Design, Simulation and Fabrication of Multiband Antenna using HFSS

D.Sharmila, M.Purnachandra Rao, P.S.V.Subbarao, S Nagakishore Bhavanam*

Abstract*: *Microstrip antennas are popular because of their low profile, light weight and low cost but narrow bandwidth and gain are the main disadvantages of this antenna. In this paper Multiband Octagonal Patch Antenna has been designed by ring slot technique for working in nine different frequencies presented in multi band C-band, X-band, Ku-band, K-band, Ka-band, Q-band and U-bands. Main applications of these bands are used in terrestrial microwave communications. In this research work, the performance of octagonal patch antenna operating at 7 different bands is analyzed. The Design methodology of the proposed research carried in 2 major modules. 1. Design of Single Octagonal Ring Slot antenna, 2. Design of Double Octagonal Ring Slot antenna. In the first design a single octagonal ring slot microstrip patch antenna is developed which resonates at six frequencies of five different frequency bands of C-band, Ku-band, K-band, Q-band and U-bands. In the second design a double octagonal ring slot microstrip patch antenna is developed which resonates at nine frequencies of six different frequency bands of X-band, Ku-band, K-band, Ka-band, Q-band and U-bands. The proposed antenna has been simulated by HFSS and measured by combinational analyzer.

Index Terms*: *Microstrip antenna, Ring slot technique, Octogonal patch, Multiband, HFSS.

I. INTRODUCTION

Fast improvement in populace needs Compact and multiband radio wire configuration to satisfy the enormous need of cutting edge remote applications. Smaller scale strip recieving wires additionally called as fix reception apparatuses comprise of a metallic fix on a grounded substrate. These are low profile, similar to planar and non-planar surfaces, straightforward and modest to manufacture utilizing present day printed-circuit innovation, precisely strong when mounted on inflexible surfaces, perfect with MMIC (Monolithic Microwave Integrated Circuit) structures, and extremely flexible as far as full recurrence, polarization, example, and impedance. These recieving wires can be mounted on the outside of elite air ship, rocket, satellites, rockets, autos, and even handheld cell phones.

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A. Research Motivation: In modern years, current communication systems necessitate antennas with multiple resonance and smaller dimension rather than conformist ones. Most prominently, the antennas should be fine impedance accorded over the going frequencies. In recent wireless communication systems, multi band behavior with decent gain is the essential for many claims, such as communiqué Satellites, Vehicle speed detection systems, Great resolution and close range directing radars aboard military airplanes which operates at different frequencies. In this wireless world, mixing of many requests is also required. So it necessitates same antenna to exertion for all of the integrated applications.

B. Problem Outline:

Micro strip antennas (MSA) additionally called as fix recieving wires involve of a metallic fix on grounded substrate. Structure of traditional microstrip fix with transfer speeds as low as a couple percents, wideband applications are extremely restricted. Different weaknesses incorporate low addition, low power taking care of ability, high Q worth and poor polarization virtue. For more than two decades, specialists have proposed a few strategies to accomplish scaling down, progress in transmission capacity if there should arise an occurrence of wideband conduct and acknowledging narrowband qualities utilizing planar microstrip reception apparatus. Because of one of a kind favorable circumstances, for example, little volume, low assembling expense and simple combination into planar circuits, planar microstrip recieving wires are perfect up-and-comers. In Multi band antennas, a single antenna has to work for multiple applications and antenna should behave as a versatile. Design challenges of multiband antenna are that, the designed antenna can operate on several bands and may have lower than average gain or materially larger in compensation. The development in use of electronic gadgets in everyday life rolled out improvements in remote correspondence frameworks.

C. Proposed Solution:

Main idea of this research is to design of multiband octagonal patch antenna using micro strip feed. Novelty in this Research is that the proposed ring slot technique is aimed to achieve multiband applications especially in Ultra High Frequency (UHF Spectrum), Super High Frequency (SHF Spectrum) and Extremely High frequency (EHF spectrum) also. Multiband Octagonal Patch Antenna is proposed to overcome the above stated issues to operate in nine different frequencies presented in different bands such as C, X, Ku, K, Ka, Q and U-bands. A regular octagon patch antenna is nothing but a variation of the circular patch antenna where segments are assigned to eight. Resonance frequency of octagonal patch depends on the feed position. The radiation pattern of this patch antenna provides high directivity (gain)

II. LITERATURE REVIEW

Design challenges of multiband antenna are discussed by researchers in the literature. Some of them are reviewed to observe the existing models and developed methodologies. So that it is possible to identify the appropriate model and technology to solve the stated challenges.

Ruixing Zhi et.al [1] presented a microstrip multiband antenna for X-band satellite communications. The design consists of two arc-shaped strips, dual inverted L-shaped parasitic stubs and partial ground plane. The design was complex with high design challenges. Nilima [2] presented a multiband antenna using DGS structure but achieved only C and X bands with complex design and performance mitigation.

Khalid et.al [3] proposed dollar symbol shaped patch array antenna for multiband applications. It has typical structure to design but operated in only k, Ku bands. Lam yae et.al [4] have designed a simple rectangular patch antenna. But it was suggested to embed with quarter wave length Spur lines, slots, parasitic elements to achieve C to Ku bands.

Punith kumar TR [5] presented an I-shaped fractal structure to meet multiband applications i.e. in C and X bands. Jyothi kapil et.al [6] presented a compact microstrip feed multiband mono pole antenna. But it is suggested to use partial ground method to resonate in dual band (x and Ku). Yahya rahmat et.al [7] discussed about technology trends, challenges and available techniques to design multiband antennas for satellite applications. The stated techniques are arrays, Meta materials, fractal structures etc.

