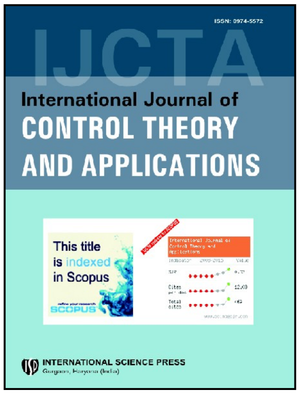

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Design, Simulation, Performance Analysis and Comparison of 1, 2x1, 4x1 & 8x1 Qwt Fed Circular Patch With a Rectangular Slit Antenna Arrays at 'L' Band for Airborne Applications

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Abstract: This paper, elucidates simulation and performance analysis of a QWT-fed 1, 2x1, 4x1 & 8x1 Circular Patch with rectangular slit Antenna arrays. The substrate material used for these antennas is RTDuorid5880 has thickness of 1.588mm and relative permittivity (år) is 2.2. The design frequency of the antenna is 2GHz and VSWR d” 2.The proposed antennas are modelled and simulated using ANSOFT HFSS. The radiation characteristics of above arrays are compared. These type of antennas are very useful for airborne applications.

***Keywords*: ** QWT (Quarter wave Transformer), Circular Patch Antenna, Gain, Return loss, Beamwidth

1. INTRODUCTION

Microstrip antennas are one of the most popular geometries are inexpensive to fabricate and can be easily made conformal to the host body. These attractive features have increased their application recently and stimulated an ever increasing effort to investigate their performance. Microstrip antenna has different shapes among circular patch antennas which is a symmetric one. In this paper the design and simulation of circular patch antenna with rectangular slit is presented. This configuration has been described earlier [1], [2]. This paper also discusses the design of 2x1, 4x1 and 8x1 element of circular patch with rectangular slit array antenna useful for airborne applications.

2. DESIGN OF SINGLE CPA WITH RECTANGULAR SLIT

The design of the microstrip line quarter wave transformer fed circular microstrip patch with rectangular slit antenna is shown in Fig.1.The design steps of the single CPA with rectangular slit are as follows:

(A) Design of Circular Patch

Radius of the patch

The radius 'R' of the patch is given by [3]:

$$R = \frac{F}{\left[1+\frac{2h}{\pi\varepsilon_r F\left[ln\left(\frac{F\pi}{2h}\right)+1.7726\right]}\right]^{1/2}} \quad (1)$$

$$\text{Where } F = \frac{8.791X10^9}{f_r\sqrt{\varepsilon_r}}$$

R = radius of the patch in mm; h = height of the patch substrate in mm; f_r = resonant frequency in Hz; ε_r = effective dielectric constant of the substrate.

Using the above expression the calculated radius is 28.52mm for 2GHz operating frequency, dielectric constant 2.2 and the height of the RTDuorid5880 substrate is 1.588mm

(B) Design of a Microstrip feed line

This design uses 50Ω microstrip to excite the patch antenna. From the known values of characteristic impedance Z_o and dielectric constant ε_r, the width of the microstrip line (W_f) is calculated as shown below [7].

$$\frac{W_f}{h} = \begin{cases} e^{\frac{8e^A}{e^{2A}-2}} & for\ \frac{W_f}{h} < 2 \\ \frac{2}{\pi}\left[B-1-\ln(2B-1)+\frac{\varepsilon_r-1}{\varepsilon_r+1}\left\{\ln(B-1)+0.39-\frac{0.61}{\varepsilon_r}\right\}\right] & for\ for\ \frac{W_f}{h} > 2 \end{cases} \quad (2)$$

$$\text{Where } A = \frac{Z_o}{60}\sqrt{\frac{\varepsilon_r+1}{2}} + \frac{\varepsilon_r-1}{\varepsilon_r+1}\left\langle 0.23+\frac{0.11}{\varepsilon_r}\right\rangle \quad (3)$$

$$\text{and } B = \frac{377\,\pi}{2Z_o\sqrt{\varepsilon_r}} \quad (4)$$

(C) Design of the Quarter wave Transformer

The quarter-wave transformer is a simple and useful method for matching real load impedance to different source impedance, and is frequently used in antennas [6].

The single section quarter-wave transformer has a length equal to quarter wave in microstrip and its characteristic impedance Z_c, should be given by [7]:

$$Z_c = \sqrt{(Z_o Z_{in})} \quad (5)$$

Where Z_0 = characteristic impedance = 50Ω

Z_{in} = input impedance of the circular patch. The width Wtr of the quarter-wave transformer can be finding out by equation (2) for calculated value of Z_c, from equation (5). With the above equation (5) the Zc of the impedance transformer is 130Ω for Zo is 50Ω and Zin is 340Ω. The geometry of the proposed circular patch antenna with rectangular slit is shown in Fig. 1.

The modeled structure of single circular patch antenna with a rectangular slit of dimensions Length (L_{slit})= 20mm and Width (W_{slit}) = 5mm are as shown below in fig. 2.

The performance charateristics of single circular patch antenna with rectangular slit are Return loss is -23.3759dB, Bandwidth 123 MHz, VSWR is 1.2957, Elevation Beamwidth is 100.7169°, Azimuth Beamwidth 69.8282°, Gain is 6.0721dB, directivity 6.199 dB and efficiency is 98% are shown below fig 3 to 10 respectively.

