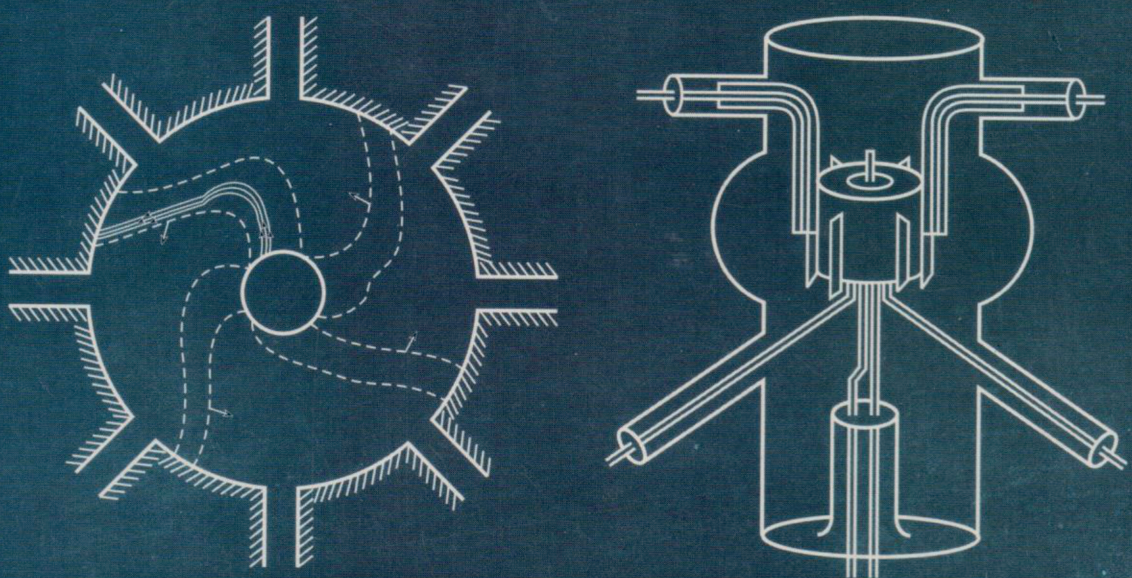
RADIO ENGINEERING

Principles of Communication Systems

G.K. MITHAL



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RADIO ENGINEERING

(Including Radar and Television)
(Principles of Communication Systems)

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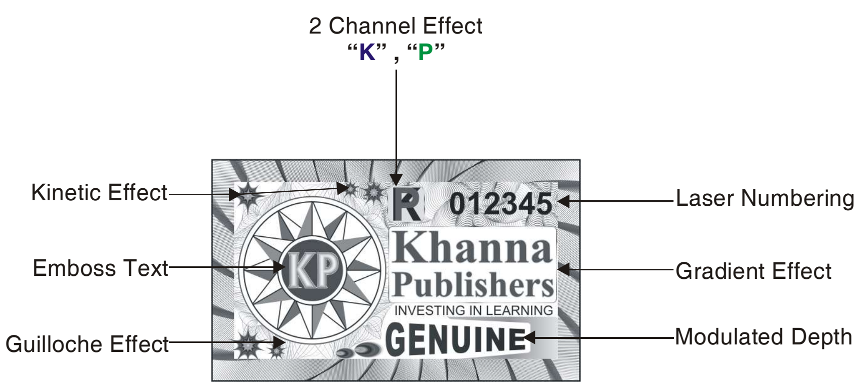

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Preface

This book aims at giving a deep insight to the vast and expanding field of communications electronics. It presents the information for students of communications engineering about the basic processes, circuit configurations and philosophies which underlie communications systems.

A glance at the contents reveals that the book is logically subdivided into a number of chapters. The first three chapters introduce the principles of communications, noise and modulation which are later used throughout the remaining part of the book. The next four chapters deal with various types of modulation methods — amplitude, frequency and radio transmitters. Chapter 8 deals with transmitter power supplies and tube cooling while next two chapters describe in detail A.M. and F.M. receivers.

Next part highlights principles of antennas & propagation and ultra high frequency takes and oscillators. Television systems give details beginning from principles, broadcast studio, transmitters receivers and colour television receivers.

Finally the basics of modern communications are dealt under principles of radar, satellite, pulse and optical communication systems.

The book finally terminates in multi-choice self-testing questions, numerical and review questions given at the end of each chapter. The author feels that these questions can go a long way in helping readers who are preparing for the UPSC engineering services examination or any other such competition.

This book has been written after consulting vast literature in the field of communications engineering. The author acknowledges with due courtesy the sources consulted in the preparation of this book.

The author is in debited to most cooperative attitude of Shri Romesh Chander Khanna during the course of preparation of this book.

Finally, the author will be highly obliged for any valuable suggestions and positive criticisms from the readers in order to improve the quality and standard of this book with an object to serve the student community in a better way.

