A Scheme to Design a Multiband Circularly Polarized Inverted L-Patch Antenna

Abstract: *This paper presents a scheme to design a novel single feed inverted L-patch circularly polarized, Microstrip patch antenna for RADAR communication, W-LAN, point to point and multipoint wireless communication. The proposed antenna fed by 50Ω impedance thin microstrip line occupies a compact volume of 34x34x0.508 mm^3, a small variation in the slot was done (inverted L- shape).Proposed design shows multiband inverted L slot patch antenna characteristics for different center frequencies, and antenna offers a 2:1 VSWR bandwidth <5%(10.047-10.906) at S_{11}d" -10 dB at center frequency of 10.204 GHz. Circular polarization is brought about by embedding a slit and by chamfering the diagonal edges of the patch. The software used for the simulation is the CST Microwave Studio which is an analytical tool that provides an accurate 3D EM simulation results for high frequency design*

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I. Introduction

Microstrip antennas are attractive due to conformability, light weight, low cost and ease of fabrication [5-7].These antennas can be fed through printed strip -line feed networks and active devices. A microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side. For a rectangular patch, the length of the patch is usually $0.3333\lambda_0 < L < 0.5\ \lambda_0$, where λ_0 is the free space wavelength. The patch is selected to be very thin such that $t \ll \lambda_0$(where t is patch thickness).The height h of the dielectric substrate is usually $0.003 \leq h \leq 0.05\ \lambda_0$. The dielectric constant of the substrate(ε_r) is typically in the range $2.2 \leq \varepsilon_r \leq 12$[1].In our case ε_r is 2.2.

The radiation mechanism in microstrip antenna is primarily due to the formation of fringing fields between the patch edge and the ground plane. For good antenna performance, it is desired that the dielectric substrate used should have a low dielectric constant and have dimensions that can be termed as electrically thick. This substrate having low dielectric constant boosts up the performance and provides better efficiency, larger bandwidth and better radiation characteristics [1].However such a configuration leads to a larger antenna size. In order to design a compact Microstrip patch antenna, substrate with higher dielectric constants must be used which are less efficient and results in narrower bandwidth [9].The above mentioned facts lead to a trade-off that must be realized between the antenna dimensions and antenna performance.

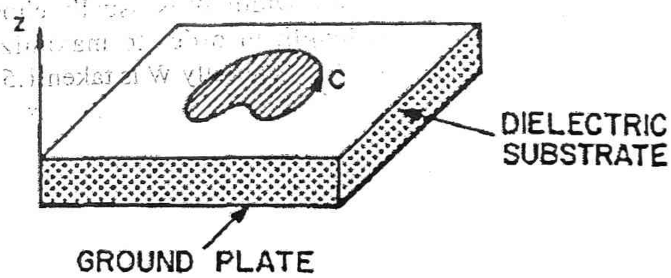


Fig. 1. General geometry of microstrip antenna without feed[2]

Figure 1 shows the general geometry of a typical microstrip patch antenna. Proposed antenna uses Microstrip line feed technique. The purpose of inset cut in the patch is to match the impedance of the feed line to the patch without the need for additional matching element. This is achieved by properly controlling the inset position[8].Patch antenna is analyzed using transmission line model as compared to cavity model. Transmission line model presents a simpler model since it provides ease of fabrication and simplicity in modeling as well as impedance matching. Circularly polarized single feed microstrip antennas are widely employed in RADAR, GPS and mobile communication systems. The advantage of single feed circularly polarized MSA is its simple structure due to absence of external polarizer[12].

However, a thin slot in a patch improves the reflection coefficient parameters i.e. return loss S_{11} parameter. For practical applications the normal range for S parameter is $S_{11} \leq -10$ dB. The parameter shows the amount of loss suffered in incident power due to the connections at the fed point of the antenna i.e. the ratio of reflected power to the incident power.

I (a) Theory of Microstrip Antenna

The metallic patch essentially creates a resonant gravity and edges of the patch form the sides of the cavity. The patch acts as a cavity with perfect electric inductor on the top and bottom surfaces and a perfect magnetic conductor on the sites. Inside the patch cavity the electric field is z directed and independent of the z coordinate. The electric field is of the form

$$E_z(x,y)=A_{mn}\cos(m\pi x/L)\cos(n\pi y/W) \quad ...(1)$$

Where L is the patch length and W is the patch width. The patch is usually operated TM_{10} mode.

Let us throw some light on the design of rectangular patch microstrip antenna. For a rectangular patch the resonant L is approximately one-half wavelength λ/2 and the width W is usually chosen to be larger than the length in order to maximize and optimize the bandwidth. Generally W is taken 1.5 times the length (W=1.5L). However, it should be kept less than twice the Length L, to avoid excitation of (0, 2) mode.