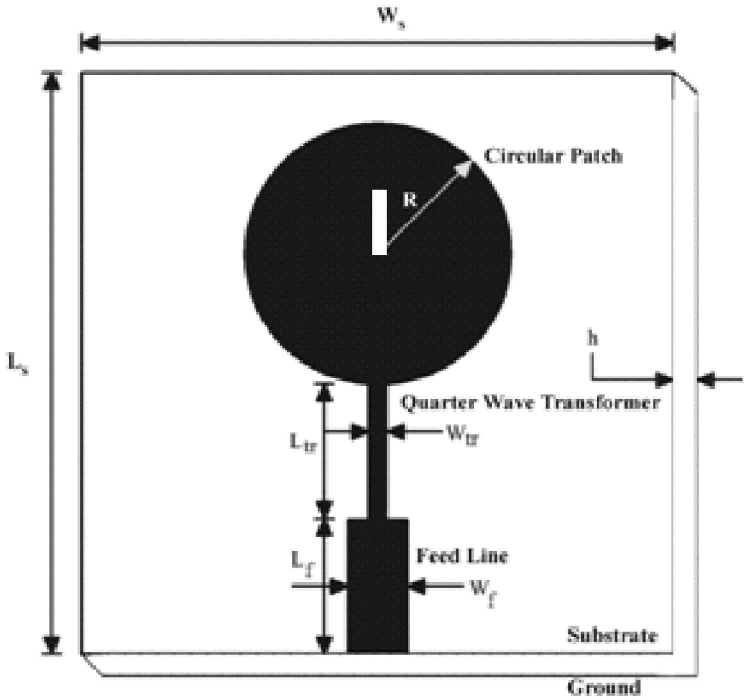

Figure 1: Geometry of the Circular Patch Antenna with a Rectangular Slit

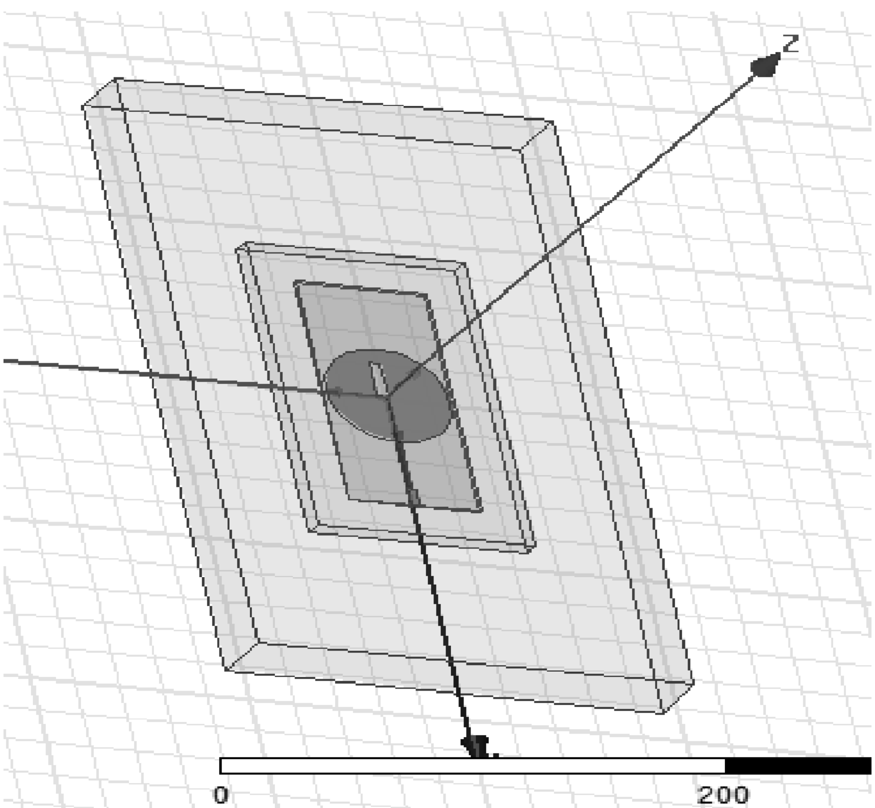

Figure 2: Structure of modeled single circular patch antenna

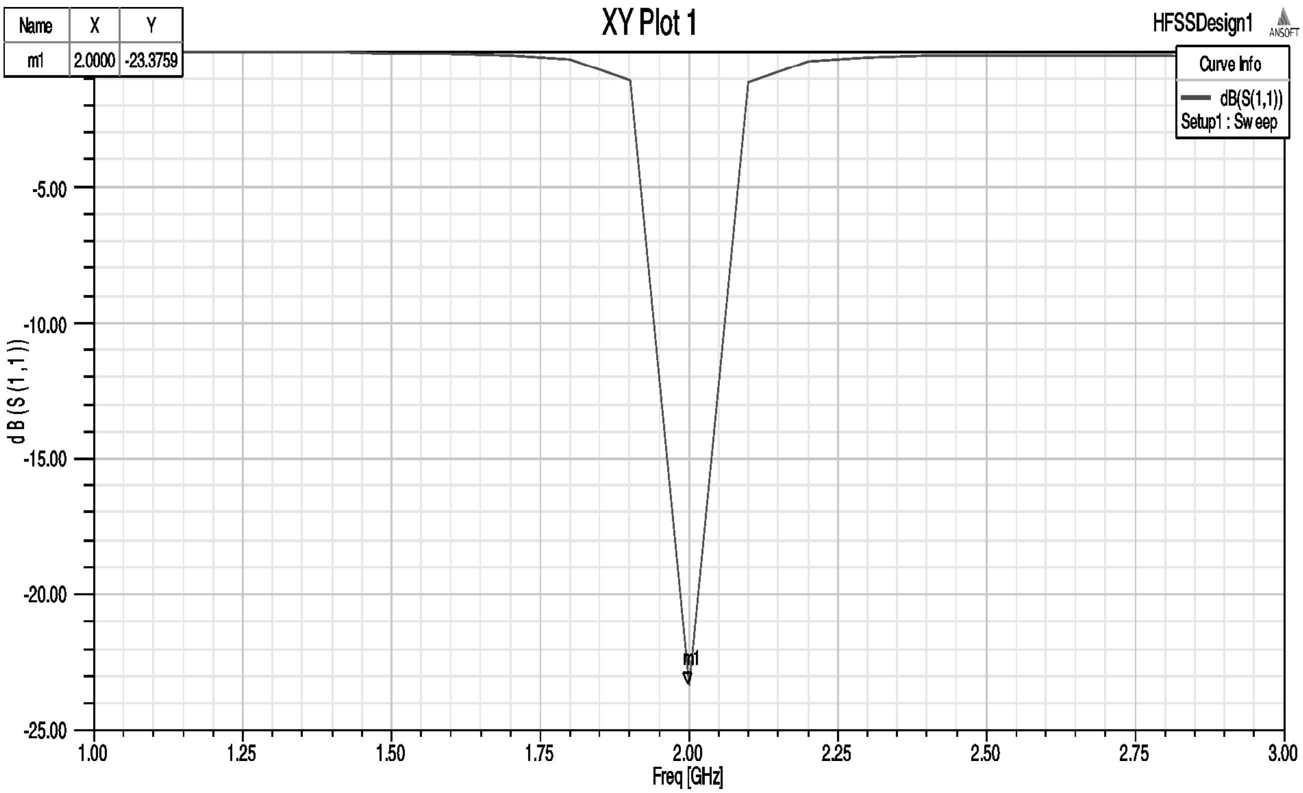

Figure 3: Return loss

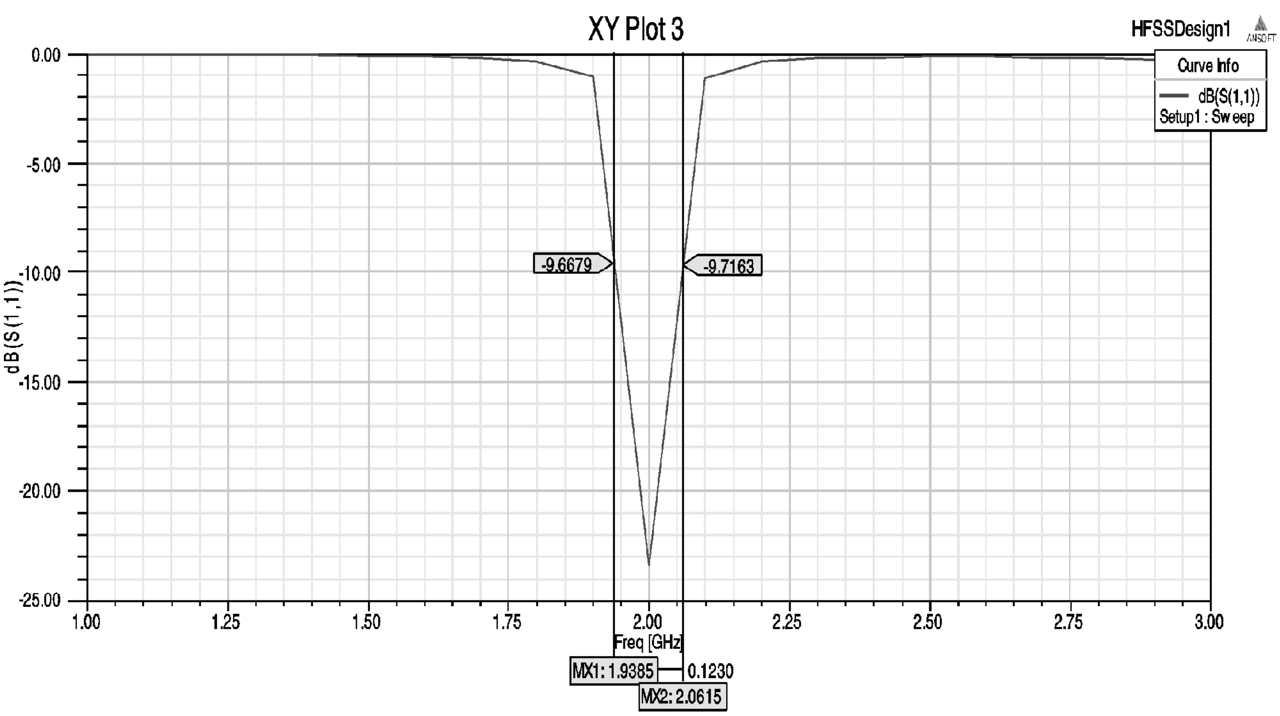

Figure 4: Bandwidth calculation

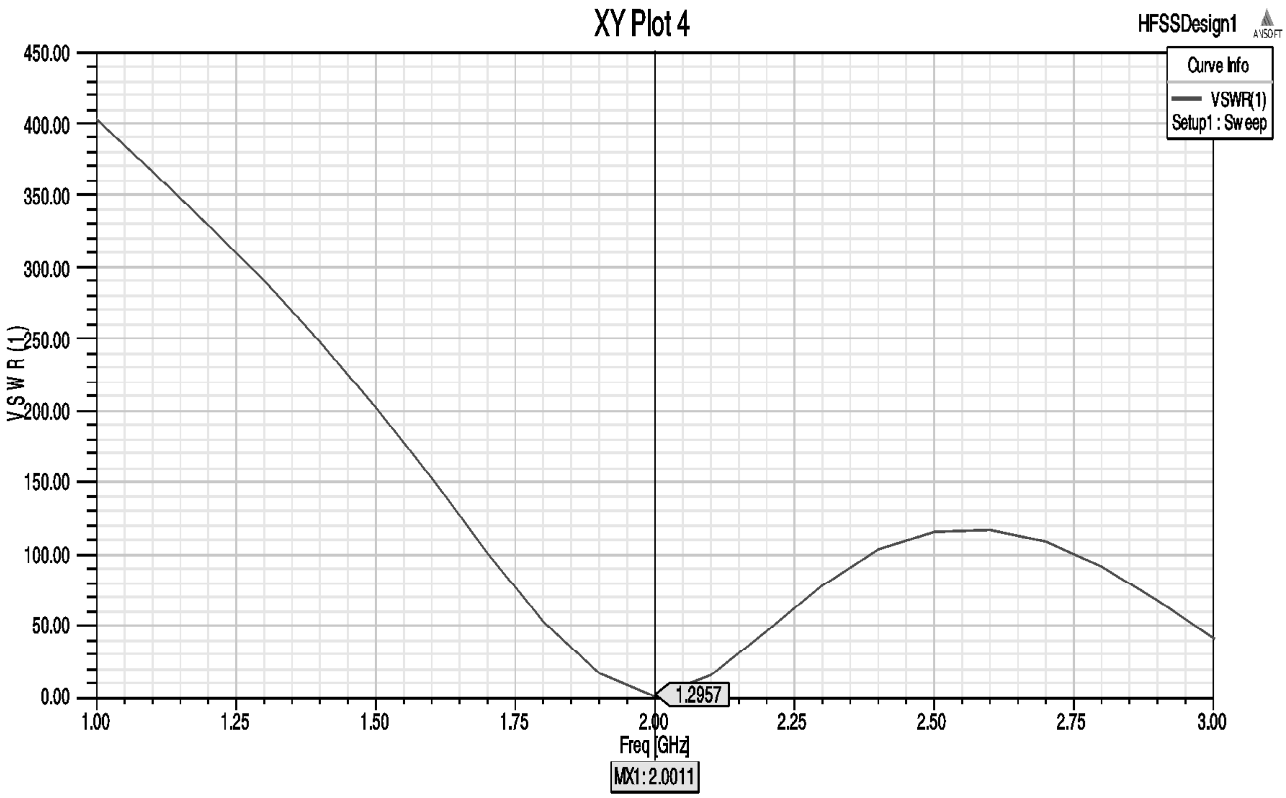

Figure 5: VSWR

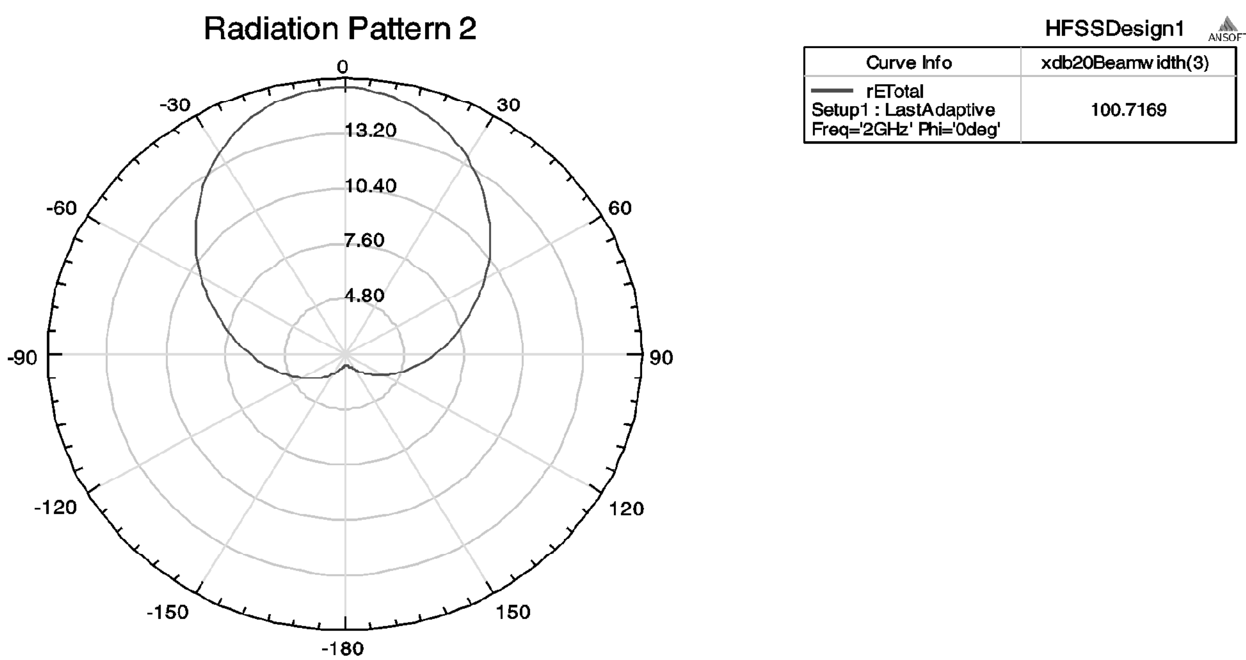

Figure 6: Elevation beamwidth

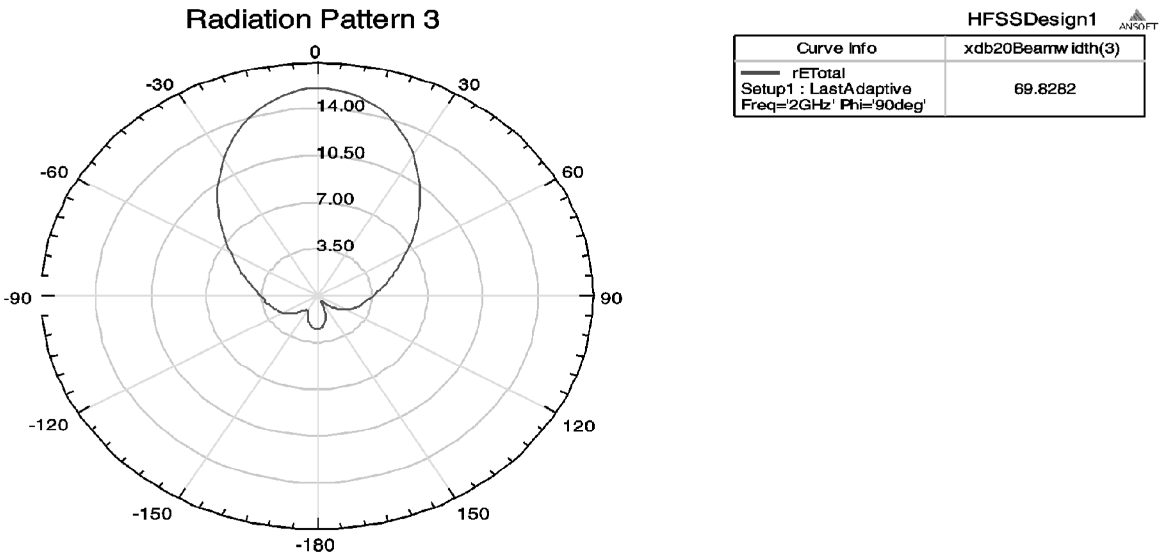

Figure 7: Azimuth beam width

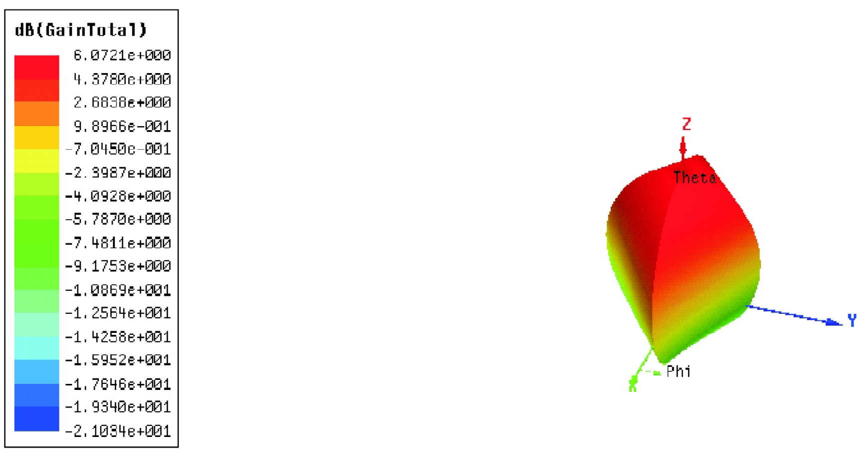

Figure 8: Gain

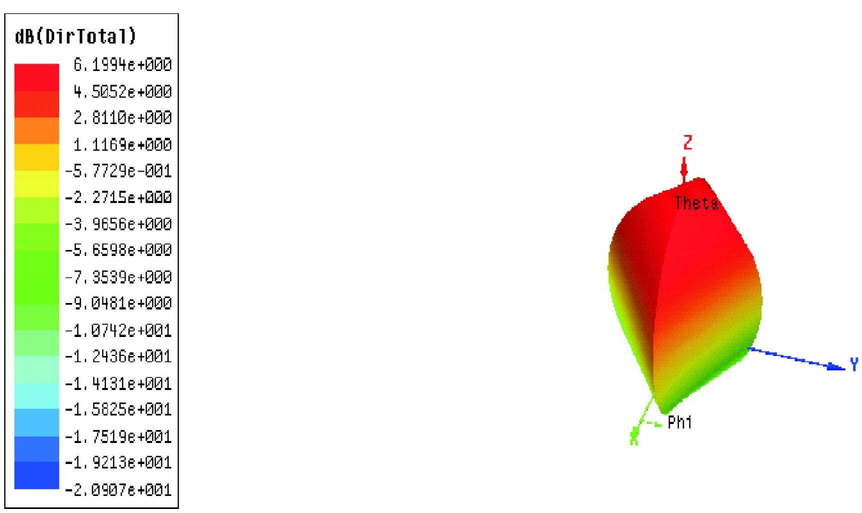

