Certificate in Community Radio Technology

7

Radio Transmission Technology

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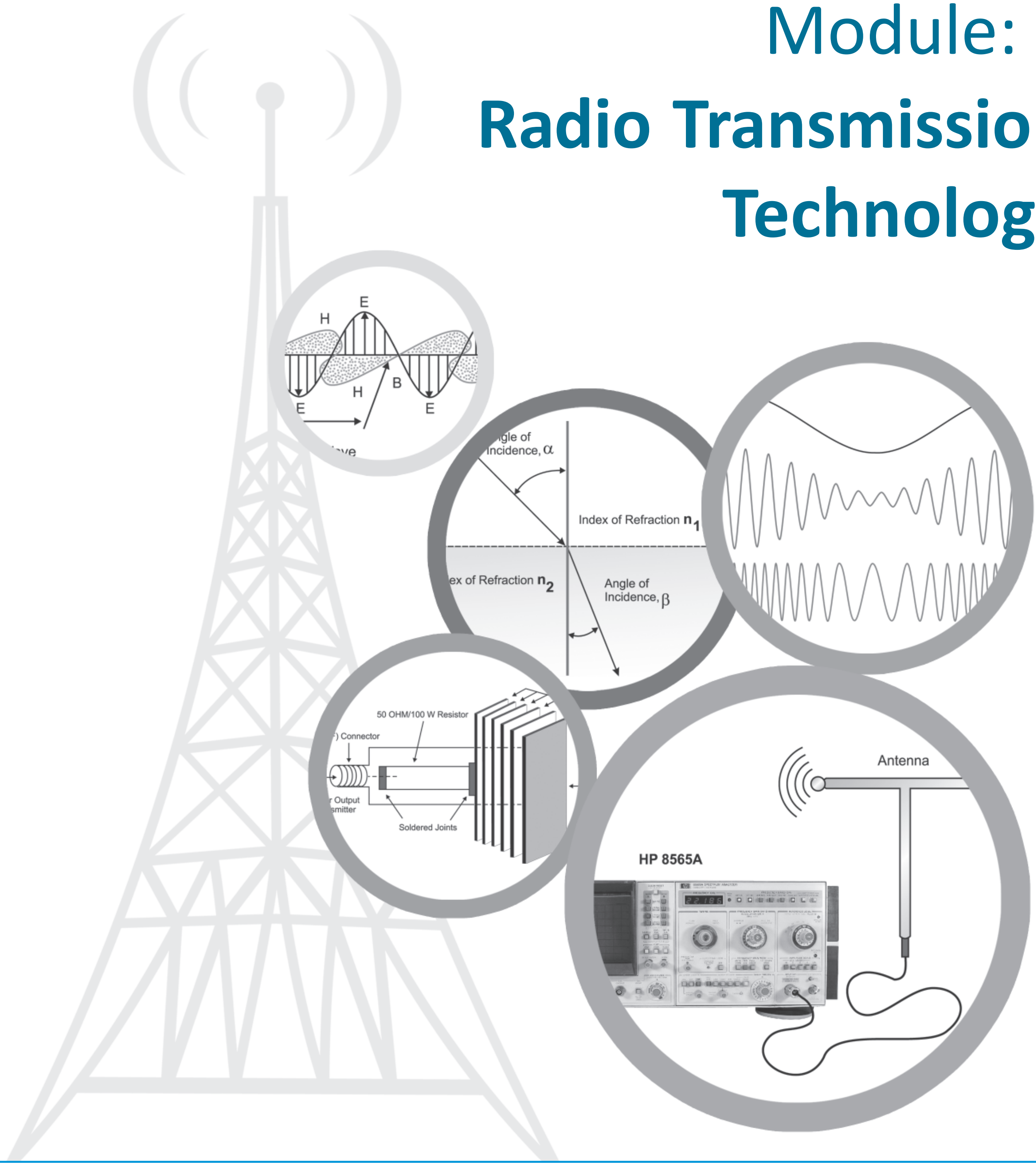
Course - III
Community Radio Transmission: System & Technology

Module: 7
Radio Transmission Technology



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Commonwealth Educational Media Centre for Asia
New Delhi

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Module 7: Radio Transmission Technology

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Certificate in Community Radio Technology

Courses	Modules	Units
Course I: Understanding Community Radio (3 Credits, 90 Hours)	**Module 1** Community Radio: An Introduction	**Unit 1 :** Community Radio: Concept and Evolution **Unit 2:** Context, Access and Equity **Unit 3:** Community Radio: Policy Guidelines **Unit 4:** Technology for CR: Guiding Principles
	Module 2 Setting up of CRS	**Unit 5:** Components of CR Station **Unit 6:** Radio Waves and Spectrum **Unit 7:** Basics of Electricity **Unit 8:** Power Backup and Voltage Stabilization
Course II: Community Radio Production: System & Technology (5 Credits,150 Hours)	**Module 3** Studio Technology	**Unit 9:** Basics of Sound **Unit 10:** Analog and Digital Audio **Unit 11:** Components of the Audio Chain **Unit 12:** Studio Acoustics
	Module 4 Audio Production	**Unit 13:** Audio Hardware and Field Recording **Unit 14:** Free and Open Source Software **Unit 15:** Telephony for Radio
	Module 5 Audio Post Production	**Unit 16:** Sound Recording and Editing **Unit 17:** Mixing and Mastering **Unit 18:** File Formats and Compression **Unit 19:** Storing and Retrieval
	Module 6 Studio Operations	**Unit 20:** Good Engineering Practices for Studio Setup **Unit 21:** Studio Equipment: Preventive & Corrective Maintenance **Unit 22:** Content Distribution: Alternative Mechanisms
Course III: Community Radio Transmission: System & Technology (2 Credits, 60 Hrs)	**Module 7** Radio Transmission Technology	**Unit 23:** Components of Transmission Chain **Unit 24:** Components of FM Transmitter **Unit 25:** Antenna and Coaxial Cable **Unit 26:** Propagation and Coverage
	Module 8 FM Transmitter Setup	**Unit 27:** Transmitter Setup: Step-by-step **Unit 28:** Transmission System-Preventive and Corrective Maintenance **Unit 29:** Transmission Setup–Good Engineering Practices
Course IV: Technical Internship (2 Credits, 60 Hrs)	**Module 9** Practical Internship Handbook	**Section A:** Introduction **Section B:** Activities to be Conducted During the Practical Internship **Section C:** The Internship Journal and Self-Assessment Paper **Section D:** Assessment of Internship **Section E:** Appendices

Video in the Module:

Coaxial Cable and FM Antenna

By Ramnath Bhat

http://tinyurl.com/q2n6wm5

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About the Module

Module Description

The first module of Course III: CR Transmission: System & Technology deals with the transmission technology used in the broadcast of community radio (CR) programmes/signals generated at the studio of the CR station. In Courses I and II, you studied about basic CR and studio production of CR programmes. In this unit, you will learn how these programmes are broadcast by a frequency modulation (FM) transmitter using radio frequency (RF) signals in FM-band for reception by FM radio receivers. The first module of Course III is on Radio Transmission Technology, which has four units. These four units cover the basic components of the transmission chain and their features and applications (Unit 23), important components of the FM transmitter (Unit 24) and FM antenna (Unit 25) as well as the propagation and coverage of FM radio frequency signals (Unit 26). This module would need about 26 hrs of study. As a part of this module, a video of antenna installation aspects is also included. After getting a good idea of FM transmission technology through this module, you will further study the practical aspects of transmitter set-up in the next module, that is, Module 8. A good understanding of the basic concepts of this module will help you learn and grasp better the practical aspects of transmitter set-up.

Module Objectives

After going through this module, you should be able to:

- Enumerate various components of the FM transmission chain and its features and applications.
- Explain various components of a typical FM transmitter as used for CRS-FM transmission.
- Describe different types of FM antenna particularly those used for CRS transmitters, their features and the coaxial cable used to connect with the transmitter.
- Explain propagation and coverage of RF signals in special reference to FM propagation.

Units in the Module

- Unit 23: Components of Transmission Chain
- Unit 24: Components of FM Transmitter
- Unit 25: Antenna and Coaxial Cable
- Unit 26: Propagation and Coverage

UNIT 23

Components of Transmission Chain

Structure

23.1 Introduction

In Units 5, 11 and 13, you learnt about the functions and use of audio mixers and audio work stations as a part of studio chain. In this unit, you will learn about various components of the transmission chain and the functions performed by each of these. The components of a transmission chain, which will be described in this unit, include the following:

- Transmission chain overview
- Live transmission (live console)
- Pre-recorded transmission (radio automation/scheduling)
- Connectivity (from studio to transmitter)
- Audio processor/limiter
- FM transmitter
- Principles of FM transmission
- Antenna (types and polarization)

We shall discuss the above components in the order as given.

You will learn in detail about FM transmitter and antenna in the next two units.

You may require about 6 hours to complete this unit including answering questions in various activities.

23.2 Learning Outcomes

After going through this unit, you will be able to:

- list and describe various components of a transmission chain such as mixer, workstation, processor, transmitter and antenna.
- describe their features and application in respect of CR stations.
- describe the requirements of connectivity between a studio and the transmitter.
- explain the necessity of using an audio processor in the transmission chain.
- explain the basic terms and concepts used in FM transmissions.
- explain different types of antennae and polarizations.

23.3 Transmission Chain Overview

The function of transmission chains is to transmit the programmes by routing them through the playback console to the studio-transmitter link, on to the audio processor and then to the transmitter, and further on to the antenna for broadcast of RF signals on air. The main components of the chain are shown in Figure 23.1. Details of all these components of a transmission chain are described in the sections below.

23.4 Live Transmission (Live Console)

In this section, you will learn the difference between a live console and a production console, and also the salient features of a live console.

A console that is used for feeding the programmes to the transmitter during transmissions is called a live console. Here the announcer selects one of the many programmes which is scheduled for transmission. He plays the selected programme from the playback equipment and routes the output of the console to the input of the transmitter through the processor. On the other hand, a production console is used for producing the programmes by mixing two or more source signals to record the requisite programme. Its output is recorded and kept for later transmission as per schedule.

Figure 23.1 illustrates a typical transmission chain used at almost all the CR stations.

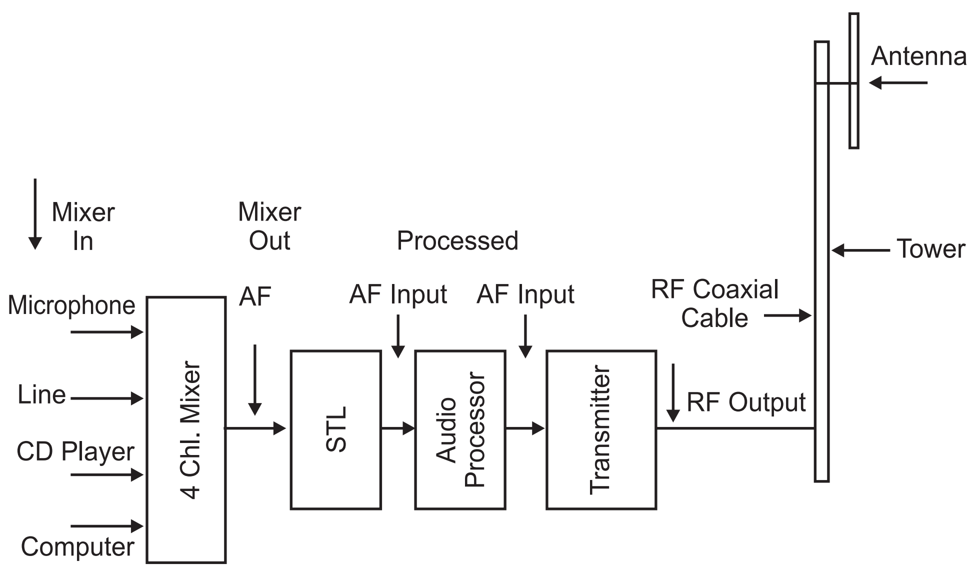


Figure 23.1: *Schematic diagram illustrating the components of transmission chain*

You may note the sequence in which the components of the transmission chain are connected in Figure 23.1. Each stage and the type of signal available at the input and output of that stage are labelled for the purpose of understanding the process. The audio mixer/console selects one out of the four input channels that is to be broadcast. A studio transmitter link (STL) feeds the selected channel to the audio processor. An STL is, however, not required where the studio and the transmitter are co-located, which is generally the case with most CR stations. The audio processor processes the audio signals to increase the average modulation and at the same time limits the audio level to protect the transmitter from over-modulation. The output of this processor is fed to the input of the transmitter. The transmitter then converts the processed audio signals into frequency modulated (FM) radio frequency (RF) signals at the rated output power. The output of the transmitter is connected to the antenna system mounted on top of the tower via an RF coaxial cable. An antenna system converts the RF out of the transmitter to electromagnetic (EM) waves travelling in all directions.

All the components of the transmission chain will be discussed in detail in this section as also subsequent sections.

Let us now begin with the first component of the chain, that is, audio mixer/ console, which is used as a live or transmission console. You have already studied about audio mixer/console in the unit on studio chain. We will here recapitulate these concepts to refresh your memory.

An audio mixer/console used in broadcast or transmission studio is an electronic device which is used to select and route one out of a number of playback equipment connected to it as input channels. The input playback equipment can be anything from the list below:

- A microphone
- A CD player
- A playback deck
- A line feed having a live programme
- A computer or a workstation

All these pieces of equipment, called the input channels, are connected to the audio mixer. An Audio Mixer is identified according to the number of input channels. For example, a 4-channel mixer will have facility to connect four channels as input channels and any one of them can be selected as output for feeding it to the next stage. These channels can be mono or stereo, digital or analog as per requirement.

Audio mixers/consoles of various models and ranges are available in the market. Prominent manufactures being Behringer, Soundcraft, Studer, Yamaha, Sonifex, etc. Cost may vary depending on the number of input and output channels, mono or stereo, analog or digital and additional features/facilities provided by the manufacturers. Since the CR stations have low budgets, simple 4/6 channel consoles are mostly used depending upon their specific requirements. Whatever may be the type/model or brand used, the principle of operation remains the same.

A typical analog mixer has three main sections, as follows.

1. Channel Inputs

All the input channels are terminated on the mixer generally through good quality audio cables by using XLR connectors. Each channel has its own switch and a fader or a knob to control its volume level. The selected channel is connected to the input bus. Some channels (like microphones) are connected to the input bus via pre-amplifiers to boost their levels.

2. Master Output

The selected channel is connected to another set of switch, fader and amplifier, called the master output channel, which feeds the selected programme to the next stage in the transmission chain after adjusting its output to a desired level. All other input channels remain isolated by keeping the switches/faders in the 'Off' position.

3. Audio Level Metering and Monitoring Facility

Audio level metering facilities are provided to monitor and control the output level to its nominal level. Usually, there are one or more volume units (VU) or peak meters to indicate the levels of each channel and the master output. Generally, a split of input or output signal is extended on a separate jack/connector (called Aux. Out) to facilitate connecting of auxiliary equipment for monitoring and measurement.

Apart from the essential components discussed above, the number of additional features is also provided in these consoles, such as

- Audio oscillator for calibration and level adjustments
- Phantom supplies for microphones
- Equalizers for correcting the frequency response
- Colour coding for quick identification of the operator

In order to maintain proper transmission standards, the output level and impedance of each equipment must match with the input level and impedance of the next stage. For example, the nominal level set at the output of audio console is 0VU (+4dBu). Audio levels in consoles are displayed in VU (see Box 1) or in decibels (see Box 2).

Note It

Box 1

VU meter

A volume unit (VU) meter is a device used for displaying the signal level in audio equipment.

The VU meter normally measures the average level of the signal. It averages the peaks and troughs of short durations and thus reflects the perceived loudness of the signal.

A value of 0VU corresponds to a voltage level of 1.23 Volts (RMS) of an alternating frequency of 1,000Hz measured across 600 ohm load. This is equal to +4 dBu (on a decibel scale with reference to 0.775V).

Note It

Box 2

Decibel (dB)

The decibel is a logarithmic unit that indicates the ratio of a physical quantity (usually power, voltage level of any signal) relative to a specified reference level. In electronics, the gains of amplifiers, attenuation of signals, and signal to noise ratios are often expressed in decibels.

A decibel symbol is often qualified with a suffix that indicates which reference quantity has been used.

For example, dBm indicates a reference level of one milliwatt, while dBu is referred to 0.775 volts RMS.

Mathematically,

Power gain in dB = $10 \log_{10} (P_1 / P_0)$, where P_1 is the power level to be measured and P_0 is the reference power.

Voltage gain in dB = $20 \log_{10} (V_1 / V_0)$, where V_1 is the voltage level to be measured and V_0 is the reference voltage.

Activity 23.1

To complete this activity, you may need about 15 minutes including writing down the answers in the space provided.

This activity will help you understand the concepts and functions of the components of a transmission chain in a CR station. This will also help you in understanding the representation of audio levels in volume units and decibel units.

Question: 1 How is a live console functionally different from a production console?

Question: 2 A VU (volume unit) question meter connected at the output of an audio mixer displays a level of '0' VU on its scale. What does '0' VU correspond to?

Question: 3 What is the decibel (dB) unit used for audio levels? Why is a decibel symbol often written with a suffix? What is the difference between dB_m and dB_u?

23.5 Pre-recorded Transmission (Radio Automation/ Scheduling)

In this section, you will learn about pre-recorded transmissions, radio automation and scheduling.

In CRS set-ups, most of the programmes are pre-recorded either in the studio or in the field. They are played from the playback or transmission studios. Nowadays, a large variety of digital audio workstations (DAW) using radio automation software are available in the market but the one that best meets the requirements is used by a particular CR station. You learnt about the details of audio workstation in Unit 13 including its recording, editing and other features. In this section, you will learn about the functional requirements as far as scheduling and automatic transmission of pre-recorded programmes are concerned.

An audio workstation is a computer-based system which is solely designed to work as an all-in-one machine. It is able to record, edit, store, retrieve and play back as desired. With the help of a customized radio automation package, the operator can schedule the transmission for a day on real-time basis. It can automatically transmit the scheduled programmes on air.

Some of the features mostly available in almost all the software are:

- Semantically searchable records from library
- Retrieval of records from the stored data
- Preview of selected programme(s)
- Scheduling (auto transmission on real-time basis)
- Automatic fault diagnosis
- Logging and certification of all audio/data
- Master fader for control of transmission levels

As you learnt in the previous section of this unit, the most important parameter is to control the output levels of the selected programme (which may be either from the workstation or any other playback channel selected by the operator) to ensure that we do not overload the chain beyond the specified levels.

Activity 23.2

To complete this activity, you may need about 15 minutes including writing down the answer in about 100 words in the space provided.

This activity will help you in understanding the concept and function of digital workstations.

Question: What is an audio workstation? Why is it becoming more popular to use it in CRS? Briefly describe its main functions.

Let us now move to the second component of the chain, that is, connectivity from the studio to the transmitter.

23.6 Connectivity (from Studio to Transmitter)

Your next step is to feed the output of the transmission studio to the transmitter, which may or may not be located in the same room. For this purpose, a suitable connectivity is required between the studio and the transmitter. In this section, you will learn about the various modes of connectivity used from the studio to the transmitter.

In most CR stations, studio and transmitter are co-located, may be in the same room or adjoining rooms. But in some of the situations, it is not possible to locate the transmitter with antenna and tower at a place where the studio is located. In such situations, it becomes necessary to provide a suitable connectivity between them.

The various modes of connectivity are as follows:

1. ***Dedicated Physical Cable Pairs***

   In most of the CR stations, the distance between the studio and the transmitter may not be so much that it requires hiring telephone or leased lines. The transmitter may be located in the same campus but at a small distance from the studio. In such cases, a good quality shielded audio cable is laid locally to provide the connectivity. The cable must be passed through suitable conduits or pipes to avoid getting damaged.

2. ***Telephone Lines or Leased Lines***

   The Department of Telecommunication is having a large network of telephone cables or lines laid in all the cities for providing telephone connections to the subscribers. This department provides and extends any number of pairs between two locations (studio and transmitter in our case) on demand. These are the easiest and cheapest modes of connectivity. However, the technical quality of this pair may or may not be up to the mark. It has limited bandwidth. Moreover, if the distance is more between the studio and the transmitter, the loss due to use of cable is huge. Nowadays, good quality broadband ISDN or leased lines are also available but they are costlier.

3. ***VHF or Microwave Links***

   The connectivity between the studio and the transmitter can also be provided by use of point-to-point VHF or microwave links if the distance is more. Technically, the quality through this link is much better, but it has got a lot of limitations and restrictions. Separate siting and frequency clearances from Wireless Planning and Coordination (WPC) are necessary like a CRS. It involves extra spectrum fees apart from cost of towers and link equipment. The option is simply not cost effective for a low-budget CR station.

