Investigation of Different Feeding Techniques on Rectangular Microstrip Patch Array Antenna

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Abstract – Wireless communication system plays a prominent role in many applications like long distance communication, mobile applications, high performance aircraft, missile applications. For this purpose wireless communication systems requires antenna with compact, flexible, ease of installation, superior gain and directivity. Rectangular single element microstrip patch antenna used in several applications, but these are not suitable for satellite communications, space crafts, and high resolution Radars because they need enhanced gain and also directivity. In view of the above facts multiple designs have been deployed to enhance the gain and directivity and low beamwidth by increasing the number of patch elements with series, parallel and individual feed network at an operating frequency of 10GHz with dielectric constant 2.2. The 4 element and 8 element design has carried out in this work by comparing with two element. Some of the system operational characteristics depend on directional properties of antenna. HFSS software is a tool for this project design and implementation. Antenna primary parameters such as impedance bandwidth, directivity, gain, radiation pattern, beamwidth were compared among all three types of feed network.

Index Terms – Wireless communication, Rectangular microstrip patch antenna, Beamwidth, Gain, Directivity, Operating frequency, HFSS (High Frequency Structure Simulator).

1. INTRODUCTION

A fundamental conducting element which provides impedance matching between source to load can act as an antenna. The morphological changes applied to conducting elements can turn into an antenna and it must also satisfy both maximum power transfer theorem and reciprocity theorem is well. Though the antennas are extensively used in communications they must be capable of radiating the energy to longer distance. Hence a flared structure is incorporated to the antenna structure [1-2].

For marine radars to measure the distance of the ships and to navigate at sea shore, the asymmetrical sum patterns are useful when the ships are subject to roll and pitch. These patterns are very useful in point to point communication and in high resolution radars [3-5].

2. MICROSTRIP PATCH ANTENNA

Microstrip patch antenna having advantages like low size, high performance, low cost, low profile antenna. With the increase in the advancement of science and technology the usage of microstrip patch antenna as been increased because of their low structural characteristics [6].

For precise and high efficiency system design requires a lossless substrate material and substrate height. Here in this pursuit ROGERS RT-DUROID 58880 is a lossless substrate material with dielectric constant value of 2.2 [7]. Generally we have different types of micro strip patch antennas like rectangular, circular, square, triangular, disk sector and many more but out of this rectangular micro strip patch antenna having essential characteristics, low cost, ease to design.

To provide better efficiency and larger bandwidth. Microstrip antennas constitutes of a narrow conducting strip whose thickness is very negotiable when compared to its operating wavelength ($t<<\lambda_0$), the height of the patch is usually dependent on the material ($h << \lambda_0$, usually $0.003\lambda_0 \leq h \leq 0.05\lambda_0$) which is separated by a fraction of λ_0 above the ground plane. For a rectangular patch, the length L of the element is usually $\lambda_0/3 < L < \lambda_0/2$ [8].

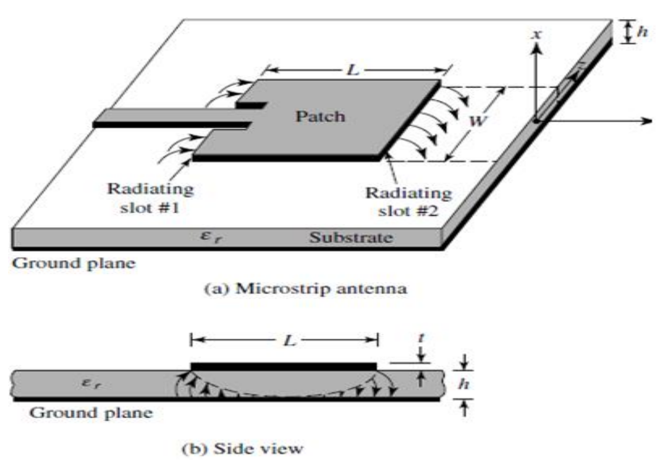

Figure 1 Rectangular Microstrip Patch Antenna

Choosing of dielectric materials in the antenna design must be given a prior importance because the dimensions of the aerial and the primary functional parameters of the antenna are appreciably based on the numerical value of the dielectric constant of the substrate material.

The basic microstrip patch antenna along with the fringing effect from the patch shown in figure 1.

3. DESIGN EQUATIONS

The entire design of the MRPA can be done by using the dimensions of the substrate, patch and the ground plane. All the required dimensions can be obtained by utilizing the transmission line model equations.

$$f_r = \frac{1}{2L\sqrt{\epsilon_{reff}\ \mu_o\ \epsilon_0}} \qquad (1)$$

$$W = \frac{\lambda_0}{2}\sqrt{\frac{2}{\epsilon_r + 1}} \qquad (2)$$

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \qquad (3)$$

$$L = \frac{1}{2 f_r \sqrt{\epsilon_{reff}}\sqrt{\mu_0\ \epsilon_0}} - 2\Delta L \qquad (4)$$

Where f_r is the resonant frequency, W is the width of the patch, L is the effective length of the patch.

4. DESIGN OF TWO ELEMENT MRPA ANTENNA

By using above mentioned transmission line model equations, the dimension of the single element patch antenna has been calculated. Length of the patch 0.9cm, width of the patch 1.19cm, inset feed length 0.295cm, feed width of 0.243cm. The model of the antenna according to above dimensions is shown in figure 2.

