Indian Journal of Science and Technology, *Vol 9(38), DOI: 10.17485/ijst/2016/v9i38/97115, October 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Linearly Polarized Microstrip Planar Filtenna for X and Ku Band Communication Systems

B. T. P. Madhav*, G. Sai Gupta, M. Rahul, O. Krishna Lahari and M. Sameera

Department of ECE, K L University, Guntur - 522502, Andhra Pradesh, India; btpmadhav@kluniversity.in, saigupta.g@gmail.com, rahul.m@gmail.com, krishnalahari@gmail.com, sameeramodali@gmail.com

Abstract

Objective: Design and analysis of a Planar filtenna to operate in X and Ku band communication systems. **Methods/Analysis**: The design of the filter consisting of planar metallic structure on the top side and a defected ground type structure on another side of the substrate. A substrate material is integrated with vias at the bottom part of the designed structure. The simulation results of the designed filtenna are carried with commercial electromagnetic tool HFSS and all the filtenna radiation characteristics are presented in this work. **Findings**: A substrate integrated waveguide filter is used in this model for RF channel selection as well as a balun. The proposed filtenna occupies a compact dimension of 12x35.5x1.6 mm. **Novelty/Improvement**: Planar structures with substrate integrated vias are acting as electromagnetic band gap structures in the current design. The surface wave related losses will be suppressed with this novel structure. Microstrip line feeding with 50 ohm impedance and easy integration are making this model suitable for multiband communication applications.

Keywords: Filtenna, Ku-Band, Linear Polarization, Substrate Integrated Waveguide, Vias, X-Band

1. Introduction

Higher frequency than 10 GHz is currently thought to be a promising contender for the future wireless communications because of its accessibility of unused wide data transfer capacity. Remote correspondence frameworks at Ku-band have pulled in additional also, more consideration for their focal points of better trade off on limit, downpour constriction, and circuit size, contrasted with frameworks at different groups like C-band and Ka-band. The linearly polarized antenna has merit of less generating polarized current, which avoids significant attenuation of energy. Omni directional antennas are required for wireless terminals for their uniform power radiation in all directions in one plane.

The planar Coaxial Collinear (COCO) antenna is a good choice for its easy manufacture using the standard Printed Circuit Board (PCB) process and easy integration with other planar microwave circuits. Substrate Integrate Waveguide (SIW) having merits of low insertion loss, high power capability, low cost, easy integration, and easy fabrication. A filtenna is a co-design of Radio Frequency (RF) filter and a radiation element. The filtenna can be used for reducing the loss introduced by transmission between the RF filter and the radiation element and for suppressing unwanted signals[1–4]. Filtenna has merits of light weight, compact size, and low cost, accurate fabrication with PCB process. Filtenna comes under the combination of filter and antenna[5,6]. Researchers proposed different filtenna structures in the literature for desired band pass and band stop operations. In this paper we are proposing a novel structure of filtenna with vias in the substrate to reduce the problems associated with surface waves[7–10]. The geometrical construction and analysis is presented clearly in the subsequent sections.

2. Filtenna Geometry and Design

The proposed filter is designed to operate in the X and Ku band communication systems. Figure 1 shows the

**Author for correspondence*

structure of the designed filtenna top side as well as bottom side. Figure 2 shows the dimensional characteristics of the filtenna and Table 1 shows the filtenna dimensions in mm. A substrate integrated waveguide type metallic cylindrical shape metallic structures are used as vias. To create the vias, initially some cylindrical portions in the substrate are removed and created hole in the substrate. The cylindrical holes are filled with cylindrical strips of PEC material. The substrate material is the sandwich of two different materials.

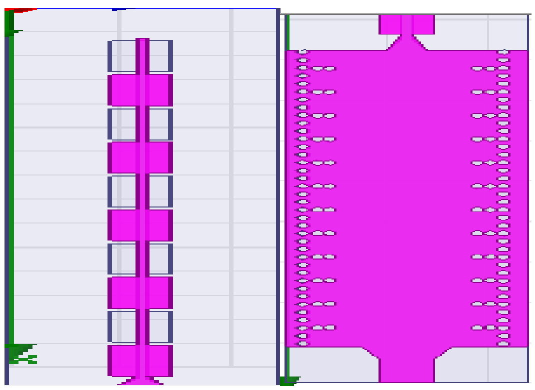

Figure 1. Filtenna model top side view and the bottom side view.