Figure 9: Directivity

Figure 10: Efficiency

3. PERFORMANCE OF 2X1 ELEMENTS ARRAY ANTENNA

The single QWT Fed circular patch with a rectangular slit antenna is used as the array element for this 2x1 elements array and the structure is as shown below fig. 11.

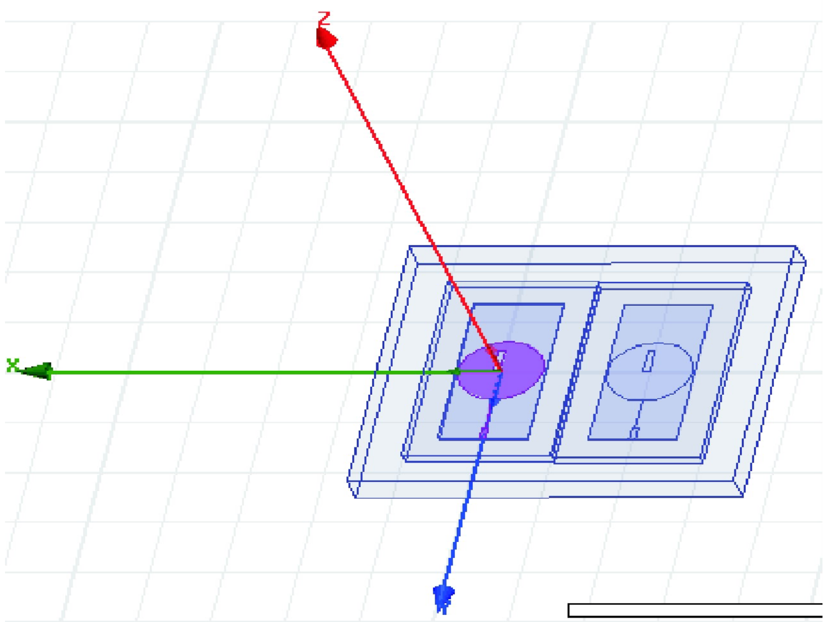

Figure 11: Structure of the 2x1 elements array

The performance charateristics of 2x1 element circular patch antenna with a rectangular slit are Return loss is -18.0777dB, Bandwidth 102 MHz, VSWR is 1.2951, Elevation Beamwidth is 45.6952^{o}, Azimuth Beamwidth 66.5869^{o}, Gain is 6.9134dB, directivity 7.0281 dB and efficiency is 98% are shown below fig 12 to 19 respectively.

