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Octagonal Ring Shaped Millimeter Wave Antenna for 5G applications

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Abstract: This project presents a novel microstrip antenna for millimeter wave-wave application. The patch is designed with an octagonal annular ring structure with Defected Ground Surface. The antenna is designed at 43.5 GHz with very good performance obtaining a reflection coefficient of 25dB. The antenna size is made below 1.2X1.2X1.6 cm which can be placed inside small electronic devices. Coaxial feed is designed at the operating frequency to provide proper matching with the 50 Ohm transmission line so that it can be used with conventional SMA connectors. The radiation efficiency of the designed antenna was found to be 66% along with 6.5dBi directivity. Operational bandwidth of the antenna was found to be between 42.4GHz to 44.8GHz. along with a VSWR of 1.08

***Index Terms* - Microstrip Antenna, Printed Patch Antenna, Millimeter-Wave Antenna**

I. Introduction

Frequency band of 30GHz to 300GHz is accepted as the millimeter Wave (mmWave) range lies between the microwave and infrared waves. Because of the small wavelength (1mm-10mm), it is possible to pack larger antenna arrays in small physical dimension. Disadvantages such as low channel capacity, limited frequency band and congestion, researchers have moved forward towards the mmWave communication, where the unused spectrum of mmWave can be used in 5G communication system [1]. The upcoming technological upgradation including smart city, Virtual Augmentation, holographic communication, etc. will require the features like low power and high speed data transfer which can be fulfilled by the 5G communications techniques [2-3]. To achieve the 5G system, two types of frequency bands are taken in to consideration. Sub-6GHz band is used for higher coverage area and relatively new mmWave frequency band for higher data rates with reduced latency. Most of the developed countries such as USA, UK, Canada have started using the mmWave band for implementing 5G systems [4]. In table 1 frequency bands used by different developed countries is given.

Table 1: 5G frequency bands in different countries

Country/Region	LF Band	HF Band
EU	L band, 3.4-3.8GHz	24.25GHz-43.5GHz
USA	UHF band	27.5GHz-71GHz
Japan	3.6GHz-4.9GHz	27.5GHz-29.5GHz
China	3.3GHz-5.0GHz	24.25GHz-42.5GHz
South Korea	3.4Ghz-3.7GHz	26.5GHz-29.5GHz

Several antenna designs have been documented for mmWave band operation. A compact mmWave antenna proposed in [5] is a potential candidate for multibeam operations. A dual polarized mmWave antenna with frequency band of 23-29GHz is presented in [6]. The antenna has MIMO capability to handle the polarization. Similar investigation on mmWave antenna can be seen in [7-9]. The antenna design presented in the given articles are complex design which may lead to fabrication errors. In this study we present a simple ring shaped patch.

II. Antenna Design and Analysis

This chapter presents the final antenna design with the design procedure and executions followed by the final design. The design of the co-axial feed from the antenna is also discussed in this chapter. The final design is an octagonal ring structure. All the simulations are carried out with CST MWS.

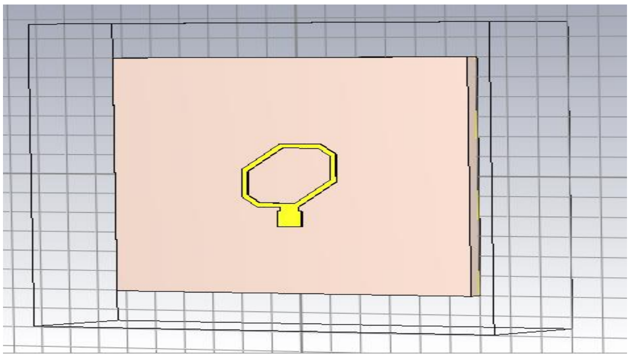


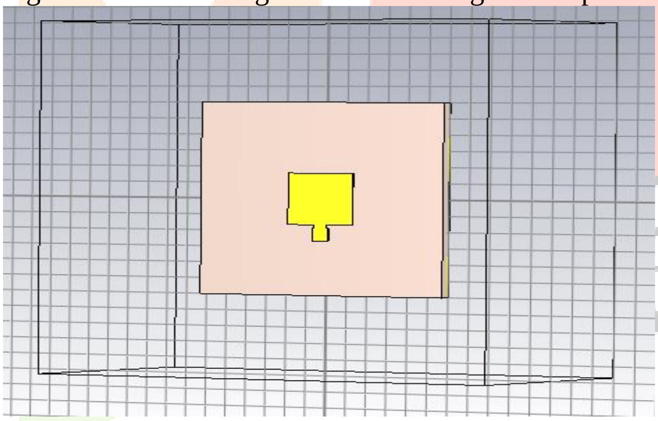
Figure 1 (Schematic Diagram of the antenna)

