IOSR Journal of Engineering (IOSRJEN)
e-ISSN: 2250-3021, **p**-ISSN: 2278-8719
Vol. 3, Issue 12 (December. 2013), ||V1|| PP 01-07

Design of Microstrip Array Antenna for Wireless Communication Application

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Abstract: - In the recent years the development in Wireless systems requires the development of low cost, minimal weight and low profile antennas that are capable of maintaining high performance over a wide spectrum of frequencies. This technological trend has focused much effort into the design of a microstrip patch antenna. The objective of this paper is to design, and fabricate a fed rectangular microstrip patch antenna (E-Shape). The operating frequencies of antenna are from 1.85GHz to 1.99GHz, which governs the resonant frequency 1.9GHz of the antenna. Two parallel slots are cut to perturb the surface current path that is corporate into the patch to expand its bandwidth. Initially we set our antenna as a single patch and after evaluating the outcomes of antenna features; operation frequency, radiation patterns, reflected loss, efficiency and antenna gain, we transformed it to a 1x2 linear array. Finally, we analyzed the 1x4 corporate feed linear microstrip patch array antenna that has been designed with dielectric constants of $\boldsymbol{\varepsilon_r}$=2.2 with fixed substrate height of h=1.5748mm (substrate RT/ Duroid 5880).

Keywords: *- Microstrip patch antenna, 1.9 GHz, single patch antenna, 1x2 linear array antenna, 1x4 linear array antenna and antenna gain.*

I. INTRODUCTION

Wireless communication has become an integral part for modern world .the most popular standard for mobile phones in today's world is CDMA. The wireless providers use individual radio frequencies multiple times by dividing a service area into separate geographical zones, or cells, each cell requires its own radio transmitter/receiver antenna. CDMA systems operate in different frequency ranges in different countries around the world. Most CDMA systems operate in the 1850 MHz to 1990 MHz frequency bands in world [1]. Microstrip patch antenna is promising to be a good candidate for the future technology. Microstrip patch antenna consists of a dielectric substrate, with a ground plane on the other side. Due to its advantages such as low weight [1], low profile planar configuration, low fabrication costs and capability to integrate with microwave integrated circuits technology [2], the microstrip patch antenna is very well suited for applications such as wireless communications system, cellular phones, pagers, Radar systems and satellite communications systems. Although patch antenna has numerous advantages, it has also some drawbacks such as restricted bandwidth, low gain, excitation of surface waves and a potential decrease in radiation pattern [3]. L-slot patch antenna [4], annular slot antenna, double patch antenna, E-shaped patch antenna[3], and feeding techniques like L-probe feed [5], circular coaxial probe feed , proximty coupled feed [6,7] are used to enhance bandwidth of microstrip patch antenna.

The bandwidth can be increased by adding loss elements but it affects efficiency of the antenna. So the better method is to use array antenna. In this design of rectangular (E-Shape) microstrip array antenna for CDMA applications, the transmitter antenna array is expected to operate within 1850MHZ-1910MHz with center frequency 1880 MHz, bandwidth 60MHz and receiver array antenna within 1930 MHZ-1990MHz with center frequency 1960 MHz, bandwidth 60MHz This antenna array is fabricated in RT/D 5880 substrate.

Antenna Array: Microstrip antennas are very versatile and are used, among other things, to synthesize a required pattern that cannot be achieved with a single element. In addition, they are used to scan the beam of an antenna system, increase the directivity, and perform various other functions which would be difficult with any one single element. The elements can be fed by a single line or by multiple lines in a feed network arrangement, so in this paper we used an array to develop the performance of this antenna. One of the essential parameters for the design of a rectangular Microstrip patch antenna (E-Shape) is the Frequency of operation (f_0) is 1.9 GHz. In our work, we initially selected the value of the substrate. Then, we evaluated the length, the width, the input impedance of the patch and the nested fed dimensions. After that, we changed the dimensions to get better performance of the antenna, i.e. radiation patterns, reflected loss, efficiency and antenna gain by simulating it using electromagnetic simulator IE3D [5,8].

