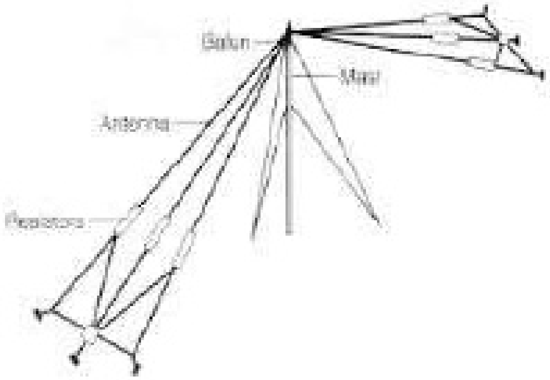
Different Types of Antennas



Wire Antenna

Aperture Antenna

Microstrip Antenna

Array Antenna

Reflector Antenna

Lens Antenna

Microstrip Patch Antenna

- Microstrip Antenna was Invented by Bob Munson in 1972 .
- Microstrip antennas are attractive due to their light weight, conformability and low cost.
- These antennas can be integrated with printed strip-line feed networks and active devices. This is a relatively new area of antenna engineering.
- The radiation properties of micro strip structures have been known since the mid 1950's.
- A Microstrip Patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side.
- The patch is generally made of conducting material such as copper or gold and can take any possible shape.
- The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

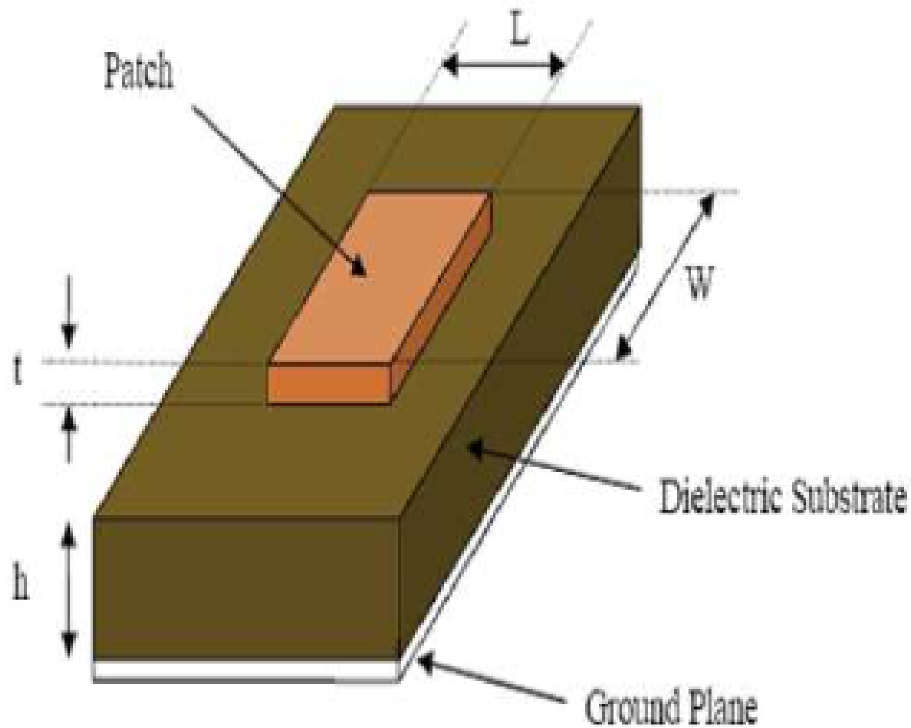
Basic Structure Microstrip patch Antenna

L = Length of the Micro-strip Patch Element

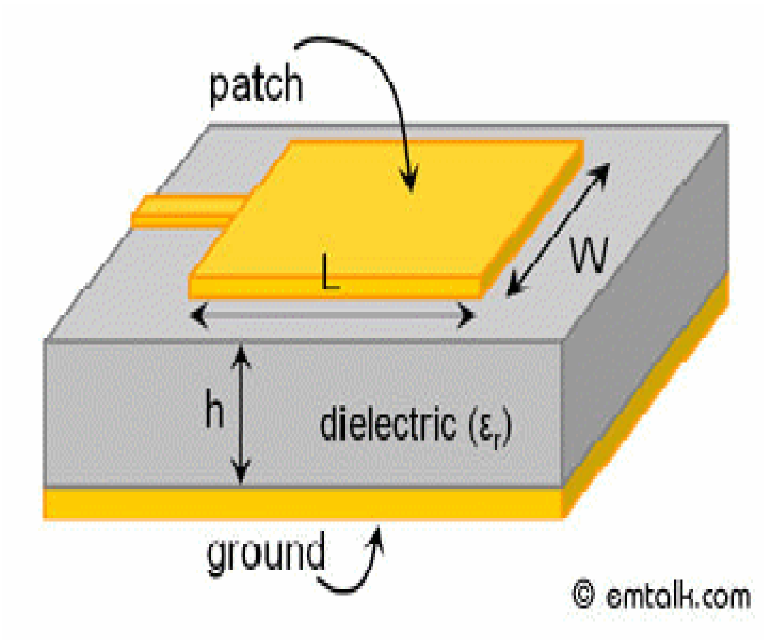
W = Width of the Micro-strip Patch Element

t= Thickness of Patch

h = Height of the Dielectric Substrate.



Microstrip Rectangular Patch Antenna



$$W = \frac{v_o}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

$$L = \frac{v_o}{2f_r\sqrt{\varepsilon_{\text{reff}}}} - 2\Delta L$$

$$\varepsilon_{\text{reff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}$$

$$\Delta L = 0.412h\frac{(\varepsilon_{\text{reff}} + 0.3)(W/h + 0.264)}{(\varepsilon_{\text{reff}} - 0.258)(W/h + 0.8)}$$

TOP VIEW OF PATCH

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1 + \frac{12h}{W}}}\right)$$

Length of metallic patch (L)

