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2×2 Antenna Array for Radiolocation Applications

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Abstract- A four element 2×2 antenna array has been designed and investigated for the radiolocation applications at the X-band frequency of 10GHz. Two different antenna array are been designed with two different radiating element shapes. One antenna array is having rectangular radiating element and the other antenna array is having circular radiating element. Performance comparison has been performed between the two antenna arrays in terms of various antenna parameters like return loss, VSWR, gain, radiation pattern, directivity, mutual coupling etc. Both the antennas are been designed on a low cost easily available FR4 glass epoxy substrate which is having a thickness of 1.6mm Coaxial feed has been used to excite the antenna elements and each element of the antenna array is fed by a independent coaxial feed. Commercial available 3D model simulator tool Ansys HFSS has been used to simulate the antenna array.

Key words- Antenna Array, X-Band, Coax feed, Mutual Coupling.

I. INTRODUCTION

With the advent of the microstrip antennas and low profile technologies in the electronics the size of the communication systems have reduced enabling the use of Radiolocation application in many new areas for identifying the object. Though microstrip antennas which are known for their small size are been used to get small size for the communication systems further miniaturization is always needed along with high gain for long coverage area. One of the best technique to increase the gain of the antenna is to develop antenna array but care has to be taken such that the array size will not affect the overall size of the communication system, so to meet the needs of the current systems we need a antenna array with considerable gain in a compact structure.

A triple band antenna array for X, Ku and K bands has been proposed in [1] where slots have been used to generate multiple resonating frequencies. An antenna array with series and parallel feed elements has been proposed in [2] which work for the frequency of 9.3GHz to 9.4GHz. A double sided antenna array radiating at two frequency bands is proposed in [3], one side of the antenna radiates for single band and the other side of the antenna array radiates for two bands. A cavity backed antenna array is shown in [4] where to increase the gain of the antenna a air cavity is been introduced in between the radiating element and ground plane.

In this paper two antenna arrays were proposed with different shapes for the radiating elements. FR4 substrate has been used to design the antennas for the X-Band frequency of 10GHz which is useful for the Radiolocation services[5]. To maintain the compact nature of the antenna array interelement spacing in the antenna array is chosen to be 0.5 times the free space wavelength[6-7].

II. ANTENNA DESIGN AND CONFIGURATION

Proposed antenna are four element antenna array aligned in 2×2 matrix format. Here we considered two different structures for the radiating elements and formed two antenna arrays. One array is having circular radiating element with a radius of 3.7mm and the other array is having a rectangular radiating element with a dimension of 6.1mm×7mm. Both the antennas are been designed on a low cost easily available Fr4 glass epoxy substrate which is having a thickness of 1.6mm Coaxial feed has been used to excite the antenna elements and each element of the antenna array is fed by a independent coaxial feed. Commercial available 3D model simulator tool Ansys HFSS has been used to simulate the antenna array. The Overall dimension of both the antenna arrays is 15mm×15mm. For the best performance of the antenna array the inter element spacing in between the antenna elements is taken as 0.5λ[8].

The dimensions of the radiating elements were calculated based upon the following equations. Equations 1 to 5 are been used to calculate the length and width of the rectangular patch[9]

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r+1)}{2}}} \tag{1}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}} \tag{2}$$

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} \tag{3}$$

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \tag{4}$$

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

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Equations 6 to 8 are been used to calculate the radius of the circular patch[10]

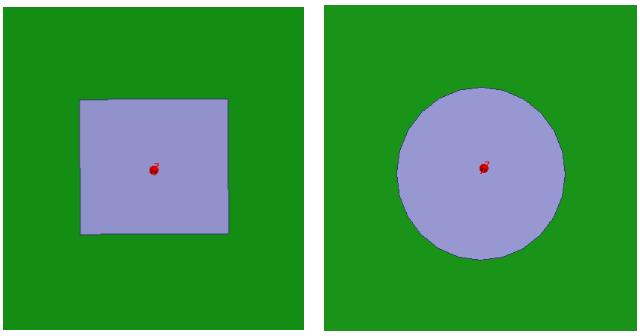
$$a = F\{\mathbf{1} + \frac{\mathbf{2h}}{\pi F \varepsilon_r}[\boldsymbol{ln}(\frac{\pi F}{\mathbf{2h}}) + \mathbf{1.7726}]\}^{-1/2} \quad (6)$$

