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Design of Stack Planar Array Antenna for C-band Radar

P. Sai Vinay Kumar, Dr M. Padmaja

Abstract— Today phased array antennas are widely used in many applications like radar tracking, satellite communication, wireless systems etc. Hence a 2*4 multilayer microstrip antenna array design is demonstrated in this paper. The designed planar array uses coaxial feeding technique for each and every individual element. Individual element of antenna consists of circular microstrip patch with FR4 substrate having dielectric constant of 4.4.The suitable design parameters are chosen using the design equations and simulated using HFSS. Obtained Simulated results are in good expected range with the return loss of -22.15 dB and gain of 12.34 dB at operating frequency of 6 GHz. Suitable beam steering is provided and it is seen that beam steering of +/-8 degrees is achieved. The final results are compared with single layer microstrip array antenna which showed improved directivity, gain and efficiency. The main objective of the design is to use for radar tracking applications with increased number of elements hence C-Band frequency is chosen to avoid the interference with existing L-Band and S-Band radar tracking antennas.

Index Terms— coaxial feed, phased array antenna, stacked patch, microstrip antenna.

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1 INTRODUCTION

The main application of the phased array antenna is to vary the phase of the antenna along azimuth and elevation without physically moving the antenna by means of electronic beam steering techniques. The relative phase of individual antenna elements is varied by feeding the signal with different phase shifts such that the obtained radiation pattern has peak gain in the desired direction and less gain in undesired direction by suppressing the side lobes. In this paper different phase angles are provided to the coaxial feed using software HFSS (13.0) and a beam steering of around 8o is achieved with a gain of 12.34 dB.

An array antenna is nothing but group of antenna elements with a common feed connected such as corporate-fed or series-fed techniques. This type of design is usually employed to have improved directivity, gain and efficiency. These structures are of low cost, easy to fabricate and are flexible to have wide range of beam steering.

The microstrip patch antennas used in array are light in weight, less cost and have many advantageous features of PCB technology. The word "Microstrip" is used because the height of the metallic substrate used in fabrication are always in micro-meter range. The elements of the patch are in wide range. Most commonly used are rectangular and circular patch. This design uses the circular patch due to its ease of mathematical calculations and its performance is analysed in array configuration.

Each element in an array is a stacked patch consisting of ground, dielectric substrate (FR4), patch with another layer of substrate and patch both having same physical dimensions and characteristics.

These type of designs are used in many applications such as weather monitoring, radar tracking, etc. and these high end applications usually use L, Ku,,C and X bands as specified by the ITU-T regulations. In this paper the chosen frequency band is C-band within the frequency range of 4 GHz to 8 GHz. In the design of the antenna it is important to choose design parameters such as dielectric material, width, length and height of the substrate, frequency of operation, type of substrate, patch and spacing between the elements, because the simulation results depends on these parameters. As the Inter element spacing of the array increases the gain of the antenna increases but there is significant back lobe level so minimum spacing gives the better performance with trade of between gain and back lobe level. as the Inter element spacing of the array increases the gain of the antenna increases but there is significant back lobe level so minimum spacing gives the better performance with trade of between gain and back lobe level. As the spacing of the stack increase the return loss and VSWR varied. The reduction of radius decreases the gain and directivity sometimes. Increasing the number of layers increases the gain. Higher the permittivity lesser the antenna size. The substrate with more thickness and less dielectric constant gives good efficiency and larger bandwidth which increases the antenna size.

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2 Design of Microstrip Antenna

The microstrip antenna consists of ground, Substrate and a very thin patch called as metallic strip placed on top of the substrate. Hence the patch tends to radiate as the spacing between the ground plane and strip increases. The radiation depends on the type of the substrate like Rogers TMM, Fr-4, Teflon(PTFE), Taconic TLY-5 etc., each having different dielectric constants, (Usually Fr-4(Er=4.4) is used in the paper), The thickness of the patch t<< , height of the substrate 0.0003 h 0.5 ., operating frequency, and other dimensions effects the gain, return loss, radiation pattern characteristics of the antenna. In this paper a circular patch is used for the design of microstrip element. It has only one parameter i.e., radius to control hence it is convenient to optimize and easy to design.

