Design and Analysis of Wideband Modified Circular Patch Microstrip Antennas for Multiple Band Operation

S. R. Chowdhury, S. Basu

***Abstract*—** This paper presents the design and analysis of a modified wideband circular patch microstrip antenna to enhance the impedance bandwidth of a conventional circular patch. Ansoft Designer V2 is employed to analyze the performance of the proposed antenna structure with single coaxial feed as well as with microstrip feed at different positions of this modified structure. The proposed antenna shows dual 10dB impedance-bandwidth of about 38% and 15% having center frequencies at 4GHz and 12GHz respectively with coaxial feed. The same structure shows 10dB impedance-bandwidth of about 14% and 79% for dual resonant frequencies at 8 GHz and 18 GHz respectively for a specific position of the microstrip feed and 35% at 22 GHz for another position of the microstrip feed which is perpendicularly oriented with respect to the first one. The patch structure is further modified by introducing rectangular finite ground plane of dimension 50mm X 50mm for both coaxial fed and microstrip fed modified circular patch and its effect on different antenna parameters are studied.

***Keywords*—** Circular Microstrip patch antenna, Dual operating frequency, Impedance bandwidth, Wideband patch antenna

I. Introduction

Microstrip patch antenna is a topic of intensive research in recent years [1]-[6] because of its light weight, low volume, thin profile configuration, low fabrication cost and increasing demand of small antennas with wider bandwidth. These criteria make it popular in the field of satellite and radar communication systems. Different Radar systems such as synthetic aperture radar (SAR), remote sensing radars, shuttle imaging radar and other wireless communication systems operate in L, Ku, C and X bands [7].Microstrip antennas are the first choice for these high frequency bands due to its light weight, low cost and robustness. The most common patch structures are rectangular and circular. Circular microstrip patch antenna has some advantages over rectangular one. For rectangular patch elements there are two degrees of freedom to control whereas for the circular patch elements there is one degree of freedom to control. Thus it is more convenient to design as well as to control the radiation pattern of the circular patch element [7]. Moreover the physical area of the circular patch is 16% less than that of the rectangular patch [8]. In the present paper a modified circular patch with an offset hole is proposed which is capable of giving reasonable gain and large bandwidth for a wide range of frequency values in C, X and K bands. Conventional printed circuit antennas have an operating impedance bandwidth nearly 2% to 3% [8]. Garima, D. Bhatnagar, V.K. Saxena and J.S. Saini enhanced the bandwidth by applying a diamond shaped slot in a conventional circular microstrip patch antenna on glass epoxy FR-4 substrate and achieved improved bandwidth of 16.93% [11]. But the proposed design of this paper is capable of achieving the impedance bandwidth of 38% using coaxial feed and 79% using microstrip feed.

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II. Antenna Design

A) Antenna1: Circular Patch Antenna

A conventional circular patch is shown in fig.1 with radius=15mm, substrate thickness h= 1.6mm, dielectric constant ε_r =2.2. Coaxial probe-feed (diameter =1mm) is located at the centre of the patch.

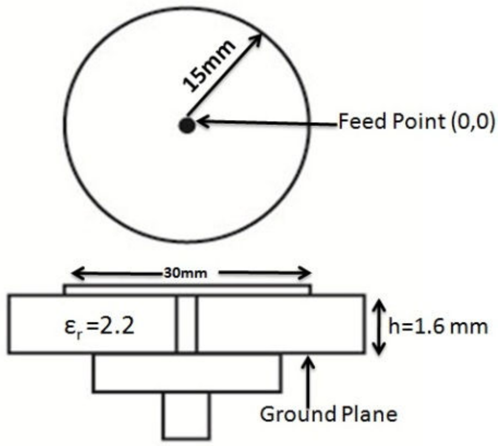

Fig: 1 Conventional circular patch

Using the above parameter values, resonant frequency of the circular patch is found to be 4 GHz, from the formula [9], [10] given below

$$(f_{rc})_{110}=(1.8412*C)/(2\pi a_e\sqrt{\varepsilon_r}) \quad (1)$$
$$\text{Where } a_e=a\{1+(2h/\pi a\varepsilon_r)[\ln(\pi a/2h)+1.7726]\}^{1/2}$$

and C is the velocity of light. Now the feed point is shifted towards the perimeter to get the best feed location at 4GHz which gives minimum return loss. The result is shown in Fig; 2 . It is seen from Fig.2 that the point (5, 0) is the best feed location as it shows the minimum return loss (-9.16dB) at 4GHz.

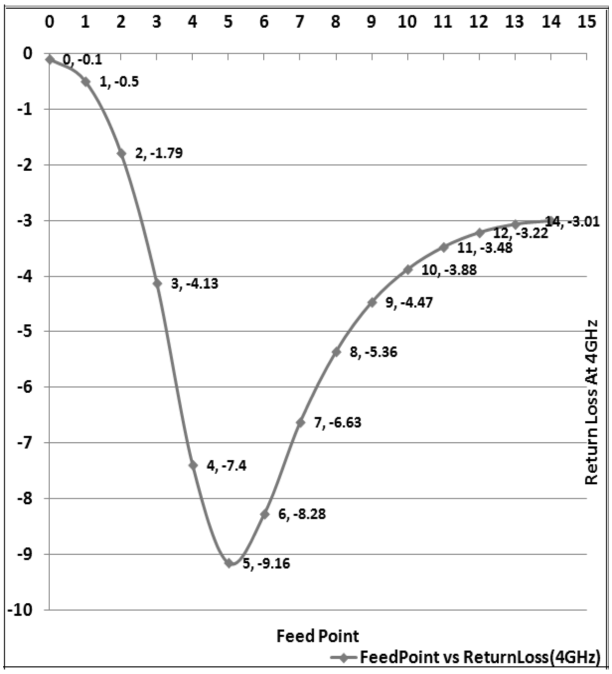

Fig: 2 Feed Points vs. Return Loss (4GHz)

B) Antenna2: Modified Circular Patch Antenna with coaxial feed

The circular patch structure is modified by placing a hole centered at (-6.25, 0) on the patch and cutting the perimeter of the patch using semicircular holes of radius 3.5mm as shown in Fig; 3.

