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Design of E-Shape Fractal Simple Multiband Patch Antenna for S-Band LTE and Various Mobile Standards

[1,]A.Janani M.Tech., [2,]A.Priya M.E., AP/ECE
[1,]*Electronics and Communication Engineering B.S.Abdur Rahman University Chennai, India*
[2,]*Electronics and Communication Engineering B.S.Abdur Rahman University Chennai, India*

ABSTRACT: in this paper, a design of a new E-shape fractal antenna for multistandard application is proposed. Fractal geometry is best suited for its self similarity and space filling characteristics. An optimized design of fourth iteration of E-shape fractal is designed to satisfy the higher multistandard mobile terminal application. Various mobile standards are obtained at the end of iteration in particular this study produces the result after fourth iteration (4EFPA) which satisfies the LTE mobile band. Several properties of the antenna such as Return loss, VSWR, Impedance is obtained and the Gain of the antenna has been improved.

Keywords—patch antenna, E-shape fractal, probe feed.

I. INTRODUCTION

In the last few years a large technological jump has taken place in the field of mobile communications due to the introduction of new mobile communication networks. The requirements on the antennas needed for the ever expanding networks are becoming continually higher. The simple dictionary meaning of an antenna is that it is usually a metallic device (as a rod or wire) for radiating or receiving radio waves. We can extract an excellent definition of antenna as "a metallic (usually) device used for radiating or receiving electromagnetic waves which acts as the transition region between free spaces and also guides structure like a transmission line in order to communicate even over long distance".

One type of antenna that fulfils most of the wireless system requirements are the microstrip antennas. These antennas are widely used on base station as well as handsets. Microstrip antennas have a variety of configurations and have been the topic of what is currently the most active field in antenna research and development. The microstrip patch antenna has increasingly wide range of applications in wireless communication systems as mobile and satellite communication systems due to their great advantages. Simply microstrip structure consists of a thin sheet of low-loss insulating material called the dielectric substrate. It is completely covered with metal on one side, called the ground plane, and partly metalized on the other side, where the circuit or the antenna patterns are printed. Components can be included in the circuit either by implanting lumped components or by realizing them directly within the circuit.

Therefore antenna miniaturization is an indispensible task in achieving an optimal design for wireless wide area network (WWAN) communication operation in the GSM, LTE and other higher multiband mobile applications. Fractal antennas are used to maximise the length or increase the perimeter [2]. In this letter, a new E-shape fractal geometry is used along with multiple wideband. The impedance matching is suited for WWAN/LTE and number of operating band is enhanced by increasing the number of iteration. The performance and the execution of E-shape fractal antenna have been designed and investigated using Ansoft HFSS (ver. 14). The further coming paragraph explains the design procedure and the basic parameters with which the antenna is being designed in the project.

II. DESIGN

A. Patch Antenna with E-Shape Fractal Design

The dimension of the antenna is a function of its operating wavelength i.e., $\lambda/4$. If the antenna size is less than $\lambda/4$, then its radiation resistance gain and bandwidth are ruined and hence it becomes inefficient. The antenna is designed using an HFSS which starts with the ground plane which is then followed by a three dielectric (fr4 and air). The ground plane is immediately followed by the fr4 with a dielectric constant ε_r= 4.4 and a thickness of h=0.8mm which is followed by air gap with the dimension similar to that of the patch with the dielectric permittivity ε_r = 1 and a thickness of h= 4 is placed in between the two fr4 substrates. The third dielectric which is also fr4 is placed above the air gap which is said to have a relative dielectric constant ε_r= 4.4, thickness h=1.6mm.

In general the patch antenna is designed with infinite ground plane. In order to diminish the size of the ground plane, the size of the plane should be six times more than the substrate thickness in all direction with respect to the patch dimension [9], the width and length of the patch is said to be 150mm and 130mm respectively, here the size of the ground plane is taken to be 4cm larger than the antenna structure. The patch is placed symmetrically above the substrate. The patch is fed by a direct connected probe along the centre line and varying the values vertically by fixing the centre line constant (y-axis) in order to achieve the best impedance matching.
The fractal geometry by which the antenna is being cut in an iterative fashion in order to match the higher multiband mobile standard is discussed in the following paragraph.