The main goal of this paper is to design with a performance analysis of a corporate microstrip line feed 1x4 array rectangular (E-Shape) microstrip patch antennas and as well as improvement of bandwidth.

The next section describes the physical parameters of antenna and the idea of operation. Section III covers the simulation process and results analysis. Section IV shows the conclusion.

II. PHYSICAL PARAMETERS OF ANTENNA

Some important antenna parameters can be calculated by the transmission line method [8-10] and is explained to ease our design process, this model is written in Matlab script and the results of each parameter are shown in table 1 below [11]. The three essential parameters for the design of a rectangular Microstrip Patch Antenna are: Frequency of center operation (f_0 =1.9 GHz), (ε_r=2.2) and (h =1.5748 mm). Calculating the wavelength (λ), since C = 3x108 m/s so λ = C /f∘ =116mm.[11]

A. Width of the Patch (w)

Numerically, the width of the microstrip patch can be calculated using the equation as [10]

$$w = c/2 f_\circ \sqrt{(\varepsilon_r + 1)/2} = 62.4 \text{ mm}$$

B. Length of the Patch (L)

The length of the patch can be calculated only if the effective dielectric constant is known [9], and the effective dielectric constant can be calculated as

$$\varepsilon_{eff} = 0.5(\varepsilon_r + 1) + 0.5(\varepsilon_r - 1)\ [\ 1 + 12h/w\ ]^{-\frac{1}{2}} = 2.285$$

The effective length is: $L_{eff} = C/(2 f_\circ \sqrt{\varepsilon_{eff}}) = 52.23$ mm ;

The length extension is:

$$\triangle L = (0.412\, h)\, (\varepsilon_{eff} + 0.3) * ((W/h) + 0.264)/(\varepsilon_{eff} - 0.258) * ((W/h) + 0.8) = 0.816 \text{ mm}$$

$$L = L_{eff} - 2 \triangle L = 50.6 \text{ mm}$$

C. Input Impedance

The input impedance can be obtained by the equation [12]; $X_f = L/\sqrt{\varepsilon_{eff}}$ =33.7 mm

Where X_f is the desired input impedance of the coaxial cable and ε_{eff} is the effective dielectric constant.

Similarly, the admittance can be found using the equation.

$Y_f = 0.5\, W = 31.2$mm

D. Ground Dimension

For practical design, it is necessary to have some finite ground plane. For optimum design of small patch antenna, it is required that the ground plane should be greater than the patch dimensions by approximately six times the substrate thickness all around the fringe [9,13]. Hence, the ground plane dimensions (L_g x w_g x h_0) would be given as:

$L_g = 6\,h + L = 59.6 \approx 60$ mm , $w_g = 6\,h + w = 71.8 \approx 72$ mm ; $h_0 = 1$mm

The above quoted physical parameter equations for antenna design is used to set the input parameters of the microstrip patch antenna. We simulate the antenna by varying the number of microstrip patches and the effect was observed on the directivity and radiation pattern.

Table 1: Optimize Parameters for E-Shaped Patch single Antenna, 1x2 and 1x4Array.

Substrate (RT/D 5880)	Rectangular patch (L, w) mm	Slots parameters (l_1 , w_1, l_2, w_2) mm	Ground L_g , w_g h_0= 1 mm	Feeding	inter-element spacing
Single	62.4; 54.6	25,11 - 31, 9.2	70, 65.3		-
1X2 array	62.4; 54.6	25,11 - 31, 9.2	150 , 80	corporate-	13.6
1X4 array	62.4; 54.6	25,11 - 31, 9.2	335 , 125	feed array	13.6

2-1 Design of Array Antenna

It is a known fact that changes in current distribution maneuvers the radiation pattern in case of arrays. In order to analyze the affect of current distribution on arrays, E-shaped microstrip antenna arrays consisting to two and four elements are designed at the specified frequency. The most critical aspect of designing antenna array is the inter-element spacing, the spacing can be between 0.2 λ to λ; but after rigorous simulations, it is observed that the results are best when the inter-element spacing is set to be 13.6 mm. The feeding network of all the designed arrays consists of corporate feeding technique with quarter wave transformers and the patch used in building arrays has the same dimensions as that of a single E-shaped patch antenna [12,14]. In order to make the design clear all the specifications of designed antenna arrays are listed in Table 1.

