UPPSC-AE 2021

Uttar Pradesh
Public Service Commission

Combined State Engineering Services Examination

Assistant Engineer

Electrical Engineering

Analog Communication and Microwave

Well Illustrated **Theory** *with*
Solved Examples and **Practice Questions**

MADE EASY Publications

Analog Communication and Microwave

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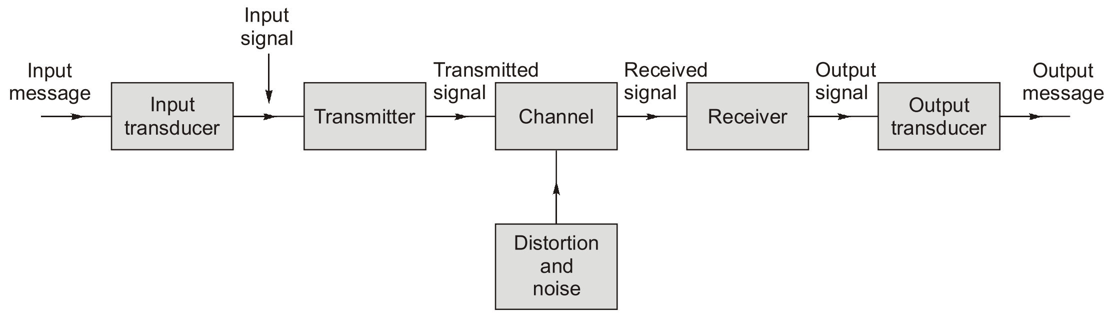
CHAPTER 1

SECTION-A

Introduction to Communication Systems

1.1 Introduction

In a basic sense, communication refers to exchange of information from sender to receiver, through a channel. In a broad sense, the term **communications** refers to the sending, receiving and processing of information by electronic means. The key components of a communication system are as follows:



Model of communication system

1. **Source :**
   - The source originates a message, such as a human voice, a television picture, an e-mail message, or data.
   - If the data is non-electric (e.g., human voice, e-mail text, television video), it must be converted by an **input transducer** into an electric waveform referred to as the **baseband signal** or **message signal** through physical devices such as a microphone, a computer keyboard or a CCD camera.

2. **Transmitter :** The transmitter modifies the baseband signal for efficient transmission. The transmitter may consist of one or more subsystems: an A/D converter, an encoder and a modulator.

3. **Channel :** The channel is a medium of choice that can convey the electric signals at the transmitter output over a distance. A typical channel can be a pair of twisted copper wires (telephone and DSL), coaxial cable (television and internet), an optical fibre or a radio link. Channel may be of two types.

   (i) Physical channel (ii) Wireless cannel

4. **Receiver :** The receiver reprocesses the signal received from the channel by reversing the signal modifications made at the transmitter and removing the distortions made by the channel.

5. **Destination :** The destination is the unit to which the message is communicated.

1.2 Primary Communication Resources

In a communication system, two primary resources are employed:

- **Transmitted power** and **channel bandwidth.**
- The transmitted power is the average power of the transmitted signal. The channel bandwidth is defined as the band of the frequencies allocated for the transmission of the message signal.
- We may therefore classify communication channels as **power limited** or **band limited.** For example, the telephone circuit is a typical band limited channel, where as a space communication link or satellite channel is typically power limited.

1.3 Modulation

- It is defined as the process by which some characteristics of signal called **"carrier"** is varied in accordance with the instantaneous value of the modulating signal a **modulating signal** or **base-band signal** or **message signal**.
- At the receiving end of the system we reconstruct the original base-band signal and this is accomplished by using a process called **"demodulation"**. **"Demodulation"** is the reverse process of **"modulation"**.

1.4 Different Signals

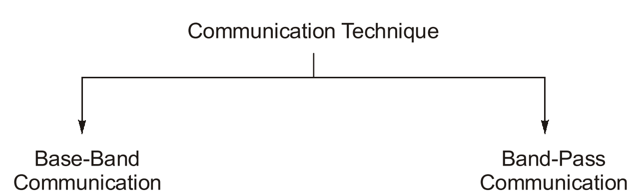
1. Base-Band Signal

- Message signal, eg. **Voice signal, Video signal**
- Low frequency range
- Minimum frequency = 0 Hz

2. Band-Pass Signal

- Frequency other than 0 Hz
- Minimum frequency $\neq$ 0 Hz

1.5 Communication Technique



Base-Band Communication:

- It doesn't use modulation technique.
- No shift in the range of frequency of the signal.
- Cannot be transmitted over long distance.

Band-Pass Communication:

- Using modulation technique.
- Shift the frequency spectrum of base-band signal.
- Long distance transmission is possible.