B. *Fractal Geometry*

The fractal geometry is the best suited for its self-similar structures. This iterative geometry can be best conveyed pictorially [1], the antenna design starts with two solid cut rectangles on the main rectangle as the first iteration as shown in Fig.1

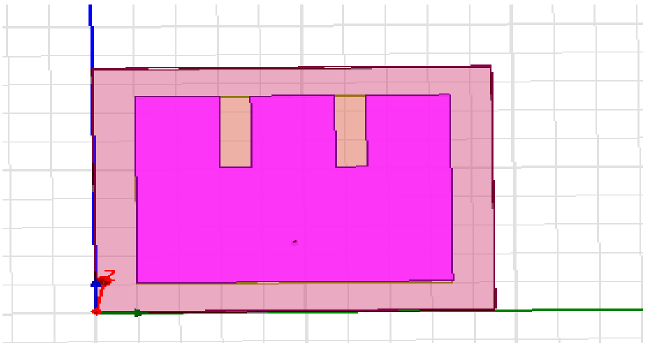

Fig.1, the pictorial representation of the proposed design for first iteration of E-shape fractal (1EFPA) is produced with optimized dimensions

Further iteration is carried out by subtracting smaller and smaller rectangles from the previously obtained rectangle which produces the design of second iteration which shown in fig. 2

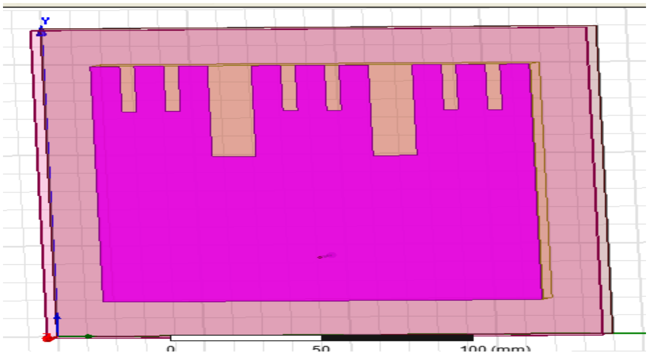

Fig.2, the pictorial representation of the proposed design for second iteration of E-shape fractal (2EFPA) is produced with optimized dimensions

Similarly the third iteration is obtained by subtracting further two solid cuts from the entire branch of the previously obtained second iteration which is shown in the Fig.3

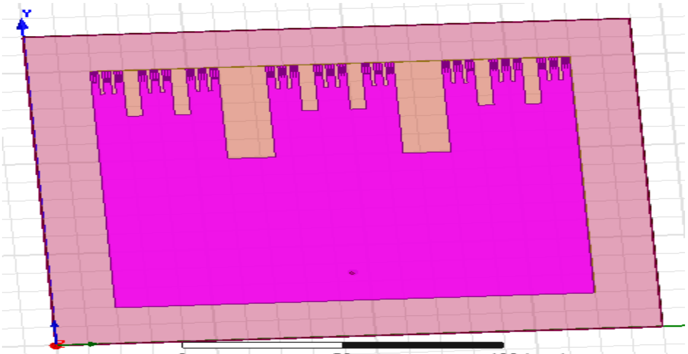

Fig.3, the pictorial representation of the proposed design for third iteration of E-shape fractal (3EFPA) is produced with optimized dimensions.

The fourth iteration is carried out by subtracting still more two solid rectangle from the previously obtained rectangle which is shown in Fig. 4

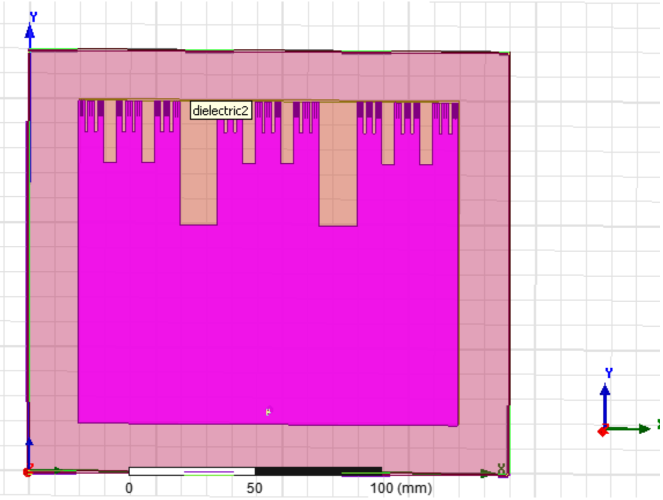

Fig.4, the pictorial representation of the proposed design for fourth iteration of E-shape fractal (4EFPA) is produced with optimized dimensions.