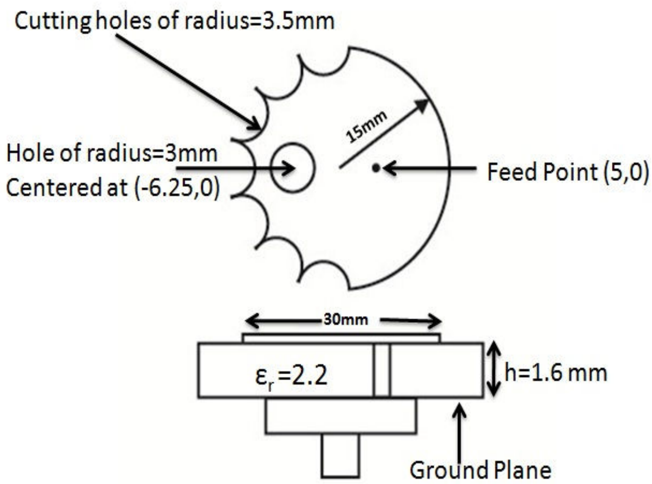

Fig: 3 Modified Circular patch with coaxial feed

C) Antenna3: Modified Circular Patch Antenna with Vertical Microstrip feed

Modified circular patch structure is fed with vertical microstrip feed of width 6mm as shown in Fig 4a.

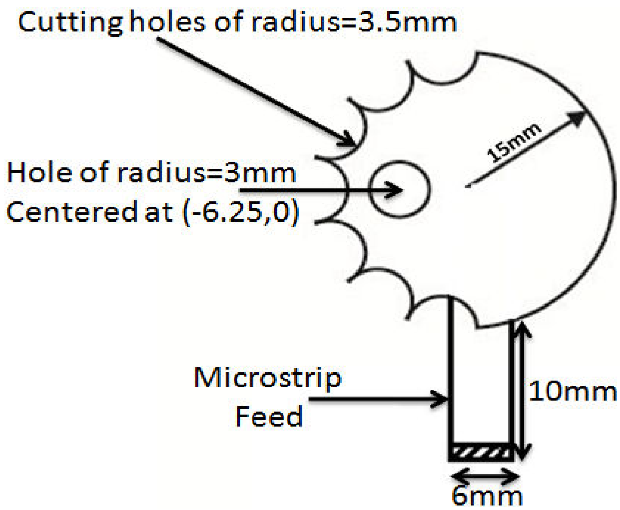

Fig: 4a Modified Circular patch with Microstrip feed at position 1.

D) Antenna4: Modified Circular Patch Antenna with Horizontal Microstrip feed

Now the feed position is altered from vertical to horizontal as shown in Fig 4b.

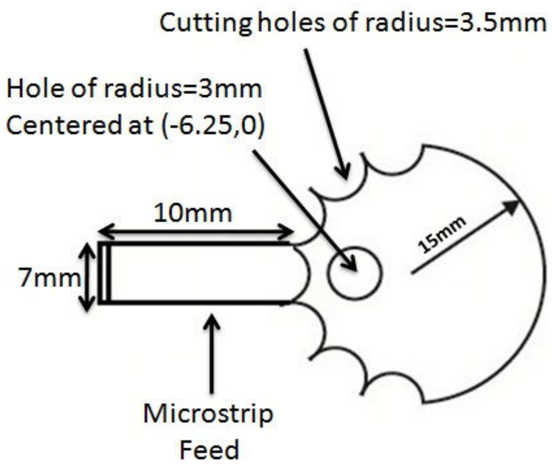

Fig: 4b Modified Circular patch with Microstrip feed at position2

D) Antenna5: Coaxial fed Modified Circular Patch Antenna with finite ground plane

Now a finite ground plane of dimension 50mm X 50mm is introduced in the coaxial fed modified circular patch (Antenna 2). The geometry of coaxial fed modified circular patch with finite ground is shown in fig: 5.

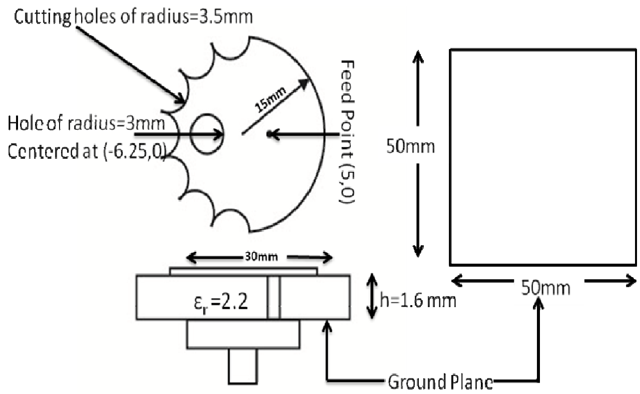

Fig: 5 Coaxial fed Modified Circular patch with finite ground plane

E) Antenna6: Vertical microstrip fed Modified Circular Patch Antenna with finite ground plane

Finite rectangular ground plane of dimension 50mm X 50mm is introduced with vertical microstrip fed modified circular patch (Fig:4a).

F) Antenna7: Horizontal microstrip fed Modified Circular Patch Antenna with finite ground plane

Finite rectangular ground plane of dimension 50mm X 50mm is introduced with horizontal microstrip fed modified circular patch (Fig:4b).

III. Results and Discussion

Simulated results of Return Loss, 3D Input Gain and Radiation Pattern obtained for the conventional circular patch (Fig-1) are shown in Fig: 6, Fig: 7 and Fig: 8 respectively. Results obtained for the modified circular (Fig-3) patch with coaxial feed are shown in Fig: 9, Fig: 10 and Fig: 11 respectively. Results obtained for modified circular patch with Microstrip feed in position 1 (Fig-4a), are shown in Fig: 12, Fig: 13, Fig: 14 and those for position 2 ((Fig-4b) are shown in Fig: 15, Fig: 16 and Fig: 17 respectively. Simulated results obtained after introducing the finite ground pane in coaxial fed modified circular patch (Fig: 5) are shown in Fig: 18, Fig: 19, Fig: 20, Fig: 21, Fig: 22, Fig: 23 and Fig: 24 for 4GHz, 13GHz and 15GHz respectively and that of for microstrip fed for both position are shown in Fig: 25, Fig: 26, Fig: 27, Fig: 28, Fig: 29, Fig: 30, Fig: 31, Fig: 32, Fig: 33 and Fig: 34.

