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Design and Analysis of an Arrow Shaped Two-Element Patch Antenna Array with Defected Ground Structure for Sub-6 GHz UWB Applications

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Abstract- An arrow shaped two-element patch antenna array for sub-6 GHz UWB applications by using the FR-4 (Flame Retardant), which is a glass-reinforced epoxy laminated substrate material. The two-element antenna array is designed with the planar ground. The designed antenna is an arrow shape, compact and planar for sub-6 GHz UWB applications. The size of the antenna is 44×48 mm (width and length), which shows the bandwidth of 2.86 GHz from 2.81 to 5.79 GHz with a return loss of -30 dB and the input impedance of the antenna array is 50 Ω. For the simulation work HFSS version15 software is used, HFSS software is a planar 3D electromagnetic simulator and all the simulated results are shown by the graph.

Keywords* — *Microstrip patch antenna, Array, Return loss, Radiation Pattern.

I. INTRODUCTION

Microstrip patch antenna has many advantages like light-weight, small size, low fabrication price, planar configuration and low profile [1]. The characteristics of a microstrip antenna make it attractive these days. In spite of these challenges, the microstrip patch antenna suffers from several drawbacks including low efficiency, high Q, limited power handling capabilities, very narrow bandwidth and spurious feed radiation. Several ways may be used to enhance the effectiveness of the antenna. The bandwidth can be raised by increasing the substrate thickness or minimizing the dielectric constant. The dielectric constant border is commonly in ($2<\varepsilon r \leq 12$) [2]-[3].

Antenna arrays are employed to produce greater gain. The greater the number of antenna elements, the greater the gain of the antenna array. Because of their electrical scale, antenna arrays are more difficult to simulate than single element antennas. In the last seven years, there has been a significant growth in the use of ultra-wideband technology in wireless communication systems. Because UWB technology has excellent potential in the advancement of utilization in wireless communication systems, the Federal Communication Commission (FCC) of the United States has authorised the unlicensed use of the ultra wideband (3.1-10.6 GHz) frequency band for the handheld wireless communication from February 2002 [4].

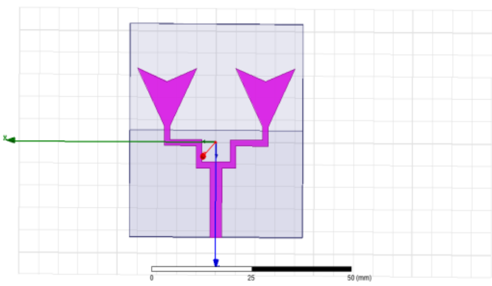
Impedance matching will be critical in improving antenna performance, particularly in terms of bandwidth. Selecting an appropriate impedance matching network while the connecting array arrangement is critical for an effective radiation mechanism. The nature of the fundamental narrow bandwidth on typical microstrip patch antennas is recognised due to fluctuations. Except for the solely feed circularly polarised components, the resonant behaviour of the input impedance affects the bandwidth restriction and is not caused by changes in the radiation pattern or gain [5]-[6].

II. ANTENNA DESIGN

A. Configuration

In the procedure of designing antenna, we used the double layer substrate material dimension is 44 mm × 48 mm (width × Length) for two-element antenna array. Dielectric thickness is 1.6 mm and dielectric constant is 4.4 for FR-4 and dielectric loss tangent is 0.025. The frequency of the antenna array is between 2.82-5.79 GHz.

Fig. 1 shows the geometry of the two-element antenna array. Fig. 1 (a) & (b) shows the top view & bottom view of two element antenna array.



(a)

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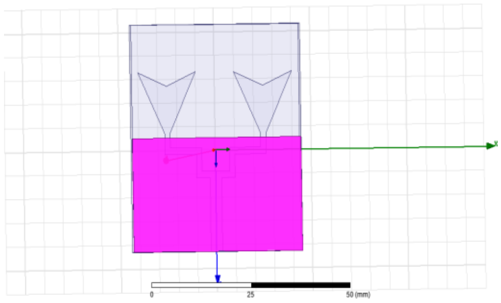

(b)

Figure 1: Geometry of the Two Element Antenna Array

(a) Top view of Two Element Antenna Array &

(b) Bottom view of Two Element Antenna Array

TABLE 1 PARAMETER VALUE OF TWO ELEMENT ANTENNA ARRAY

Substrate	FR-4
Centre Frequency	2.82-5.79 GHz
Height of Substrate	1.6 mm
Loss Tangent (tan**δ**)	0.025
Dielectric constant (ε_r)	4.4
Copper Thickness	0.4 mm
Width of the antenna (W)	44 mm
Length of the antenna (L)	48 mm

B. Equations for Antenna Designing

The practical dimensions are calculated of two-element patch antenna array are calculated by using the following sets of formulas [2]:

Width:

$$W=\frac{c}{2fr\sqrt{\frac{\varepsilon r+1}{2}}} \quad (1)$$

Where c= velocity of light in free space,

$\mathcal{E}r$ = dielectric constant,

fr = resonant frequency,

W= patch of non-resonant width [7, 8].