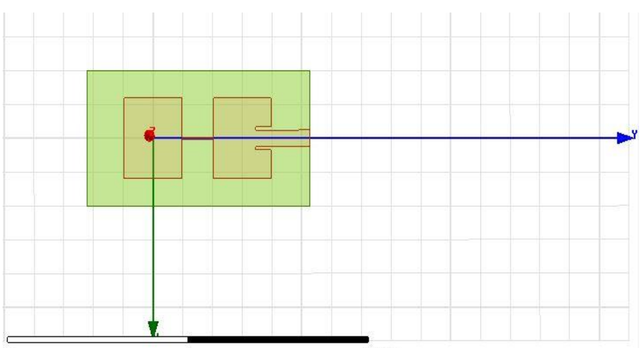

Figure 2 Two Elements MRPA with Series Feed

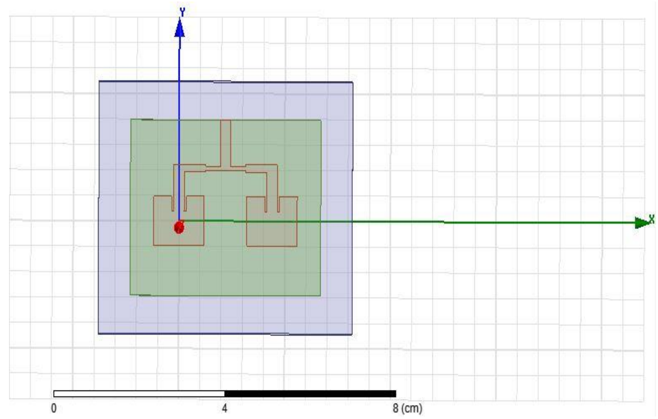

Figure 3 Two Elements MRPA with Parallel Feed

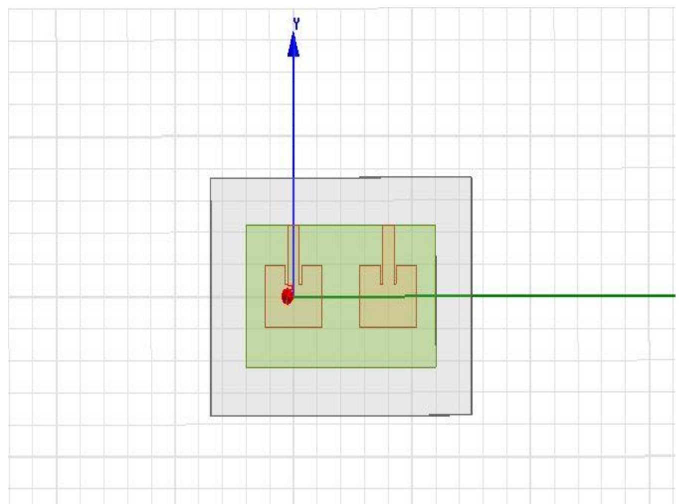

Figure 4 Two Elements MRPA with Individual Feed

5. DESIGN OF FOUR ELEMENT MRPA ANTENNA

- Four Element MRPA Antenna with Series Feed Network

The same dimensions of the single element patch antenna are also used in design of the 4 element antenna with series feed. The separation gap between two patches is $\lambda/2$.

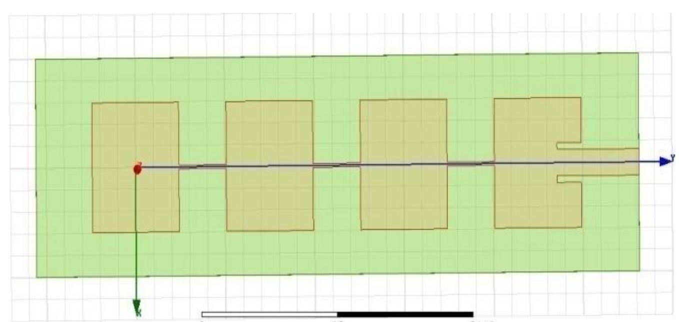

Figure 5 Four Elements Rectangular Microstrip Patch Antenna with Series Feed

The feeding port always exists at the extreme end patch out of 4 elements. All the 4 elements are interconnected with a narrow feedline [9].

- Four Element MRPA Antenna with Parallel Feed

The same dimensions of the single element antenna were used here as well. The separation gap between all the patch elements is λ/2. The parallel feed to these entire patch elements is designed using T-network impedance matching configuration [10].

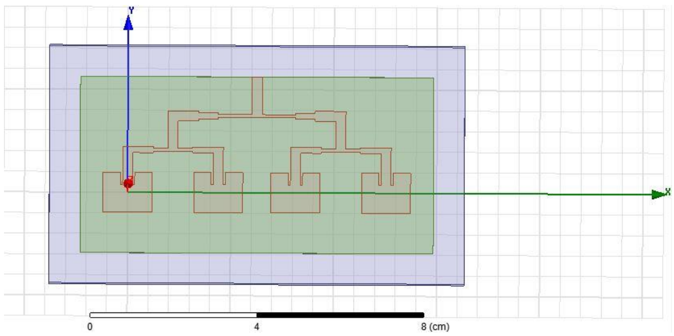

Figure 6 Four Elements Rectangular Microstrip Patch Antenna with Parallel Feed

- Four Element MRPA Antenna with Individual Feed

For the same single element antenna, by altering the position on the same plane the four element antenna with individual feeding network can be derived. Here, there is no necessity of arranging 4 feed points for 4 elements. The same feed point of single element can be used for exciting all the elements [11].

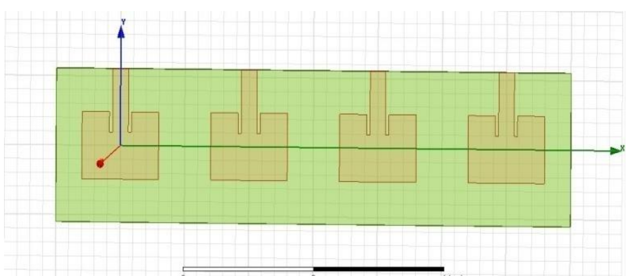

Figure 7 Four Elements Rectangular Microstrip Patch Antenna with Individual Feed

6. DESIGN OF EIGHT ELEMENT MRPA ANTENNA

- Eight Element MRPA Antenna with Series Feed Network.

The 8 element design of patch array antenna network is also utilizing the dimensions of the one element antenna. Upon the substrate all the 8 elements were placed serially and the feeding is provided to the last element in the array.

The space consumption of the 8 element array is more when compared to the 4 elements and single element antenna. All the patch elements are separated by a gap of λ/2 and the lumped port excitation has been given using 50ohm feedline.

