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Dual band X shape Microstrip Patch Antenna for Satellite Applications

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Abstract

In this article electrically small, dual band, triple frequency X shaped patch antenna on a substrate of ceramic-PTFE composites is presented. The proposed X shape patch antenna with five rectangular slots produces dual band operation for Ku band applications and one for K band applications. In order to achieve multiband operation in conventional rectangular slot, it is introduced three equilateral triangle slots in left, right and upper edge respectively, and two small triangular slots are protruding both sides of the feed line. The simulated -10dB return loss bandwidths were 528 MHz, 576 MHz and 804 MHz at 15.33 GHz, 17.6 GHz and 18.90 MHz center frequency. The corresponding symmetric and almost steady radiation patterns have peak gains of 4.80 dBi, 6.42 dBi and 3.91dBi making the proposed antenna suitable for K and Ku band satellite applications. The radiation pattern, antenna efficiency input impedance was also analyzed.

Keywords: Dualband; Satellite; patch antenna; Slotted; Triangular; Ku/K band;X shape.

1. Introduction

Traditionally each antenna operates at a single frequency but with the rapid development of modern wireless communication system and their applications, wider bandwidth is required, where a different antenna for different applications. On the other hand, there is a great demand for wireless devices that are lightweight, small, attractive

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and multitasking. Currently, in radar and space satellite communication application, microstrip patch antennas have great demand due to their low profile, mechanical robustness, compatible with MMIC designs, relatively compact and light in weight and double frequency operation. They are easy and low-cost to manufacture and can be conformable in planar and non-planar planes. But, unfortunately they have some limitations and disadvantageous such as relatively low efficiency and low power, spurious feed radiation, narrow frequency bandwidth and relatively high level of cross polarization radiation [1-2]. To overcome these limitations and disadvantageous, researchers have been proposed and investigated many techniques such as slotted patch antennas, microstrip patch antennas on an electrically thick substrate, probe feed stack antenna and the use of various feeding and impedance matching techniques, the use of multiple resonators [3-11]. Presently, wider bandwidth is required for the increasing demand of modern wireless communication system applications. Generally each antenna performs its function at a single frequency, so different antennas require for different applications that will cause a restricted place and space problems.

Considerable research effort has gone into the design of multiband antennas. A 41 mm×14 mm slotted multiband antenna was designed which three frequency bands had centered at 0.9 GHz, 1.8 GHz and 5.2 GHz [12]. A 38 mm×3 mm planar multiband antenna was proposed for GPS, DCS, and WLAN applications [13]. A planar dual L-shaped antenna 30.5mm×21.5 mm operating in the 1.569 GHz–1.585 GHz and 1.850 GHz–1.990 GHz bands has been pro-posed [14]. A 2.4 GHz and 5.8 GHz dual band antenna were proposed for the ISM band using a backed microstrip line [15] 30mm×20 mm overall on an FR4 substrate and achieved a maximum gain of 4 dBi. However, the reported antennas were either larger, had a narrow bandwidth, low gain or were less efficient. There is still room to explore miniature antennas with wider bandwidth, and higher gain and efficiency.

In this study, a new X shaped slotted multiband antenna was designed with a 1.905 mm high dielectric material substrate with bandwidths of 528 MHz (15.104 GHz–15.632 GHz) , 576 MHz (17.336 GHz– 17.912 GHz) and 804 MHz (18.476 GHz-19.280 GHz) and 4.80 dBi , 6.72 dBi and 3.91 dBi peak gain.

2. Antenna Design Architecture and Optimization

The geometry of the proposed patch slotted antenna is shown in Figure 1 Proposed X shaped .The optimal geometrical parameters of the proposed shape antenna are obtained by using Ansoft's 3D full wave electromagnetic simulator HFSS which is based on Finite Element Method (FIT) . It is printed on Rogers RT/Duroid 6010 composite material substrates of thickness h =1. 905 and relative permittivity εr=10. 2, loss tangent tanδ =0. 0023. This material features ease of fabrication and stability in use. They have tight dielectric constant and thickness control, low moisture absorption, and good thermal mechanical stability. About 50 ohm a microstrip feed line etched on the down side of the radiating patched with dimensions of *Lf* and *Wf*. The antenna has a compact structure and total dimension is about 9.50 × 7.96 × 1.905mm^3 but radiating dimension is 8.5 × 7.96×1.905 mm^3 and the ground plane area is 2.5 mm×7.96 mm.