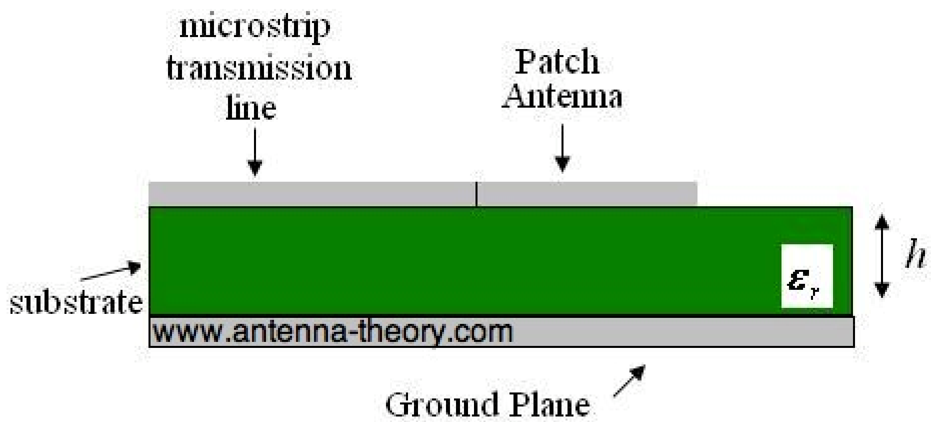
$$L = L_{eff} - 2\Delta L$$

Where

$$L_{eff} = \frac{C}{2 f_r \sqrt{\varepsilon_{eff}}}$$

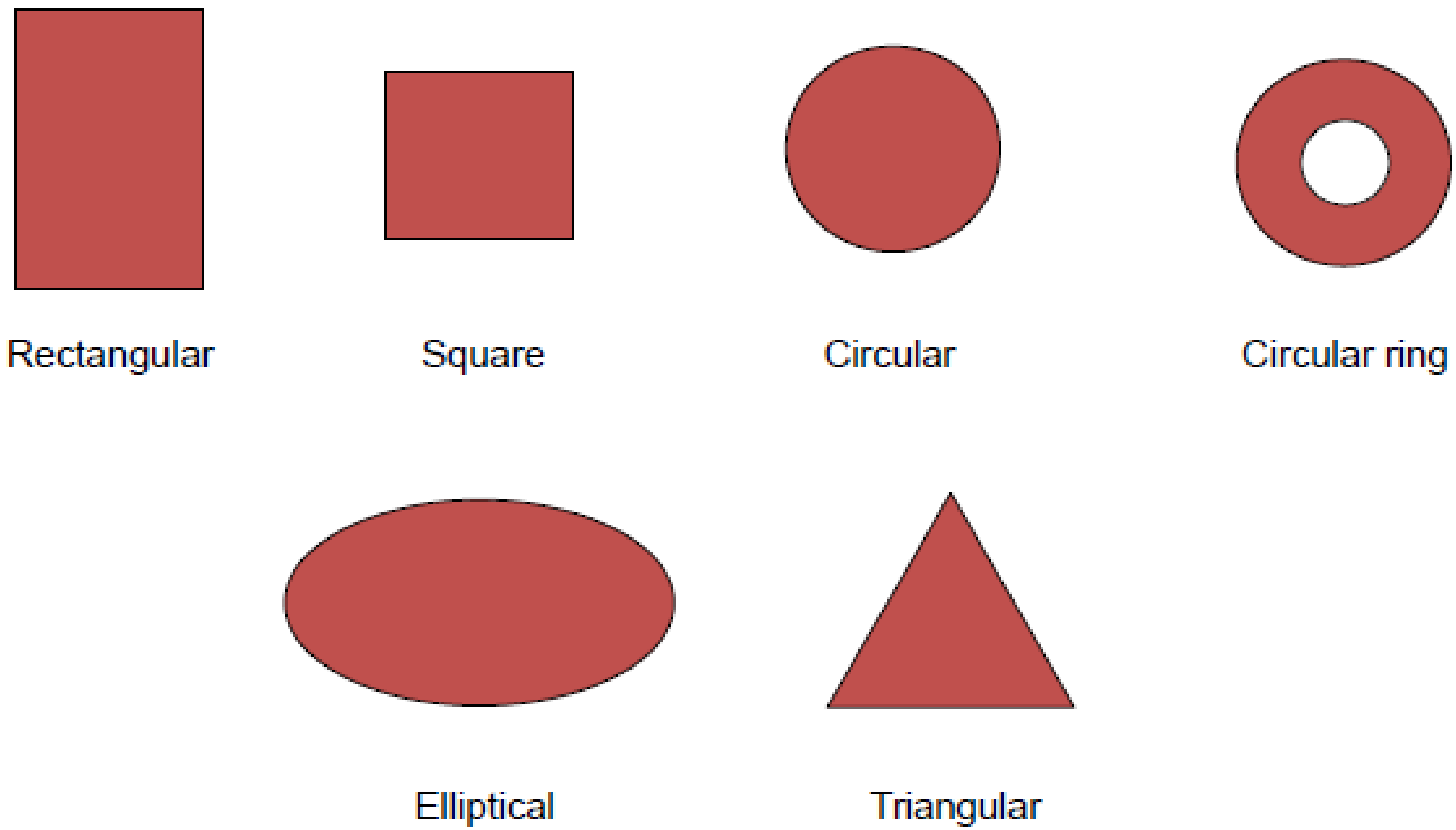
B. Calculation of Length Extension

$$\frac{\Delta L}{h} = 0.412 \frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$



SIDE VIEW OF PATCH

Some of the Typical Shapes of Patch



Substrate Material(FR4 Epoxy)

- The Dielectric Substrate Material we are using in our Design is FR4 Epoxy
- Where "**FR" means Flame Retardant and type 4 indicates** Woven Glass reinforced Epoxy resin.
- The Range of the dielectric constant of FR4 Epoxy typically depends on glass resin.
- This material is popular and cost effective Compared to other PCB material.
- FR4 is most Commonly Used as an electrical insulator possessing considerable mechanical Strength.
- FR4 is also used in the construction of relays, switches, standoffs, busbars, washers, transformer and screw terminal strips.

- The thickness of the ground plane or of the microstrip is not critically important.
- Typically the height *h* is much smaller than the wavelength of operation, but should not be much smaller than 0.025 of a wavelength (1/40th of a wavelength) or the antenna efficiency will be degraded.
- The width *W* of the microstrip antenna controls the input impedance.
- Larger widths also can increase the bandwidth.

- The frequency of operation of the patch antenna is determined by the length *L*. The center frequency will be approximately given by:

$$f_c \approx \frac{c}{2L\sqrt{\varepsilon_r}} = \frac{1}{2L\sqrt{\varepsilon_0 \varepsilon_r \mu_0}}$$

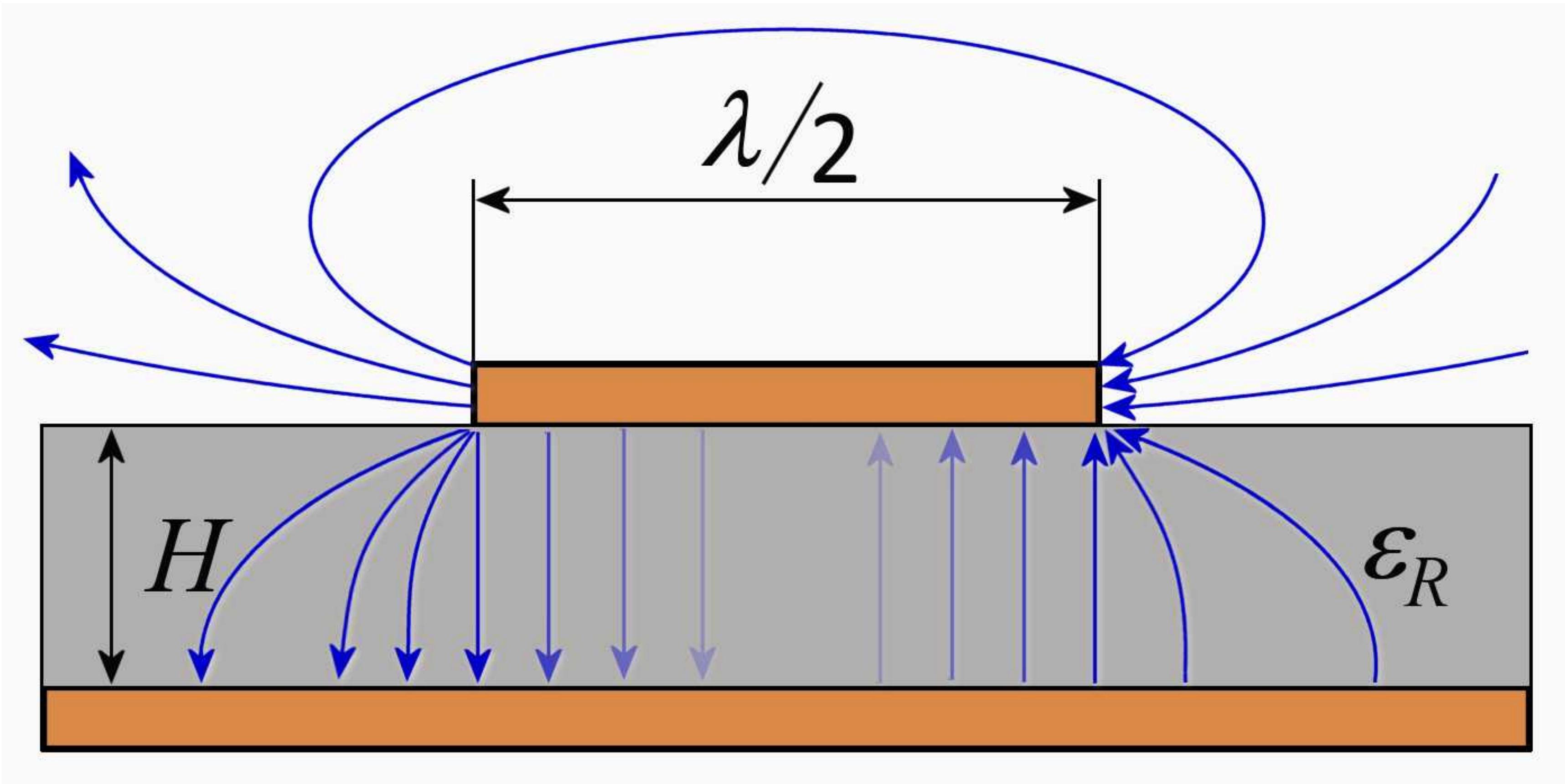
- the input impedance will be on the order of 300 Ohms. By increasing the width, the impedance can be reduced.
- However, to decrease the input impedance to 50 Ohms often requires a very wide patch antenna, which takes up a lot of valuable space.
- The width further controls the radiation pattern.

$$E_\theta = \frac{\sin\left(\dfrac{kW \sin\theta \sin\phi}{2}\right)}{\dfrac{kW \sin\theta \sin\phi}{2}} \cos\left(\frac{kL}{2} \sin\theta \cos\phi\right) \cos\phi$$

$$E_\varphi = -\frac{\sin\left(\dfrac{kW \sin\theta \sin\phi}{2}\right)}{\dfrac{kW \sin\theta \sin\phi}{2}} \cos\left(\frac{kL}{2} \sin\theta \cos\phi\right) \cos\theta \sin\phi$$

- this transmission line cannot support pure Transverse Electric-magnetic (TEM) mode of transmission, since phase velocities would be different in the air and the substrate.
- Instead, the dominant mode of propagation would be the Quasi-TEM mode.

