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Dual Band Minkowski Microstrip Fractal Antenna for Improved Bandwidth using Stacking Technique with Probe Feeding

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ABSTRACT

A novel dipole stacked microstrip fractal patch antenna element is printed on the circuit board and analyzed for different antenna parameters. Here a planar microstrip fractal antenna is used as a base, which is a probe fed. This patch antenna radiation helps the minkowski antenna as a parasite. The objective of this paper is to design a stacked Minkowski microstrip fractal antenna upto third iteration. The prototype antenna is designed using probe feeding technique on FR4 substrate with thickness of 1.6mm whose dielectric constant is 4.4. These antennas are optimized to operate under multibands of 1.9 GHz suitable for personal communication services (pcs) such as cellular radio applications and 3.4 GHz high performance wireless antenna range used for WiMAX applications. Simulation is carried out using IE3D simulator and it is observed that the simulated results are in good agreement with the experimental results. The parameters resonant frequency S11, bandwidth and gain are used for analysis of the different configurations. Comparison of resonance, gain and bandwidth are carried for with and without stacking.

Keywords: Fractals, microstrip antennas, Minkowski antenna, iterations, stacking

1. INTRODUCTION

Antenna is a very important component for the wireless communication systems using radio frequency and microwaves. By definition, an antenna is a device used to transform an RF signal, traveling on a conductor, into an electromagnetic wave in free space. The IEEE Standard Definitions of Terms for Antennas (IEEE Std 145-1983) define the antenna or aerial as a "means for radiating or receiving radio waves". In other words, it is a transitional structure between free space and a guiding device that is made to efficiently radiate and receive radiated electromagnetic waves. Antennas are commonly used in radio, television broadcasting, cell phones, radar and other systems involving the use of electromagnetic waves. Antennas demonstrate a property known as reciprocity, which means that an antenna will maintain the same characteristics regardless if it is a transmitting or a receiving device.

One of the applications of a one way wireless communication is the terrestrial television. Terrestrial television (also known as over-the-air, OTA or broadcast television) is the method of television broadcast signal (can be analog or digital) delivery by using radio waves from broadcast stations to televisions at homes using air as the medium. In terrestrial TV system, the transmitters (broadcast stations) are transmitting the TV signal with high power and very tall antenna transmitters located on the ground to transmit radio waves to the surrounding area.

One of the other types of the antenna is the planar antenna. The planar antenna has the most variation compared to any other types of antenna. Due to its advantages such as low profile and the capability to be

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fabricated using the printed circuit technology, antenna manufacturers and researchers can come out with a novel design of antenna in house which will reduce the cost of its development. Planar antennas are also relatively inexpensive to manufacture and design because of the simple 2-dimensional physical geometry. They are usually employed at UHF and higher frequencies because the size of the antenna is directly tied to the wavelength at the resonant frequency.

Fractal geometries have been applied to microstrip antenna design to make multiband and broadband antennas. In addition, fractal geometries have been used to miniaturize the size of the antennas. However, miniaturization has been mostly limited to the wire (dipole and loop) antennas. The geometry of the fractal antenna encourages its study both as a multiband solution and also as a small (physical size) antenna. One should always expect a self similar antenna (which contains many copies of itself at several scales) to operate in a similar way at several wavelengths. That is, the antenna should keep similar radiation parameters through several bands. Also, the space-filling properties of some fractal shapes (the fractal dimension) might allow fractal shaped small antennas to better take advantage of the small surrounding space [14]. The fractal antenna is formed by applying a generator shape repetitively at a constant scale factor and results in an antenna with log-periodic characteristics.

To overcome the issues, paper presents a study and design of proposed antennas with

a) Designing multiband antennas with consistent return loss, radiation pattern, and bandwidth and gain analysis over two frequency bands are done.
b) The cost of the substrate is another prime parameter which has to be considered.
c) Proposed method designs miniaturization of the handheld communication devices which demand for small antennas with convincing specifications such as bandwidth, pattern characteristics.
d) The proposed design and analysis aims in proposing modified Minkowski microstrip fractal antennas for multiband wireless applications.
e) In the present paper the design calculation for a Minkowski microstrip fractal antenna using transmission line model for probe feeding with and without stacking is carried out.

The next part of the paper follows as: In section 2, a literature review is mentioned which are very near to the proposed design. Section 3 introduces the antenna design along with the fabricated diagrams with elaboration. In section 4, experimental result are discussed. In section 5, conclusion details for overall work and future developments are explained.

