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A COMPREHENSIVE DESIGN OF CIRCULAR PATCH ANTENNA ARRAY BASED ON HFSS

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Abstract - *The work is to design a circular patch antenna array resonating at 1280 MHz and it is simulated for lower atmospheric boundary applications by using HFSS tool. The high integration configuration of electronic devices has become increasingly demanding for miniaturized antennas, especially in systems for satellite communication. Circular patch antenna array is designed by depositing circular patches over air substrate and is fed using coaxial feeds. Antenna parameters such as gain, return loss, VSWR, directivity, reflection coefficient and radiation pattern are analyzed. Circular patch antennas produce more gain and less return loss compared to rectangular microstrip patch antenna. The compact size and higher directivity of circular patch antenna array, makes it more configurable. In this paper, the design goal is to suppress the relative sidelobe level (SLL) with respect to main beam for circular patch antenna array.*

***Key Words*: Circular array, Lower Atmospheric Application, HFSS, Sidelobe Level, Return loss, VSWR, Directivity, Gain.**

1. INTRODUCTION

Antenna basically converts electrons to photons or vice versa. The basic principle involved with antenna are that the radiation is produced by accelerated charge. When the separation between the conducting wires reaches the particular wave length or more, it may tend to radiate and the open end of the transmission lines act as antennas which may launch a free space wave. On the basis of radiation, Omni-directional antennas are weak directional antenna, as they radiate and receive less energy in all direction. While, Directional antennas radiate and receive in a particular direction.

Light weight, higher efficiency, higher gain, higher directivity and minimum return loss characteristics of circular microstrip patch antennas have gained a lot of importance in communication application. Circular antennas show better results in terms of return loss and VSWR compared to rectangular. Also, circular patch antenna shows better results when bandwidth and sidelobe are considered. Antennas with more directivity can be used in improving network performance as they increase the alleviating contention and the communication range.

Assembly of radiating elements, electrically or geometrically, configures antenna array. Elements in antenna array are usually identical. The concept of antenna array was first introduced in military application in 1940s. This development was significant in wireless communication as it improved the reception and transmission patterns of the antennas. The array also enables the antenna system to be electronically steered or guided in a particular direction, without mechanically moving the structure [1].

In most recent application, it is necessary to have highly directional antenna. Array antennas have a high gain and directivity compared to individual element radiating. There are various controls that may be used in shaping the pattern. Namely, geometrical configuration, relative displacement between elements, excitation amplitude of individual elements, excitation phase and relative pattern of individual pattern [2]. In this paper, the design goal is to suppress the relative sidelobe level with respect to main beam. This is done by designing a relative spacing between elements, with uniform excitation over array aperture.

2. ANTENNA SIMULATORS

Electro-magnetic simulator is a valuable tool in antenna design and integrated platform providing the designer the ability to virtually design and evaluate. This software based on different computation method can be classifies as Finite Element Method (FEM) and Finite difference Time Domain (FDTD).

A. FDTD: This method is a numerically analysis technique, used for modelling computational analysis. As it is a time domain method, it covers a wide range of frequencies.

B. FEM: This method is a numerical technique for finding solutions to boundary value problems for differential equations. CST Studio, FEKO, Antenna Magus, HFSS, etc. are the various used simulations software.

Here, we choose High Frequency Simulations Software (HFSS), to explain the basics of an antenna array while keeping complexity level at the minimum. HFSS uses the FEM solver techniques. This software has a powerful antenna design functions, it can calculate various antenna parameters [3].

3. DESIGN PROCEDURES

An antenna array is a set of spatially separated antenna elements. It has a performance better compared to single elements. Here, a circular microstrip patch antenna array is designed with 7 elements with coaxial feeds and is simulated using HFSS. Geometrical configuration, interelement spacing, coaxial probe dimensions are the major controls used for shaping of antenna pattern.

A circular microstrip patch element may be characterized by a single parameter of interest, that is, radius of circle. The radius a, can be determined by using expression (1)[4].

$$a = \frac{F}{\left\{1+\frac{2h}{\pi\varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}} \qquad \text{.......... (1)}$$

With,

$$F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}} \qquad \text{.......... (2)}$$

Where,
h is height of substrate,
ε_r is dielectric constant of substrate,
f_r is operating frequency.

The geometrical configuration of elements depends on the inter elements spacing and feed lines. A spacing of λ/2 is implemented in order to acquire a symmetric radiation pattern in both directions (□=0 and 180 deg) [5]. The electrical signals are fed through coaxial probes, from the microwave source. Table 1 shows various antenna dimensions and other parameters.

Table 1: Antenna Dimension and Parameters

Parameters	Dimensions
Operating Frequency, f_r	1280 MHz
Height of Substrate, h	10 mm
Dielectric Constant of Substrate (air), ε_r	1
Radius of patch, a	61.2 mm
Inter-element Spacing	140 mm
Coaxial probe conducting radius	2 mm

The obtained design on HFSS simulation software is shown in Fig 1.

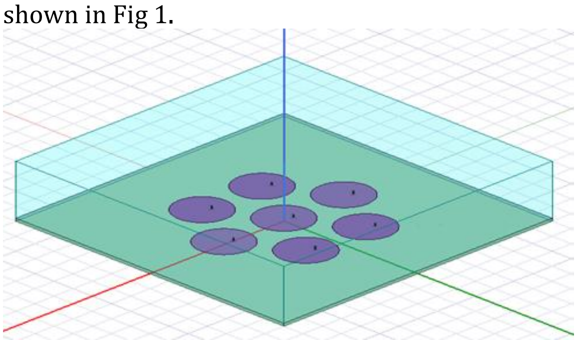

Fig 1: Antenna Design on HFSS

4. PARAMETERS OF INTEREST

A. Input Impedance:

For an efficient transfer of energy, the impedance of antenna and of the transmission cable must be similar. The transceivers and their corresponding transmission lines are usually designed for 50-ohm impendence. If impendence difference occurs, there will be mismatch, which leads for the requirement of impendence matching circuit [6].