Laying of dedicated physical pairs for providing connectivity from the studio to the transmitter is the best possible option. The losses due to length of the cable can easily be compensated at the input transmitter.

23.7 Audio Processor/Limiter (if not Processed through the PC)

In Unit 17, you learnt about adjusting and balancing of levels at the mixer output. In this section, you will learn why it is necessary to process these audio signals again before feeding them to the transmitter.

Normally, the audio signals received from the broadcast studio are already processed and level controlled through the transmission console. However, since live consoles use different types of live or pre-recorded programmes, the recording levels may not be uniform.

An audio processor/limiter is needed to:

- Protect the transmitter against over modulation
- Increase average modulation or loudness

A large variety of audio processors are available in the market with varying range of features. The prominent ones are Orban, Alto pro, Behringer and Veronica. Whatever may be the type and brand of processor, the basic functions remain the same.

Every audio processor has the following three components:

- The compressor
- The limiter
- The peak clipper

The compressor is used to compress the large dynamic range of signals in a programme. It increases the average modulation level and thereby loudness in the programme.

The limiter limits the peaks in programmes beyond a set level to protect the transmitter from over-modulation.

The peak clipper cuts very high peaks, which are otherwise beyond the limiting level.

Various controls are provided in every processor to set the compression ratio, attack time, release time and thresholds of limiting and clipping. These are to be adjusted in accordance with the procedures given in the operating manual of each processor. The points to be kept in mind are:

- Nominal input levels of transmitters to get desired deviation.
- Quality of programme may not get deteriorated due to over-setting of compression and limiting.

You will learn about setting of controls and alignment of a transmission chain in practical workshop.

23.8 FM Transmitter

The next component of the tranmitter chain is the main FM transmitter, which is used to generate the frequency modulated RF signal of required power for feeding the transmission antenna for broadcast of RF signals. The FM transmitter is generally a stand-alone unit housed in a rack mountable box. Generally, a transmitter with 50 or 100 watt of power is used for CRS. The output of the transmitter is fed to the transmitting antenna mounted on the pole or tower. You will learn more about FM transmitters in the next unit.

Activity 23.3

To complete this activity, you may need about 15 minutes including writing down the answers in the space provided.

This activity will help you learn the necessity and functions of connectivity and audio processor in the transmission chain.

Question: 1 Why is connectivity required from a studio to a transmitter?

Question: 2 What are the essential technical requirements which the connectivity link must fulfil?

Question: 3 Differentiate briefly between the functions of a compressor and a limiter in an audio processor.

23.9 Principles of FM Transmission

The next and the most important component in the transmission chain is the FM transmitter. An FM transmitter converts processed audio signals to frequency modulated RF signals before feeding them to the antenna system. In Unit 24, you will learn in detail about the functions and descriptions of each subunit within the transmitter. In Unit 6, you were introduced to frequency bands used in FM radio broadcasting. In this section, you will recapitulate/learn various terms used in understanding the basic principles of FM transmission.

Frequency Modulation

Frequency modulation is a type of modulation in which the frequency of the carrier wave is changed by the instantaneous amplitude of the modulating signal, whereas frequency of the modulating signal changes the rate of change of the carrier wave. In this process, the amplitude of the modulated carrier wave is kept constant, which is the most important feature of frequency modulation.

Modulating Signal

Audio frequency signal containing the information or content of the programme (output of mixer), which is to be transmitted, is called modulating signal. This signal is a complex wave containing frequencies varying from 30 Hz to 15 kHz with varying amplitudes. In case of stereo transmissions, about which you will learn later in this section, the maximum frequency of the modulating signal can go up to 53 kHz.

Carrier Wave

It is the radio wave that acts as a carrier to transmit the message/information contained in the modulating signal to the listeners through the electromagnetic wave radiated by the antenna. The frequency of the carrier wave is the frequency that is allotted to a particular radio station in the VHF band (88 to 108 MHz). For example, if 90.4 MHz is allotted to a particular CR station, then 90.4 MHz is called the carrier frequency for that station. Each radio station is identified by its allotted carrier frequency. If frequency of this carrier wave is varied with the modulating signal, frequency modulated wave is obtained.

Figure 23.2 illustrates the principle of frequency modulation (FM).

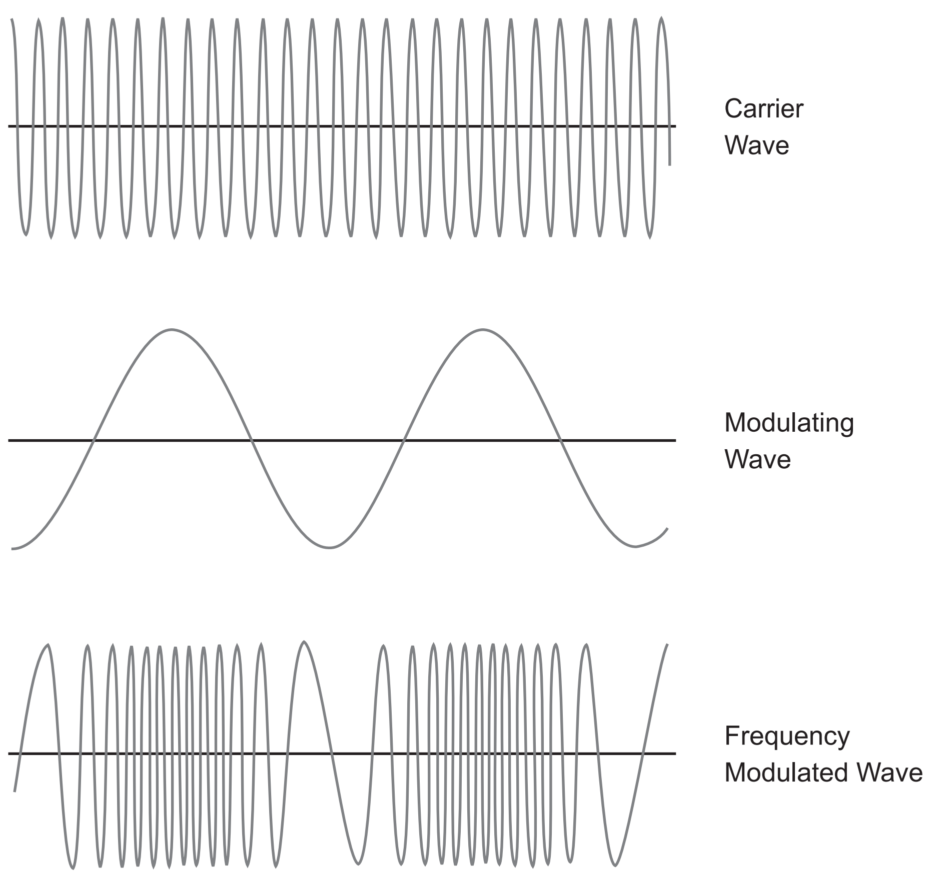


Figure 23.2: *The principle of frequency modulation*

Figure 23.2 shows three types of waves, namely carrier wave, modulating signal and the frequency modulated output wave. You should note the difference in wave shapes of the three waves. In all the three waves, the X-axis represents the time (i.e., number of cycles travelled by a wave in one second) and the Y-axis represents the amplitude. The first wave on the top is the un-modulated carrier wave. It represents the frequency of the radio station. Its amplitude and frequency remain constant. The middle one represents the audio signal, also known as the modulating signal. It is the signal that changes the frequency of carrier wave to get the FM wave (bottom wave). An important point to note here is that as the amplitude of modulating signal increases (during positive half cycle of modulating signal), the frequency of carrier wave also increases. As the amplitude of modulating signal decreases (during negative half cycle of modulating signal), the frequency of carrier wave also decreases. Another point which you should note here is that the amplitude of the carrier wave remains the same before and after modulation.

Frequency Deviation

The amplitude of the modulating signal causes the carrier frequency to deviate (shift) on both sides of its central frequency by a certain amount. This amount of deviation is measured in kHz. Deviation is proportional to the amplitude of the modulating voltage. If we increase the amplitude of the modulating signal, the deviation also increases. In the Indian system of FM broadcasting, the maximum deviation allowed is +/- 75 kHz, which is treated as equivalent to 100% modulation in case of amplitude modulated (AM) transmissions.

Example:

If 0.5V level of audio signal deviates the FM carrier frequency by 10 kHz, then the deviation produced by 2V level of audio signal will be 40 kHz {(10/0.5)x2 = 40}.

Deviation Ratio

The ratio of maximum deviation from the carrier frequency to the maximum frequency in the modulating signal is called the deviation ratio.

Deviation ratio = Maximum frequency deviation/Maximum frequency in the audio signal

A deviation ratio of 5 (75 kHz/15kHz = 5) is the maximum allowed in case of FM broadcasting.

Modulation Index

The rate at which the carrier frequency shifts from its centre frequency to give a certain deviation depends on the frequency of modulating signal. The ratio of frequency deviation to the frequency of modulating signal is called the modulating index.

Modulation index = Frequency deviation in kHz/ Modulating frequency in kHz.

For example, If 5 kHz audio frequency (1V level) causes a frequency deviation of 20 kHz, the modulation index will be 4 (20 kHz/5kHz =4).

Note It

Note that the change in modulating frequency (with same amplitude) does not change the deviation; however, it changes the modulation index.

Bandwidth in FM

In FM broadcasting, bandwidth is the frequency band around carrier frequency containing sidebands of significant amplitudes. Bandwidth is dependent on the number of sidebands produced by the modulating signal and varies with modulation index. It is a complex process. In practice, it is determined by a rule of thumb called Carson's Rule.

Carson's Rule

It states that the bandwidth of modulated FM wave is twice the sum of deviation and the highest modulating frequency. For example, if the maximum deviation is 75 kHz and the maximum modulating frequency present in the modulating AF frequency is 15 kHz, then according to Carson's Rule, bandwidth works out to be 180 kHz [2 (75 + 15) = 180 kHz].

To prevent adjacent channel interference, a guard band of 20 kHz is provided. Thus, the maximum permissible bandwidth in FM broadcasting is 200 kHz.

Pre-emphasis

In speech and music, amplitude levels of high frequencies are always much weaker than those of low frequencies. Therefore, high frequencies with low amplitude are not able to cause sufficient deviation in FM. This effect causes reduction of signal to noise ratio at high frequencies.

In order to overcome this problem, high frequencies in the programme content are boosted by passing them through an RC network having a time constant of 50 or 75 microseconds. In India, pre-emphasis with 50 microsecond time constant has been adapted.

De-emphasis

A corresponding attenuation to high frequencies is necessary to be given in the receiver to get back the original level of high frequencies. This process is called de-emphasis. The time constant of de-emphasis has to be same as that of pre-emphasis, that is, 50 microseconds. By now, you might have understood why it is necessary to follow the same standards for a transmitter and a receiver to be compatible.

Mono/Stereo Transmissions

Most of the programmes broadcast by the CR stations are monophonic. However, FM transmitters are capable of transmitting stereo programmes. For this, the transmitter has to be equipped with an inbuilt stereo encoder card to enable L and R channels of stereo signals to be broadcast on a single channel transmitter. The encoder combines the three components, namely mono signal (30 Hz to 15 kHz), stereo signal (23 kHz to 53 kHz) and pilot frequency (19 kHz) to give multiplexed output signal called 'MPX' signal. This composite MPX signal is then used to frequency modulate the carrier to give a frequency deviation of +/- 75 kHz. In order to standardize the transmissions, a pilot tone system is used for stereophonic transmissions. Here, a pilot frequency (19 kHz) is added (at a low level of about 10%) along with monophonic and stereophonic signals. This pilot tone is used by the receivers to detect the stereo broadcast.

Transmission of Radio Data System (RDS)/Subsidiary Channel Authorization (SCA)

Radio text data (like station code, auto tuning, traffic information) and a supplementary speech quality channel (like support commentary) can also be transmitted simultaneously in addition to monophonic and stereophonic programmes by using subcarriers of 57 kHz and 67 kHz respectively. With the addition of RDS and SCA signals, the composite multiplexed output signal gets modified as shown in Figure 23.3.

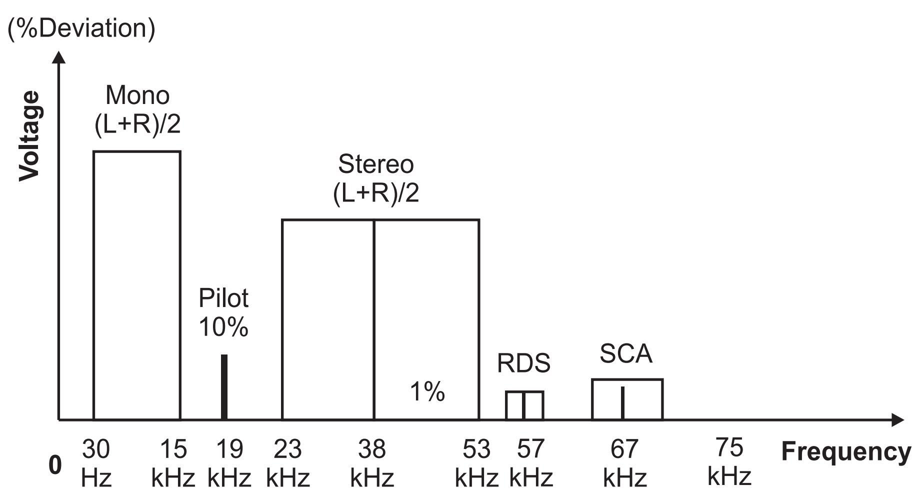


Figure 23.3: *Stereo multiplex baseband with RDS and SCA signals*

In Figure 23.3, the X-axis represents the frequency and the Y-axis represents the voltage or the percentage of deviation produced on each wave. Here also, you should note the relative placements of monophonic, stereophonic, RDS and SCA channels in the final composite multiplexed (MPX) output, called baseband signal. As can be seen in Figure 23.3, the monophonic transmission occupies the frequency band from 30 Hz to 15 kHz, whereas stereophonic transmission occupies a frequency band from 23 kHz to 53 kHz. Additional information to be broadcast using RDS and SCA is placed at 57 kHz and 67 kHz, respectively. The composite MPX output level is maintained in such a way that the maximum deviation due to this signal does not exceed +/- 75 kHz. Because of this feature of placement of frequencies, all these programmes can be simultaneously transmitted in FM. The listeners can receive any number of the programmes or data depending upon the availability of receivers/encoders with them.

Transmission Standards

In order to ensure compatibility of the transmitting and the receiving equipment, it is essential to have well-defined standards. Serious difficulties are felt by receiver manufacturers if uniform transmission standards are not adopted by the broadcasters. CCIR recommendation 450-1 defines the transmission standards for both monophonic and stereophonic transmissions (see Box 3).

Note It

Box 3

Transmission Standards for FM Broadcasting in India

1. Frequency Band = 88–108 MHz
2. Frequency Spacing = 100 kHz
3. Channel Bandwidth = 180 kHz
4. Max Frequency Deviation = +/- 75 kHz
5. Pre-emphasis Characteristics = 50 microseconds

A. Monophonic transmissions

1. Modulating frequency range (AF) = up 15 kHz

B. Stereophonic, RDS and SCA transmissions

1. Pilot tone system using frequency of 19 kHz

2. Sub carrier frequency for stereo = 38 kHz
3. Amplitude modulated with suppressed subcarrier system is used
4. Sidebands = +/–15 kHz of 38 kHz
5. Stereo channel (L – R difference signal)bandwidth = 30 kHz (23 kHz–53 kHz)
6. RDS sub carrier = 57 kHz (Deviation +/–2.2 kHz)
7. SCA sub carrier = 67 kHz (Deviation +/–5 kHz)

Activity 23.4

To complete this activity, you may need about 15 minutes including writing down the answers in the space provided.

This activity will help you in learning and understanding the basic principles of FM transmission.

Question: 1 What is frequency modulation (FM)? How does it differ from amplitude modulation (AM)?

Question: 2 What is meant by the term 'frequency deviation'? How much change in frequency deviation do you expect if the level of modulating audio signal is doubled?

Question: 3 Why are transmission standards necessary in FM broadcasting?

23.10 Antenna (Types and Polarization)

In this section, you will learn about the types of antenna and polarization used in CR stations. While only the functional details will be described in this section, more details of these components will be given in Unit 25.

The frequency modulated output of the transmitter is fed to the FM antenna via a low-loss coaxial cable.

Antenna is the final component in the transmission chain which actually converts the modulated FM carrier into electromagnetic waves.

Types of Antennae and Polarization

Different types of antenna are used in FM broadcasting. Practical antennae are classified into different types on the basis of their size, shape, method of mounting and the polarization used. The shape can be straight, folded, loop or helix. The basic type of antenna used is the dipole antenna. When the total length of two parts of the dipole antenna is equal to a half wavelength, it is called a half-wave dipole. When a number of radiating elements are mounted one above the other, it is called an antenna array. This increases the gain of the antenna. In most CR stations, 2-bay antennae are used.

Polarization is defined as the orientation of electric field component of the electromagnetic wave with respect to the ground plane. Three types of polarizations are used in FM broadcasting, namely,

- Horizontal
- Vertical
- Circular

Vertical polarization is most commonly used in CR stations especially because of its ability of providing higher and better signals in the case of portable radios.

Transmitter output is connected to an antenna through a coaxial cable. You will learn about the details regarding this in the next unit.

Activity 23.5

To complete this activity, you may need about 10 minutes including writing down the answers in the space provided. This activity will help you in understanding the functional characteristics of antenna system.

Question: 1 What is the function of an antenna in a transmission chain? Which type of antenna is commonly used in CR stations? What will happen if a 4-bay antenna is used instead of a 2-bay antenna?

Question: 2 Write down the names of three types of antenna polarizations used in FM broadcasting. Which type of polarization is preferred for a CR station?

(i) ....

(ii) ....

(iii)..

23.11 Let Us Sum Up

In this unit on 'Components of Transmission Chain', you have learnt that:

- A transmission chain starts with an audio mixer through which the presenter plays back the selected pre-recorded or live programme and connects it to the next stage after controlling its levels.
- Pre-recorded transmissions can also be sent to the next stage automatically as scheduled by the operator by use of audio workstations.
- Physical cable pairs provide connectivity between the studio and the transmitter.
- In order to maintain proper transmission standards, the output level and impedance of each equipment must match with the input level and impedance of the following stage.
- An audio processor is used to process and control the signal levels before feeding them to the transmitter. Basically, it performs two functions. It compresses the signal to increase average modulation or loudness and limits the peaks that exceed beyond safe limit.
- An FM transmitter is a device that converts audio signals to frequency modulated (FM) radio frequency (RF) signals. The amplifier stages in the transmitter boost the level of RF signal to the desired output power (e.g., 50 or 100 Watts).
- Frequency modulation (FM) is the type of modulation through which the message contained in the audio signals is superimposed on the carrier wave by changing its frequency. The amount of shift in the carrier wave (called deviation) is proportional to the amplitude of the audio frequency. In FM broadcasting, the maximum deviation allowed is +/- 75 kHz.
- In case of stereo transmissions, a pilot tone system is followed in which a pilot frequency of 19 kHz is transmitted at a low level along with mono and stereo signals.
- The output of transmitter is fed to an antenna system by the use of a low-loss coaxial cable. The final component of the chain is the antenna, which converts the RF power output of the transmitter into electromagnetic (EM) waves.

23.12 Model Answers to Activities

Answers to Questions from Activities 23.1 to 23.5.

Activity 23.1

1. A console, which is used for transmission of different programmes simultaneously on air, is called a live or transmission console, whereas a normal production console is used in studios to record a new programme.
2. A VU (volume unit) meter normally measures the average level of audio signals in volume units. A '0' VU corresponds to a voltage level of 1.23 volts (RMS) of an alternating frequency of 1,000 Hz measured across 600 ohm load. This is equal to + 4 dB_u on a decibel scale with reference to 0.775 volts.
3. A decibel (dB) is a logarithmic unit indicating the ratios of the audio levels relative to specified reference level. A decibel symbol is often written with a suffix that indicates which quantity has been used as reference. A dB_m indicates that 1 milliwatt is taken as reference, whereas dB_u means 0.775 V (RMS) has been taken as reference.

Activity 23.2

An audio workstation is a computer-based system that is designed to work as an all-in-one machine. It can be used for recording, editing, storing, retrieving and playing back any programme at any time. Selecting a desired programme from a library of stored programmes has become as fast as a click of a mouse. Because of these features, the use of audio workstations is becoming more popular in CRS. Apart from the above mentioned functions, other important features include auto-scheduling, logging of time/date and programme information, and automatic fault diagnostics.

