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A Modified Multiband Bow Tie Antenna Array used for L band Applications

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***Abstract*— This paper presents design of multiband Bow Tie Antenna array having tuned at 1.10GHz,1.74GHz,2.16GHz and 2.58GHz frequencies which can be used for Mobile Satellite services, point to point, TV pickup and subscriber radio system (SRS). Proposed antenna is simulated on HFSS virtual tool. Antenna array provides gain of -11.49 dB and directivity of -10dB. The performance of Array is also compared with Single bow tie antenna.**

***Keywords*—Microstrp patch antenna; Impedance Bandwidth; HFSS; bowtie antenna; corporate feed network.**

I. INTRODUCTION

In today's wireless communications, microstrip antenna is very popular for UHF applications due to its low profile, light weight, ease of fabrication and compatibility with printed circuits [1]. Narrow bandwidth and low gain are some major limitations of patch antenna. Several efforts made for increasing bandwidth from 1953 by G.A. Deschamps [2] to present by many researchers. Micro strip patch antenna consists of metallic patch over grounded dielectric substrate. The resonant frequency of patch depending on width of patch, dielectric constant and height of substrate [3]. Bandwidth can be improved by increasing width of patch, decreasing the dielectric constant of substrate and increasing the height of substrate [4]. But due to this, total volume of patch antenna increases so losses increase simultaneously and efficiency decreases [5]. The Aperture coupled antenna provides simple structure, small conductor loss, wider bandwidth and good isolation between the feed network and radiating element [7]. Another technique to enhance bandwidth is cutting slots of different shapes like H shape [6], U shape [7], Annular Ring shape [8] ,L shape [9] ,Inverted F Shape [10] etc, in the patch which decreases the capacitance and Quality factor. Stacked arrangement of patches is also a popular technique for the enhancement of bandwidth [11].

In our previous paper [12], for bandwidth enhancement, two triangular slots are cut in the rectangular patch that triangular slotted rectangular patch or Bow-Tie shaped patch antenna having wider bandwidth than H Shape. When bandwidth of single bow tie antenna is increased beyond a specific limit then gain and directivity are effected [13]. For increasing the directivity and gain, in this paper the array of bow tie antenna is used. In this paper, four element multiband bow tie antenna array using corporate feed network is simulated using HFSS and analysis is carried out in comparison to single bow tie antenna.

This Paper is divided into seven sections. Section I describes the introduction. Analysis methods and design equations of microstrip antenna are presented in section II. Section III consists of introduction of array and different feed techniques used for microstrip antenna array. Proposed antenna geometry and simulation results are discussed in section IV and V respectively. Section VI describes the comparison of bow tie antenna and antenna array. Paper is concluded in section VII.

II. ANALYSIS METHOD FOR MICROSTRIP ANTENNA

There are several types of analysis model available for microstrip patch antenna transmission line model [14], cavity model [15], and full wave model (which include primary integral equations/moment method) [16] in which transmission line model is simplest and having good physical insight.

In transmission line model, the microstrip antenna is represented by two slots which has width W, height h and separated by a transmission line of length L. The microstrip line is essentially a nonhomogeneous line of two dielectrics, the substrate and air.

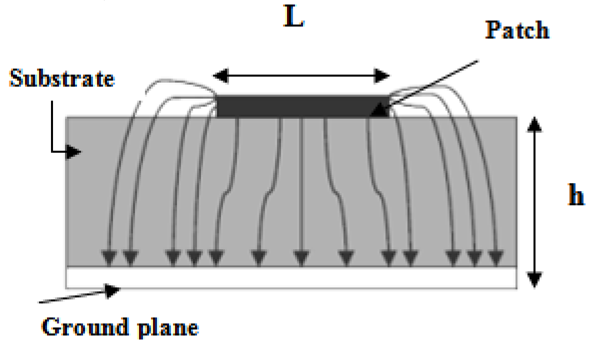

Fig.1. Electric field lines between patch and ground plane.

Most of the electric field lines reside in the substrate and parts of some lines in air, as shown in figure 1. Pure transverse electric magnetic (TEM) mode of transmission cannot be supported by this transmission line because the phase velocities would be different in the air and the substrate. So, the dominant mode of propagation would be the quasi-TEM mode and an effective dielectric constant (ε_{re}) obtained in order to account for the fringing and the wave propagation in the line.

The dielectric constant ε_{re} is kept slightly less then ε_r because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air as shown in Figure 1.