Fringing Fields for Microstrip Antennas



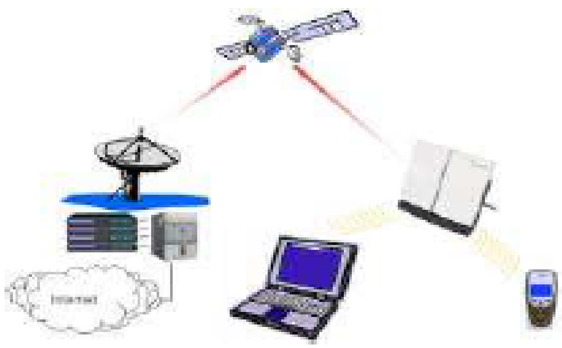
Microstrip Antenna Resonates at

X-Band	8-12GHz
Ku-Band	12-18GHz
K-Band	18-26GHz
Ka-Band	26-40GHz

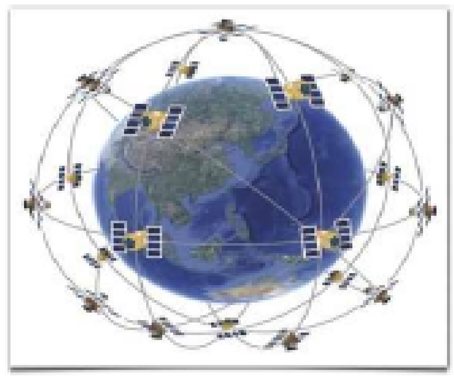
Advantages and Disadvantages of MSA

Sr. No.	Advantage	Disadvantage
1.	Low weight	Low efficiency
2.	Low profile	Low gain
3.	Thin profile	Large ohmic loss in the feed structure of arrays
4.	Required no cavity backing	Low power handling capacity
5.	Linear and circulation polarization	Excitation of surface waves
6.	Capable of dual and triple frequency operation	Polarization purity is difficult to achieve
7.	Feed lines and matching network can be fabricated simultaneously	Complex feed structures require high performance arrays

Application of MSA



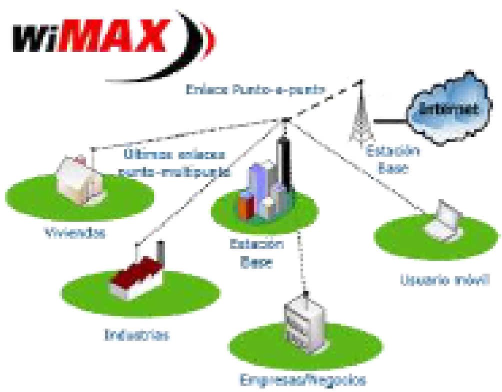
Mobile and satellite communication System



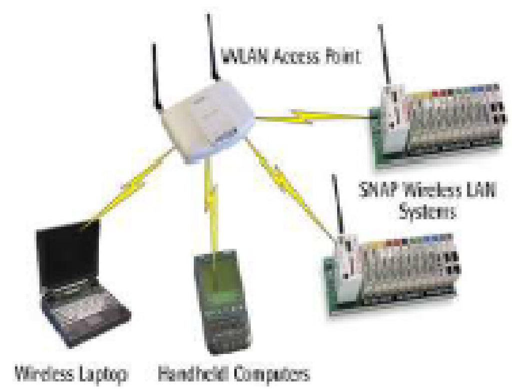
Global Positioning System(GPS)

Direct Broad Cast Television(DBS)

Radio Frequency Identification (RFID)



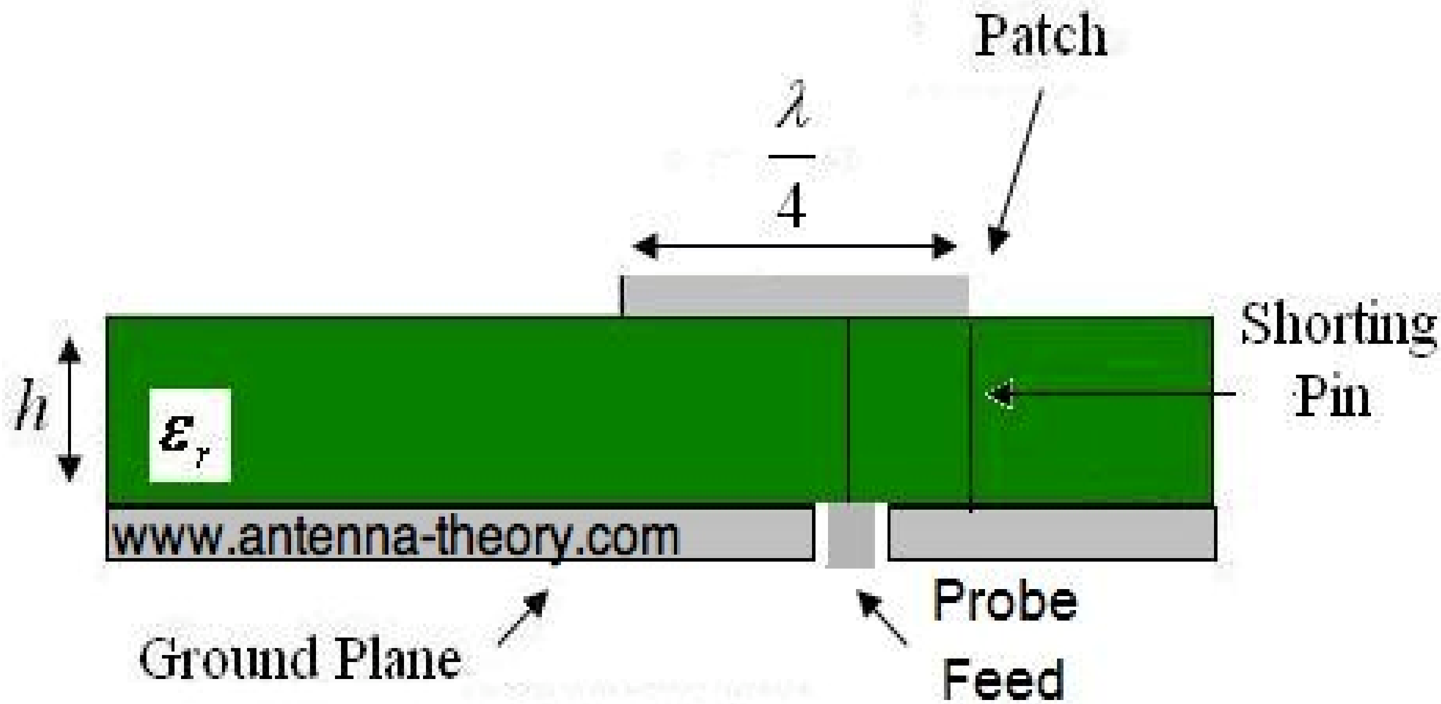
Worldwide Interoperability for Microwave Access (WiMax)



Wireless LAN's

Planar Inverted F-Antenna (PIFA)

- Increasingly used in the mobile phone market.
- The antenna is resonant at a quarter-wavelength (thus reducing the required space needed on the phone),
- and also typically has good SAR properties.
- This antenna resembles an inverted F, which explains the PIFA name.
- The Planar Inverted-F Antenna is popular because it has a low profile and an omnidirectional pattern.