Length:

$$L = L_{eff} - 2\Delta L \quad (2)$$

Patch Length Extension:

$$\Delta L = 0.412h\frac{(\varepsilon reff+0.3)(\frac{w}{h}+0.264)}{(\varepsilon reff+0.258)(\frac{w}{h}+0.8)} \quad (3)$$

Effective Length:

$$L_{eff} = \frac{c}{2fr\sqrt{\varepsilon reff}} \quad (4)$$

Effective Dielectric Constant:

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r+1}{2}\left[1+12\frac{h}{w}\right]^{-\frac{1}{2}} \quad (5)$$

In the above equations, h is the height and w is the width.

III. RESULTS AND DISCUSSION

The designed antenna is to be used for the sub-6 GHz applications specifically for the wireless local area network (WLAN). The dielectric material used is FR-4 which has a dielectric constant 4.4. The thickness of the dielectric material is selected for the better efficiency, better radiation and return loss. The proposed antenna array is simulated by using HFSS version 15 software. The important parameter is return loss which is helpful to calculate the bandwidth of the antenna structure is its S_{11} parameter in decibel verses frequency. The return loss of the proposed antenna array is shown in Fig. 2, which has the lower cut off frequency is 2.18 and the higher cut off frequency is 5.67 GHz with a return loss of -30 dB and the input impedance is 50 Ω.

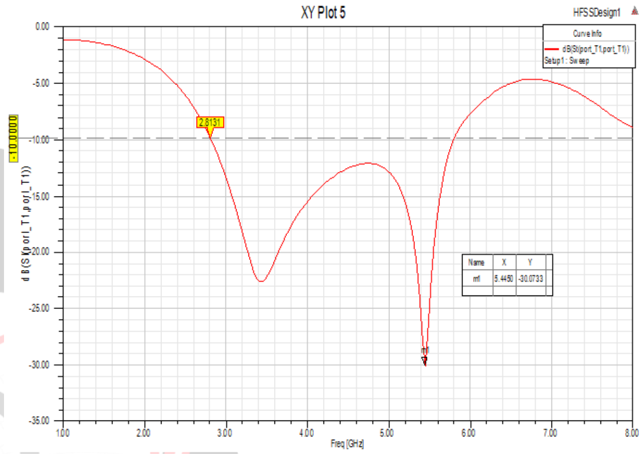

Figure 2: Simulated S11 of Two Element Antenna Array

The voltage standing wave ratio (VSWR) is an assessment of how well radio-frequency radiation is delivered from a source of power to a destination via a transmission line. Figure 3 illustrates the VSWR resulting pattern of the antenna array.

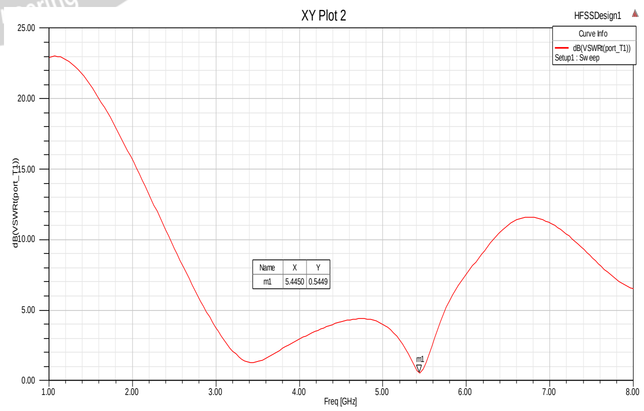

Figure 3: Frequency Vs Curve of Two Element Antenna Array.