2.1.1. single Element Antenna

The geometry of proposed antenna is shown in figure 1. The design consists of E patch and a rectangular radiator. The structure is mounted on 70×65.3 mm ground plane. Patch antenna, radiator and ground plane are made of 17µm thick copper sheet. The antenna is coaxial fed where the location of the Edge on the E patch is shown in figure 1a. The dimensions of the antenna are given in Table 1and the shaped single antenna is shown in Fig. 1.a.

2.1.2. 1x 2 Array Antennas

The designed two element antenna arrays consists of two E-shaped patches of similar dimensions as that of single E-shaped antenna with corporate feeding technique and have quarter wave transformers for impedance matching. The input impedance of the feeding network is of 50Ω and SMA connector of same impedance is used. All the necessary dimensions of two element array is listed in Table 1 and the shaped 1x2 arrays is shown in Fig. 1.b

2.1.3. 1x 4 Array Antennas

The designed four element array consists of four E- shaped patches configured in the form of an array. The same feeding technique of corporate feed with transformers for impedance matching, SMA connector of 50Ω and inter-element spacing of 13.6 mm is used for designing the array. All the dimensions are listed in Table 1and the shaped 1x4 arrays is shown in Fig 1.c.

III. RESULT AND DISCUSSIONS

The performance of the antenna has been investigated by varying the number of microstrip elements in the antenna array. In this paper, we have shown the results for a single, 1x 2, and 1 x 4 antenna array elements and the effect on the gain, directivity and scattering pattern is observed.

The proposed antenna element is analyzed using the full-wave method of moment (MoM) technique with the aid of the zeland-IE3D full-wave electromagnetic simulator [5]. to calculate return loss, VSWR, impedance bandwidth, Current distribution and gains.

Fig. (2) Shows the simulated return loss (S11) parameter is better than -10dB within the frequency range of (1.84 -2.05) GHz, which means 11 % band-width enhancement

$$BW = \frac{(f_{L} - f_{H})}{f_{C}} X100$$

Fig 3 shows the graph of VSWR. The minimum value of VSWR of a single, 2x1 and 4x1 antenna arrays is about 1.15, 1.2, 1.6 at 1.9 GHz. The value of VSWR should be less than 2 for desirable communication.

Fig.4 Shows the simulated Directivity of the proposed patch antenna at various frequencies is shown in the figure, the maximum achievable Directivity of a single, 2x1 and 4x1 antenna arrays is 7dBi, 9dBi, 12dBi at the frequency of 1.9 GHz and the gain variation is one dBi between the frequency ranges of 1.85 GHz to 1.99 GHz.

Fig. 5 Shows the simulated gain of the proposed patch antenna at various frequencies is shown in the figure, the maximum achievable gain of a single, 2x1 and 4x1 antenna arrays is 5dBi ,7.5 dBi, 11dBi at the frequency of 1.9 GHz and the gain variation is 2dBi between the frequency ranges of 1.85 GHz to 1.99 GHz.

Fig 6 shows the antenna and radiation efficiency. The maximum radiation efficiency is occurred 80 % and maximum antenna efficiency is obtained about 77%.

Fig 7&8 shows the 3D and 2D radiation pattern view of proposed antenna of a single, 2x1 and 4x1antenna arrays.

