Study on Stacked Fractal Antennas for a Multiband Operation

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Abstract – A revolutionary progress in the 21st century for the wireless and mobile communication industry has influenced the improvement of modern communication equipment. Such equipments are having an ultra-compact size with many features. The basic element in wireless communication has experienced incredible improvements specifically in the track of compactness and broad bandwidth. In the radio frequency range the antennas design and usage are prominent. Since the handsets are having a limited space it is difficult to install more than one antenna. To overcome these problems, the fractal shaped antennas are designed and studied. A structure of fractal is an uneven or fragmented geometric shape that can be fragmented into parts, each of which is a reduced size copy of whole. The shapes of fractals do not have characteristic size. Each fractal consists of multiple iterations of a single fundamental shape. The repetitions can continue infinitely, to get a shape within a finite boundary for an infinite length or area. The fractal antennas have a finite structure at arbitrary small scales, are difficult to describe in traditional Euclidean geometries and their construction and design is simple and recursive.

Keywords – Stacked Fractal, Antennas

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INTRODUCTION

During the last decade, the wireless communication has increased in several categorize of scale influenced by methods using the digital and radio frequency based designing. Medium and LSI (Large Scale Integration) and other tininess technology VLSI (Very Large Scale Integration) have made the microwave devices portable, cheaper and much trustworthy. The advances may continue at a faster rate in the coming decades. The long range of communication wires is impractical and impossible. The following terms are listed in the telecommunication engineering to explain the communication systems:

- Transceivers
- Controllers
- Networks controlled through computers
- Equipment workstation etc

Communication systems need power through,

- Carrier frequency (RF)
- IR emitters
- Optical wave technology
- Natural illumination
- Audio energy, etc.

There is a need to convey data without using wire systems. Data transmitted in the way include short and far distances.

A few applications are,

- Two-point communication
- Broadcasting communication
- Mobile communication networks
- Other wireless networks

In wireless communication, the antenna is considered as an important component by the use of carrier frequency and microwaves. By definition, an antenna is a device or equipment employed to transform a radio frequency signal through a conductor into space as an electromagnetic radiated wave. In IEEE the term for an antenna (IEEE Std 145-1983) describes it as an aerial component, a resource for radiation and (or) receiver of radio waves. In an alternative manner, the antenna is a midway construction between the air as a media and the waveguide equipment that is designed and operated to transmit and receive microwave radiations. The real time applications of antennas are in super heterodyne receivers, TV broadcasting, mobile phones, microwave radars and other communication systems which use electromagnetic waves. For both transmission and receiving, the antennas maintain a unique property called reciprocity, which means the same characteristics at both the ends.

An important use for single side communication is the terrestrial television. Terrestrial television (which means over-the-air (OTA) or broadcast television) is a technique of propagation of TV signal by the use of radio waves from broadcast stations to televisions. Here the air is used as the medium. In terrestrial TV systems, the transmitters (broadcasting stations) transmit the TV signal having a high power using different modulation techniques and big relays are deployed on the ground at many places to spread radio waves to the nearby areas called regenerating stations.

Even a small antenna can pick up the signal. The limiting parameter for the broadcast television is the range. The various frequency ranges in terrestrial TV are the very high frequency (VHF) and the ultra- high frequency (UHF). Yagi-Uda antenna (variation of the dipole) is an antenna used for terrestrial television receivers. These antennas are installed on the top of building structures. We have another type of antenna known as a planar antenna. This antenna has significant characteristics when compared with any other types of antenna. Because of a small contour and the ease of fabrication using the printed circuit board technology, this antenna can be manufactured and designed by the researchers at reduced costs. These antennas are 2- dimensional and are used at UHF and higher frequencies. Micro strip antenna with the fractal geometrics is employed to design multiband and broadband antennas. Also, fractal micro strip geometries are suitable to miniaturize the size of the antennas. Geometry of fractal antennas supports the studies of multiband solution and in miniaturizing the antenna. The self- similar antenna has many copies of itself at several scales to operate in a similar way at several wavelengths. Following are the properties.

- Antenna should have similar radiation parameters through several bands.
- Space- filling properties of some fractal shapes

Antennas

The antenna defined in a dictionary as “a usually metallic piece of equipment” (as a rod or wire) which radiates and receives the radio waves as shown in Figure 1.1. An antenna is a transition or switching device.