Where

$$F = \frac{\mathbf{8.791 \times 10^9}}{f_r \sqrt{\varepsilon_r}} \quad (7)$$

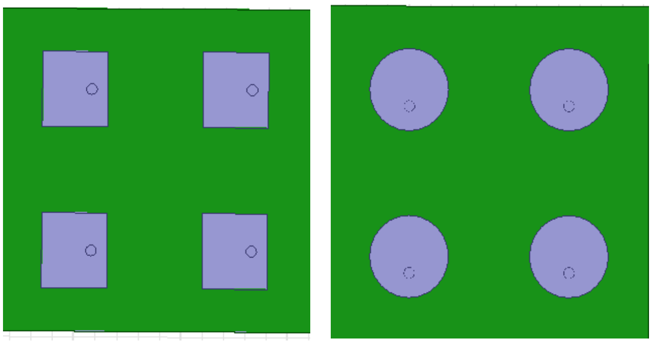
$$a_e = a\{\mathbf{1} + \frac{\mathbf{2h}}{\pi a \varepsilon_r}[\boldsymbol{ln}(\frac{\pi a}{\mathbf{2h}}) + \mathbf{1.7726}]\}^{1/2} \quad (8)$$

The simulated antenna structures of the proposed rectangular and circular antenna elements and antenna arrays are shown in the figure 1,2 below respectively.



(a) Rectangular Patch **(b) Circular Patch**

Fig. 1 Geometry of the proposed antenna element

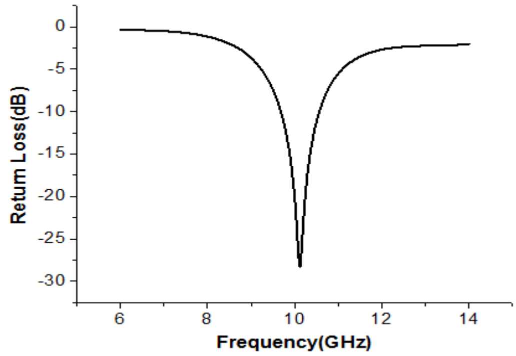


(a) Rectangular Patch **(b) Circular Patch**

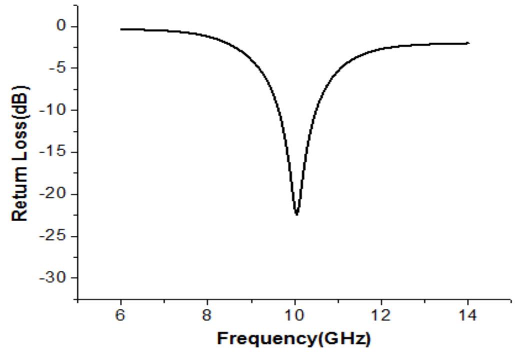
Fig. 2 Geometry of the proposed antenna array

III. RESULTS

The performance of the proposed antenna array are analysed using Ansys HFSS software. Various antenna parameters like return loss, VSWR, gain, radiation pattern, directivity, mutual coupling and impedance matching were studied. All the above mentioned parameters were analyzed for both the antenna arrays. Figure 3 below depicts the return loss plot of the antenna arrays. Observed a return loss of -27dB for rectangular patch and -22dB for the circular patch antennas. both the antennas were operating at the center frequency of 10GHz. From the plots it is observed that the rectangular patch is having better impedance matching compared to circular patch.