IV. TESTING AND VALIDATION

In this paper we tested our design by using electromagnetic simulator (IE3D). This is an integral equation, method of moment, full-wave electromagnetic simulator. It includes layout editor, electromagnetic simulator, schematic editor and circuit simulator, near field calculation program, format converter, current and field display program. IE3D employs a 3D non-uniform triangular and rectangular mixed meshing scheme. It solves the current distribution, slot-field distribution, network s-parameters, and radiation patterns, near field on an arbitrarily shaped and oriented 3D metallic structure in a multi-layered dielectric environment. Simulation Output of 1x2 and 1x4 arrays antenna: After finishing our design for 1x2 and 1x4 arrays antenna, we tested it by IE3D. We obtained Figures: 2, 3, 4,5,6,7 and 8. The summary of outcomes is shown below in Table 2. [5]

V. CONCLUSION

Three different configurations of microstrip were designed based patch antennas by setting the input operating frequency of CDMA systems devices, i. e. 1.9 GHz. The directive gain of a a single, 1x2 and 1x4 arrays antenna is observed to be 5 dB, 7 dB and 12 dB. The results showed that 1 x 4 rectangular microstrip antenna array can work as an efficient microstrip antenna as it shows improved BW efficiency, directivity, gain

and radiation pattern. Moreover the patch area is very small as compared to conventional antenna and the directivity is high 12 dB as compared to the conventional antenna. Hence the antenna can operate well at the frequency 1.9 GHz as is required for operating the CDMA devices. It may be concluded that this antenna shows high directivity with reduced size. Due to increase in the directivity, it may be possible that this antenna can work for CDMA devices up to some Km in a more efficient manner than the available conventional antennas.
E-shaped antenna is designed and simulated over IE3D simulation software Ver. 14.2. The substrate used for the designing purpose has substrate thickness of 1.5748mm, dielectric constant 2.2 and loss tangent 0.0009. The designed antenna structure provides good results in Table 2.

Table 2: Results of 3 simulation single antenna, 1x2 and 1x4 arrays antenna.

Number of element	*S_{11} dB*	*VSWR*	*Gain dB*	*Directivity (dB)*	*Antenna efficiency*	*radiation efficiency*	*BW efficiency*
Single at 1.9GHz	*-25*	*1.15*	*5*	*7*	*63 %*	*88 %*	*8 %*
1X2 array at 1.9GHz	*-29*	*1.2*	*7.5*	*9*	*80 %*	*80 %*	*11 %*
1X4 array at 1.9GHz	*-13*	*1.5*	*11*	*12*	*77 %*	*80 %*	*16 %*

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Antenna single Patch Antenna   Antenna 1X2 Patch Antenna   Antenna 1X4 Patch Antenna