U chakraborthy [8] proposed a rectangular microstrip antenna which is realized by two different single slotted antenna with slotted ground plane. But still it resonated at only C and X bands. Hattan F. et.al [9] presented a reconfigurable multiband C- slot patch antenna with dual patch. It is operated in dual band by incorporating PIN diodes as switches.

Aidin Mehdipour et.al [10] proposed a low profile planar monopole antenna to be operated in S and C bands. Antenna comprised of three radiating elements together with additional strip to control the antenna performance.

From the literature, it is observed that different complex structures, CPW feed techniques, lumped elements insertion and multiple elements with different patch shapes were used to achieve multiband applications. Still it is possible to resonate at 2-3 frequency bands only. Many design Challenges and performance mitigation parameters are also observed. Especially all the antennas are operating only from LF to Super High Frequency (SHF).

A. Objectives of Proposed Research Work:

Main idea of this research is to design of multiband octagonal patch antenna using micro strip feed. Novel contribution in this research work is that the proposed antenna is aimed to operate also in Extreme High frequency (EHF) Spectrum. It is predicted that EHFs will enhance the performance of the next generation of High Throughput Satellite (HTS) programs by reducing the number of hubs required. This, in turn, will help to reduce the cost per bit.

Proposed antenna’s size is minimum and simple structure compared to existing models and it can operate in six different bands. A quite unimportant antenna can proficiently emit high frequency EM waves is desirable in modern applications. In this thesis, design and performance study of dual ring octagonal patch antenna which can be operated in C, X, Ku, Ka, Q and U- band in terms of VSWR, Gain, Return loss and Radiation pattern.

The objectives of the proposed research are as follows:

1. To design and simulate Single Octagonal Ring Slot antenna.
2. To design and simulate Double Octagonal Ring Slot antenna.
3. Fabrication and testing of both the models

III. METHODOLOGY AND EXPERIMENTAL RESULTS

Design of a multiband antenna is proposed to meet the huge demand of wireless communications and its advanced applications. In the literature, many existing models were using microstrip patch antennas comfortably to meet the multiband resonance. It is observed that microstrip patch with different shapes with suitable excitation helps to performance enhancement in multiband. In this proposed research work, a novel structure of microstrip patch antenna is proposed to operate in six different bands such as X-band, Ku-band, K-band, Ka-band, Q-band and U-bands and resonating at nine different frequencies. The Proposed model is designed and simulated using ANSYS-HFSS software. HFSS is the software for high-efficiency research, advancement, and effective prototyping.

A. **Design of Single Octagonal Ring Slot Antenna:**

The first objective of the proposed research is to design a single ring Octagonal antenna aimed to use for multiband applications. Different shapes like pentagonal, hexagonal antenna also designed. But improvement of return loss is the novel approach in this design. The geometry of the Octagonal MPA is illustrated and it comprises of an octagonal patch through length (L), width (W).The geometric center of the patch is denoted as P.

The patch is etched on a substrate of thickness, h and dielectric permittivity, εr. Octagonal patch antenna resonates at two frequencies determined primarily by the L and W dimensions of the geometry. The proposed model schematic view is shown in figure 1. It also serves to achieve beam shaping.

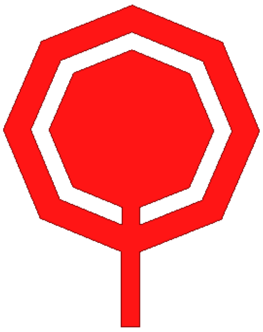
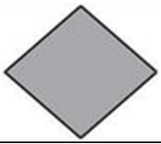
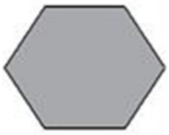
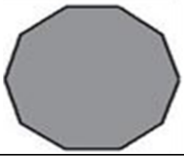
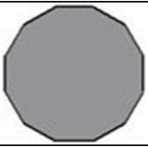


Fig. 1: Schematic View of proposed model microstrip Patch

The reason for taking octagonal shape has been discussed in detailed manner. Table 1 shows five different shape of polygons unit cell designed in the same substrate of fast Film TM-27. The simulation results show different bandwidth percentage for each polygon unit cell shape. The octagon unit cell AMC (with 8-edges) shows the highest bandwidth percentage compared to others. It increase 57.14 % of bandwidth compared to the tetragon (4-edges) shape.

Different shapes of patch and its design and performance efficiencies are listed in table 1, the octagon shape will be used for further modification. The full patch octagon AMC is modified by introducing slots into the shape.

Table 1: Bandwidth coverage for different shapes of unit cell polygon

AMC unit cell	Shape	Band Width
Tetragon		77%
Hexagon		104%
Octagon		121%
Decagon		98%
Dodecagon		97%

A1. Simulation Results:

Proposed antenna is simulated using HFSS software & corresponding graphs are obtained to analyse the performance interms of output parameters, such as return loss, gain, radiation pattern and VSWR.

A1.1. Return Loss vs Frequency:

It is the power that is reflected by the antenna at the end of the transmitter/receiver. Lower the RL higher will be the efficiency of antenna. RL graph or |s| dB graph of this circular patch antenna is shown in figure 2.

