

SINGLE LAYER MONOPOLE FRACTAL GEOMETRIE ANTENNA FOR APPLICATION OF ISM/WLAN/BLUETOOT

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Abstract— Modern communication system require antenna with wider bandwidth, smaller dimension, high gain and high efficiency. Various antennas for wide band operation have been studied for communication and radar system. The proposed antenna has been simulated and optimized using IE3D Simulator to cover standard frequency bands like at (3.54GHz,4.071GHz,9.061GHz), ISM/WLAN/Bluetooth band (Operating freuencuies:2.32GHz), Wi-Max(3.4-3.69GHz,Operating Frequencies: 3.54GHz), Hiper Lan2(2.12-2.32GHz, operating frequencies: 2.32GHz) communication. In this Dissertation, We compare both result and we analyze that like VSWR ($VSWR \leq 2$) and Return Loss dB (Return loss ≤ -9.5 dB) and almost 100% radiation Efficiency for 2.53GHz frequencies . I also fabricate this antenna and measure return loss for various resonant frequencies. Practical result shows antenna resonant at ten different frequencies within range 1-20GHz. which shows antenna work as good multiband antenna.

Keywords: Monopole, circular polarized, application of ISM/WLAN/BLUETOOTH optimized using IE3D

Introduction

In Today's world, in order to face the technological development, men need to keep up with the evolution. This evolution leads to the development of cellular devices. This brought up many new areas of investigation the one with main interest for this dissertation is the research of antennas with fractal geometries. The main problem of common antennas is that they only operate at one or two frequencies, restricting the number of bands that equipment is capable of supporting. Another issue is the size of a common antenna. Due to the very strict space that a handset has, setting up more than one antenna is very difficult. To help these problems, the use of fractal shaped antennas is being studied.

This has initiated antenna research in various directions, one of which is by using fractal shaped antenna elements.

History

A microstrip antenna idea was firstly introduced in 1950's but it became popular and took place in various applications in 1970's. Recently, microstrip antennas are widely used in several applications where small size, low weight and cost, high performance and easily fabricated and installed antennas are required such as air borne, space borne commercial and military applications and mobile and wireless technologies. Some other advantages of microstrip antennas are that they are conformable to planar and non-planar surfaces, easily fabricated using printed circuit technology, and they are

mechanically robust. Microstrip patches are resonant type antennas. Thus, impedance bandwidths are narrow. For reducing the size of antenna, fractal geometries have been introduced.[1]

In 1951, Mandelbrot proposed the fractal geometries, which were extensively used in various science and engineering fields. The word of fractal comes from the word of Latin language's facts. The concept of fractals applied for geological application. The most famous application is use by Mandelbort. He use the concept of fractal for synthesize landscape of cost line in Britain. Mandelbort also called as father of fractal geometry. However some mathematicians had remarked and proposed many geometry of fractal such as Georg Cantor (1872), Giuseppe Peano (1890), David Hilbert (1891), Helg Von Koch (1904),WaclawSierpinski (1916),Gaston Julia (1919) and FalixHausdroff (1919). These mathematicians played a key role in Mandelbrot's concept a new geometry. Then Mandelbrot demonstrate that these early mathematical fractals have many features in common with shapes found in nature. For this reason he publishes his book with the title "The Fractal Geometry in Nature" in 1982 [1].

Literature Survey

It is focusing on various types of fractal geometry antenna uses for multiband

HomayoonOraizi and ShahramHedayati"**Miniaturized UWB Monopole Microstrip Antenna design by the Combination of Giuseppe Peano and Sierpinski Carpet Fractals**" [1]

A fractal monopole antenna is presented for the application in the UWB frequency range, which is designed by the combination of two fractal geometries. The first iterations of Giuseppe Peano fractal are applied on the edges of a square patch, and a Sierpinski Carpet fractal is formed on its surface. The feed circuit is a microstrip line with a matching section over.