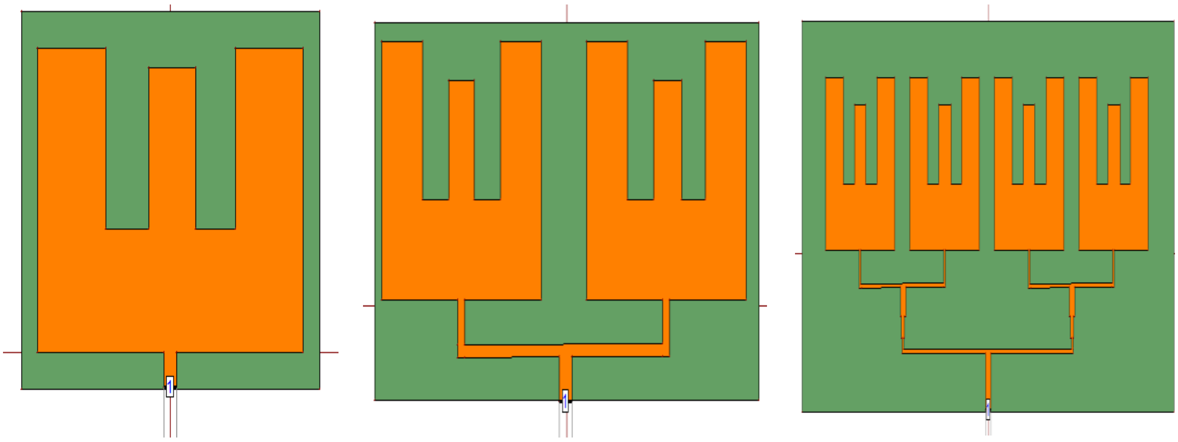

Fig. 1. Geometry of E-shaped microstrip antenna,

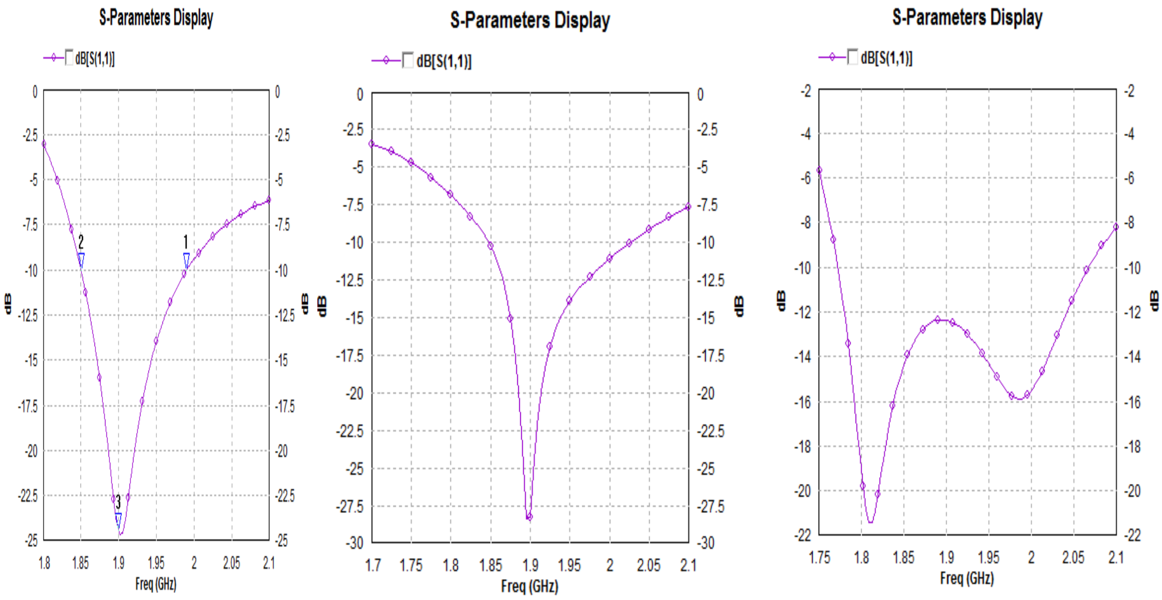

Fig 2 shows the return loss verses frequency.-25dB; -29dB; -13dB at 1.9GHz

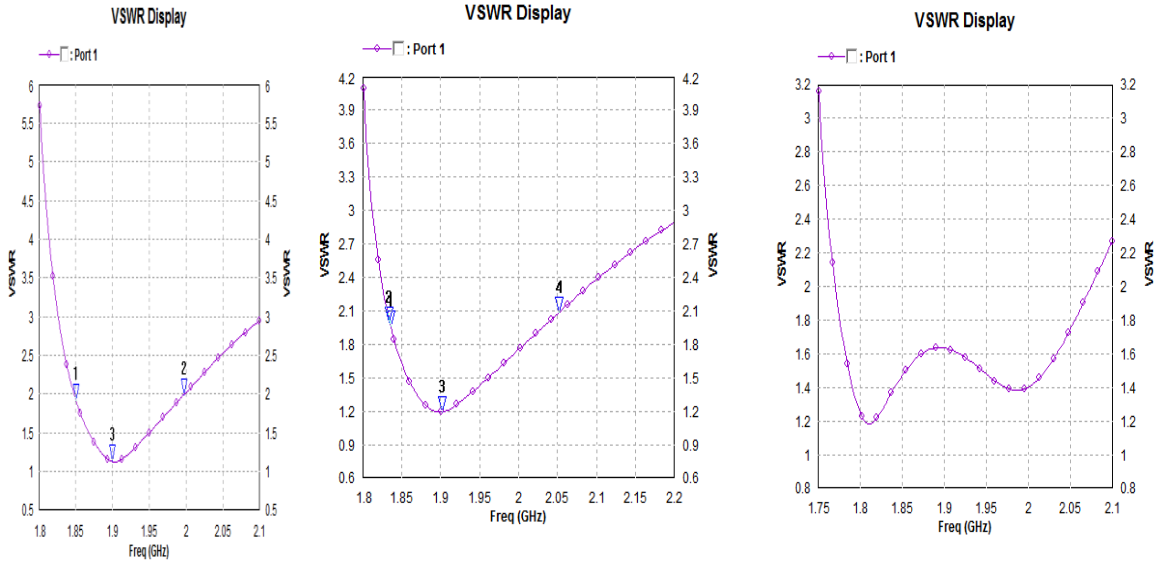

