Design of Multiband Stacked Microstrip Patch Antenna for RFID and Radar Systems

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Abstract—**This paper proposes A Circularly Polarized Stacked Microstrip patch antenna. The Circular Polarization is achieved by corner truncation, embedding slits and slots. Circular Polarisation performance is achieved by varying the size of the inclined slots and corner truncations. Optimization is achieved by variation of the patch parameters. The Stacked Patch antenna provides better mobility, better orientation between the transmitter and receiver than the Linearly Polarized Antenna. The proposed antenna is designed to operate in C band (4-8) GHz for RFID and radar systems.**

Keywords—Circular Polarization, axial ratio, Microstrip Antenna

I. INTRODUCTION

The Microstrip Patch antenna is one of the widely used antennas in applications that require circular polarization. Microstrip antennas are popular for wireless communication as far as they offer the benefits of low profile, low weight, compact, conformal to surfaces, easy fabrication. Microstrip antennas have inherent disadvantage of narrow bandwidth and low gain [1-3]. The techniques to increase impedance bandwidth of patch antennas such as aperture coupled feed, corner truncation, inclined slots and slits are proposed.

Circularly polarized (CP) antennas are increasingly important in wireless communications, since they allow signal reception irrespective of the orientation of the receiving antenna with respect to transmitting antenna [4,5]. It also suppress Multipath Interference. CP antennas are widely used in portable devices. For example Radio Frequemcy Identification (RFID) reader antenna, WLAN, GPS and mobile phone etc [1].

The parameters for CP patch antennas are the Voltage Standing Wave Ratio <2 or S11<-10dB and the axial ratio bandwidth (AR<3dB) [6]. The use of CP antennas presents an attractive solution to achieve this polarization match. In general microstrip antenna on its own doesn't generate circular polarization. Eventually some changes should be done to the antenna [4].

In the proposed design, four layers is introduced where in the foam material is used as a substrate, with copper as the conducting ground.

The paper is organized as follows. In section II design parameters of the antenna is introduced. In section III detailed analysis of the design is done and results are observed. Section IV concludes the paper.

II. DESIGN PARAMETER

A. Basic patch Antenna Geometry

In its most basic form, a Micro strip patch antenna consists of a radiating patch on one side of a dielectric substrate of any material having the ground plane at bottom on other side as shown in Figure 1.

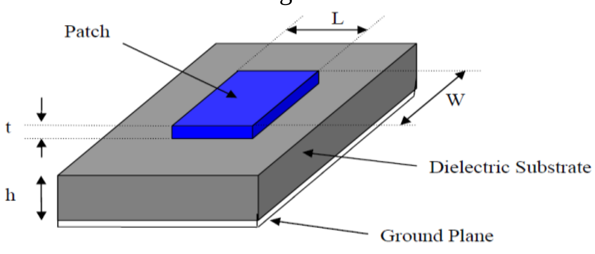


Fig 1. Structure of Micro strip antenna

The basic structure of rectangular micro strip patch antenna is considered here.

B. Antenna Design

The conventional micro strip antenna design method is used here. Designing the patch antenna is to employ the following equations (1-4):

i. Width (*W*):

$$W = \frac{C}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

Where;
c -Velocity of light, 3 x 10^8 m/s
f_r - Frequency of operation
ε_r - Dielectric constant

ii. Effective Dielectric constant (εreff):

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-0.5} \quad (2)$$

Where,
ε_r - Dielectric constant
h - Height of dielectric substrate
W - Width of the patch
ε_{reff} - Effective dielectric constant

iii. Effective Length (Leff):

$$L_{eff} = L + 2\Delta L \quad (3)$$

Where,

L_{eff} - Effective length

ΔL - Change in length

iv. Patch length extension (ΔL):

$$\Delta L = 0.412\frac{h\left(\varepsilon_{reff}+0.3\right)\left(\frac{w}{h}+0.264\right)}{\left(\varepsilon_{reff}-0.258\right)\left(\frac{w}{h}+0.8\right)} \qquad (4)$$

The Figure 2 shows the structure of proposed antenna developed with stacked patch structure consisting of four layers with foam substrate, with microstrip line feeding and copper as conducting ground.

