Design and Analysis of a Patch Antenna on a Finite Rectangular Ground Plane

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Abstract – Micro-strip single elements or small sub arrays with relatively small ground plane have been used in a number of special telemetry and traffic control transceivers as well as in more conventional land mobile cellular and satellite systems. The size, shape, thickness and dielectric constant of the ground plane and the substrate affect the radiation and impedance characteristics of the printed board element. Although these effects are often considered to be detrimental, it is possible, however, to use the physical parameters and the shape of the ground plane to modify the antenna performance in a predictable manner. For example a slightly rectangular ground plane with corrugation has been used to control the pattern of an element in the vertical plane. A novel design for of a circular patch printed on a finite substrate is reported. Its ease of fabrication and predictable performance are among the interesting features of this new design. A simple analysis of the radiation and resonance characteristics of this printed board element is presented along with some initial experimental results.

Keywords - Directivity**,** Efficiency, antennas

I. INTRODUCTION

Wireless communications have progressed very rapidly in recent years, and many mobile units are becoming smaller and smaller. To meet the miniaturization requirement, the antennas employed in mobile terminals must have their dimensions reduced accordingly. Planar antennas, such as microstrip and printed antennas have the attractive features of low profile, small size, and conformability to mounting hosts and are very promising candidates for satisfying this design consideration. For this reason, compact, broadband and wideband design technique for planar antennas have been attracted much attention from antenna researchers. Very recently, especially after the year 2000, many novel planar antenna designs to satisfy specific bandwidth specifications of present day mobile cellular communication systems including the global system for mobile communication
(GSM; 890 – 960 MHz), the digital communication system (DCS; 1710 – 1880 MHz), the personal communication system (PCS; 1850 – 1990 MHz), and the universal mobile telecommunication system. The aim of our project is to design an antenna which operates at 5.4GHz frequency.

II. ANTENNA

Antennas are a very important component of communication systems. To radiate or receive electromagnetic waves an antenna is required. An Antenna or Aerial is a system of elevated conductors which couples or matches the transmitter or receiver to free space. A transmitting antenna connected to a transmitter by a transmission line, forces electromagnetic waves into free space which travels in space with velocity of light. Similarly, a receiving antenna connected to a radio receiver, receives or intercepts a portion of electromagnetic waves travelling through space.

III. ANTENNA PARAMETERS

An antenna is a transformer between a transmission line and free space. To describe an antenna, we must characterize its properties as a transmission line load (input impedance) and the distribution of the electromagnetic energy that it radiates into space (radiation pattern). Antennas are characterized by a number of performance measures which a user would be concerned with in selecting or designing an antenna for a particular application. There are a number of key parameters and concepts that we can use to describe antenna properties. They are:

- Directivity
- Input Impedance
- Axial Ratio
- VSWR
- Return Loss
- Band Width
- Radiation Intensity
- Antenna Efficiency
- Antenna Gain
- Effective Aperture
- Polarization of waves

Radiation Pattern - A radiation pattern defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. This power variation as a function of the arrival angle is observed in the antenna's far field. Typically, because it is simpler, the radiation patterns are plotted in 2-d. In this case, the patterns are given as "slices" through the 3d plane. Standard spherical coordinates are used, where θ is the angle measured off the z-axis, and φ is the angle measured counterclockwise off the x-axis.

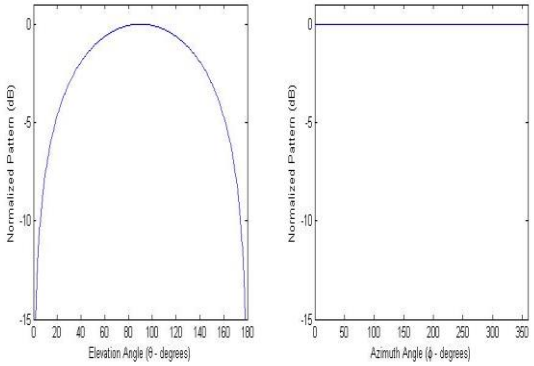

Fig 1: Two-dimensional radiation patterns

A. Linear Polarization - A plane electromagnetic (EM) wave is characterized by travelling in a single direction (with no field variation in the two orthogonal directions). In this case, the electric field and the magnetic field are perpendicular to each other and to the direction the plane wave is propagating. As an example, consider the single frequency E-field given by equation (1), where the field is traveling in the +z-direction, the E-field is oriented in the +x-direction, and the magnetic field is in the +y-direction.

$$E = \cos(2\Pi f(t - \tfrac{z}{c}))\hat{x} \qquad (1)$$

In equation (1), the symbol is a unit vector (a vector with a length of one), which says that the E-field "points" in the x-direction.

