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Study of Various Fractal Antenna Geometry for Multiband Wireless Applications

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Abstract:

This paper presents study of various fractal geometry for multiband wireless applications. As, today owing to increase in multi-functionality systems demand for antennas which can cover joint band has arisen. Fractal shaped antenna designs are considered as an appropriate way for designing these advanced multiband antennas. The purpose of this paper is to study a number of innovative fractal design concepts of microstrip patch antenna for various wireless applications.

Keywords **—** *Efficiency, Feed, Fractal, Multiband, VSWR.*

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I. INTRODUCTION

With the advent of time, the phases of the communication have been changed drastically from handwritten letters to emails. Now-a-days, we are using modern wireless technology for transmission or reception of the messages or signals. We can say antennas are the backbone and almost everything in the wireless communication, without which the world could have not reached at this age of technology. The wireless communication system is of no use without proper designing of antenna. [1]. In the changing technology era, demand of compact size, low cost and multifunctional antenna is increasing. Antenna is same as ear or eye for any electronic circuit. Today, we have various wireless communication applications; such as, Wi-MAX, WLAN, Wi-Fi, Satellite Communication, Mobile/Microwave Communication, Bluetooth ,GPS, Point-to-Point high speed communication, UWB, GPRS etc.[5] -[7].

Due to the huge usage of communication devices, demands of low cost, multifunctional antennas with small size, high performance parameters are essential. During last two to three decades, patch antenna has become a suitable type of antenna because of its advantageous characteristics like conformal nature, low manufacturing cost, light weight and easy fabrication process, for multiple wireless communication systems in a single antenna [1]. These patch antennas can also be mounted to any kind of surfaces comfortably. However, conventional patch antennas have number of drawbacks such as; narrow bandwidth, low gain, low power handling capacity and single band of operation. Different researchers have suggested several methods to overcome these limitations.

There are various ways by which a patch antenna can work as multiband antenna as, making slot, PIFA structures, removing narrow slits, stacked patch, fractal shape etc. Fractal geometry is a very useful technique to make the patch antenna for multiband applications. Fractals geometries have been used in antennas since 1988 . They have various advantages as multiband performance, wide bandwidth, good gain and directivity performance with small size antenna results from constructive interference with multiple current maxima, afforded by the electrically long structure in a small area. Fractal patch antennas can be designed in various different shapes; such as Sierpinski carpets, Sierpinski gaskets, Minkowski loops and Koch Islands etc.

II. PROPERTIES OF FRACTAL ANTENNAS

Fractal antennas have various useful properties. Some of them are as follows:

i. Fractals are self-similar structures/geometries. They are created by using copies of it but at different scales.
ii. Fractal antennas have the space-filling property. This property leads to the packing of more and more antennas in small volumes.
iii. Fractal geometries are designed using an iterative process. These antennas show multiband behavior corresponding to each iteration. Thus, single antenna can radiate at more than one frequency.
iv. Fractal antennas help to miniaturization size of antenna. These antennas resonate at lower frequencies with smaller physical size as compared to the ordinary antennas.
v. Fractal antennas are easy to model, low profile and their cost of fabrication is also very less.
vi. Fractal antennas have sharp edges and discontinuities which help to increase the electrical length of the antenna and make it radiate efficiently.
vii. Fractal antennas are robust. They show much prevention against heat or mechanical strain.
viii. Fractal antennas are easy to feed and provide flexibility to design. The entire geometry is similar to the initiator and is easy to design.
ix. Fractal antennas lead to packing of more energy in smaller volume, which results in high quality factor.