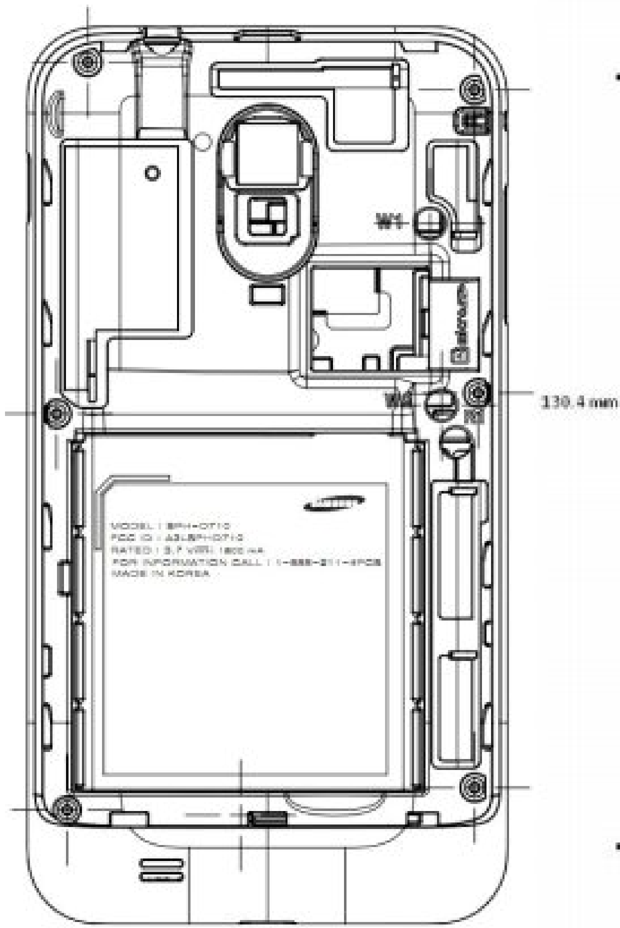


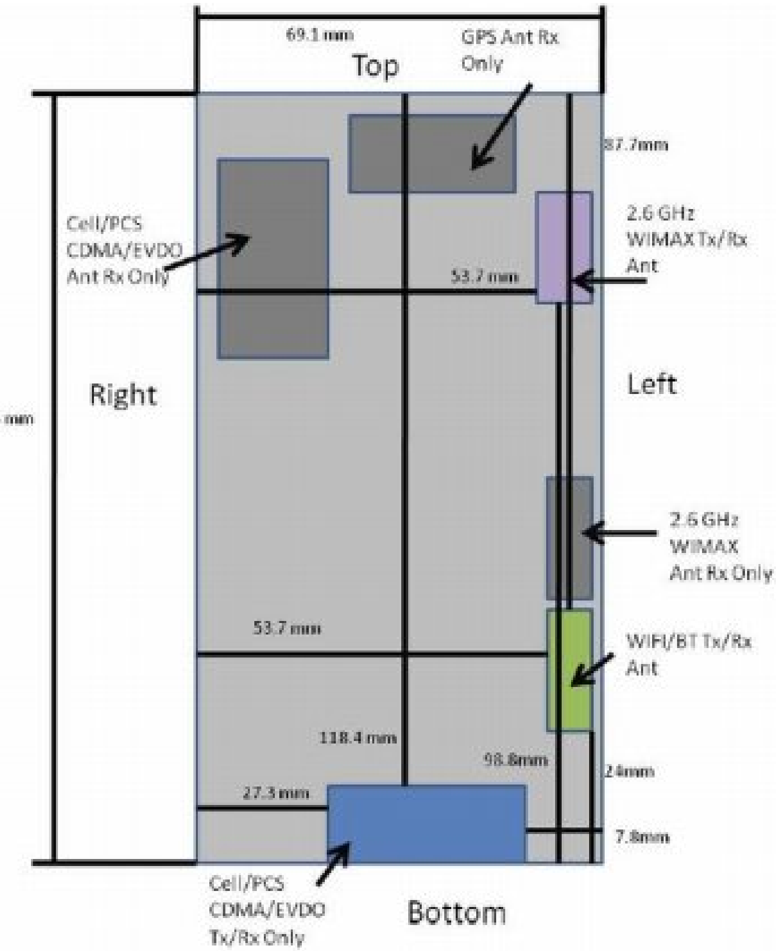
Patch
$\frac{\lambda}{4}$
Shorting
Pin
h
ε_r
www.antenna-theory.com
Ground Plane
Probe
Feed

Specific Absorption Rate

- measure of how transmitted RF energy is absorbed by human tissue. SAR is a function of the electrical conductivity, the induced E-field from the radiated energy and the mass density of the tissue.
- The SAR is calculated by averaging (or integrating) over a specific volume (typically a 1 gram or 10 gram area)
- The units of SAR are W/kg, or equivalently, mW/g.

The antenna types and locations on the Samsung Galaxy S



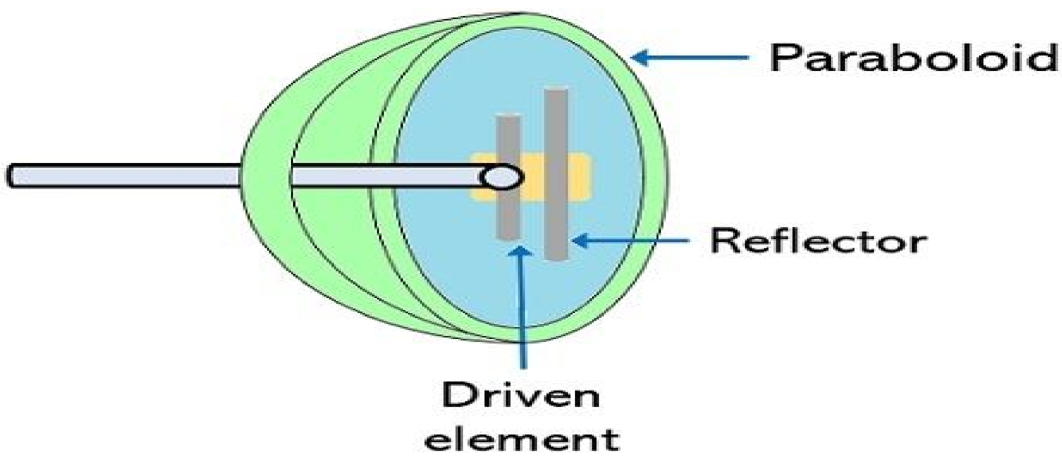


PARABOLIC ANTENNA

- curved surface with the cross-sectional shape of a parabola, to direct the radio waves.
- The most common form is shaped like a dish and is popularly called a dish antenna or parabolic dish.
- reflecting surface having the shape of a **Paraboloid** .
- used to collect and re-radiated the electromagnetic energy.

- distinctive shape **offers high gain** and **narrow bandwidth**.
- **Frequency Range:** is above 1MHz.
- These antennas are widely used for radio and wireless applications.
- used both at transmitting as well as receiving antenna.

- it transforms the plane wave from the axis towards the focus into the spherical wave.
- While the spherical wave from, a point source present at focus is transformed into the plane wave and is parallelly propagated along the axis.



Paraboloidal reflector with dipole source at focus

WORKING

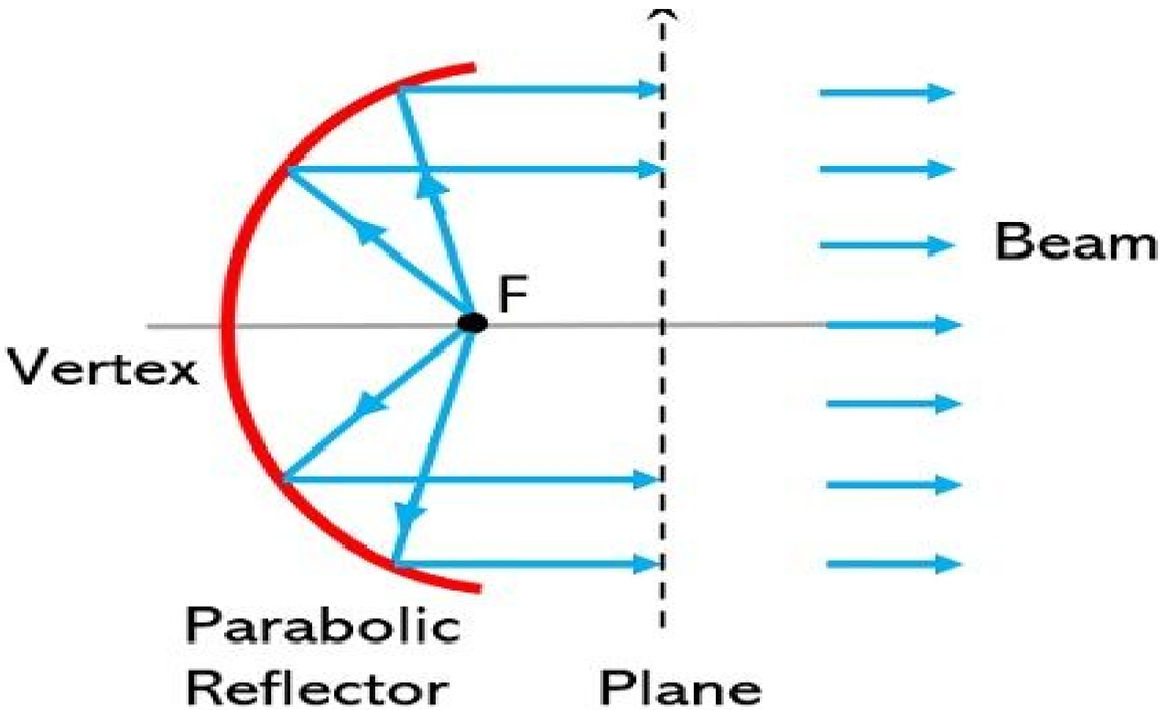
- At the transmitting end, the signal from the feed is focused towards the parabola.
- This implies that wave emerging from the feed strikes the parabolic reflector and from here it is further reflected as collimated wave-front in the desired direction.