Fig. 3. Shows the simulated result of the VSWR =1.1; 1.2; 1.6 at 1.9GHz

single Patch Antenna | Antenna 1X2 Patch Antenna | Antenna 1X4 Patch Antenna

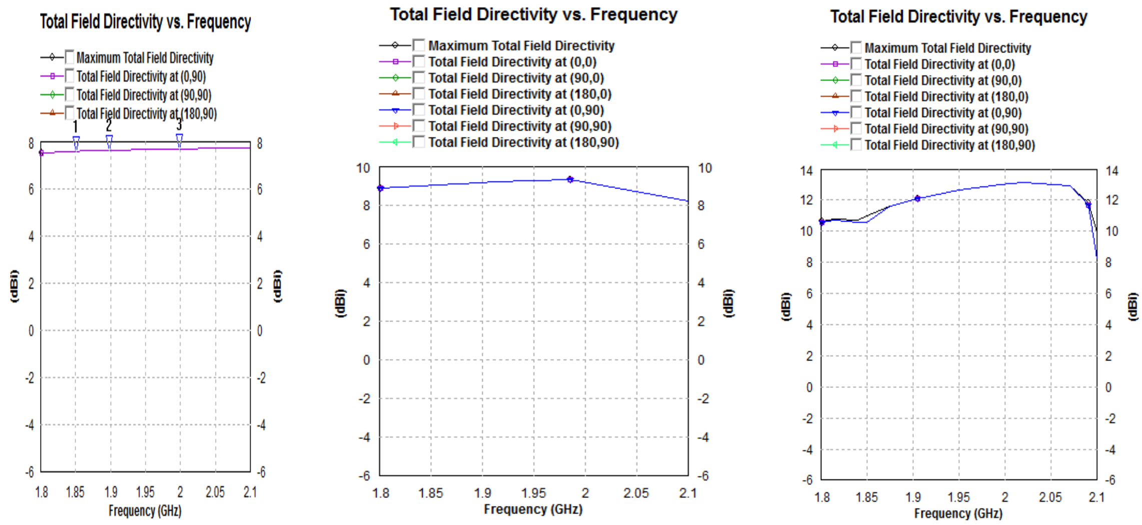

Fig. 4 Shows the simulated Directivity at various frequencies : 7dB;9dB;12dB at 1.9GHz