—G.K. Mithal

Contents

1

Principles of Communication System

1.1. General Communication System

With the advancement of society, there arose the desire of individuals to communicate with their relatives, friends or associates at distant points on the globe. The science of *communication* involving long distances is called *telecommunication* (the word *tele* standing for long distance). Technically speaking, the term *communication* signifies transmission, reception and processing of information by electric means. The earliest communication system namely line telegraphy originated in eighteen forties. Line telephony came a few decades later while radio communication became possible in the beginning of twentieth century on invention of triode valve. Radio communication was greatly improved during World War II. In subsequent years it became more widely used through the invention of transistor, integrated circuits and other semiconductor devices. In recent years, communication has become more widespread with the use of satellites and fibre optics. Today there is an increasing emphasis on the use of computers in communication.

1.2. Basic Constituents of Communication System

Modern communication system consists of the following three :

(*i*) Collation (sorting), processing and storage of information.
(*ii*) Actual transmission of information involving further processing and also reducing noise.
(*iii*) Reception of information involving such processing steps as decoding, storage and interpretation.

Typical examples of communication system are : line telephony and telegraphy, radio telephony and telegraphy, radio broadcasting, point-to-point and mobile communication (civil or military), computer communication, radar, television broadcasting, radio telemetry, radio aids to navigation, radio aids to aircraft landing etc. Some of these are treated in subsequent chapters.

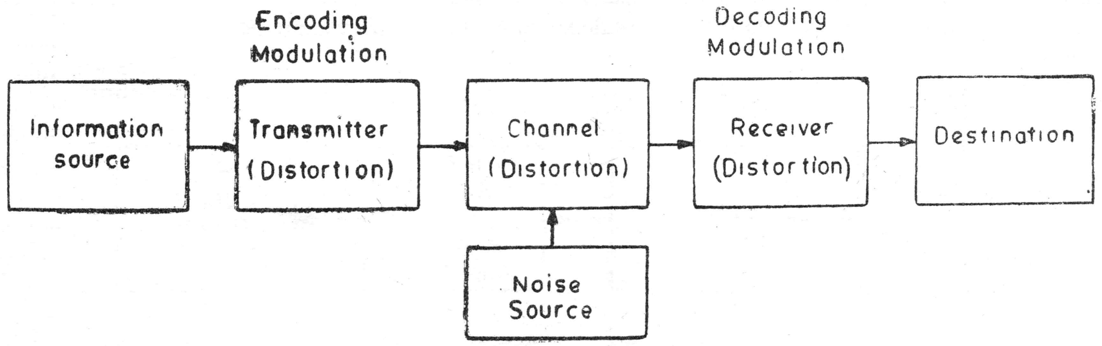

Fig. 1.1. Block diagram of a general communication system.

Fig. 1.1 gives the block diagram of a general communication system. In this context, it is necessary to define and discuss a few important terms such as information, message and signal, channel, noise and distortion, modulation and demodulation, coding and decoding etc.

1.2.1. Information Source. Any communication system serves to communicate a message or information. This message originates in the information source. In general, there may be several messages in the form of words, groups of words, code symbols etc. Out of these messages, only the desired message is selected and conveyed. This applies more rigorously to telegraphy rather than entertainment broadcasting. It may be shown, however, that it applies to all forms of communications. The set of messages consists of various messages distinguishable from one another. These messages may be in the form of words, groups of words, code symbols etc.

Out of the total message, usually only a part is conveyed. This *part of the message which is conveyed* is called *information*. The amount of information contained in any message is expressed in *bits* or *dits* and depends upon the number of choices that must be made. Greater the total number of possible selections, larger is the amount of information conveyed. The meaning (or lack of meaning) or the information is immaterial from this consideration ; the quantity of information alone is important. However, no real information is conveyed by a redundant (or totally predictable) message. Redundancy is normally considered wasteful. However, it is useful in entertainment, in teaching etc. Further it helps a message in remaining intelligible under difficult and noisy conditions.

1.2.2. The Transmitter. Fig. 1.2 gives the block diagram of a high level amplitude modulated broadcast transmitter. The message from the information source may or may not be electrical in nature. In the latter case, it is first converted into corresponding electrical form with the help of a suitable *transducer*. In the case of radio broadcast transmitter, a microphone converts the information in the form of sound waves into corresponding electrical signal. Next this electrical signal is processed to restrict its range of audio frequencies (5 kHz in amplitude modulation radio broadcast) and is often either *compressed* or *limited* in amplitude range. In wire telephony, no real processing is needed. However, in long distance radio communication or broadcast, signal amplification is necessary before modulation. The signal or message in a radio transmitter is amplified in several stages of small signal amplifiers (voltage amplifiers) and large signal amplifiers (power amplifiers) and may be possibly encoded, to make it suitable for transmission and subsequent reception. Finally the signal or information amplitude modulates the *carrier* (high frequency sine wave) as shown in Fig. 1.2. The actual modulation method differs from system to system. Thus the modulation may be done at high carrier level or low carrier level. Fig. 1.2 illustrates the high level modulation system. In this case, the stable carrier voltage of desired frequency is generated in a so called *master oscillator* which may be a crystal oscillator. This stage is followed by a *buffer amplifier* to isolate master oscillator from the influence of modulation done at a later stage. The buffer amplifier is followed by a chain of R.F. voltage and power amplifiers and finally fed to the R.F. output power amplifier where the carrier gets amplitude modulated. Fig. 1.2 shows an amplitude modulation transmitter. However, a system may use *amplitude modulation, frequency modulation, phase modulation* or any variation or combination of these depending on the actual requirement.