- While at the receiving end, the electromagnetic wave from the transmitting antenna when reaches the reflector antenna, then is converted into the spherical wave and is further directed to change to electrical form which is required at the respective circuit.

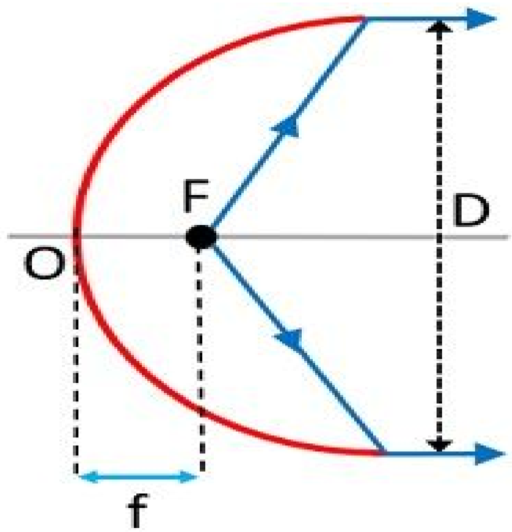
What is a parabola?

- A parabola is regarded as a 2-D plane curve.
- While a reflector antenna must possess a three-dimensional structure.

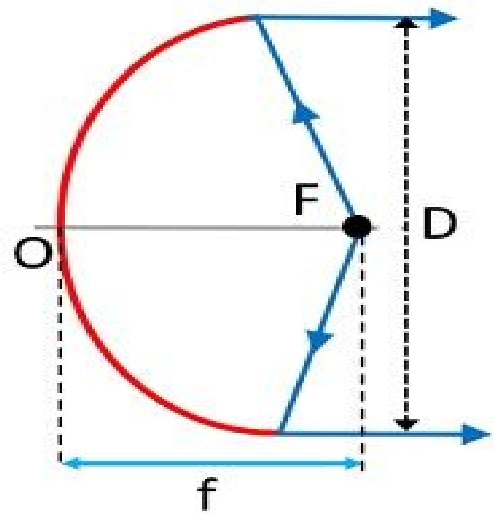
Working Principle of Parabolic Reflector



Ray representation through parabolic reflector

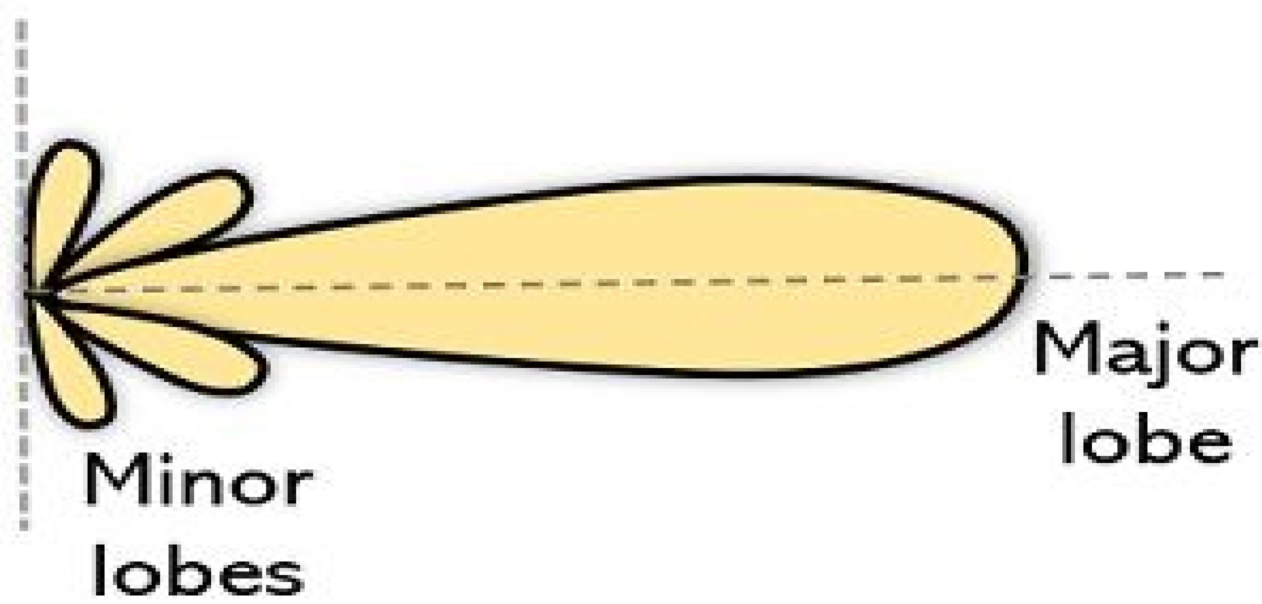


Focus inside the aperture plane



Focus outside the aperture plane

Radiation Pattern



Radiation Pattern of Parabolic Reflector

Advantages

- The use of parabolic reflectors reduces minor lobes.
- It offers high gain and directivity.
- The amount of power wastage is comparatively less than other antennas.
- It provides flexibility in positioning the feed element.
- The use of parabolic reflector helps to provide easy beam adjustment.
-

Disadvantages

- The size of the structure quite large.
- The overall cost of the system is high.
- The small element of paraboloid causes some amount of power obstruction.
-

Applications of Parabolic Reflector

- The high directive gain offered by these antennas makes it suitable for various applications like:
- Satellite communication
- TV signal broadcasting
- Wireless communication
- Radio astronomy
- Parabolic microphones and
- Lighting devices such as car headlights, etc.

Lens Antenna

- we have discussed till now, used the **plane surface**.
- The lens antennas use the **curved surface** for both transmission and reception.
- **Lens antennas** are made up of glass, where the converging and diverging properties of lens are followed.
- The lens antennas are used for **HF** applications.

- These antennas consist of a dipole or horn antenna followed by a lens.
- Used at HF as they can be quite bulky at lower frequencies.
- The size of the lens used depends on the operating frequency - the higher the frequency the smaller the lens.
- uses the **convergence** and **divergence** properties of a lens to transmit and receive signals.
- The frequency range -starts at **1000 MHz** but its use is greater at **3000 MHz and above**.

- A normal glass lens works on the principle of refraction.

- The **principle of refraction utilized by the optical lens for light in order to re-radiate the received energy in the desired direction**.
- **Definition**: The lens antenna is 3-D electro-magnetic device which has refractive index other than unity.

  It consists of electro-magnetic lens along with feed. This antenna is similar to glass lens used in optical domain.
- **Definition**: A type of antenna that is designed to collimate the incident divergent energy in order to convert it into plane waves using proper lens material is known as **Lens Antenna**.

