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Design and Analysis of Symmetric and Asymmetric Series Feed Radar Antenna

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Abstract: *This paper work consists a comparative study on symmetric and asymmetric series feed antenna array that is resonating at 10 GHz. The antenna designed is a microstrip antenna the conducting material taken is copper and the dielectric material FR4 glass epoxy. For the creation of antenna array a single element patch is designed that is radiating in the required frequency. The designed antenna can be used for radar application. The fundamental antenna parameters have been compared and studied on the array antenna like Directivity, Gain, Radiation pattern and Return loss. The design and simulation work is done in Ansys HFSS*
Keywords– *Antenna array, Directivity, Gain, Radar antenna, Radiation pattern, Return loss*

I. INTRODUCTION

As mankind has evolved technology has also evolved with him. Today we stand in an arena where we can‟t even think a few minutes of our life without technology especially wireless technology. The introduction of microstrip patch antenna and their arrays have lead to extensive application in wireless technology it is because of their low profile, compatibility and low cost fabrication. Microstrip patch antennas are very versatile. Microstrip patch antennas and their arrays are widely used in the microwave frequency range. They are highly applied in satellite communication, radar for missiles and telemetry global positioning systems and many more, innovations in their application just seems to be never ending. Antennas play an important role in the field of communication they are the backbone and almost everything in wireless communication without which the world we are standing could have not reached at this age of technology

In high performance areas like air crafts, space craft satellites and missile applications normal antennas have limitations to be used due to their big size, higher weight and high cost, thus the evolution of low profile antenna took place. Microstrip antennas meet all the requirements including aerodynamic profile for high performance applications. These antennas are of low cost low profile conformable to planar and non-planar structure, inexpensive to manufacture using printed circuit technology (PCB) used in modern engineering. Microstrip antennas gained their attention starting in the 1970s although the idea can be traced to 1953. The term "microstrip" comes because the thickness of the metallic strip is in micro-meter range.

A. Microstrip Antenna Structure

Microstrip antenna‟s simplest structure consists a patch on top of a dielectric substrate usually the patch placed on the top of the substrate is made up of copper or gold this is the patch that radiates. Below the substrate there is a ground plane as shown in Fig 1. The radiating patch can be of any shape like rectangle, square, circles etc. Numerous substrates can be used for the design of these antennas and their dielectric constant (ϵ_r) usually varies from $2.2 \le \epsilon_r \le 12$. Antennas having thicker substrates and lower end range of ϵ_r have good performance and efficiency. The radiating patch is excited by feeding. Feeding an antenna is a technique in where the antenna is excited by the radio wave signals or in other words where the radio waves are feed to the antenna for transmitting antenna or in receiving antenna to collect the incoming signals which is then converted. There are several feeding techniques the most commonly four feeding techniques used are coaxial feeding, microstrip feeding, aperture feeding and proximity coupling feeding.

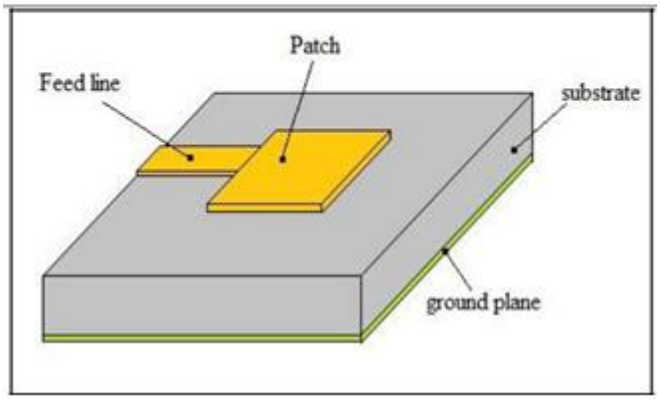


Fig 1: Isometric view of a simple rectangular microstrip antenna

B. Antenna array

In some cases single antenna does not meet the requirements for some radiation purposes at that time we need to use antenna arrays. Antenna arrays is a set of individual antennas that coordinately sinks and acts as a single antenna. Usually with the increase in antenna elements the directivity, gain also increases. Here the feeding techniques used to excite the patches are mainly of three type‟s series, series cooperative and cooperative feed. This paper only concentrates in the series feeding technique. In this type of feed the first element gets the maximum power from the feed and decreases as the elements passes by. The performance of an antenna is measured in terms of its parameters the parameters taken here are directivity, gain, return loss, radiation pattern and bandwidth.

II. ANTENNA DESIGN AND METHODOLOGY

A. Rectangular patch design:

To design a rectangular patch one should know the length and width of the patch. Here formulas from "antenna theory analysis and design" by Balanis[10]. They are as below.

