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Comparison between Different Antenna Designs Operating at Different Frequencies for GPS Applications

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Abstract

A wearable antenna is meant to be a part of the clothing used for communication purposes, which includes tracking, navigation, mobile computing and public safety. We described the design and development of rectangular array patch antennas. In this paper, several designs of microstrip arrays antennas, suitable for interaction between antenna and human body, are presented. We presented two antennas with different geometry and frequencies but both have operation point for GPS application. Specifically, 2x1, 2x2, 2x4 and single element are designed and simulated by a full wave simulator (IE3D). Moreover, this paper presents a comparison between both rectangular and square antenna arrays. The resonance frequency for square antenna is 1.3GHz and for rectangular is 1.575 GHz.
In this paper, Inset feed techniques are applied to the rectangular microstrip patch antenna.

Keywords: microstrip antenna array, rectangular microstrip antenna, square microstrip antenna, resonant gain, Return loss, 3D radiation

1. Introduction

The design of microstrip patch antenna with high gain suitable for GPS applications is described in [1].
Microstrip antenna has been widely used in radio equipments from 100MHz to 100GHz, especially for the devices in the aircraft and ground portable devices. Microstrip antennas are often given priority for the application which low profile radiators are required, even if some performances are not as good as the general antennas.

The Objective of this system is to increase MPA compatible with human body and improve characteristics of antenna like gain, return loss, bandwidth and beam width. This antenna is fabricated with clothes of soldier. This antenna is called "Wearable Antenna for GPS Applications".

2. Antenna Array

We can use single patch antenna but in order to improve the performance of the antenna we will investigate antenna arrays. We will use 2x1, 2x2 and 2x4 antenna arrays. Our designed antenna operates in two frequencies 1.3GHz and 1.575GHz.
We selected relative dielectric constant $\varepsilon = 2.2$ and the thickness h of substrate to be 3.175mm for all designed described below.
We evaluated the length, width and the input impedance of the patch. Then we investigated radiation patterns, reflected loss, efficiency and antenna gain using electromagnetic simulator IE3D.

2.1 Antenna Array Design

2.1.1 Design and Network Analysis for single Antenna

The design of single patch antenna is shown below in figure 1. Specified by calculating the half wavelength value and then subtracting a small length to take into account the fringing fields [2-4]

- We chose patch length L = 76mm
- Patch width =76 mm
- Patch width of 50 Ω line = 2 mm
- Patch Length of the 50 Ω line = 25 mm
- Patch Width of the 50 Ω line = 15 mm
- Patch Length of the 50 Ω line = 30 mm

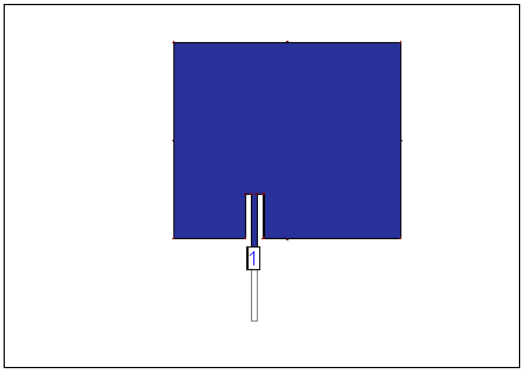

Figure 1. Geometry of Single Microstrip antenna array with Inset feed.

2.1.2 Design and Network Analysis for 2x1 Antenna Array

The design of 2x1 antenna array is shown below in figure 2.

- Length and width of the Patch 76 mm
- Width of the 50 Ω line = 4 mm
- Length of the 50 Ω line = 8 mm

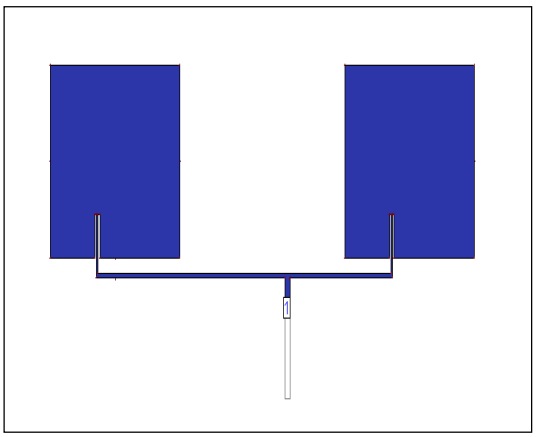

Figure 2. Geometry of 1x2 Microstrip antenna array with Inset feed.