B. VSWR:

In a perfectly matched system, 100% power may be transmitted. Voltage Standing Wave Ratio (VSWR) for such system will be 1. It can be expressed as maximum voltage over minimum voltage of a standing wave from source to load, as expression (3) [7].

$$VSWR = \frac{V_{MAX}}{V_{MIN}} = \frac{V_{fwd}+V_{ref}}{V_{fwd}-V_{ref}} = \frac{1+\sqrt{\frac{P_{ref}}{P_{fwd}}}}{1-\sqrt{\frac{P_{ref}}{P_{fwd}}}} \qquad \text{.......... (3)}$$

V_{fwd} is the forward voltage and V_{ref} is the reflected voltage.

C. Return Loss:

It is the logarithmic ratio that indicates the power reflection from the antenna to the power fed into the antenna from the transmission line. Reflection coefficient Γ, indicates the ratio of reflected voltage to forward voltage. It describes how much of Electromagnetic wave is reflected back due to impedance mismatch. This is given by expression (4) [4,7].

$$\Gamma = \frac{V_{ref}}{V_{fwd}} = \frac{VSWR-1}{VSWR+1} \qquad \text{.......... (4)}$$

Return loss in dB may be given by expression (5).

$$RL(dB) = 20\log_{10}(\Gamma) \qquad \text{.......... (5)}$$

More the return loss, less is the reflection and therefore the VSWR.

D. Directivity and Gain:

Directivity measures how much directional an antenna's radiating pattern is. Isotropic elements radiate in all directions and their directivity will always be 1. While for non-isotropic, it is the ratio of radiation intensity in a reference direction to radiation intensity of isotropic source [7]. This is given by the expression (6).

$$D = \frac{U}{U_0} = \frac{4\pi U}{P_{rad}} \qquad \text{.......... (6)}$$

Gain describes how strong an antenna can transmit or receive in specific direction [7]. This is given by expression (7).

$$Gain\ (G) = 10log_{10}\left(\frac{4\pi d}{\lambda}\sqrt{\frac{P_r}{P_t}}\right) \quad ....\ (7)$$

E. Sidelobes Level:

Some antennas inevitably radiate in other direction than preferred path. No antennas can radiate all the energy in one preferred direction. The peak of these signals are the side lobes (specified in dB), which are down from the main lobe.

F. Antenna Efficiency:

It describes how efficient an antenna is, to convert frequency power provided at input line into radiated power [7]. It is given in terms of gain G and directivity D, expression (8).

$$G = \varepsilon_r D \quad ....\ (8)$$

5. SIMULATED RESULTS

The designed circular patch antenna array is simulated in HFSS simulation tool. The corresponding results are obtained. As shown in figure plots, the antenna array resonates at 1280MHz as desired and the return loss, gain, directivity was found to be -28.2874, 16.49 dB, 16.32 dB respectively.

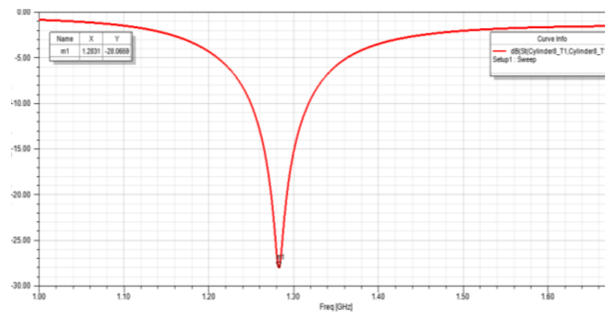

Fig 2: Simulated Return Loss

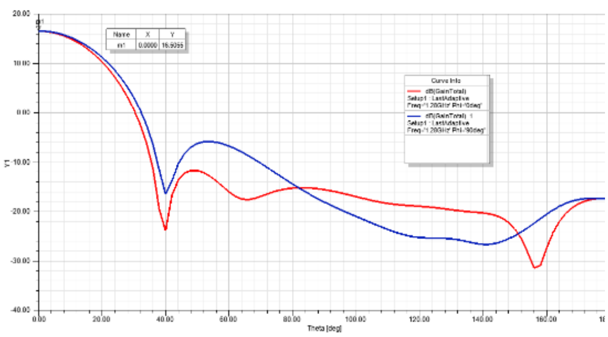

Fig 3: Simulated 2D Gain Report

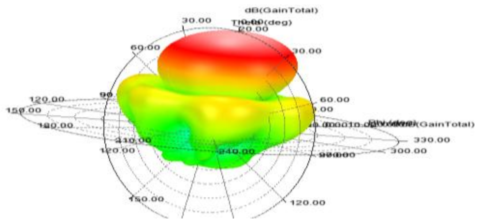

Fig 4: Simulated 3D Gain Plot

6. CONCLUSION

Antennas are an integral and important part of wireless communication system. The circular patch antenna array is designed at a resonating frequency of 1280MHz. The design is simulated using HFSS simulation tool. It is found to yield better values in terms of Gain, Return loss, Reflection coefficient and VSWR. Hence, the designed array can also be used in the applications of wireless sensor networks (WSN), due to compact size and comparatively high gain performance with that of rectangular array antennas.

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