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Design & Simulation of Back to Back F Shape Slotted Rectangular Microstrip Patch Antenna for Satellite Communication

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Abstract

In this paper we have analyzed and designed a back to back F shaped slotted rectangular patch antenna in C band. The proposed antenna design is able to operate at 6 GHz frequency and thus antenna becomes a necessity for many applications in satellite communication. Using proposed antenna design and probe feeding at proper position we find the resultant return loss, VSWR and bandwidth. We are using IE3D simulation software for designing and analysis. We have observed that using slotted patch antenna and using probe feed at proper location we can get better VSWR and bandwidth.

1. Introduction

Micro-strip patch antennas have drawn the attention of researchers over the past decades. However, the antennas inherent narrow bandwidth and low gain is one of their major drawbacks. This is one of the problems that researchers around the world have been trying to overcome. The patch antenna has been rapidly used in various fields like space technology, aircrafts, missiles, mobile communication, GPS system, and broadcasting. Patch antennas are light in weight, small size, low cost, simplicity of manufacture and easy integration to circuits. More important is these can be made out into various shapes like rectangular, triangular, circular, square etc. Many techniques have been suggested for achieving circular radiation pattern. These techniques includes: using square, circular, pentagonal, equilateral triangular, ring, and elliptical shapes which are capable of circular polarization operation. However square and circular patches are widely utilized in practice. However, high bandwidth, small size, simplicity, and compatibility to the rest of the RF front-end are desirable factors of an antenna. Enormous effort has been invested on designing frequency independent or very wide band antennas. One of the major drawbacks of such antennas is their relatively large size which can potentially eliminate their use for mobile wireless applications. It is a well-known fact that slot antennas present really appealing physical features, such as simple structure, small size and low cost, micro-strip slot antennas are extremely attractive to be used in emerging UWB applications. Using a circular slot in the radiating patch creates circularly polarized radiation pattern. By cutting a modified slot of suitable dimensions at the radiating patch a new fed configuration can be constructed. In this paper, a compact size micro-strip back to back F shaped slot antenna is proposed with dielectric substrate as silicon with εr=2.2. Various attempts are made to adjust the dimensions of the patch to improve the parameters like bandwidth, gain, radiation pattern in 2-D and 3-D using IE3D [14].

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2. Antenna Design

The proposed antenna design by cutting back to back F shaped slots in Rectangular patch as shown in fig. (1). Cutting of theses slots in antenna increases the current path which increases current intensity as a result efficiency is increased. The dimension of the patch are L=15.21 mm and W=19.76 mm. Inside this rectangular patch three C shaped slots are cut. The antenna is fabricated on a substrate of dielectric constant 2.2 and thickness h=2.5 mm. The probe feeding is used for optimum results.

Steps for calculating the dimension of patch

Step 1: Calculation of the Width (W)

The width of the Microstrip patch antenna is given as:

$$W = \frac{c}{2 f_0 \sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

Substituting c = 3.00e+008 m/s, εr = 2.2 and fo = 6.0 GHz, we get: W **= 0.01976 m = 19.764 mm**

Step 2: Calculation of Effective Dielectric Constant ($\varepsilon reff$)

The effective dielectric constant is:

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

Substituting εr = 2.2, W = 19.76 mm and h = 2.5mm we get: $\varepsilon reff$ = **1.9781**

Step 3: Calculation of the Effective length ($Leff$)

The effective length is:

$$L_{eff} = \frac{C}{2 f_0 \sqrt{\varepsilon_{reff}}}$$

Substituting $\varepsilon reff$ = 1.9781, c = 3.00e+008 m/s and fo = 6.0 GHz we get: $Leff$ **= 0.017775 m =** 17.775**mm**

Step 4: Calculation of the Length Extension (ΔL)

The length extension is:

$$\Delta L = 0.412h \frac{(\varepsilon_r + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 8\right)}$$