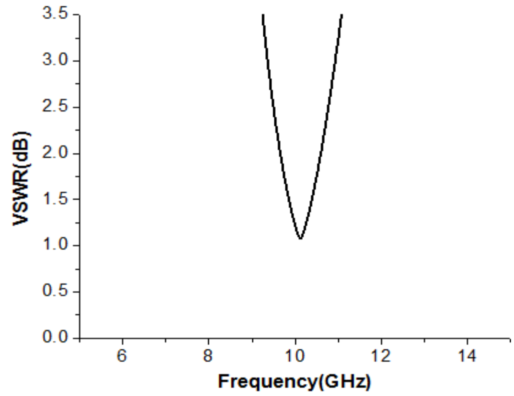
(a) Rectangular Patch



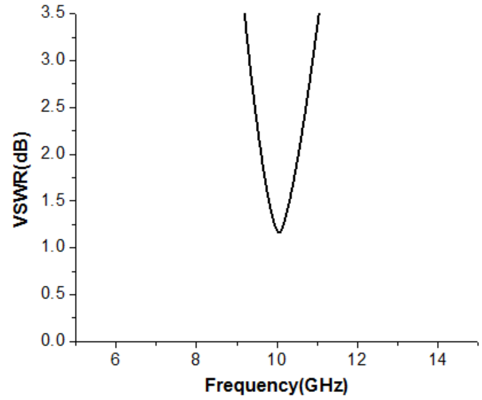
(b) Circular Patch

Fig. 3 Return loss of antenna element

Figure 4 below depicts the VSWR plot of the antenna arrays.



(a) Rectangular Patch



(b) Circular Patch

Fig. 4 VSWR of antenna element

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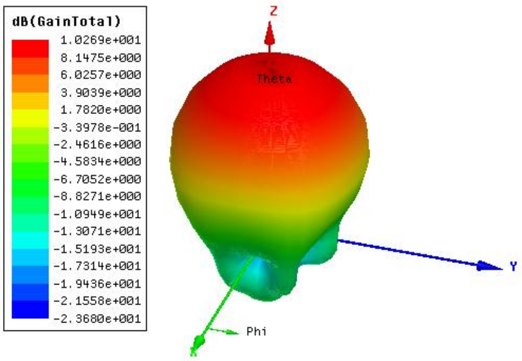
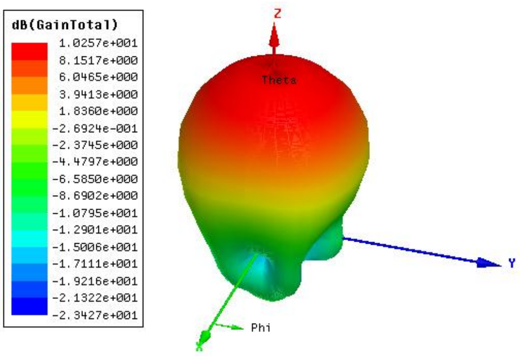
Observed a VSWR of 1.08 for rectangular patch and 1.16 for the circular patch antennas at the operating frequency of 10GHz. Figure 5 below depicts the Gain of the antenna arrays. Observed a gain of 10.26dB for rectangular patch and 10.25dB for the circular patch antennas at the operating frequency of 10GHz. From the results it can be observed that the shape of the radiating elements is not having any effect on the gain of the antenna.