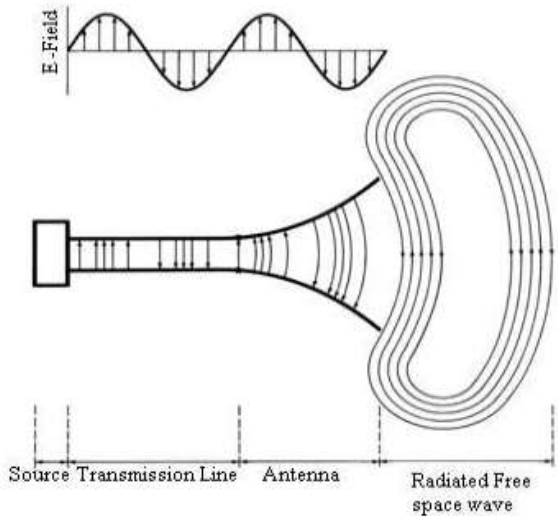

Figure 1.1 Antenna as a switching device (Balanis 2005)

In Figure 1.1, the source is represented as an ideal signal generator which has,

- Characteristic impedance Zc for the line
- A load ZA [ZA = (RL+ Rr) + jXA]
- Load resistance RL
- Rr is the resistance of radiations
- XA is an imaginary part of the impedance.

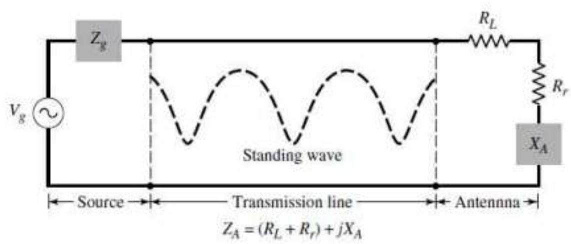

Figure 1.2 Transmission-line The venin equivalent of antenna in transmitting mode (Balanis 2005)

Figure 1.2 shows transmission-line Thevenin equivalent of an antenna in transmitting mode. RL represents the conduction and dielectric losses linked with the antenna structure. The reactance XA is related to radiation of the antenna.

Types of antennas

Wire antennas

The form of wire antennas can be categorized as

- Straight cable (dipole)

- Loop
- Helix
- Rectangular

As shown in Figure 1.3, loop antennas cannot be restricted to rounded shapes always. It can be in the form of

- Rectangle
- Square
- Ellipse or any other pattern.

The circular loop antenna is commonly used since it is very simple in construction.

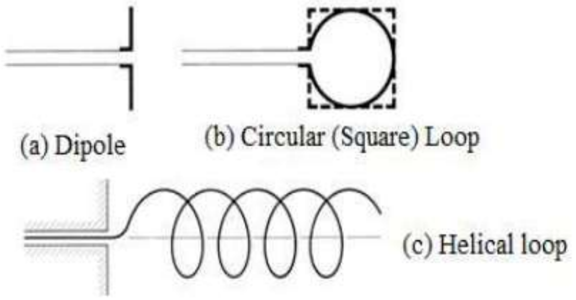

Figure 1.3 Wire antenna configurations (Balanis 2005)

Aperture antennas

Figure 1.4 shows some forms of aperture antennas. These are applicable for airplane and spaceship and can be fixed on the casing. Also, they can be enclosed with a dielectric material.

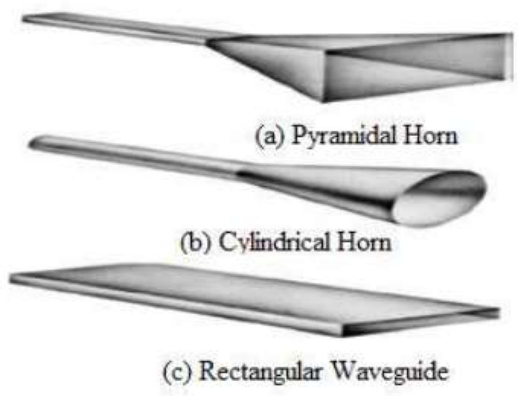

Figure 1.4 Aperture antenna configurations (Balanis 2005)

REVIEW OF LITERATURE

The work done by Martínez-Vazquez (2006) stated that the introduction of new, multi standard mobile phone devices is a challenge for antenna designers, as they have to implement integrated antennas with multiband operation within a volume that is rapidly shrinking. In this paper, research results concerning the input return loss, radiation characteristics, and efficiency of internal, planar, multiband patch antennas are presented. This technique utilized in the research work for the microstrip planar antennas with fractal nature [61].