Functions Of A Lens Antenna

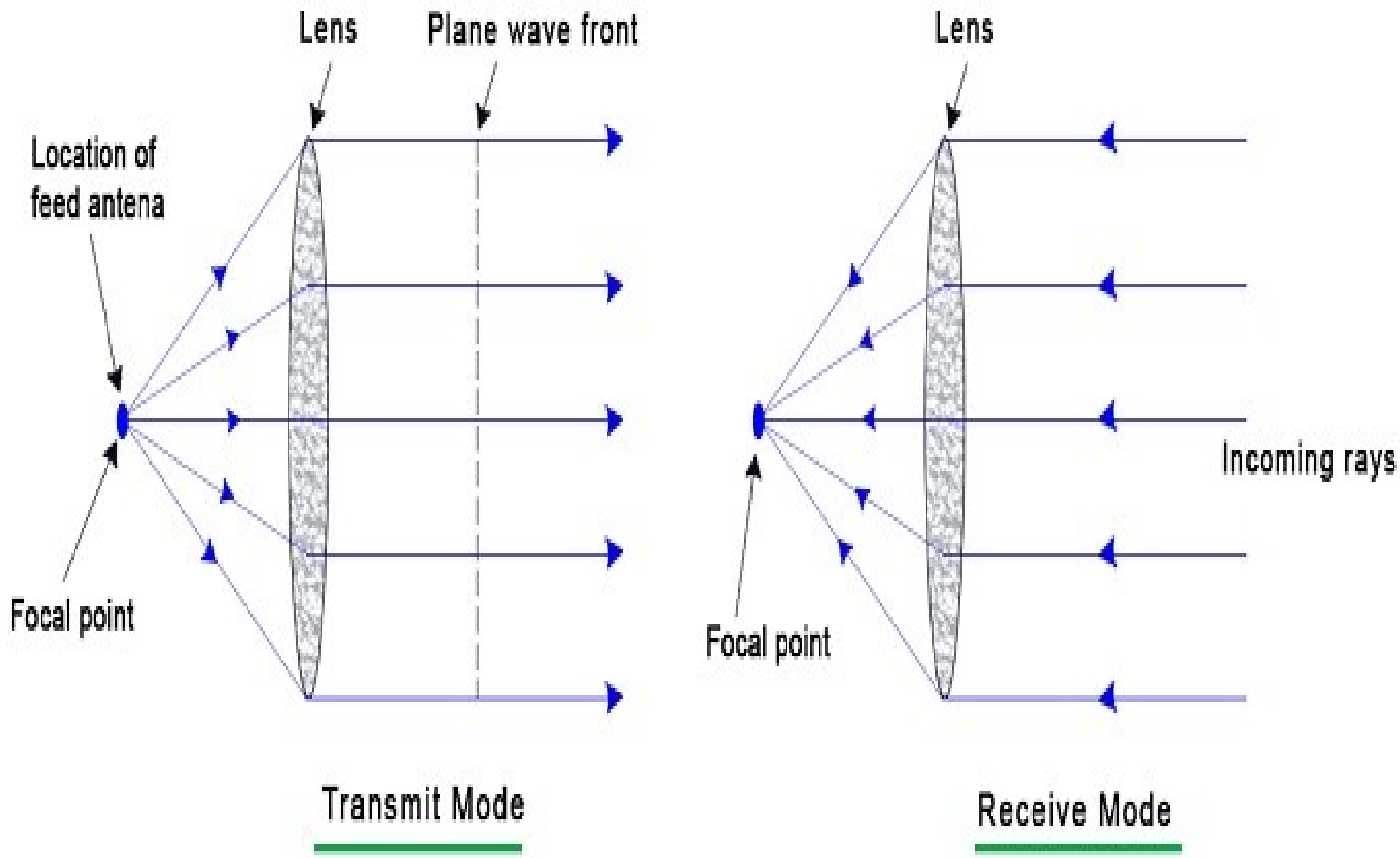
- It generates plane wavefront from spherical.
- It forms incoming wavefront at its focus.
- It generates directional characteristics.
- It is used to collimate electromagnetic rays.
- It controls aperture illumination.

- Lens antenna is regarded as a radiator which operates on collimated action of optical lens.
- Its operation is similar to **Reflector Antennas**.
- the reflector antenna that allows the energy falling on its surface to collimate in the desired direction.
- Thus, results in converting the spherical waves into plane waves.
- This causes an increase in the directive gain offered by the antenna arrangement.
- Similar to a Parabolic Reflector, a lens antenna is designed to collimate the incident energy which is diverging in nature, in the desired direction.
- This prevents the undesired spreading of the energy thereby improving the efficiency.

Operating Principle

- Lens antennas use the ***principle of the converging lens* in order to collimate the energy that incident on it**.
- In a similar way in case of lens antenna, the point source acts as the feed that emits the microwave energy towards the surface of the optical lens.
- This **optical surface forces the radiated spherical wavefronts to get changed into collimated one**.

- The collimating lens is made of dielectric material which possesses the finite value of dielectric constant.
- But these can also be constructed with materials that exhibit less than unity refractive index at radio frequencies.
- It somewhat displays reciprocity theorem thus is used at the transmitting as well as receiving ends.


Lens
Plane wave front
Location of
feed antena
Focal point
Transmit Mode
Lens
Incoming rays
Focal point
Receive Mode

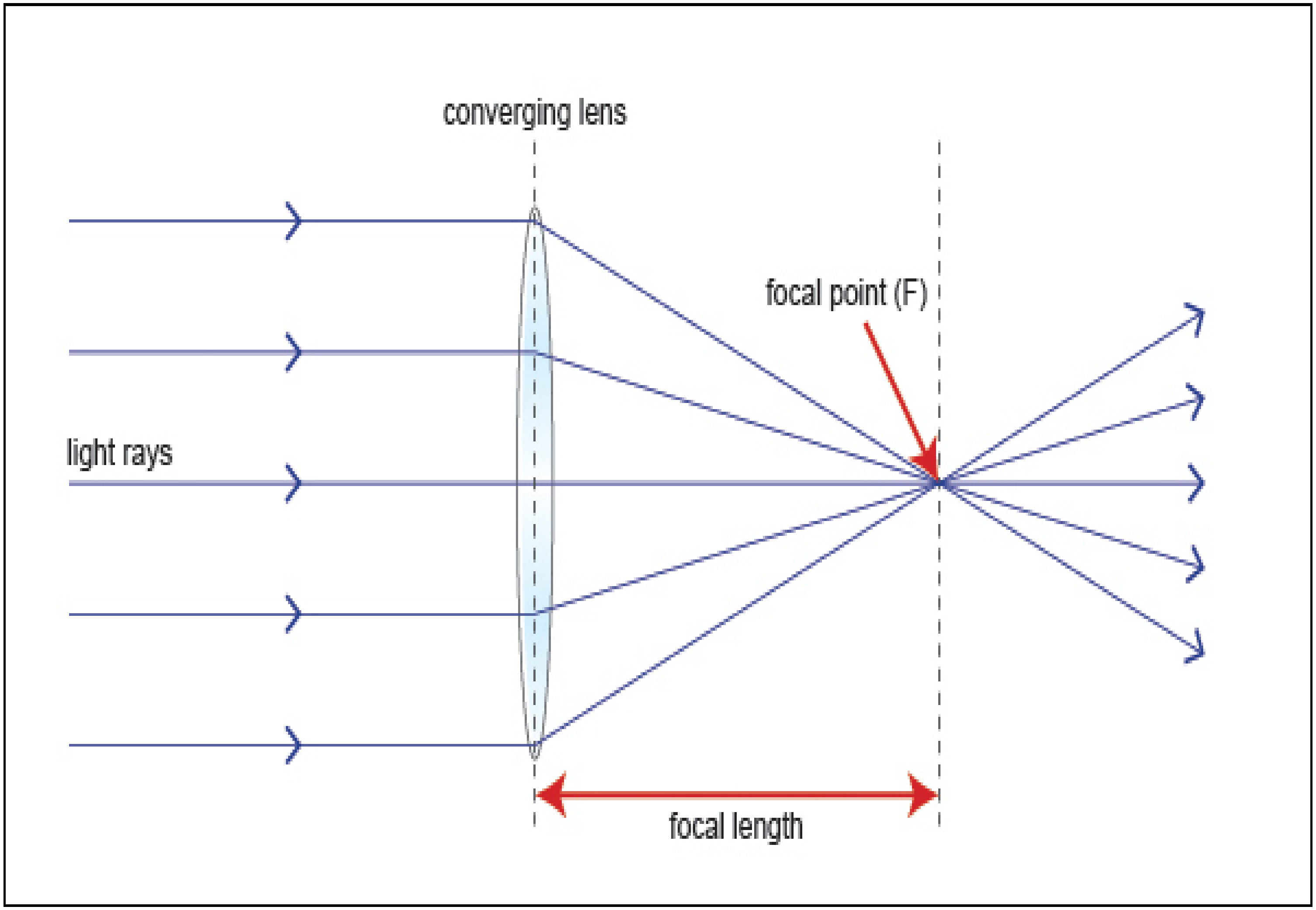
Construction of Lens Antenna

- If a light source is assumed to be present at a focal point of a lens, which is at a focal distance from the lens, then the rays get through the lens as collimated or parallel rays on the plane wavefront.
- The rays that pass through the centre of the lens are less refracted than the rays that pass through the edges of the lens.
- All of the rays are sent in parallel to the plane wave front. This phenomenon of lens is called as **Divergence**.

- The same procedure gets reversed if a light beam is sent from right side to left of the same lens.
- Then the beam gets refracted and meets at a point called focal point, at a focal distance from the lens.
- This phenomenon is called **Convergence**.

- While transmitting, the lens is placed in such a way that the feeding antennas is located at its focal point, this way we get collimated or parallel rays at the output of the lens.
- The feed is usually a horn antenna that generates a spherical wavefront or an antenna array that produces a cylindrical wavefront.
- While receiving, when the incident rays strike the lens they get refracted and get converged to the focal point where the receptor is located.
- These types of antennas are used for HF applications that require wide bandwidths.

