CHAPTER 8

WAVE MOTION AND THE THEORY OF MODULATION

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SECTION 1 : INTRODUCTION TO ELECTROMAGNETIC WAVES

(i) Wave motion (ii) Electromagnetic spectrum (iii) Wave propagation.

(i) Wave motion

Before considering the various methods of radio reception, it is desirable to have an understanding of the nature of radio waves and of how they are used to transmit intelligence.

The theory of electromagnetic radiation (Refs. 1, 2, 3) is essentially a mathematical one and any attempt to reduce the theory to non-mathematical terms requires certain assumptions to be made which are not strictly true.

It should be noted that sound waves in air, waves in water and radio waves are propagated in entirely different ways.

In the case of sound, the waves are called " longitudinal " and consist of alternate compressions and expansions of air.

The layers of air as shown in Fig. 8.1 do not move steadily forward with the wave but move to and fro through a limited path in the direction of motion of the wave.

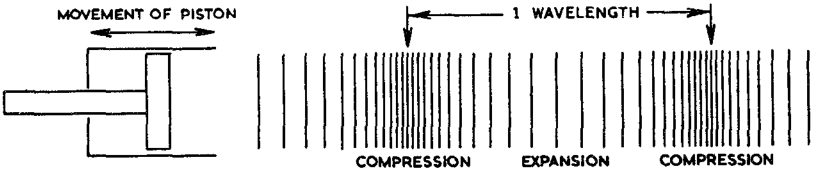

FIG. 8.1

Fig. 8.1. *Representation of a sound wave in air.*

Referring to Fig. 8.2 and assuming this to be a representation of a water wave, it will be seen that as the wave progresses, a particle (such as a cork) as shown in the figure, moves in a vertical direction which is at right angles to the direction of motion of the wave. This form of wave motion is known as " transverse."

The distance between two successive crests is a measure of the length of the wave, i.e. the wavelength, and the number of complete waves (or cycles) passing any point in one second denotes the frequency in cycles per second.

The medium in which the wave is transmitted determines the speed or velocity of propagation. In the case of sound waves in air, the velocity is approximately 3.4×10^2 metres per second. The velocity of sound in some common media is given in Chapter 20 Sect. 8(iii).

Electromagnetic waves are also transverse. However, radiated electromagnetic energy consists of two component fields, respectively magnetic and electric, both in phase, existing at right angles to each other and to the direction of motion of the wave. In contrast to sound waves in air, electromagnetic waves in free space have a velocity of 3×10^8 metres per second.

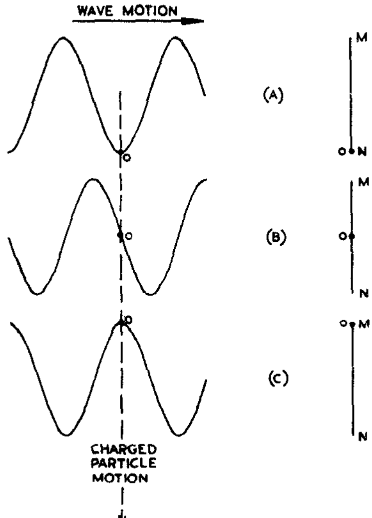

FIG. 8.2

Fig. 8.2. *Representation of a water wave.*

(ii) Electromagnetic frequency spectrum (Ref. 4)

Type of radiation	Wavelength
Hertzian Waves (used for radio communication)	30 000 M – 0.01 cm
Infra Red	0.04 cm – 0.000 07 cm
Visible Light*	7000 A° – 4000 A°
Ultra Violet	4000 A° – 120 A°
X-Rays	120 A° – 0.06 A°
Gamma Rays	1.4 A° – 0.01 A°
Cosmic Radiation	about 0.0001 A°

1 Angstrom unit A° = 1×10^{-8}cm.

(iii) Wave propagation

Assuming a simple non-directional aerial, the electromagnetic waves are radiated in straight lines at all angles. That portion of the radiation at a large angle to the horizontal is called the " sky " wave. Depending upon the frequency and the angle of radiation, this wave may be reflected by an ionized layer in the earth's upper atmosphere and thus return to the earth at a considerable distance from its origin. By making use of this phenomenon, long distance short wave communication can be accomplished.