The expression for effective refrective index ε_{re} is represented by equation (1)

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-0.5} \qquad (1)$$

Where ε_{re} = Effective dielectric constant, ε_r = Dielectric constant of substrate, h = Height of dielectric substrate, W = Width of the patch

The length of the patch must be slightly less than λ/2 for operating in the fundamental TM_{10} mode (λ is the wavelength in the dielectric medium and is equal to $\lambda o/\sqrt{\varepsilon_{reff}}$ where λ_o is the free space wavelength) [17]. The field varies λ/2 cycle along the length and no variation along the width of the patch in the TM_{10} mode. Two slots are separated by a transmission line of length L and open circuited at both the ends which represents the equivalent circuit of microstrip antenna as shown in fig 2. The voltage is maximum along the width and current is minimum due to the open ends. There are normal and tangential components with respect to the ground plane of the fields at the edges.

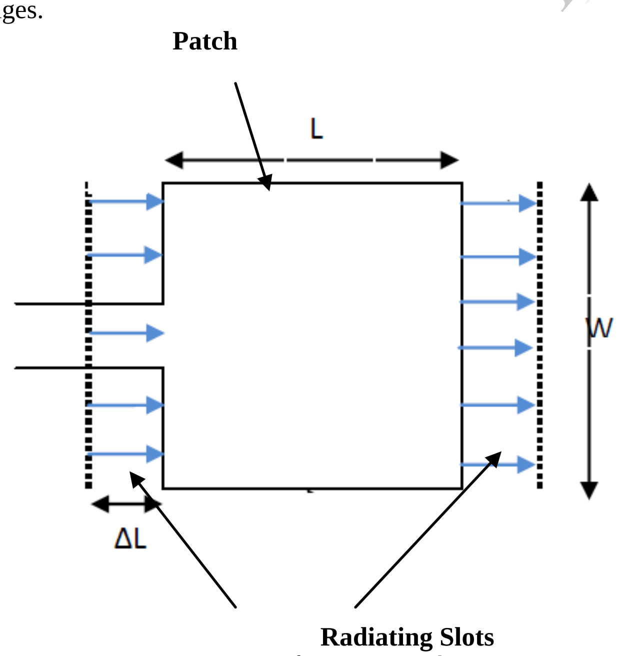

Fig.2. Top View of Microstrip Patch antenna

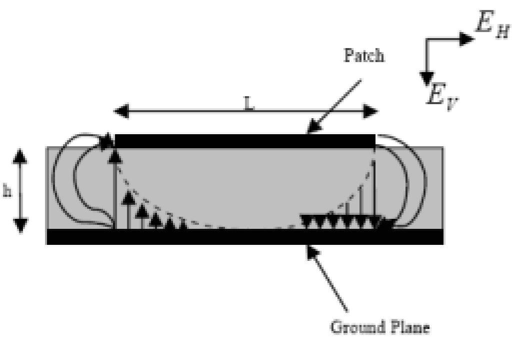

Fig.3. Side View of Microstrip Patch antenna

Length of the patch L is now been extended on each end by a distance ΔL.

$$\Delta L = 0.412h + \frac{\varepsilon_{re} + .30}{\varepsilon_{re} - .258}\left(\frac{W/h + .264}{W/h - .813}\right) \qquad (2)$$

The effective length of the patch L_{eff} now becomes

$$L_{eff} = L + 2\Delta L \qquad (3)$$

For a given resonance frequency f_0, the effective width W *is*

$$W = \frac{c}{2fr}\left(\frac{\varepsilon_r + 1}{2}\right)^{-.5} \qquad (4)$$

III. ARRAY FUNDAMENTALS

A. Array theory

To increase the gain and directivity of single element antenna, number of antennas are placed with equal inter-element spacing λ/2, is called as antenna array. As the no. of antenna elements are increased, the narrower beam width and high directivity can be achieved [15]. For a linear array of N even identical elements with uniform spacing positioned symmetrically along the y axis, Array factor (A_{factor})can be written as equation (5)

$$A_{factor} = W_1 e^{j\psi_1/2} + W_2 e^{j3\psi_2/2} + \ldots + W_{N/2} e^{j(\frac{N-1}{2})\psi_{N/2}} + W_1 e^{-j\psi_1/2} + W_2 e^{-j3\psi_2/2} + \ldots + W_{N/2} e^{-j(\frac{N-1}{2})\psi_{N/2}} \qquad (5)$$

After simplification, this equation can be written as

$$A_{factor} = \sum_{M=1}^{N/2} \cos((2n-1))\psi_N W_M$$

Where $\psi_N = \frac{\pi d}{\lambda} sin\theta sin\phi + \beta_N$, W_N is amplitude and β_N is phase excitation of individual elements.