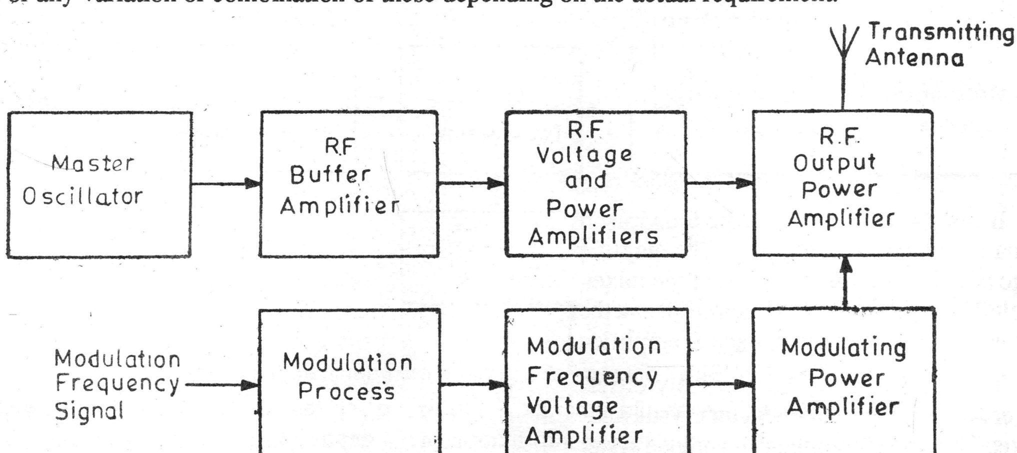

Fig. 1.2. Block diagram of high level broadcast transmitter.

1.2.3. The Channel and the Noise Source. With reference to the block diagram of Fig 1.1, the term channel implies the medium through which the message travels from the transmitter to the receiver. The acoustic channel, *i.e.* sound waves as produced by say shouting, cannot be used for long distance communication. Similarly conventional visual channel also cannot be used. Of course, modified visual channel namely *laser* is being used for communication. In this context, the term channel is, therefore, restricted to radio, wire and fibre optic channels. It may, however, be noted that the term channel is also often used to indicate the frequency range allocated to a given service or transmission. Thus a television channel occupies a bandwidth of 7 MHz while an amplitude modulation broadcast channel occupies a bandwidth of 10 kHz.

During the process of transmission and reception, the signal gets deteriorated due to (*i*) distortion in the system and (*ii*) noise introduced in the system. The noise so introduced is an *unwanted energy,* usually of a *random character* and may be caused by various sources. The noise gets superimposed on the signal. With severe noise, the signal-to-noise power ratio becomes so poor that the signal becomes unintelligible and hence useless. In Fig 1.1 giving the block diagram of a general communication system, only one source of noise is indicated, the one associated with the channel. This is done to simplify the bolck diagram. In fact, noise may get added to the signal at any point in the communication system. However, the noise has its greatest damaging effect when the signal is weakest. This implies that the noise in the channel or at the input to the receiver is most effective in deteriorating the signal-to-noise ratio. This aspect of noise is considered in chapter 2.

1.2.4. The Receiver. Receivers in communication systems are of widely different varieties depending on the system requirements such as modulation system used, operating frequency, range of the system, type of display etc. However, most of the radio receivers are of the superheterodyne type, the block diagram of which is shown in Fig. 1.3.

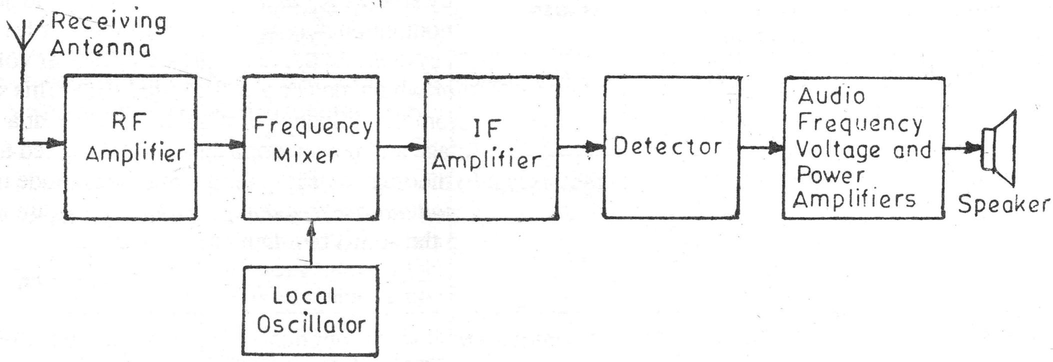

Fig. 1.3. Block diagram of superheterodyne receiver.