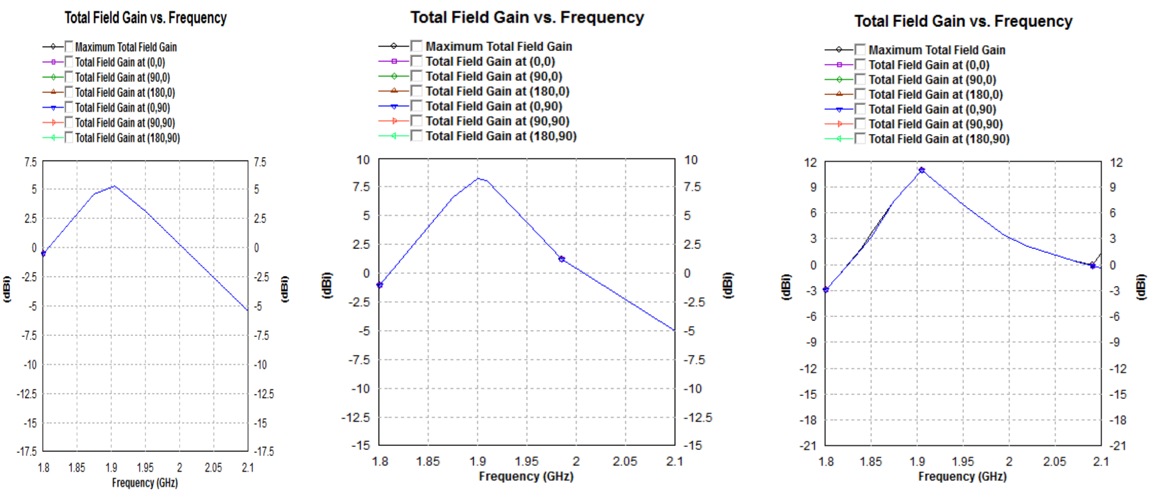

Fig. 5 Shows the simulated gain at various frequencies: 5dB;7.5dB;11dB at 1.9GHz

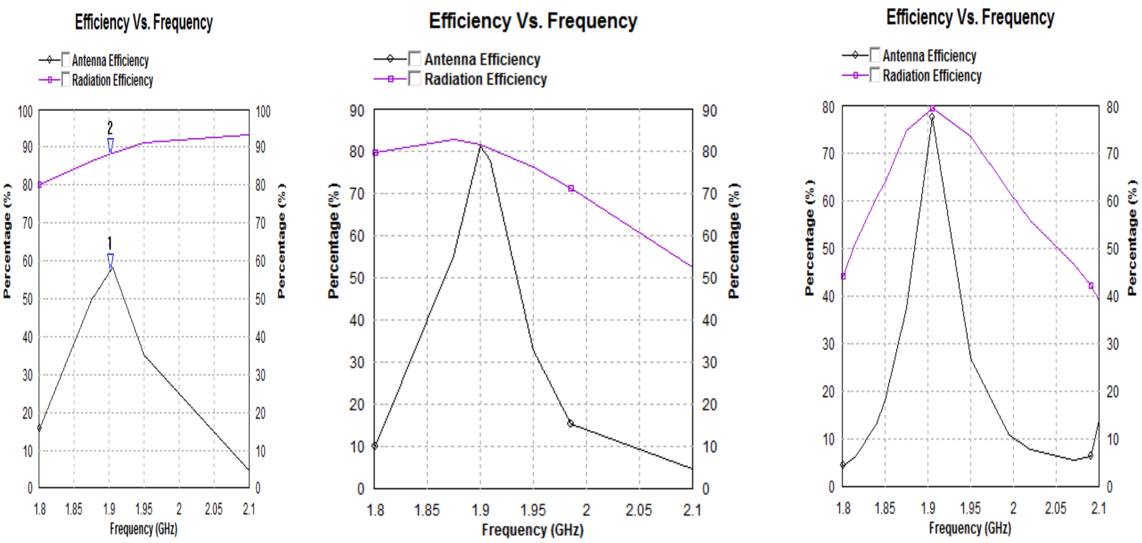

Fig 6 shows the antenna and radiation efficiency =63, 88 % ;80,80 %;77,80 % at 1.9GHz