The width „W‟ of the radiating patch is given as:

W = (1)

Where = Dielectric constant

(Speed of light in vacuum)

The fields along the edges of the patch undergo fringing. Therefore there is a variation in the length. Also some of the waves travel in the substrate and some in the air, an effective dielectric constant is formed and which results in Leff ,the effective length and ΔL is due to the fringing effect on one side of the patch since there are two sides of the length it results to 2 ΔL and finally the length of the patch is derived by subtracting 2 ΔL from Leff.

The Length „L‟ of the resonating patch is given by

L= Leff-2 ΔL (2) Leff is given by

Leff = (3)

ΔL is given by

ΔL= 0.412h (4)

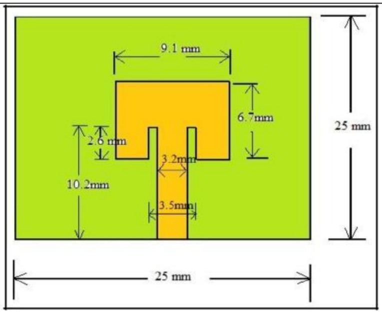
is given by

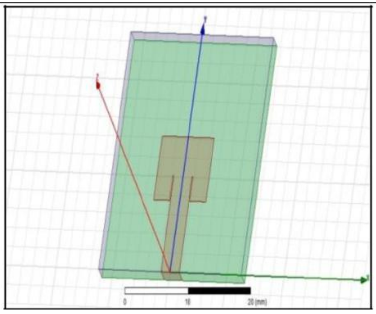
(5)

√

B. Design of single patch antenna for 10GHz

All these formulas have been programed in matlab and by substituting the values of the thickness of the substrate as 1.6mm, resonating frequency 10GHz, dielectric constant as 4.4, the values of the width and length are 9.1mm and 6.7mm respectively. The width of the feed line is taken as 3.2mm which has an impedance of 50 ohm and the length is varied in HFSS and taken as 10.2mm. Fig 2 shows the designed single patch, the dimensions are clearly depicted in Fig 2(a) and in Fig 2 (b) the patch that is simulated in HFSS is shown





(a) Dimension of the single patch (b) Simulated single patch in HFSS Fig 2: Design of the single patch at 10 GHz

C. Designing of antenna arrays

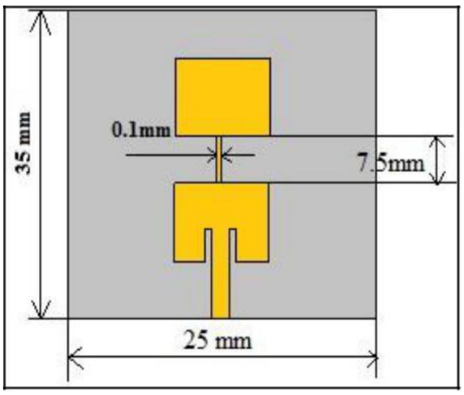
After designing a single patch that resonates at 10 GHz, Next step is to design the antenna array to get higher gain, directivity and bandwidth. Each element is feed serially. One advantage of this feed is that the return loss is agreeable and the structure is easily attained. Steps involved in implementing an antenna array:

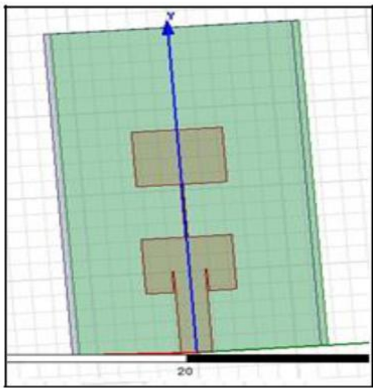
a) Design a single patch antenna resonating in the required frequency.
b) Choose the antenna array feed type.
c) Design the patch antenna array with spacing half wavelength or quarter wavelength

1) Designing symmetric series feed antenna array

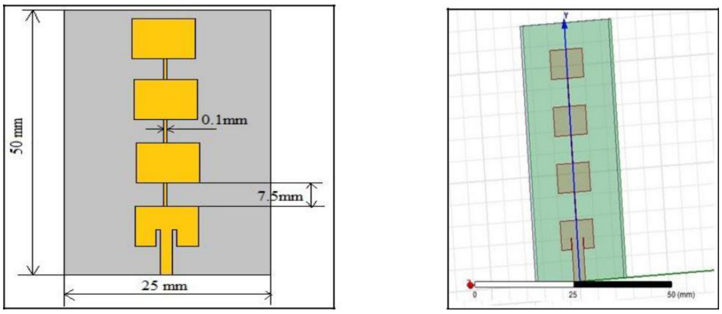
The simplest form of array is the series feed array. The patches are placed at a distance of $\lambda/4$ that is 7.5mm the centers of the patches are approximately $\lambda/2$ that is 15mm.Here the arrangement is linear. In a symmetric series feed the structure becomes symmetric if sectioned along the y axis as shown in Fig 3(b) and

