5.4 EM Wave Polarization

It is important to know that the direction of the electric field vector changes with time for a uniform plane wave which decides the polarization of the wave. This is because some applications can only receive or transmit one type of polarized EM waves and the best example is different antennas in RF applications is designed for one type of polarized wave.

In a plane EM wave, the electric field oscillates in the x-z plane while the magnetic field oscillates in the y-z plane. Hence, it corresponds to a polarized wave. The plane in which the electric field oscillates is defined as the plane of polarization.

The polarization is nothing but a way in which an electric field varies with magnitude and direction. The polarization can be linear, or circular, or elliptical polarization. Let us consider that $\bar{E}_x$ and $\bar{E}_y$ are the electric fields directed along the x- axis and y-axis respectively, and also $\bar{E}$ be the resultant of $\bar{E}_x$ and $\bar{E}_y$.

Linear Polarization

If an electric field of an EM wave is parallel to the x- axis, then the wave is said to be linearly x- polarized. A straight wire antenna parallel to x-axis could generate this type of polarized wave. In a similar way, y-polarized waves are generated and defined along the y-axis.

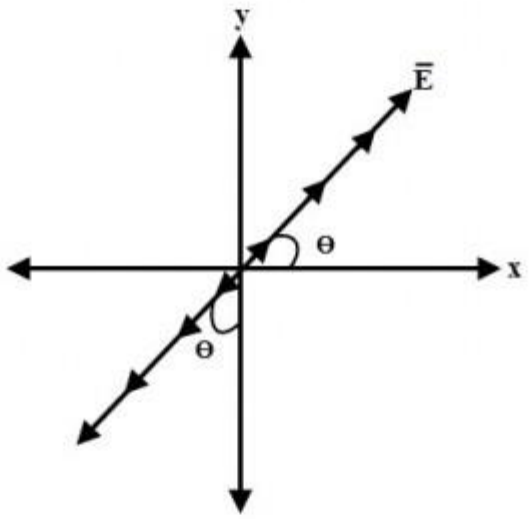
Suppose $\bar{E}$ has both $\bar{E}_x$ and $\bar{E}_y$ components which are in phase having different magnitudes. The magnitudes of $\bar{E}_x$ and $\bar{E}_y$ reach their maximum and minimum values simultaneously as $\bar{E}_x$ and $\bar{E}_y$ are in phase. So at any point on the positive z axis, the ratio of magnitudes both the components is constant.

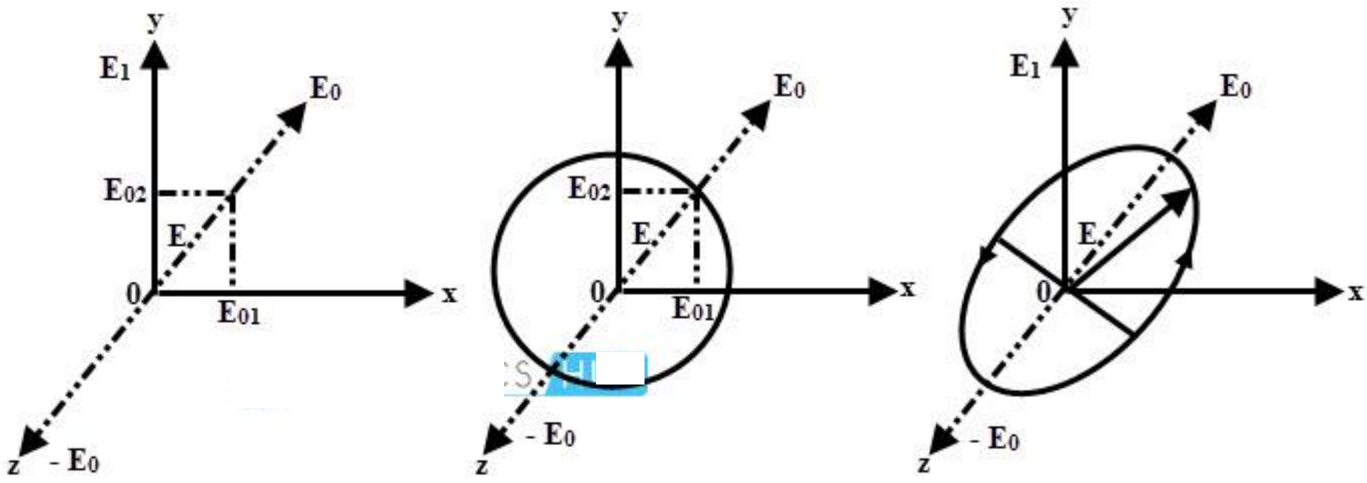
Therefore, the direction of the resultant electric field $\bar{E}$ depends on the relative magnitudes of $\bar{E}_x$ and $\bar{E}_y$. Thus the angle made by the $\bar{E}$ with x-axis is given by

$$\theta = \tan^{-1} E_y / E_x$$

Where E_y and E_x are the magnitudes of the $\bar{E}_y$ and $\bar{E}_x$ respectively.