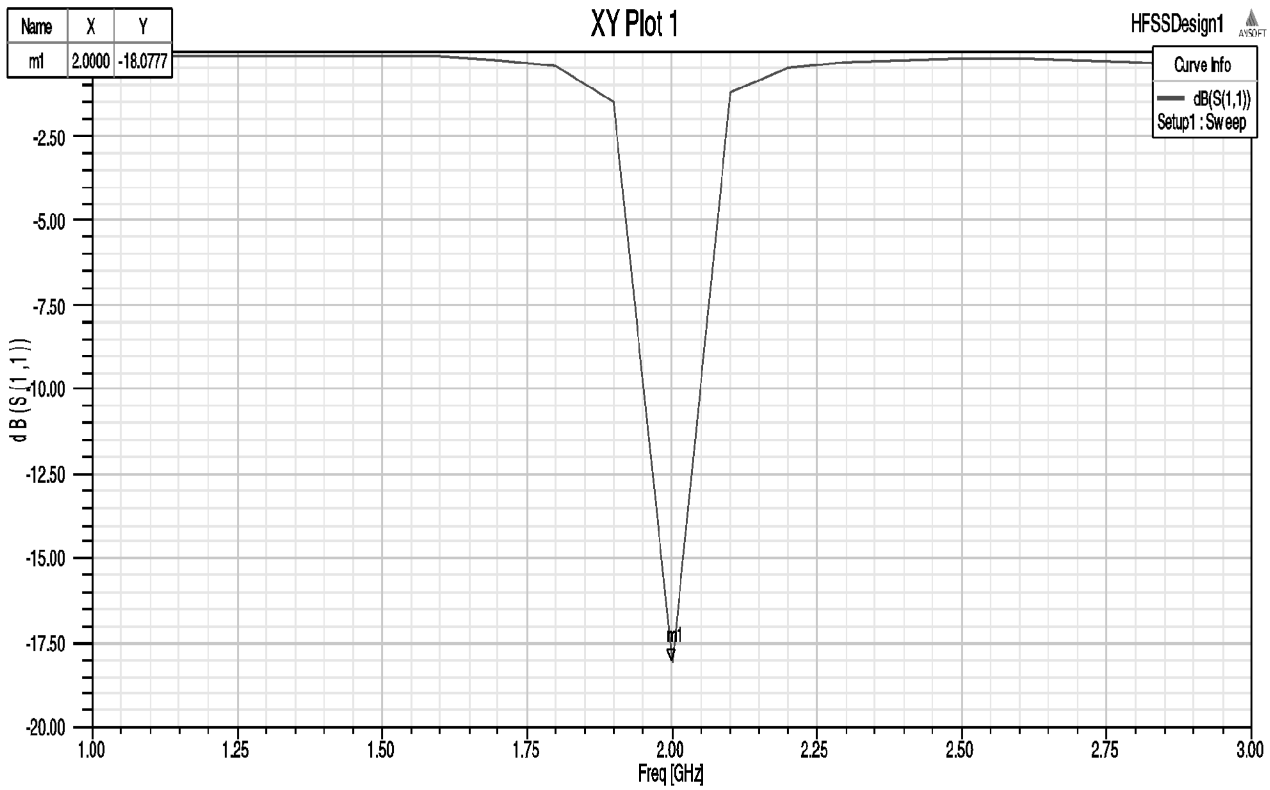

Figure 12: Return Loss

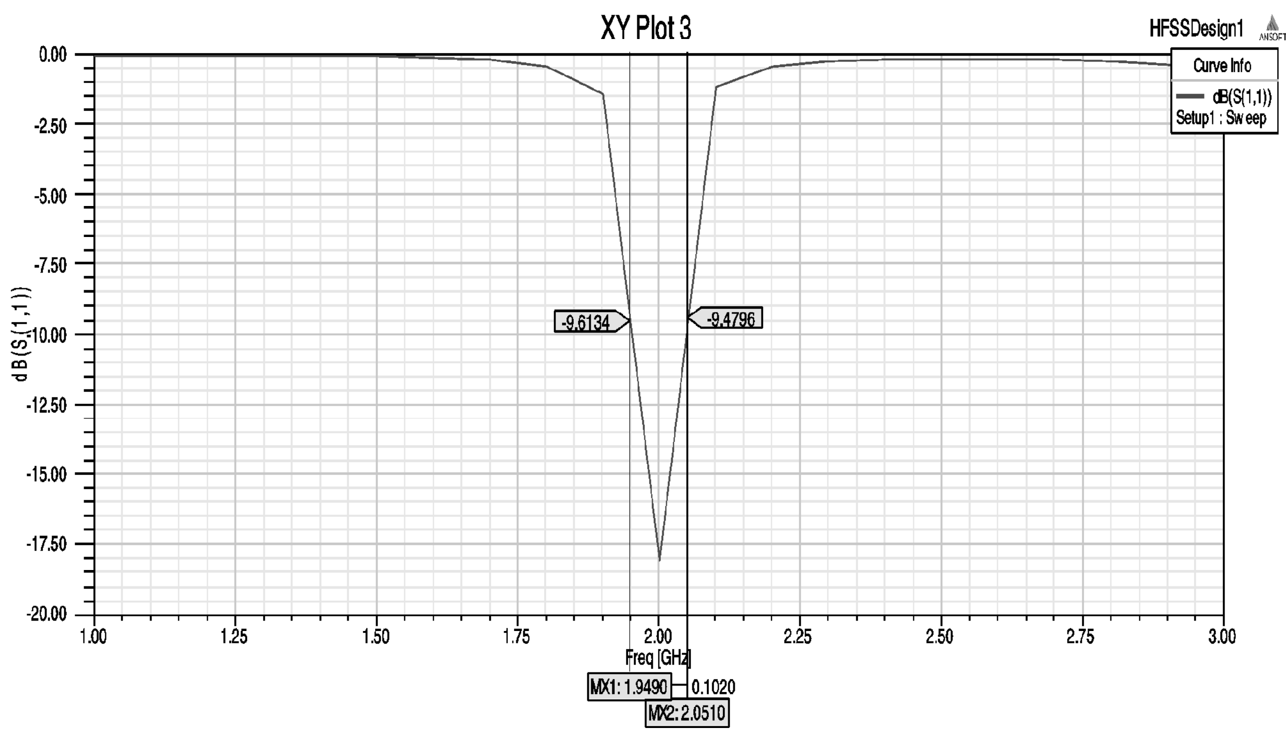

Figure 13: Bandwidth Calculation

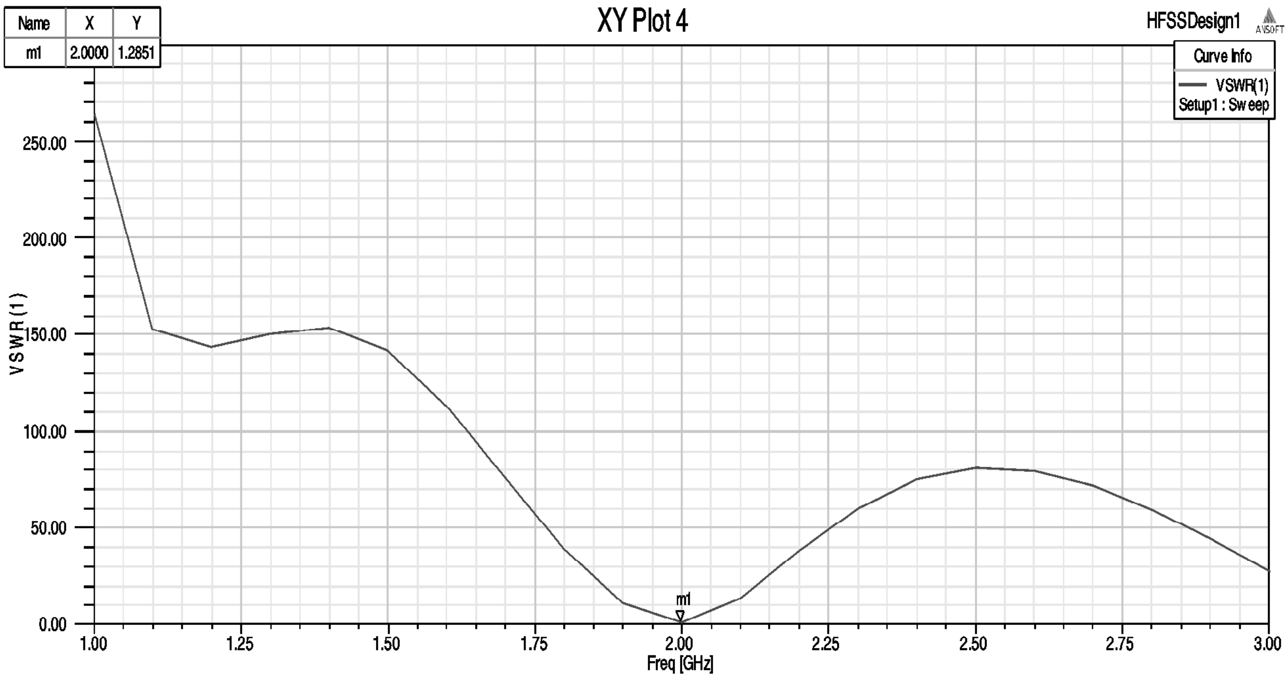

Figure 14: VSWR

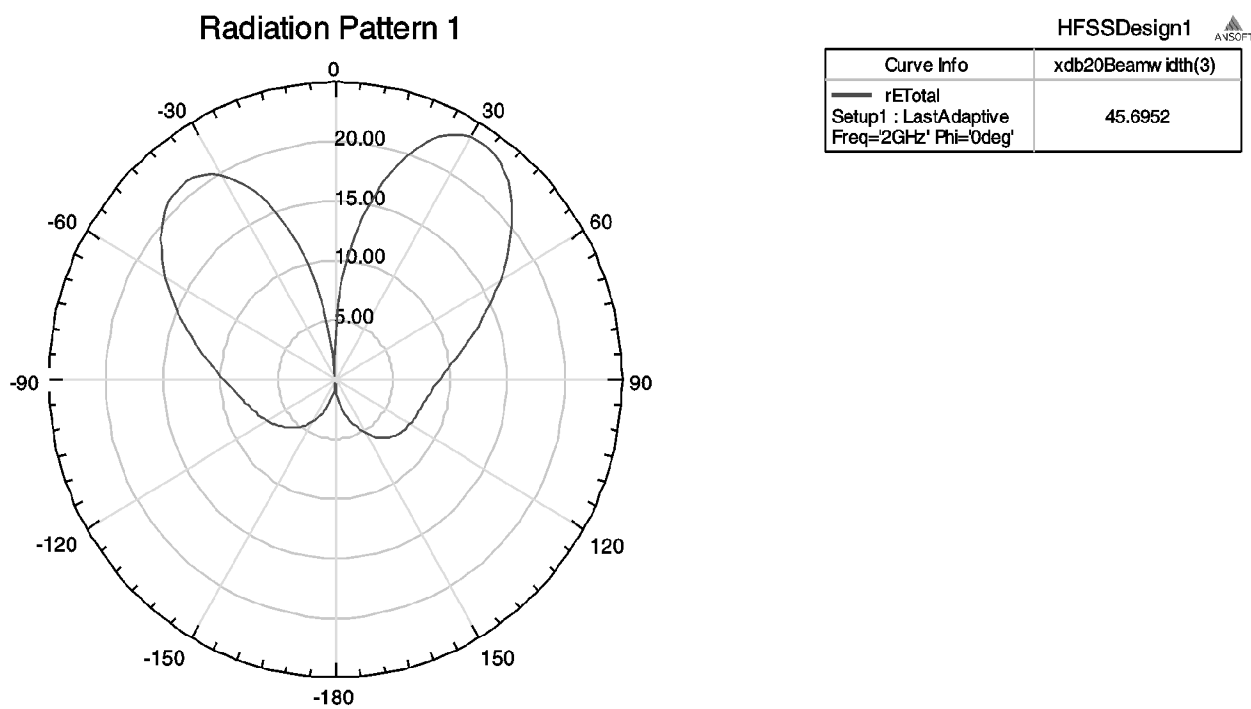

Figure 15: Elevation beamwidth

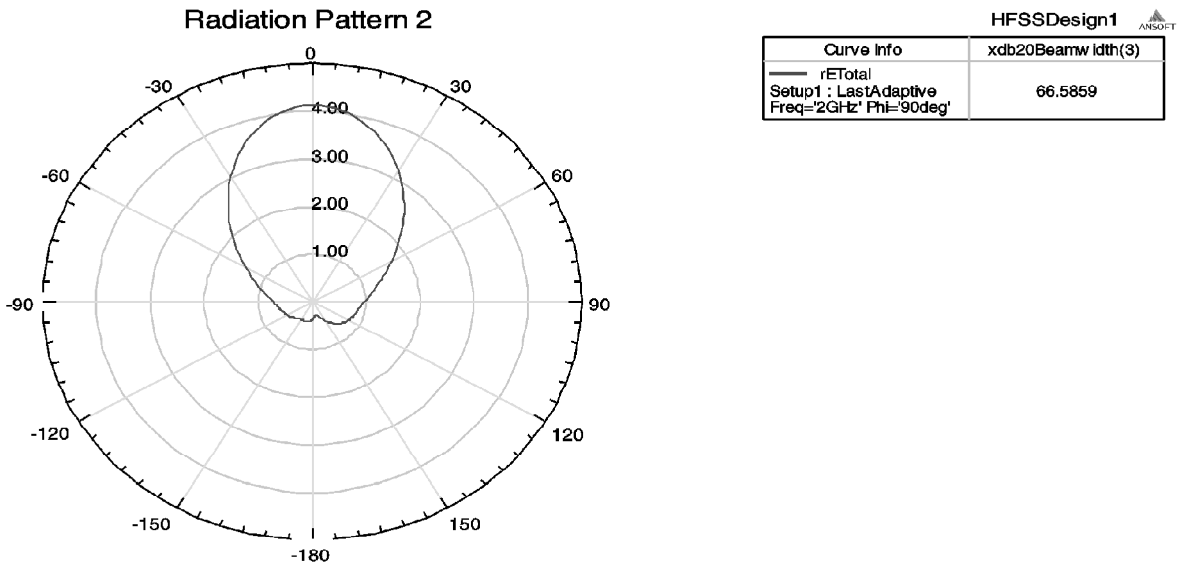

Figure 16: Azimuth beamwidth

Figure 17: Gain

Figure 18: Directivity

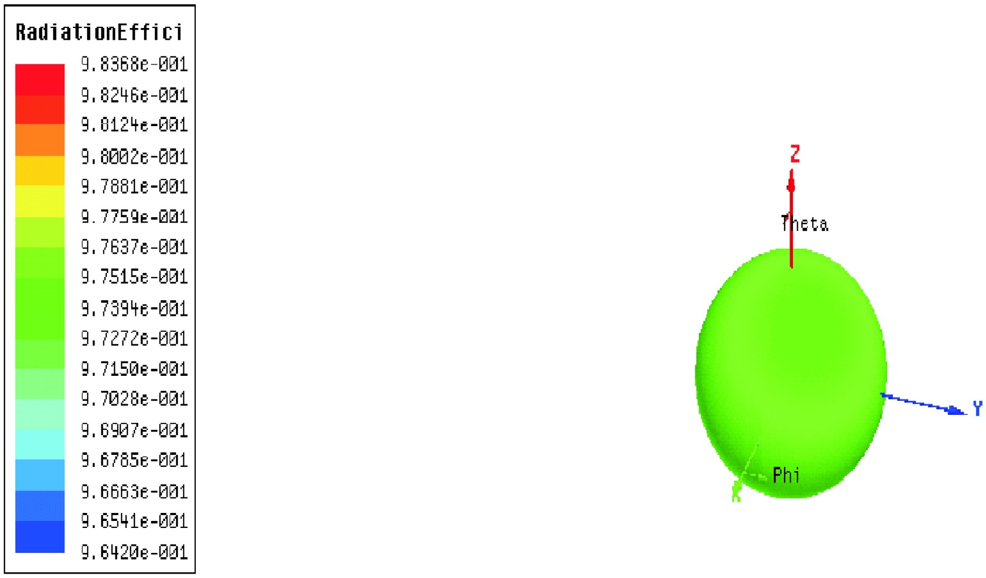

Figure 19: Efficiency

4. PERFORMANCE OF 4X1 ELEMENTS ARRAY ANTENNA

The structure of the 4x1 elements array is shown below fig. 20.

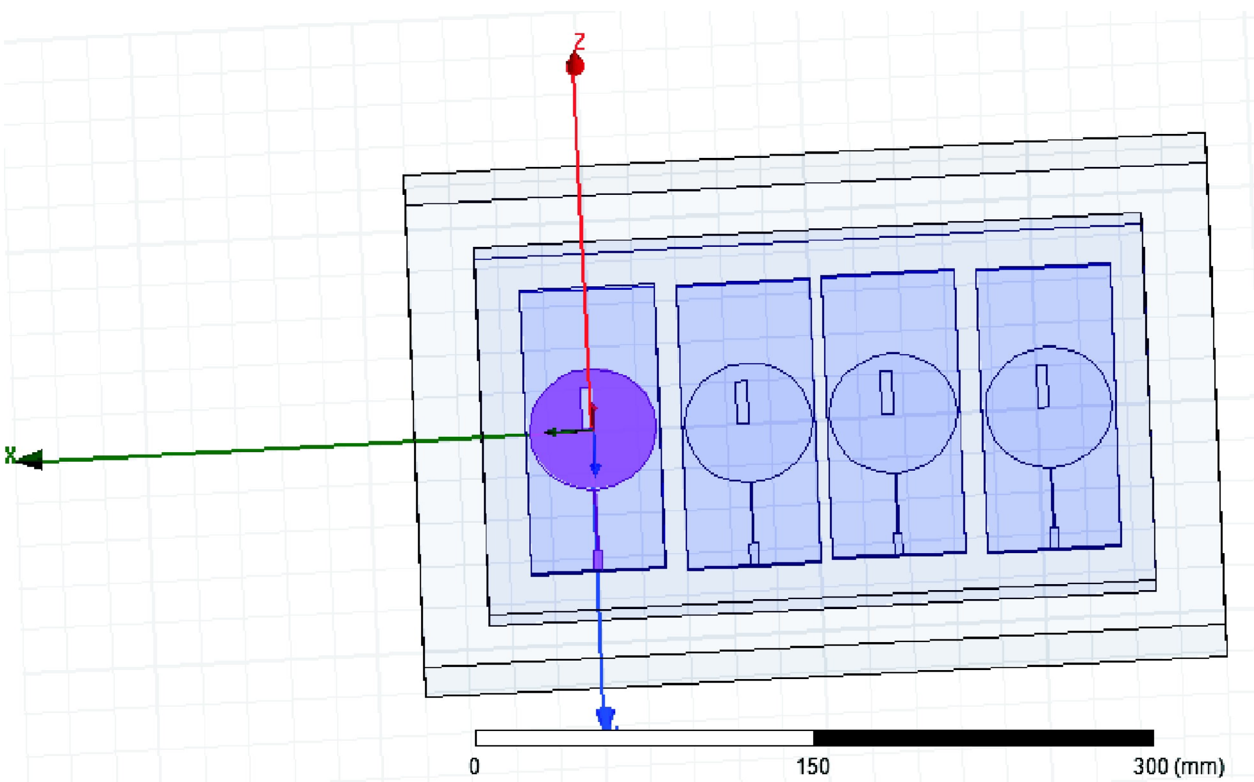

Figure 20: Structure of the 4x1 element array

The performance charateristics of 4x1 element circular patch antenna with a rectangular slit are Return loss is -11.8207dB, Bandwidth 36.7 MHz, VSWR is 1.6897, Elevation Beamwidth is 44.5062°, Azimuth Beamwidth 72.7523°, Gain is 8.0157dB, directivity 8.2261 dB and efficiency is 96% are shown below fig 21 to 28 respectively.

