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Design of Circularly Polarized Broadband Microstrip Patch Array Antenna using HFSS for WLAN Application

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ABSTRACT

The design of a stripline fed network producing a conical beam circular polarized microstrip patch array antenna is presented in this article. A circularly-polarized conical-beam microstrip patch antenna, with a coplanar conductor pattern, is realized as an array of a number of stripline-fed slotted patches whose diagonal corners are cut off and whose feed lines meet at a central point with a square slot cut at the centre of the patch. There is good agreement between the simulated and experimental results for the return loss and axial ratio. The antenna is intended for short-range low power WSN applications, such as Bluetooth, WiFi etc.

Key words: Conical beam, circular polarized antennas, Ansoft HFSS, axial ratio

INTRODUCTION

A microstrip antenna in its simplest configuration consists of a radiating patch on one side of a dielectric substrate, which has a ground plane on the other side. The patch conductors, normally of copper, can assume virtually any shape, but regular shapes are generally used to simplify analysis and performance prediction [1-2]. Ideally, the dielectric constant, εr, of the substrate should be low ($\varepsilon r < 2.5$), to enhance the fringe fields that account for the radiation. However, other performance requirements may dictate the use of substrate materials whose dielectric constant can be much greater. Various types of substrates having a large range of dielectric constant and loss tangent values have been developed [1]. Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. Narrow bandwidth and gain are the main bottleneck for microstrip patch. The bandwidth of a patch antenna can be substantially improved through the use of thick substrate. The grounded dielectric substrate supports surface wave modes, which lower the antenna efficiency. Thus the maximum substrate thickness (and hence bandwidth) is limited by the radiation efficiency required [3]. Microstrip patch antennas also overcome the problem of backward radiation.

Now a day's interest in compact circularly polarized (CP) antennas at a fixed operating frequency has increased. Various single- and dual-band CP patch antennas have been investigated and reported in literature. The CP antennas are classified as a single feed type or dual feeds type depending on the number of feed point necessary to generate the CP waves. Many designs of single-feed, circularly polarized microstrip antennas with modified rectangular and elliptical patches are reported in [4-6] also include embedding a Y-shaped slot of unequal arm lengths, adding a tuning stub [7]. For feeding these compact CP designs, a probe feed or an edge-fed microstrip-line feed can be used.

The objective of this paper is to investigate and analyze the design of circularly polarized microstrip patch antenna at ISM band. To accomplish the objective, the Finite Element Method (FEM) based HFSS software package that is capable of solving antenna problems is used. A broadband simulation enables us to receive the S-parameters for our entire frequency range and, optionally, the electromagnetic field patterns at various desired frequencies from only one simulation run. The study includes the development of patch antenna model, antenna simulation, and analysis of results based on various outputs of the HFSS software package. The author tried to design novel Microstrip Antennas with Circular Polarization (MACP) that can handle wide band operation for different wireless mobile communication systems. These proposed antennas can be of good utility in the emerging fields of wireless communication. The designed antennas are also suitable for handling mobile streaming video, data and can be used in wireless communication and many military applications.

DESIGN AND ANALYSIS OF CP CONICAL BEAM ANTENNA

This antenna array consists of four 45 x 46 mm2 rectangular patches distributed over one horizontal plane in a circular formation with 90° spacing [8]. Inserting a nearly-square slot of size 10 x 11 mm2 into each rectangular patch and diagonally truncating two corners of the patch will cause excitation of two orthogonal modes with approximately equal magnitude and 90° relative phase, thus creating the required circular polarization. Antenna is mounted 1 cm above a 300 x 300 mm2 ground plane with Air as dielectric substrate. The feed network has been designed to permit equal and co-phased feeding of all the patches from a central pin at which the feed lines are parallel connected and which is fed from an SMA connector on the underside of the ground plane. For simplicity of construction, the feed lines use the same spacing as the patches.

Dielectric constant of Air as a substrate is 1. Thickness of the copper sheet is 0.5mm. Using the design theory and calculations the present antenna has been designed and optimized for the optimal antenna configuration using HFSS (a FEM based simulation solver). The antenna structure is presented in Figure 1 where the important dimensions after this study were found to be: w1= 34, w2 = 33, w3 = 21.75, w4 = 9.75, s1 = 17.4, s2 = 16, s3 = 34, s4 = 10, lf = 31.25, wf = 2.5, c1= 12 (all dimensions are in mm). The fabricated prototype of designed antenna is shown in figure. 3.