Kin-Lu Wong, Senior Member, IEEE, Gwo-Yun Lee, and Tzung-WernChiou "A Low-Profile Planar Monopole Antenna for Multiband Operation of Mobile Handsets" [3]

A novel planar monopole antenna with a very low profile (antenna height less than 0.04 times the operating wavelength in the free space) and capable of multiband operation is presented. The presented antenna has a planar rectangular radiating patch in which a folded slit is inserted at the patch's bottom edge.

Douglas H. Werner, Randy L. Haupt and Pingjuan L. Werne J "Fractal Antenna Engineering: The Theory and Design of Fractal Antenna Arrays"[5]

Fractal antenna engineering represents a relatively new field of research that combines attributes of fractal geometry with antenna theory. Research in this area has recently yielded a rich class of new designs for antenna elements as well as arrays. **Abolfazl Azari "A New Super Wideband Fractal Microstrip Antenna" [6]**

The concepts of fractals can be applied to the design of ultra wideband antennas. Applying fractals to antennas allows for miniaturization of antennas with multi-band and broad-band B. R. Franciscatto, T. P. Vuong and G. Fontgalland properties. **B. R. Franciscatto, T. P. Vuong and G. Fontgalland "High gain Sierpinski Gasket fractal shape antenna designed for RFID" [7]**

In this paper a high gain Sierpinski fractal shape antenna (reader) for RFID applications is presented. It has been observed that the fractal geometry presented in the preceding literature could be an interesting solution for the antenna design in RFID applications,

Asit K. Panda, Manoj K. Panda and Sudhansu S. Patra "A Compact Multiband Gasket Enable Rectangular Fractal Antenna" [9]

A compact printed CPW feed multiband Gasketed carpet antenna is investigated in this paper. The simulated results indicate that the antenna exhibits a good return loss, and the antenna gain is above 5 dB at the designed frequency and other multiband frequencies suitable for IEEE WLAN (2.4-2.484 GHz), WiMAX (3.4-3.69 GHz) & WIFI (5.1-5.825GHz) as well other wireless communication system.

Ashish A. Lale, Bhagwan V. Khiste and Sanjay Khobragade "Study of Sierpinski triangle gasket" [11]

A set of Sierpinski triangle antennas using a coplanar capacitive feed strip has been presented in this paper. Based on experimental studies it is demonstrated that the triangular patch antenna gives the best performance having bandwidth, and with a good broadside radiation patterns throughout this band.

L. S. Araújo, C. P. do Nascimento Silva, L. C. Barbosa, A. J. Belfort de Oliveira "A novel Sierpinski carpet fractal dipole" [12]

The inclusion of slots in the geometry of iteration 2 of the original Sierpinski dipole, creating the fractal generator, permitted currents to flow near their edges, which changed significantly the electromagnetic performance of the antenna. Squares formed by the slots in the dipole determine the number of resonances that appear for each iteration. • Problem Identification

In literature survey I discussed various fractal geometry were applied for the design and realization of frequency-independent and multiband antennas. Multiplication of an antenna size by a factor generally decreases the operating frequency of the antenna by the same factor. If an antenna is much smaller than the wavelength of the operating frequency, its efficiency deteriorates drastically since its radiation resistance decreases and the reactive energy stored in its near field increases. These two factors make the matching of a small antenna to its feeding network difficult. Consequently,

fractal antennas are a viable candidate for their miniaturization. Antenna geometries and dimensions are the main factors determining their operating frequencies. [5] In order for an antenna to work equally well at all frequencies, it must satisfy two criteria: it must be symmetrical about a point, and it must be self-similar, having the same basic appearance at every scale: that is, it has to be a fractal. Most of researcher works on designing fractal antenna by use of common fractal geometries like such as Koch, Tee-Type, Sierpinski carpet, Sierpinski gasket, Hilbert curves and Cantor Set. These types fractal antenna can achieve multiband behavior by implementing more than 2nd iteration. Most of researcher conclude that when going to higher iteration antenna achieve more multiband behavior. As the iterations go on increasing the loading causes multiple resonance and a shift down in resonance frequency, which may lead to an effective antenna miniaturization and multiband characteristics. However, for iterations higher than the second iteration, the antenna design becomes quite complicated and its fabrication becomes very difficult. So that the Hybrid techniques is very useful for achieve multiband behavior of antenna. [3]