Feeding techniques in microstrip antenna is very important for obtaining efficient radiation patterns. These are generally done in four ways however we will mainly emphasis only those related to the above antenna. The most common is the co-axial feed line method where the centre conductor of the feed penetrates the substrate to make the direct contact with the patch. For linear polarization, the patch is usually fed along the centre line i.e. y=W/2. Another common feeding method (used in this paper) is the direct con act microstrip feed line method. Its is also known as inset feed as it controls the resonant input resistance of the contact point.

Another parameter is the resonance frequency, the resonance frequency for TM one-zero mode is given by

$$f_0 = \frac{c}{2L_e\sqrt{\epsilon_r}} \quad ... (2)$$

Where c is the velocity of light in the vacuum. L_e is the effective length taken into the account the fringing effects and is given by

$$L_e=L+2\Delta L \quad .....(3)$$

ΔL is given by the expression below

$$\frac{\Delta L}{h} = 0.412\left(\frac{(\epsilon_{eff}+0.3)}{(\epsilon_{eff}-0.258)}\left(\frac{\frac{W}{h}+0.264}{\frac{W}{h}+0.8}\right)\right) \quad ... (4)$$

Where h is the height of the substrate and ε_{eff} is given as

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2}+\frac{\epsilon_r-1}{2}\left(1+\frac{12h}{W}\right)^{-1/2} \quad ... (5)$$

II. ANTENNA GEOMETRY AND DESIGN

Figure 2 shows the geometry of the proposed antenna in inverted L-slot type configuration. As shown earlier, the dimensions of the slot are 34x34x0.508 mm^3. The inset recess dimensions are calculated [5] and length of the recess is 10.4 mm and width is 4 mm. In order to make it a circularly polarized antenna [2], two steps are taken First is to chamfer the diagonal edges with an angle =45 degree and taking W=L=3.3 is to cut a slit of length=9.7 mm and width =1 mm in straight and almost equal in dimensions the perpendicular slit is chamfered.

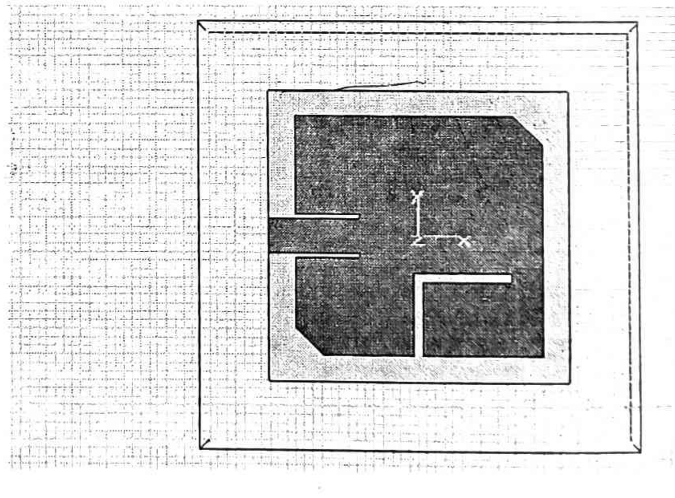


Fig. 2 Geometry of the antenna (W=34mm, L=34mm, h=0.508, Ws=4, Ls=10.4, Wsl=1 mm, Lsl=9.7 mm)

Figure 3 shows the surface current distribution of the proposed antenna for center frequency of 10.2 GHz.

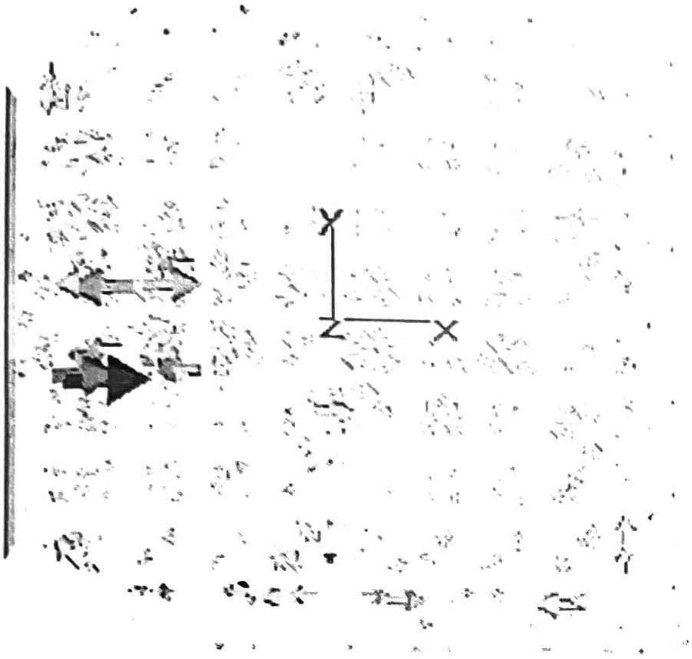
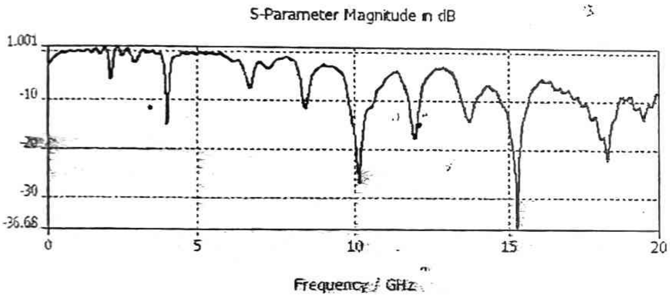