In the designed E-shape fractal, surface of the radiating patch reduces with increase in the number of iteration, as for the prototype Koch fractal antenna [6], with increase in the iteration the size of the radiating patch increases and the resonant frequency reduces.
The width of the patch which is to be subtracted starts with W_1=15mm for the first iteration then it reduces for further iterations. The height of the rectangle which is to be cut from the main rectangle is h_1=50 which would be reduced for further iterations by nearly half the height from the previous iterations. In general at the end of iteration 3^k new branch appears where k represents the number of iteration.
The new resonant frequency emerges when the height of second dielectric h (air) is varied for iteration. The value of h for air is varied from 2.5 to 15mm results new resonant frequency for every iteration, but frequency appeared for previous iteration remains same without any change.
The analysis and the experimental results of various graphs based on different iteration are obtained which are discussed as follows.

III. EXPRIMENTAL RESULTS AND DISCUSSION

A parametric study of the proposed patch was carried out to achieve multiband performance. The effects of different iterations of E-shape fractal have been investigated based on the antenna performance. The first iteration is done by two solid cuts in the main rectangle which reveals three parts (1EFPA); second iteration is done by two solid cuts again.

On all the newly obtained three branch which becomes nine branch (2EFPA),similarly third and fourth iterations is done that results as twenty seven branches (3EFPA).
The 1EFPA produces a result which matches with the GSM 850/900 bands, the next design which is followed by second iteration result satisfies the GSM850/900/DCS/PCS/UMTS, the third iteration results satisfies with LTE2300/2500 and the fourth iteration satisfies with S-Band without any change in the behaviour of the previous iterations. As the number of iteration increases, though a new frequency band appears, the previous iteration's band remains same there is a shift in the frequency which ensures the multiband trait of the E-shape fractal antenna.
The simulated values are obtained and the specific results for the first iteration return loss Fig. 5, vswr Fig. 6, impedance Fig. 7, gain Fig. 8, which are shown below

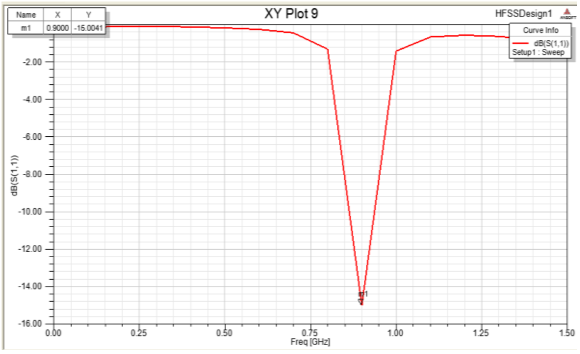

Fig. 5 simulated return loss for first iteration.

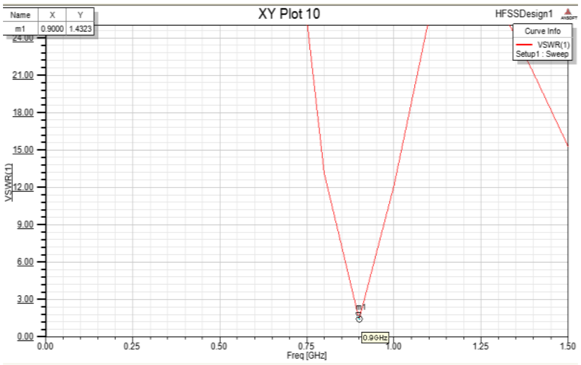

Fig. 6 simulated VSWR for first iteration.

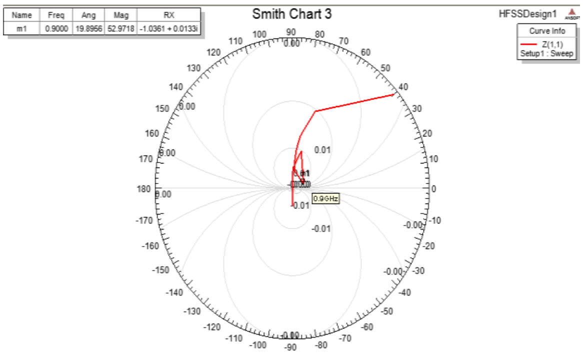

Fig. 7 simulated impedance for first iteration.

