ISSN (online) : 2277-5390
ISSN (Print): 2277-5382

Triple band microstrip delete patch antenna for satellite related applications

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Abstract

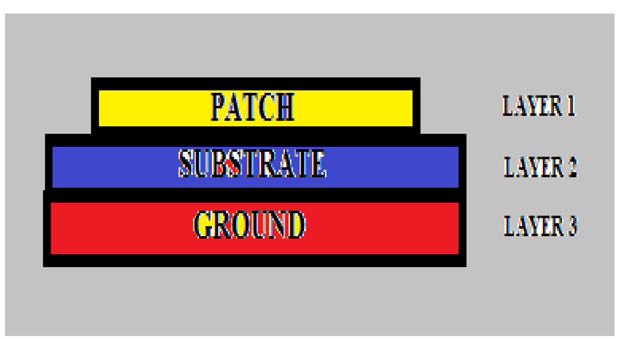
Objectives: To design a triple band microstrip delete patch antenna to be used mainly for satellite communications. The structure may be utilized additionally for RF devices and aviation.
Methods/Statistical analysis: The proposed geometry uses numerical Finite Element Method to subdivide a large problem into small and simple finite elements. The applied simple equations modelling these finite elements are then stacked into a wider system of equations that would represent the entire problem. Various methods from the calculus of variations then approximate a solution by minimizing an associated error function. The proposed antenna geometry uses a 1.6 mm FR4 epoxy substrate with a probe feeding technique. The used software is HFSS. The design has been analysed in terms of reflection coefficient, bandwidth, radiation pattern, gain, directivity and VSWR.
Findings: Using HFSS based on FEM, the design has been analysed in several aspects. Compared to both single band rectangular and circular reference MSA's, the proposed multi band design offers highly improved characteristics as listed in Table.
Application/Improvements: The structure is suited mainly for satellite applications. The 50 MHz bandwidth extending from 3.79 GHz to 3.84 GHz may be used for satellite communications and fixed microwave, the 80 MHz bandwidth from 4.63 GHz to 4.71 GHz for fixed satellite applications and the 210 MHz bandwidth extending from 5.21 GHz to 5.42 GHz may be used for RF devices, satellite communications and aviation.

Keywords: Delete patch, satellite applications, RF devices, aviation.

1. Introduction

The range of frequencies lying between different bands including 3.79 GHz to 3.84 GHz, 4.63 GHz to 4.71 GHz and 5.21 GHz to 5.42 GHz may be used for satellite applications. In addition, two frequency ranges out of them may also be used for RF devices and aviation. These applications make use of small sized, light weighted microstrip patch antennas as shown in figure 1 which have a dielectric substrate resting between a metallic patch and a ground plane [1].

Figure 1.Three layer structure of microstrip patch antenna



The proposed prototype uses a FR4 epoxy substrate with a thickness of 1.6 mm, relative permittivity of 4.4 and a dielectric loss tangent of 0.02. The structure is formed by the combination of rectangles with different lengths and widths. The introduction of 3 narrow vertical slits in the structure makes it look much like the delete icon available in the modern day hand devices.

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In [2] proposed a Coplanar Waveguide (CPW) fed slot antenna that can be used for wideband applications. A CPW with a U-shaped tuning stub excites the slot antenna. Analyzation of the S11 parameter and the radiation patterns has been done. Based on the facilities available in the fabrication unit, the structure was redesigned and then the parameters were measured.

In [3] proposed a suspended microstrip Patch Antenna with inverted V-shaped ground plane. Parametric analysis was done and the basic parameters including the return loss, gain, radiation pattern and polarizations were simulated, measured and found to confirm to the acceptable standards.

In [4] proposed the design of a compact single-layer circularly polarized patch antenna designed for HORYU-IV nanosatellite S-band communication. The antenna as such has high gain and is circularly polarized.

In [5] proposes a microstrip patch antenna designed using a FR-4 substrate with a dielectric constant of 4.3. The simulated results achieve a reflection coefficient below -10 dB at centre frequency of 5.75 GHz. The proposed antenna will be potentially useful in wireless communication areas such as WLAN/WiMAX.

The section II gives an insight into the antenna geometry and specifications. The section III includes results. The final sections of the paper include conclusion and references.

