A Compact Low-Profile T- Shaped Strip Loaded Filtenna

Ashish Chandelkar(1), Pratap Singh Katara (2), and Arvind Kumar(1)
(1) Dept. of Electronics and communication, Visvesvaraya National Institute of Technology, Nagpur, India
(2) Government Polytechnic College Agar, MP, India

Abstract

In this article a compact, low-profile T-shaped strip loaded filtenna is presented which is satisfying the band pass filtering antenna characteristics. The proposed filtenna is single layer structure, top layer of the filtenna contains a rectangular patch and etched with two pair of slots along Y -axis and a pair of symmetrical T-shaped strip. The simulation results of the proposed filtenna shows that S-parameter is -25 dB and -40.31 dB at 6 and 6.17GHz, respectively and the impedance bandwidth of 5.5% with a compact size of $0.44\lambda_0 \times 0.30\lambda_0 \times 0.017\lambda_0$.

1. Introduction

In today's world of communication, the broadband, multifunctional and miniaturized components are in high demand for 5G Communication applications [1]. In this context the integration of components is having advantages of low profile, small size and multifunctional features such as multiband and wideband, with the single structure additionally having disadvantages of insertion loss and tuning between the integrated components [2]. The filtering antenna is the excellent example of multifunctional component having features of filter and antenna at the same time.

There are three techniques of designing of filtering antenna. The initial approach is filters and antenna are developed individually and coupled with 50-ohm transmission line. The second approach is the co-design process, in this the last stage resonator is replaced by an antenna. The third approach is the fusion technique, in this integration of resonant structure paralleled with the antenna [3]. All the above designed approaches are possible by utilizing various techniques such as etching slots on radiating patches [4], employing defected ground structures, stacked parasitic patches [5], shorting pins and also utilizing different kind of feeding techniques such as coupling probe method, multi-stub feed line [2], parasitic non-radiating strip. The major purpose of utilizing all of this strategy is to establish a radiation null near the pass band edges resulting in sharp band edge skirt and high suppression level in stop band [5][6].

In this paper compact low profile filtering antenna is proposed in section 2 antenna configuration, design and working principle explained. In section 3 experiment discussion as follows.

2. Filtenna Design and Analysis

2.1 Filtenna Configuration

Figure 1 illustrates the antenna structure that is being suggested, with its optimal dimensional specifications. The component is constructed on a single-layer substrate utilizing a rectangular slab composed of Rogers' RT-Duroid-5880 material. This material has a relative permittivity of 2.2, a loss tangent of 0.0009, and a thickness of 1.575 mm. The top layer of the substrate consists of a rectangular patch with two pairs of rectangular slots etched along the Y-axis, as well as a symmetrical pair of T-shaped strips positioned at the edges of the rectangle patch. The bottom of the substrate is cladded with a thick copper layer of 0.035 mm thickness, which acts as a ground layer. A probe feeder is situated along the middle axis in Y-direction. The optimum dimension of the proposed filtenna is displayed in Table 1.

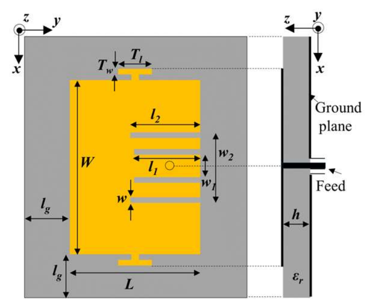

Figure 1. Top view and Side view proposed filtenna.

Table 1
Dimensions of the proposed filtenna (in mm)

Parameter	***W***	***L***	l_1	l_2	w_1
Value	22	15	7.6	8	1.45
Parameter	T_l	T_w=w	***H***	l_g	w_2
Value	3	0.65	1.575	5	7

2.2 Design Mechanism

The designing concept features a coaxial-fed conventional rectangular patch. The resonance frequency f_{mn} of a TM_{mn} mode of a rectangular patch can be determined using (1)

$$f_{mn} = \frac{c}{2\sqrt{\varepsilon_r}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2} \qquad (1)$$

Here-

f_{mn} is the resonance frequency, c is the speed of an electromagnetic wave in vacuum, ε_r is the relative permittivity of the medium, m and n are positive integer, a and b are dimensions corresponding to length of the rectangular patch along X-axis and Y-axis respectively. At this stage the antenna is resonating at its fundamental TM_{10} at 6 GHz and bandwidth is narrow but didn't achieve the filtering antenna characteristics.

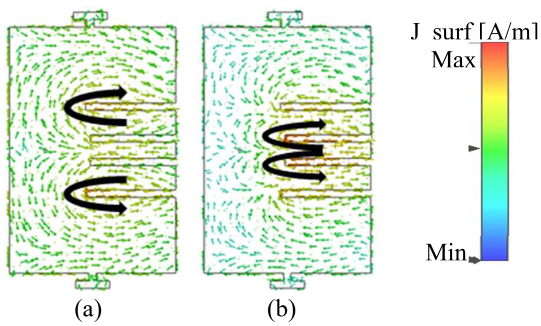

Figure 2. Surface current distribution of proposed filtenna (a) at lower radiation null frequency 5.47 GHz (b) at lower upper radiation null frequency 6.97 GHz.