Fractal Antenna Elements

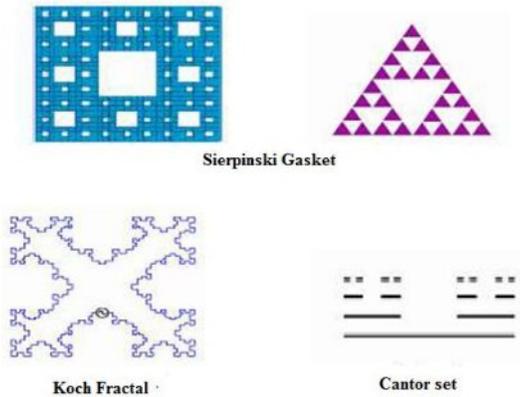
The first application of fractals to the field of antenna theory was reported by Kim and Jaggared. They introduced a methodology for designing low side lobe arrays that is based on the theory of random fractals [3]. The fact that self-scaling array can produce fractal radiation pattern was first established in 1992. This is accomplished by studying the properties of a special type of non-uniform linear array, called a weierstrass array, which has self-scaling element spacing and current distribution for reducing the size of antenna, fractals geometries have been introduced in the design of antenna fractal geometries have two antennas. Fractal geometries have two common properties: self-similar property, space filling property. The self-similarity property of certain fractals results in multiband behaviour. Using the self-similarity properties a fractal antenna can be designed to receive and transmit over a wide range of frequencies. While using space filling properties, fractal makes reduce antenna size.

There are many benefits when I applied this nature power (fractals) to develop various antenna elements. By applying fractals to antenna elements:

- I can create smaller antenna size.
- Achieve resonance frequencies that are multiband.
- May be optimized for gain.
- Achieve wideband frequency band.

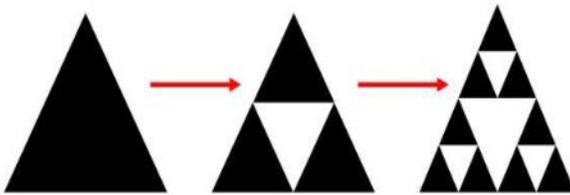
Most fractals have infinite complexity and detail that can be used to reduce antenna size and develop low profile antennas. For most fractals, self-similarity concept can achieve multiple frequency bands because of different parts of the antenna are similar to each other at different scales. The combination of infinite complexity and detail and self-similarity makes it possible to design antennas with very wideband performances.

There are many fractal geometries that have been found to be useful in developing new and innovative design for antennas. Figure 1.2 shows some of these unique geometries.



**Example of Fractal Antennas[3]
Sierpinski Gasket**

The Sierpinski Gasket use triangles. The Sierpinski fractal has been generated through three iterations using the decomposition algorithm. In the decomposition algorithm, an equilateral triangle is taken and joining the midpoints of each side of the triangle, a central inverted triangle is removed from the parent triangle. Three half-scaled triangles are obtained the same process is repeated on each of these three triangles and so on this process is carried out up to three iterations [4].



**Fig. Three Stages in Construction of Sierpinski Gasket [4]
Sierpinski Carpet**

The Sierpinski carpet is constructed similar to the Sierpinski gasket, but it use squares instead of triangles. Sierpinski Carpet fractal is implemented by cutting slots in the patch area [5]. In order to start this type of fractal antenna, it begins with a square in the plane, and then divides it into nine smaller congruent squares where the open central square is dropped. The remaining eight squares are divided into nine smaller congruent squares.