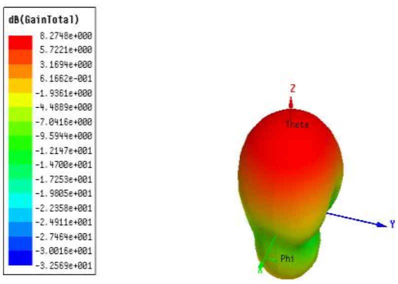

Fig. 8 simulated gain for first iteration.

The application which matches with the result of the first iteration is GSM which stands for Global System for Mobile Communication is a standard set developed by the European Telecommunications Standards Institute (ETSI) to describe protocols for second generation (2G) digital cellular network used by mobile phones.

The simulated values are obtained and the specific results for the second iteration return loss Fig. 9, vswr Fig. 10, impedance Fig. 11, gain Fig. 12, which are shown below

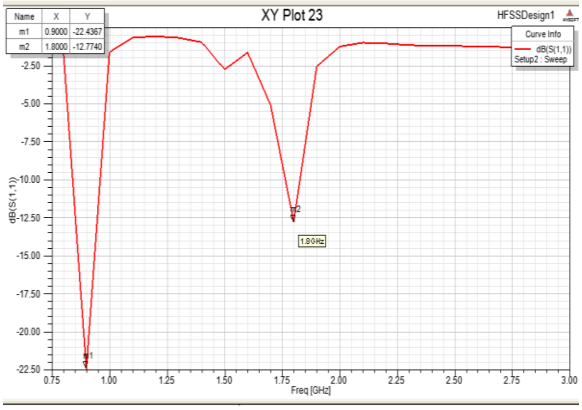

Fig. 9 simulated return loss for second iteration.

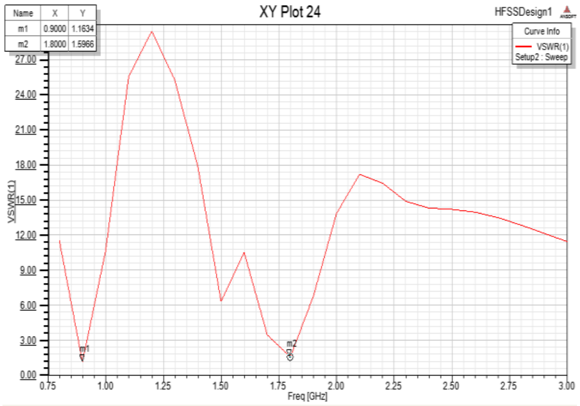

Fig. 10 simulated VSWR for second iteration.

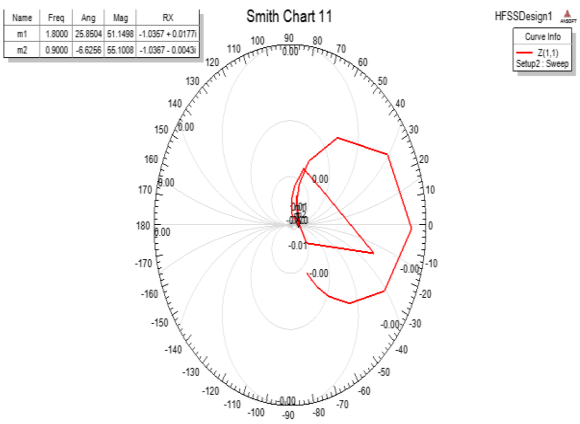

Fig. 11 simulated impedance for second iteration.

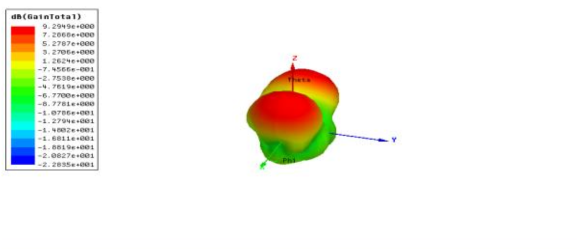

Fig. 12 simulated gain for second iteration.