In order to achieve sharp band edges, roll off, wider impedance bandwidth and realizing the filtering characteristics the radiation nulls are preferred at above and below the resonance frequency for that in next stage a pair of rectangular slots is etched out along the Y-axis and obtained an upper radiation null above the resonance frequency due to the additional current that flow around the slots. Similarly for the lower radiation null one more rectangular slot etched out along the Y-axis. Around the slots the surface current is in opposite direction and out of phase which is responsible for the creation of lower and upper radiation nulls as shown in figure 2 (a) and (b) and further to improve the suppression level at the upper and lower radiation nulls the symmetrical T- shaped strips is fixed at the edges of the rectangular patch these strips are increasing the effective area of the patch and provides controllability to the suppression level around the nulls.

2.3 Parametric Study

For further analysis of filtering characteristics of the proposed filtenna the filtenna parameters T_l is varying which is responsible for the suppression level at the lower radiation null as shown in figure 3(a) and (b) as the T_l length is increasing the s-parameter is not affecting much but in figure 3(b) can see the suppression level at the lower radiation null is increasing. Further analysis is done at the upper radiation null as shown in figure 3(c) and (d) as the length l_1 of slot is increasing the upper radiation null is shifting towards the lower frequency and this parameter is providing controllability and selectivity to the upper radiation null.

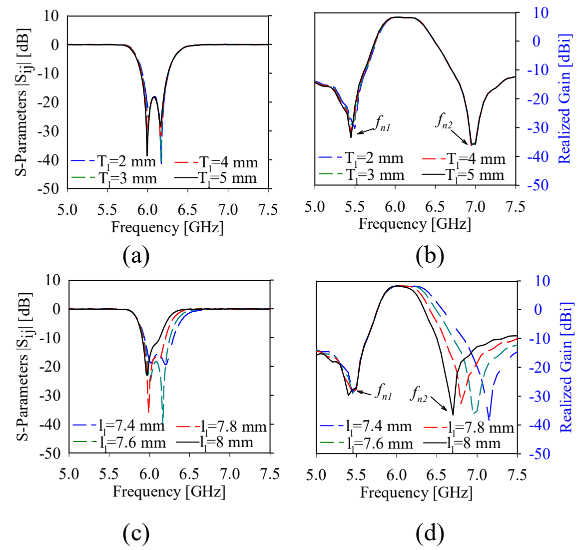

Figure 3. Simulated S_{11} and realized gain of the proposed filtenna (a) & (b) By varying T_l (c) & (d) By varying l_1.

3. Experimental Results

In figure 4 the s-parameter and realized gain of the proposed filtenna is presented. The simulated s-parameter is $|S_{11}| < -10$ dB criterion is -40.31 dB around the resonance frequency of 6.17 GHz, lower and upper radiation nulls occur at 5.47 GHz and 6.97 GHz respectively which execute an impedance bandwidth is 5.5 %. The simulated realized gain is 8.38 dBi and shows the stability in pass band region and suppression level is below -10 dB in the stop band region as depicted in figure 4.

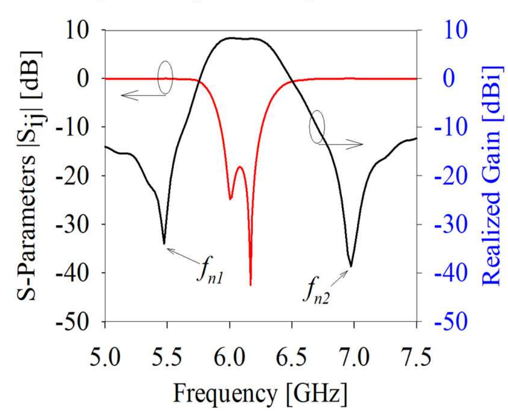

Figure 4. Simulated S-parameter and gain the proposed filtenna.

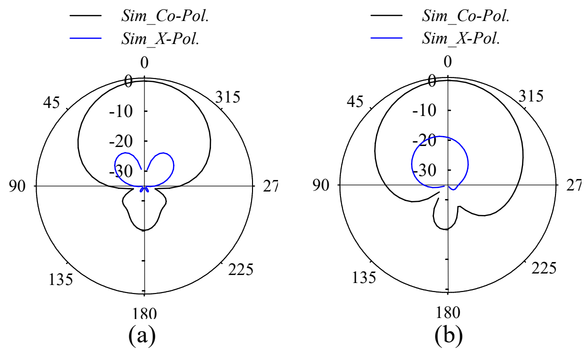

Figure 5. Simulated radiation pattern of the proposed filtenna (a) at cut angle 0º (b) at cut angle 90º.

Figure 5 (a) and (b) shows the simulated radiation pattern at resonance frequency 6.17 GHz at two cut planes of 0º (E-plane) and 90º(H-plane). The radiation in the boresight direction is unidirectional and higher front to back ratio, cross polarization level is below then -20 dB.

4. Conclusion

In this paper a compact low-profile T-shaped strip loaded filtenna is presented. The filtering antenna has designed and result has discussed. The proposed filtenna has Very low profile of $0.032\lambda_o$ (λ_o is free space wavelength at resonance frequency 6.17GHz). The simulated results show that the filtenna is suitable for the 5G wireless communication application.

5. References

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