B. Circular Polarization - Suppose now that the E-field of a plane wave was given by equation (2):

$$E = \cos\left(2\Pi f(t - \tfrac{z}{c})\right)\hat{x} + \sin\left(2\Pi f(t - \tfrac{z}{c}\right) \qquad (2)$$

In this case, the x- and y- components are 90 degrees out of phase. If the field is observed at (x,y,z) = (0,0,0) again as before, the plot of the E-field versus time would appear as shown in Figure .

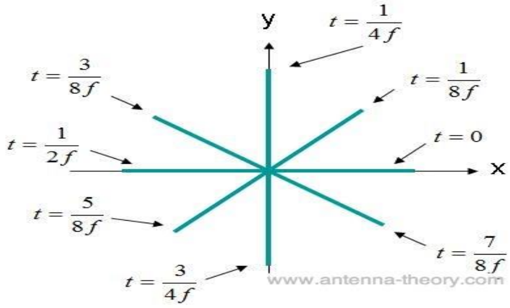

Fig 2: E-field strength at (X,Y,Z)=(0,0,0) for field of eq. (2)

The E-field in the figure rotates in a circle. This type of field is described as a circularly polarized wave. To have circular polarization, the following criteria must be met:

Criteria for Circular Polarization:

- The E-field must have two orthogonal (perpendicular) components.
- The e-field's orthogonal components must have equal magnitude.
- The orthogonal components must be 90^0 out of phase.

If the wave is travelling out of the screen, the field is rotating in the counter-clockwise direction and is said to be Right Hand Circularly Polarized (RHCP). If the fields were rotating in the clockwise direction, the field would be Left Hand Circularly Polarized (LHCP).

C. Elliptical Polarization - If the E-field has two perpendicular components that are out of phase by 90 degrees but are not equal in magnitude, the field will end up Elliptically Polarized. Consider the plane wave travelling in the +z-direction, with E-field described by equation (3):

$$E = \cos\left(2\Pi f(t - \tfrac{z}{c})\right)\hat{x} + 0.3\sin\left(2\Pi f(t - \tfrac{z}{c})\right) \qquad (3)$$

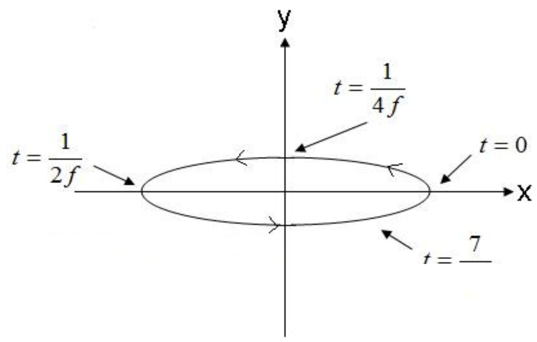

Fig 3: tip of e-field for elliptical polarized wave of eq. (3)

The field travels in the counter-clockwise direction, and if travelling out of the screen would be Right Hand Elliptically Polarized. If the E-field vector was rotating in the opposite direction, the field would be Left Hand Elliptically Polarized.

In addition, elliptical polarization is defined by its eccentricity, which is the ratio of the major and minor axis amplitudes. For instance, the eccentricity of the wave given by equation (3) is 1/0.3 = 3.33. Elliptically polarized waves are further described by the direction of the major axis. The wave of equation (3) has a major axis given by the x-axis. Note that the major axis can be at any angle in the plane, it does not need to coincide with the x-, y-, or z-axis. Finally, note that circular polarization and linear polarization are both special cases of elliptical polarization. An elliptically polarized wave with an eccentricity of 1.0 is a circularly polarized wave; an elliptically polarized wave with an infinite eccentricity is a linearly polarized wave.

IV. DESIGNED MODEL OF A CIRCULAR PATCH

Draw a rectangular box using HFSS and assign it as Rogers RT/duroid 5880 substrate whose dielectric constant is 2.2. Give the thickness of the substrate as 0.3cm. Place a circular Patch with radius 0.97cm on the top of the substrate and on the other side of the substrate place the ground plane.

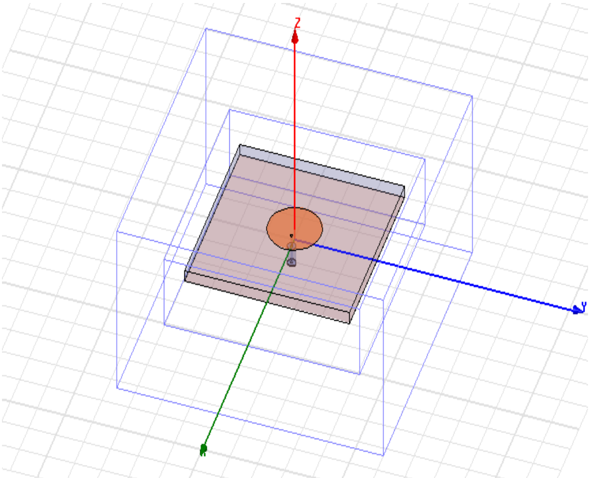

Fig 4: Designed model of a circular patch

V. APPLICATIONS OF CIRCULAR PATCH OPERATING AT 5.4GHZ

- GHz band applications
- IEEE 802.11a Wireless LAN
- Wi-Fi systems
- Radio Local Area Networks

VI. RADIATION PATTERN

The radiation pattern of the antenna can be defined as the spatial distribution of a quantity that characterizes the electromagnetic field generated by an antenna. It represents the energy radiated from an antenna in each direction, often pictorially.