Design Procedure

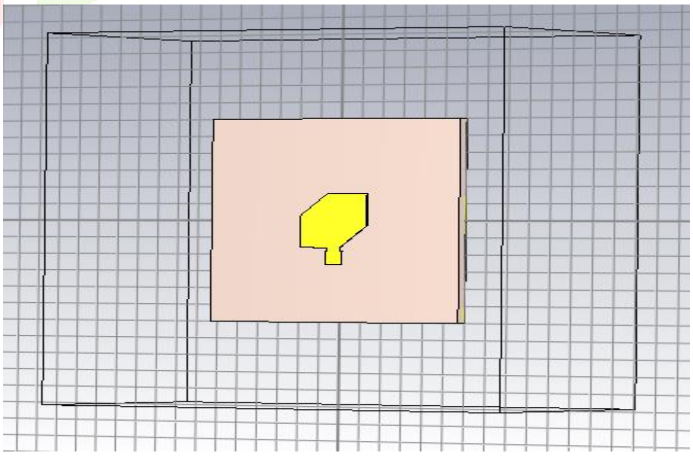
The antenna design of Millimeter Wave is done with a simple microstrip patch antenna. Dimensions for the patch antenna are approximated using the formulae available from transmission line model(TLM). Although TLM fails to give exact calculation of higher frequency, The initial design is done with the approximation and fine-tuned to operate at 40GHz. Fig a shows the simple square patch design. Th dimension for the same is given in table a. For the antenna design FR-4 substrate is used with thickness of 0.51mm.

The obtained parameters as shown in fig b was not satisfactory and further improvement is done with increasing the radiation edges. This is achieved by making a octagonal patch instead of simple patch

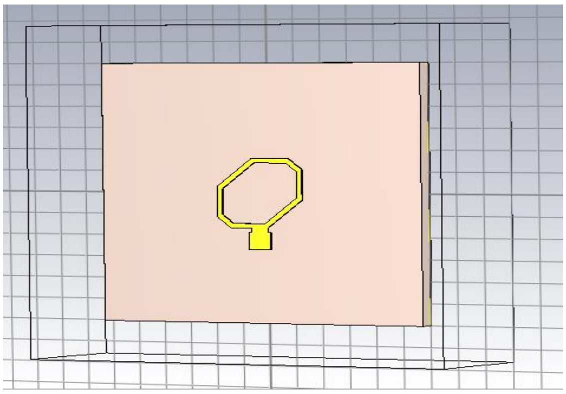
To increase the matching and improve the return loss, two concentrate at the patch of antenna1 is cut out as shown in fig : c . With this design the S-Parameter value was improved upto -40dB with unchanged frequency. Design parameters and ther dimensions are given in table 1 . Fig 3 shows the design of the patch with the design variables.



a. Antenna-1



b. Antenna-2



c. Antenna-3

Figure 2- Different Stages of Antenna Design

To achieve the resonance frequency at mmWave band solid patch is replaced with octagonal ring patch(ORP). The shape of the patch is made with octagonal ring and it is connected with to the co-axial cable. The shape of the antenna after giving all dimensions is shown at fig c, and the parameter values used for the ORP antenna

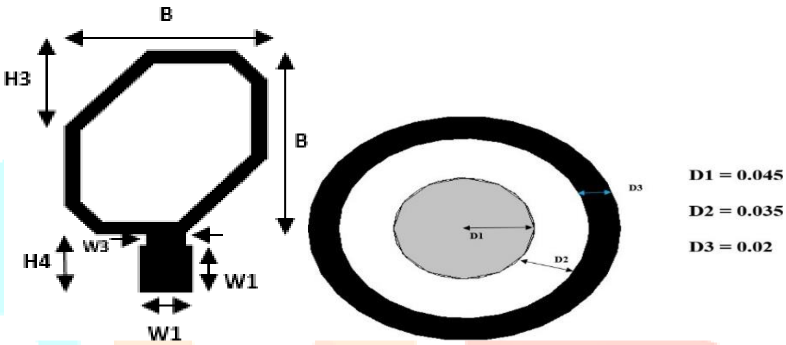


Figure 3- Design parameters of of the Patch and Coaxial feed

Antenna design parameters with the detailed dimensions are shown in figure 3 along with the values given in Table 1

Table-1- Antenna Design Parameters

Parameter	**Value(mm)**
H1	0.51
H2	0.05
H3	0.5
H4	1
A	12
W1	0.8
W2	0.10
W3	0.6
W4	0.5
B	3.2

III. Results and Discussion :

In this section the results for the ORP antenna is presented. Antenna parameters such as 3-D farfield , Radiation pattern, VSWR , Impedance are given. From the obtained S-Parameter curve as shown in figure 4, the resonating frequency of the antenna as found to be 43.5 GHz. The operational bandwidth is 42.5GHZ to 44.7GHz around 2.2GHz

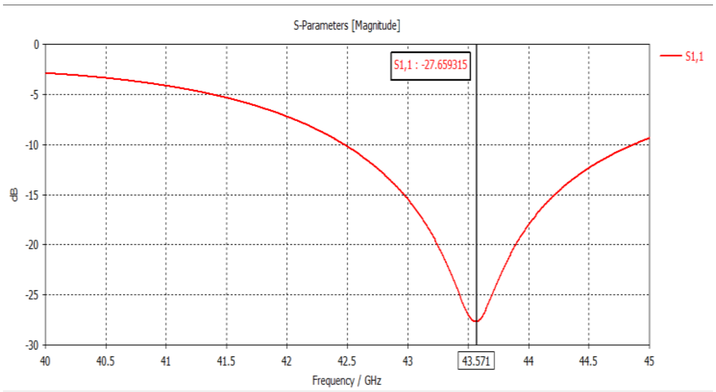


Figure 4- S-Parameter

VSWR of the proposed antenna is within the range of 1 to 2 throughout the frequency band. VSWR curve is shown in figure 5.