Substituting $\varepsilon reff$ = 1.9781, W = 19.764 mm and h = 2.5 mm we get: ΔL = **1.2801mm**

Step 5: Calculation of Actual Length of Patch (*L*)

The actual length is obtained by:

$$L = L_{eff} - 2\Delta L$$

Substituting $Leff$ = 17.775 mm and ΔL = 1.2801mm we get:
L = **15.214 mm**

Step 6: Calculation of the Ground Plane Dimensions (*Lg* and *Wg*)

The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. It has been shown that similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Hence, for this design, the ground plane dimensions would be given as:

$Lg = 6h + L = 6(2.5) + 15.214 =$ **30.21mm**
$Wg = 6h + W = 6(2.5) + 19.764 =$ **34.764 mm**

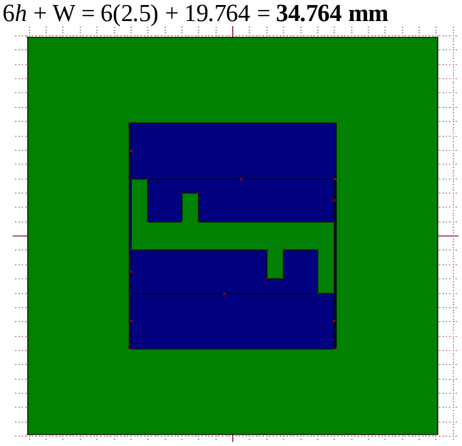

Fig: 1. Proposed Rectangular Micro-strip Patch Antenna with Back to Back F Shaped Slots

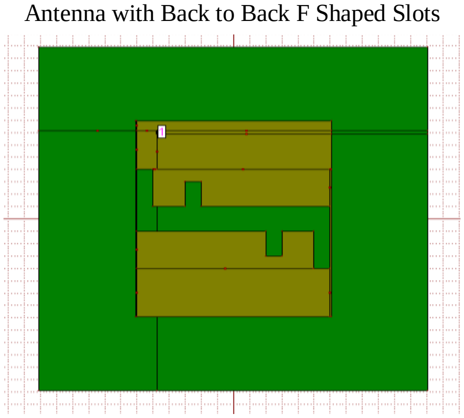

Fig: 2. Proposed Rectangular Micro-strip Patch Antenna with Back to Back F Shaped Slots Feed at (-5.75, 8.75) Point

3. Simulation Result

The simulation of micro-strip patch antenna is done by using IE3D simulation software [14]. The VSWR graph for a back to back F shaped slotted rectangular patch antenna is shown in figure (3). The VSWR value is close to unity. The VSWR for this back to back F shaped slotted antenna is 1.411. The simulated radiation pattern in 3D are shown in figure (4), the Smith chart is shown in figure (5), the return loss graph is shown in figure (6) and it is -17.78 dB, the total field gain & frequency is shown in figure (7), the total field directivity & frequency graph is shown in figure (8), the axial ratio & frequency is shown in figure (9), the antenna efficiency & frequency is shown in figure (10), the radiating efficiency & frequency is shown in figure (11) and the 3D radiation pattern for 6 GHz frequency for the back to back F shaped Slotted rectangular micro-strip patch antenna is shown in figure (12).

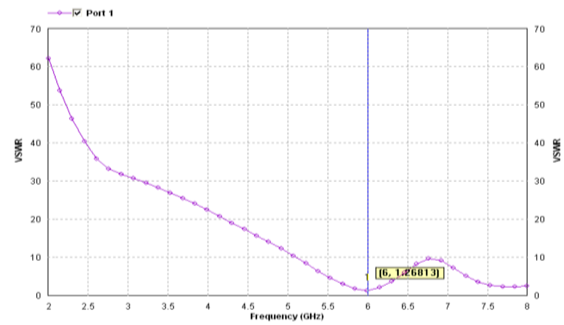

Fig: 3. VSWR of the Proposed Rectangular Microstrip Patch Antenna with Back to Back F Shaped Slots