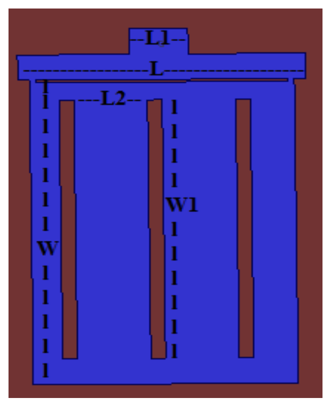
2. Antenna geometry and its specifications

The antenna design is much similar to the delete icon that can be seen in different applications as shown in figure 2.

The geometry of the proposed antenna is shown in Figure 3.

Figure2.DeleteIcon

Figure3. Proposed antenna geometry



The geometric specifications of the proposed antenna have been listed in Table 1.

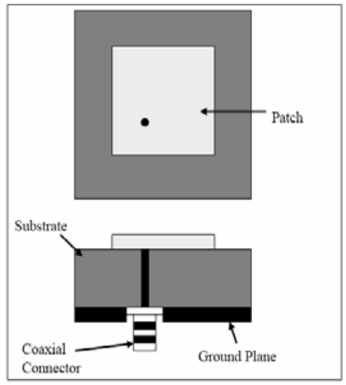
Table 1. Geometric specifications of proposed antenna (mm)

Parameters	Dimensions (mm)
L	49
W	60
L1	10
W1	51
L2	12.5

2.1. Design considerations

The design uses a 1.6 mm FR4 epoxy substrate and a coaxial feed technique. The use of coaxial technique as in figure 4 is due to several advantages offered by it including easy fabrication, low spurious radiation and simple matching techniques.

Figure4. Coaxial feeding technique



The tabulated equations representing the design criteria for rectangular microstrip patch antenna shown in Table 2.

Table 2. Design equations for the proposed antenna

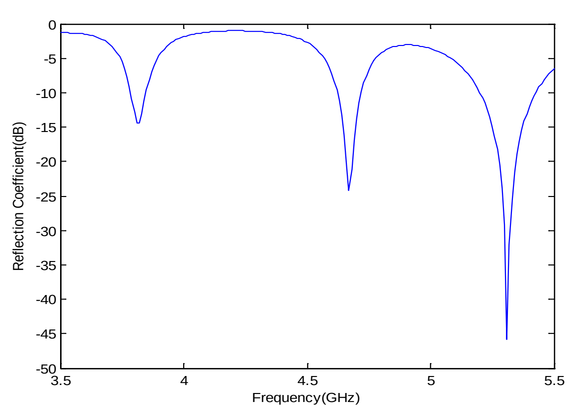
Parameter	Formula
Width of the radiating metallic patch (*W*)	$w = \left(\frac{c}{2 \times f_r}\right)\left(\sqrt{\frac{\varepsilon_r + 1}{2}}\right)$
Effective dielectric constant of the substrate ε_{reff}	$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \times \sqrt{\left(1 + \left(\frac{12h}{w}\right)\right)}$
Effective length of the metallic patch (L)	$L = \frac{c}{2 \times f_r \times \varepsilon_{reff}} - 2\Delta l$
Extension Length for patch (ΔL)	$\Delta l = .412 \times h \times \left[\left(\frac{\varepsilon_{reff} + 0.03}{\varepsilon_{reff} - .258}\right) \times \left(\frac{w + 0.264h}{w + .8h}\right)\right]$

3. Results and discussion

3.1. Reflection coefficient and bandwidth

Figure 5 shows that the design offers 3 band of frequencies including the 3.79 GHz to 3.84 GHz with a reflection coefficient [6] of -14.5 dB at 3.82 GHz. Another band of 4.63 GHz to 4.71 GHz resonant at 4.67 GHz has a reflection coefficient of -24.3dB. Yet another band of 5.21 GHz to 5.42 GHz hasa reflection coefficient of -45.8 dB achieved at 5.31GHz.The provided bandwidths are 50 MHz, 80 MHz and 210 MHz respectively.

Figure 5. Reflection coefficient curve for the proposed geometry



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3.2. Radiation pattern and gain

Figure 6 shows the plot of the overall radiation pattern [7] of the proposed geometry.