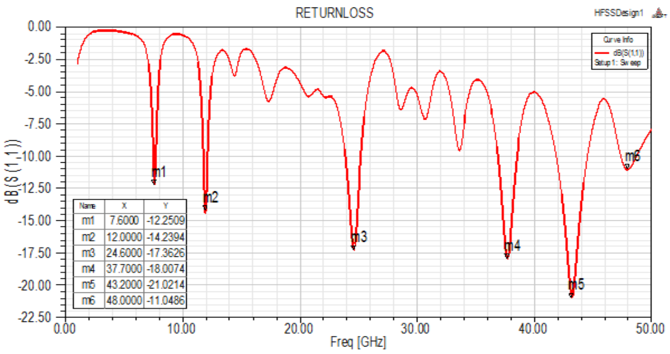


Fig. 2 Return Loss vs frequency plot for the proposed model

It is observed that return loss is less than -10 dB for six frequencies in five different bands. The Resonant Frequency is the frequency at which antenna radiates maximum and has lowest return loss. From above graph it is clear that antenna radiation is maximum at six frequencies of 7.6GHz, 12GHz, 24.6GHz, 37.7GHz, 43.2GHz and 48GHz. Return loss is calculated from the formula given below:

$$RL = -20\log 10|\Gamma|$$

Where, Γ = reflection coefficient.

A1.2. VSWR vs Frequency plot:

VSWR is the measure of in what way thriving antenna's impedance is matched with TL. To convey power to an antenna, impedance of TL must be corresponding with impedance of antenna. VSWR is a task of reflection co-efficient, which designates the power replicated by antenna. If reflection co-efficient is Γ, then VSWR is given by:

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|}$$

If VSWR is 1 that specifies Γ is conserving assessment of 0 which is not practically possible, constantly there is certain expanse of replication happens for whichever antenna practically. So 1<VSWR<2 is for good radiation purposes.

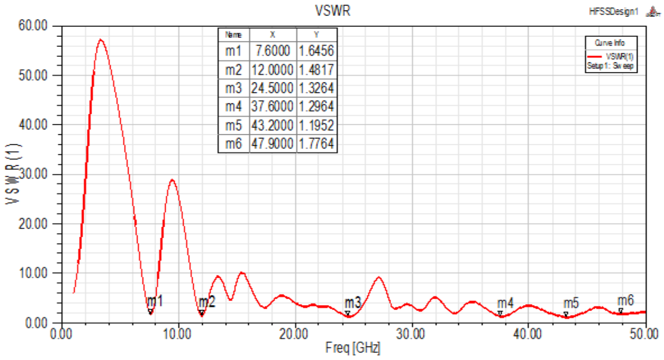
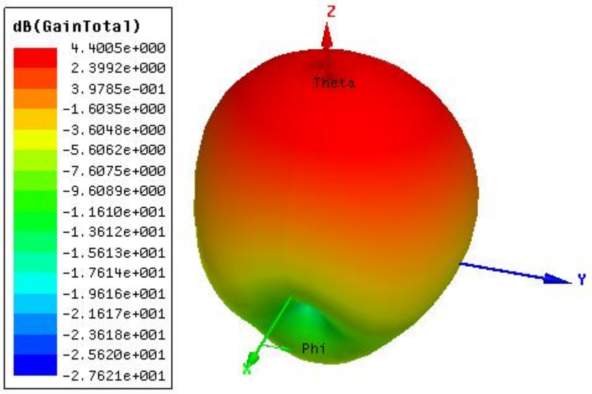


Fig.3: VSWR vs frequency plot for the proposed model

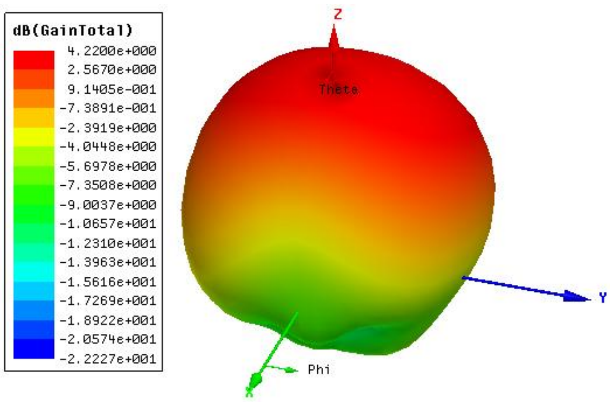
For return loss to be <-10 dB, VSWR ought to be <2. The VSWR plot for the proposed model is shown in figure 4. From above graph, it is clear that in the working frequencies i.e. 7.6GHz, 12GHz, 24.6GHz, 37.7GHz, 43.2GHz and 48GHz VSWR worth is less than 2, hence antenna will work well in this frequency range.

A1.3. Gain of the Antenna:

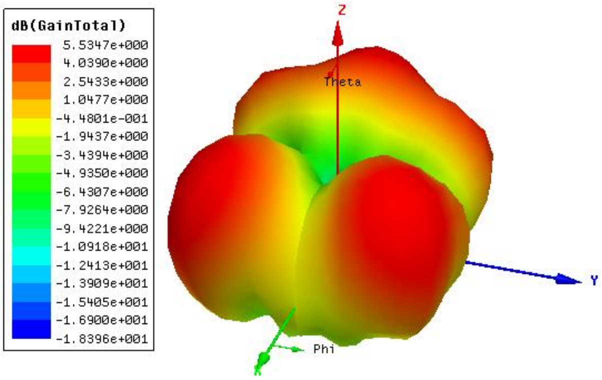
Gain of antenna is definite as "the ratio of the intensity, in a specified bearing, to the radiation intensity that would be gotten if the power putative by the antenna remained exuded isotropically." 3D and 2D Gain plots at resonating frequencies of proposed antenna are shown in figure 4 (a) to (f).