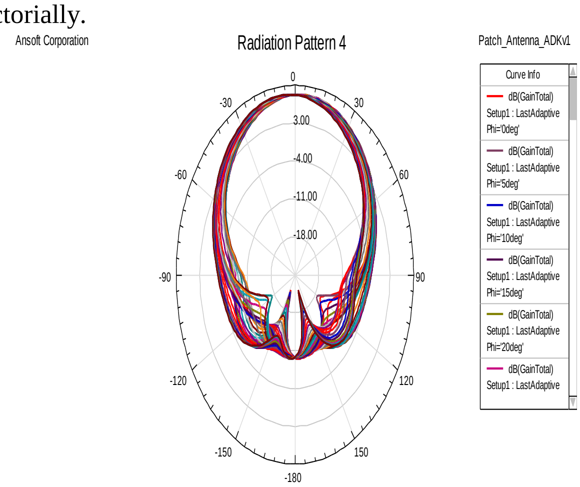

Fig 5: Radiation Pattern of Gain Total

The Figure 4 shows the radiation pattern in Phi direction and in theta direction. The curves plotted in different colors shows the radiation in different directions. The directions vary from -180^0 to +180^0. Select the desired directions in which we want to see the radiation. To view the radiation pattern click on HFSS>Results>Radiation plot in that select the required direction i.e. either theta or in phi direction and select the radiation direction and click done. From the radiation plot we can observe that the radiation from the antenna is maximum in the direction perpendicular to antenna and s minimum in the other direction and there are no any back lobes.

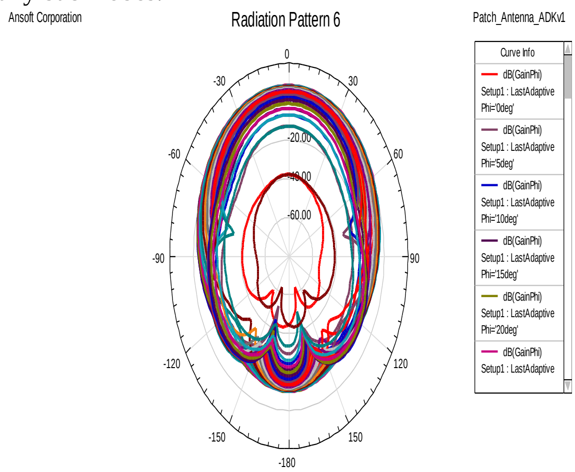

Fig 6: Radiation Pattern of Gain along Phi Direction

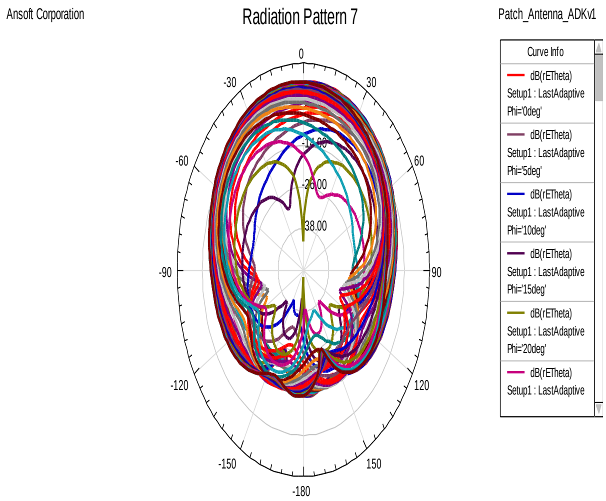

Fig 7: Radiation pattern of gain along teta direction

VII. CONCLUSION

Finally, the optimum dimensions of a circular patch antenna for 5.4 GHz Wireless applications have been investigated. The performance properties like Return Loss, Gain along theta direction, Gain along phi direction, Radiation pattern in 2-D, 3-D, input impedance, axial ratio, VSWR are simulated using HFSS software and are analyzed for the optimum dimensions and the proposed antenna works well at the required 5.4 GHz frequency.

VIII. FUTURE SCOPE

Patch antennas are extremely versatile antennas which can be utilized for many applications due to how simple it is to create different geometries. As a project we would like to implement the WLAN frequencies i.e., we would like to implement a circular patch antenna that will operate at multiple frequency bands, and to verify the performance like return loss, VSWR, gain along Theta, Phi directions, radiation pattern in 2-D and 3-D, axial ratio, input impedance using HFSS software which is a high performance full wave EM field simulator for arbitrary 3D volumetric passive device modeling.

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