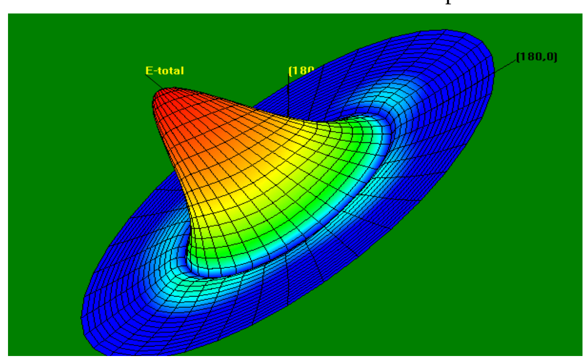

Fig: 4. Radiation Pattern in 3D of the Proposed Rectangular Micro-strip Patch Antenna with Back to Back F Shaped Slots

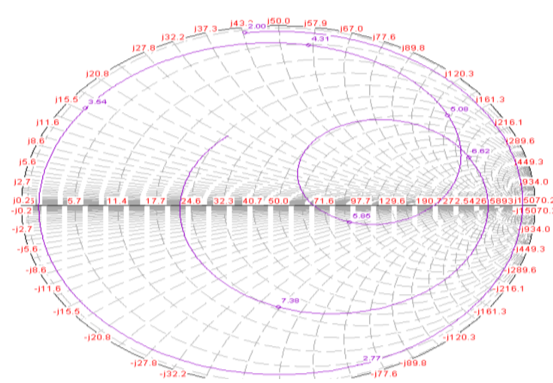

Fig: 5. Smith chart of the Proposed Rectangular Micro-strip Patch Antenna with Back to Back F Shaped Slots

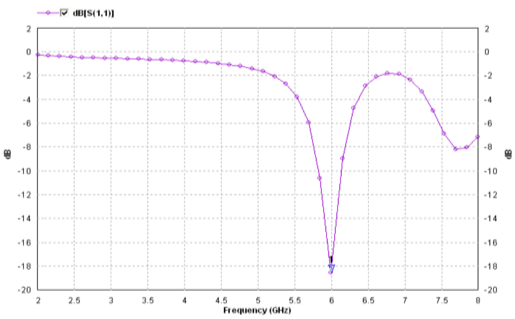

Fig: 6. Return Loss of the Proposed Rectangular Microstrip Patch Antenna with Back to Back F Shaped Slots

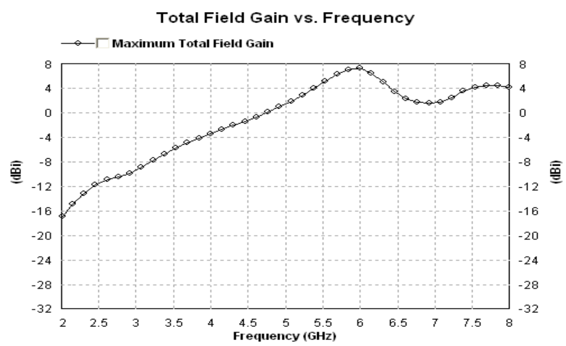

Fig: 7. Total Field Gain & Frequency of Rectangular Micro-strip Patch Antenna with back to back F Shaped Slots

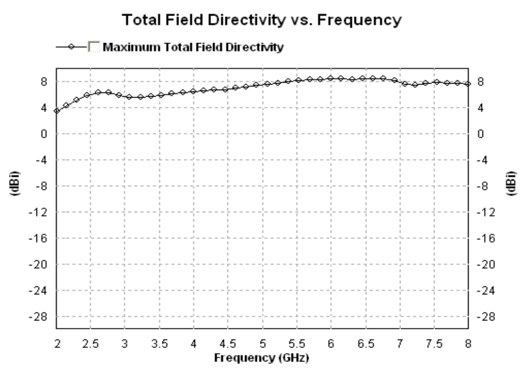

Fig: 8: total field directivity & frequency of Rectangular Micro-strip Patch Antenna with back to back F Shaped Slots