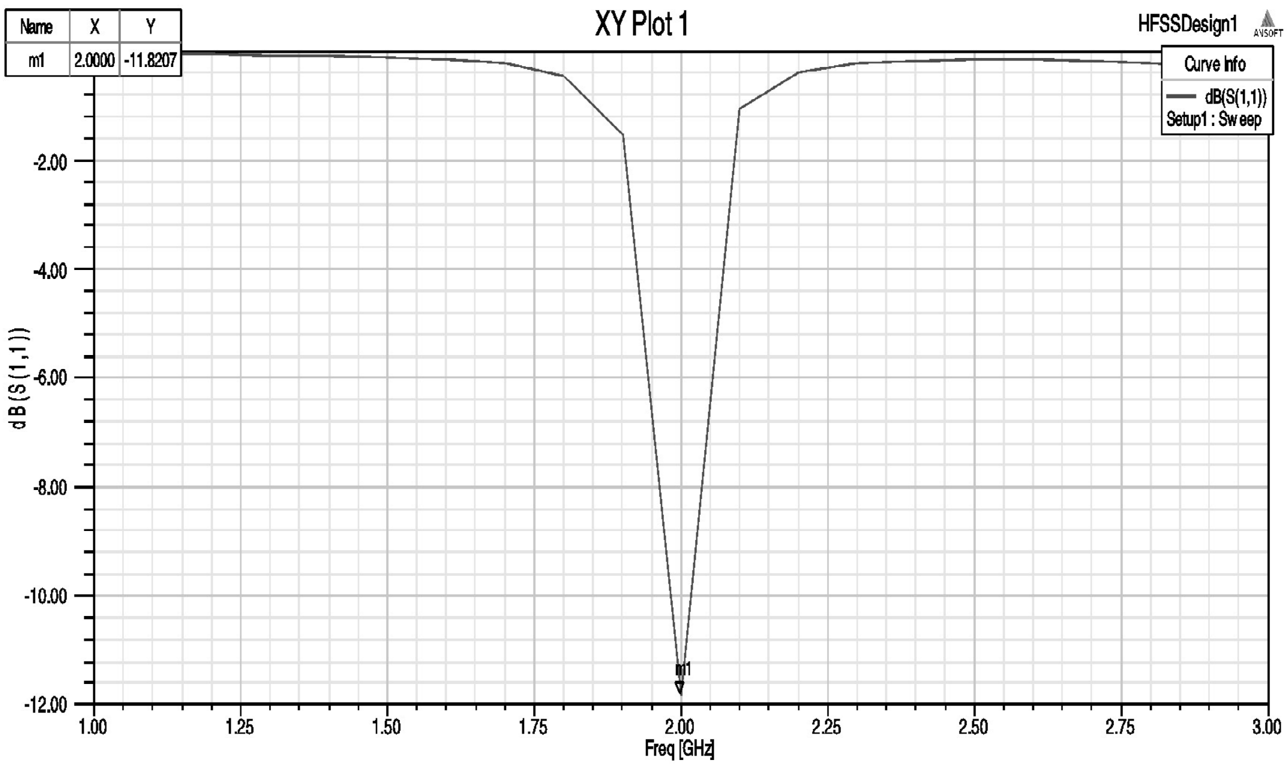

Figure 21: Return loss

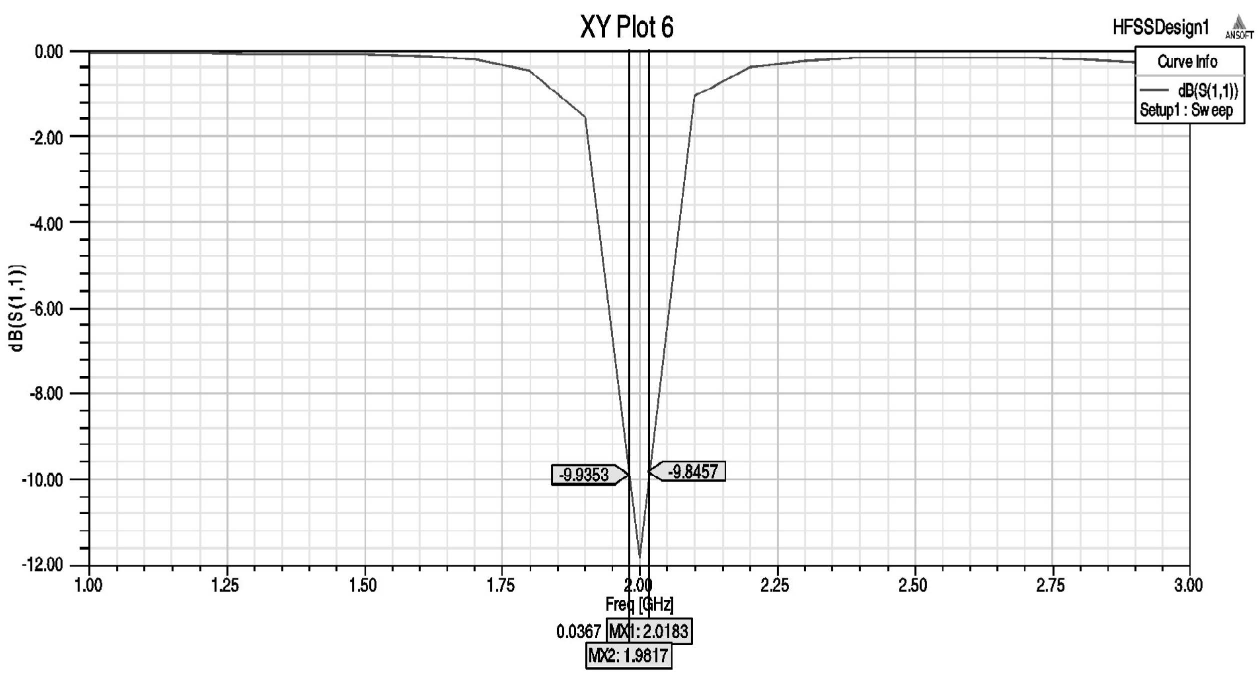

Figure 22: Bandwidth Calculation

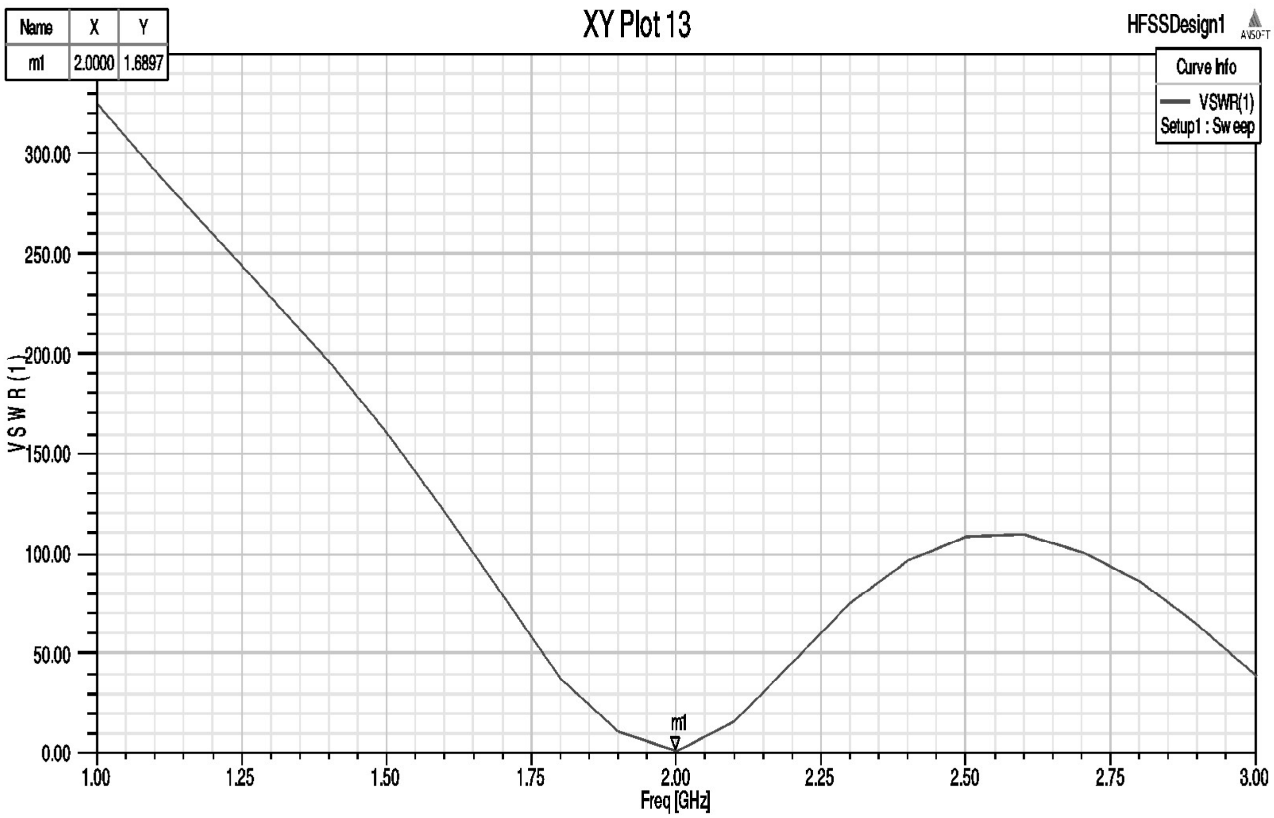

Figure 23: VSWR

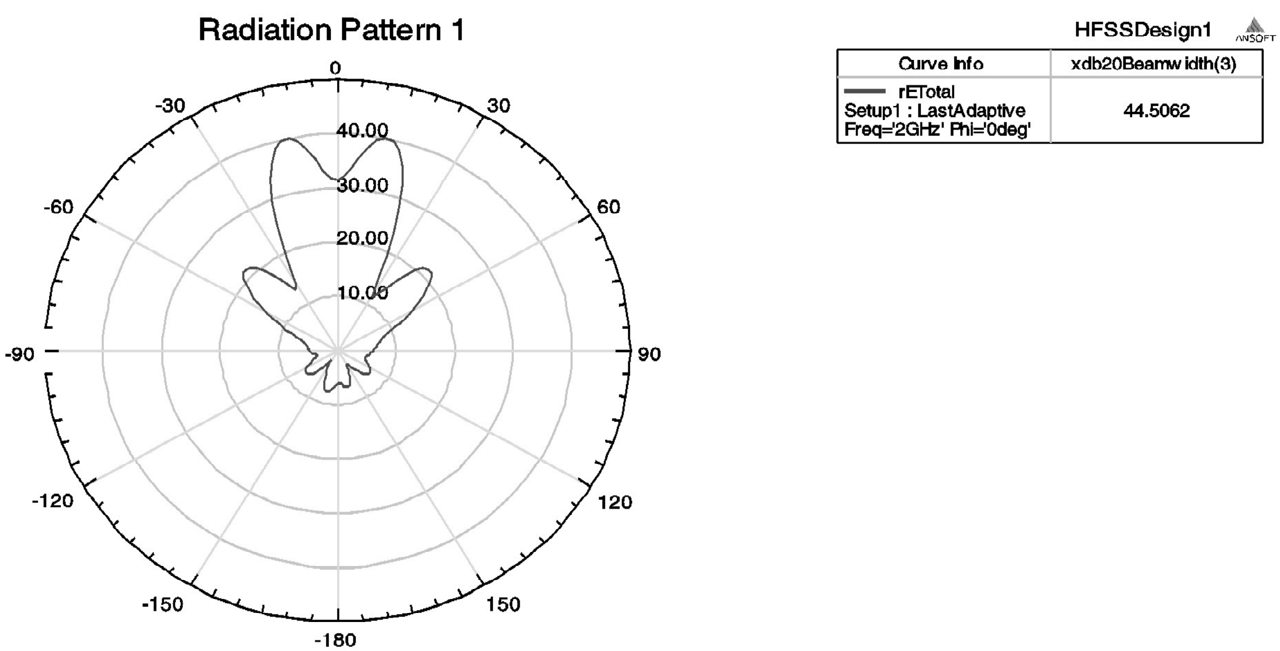

Figure 24: Elevation Beamwidth

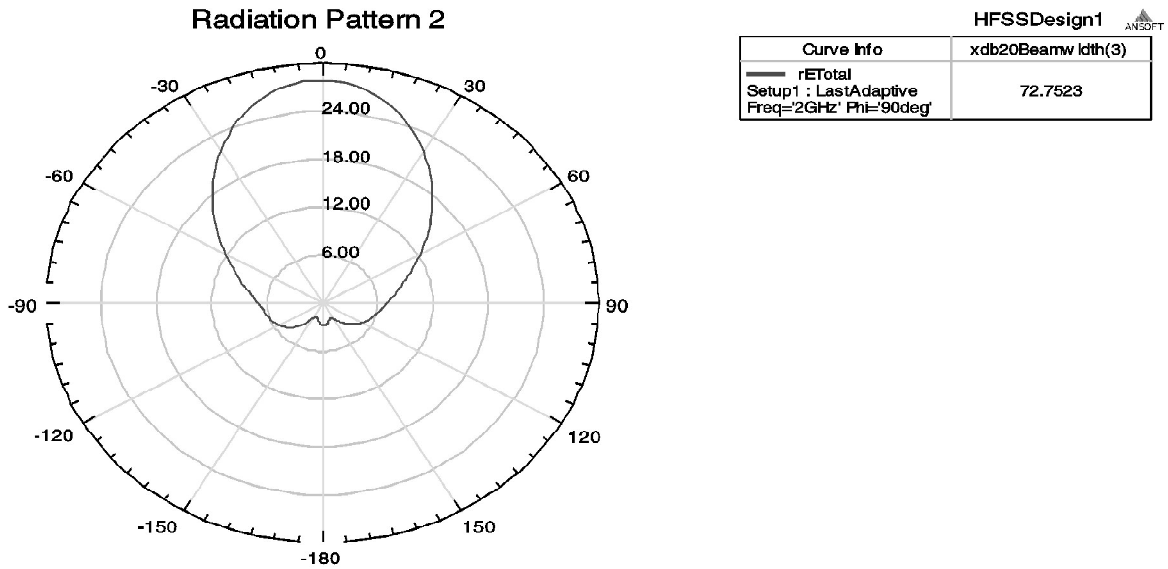

Figure 25: Azimuth Beamwidth

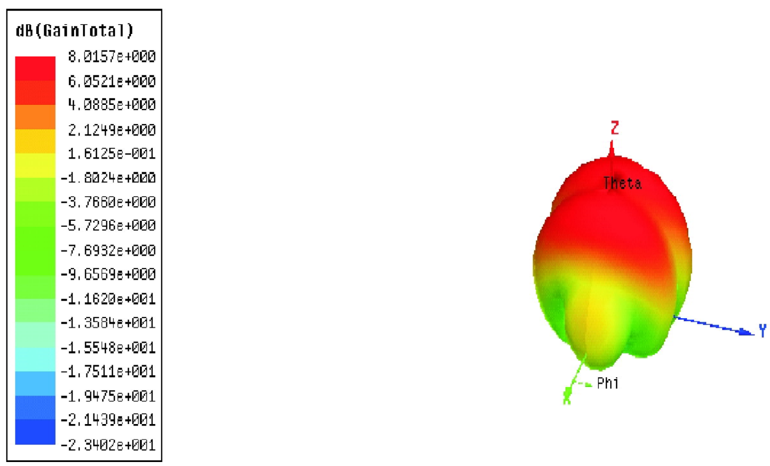

Figure 26: Gain

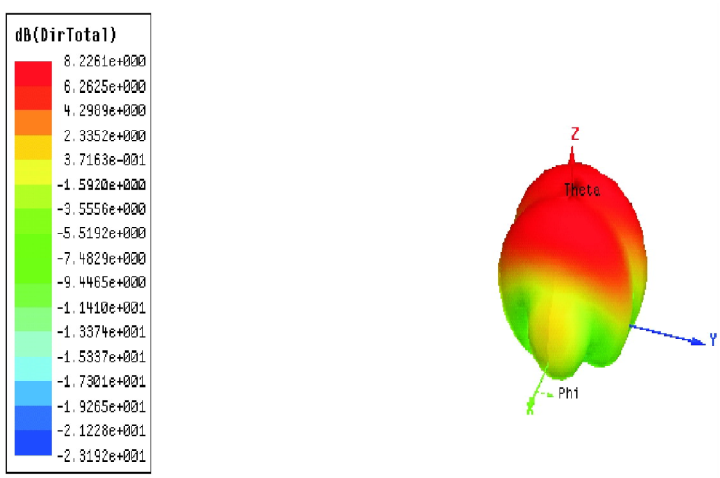

Figure 27: Directivity

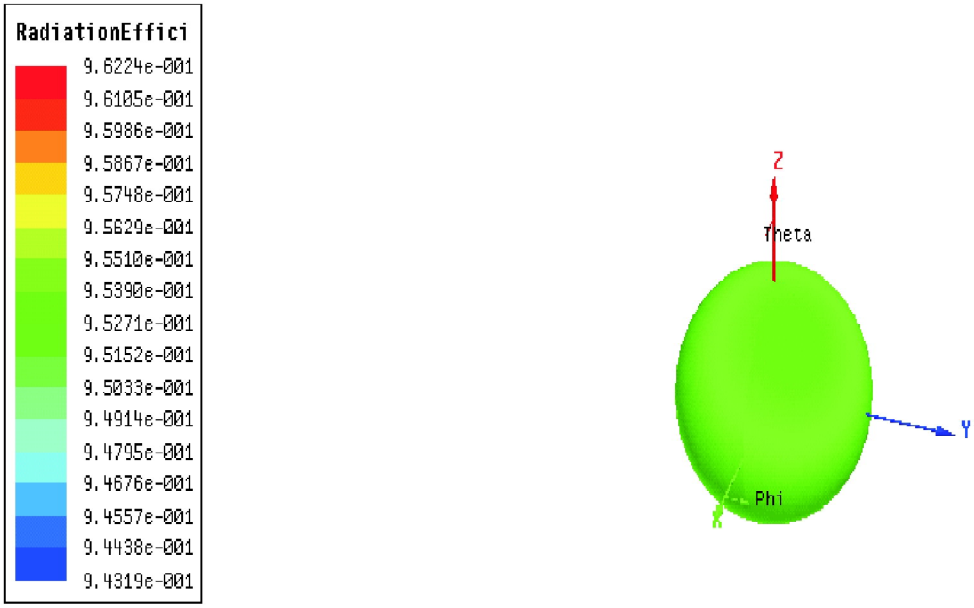

Figure 28: Efficiency