(d) .In Fig 3 (a) and (c) the dimensions of the series feed array of 2 and 4 element are shown respectively and in Fig 3(b) and (d) the designed and simulated series feed antenna in HFSS is shown .The array patches are matched with high impedance transmission line. The width and the impedance of the transmission line are inversely proportional. Here the width of the transmission line used to excite and match the array patches are 0.1mm approximately of 200ohm for the copper material with substrate of glass epoxy. The impedance also depends on the thickness of the substrate. The formulas for calculating the impedance of the transmission line is taken from [12]. Initially array for two elements is made and the number of the element is increased to four.





(a) Dimension of series array 2x1 (b) Simulated series array 2x1 in HFSS

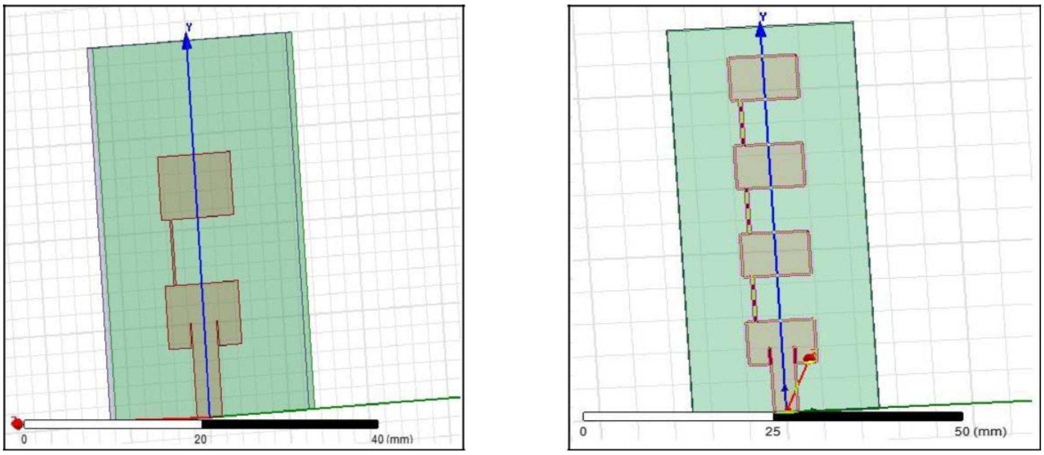


(c) Dimension of series array 4x1 **(d) Simulated series array 4x1 in HFSS**

Fig 3: Design of the symmetric series feed antenna array at 10 GHz

2) Designing an asymmetric series feed antenna array

For asymmetric series feed antenna array the high impedance matching feeding transmission line are placed in an asymmetric way as shown in the Fig 4 (a) and (b). The high impedance feeding lines are moved to right side of the patches. The antenna is asymmetric along the y axis of Fig 4 (a) and (b).



(a) Simulated series array 2x1 in HFSS **(b) Simulated series array 4x1 in HFSS**

Fig 4: Design of the asymmetric series feed antenna array at 10 GHz

III. RESULTS AND DISCUSSIONS

Table 1: Antenna parameters of single a patch

Type of antenna	Directivity (dB)	Gain (dB)	Return loss (dB)	Bandwidth (%)
Single patch antenna	5.7	5.2	-48.6	3

From Table 1 it is seen that after simulation the single patch antenna have an appreciable directivity (5.7dB), gain (5.2 dB) and a narrow bandwidth (ranging from 9.85GHz to10.15GHz) therefore providing a good resolution for radar antenna at 10 GHz. Fig 5 shows the impedance matching of the single antenna at 10 GHz, its seen that the return loss is found to have a value of -48 dB. From the radiation pattern shown in Fig 6 it is evident that there are no side lobes for the single radiating patch.