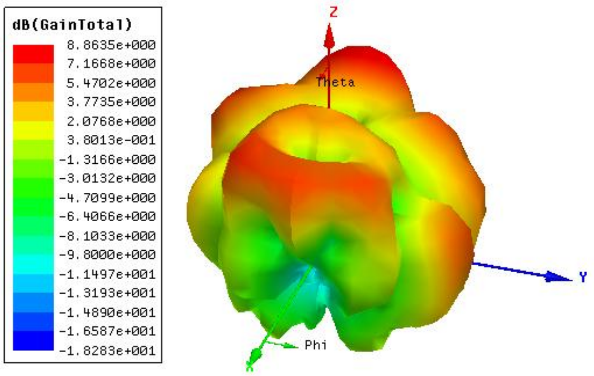
(a) 3D Gain representation at 7.6GHz



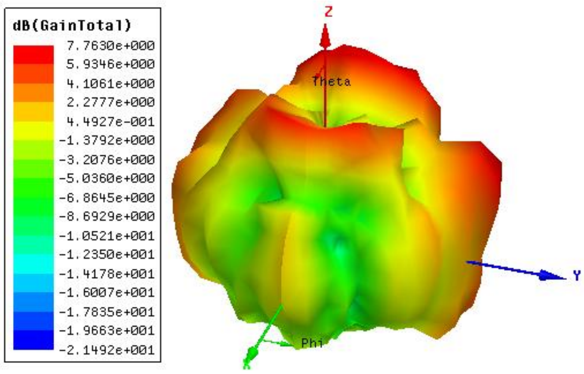
(b) 3D Gain representation at 12GHz



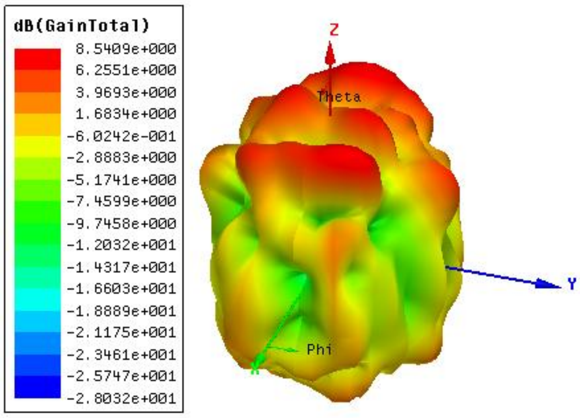
(c) 3D Gain representation at 24.6GHz



(d) 3D Gain representation at 37.7GHz



(e) 3D Gain representation at 43.2GHz



(f) 3D Gain representation at 48GHz

Fig. 4: (a) to (f) 3D gain plots at various operating frequencies

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A2. Fabricated Antenna Model:

From the above discussed sections, it is observed that the proposed antenna shows six resonant frequencies which are applicable to C, Ku, K, Q and U Communication band applications. The Designed and Manufactured Octagonal micro strip patch antenna has been shown in below figure 5 and the test setup picture has been shown in figure 6.

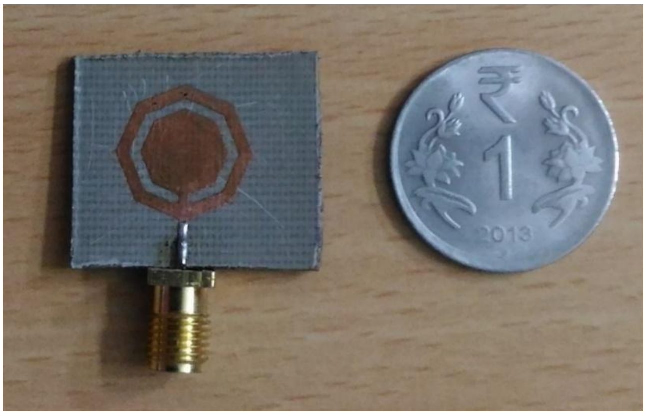


Fig. 5: Fabricated Antenna Model

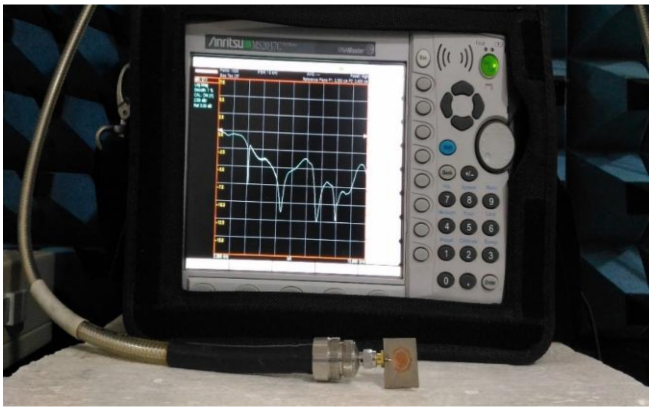


Fig. 6: Measurement Setup

In this design, a simple microstrip feed octagonal ring slot microstrip patch antenna has been proposed. This antenna is simulated using HFSS software and performance of the antenna such as gain, S-parameter and radiation pattern are measured using Combinational analyzer.

B. Design of Dual Octagonal Ring Slot Antenna:

The Second Objective of the proposed research is to design a dual Octagonal ring slot antenna. It is observed that first model is operating at six resonating frequencies of five different spectra. The Second model is aimed to operate in more frequency bands with improved performance. The shape of the patch is modified as Dual octagonal ring slot and the dimensions of the substrate are considered as 21mm×24mm×1mm, and the sides of the dual octagonal ring slot antenna are taken as 4.59mm, 4.20mm, 3.82mm, 3.44mm and 3.06mm. The length and width of the feed line is given as 7.20mm×1mm. The schematic view of the proposed model using HFSS represented in figures 7.