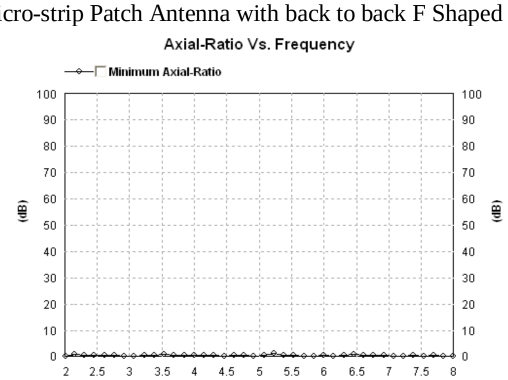

Fig: 9: Axial Ratio & Frequency of Rectangular Micro-strip Patch Antenna with Back to Back F Shaped Slots

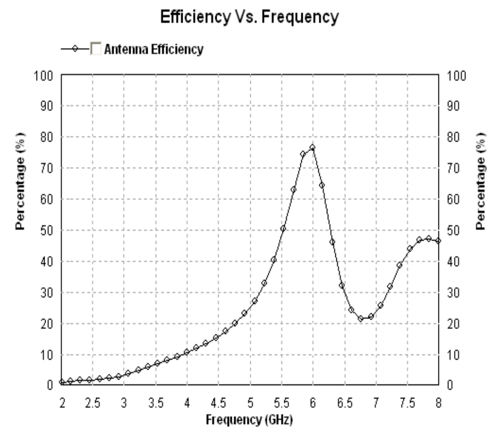

Fig: 10. Antenna Efficiency & Frequency of Rectangular Micro-strip Patch Antenna with back to back F Shaped Slots

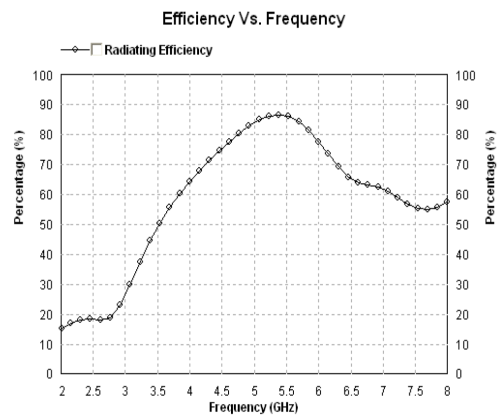

Fig: 11. Radiating Efficiency & Frequency of Rectangular Micro-strip Patch Antenna with back to back F Shaped Slots

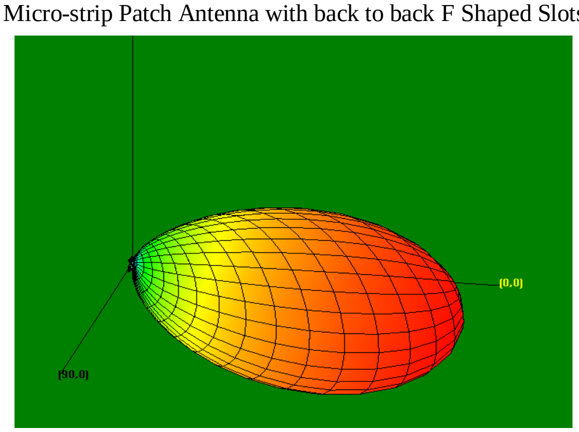

Fig: 12. 3D Radiation Pattern for 6 GHz Frequency of Rectangular Micro-strip Patch Antenna with Back to back F Shaped Slots

4. Conclusion

It is observed that a probe feed, back to back F shaped slotted rectangular micro-strip patch antennas is presented. The proposed antenna has a compact size of (15.21 x 19.76 x 2.5) and it can effectively covers the Satellite Communication, and the application of C band of communication system.

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