2. LITERATURE REVIEW

In this paper [1], the author mentioned that, a self-similarity property 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 a overall scenario of the fractal antennas.

Paper [2] describes the design and simulation of novel square shape fractal antenna using Hfss11.1 electromagnetic simulation software. The fractal structure is advantageous in generating multiple frequencies or enhancing bandwidth. Square shape fractal antenna gives better performance in return loss, efficiency and directivity. This fractal antenna can be used in the Wi-Fi. The literature work of this paper describes the proposed fractal antenna which seems to be an interesting configuration for use in application where a large frequency separation is required. The bandwidth effect changes with the change in resonant frequencies and VSWR is within the accepted level.

In this paper [3], author developed the framework for a more general theoretical treatment of frequency-independent antennas. The literature of this paper concentrates on generalization of frequency-independent antenna theory, which is accomplished by removing the restrictions imposed by a past reliance on classical Euclidean geometry in favor of adopting a more modern fractal geometric interpretation. Of particular interest in this paper, is the application of this new theory of self-similar fractal radiators to the development of a multiband linear array design methodology for which the directive gain is a log-periodic function of frequency.

In this paper [4], a numerical based analysis on fractal geometries was conducted and described that applying fractals to antenna elements allows for smaller, resonant antennas which are multiband/broadband and may be optimized for gain. In this paper, they carried a framework to prove Fractal antennas worthwhile, high performance, resonant antennas for many practical applications. Usually fabricated as or on small circuit boards, they allow new versatility in their use with wireless devices.

In this paper [5], author developed reconfigurability by varying the basic configuration of the geometry which has already undergone resonation. This paves way for compactness through modifying the resonating structures, self-similar and space-filling fractal geometry which finds application in designing multiband and miniaturized antennas. The literature of this paper states about the goal of a reconfigurable radiator, i.e. one that can adjust its operating frequency, bandwidth, and/or radiation pattern to accommodate changing requirements. Accordingly in our paper, we arrived at designing a stack structure wherein we can use this prototype antenna for 2 types of applications at a time.

In this paper [6], single element microstrip antenna for dual-frequency operation have been investigated. By placing shorting pins at appropriate locations in the patch, the ratio of two-band frequencies can be varied from 3 GHz to 1.8 GHz. In many applications a smaller ratio is desired and this can be achieved by introducing slots in the patch. The literature of this paper developed a hybrid multiport theory and theoretical results are found to be in excellent agreement with the measured ones. In our paper instead of slots, a multiband is achieved by using a stacked structure of planar microstrip antenna as base and a Minkowski as a parasite antenna, to achieve a multiband.

In this paper [7], author describes an analysis of U-slot loaded patch stacked with H-shaped parasitic elements. The literature of this paper says that the antenna exhibits dual resonance and both the resonance frequency (upper and lower) depend directly on slot width and inversely on slot length.

Both upper and lower resonance frequency increase with increasing value of height of the gap. Typically the bandwidth at lower and upper resonance is found to be 3.66 % and 10.25 %. The literature of this paper shows only the resonance and only the radiation pattern are considered but in our paper there is an effort of increasing the bandwidth and gain by various iterations.

In this paper [8], a novel genetic antenna with electrically-small property is presented. To make use of the simple and low cost microstrip fabrication techniques, this antenna adopts a two-dimensional microstrip structure rather than the commonly-used three-dimensional wire structure. It includes a 7-segment microstrip line as its radiator and is directly fed from a 50 Ù coaxial line without an impedance transformer that is necessary for most electrically-small antennas. The literature of this paper describes that, a parallel Genetic Algorithm (GA) in conjunction with the Finite Different Time Domain (FDTD) method. In our prototype antenna, MOM method is used for design and fabrication.

In this paper [9], Fractal geometry is developed by a recursive generating methodology that results in contours with infinitely intricate fine structures. This geometry, which has been used to model complex objects found in nature such as clouds and coastlines, has space-filling properties that can be utilized to miniaturize antennas. These contours are able to add more electrical length in less volume. This paper of literature review described miniaturizing wire and patch antennas using fractals. Fractals are profoundly intricate shapes that are easy to define. It is seen that, even though the mathematical foundations call for an infinitely complex structure, the complexity that is not discernible for the particular application can be truncated.

In this paper [10], they developed a miniaturization model of a square loop antenna using a non-return to zero pulse as a generator instead of the square pulse in Minkowski fractal model that allows an increase in the total electric length without occupying more space. This led to an easy matched compact loop antenna, but with a small sacrifice of the gain. The paper literature describes that the antenna was created by using the generator for 3/2 curve fractal to increase the electrical lengths to fit in a small area.