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From [10] the design equations of the first order circular patch for the approximation of the radius are given.

$$R = A\{1+\frac{2h_t}{\Pi F \varepsilon_r}[\ln(\frac{\Pi A}{2h_t})+1.7726]\}^{\frac{-1}{2}} \quad (1)$$

Where

$$A = \frac{8.791\times10^9}{f_o\sqrt{\varepsilon_s}} \quad (2)$$

The fringing effect is not taken into consideration while calculating the Eq1. Because the fringing effect makes the radius of the patch electrically large.

The effective radius of the microstrip patch antenna is given by

$$R_e = R\{1+\frac{2h_t}{\Pi R\varepsilon_r}[\ln(\frac{\Pi R}{2h_t})+1.7726]\}^{\frac{1}{2}} \quad (3)$$

$$(f_r)_{110} = \frac{1.8142 * C_v}{2\pi R_e\sqrt{\varepsilon_s}} \quad (4)$$

3 ANTENNA DESIGN AND SIMULATION RESULTS

A two layered planar array with 8 elements is designed with 6.74 mm radius of patch having the substrate dimensions 96mm*48mm*1.2mm with the inter element spacing is taken to be 24mm which is . Each element is provided with individual coaxial feeding technique with 1W power supply. The design is as shown in the figure

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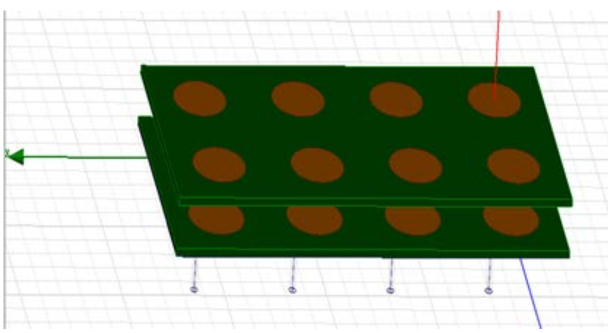

Fig. 1. 3D Model Top View of 2*4 two Layer Planar array antenna

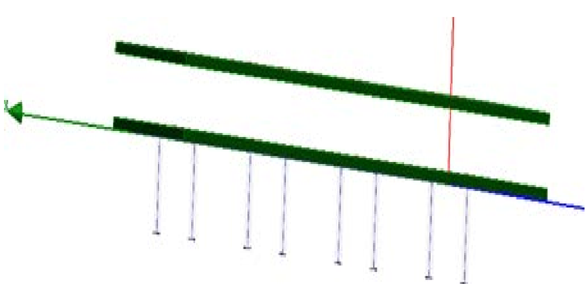

Fig 2: 3D Model side View of 2*4 two Layer Planar array antenna

The simulated return loss of 2*4 Double Layer Planar array antennas is approximately -22.15 dB with VSWR of 1.35 dB and a gain of 12.34 dB for all the 8 elements