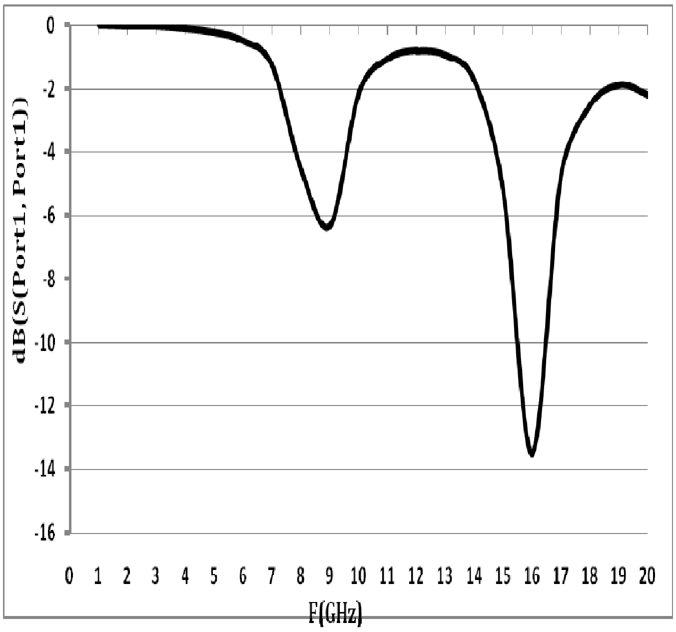

Fig: 6 Return Loss Vs Frequency of Circular patch. R=15mm, h=1.6mm.Feed point= (0, 0).resonant frequency=16GHz.

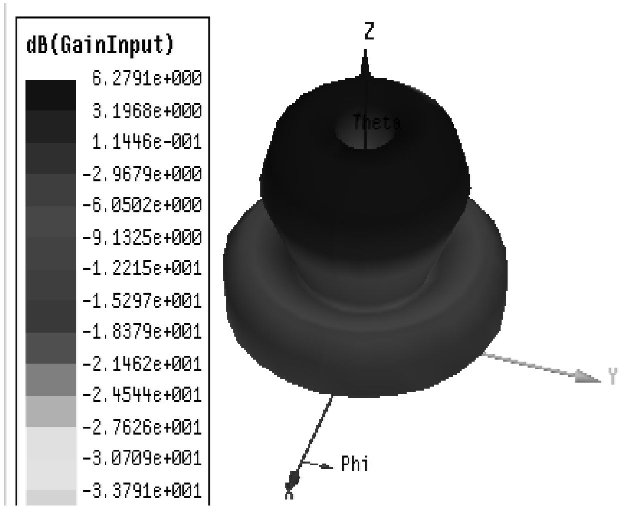

Fig: 7 3D Input Gain of Circular patch. R=15mm, h=1.6mm, Feed point= (0, 0).resonant frequency=16GHz

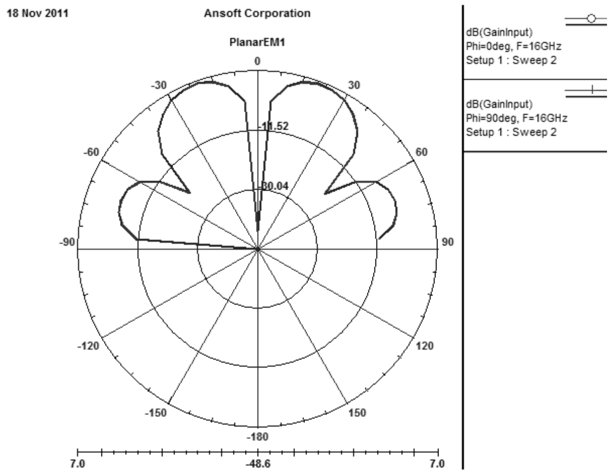

Fig: 8 Radiation Pattern of Circular patch. R=15mm, h=1.6mm.Feed point= (0, 0).resonant frequency=16GHz

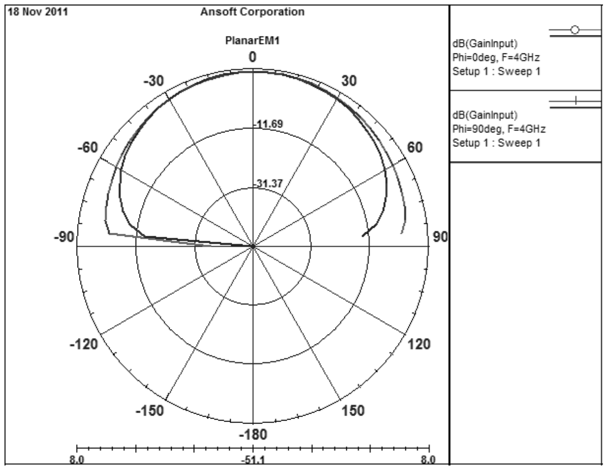

Fig: 11 Radiation Pattern of Modified Circular patch with coaxial feed. R=15mm, h=1.6mm.Feed point(5, 0).resonant frequency=4GHz

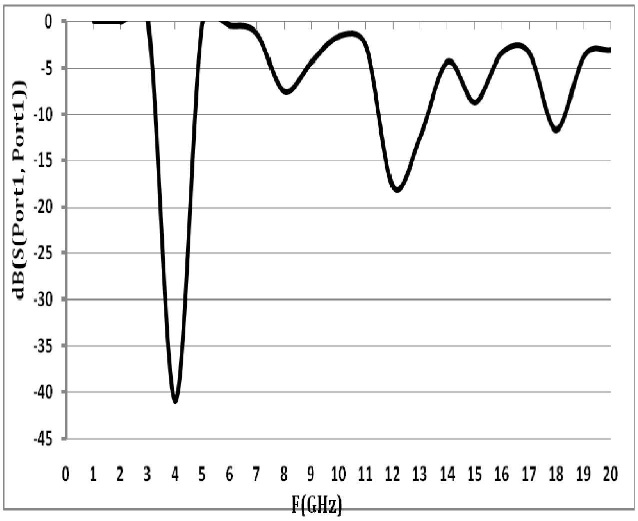

Fig: 9 Return Loss Vs Frequency of Modified Circular patch with coaxial feed. R=15mm, h=1.6mm.Feed point= (5, 0).resonant frequency=4GHz & 12GHz.

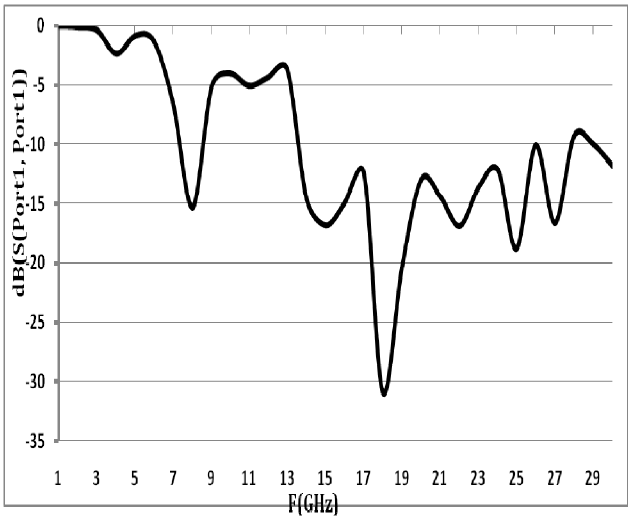

Fig: 12 Return Loss Vs Frequency of Modified Circular patch with Microstrip feed at position1. R=15mm, h=1.6mm, resonant frequency=8GHz & 18GHz.