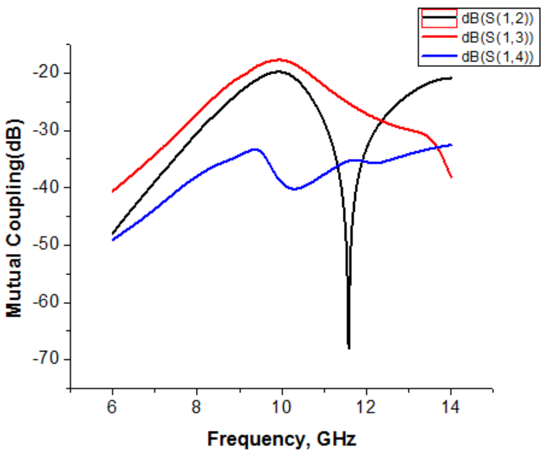
(a) Rectangular Patch



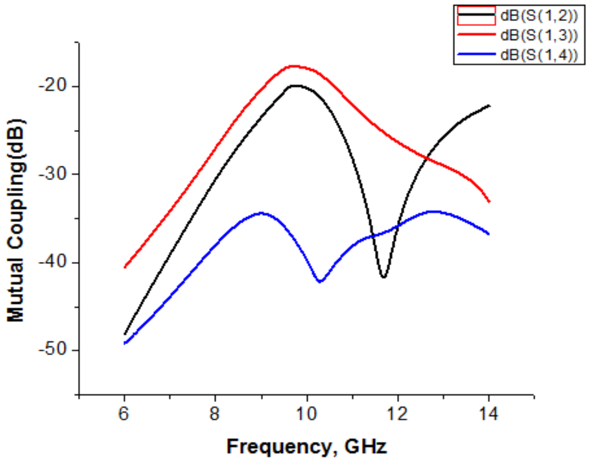
(b) Circular Patch

Fig. 5 Gain of antenna array

Figure 6 below depicts the Mutual coupling of the antenna array elements. The is most important parameter in antenna array if not addressed properly will effect the performance of the antenna array. From the plots it is evident that the mutual coupling effect is not effected by the shape of the antenna elements. Both the arrays are having a minimum coupling of -18dB which is acceptable for most real time applications.



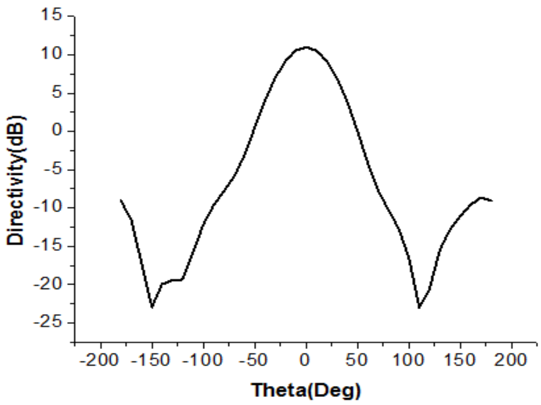
(a) Rectangular Patch



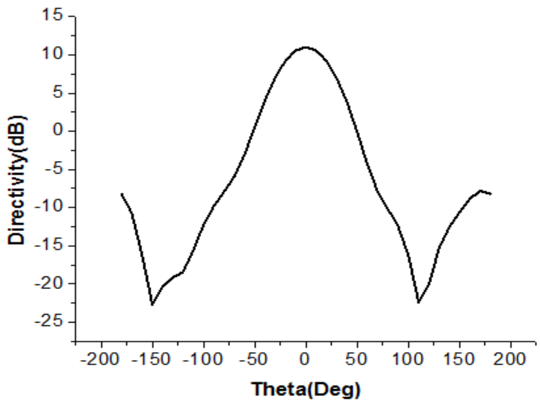
(b) Circular Patch

Fig. 6 Mutual Coupling of antenna array

Figure 7 below depicts the Directivity of the antenna arrays. Observed a directivity of 10.89dB for rectangular patch and 11.28dB for the circular patch antennas at the operating frequency of 10GHz. From the results it can be observed that the shape of the radiating elements is having a slight effect on the directivity of the antenna.



(a) Rectangular Patch



(b) Circular Patch

Fig. 7 Directivity of antenna array

Figure 8 below depicts the elevation plane and azimuthal plan radiation patterns of the antenna arrays. Observed a uniform radiation pattern without any nulls for both the