5. PERFORMANCE OF 8X1 ELEMENT ARRAY ANTENNAS

The structure of the 8x1 element array is shown in below fig. 29.

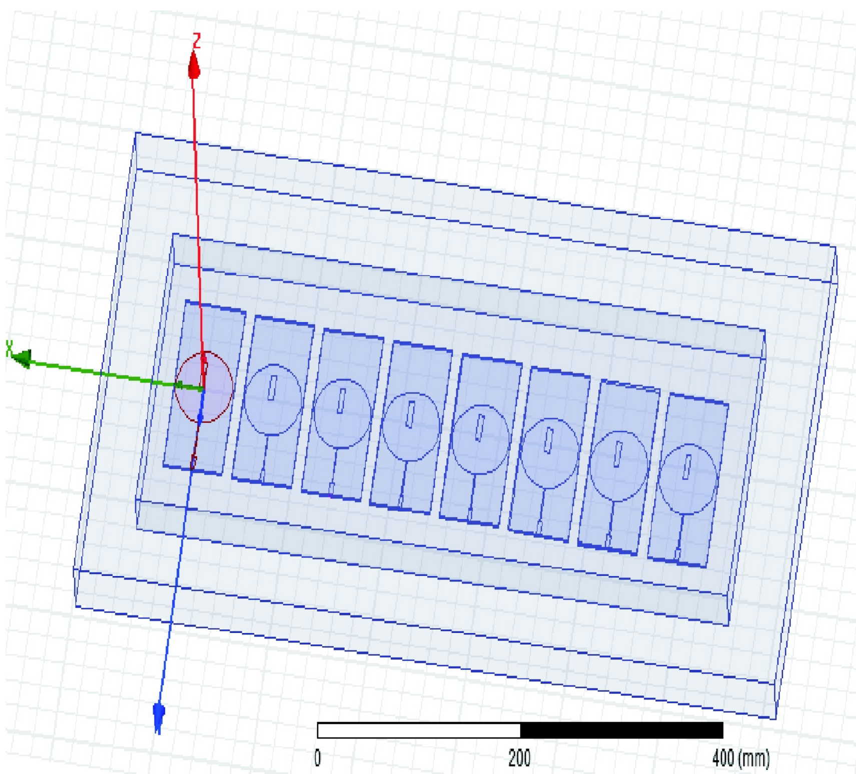

Figure 29: Structure of the 8x1 element array

The performance charateristics of 8x1 element circular patch antenna with a rectangular slit are Return loss is -9.9215dB, Bandwidth 19.4 MHz, VSWR is 1.9373, Elevation Beamwidth is 18.7676°, Azimuth Beamwidth 71.9563°, Gain is 11.830dB, directivity 11.975 dB and efficiency is 97% are shown below fig 30 to 36 respectively.