Activity 23.3

1. A suitable line or link connectivity is required for feeding the programmes from the output of transmission studio to the input of the transmitter.
2. Connectivity (line or link) should not offer any attenuation (loss) to the audio signals. Its frequency response should be flat up to 15 kHz. It should not have any noise, distortion or break.
3. A compressor circuit compresses the dynamic range of the programme according to the preset ratio to increase the average modulation level (loudness). The limiter circuit limits the peaks in the programmes to protect the transmitter from over-modulation.

Activity 23.4

1 In frequency modulation (FM), the frequency of the carrier wave is changed in accordance with the instantaneous amplitude of the modulating signal. In amplitude modulation (AM), the amplitude of the carrier wave is changed in accordance with the instantaneous amplitude of the modulating signal.

2 The amplitude of the modulating signal causes the carrier frequency to deviate (shift) on both sides of its central frequency by certain amount expressed in kHz. This shift in frequency is called frequency deviation. If amplitude of the modulating signal is doubled, the deviation produced will also be doubled.

3 Transmission standards are necessary to ensure compatibility of transmitting and receiving equipment. For example, a receiver manufacturer must know the system of modulation used in the transmitter.

Activity 23.5

1 The function of an antenna is to emit the RF output of the transmitter as electromagnetic (EM) waves into the air medium. A 2-bay vertically polarized antenna is commonly used in CRS. By using a 4-bay antenna, the antenna gain will increase, thereby increasing the coverage.

2 Three types of antenna polarizations used are horizontal, vertical and circular polarizations. Vertical polarization is commonly used in CRS.

UNIT 24

Components of FM Transmitter

Structure

24.1 Introduction

As you know by now, the FM transmitter is one of the most critical components in the transmission chain. It is a piece of equipment without which a CR station cannot exist. A technician engaged in running a CR station must understand the FM transmitter in a greater detail, with its general designing concepts, various blocks and functions, areas of vulnerability, precautionary maintenance and troubleshooting. In this unit, you will learn about the various components of an FM transmitter. Many of these components are essentially used in community broadcast, while some of the components that you will find here may not be found in transmitters used in community broadcast systems. However, it is necessary for you to understand how an FM transmitter in its totality looks like. After understanding the basic transmitter in this unit, you will learn about transmitting antenna and propagation in the subsequent units.
Thereafter, you will get an opportunity to have hands-on practical on a transmitter to get familiarized with practical aspects. You will take about eight hours to complete this unit.

24.2 Learning Outcomes

After going through this unit, you will be able to:

- identify various parts of an FM transmitter.
- clearly explain its functions and understand its criticality.
- identify faults and suggest remedial measures.
- outline the basic maintenance of a transmitter.

24.3 FM Transmitter Overview

An FM transmitter comprises the following main units:

- Power supply
- Exciter
- Modulator
- Amplifier
- Filter

A block diagram of the transmitter is shown in Figure 24.1.

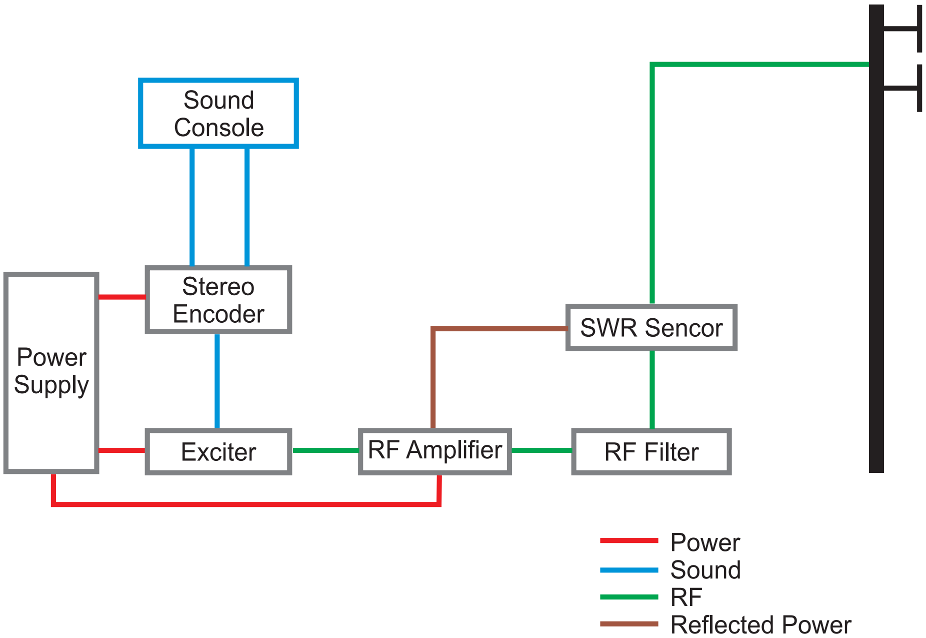


Figure 24.1: *Block diagram of an FM transmitter*

Opened out details of the transmitter

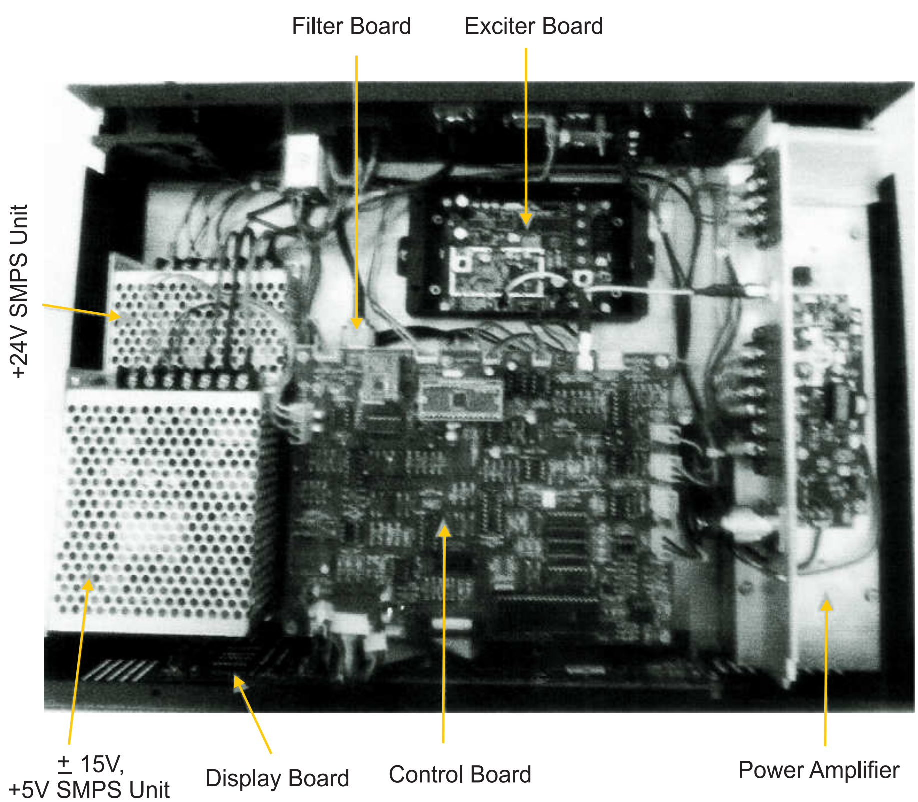


Figure 24.2: *Opened out details of a transmitter*

Detailed descriptions of the different units of a transmitter are given in the sections below.

24.4 Power Supply

It is very important to understand power supply in greater detail for proper handling of the transmission system. It has been observed that malfunctioning of power supply is responsible for different troubles that creep into the transmission system. To understand power supply, you have to first understand alternate current, its conversion to direct current and supply of different voltages to the transmission system.

24.4.1 Alternate Current

You have learnt about alternate current in the unit titled 'Basics of Electricity'. Alternating current supply, as you may know, approximates 230 V in 50 Hertz cycle that powers most of the appliances in our homes. When you plug in any home appliance like TV or washing machine, you don't know what is really flowing out of the wall socket as you assume that it would be a supply of 230 V.

However, when you power in a sophisticated and critical component like an FM transmitter, it is important to know whether what is flowing out of the wall socket is appropriate for the system.

How to check the wall socket is a subject that you have already learnt in the unit on Basics of Electricity, but here it is necessary to ascertain whether the quality of the cable and the plug that supplies 230 V AC power to the transmitter is proper and supplies consistent power to the transmitter. Generally, the cable is supplied by the transmitter manufacturer based on the flow of current required by the transmitter. An engineer's job is to ascertain that the same and not a similar cable is used for this purpose. If for some reason the cable is misplaced or has become faulty, which is highly unlikely, it is necessary to check with the manufacturer the type of cable that should be used.

In many cases you must have seen that the cable that has a three pin plug on one end does not fit properly in the socket due to use of a non-standard socket. In such cases, do not use any temporary measures and arrange for a proper cable.

24.4.2 Switch Mode Power Supply (SMPS)

Since most of the units of the transmitter require DC supply for its operation, almost all the transmitters convert 230 V AC power to DC power of various voltages as per the requirement of the transmitter. This function is carried out by a Switch Mode Power Supply (SMPS). SMPS is used in almost everything in our day-to-day life. Take any electronic device that is handy to you right now, for example, your mobile phone. The charger of your mobile phone is an SMPS. It takes 230 V AC from your wall socket and supplies the required DC current to your mobile battery for charging. Similarly, the charger of a laptop is also an SMPS. If you open a computer box, you will find an SMPS inside, supplying power to the various components of the computer like mother board, DVD ROM, or hard disk.

In a normal FM transmitter, there is a requirement of different DC voltages for different functions. In some transmitters, a single SMPS supplies different voltages, whereas in some transmitters, different voltages are supplied by different SMPS.

All SMPS units have both input and output. In most cases, the input would be 230 V AC current, whereas the output will differ based on the design of the transmitter or a specific function that the SMPS is expected to carry out.

24.5 Audio Processing

24.5.1 Compressor/Limiter

In many transmitters, especially designed for low-powered and low-cost community radio transmitters, the compressor is found within the transmitter box. You have learnt about the function of compressors in greater details in Unit 23 titled “Component of Broadcast Chain”. The limiter or compressor that is found inside the transmitter box or sometimes even part of the exciter has no or very little manual control. These limiter exciters are optimized at 100 per cent for broadcast. That means it will give a consistent level of sound without over-modulating the transmitter.

As you already know, compressor/ limiter is an automatic volume/level control or, let us say, programmed volume/level control that keeps the audio level at a consistent loudness. When someone speaks too loud, it will automatically reduce the volume and when someone speaks too softly, it will automatically increase the volume.

24.5.2 Stereo Encoder

You have studied about stereo sound in Unit 9 on Basics of Sound. Stereo is a sound that is divided into left and right channels given to different speakers. Now you may wonder what if you want to broadcast stereo sound (two L and R channels) through your transmitter. The problem here is that the transmitter works only on one frequency and cannot carry two different channels-left and right-in the stereo.

The solution is that you combine the two channels into one signal and feed it to the transmitter. This process is called multiplexing/encoding. Any stereo tuner receiving this signal decodes the multiplex back into separate left and right audio signals. The stereo coder and the receiver decoder synchronize with each other using a 19 kHz pilot tone, which is also added to the multiplex signal. Thus, the decoded signal will play out of a stereo radio in two separate channels-left and right-with two speakers attached to the radio.

Please note that most transmitters used in CR stations transmit it mono. There are two reasons for this. The most important reason is that most of the radio receivers used by the community members are low-cost mono. So, even if a CR transmits stereo signals, a majority of its listeners are going to listen it in mono. Second, reception of stereophonic signal requires higher signal. As a result, a stereo transmitter may have smaller coverage area as compared to a mono transmitter of the same power.

24.6 Exciter

Exciter is a very important part of the transmission system. The exciter, as its name suggests, excites the transmission system. In this part, radio signals of low power are generated, locked to a frequency and then modulated with audio frequency. This clearly means that there are three processes taking place here simultaneously. To understand the functioning of an exciter, you need to study radio signal generation, locking it to a frequency and modulating it to carry the audio signal.

It would be sufficient here to know that radio signals are generated through oscillation at a desired frequency. To achieve the desired frequency, all modern transmitters use a technology called phase-locked loop. This technology is used to ensure that oscillation does not deviate from the desired frequency.

24.6.1 Phase-locked Loop (PLL)

PLL is the abbreviation of phase-locked loop, a concept that is widely used in any kind of synchronization process. In a transmitter, it is used to achieve a steady frequency, say 90.4 MHz, at which a transmitter would radiate.

In the world of electronics, it is quite a complex concept, but for our purpose let us try and understand with an example. Every household in your neighborhood will have a wall clock and you must have noticed many of them showing slightly different time. Now, if these clocks are left to themselves, your neighborhood will never know what the accurate time is. So, you need to introduce one reference time, which could be Indian Standard Time (IST). Thus, every time a clock deviates, the owner of the clock can adjust the time to IST. Now imagine this process is automatized. Every time a clock deviates from the IST, it corrects itself. This kind of mechanism can be put in place with PLL.

In the case of CR transmitters, every time a frequency oscillator deviates from a set frequency–let us say, 90.4 MHz–an electronic circuit brings the oscillation back to 90.4 MHz. Thus, frequency generation with PLL becomes rock steady.

24.6.2 Audio Modulation

Now, your exciter has generated the frequency that needs to be modulated with sound. Remember the full form of FM-frequency modulation. As you know, sound broadcasting can be carried by two different modes. One is called amplitude modulation (AM) and the other is called frequency modulation (FM). You have already learnt about them in Unit 24. For recapitulation, however, the wave forms of both these types of modulated signals are reproduced in Figure 24.3.

In an exciter, there is a process of modulating radio frequency with audio signals in frequency modulation mode. It is here that the signal to noise ratio is determined and so also the level of modulation. It is also here that where the modulation level is generally adjusted.

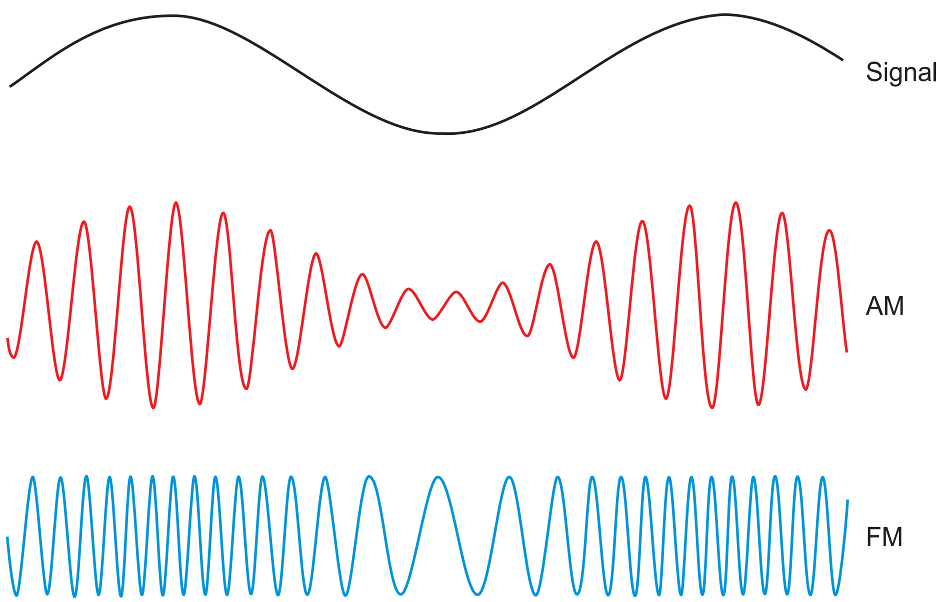


Figure 24.3: *AM and FM modulation*

24.6.3 First Stage Amplification

The modulated frequency generated with the help of PLL is generally very low in terms of power. It may be sometimes in a few milliwatts. Before the RF power is supplied to the amplifier, it needs to be pre-amplified to a level suitable for the amplifier design. For example, if your amplifier is designed to give 20 dB gain (You may find this in detail in the technical specification document provided by your transmitter manufacturer), then 1 W of RF power will be amplified to 100 W. That makes it necessary for the exciter to generate 1 W, so that an amplifier can amplify it to 100 W.

Activity 24.1

Answer the following questions:

Question-1: What is the role of a PLL circuit?

Question 2: Draw a diagram showing amplitude modulation and frequency modulation and briefly explain the difference between the two.

Question 3: If possible, visit the nearest CR station and check power output of the exciter. You may refer to the manufacturer's literature. Write your observations.

24.7 Amplifier

RF amplification is a complex process. To begin with, it requires a low power radio signal that will have to pass through the final stage output transistor and induction coils. Also required is a filter circuit to cut out spurious and harmonics. Here, we will discuss the important components/process of amplification.

24.7.1 SMPS

As discussed earlier, the amplifier of the transmitter will require DC voltage. The power unit inside your transmitter box, known as SMPS, would be giving necessary DC voltage to the amplifier. In any transmitter, this would be the most critical and vulnerable component. If you find your amplifier not working, the first thing you need to check if the SMPS output voltage being supplied to the amplifier.

24.7.2 RF Input

The main function of an amplifier is to take small amount of RF power and amplify it to the necessary levels. That means there would be an RF power inlet in the amplifier. Different amplifiers have different input sockets: some use SO239 or UHF type sockets; some may use N type sockets; and some amplifiers use BNC types. If your exciter unit and amplifier unit are in the same box, the connectivity may differ. But remember that RF power is never carried anywhere without shielded cables. So, from the exciter unit to the amplifier you will see a coaxial cable, which transports the RF power to the amplifier.

24.7.3 Main Pallet (Circuit Board)

The main pallet is the printed circuit board that handles the entire amplification process. On this board you will find various coils, trimmers, RF chokes and other electronic components. Unless you are in a position to understand the whole process in great detail, it is most advisable to refrain from touching this part of the amplifier in the absence of proper tools and testing equipment.

24.7.4 Heat Sink

Most of the amplifier pallets are mounted on a heat sink, which is made of high grade aluminium blocks designed in such a way that it has the maximum surface area in a small form factor to absorb and radiate maximum heat. As the amplifier will generate radio frequency signals, it will also generate heat in proportion to the RF power. This heat has to be captured and thrown away from the amplifier unit. The heat sinks are used to capture all the heat that the amplification process generates.

The heat sink is supplemented by DC fans. In some transmitters, the fans are used to bring in cool air from outside in the transmitter box to keep the heat sink cooler. In some cases, the fans are used for throwing out hot air. But in many transmitters the fans work in both directions, that is, bring in cool air and throw out hot air. Fans are the only moving parts in the transmitter and quite likely to develop snag. These fans have ball bearings that can be damaged by their close proximity to RF.

24.7.5 Main Output Transistor

This output transistor is the core of your entire transmission system. It is this electronic part that generates the power output. It is one of the most expensive and vulnerable parts in the transmitter. It can easily be destroyed and, once damaged, it cannot be repaired. It is advisable not to touch or fiddle with it during maintenance

24.7.6 Standing Wave Ratio (SWR) Mismatch and Thermal Protection

Advanced transmitters available in the market have built-in protection for high SWR and thermal overloads. The function of the SWR protection circuit is to ensure that the transmitter is protected against very high SWR by switching off the transmitter (You will learn about it in the unit on Antenna). This circuit will fold up the power of the transmitter if it detects a very high SWR. The high SWR could be caused by many conditions such as damage to the antenna, break in the feeder cable or malfunctioning of connectors. If this condition persists, the reflected power will damage or sometimes even destroy the main output transistor.

Similarly, if the cooling mechanism of the transmitter fails, the transmitter will start getting heated up due to RF power. Thermal overload protection is provided to take care of this eventuality and shut down the transmitter.

24.7.7. Display Panel

Though it is not absolutely necessary, it is quite useful to have a display panel on the transmitter. This panel displays operating parameters of a transmitter when switched on. It could display the following parameters:

- Operating Frequency
- Output Power
- Reflected Power

Audio Levels or Modulation Levels

There are many advanced transmitters that provide the facility of changing certain parameters like frequency. But all transmitters do not let the user change the parameters from the control panel.

Please note that parameters shown in the display are for reference only. Sometimes the actual parameters measured with calibrated test equipment, which you may otherwise not find in a CR station, could differ from what is displayed in the built-in display panel.