2.1.2 Design and Network Analysis for 2x2 Antenna Array

The design of 2x2 patch array is shown below in figure 3.

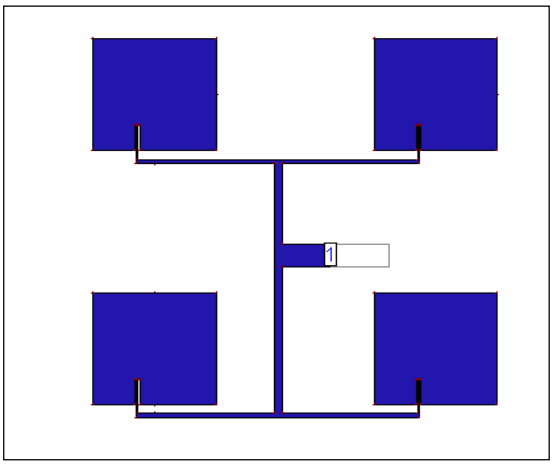

Figure 3. Geometry of 2x2 Microstrip antenna array with Inset feed.

2.1.3 Design and Network Analysis for 2x4 Antenna Array

The design of 2x4 antenna array is shown below in figure 4.

- Length and width of the Patch = 76 mm
- Width of the 50 Ω line = 20 mm
- Length of the 50 Ω line = 48 mm

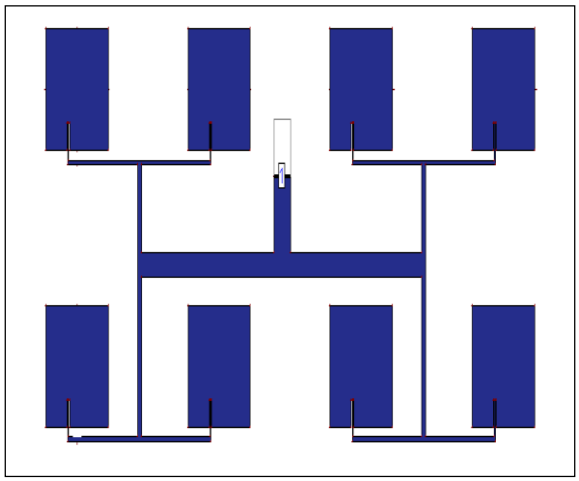

Figure 4. Geometry of 2x4 Microstrip antenna array with Inset feed.

3. Results on Performance Characteristic of Wearable Antenna

3.1 Return Loss Characteristics

The inset feed [5, 6] is used in the design for single, 1x2, 2x2 and 2x4 Microstrip array antennas. Figures 5, 6, 7 and 8 demonstrate the return loss of single microstrip patch antenna, 2x1, 2x2 and 2x4 respectively. The excitation for antenna happened at -10 dB, at this value, the antenna switched on.

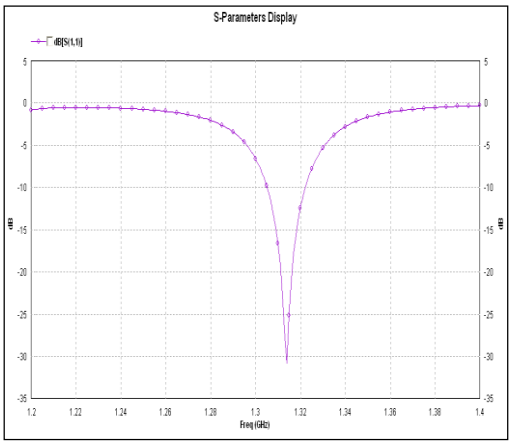

Figure 5. Return Loss Characteristics single Microstrip antenna.