Fig 3 **Surface current distribution of simulated antenna[12].**

As shown in Figure 4 and 5, the antenna shows multiple frequency resonating nature.



F ig. 4. **S11 parameters /Return loss of the multiband antenna**

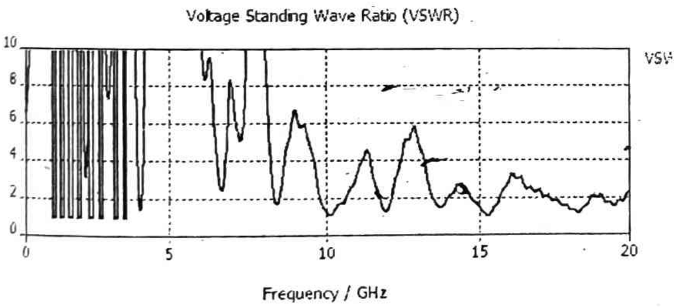


Fig. 5. VSWR v/s FREQUENCY curve.

Figure 5, 6, and 7 shows the electrical characteristics of the antenna. Fig. 8 shows the axial ratio. Figure 9 shows the axial ratio v/s θ graph, which shows that the antenna has circular polarization and Figure 10 and 11 depicts the right hand and left hand circular polarization of the far field.

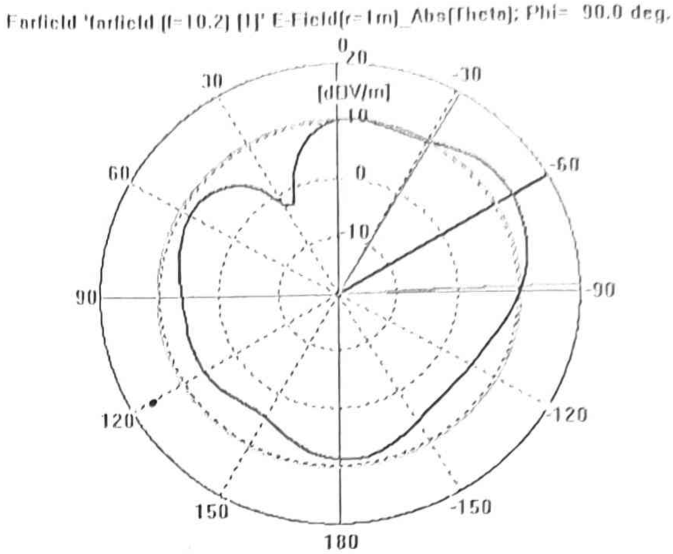


Fig. 6. Electric field[12]

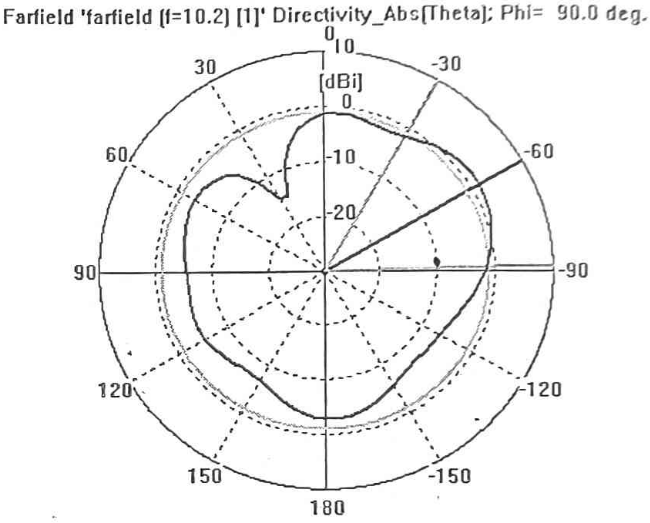


Fig. 7. Directivity[12]

