RESEARCH ARTICLE

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Design of Compact Bow-Tie Slotted Antenna for Satellite Communication

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Abstract

A printed antenna using slot loading technique is adapted in the design to achieve multiband. A rectangular microstrip (printed) antenna with a Bow-Tie shape slot embedded on the radiating patch using a glass epoxy substrate with dimensions 3.34 x2.47 x 0.16 cms. The antenna is simulated using 3D electromagnetic simulator software HFSS and fabricated using photolithography. Vector Analyzer is used to measure the experimental results. The fabricated antenna has return losses of -20.00 dB, -25.09 dB, and -26.45 dB at three independent frequencies 4.62 GHz, 8.14 GHz, and 12.41 GHz. The antenna operates at a frequency range of 4.62 GHz to 12.41 GHz, which supports satellite (space to earth) 5.441 and mobile communication 5.463 applications.

Keywords: Bow-tie shape, Glass epoxy, HFSS, Photolithography.

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Introduction

The advancement of remote frameworks and the speculation of their work lately we have utilized minimum number of antennas for better performance in the communication system field More data must be transferred and received, mainly in satellite and mobile communication, which increases the need of antennas in the systems. As a result, the optimum method for achieving a smaller system size is to use a multiband antenna. The printed antenna with different techniques results in multiband antenna such as slot loading, shorting pins, embedding defective ground structure, FSS and EBG structures, etc.[1-5] An E shaped patch antenna has proposed and simulated using HFSS software for mobile and satellite applications.[6] A multiband antenna is designed by C shaped slot loading on the radiating patch on the low permittivity substrate RT duroid, results in compact with three resonating band for the ISM band application.[7] Using partial ground method and I shaped radiating patch with slot are loaded. The antenna results in peak gain of 3dB and is resonating at three different frequencies which is suitable for C and X-band application.[8] Further, a microstrip antenna with Bowtie shape is designed for X band application and resonates at two different frequencies with gain of 9 dBi.[9] Using a finite integration technique printed antenna is suggested and simulated using CST microwave studio and analyzed for different substrate material and thickness. The antenna results in increase in bandwidth up to 50% showing application for ultra wide band.[10] A bowtie-structured antenna is suitable for radar communication which results in highest gain of 7 dB with the bandwidth of 65.[11,12] According to prior research, a bow tie-shaped antenna was constructed, however size reduction with enhancement in bandwidth was not obtained. Hence in this present work printed antenna is designed using Bow-Tie shaped slot on the conducting patch. The suggested structure shows good return loss with high gain of 6.85 dB and exhibit size reduction of 23% along with an overall impedance bandwidth of 30.33%.

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Antenna Design Equations

The basic conventional antenna for frequency *fr* = 6 GHz using FR4 substrate with a dielectric constant of er = 4.4. Using equations (1–7) dimensions of the rectangular patch is computed.

- Width of the radiating patch, the width is in cms.

$$W = \frac{c}{2fr} \times \sqrt{\frac{2}{\epsilon r+1}} \text{ -------1}$$

- Effective dielectric constant is given by,

$$\epsilon eff = \frac{\epsilon r+1}{2} + \frac{\epsilon r+1}{2\sqrt{1+12\frac{h}{w}}} \text{---------------}2$$

h = height of the patch
w = width of the patch.

- Length extension ΔL on each side is calculated by,

$$\Delta L = 0.41h \times \frac{(\epsilon eff+0.3)}{(\epsilon eff-0.258)} \times \frac{(\frac{w}{h}+0.264)}{(\frac{w}{h}+0.8)} \text{------------}3$$

Where ΔL is the patch length extension measured as millimeter,
h = height of the patch
w = width of the patch and
e_{eff} is the effective dielectric constant of the substrate and is dimensionless.