Figure 6. Radiation pattern

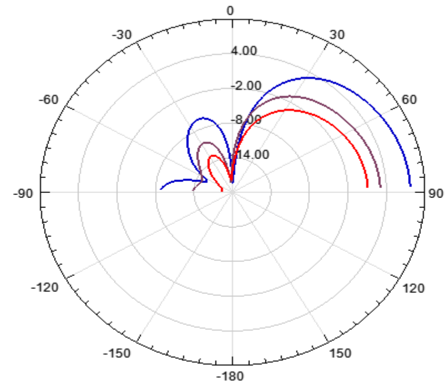
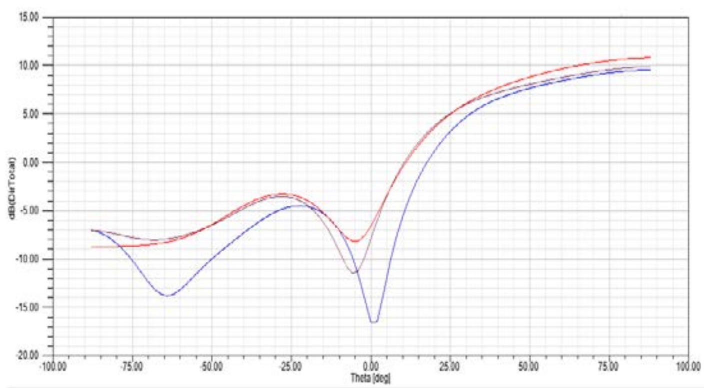


Figure 6 shows, the red curve denotes shows a maximum gain [8] of 1.1 dBi achieved at3.82 GHz, a peak gain of 3dBiat 4.67 GHzde noted by the purple curve, blue curve denotes those at 5.31 GHz with a maximum gain of 7.7dBi.

3.3. Directivity

Figure 7 shows the angular variations of directivity [9] at different resonant frequencies that achieves a maximum value of 10.8 dB at 3.82 GHz, 9.9 dB at 4.67 GHz and7.7 dB at 5.31 GHz.

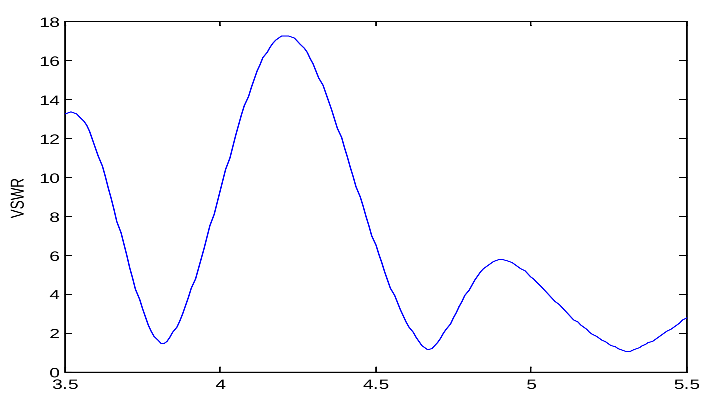
Figure 7. Directivity variations for the proposed antenna at different resonant frequencies



3.4. VSWR

The VSWR [10] expresses the matching extent between the impedance and the transmission line that has a value of 1.5 at 3.82 GHz, 1.1 at 4.67 GHz and 1 at 5.31 GHz for the proposed geometry as shown in figure 8. The attained values are less than 2 and satisfy the required condition.

Figure 8. Variations of VSWR with frequency



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The results are tabulated in Table 3.

Table 3. Tabulated results

Resonating Freq(GHz)	Reflection Coefficient(dB)	Gain(dBi)	BW(MHz)
3.82	-14.5	1.1	50
4.67	-24.3	3	80
5.31	-45.8	7.7	210

4. Conclusion

Triple band microstrip delete patch antenna for satellite applications and a few others was designed. The structure was found to be resonant at different frequencies with reflection coefficient, gain and bandwidth as listed in Table 3.

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The Publication fee is defrayed by Indian Society for Education and Environment (iSee). www.iseeadyar.org

Citation:

Deepanshu Kaushal, T. Shanmuganantham. Triple band microstrip delete patch antenna for satellite related applications. *Indian Journal of Innovations and Developments.* 2016; 5(12), December.