24.7.8 Filter

Every oscillation process generates spurious signals, which are not intended to be generated. These signals could be anywhere in the radio frequency spectrum. They could even be harmonics in the exact multiple of the operating frequency but in a completely different band of spectrum. The spurious signals do not affect your transmission as much as it affects other equipment that may be using RF spectrum. Any transmitter that generates a spurious beyond the prescribed limit is known as a “dirty transmitter”.

ITU(R) and other national regulatory bodies have specified limits for spurious and harmonic radiations. It is, therefore, necessary that a transmitter filters out such radiations. For this purpose, all transmitters have a filter that suppresses the spurious and harmonious signals. There are different designs of filters but all of them are located at the last stage before the RF signals go out to the antenna through the feeder cable.

24.7.9 Switchover Panel

There is a general practice in radio stations to always keep a back-up transmitter. If one of the transmitters fails, the broadcast could be switched over to the spare transmitter. A community FM transmitter can use an automatic switchover system or a manual switchover system for this purpose. In an automatic system, both the transmitters are kept simultaneously switched on. The power of one transmitter is sent to the antenna system, while the second transmitter power would be sent to a dummy load that will convert the power into heat and absorb.

In the case of a manual system, you have to physically disconnect the malfunctioning transmitter from the audio and antenna system and connect the spare transmitter.

If your station is well-designed and you are well versed with the process of switching over, it may take less than a minute.

Please remember that automatic switchover panel would consume a bit of power. In high-powered systems, like that of a commercial radio station, this loss of power could be considered negligible, but in a CR station where the permitted power is just 50 W, even a single watt loss is undesirable. For this reason, most CR stations prefer manual switchover.

24.8 Transmitter Maintenance and Fault Diagnosis

After getting an idea about the components of an FM transmitter and the functions of its parts, it will be desirable to have an idea about the basic maintenance of an FM transmitter and fault diagnosis techniques. These are detailed below:

Note It

Box-1

Transmitter Maintanance and Checkup

A transmitter is very critical and perhaps one of the most expensive pieces of equipment in a CR station. Experience shows that an FM transmitter can run flawlessly for years if it is installed properly and maintained with meticulous regularity. Here are some of the maintenance tasks that should be carried out on daily, weekly and monthly bases.

Daily Tasks:

1. Ensure that the transmitter area/room is properly cleaned and no dust is allowed to settle in any corner.
2. Check the power and reflected power on the front panel and make a note of it in a log book so that if any fault is developing you have a historic perspective.

3. Check the modulation levels on the front panel and audio quality on a standard radio receiver. Look out for any hum or unusual sound.
4. Check all the connectors for any visible sign of stress, heat or any abnormality.
5. Give a visual check of the antenna system and see if there is any misalignment.

Weekly Tasks:

1. Take a weekly maintenance shutdown if your radio station is running 24 hours.
2. Check the phase, neutral and earthing of your AC power supply. Use multi meter for the purpose.
3. In monsoon season ensure that humidity level is under control in the transmitter area

Monthly Task

1. If you have manually switchable 1+1 configuration, then switch the operational transmitter from A to B or the reverse.
2. De-dust the transmitter with an air blower. Remember to necessarily open the lead of the transmitter. An electric blower (not the one used for hair styling) is generally used for cleaning.

Note It

Box 2

Troubleshooting:

If one fine morning, or not so fine morning, you start receiving calls from your listeners that they cannot hear anything, or you switch on the transmitter and the power indicator does not show power or shows inadequate power, the first thing you should do is not to panic. Please follow the diagnosis methodology as mentioned here.

- First of all, tune your radio to the frequency of your radio station. If you hear complete silence, it means the transmitter is working fine but the trouble is with your speech input equipment. Check your mixer or the source output and also the connectivity between your audio source and the transmitter.

- If your callers say they cannot hear anything, please calm them down and ask the following questions:
  - Ascertain if they cannot hear anything or they can hear your station with a lot of noise.
  - Ask what kind of radio receiver they are using.
  - Ask since when they have been facing this trouble.
- Give a quick look at the front panel power meter on your transmitter. Check the forward and reflected power. You may come across the following situations:
  - Power is very less than stipulated 50 W: In this circumstance, first check the reflected power. If it shows more than 1.8 SWR, you know that the trouble is with your antenna system. Check all connectivity and the antenna alignment. In such circumstances, it is advisable to switch off the transmitter or switch over to a back-up transmitter.
  - You may see there is no power at all: In this situation, tune in your radio receiver close to the transmitter, if you cannot hear your station at all, then the origin of the fault could be at the exciter level. But if you can hear your station well, it means the amplification process is not working due to some fault in the amplifier.

Even if you find the fault, do not carry out any repair before talking to the supplier of your transmitter. Please call your supplier, explain the problem and discuss your diagnosis before you carry out any repair.

Activity 24.2

Answer the following questions

Question 1: What is the function of an RF filter?

Question 2: Draw a block diagram of a transmitter describing the generation of an RF carrier, modulation and process of amplification.

24.9 Let Us Sum Up

Now we know that an FM transmitter is divided mainly in two sections, namely an exciter and an amplifier. Both the sections could be in one box or separate boxes. Both the sections will require separate DC power current, which is provided by a Switch Mode Power Supply (SMPS).

The exciter generates small amount of RF power and supplies it to the amplifier, which in turn amplifies the power and propagates it through an antenna. This simple process also involves modulation of frequency with sound and filtration of spurious and harmonics. All transmitters have front panel display that shows some of the basic parameters like operating frequency, output power, reflected power, modulation levels, etc. A good transmitter must have a thermal and SWR protection.

Remember a transmitter does not require much tweaking once installed correctly. All that a technician is expected to do is to keep the transmitter in a clean and dust-free environment and regularly monitor its operations.

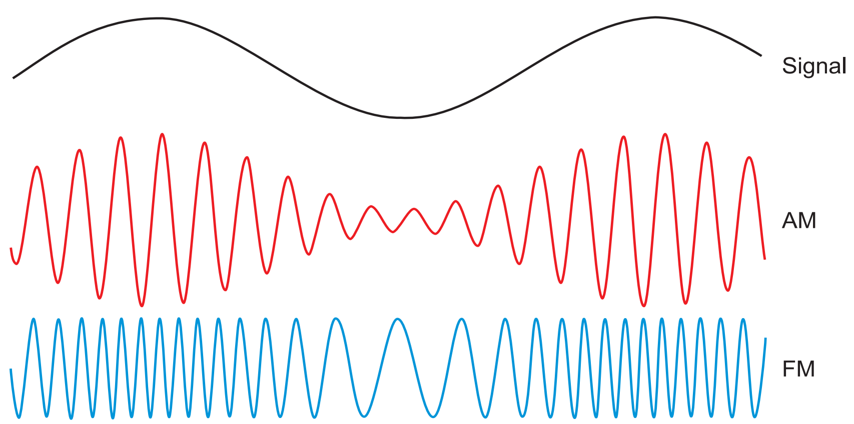
24.10 Modal Answers to Activities

Activity 24.1

1. A phase-locked loop (PLL) is a control system that generates output based on input reference signal. A PLL circuit comprises a variable frequency oscillator and phase detector. The circuit takes the phase of an output oscillator and compares its frequency with the phase of the input and its frequency. On any variation it corrects the frequency of output phase.

   In a CR transmitter, the PLL is used at the exciter stage to lock the exciter frequency to the desired frequency allocated to the radio station by the government (WPC, DOT).

   PLLs are widely used in many types of electronic applications including radio, telecommunications and computers.



2. As can be seen in the diagram, in the case of AM the sound signal affects the amplitude of the carrier wave, whereas in FM the frequency of the carrier itself is modulated with the sound wave. The difference is that AM can travel very long distance but the sound quality is not as good, whereas in FM, though it travels comparatively shorter distance, it produces a very good sound quality.

Activity: 24.2

1. As we all know, the oscillation process produces some amount of spurious and harmonics. Spurious is a frequency not deliberately created but gets generated in the process of oscillation. Any other signal that a transmitter generates outside its desired frequency is called harmonics. There are international standards for spurious and harmonics.

   An RF filter is designed to filter out these spurious and harmonics so that a transmitter does not generate a signal that can interfere with other devices. In short, it keeps the spectrum clean.

24.11 Additional Readings

- Gibilisco, S. (2002). *Teach yourself electricity and electronics*. New York: McGraw Hill.
- Noll, A. Michael. (2001). *Principles of modern communications technology.* Artech House.
- HYPERLINK “http://www.itu.int/rec/R-REC-BS.450-3-200111-I/en”Transmission standards for FM sound broadcasting at VHFHYPERLINK “http://www.itu.int/rec/R-REC-BS.450-3-200111-I/en”. *ITU Rec. BS.450*. International Telecommunications Union.

UNIT 25

FM Antenna and Coaxial Cable

Structure

25.1 Introduction

In Unit 23, you learnt about the components of a transmission chain. Then in Unit 24, you learnt about the main component of the transmission chain, the FM transmitter. The output of the transmitter is connected to the antenna for on-air broadcast of RF signals. You were introduced to the types of antenna and polarization in Unit 23. In this unit, you will learn about the constructional details, technical specifications, functions and application aspects of the following components of the complete antenna system.

- Dummy load
- Coaxial cable
- Antenna system
- Supporting structure of antenna system
- Lightning arrestor
- Grounding system

As a part of this unit, in the video on "Types of Antenna and Installation", you will see the different types of antennae and their mounting arrangements on towers/ poles. You will also see how tower foundations, grounding and lightning arrestor arrangements are provided in a typical CR station.

You will learn about propagation and coverage aspects linked with the different types of antennae in the next unit, that is Unit 26, on propagation and coverage aspects.

You may need about 6 hours to complete this unit including answering the questions given in the activities.

25.2 Learning Outcomes

After reading this unit, you will be able to:

- list and describe the types of dummy load, coaxial cables, FM antennae and supporting towers used in a typical CR station.
- describe the constructional details of dummy load and its application.
- describe the constructional details of coaxial cables and their characteristics.
- identify and describe different types of FM antennae.
- define polarization and underline the significance of different types of polarization.

- differentiate between horizontal and vertical radiation patterns produced by practical antennae.
- list and describe different types of towers used in CR stations.
- explain the meaning and significance of VSWR.
- justify the necessity of lightning arrestor and grounding system.

We will begin with dummy load.

25.3 Dummy Load

In this section, you will learn about the purpose, constructional details and working principle of dummy loads provided in CR stations.

Dummy load is a device that is used to test the working of a transmitter before its output is connected to a cable and an antenna. The difference between a dummy load and an antenna is that a dummy load converts the RF energy into heat and not into electromagnetic waves, as is done by an antenna. Dummy loads are available in different types depending upon their power handling capacities. Dummy loads used for testing of high-power transmitters require forced air or water cooling. Since the power of a transmitter to be tested in CR stations is of the order of only 50 to 100 W, a small dummy load capable of dissipating a power of 100 W with convection cooling is sufficient.

Figure 25.1 shows the cut-out details of a typical dummy load capable of dissipating 100 W power, which is commonly used in CR stations.

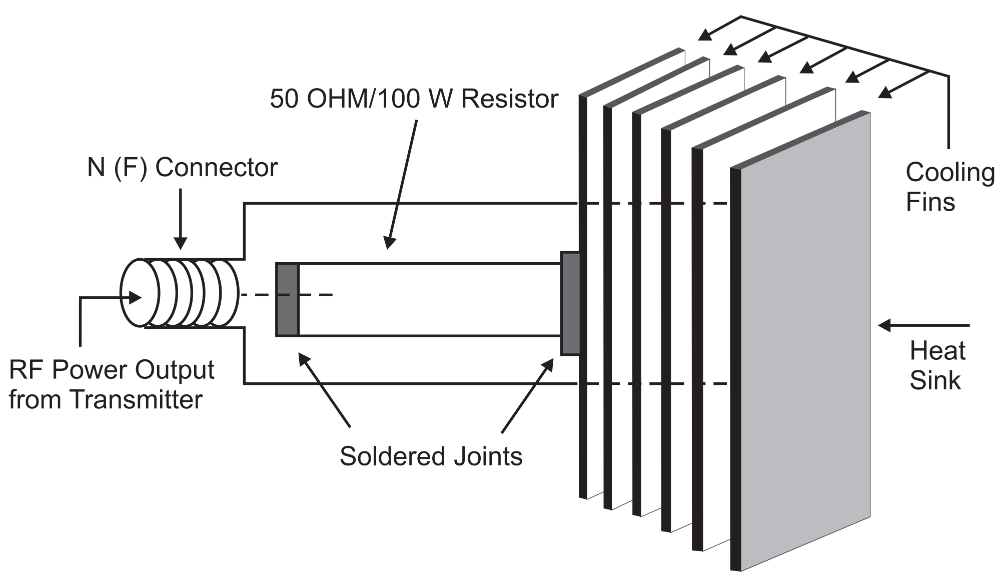


Figure 25.1: *Cut-out details of dummy load*

As can be seen in Figure 25.1, a dummy load consists of a 50 ohm/100 W non-inductive carbon resistor mounted on a heat sink having a large surface area and fins to dissipate the heat. One terminal of the resistor is connected to an 'N' (Female) type of connector and the other terminal is connected to the body of heat sink. When RF power of transmitter is connected to a dummy load via 'N' connector, it gets heated like any other heater. The heat produced in the resistor is dissipated in air by the heat sink. The surface area of heat sink is large enough to dissipate heat generated in the resistor to the surrounding air without raising its temperature.

The basic technical specifications/requirements of a dummy load are as follows:

- It should be purely resistive.
- It should not radiate RF energy in the air medium.
- Its power dissipation capacity must not be less than that of transmitter power.
- Its impedance should remain constant and should not vary with application of RF power.
- VSWR (Voltage Standing Wave Ratio, which will be explained later) of a perfectly matched dummy load is unity (1:1) but should not exceed 1.05:1.

Specifications of different models supplied by different firms vary according to the design of their products but you have to see that the minimum specified requirements are met while selecting a dummy load.

Activity 25.1

To complete this activity, you may need about 10 minutes including writing down the answers in the space provided. This activity will help you in understanding the constructional and functional details of the dummy loads.

Question 1: What is the purpose of providing a dummy load in a CR station?

Question 2: Why are non-inductive resistors used in the construction of a dummy load?

Question 3: Why are fins and a large surface area provided in a dummy load?

Question 4: What should be the input impedance of a dummy load?

Question 5: Why are water-cooled/oil-cooled dummy loads used with high-power FM transmitters?

Now let us discuss the next important component of a transmission chain, that is, a coaxial cable and connectors.

25.4 Coaxial Cables and Connectors

In this section, you will learn about the purpose, constructional details and characteristics of the types of coaxial cables commonly used in CR stations.

The cables used for connecting the RF output of a transmitter to the antenna system are called coaxial cables. They come in different sizes and ratings. The size and type of coaxial cable depends on the power of the transmitter and attenuation (loss) of cable at the operating frequency. Since CRS set-up consists of a low power transmitter of the order of 50 W to 100 W, a low-loss cable of ½" size having foam dielectric is sufficient. Figure 25.2 shows the constructional details of a typical coaxial cable.

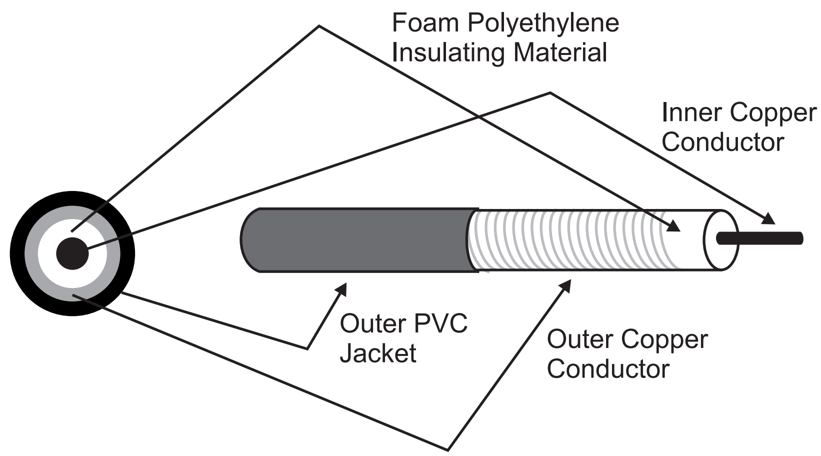


***Figure 25.2**: Schematic diagram showing construction of coaxial cable*

As can be seen in Figure 25.2, a coaxial cable is made of two conductors, called the inner conductor and the outer conductor. The inner conductor is usually made of aluminium or copper and the outer conductor is made of corrugated copper sheet. The inner conductor is held in central position of the outer tubular conductor throughout the length of the cable by use of a uniform layer of insulating foam polyethylene dielectric material. A protective layer of PVC jacket is provided over the outer conductor to avoid any possible damage during handling and use.

Materials used for making inner and outer conductors may vary from manufacturer to manufacturer. However, the constructional design remains the same. Higher sized cables (Cables of size higher than 7/8") are available with air or foam dielectric which can be procured as desired by the user. Cables with air dielectric require pressurization to avoid entry moisture in them.

Important terms/specifications commonly used in identification and selection of coaxial cables are as follows:

Characteristic Impedance

The characteristic impedance of a coaxial cable, usually denoted as $Z_{0,}$ is defined as the ratio of the voltage to the current for a single propagating wave (frequency). Its unit of measurement is ohms. The characteristic impedance of a coaxial cable normally used in CRS is 50 ohms.

Power Rating

The power rating of a cable is the average power that it can transfer continuously to the antenna system without any heating and change in its designed parameters at its operating frequency. It is frequency dependent. The average power rating decreases as the operating frequency increases. Its unit of measurement is watts or kilowatts.

Attenuation

When any RF signal travels in a coaxial cable, its power gets attenuated over the length of the coaxial cable. This attenuation or loss is expressed in dB (decibels) per 100 metre length.

See Box 1 for its mathematical formula.

Box 1

The attenuation (α) of RF cables is defined as follows:

$$\alpha = 10 \log (P_1/P_2) \text{ in dB/100m}$$

where,

P_1 = Input power fed into a cable terminated with the nominal value of its characteristic impedance

P_2 = Power reached at the end of the cable

Attenuation is the frequency dependent and is expressed as dB per unit of length. It increases as the frequency increases.

The material used in construction of the cable affects all the three parameters of a coaxial cable, as mentioned above.

Cables are normally received with end connectors connected to them. In case, if it is necessary to fix connectors on site, appropriate connectors as recommended by the manufacturer are to be used. You will learn more about the method of fixing these connectors in Unit 29 and practical workshop.

Activity 25.2

To complete this activity, you may need about 10 minutes including writing down the answers in the space provided.This activity will help you in understanding the characteristics of an RF coaxial cable.

Question 1: Why should we use a low-loss cable in a CRS?

Question 2: What type of dielectric material is used between inner and outer conductors of a typical ½" coaxial used in CRS?

Question 3: What do you mean by the term characteristic impedance of a coaxial cable?

Question 4: 50 W output of a transmitter is fed to an antenna. Calculate the attenuation in decibel units if only 25 W reaches the antenna?

Question 5: What is the relation between average power rating and frequency of operation in an RF coaxial cable?

Now we move to the last and most important component in a transmission chain in a CR station, that is, its antenna system.

25.5 Antenna System

In previous sections, you learnt about dummy loads and coaxial cables. The RF output from the transmitter is fed to the antenna system via a coaxial cable. It is the antenna that converts the RF output of the transmitter into electromagnetic waves received by listeners through their receivers. It is, therefore, the antenna that plays a major role in affecting the coverage of the station. In this section and the subsections that follow, you will learn in detail about the following characteristics of antennae:

- Types of antennae
- Gain of antennae
- Polarization
- Radiation patterns

Let us begin with the types of antennae commonly used in CR stations.

25.5.1 Types of Antennae

FM antennae come in different sizes and shapes. They are usually classified into different types according to their size, shape and number of radiating elements, type of polarization and mounting arrangements used depending upon the technical specifications required. The basic radiating element is a dipole of half wavelength in different shapes like straight, folded, loop, helix or slot depending upon the design. The thickness and type of material decide the mechanical strength, impedance and power handling capacity of the antenna. When a number of radiating elements are mounted one above the other, the gain of the antenna increases, thereby increasing the coverage area. In the subsections that follow, you will learn in detail about the different types of antennae depending upon their mounting arrangements, number of elements used and type of polarization.

Side Mounted and Panel Antennae

Besides the basic design aspects, there is another classification of antennae, which is based on their mounting on tower and which is more relevant to the user. Under this classification, antennae can be categorized into the following two categories:

- Side-mounted antennae
- Panel antennae

However, in the case of CR stations, only the former type, that is, side-mounted antennae are used because of their lower costs and ease of mounting. As such, only these will be discussed here.

