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Design of a Wide Band microstrip patch antenna for X-band and Ku-band Applications

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Abstract-In this paper, various structures of patch antennas are designed with FR4 substrate material. All the proposed antennas are designed without distorting the ground. For simulations, industrially accessible High Frequency Structural Simulator (HFSS) is used in this investigation. The characteristics like VSWR, Return loss, Axial ratio are studied and based on the results the best structure is selected which resonates at two frequencies one in the X-band (8GHz-12GHz) and the other in the Ku-band (12GHz-18Ghz). The s11 value crosses the -20 dB line at both resonant frequencies (8.96GHz and 13.36GHz) and the VSWR has an average value of 1.5 at both resonant frequencies. The proposed patch antenna structures are excited with lumped port and discussed below.

Keywords— FR4 substrate material, X-band, Ku-band, HFSS, Lumped Port

1. INTRODUCTION

The main success of microstrip patch antenna is thus it is meeting the satisfactions of new generation technology. The last few years' study says that the patch antenna structures improving from one year to the next year based on the performance. The main use of patch antenna is when it is incorporated in mobiles for mobile communications to decrease severe radiation. Several shapes are designed in order to reduce the effect of radiation [2-4].

The less use of microstrip patch antenna was because of its narrow band range, less distance propagation and its poor efficiency. To make narrow band to wide band many procedures have been done and are raised in the subject of antenna design. [6].

The main use of the microstrip patch antenna in the present remote correspondence framework was because of its low profile characteristic; size is compactable, consistably configurable, minimal effort, simple to manufacture and coordinate. Patch is the main part of the microstrip patch antenna and ground, substrate are the other parts of it. The patch is printed on the substrate [5].

The main reason to reduce the size of the patch antenna were to improve the bandwidth and it can also be accomplished by creating slots on the both ground and on the patch. The slots are created by taking proper length and width of the slots [1, 7-9]. The main problem that scientists and researchers facing is to design an antenna in the X band range and Ku band range because of its use in satellite and radar communications. For such type of antennas, the band required is wide band, it has high bit rate and distance range is less. So now the challenge is to satisfy the above three properties [9-10].

A rectangular microstrip patch antenna is designed in this reference which has a unique layer and bandwidth is felt short of 20 percent. This antenna has a bandwidth of 1 GHz and it is achieved with a low gain of 1.5dB at the operating frequency [12 In this reference an antenna was proposed which has a high bandwidth and the antenna structure has a circularly rotatable patch structure. The slot enhances the bandwidth. [13].

The antenna proposed in this reference has both length and width of 70mm that makes it a giant look like structure. Apart from this all the results are good for this structure, it has a large wide band of bandwidth 2ghz with a magnitude gain of 2dB at its operating frequency [14]. Two slot antennas which are in E-shaped were designed. This antenna has both length and width of 85mm that makes the structure large and less compactable. The results of this antenna are pretty good in gain and bandwidth with the help of microstrip line and CPW feeding technique. By looking the entire structure, it looks like a fork standardization stub to enlarge the bandwidth [11].

This paper mainly focuses on the antenna parameters like return loss and VSWR at two operable frequencies. In this paper three different patch structures are designed with only FR4 substrate material, the three structure designed such a way that only rectangular slots are created on the substrate and the ground is left as plane. The three structures are operable in the range of 8-16 Ghz and their characteristics are known with the help of HFSS.The three different structures are discussed below this section and the substrate thickness is 1.6 in all the three cases and lumped port excitation is given every structure.

2. ANTENNA STRUCTURES AND DESIGNS

The geometry of the designed antenna structure 1 has been shown in Fig. 1. The antenna comprises of a rectangular slot on the radiating patch. The rectangle slot is kept inside the main radiating patch. The second antenna structure has a hexagonal slot inside the patch and the two rectangular slots one inside the other is placed adjacent to the main patch and it is shown in Fig. 2. The third design structure which is shown in Fig. 3 is quite similar to that of the previous structure but the main change is that the adjacent patch structure here is a U shaped slot which is rotated. The design process begins with the radiating patch with substrate, ground plane and a feed line. It is printed on a 1.6 mm thick FR4 substrate that contains relative permittivity of 4.4 and relative permeability of 1. The ground is kept plane in all the three structures and the lumped port excitation is given for the three structures.