In this paper [11], various techniques and geometries have been introduced for size reduction of Microstrip patch antennas, since this class of antennas in spite of inherent application deficiencies, possess preferred benefits in comparison with other choices. The literature described on the evaluation on a novel microstrip patch antenna using Minkowski fractal geometry. Simulation and experimental results indicate efficiency of this technique from the viewpoint of miniaturization for four designed patch antennas by four different depression coefficients. Simulation results are obtained using Ansoft HFSS simulation tool and no experimental analysis is carried out.

In our paper IE3D software is used for simulation purpose and experimental analysis also carried out for stacked Minkowski using VNA.

This paper [12], presents a rhombic patch monopole antenna applied with a technique of fractal geometry. The antenna has multiband operation in which the generator model describes that the antenna is working as a monopole and the analysis is carried for only final prototype model of antenna.

In this paper[13], the tuning holes on the Minkowski antenna serves well to be a choice as a wearable antenna for on-body communication system and only two iterations with simulations were carried out.In our paper instead of tuning holes we have considered microstrip fractal iterations up to third iterations.

3. SYSTEM DESIGN

In many of the designs, the essential resonance of a stack antenna can be either electric or magnetic. An electric resonance generates an electric dipole mode, and a magnetic resonance generates a loop mode. In planar version, the most adopted driven element was often selected to be electric dipole, because it would bring the stack antenna a broad bandwidth characteristic. In our paper, the configuration consists of two stacked dielectric substrate isolated by air as shown in figure1. There is a rectangle patch on the top of the first substrate.

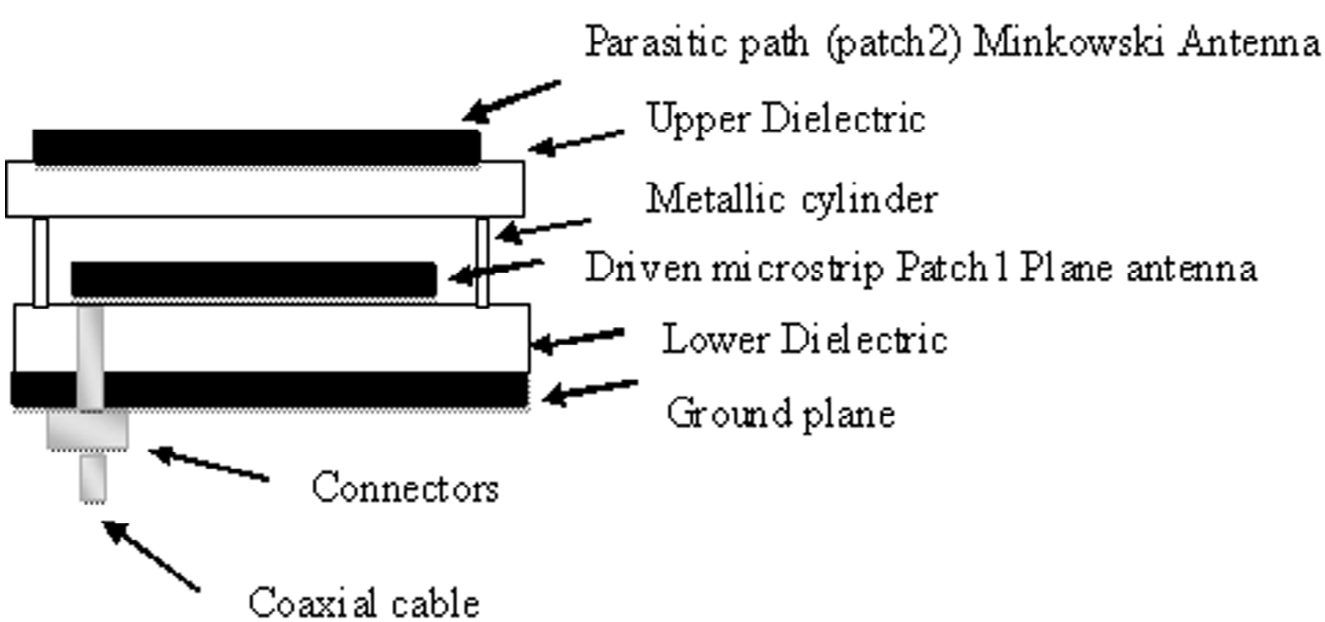


Figure 1: Arrangement of stacking

In this paper, a planar microstrip patch is chosen as a driving element. The advantages include its integrated ground plane and ease of fixing it on the other platforms. Figure 2 shows the dimensions for proposed electrically small antenna, with Figure 2(a) shows upper Minkowski antenna layer and figure 2(b) represents a driven layer, with a substrate. A gap of 3.2 mm is maintained between the two layers and two metallic cylinders are used to inter connect the layers. Table 1 summarizes the parameter and the dimensions employed.