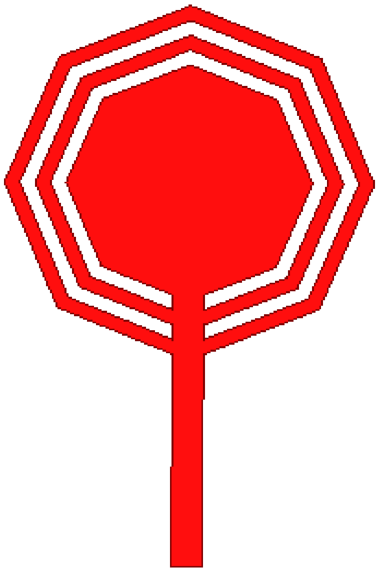


Fig. 7: Schematic View of double octagonal ring model

B1. Simulation Results:

Proposed model simulated using HFSS and Output parameters are to be analyzed. Simulated results of the proposed model will be discussed to analyze the performance.

B1.1. Return Loss vs Frequency:

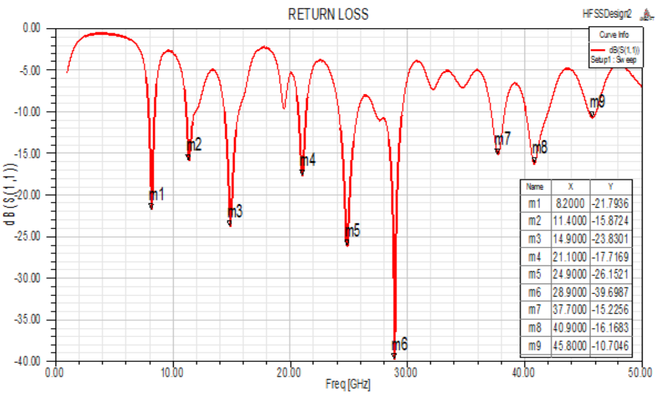


Fig. 8: Return Loss vs Frequency of the proposed antenna

Fig.8 represents the S11 Vs frequency curve. It is observed that return loss is less than -10dB for nine frequencies in six different bands. The Resonant Frequency is the frequency at which antenna radiates concentrated and has lowest RL. From above graph it is clear that antenna radiation is maximum at nine frequencies of 8.2GHz, 11.4GHz, 14.9GHz, 21.1GHz, 24.9GHz, 28.9GHz, 37.7GHz, 40.9GHz, and 45.8GHz.

B1.2. VSWR vs Frequency Plot:

VSWR is the measure of in what way thriving antenna's impedance is matched with TL. If the obtained VSWR value 1<VSWR<2 is for good radiation purposes. The VSWR plot is shown in the figure 9.

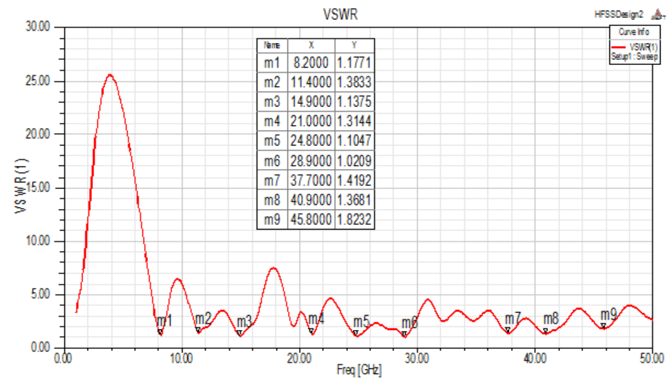
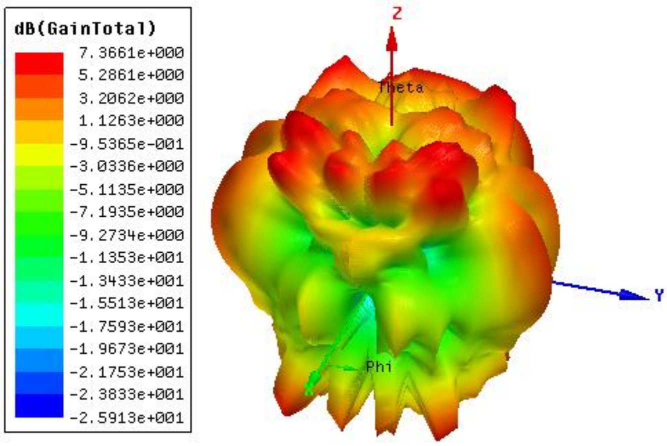


Fig. 9: VSWR vs Frequency for proposed model

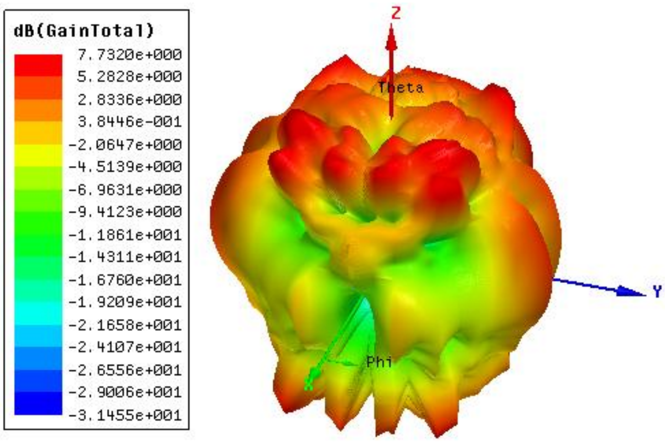
For return loss to be <-10 dB VSWR should be < 2. The VSWR plot for the proposed model is shown in figure 5.4. From graph it is clear that in the nine frequencies of 8.2GHz, 11.4GHz, 14.9GHz, 21.1GHz, 24.9GHz, 28.9GHz, 37.7GHz, 40.9GHz, 45.8GHz VSWR value is <2, hence antenna will work well in this frequency range.