B. Array feed networks

Basically there are two types of feed networks: Series feed network and corporate feed network.

In series feed network, the elements can be fed by a single feed line. In this technique, any changes in one of the elements affects the performance of others so the technique is limited to arrays with fixed beam or those which are scanned by varying the frequency but it is used in linear or planner array [16,17,18].

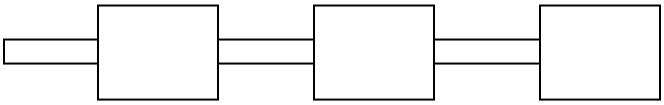

Fig.4. Series Feed network

In corporate feed network, there are multiple feed lines. It is used to provide power splits of 2^n (i.e. n=2, 4…etc). This can be achieved by quarter wavelength transformers. With this method feed of each element can be controlled and it is ideal for scanning shaped beam array or multiple beam array and phased arrays. The phase of each element can be controlled using phase shifters [18].

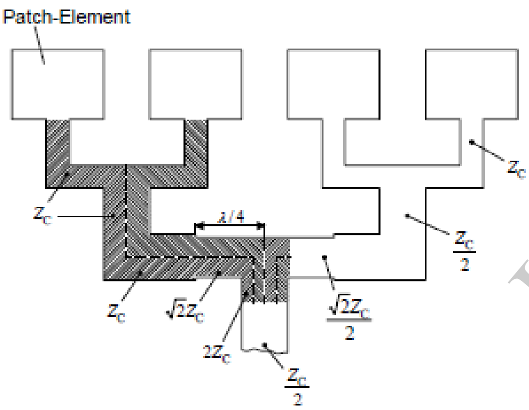

Fig.5. Corporate Feed network

As shown in figure, 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 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 [18-19].

IV. PROPOSED ANTENNA GEOMETRY

Proposed antenna is designed on the FR4 substrate of 400*200*1.6 cube mm having relative permittivity 4.4. Each elements of bowtie shaped patches are separated by distance of 62.5 mm apart from each other and fed by Corporate type feed network (symmetrical fed network) as shown in figure 6.

Bow tie patch is created by cutting two optimized triangular slots in rectangular patch of 36.25*27.9 square mm.

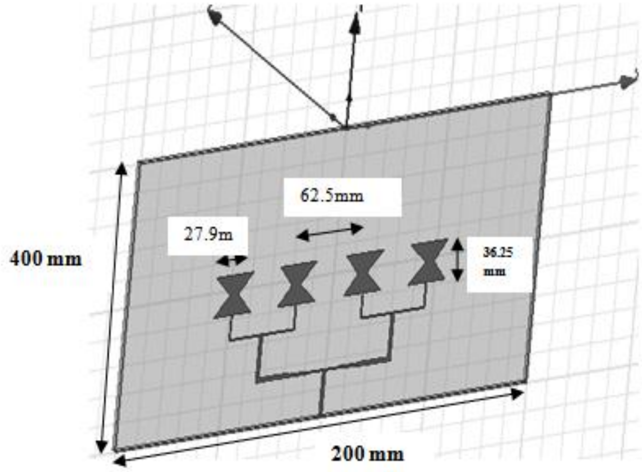

Fig.6. Geometry of Proposed Antenna Array

V. SIMULATED RESULTS

The simulated return loss versus frequency plot is shown in figure 7. It is observed that antenna is tuned in four bands at resonant frequency 1.10GHz, 1.74GHz, 2.16GHz and 2.58GHz.

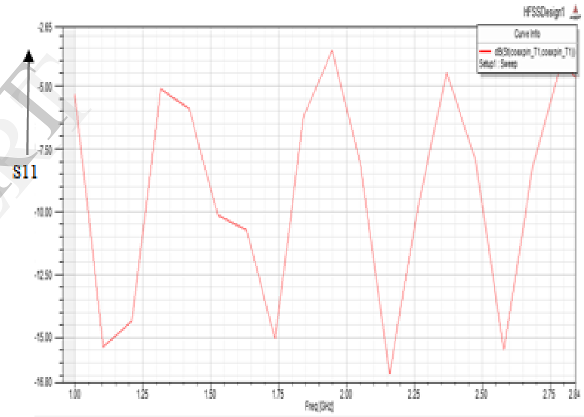

Fig.7. Return loss versus frequency plot.

The radiation pattern in 3D is shown in figure 8. The radiation is obtained above the ground plane.