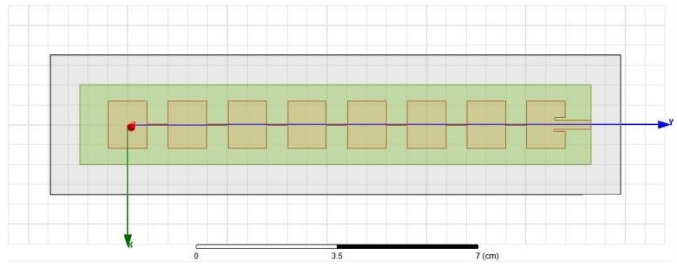

Figure 8 Four Elements Rectangular Microstrip Patch Antenna with Series Feed

- Eight Element MRPA Antenna with Parallel Feed Network

As in the case of 4 element array, the feeding network is arranged in a parallel manner to all the available 8 elements in the array. T- Network is basic configuration for the design of the feedline. Here 50Ohm, 70Ohm and 100Ohm lines are designed as per requirement [12].

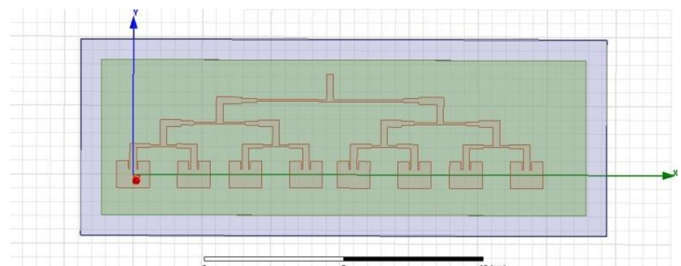

Figure 9 Four Elements Rectangular Microstrip Patch Antenna with Parallel Feed

- Eight Element MRPA Antenna with Individual Feed Network

All the eight elements of the microstrip patch antenna array are provided with the individual feed by exactly matching the feedline impedances of single element antenna. The terminating lines are 50Ohm of impedance (z_0) [13].

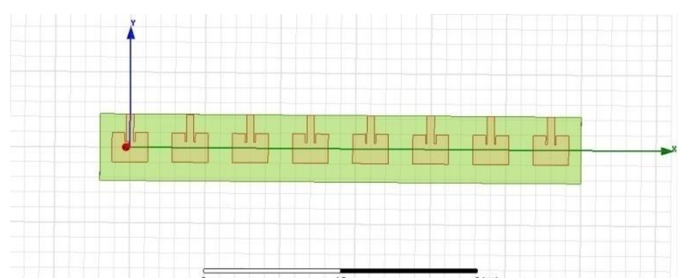

Figure 10 Four Elements Rectangular Microstrip Patch Antenna with Individual Feed

7. RESULTS AND DISCUSSIONS

The following section gives result analysis of all the above mentioned designs are shown below with their plots.