The work done in Mahatthanajatuphat et al., (2009) mentioned on rhombic patch monopole antenna designed with the concept of fractals. The antenna exhibits multiband operation where the generator describes that the antenna is working as a monopole patch, and the analysis carried for the final prototype model of antenna. Here in our work the concept of a monopole with Sierpinski and Minkowski is considered [54].

The work done in Saini et al., (2015) presented the design of a compact multiband patch antenna for X-band with enhanced bandwidth. Here the slots created on the ground plane provide an optimized patch area subsequently reducing in antenna size as compared to a typical microstrip patch. These antennas are meant for satellite communication and radar applications. The various parameters like return loss, radiation pattern, voltage standing wave ratio (VSWR) and gain are evaluated and compared with measured results. Simulation results show their designed antenna cover an impedance bandwidth of 2.47 GHz in X-band frequency range. The overall dimensions of the antenna presented are 30 mm × 32 mm× 0.8 mm [82].

In our work an investigation is done for the range of 2.4 GHz, and above mentioned parameters, simulation results, measured results, and their comparison carried out with modified Sierpinski and modified Minkowski antennas.

Feeding of antennas

The work done in Das et al., (2012) presented a single layer, single feed compact slotted patch antenna. A reduction of resonant frequency has been observed significantly by cutting two equal slots which are the uniting one triangular and another rectangular slot at the upper right and lower left corner from the usual micro strip patch antenna. The simulated antenna size reduced by 48.89%. An increased frequency ratio is observed when compared to a conventional microstrip patch antenna.

The work done in Cohen (2013) stated that by application of fractals to the antenna elements, a smaller, resonant antenna achieved, and optimized for gain. By the addition of fractals, they do not use additional loading components, and they are cost-effective to fabricate. Fractals installed in constraining form factors such as the skin of hand-held transceivers. Fractal antennas prove meaningful, high performance, and resonant for many practical applications. Usually fabricated or on small circuit boards, they allow new versatility in their use with wireless devices.

The principle of applying fractals to the designed base /reference antenna is carried out for two types of modified structures of Sierpinski and Minkowski antennas.

Multiband and reconfigurability

A reconfigurable antenna is an antenna used for modifying its frequency and radiation properties in a controlled and reversible manner. The reconfiguration ability of reconfigurable antennas is used to maximize the antenna performance in a changing scenario or to satisfy changing operating requirements. The advantage of using a reconfigurable antenna is to operate it in multiband where the total antenna volume reused, and therefore the overall size can be reduced.

The work done in Werner et al., (2012) stated that a fractal is a recursively generated object having a fractional dimension. Many objects, including antennas, can be designed using the recursive nature of a fractal. The present work provides a broad overview of recent developments in the field of fractal antenna engineering, with importance given to the theory and design of fractal arrays. Also, important properties of fractal such as self- similarity helping multi- band characteristics are presented.

The work done in Werner et al., (2013) say, “Engineering of fractal antenna symbolizes a uniting characteristic of fractal geometry.” The investigation has given a way for new designs of antenna elements and arrays [98].

The work done in Puente et al., (2014) presented that fractal antennas have been renowned as patch antennas. The fractal tree is generated at random by deposition technique to attain multiband property. Later in the year 2000, an iterative model for Sierpinski gasket fractals was introduced. He developed a wire antenna anticipating its response as a task of its angle. The various dipole and planar fractal antennas using computer aided design were proposed .

The work done in Werner and Suman Ganguly (2013) stated that self resemblance of fractal geometry is a potential candidate to realize miniaturized multiband antennas, dual band, compact size, low profile and conformal. The literature of this paper explained an overall scenario of the fractal antennas.

The work done in Gianvittorio and Rahmat-Samii (2013) stated that fractal geometry developed by self- generating techniques that result in contours with infinitely excellent complex structures. He approximated the different objects in nature to fractal structures. The geometry utilized for modeling up on clouds and coastlines. This geometry which has been used to Model complex objects found in nature such as clouds and coastlines and a miniaturization of antenna carried out using space-filling properties. These contours are used in our work which can add more electrical length in less volume. The complexity that is not discernible for the particular application is truncated.

