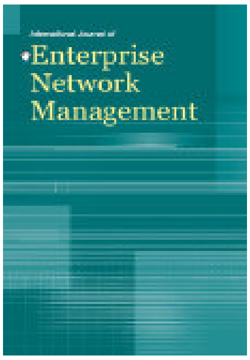

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Novel design and implementation of irregular fractal arrow head structure microstrip antenna for sub 6 GHz 5G applications

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Abstract: This article is based on a novel compact irregular fractal shape antenna with an arrow-head structure (IFAS). The presented antenna is devised for 3.2 GHz operating frequency and its implementation is mainly focused on 5G mobile applications. Though many antenna types are available, a fractal antenna has the advantages of having a compact size, good multiband performance with wide bandwidth, and provides consistent performance. The Antenna design involves two iterations which uses fractal techniques. The dimension of the proposed antenna is 17.8 × 35 mm with a thickness of 1.6 mm which makes it complete, and this antenna has been stimulated using high frequency structural simulator (HFSS) software. The proposed antenna covers multiband frequency which is observed from simulation and measured to be between 3.2 GHz (Sub 6 GHz) and 9.50 GHz (X-Band). The antenna was simulated on a FR-4 dielectric substrate material and achieved the best result. The Result graphs like reflection coefficient, impedance, radiation pattern, and gain parameters are shown and reviewed in this article.

Keywords: 5G technology; micro-strip fractal antenna; arrow-head shape; millimetre-wave communication.

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1 Introduction

In the past few years, economic and community advancements were highly transformed by the developments in the domain of mobile communication. As a consequence, 5G technology has turned out as a pedestal of the future 21st century. 5G technology is an upcoming technology with progressive and inventive services. 5G is the futuristic technology which promises exceptionally high data speed, least delay, more connectivity, and better quality of service. In order to do something different from what is usually done, it is noteworthy to say that 5G technology will unbind novel scopes for development (Matin, 2018; Meena et al., 2019). 5G technology will eventually bring revolution in the sectors of industry, education, healthcare, and other fields because it supports IoT and many other new technologies. In comparison to the previous generations of mobile technology, 5G is predicted to give 100–1,000 times better data speed. In order to give high data speed, 5G networks have been nominated to make use of higher bandwidths (Li et al., 2017). To enhance the accessibility, research has been moved to millimeter-wave frequencies. Many antenna techniques have been employed to attain higher bandwidths among which fractal geometric is the most sought due to its iterative property. Better Impedance matching and frequency bands are acquired in fractal antennas compared to regular antennas (Kiran et al., 2018; El Shorbagy et al., 2016).

In the advancement of mobile technology, Fractal antennas are exceptionally constructive. The reduction in size and multiband functionality of fractal antennas are the key advantages. An irregular fractal antenna has been presented in this paper which is an arrow-head structure. The antenna's performance was also studied with the help of numerical analysis (Krzysztofik and Brambila, 2017; Singh, 2018). The presented shape in this manuscript is very small in dimension and is planned to run in the frequency range of 3.2 GHz which proves to be advantageous for future 5G mobile communication. In the next sections, the calculations, design, parametric analysis, and results like Reflection Coefficient, gain, VSWR, impedance, and radiation pattern will be discussed.

2 Literature survey

To meet the ever-increasing needs and demands for high-speed technology-based applications, the in- depth research in the fifth generation (5G) technology is an indication of technological revolution. The third-generation partnership project (3GPP) which releases the timely up gradation in 5G technology allows the researchers to clear the research objectives and grant towards the development (Nakmouche et al., 2021). The 5G technology is supported by smart phones as well as various IOT devices in order to provide various services such as smart cities, smart buildings, etc. All these will need a 5G antenna which has stable radiation pattern, low latency and low path loss. 5G technology includes many new techniques like massive MIMO, digital or hybrid beam forming, ultra-dense networks, novel multiple access methods, etc. But, to achieve these high-level techniques and a proper physical infrastructure, the designers have to face many challenges (Malik et al., 2018).