- Effective length of the patch is,

$$L_{eff} = \frac{c}{2fr\sqrt{\epsilon eff}} \text{-----------}4$$

- Actual length of the patch,

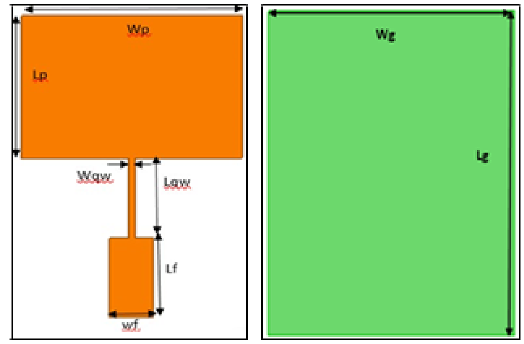
$$L = L_{eff} - 2\,\Delta L \text{ ------------ } 5$$

- Ground Plane Dimensions,

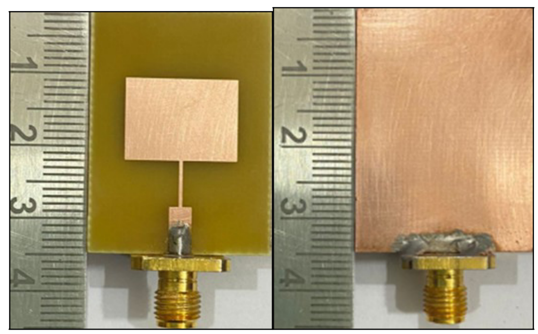
$$L_g = 6h + L \text{--------- } 6$$

$$W_g = 6h + w \text{ ---------}7$$

Using equation 1 to 7, the dimensions of basic antenna are calculated and shown in Table 1. Later, designed antenna is simulated with 3D electromagnetic simulator software. The simulated antenna is resonating at single frequency with a narrow bandwidth of Bw = (5.94–5.74)% = 3.28%. A simulated antenna and fabricated prototype of conventional antenna using FR4 substrate is shown in the Figure 1 (a and b) with top and bottom view. To overcome the narrow bandwidth and achieve multiple resonance frequency, the slot loading technique has been adapted.



(a)



(b)

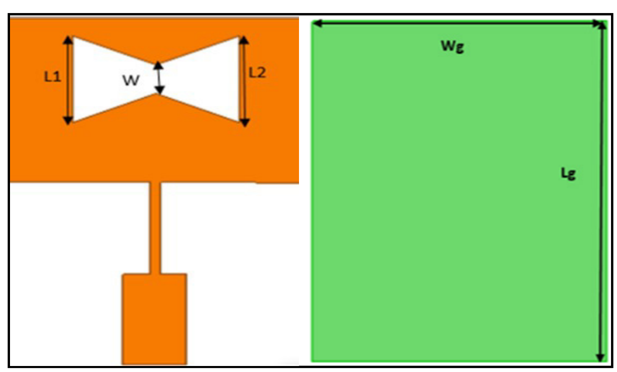
Figure 1: Conventional antenna Front and Rear view. (a) Simulated Antenna (b) Fabricated Prototype.

Table 1: Dimensions of the conventional antenna.

S. no	*Parameters*	*Values in cms*
1	Width of the patch	1.13
2	Length of the patch	1.51
3	Feed line width	0.45
4	Feed line length	0.63
5	Width of the quarter wave feed	0.30
6	Length of the quarter wave feed	0.63

Proposed Antenna Design

The designed printed antenna is embedded with Bow-tie shaped slot on the conducting patch. Slots has length $L_1 = L_2 = 0.6$ cm with width w = 0.2 cm to form the required slot. The proposed structure is simulated using HFSS software (high frequency structure simulator) on the conventional microstrip antenna to enhance the parameters using slot loading technique and the structure dimensions are evident in image 2 (a & b). The tested proposed antenna after fabricated is evident in figure 3(a & b).



(a) **(b)**

Figure 2: Geometry of the designed structure (a) Front view (b) Rear view.

Discussion and Results

A vector analyzer is used to measure the predicted antenna results. The measured values of the parameters of the designed antenna, such as return loss, VSWR, and radiation pattern, are compared to the simulated values.

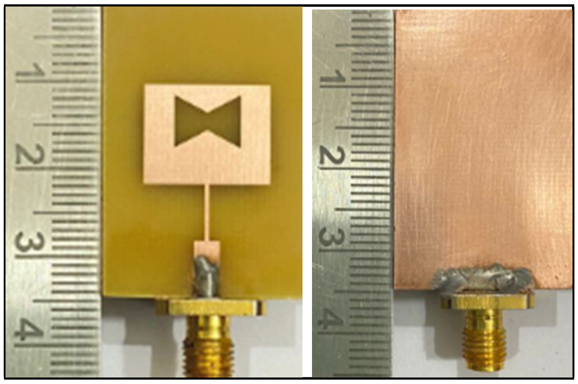


Figure 3: Fabricated designed structure (a) Front view (b) Bottom view.