B1.3. Gain of Antenna:

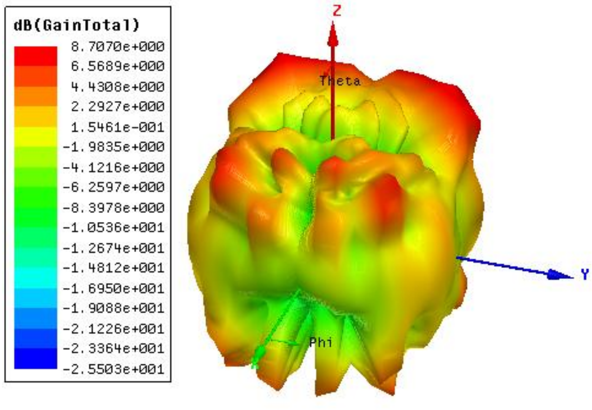
Gain of antenna is a key parameter which combines both directivity and electrical efficiency. The 2D and 3D gain plots at resonating frequencies of Proposed model is obtained using HFSS and shown in the figure 10 (a) to (i).



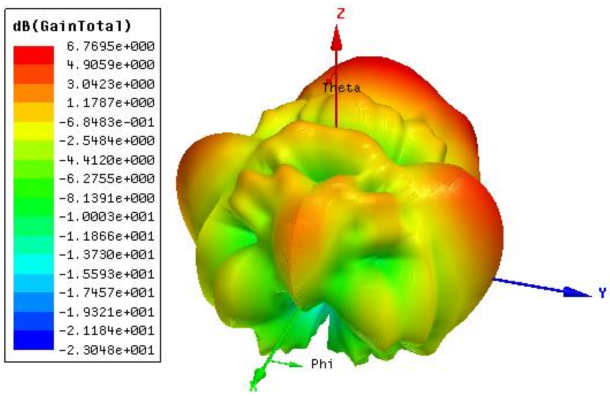
(a) 3D gain representation at 8.2GHz



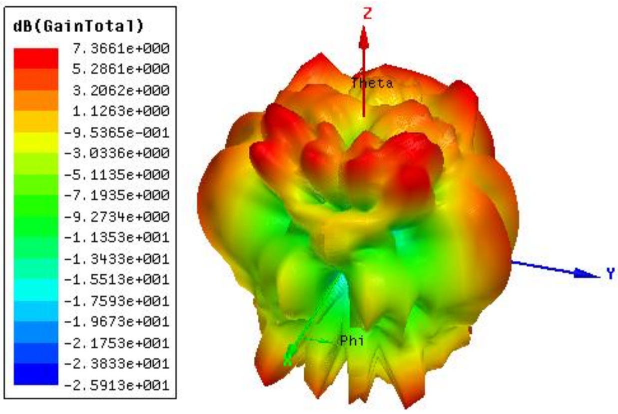
(b) 3D gain representation at 11.4GHz



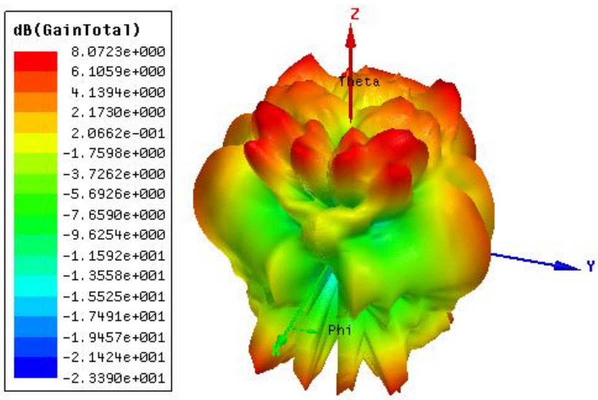
(c) 3D gain representation at 14.9GHz



(d) 3D gain representation at 21.1 GHz



(e) 3D gain representation at 24.9 GHz



(f) 3D gain representation at 28.9 GHz

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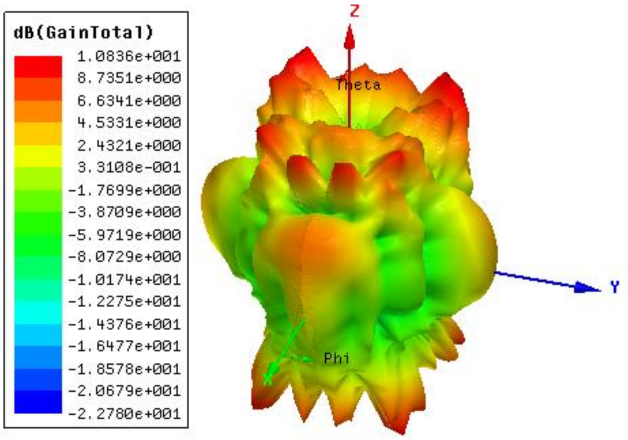
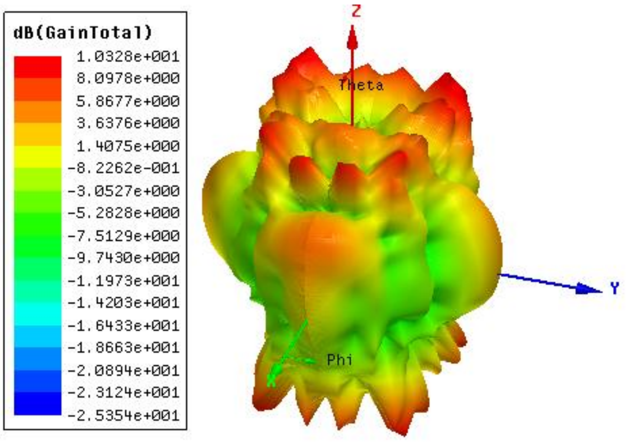
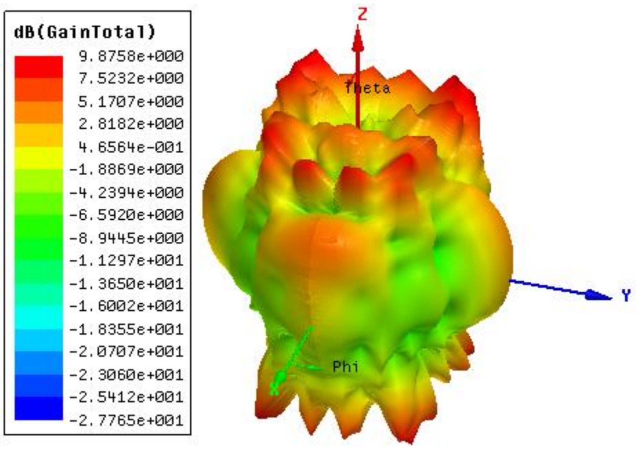