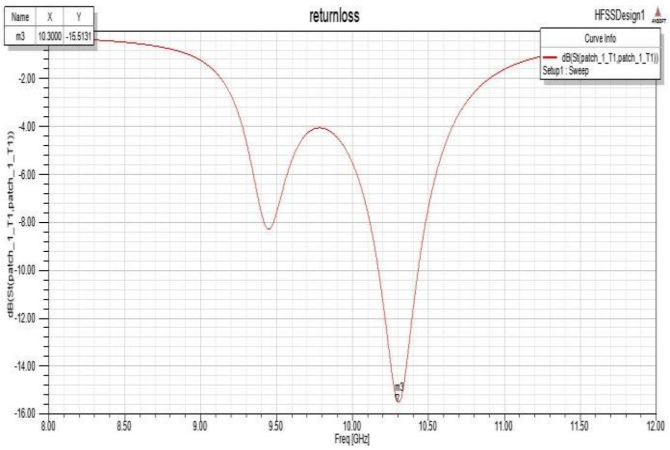

Figure 11 Return loss of Two Element MRPA with Series Feed

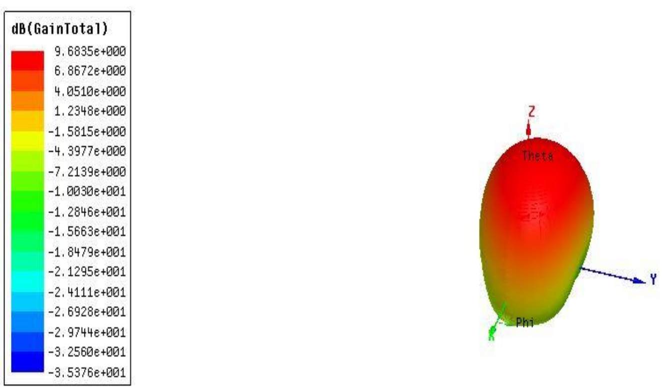

Figure 12 Gain of Two Element MRPA with Series Feed

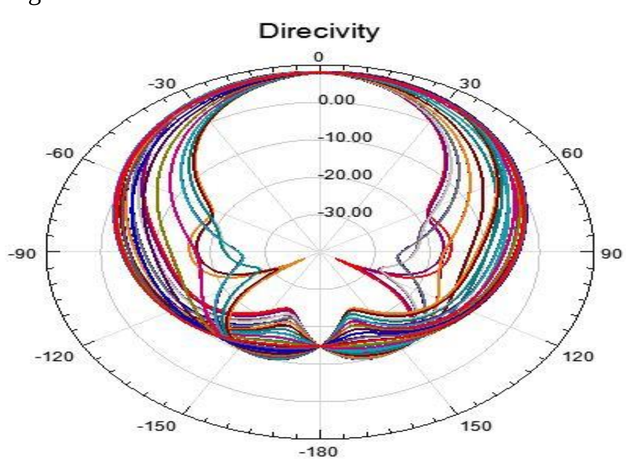

Figure 13 Directivity of Two Element MRPA with Series Feed

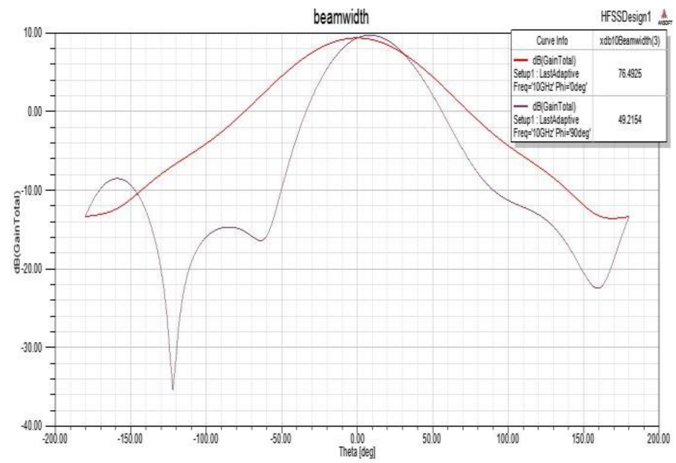

Figure 14 Beamwidth of Two Element MRPA with Series Feed

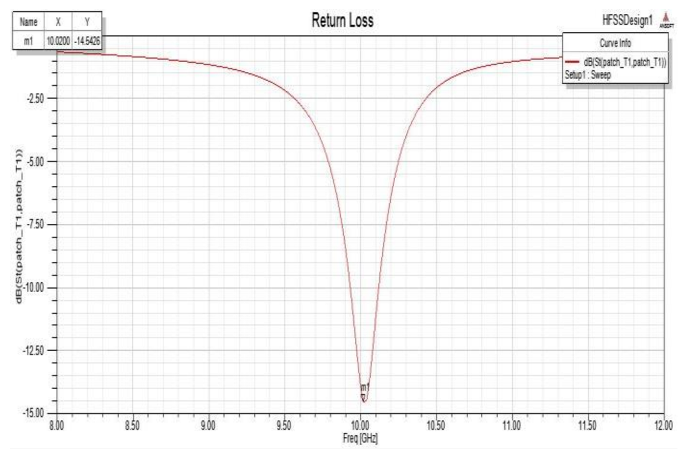

Figure 15 Return loss of Two Element MRPA with Parallel Feed

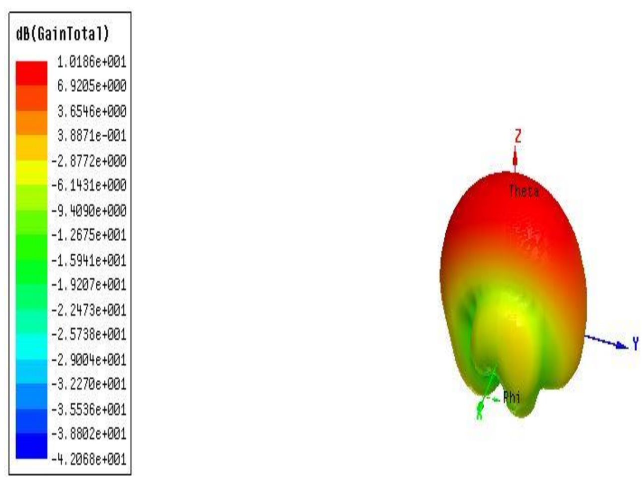

Figure 16 Gain of Two Element MRPA with Parallel Feed

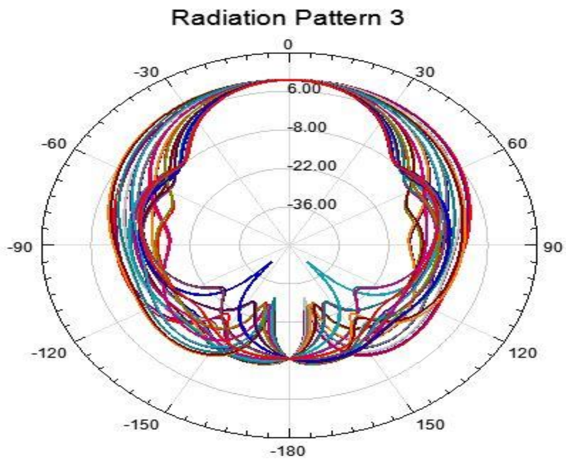

Figure 17 Directivity of Two Element MRPA with Parallel Feed

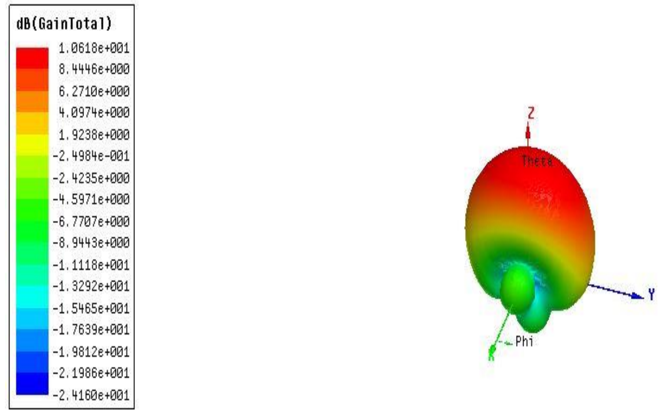

Figure 20 Gain of Two Element MRPA with Individual Feed

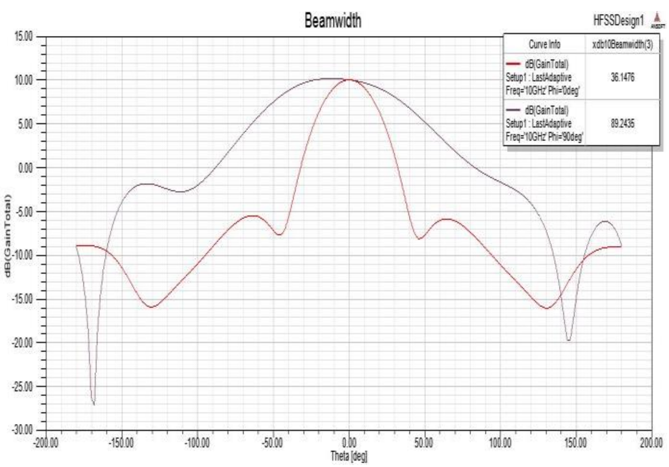

Figure 18 Beamwidth of Two Element MRPA with Parallel Feed

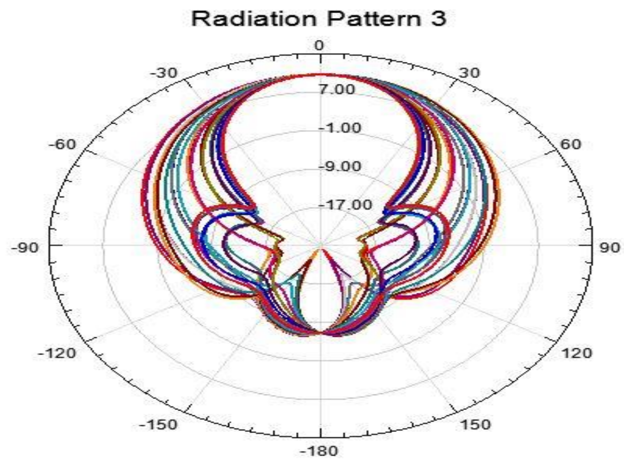