3.1. Experimental Setup

A dual-band characteristic of stacked Minkowski microstrip antenna is simulated using IE3D and experimentally analyzed using the Vector Network Analyser (VNA). The proposed antenna is a probe fed one. Impedance matching is done using 50 Ω coaxial cable. This antenna works well in the frequency around 1.9 GHz and 3.4 GHz used for the WiMax applications. It is basically a low cost, light weight medium gain antenna.

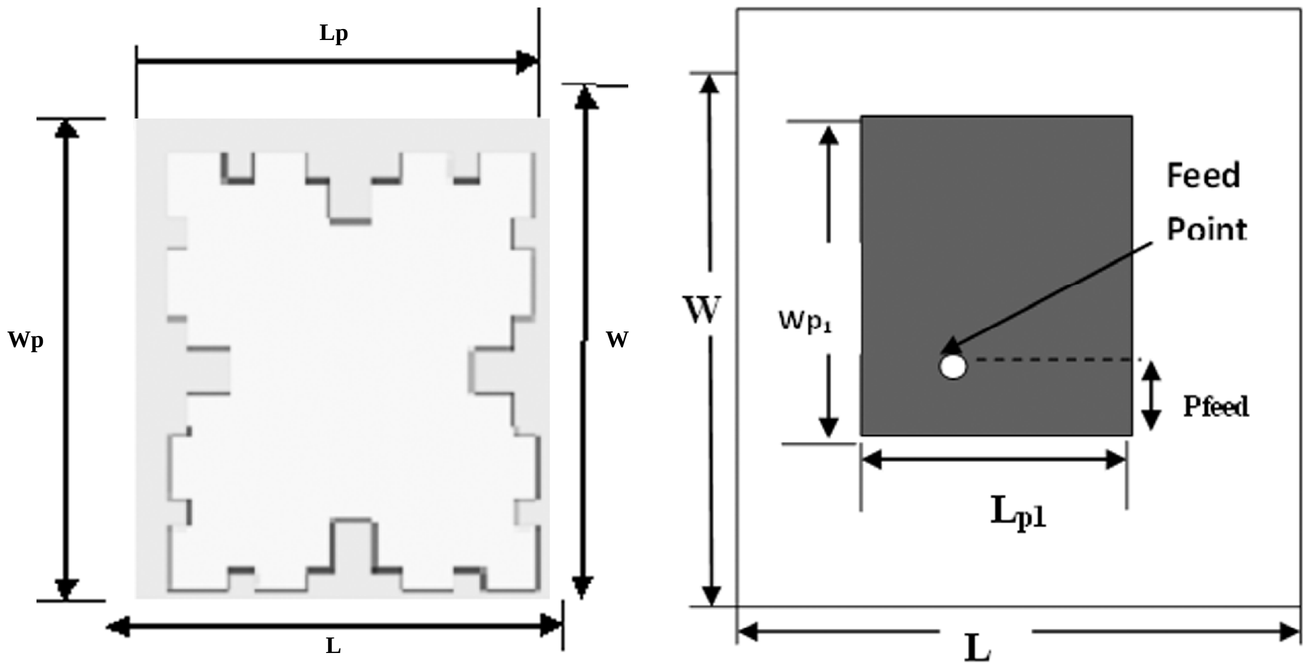


Figure 2: Dimensions of the proposed antenna with (a) upper Minkowski antenna layer and (b) driven layer

Table 1
Parameter and dimensionsof antenna

Parameter	*Dimension in mm*
L	54
W	54
h_{air} *(gap between layers)*	3.2
L_{P1}	42
W_{P1}	54
p_{feed}	17
L_{p1}	54
W_{p1}	48
p_m	4
D_m *(dia of feed)*	1.3