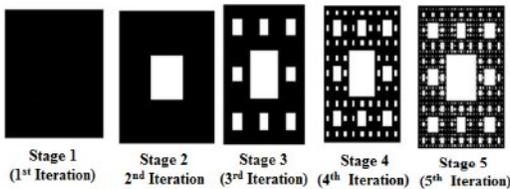
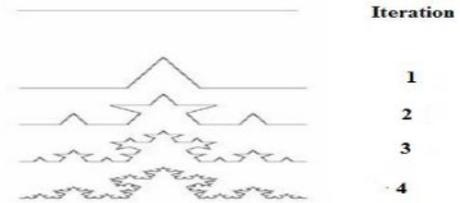


Fig. Steps of Iteration to get Carpet Geometry [5]

Koch Curves

The geometric construction of the standard Koch curve is very simple. It starts with a straight line as an initiator. This is

partitioned into three equal parts, and the segment at the middle is replaced with two others of the same length. This is the first iterated version of the geometry and is called the generator. The process is reused in the generation of higher iterations.



**Fig. 1.5 Steps of Construction for Koch Curve Geometry [5]
The Cantor Set Geometric**

The Cantor Set is created by the following algorithm. It starts with the closed interval $[0, 1]$.

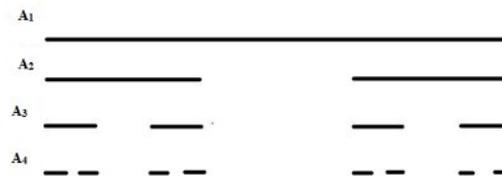


Fig. Steps for the Cantor Set Geometry [5]

Say it as set A_1 or the 0th (initial) set. Delete the middle open third. This leaves a new set, called A_2 $[0, 1/3] \cup [2/3, 1]$. Each iteration through the algorithm removes the open middle third from each segment of the previous iteration. Thus, the next two sets would be A_3 $[0, 1/9] \cup [2/9, 1/3] \cup [2/3, 7/9] \cup [8/9, 1]$ and according to the previous one A_4 set will be A_4 $[0, 1/27] \cup [2/27, 1/9] \cup [2/9, 7/27] \cup [8/27, 1/3] \cup [2/3, 19/27] \cup [20/27, 7/9] \cup [8/9, 25/27] \cup [26/27, 1]$ can see that the set becomes sparser as the number of iteration increases. [5]

Giuseppe Peano fractal

The initiator and generator of the Giuseppe Peano fractal are shown in Fig. where the horizontal line sections are equal and the vertical ones are also equal [2]. The fractal dimension may be changed by varying the length of horizontal and vertical line sections, as shown in Fig. 1.7 (b) [5].

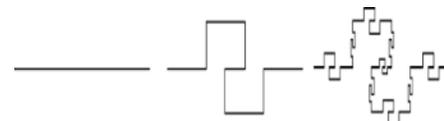


Fig. Initiator and Generator of the Giuseppe Peano Fractal [5]

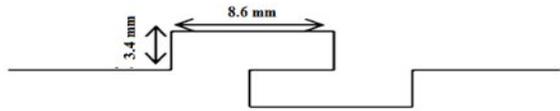
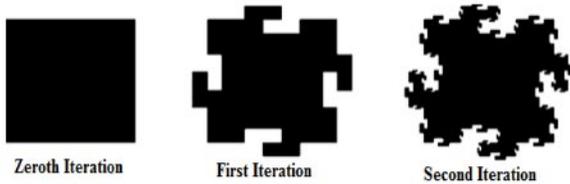


Fig. 1.7 (b) Example for Generation of the Giuseppe PeanoFractal[5]



Giuseppe Peano Fractal up to Second Iteration[5]

Hilbert curves

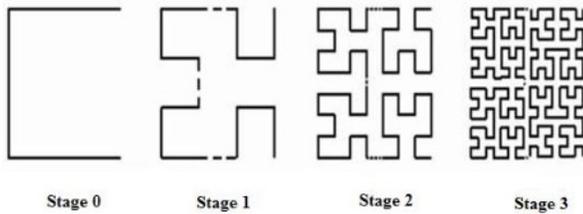


Fig.Four Stages in Construction of Hilbert Curves [5]

Figure 1.8 shows the first some iteration of Hilbert curves. It can be noticed that each successive stage consists of four copies of the previous, connected with additional line segments. This geometry is a space-Filling curve, since with a larger iteration, one may think of it as trying to fill the area it occupies. Additionally the geometry also has the following properties: self-Avoidance (as the line segments do not intersect each other), simplicity (since the curve can be drawn with a single stroke of a pen) and self-similarity [5].