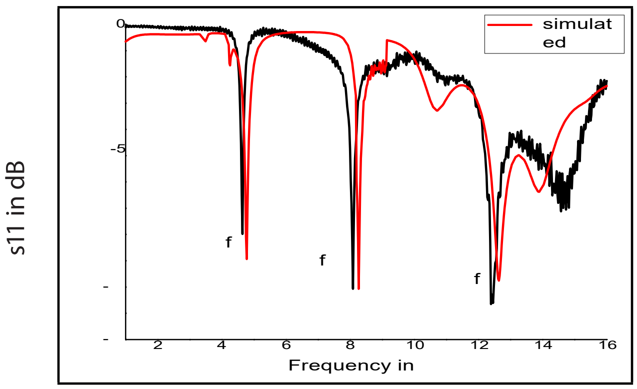


Figure 4: Return loss versus frequency plot.

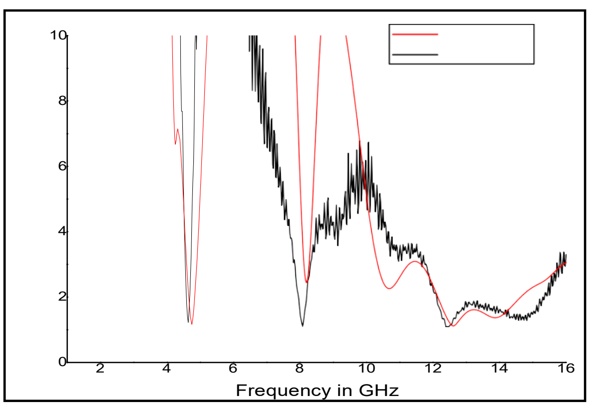


Figure 5: VSWR versus frequency plot.

Return Loss

Return loss provides the quantity of power lost to the load. Variation of return loss with respect to frequency plot as evident in the image 4. As evident on the plot, specified antenna is resonating at three different frequencies f_1= 4.75 GHz f_2 = 8.14 GHz and f_3 =12.41 GHz with return loss -20 dB, -25.09 dB and -26.45 dB, respectively, making them to suitable for satellite and radar application. The bandwidth is determined to be B_{w1} = (4.67- 4.57)% = 2.16%, B_{w2} = (8.21-7.97)% = 2.97% and B_{w3} = (15.22-12.09)% = 25.20%.

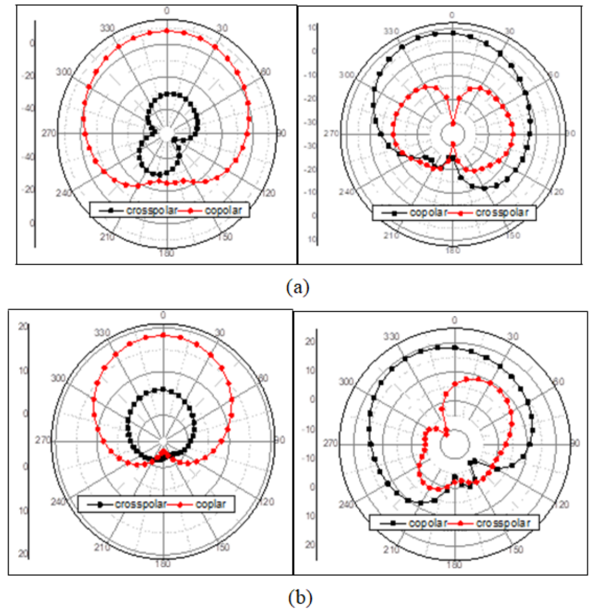
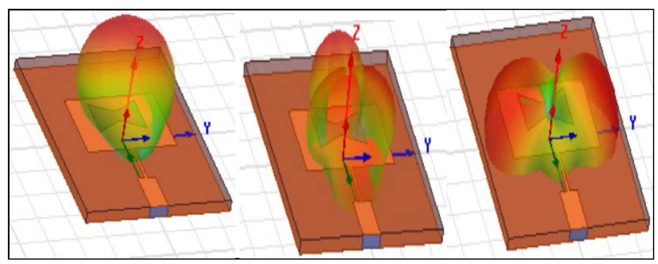


Figure 6: 2D Radiation Plot (a) 4.75 GHz (b) 8.14 GHz.