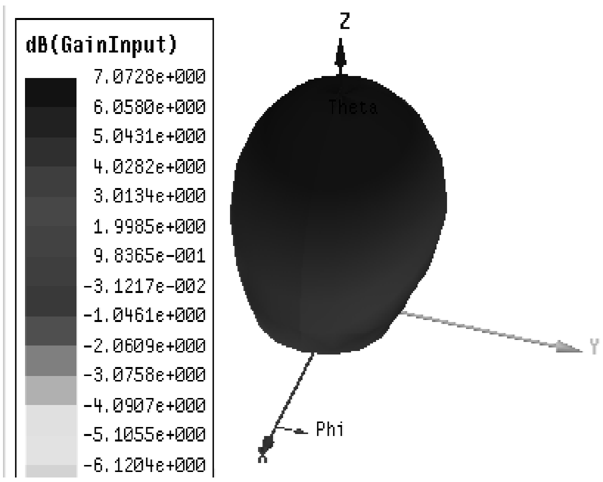

Fig: 10 3D Input Gain of Modified Circular patch with coaxial feed. R=15mm, h=1.6mm, Feed point (5,0).resonant frequency=4GHz

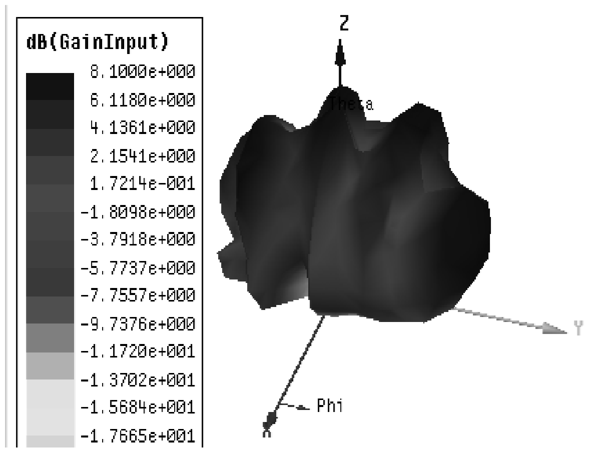

Fig: 13 3D Input Gain of Modified Circular patch with Microstrip feed at position 1. R=15mm, h=1.6mm, resonant frequency=18GHz

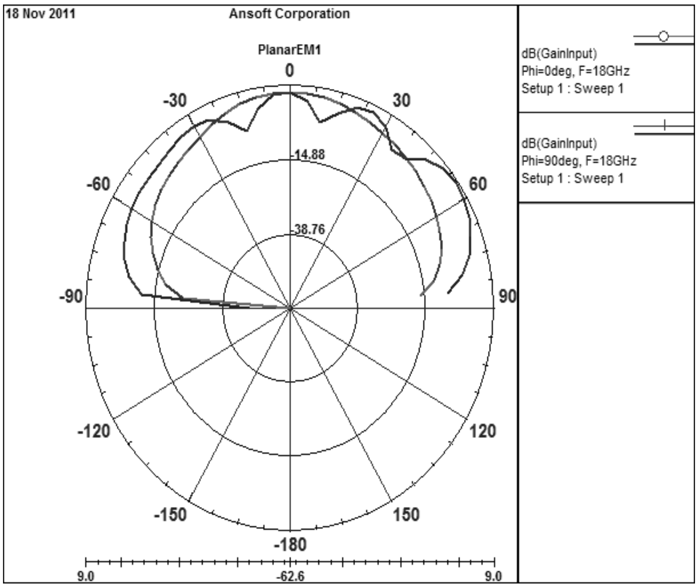

Fig: 14 Radiation Pattern of Modified Circular patch with Microstrip feed at position 1. R=15mm, h=1.6mm.Feed, resonant frequency=18GHz

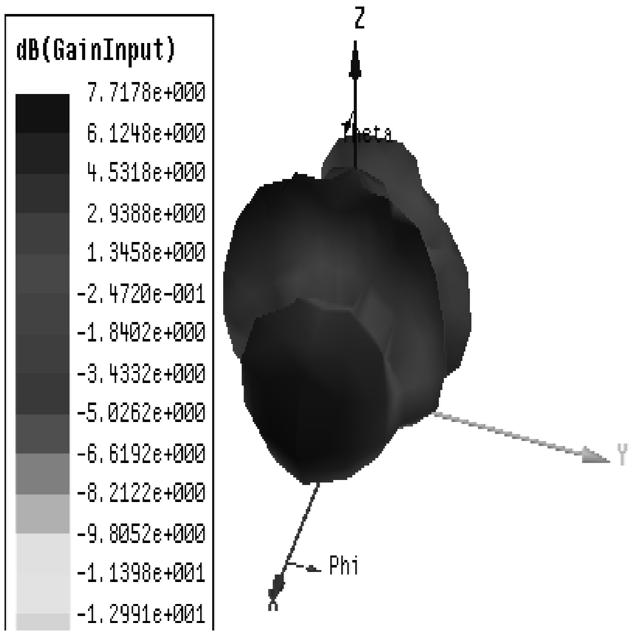

Fig: 16 3D Input Gain of Modified Circular patch with Microstrip feed at position 2. R=15mm, h=1.6mm, resonant frequency=22GHz

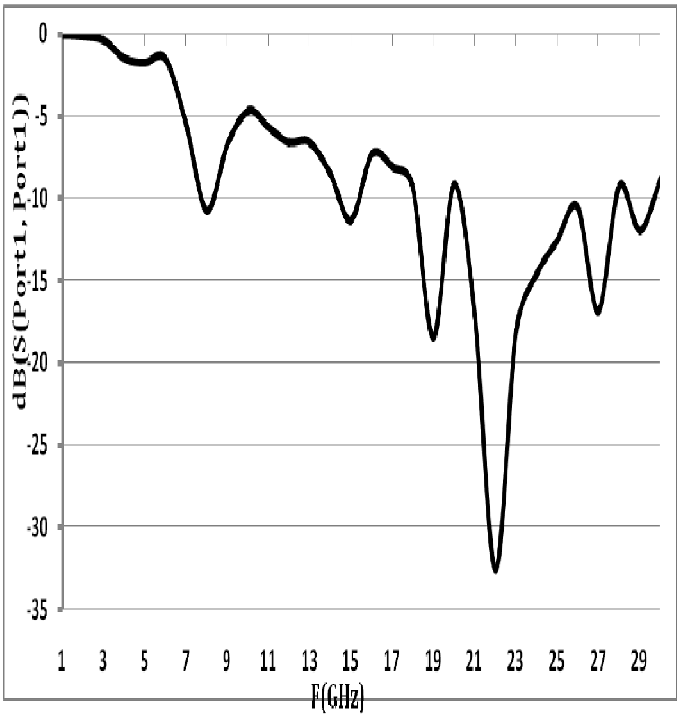

Fig: 15 Return Loss Vs Frequency of Modified Circular patch with Microstrip feed at position 2. R=15mm, h=1.6mm, resonant frequency=22GHz.