The application which matches with the result of second iteration is GSM from the previous iteration and newly emerged DCS which stands for Distributed Control System which refers to a control system usually of a manufacturing system which is used to control the production line in the industry.
The simulated values are obtained and the specific results for the third iteration return loss Fig. 13, vswr Fig. 14, impedance Fig. 15, gain Fig. 16, which are shown below

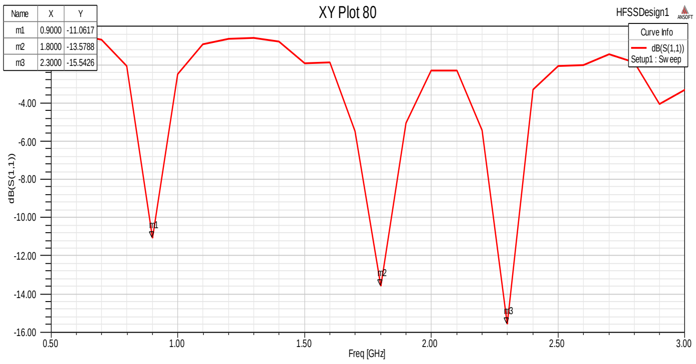

Fig. 13 simulated return loss with total h between ground and patch is h=7.6

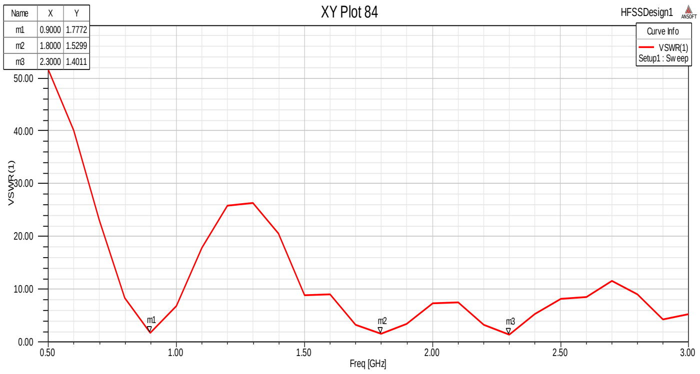

Fig. 14 simulated vswr for the dielectric height h=7.6

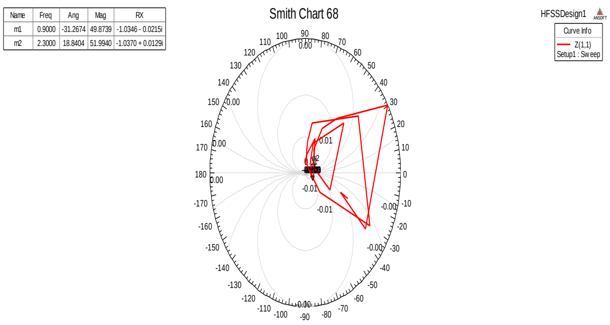

Fig. 15simulated impedance chart

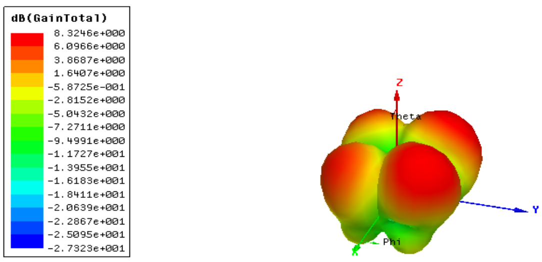

Fig. 16 simulated gain with the value of gain = 8.3db

The application which matches with the result of third iteration is GSM and DCS from the previously iterations and the newly emerged LTE standard which stands for Long Term Evolution for wireless communication of high speed data for mobile phones and data terminals which is mainly used for Wi-Max applications.

The simulated values are obtained and the specific results for the fourth iteration return loss Fig. 17, vswr Fig. 18, impedance Fig. 19, gain Fig. 20, which are shown below