In recent years much work has been done in forecasting frequencies that will give best results for communication between any two points at any given time. These predictions, based on a study of the ionosphere, are published regularly in different parts of the world and are an exceedingly valuable aid to reliable communication services. A handbook has been published explaining the basis of the predictions and the methods used in forecasting (Refs. 5, 6, 7, 8, 9, 10). This subject is covered more comprehensively in Chapter 22, Sect. 6.

For the effect of the ionosphere on the reception of radio signals see Chapter 22, Sect. 6.

*For further details, see Chapter 38 Section 13 and Fig. 38.8.

SECTION 2 : TRANSMISSION OF INTELLIGENCE

(i) Introduction (ii) Radio telegraphy (iii) Radio telephony.

(i) Introduction

There are several methods of conveying information using the radiated waves. By switching on and off the transmitter in accordance with a prearranged code, audible sounds will be heard in a suitable receiver. This is known as radio telegraphy. Alternatively the intelligence in the form of speech or music can be superimposed on the transmitted radio frequency by a process of " modulation." This is referred to as radio telephony. There are four major types of this latter system of transmission, known as amplitude, frequency, phase and pulse modulation (Refs. 17, 18, 33).

(ii) Radio telegraphy

This is used primarily for communication purposes over long distances. By means of automatic transmission and reception it is possible to convey messages at a rapid rate half way round the world. Such circuits are less susceptible to interference and mutilation of the message text than corresponding circuits using radio telephony. A radio telegraph (C.W.) transmitter usually consists of a crystal oscillator followed by several r-f power amplifier stages. An automatic or manual switch, operating in a power circuit supplying current to one of the r-f amplifier electrodes, serves to turn the r-f power on or off as required by the coded messages (Ref. 11).

(iii) Radiotelephony

(A) Amplitude Modulation (A-M)

This is commonly used in local medium frequency and long distance shortwave broadcast transmitters. The amplitude of the r-f radiated wave (the carrier) is varied at an audio frequency rate according to similar variations of the intelligence which it is required to transmit. This is usually accomplished by varying the plate voltage of a r-f amplifier by the audio signal. The r-f amplifier may be in the final transmitter stage, in which case a large audio power is required for complete modulation—50% of the modulated r-f stage plate input power. This is called " high-level " modulation. As an alternative, modulation can be employed at an early stage in the transmitter, and linear r-f amplifiers used to raise the power level to that required. Much smaller powers are necessary for this " low-level " modulation system, but the Class B linear r-f amplifiers are less efficient than the Class C counterparts used in the " high-level " method of modulation. Both systems are used extensively, but most high power transmitters employ " high-level " modulation. With amplitude modulation, the power output of the transmitter varies, but the phase and frequency of the carrier remain unaffected (Refs. 12, 13).

(B) Frequency Modulation (F-M)

This is now coming into its own in the mobile equipment field. While it is being used to supplement medium frequency A-M broadcasting, F-M may also be used for the audio channel of television (TV) transmitters. In this system the carrier frequency is varied at audio frequency above and below the unmodulated carrier frequency. This can be achieved by using a reactance valve to alter the frequency of the transmitter master oscillator, the reactance valve being controlled by the audio frequency signal.

In contrast to A-M, the power output from an F-M transmitter does not change, but the frequency of the carrier varies, the deviation in frequency being proportional to the amplitude of the modulating signal (Refs. 14, 15, 16, 24, 32, 33).

(C) Phase Modulation

In this system the audio signal is used to shift the phase of the carrier, the change in phase angle being proportional to the instantaneous amplitude of the modulating signal. The carrier frequency also changes but the power output remains constant.

P-M is not yet in general use and will therefore not be considered further (Refs. 19, 20, 21, 22, 23, 24, 31, 33).

(D) Pulse Modulation

The numerous variations of this system are finding their chief application in the very high frequency communication field. Radar and related distance measuring equipments rely largely on pulse modulation for their successful operation. This modulation system is outside the scope of the Handbook (Refs. 25, 26, 27, 28, 29, 30, 33).

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