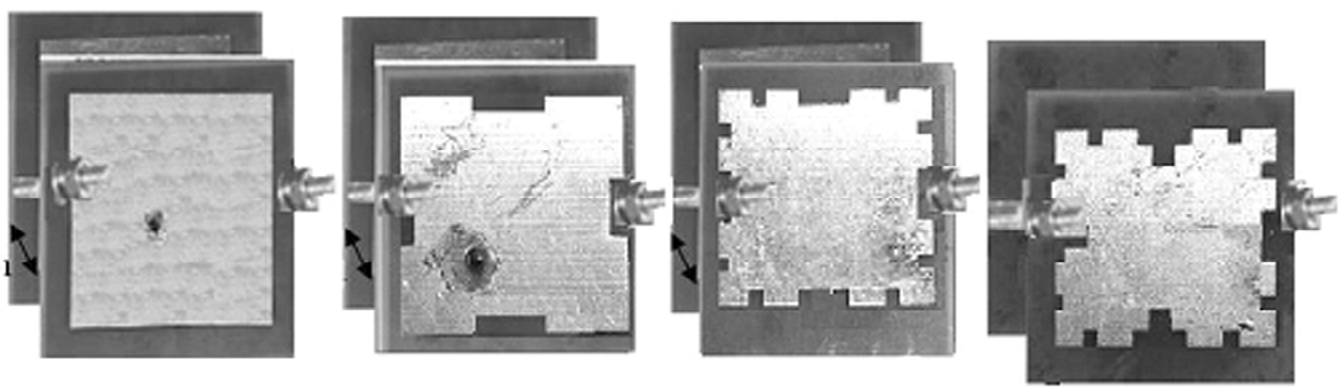
Figure 3 shows the prototype of the fabricated small antenna. Driven and parasitic elements are printed on the 54 × 54 mm^2. FR4 substrate with permittivity $\varepsilon = 4.4$ and $\tan \sigma = 0.001$ specified by the design as illustrated in figure 2. The proposed antenna is a double layer stacked antenna separated by air and fed by a coaxial cable with characteristic impedance equal to 50 Ω on the back ground. It is connected to the VNA cable and a connector and its network characteristics are measured.

4. RESULTS AND DISCUSSION

The simulated and measured reflection coefficient, bandwidth of the proposed antenna for stack and unstacked is shown in the table 2.

Figure 4(a) and 4(b) show the graph of simulated values and stack details of resonances obtained from zero iterations to third iterations. An increase in the resonance is observed with the increase of iterations and the corresponding values are recorded in the table 2.

Figure 5(a) and 5(b) show the graph of experimental values and the stacked values for different iterations using probe feed. Almost the same response is observed as mentioned above for simulated results and the values are recorded in table2. Figure 6 shows the comparison and variations of bandwidth and the resonance for different iterations for simulated and experimental values.



(a) (b) (c) (d)

Figure 3: Photogragh of the proposed antenna for different iterations
(a) Reference model (b) I iteration (c) II iteration (d) III iteration

Table 2
Reflection coefficient and bandwidth of the proposed antenna

Parameter	*Reference model*		*I iteration*		*II iteration*		*III iteration*	
	Simulated	*Measured*	*Simulated*	*Measured*	*Simulated*	*Measured*	*Simulated*	*Measured*
				I Resonance				
Resonance frequencyf_1(GHz)	1.8	1.8	1.8	1.85	1.8	1.9	1.8	1.9
Bandwidth,(MHz)	50	64	180	200	245	230	220	410
S_{11}(dB_i)	10.5	11	12	13	12.5	17	20	22
Gain (dB_i)	0	0	1	1.5	1.8	2.5	2	4
				II Resonance				
Resonance frequencyf2 (GHz)	3.3	3.3	3.3	3.3	3.3	3.4	3.3	3.4
Bandwidth,(MHz)	55	72	200	180	240	310	350	430
S_{11}(dB_i)	11.2	10.5	13	12	07	12	19	24
Gain (dB_i)	0	0	2	2.5	3	2.75	3	6