The simulated current distribution of resonant frequency from 2.18 GHz - 5.67 GHz in the antenna array is shown in Fig.4. The top & bottom view of current density

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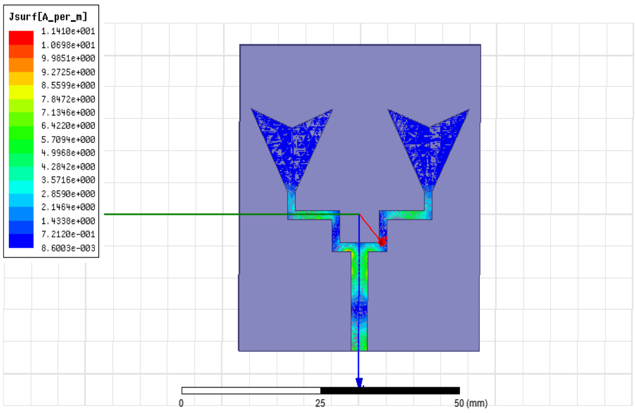
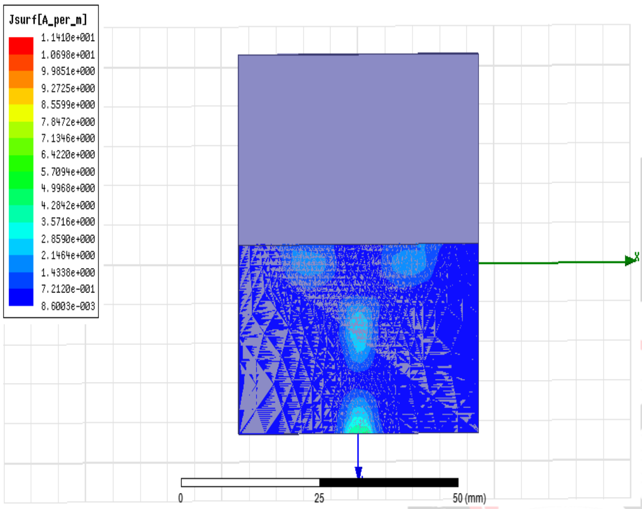
distribution is shown in the Fig. 4 (a) & 4 (b) which is showing that how the antenna pursuing a beam.



(a)



(b)

Figure 4: Current distribution of Two-Element Antenna Array (a) Front view (b) Back view.

From the obtained result the resonating frequency. Fig. 5 illustrated the far field radiation patterns, which shows the gain at the overall resonated frequency band. Fig. 6 shows the simulated 3D polar plots of the antenna array.

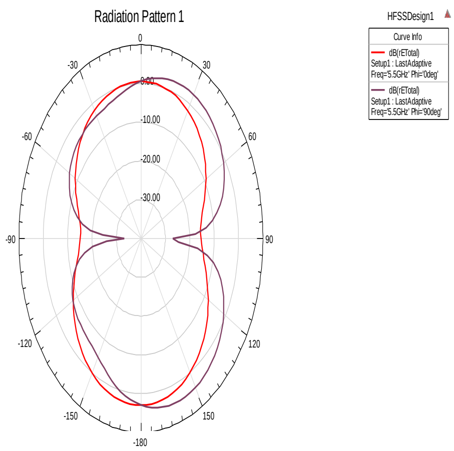


Figure 5: Radiation pattern of Two-Element Antenna Array

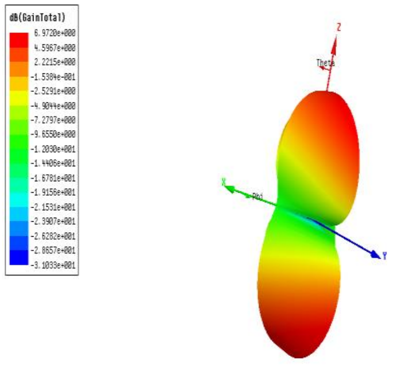


Figure 6: 3D Polar Plot of Two-Element Antenna Array

TABLE 2 RESULTS OF TWO-ELEMENT ANTENNA ARRAY

Parameters	Antenna array
Resonance Frequency	2.18 - 5.79 GHz
S11	-30.14 dB
Gain	3.592 dB

IV. CONCLUSION

The proposed antenna array performance was improved in terms of thickness of the feed line and thickness of the substrate material. We used the DGS background at the bottom of the antenna array. The gain and directivity can be varied using the parametric analysis. The proposed antenna array can be satisfying all the array standards of the microstrip patch antenna. A proposed two element microstrip patch antenna array resonated from 2.18 GHz-5.79 GHz frequency band with 50 ohms input impedance which covers the sub-6 GHz spectrum. So we can clearly say that the antenna array is applicable to the UWB applications.

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