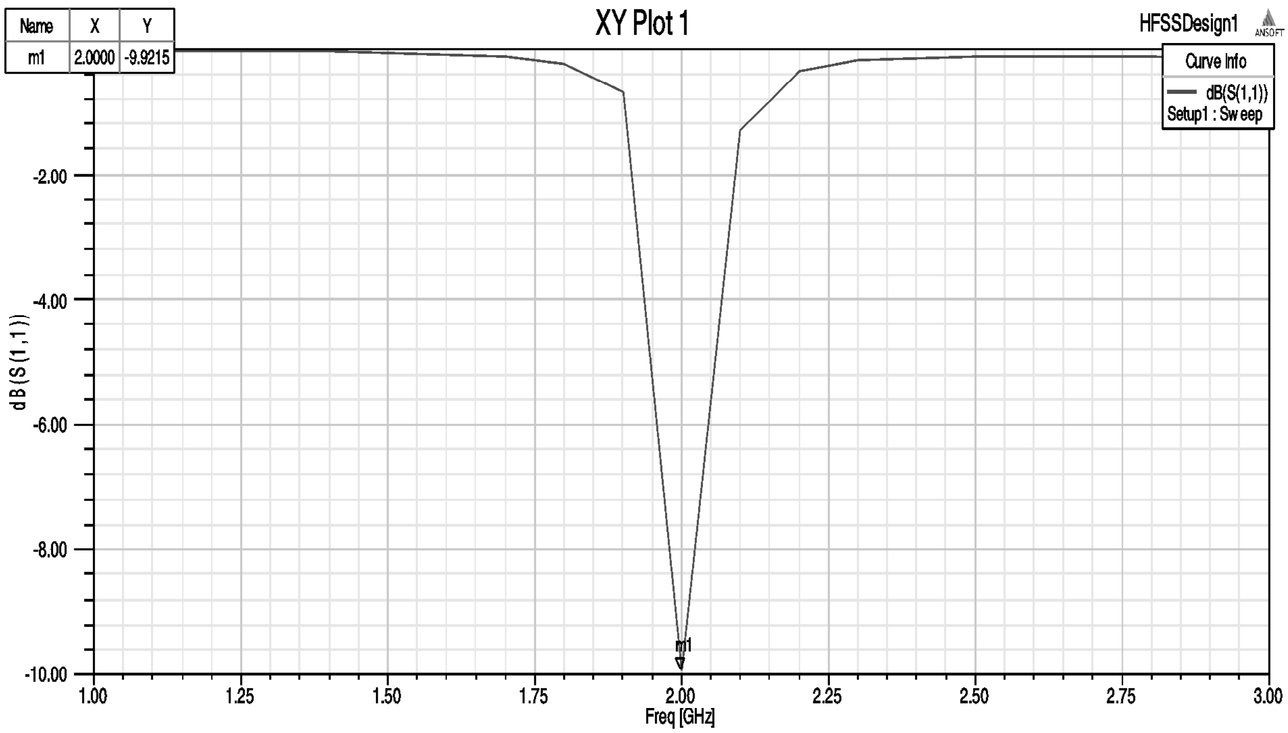

Figure 30: Return loss

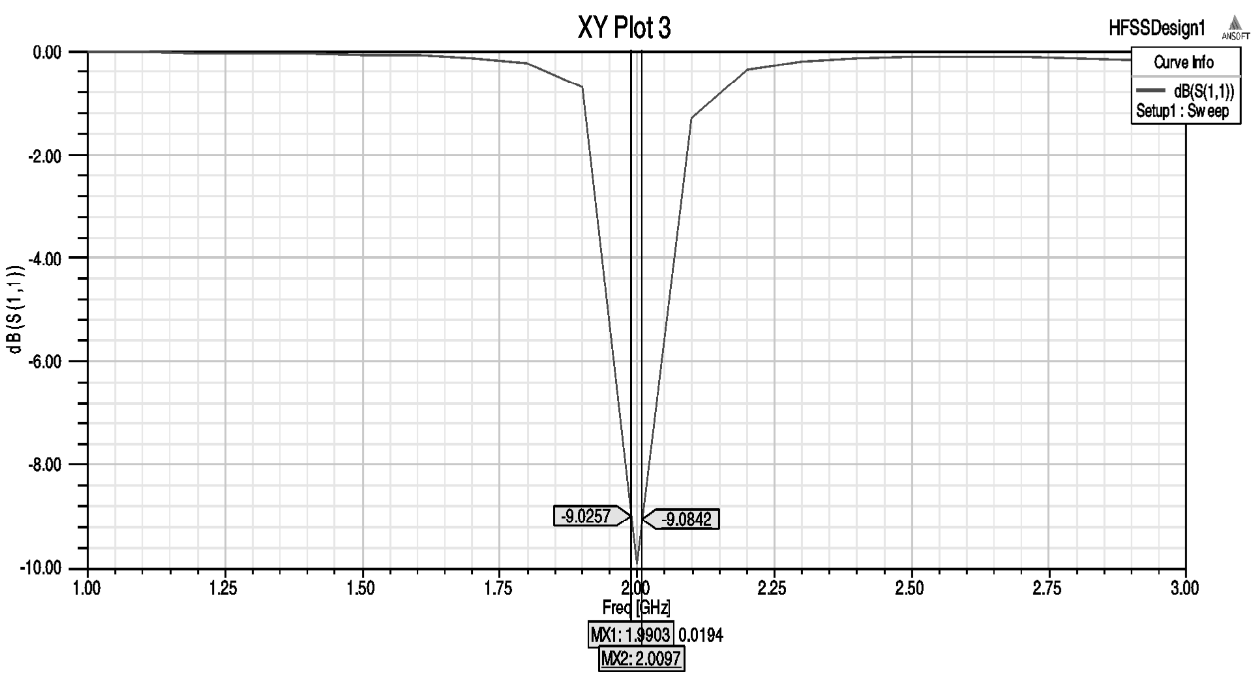

Figure 31: BandWidth Calculation

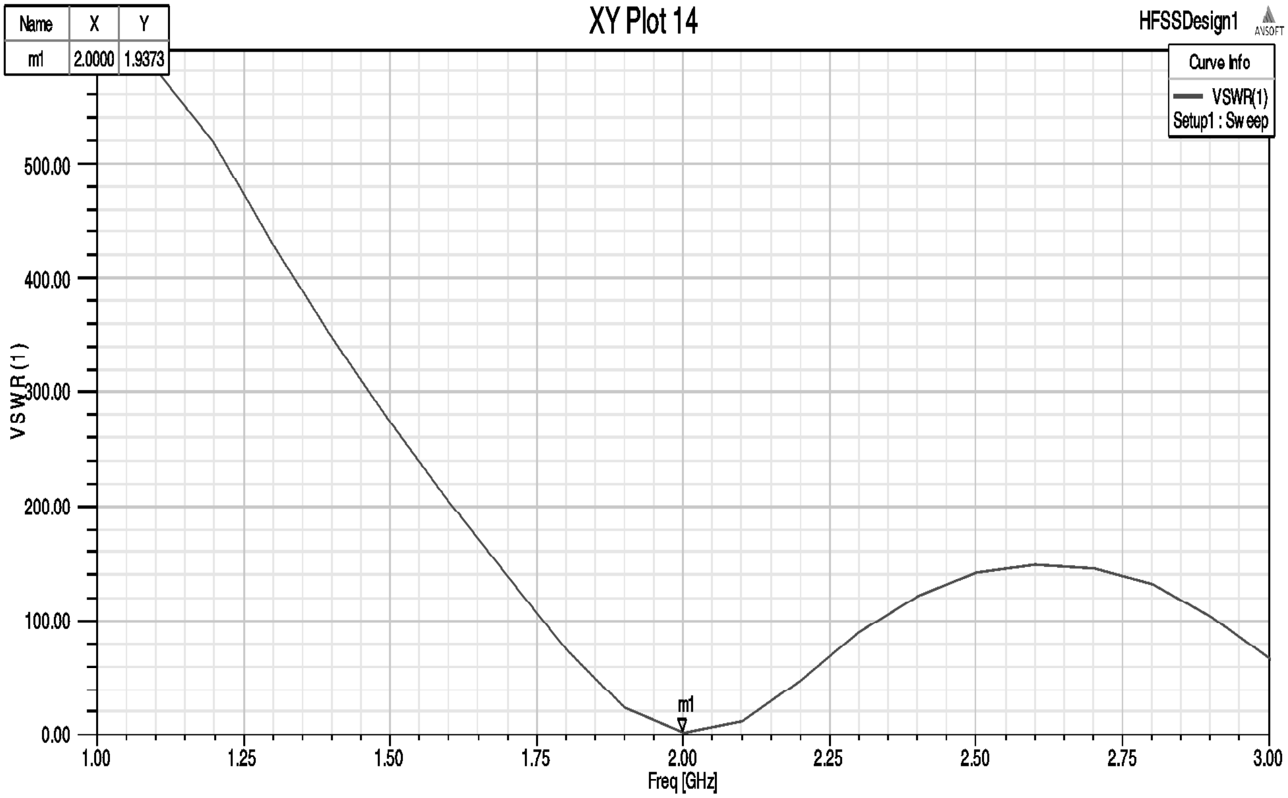

Figure 32: VSWR

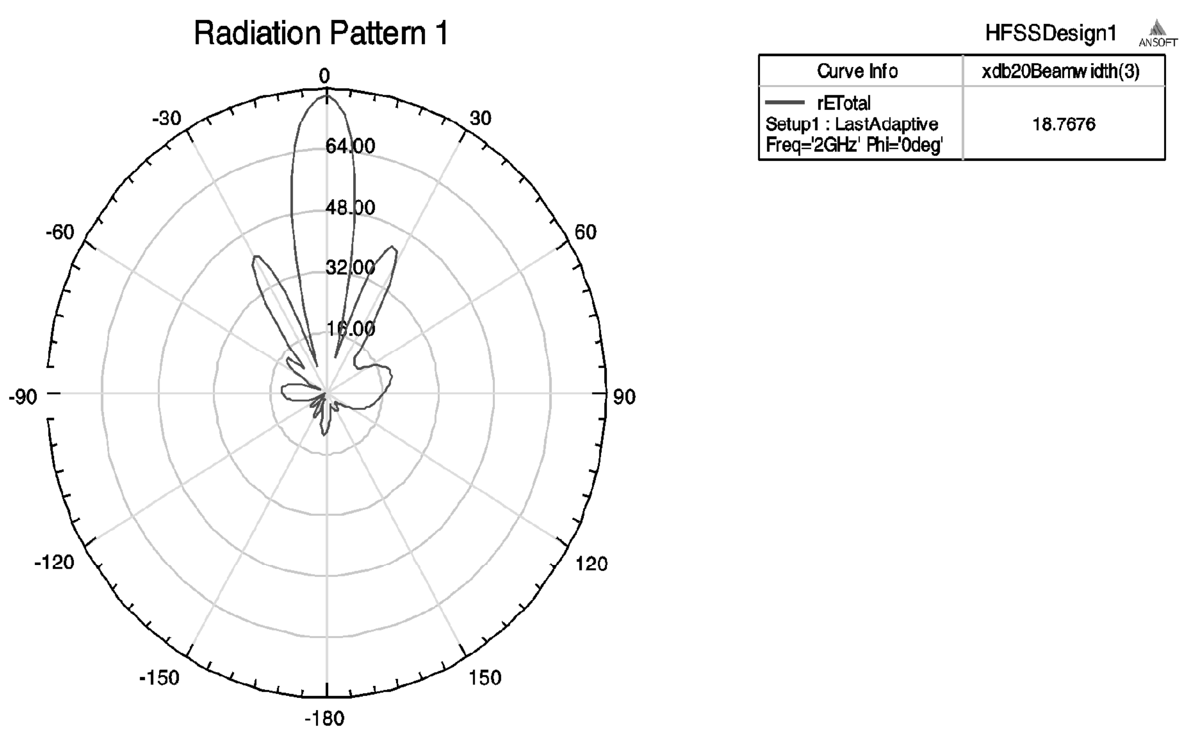

Figure 33: Elevation Beamwidth

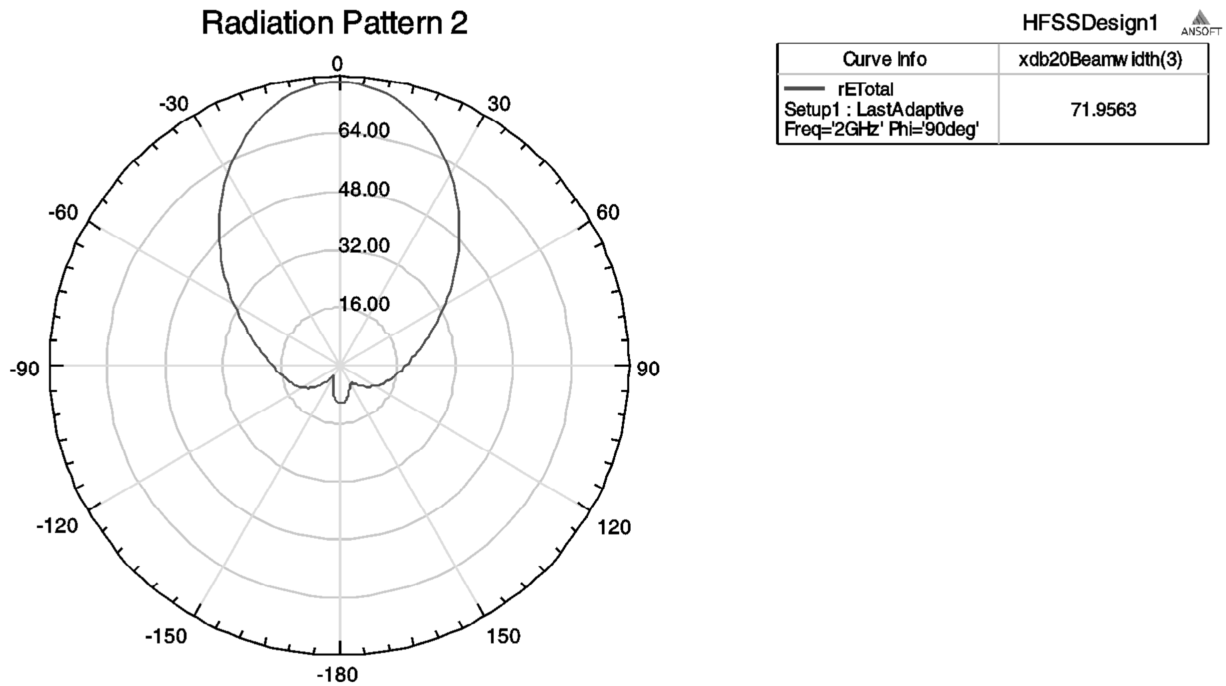

Figure 34: Azimuth Beamwidth

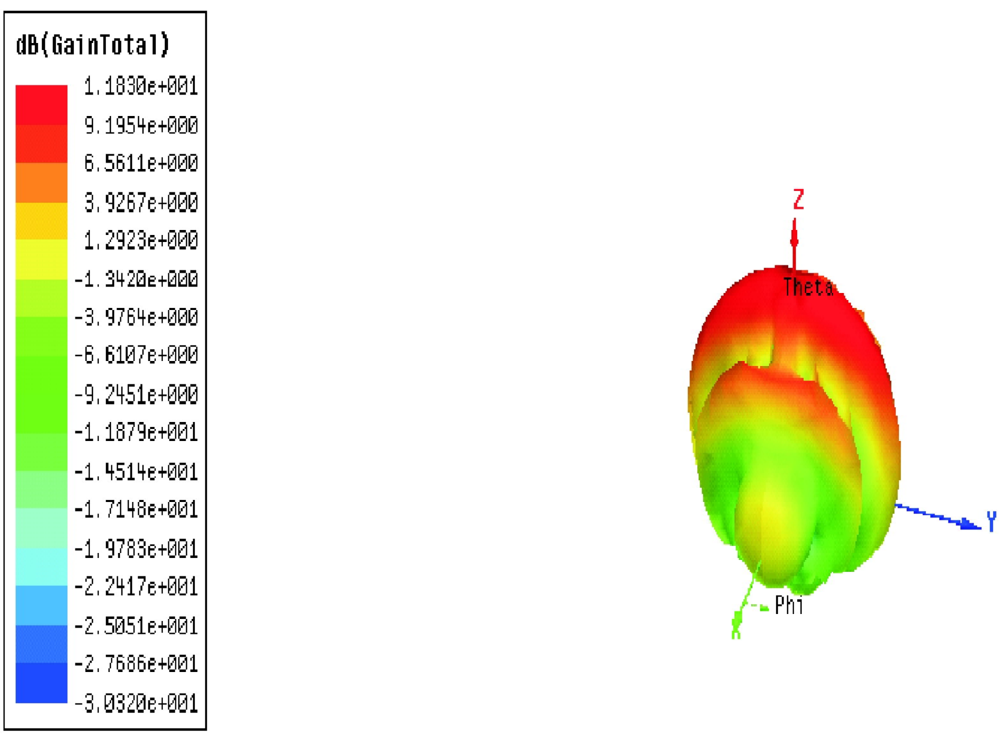

Figure 35: Gain

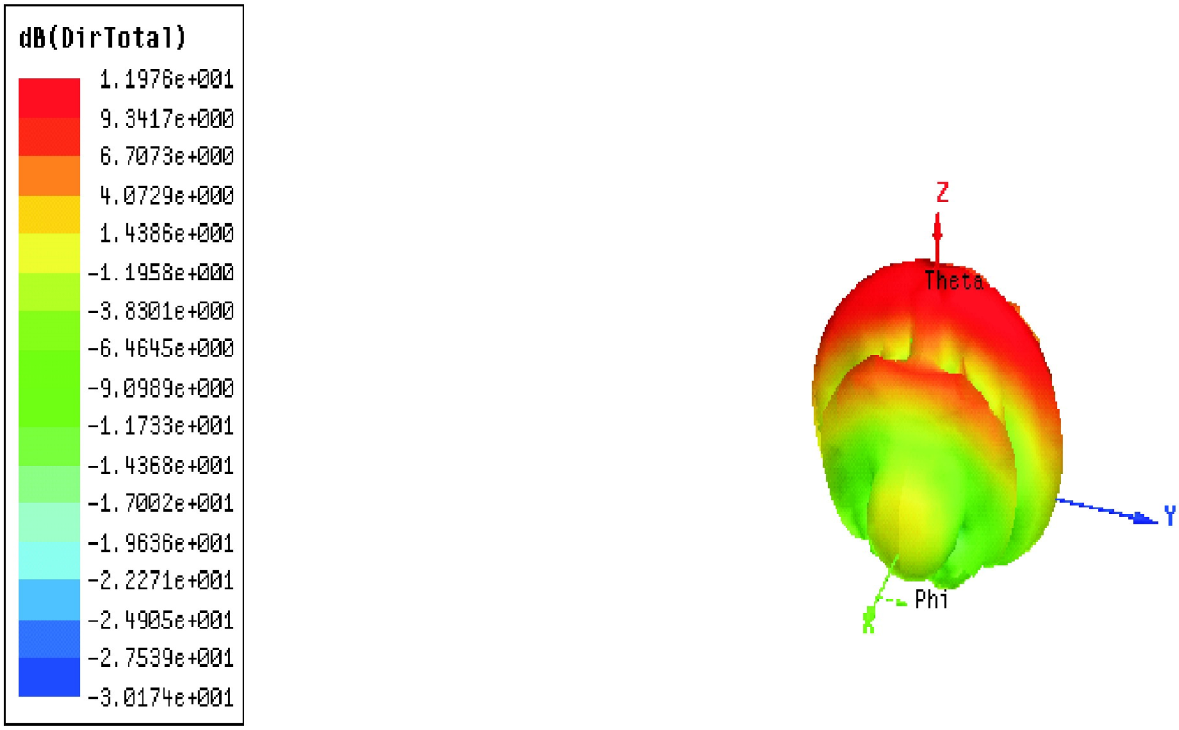

Figure 36: Directivity

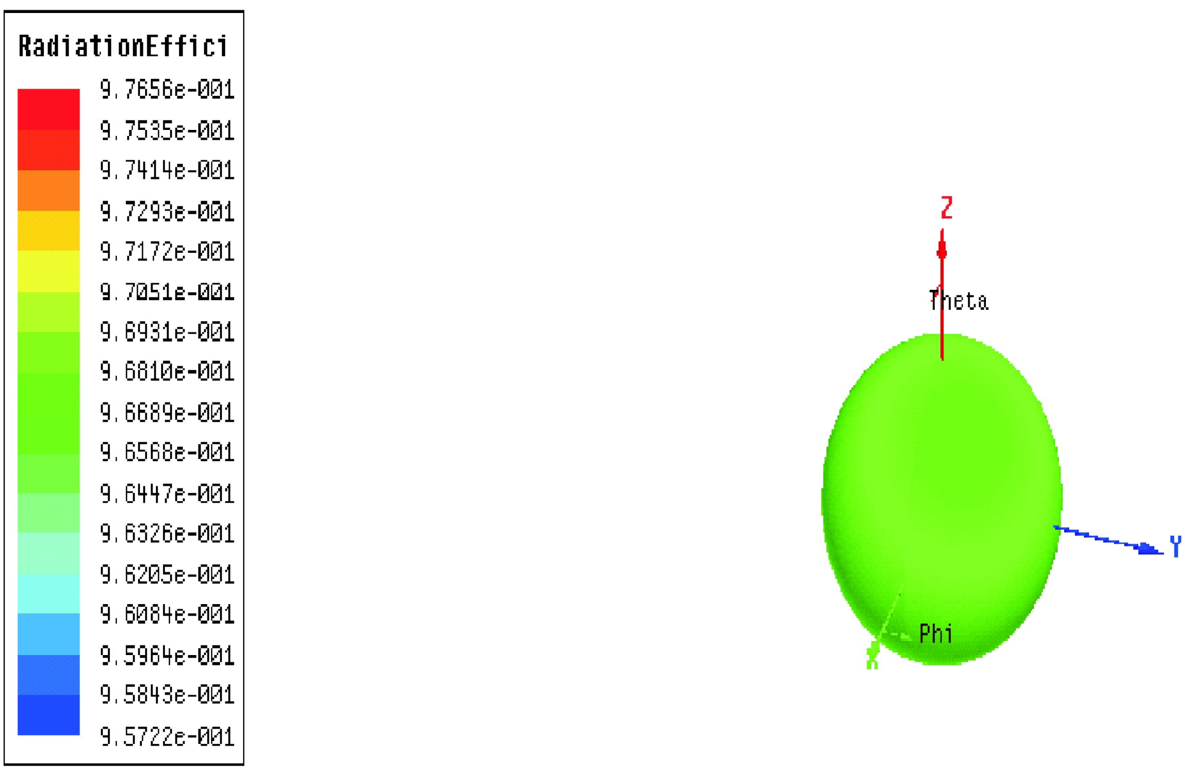

Figure 37: Efficiency

6. DISCUSSION

The radiation characteristics of above arrays are compared. The arrays of the proposed Circular Patch antenna with a Rectangular slit are successfully modeled and simulated using ANSOFT HFSS and the radiation characteristics of the proposed array antennas are summarized in the table 1.

Table 1
Radiation characteristics of the proposed antenna arrays

Sl.	*Parameter*	*No. of Elements*			
		1	*2x1*	*4x1*	*8x1*
1	Frequency (GHz)	2	2	2	2
2	Return loss (dB)	-23.37	-18.07	-11.82	-9.92
3	Bandwidth (MHz)	123	102	36.7	19.4
4	VSWR	1.29	1.28	1.68	1.93
5	Elevation HPBW (^{o})	100.7	45.69	44.50	18.76
6	Azimuth HPBW (^{o})	69.82	66.58	72.75	71.95
7	Gain (dB)	6.07	6.91	8.01	11.83
8	Directivity (dB)	6.19	7.02	8.22	11.97
9	Efficiency (%)	98	98	96	97

4. CONCLUSION

The proposed array antennas are successfully modeled and simulated using Ansoft HFSS. From the results we conclude that as the number elements increases gain increases and beamwidth decreases. The radiation characteristics obtained by this proposed antenna is very much useful for air borne applications.

5. ACKNOWLEDGMENTS

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