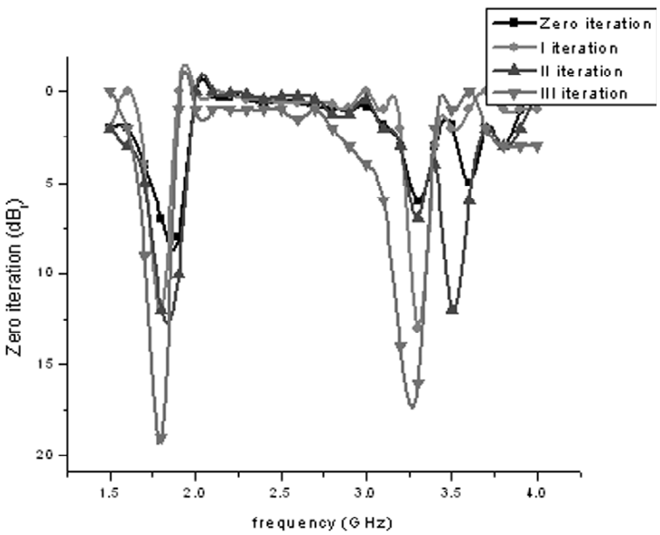


Figure 4(a): Simulated values for different iterations

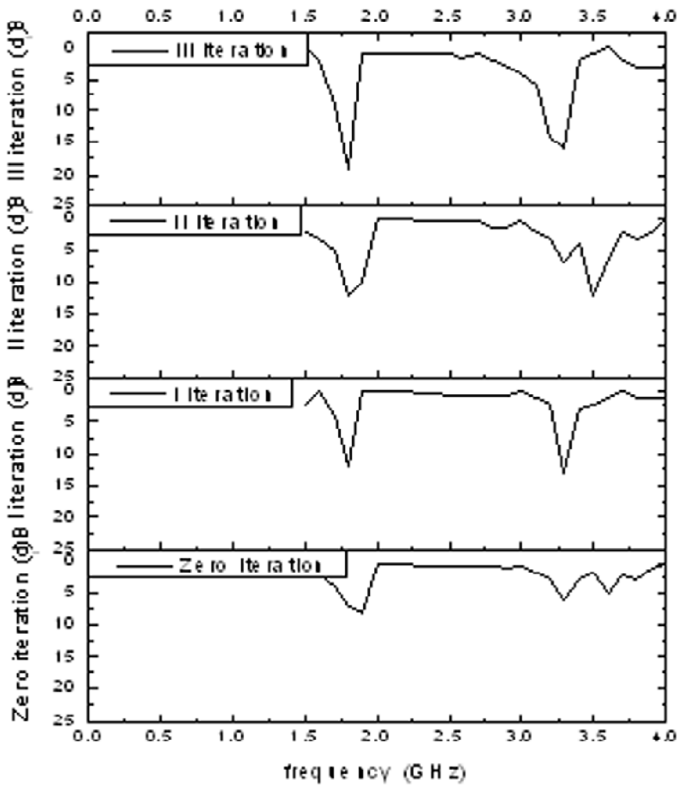


Figure 4(b): Stack details for different iterations

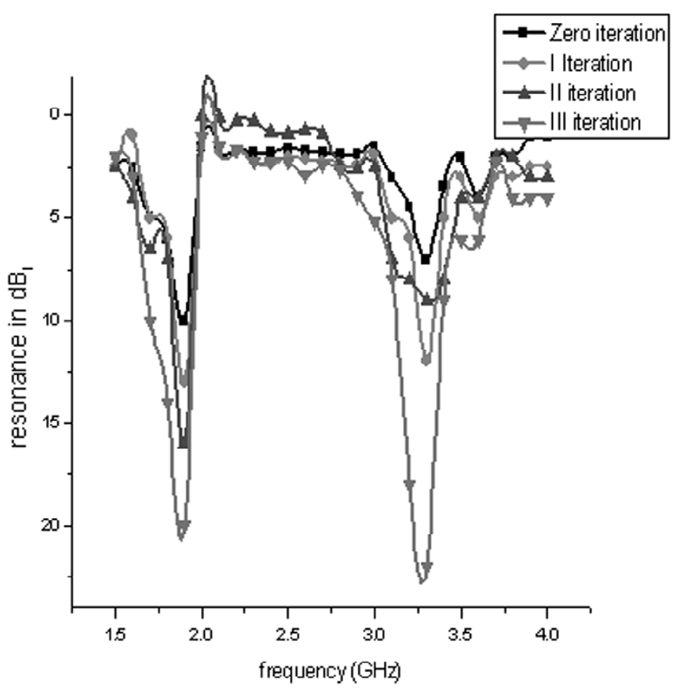


Figure 5(a): Simulated values for different iterations

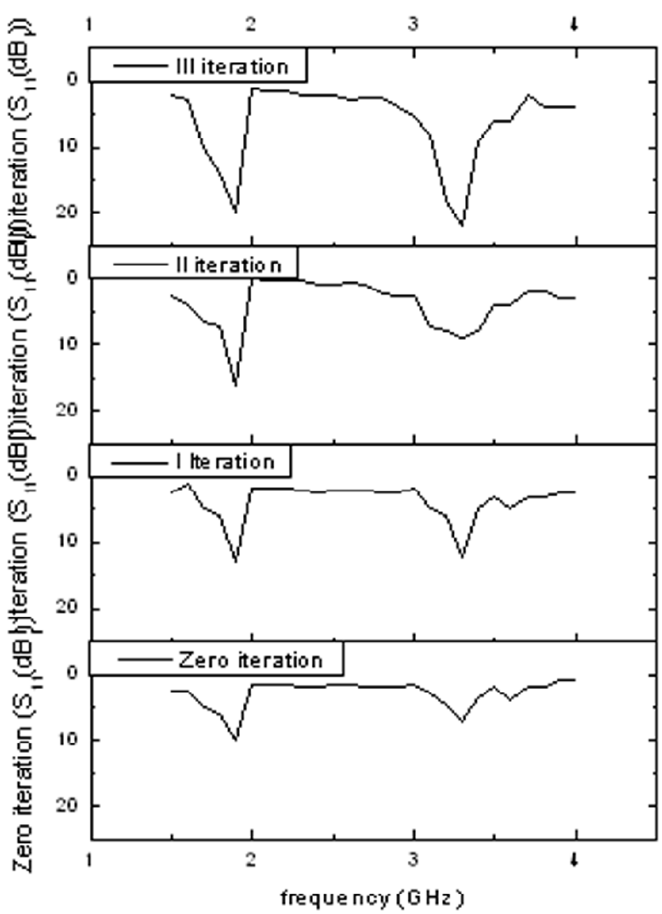


Figure 5(b): Stack details for different iterations

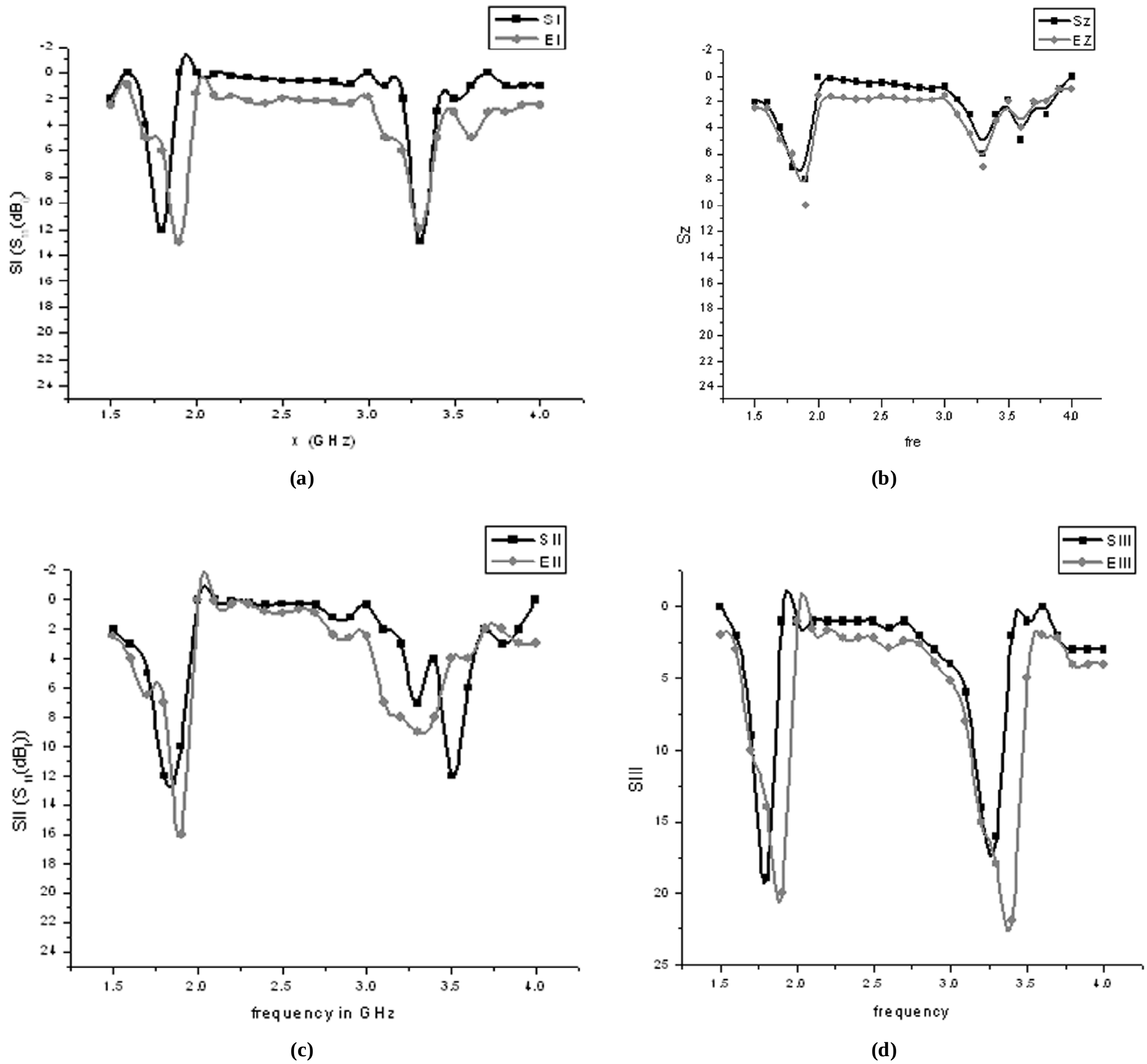


Figure 6: Comparison and variations of bandwidth and the resonance Zero iteration (a) zero iteration (b) I iteration (c) II iteration (d) III iteration

The 3 dB fractional bandwidth (FBW3 dB) for simulation results indicates that the bandwidth for first resonance (1.8 GHz), is varying from 50 MHz to 220 MHz and second resonance (3.3 GHz), bandwidth extended from 55 MHz to 350 MHz.