Mounting of Side-mounted Antenna

An antenna can be mounted on the top of the tower or side of a tower section, as illustrated in Figure 25.3**.**

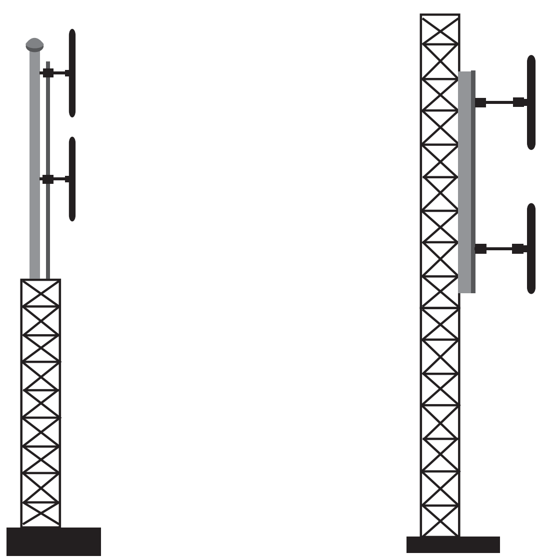


Figure 25.3: *(A)* Pole-mounted antenna *(B)* Side-mounted antenna

Figure 25.3 (A) shows the mounting arrangement of an antenna on the top of the tower. In this arrangement, two dipoles are mounted on a pole, which is fixed on the top of the tower. The thickness of the pole is smaller than the size of a cross section of the tower. In this case, the horizontal radiation pattern is nearly omni-directional. Figure 25.3 (B) shows an antenna mounted on the side of the tower. In this case too, the dipoles are mounted on a pole (called supporting structure) and the pole is clamped to the tower at a suitable distance. Even though the size of the supporting structure section is chosen to be much less as compared to the size of the supporting tower, the radiation pattern gets some directivity (pattern gets elongated due to more signal strength) in a particular direction due to presence of reflecting surface of the tower section. The type of mounting can be decided based upon the conditions existing at the site. Irrespective of the mounting, the most commonly used antenna in CR stations is described below.

Most Commonly Used Antenna in CRS* – *2-Bay Vertically Polarized Antenna

Now you will learn more about a typical 2-bay vertically polarized FM antenna, which is most commonly used in CR stations. Only physical construction and technical specifications will be described here, whereas radiation, propagation and coverage aspects will be described in Unit 26.

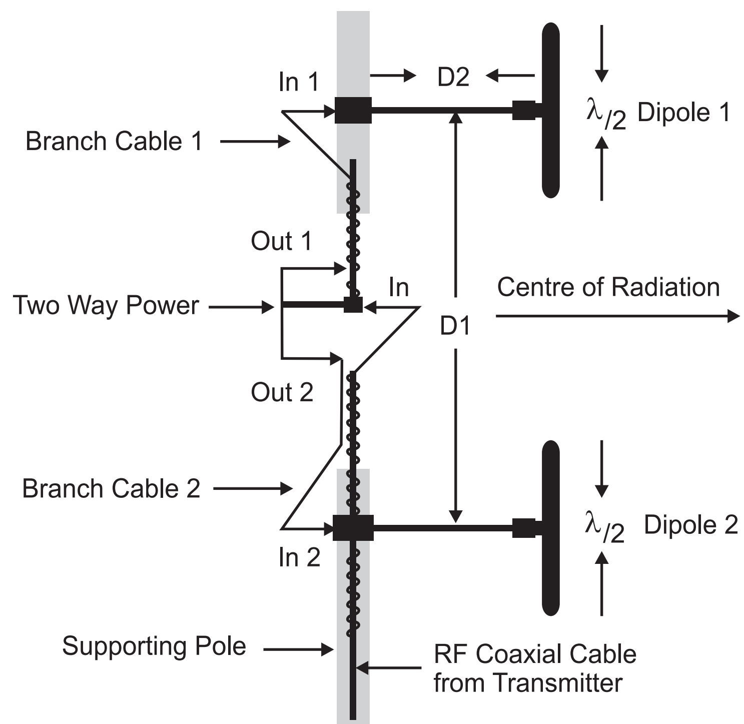


Figure 25.4: *Schematic diagram of 2-bay vertically polarized antenna*

Figure 25.4 illustrates a schematic diagram showing two dipoles of half wavelength each mounted on the pole. The output of the transmitter is connected to the input of a two way power divider, which gives two outputs equal in amplitude and phase that are fed to two dipoles through branch feeder cables. The spacing between two dipoles (D1) is very important and decides the gain and bandwidth. The material and thickness of dipoles decide the power handling capacity. With this type of antenna configuration, antenna gain of 3 dB (two times the power) and nearly omni-directional pattern is possible. Basic technical specifications and requirements of CR stations can easily be achieved with this type of antennae.

See Box 2 for relation between wavelength (denoted by λ, read as Lamda) and the operating frequency.

Box 2

Wavelength (λ) in meters = c/f

Where c is the velocity of light in vacuum = 3×10^8 m/s and f is the frequency of operation in Hertz.

Now we will discuss the types of antennae with reference to polarization.

25.5.2 Gain of Antenna

Gain of antenna is the gain that a particular antenna gives with reference to a standard single half dipole. It is expressed in dB. Normally CRS deploys a 2-bay vertically polarized antenna, which has a gain of 3 dB.

25.5. Polarization

In Unit 23, you were introduced to the basic idea of some types of polarizations. In this subsection, you will learn in detail about the concept of polarization and the types of polarization. Each type of polarization will be discussed with its application in a practical antenna.

Figure 25.5 illustrates the graphical representation of an EM (electromagnetic) wave.

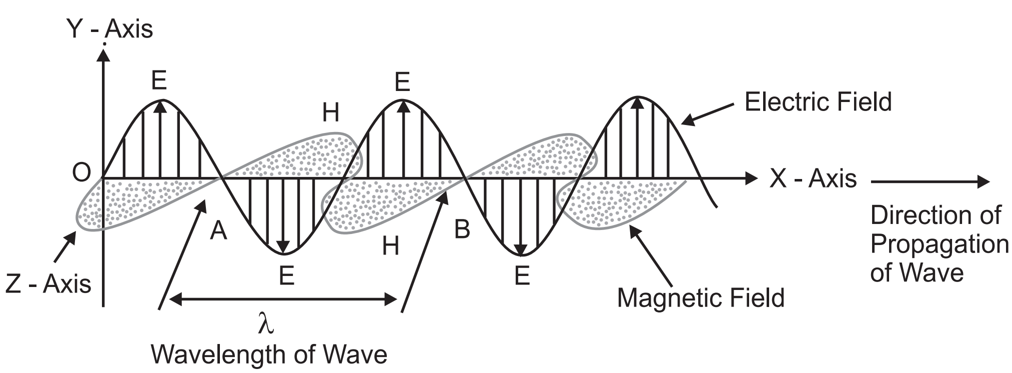


Figure 25.5: *Graphical representation of a plane wave*

As can be seen in Figure 25.5, an electromagnetic wave has two components, electric field **E** and magnetic field **H,** which are perpendicular to each other. Both are also perpendicular to the direction of travel of the wave. The direction of each component of electromagnetic wave should be noted. In this figure, direction of travel of wave is along X-axis, direction of E component is along Y-axis and that of H component is along Z-axis. *The plane of electric field E with respect to the ground is called the plane of polarization.* The wave shown in this figure is a vertically polarized wave.

Types of Polarization

Basically, three types of polarization are used in FM broadcasting:

1. Horizontal polarization
2. Vertical polarization
3. Circular polarization

Horizontal Polarization

When the plane of electric field component E is parallel to the ground, it is called horizontal polarization.

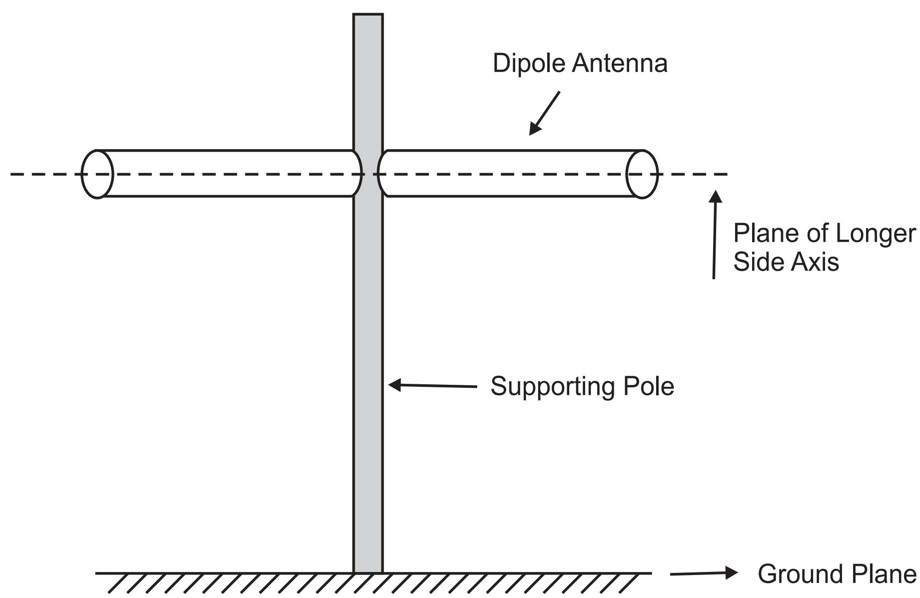


Figure 25.6: *Horizontally polarized antenna*

Figure 25.6 shows a horizontally polarized antenna. Note the direction of mounting of the longer side axis of the antenna. Physically, the radiating dipole element is mounted parallel to the ground and therefore, the antenna is called horizontally polarized antenna.

Vertical Polarization

If the orientation of electric field **E** is perpendicular to the ground, it is called vertical polarization.

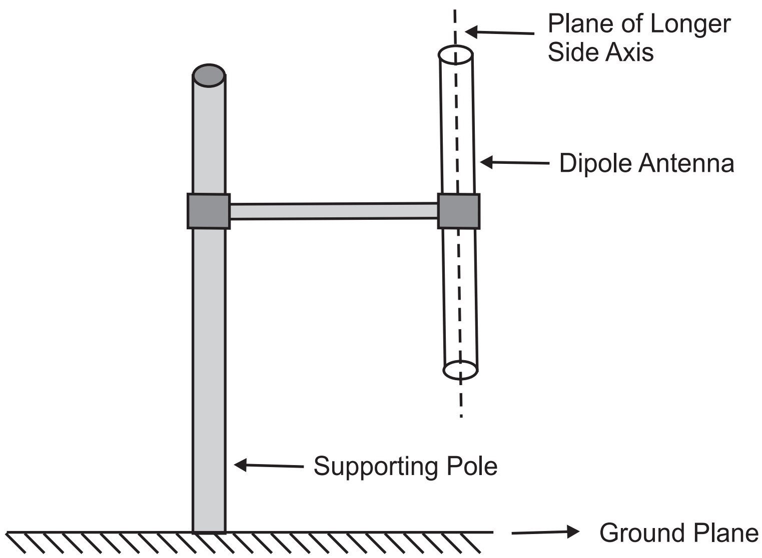


Figure 25.7: *Vertically polarized antenna*

As can be seen in Figure 25.7, the radiating dipole element is mounted perpendicular to the ground and the antenna is, therefore, called a vertically polarized antenna.

Circular Polarization

In circular polarization, two radiating dipole elements are mounted perpendicular to each other as shown in Figure 25.8. As a result, the **E** component of electromagnetic wave radiated by each dipole will be at right angle to each other. The resultant vector **E** of these two electric fields produced by each antenna travels in a circle. Such type of a wave is called circularly polarized wave.

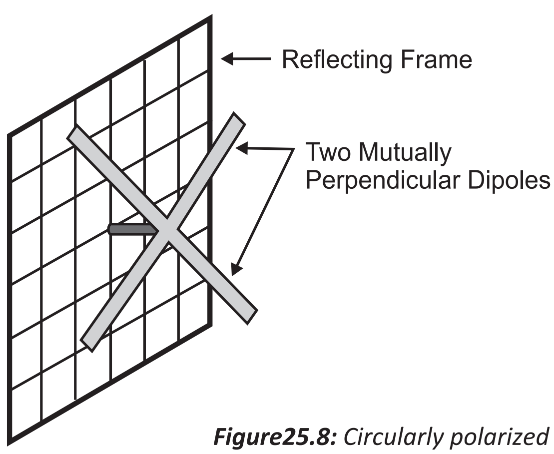


Figure25.8: *Circularly polarized antenna using crossed dipoles*

Figure 25.8 shows the mounting arrangement of a circularly polarized antenna. Here also note the mounting arrangement of two dipoles. These are mounted mutually perpendicular to each other. Practically, a circularly polarized antenna can be made in different forms and combinations by bending the dipoles, fixing the dipoles in right crossed or in crossed V shapes.

Choice of Polarization

Almost all the FM broadcasters in India, operating on high power, are using circularly polarized antennae to cater to both fixed and vehicular reception. However, in case of CRS which are operating on low power, a vertically polarized antenna is usually preferred because it is better suited for portable receivers and offers better antenna gain than the circularly polarized antenna.

Now, in the subsection that follows, you will learn an important characteristic of antenna called radiation pattern.

25.5.4 Radiation Patterns

When an RF output of the transmitter is fed to an antenna, it radiates electromagnetic waves in all directions producing different types of patterns. You will learn more details on radiation patterns in Unit 26. In this section, you will learn about the two important performance patterns produced by FM antennae called horizontal and vertical patterns.

Horizontal Pattern (Azimuthal Pattern)

A dipole antenna when mounted in a vertical position produces a horizontal pattern like a sphere radiating in all the radial directions. This pattern is used for calculating the field strength radiated along various radial directions.

Vertical Patterns

Vertical patterns of an antenna give the values of fields produced by the antenna in various angles of radiation in the vertical plane. The shape of pattern depends upon the length of the dipole and inter-bay spacing in terms of wavelength. As the length of dipole is increased from half wavelength to one wavelength or more, apart from the main lobe (Vertical Radiation Pattern), a number of side lobes also get generated. Study of these lobes gives a fair idea of formation of nulls in particular directions. The nulls can be filled by shifting the phase of the currents in one or more dipole elements of the array.

Horizontal and vertical patterns produced by a half-wave dipole are illustrated in Figure 25. 9.

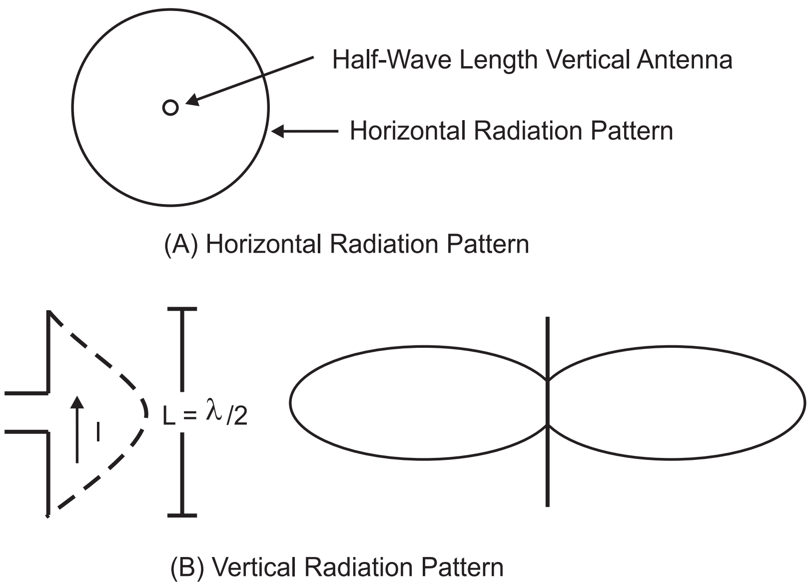


Figure 25.9: *Horizontal and vertical patterns of a half-wave dipole antenna*

Figure 25.9 (A) shows the top view of the horizontal pattern produced by a half-wave dipole antenna. Here, the dipole antenna is located in the centre. Horizontal pattern is a circular pattern giving signal levels in all azimuthal directions. Interpretation of horizontal pattern helps in knowing the field strength received along various radials while plotting coverage contours of any radio station. Figure 25.9 (B) shows the vertical pattern of a half-wave dipole. The main lobe of the vertical pattern looks like the number '8' spread horizontally. As can be seen in the figure, radiation along the vertical axis is practically nil. Vertical pattern helps in understanding the formation of side lobes and taking necessary action in taking care of nulls in the coverage area.

Hope you have already got an idea regarding the coaxial cable and antenna in the aforementioned sections of this unit. To make it easily understandable and before we will proceed further to study about the types of masts that are required for mounting the antenna, let us watch a video on antenna and coaxial cable. To watch this video, please visit the CEMCA YouTube site in this URL- http://tinyurl.com/q57aocx .

Coaxial Cable and FM Antenna

http://tinyurl.com/q57aocx

Activity 25.3

To complete this activity, you may need about 10 minutes including writing down the answers in the space provided. This activity will help you in understanding the important characteristics of an antenna on the basis of its type, mounting arrangement and the polarization used.

Question 1: Name the types of information available if we say an antenna used in a CR station is '2-bay vertically polarized pole-mounted dipole antenna'.

Question 2: What will be the type of polarization called if we mount two dipoles perpendicular to each other on the side of a tower and feed them with equal power?

Question 3: What information can we draw from the interpretation of a horizontal radiation pattern of an antenna?

Question 4: How can we get the same coverage if we use a single antenna instead of a 2-bay antenna?

Question 5: If your station is working at 100 MHz, what will be its wavelength in metres? What will be the length of a half-wave dipole used in the station?

25.6 Types of Mast/Tower

In the previous section, you learnt about the various types of antennae, polarization and the radiation patterns produced by them. You also learnt that mounting arrangement affects the pattern and the height of mast affects the coverage. In this section, you are going to learn about the following aspects of masts used for mounting an antenna:

1. Types of masts
2. Location
3. Foundation
4. Mounting of antenna on tower
5. VSWR

You will learn all these aspects of tower in the order they are given above. Let us begin with types of masts.

Types of Masts/Towers

The coverage of a CR station depends on the height of the antenna above the ground level. Higher the antenna, larger is the coverage. Masts or towers are required for supporting the antenna system at a desired height.

The towers for FM broadcast fall into two categories:

1. Self-supporting towers
2. Stayed or guyed masts

Self-supporting towers occupy a small area of ground and are therefore, attractive when the available open site area is restricted. They are usually of lattice construction. They require relatively less maintenance.

Stayed masts, also called guyed masts, occupy a considerable large space for anchoring the guys. They may be tubular or lattice.

Steel towers are more economical and less prone to twisting or bending.

Examples of self-supporting towers and guyed masts are shown in Figure 25.10.

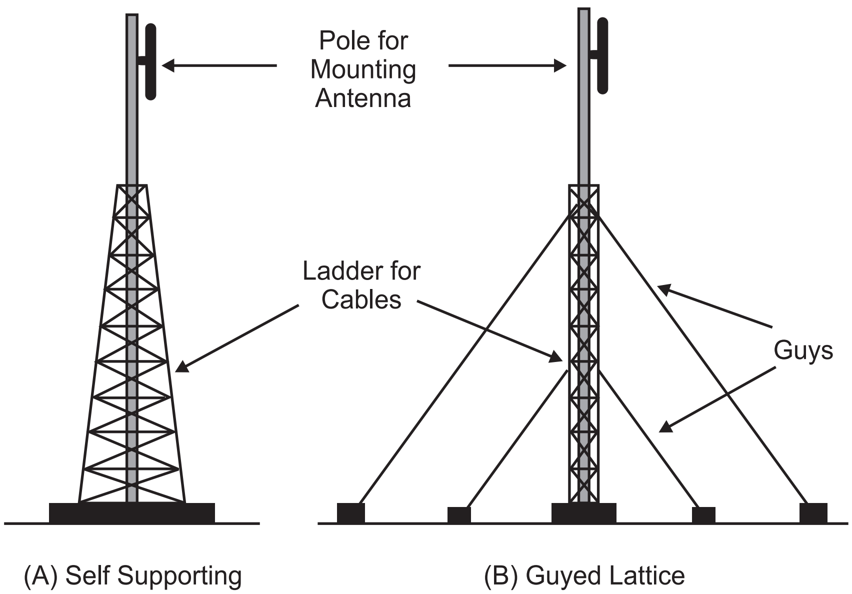


Figure 25.10: *Types of towers*

As seen in Figure 25.10, poles are mounted on top of both types of towers. Note the difference between the two types. The base and dimensions of tower sections are wider in case of a self-supporting tower, whereas a guyed tower is thinner but guys spread over a large area are required for supporting the tower.