Hexagonal Fractal

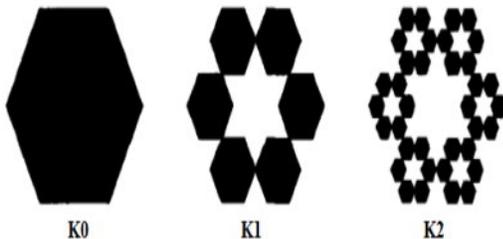


Fig. First Three Iteration of the Hexagonal Fractal[5]

The hexagonal fractal is constructed by reducing a hexagon generator shape to one third its former sizes, and grouping six smaller hexagons together. The first three hexagonal fractal iterations are displayed in Figure 1.9. The hexagonal fractal antenna is observed to possess multiband behaviour similar to the Sierpinski gasket antenna. However, the hexagonal fractal

antenna resonant frequencies repeat with a factor of three whereas the Sierpinski gasket antenna resonant frequencies repeat with a factor of two in frequency [6].

Design procedure

In the typical design procedure of the microstrip antenna, the desired resonant frequency, thickness and dielectric constant of the substrate are known or selected initially. In this design of rectangular microstrip antenna, FR 4 dielectric material ($\epsilon_r=4.4$) with dielectric loss tangent of 0.02 is selected as the substrate with 1.6 mm height. Then, a patch antenna that operates at the specified operating frequency $f_0 = 2.4$ GHz can be designed by the following steps using transmission line model equations. The antenna is excited by the INSET feed away from the center of the patch.

PROPOSE DESIGN PARAMETERS

A. Equations:

- Calculation of the width W of antenna, which is given by:

$$W = \frac{c}{f_0 \sqrt{\epsilon_{eff}}}$$

Substituting $c = 3.00 \cdot 10^8$ m/s, $\epsilon_r = 4.4$ and $f_0 = 2.4$

GHz,

$$W = \frac{300}{2.4 \sqrt{4.4}} = 38 \text{ mm}$$

- Calculation of Effective dielectric constant (ϵ_{eff}):
The effective dielectric constant is:

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(\frac{W}{L} \right)^{-1}$$

$$\epsilon_{eff} = \frac{4.4 + 1}{2} + \frac{4.4 - 1}{2} \left(\frac{38}{31.458} \right)^{-1}$$

$$\epsilon_{eff} = 4.085$$

- Calculation of the effective length, L_{eff} which is given by:

Sr.No	Geometry parameter	Value
1	Operating frequency	2.4 GHz
2	Relative dielectric constant	4.4
3	Loss tangen δ	0.02
4	Substrate thickness(h)	1.6mm

$$L_{eff} = \frac{c}{f_0 \sqrt{\epsilon_{eff}}}$$

$$L_{eff} = \frac{300}{2.4 \sqrt{4.085}} = 31.458 \text{ mm}$$

- Calculation of the length extension, ΔL , which is given by:

$$\Delta L = 0.412 \cdot 1.58 \left(\frac{31.458}{38} \right)^{-1}$$

$$\Delta L = 0.412 * 1.58 \frac{h}{\sqrt{\epsilon_{eff}}}$$

$$\Delta L = 0.729$$

• Calculation of the effective length extension of patch L which is given by:

$$L = L_{eff} - 2 \Delta L$$

$$L = 31.458 - 2 * 0.729$$

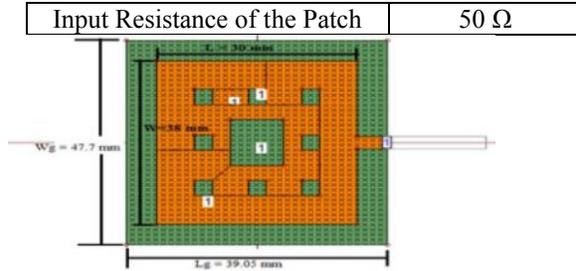
$$L = 30 \text{ mm}$$

Calculation of the ground plane dimensions (L_g and W_g):