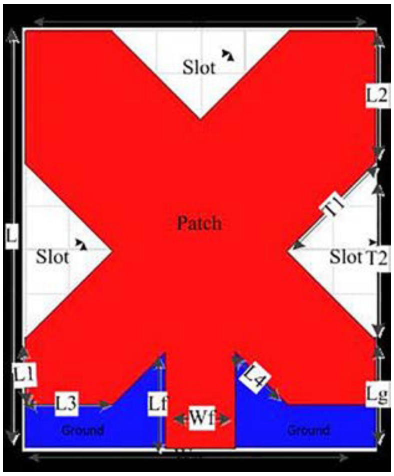


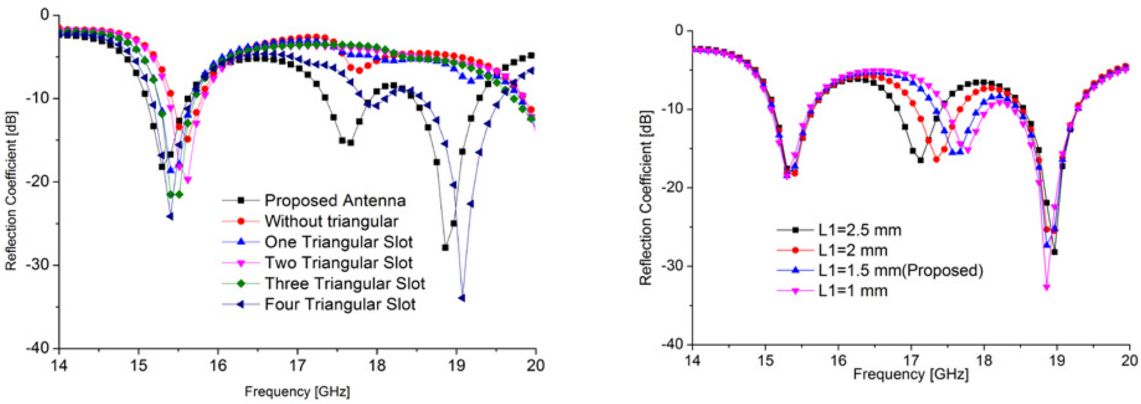
Fig. 1 Proposed antenna layout

Actually the radiating patch is a rectangular structure with five triangular slots. The area and the position of these five triangular slots are responsible for varying resonance frequency. Each triangular slot has two arms equal and third arm's length is twice than others. Because of these three triangular slots, current lines are changed. The current is to flow around the patch. So the effective length of the current lines becomes longer and the antenna size becomes miniature. In order to achieve good impedance matching and symmetrical excitement, proposed shaped antennas feeding is selected to the centered at the midpoint of the y axis length of the antenna. Equilateral slots are applied to achieve the multi band performances with sufficient -10 dB impedance bandwidth. In Table 1, all the exhaustive parameters of the proposed shape antenna are summarized.

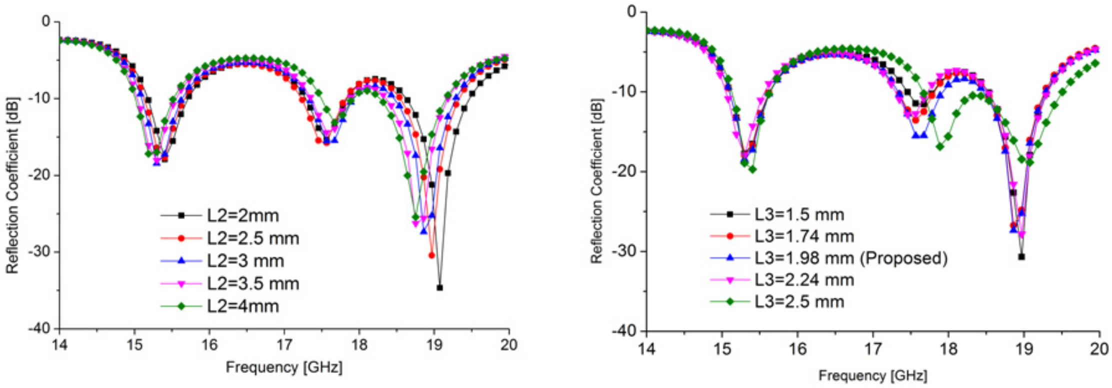
Table 1 Parameters of the proposed antenna

