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Bandwidth Enhancement of Corporate Fed Bowtie Antenna Array operating in L Band by Changing the Substrate Material and Ground Plane Length

Tapan Nahar
Research Scholar
Department of ECE
Poornima College of Engineering, Jaipur

O. P. Sharma
Professor
Department of ECE
Poornima College of Engineering, Jaipur

ABSTRACT
This paper presents analysis of Multiband Corporate fed Bowtie Antenna Array having tuned in L Band. Bandwidth performance is analyzed for different substrate materials and effect of ground plane is presented. Simulation result shows that proposed antenna using Roggers RT/Duroid matarial is tuned at frequencies 1.05 GHz, 1.63GHz, 2.25GHz and 2.92GHz and provides 40.95%, 18.40%, 14.66% and 17.97% bandwidth respectively. Proposed antenna can be used for applications such as WCDMA, Mobile Satellite services, point to point, TV pickup and subscriber radio system (SRS). The antenna is simulated on HFSS virtual tool.

General Terms
Antenna design & analysis, RF design, Wireless communication, Microstrip antennas.

Keywords
Microstrip patch antenna, substrate material, Impedance Bandwidth, HFSS bowtie antenna, corporate feed Network.

1. INTRODUCTION
The Microstrip antennas are best suited where size, weight, cost, and ease of installation demand a low profile antenna [1]. It is widely used in high performance space crafts, aircrafts, satellite applications, wireless communication, radar and mobile communications. It is suitable for planner as well as non planer surfaces. It can be fabricated using printed circuit technology so it is simple and inexpensive. But there are several operational disadvantages of this antenna the bandwidth, efficiency, gain and power handling capacity of microstrip antenna is very low. Many scientists have done the research for increasing the bandwidth and gain. The gain of antenna can be increased by using the array configuration [2]. Microstrip patch antenna is made of metal patches placed on dielectric substrate and fed by microstrip or coplanar transmission line. The resonating frequency, radiation pattern, antenna impedance and polarization can be controlled by properly selecting the shape and dimension of patch [3]. Bandwidth of microstrip patch antenna can be increased by increasing the width and height of patch and decreasing the dielectric constant of substrate [4]. Losses are increased and efficiency is decreased because of increment in the volume [5]. Bandwidth is also dependent on impedance matching. There are several impedance matching techniques like quarter wave line [4-6], aperture coupled feeding technique [7] and slotted patches. Different shapes of slots like H shape [4], U shape [7], annular ring shape [8], L shape [9] and inverted F shape [10] are popular. Bandwidth can also be increased by stacking of patches [11].

In this paper, two triangular slots are cut in the rectangular shaped patch to make a bowtie shaped structure [12]. Array of four patches are fed by corporate fed network. The proposed antenna is simulated on HFSS virtual tool. The corporate fed networks and triangular slots are used for increasing the bandwidth and array is used for increasing the gain.

This Paper is divided into five sections. Section I describes the introduction. Antenna geometry is presented in section II. Section III consist the simulation results of bow tie shaped antenna array. Performance analysis of proposed antenna by changing the ground plane length and substrate material is discussed in Section IV. Paper is concluded in section V.

2. ANTENNA GEOMETRY
Proposed antenna is designed on the FR4 substrate of 400*200*1.6 cube mm having relative permittivity 4.4. Each triangular shaped patches are separated by distance of 62.5 mm far apart from each other and fed by Corporate type feed network (symmetrical fed network) as shown in Fig 1. Triangular patch having 62.5 mm base and 27.9 mm height. Two triangles are arranged in bow-tie shaped as shown in figure 1.