The work done in Onufriyenko (2013) worked on fractal wire antennas, and he stated that design of antennas done for those dimensions not restricted to integers. A distinguishing improvement was observed compared to the traditional antennas. Such antennas have shown an input impedance match and a prospect for the miniaturized antennas along operation ability over different bands of frequencies. The reason is that the self-similar property of fractal geometry used for operating a fractal antenna at various frequencies. Lastly, it was mentioned by him that the fractals correspond to a set of the geometry having fractals correspond to a class of geometry with very exclusive properties that can be attractive for an antenna designer.

The work done in Bernhard (2013) stated that reconfigurability achieved by varying the configuration of the geometry which has already undergone resonance. This provides a way for compactness through modifying the resonating structures, self-similar and space-filling fractal geometry which find application in designing multiband and miniaturized antennas.

The work done in Mustafa Khalid (2014) stated that due to the recent technology of the world for an increasing demand for wireless communication, there the design should be of compacted, working for multiband, and modest gain antennas for the handheld communication system. Such devices are used in military and commercial communication systems. He explained for combined fractal antenna of 2D and 3D configurations as shown in Figure 1.1.

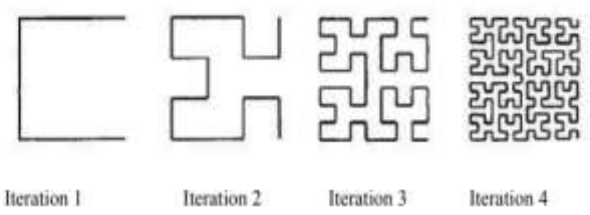

Figure 1.5 Construction of Hilbert geometry (Mustafa Khalid 2007)

OBJECTIVES OF THE STUDY

- Design and study of two types of modified monopole fractal antennas namely Sierpinski and Minkowski micro strip fractal antennas.

- To carry the simulation using software based on the Method-ofMoments (MoM) simulation technique.

RESEARCH METHODOLOGY

The design technology of the antennas proposed in this thesis has low cost and the antennas are planned to operate at useful frequencies. An effort is made to design for keeping layers of an antenna on one another called stacking to have multi- resonance points. In antenna design we have two types, one is the microstrip plane antenna, and the other is fractals on microstrip. In our research, we have used the second method where a fractal is cut and removed by successive iterations for the purpose of designing a multiband antenna. The Sierpinski and Minkowski microstrip antennas were selected for our research as these antennas are simple to study and design. As a major step, a general design plan was prepared to determine the constraints imposed on that plan.

DATA ANALYSIS

Here is design, implementation with experimental analysis of Minkowski microstrip fractal antennas for different configurations carried out to name them as modified Minkowski carpet antenna.

The analysis for without stacking is done with Infinite ground plane (Microstrip line)

The analysis for with stacking is done with following methods

- Minkowski fractal microstrip antenna for improved bandwidth using stacking technique with strip line feeding

- Design and simulation of Minkowski stacked microstrip fractal antenna with probe feeding.

Infinite ground plane (Microstrip line)

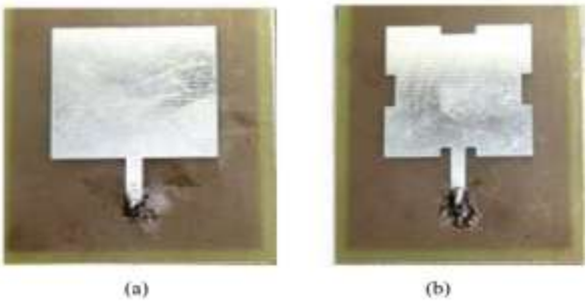

Figure 1.6 shows the fabricated antennas.

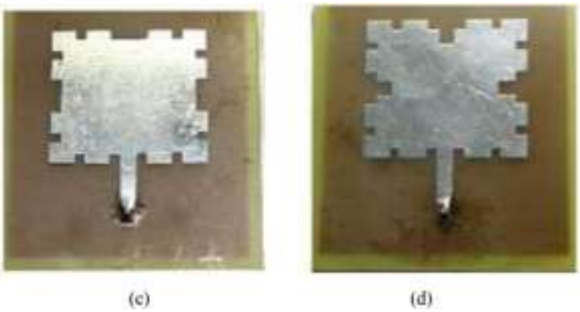

Figure 1.7 Fabricated views of Minkowski antenna a) Reference antenna (b) First iteration (c) Second iteration and (d) Third iterated antennas