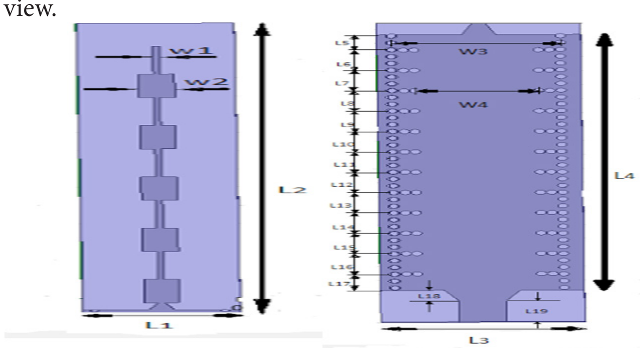

Figure 2. Filtenna model dimensional view.

Table 1. Filtenna dimensions

Parameters	Length(mm)
W1	0.50
W2	6.45
W3	9.90
W4	7.32
L1	12.0
L2	80.0
L3	12.0
L4	35.5
L5,L17	2.14
L18	1.50
L19	3.00
L6, L7, L8, L9, L10, L11, L12, L13, L14, L15, L16	2.86
L2+L4+L18+L19	120

The overall dimension of the filtenna is around 12 x 35.5 x 1.6 mm on Taconic substrate material with dielectric constant 2.5 and loss tangent 0.666. The gap of patch elements on the top side of the substrate are connected with conducting lines in such a way that impedance of 50 ohms attainable at feed point on the feed line. The substrate integrated waveguide effective length and width are calculated by the corresponding central resonant frequency.

$$f_{101} = \frac{c}{2\sqrt{\epsilon_r \mu_r}}\sqrt{\left(\left(\frac{1}{W_{eff}}\right)\right)^2 + \left(\frac{1}{L_{eff}}\right)^2} \qquad (1)$$

Where ϵ_r and μ_r are relative permittivity and relative permeability of substrate and c is the velocity of light in free space. The antenna parameters with respect to results are presented in next section.

3. Results and Discussion

The filtenna characteristics are analysed and presented with HFSS tool in this section. The Return loss characteristic of the modelled filtenna is presented in Figure 3. The designed filtenna shows multiband characteristics in X and Ku bands with minimum loss at 17 GHz respectively. The impedance bandwidth of the designed filtenna at 13 GHz is around 15.3% and at 15.5 GHz it is around 12.9%. The bandwidth at each resonating frequency is somewhat narrow in the range but gain at resonating frequencies is very high when compared with conventional antennas working in that operating band.

The radiation patterns of the filtenna at different resonating frequencies are presented in Figure 4, 5, 6. Figure 4 shows that the radiation pattern of the filtenna at 12.8 GHz in E and H-plane. At 12.8 GHz filtenna is showing omni directional radiation with low cross polarization in h plane and monopole like radiation in e plane. Figure 5 and 6 are also giving similar kind of patterns at 14.3 GHz and at 15.8 GHz.

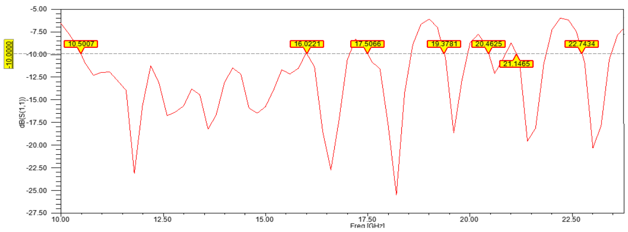

Figure 3. Returnloss vs frequency.

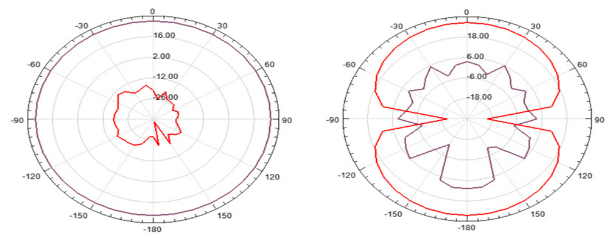

Figure 4. Radiation pattern of filtenna at 12.8 GHz in E and H-plane.