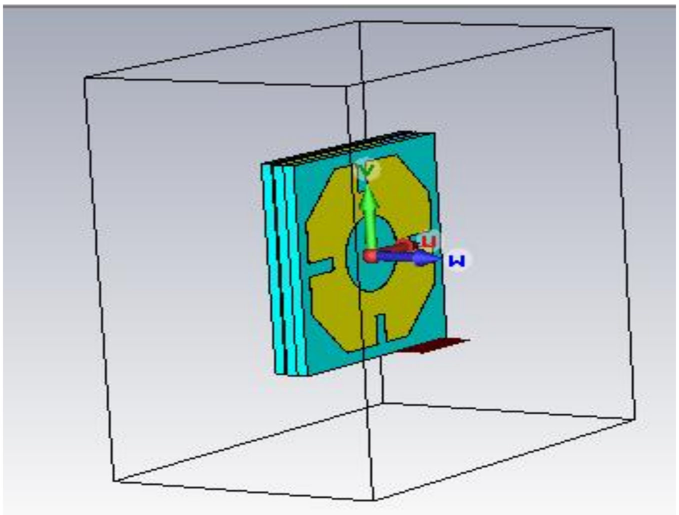


Fig 2: Structure of proposed stacked patch antenna using CST studio suite (side view)

The optimization is obtained by truncating the corners of the patch and by introducing inclined slots and slits in the patches. Since the circular polarization cannot be obtained directly, the slits and subsequent slots has to be adjusted in accordance with the patch dimension. The Figure 3 shows the bottom patch involving four layers, out of which the first patch is designed with four corners truncations and two inclined slots.

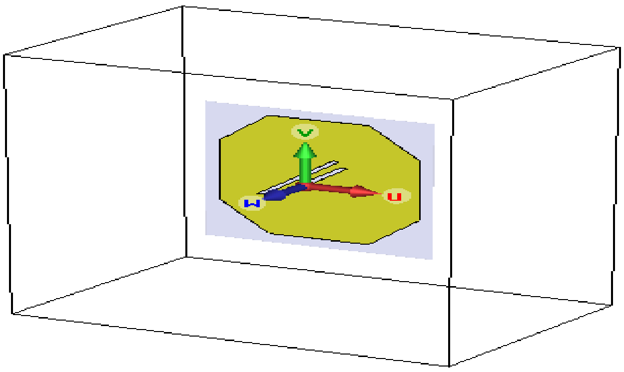


Fig 3: Bottom patch of the stacked antenna

The Figure 4 shows the second layer patch which is designed with two corners alone truncated since it provides more optimization when truncated with two opposite corners. Inclined slots introduced in the first patch is reduced to one inclined slot in the second patch with one inclined slot of 12 mm and the same dimensions are carried out as of patch 1.

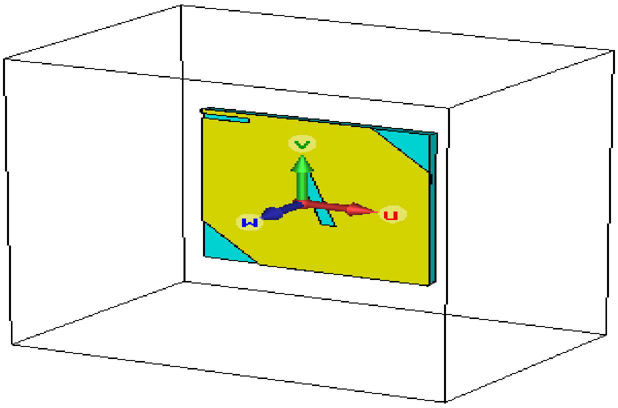


Fig 4: Second layer patch of the Proposed Stacked patch antenna

The Figure 5 shows the middle patch which is designed with embedding slits at the opposite edges and truncation is done on all the four corners. The same foam material is used as a substrate here.