RESULTS AND DISCUSSION

In this part, a result and discussion by the comparison of Sierpinski carpet micro strip fractal antenna for various iterations are analyzed for various feeding methods. The radiating elements based on a copper patch and analysis is carried out up to the third iteration for multiband operations. Above mentioned steps are also carried for Minkowski micro strip fractal antenna and concluded at the end of each comparison. The antenna designed on 1.6mm thick FR4 substrate having a dielectric constant of 4.4 and feeding done by using different types. The designed antennas are the optimized function in multiband between 2-14 GHz.

Sierpinski antennas

Summary of results of implementation and comparison of two types of feeding micro strip line feed and probe feed for simulation results

The below Figure 1.8 shows a graph of comparison between the micro strip line and probe feed of simulated values, taken from Details of the simulation results for the third iteration for micro strip line feed and details of the results to the third iterations for probe feed (Table 4.4) in the paper. Below Figure 1.1 shows the comparison for micro strip feed and probe feed. It reveals that that there is a better performance of micro stripline feed with respect to the return loss in the designed frequency of 6.6 GHz. Also positive gain of around 6 dBi is observed from the graph of Figure 1.8 b with the probe feed configuration.

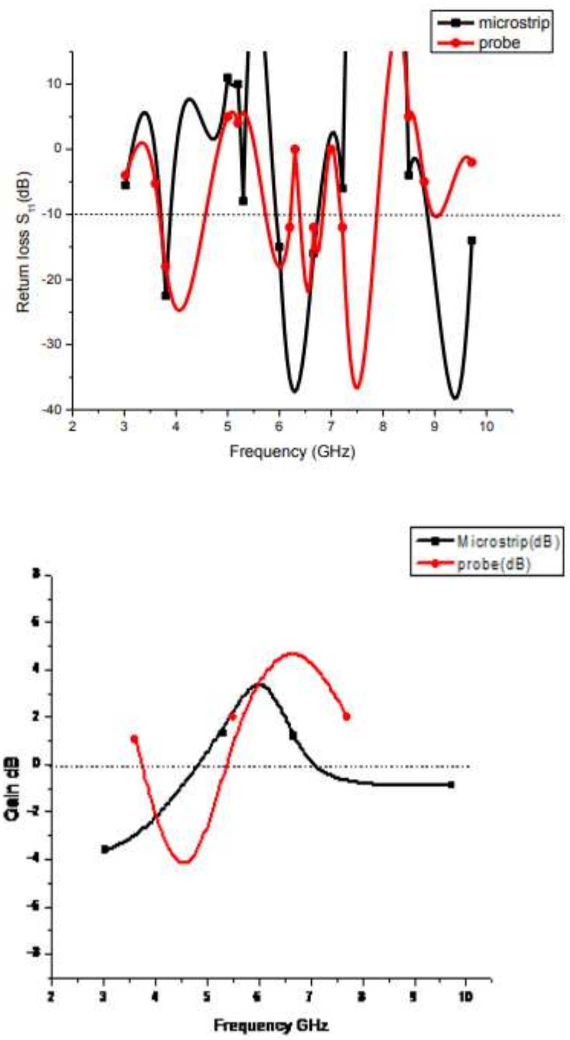

Figure 1.8 Comparison for micro strip feed and probe feed (a) Return loss and (b) Gain

CONCLUSIONS

This paper gives a summary of the research work carried out and the scope for further research work is also indicated. The intention of this study is to investigate the compact micro strip fed planar antennas in different category. Different types of micro strip fed antennas are mainly developed in the research work, for different feedings. A square micro strip Sierpinski carpet antenna is constructed using fractal geometry for multiband operation. Applying Fractals to antennas allows for smaller size antennas with wideband and multi-band properties called fractal antennas. The measured results indicate that the fractal antenna exhibits a good input return loss at the designed frequency and other multiband frequency which occurs at nearly six resonance frequencies with a return loss greater than 10 dB. The radiation pattern shows these antennas can perform similarly to dipole antennas. The antennas designed and analyzed are best candidates for future broadband wireless communications. Numerical simulation and experimental studies presented here show that the multiband characteristics of this antenna are affected only when the fractal dimension changes. One of the advantages of fractal geometries is in reducing antenna size.

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