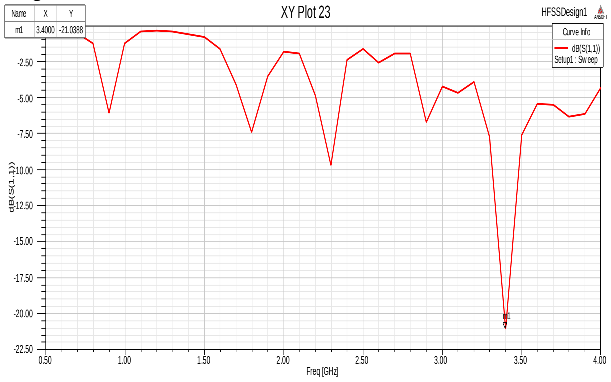

Fig.17 simulated return loss for fourth iteration

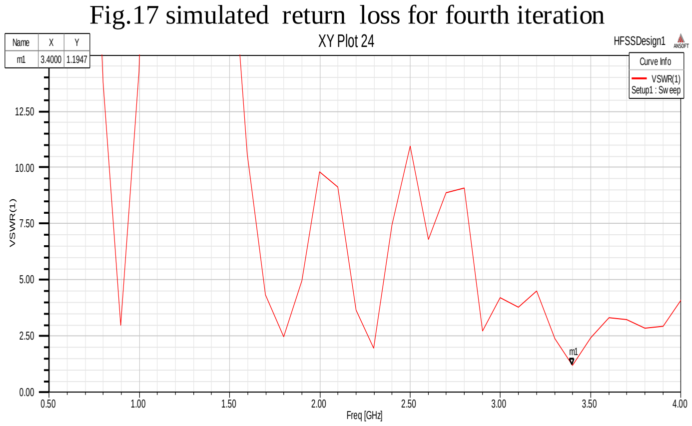

Fig. 18 simulated vswr for fourth iteration

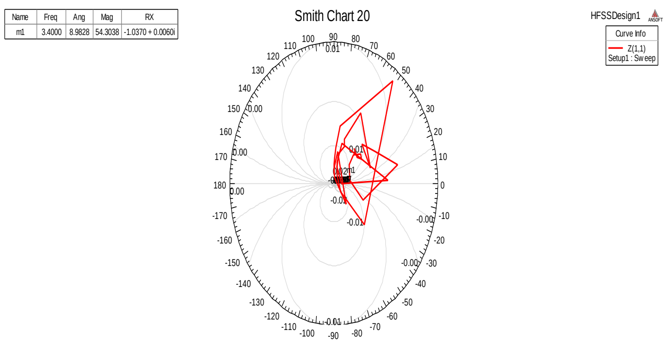

Fig. 19 simulated impedance chart for fourth iteration

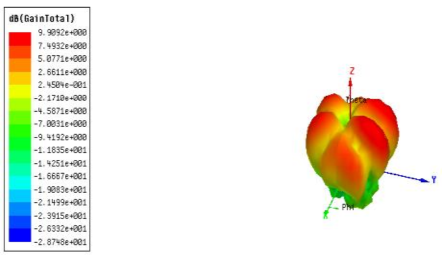

Fig. 20 simulated gain with the value of gain = 9.9db

The application which matches with the result of fourth iteration is GSM, DCS, and LTE from the previous iteration and newly emerged 4th iteration which satisfies S-band which is mainly used for Amateur radio is the use of designated radio frequency spectrum for the purpose of private recreation, wireless experimentation and emergency communication.

The hardware implementation of the antenna along with network analyser is shown below Fig 21.

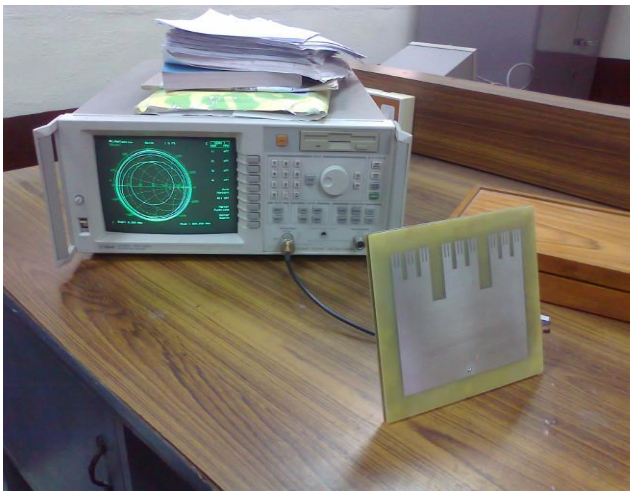

Fig 21 Antenna design with network analyser

The conclusion and the analysis are discussed in the last paragraph.s

IV. CONCLUSION

A new E-shape fractal patch antenna has been designed and the simulated results have been produced. The antenna is designed to operate at higher multiband applications. Various iteration produces the result which satisfies various mobile standards. The main parameters at the operating bands such as return loss, impedance, gain have been studied.

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