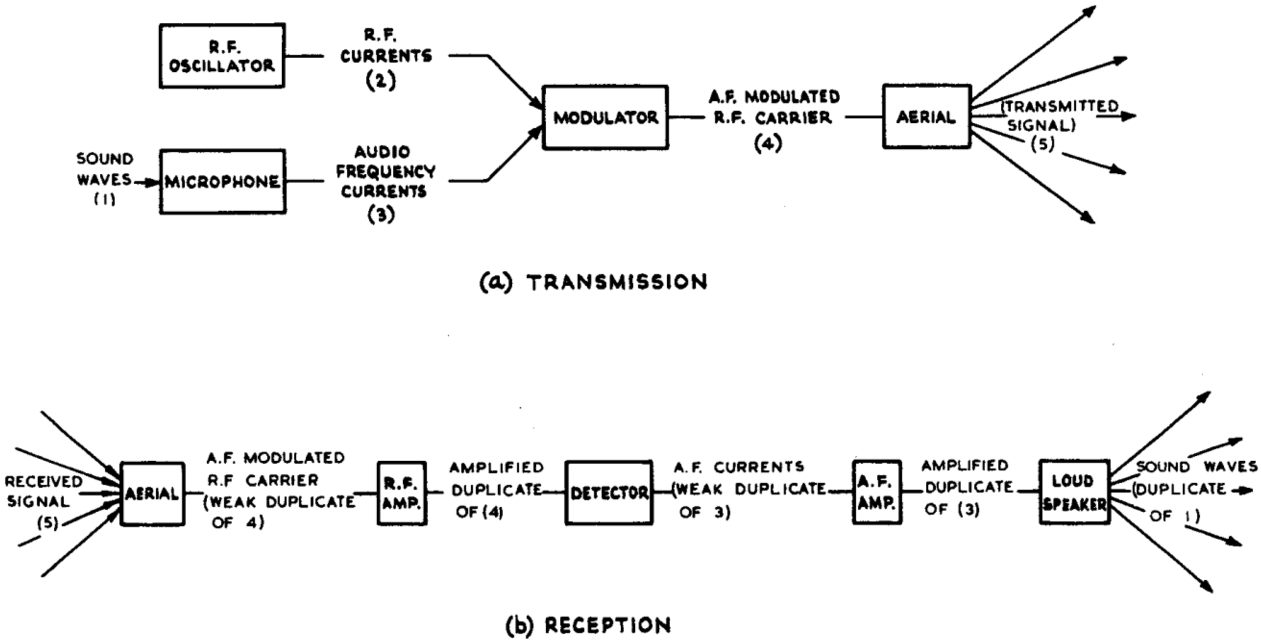



FIG. 15. BLOCK DIAGRAM OF TRANSMISSION & RECEPTION OF RADIO SIGNALS.

9. SUMMARY.

9.1 Fig. 15 summarises the whole process of Transmission and Reception. The sound waves impressed on the microphone are used to modulate an R.F. carrier, and the modulated R.F. waves are impressed on a receiving aerial. The required one is selected from among those received, amplified, demodulated (or detected), further amplified, and applied to a loud speaker which produces sound waves which are a reasonable duplicate of those originally impressed on the microphone.

END.