Parameter	Value (mm)
L	9.5
W	7.96
Lg	2.5
Wg	7.96
Lf	2.2
Wf	1.6
L1	1.5
L2	3
L3	1.98
L4	1.69
T1	2.82
T2	4.0
h	1.905

Figure 2a shows the effects of the no. of triangular slots in the conventional rectangular shape to five triangular slot patches. It is clearly said that the proposed antenna reflection coefficient is better than others. The proposed shaped which is shown in Fig. 1 is obtained by cutting five triangular slots in the conventional rectangular slots. In Fig. 2b, c and d, the authors have investigated the different values of L1, L2 and L3. From these figures, it could be easily observed that the L1=1. 5mm, L2=3mm and L3=1. 98mm are the best parameter for good impedance bandwidth and reflection coefficient.



(a) (b)

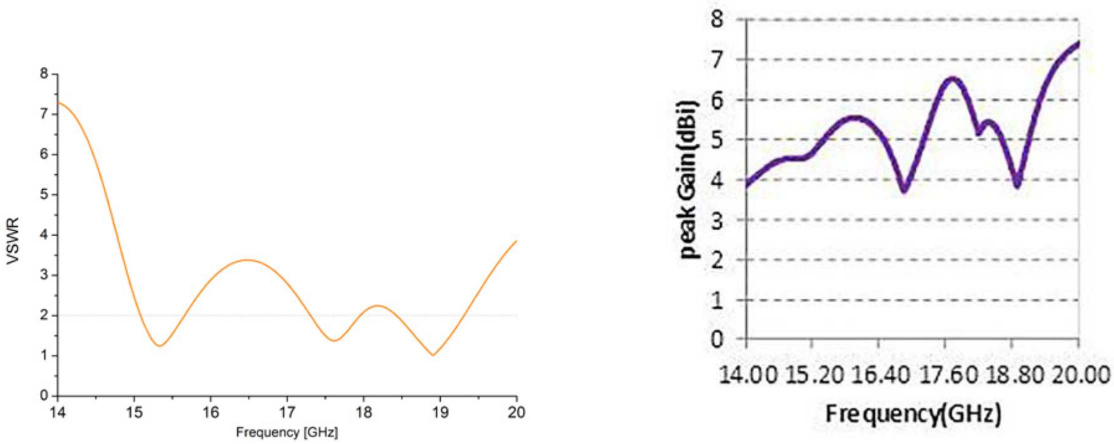


(c) (d)

Fig. 2 Simulated return loss for different values of a) no. of triangular slots b) L1 C) L2 d) L3

3. Results and Discussions

The different characteristics of the proposed shape antenna are investigated and optimized by commercially available finite element based software HFSS (High Frequency Structured based Simulator). The VSWR and peak gain of the final shape are shown in Fig. 3a and b.



(a) (b)

Fig. 3 a) VSWR and b) peak gain with frequency of the proposed shaped antenna

In that figure, the first operating frequency is 528 MHz from 15.104 -15.632 GHz and the second one is 576 MHz from 17.336-17.912 GHz , third one is 804 MHz from 18.476-19.280 GHz where return loss is achieved in less than -10 dB. The resonance frequencies of this region are 15.33 GHz, 17.61GHz and 18.90 GHz where maximum return loss -19.20 dB, -16.045 dB and -45.47dB respectively. Again as shown in Figure 3b, the average peak gain of the proposed antenna for first band is almost 4.80 dB, for second band is 6.42dB and for third band is about 3.91 dB.It is marked from the return loss and the gain curve that the proposed shape antenna is utterly capable of transmitting and receiving in the desired Ku band of 15.33 and 17.61 GHz respectively and K band of 18.90 GHz with a better peak gain characteristic than others [16-20].