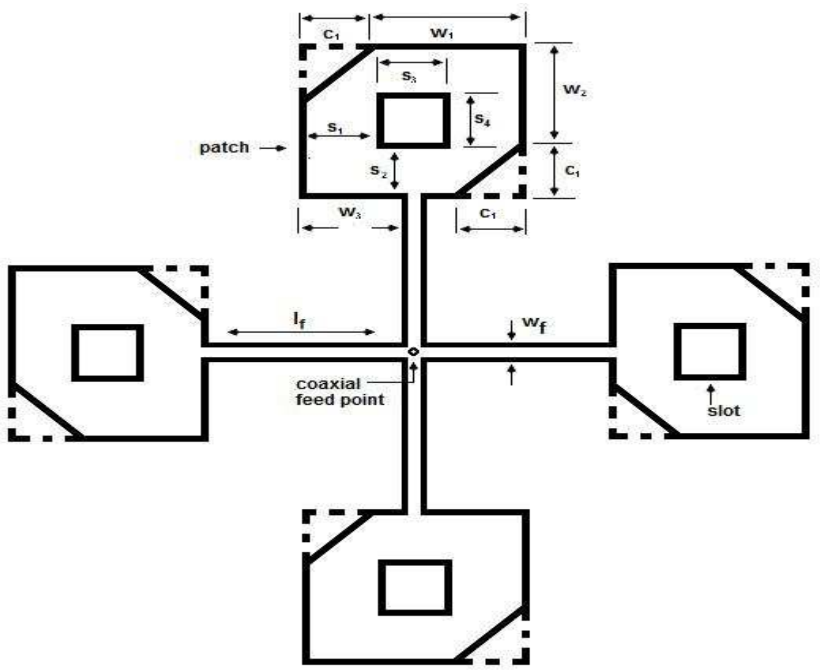

Fig.1 Geometry of the proposed four elements antenna array

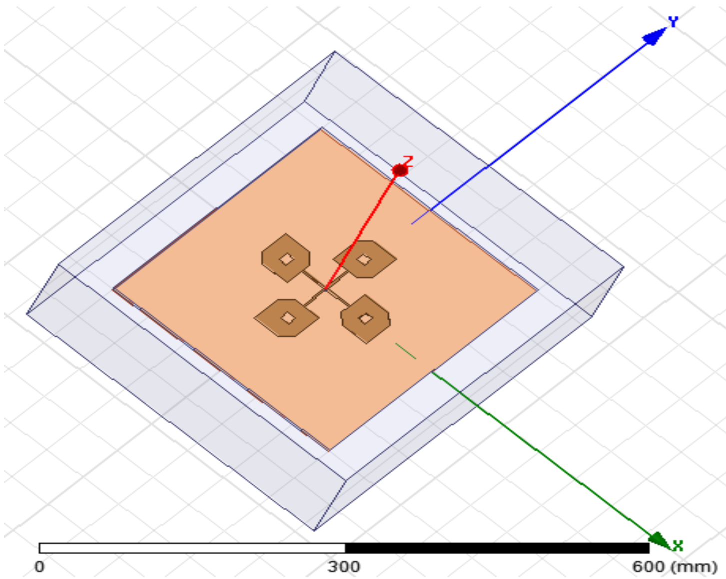

Fig.2 Structure of CP conical-beam microstrip patch antenna

Fig .3 Antenna under test after fabrication

RESULTS AND DISCUSSION

Rigorous simulation exercises have been carried out with HFSS 13.0 [9], a FEM based commercially available simulator solver. The variation of simulated reflection coefficient with frequency for the designed antenna is shown in fig. 4. For CP conical beam Antenna the simulated and experimental results have been compared. Simulated result shows S_{11}<-10dB from 2.2697 - 2.4766GHz. Whereas the fabricated antenna shows to operate over the frequency band 2.33 – 2.445 GHz with S_{11} < -10 dB. This result closely follows the simulated result.