In a simple superheterodyne broadcast receiver shown in Fig. 1.3, the voltage induced in the receiving antenna is fed to R.F. amplifier. The amplified carrier voltage from R.F. amplifier and the local oscillator voltage are heterodyned or mixed in the mixer stage resulting in intermediate frequency (I.F.) voltage. This I.F. voltage is amplified in I.F. amplifier and then fed to the dectector, at the output of which we get the original signal voltage. This audio voltage is amplified and fed to the loud speaker.

The receivers may be of widely different varieties. Thus the simplest radio receiver is the crystal receiver having one semiconductor crystal and headphones while the most complex receiver is the microwave radar receiver using complicated antenna system, visual display system requiring sweep circuits, high voltage circuits and synchronizing circuits. Further the destination and the purpose of the receiver influences the receiver construction. Thus depending on the system, the output of the receiver may be fed to a loud speaker, radar display system, television picture tube, punched card, video display unit, teletype-writer, pen recorder or a computer. In each such system, the receiver design is different. It is essential, however, that perfect agreement must exist between transmitter and receiver concerning the modulation methods, coding methods and also the timing or synchronization in certain systems.

1.3. Need for Using High Carrier Frequency

On the carrier frequency depends several factors such as the radiation efficiency, size of antenna, ease of selection of radio signal in the receiver, range of communication etc.

The transmitting antenna radiates efficiently, *i.e.* radiates large fraction of the total power fed to it if its dimensions are comparable with the carrier wavelength. The size of the antenna conductor is, therefore, inversely proportional to the carrier frequency. Higher the carrier frequency, the smaller and hence economical is the antenna structure needed. From this consideration, higher carrier frequencies are preferred.

Further, higher the carrier frequency, the better is the selection of signal in the receiver. From this consideration also higher carrier frequencies are preferred.

1.4. Classification of RF Spectrum

Carriers of wide range of frequencies are used in radio communication systems for different types of services. Table 1.1 gives classification of electromagnetic spectrum used for radio communication. Table also gives the propagation characteristics and the type of services involved.

Table 1.1. Standard Classification Spectrum of Frequency used in Radio Communication

Carrier Frequency	*Free space Wave-length (metres)*	*Class*	*Propagation Characteristic*	*Service*
10—30 kHz	$3 \times 10^4 - 10^4$	Very low Frequency (VLF)	At all times of day and year. Attenuation is low.	Long distance point to point communication.
30—300 kHz	$10^4 - 10^3$	Low Frequency (LF)	During day time absorption exceeds that with VLF. During night time, propagation is similar to VLF.	Long distance point to point communication ; Navigation.
300—3000 kHz	$10^3 - 10^2$	Medium Frequency (MF)	Day time attenuation is high ; Night time attenuation is low (ionospheric propagation).	Broadcasting ; Ship to shore communication.
3—30 MHz	$10^2 - 10$	High Frequency (HF)	Ionospheric propagation.	National and International broadcast ; point-to-point telephone and telegraph communication; Aviation.
30—300 MHz	$10 - 1$	Very High Frequency (VHF)	Tropospheric propagation (typical range equals line of sight).	Radar ; Television ; F.M. Broadcast ; Short distance communication.
300—3000 MHz	$1 - 0.1$	Ultra High Frequency (UHF)	do	Fascimile ; Television Relay ; Air navigation.
3000—30,000 MHz	$0.1 - 0.01$	Super High Frequency (SHF)	do	Radar navigation ; Radio Relay.

1.5. Modulation

Definition. The process of modulation implies varying some characteristic of a high frequency sinusoidal voltage called the *carrier voltage* in accordance with the instantaneous value of another voltage called the modulating voltage. The carrier voltage v_c may be represented by the equation,

$$v_c = V_c \cos(\omega_c t + \phi) \qquad \ldots(1.1)$$

where v_c is the instantaneous value of carrier voltage

V_c is the amplitude of the carrier voltage

ω_c is the angular frequency of the carrier voltage in radians/second

ϕ is the phase angle relative to some reference.

We may now vary any of the three quantities namely amplitude, frequency and phase angle, in accordance with the modulating voltage. The resulting modulations are referred to as the amplitude modulation, frequency modulation and phase modulation respectively.

Need for modulation. The modulating signal in AM radio broadcast extends over frequency range 0 to 5 kHz. This signal amplitude modulates the high frequency carrier. As an alternative to the use of a modulated carrier for transmission of messages over long distances, let us explore the possibility of transmitting the modulating signal itself. The major drawback is that the efficiencies of radiation of energy from the transmitting antenna and reception by receiving antenna at such low frequencies (upto 5 kHz) are extremely low for usual heights of these antennas. For efficient radiation and reception, the antennas should have heights comparable to quarter wavelength of the frequency used. This is 75 metres at 1 MHz, in the broadcast band and at 5 kHz it gets increased to 15,000 metres. A vertical antenna of such a height is unthinkable.