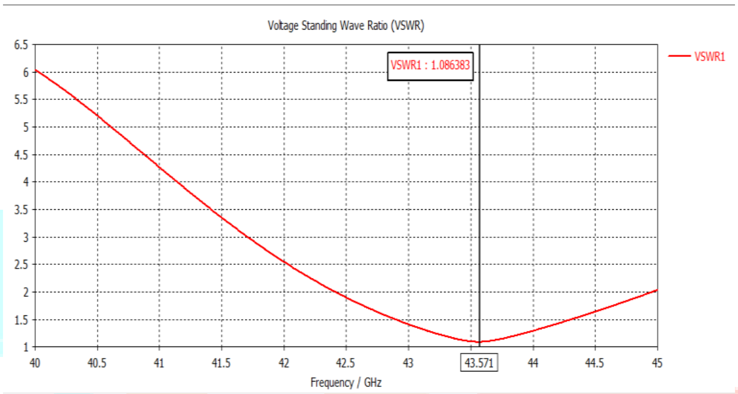


Figure 5- VSWR

Figure 6 presents the 3-D radiation pattern of the antenna which is nearly orthogonal radiation. The radiation pattern is shown at 43.5GHz, where the minimum return loss is obtained.

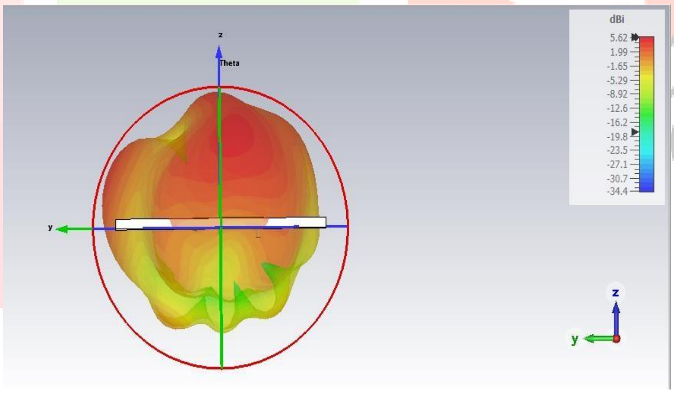


Figure 6 (3D- Radiation Pattern at freq=43.5GHz)

In figure 7 2-D radiation pattern is shown at 43.5GHz phi=0deg. The radiation pattern shows that the antenna behaves as a point source radiating nearly uniform manner in the azimuth angle direction.

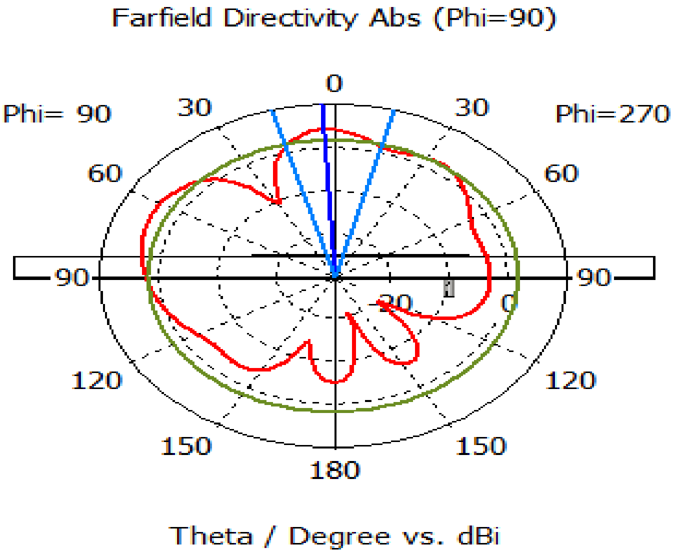


Figure 7 (2D- Radiation pattern at Phi=0deg, freq=43.5GHz)

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IV. Conclusion

V. A low-profile wideband patch antenna with octagonal ring is presented in the paper. The operating band of the antenna is 42.5GHz to 44.5GHz. with resonating frequency of 43.5GHz. The wideband obtained in the antenna is useful for 5G MMW band. With a stable radiation pattern the antenna exhibits a gain of 5.6dBi at the resonant frequency. With a low profile and the above discussed factors the proposed antenna is a good candidate for 5GMMW antennas including smart devices and sensors.

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