Antenna

9.1. Introduction to Antenna

The study of antennas and microwaves is a fundamental part of communication and electronic engineering. Antennas act as the interface between electrical circuits and electromagnetic waves, while microwaves refer to electromagnetic waves with frequencies typically ranging from 1 GHz to 300 GHz. These frequencies are used in radar systems, satellite communications, wireless networks, and microwave ovens.

9.2. What is an Antenna?

An antenna is a device that converts electrical signals into electromagnetic waves and vice versa. It transmits or receives radio waves, enabling wireless communication between devices.

9.2.1 Types of Antennas

1. Dipole Antenna: The simplest form, used in radios and TV receivers.

2. Monopole Antenna: Usually mounted on a conductive surface, such as car antennas.

3. Loop Antenna: Used in low-frequency communication systems.

4. Patch (Microstrip) Antenna: Compact and widely used in mobile phones and satellites.

5. Horn Antenna: Common in microwave and radar applications.

6. Parabolic Reflector Antenna: Used in satellite dishes for long-distance communication.

9.2.2 Basic Parameters of Antennas

• Gain: Measures how well an antenna directs energy in a specific direction.

• Radiation Pattern: The spatial distribution of the radiated power.

• Bandwidth: The range of frequencies over which the antenna performs efficiently.

• Polarization: The orientation of the electric field (linear, circular, or elliptical).

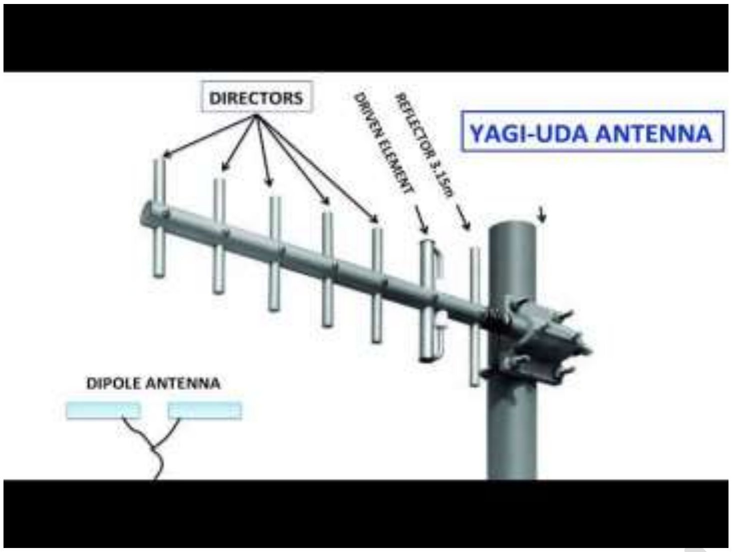
• Efficiency: Ratio of radiated power to total input power.

Mathematically, the power radiated by an antenna can be expressed as:

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi R)^2 L}$$

Symbol	Definition	Unit
P_r	Received power at the receiving antenna	watts (W)
P_t	Transmitted power from the transmitting antenna	watts (W)
G_t	Gain of the transmitting antenna (linear, not in dB)	—
G_r	Gain of the receiving antenna	—
λ	Wavelength of the transmitted signal	meters (m)
R	Distance between the two antennas	meters (m)
L	System or path loss factor (≥ 1)	—

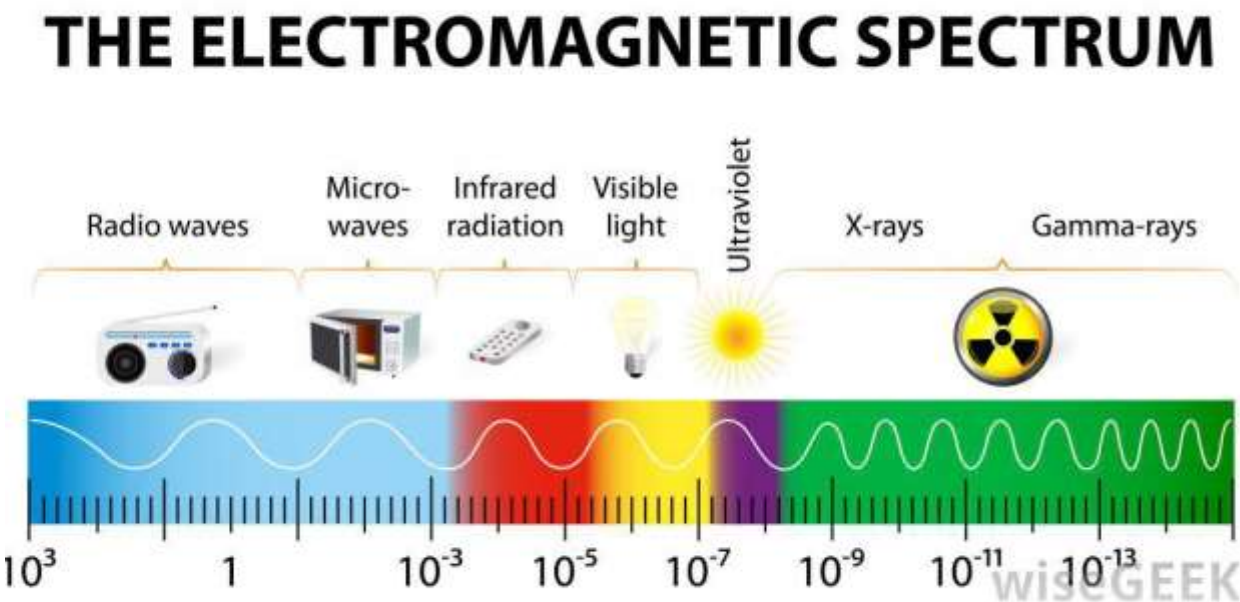
This formula is known as the Friis Transmission Equation.