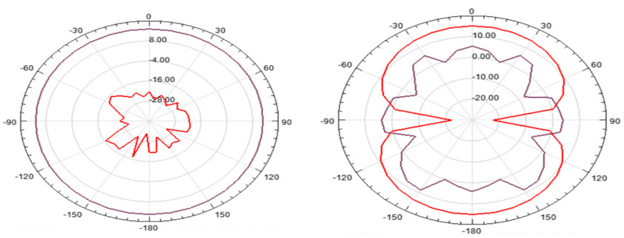

Figure 5. Radiation pattern of filtenna at 14.3 GHz in E and H-plane.

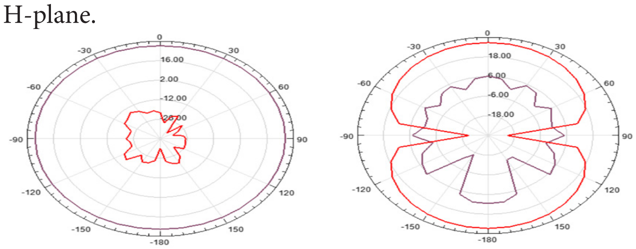

Figure 6. Radiation pattern of filtenna at 15.8 GHz in E and H-plane.

Figure 7 shows the current distribution characteristics of the filtenna at centre resonant frequency. The current elements are mostly focussed on the conducting patch centre rather than the side edges of the patch element. Figure 8 shows the electric field distribution and Figure 9 shows the magnetic field distribution of the filtenna at centre resonant bands of frequency. The electric field intensity is distributed at different edges on the surface of the patch element with weak zone at lower part of the radiating element. The magnetic field intensity shows weak on the ground plane but somehow strong on the radiating element.

Figure 10 shows the 3-Dimensional radiation pattern of the designed filtenna. Filtenna is radiating with omni directional pattern in yz-plane. In xz-plane filtenna is showing monopole light radiation with maximum gain in z direction.

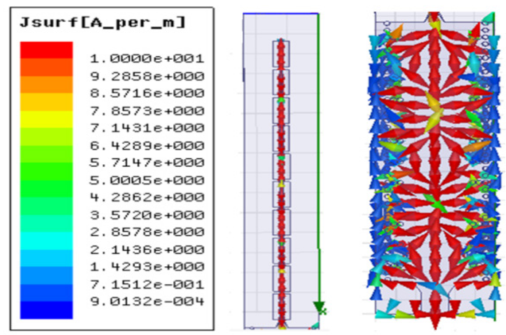

Figure 7. Current distribution at 15.8 GHz.

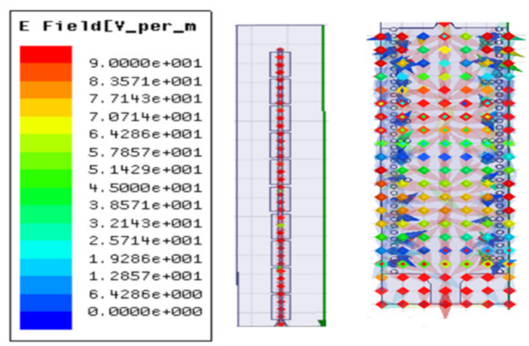

Figure 8. E-field distribution at 15.8 GHz.

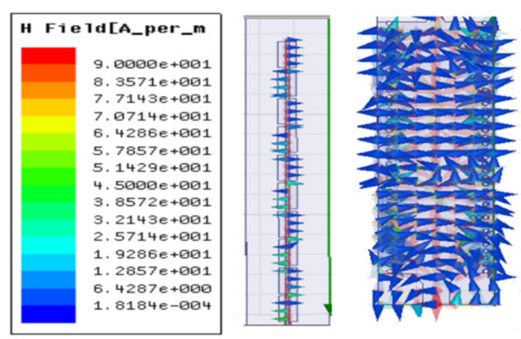

Figure 9. H-field distribution on filtenna at 15.8 GHz.

Figure 11 shows the gain characteristics of the designed filtenna with change in resonating frequency .A peek realised gain of 30 dB is attained at 15.8 GHz and an average gain of 12dB is attained with operating X and Ku band.