Designing an antenna along with microwave system and achieving the radio propagation environment characteristics for 5G technology is also a major challenge. Though many researches have been made on 5G antenna system, an efficient solution has not yet been found. 5G will not only speed up the data rates, but will also enable many new technologies like IoT, virtual reality, autonomous cars, smart cities and many more (Sandi et al., 2021). Along with conventional band, 5G uses higher frequency bands like mm wave to achieve higher speed. An antenna design must provide less interference and reliable communication along with increased power, larger bandwidth and higher gain using a low profile and array antennas. These requirements make the antenna design more challenging for the designers. Thus, they will need better and innovative ideas and efficient solutions for designing an antenna for 5G applications. This paper (Faisal et al., 2018) is designed by Zeland's IE3D and operated at 28 GHz band. It has a bandwidth of 9.82 dB with the return loss of 1.29 GHz and efficiency of 42 dB. The current network uses sub-6 GHz, but it is not possible for the available spectrum resource to support 5G. So, telecom moved to a higher range of 6–300 GHz. The antenna band is bulky in size and some of those do not cover the whole frequency band. So the antenna is a milestone (Ramesh et al., 2019). It is a rectangular patch microstrip antenna with the frequency of 28 GHz and designed with computer simulation technology (CST) of 28 GHz band and (best to return loss performance obtained). It was used for different patch conductor with same dimensions. Return loss criteria were obtained. Antenna efficiency performance was vice-versa. It is important for predicting the effect of different patch cladding with an in-built microstrip antenna (Rimon et al., 2015). This paper is proposed with the frequency of 28 GHz. The performance of the antenna had a return loss and bandwidth and efficiency gain. The purpose has high frequency structural simulator (HFSS) and VSWR. It is modified by 28 GHz for 5G applications (Abdullahi et al., 2019). Microstrip slot antenna consists of ellipse shaped radiating patch fed by a 50 Ω micro-strip line on the Rogers RT5880 substrates. A rectangle shaped slot is etched in the ground plane to enhance the antenna bandwidth. However it works in a single direction (Li et al., 2017).

The objectives and requirements of mID-wave antennas for 5G were reviewed. Recent advances in mID-wave antenna design were reported and design guidelines were discussed. In particular, four different designs that were reported recently in the literature have been identified based on their attractive characteristics that support 5G requirements and applications (El Shorbagy et al., 2016).

The inference acquired from the survey done is that as the size reduces, the performance does reduce, but the usage of the right optimisation technique can definitely improve the results. With the reduction in relative permittivity, the thickness of the antenna reduces and the gain increases accordingly. Keeping in mind the above considerations, the antenna is designed in a miniaturised size applying the appropriate optimisations, and the desired results of high gain and better return loss are obtained.

3 Design and implementation

The figure and composition of the suggested antenna are shown in Figure 1. The antenna is designed and implemented on an FR-4 Epoxy substrate material with εr = 4.4, relative permeability 1, dielectric loss tangent = 0.02 with a thickness h = 1.6mm using HFSS which is based on the finite element method. The major concern of this paper is to design an irregular fractal antenna of 3.2 GHz to analyse the result of the antenna as well as to examine the performance of the antenna. The calculations are made by using the formulae for substrate material length and width. The formulae for substrate and ground length and width are similar, hence the values are also similar. The patch position, length, and width of the antenna are also calculated using the formulae. The length and width of the feed line are calculated using the formula. Ports position, length, and width are also calculated.

$$Width\ of\ the\ patch = Width = \frac{\lambda}{2}\sqrt{\frac{2}{\in_r + 1}} \tag{1}$$

$$Length\ of\ the\ patch\ L = L_{eff} + 2\Delta L \tag{2}$$

$$L_g = L + 6h \tag{3}$$

$$W_g = W + 6h \tag{4}$$

$$Position\ of\ \ patch = \left(\frac{L_g - L}{2}, \frac{W_g - W}{2}, h\right) \tag{5}$$

These parameters are taken into account to design the appropriate irregular fractal antenna for 3.2 GHz. The major task is to calculate the length, and width of the patch, substrate, ground, and the suitable position of the feed probe on the Fractal antenna. The dielectric constant plays a very important role in determining the parameters used in designing. The dielectric constant and the dielectric height are considered. By using all the calculated parameters, an irregular fractal antenna for 3.2 GHz has been built by ANSYS HFSS. Based on the calculation formulae, the length and width of the ground and substrate position of the feed probe are calculated.