Whatever may be the type of tower, essential technical requirements are as follows:

1. Towers must be strong enough to withstand the maximum wind speeds recorded in that area.
2. Clamping of antenna must be done properly to avoid any bending or twist of dipoles.
3. Galvanizing of steel members (coated with zinc) by the 'hot-dip' process and painting must be done at regular interval to avoid rusting and corrosion.
4. Provision should be made for lightning arrestor, ladders for climbing and cable routing.
5. Provision must be made for aviation obstruction lights as per rules in force.

25.6.1 Location

In this subsection, you will learn about the location of towers. Location of towers is important from the point of view of foundation and the coverage.

Since the objective of CR stations is to serve to a particular community residing in a small concentrated area or an institution like a university campus, the choice of location of the site is to a large extent limited to the available area. However, important points worth noting for deciding the location are as follows:

- Location should be at the centre of the service area and preferably at the elevated place.
- Location should be on firm ground.
- Land should not be low lying or marshy.
- An open space of about 6 x 6 M is required for the tower.
- The location of tower should be as near to the transmitter room as possible.
- Location of guy anchors should be exactly at 120 degrees from each other.

25.6.2 Tower and Foundation

In this subsection, you will learn about the points to be considered while deciding the tower and its foundation.

While erecting any tower, whether guyed or self-supporting, the design aspects relating to the structural stability, dead load of tower and antenna system and the wind speed must be considered.

It is a general practice that all the foundation and erection drawings are supplied by the firm delivering the tower. Technicians/engineers supervising the erection work must ensure that foundation and erection drawings are followed. The quality of material used by the contractor should also be strictly checked to avoid any untoward incident in future.

25.6.3 Mounting of Antenna and Cable on Tower

In this subsection, you will learn about the mounting of antenna and cable on tower. Mounting of antenna is a highly skilled job. All personnel required to work on high structures must undergo training before doing so. Normally, all the antenna and other accessories are shipped in dismantled condition, which are assembled on site.

The following instructions/guidelines must be followed while assembling and mounting of an antenna:

- Personnel should be equipped with protective clothing, hard hats and safety belts.

- Drawings and instructions for assembling on site must be understood clearly.
- Spacing between the dipoles must be maintained as per the drawings supplied by the manufacturer.
- A proper branch feeding cable for the respective dipole must be used as per drawing.
- The supervisor at ground must explain and confirm that the rigger/mast technician understands the instructions and guidelines in his language properly.
- Proper connectors supplied by the manufacturer must be fixed correctly as per instructions. Any wrong connector used or improperly fixed results in mismatch and correspondingly a loss of RF power.
- For supporting the RF cables, horizontal and vertical racks must be used.
- The cable must be clamped at every metre of the length with cable clamps of appropriate size.
- There should not be any sharp bends in RF cables. These bends may damage the cables.

25.6.4 VSWR

Now let us discuss a very important parameter called VSWR (Voltage Standing Wave Ratio), which is a measure of mismatch between the antenna and the cable. Our main purpose is to transfer all the output power of the transmitter to the antenna. To make this maximum power transfer possible, the characteristic impedance of the coaxial cable should match with the input impedance of the antenna.

When the impedance of the antenna differs from the specified value, part of the energy is reflected back towards the transmitter as reflected wave. The interaction between the forward and reflected waves sets up a voltage pattern in the cable, which varies between maximum and minimum values as shown in Figure 25.11.

VSWR is the ratio between the maximum and minimum values of voltage of the standing wave.

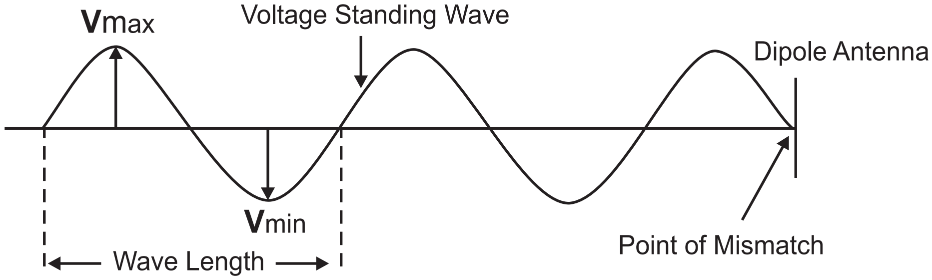


Figure 25.11: *Voltage Standing Wave Ratio*

Figure 25.11 shows a graphical representation of a standing wave formed by interaction of the incident wave and the reflected wave at the point of mismatch. The voltage standing wave has got a point of maxima and a point of minima. The ratio of Vmax to Vmin is called the VSWR. If this matching is perfect, no power is reflected back and VSWR is equal to unity (1:1).

You will learn more about VSWR measurements of antenna in Unit 29.

In the next section, you are going to learn about the protection of towers against lightning.

25.7 Lightning Arrestor

In this section, you will learn about lightning arrestor, which is provided on top of every tower to protect the tower, antenna system, coaxial cable, transmitter and operating personnel from lightning.

Virtually, all masts are subject to lightning strikes, and in tropical areas this incidence is high. The effects of lightning are well-known and the high levels of electrical energy that are generated can result in severe damage to a transmitting installation and even to the staff. It is not possible, of course, to prevent occurrence of lightning strikes but their effects can be minimized by careful design. Lightning tends to strike the highest well-defined point in an area. Masts or towers, particularly those sited on hills, are more vulnerable. The discharge of electrical energy associated with a lightning strike takes the form of a high-current pulse that passes from the point of strike (the top of mast) to the point of lower potential (usually the ground). The route taken by the discharge current can be via more than one path. It is very difficult to predict the path taken by lightning current. However, this path can be channelized by putting lightning arrestor on top of the tower. Lightning arrestor is of a very highly conductive material and connected to the nearest earth pit via copper strap. The earth pit is preferably provided in the wettest part of the site between the mast and the building. The purpose is to provide a low resistance path so that the voltage induced in the arrestor due to lightning is immediately connected to the earth before causing any damage to the equipment and staff. To ensure that lightning currents flow directly to earth without damaging the equipment and staff, it is essential that a transmitting station must have comprehensive grounding system. You will learn about this grounding system in the next section.

25.8 Grounding

In this section, you are going to learn about the grounding system, which is an essential requirement for protection of the equipment and the staff against lightning.

The objectives of grounding are to:

1. Provide safety to the equipment and personnel against lightning.
2. Reduce losses in radiating antenna system.

Earthing System

The earthing system consists of an ordinary plate or an extensive network of driven conductors and plates (called electrodes), buried deep into the soil. For this purpose, earth pits giving very low resistance value are made. Different types of earth pits are used. The most commonly used is GI Pipe earthing.

Alternate layers of salt and charcoal are added along with good earth to retain moisture and achieve good conductivity. The purpose is to get very low-resistance value of the order of less than 1 ohm. Where the ground is rocky, it may not be possible to excavate a pit to sufficient depth and in that case several smaller pits joined by copper straps should be used.

You will learn about the method of making earth connections and measurement of earth conductivity in Unit 28 and in practical workshop.

Activity 25.4

During your visit to a CR station, take a look at the dummy load, coaxial cable, antenna system, tower, lightning arrestor and grounding system used at that station. Note down the specifications for the important parameters of items studied in this unit. Fill in the details in the proforma given below. This will help you identify the types of these items and visualize their significance. You can refer to manufacturers' manuals in this regard.

A. Dummy load

Sl. No.	Parameter	Specification
1	Make	
2	Model no.	
3	Power rating	
4	Input impedance	
5	Type of cooling	

B. Coaxial cable

Sl. No.	Parameter	Specification
1	Size of cable	
2	Length of cable	
3	Make4Model no.	
5	Power rating	
6	Characteristic impedance	
7	Type of connectors	

C. Types of antenna

Sl. No.	Parameter	Specification
1	Type	
2	Make	
3	Model	
4	Number of radiating elements used	
5	Polarization used	

D. Supporting towers and mounting of antenna system

Sl. No.	Parameter	Specification
1	Type of tower	
2	Height of tower	
3	Height of antenna	
4	Mounting of antenna	
5	Foundation of tower	

E. Lightning arrestor and grounding system

Sl. No.	Parameter	Observations
1	Number of earth pits used	
2	Type of earth pit	
3	Watering arrangement	
4	Use of lightning arrestor	
5	Grounding of tower	

25.9 Let Us Sum Up

In this unit on FM antenna and coaxial cable, you have learnt that:

- **Dummy load** is required for testing the transmitter before it is connected to the antenna. The dummy load converts the RF power into heat without any RF radiations. The power rating of dummy load should not be less than the transmitter output power.
- **RF coaxial cable** is used to transfer transmitter output power to the antenna system. Feeder cables mostly used are low-loss cables. Power rating and attenuation are both frequency dependent. Power rating decreases as the frequency increases, whereas attenuation increases with increase in frequency.
- The **antenna system** is required to convert RF output of the transmitter into electromagnetic waves. We have also discussed various types of antennae and classified them into different categories according to design, construction and mounting arrangements. Important parameters of FM antennae are horizontal and vertical radiation patterns and the VSWR (Voltage Standing Wave Ratio). VSWR is the measure of degree of mismatch at the input of the antenna.
- **Towers** are required to mount the antenna system. We have, discussed two types of towers, namely self-supporting and guyed towers. Self-supporting towers are more stable and require smaller area for foundation. Foundation and structural designs are based on height of tower, dead load and wind load of antennae.
- To protect tower, antenna cable and operating staff from lightning, use of lightning arrestor and grounding of tower and cable is necessary. The tower, cable and body of the transmitter and electrical panels should be connected to the nearest earth pit by use of double copper strips. The location of the earth pit should be preferably in the wettest place to retain moisture and as near to the tower as possible. The earth resistance of earth pit should be less than one ohm.

25.10 Model Answers to Activities

Answers to questions given in Activities 25.1 to 25.3.

Activity 25.1

1. Dummy load is provided to check the output and performance of the transmitter before it is connected to the antenna.
2. Non-inductive resistors are used in the construction of a dummy load because dummy load should dissipate the RF power into heat and not radiate into air medium.
3. Large surface area and the fins help quick transfer of heat produced in the resistor of dummy loads into the room with raising the temperature.
4. Input impedance of the dummy load should be equal to the output impedance of the transmitter. It is equal to 50 ohms normally.
5. When the high power transmitters are tested on the dummy load, the heat transfer rate of convection or air cooled is not fast. Water-cooled or oil-cooled dummy loads are more efficient in quick transfer of heat.

Activity 25.2

1. The attenuation offered by low-loss cable is very less and as a result maximum power of transmitter can be fed into the antenna.
2. The dielectric material usually used is foam polyethylene.
3. The characteristic impedance of a coaxial cable is the ratio of voltage to the current for a single propagating wave (frequency).
4. Attenuation of a coaxial cable = 10 log P_1/ P_2 where P_1 is input power and P_2 is the power reaching at other end. Substituting the given values, we get attenuation = 10 log 50/25 = 10 log 2 =10x 0.3010 = 3 dB
5. The average power rating of a cable is inversely proportional to the frequency of operation. If frequency increases, average power decreases and vice versa.

Activity 25.3

1. It indicates that two dipoles have been used. It is a pole mounted antenna. Its polarization is vertical.

2. It will be called circular polarization.
3. From the interpretation of horizontal pattern, we can know the field strength in all the radial direction from the location of the antenna.
4. With a single antenna, the transmitter power required will be double than what is used with a 2-bay antenna for the same coverage.
5. Using the equation, Wavelength = Velocity of light in meters/frequency in Hz = $3x\ 10^8$ / 100 X 10^6 = 300/100 = 3 m. Length of half-wave dipole = ½ x 3 = 1.5 m

Activity 25.4

The information gathered in the activity should be your own and hand-on experiences.

UNIT 26

Propagation and Coverage

Structure

26.1 Introduction

In the previous unit 'FM-Antenna on RF Cable', you learnt about the components, which are used after the output stage of transmitter. These include dummy loads used for internal testing of transmitter; type of coaxial cable that connects the transmitter output to the antenna; types of antenna used for radiation of RF signal; tower and mounting of an antenna; VSWR; lightning arrestor; grounding; etc. The coaxial cable, also known as RF feeder line, carries the transmitter power from its output up to the antenna, which is normally mounted on top of the tower, and from there the RF propagates in various directions.

In this unit, you will learn about propagation and coverage of RF signals, particularly, FM broadcasting in VHF band. In order to have better understanding on propagation, we need to know about various RF frequency bands and their ranges, which are described under Section 26.3. The RF signals are radiated from the antenna and they propagate in different directions. RF signals, depending upon their frequency band, propagate through various layers of atmosphere. In Section 26.4, you will learn what the various layers of atmosphere are and how different RF signal behaves while passing through these layers. This section also mentions about phenomena like reflection, refraction, diffraction, ducting, etc., which RF signal encounters while propagating through various layers of atmosphere. In Section 26.5, you will learn about radio coverage and how it is affected by various factors like frequency, power of transmitter, gain of antenna, height of antenna, terrain condition, presence of environmental noise and also effective radiated power (ERP), which is a very common term used in planning of coverage. This section also defines shadow areas/shadow zones, which occur when RF signals are blocked by terrain condition or poor availability of signal. Shadow regions can be minimized and radio coverage can be maximized by proper selection of site where the antenna can be located at the highest available point/place. Such locations can be identified by examining the topography of the area and analysing toposheets of that particular region. In Section 26.6, you will learn about topography including toposheets and their usage. For planning of FM radio coverage, it is essential to understand the ITU-defined planning parameters, like channel spacing, minimum usable field strength, protection ratio, etc. These parameters are defined in Section 26.7. Field strength measurement is very commonly carried out for checking availability of radio coverage around a transmitter. Learning this in Section 26.8 and also drawing a radio coverage map by plotting the minimum required field strength measured around the transmitter antenna will help you have good understanding of the FM transmitter of a CR station.

You will take about 6 hours to complete this unit.

26.2 Learning Outcomes

After going through this unit, you will be able to:

- **define:**
  - (i) RF spectrum and various bands.
  - (ii) Various layers of atmosphere and what kind of radio waves propagates through them.
  - (iii) The parameters used for coverage planning of FM radio network.
- **list and describe:**
  - (i) The factors responsible for affecting radio coverage and creation of shadow region.
  - (ii) Various parameters used for planning of RF coverage network.
- **analyse:**
  - (i) the toposheet for selection of optimal location for transmitter tower to provide better coverage.
  - (ii) the field strength measurement data and check availability of desired signal for adequate radio coverage.
- **undertake field strength measurements survey and draw a coverage map.**

26.3 What is Spectrum?

Radio wave and spectrum subjects have already been described in detailed under Sections 6.3 and 6.4 of Unit 6 (Module 2). However, to refresh your memory, a brief overview on this subject is given below.

Electromagnetic spectrum is used to carry electromagnetic signals through space. The radio frequency spectrum, which is a part of electromagnetic spectrum, is shared by various radio communication services for variety of applications including public telecommunication services, aeronautical/maritime safety communications, radio and television broadcasting, radars, seismic surveys, rocket and satellite launching, earth exploration, natural calamities forecasting, etc.

The whole of the electromagnetic spectrum covers a huge range of frequencies. Radio frequencies themselves extend over a very large range as well. The range is further divided into different frequency bands as given in Table 1. Frequencies above 1 GHz are normally known as microwaves. As per National Frequency Allocation Plan (NFAP), 87–108 MHz band is used for FM radio broadcasting in India.

Table 1: RF Spectrum Bands

From	To	RF spectrum band
3 kHz	30 kHz	Very low frequency (VLF)
30 kHz	300 kHz	Low frequency (LF)
300 kHz	3 MHz	Medium frequency (MF)
3 MHz	30 MHz	High frequency (HF)
30 MHz	300 MHz	Very high frequency (VHF) **(FM Band 87 – 108 MHz)**
300 MHz	3 GHz	Ultra high frequency (UHF)
3 GHz	30 GHz	Super high frequency (SHF)
30 GHz	300 GHz	Extra high frequency (EHF)

Some bands used in microwaves:

Bands	Frequency range	Bands	Frequency range
L band	1 to 2 GHz	K_u band	12 to 18 GHz
S band	2 to 4 GHz	K band	18 to 26.5 GHz
C band	4 to 8 GHz	K_a band	26.5 to 40 GHz
X band	8 to 12 GHz		

RF spectrum is a valuable, scarce and finite natural resource that is needed for various services and applications. Therefore, its utilization is to be planned scientifically and carefully so that the scarce resource is managed effectively and optimally.

Activity 26.1

To complete this activity, you may need about 10 minutes including writing down the answers in the space provided below.

Question: 1 What is a microwave? Name some radio services that operate in microwave bands.

Question: 2 What is NFAP? Who is responsible for preparing this document?

26.4 Layers of Atmosphere and Radio Wave Propagation

The atmosphere consists of several layers. These layers are further divided based on the characteristics of the gases found in them. Each layer in the atmosphere is also referred to as a sphere. Radio waves, which are divided in different frequency bands, propagate differently in various layers of the atmosphere. This section describes layers of atmosphere, their distance from the surface of the earth, and how radio waves behave while propagating in these layers due to change in ionization and density of gases present.

Though the transmission of RF waves from a CR station's FM transmitter follow VHF propagation, learning about propagation of other waves MW, SW, microwaves will be helpful.

26.4.1 Troposphere

The first layer of the atmosphere is called the troposphere. It is the lowest part of atmospheric layer, extending from the earth's surface up to the bottom of the stratosphere. It starts from the surface of the ground and extends up to 10 km above the surface, as shown in Figure 26.1. The troposphere is the layer that we live in. The boundary between the troposphere and the stratosphere is called the 'tropopause'. The troposphere is characterized by decreasing temperature with height (at an average rate of 6.5^{o} C per kilometer).

Most of the radio transmissions operate in the lower layers of the earth's atmosphere, which is the troposphere. Some of the radio systems operating in this sphere are point-to-point, point-to-multi point, line-of-sight radio links in VHF and UHF bands, mobile radio networks in VHF and UHF bands, TV and FM broadcasting, etc.

It has been observed that the troposphere has an increasing effect on radio signals and radio communications systems, particularly, on frequencies above 30 MHz with the result that the radio signals are able to travel over greater distances beyond the line of sight.

The reason for radio signals travelling longer distance is that the refractive index of the air closer to the ground is slightly higher than that higher up. As a result, the radio signals are bent towards the area of higher refractive index, which is closer to the ground. It thereby extends the range of the radio signals.

26.4.2 Stratosphere

The next layer of atmosphere is called the stratosphere. It is the second layer of the atmosphere, as one moves upward from earth's surface. The stratosphere is above the troposphere and below the ionosphere. The top of the stratosphere occurs at a height of 50 km from ground. The boundary between the stratosphere and the ionosphere is called the stratopause. These are indicated in Figure 26.1. The stratosphere has either constant or slowly increasing temperature with height.

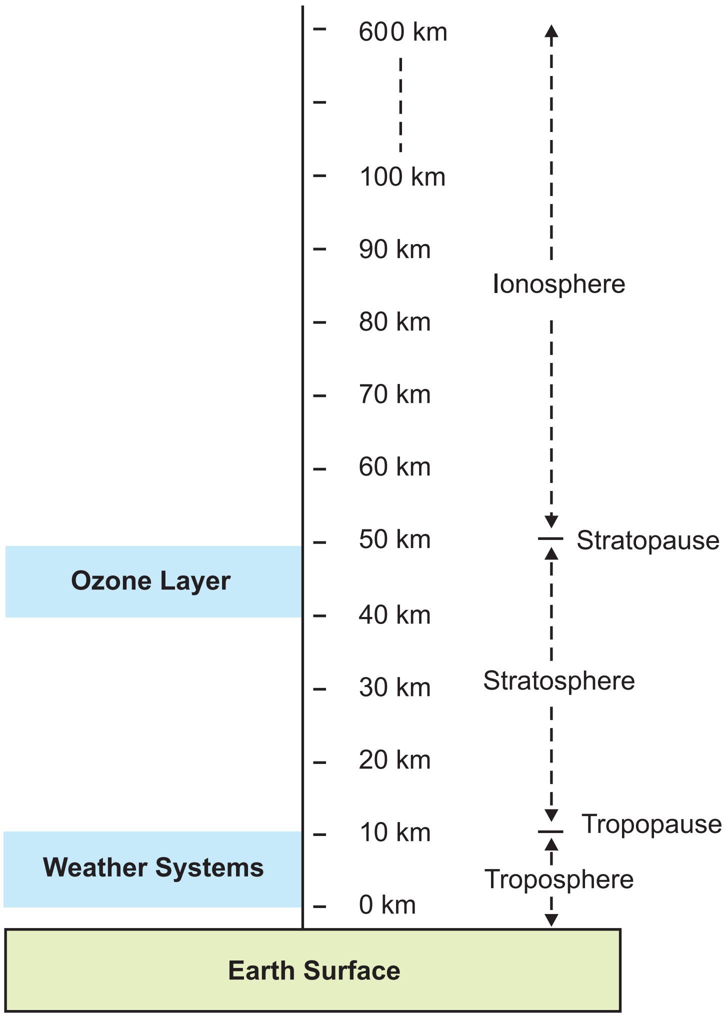


Figure 26.1: *Layers of atmosphere and their distances from earth surface*

26.4.3 Ionosphere

The ionosphere is the third layer of the atmosphere, as one moves upward from earth's surface. This layer is ionized by solar wind. It has practical importance because, among other functions, it influences radio propagation to distant places on the earth. This layer basically starts from the height of 50 km above the earth and extends up to the height of about 600 km. In case of radio waves passing through this layer or somehow penetrating into it, they will be affected by the specific phenomena of this layer. Some of the communication systems that experience these effects are those working in MF and HF radio transmission bands as well as satellite and space communication systems where one or both end point terminals are located on the ground. The ionosphere is sub-divided into several layers as described below and also shown in Figure 26.2.