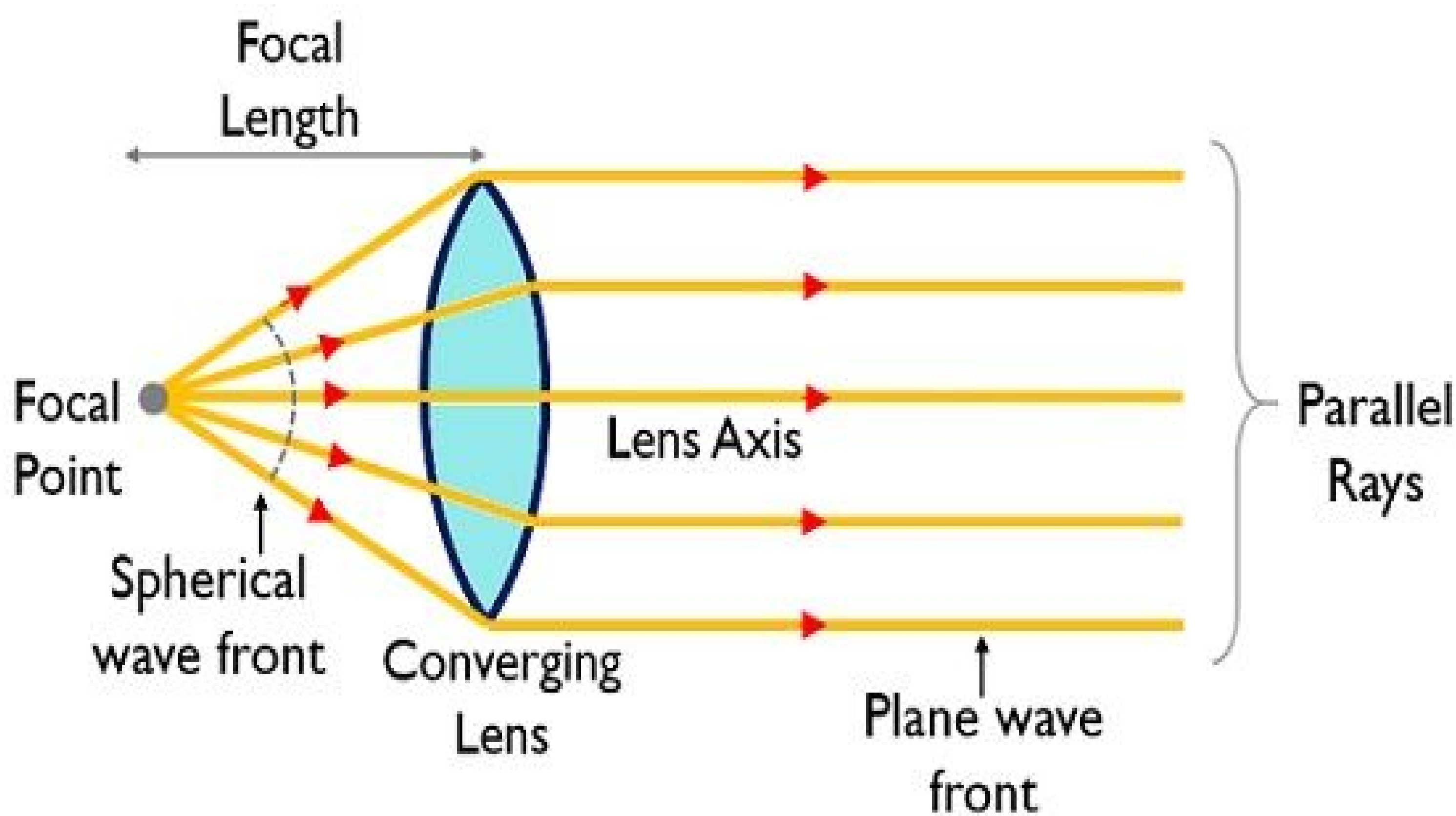
- The ray diagram represents the focal point and focal length from the source to the lens.
- The parallel rays obtained are also called as Collimated Rays.
- It is because of this **reciprocity**, the lens can be used as an antenna, as the same phenomenon helps in utilizing the same antenna for both transmission and reception.


converging lens
focal point (F)
light rays
focal length

- To achieve the focusing properties **at higher frequencies, the refractive index should be less than unity**.
- Whatever may be the **refractive index, the purpose of lens is to straighten the waveform**.
- Based on this, the **E-plane and H-plane lens are developed, which also delay or speed up the wave front**.

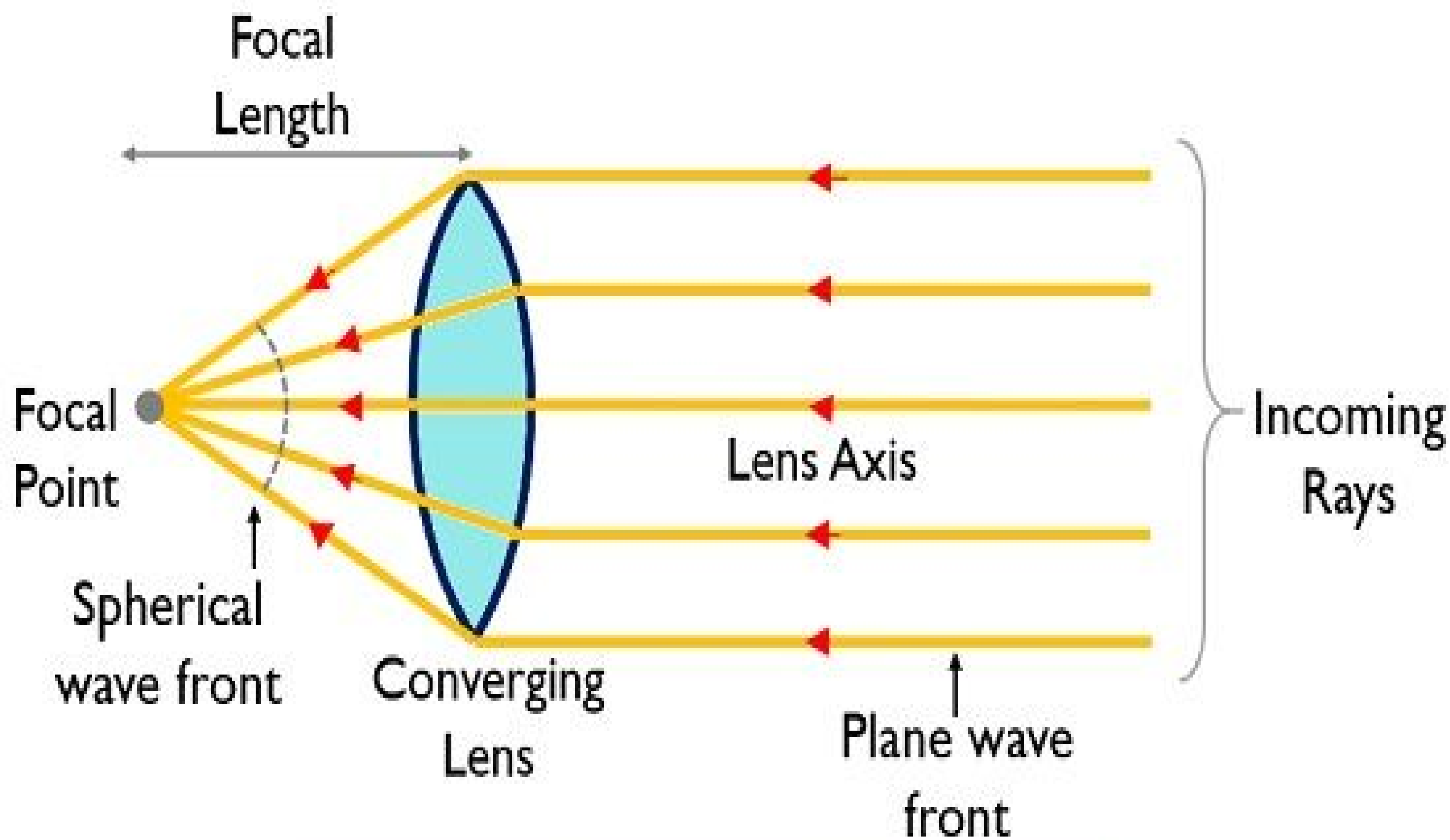
Working of Lens Antenna

- Consider that we have a converging type of optical lens present at a certain position and source from where the energy is to be released is present at the focal point at a distance of focal length along the axis of the optical lens.