1.6 Need of Modulation

1. **To decrease the length of transmitting and receiving antenna**
   For a message at 10 kHz, the antenna length 'l' for practical purposes is equal to $\lambda/4$ (from antenna theory) i.e.,

$$\lambda = \frac{3\times10^8}{10\times10^3} = 3\times10^4 \text{ m}$$

and
$$l = \frac{\lambda}{4} = \frac{3\times10^4}{4} = 7500 \text{ m}$$

   An antenna of this size is impractical and for a message at 1 MHz

$$\lambda = \frac{3\times10^8}{1\times10^6} = 300 \text{ m}$$

$$l = \frac{\lambda}{4} = 75 \text{ m} \quad \text{(practicable)}$$

2. **To allow the multiplexing of signals**
   By translating the all signals from different sources to different carrier frequency, we can multiplex the signals and able to send the all signals through a single channel.
3. **To remove the interference**
4. **To improve the quality of reception i.e. increasing the value of S/N ratio**
5. **To increase the range of communication**

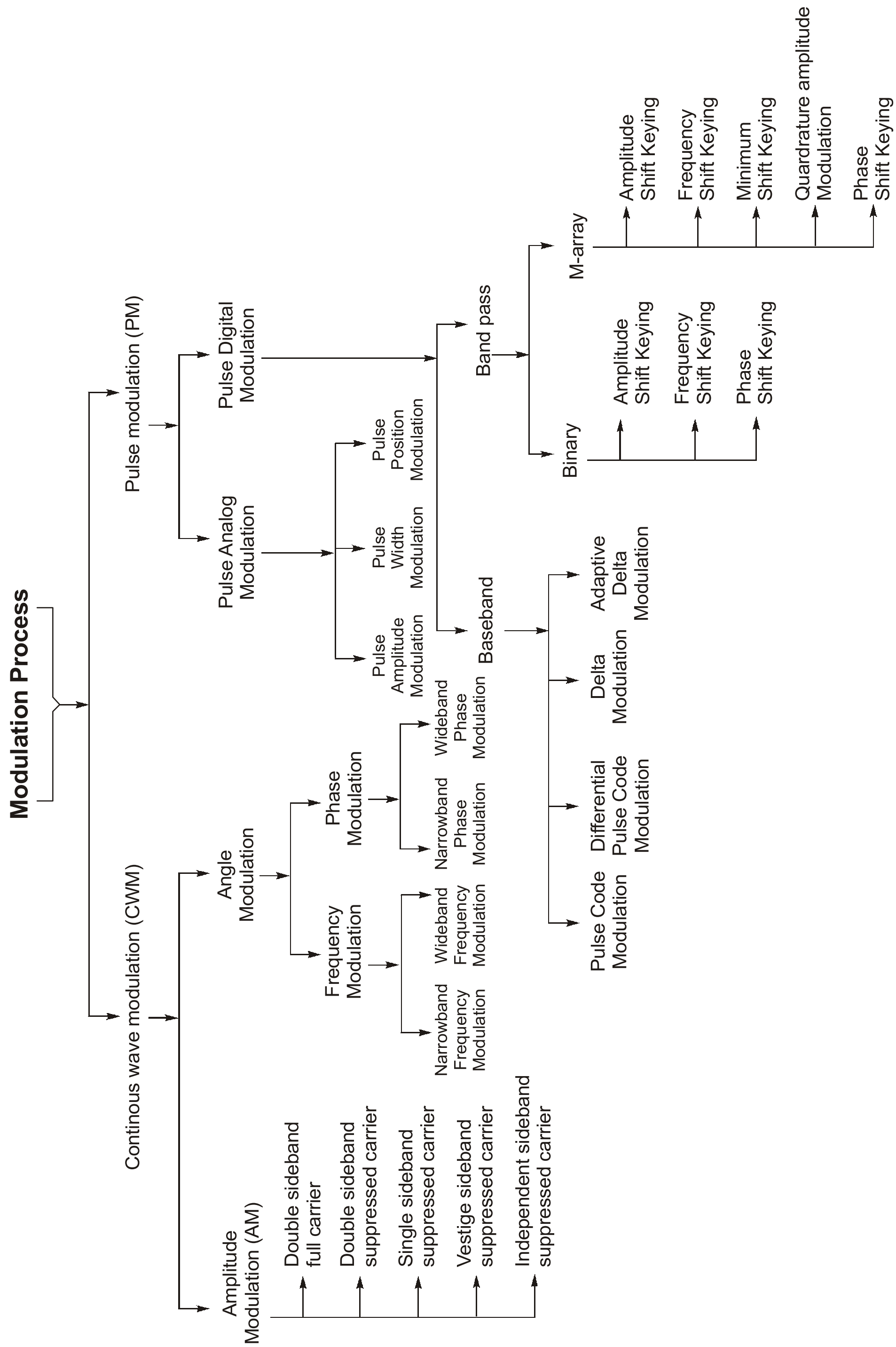
Example - 1.1 Modulation is Primarily accomplished to:
(a) Produce side band
(b) Mix two-waves of different frequencies
(c) Improve transmission efficiency
(d) Transmit audio-frequency signal over long distance [UPPSC]