Figure 21 Directivity of Two Element MRPA with Individual Feed

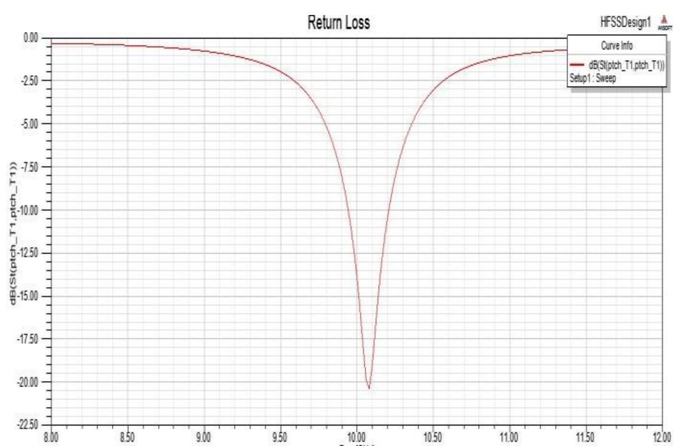

Figure 19 Return loss of Two Element MRPA with Individual Feed

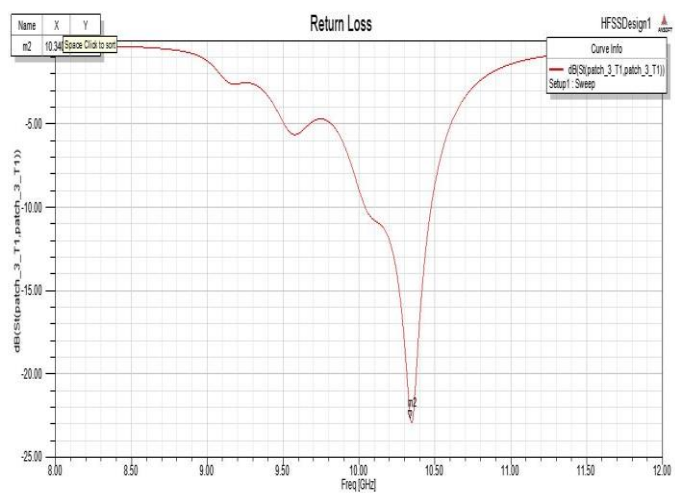

Figure 22 Return loss of Four Element MRPA with Series Feed

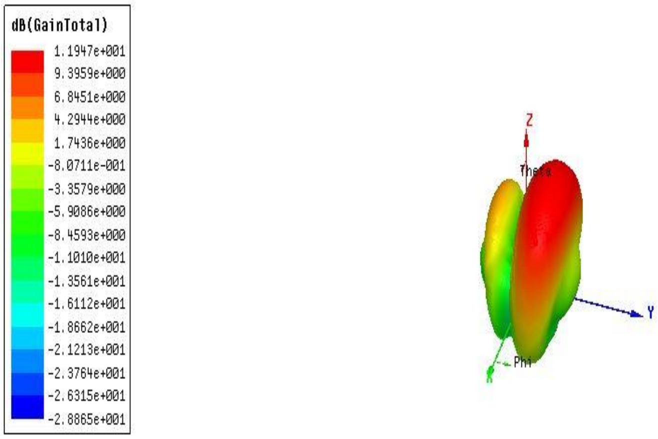

Figure 23 Gain of Four Element MRPA with Series Feed

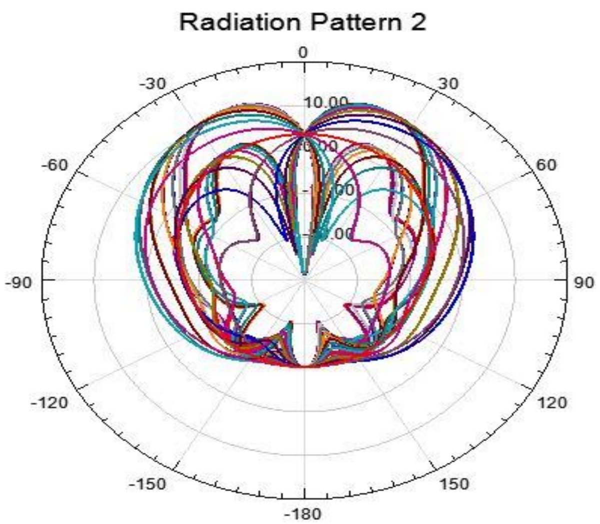

Figure 24 Directivity of Four Element MRPA with Series Feed

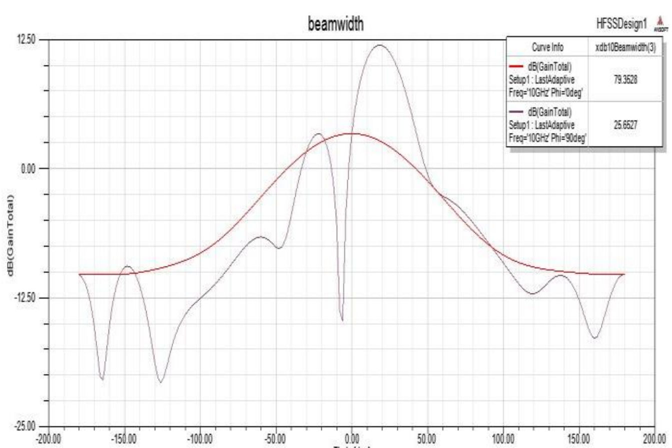

Figure 25 Beamwidth of Four Element MRPA with Series Feed

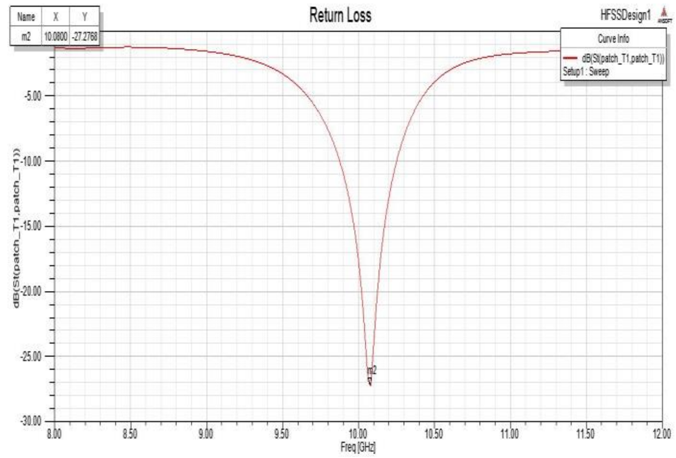

Figure 26 Return loss of Four Element MRPA with Parallel Feed

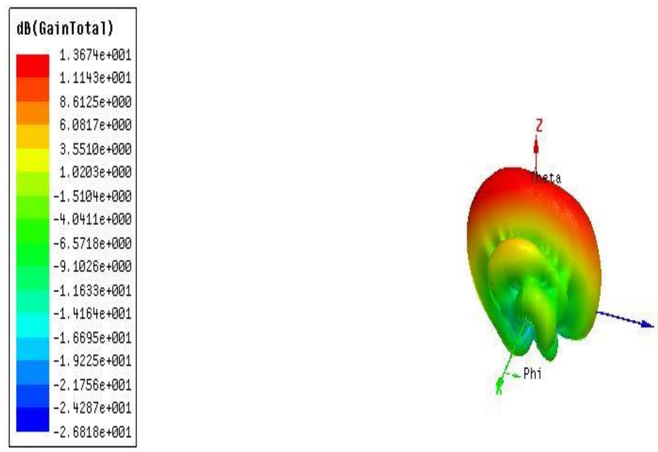

Figure 27 Gain of Four Element MRPA with Parallel Feed

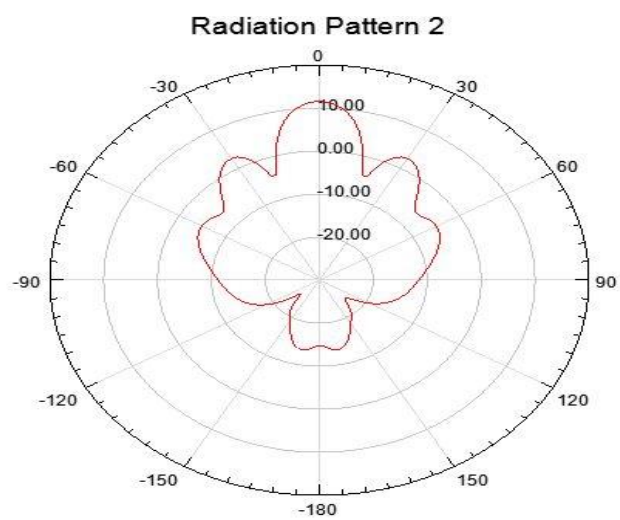

Figure 28 Directivity of Four Element MRPA with Parallel Feed

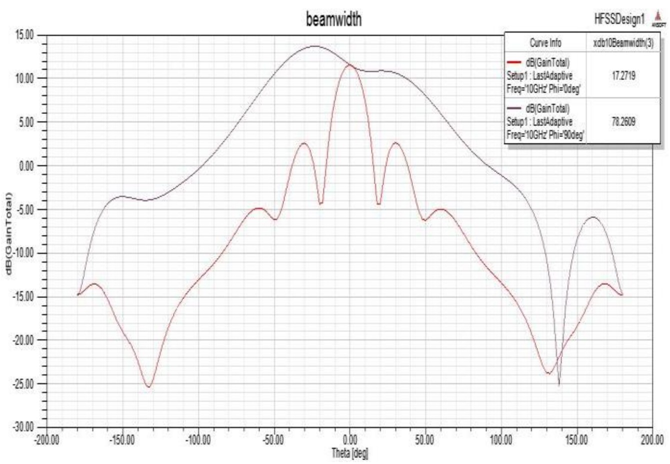

Figure 29 Beamwidth of Four Element MRPA with Parallel Feed