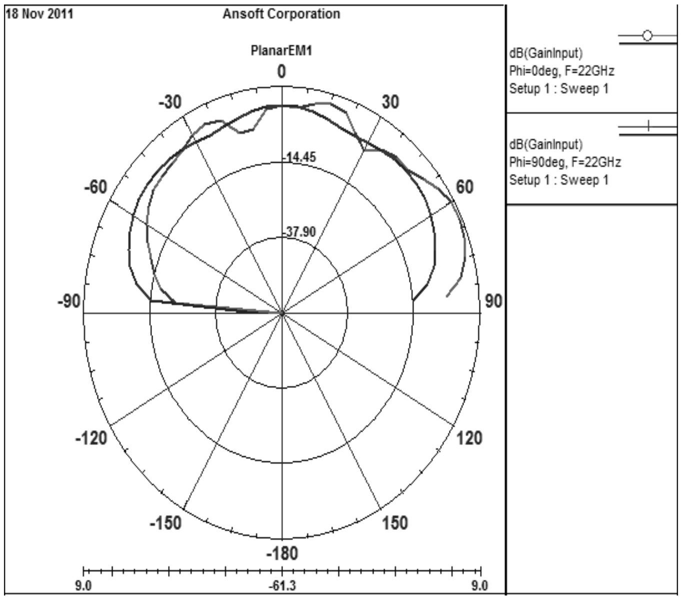

Fig: 17 Radiation Pattern of Modified Circular patch with Microstrip feed at position2 R=15mm, h=1.6mm.Feed, resonant frequency=22GHz

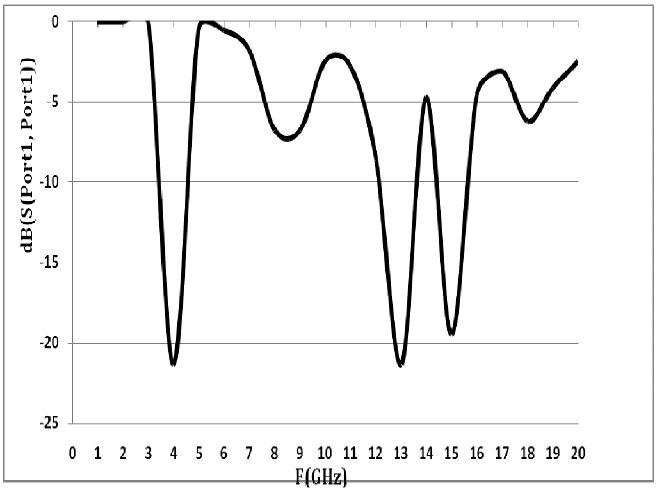

Fig: 18 Return Loss Vs Frequency of Coaxial fed Modified Circular patch with finite ground plane. R=15mm, h=1.6mm.Feed point= (5, 0).resonant frequency=4GHz, 13GHz & 15GHz.

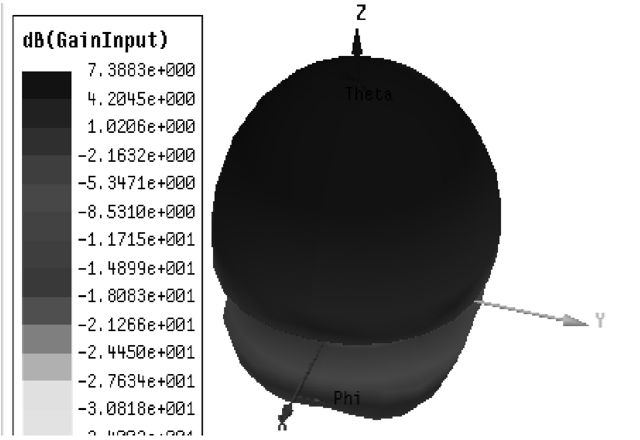

Fig: 19 3D Input Gain of Coaxial fed Modified Circular patch with finite ground plane. R=15mm, h=1.6mm, Feed point (5, 0).resonant frequency=4GHz

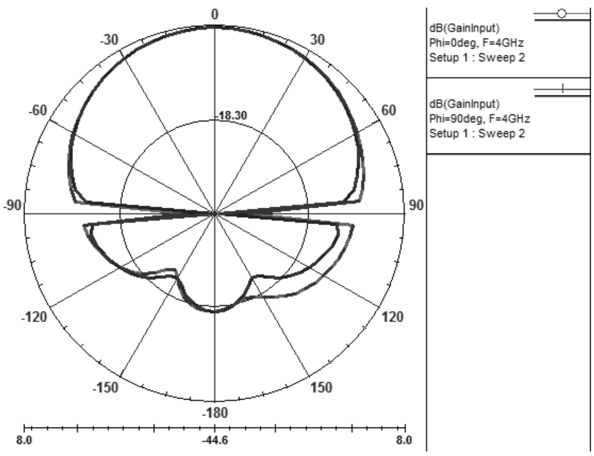

Fig: 20 Radiation Pattern of Coaxial fed Modified Circular patch with finite ground plane. R=15mm, h=1.6mm.Feed point (5, 0).resonant frequency=4GHz

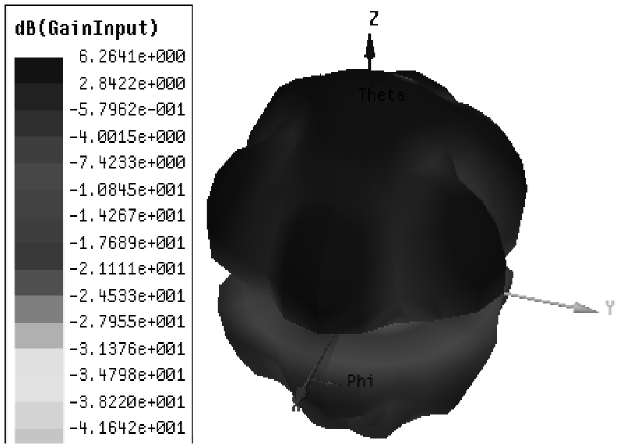

Fig: 21 3D Input Gain of Coaxial fed Modified Circular patch with finite ground plane. R=15mm, h=1.6mm, Feed point (5, 0).resonant frequency=13GHz