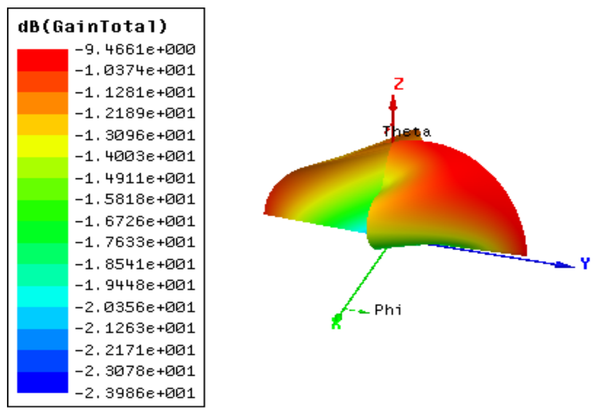

Fig.8. Radiation pattern in 3D.

The gain versus angle plot is shown in figure 9.

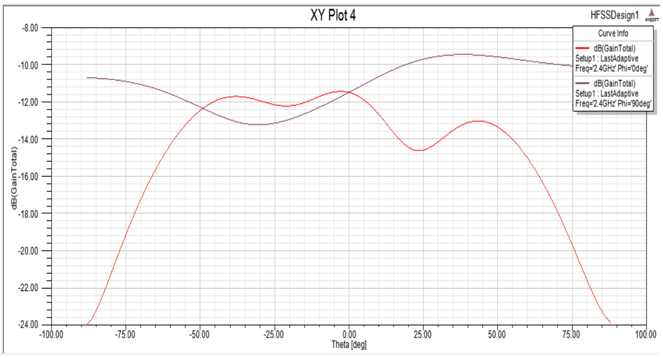

Fig.9. Gain versus angle plot

VI. COMPARATIVE ANALYSIS

The single bow tie antenna which is made by cutting two optimized triangular slots on rectangular patch of 36.25*27.9 square mm. FR4 substrate is used having 400*200*1.6 cube mm dimension and relative permittivity 4.4. It is observed that Single Bow tie antenna is resonant from 2.47 GHz to 2.63GHz at center frequency 2.56GHz. It provide -36.75dB gain and -36.675 dB directivity at $\phi=0$ and 6.25% bandwidth.

for increasing the gain Bow tie Antenna array is used which is tuned in four multiband and provide -11.49 dB gain and -10dB directivity which is greater than single bow tie antenna. 19.09% bandwidth at 1.10GHz, 15.5% Bandwidth at 1.74GHz, 8.56% Bandwidth at 2.16GHz and 6.20% Bandwidth at 2.58GHz respectively are obtained for array arrangement. Gain and directivity comparison is shown in figure 10 and Bandwidth Comparison is shown in figure 11.

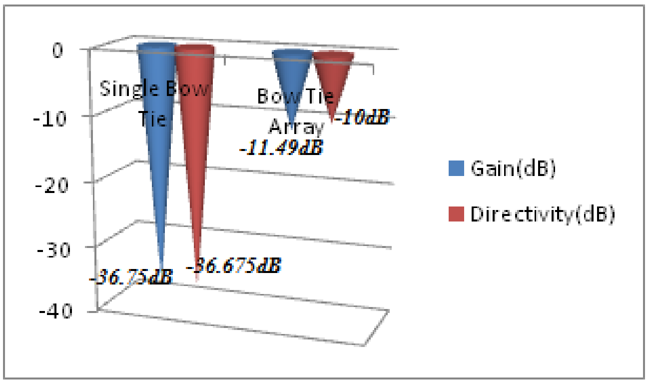

Fig.10. Gain and directivity comparison chart

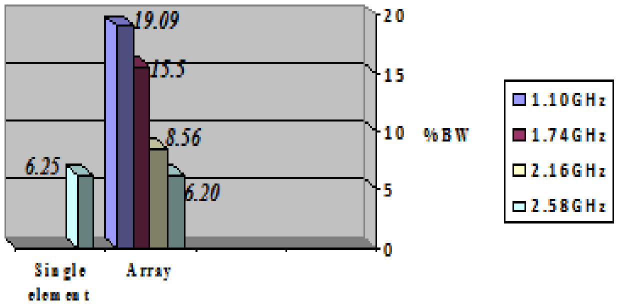

Fig.11. Bandwidth comparison chart

VII. CONCLUSION

Proposed antenna array of bow tie patches provide significant enhancement in gain and bandwidth in L Band and can be used for large number of applications like Mobile Satellite services, point to point, TV pickup and subscriber radio system (SRS).

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