D Layer

The D layer is located above the stratosphere. It is the innermost layer of ionosphere. Its range is from 50 km to 115 km with reference to the surface of the earth. The intensity of ionization is higher in the D layer because it is composed of the heavier gasses. High-frequency (HF) radio waves are not reflected by the D layer but suffer loss of energy therein. This is the main reason for absorption of HF radio waves, particularly, at 10 MHz and below with progressively smaller absorption as the frequency gets higher. The absorption is small at night and greatest about midday. The layer reduces greatly after sunset. A common example of the D layer in action is the disappearance of distant MW broadcast band stations in the daytime.

E Layer

The E layer is located above the D layer. It is the middle layer of ionosphere. Its range is from 115 to 160 km from the surface of the earth. The intensity of ionization is lesser in the E layer as compared to D layer because it is composed of less heavy gasses. This layer can only reflect radio waves having frequencies lower than about 10 MHz and may contribute a bit to absorption on frequencies above.

Sporadic-E (E_s)

The E_s layer (sporadic E layer) is characterized by small and thin clouds of intense ionization. Sporadic-E events may last from just a few minutes to several hours. This propagation occurs most frequently during summer months.

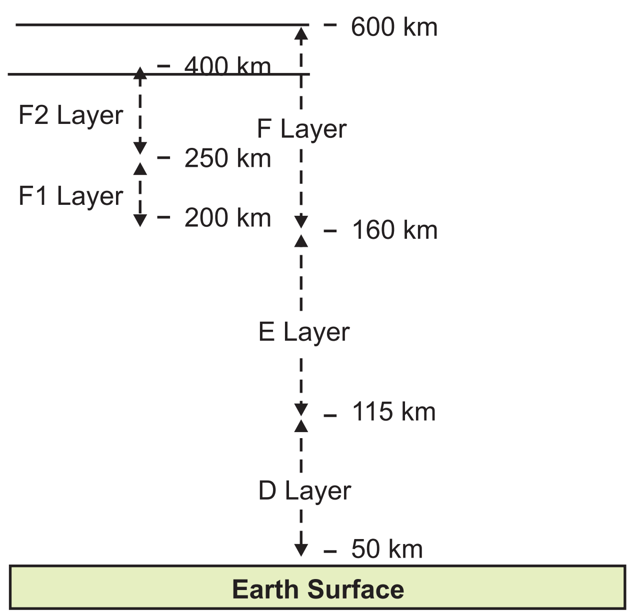


Figure 26.2: *Layers of ionosphere and distances from the earth surface*

F Layer

The F layer extends from about 200 km to about 600 km above the surface of the earth. It is the densest point of the ionosphere, which implies signals penetrating this layer will escape into space. The F layer consists of one layer at night, but during the day, a deformation often forms in the profile that is labelled as F1 and the other part as F2.

F1 Layer

The F1 layer is located above the E layer. Its range is from 200 to 250 km with respect to the earth. The intensity of ionization is lesser in the F1 layer with respect to E layer.

F2 Layer

This layer is located above the F1 layer. Its range is from 250 km to 400 km with respect to the earth. The intensity of ionization is lesser in F2 layer with respect to F1 layer. The F2 layer remains by day and night responsible for most skywave propagation of radio waves, facilitating high frequency (HF, or shortwave) radio communications over long distances.

26.4.4 Ground Wave/Sky Wave/Space Wave

Radio waves travel from one point to another (e.g.,a transmitter to a receiver) by different ways. These are mainly ground waves, sky waves and space or tropospheric waves.

The ground waves travel closer to the surface of the earth. The sky wave propagation, usually called ionospheric propagation, results due to bending of wave-path through ionosphere. This method of propagation accounts for long distance radio communication through shortwave both, during day and night time and also through medium wave during night.

Space wave represents energy that travels from the transmitting to the receiving antenna through earth’s troposphere. Space wave propagation becomes essential in VHF bands because ground wave is attenuated to a negligible amplitude within a few hundred metres, while the ionosphere is not able to reflect any energy back to the earth in VHF range.

26.4.5 Effects of Wave Propagation in Different Media

When lights travel from one medium to another, three things happen: (i) some lights are reflected, (ii) some lights are absorbed and (iii) some get refracted.

Similarly, when radio wave propagates, the following can occur when the wave passes from one medium to another:

i) Reflection: some waves get reflected back into the same medium.
ii) Absorption: some waves get absorbed by the medium.
iii) Refraction: some waves get transmitted into the second medium at a different direction and velocity.

However, when a radio wave encounters an obstacle on its propagation path, it may bend around the obstacle. This bending phenomenon is called diffraction. Also, when a wave propagates in troposphere, another special phenomenon 'ducting' occurs due to temperature inversion.

Reflection

Reflected waves are neither transmitted nor absorbed, but are reflected from the surface of the medium they encounter. The basic analogy is similar to reflection of light by a mirror. If a wave is directed against a mirror, the wave that strikes the surface is called the incident wave, and the one that bounces back is called the reflected wave. This also occurs when a wave is transmitted skyward, reflect off the ionosphere, and returns to a receiving station. The angle of reflection equals the angle of incidence. Reflection of wave is illustrated in Figure 26.3, where the incident wave forms angle i to normal reflected at an angle r and travels in a different direction.

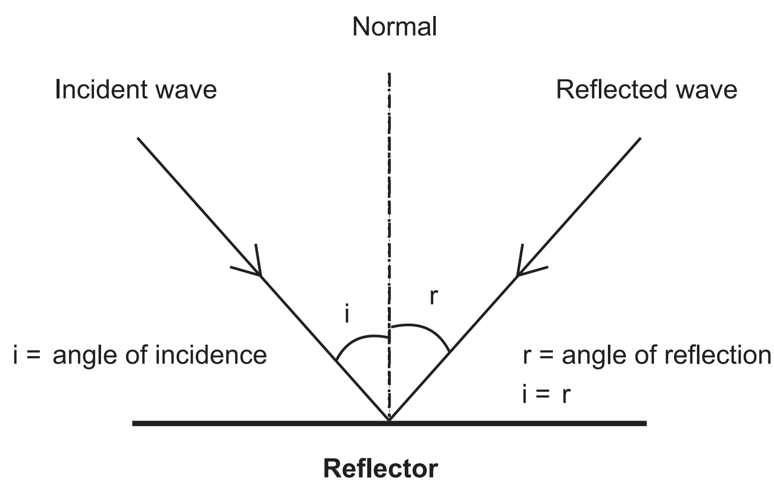


Figure 26.3: *Reflection of wave*

Refraction

The radio waves propagating in the earth's atmosphere always experience the wave refraction phenomenon. As the height increases, the air density and consequently its refractive index decreases. This non-homogeneous characteristic of air in the atmosphere causes deviation in the wave propagation path, so that they do not travel further in a straight direction. When the rate of refractive index changes linearly, the ray path would be an arc of a circle. Figure 26.4a shows a simple case of refraction where the refracted wave bends inward when it travels from one medium into another. The bending phenomenon is clearly visible. In Figure 26.4b, the same phenomenon is described in detail where the wave from medium 1 having refractive index n_1 travels to medium 2 with refractive index n_2. If the refractive index of medium 2 is higher than medium 1 then the wave will bend inward. If the refractive index of medium 2 is lower, it would bend outward. If we draw a normal at the point where the wave from medium 1 enters into medium 2, then it forms an angle α known as angle of incidence. In medium 2, the refracted wave bends inward forming angle of refraction β.

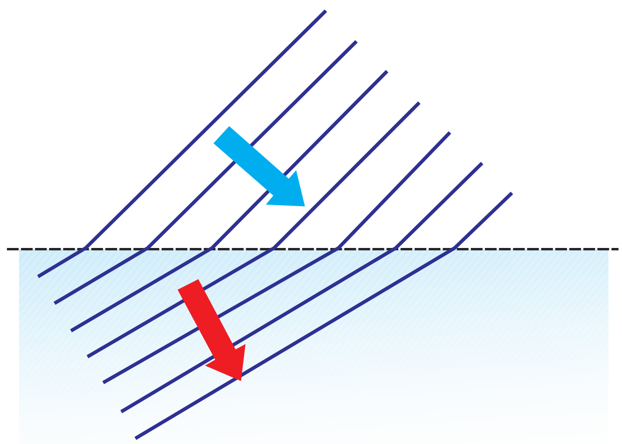


Figure 26.4a: *Refraction of wave*

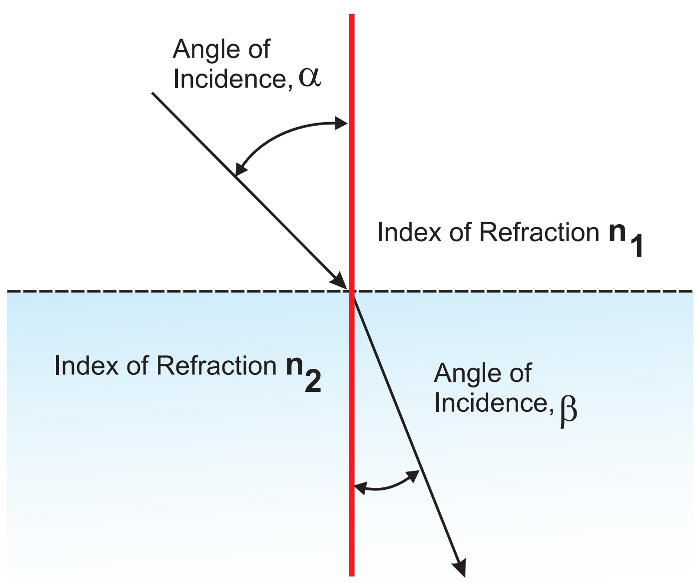


Figure 26.4b: *Refraction of wave with angle of refraction β*

Figure 26.4c shows how short wave frequencies get refracted from the ionosphere and return to the earth's surface at a longer distance. Because of this phenomenon, short wave signals travel several thousands of kilometres.

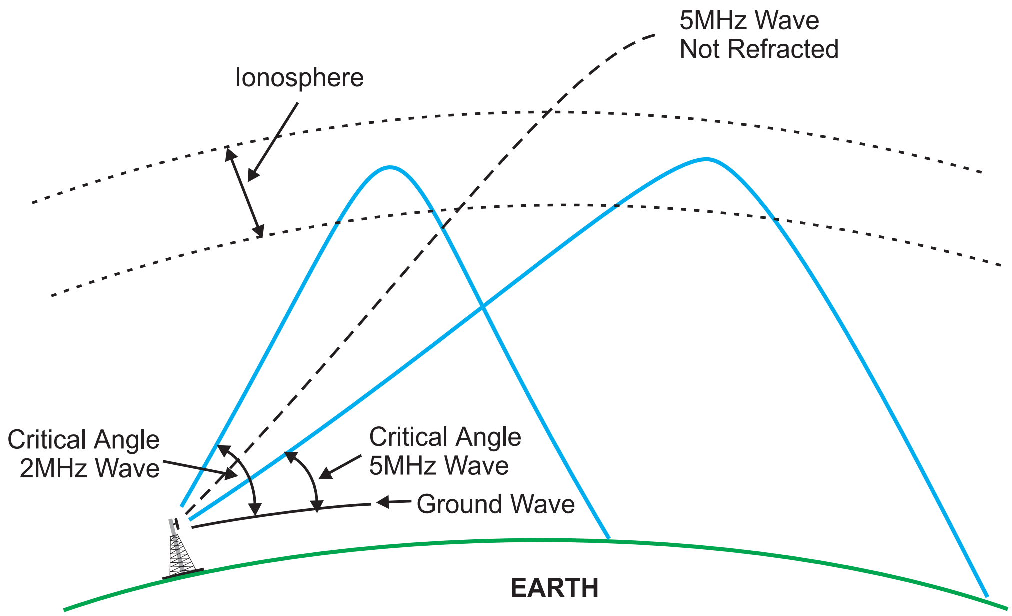


Figure 26.4c: *Short wave frequencies get refracted by ionosphere and travel longer distance*

Diffraction

When a radio wave encounters an obstacle in its path, it bends around the obstacle. This bending is called diffraction, and results in a change of direction of part of the energy from the normal line-of-sight path. Figure 26.5 shows a wave that is diffracted after it came across a partial obstructed object. When a wave front strikes the edge of an object, as shown in the figure, it bends inward and travels further in a different direction. Before reaching the object, the wave front was travelling in a horizontal direction and after passing through the edge of the object, it started travelling downward. This phenomenon is called diffraction.

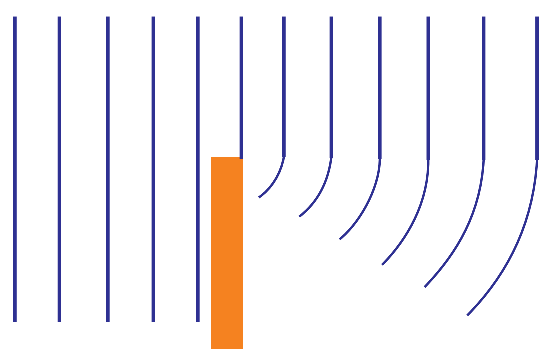


Figure 26.5: *Diffraction of wave*

Ducting

Ducting is one of the propagation phenomena that happen in the troposphere. Tropospheric ducting occurs when a radio signal is reflected off the troposphere and continues on a path that allows the signal to travel much farther than it normally would. This occurs when the temperature in the atmosphere experiences an inversion. When a temperature inversion occurs, radio waves that would normally continue into space beyond the earth's atmosphere are instead reflected and they continue to follow the curvature of the earth. Radio waves have been able to travel in excess of 1,000 km because of tropospheric ducting. TV signals travel longer distance over sea surface because of ducting. Figure 26.6 shows how the radio waves propagate because of total internal reflection between two layers forming a duct above the surface of the earth.

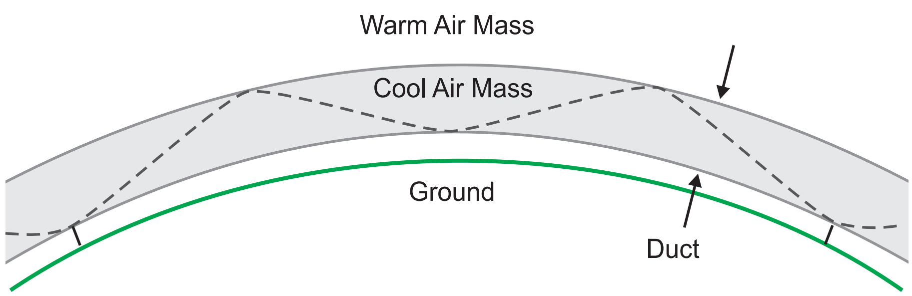


Figure 26.6: *Ducting*

Activity 26.2

To complete this activity, you may need about 15 minutes including writing down answers in the space provided below.

Question: 1 Name various types of radio communication systems that operate in VHF band in India.

Question: 2 What are the various effects that take place when VHF signal propagates in the troposphere?

26.5 Factors Affecting Coverage and Shadow Areas

RF signals are transmitted from the antenna of radio transmitters. These RF signals, depending on the frequency of operation, propagate through different layers of the atmosphere and reach various places. Radio receivers help in detecting these signals and reproduce the audio frequencies after demodulating them. However, the receiver can only be able to detect the signals that are above the minimum usable field strength. Availability of the area around the transmitting station which gets the signal of this strength or more is known as radio coverage area. Places where these signals do not reach from the transmitter due to obstruction of propagation condition are called shadow zones or shadow areas. The following sections explain these phenomena in detail.

26.5.1 Factors Affecting Coverage

Transmitter antenna radiate energy in all directions. Depending upon the design of antenna (e.g., directional or omni-directional), the intensity of energy radiation varies in different directions with respect to distance. As the distance from the location of the antenna increases, the intensity of the received signal decreases. The distance where the strength of received signal is just sufficient for the receiver to detect it without any interference is called radio coverage range. These distances from the transmitter/antenna in different directions around the antenna define radio coverage range.

RF coverage or availability of desired level of RF signal in a particular target area gets affected by various factors. Some of these major factors that affect the coverage of RF signals are as follows:

- The frequency on which the transmitter is operating
- The effective radiated power of the transmitting station, that is, ERP
- The type and design of antenna
- The height and location of the antenna
- The terrain profile and condition
- The amount of electromagnetic noise

Each of these above factors affects radio coverage and is taken into consideration in determining how far the radio signal would be able to provide effective coverage.

Frequency on which the transmitter is operating

Frequencies in higher order bands cover lesser area. In case of medium wave transmissions, the lower order band, e.g., around 600 kHz, provides wider coverage than higher order bands, say at 1500 kHz, under similar ground conditions (conductivity). An FM transmitter operating in VHF FM band (87 – 108 MHz) provides almost similar coverage.

Effective rated power of the transmitter

As a general rule, it can be said that the coverage of radio transmitter increases with its output power. The higher the power, greater is the coverage distance. Also since VHF is a line-of-sight propagation, the coverage is restricted by availability of line-of-sight. As such, increasing transmitter power beyond a certain point may not be able to increase its coverage range. However, in actual terms, it is the effective radiated power (ERP) of the transmitting station (which includes the contribution of the antenna system) that determines the coverage and not the transmitter power alone. You will learn about ERP in detail later in this subsection.

Type and design of antenna

The type and design of an antenna decide its gain. This gain increases the ERP, e.g., a 10 kW FM transmitter having an antenna of gain 3 dB would radiate 20 kW as ERP. A directional antenna has more gain in a particular direction, and thereby increases the range or coverage in that direction.

Antenna height and location

The most critical coverage factor is the height and location of the antenna. This is because the range of a radio coverage is theoretically limited to the radio horizon as reached by the radio antenna. Basically, the higher the height of the antenna, the greater the area it will cover. Therefore, FM antennae installed on hilltops provide wider coverage.

Terrain profile and condition

As radio waves follow a line-of-sight path, terrain variations can cause obstruction to propagation. Hills and valleys or any kind of high-rise structure that come in the direction of the line-of-sight path obstruct propagation. In such cases, if we increase the antenna height, we can reduce such obstruction, and thereby increase coverage.

Amount of electromagnetic noise

Presence of electromagnetic noise, industrial noise, or environmental noise around the receiver affects detection of weak RF signals and thereby affects radio coverage.

26.5.2 What is ERP?

Most of us are well aware of transmitter power, which the transmitter delivers to the feeder/RF cable that is connected to the antenna. However, this power may not be the same what the antenna delivers or radiates. It is mainly because of two factors: (i) the feeder/RF cable including multiplexer/diplexer/connectors causes some losses and (ii) the antenna may provide some gain depending upon its design. This gain of antenna varies with its type and directivity. Therefore, the ERP includes all gain and loss factors on the transmitting side and usually expressed in dBm, or dBw, or dBkw, etc. In fact, ERP is the product of the transmitter output power and antenna gain in the desired direction taking into account all losses caused by the RF feeder, connectors, etc.