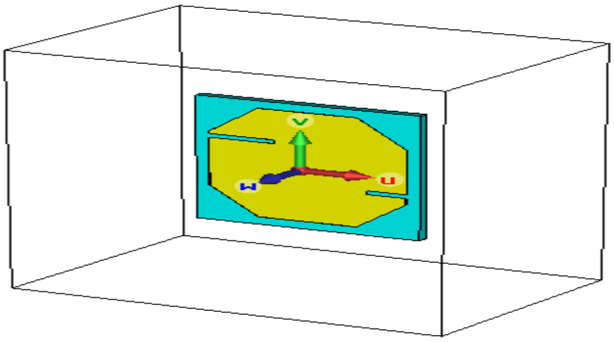


Fig 5: Middle patch of Proposed Stacked Patch antenna

The feed technique used is the microstripline feeding. The advantage of stacked patch antenna is such that when a feed is connected to one patch, the other patches receive excitation from the fed patches. The Figure 6 shows the perspective view of the proposed antenna design.

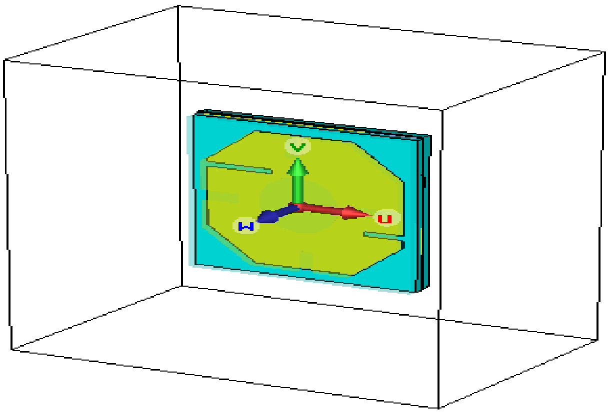


Fig 6: Perspective view of the proposed stacked patch antenna

The patches are all excited with a common feed with the view of tolerating the changes in the polarization signal. The introduction of gap between the substrate and the patch shows the variation in bandwidth. This type of antennas are designed to provide improved bandwidth and axial ratio < 3 dB.

III. RESULTS AND DISCUSSION

The various parameters are obtained using the design analysis of CST Studio suite.

The Figure 7 shows the S-parameter plot. S-parameter refers to the ratio of voltage out to voltage in. S-parameters are defined for a given set of frequencies and port impedance and vary as a function of frequency. The return loss is also observed to be -23,-31 for the multiband frequencies obtained at 5.9 GHz and at 8 GHz.

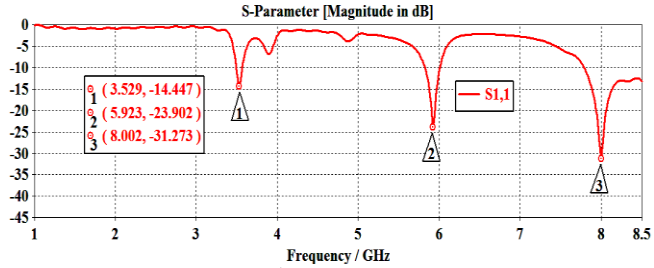


Fig 7: S-parameter plot of the Proposed Stacked Patch antenna

The Figure 8 shows the Voltage Standing Wave Ratio plot. VSWR plot is a measure that conveys how well the system is matched and how much of energy is getting into the antenna. If the VSWR is low, it says the how well the antenna is matched. The VSWR, when it is observed to be low also conveys that it is good for amplifier load effects. The VSWR is observed to be 1.3 and 1.06 for 5.9 and 8 GHz respectively.

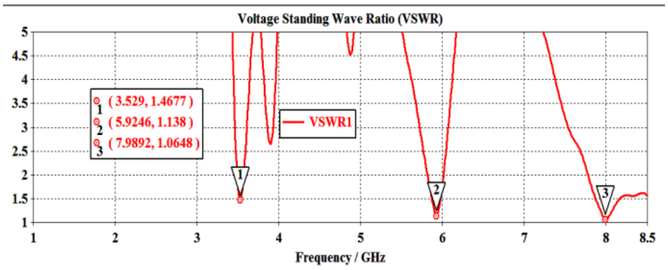


Fig 8: VSWR plot Proposed Stacked Patch Antenna

The Figure 9,10 shows the Directional radiation pattern of the proposed antenna. Directivity is a Figure of merit of an antenna. It measures the density of power that the antenna radiates in the direction of its strongest emission, radiating the same total power. Here the directivity is observed to be around 4.62 dB for the 5.9 GHz, 7.58 dB gor 8 GHz respectively.