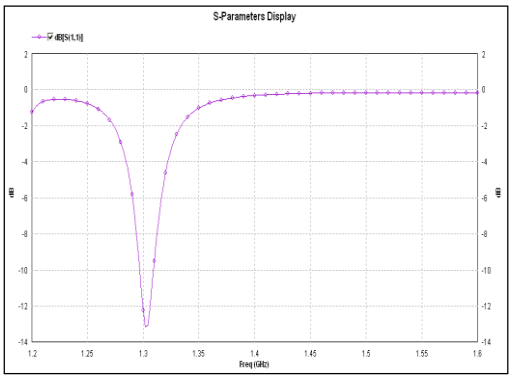

Figure 6. Return Loss Characteristics 1x2 Microstrip array antenna.

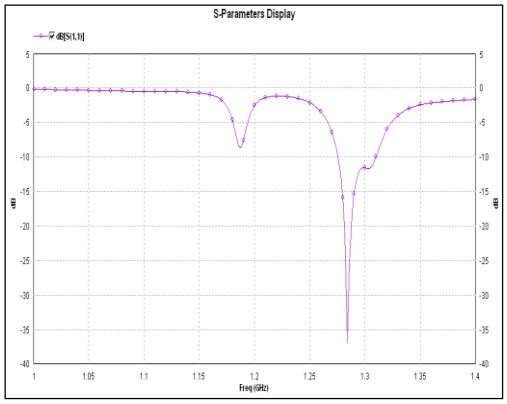

Figure 7. Return Loss Characteristics 2x2 Microstrip array antenna.

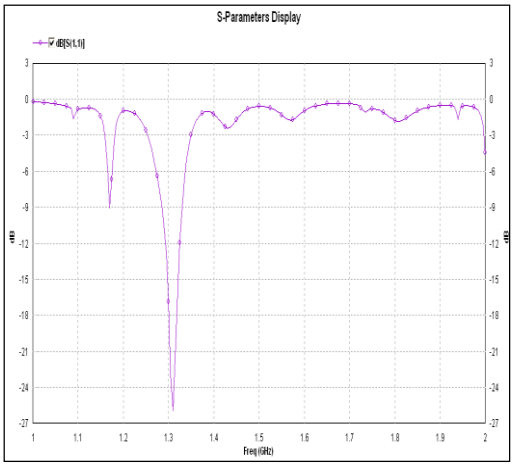

Figure 8. Return Loss Characteristics 2x4 Microstrip array antenna.

Summary of results of simulation are shown below in table 1

Table 1: Comparing between single, 1x2, 2x2 and 2x4 Microstrip array antenna

Array/Dimension	Resonant Frequency (GHz)	Bandwidth (MHz)	S11 parameter (dB)
Single	1.31	17 MHz	-30.498
1x2	1.3	12 MHz	-13.125
2x2	1.28	35 MHz	-35.59

3.2 Far-field Radiation Pattern Characteristics

Figures 9, 10, 11 and 12 show the radiation pattern of inset feed for the antennas (Single, 1x2, 2x2 and 2x4).
After we simulated we get the value of return loss and we get the operating frequency.

At this frequency, we get the maximum gain.
We consider as the element (antenna) is increased, the gain is increase and the beam-width is decreased. But we must know when we use array antenna the side lob is increased. To avoid this problem we increase the space between radiating elements.