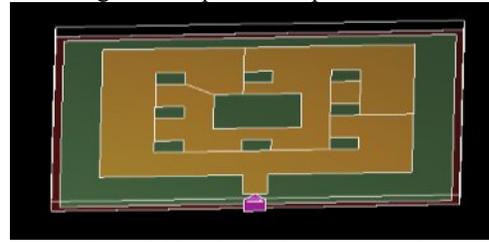
- $L_g = 6h + L = 6(1.6) + 30 = 39.6 \text{ mm}$
- $W_g = 6h + W = 6(1.6) + 38 = 47.6 \text{ mm}$

PROPOSE DESIGN DIMENSION

Design of Single Band Microstrip Patch Antenna	
Width of the Patch(W)	38 mm
Effective dielectric constant of the Patch (ϵ_{eff})	4.085
Length of the Patch(L)	30 mm
Maximum iterations	3



2D Design of Sierpinski Carpet Fractal Antenna



3D Design of Sierpinski Carpet Fractal Antenna

SIMULATION RESULT OF SIERPINSKI CARPET ANTENNA

Sr.No	Frequency (GHz)	Return Loss(dB)	VSWR	Gain (dBi)	Directivity in dBi	Antenna Efficiency (%)	Radiation Efficiency(%)	Impedance(Ω)
1	2.28	-10.96	1.86	3.14	3.55	90.89	100	80.16
2	2.32	-11.90	1.71	3.26	3.58	93.05	100	73.68
3	2.53	-29.42	1.07	3.67	3.67	99.78	100	52.61
4	3.54	-7.62	2.47	3.14	4.07	82.12	100	122.53
5	4.07	-18.81	1.25	4.17	4.23	98.68	100	57.86
6	9.06	-8.07	2.30	4.81	5.54	84.40	100	104.16
7	14.82	-11.04	1.77	5.68	6.36	85.41	92.70	54.43
8	19.99	-7.27	2.22	4.53	5.43	81.27	100	23.63

Return Loss Plot of Sierpinski Carpet Antenna

The Inset feed used to design the rectangular patch antenna. The center frequency is selected as the one at which the return loss is minimum. The bandwidth can be calculated from the return loss (RL) plot. The bandwidth of the antenna is said to be those range of frequencies over which the return loss is below than -7.5 dB, which is equivalent to 2.5:1 VSWR. Return loss graph is shown in figure 3rd Iteration Sierpinski carpet antenna. The Implemented Sierpinski carpet antenna simulated return loss data and its operating frequency are as shown in table

- Return Loss Plot for 1st Iteration

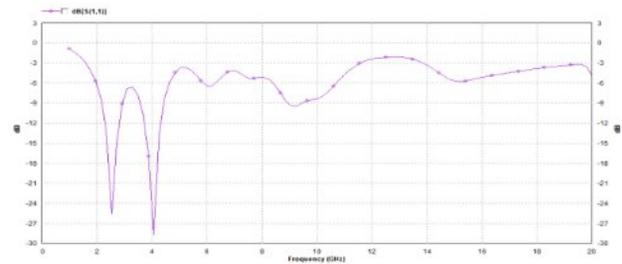
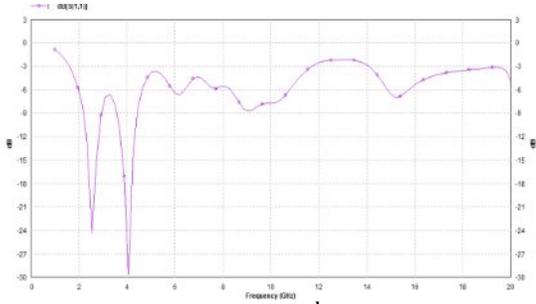