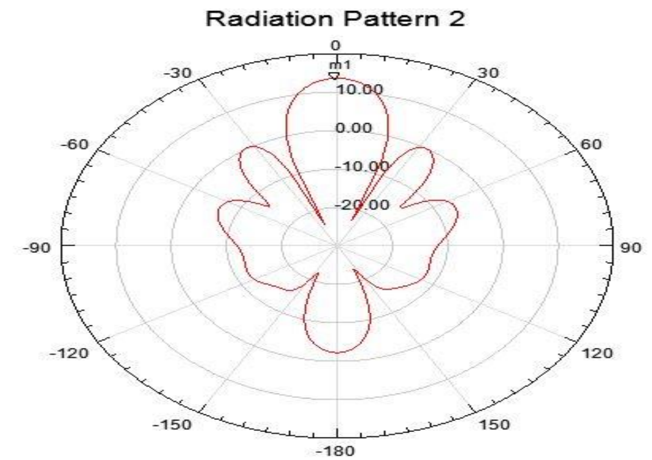

Figure 32 Directivity of Four Element MRPA with Individual Feed

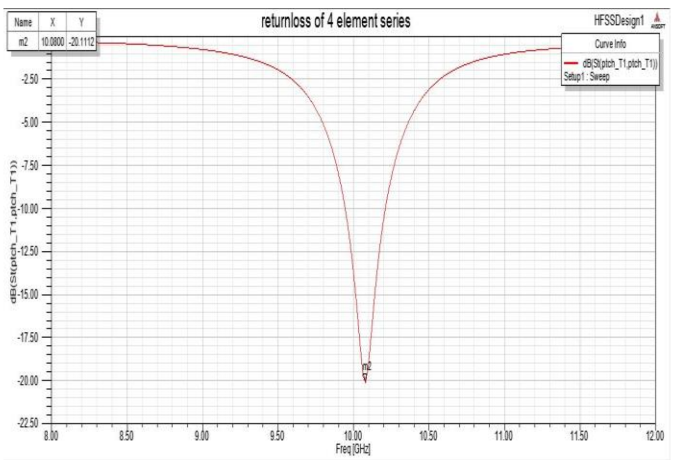

Figure 30 Return loss of Four Element MRPA with Individual Feed

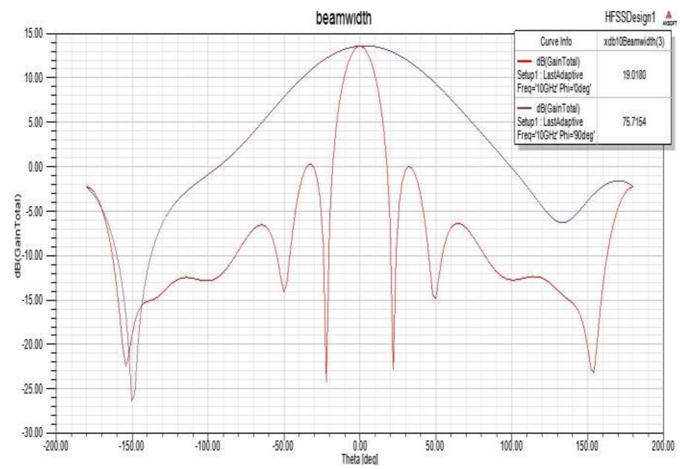

Figure 33 Beamwidth of Four Element MRPA with Individual Feed

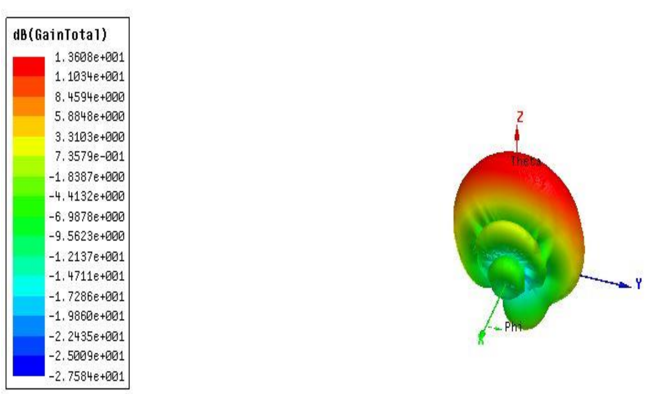

Figure 31 Gain of Four Element MRPA with Individual Feed

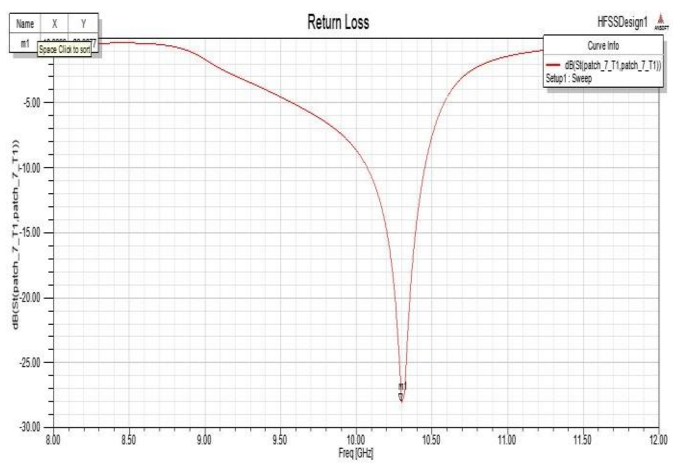

Figure 34 Return loss of Eight Element MRPA with Series Feed

Figure 35 Gain of Eight Element MRPA with Series Feed

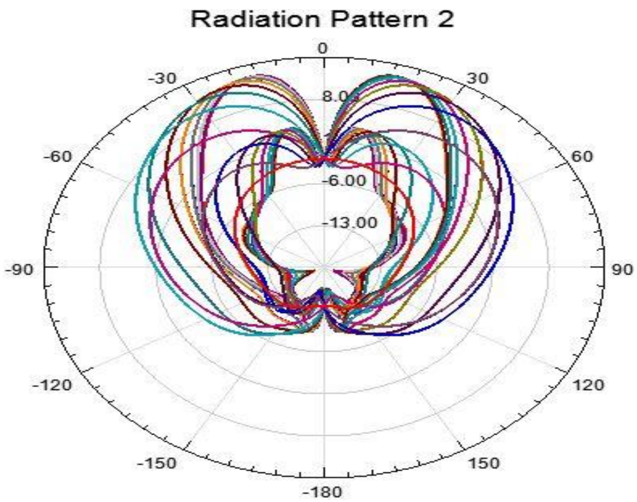

Figure 36 Directivity of Eight Element MRPA with Series Feed

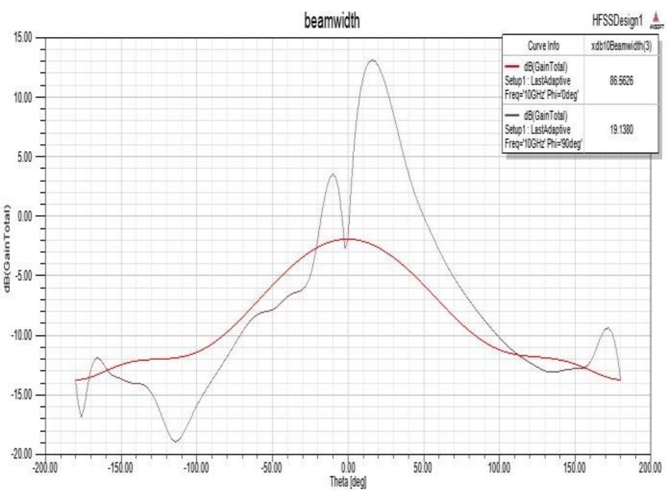

Figure 37 Beamwidth of Eight Element MRPA with Series Feed

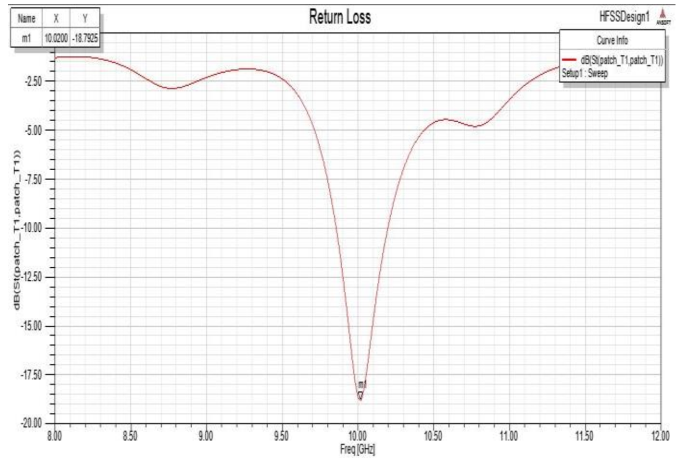

Figure 38 Return loss of Eight Element MRPA with Parallel Feed

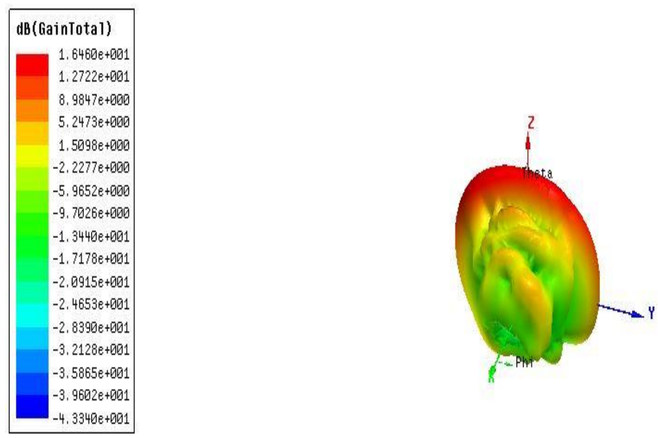