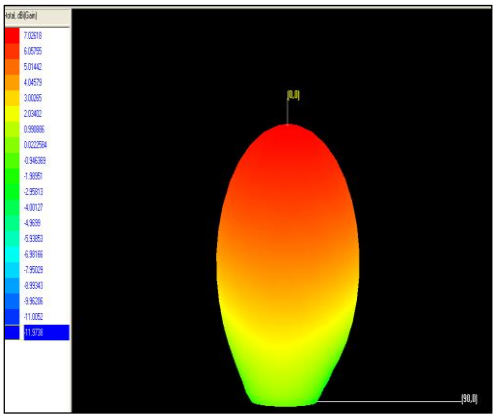

Figure 9: Single Antenna 3D radiation pattern for inset feed

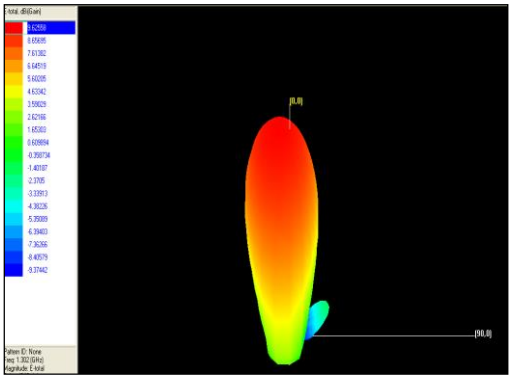

Figure10: 1x2 Antenna 3D radiation pattern for inset feed

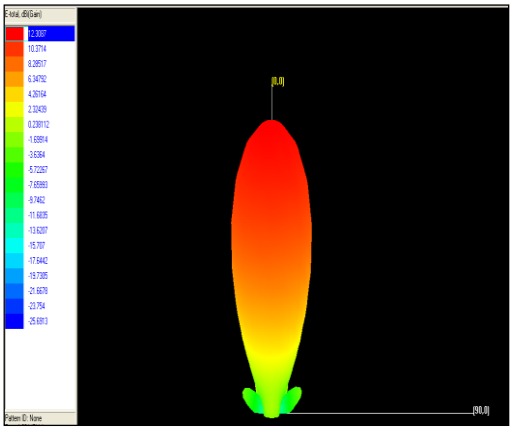

Figure 11: 2x2 Antenna 3D radiation pattern for inset feed

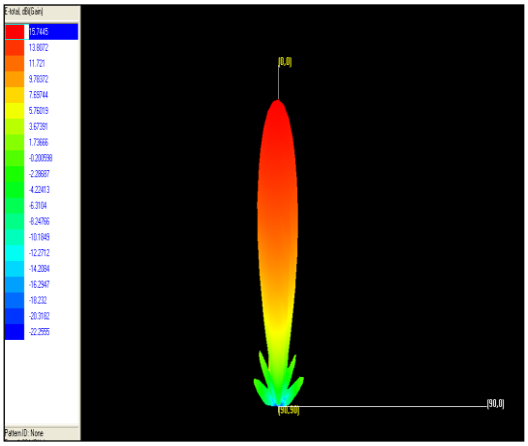

Figure 12: 2x4 Antenna 3D radiation pattern for inset feed

There is other important parameter for antenna which is called “beam-width”. We can get the beam-width from the 2D- radiation at half-power (-3dB) from the two side of 2D radiation and take difference between two values.