(g) 3D gain representation at 37.7GHz



(h) 3D gain representation at 40.9GHz



(i) 3D gain representation at 45.8GHz

Fig. 10: (a) to (r) 3D and 2D representation of Gain for proposed model at various resonating frequencies

B2. Fabricated Antenna Model and Measurement Setup

It is observed that the proposed antenna model shows nine resonant frequencies which are applicable to X, Ku, K, Ka, Q and U band Communication Band applications. The Designed and Manufactured Octagonal micro strip patch antenna and measurement setup has been shown in figures 11 and 12.

Fig.11: Fabricated dual octagonal ring slot Antenna Model

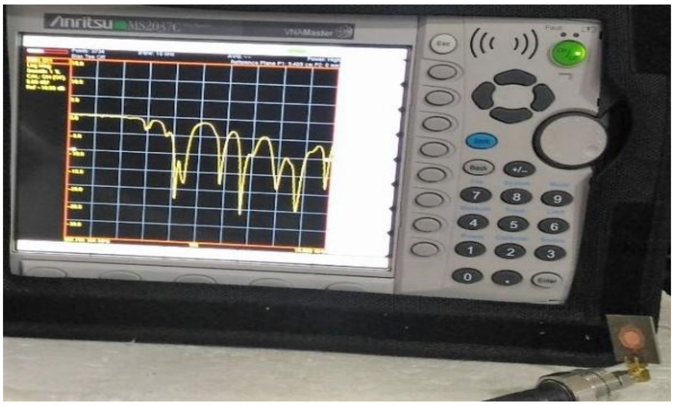


Fig. 12: Measurement Setup

In this design, a simple microstrip feed dual octagonal ring slot microstrip patch antenna has been proposed. This antenna is simulated using HFSS software and then fabricated. The fabricated model has tested using combinational analyzer. The output parameters of the antenna such as gain, S-parameter and radiation pattern are measured.

IV. COMPARISON OF SINGLE AND DOUBLE OCTAGONAL RING SLOT ANTENNAS

This chapter presents comparison of designed single and double octagonal ring slot antenna with microstrip line feed which are discussed in the previous chapters. Both the antennas are quite similar (All the design parameters are chosen to be same in order to make a comparative study). The only difference is the second design uses an additional ring slot (The first model is designed with one ring slot but the second model is designed using two ring slots). The additional slot is used to increase the operating frequencies.

The first antenna model radiates at only six frequencies in the proposed five bands but the second antenna model radiates at nine frequencies in the proposed five bands. Both the antenna are useful for the multiband applications Both of them are simulated and fabricated using a Rogers RT Duroid 5880 substrate with dielectric constant of 2.2 and thickness of 1 mm.

The design is analyzed by Finite Element Method based HFSS Simulator Software (version 14.0) by which Return loss, 3D polar plot, Radiation patterns, Gain, VSWR of the antennas are computed. After comparison it is proved that the antenna using dual ring slots shows improved performance in terms of Return Loss, Gain, VSWR and Bandwidth etc.

A. Simulated Results Discussion

The comparison of both the models is carried by obtaining the comparison graphs from HFSS. The comparison plots will give the performance enhancement interms of no.of operating frequencies, returnloss and Gain.

A1.1. Return Loss:

With Single Ring Slot:

From the obtained graphs, it is clear that first model antenna radiation is maximum at six frequencies of 7.6GHz, 12GHz, 24.6GHz, 37.7GHz, 43.2GHz and 48GHz. It is observed that the return loss obtained is <-10dB.

With Dual Ring Slot:

From the obtained graphs, it is clear that the second model antenna radiation is maximum at nine frequencies of 8.2GHz, 11.4GHz, 14.9GHz, 21.1GHz, 24.9GHz, 28.9GHz, 37.7GHz, 40.9GHz, and 45.8GHz. It is observed that the return loss obtained is <-20dB, which resembles good impedance matching.

The comparison plot for both the models are plotted and shown in figure 13. From the graph, it can be observed that the antenna with dual ring slot has good return losses compared to the antenna with single ring slot.