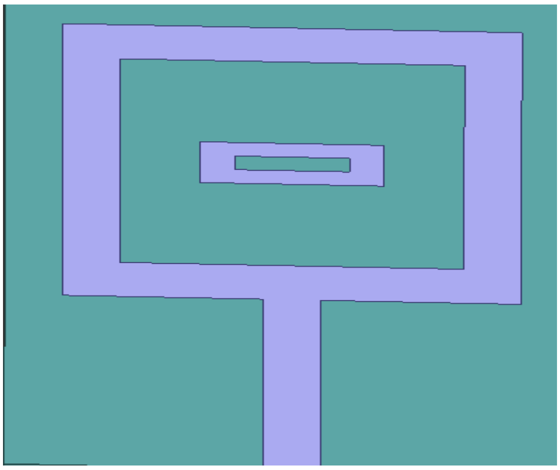

Fig1:Structure of Antenna 1 Top View

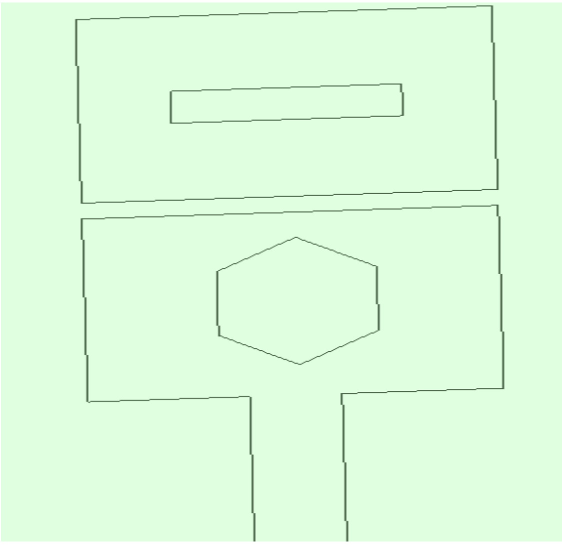

Fig 2:Structure of Antenna 2 Top View

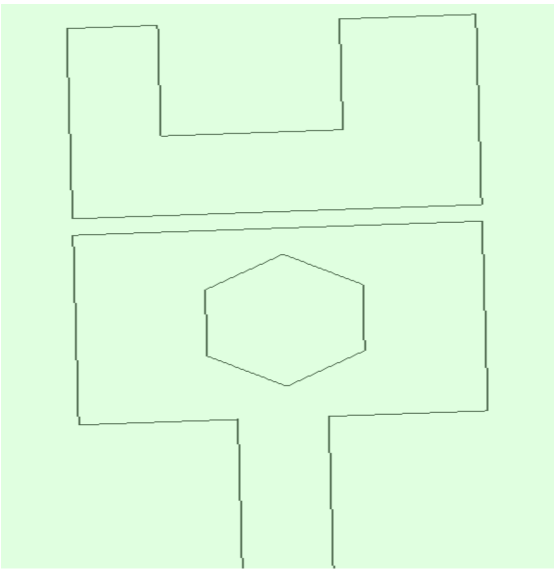

Fig 3:Structure of Antenna 3 Top View

From the transmission line model(TEM) the basic geometry design of the proposed microstrip patch antenna was designed by utilizing the below equations, length and width can also be calculated.

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

$$L=\frac{c}{2f_o\sqrt{\varepsilon_r}}-2\Delta l \qquad (2)$$

Where L and W are the length and width of the rectangular patch, C is the speed of the light in vacuum, *f0* is the required frequency of operation. The effective dielectric constant is calculated as

$$\varepsilon_e=\frac{1}{2}(\varepsilon_r+1)+\frac{1}{2}(\varepsilon_r-1)\sqrt{(1+\frac{10h}{W})} \qquad (3)$$

Practically the size of the antenna is larger to look at than its physical size, since the fringing field exists around the boundary of the patch, *Δl* takes into account this effect and can be explained as:

$$\Delta l=0.412h\frac{(\varepsilon_e+0.3)[\frac{w}{h}+0.8]}{(\varepsilon_e-0.258)[\frac{w}{h}+0.8]} \qquad (4)$$

The dimensions of the three structures are:

For the structure 1 the dimensions of the substrate are 70x50, it consists of two rectangular patches the inner most rectangular patch and the outer most rectangular patch, the inner most rectangular patch is mounted by the upper patch.

For the structure 2 the dimensions of the substrate are 16x18, it has two rectangular patches. The main rectangular patch has a polygon of six sides inscribed in it. The other patch has a rectangular slot inscribed in it. The main rectangular patch is feed with a microstrip feed line which will excite the antenna. The current will flow with the help of these feed line and the other patch will get current through mutual coupling.

The structure 3 is modified from the structure 2 and the only difference is the supporting patch is changed from the above. In the above structure 2 the supporting patch has a rectangle inscribed in the other rectangle whereas in this structure the supporting patch is in U-shape.