Answer: (d)

NOTE

Important Terms :
- *Baseband signal* is a signal having significant frequency component near to zero or low frequencies.
- *Bandpass signal* is a signal having significant frequency component away from zero frequency or low frequency.
- *Spectrum* means frequency domain representation of a signal.
- *Noise* is mainly added to signal in the channel.
- *Bandwidth* of a signal is defined as band of group of frequencies for which amplitude of signal is not zero.

1.7 Types of Modulation



1.8 An Exam Oriented Approach

Communication is a modern technology is undergoing many changes. The main focus of a student should be to single out on optimum path in which he develops a theoretically strong background of the subject while keeping in mind that he should be able to solve questions asked in various exams using the theory they have studied. Focusing on one aspect leads to failure in written exam or in the interview. Thus this book and communication both have the same approach and that is "optimization" and being a communication engineer one should have this approach too.

EM Spectrum

Frequency (f) range	Wavelength (λ) range	EM Spectrum Nomenclature	Typical Application
30 – 300 Hz	$10^7 – 10^6$ m	Extremely low frequency (ELF)	Power line communication
0.3 – 3 kHz	$10^6 – 10^5$ m	Voice frequency (VF)	Face to face speech, communication intercom
3 – 30 kHz	$10^5 – 10^4$ m	Very low frequency (VLF)	Submarine communication
30 – 300 kHz	$10^4 – 10^3$ m	Low frequency (LF)	Marine communication
0.3 – 3 MHz	$10^3 – 10^2$ m	Medium frequency (MF)	AM broadcasting
3 – 30 MHz	$10^2 – 10^1$ m	High frequency (HF)	Landline telephony
30 – 300 MHz	$10^1 – 10^0$ m	Very high frequency (VHF)	FM broadcasting, TV
0.3 – 3 GHz	$10^0 – 10^{-1}$ m	Ultra high frequency (UHF)	TV, Cellular telephony
3 – 30 GHz	$10^{-1} – 10^{-2}$ m	Super high frequency (SHF)	Microwave oven, radar
30 – 300 GHz	$10^{-2} – 10^{-3}$ m	Extremely high frequency (EHF)	Satellite communication, radar
0.3 – 3 THz	0.1 – 1 mm	Experimental	For all new explorations
3 – 430 THz	100 – 0.7 µm	Infrared	LED, Laser, TV remote
430 – 750 THz	0.7 – 0.4 µm	Visible light	Optical communication
750 – 3000 THz	0.4 – 0.1 µm	Ultraviolet	Medical application
> 3000 THz	< 0.1 µm	X-rays, gamma rays, cosmic rays	Medical application

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SECTION-B

CHAPTER 1

Introduction

The term microwave refers to alternating current signals with frequencies between **300 MHz (3×10^8 Hz) and 300 GHz (3×10^{11} Hz)**, with a corresponding electrical wavelength between $l = c/f = 1$ m and $l = 1$ mm, respectively. Signals with wavelengths on the order of millimeters are called **millimeter waves**. Figure shows the location of the microwave frequency band in the electromagnetic spectrum. Because of the high frequencies (and short wavelengths), standard circuit theory generally cannot be used directly to solve microwave network problems. In a sense, standard circuit theory is an approximation or special use of the broader theory of electromagnetics as described by Maxwell's equations. This is due to the fact that, in general, the **lumped circuit element approximations of circuit theory are not valid at microwave frequencies**.

ELF	Extremely Low Frequency	3-30 Hz
SLF	Super Low Frequency	30-300 Hz
ULF	Ulta Low Frequency	300 Hz-3 kHz
VLF	Very Low Frequency	3 kHz- 30 kHz
LF	Low Frequency	30 kHz-300 kHz
MF	Medium Frequency	300 kHz-3 MHz
HF	High Frequency	3 MHz-30 MHz
VHF	Very High Frequency	30 MHz-300 MHz
UHF	Ultra High Frequency (decimeter waves)	300 MHz-3 GHz
SHF	Super High Frequency (centimeter waves)	3 GHz-30 GHz
EHF	Extremely High Frequency (millimeter waves)	30 GHz-300 GHz
	submillimeter waves	300 GHz-3000 GHz
IR	Infrared	3000 GHz-416,000 GHz

Microwave components are often distributed elements, where the phase of a voltage or current changes significantly over the physical extent of the device, because the device dimensions are on the order of the microwave wavelength.