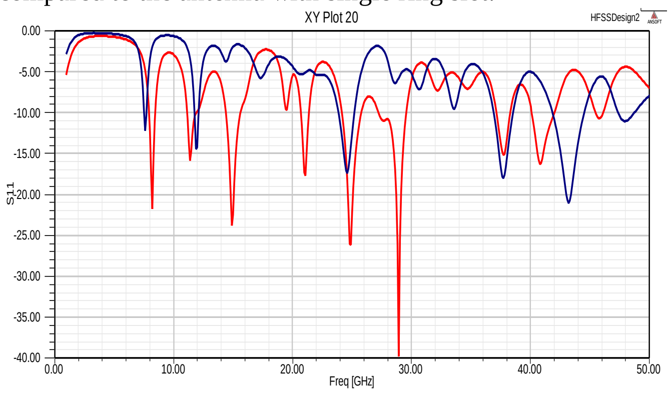


Fig. 13: Return Loss comparison for both the proposed Antenna Models
(--- with single ring slot, --- with dual ring slot)

Return Loss of both the models' comparison plot is shown in figure 6.1.It is observed that single ring slot model has minimum -10dB (S11<-10dB) for 6 different bands only. The second model with dual ring has minimum S11<-20 dB upto -35dB for nine different frequencies.

A1.2. VSWR:

The comparison plot for VSWR of both the models are obtained using HFSS. Both the models' VSWR is in justified range (1 to 2) as shown in figure 14.

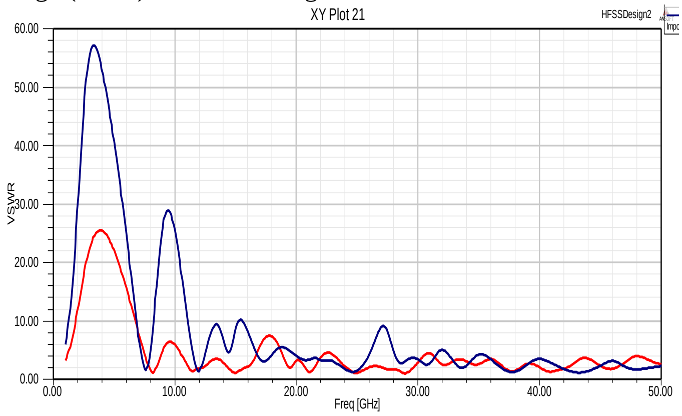


Fig.14: Compared VSWR of Two proposed Antenna Models
(--- with single ring slot, --- with dual ring slot)

A1.3. Gain Comparision:

The Gain comparison for both the models is tabulated in Table 2. The first model has gain ranging from 4.4dB to 8.5 dB for six different frequencies. Where the Proposed final model has high gain ranging from 7.3dB to 10.8 dB for nine different frequencies.

Table. 2: Gain comparison in different phases of proposed design

S.No	Frequency in GHz	Gain in (dB) in Single Slot Antenna	Frequency in GHz	Gain in (dB) in Dual Slot Antenna
1	7.6	4.4	8.2	7.3
2	12	4.2	11.4	7.7
3	24.6	5.5	14.9	8.7
4	37.7	9.1	21.1	6.7
5	43.2	8.1	24.9	7.3
6	48	8.5	28.9	8.0
7	-		37.7	10.8
8	-		40.9	10.3
9	-		45.8	9.8

A1.4. Directivity Comparison:

The Directivity comparison for both the models are listed in table 3.

Table. 3: Directivity comparison in different phases of proposed design

S.No	Frequency in GHz	Directivity in (dB) in Single Slot Antenna	Frequency in GHz	Directivity in (dB) in Dual Slot Antenna
1	7.6	3.0	8.2	6.8
2	12	3.7	11.4	7.1

3	24.6	5. 6	14.9	7.9
4	37.7	8.9	21.1	6.7
5	43.2	8.3	24.9	6.8
6	48	9.2	28.9	7.3
7	-		37.7	9.9
8	-		40.9	9.9
9	-		45.8	10.0

From the above tables, easily understand that the antenna using dual ring slot has improved gain and directivity compared to the antenna with single ring slot. The above comparison clearly reveal that the proposed antenna model using dual ring slot is proved to have better characteristics in terms of Peak gain, Band width, Overall gain of antenna, Radiation pattern etc. than the one with single ring slot. So we can clearly say that Dual ring octagonal slot antenna is good to use in multiband applications compared to antenna with and without single ring slot.

It is observed that the first antenna model resonates at six frequencies of five different frequency bands of C-band, Ku-band, K-band, Q-band and U-bands and the second antenna model resonates at nine frequencies of six different frequency bands of X-band, Ku-band, K-band, Ka-band, Q-band and U-bands

V. CONCLUSION

Multi patch antenna has Narrow bandwidth and less gain as the main disadvantages. In order to improve the performance of multi patch antenna, Slot antenna s are proposed. In this Research, two designs were proposed for multi band applications. The proposed method used ring slot technique to achieve multiband applications.

In the proposed model, Octogonal patch is developed to achieve compact size with better performance.

In the first design a single octagonal ring slot microstrip patch antenna is developed which resonates at six frequencies of five different frequency bands of C-band, Ku-band, K-band, Q-band and U-bands

In the second design a double octagonal ring slot microstrip patch antenna is developed which resonates at nine frequencies of six different frequency bands of X-band, Ku-band, K-band, Ka-band, Q-band and U-bands.

The design of proposed antennas has been completed using HFSS software. The simulation gave results good enough to fabricate it on hardware and the fabricated results are in good judgment with the simulation results.

The proposed octagonal antenna can be used for Military requests like missile management, marine radar, air-borne tracking, Fixed satellite service (FSS) like television transmission, Broadcast Satellite Service (BSS) like telecommunication, wireless communication and Satellite altimetry.

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