9.3Introduction to Microwaves

Microwaves are used in radar, radio transmission, cooking and other applications that have become essential in our modern society. Microwaves are electromagnetic waves generally defined as lying within the frequency range of 100 MHz (3 m wavelength) to 300 GHz (1 mm wavelength). Above 30 GHz, because wavelengths are measured in mm, it is the convention to call them mmWaves. The optical frequency regime begins above 300 GHz with infrared. The radio frequency range extends down from the microwave region to as low as 3 KHz (100,000 m wavelength). It is important to understand that these are all electromagnetic waves that obey the same classical laws.

Because the dimensions of common discrete electrical components (e.g. carbon resistors, mica capacitors, wire-wound inductors) and the wires connecting them become large relative to a wavelength at microwave frequencies and above, they are no longer suitable for the construction of microwave circuits. Distributed “printed” circuit components, waveguide and specialized active components (i.e. amplifiers) with microscopic internal dimensions are used instead, until wavelengths become so small that optical techniques, such as the use of lenses and mirrors, are employed.



The speed of propagation (also called the speed of an electromagnetic wave) in free space is given by:

$$c = f\lambda$$

Symbol	Meaning	Typical Unit
c	Speed of propagation of the wave in free space	meters per second (m/s)
f	Frequency of the wave	hertz (Hz)
λ	Wavelength of the wave	meters (m)

Characteristics of Microwaves

- Short wavelength and high frequency.

- Capable of line-of-sight transmission.
- Easily directed using antennas.
- Low interference and high bandwidth.
- Require special transmission media such as waveguides.

9.4 Advantages of Microwaves

1. High Data Transmission Rate:

The large bandwidth of microwaves supports faster communication.

2. Smaller Antenna Size:

As the frequency increases, the wavelength decreases — allowing smaller antenna dimensions.

$$L_{\text{antenna}} = \frac{\lambda}{4}$$

3. Long-Distance Communication:

Used for satellite and terrestrial links due to low attenuation.

4. Less Interference:

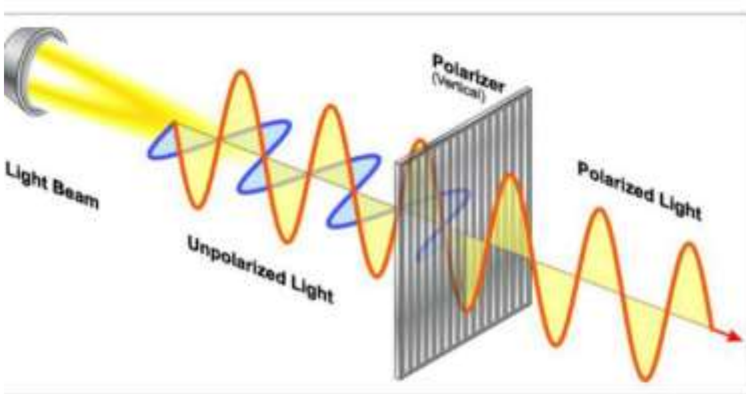
Microwave frequencies are less affected by atmospheric noise.

5. Efficient Point-to-Point Transmission:

Suitable for radar, satellite, and cellular systems.

6. Versatility:

Used in communications, radar, medicine, and industrial heating.



9.5 Applications of Microwaves

• Communication Systems: Used in satellite, radar, and mobile networks (5G).

• Medical Field: Employed in diathermy and cancer treatment.

• Industrial Heating: Used in drying and cooking processes (e.g., microwave ovens).

• Remote Sensing and Radar: Used for weather forecasting and navigation.

9.6 Microwave Components

1. Waveguides: Hollow metal tubes used to guide microwaves efficiently.

2. Cavity Resonators: Used to store microwave energy and generate oscillations.

3. Microwave Amplifiers: Increase signal strength (e.g., traveling wave tubes).

4. Circulators and Isolators: Control the direction of signal flow and prevent feedback.

9.7 Relationship Between Antennas and Microwaves

Antennas operating at microwave frequencies require precision design due to small wavelengths and higher losses.

At these frequencies:

• Horn antennas are used for transmission in microwave labs.

• Parabolic dishes focus the waves into narrow beams for long-distance communication.

• Microstrip patch antennas are used in 5G, GPS, and satellite systems.