Figure 12 shows the prototyped antenna front view and Figure 13 shows the back view on FR4 substrate material. The filter structure with vias can be observed from the prototyped model. The proposed filtenna is tested on vector network analyzer and results are presented in Figure 14.

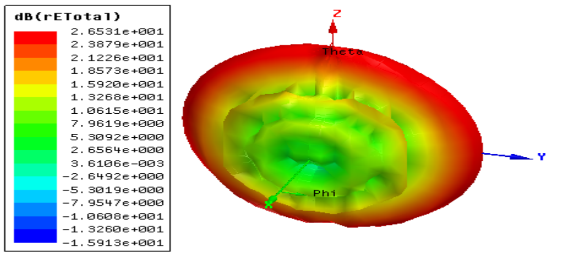

Figure 10. 3-dimensional radiation pattern of the filtenna.

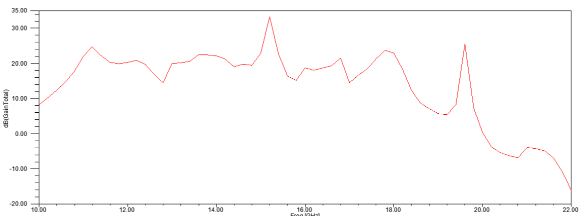

Figure 11. Frequency in GHz vs gain in dB.

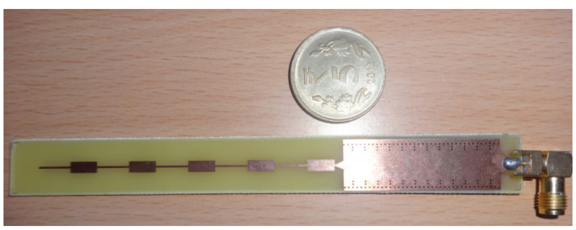

Figure 12. Prototyped filtenna model front view.

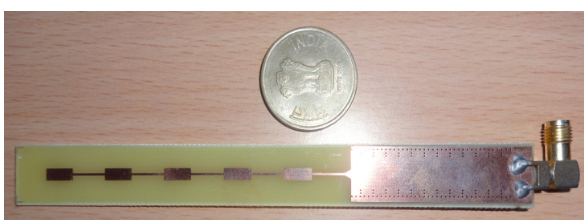

Figure 13. Prototyped filtenna model back view.

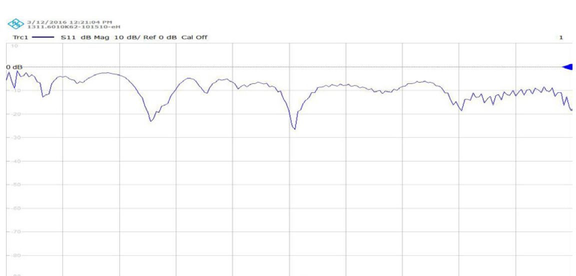

Figure 14. Measured S_{11} result on ZNB 20 vector network analyzer.

The measured results from ZNB 20 vector network analyzer are showing good agreement with the simulation results attained from HFSS electromagnetic tool. The range of the network analyzer is limited to 15 GHz at our place, so we got the results in that range only. Between 1 to 15 GHz the obtained results from ZNB-20 VNA are almost similar to simulated S_{11}.

4. Conclusion

A multiband filtenna model is designed in this work to operate in the X and Ku bands for communication systems. Wideband characteristics are obtained from this filtenna model at lower operating band and multiband characteristics are attained at higher operating band. Bandwidth of 6 GHz at lower band and impedance bandwidth of 46% are the most attractive features of this filtenna. At higher band filtenna model is showing considerable bandwidth of not less than 800 MHz at resonant frequencies. The proposed filtenna model is fabricated on FR4 substrate and the prototyped model is tested on ZNB-20 vector network analyser for validation. Peak realized gain of 30 dB and average gain of 12 dB is attained from the proposed filtenna in the desired band, which is the highest from this type of filtenna models proposed in the literature.

5. Acknowledgements

Authors like to convey their gratitude to ECE department of K L University and Department of Science and Technology through FIST grant SR/FST/ETI-316/2012.

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