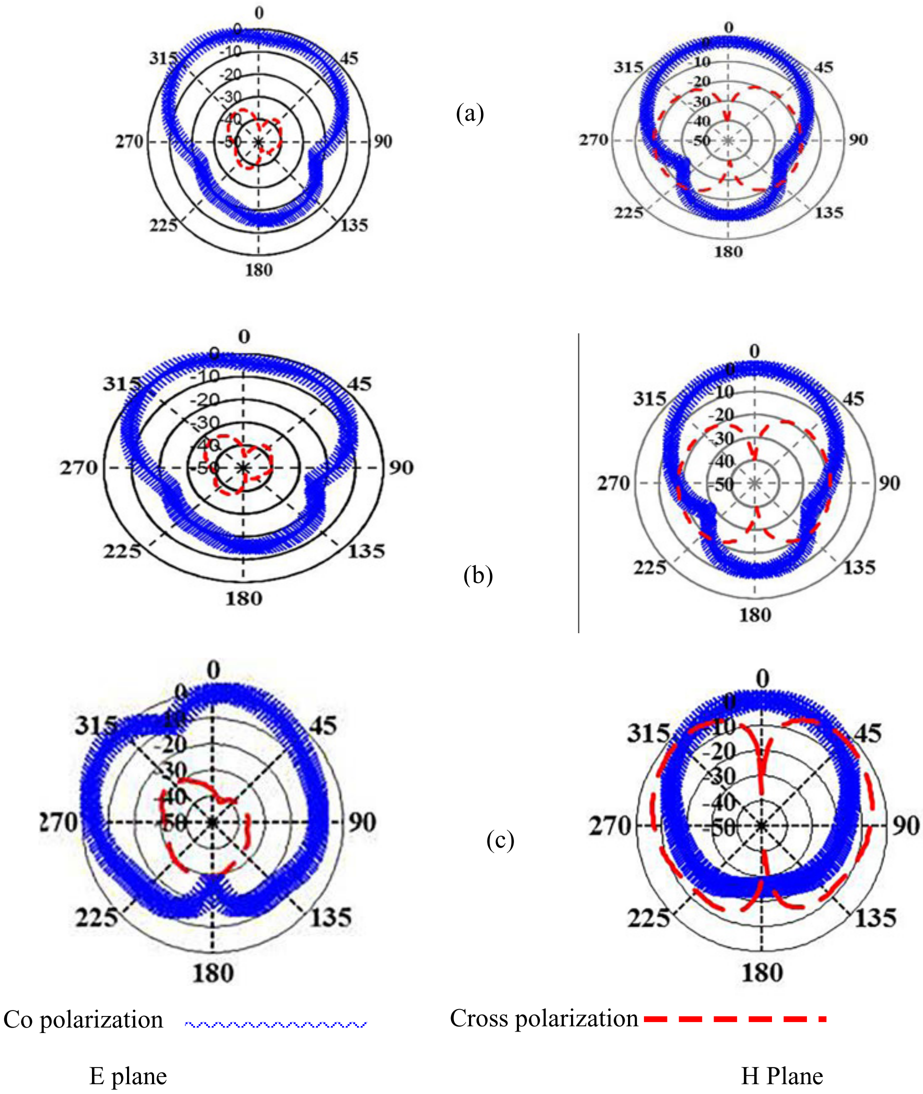


Fig. 4: Radiation pattern of the proposed shape antenna at a) 15.33 GHz b) 17.61GHz and c) 18.90 GHz

The radiation pattern in the azimuth plane (E plane) and elevation plane (H-plane) of the proposed antenna at different resonance frequency is depicted in Figure 8. The co–polarization is low compared to cross polarization. From the E plane, broad beam width is identified in the main beam of co-polarized. From the radiation pattern, it can be easily said that the designed antenna produces omnidirectional radiation and almost stable radiation pattern throughout the whole operating band with low cross polarization.

4. Conclusion

A new X shaped microstrip line feed patch antenna has been designed and evaluated in this work. The feeding technique, the adjusted slotted patch shape and the dimensions of the antenna made it possible to modify the acceptable reflection coefficient and characteristics of the radiation pattern in the expected frequency. The different parametric study, gain and radiation efficiency of the proposed antenna were analyzed and discussed. Finally, it can be concluded that the high dielectric ceramic-PTFE composites material which typical application such as Space Saving Circuitry , Patch Antennas, Satellite Communications Systems, Power Amplifiers , Aircraft Collision Avoidance Systems and Ground Radar Warning Systems and for omnidirectional radiation pattern , the proposed triple band antenna can be a competitive solution for the current needs to be adopted with multi technology wireless devices in a Ku / K band (satellite and radar) applications compare to other available dual band multi frequency antennas.

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