Table 1 Parameters of the proposed antenna

Parameter		*Size (mm)*
Ground plane length	(Lg)	35.6
Ground plane width	(Wg)	35.6
Radiating layer length	(Lp)	17.8
Radiating layer width	(Wp)	35
Transmission line(feed) length	(Lf)	13
Transmission line (feed) width	(Wf)	2
Substrate (insulator) thickness	(Hs)	1.6
Patch slot length	(Ls)	3
Patch slot width	(Ws)	3

Figure 1 Arial view (see online version for colours)

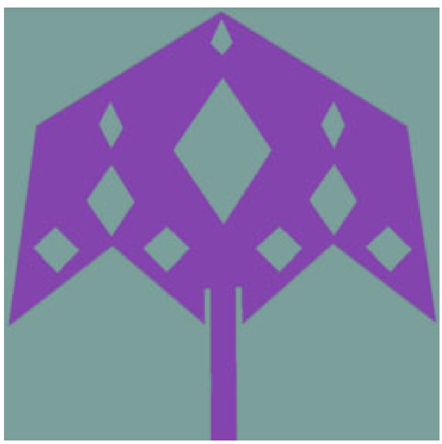
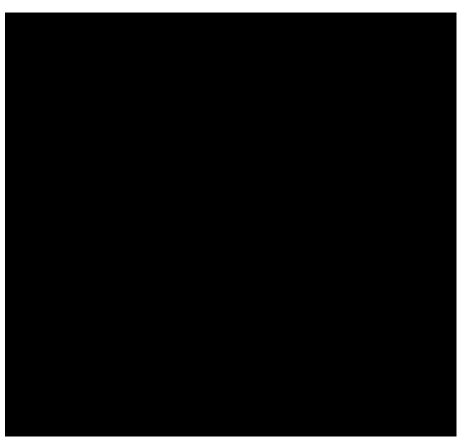


Figure 2 Bottom view (see online version for colours)



The proposed antenna model has been designed with the help of the parameters. In an adequate simulation environment, the radiation boundary has been built along with all the calculated parameters. Lumped port which is of height 1.6 mm and width of 3 mm are employed to excite or end passive circuits and antennas, in addition to compute frequency responses of devices like insertion loss concerning with S parameters. They are used to excite or terminate passive circuits and antennas as well as to compute frequency responses of devices such as impedance matching and insertion loss in terms of S-parameters. Some major analysis should be performed to analyse the efficiency of the antenna. Hence, antenna parameters like return loss, gain, characteristic impedance and radiation pattern will be determined in result analysis.

With the help of calculations, the irregular fractal antenna for 3.2 GHz frequency has been designed. The calculation formulae and results are mentioned in the previous section. After the validation and simulation, some vital parameters are observed to determine the efficiency of the irregular fractal antenna for 3.2 GHz frequency range.

4 Fabrication and measurement

The design results are good performance, high gain, broader bandwidth, and clear radiation pattern. The simulation is carried out using ANSYS HFSS software. The presented irregular fractal arrow-head shape design is simulated for the operating frequency of 3.2 GHz. Return loss usually mentioned by the S11 parameter has been investigated. The results of return loss have been illustrated by HFSS.

Figure 5 exhibits that the return loss is very less for 3.2 GHz is –30.486 dB. Since a high return loss may reduce the performance efficiency of the designed antenna, we consider return loss to be an important parameter. Because of the high return loss, it could be exceedingly reduced. These outcomes also confirm the exact position of the feed probe in the patch for the required frequency.

Figure 3 Fabricated prototype antenna top view (see online version for colours)

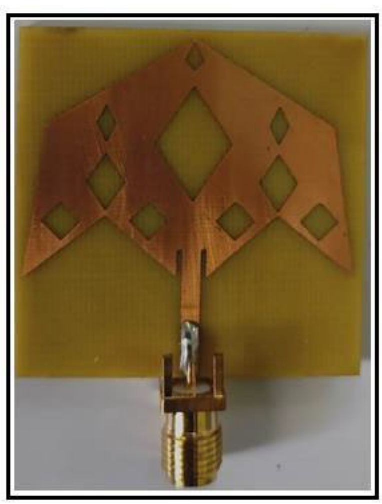
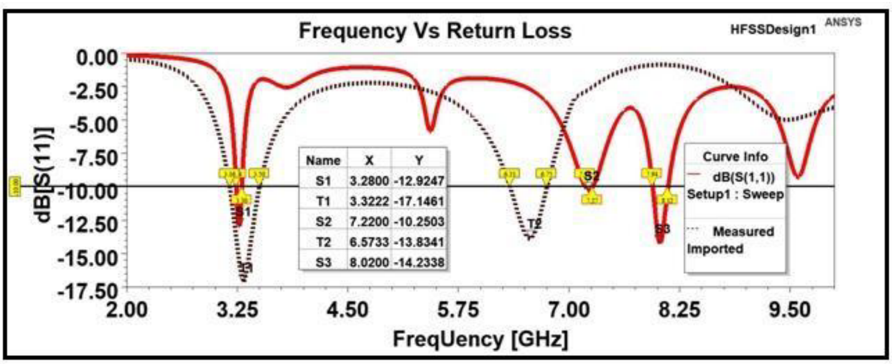