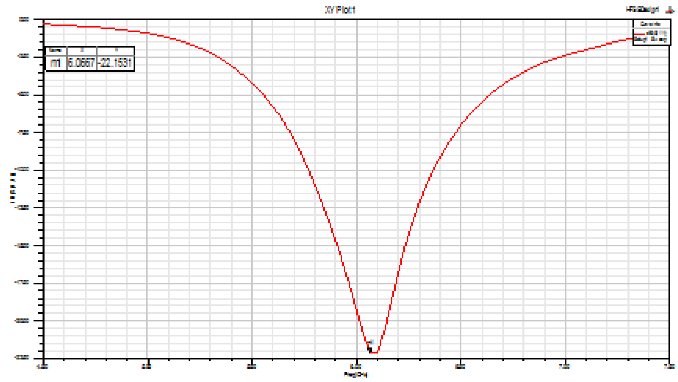

Fig 3: Return loss characteristic of 2*4 two Layer Planar array

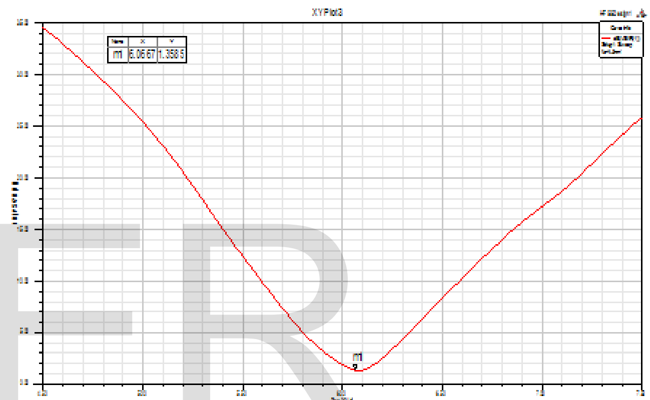

Fig 4: VSWR Plot of 2*4 two Layer Planar array antenna

The below plot shows the total gain of the antenna which is 12.34 dB.

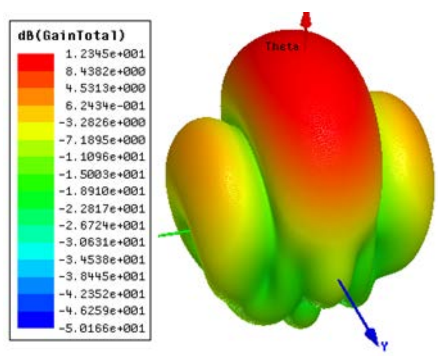

Fig 5: 3D Gain Plot of 2*4 two Layer Planar array antenna

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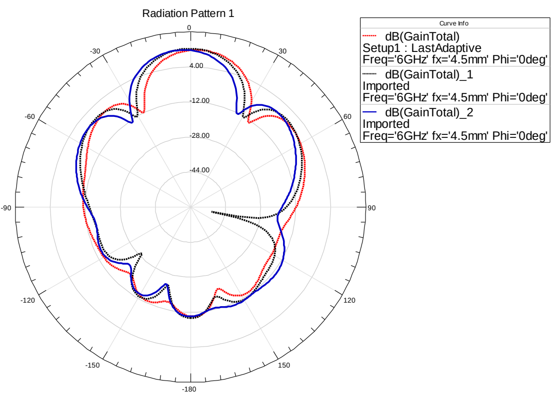
4 BEAM STEERING



The following graph shows the E-Plane and H-Plane radiation patterns of the stacked 8 element array. In order to achieve beam steering a positive and negative phase shift of 100 for all the elements is given. It is seen that a beam steering of +/- 8 degrees is achieved.

Fig 6: E Plane Radiation Pattern of 2*4 two Layer Planar array antenna

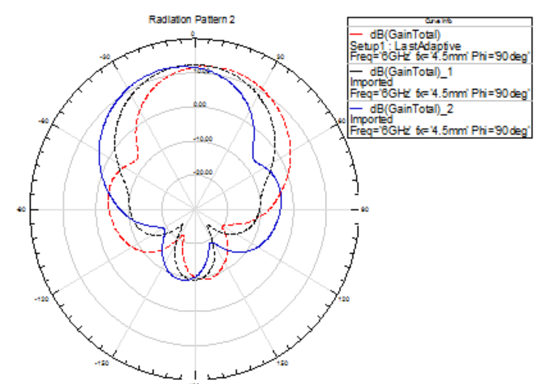


Fig 7: H Plane Radiation Pattern of 2*4 two Layer Planar array antenna

Comparison of single and stacked Layer 2*4 Array

Antenna Parameters	*Single layer Array (2*4)*	*stacked Array (2*4)*
Frequency of operation	6 GHz	6 GHz
Return Loss (dB)	-18.92	-22.15
VSWR (dB)	1.97	1.35
Directivity	21.99	24.04
Gain (dB)	11.82	12.34
Radiation Efficiency	69	71

5 CONCLUSION

A stacked antenna array is designed for C-band operations. The results show that the stacked array performed well in terms of gain, efficiency and directivity. Achieved a beam steering of about +/- 8 degrees. The paper showed the performance of the antenna in each level and compared the results.

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