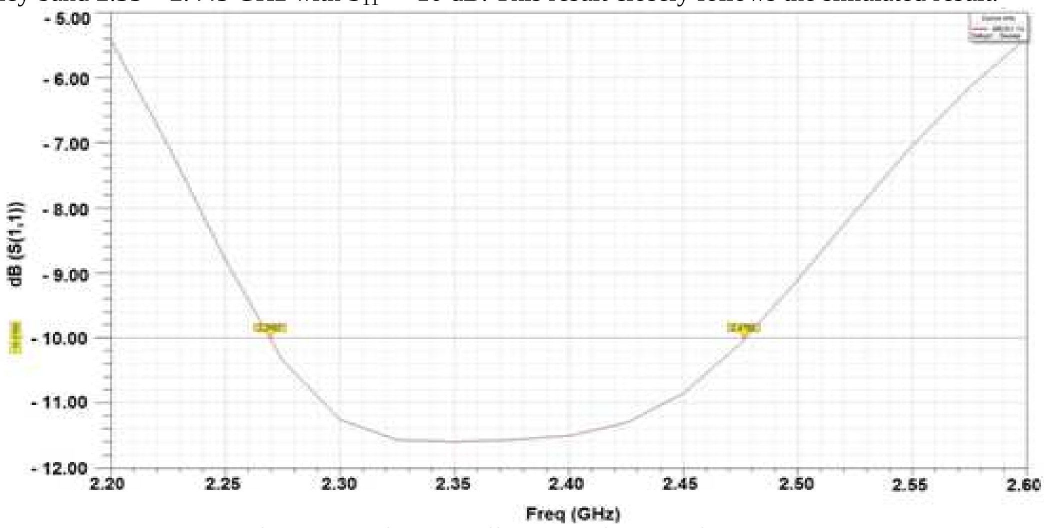

Fig. 4 Variation of simulated reflection coefficient with frequency for the designed antenna

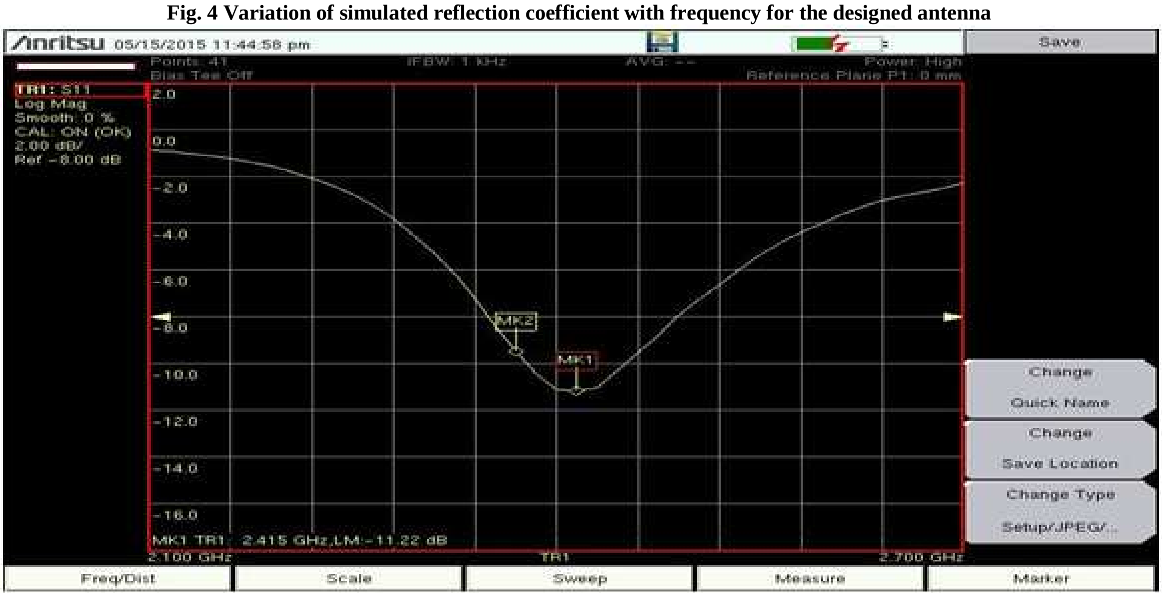

Fig. 5 Variation of measured reflection coefficient with frequency for the designed antenna