Figure 4 Fabricated prototype antenna bottom (see online version for colours)

Figure 5 Comparison reflection coefficient of software and hardware for the proposed antenna (see online version for colours)



There are mainly three dips in the graph which indicates that the antenna is working at 3.2 GHz, 7.2 GHz and 8.18 GHz where their losses are –30.4836 dB, –15.1770 dB and –11.5792 dB respectively. We need to consider the separating frequency which has the minimum return loss.

The most important parameter of any antenna is the radiation pattern. The direction and gain of this antenna are also represented by the radiation pattern. Along with far field parameters and predefined tilt, the radiation pattern can be attained. Furthermore, the electric and magnetic field radiation are showed by the HFSS simultaneously. In order to overcome the interference problems, the back lobes are excluded. Even in the case of cellular communication, the co channel and adjacent channel interferences are reduced.

The gain and direction of the lobes are indicated by the angles. An important parameter to be considered in antenna designing is the gain. 3D gain plot determines the antenna efficiency.

Figure 6 Gain chart (see online version for colours)

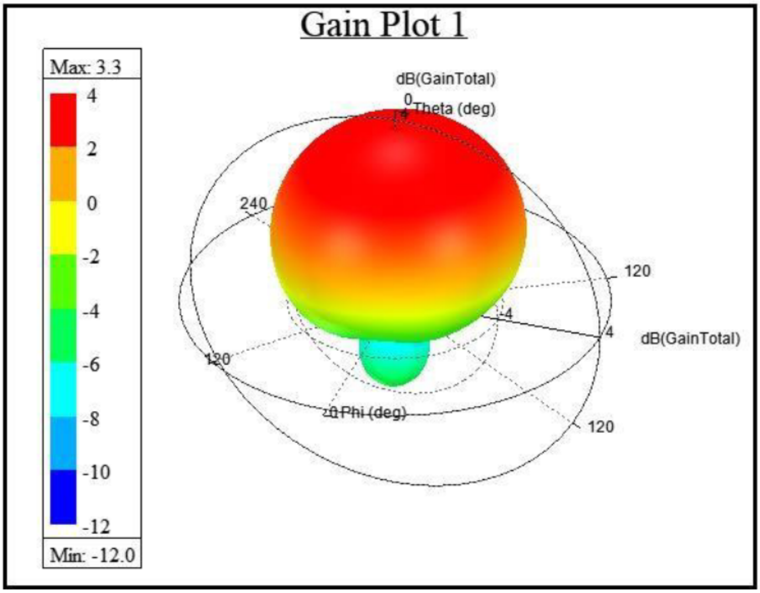


Figure 7 Smith chart (see online version for colours)