III. LITERATURE SURVEY

A large number of Fractal Antenna design approaches have been proposed for various wireless applications. Wide research has been made to improve the performance parameters of a MPA in the previous years. Here, in this paper motivation and study of the MPA fractal geometry based on its performance parameters have been discussed. The research carried out by researchers in this field is listed as:

Guru Prasad Mishra et. al. [2017] presented the design of Sierpinski fractal antenna with three different patch geometries i.e. rectangular, circular and triangular. To verify the effect of fractal a 2x2 fractal antenna array is designed and studied. Comparative study ,among fractal based defected patch and defected ground plane structures , for the entire single antenna and array cases, is performed in this paper. All the antennas are designed to operate at 28 GHz frequency and FR-4 material is used as substrate. The proposed multiband antenna geometry and its array have extensive applications in Ka band and other wireless communication systems[1].

Manpreet Kaur et. al. [2015] T-shaped patch antenna has been designed and fractal geometry has been applied to it in order to obtain self-similar characteristics. Patch length has been taken as square of length 36mm. Dimension of ground has been taken as 50 mm. The substrate used in this paper is FR-4. This antenna can be useful for Wi-Max and WLAN, satellite and radar applications[2].

Athira .P et. al. [2014] presents design and simulation of a novel miniaturized fractal patch antenna which can resonate at 3.1GHz, 3.8GHz, 5.6GHz, 6.9GHz and 7.7GHz frequencies .The size of the antenna is compacted by 30% in comparison with a regular Sierpinski gasket antenna. The geometry of Sierpinski gasket is fully determined by height, flare angle, iteration number and scaling factor. Positions of different bands can be controlled by proper adjustment of the above factors[3].

B. Hephzibah Lincy et. al. [2013] proposed octagonal shaped fractal antenna for different frequency range 1GHz- 18GHz and 10GHz – 40GHz. Omni-directional radiation pattern is obtained at different frequencies and the design exhibits good wideband characteristics[4].

M. Ali. Dorostkar et. al. [2013] proposed r-shaped fractal antenna for wideband communications. The proposed antenna is made of iterations with 900 rotations in each step. Results show that the proposed fractal geometry can operate over a wide bandwidth range from 880 MHz to 2720 MHz . This antenna is suitable for various wireless applications such as RFID, GPS, DCS, PCS, UMTS, ISM, WiFi and Bluetooth[5].

Bharathraj Kumar Medhal et. al. [2020] proposed Minkowski patch antenna which increases the efficiency of monopole antenna. Minkowski Iteration Fractal antenna technique is used to optimize the design in iterative manner for bandwidth and frequency tuning for wideband applications. The patch dimension of the MMPA is $25\times20\ mm^2$[6].

K.Annaram et. al. [2015] presents a tiny fractal antenna for IEEE 802.11b/g wireless applications. It is observed that the resonance frequency of the projected antenna is significantly lowered, due to the inclusion of Koch fractals. Also it can show the way to large amount of size reduction[7].

Yogesh Bhomia et. al.[2014] presents a design of rectangular fractal patch antenna using iteration methods by cutting different slots on rectangular microstrip antenna. This design is achieved by using three stages of iteration and a probe feed. The radiation pattern of the proposed fractal shaped antennas maintained because of the self similarity and center symmetry of the fractal shapes. With fractal shapes patch antenna is designed on a FR4 substrate of thickness 1.6mm and relative permittivity of 2.2 and mounted above the ground plane at a height of 6 mm [8].

M.M.Rahman et. al. [2019] presents an octagonal fractal microstrip patch antenna. This antenna can be used for 45 GHz –95 GHz frequency range. This antenna can be used in commercial telecommunication systems, satellite systems, radar systems and military telecommunication systems. The proposed fractal antenna is capable of operating at 50 GHz, 60.24 GHz, 72.72 GHz, 82.93 GHz and 94.45 GHz frequency and would be suitable for wideband wireless application[9].

Vasujadevi M. et. al. [2018] This paper proposes design of a novel fractal antenna for multiband applications. The antenna geometry consists of FR4_epoxy material with dielectric constant of 4.4, height 1.6 mm. The operating frequency is taken as 2.4GHz. The antenna geometry is simulated using Ansoft HFSS software. The proposed antenna resonates at different frequencies. The results are measured. Here the geometry of fractal antenna is analyzed for the C band resonating at 6.2 GHz, X band resonating at 11.9 GHz and Ku band resonating at 13.8 GHz for S11<-10db[10].