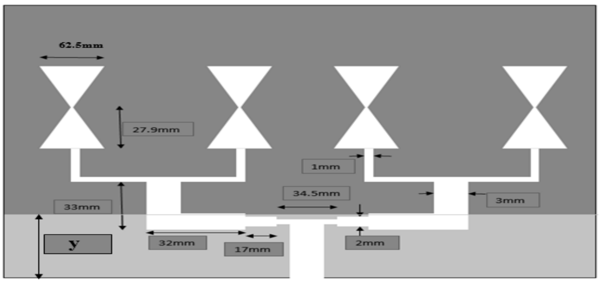

Fig 1: Geometry of Bowtie Shaped Antenna Array

All elements are connected to central feed port via equal length to provide uniform phase distribution. Due to symmetrical properties of network, each individual element is separated by distance of λ/2 from each other in linear way along y-axis. Spacing of λ/2 is chosen to reduce combat fading. Due to this spacing, the signals received from different antenna elements are independent in uniform scattering environment. It should be less or equal to λ/2 (the nyquist rate) to avoid aliasing [13-14]. The partial ground plane of length y is used.

3. SIMULATION RESULTS
Proposed antenna is simulated on HFSS virtual tool. The simulated return loss versus frequency plot is shown in Fig 2. It presents the reflections of antenna towards source due to mismatching of impedances with respect to frequency. It is observed that antenna resonates at 1.17GHz, 1.65GHz, 2.12 GHz and 2.5 GHz frequencies and providing bandwidth 16.23%, 12.9%, 8.47% and 7.2% respectively.

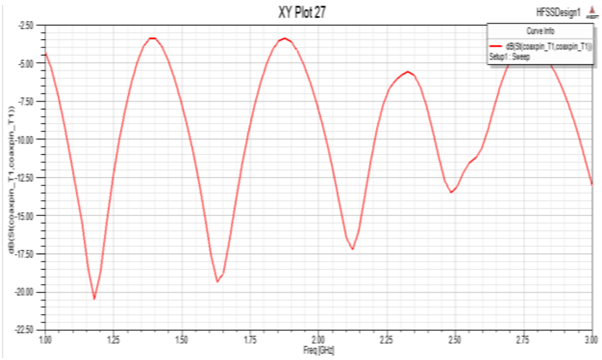

Fig 2: Return loss versus frequency plot.

The radiation pattern in 2D is shown in Fig 3. The radiation is obtained between -90 degree to +90 degree which represents that it is above the ground plane.

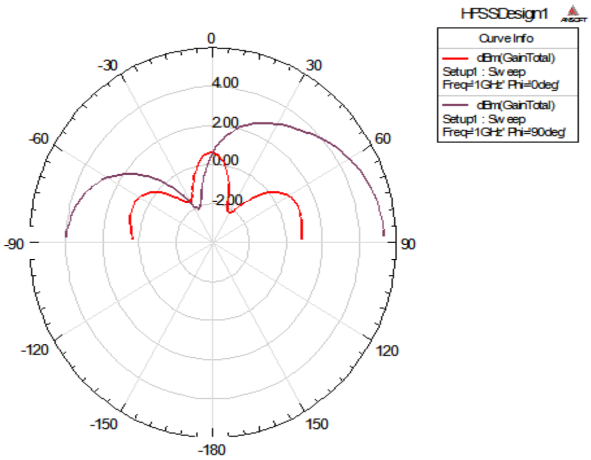

Fig 3: Radiation pattern in 2D.

The radiation pattern in 3D is presented in Fig 4.

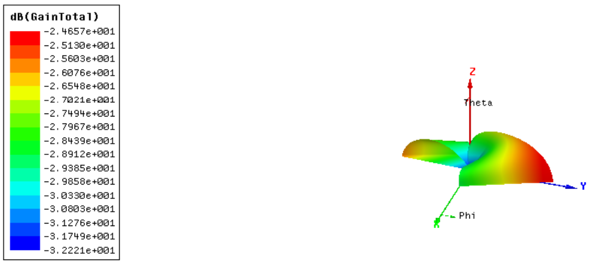

Fig 4: Radiation pattern in 3D.

Simulated VSWR of proposed antenna v/s frequency plot is presented in Fig 5.

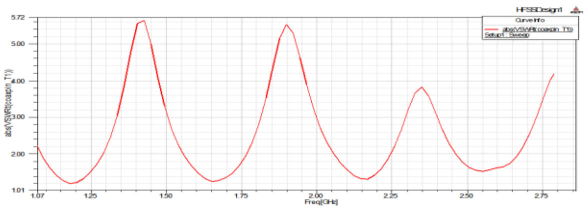

Fig 5: VSWR v/s frequency plot.