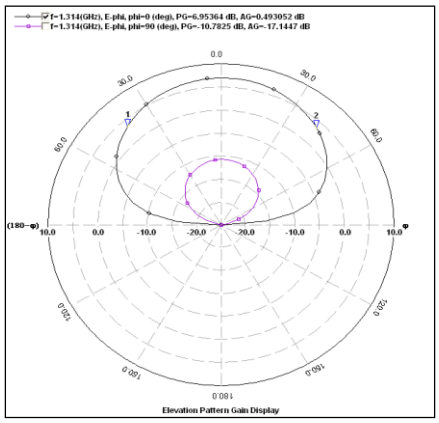

Figure 13: 2D radiation power with Inset feed for single antenna

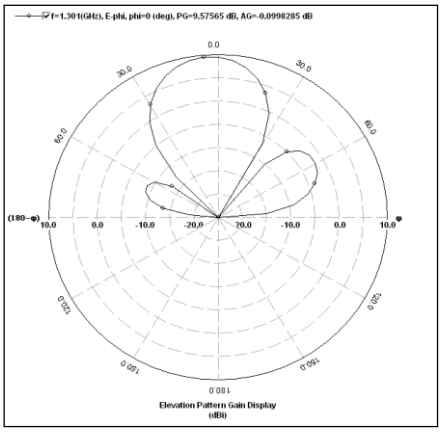

Figure 14: 2D radiation power with Inset feed for 1x2 antenna

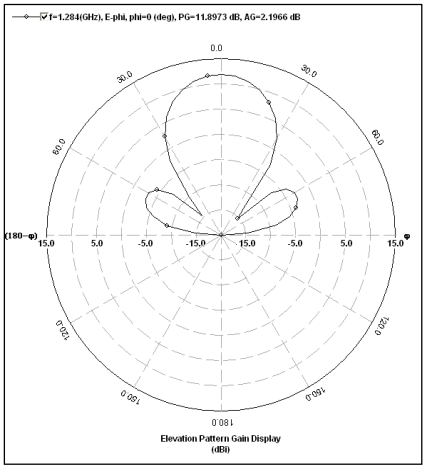

Figure 15: 2D radiation power with Inset feed for 2x2 antenna

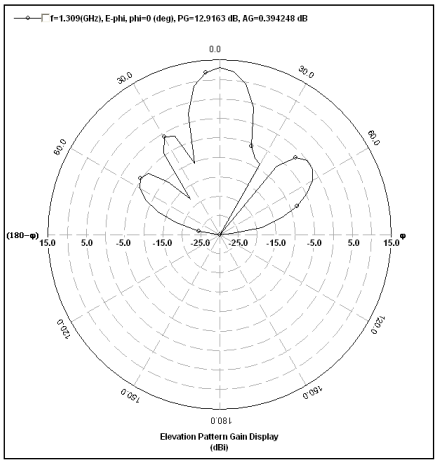

Figure 16: 2D radiation power with Inset feed for 2x4 antenna

Table 2: Essential parameter of Single, 1x2, 2x2 and 2x4

Array/Dimension	Gain (dBi)	3 dB beam-width
Single	7.03	84.259 º
1x2	9.627	43.46 º
2x2	12.31	47.528º
2x4	15.74	23.5º

There's another frequency used for GPS which is 1.575 GHz. We will compare between two frequencies (1.3 GHz and 1.575 GHz) with different antenna parameters: Return loss, gain, bandwidth and beam-width.

4. Antenna Array Design

4. 1 Design and Network Analysis for single Antenna

Antenna design for a single patch antenna with inset feed is shown below in figure 17.

- Length and width of the Patch = 64.1 mm
- Width of the 50 Ω line = 2 mm
- Length of the 50 Ω line = 25 mm

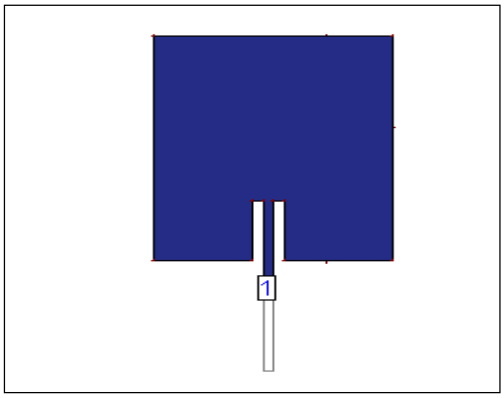

Figure 17. Geometry of Single Microstrip antenna array with Inset feed.

4.2 Design and Network Analysis for 2x1 Antenna Array

Antenna design for 2x1 patch antenna with inset feed is shown below in figure 18

- Length and width of the Patch = 76 mm
- Width of the 50 Ω line = 4 mm
- Length of the 50 Ω line = 8 mm

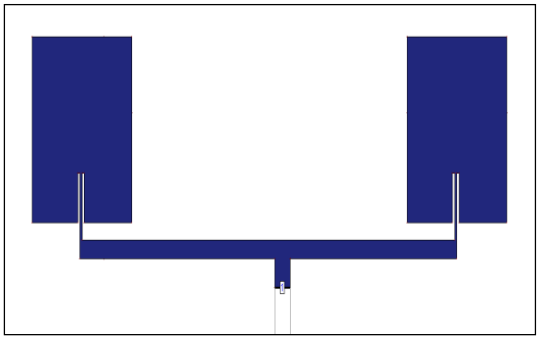

Figure 18. Geometry of 1x2 Microstrip antenna array with Inset feed.

4.3 Design and Network Analysis for 2x2 Antenna Array

Antenna design for 2x2 patch antenna with inset feed is shown below in figure 19.

- Length and width of the Patch = 64.1 mm
- Width of the 50 Ω line 15 mm
- Length of the 50 Ω line 30 mm

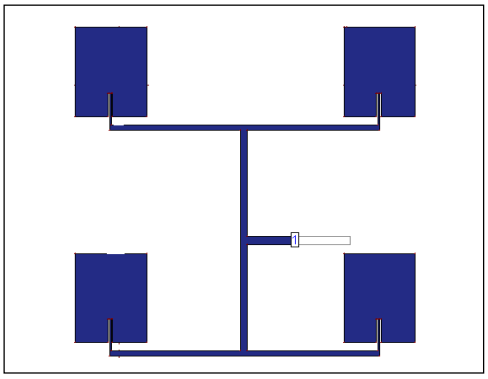

Figure 19. Geometry of 2x2 Microstrip antenna array with Inset feed.