single Patch Antenna Antenna 1X2 Patch Antenna Antenna 1X4 Patch Antenna

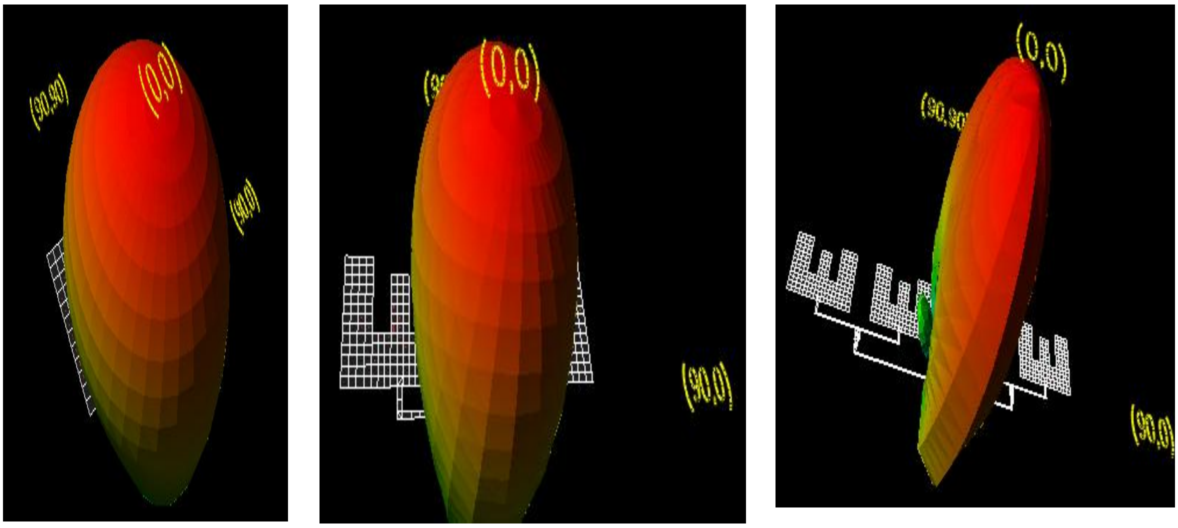

Fig. 7 shows the 3D radiation pattern view of proposed antenna 1; 2x1; 4x1.

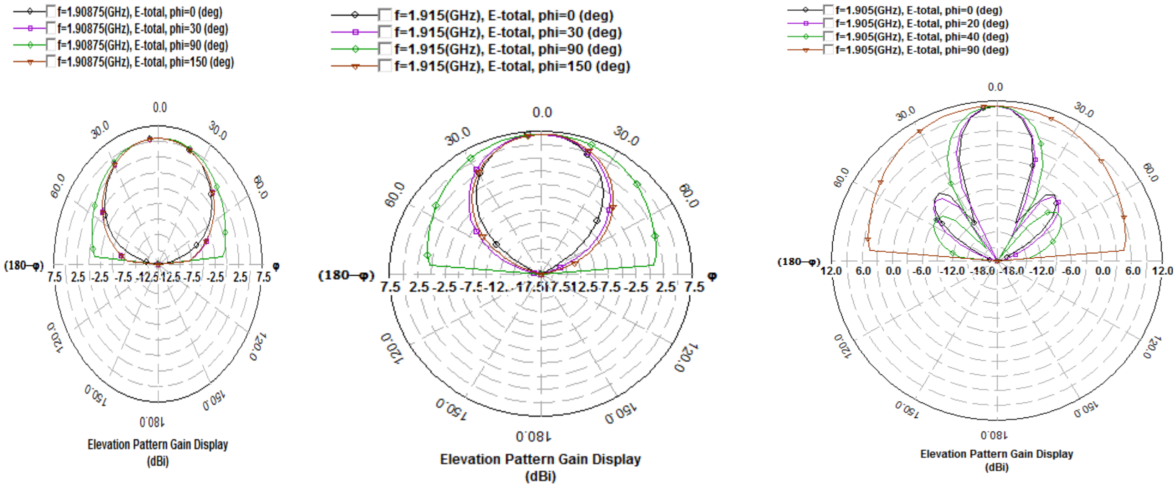

Fig. 8 shows the 2D radiation pattern view of proposed antenna 1; 2x1; 4x1.