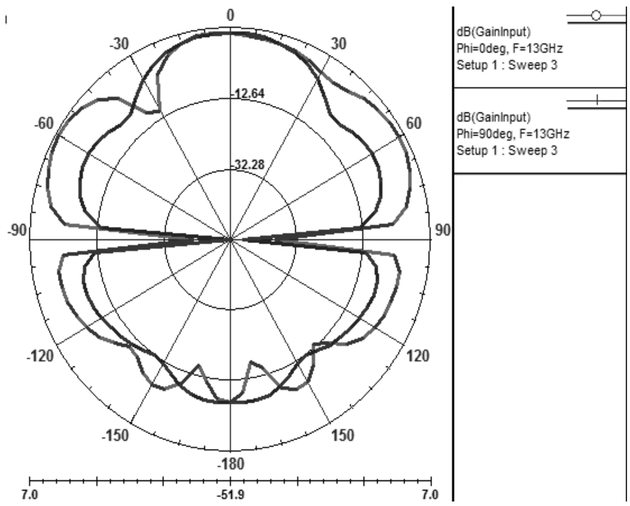

Fig: 22 Radiation Pattern of Coaxial fed Modified Circular patch with finite ground plane. R=15mm, h=1.6mm.Feed point (5, 0).resonant frequency=13GHz

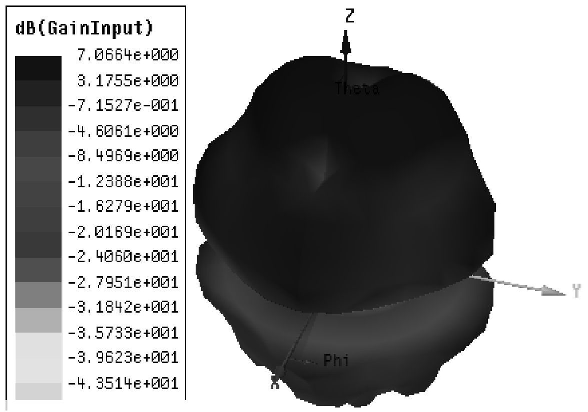

Fig: 23 3D Input Gain of Coaxial fed Modified Circular patch with finite ground plane. R=15mm, h=1.6mm, Feed point (5, 0).resonant frequency=15GHz

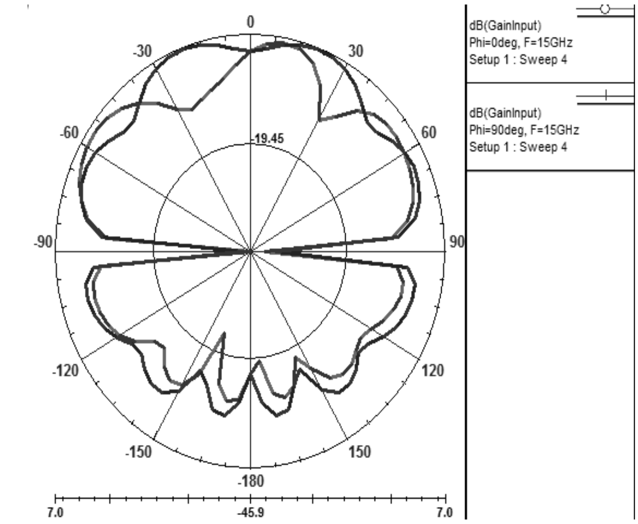

Fig: 24 Radiation Pattern of Coaxial fed Modified Circular patch with finite ground plane. R=15mm, h=1.6mm.Feed point (5, 0).resonant frequency=15GHz

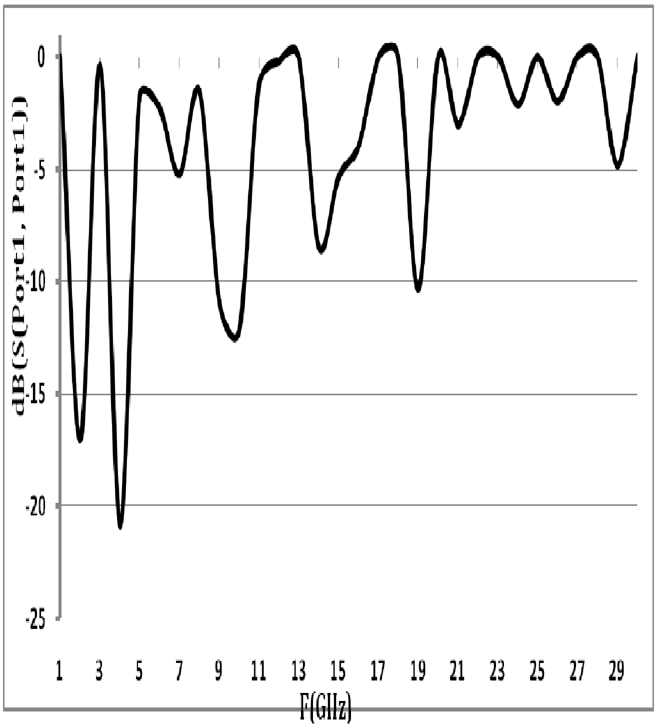

Fig: 25 Return Loss Vs Frequency of Vertical Microstrip fed Modified Circular patch with finite ground plane. R=15mm, h=1.6mm, resonant frequency=2GHz & 4GHz.