3. RESULTS AND DISCUSSION

The simulated results of the above three structures are done by using High Frequency Structural Simulator(HFSS) and the values are imported to third party application for the plot of the results. The return loss (s11) vs frequency plots are plotted for all the three structures and the remaining parameters are discussed below and tabulated in table 1.

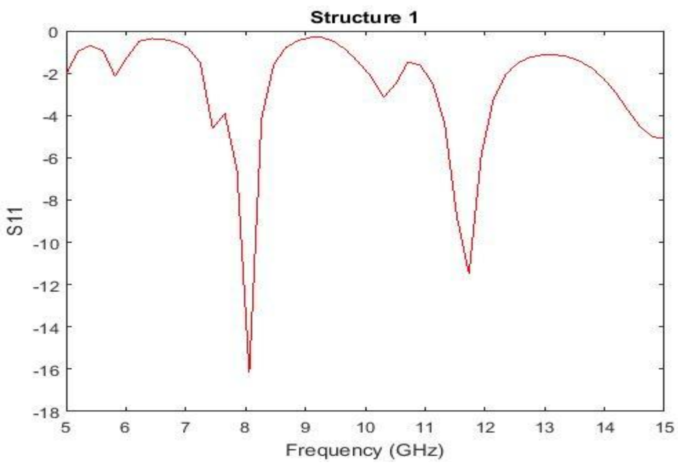

Fig 4: Return loss Vs frequency plot (Structure 1)

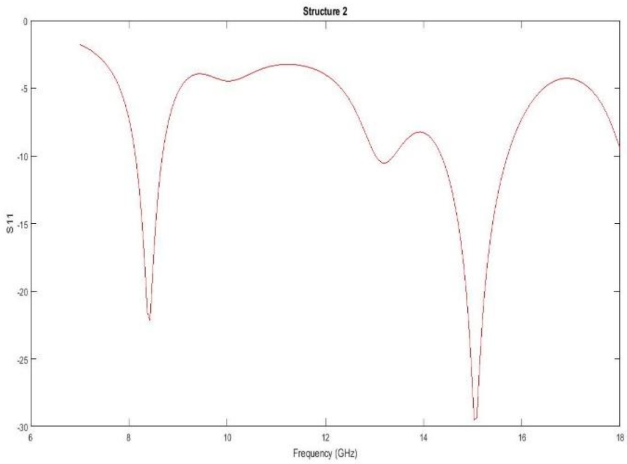

Fig 5: Return loss Vs frequency plot (Structure 2)

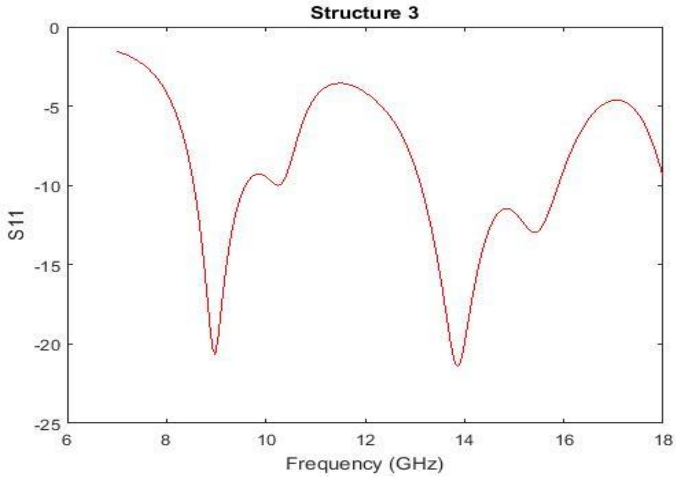

Fig 6: Return loss Vs Frequency plot (Structure 3)

FACTOR	STRUCTURE 1	STRUCTURE 2	STRUCTURE 3
FREQUENCY (GHz)	8.06 11.73	8.46 13.29 15.25	8.94 13.84
RETURN LOSS(S11)	-16.07 -11.43	-20.91 -10.75 -26.05	-20.66 -21.33
VSWR	2.72 4.73	1.2 1.82 1.63	1.61 1.60

Table 1: Comparison Of Parameters

4. CONCLUSION

Thus, a microstrip patch antenna of three different structures is seen and their return losses are plotted using HFSS. Among the three different structures the structure three which is shown in structure 3 has more return loss when compared to others. All the return loss values of these three structures are tabulated in table 1.The drawbacks of structure 1 are it has more VSWR value in the two resonant bands and the size of the antenna is large when compared to other two structures and the two resonant frequencies are in the x-band region only. These demerits are covered in structure 2 but unfortunately it is resonating at three different bands out of which the second resonating band has a low return loss value. The third structure which is quite similar to that of the structure 2 has low size, two resonating bands, low VSWR value and has very low return loss values. It can be effectively used in the satellite and radar applications.

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