Figure 39 Gain of Eight Element MRPA with Parallel Feed

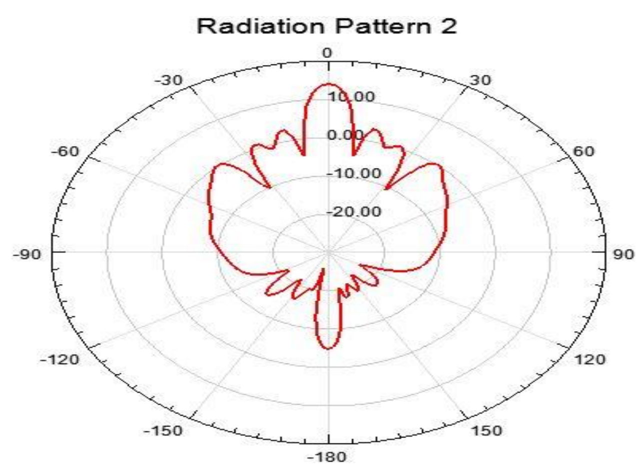

Figure 40 Directivity of Eight Element MRPA with Parallel Feed

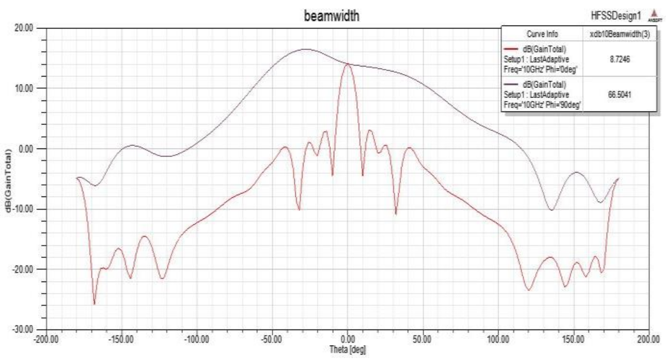

Figure 41 Beamwidth of Eight Element MRPA with Parallel Feed

Number of patch Elements	Return Loss	Gain	Directivity	Beamwidth
Two element series	-15.5dB	9.62dB	9.70 dB	49^0
Four element series	-22.7dB	11.9dB	11.95 dB	40^0
Eight element series	-28.0dB	13.2dB	13.3 dB	34^0
Two element parallel	-14.5dB	10.2dB	10.2dB	36^0
Four element Parallel	-27.5dB	13.0dB	13.73 dB	17^0
Eight element parallel	-18.8dB	16.5dB	16.5dB	9^0
Two element Individual	-19.7dB	10.6dB	10.63dB	40^0
Four element Individual	-20.1dB	13.6dB	13.65 dB	20^0
Eight element Individual	-20.4dB	16.6dB	16.62 dB	11^0

Table 1 Comparison Between All Different Feeding For MRPA

From the above tabular data, there are few conclusions that can be made, by which the performance analysis of the MRPA antenna can be illustrated. The maximum gain that can be attained is 16.59dB for an eight element patch array with individual feed.

8. CONCLUSION

The designed array antenna whose central frequency is around 10GHz can be adopted into Radar applications because of its low beam width. Return loss is increasing when the antenna is feeding in serial way, and coming to parallel feed there is fluctuation in the value of return loss because of the number of elements. Whereas is individual feed, the variation in the return loss also increases but it is negotiable. Irrespective of whether an antenna is series, parallel or individual feed, if the number of patch elements increases then the Gain and Directivity increases whereas beam width decreases. Hence it can be concluded that when compared to all three types of feeding methods, individual feed offers better results in terms of Gain and Directivity.

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