Mathematically, ERP can be calculated as:

ERP = (Transmitter Power – Feeder/RF cable loss) x Antenna gain

For example, a 100w FM transmitter having a 30-meter long RF feeder cable causes a loss of 1dB and the gain of antenna is 4dB. Then, its ERP will be:

Transmitter power – Feeder cable loss + Antenna gain (all in dB)

= 100w (or 20 dBw) – 1 dB + 4 dB

= 23 dBw

= 200w (3 dB gain doubles the power)

26.5.3 Shadow Areas

In FM broadcasting network, reception of radio service gets hampered because of inadequate signal or any obstruction between the transmitting station and the targeted areas. These areas are called shadow zones or shadow areas. As an example, if the transmitter in a valley is located on one side of a hill, the other side will have no RF signal and thereby creates shadow areas.

Activity 26.3

To complete this activity, you may need about 5 minutes.

Qestion: 1 Find out the ERP of a transmitter having output power 200 w, losses due to feeder cable and joints 1.5 dB and antenna gain 4.5 dBi.

26.6 Topography

Topography is a broad term used to describe the detailed study of the earth's surface. It is a detailed description of a place or region located on a map. While topography includes vegetative and man-made features, it more commonly refers to a horizontal point of latitude and longitude. This includes changes in the surface such as mountains and valleys as well as features such as rivers, roads and buildings. Topography is closely linked to the practice of surveying, which is the practice of determining and recording the position of points in relation to one another.

Toposheet

India, with an area of 32,87,263 km^2, is covered by both topographical and geographical maps. The topographical maps are on sufficiently large scale of 1:25,000, 1:50,000, which are ideally suited for the professional work of geologists, geographers, foresters, engineers, planners, tourists, mountaineers, etc. On the other hand, the geographical maps are on such a small scale of less than 1:2,50,000 that they are useful mainly for synoptic views.

India is covered by nearly 385 toposheets on 1:2,50,000 scale, which are also called degree sheets. Each degree sheet has 16 toposheets of 1:50,000 scale and the whole of the country is covered by 1:50,000 rigorous metric surveys in more than 5,000 toposheets. Each 1:50,000-scale sheet contains four 1:25,000-scale sheets. Guide maps on scale of 1:10,000 and smaller are available for towns and cities in various states.

Topographic maps provide the graphical portrayal of objects present on the surface of the earth. These maps provide the preliminary information about a terrain and thus are very useful for engineering works, including planning of radio coverage network. For most part of India, topographic maps are available, which are prepared by the Survey of India. To identify a map of a particular area, a map numbering system has been adopted by the Survey of India.

For broadcast radio network planning, toposheets are useful for locating highest points where an antenna can be installed so that maximum coverage is achieved. However, since CR stations have to be located near the area of the target community, the coverage planning has to take into account the topography of a target area with a smaller community, which may not have much variation in topology.

26.7 Signal Requirements and Coverage Planning Parameters

The coverage planning of an FM transmitter in VHF band-II (for FM broadcasting in India it is 87–108 MHz) is a complex process. Preparation on planning of FM network requires understanding of minimum usable field strength, protection of wanted signal from other transmitters, noise protection requirements for city and rural areas, etc. To get a clear understanding of coverage planning, these parameters are explained below.

26.7.1 Transmission Characteristics (ITU-R BS-450-2)

ITU has defined FM transmission characteristics as per its recommendation BS-450-2. These characteristics define permissible range of parameters like AF bandwidth, maximum deviation, bandwidth of emission, pre-emphasis, maximum spurious emission, etc. These terms were defined and explained in Unit 23. However, for easy reference, these are summarized below:

AF bandwidth	:	15 kHz
Maximum deviation	:	± 75 kHz (Stereo Multiplex Signal)
Bandwidth of emission	:	180 kHz
Pre-emphasis	:	50 µ sec
Frequency tolerance	:	2000 Hz
Maximum spurious emission	:	– 60 dBc (60 dB below carrier)

26.7.2 Channel Spacing

Channel spacing is the difference in frequency between successive FM carriers. It is measured in kHz.

- Monophonic reception : optimum between 75 kHz and 100 kHz
- Stereophonic reception : optimum between 100 kHz and 150 kHz
- Optimum channel spacing : 100 kHz (used in India)
- Minimum frequency separation between transmitters co-located in the same city is 400 kHz (theoretically). But in India 800 kHz separation is presently being used between two transmitters operating in the same city in most of the places.

26.7.3 Minimum Usable Field Strength (E_{min})

For FM radio broadcasting, ITU has given, vide its Recommendation BS-450, different level of signal strength that are required for providing coverage to different geographical locations (Rural, Urban and Semi-Urban). ITU has also defined these parameters according to the type of reception, that is, mono or stereo as given in Table 2. While working out these recommendations, noise levels in different set of locations namely rural, urban and large city have been taken into consideration.

Table 2: Minimum Usable Field Strength

	Monophonic Reception	**Stereophonic Reception**
Rural Area	48 dB(mv/m)	54 dB(mv/m)
Urban Area	60 dB(mv/m)	66 dB(mv/m)
Large City	70 dB(mv/m)	74 dB(mv/m)

The field strength received from a given transmitter varies not only with location, but also with time. Therefore, FM radio services are normally planned to be available for 99% of the time in the case of national networks and 95% of the time for local services.

26.7.4 Radio Frequency Protection Ratio

A protection ratio is the required difference in field strength between a wanted and an interfering signal, and is normally expressed in dB. The required ratio falls as the frequency separation between the two stations increases, and is tabulated in Table 3.

Table 3: Protection Ratio

Frequency Spacing	**Monophonic**		**Stereophonic**	
(kHz)	***Steady***	***Troposphere***	***Steady***	***Troposphere***
0	36	28	45	37
100	12	12	33	25
200	6	6	7	7
300	–7	–7	–7	–7
400	–20	–20	–20	–20

26.7.5 CRS Frequencies

For proper operation of CR stations, WPC has identified specific frequency spots. These are 90.4, 90.8 and 107.8 MHz. As such, normally a CRS is allotted one frequency out of these frequencies. In addition, 91.2 MHz is also allotted wherever it is possible to do so.

Activity 26.4

To complete these activities, you may need about 10 minutes including writing down the answers in the space provided below.

Question:1 What is the channel spacing in VHF FM broadcasting? In USA, UK, Japan and India, what channel spacing is used in FM channels?

Question:2 Define protection ratios for co-channels (channels with same frequency repeated and at a different location) for stereophonic transmission in steady state.

26.8 Field Strength Measurements and Drawing an Actual Coverage Map

Measurement of field strength is important and essential to ensure effective planning and coverage of radio services, be it SW, MW or FM. Field strength meters measure the strength of RF signal available, which indicates whether the strength is good enough for desired reception. A field strength meter is quite commonly used for this purpose and therefore it is necessary to understand its operation and use. Also, it is necessary to learn the process of plotting and preparing of actual coverage map from these readings.

26.8.1 Field Strength Meter

A field strength meter is a microvolt meter or test receiver coupled with a suitable pick-up device (antenna) for measuring electrical and magnetic field strength.In broadcasting, it is used for propagation measurements, determination of coverage, radiation patterns of antennae, etc.

Basic Principles

A field strength meter comprises the following three essential parts:

- Pick-up device or transducer (antenna)
- Voltage measuring device
- Built-in calibration oscillator

Field strength is measured by comparing the voltage induced in the antenna circuit with the output of the built-in calibration oscillator.

Field Strength Measurement

A typical field strength measurement set-up is shown in Figure 26.7. It comprises a field strength meter, an antenna and a connecting cable. The antenna is connected to the input of the field strength meter through a cable. The measurement is carried out in two steps:

- First, the detector output of the receiver is adjusted up to certain indication E_o dB (µv/m) with the help of the attenuator.
- Second, the known output from calibration oscillator is fed to the receiver and the attenuator value is adjusted so as to get same output in the indicating device, that is, E_o dB (µv/m).

Measurement Range: Typical range –10 to + 160 dBµ

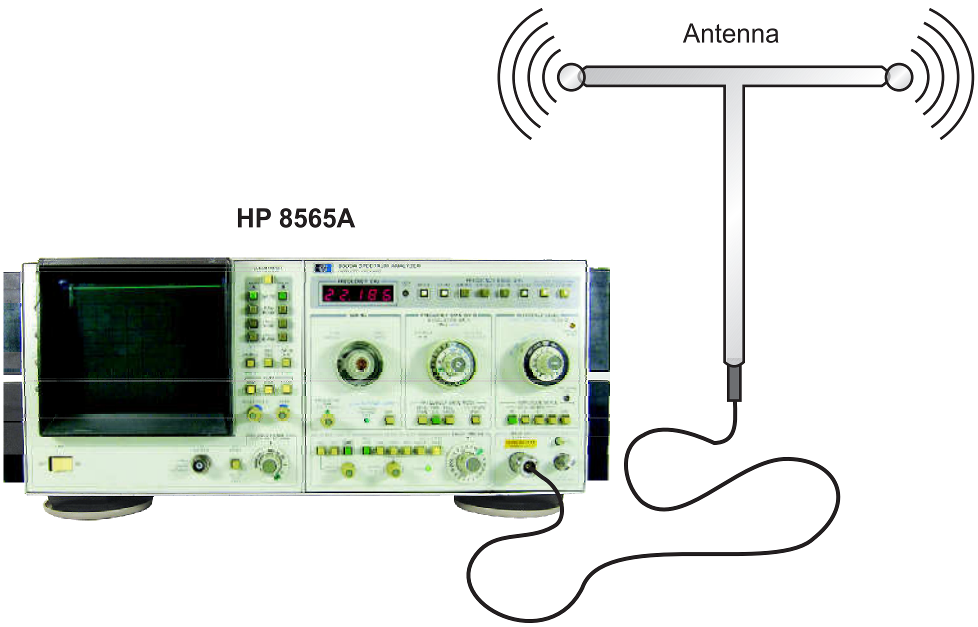


Figure 26.7: *Field strength measurement set-up*

Normally, field strength measurements are recorded when the CR station is set up or there is an issue of coverage not being satisfactory.

26.8.2 Drawing an Actual Coverage Map of an FM Transmitter

Let us carry out field strength measurement survey of a 300 w FM transmitter located in North-West Delhi to ascertain stereo and monophonic FM coverage. Since Delhi is an urban city, the desired field strength value should be 74 dB µv/m and 70 dB µv/m, respectively, for stereophonic and monophonic transmissions. These field strength values are measured and verified in a given direction at a particular distance from the FM transmitter. These distances for both stereo and mono transmissions are noted as shown in Table 4.

Table 4: Field strength measurement and coverage distance of 300 w FM transmitter

	Angle/Direction	**Distance in km for**	
		Stereo (74 dB µv/m)	**Mono** (70 dB µv/m)
1	0° / East	6.1	9.2
2	45° / North-East	6	8.9
3	90° / North	6.7	10.1
4	135° / North-West	6.2	10.3

5	180° / West	6.2	10.2
6	225° / South-West	6.1	10.4
7	270° / South	5.9	10
8	315° / South-East	5.8	9.8

Distances noted above (Table 4) for stereo and mono field strength values are plotted around the transmitter on a map, as shown in Figure 26.8. For stereophonic FM coverage, distances from the transmitter are marked in double line red colour around the transmitter. Areas under this double line red contour show coverage of stereo service. Similarly, areas under single line in grey colour contour around the transmitter show coverage map for mono service.

Figure 26.8: *Actual coverage map of a 300 w FM transmitter*

Activity 26.5

To complete this activity, you may need about 10 minutes including writing down the answer in the space given below.

Question: 1 Explain the procedures for measurement of field strength?

26.9 Let Us Sum Up

RF spectrum is defined in the range from 3 kHz to 300 GHz. This is further divided into various bands known as VLF, LF, HF, VHF, UHF, SHF and EHF. A spectrum over 1 GHz is known as a microwave.

Propagation of RF waves takes place in various layers of the atmosphere. These layers are known as troposphere, stratosphere and ionosphere. Most of the communication systems operate in troposphere. However, HF propagation through ionosphere helps in providing SW broadcast to longer distances.

Radio waves, while propagating in various medium (e.g., in troposphere), encounter reflection, refraction, diffraction, ducting, etc. These effects help operation of different types of communication systems for various purposes, e.g., refraction of HF by ionosphere facilitates short-wave broadcasting to longer distances, whereas troposphere/ducting extends microwave communication over longer distances.

Radio signals from FM transmitters propagate from the antenna and travel in different directions. These signals provide radio coverage but get attenuated with distance while travelling. The distance from the antenna at which the signal is attenuated to just minimum value, which is receivable by the receiver, defines radio coverage range. Radio coverage is affected by various parameters like frequency, transmitter power, antenna design and gain, antenna height and location, terrain condition, presence of noise, etc. Effective radiated power (ERP), which is the net output power radiated from the antenna after taking into account all losses and gain of the antenna, affects radio coverage. Radio coverage is normally not uniform around the transmitter because of terrain condition, which may cause obstruction to its propagation path. Such areas where radio signal strength is poor or is not available are called shadow areas.

Selection of antenna location is important, particularly when the terrain profile is not uniform and comprises hills and valleys. Proper selection of site helps in providing maximum radio coverage and minimizes shadow areas. Therefore, for site selection, knowledge on topography and use of toposheets are essential.

Understanding of planning parameters like channels spacing, minimum usable field strength, protection ratio, etc. is essential for FM radio coverage calculations and network planning. These parameters are defined in ITU-R recommendations. While planning FM radio coverage, one has to ensure that minimum usable field strengths are available within the targeted area and the wanted signal is protected from interference from other existing FM transmitters.

Field strength measurement survey is conducted to find out actual radio coverage of FM transmitters. When plotted over a map, these values indicate coverage of that radio service.

26.10 Model Answers to Activities

Activity 26.1

1. Microwave refers to electromagnetic energy having a frequency higher than 1 GHz, corresponding to wavelength shorter than 30 centimetres.

   Various radio services operate in microwave bands:

   i) Microwave links used for radio communication; for sending programme from the studio to the transmitter through STL (Studio-Transmitter Link)

   ii) Satellite communication: Up-linking to satellite, down-linking from satellite, satellite broadcasting (DTH service)

   iii) Telecommunications services

2. NFAP is the abbreviation of National Frequency Allocation Plan. This plan defines allocation of various services in different frequency bands. All spectrum users plan their services as per the provision given in the NFAP. Wireless Planning and Coordination (WPC) Wing of the Ministry of Communication and IT is responsible for preparing this plan. This plan is reviewed periodically, once in two years, in consultation with major spectrum users.

Activity 26.2

1. i) FM radio broadcasting (87–108 MHz)

   ii) Television broadcasting 54–68 MHz in Band-I; 174-230 MHz in Band-II

   iii) VHF radio links

   iv) VHF communications, walkie-talkie, etc.

   v) Aeronautical services

2. When VHF signal propagates in the troposphere, it may get reflected, absorbed, refracted or diffracted.

   When there is a temperature inversion, particularly over ocean, ducting may take place.

Activity 26.3

1. ERP = Transmitter power –Feeder cable loss + Antenna gain

   Transmitter power = 200 w = 23 dBw

   (1w = 0 dBw; 10w = 10 dBw; 100w = 20 dBw, 200w = 23 dBw), (3 dB gain doubles the power)

   Losses = 1.5 dB

   Gain = 4.5 dBi

   ERP = 23 dBw – 1.5 dB + 4.5 dBi = 26 dBw = 400 w

Activity 26.4

1. Channel spacing is the spacing between the main carrier frequency and the next immediate carrier. In FM broadcasting, FM channel carriers are separated by 100 kHz. For example, carrier of FM Gold in Delhi is 106.4 MHz and the next adjacent carrier frequency would be 106.5 MHz.

   Channel spacing for FM broadcasting in USA is 200 kHz, in UK it is 100 kHz, in Japan it is 100 kHz and in India it is 100 kHz.

2. Protection ratio is a value that ensures protection of wanted signals from unwanted signals. When co-channel frequencies of FM transmitters are repeated at different locations, within the coverage area of the wanted FM transmitter must be protected by the other FM transmitters operating in the same frequency at a different location. Protection ratio for these co-channels will depend on the type of coverage, that is, mono or stereo/steady or tropospheric. These values for co-channels or adjacent channels are defined in ITU-R, BS-450-2. According to the ITU rec, protection ratio for co-channel stereophonic transmission in steady state is 45 dB.

Activity 26.5

1. The field strength measurement set-up comprises a field strength meter/spectrum analyser, a calibrated antenna and a connecting cable. The antenna is connected to the input of the field strength meter through a cable. When measuring with a field strength meter, it is

important to use a calibrated antenna such as the standard antenna supplied with the meter. For precision measurements, the antenna must be at a standard height. A value of standard height frequently employed for VHF and UHF measurements is 10 metres.

The measurement is carried out as mentioned below:

- Calibrated antenna is to be installed at a standard height.
- Antenna is connected to the field strength meter.
- Meter is calibrated.
- Field strength readings are taken and corresponding distance from the transmitter is also noted.

26.11 Additional Readings

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Glossary

Antenna	is a device (transducer) that converts guided waves in cables into free space waves or vice versa.
Antenna Aperture (physical)	is a measure of the actual physical size of the antenna (physical cross section perpendicular to direction of propagation).
Antenna Gain	is the ability of the antenna system to give more field strength at a point in comparison to that would have been given by a single half-wave dipole when fed with the same power as that of the antenna system.
Antenna Efficiency	is the ratio of the radiated power to that of the input power supplied to the antenna.
Beam Width	of the antenna is a measure in degrees on the main lobe of the radiation pattern between the points where the radiated power has fallen to half of its maximum value.
CCIR	stands for Consultative Committee on International Radio-Regulations.
Dipole	is a pair of electric charges or magnetic poles that have equal magnitudes but opposite signs and are separated by a small distance.
Dynamic Range	is the difference between the lowest and the highest levels of notes produced by any musical instrument or a frequency operating system.
ERP	(Effective Radiated Power) means the total output power thrown in the air by the antenna system. This is generally calculated with a mathematical formula that takes into account the output power, cable loss and antenna gain.
ERP (Effective Radiated Power)	is the product of input power to the antenna and antenna gain. The power fed to the antenna as used here is equal to the transmitter power minus the losses in a coaxial cable.
Equalization	is a process through which the frequency response of any equipment is adjusted to the desired value.
Exciter	is the first stage of FM broadcasting where the RF signal is generated and modulated.
Free space	is a space that does not interfere with normal radiation and propagation of radio waves.

Half-wave Dipole	is an antenna whose length of its longer side is equal to half the wavelength at the frequency of operation.
Isotropic Radiator	is a radiator that radiates energy uniformly in all directions.
ITU	stands for International Telecommunication Union.
Heat Sink	is a specially designed aluminum plate to absorb heat.
Layers of Atmosphere	include troposphere, stratosphere, and ionosphere. The atmosphere consists of these layers. Ionosphere is further divided into D layer, E layer and F layer.
Minimum Usable Field Strength:	In case of FM radio broadcasting, different levels of signal strength is required for providing coverage to different geographical locations (rural, urban, semi-urban, etc). ITU defined these parameters according to the type of reception, that is, mono or stereo for different geographical condition, e.g., for stereophonic reception in rural areas it is 54 dB (mv/m).
NFAP (National Frequency Allocation Plan)	The Wireless Planning and Coordination (WPC) Wing of the Ministry of Communication and IT is responsible for preparing this plan. This plan is reviewed periodically, once in two years, in consultation with major spectrum users. This plan defines allocation of various services in different frequency bands. All spectrum users plan their services as per the frequency provisions in the NFAP.
Nominal Level	is the operating level at which the electronic equipment is designed to operate.
Output Power	is the total output that is measured at the transmitter equipment output.
Protection Ratio	is the required difference in field strength between a wanted and an interfering signal, and is normally expressed in dB.
Phantom supply	is a dc supply required for the operation of certain microphones for polarizing their transducer elements.
PLL (Phase Lock Loop)	is an electronic concept that helps devices to stick to a desired frequency.
RF Amplifier	is a device that amplifies the RF signal before sending it to the antenna.
RF Filter	is an electronic device that cuts out spurious and harmonics from radio frequency signals.
Reflected Power	is a portion of the output power thrown by the antenna system back to the transmitter.

Standing Wave Ratio (SWR)	is the ratio between the output power and the reflected power.
Shadow Areas	are the uncovered areas between transmitters or within the targeted areas of a transmitter due to unavailability of the desired level of RF signal because of obstruction or poor signal strength.
Signal to Noise Ratio (SNR)	is the ratio of nominal signal level to the noise level present in it.
SMPS (Switch Mode Power Supply)	converts alternate current into direct current and produces regulated supply.
Wavelength	is the length (in metres) of one cycle of the frequency of operation.
WPC (Wireless Planning and Coordination)	is a Wing of the Department of Telecommunications, which is responsible for planning of wireless services in the country. WPC issues the licence for operating frequency of a CR station.

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