It may be observed that VSWR of proposed antenna is minimum at four frequencies 1.17GHz, 1.65 GHz, 2.12 GHz and 2.50 GHz.

The axial ratio variation with frequency of simulated proposed antenna is shown in Fig 6.

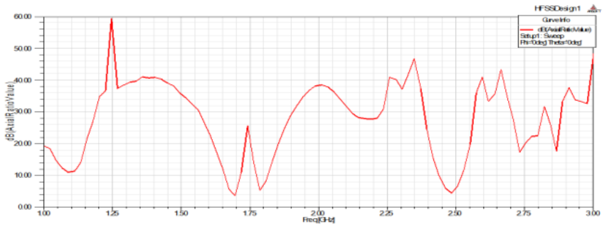

Fig 6: axial ratio v/s frequency plot.

From the axial ratio v/s frequency plot, it may be observed that value of axial ratio for proposed arrangement is greater than desired 3dB value means it is linearly polarized.

Smith chart represents the variation of simulated input impedance of proposed arrangement as a function of frequency which is shown in Fig 7.

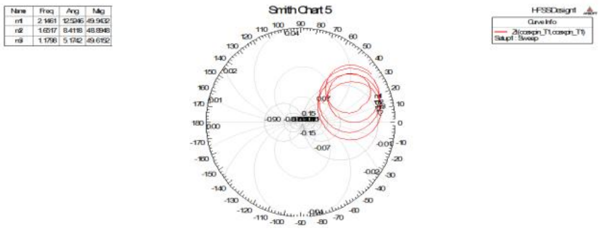

Fig 7: Smith Chart of proposed antenna

The input impedance of this proposed arrangement at resonance frequency 1.1798 GHz 1.65 GHz and 2.14 GHz is 49.6152[5.1742, 48.8948[8.4118 and 49.9432[12.5246 which again suggests excellent matching between feed arrangement and antenna at resonant frequency.

Gain of proposed antenna using HFSS is presented in Fig 8. Gain value at resonant frequency 2.12 GHz is 18dBm.

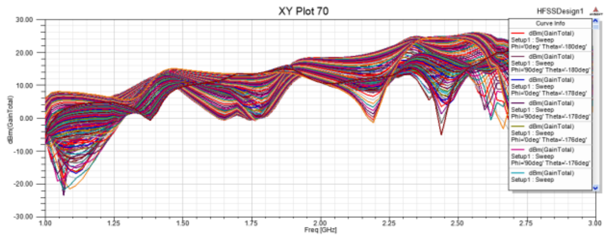

Fig 8: Gain v/s frequency plot

4. PERFORMANCE ANALYSIS OF BOWTIE ANTENNA ARRAY

It is observed from the simulation results that antenna has small bandwidth of 16.23% at 1.17GHz frequency. For further enhancement of bandwidth, two strategies are adopted.

4.1 Variation in Ground Plane Length

It is observed that bandwidth of antenna is improved by changing the length of ground plane and there is very less variation in bandwidth when the width of ground plane is varied represented in Fig 9 and Table 1.

Table 1. Effect of ground plane length

S. No.	Ground plane length(y) in mm	% Bandwidth		
		Fr=1.17 GHz	Fr=1.65 GHz	Fr=2.12 GHz
1	20	16.23	12.72	8.37
2	50	17.09	12.12	8.83
3	100	15.38	12.05	8.37
4	150	16.23	12.12	8.37

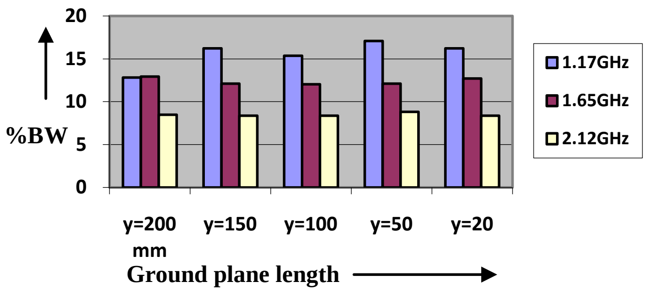

Fig 9: Bandwidth versus ground plane length plot.