The 3 dB fractional bandwidth (FBW3 dB) for experimental results indicates that the bandwidth for first resonance around 1.9 GHz, is varying from 64 MHz to 410 MHz and for second resonance 3.3-3.4 GHz the bandwidth extended from 72 to 430 MHz. The bandwidth demonstrated that the high quality factor (Q) and strong resonance characteristics of the electrically small antenna. Figure 6(a) to 6(b) shows the comparison and variations of bandwidth and the resonance for various iterations.

In the 3rd iterations the measured resonant frequency is about 1% higher than the simulated one, which can be contributed to fabrication process and dielectric constant tolerance in a frequency regime.

The gain variations for the third iterations of simulated and experimental results are shown in figure 7. For simulation analysis a gain of 2 dB and 3dB at resonance frequencies are observed. And for the experimental analysis 4dB and 6 dB are observed.

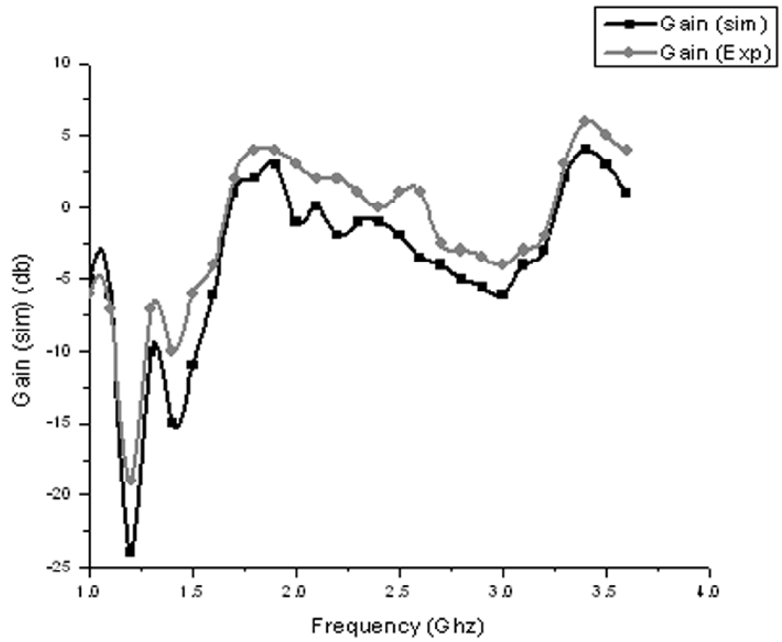


Figure 7: Graph of total field gain versus frequency

5. CONCLUSION

A dual-band electrically small antenna based on with or without stacking for a probe feeding is proposed and experimentally studied in this paper. The new structure consists of a microstrip patch antenna as driven element and a Minkowski as a parasitic element. Nearly complete matching of values were observed. The optimized bandwidths are obtained after the third iterations, also a gain improvement is observed between the simulation result to the experimental result for third iterations. A bandwidth enhancement for resonance values for simulated analysis at 1.9 GHz and 3.3 GHz are 170 MHz and 295 MHz respectively. Similarly a bandwidth enhancement for resonance values for experimental analysis at 1.9 GHz and 3.3 GHz are 346 MHz and 358 MHz respectively. An increase in gain is also observed for experimental analysis. Still enhanced bandwidth would be obtained by introducing a NIC matching circuit based on non-Foster element.

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