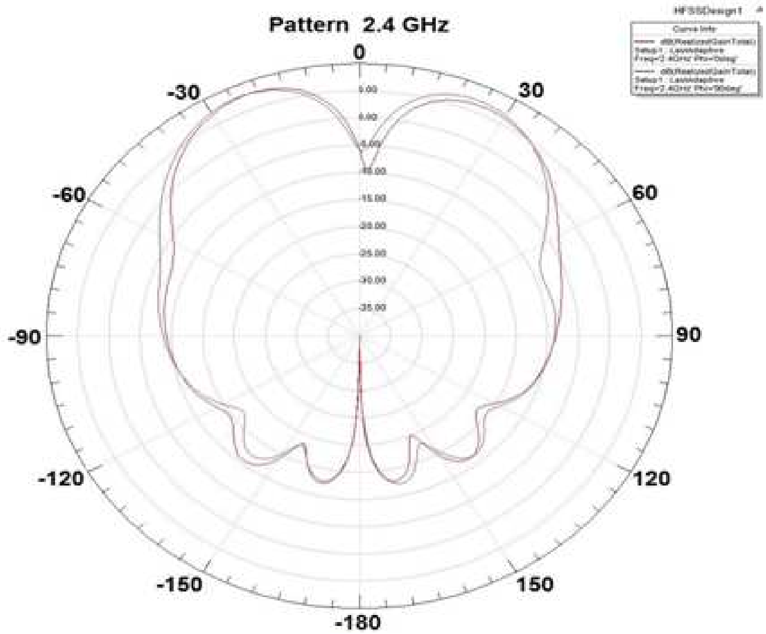

Fig. 6 Simulated radiation patterns of the proposed antenna at 2.45 GHz for plane: θ=±20°

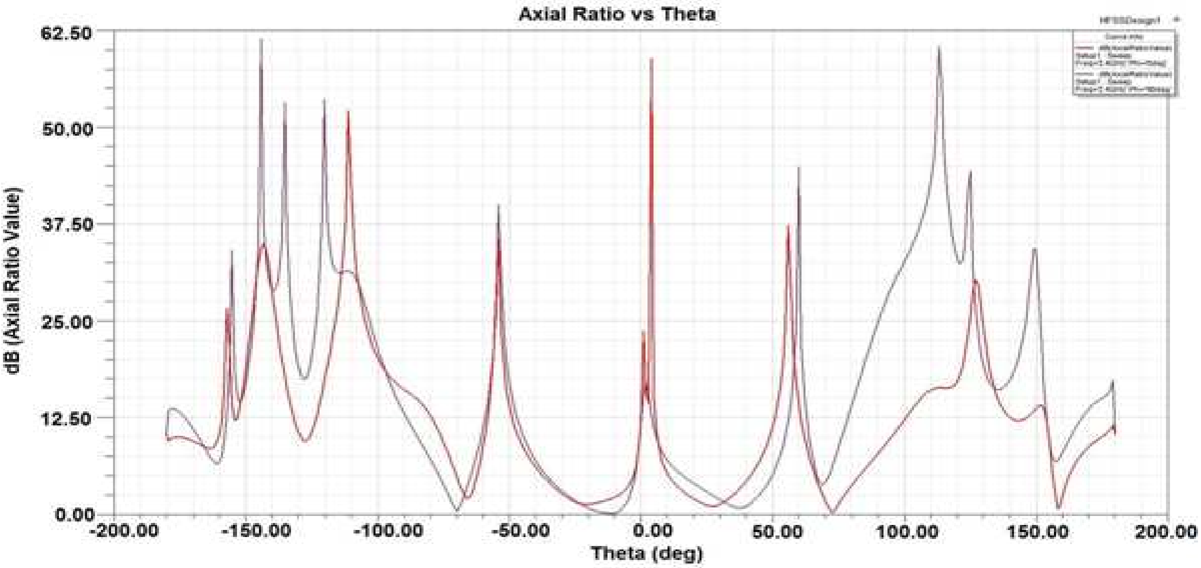

Fig. 7 Simulated axial ratio against elevation angle 2.45GHz, for 1.4 at $\varphi = 0^0$ and $\theta = 20^0$ and 0.9 at $\varphi = 0^0$ and $\theta = 20^0$