1.1 Approximate Band Designations

L-band	1 - 2 GHz
S-band	2 - 4 GHz
C-band	4 - 8 GHz
X-band	8 - 12 GHz
Ku-band	12 - 18 GHz
K-band	18 - 26 GHz
Ka-band	26 - 40 GHz
U-band	40 - 60 GHz

1.2 Applications of Microwave Engineering

Just as the high frequencies and short wavelengths of microwave energy make for difficulties in analysis and design of microwave components and systems, these same factors provide unique opportunities for the application of microwave systems. This is because of the following considerations :

- Antenna gain is proportional to the electrical size of the antenna. At higher frequencies, more antenna gain is therefore possible for a given physical antenna size, which has important consequences for **implementing miniaturized microwave systems**.
- More bandwidth (information-carrying capacity) can be realized at higher frequencies. A 1% bandwidth at 600 MHz is 6 MHz (the bandwidth of a single television channel), and at 60 GHz a 1% bandwidth is 600 MHz (100 television channels).
- **Microwave signals travel by line of sight and are not bent by the ionosphere** as are with lower frequency signals. Satellite and terrestrial communication links with very high capacities are thus possible, with frequency reuse at minimally distant locations.
- Today, the majority of applications of microwaves are related to radar and communication systems. Radar systems are used for detecting and locating air, ground, or seagoing targets and for air-traffic control systems, missile tracking radars, automatic collision-avoidance systems, weather prediction, motion detectors, and a wide variety of remote sensing systems.
- Microwave communication systems handle a large fraction of the world's international and other long-haul telephone, data, and television transmissions. And most of the currently developing wireless telecommunication systems, such as direct broadcast satellite (DBS) television, personal communication systems (PCSs), wireless local area computer networks (WLANS), cellular video (CV) systems, and global positioning satellite (GPS) systems, operate in the frequency range 1.5 to 94 GHz, and thus rely heavily on microwave technology.

1.3 Advantage of Microwave

- The use of microwave improve the directive properties (beam width).

  Beam width $\propto \frac{\lambda}{D}$. Where, λ = wave length ; D = Diameter of antenna
- Microwave increases the bandwidth availability.
- The power requirement at microwave frequency range is low.
- Microwave increases the reliability by decreasing fading effect.
- Microwave enables the study and research into extra territorial signal coming from sun or other stars.

Example - 1.1 Match List-I (Microwave band) with List-II (Frequency used in satellite communication) and select the correct answer using the codes given below the lists:

List-I	List-II
A. C-band	1. 12 GHz to 14 GHz
B. Ku-band	2. 24 GHz to 26 GHz
C. Ka-band	3. 20 GHz to 30 GHz
	4. 4 GHz to 6 GHz

Codes:

	A	B	C
(a)	4	2	1
(b)	2	1	3
(c)	4	1	3
(d)	3	4	2

Answer: (c)

Example - 1.2 Match List-I (Designation of Radar Frequencies) with List-II (Frequency Range) and select the correct answer using the codes given below the lists:

	List-I		List-II
A.	S	1.	18 – 26.5 GHz
B.	X	2.	2 – 4 GHz
C.	Ku	3.	8 – 12.4 GHz
D.	K	4.	12.4 – 18 GHz

Codes:

	A	B	C	D
(a)	1	3	2	4
(b)	1	4	2	3
(c)	2	3	1	4
(d)	2	4	1	3

Solution: (c)

Designation	Frequency range (in GHz)
HF	0.003 - 0.030
VHF	0.030 - 0.300
UHF	0.300 - 1.000
L band	1 - 2
S band	2 - 4
C band	4 - 8
X band	8 - 12
Ku band	12 - 18
K band	18 - 27
Ka band	27 - 40
Millimeter	40 - 300
Submillimeter	> 300

Example - 1.3 X-band frequencies are in which one of the following ranges?

(a) 3.5 to 5.5 GHz
(b) 5.5 to 8.0 GHz
(c) 8.0 to 12.0 GHz
(d) 12.4 to 16.4 GHz

Answer: (c)

Example - 1.4 Bandwidth of the order of 12 MHz can be realized easily using carriers in which range?

(a) VHF
(b) UHF
(c) Microwaves only
(d) Optical frequency and microwaves

Solution: (c)

Microwave frequencies range from 1 GHz to 1000 GHz. Therefore, bandwidth of the order of 12 MHz can be realized easily using carriers in microwave range.

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