4.4 Design and Network Analysis for 2x4 Antenna Array

Antenna design for 2x4 patch antenna with inset feed is shown below in figure 20.

- Length and width of the Patch = 64.1 mm
- Width of the 50 Ω line = 20 mm
- Length of the 50 Ω line = 48 mm

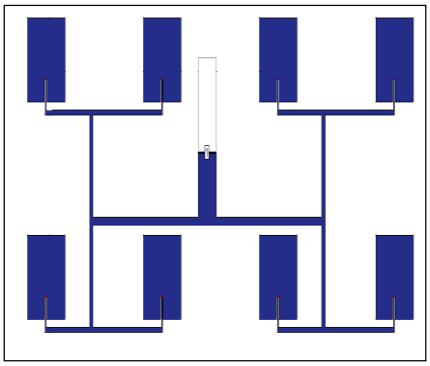

Figure 20. Geometry of 2x4 Microstrip antenna array with Inset feed.

5. Results on Performance Characteristic of Wearable Antenna

5.1Return Loss Characteristics

The inset feed is designed for single, 1x2, 2x2 and 2x4 Microstrip array antennas. Figures 21, 22, 23 and 24 demonstrate the return loss of single, 2x1, 2x2 and 2x4 antenna arrays

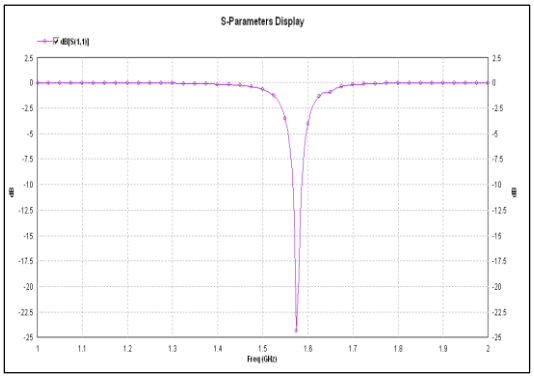

Figure 21. Return Loss Characteristics single Microstrip antenna.

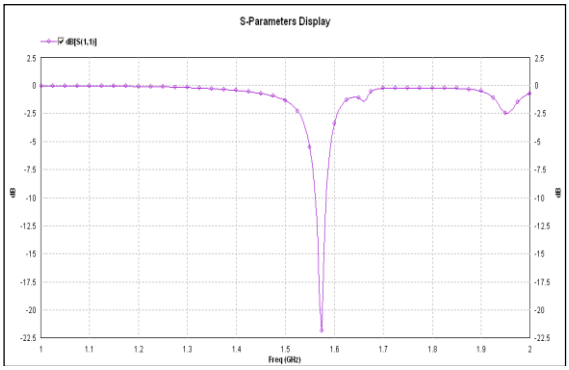

Figure 22. Return Loss Characteristics 1x2 Microstrip array antenna.

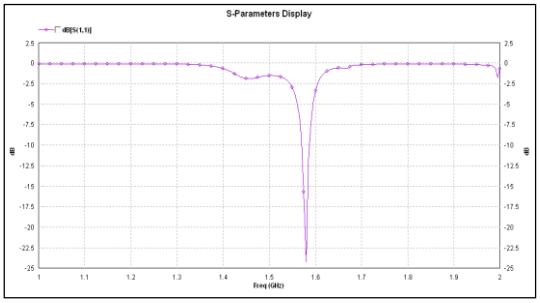

Figure 23. Return Loss Characteristics 2x2 Microstrip array antenna.

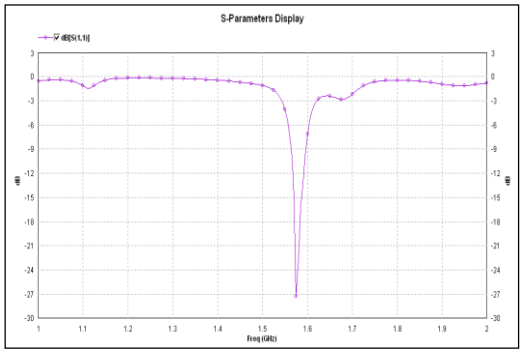

Figure 24. Return Loss Characteristics 2x4 Microstrip array antenna.