Another reason for not radiating modulation signal itself is that frequency range of audio signal is from 20 Hz to 20 kHz. If there are several stations operating over this same frequency range, the programmes of different stations will get mixed up.

Thus in order to keep the various signals separate, it is necessary to translate or shift them to different portions of the frequency spectrum of electromagnetic waves. Each station is allocated a band of frequency. This also overcomes the drawback of poor radiation efficiency at low frequency. Thus in amplitude modulation broadcast, maximum signal frequency permitted is 5 kHz. Ampltude modulation results in bandwidth requirement of 10 kHz (accommodating the lower and the upper sidebands). Hence broadcast channels may be placed adjacent to each other, each channel occupying 10 kHz bandwidth. Thus stations may be allotted bandwidths say from 990 to 1000 kHz, 1000 to 1010 kHz and so on. In the radio receiver, a tuned circuit at the input selects the desired station and rejects all other stations. The tuning of such a tuned circuit is usually kept variable and is done by a tuning control. Thus the receiver can easily select any desired transmission having carrier frequency within a predetermined range such as Medium Wave Band, Short Wave Band or Very High Frequency (VHF) Band.

We thus see that the separation of signals in the frequency spectrum has removed a number of difficulities encountered in the absence of modulation. But the fact remains that an unmodulated carrier by itself cannot be used to transmit intelligence. It contains no information. In a continuous wave modulation system, one of the parameters namely amplitude or frequency is varied in accordance with the signal. It is this variation of carrier which contains the intelligence.

1.6. Bandwidth Requirement

The frequency bandwidth required for a given transmission depends on the *maximum modulation frequency* and the *nature of modulation*. The modulating voltage is hardly ever a single sinusoidal voltage. In a practical system it consists of several sinusoidal voltages having frequencies extending over a frequency band. Thus electrical signal produced by a speech or musical instrument may extend over the audio frequency range of 20 Hz to 20 kHz. This is rather a wastefully large frequency bandwidth. Hence in practice, it is pruned to range 0-3 kHz for telegraph, 0-5 kHz for AM broadcast and 0-15 kHz for FM (Frequency modulation) broadcast. Radio telephony or carrier current telephony uses a single sideband working using amplitude modulation. Hence bandwidth requirement per channel is only 3 kHz. AM broadcast uses double-sidedband system thus requiring per channel bandwidth of $2 \times 5 = 10$ kHz. Frequency modulation produces sidebands extending theoretically upto infinity but the so called *significant sidebands* extend usually only upto fifth order sideband. Hence with maximum modulating frequency of 15 kHz, the total bandwidth requirement per FM broadcast channel is $2 \times 5 \times 15 = 150$ kHz.

We have seen that the bandwidth of the modulated transmission depends upon the bandwidth of the modulating signal itself. In case the modulating signal consists of sinusoidal signals, the matter is rather simple; the bandwidth occupied simply equals the frequency range between the lowest and the highest sinewave signals. However if the modulating signals are not sinusoidal, the matter gets slightly complicated. The frequency spectrum occupied by such a non-sinusoidal wave is then determined making use of Fourier analysis.

1.6.1. Frequency Spectra of Non-sinusoidal Waves. Any non-sinusoidal single valued periodic wave such as square wave, triangular wave or saw-tooth wave may be broken down or resolved through process of *Fourier analysis* into a series of cosine and /or sine waves consisting of a fundamental frequency (equal to the repetition rate of the non-sinusoidal waveform) and harmonics thereof. There are an infinite number of such harmonics. Thus a non-sinusoidal periodic wave of repetition rate 100 times per second will consist of terms of (*i*) fundamental frequency 100 Hz and (*ii*) harmonics at 200 Hz, 300 Hz and so on. No other frequencies will be present. In certain cases, however, only even harmonics or only odd harmonics may be present depending on the waveform of non-snuisoidal wave. Although the harmonics theoretically extend upto infinity, but in general, higher the harmonic, lower is its relative amplitude. Hence in the calculation of effective bandwidth of the non-sinusoidal wave, the higher harmonics beyond say 7th or 8th having very small amplitudes are usually ignored. We thus see that for such non-sinusoidal periodic modulation wave bandwidth requirement is considerably greater than that for a sine wave of the same repetition frequency.