Lens in Transmitting Mode

Electronics Desk



Lens in Receiving Mode

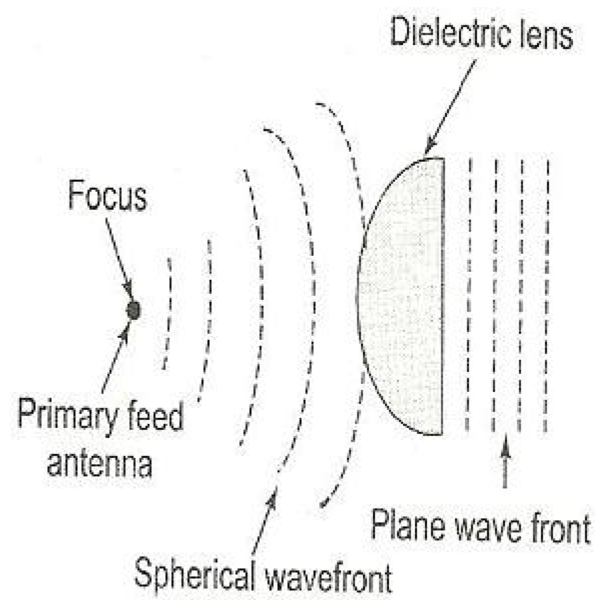
Electronics Desk

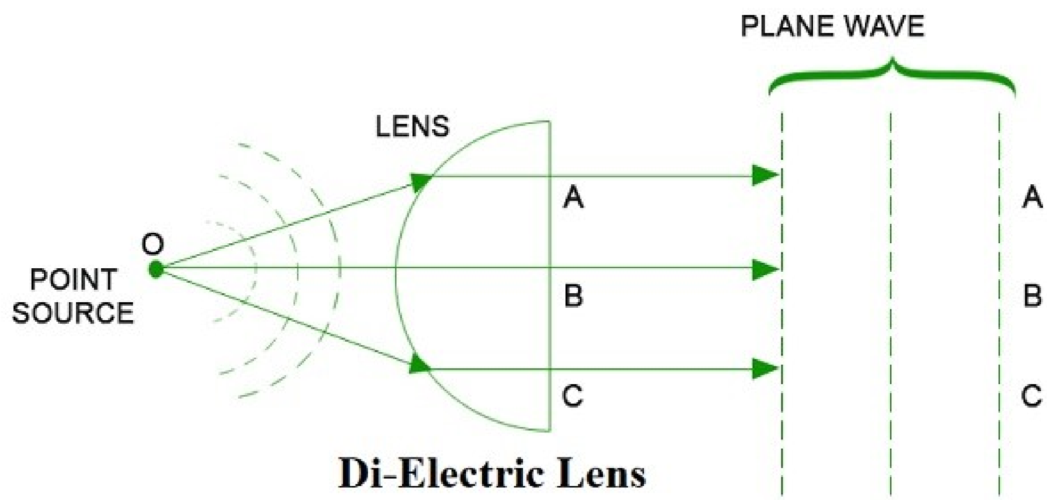
Types of Lens Antennas

- The following types of Lens Antennas are available:
  - Di-electric lens or H-plane metal plate lens or Delay lens
  - E-plane metal plate lens
  - Non-metallic di-electric type lens
  - Metallic or artificial dielectric type of lens

Dielectric Lens Antenna

- Spherical wavefront produced by primary feed antenna is converted into plane wavefront by dielectric lens.
- It is also known as Delay Lens antenna due to the fact that outgoing EM rays are collimated & delayed by lens material.
- It is useful at higher frequencies, it becomes heavy and bulky at frequencies less than 3 GHz.
- It is made of polystyrene or lucite & polyethylene.

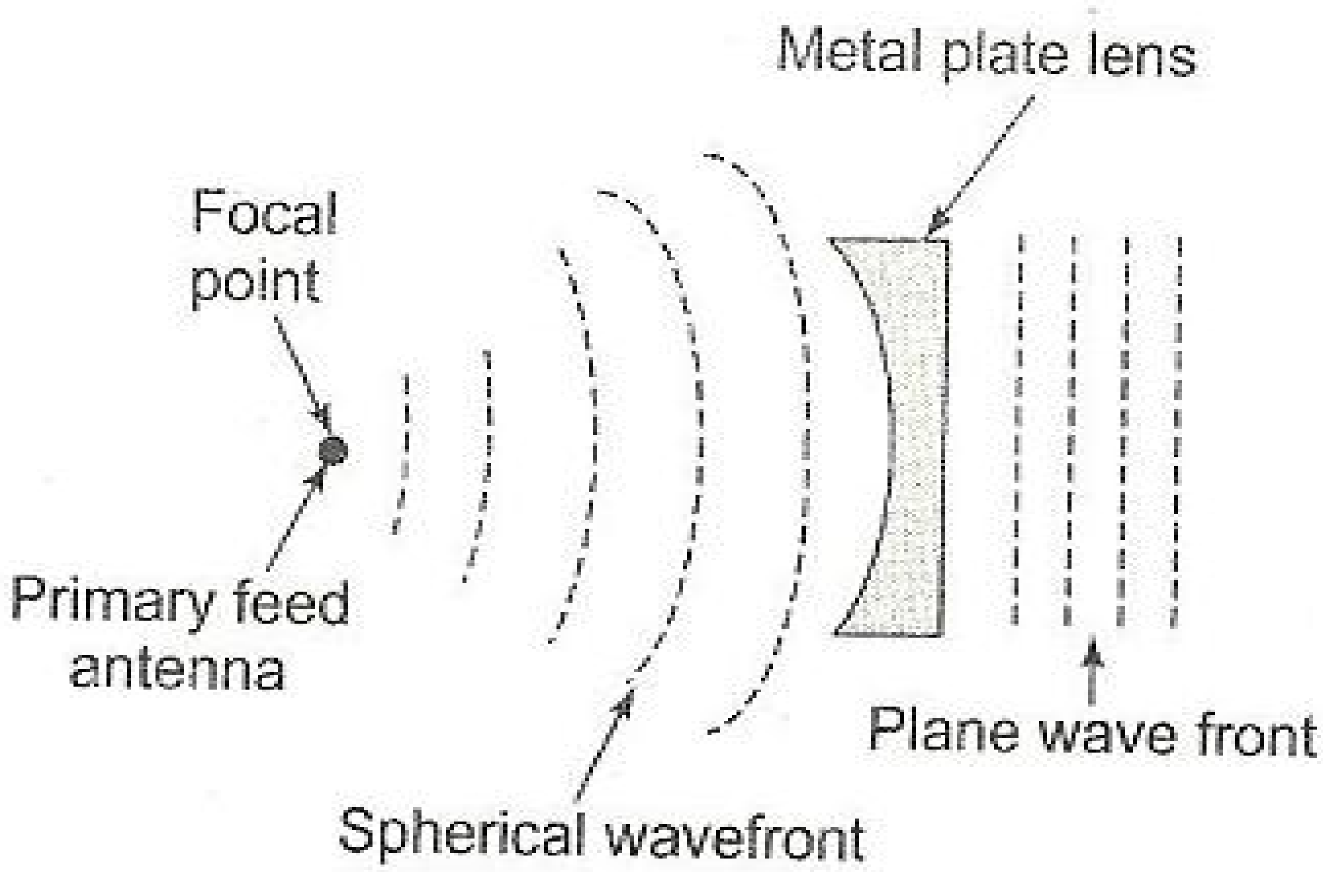




Di-Electric Lens

E-PLANE Metal Plate Lens Antenna

- Spherical wavefront is converted into plane wavefront but here outgoing wavefront is speeded up by material of lens.
- **Advantages**
  - feed antennas in the design do not obstruct the aperture.
- **Disadvantages**
  - they are costlier for same gain/bandwidth in comparison to reflector antenna.


Metal plate lens
Focal point
Primary feed antenna
Plane wave front
Spherical wavefront

Advantages

- In lens antennas, feed and feed support, do not obstruct the aperture.
- It has greater design tolerance.
- Larger amount of wave, than a parabolic reflector, can be handled.
- Beam can be moved angularly with respect to the axis.

Disadvantages

- Lenses are heavy and bulky, especially at lower frequencies
- Complexity in design
- Costlier compared to reflectors, for the same specifications

Applications

- Used as wide band antenna
- Especially used for Microwave frequency applications
- The converging properties of lens antennas can be used for developing higher level of antennas known as Parabolic reflector antennas, which are widely used in satellite communications.