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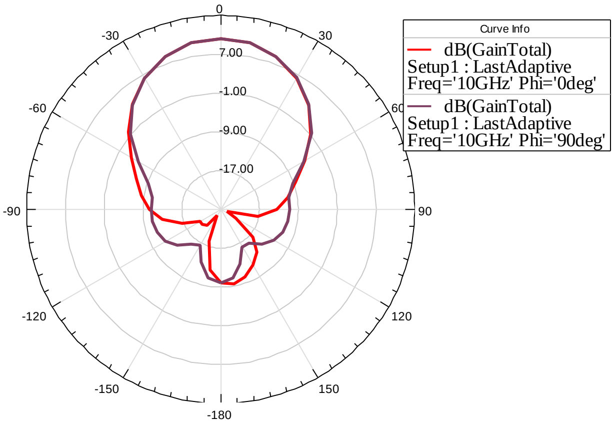
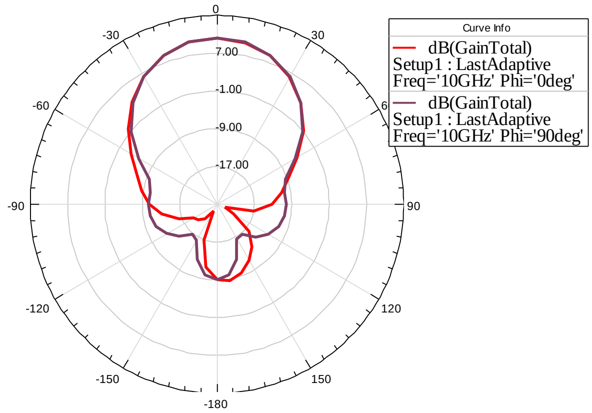
models. As the size of the antenna array is very small there are no observable levels of side lobes in the radiation patterns.



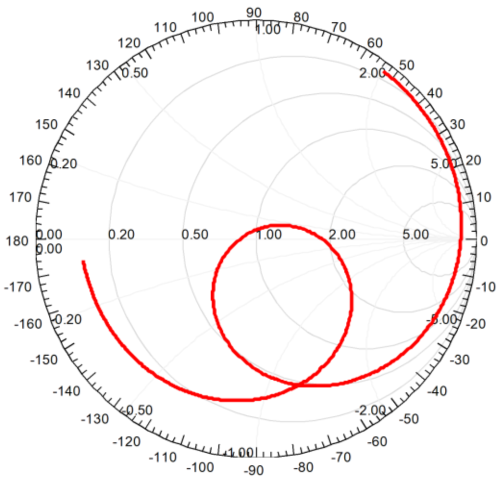
(a) Rectangular Patch



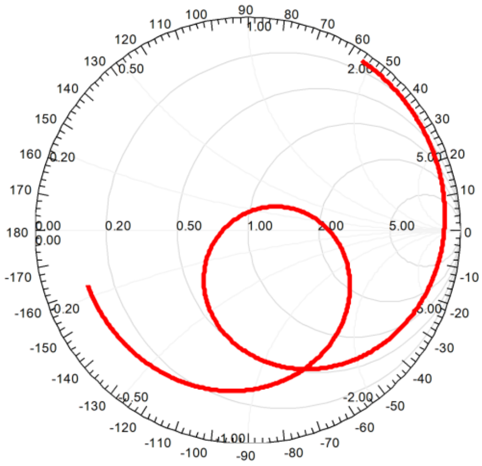
(b) Circular Patch

Fig. 8 Radiation Pattern of antenna array

Figure 9 below depicts the smith chart plots of both the antenna arrays. From the plots it is evident that the both the antennas are having proper impedance matching.



(a) Rectangular Patch



(b) Circular Patch

Fig. 9 Smith Chart of antenna element

IV. CONCLUSION

In this paper, 2×2 antenna array are proposed with circular patch and rectangular patch for the X-and frequency of 10GHz which is used for the radiolocation applications. A comparative study have been performed in terms of the antenna parameters. It is observed that the impedance matching is better in the antenna with rectangular patch compared with the antenna with circular patch. But the performance of the antenna array with circular patch is superior to antenna with rectangular patch in terms of directivity. All the other antenna parameters are not having any considerable effect of the patch shape on their performance. From the obtained results it is evident that both the proposed antenna arrays are best suited for the X-band radiolocation applications.

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