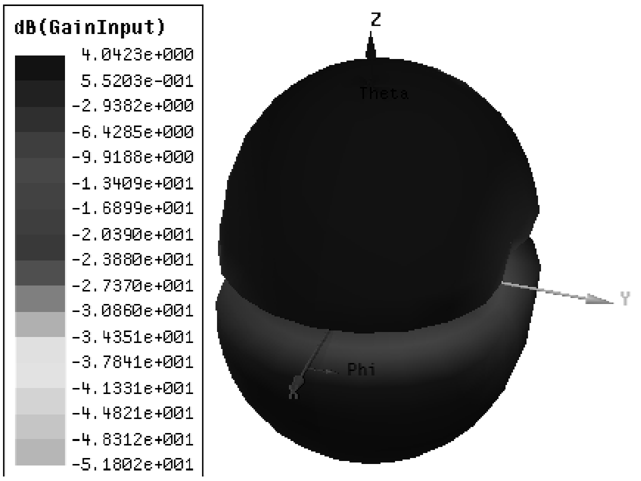

Fig: 26 3D Input Gain of Vertical Microstrip fed Modified Circular patch with finite ground plane. R=15mm, h=1.6mm, resonant frequency=2 GHz

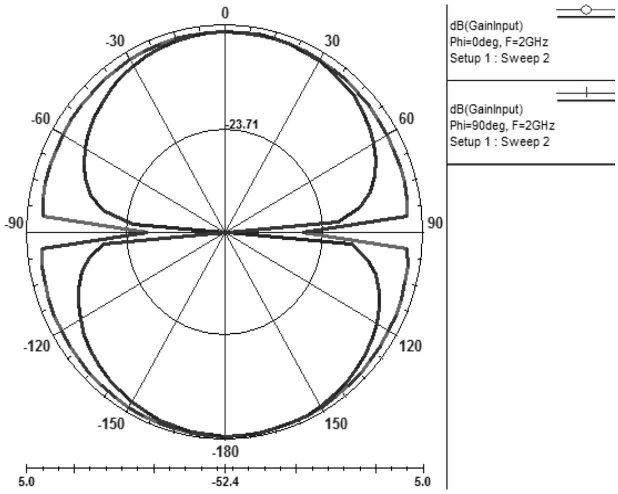

Fig: 27 Radiation pattern of Vertical Microstrip fed Modified Circular patch with finite ground plane. R=15mm, h=1.6mm, resonant frequency=2 GHz

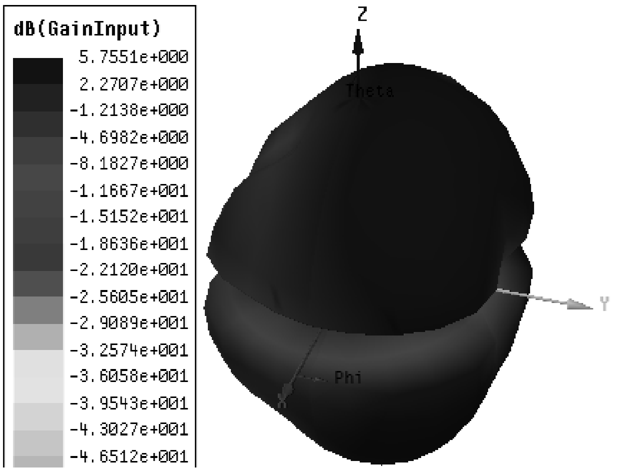

Fig: 28 3D Input Gain of Vertical Microstrip fed Modified Circular patch with finite ground plane. R=15mm, h=1.6mm, resonant frequency=4 GHz

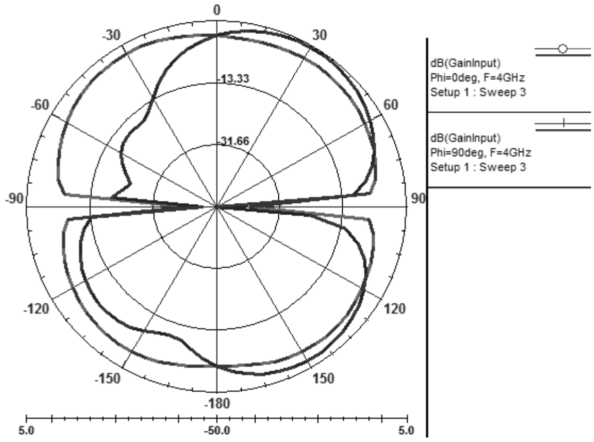

Fig: 29 Radiation pattern of Vertical Microstrip fed Modified Circular patch with finite ground plane. R=15mm, h=1.6mm, resonant frequency=4 GHz

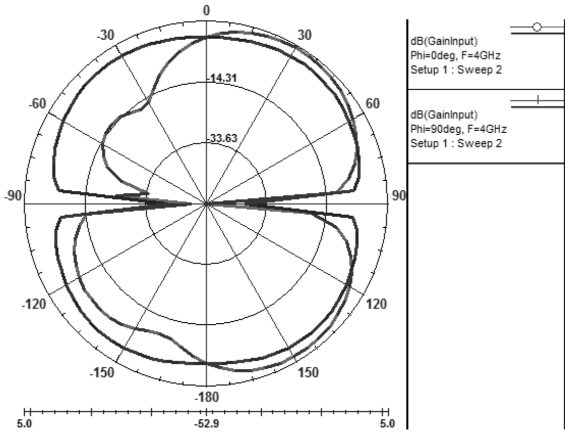

Fig: 32 Radiation pattern of Horizontal Microstrip fed Modified Circular patch with finite ground plane. R=15mm, h=1.6mm, resonant frequency=4 GHz

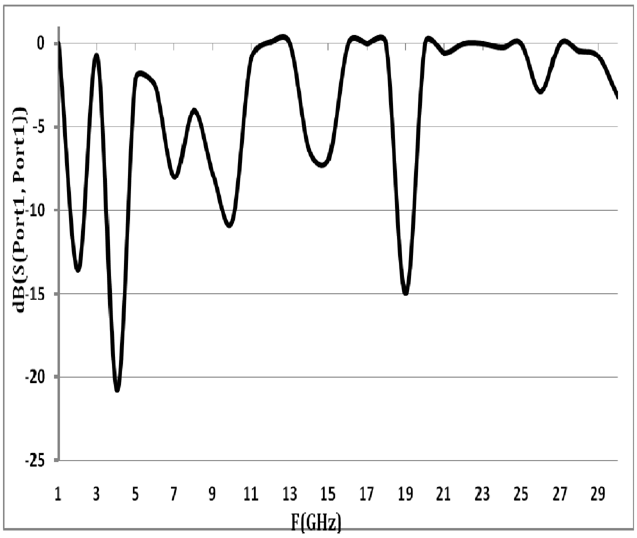

Fig: 30 Return Loss Vs Frequency of Horizontal Microstrip fed Modified Circular patch with finite ground plane. R=15mm, h=1.6mm, resonant frequency=4GHz & 19GHz.