As the length y of ground plane is decreased the bandwidth is increased. Optimum ground plane length is 50 mm where bandwidth is 17.09% at 1.17GHz and 8.83% at 2.12GHz frequency.

4.2 Variation in Substrate Materials

As refractive index of substrate material is decreased, the bandwidth of antenna is increased but losses are also increased. Three materials are used: FR4 (εr=4.4), Epoxy Kevlar (εr=3.6) and Roggers RT/Duroid (εr=2.2). Comparative analysis of bandwidth is represented in Fig 10 and Table 2.

Table 2. Effect of substrate material on bandwidth

S. No.	Substrate Material	% Bandwidth			
		First resonant frequency	Second resonant frequency	Third resonant frequency	Forth resonant frequency
1	FR4	17.09	12.12	8.83	--
2	Epoxy Kevlar	17.82	12.707	12.765	8.77
3	Roggers RT/Duroid	40.95	18.4	14.66	17.97

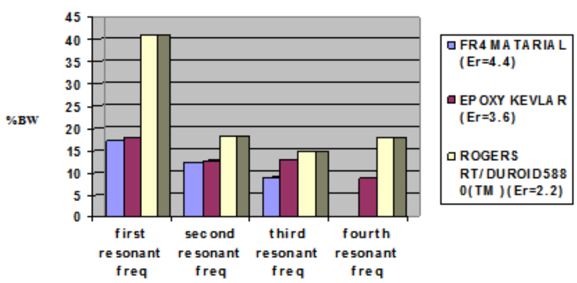

Fig 10: Bandwidth plot for different substrate material

It may be observed from Fig 10 that there is significant enhancement in bandwidth for substrate of low dielectric constant. Maximum bandwidth is achieved by using RT/Duroid substrate but losses are also increased but if these losses are under permissible limit for some applications than it is good option.

The effect of refractive index on return loss is represented in Fig 11 and Table 3.

Table 3. Effect of substrate material on return loss

S. No	Substrate Material	Return loss in dB			
		First resonant freq.	Second resonant freq.	Third resonant freq.	Forth resonant freq.
1	FR4	-21	-19	-17	-13.5
2	Epoxy Kevlar	-40	-30	-24.5	-15.5
3	Roggers RT/Duroid	-25	-24	-41	-29

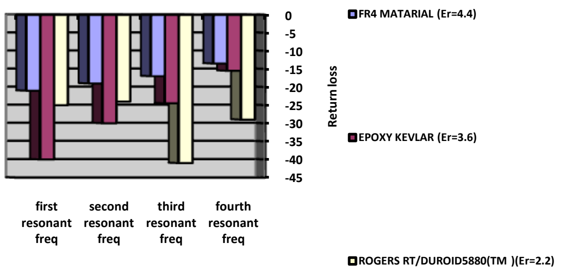

Fig 11: Return loss for different materials

It may be observed from the Fig 11 and Table 3 that return loss is increased at first and second resonant frequencies for Roggers RT/Duroid substrate which has lowest dielectric constant in above mentioned geometries. The wide bandwidth factor can be utilized if losses are accepetable for any specific application.

5. CONCLUSION

In this paper, the performance of Bow tie antenna array is analyzed. Bandwidth is increased due to decreasing the ground plane length and almost constant due to changing the ground plane width. As the refractive index is decreased the bandwidth of proposed antenna is increased. For Rogers RT/Duroid material , the same geometry provides 40.95%, 18.40%, 14.66%, 17.97% and 8.85% at 1.05GHz, 1.63GHz, 2.25GHz, 2.92GHz and 3.5GHz respectively which can be used for WCDMA, Mobile Satellite services, point to point, TV pickup and subscriber radio system (SRS). Stacked arrangement of patches and modified ground plane structure can be used for achieving more enhancements in bandwidth. Gain can be further enhanced by increasing the no. of elements in array configuration.

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