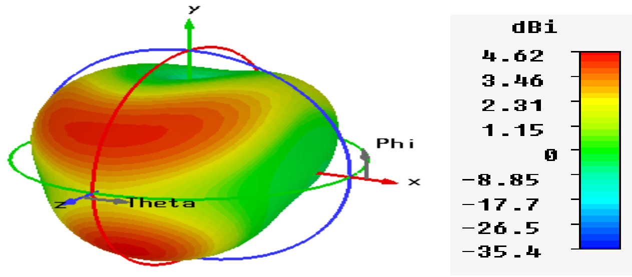


Fig 9: Directional radiation pattern of the Proposed stacked patch antenna at 5.9 GHz

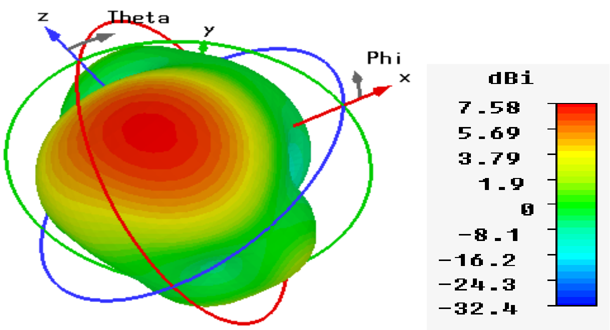
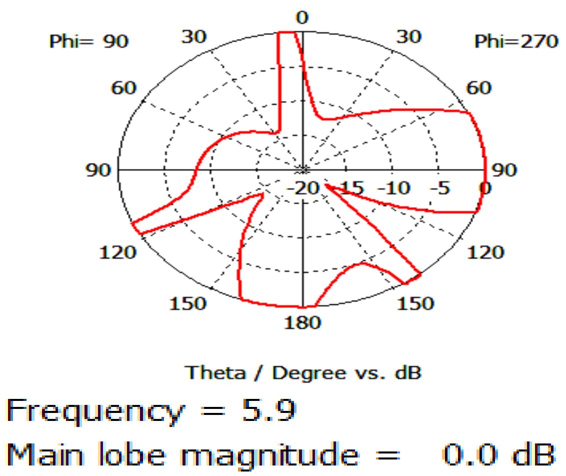


Fig 10: Directional radiation pattern of the Proposed stacked patch antenna at 8 GHz.

The Figure 12, 13 and 14 shows the axial ratio of the proposed stacked patch antenna. Axial ratio for elliptical polarisation must be less than 3dB and it is a measure of polarization ellipse. In general the axial ratio of the antenna is defined as the ratio of the major axis versus minor axis of the polarization ellipse expressed in dB, generally the axial ratio lies in the range (1<AR<infinity). For circular polarization, it should be 1 or below 1dB. The measures of axial ratio for particular frequencies are 0 dB for 5.9 and 8 GHz respectively.



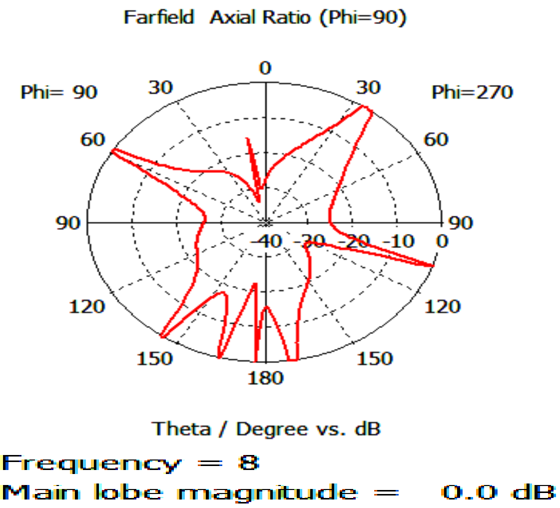


Fig 13: Axial Ratio of the Proposed Stacked Patch antenna at 8 GHz

IV. CONCLUSION

In this paper the circularly polarized stacked patch antenna is proposed. It is observed that the return loss is minimized and the axial ratio equal to less than 1 dB is obtained. The proposed antenna designed for C band performs well for the C band applications for RFID and radar systems. The circularly polarised stacked patches are substantially gaining importance in wireless communications.

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