Table 3: Comparing between single, 1x2, 2x2 and 2x4 Microstrip array antenna

Array/Dimension	Resonant frequency (GHz)	Bandwidth (MHz)	S11 parameter (dB)
Single	1.575	21.47 MHz	-24.179
1x2	1.575	23.73 MHz	-21.59
2x2	1.579	16.9 MHz	-23.619
2x4	1.575	29.37 MHz	-27

5.2 Far-field Radiation Pattern Characteristics

Figures 25, 26, 27 and 28 show the radiation pattern of inset feed for the antennas (Single, 1x2, 2x2 and 2x4).
After we simulated we get the value of return loss and we get the operating frequency.

At this frequency, we get the maximum gain
We noticed that as the number of antenna elements is increased the gain is increased and the beam-width is decreased. We observed that, when we used array

antenna the side lob is increased. To avoid this problem we increase the space between radiating element.

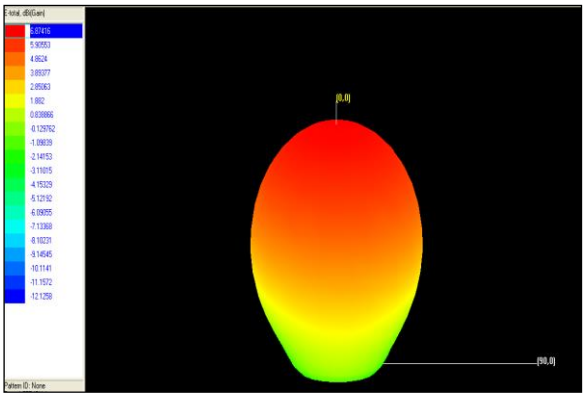

Figure 25: single Antenna 3D radiation pattern for inset feed

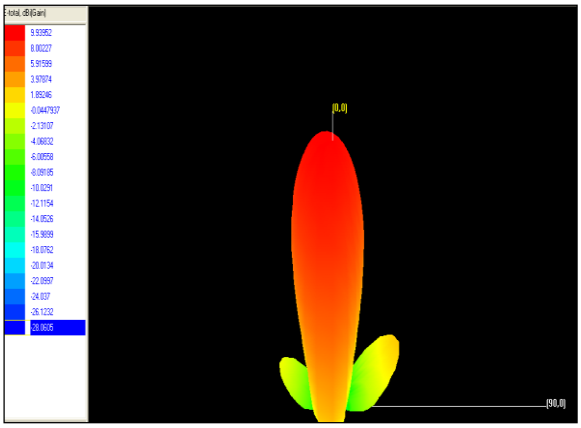

Figure 26: 1x2 Antenna 3D radiation pattern for inset feed

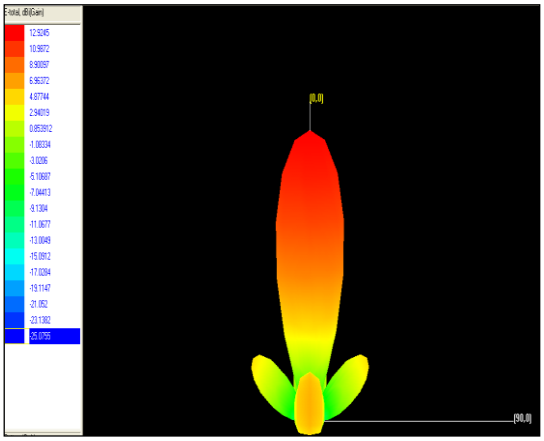

Figure 27: 2x2 Antenna 3D radiation pattern for inset feed

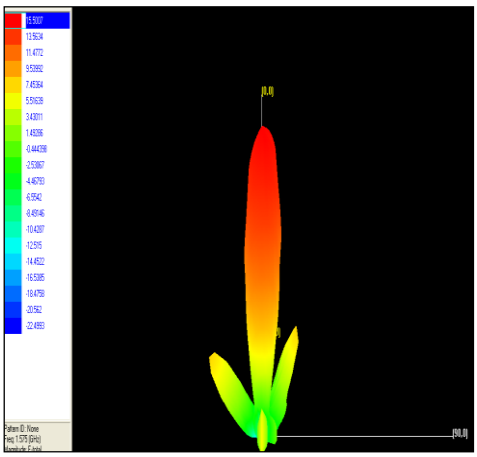

Figure 28: 2x4 Antenna 3D radiation pattern for inset feed

There is other important parameter for antenna which is "beam-width". We can get the beam-width from the 2D- radiation at half-power (-3dB) from the two side of 2D radiation and taken the difference between two values.