Formulas for frequently encountered non-sinusoidal waves are given below. Thus if the non-sinusoidal wave has amplitude A and repetition rate $\omega / 2\pi$ per second, then it may be represented as follows :

(*i*) *Square Wave*

$$v = \frac{4A}{\pi}\left[\cos \omega t - \frac{1}{3}\cos 3\,\omega t + \frac{1}{5}\cos 5\,\omega t - \frac{1}{7}\cos 7\,\omega t + \ldots\ldots\right] \qquad \ldots(1.2)$$

(*ii*) *Triangular Wave*

$$v = \frac{4A}{\pi^2}\left[\cos \omega t + \frac{1}{9}\cos 3\,\omega t + \frac{1}{25}\cos 5\,\omega t + \ldots\ldots\right] \qquad \ldots(1.3)$$

(*iii*) *Sawtooth Wave*

$$v = \frac{2A}{\pi}\left[\sin \omega t - \frac{1}{2}\sin 2\,\omega t + \frac{1}{3}\sin 3\omega t - \frac{1}{4}\sin 4\,\omega t + \ldots\ldots\right] \qquad \ldots(1.4)$$

The presence of component sine waves in correct proportions as given by Fourier analysis may be verified by the following two methods :

I. *By graphical synthesis.* Thus we draw the appropriate sine wave components taken from the formula derived by Fourier analysis and add up these components. We then arrive back at the given non-sinusoidal periodic wave. This method has the advantage that it makes possible for us to see the effect on the overall waveform of the absence of some of the constituent sine waves say the higher harmonics.

II. *By use of wave analyser.* Wave analyser is basically a high gain tunable amplifier with a narrow pass band. Thus we may tune to each component sine wave in turn and measure its amplitude.

SUMMARY

Basic constituents of a communication system

(*i*) Collation, processing and storage of information.
(*ii*) Actual transmission of information.
(*iii*) Reception of information involving decoding, storage and interpretation.

Transmitter. It consists of :

(*i*) a transducer to convert the information into electrical signal
(*ii*) modulation processing stage (usually a volume compressor or limiter)
(*iii*) modulation frequency voltage and power amplifiers
(*iv*) master oscillator
(*v*) RF buffer amplifier to isolate the master oscillator
(*vi*) RF voltage and power amplifiers
(*vii*) RF output power amplifier constituting the modulated amplifier, and
(*viii*) the transmitting antenna.

The Channel. It signifies the medium through which the message travels from the transmitter to the receiver.

The Receiver. A super heterodyne radio receiver consists of :

(*i*) an RF amplifier to amplify the weak RF signal
(*ii*) local oscillator
(*iii*) frequency mixer to mix or heterodyne the incoming RF signal with the local oscillator output thereby producing the intermediate frequency (IF) signal
(*iv*) the IF amplifier
(*v*) detector to reproduce the original information (audio signal)
(*vi*) audio frequency voltage and power amplifiers, and
(*vii*) speaker to reproduce the original sound signal.

Need for high carrier frequency. The transmitting antenna radiates efficiently if its size approximates $\lambda / 4$. Hence higher the frequency, smaller the antenna structure needed.

Classification of R.F. spectrum. Spectrum is classified as :

Very Low Frequency	:	10—30 kHz
Low Frequency (LF)	:	30—300 kHz
Medium Frequency (MF)	:	300 kHz—3 MHz
High Frequency (HF)	:	3—30 MHz
Very High Frequency (VHF)	:	30—300 MHz
Ultra High Frequency (UHF)	:	300—3000 MHz
Super High Frequency (SHF)	:	3000—30,000 MHz

Modulation. Modulation consists in varying some characteristic (usually amplitude, frequency or phase angle) of a high frequency sinusoidal voltage, called the carrier voltage, in accordance with the instantaneous value of another voltage, called the modulating voltage. Three principal types of modulation are : amplitude modulation, frequency modulation and phase modulation.

Need for Modulation. The signals are shifted to different parts in higher part of the frequency spectrum thereby disallowing mixing up of programmes and permitting efficient radiation of energy.

Bandwidth Requirement. In AM broadcast, the bandwidth required equals twice the maximum modulation frequency. In amplitude modulation radio telephony, single sideband system is used and hence the bandwidth requirement equals the maximum modulation frequency. In FM broadcast, the significant sidebands usually extend upto fifth order. Hence with maximum modulation frequency of 15 kHz, the bandwidth requirement equals $2 \times 5 \times 15 = 150$ kHz.

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REVIEW QUESTIONS

1.1. What are the basic constituents of a communication system ?

1.2. Draw the block diagram of a general communication system and explain briefly the function of each stage.

1.3. Distinguish between the terms "message" and "information".

1.4. What is meant by the term "channel" as applied to a communication system ?

1.5. Draw the block diagram of a typical high-level broadcast A.M. transmitter. Explain briefly the function of each stage.

1.6. What is meant by the term "noise" ? At what stage in the communication does the noise most severely affect the signal?

1.7. Draw the block diagram of a typical A.M. superheterodyne receiver and explain the function of each stage.

1.8. Why is a high carrier frequency needed in a communication system ?

1.9. What is meant by the term modulation ? What are the principal types of modulation used in communication systems ?

1.10. What is the need for modulation in a communication system ?

1.11. On what factors does the bandwidth requirement of a communication system depend ?

1.12. Describe the methods of verifying the presence of component sine waves in correct proportions in the Fourier series representing a non-sinusidal periodic wave.