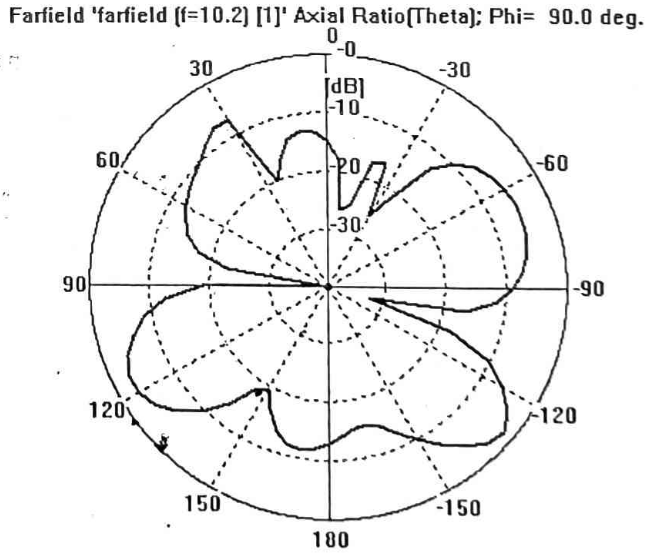


Fig. 8. Axial Ratio

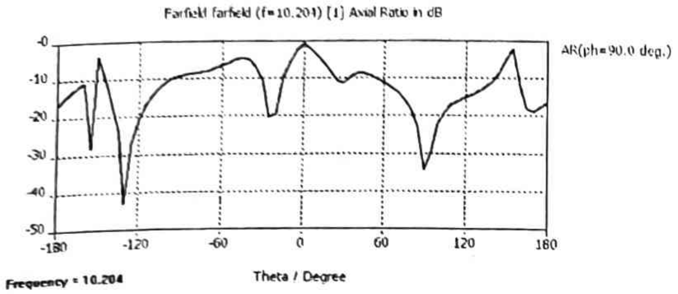


Fig. 9. θ v/s Axial Ratio graph

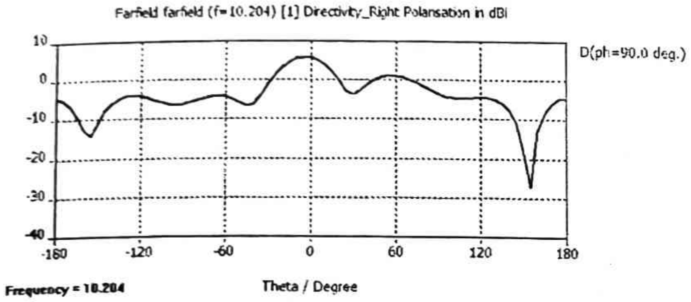


Fig. 10. θ v/s Axial Ratio graph

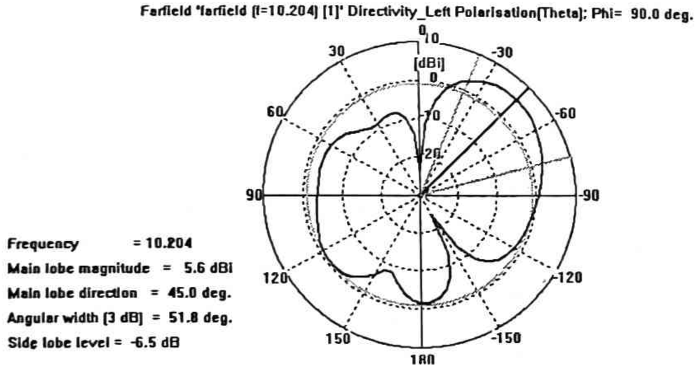


Fig. 11. Polar Plot of LHCP θ v/s Axial Ratio graph

III. RESULTS AND DISCUSSION

Proposed antenna is simulated by taking ε_r=2.2.Antenna is resonating for multiple frequencies ranging from 10-18 GHz. By taking S_{11} ≤-10 db and VSWR= 2:1 the bandwidth calculated for every resonating frequency comes out to be>3%.The performance of the above antenna was better than the normal slot circularly polarized multiband antenna as the return loss was appreciably enhanced to 36.68 dB.

IV. Conclusion

The proposed scheme of single micro-strip line feed, circularly polarized, multiband, inverted L-slot type patch antenna has been successfully simulated. The best value of return loss was obtained at frequency (10.204GHz to-36.68dB) and the maximum bandwidth was available at the center frequency of 10.204 GHz is <5 %(10.047-10.906 GHz).The proposed antenna's multiband characteristics can be used in various applications like weather monitoring, military operations and commercial advanced data rate wireless communication services. The inclusion of inverted L-slot raises the performance of the antenna by further reducing the return loss of the antenna.

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