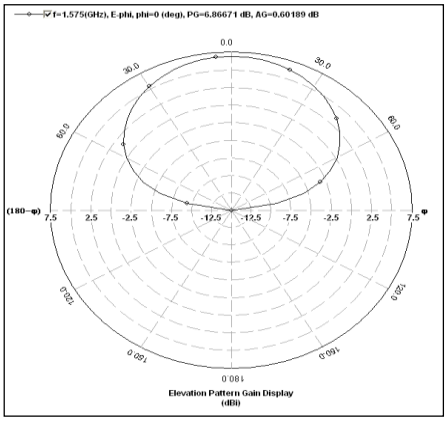

Figure 29: 2D radiation power with Inset feed for single antenna

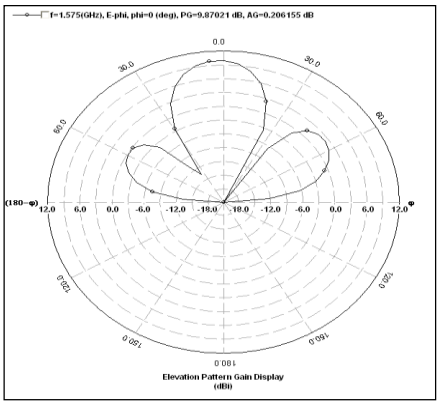

Figure 30: 2D radiation power with Inset feed for 1x2 antenna

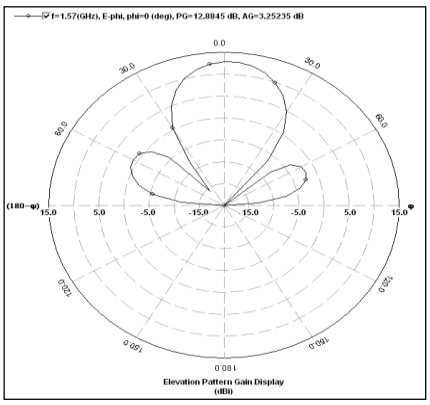

Figure 31: 2D radiation power with Inset feed for 2x2 antenna.

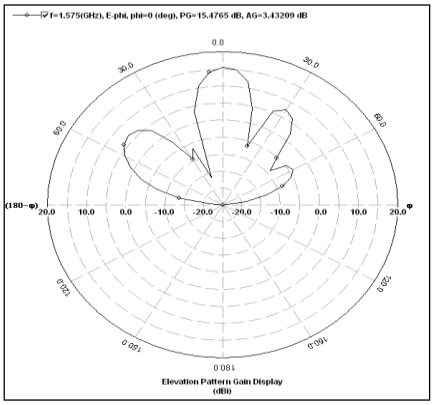

Figure 32: 2D radiation power with Inset feed for 2x4 antenna

Table 4: Essential parameter of Single, 1x2, 2x2 and 2x4

Array/Dimension	Gain (dBi)	3 dB beam-width
Single	6.07	88.93
1x2	9.98	37.27
2x2	12.92	44.286
2x4	15.50	22.6

6. Conclusion

Finally, we noticed after we have viewed all simulated parameters for two operating frequencies 1.3GHz and 1.575GHz that the efficiency and the best geometry was the antenna with 1.575GHz. In one hand, the Beam-width must be smaller because with satellite the beam-width at 2 x 4 array antenna for 1.3GHz is 23.5° but the beam- width for 1.575 GHz at 2 x 4 array antenna is 22.6°.On the other hand, the gain at 1.3 GHz for 2 x 4 antenna is larger than the gain at 1.575 GHz in the same dimension and it equal to 15.74 dBi.

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