Megha Shringi et. al. [2019] presents novel planar micro-strip antenna for quad band applications. The antenna geometry consists of symmetrically step slotted rectangular patch at right and left edges with a U shaped slot etched inside the patch along with a partial ground to achieve multiband operation. The proposed antenna is simulated on an FR-4 substrate of dielectric constant of 4.3, loss tangent 0.02 and 50Ω microstrip feed line. The antenna geometry occupies an area of 23×22×1.5mm^3. This antenna can operate at four different resonant frequencies 2.5GHz , 5.1GHz , 9.95GHz and 14.6GHz which meet the requirements of the Wi-Max, WLAN, X-band and Ku-band[11].

Vandana G. Sawant et.al. [2019] proposed high gain and efficient suspended minkowski fractal antenna . In this paper compact microstrip antenna suspended at the height of 1.5mm is designed and implemented. Total height of the antenna structure is increased to 3.09mm with gain of 2 dBi .The achieved bandwidth is 116 MHz with the 36% size reduction[12].

Yadwinder Kumar [2018] presents Hybrid fractal microstrip patch antenna by combining Koch and Meander like geometries. The proposed antenna exhibits dual band behavior. 1st band is narrow and resonates at 4.15 GHz and 2nd is wide band and resonates at 4.45 GHz and 4.73 GHz frequencies. It has compact and planar structure suitable for wireless applications. IFS mathematical approach has been used to obtain the fractal structure using scripting method in HFSS simulator. It exhibits good radiation properties and has VSWR < 2 for all resonating frequencies. Proposed antenna structure has been simulated on easily available and low cost FR4 substrate[13].

IV. ADVANTAGES

Fractal antenna design approach has many advantages, such as

- Miniaturization : Smaller size for multiband performance
- Frequency independent and provides multi-frequency performance
- More design and use versatility
- Added inductance and capacitance without components
- Consistent performance over huge frequency range
- Close packing of antennas
- Designed for harshest conditions
- Powerful solutions possible
- Use one antenna instead of many for Wide band or multiband purpose
- Lowers cost and enhances desirability
- Enables small, efficient, reliable antennas
- Greater versatility, new packaging options
- Small arrays with excellent steer ability with reduced mutual coupling
- In use by military and commercial customers
- Low profile: Smaller in size, Lighter in weight and less in cost
- Good impedance matching
- Use of fewer components
- Provides space filling, self similarity and scaling properties
- Provides increased bandwidth
- Provides enhanced gain and directivity
- Uses the essential combination of inductance and capacitance providing multiple resonances for the similar structures.

V. LIMITATIONS

- Loss of gain in some cases
- Complex structure and complexity in modeling the antenna
- Numerical analysis limitations: Mathematical limitations
- The benefits begin to diminish after first few iterations
- Benefits are lessen in size after first few iteration
- Not so beneficial after first few iterations

VI. CONCLUSIONS

In this paper, we have discussed various designs and applications of fractal patch antenna. From this paper we can conclude that there are many fractal techniques that can be used to design an antenna for multiband wireless applications. Each one has its own advantages and limitations. These various approaches for mutiband fractal patch antenna considered the different attributes related to performance analysis of an antenna such as; wide/ mutiple bandwidth, low VSWR, high gain, high radiation efficiency and small size etc. The paper also provides a Literature Review for different fractal designs for multiband or wideband patch antenna performance. From this paper we can summarize the following key points of fractal in antenna geometry:

- As number of iterations of fractal increase, resonant frequency increases which results in lower return losses.
- Multiband/ wideband frequency response can be obtained from antenna's fractal geometry.
- Compact size antennas with excellent efficiencies and gains can be achieved using fractal geometries.
- Using fractal design approach multi-frequency characteristics having specified stop bands as well as specific multiple pass bands can be possible.
- Various parameters of antenna can be obtained using fractal geometry , no need to add discrete components.

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