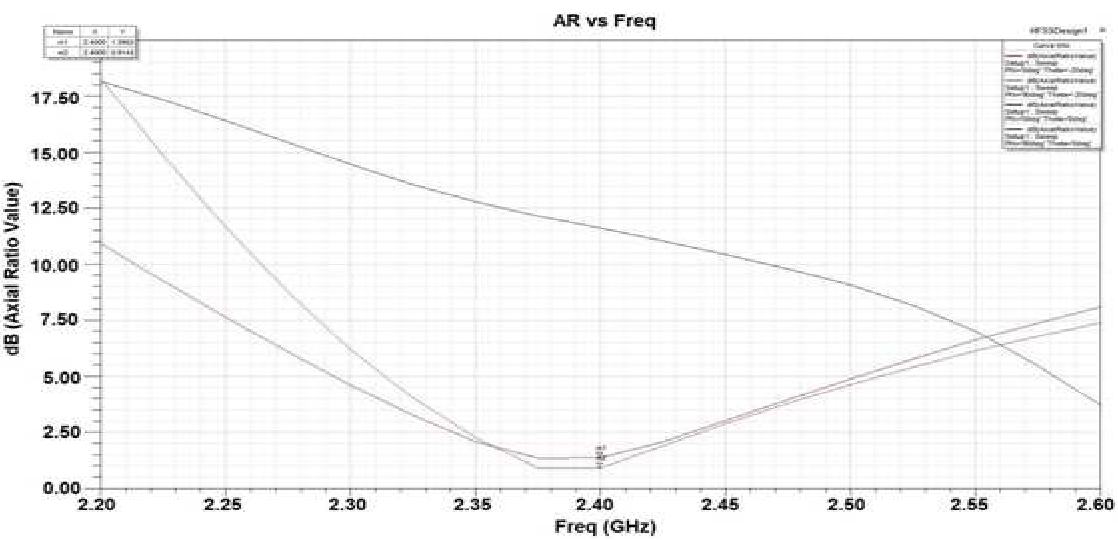

Fig. 8 Simulated axial ratio against frequency of the designed antenna

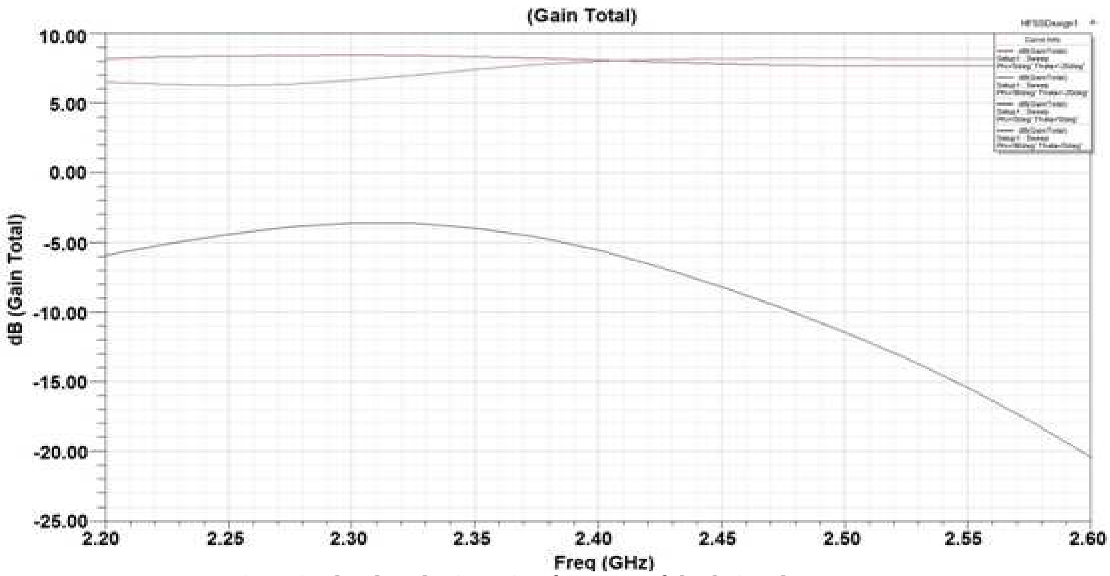

Fig. 9 Simulated total gain against frequency of the designed antenna

The simulated radiation pattern showing to maintain the desired conical pattern shape with a direction of maximum radiation at $\theta = +20^0$ and $\theta = -20^0$. Simulated axial ratio of 1.4 at phi = 0^0 and theta = 20^0 and 0.9 at phi = 0^0 and theta = 20^0 (at the frequencies of interest for the ISM 2.4 GHz band) have been observed. The simulated gain flatness have been observed to be maintained between 6-8dB over a frequency range from 2.2 to 2.6 GHz.

CONCLUSION

A conical-beam, circularly-polarized coplanar four element antenna array was presented. The proposed antenna array was designed to operate at the ISM 2.4 GHz band and performance of the conical beam patterns was characterized and verified with measurements and shown to have acceptable axial ratio. The present antenna design can be used as a good candidate for applications in short-range wireless communication systems, particularly wireless sensor networks, where the conical beam will give advantages of energy saving and reduced co-channel interference. Other applications could include indoor WLAN antennas for mounting on ceilings or other horizontal surfaces.

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