Fig 5: Return loss of single patch antenna

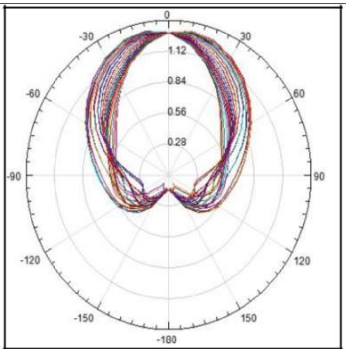


Fig 6: Radiation pattern of single patch antenna

Table 2: Antenna parameters of 2x1antenna array

S no	Type of antenna array	Directivity (dB)	Gain (dB)	Return loss (dB)	Bandwidth (%)
1	Symmetric Series feed array	7.75	6.3	-14.3	3
2	Asymmetric series feed array	8.25	6.67	-18.3	5

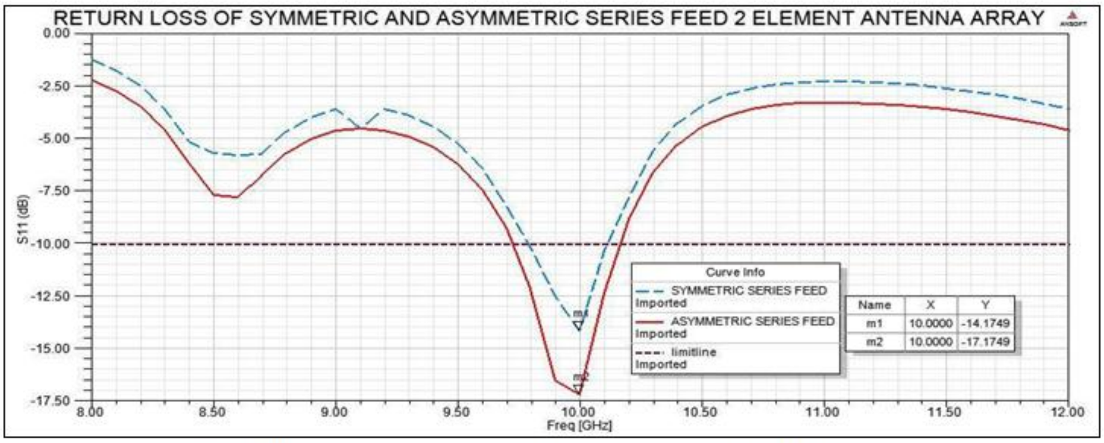
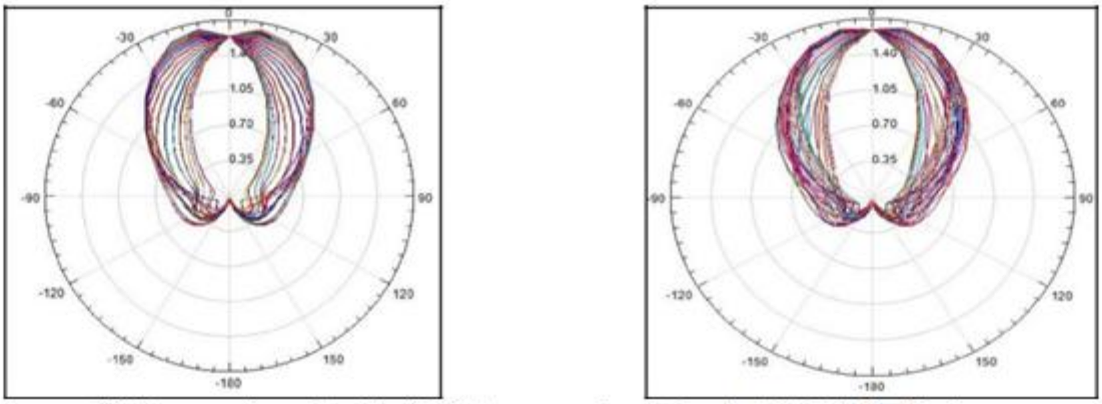


Fig 7: Return loss of symmetric and asymmetric series feed 2x1antenna array



(a) Symmetric series feed (b) Asymmetric series feed Fig 8: Radiation pattern of 2x1 antenna array

Table 3: Antenna parameters of 4x1antenna array

S no	Type of antenna array	Directivity (dB)	Gain (dB)	Return loss (dB)	Bandwidth (%)
1	Symmetric Series feed array	8	7.2	-16.3	5
2	Asymmetric series feed array	8.81	7.13	-20.3	7