OBJECTIVE TYPE QUESTIONS

Pick up the correct choice :

1.1. The highest modulation frequency typically used in AM, broadcast is :
(*a*) 5 kHz (*b*) 10 kHz
(*c*) 15 kHz (*d*) 1 MHz.

1.2. The channel bandwidth of television broadcast is :
(*a*) 4.25 MHz (*b*) 5 MHz
(*c*) 7 MHz (*d*) 10 MHz.

1.3. The highest modulation frequency typically used in FM broadcast is :
(*a*) 5 kHz (*b*) 10 kHz
(*c*) 15 kHz (*d*) 25 kHz.

1.4. The bandwidth requirement of a telephone channel is :
(*a*) 3 kHz (*b*) 5 kHz
(*c*) 15 kHz (*d*) 25 kHz.

1.5. The high frequency range extends from :
(*a*) 300—3000 kHz (*b*) 3—30 MHz
(*c*) 30—300 MHz (*d*) 300—3000 MHz.

1.6. The very high frequency (VHF) range extends from :
(*a*) 3—30 MHz (*b*) 30—300 MHz
(*c*) 300—3000 MHz (*d*) 3000—30,000 MHz.

1.7. The ultra high frequency (UHF) range extends from :
(*a*) 3—30 MHz (*b*) 30—300 MHz
(*c*) 300—3000 MHz (*d*) 3000—30,000 MHz.

1.8. Periodic square wave consists of the following Fourier terms :
(*a*) fundamental plus sine odd harmonics
(*b*) fundamental plus cosine odd harmonics
(*c*) fundamental plus cosine even harmonics
(*d*) consine odd and even harmonics.

1.9. Periodic triangular wave consists of the following Fourier terms :
(*a*) fundamental plus sine odd harmonics
(*b*) fundamental plus cosine odd harmonics
(*c*) fundamental plus sine even harmonics
(*d*) fundamental plus cosine even harmonics.

1.10. Periodic saw-tooth wave consists of the following Fourier terms :
(*a*) fundamental and sine wave even and odd harmonics
(*b*) fundamental and cosine wave even and odd harmonics
(*c*) fundamental plus cosine odd harmonics
(*d*) fundamental plus sine odd harmonics.

ANSWERS

1.1. (*a*)	1.2. (*c*)	1.3. (*c*)	1.4. (*a*)
1.5. (*b*)	1.6. (*b*)	1.7. (*c*)	1.8. (*b*)
1.9. (*b*)	1.10.(*a*)		

2

Noise

2.1. Introduction

With reference to an electrical system, noise may be defined as *any unwanted form of energy* which tends to interfere with proper reception and reproduction of wanted signal. Several disturbances of electrical nature results in noise in the output of the electrical system. Thus in an A.M. broadcast receiver, noise may cause hiss in the loudspeaker output. In a television receiver, noise may appear in the picture tube in the form of "snow" (in black and white TV receiver) or confetti, *i.e.* coloured snow (in colour TV receiver). In pulse communication system, noise may result in unwanted pulses or may cancel one or more wanted pulse thereby causing serious errors in reproduction. Similarly in Radar system, noise produces spiky pulses in the output reproduced on the indicator. Thus in any communication system, for a given transmitted power, noise limits the range of the system. It adversely affects the sensitivity of a receiver by placing a limit on the weakest signal that can be amplified. In several communication system such as Radar system, noise tends to impose a limit on the bandwidth of the system.

2.2. Classification of Noise

Noise may be put into following two categories :

(A) *External noises, i.e.* noise whose sources are external to the receiver or communication system.
(B) *Internal noises, i.e.* noises which get generated within the receiver or communication system.

External noises can not be easily treated quantitatively. Further at a given geographical location, the external noises are uncontrollable. Hence for reducing the adverse effect of external noise, the only choice left is to shift the system to another location having smaller external noise. It is for this reason that radio telescopes are always located away from industrial areas where various electrical processes produce large electrical noise. For the same reasons, satellite earth stations are located in noise free valleys. Internal noises, on the other hand, can be treated quantitatively and can also be reduced by proper receiver design. Since this noise is randomly distributed over the entire frequency spectrum, the noise present in a given bandwidth B is the same at any frequency in the frequency spectrum. Thus the random noise power is proportional to the bandwidth over which it is measured.

External noises may be classified into the following three types :

(i) Atmospheric noises
(ii) Extraterrestrial noises
(iii) Man-made noises or industrial noises.

Internal noise may be put into the following four categories :

(i) Thermal noise or white noise or Johnson noise
(ii) Shot noise
(iii) Transit time noise
(iv) Miscellaneous internal noises.

These are briefly treated below.

2.3. Atmospheric Noise

Atmospheric noise or static is caused by lightning discharges in thunderstorms and other natural electrical disturbances occurring in the atmosphere. These electrical impulses are random in nature. Hence the energy is spread over the complete frequency spectrum used for radio communication. Atmospheric noise accordingly consists of spurious radio signals with components spread over a wide frequency range. These spurious radio waves constituting the noise get propagated over the earth in the same fashion as the desired radio waves of the same frequency. Accordingly at a given receiving point, the receiving antenna picks up not only the signal but also the static from all the thunderstorms, local or remote.