(a) **(b)** **(c)**

Figure 7: 3D Polar plot gain (a) 4.75 GHz (b) 8.14 GHz (c) 12.41 GHz.

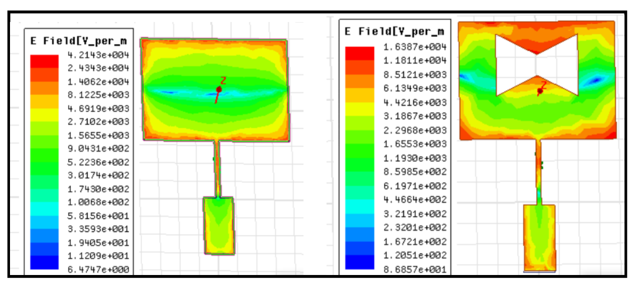


Figure 8: Current Distribution (a)Conventional Antenna (b) Proposed Antenna.

Using network analyzer fabricated antenna parameters are tabulated. Tested and simulated return loss plot in figure 4 shows acceptable values.

Voltage Standing Wave Ratio

The voltage standing wave ratio demonstrates how the feed line and antenna are matched. The antenna is constructed for 50-ohm impedance that matches for an antenna, and

Table 2: Summarizing previous work with present work.

Reference	*Frequency in GHz*	*No of Bands*	*Substrate*	*Gain in dB*
[12]	2.4 5	2	FR4	6.71
[13]	2.06 4.93 7.44	3	FR4	4.65
[14]	2.58	1	FR4	15dB
[Proposed work]	4.75 5.72 12.63	3	FR4	6.85

the VSWR values are measured and forecasted. The VSWR values must be always positive and should vary between 1 and 2 values. The suggested antenna for three working frequencies shows VSWR values less than 2. From the figure 5 it is evident that the V_{swr1} = 1.23, V_{swr2} = 1.12 and V_{swr3} = 1.15 are clearly less than 1.3.

Radiation Pattern

2D radiation pattern of the microstrip antenna for E plane and H plane are measured. Figure 6 (a) and (b) depicted the radiation patterns of E and H plane co-polar and cross-polar radiation for the two working frequencies f_1 = 4.75 GHz, f_2 = 8.14 GHz. It is evident from the 2D radiation pattern that antenna is showing Omni directional radiation pattern with lesser polarization level.

3D Polar plot Gain and Current Distribution.

The 3D radiation plots of the suggested prototype for different working frequencies are analyzed and compared. Figure 7(a), (b) and (c) shows the 3D gain plot for triple bands. The gain G_1 = 1.59 dB for first resonant frequency, G_2 = 5.72 dB for the second working frequency and G_3 = 6.85 dB for the third resonance respectively.

In Figure 8 (a) and (b), current distribution of the suggested antenna is compared with the conventional antenna. The current distribution in the conventional antenna shows near the radiating edges of the conducting patch. In case of the proposed antenna current gets more paths to radiate near the Bow-Tie shaped slots as compared with the basic antenna. Hence its gives rise to new resonance resulting in multiple bands. Table 2 summarizes the comparison of the current and past work.. The antenna with the bowtie shape in the present study evident adequate gain with a virtual size reduction of 23%, which is not accomplished in earlier research.

Conclusion

A compact printed antenna with Bow-Ties shaped slot is embedded for multiband application with dimensions 3.34 x 2.47 x 0.16 cm. A parametric study of proposed antenna is carried out and it shows triple band in nature with considerable return loss. The antenna is also evident for highest gain of 6.85 dB with increase in overall bandwidth up to 30.33% as well as virtual size reduction of 23% as compared to the conventional antenna. Since the antenna is resonating at 4.62 GHZ to 12.41, it is suitable for fixed satellite (space to earth) and Mobile (5.463) communication application.

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