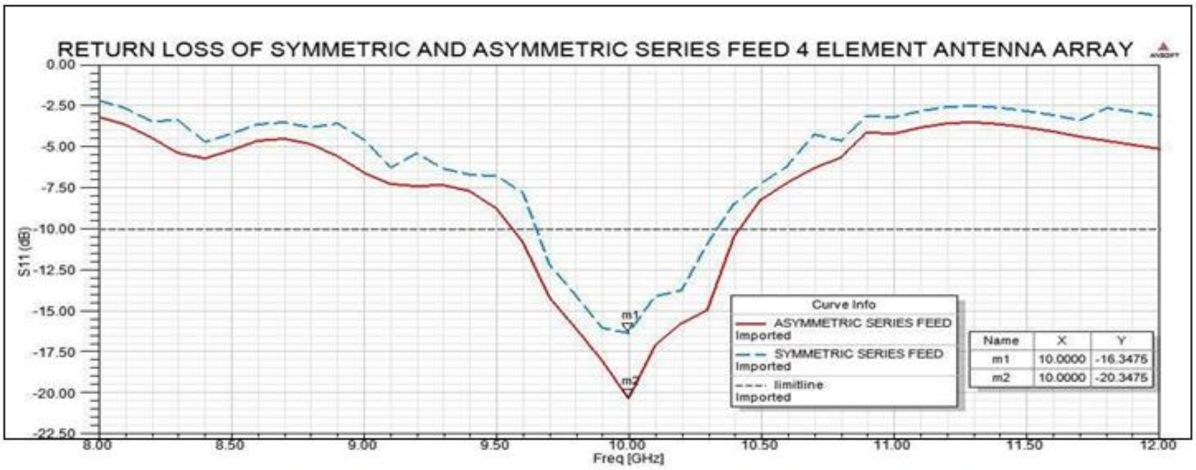
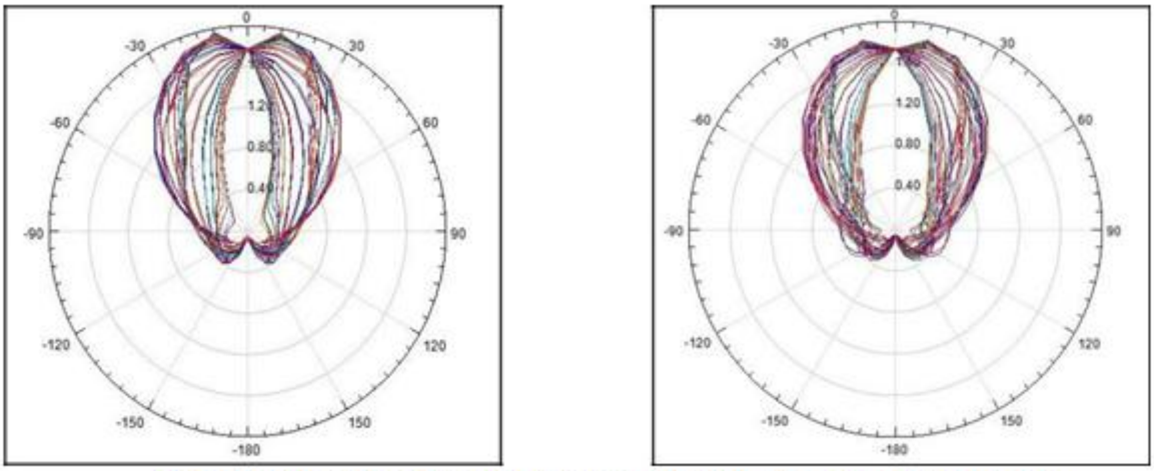


Fig 9: Return loss of symmetric and asymmetric series feed 4x1antenna array



(a) Symmetric series feed (b) Asymmetric series feed Fig 10: Radiation pattern of 4x1 antenna array

Table 2 contains the simulated antenna parametric results of the symmetric and asymmetric series feed of 2x1antenna array similarly Table 3 contains the simulated antenna parametric results of the symmetric and asymmetric series feed of 4x1antenna array .From Table 2 and Table 3 it is observed that to achieve a better impedance matching it is wise to choose asymmetric series feed type .The directivity and gain are almost the same for both the series feed types but still asymmetric series feed has an upper hand. The bandwidth is higher in the asymmetric feed type therefore can be used for communicative applications. For implementing antenna with higher resolution, symmetric feed type is better. From Fig 8 (a) and (b) there is no much difference in the radiation pattern of the two series feed types similarly the is no much difference between the radiation patterns in Fig 10 (a) and (b) . From Table 1, Table 2 and Table 3 it is clearly inferred that the directivity, gain and bandwidth increase with increase in the number of elements in an array.

IV. CONCLUSION

In this paper a low cost radar antenna array with symmetric and asymmetric series feed has been designed and simulated and a comparative parametric study is done. It is inferred that the asymmetric feed type achieves a better impedance matching than the symmetric feed type along with higher bandwidth. The symmetric feed type has better resolution since it has narrow bandwidth which makes is advisable for specific applications like radar. Asymmetric feed type can be used for communicative application as it has better bandwidth. The bandwidth, directivity and gain increase with number of elements in the array. Future study can be done by changing the feed locations of the high impedance transmission line and by also increasing the number of elements

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