The field strength of atmospheric noise varies approximately inversely with the frequency. Thus large atmospheric noise is generated in low and medium frequency (broadcast) bands while very little noise is generated in the VHF and UHF bands. Further VHF and UHF components of noise are limited to the line-of-sight (less than about 80 km) propagation. For these two reasons, the atmospheric noise becomes less severe at frequencies exceeding about 30 MHz.

Static from local atmospheric sources is usually more severe than that from distant sources but is less frequent. Static from distant sources varies in intensity according to the variations in propagation conditions. Hence during night time, atmospheric noise at both medium and high frequencies propagate through the ionosphere and hence noise level is high. However, during day time, medium waves travel using only surface wave propagation resulting in increased attenuation with distance.

2.4. Extraterrestrial Noise

There are numerous types of extraterrestrial noises or space noises depending on their sources. However, these may be put into following two-sub-groups :

(*i*) Solar noise (*ii*) Cosmic noise.

Solar Noise. This is the electrical noise eminating from the Sun. Under quiet conditions, there is a steady radiation of noise from the Sun. This results because sun is a large body at a very high temperature (exceeding 6000 deg C on the surface), and radiates electrical energy in the form of noise over a very wide frequency spectrum including the spectrum used for radio communication. But the condition of the sun varies and follows an eleven year cycle. Thus at the peak of this cycle electrical disturbances erupt causing corona flares and sun spots. This noise from electrical disturbance is in addition to the quiet noise from the sun. Although this additional noises comes from a small portion of the sun's surface, it may still be greater than the "quiet" solar noise.

This solar cycle repeats these electrical disturbances approximately every eleven years. Further if a line is drawn joining these eleven year peaks, we find that these peaks follow a 100 year cycle. Finally these 100 year peaks appear to increase in intensity.

Cosmic Noise. Distant stars are also suns and have high temperatures. These stars, therefore, radiate noise in the same way as our sun. The noise received from these distant stars is *thermal noise (or black body noise)* and is distributed almost uniformly over the entire sky. We also receive noise from the centre of our own galaxy (the Milky Way), from other distant galaxies and from other virtual point sources such as *quasers* and *pulsers*. This *galactic noise* is very intense but since it comes from very distant sources, the angle subtended by the earth is very small. Hence the strength of galactic noise received on earth gets diminished.

We conclude that the space noise is significant at frequencies in the range from about 8 MHz to somewhat above 1.43 giga-hertz (GHz), where this frequency 1.43 GHz corresponds to 21 cm hydrogen *line*. In the frequency range of 20 to 120 MHz, the space noise forms the strongest noise component next only to the man-made noise. However, below 20 MHz, not much of the space noise penetrates through the ionosphere to reach the earth. Also the space noise disappears at frequencies in excess of 1.5 GHz probably due to its absorption by hydrogen in interstellar space.

2.5. Man-Made Noise (Industrial Noise)

By man-made noise or industrial noise is meant the electric noise produced by such sources as automobiles and air craft ignition, electric motors and switch gears, leakage from high voltage lines, fluorescent lights, and numerous other heavy electrical machines. Such noises are produced by the arc discharge taking place during operation of these machines. Such man made noise is most intensive in industrial areas, densely populated urban and suburban areas. Man-made noise in such areas far exceeds all other sources of noise in the frequency range extending from about 1 MHz to 600 MHz.

The nature of industrial noise is highly variable. Hence it can be analyzed only statistically. However, the received man-made noise increases as the receiver bandwidth increases.

2.6. Thermal Noise

The *thermal noise, agitation noise, white noise* or *Johnson noise* is the random noise generated in a resistor or the resistive component of a complex impedance due to rapid and random motion of the molecules, atoms and electrons.

About the Book

This book aims at giving a deep insight to the vast and expanding field of Principles of Communications. It presents the information for the students of communications engineering about the basic processes, circuit configurations and philosophies which underlie communications systems.

The first three chapters introduce the principles of communications, noise and modulation which are later used throughout the remaining part of the book. The next four chapters deals with various types of modulation methods -- amplitude, frequency and radio transmitters. Chapter 8 deals with transmitter power supplies and tube cooling while next two chapters describe in detail about A.M. and F.M. receivers.

Next part highlights principles of antennas & propagation and ultra high frequency takes and oscillators. Television systems give details, beginning from the principles then on to broadcast studio, transmitters, receivers and colour television receivers.

Finally the basics of modern communications are dealt under the principles of radar, satellite, pulse and optical communication systems.

Finally each Chapter terminates in multi-choice self-testing questions, numerical and review questions given at the end of each chapter. The author feels that these questions can go a long way in helping readers preparing for the UPSC engineering services examination or any other competition.

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