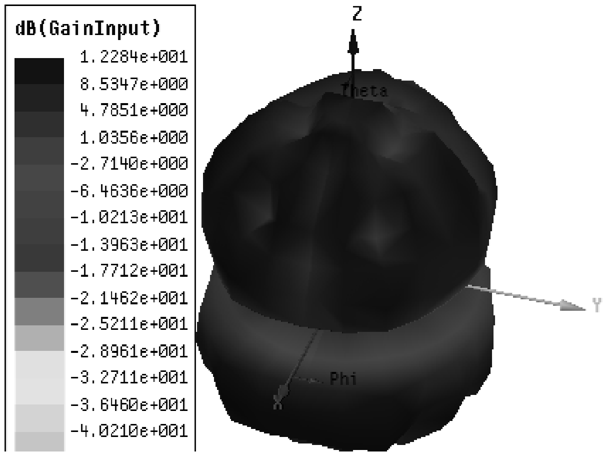

Fig: 33 Radiation pattern of Horizontal Microstrip fed Modified Circular patch with finite ground plane. R=15mm, h=1.6mm, resonant frequency=19 GHz

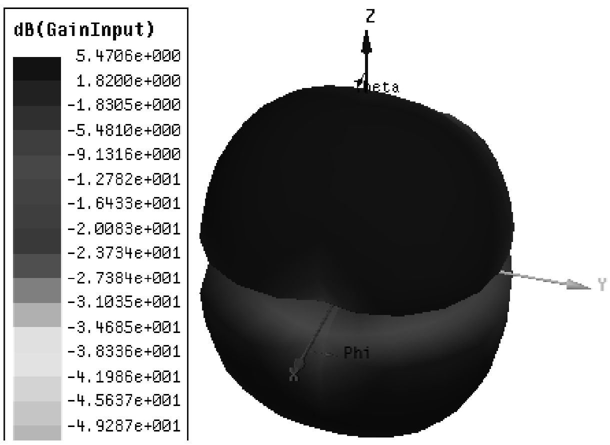

Fig: 31 Radiation pattern of Horizontal Microstrip fed Modified Circular patch with finite ground plane. R=15mm, h=1.6mm, resonant frequency=4 GHz

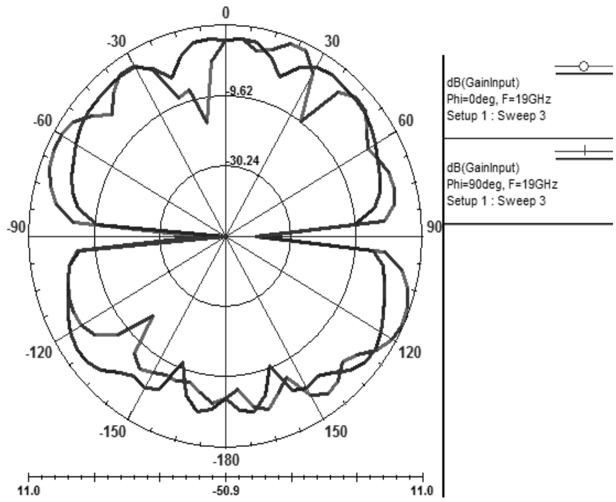

Fig: 34 Radiation pattern of Horizontal Microstrip fed Modified Circular patch with finite ground plane. R=15mm, h=1.6mm, resonant frequency=19 GHz

TABLE I:
Simulation results for different structures

Properties	Antenna1	Antenna2		Antenna3		Antenna4
Resonant Frequency (GHz)	16	4	12	18	8	22
Return Loss (dB)	-13.5	-40.8	-17.8	-30.8	-15.3	-32.5
VSWR	1.54	1.02	1.29	1.06	1.41	1.05
Gain (dB)	6.27	7.07	4.77	8.1	4.93	7.7
10dB-Impedance B/W (%)	5	38	15	79	14	35

So from the simulation results of different patch structures shown in Table I, it is evident that a huge enhancement of 10dB impedance bandwidth of 38% at 4GHz and 15% at 12GHz has been achieved by Modified Circular Patch Antenna with coaxial feed. Moreover Gain (7.078dB at 4GHz) and Return Loss (-40.89dB at 4GHz and -17.87 at 12GHz) are also improved. The 10dB impedance bandwidth is further enhanced by changing the feeding technique from coaxial to microstrip feed on the same modified circular patch structure. For microstrip feed at position2 the 10dB impedance bandwidths are 9.63% at 19GHz, 35% at 22GHz and two small responses are found at 8GHz (-10.74dB) and 15GHz (-11.32dB) and for microstrip feed at position1 the 10dB impedance bandwidths are 79% at 18 GHz and 14% at 8GHz.

TABLE II:
Comparison between simulated results of infinite and finite ground plane coaxial fed modified circular patch

Properties	**Antenna 2**		**Antenna 5**		
Resonant Frequency (GHz)	4	12	4	13	15
Return Loss (dB)	-40.8	-17.8	-21.31	-21.31	-19.43
VSWR	1.02	1.29	1.19	1.19	1.24
Gain (dB)	7.07	4.77	7.388	6.264	7.066
10dB-Impedance B/W (%)	38	15	27.25	11.9	8.4

Data of Table II shows the difference between an infinite and finite ground plane. Coaxial fed Modified circular patch resonates at dual frequencies (4 GHz and 12 GHz) when the ground plane considered infinite and the same structure resonates at three resonant frequencies (4GHz, 13GHz and 15 GHz) when finite ground plane is introduced.

TABLE III:
Comparison between simulated results of infinite and finite ground plane Microstrip fed modified circular patch

Properties	Vertical Feed				Horizontal Feed		
	Antenna3		Antenna6		Antenna4	Antenna7	
Resonant Frequency (GHz)	18	8	2	4	22	4	19
Return Loss (dB)	-30.8	-15.3	-17	-20.8	-32.5	-20.8	-15
VSWR	1.06	1.41	1.33	1.2	1.05	1.2	1.44
Gain (dB)	8.1	4.93	4.04	5.75	7.7	5.47	12.28
10dB-Impedance B/W (%)	79	14	41.5	27.5	35	28	3.4

From Table III it is evident that the resonant frequency and bandwidth tends to decrease when rectangular finite ground is introduced with microstrip fed modified circular patch for both position. Moreover for finite ground plane return loss is increased and as a consequence VSWR is also increased which denotes poor impedance matching.

IV. Conclusion

Narrow bandwidth is a disadvantage of conventional microstrip patch antennas. The proposed modified circular patch antenna can overcome this disadvantage providing large bandwidths in C, X and K bands with reasonable gain values for both infinite and finite ground plane. From the analysis of the proposed modified circular patch structure it is found that bandwidth with microstrip feed is broader than coaxial feed for both infinite and finite ground plane. However, resonant frequency takes higher value in case of microstrip feed for infinite ground plane and resonant frequency for finite ground plane is greater than that of infinite one.

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