With respect to time, this angle is constant and hence the wave is said to be linearly polarized. Therefore, the polarization of the uniform plane propagating in a z- direction is linear when $\bar{E}x$ and $\bar{E}y$ are in phase either with unequal or equal magnitudes.





Linear Polarization Circular Polarization Elliptical Polarization

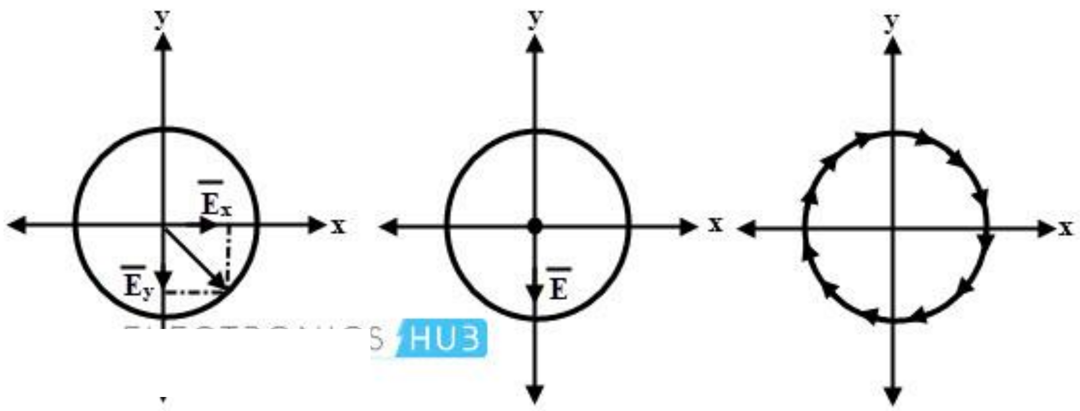
Circular Polarization

If the two planes $\bar{E}y$ and $\bar{E}x$ (which are orthogonally polarized) are of equal in amplitude but has 90 degrees phase difference between them, then the resulting wave is circularly polarized. In such case at any instant of time, if the amplitude of the any one component is maximum, then other component amplitude becomes zero due to the phase difference.

It is also described as if the amplitude of any one component gradually increases, then amplitude of other component gradually decreases and vice-versa. Thus the magnitude of the resultant vector $\bar{E}$ is constant at any instant of time, but the direction is the function of angle between the relative amplitudes of $\bar{E}y$ and $\bar{E}x$ at any instant.

If the resultant electric field $\bar{E}$ is projected on a plane perpendicular to the direction of propagation, then the locus of all such points is a circle with the center on the z- axis as shown in figure.

During the one wavelength span, the field vector $\bar{E}$ rotate by 360 degrees or in other words, completes one cycle of rotation and hence such waves are said to be circularly polarized.



Circular polarization with 90 degrees phase shift between $\bar{E}x$ and $\bar{E}y$ which are having equal amplitudes

Circular polarization is generated as either right hand circular polarization (RHCP) or left hand circular polarization (LHCP). RHCP wave describes a wave with the electric field vector rotating clockwise when looking in the direction of propagation.

For a LHCP wave the vector field rotates in anticlockwise direction. Therefore, the polarization of a uniform plane wave is circular if the amplitudes of two components of electric field vector are equal and having a phase difference of 90 degrees between them.

Elliptical Polarization

In most of the cases, the components of the wave have different amplitudes and are at different phase angles other than 90 degrees. This results the elliptical polarization. Consider that electric field has both components $\bar{E}_x$ and $\bar{E}_y$ which are not equal in amplitude and are not in phase.

As the wave propagates, the maximum and minimum amplitude values of $\bar{E}_x$ and $\bar{E}_y$ not simultaneous and are occurring at different instants of the time. Thus the direction of resultant field vector varies with time.

If the locus of the end points of the field vector $\bar{E}$ traced then one can observe that the $\bar{E}$ moves elliptically on the plane. Hence such wave is called as elliptically polarized.