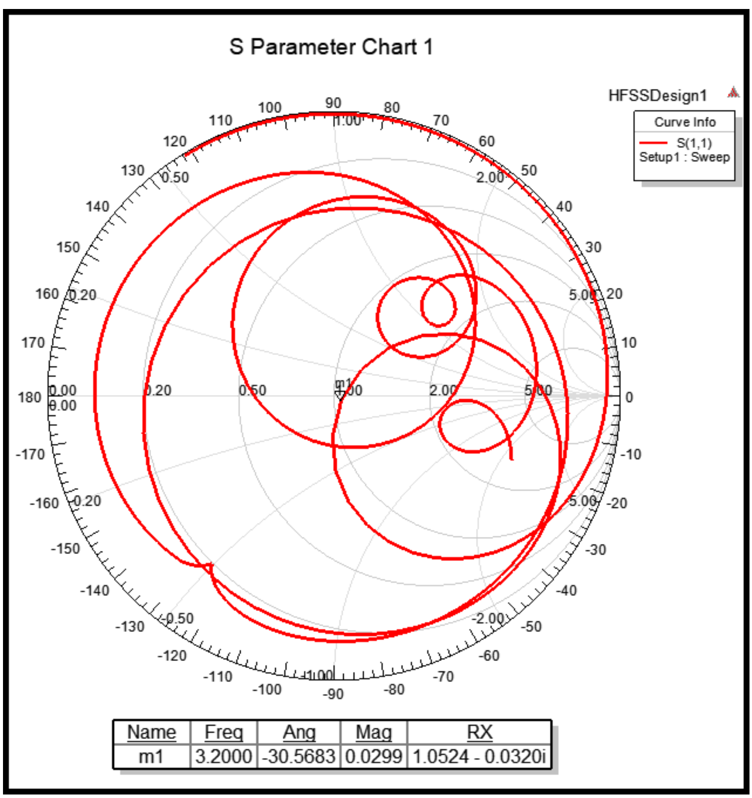
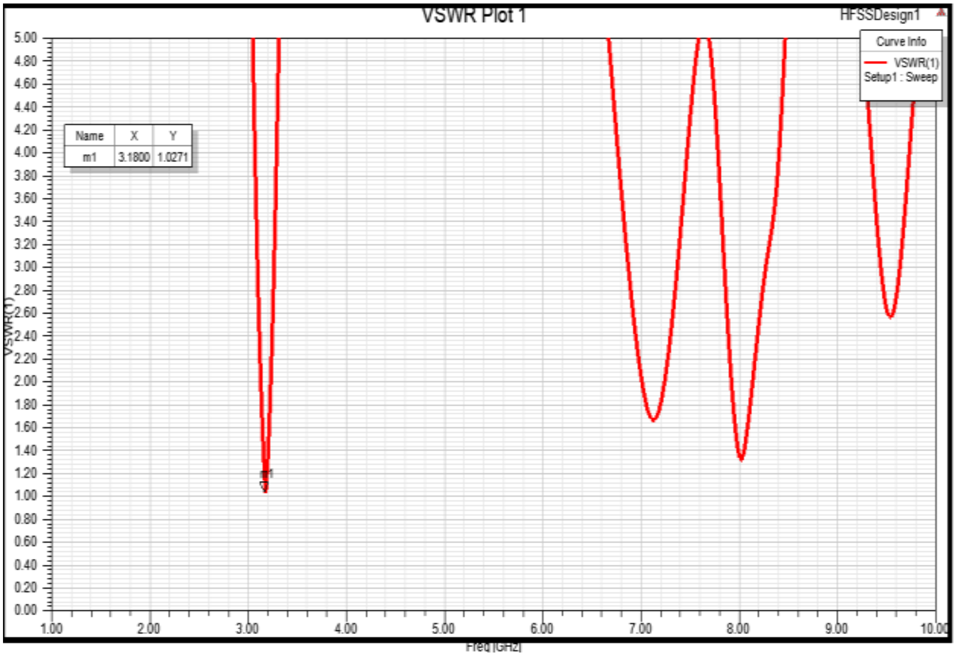


Figure 8 VSWR chart (see online version for colours)



Gain is the key parameter to be considered in the performance analysis of micro-strip fractal antenna. From Figure 6, the gain of the antenna is determined to be 3.3 dB. For 3.2 GHz frequency, it is clearly determined that RL and impedance are reasonable based on the previous results. Hence, the obtained moderate gain can justify the performance of the designed micro-strip fractal antenna. From Figure 7 and Figure 8, we find that the real value is unit circle (i.e.) 1.05 and it is observed that it is capacitive in nature and the value of VSWR is found to be 1.07 which is considered to be very much suitable for antenna applications.

5 Conclusions

In this article, a compact miniaturised, low profile, irregular fractal arrow head shaped antenna (IFAS) has been designed, determined and optimisations were made for the applications of 5G application. An Irregular shape fractal antenna has been designed at 3.2 GHz. The proposed antenna design is used for Sub 6 5G mobile applications. The covered frequency bands are 3.2 GHz (Sub 6 GHz) and 9.50 GHz (X-band). Accurate measurements are made to obtain a compact antenna, the designed antenna has –12.92 dB reflection coefficient with 1.02 VSWR. The designed antenna results are with broader bandwidth and good radiation pattern. The antenna is of low cost, compact size with better efficiency and stable radiation pattern. Thus, by iterating further, we can determine many other ranges of frequencies.

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