Fig. Return Loss Graph of 1st Iteration Sierpinski Carpet Antenna

- Return Loss Plot for 2nd Iteration



Return Loss Graph of 2nd Iteration Sierpinski Carpet Antenna

- Return Loss Plot for 3rd Iteration

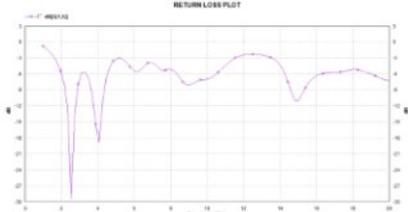


Fig. Return Loss Graph of 3rd Iteration Sierpinski Carpet Antenna

Other analyze results for 3rd Iteration Sierpinski carpet antenna
VSWR Plot of Sierpinski carpet antenna

Voltage standing wave ratio (VSWR) of proposed Sierpinski carpet Microstrip antenna shown in figure 5.2 and table 5.3.

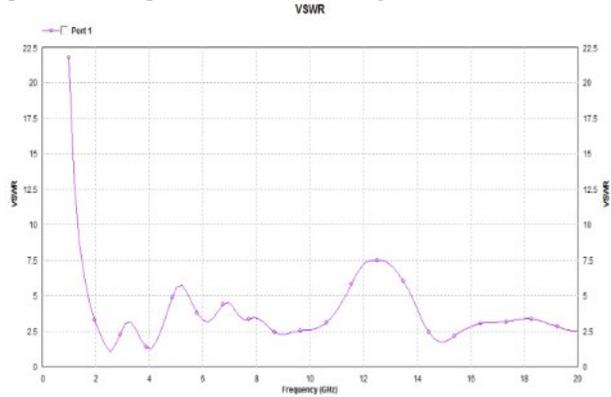
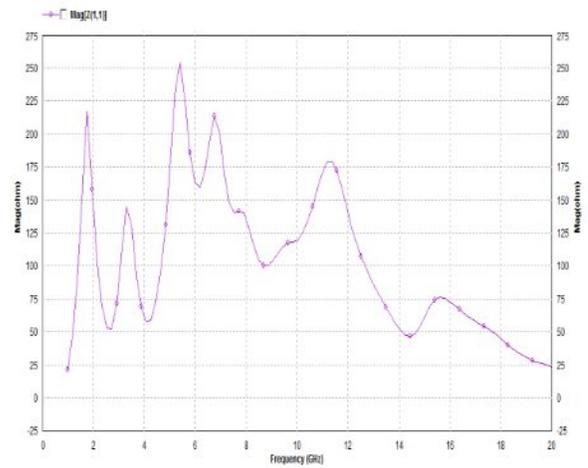
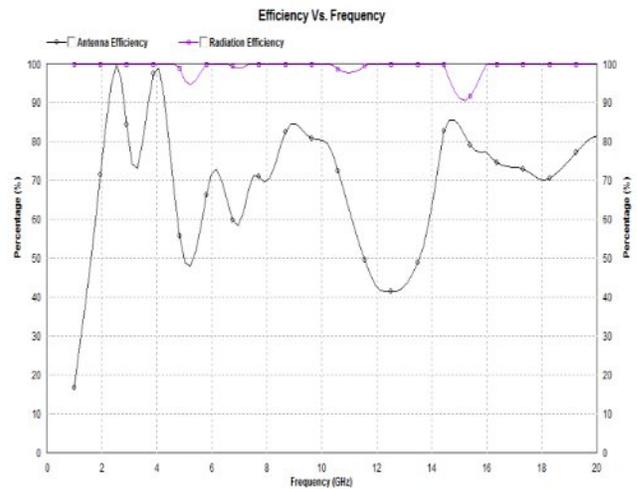


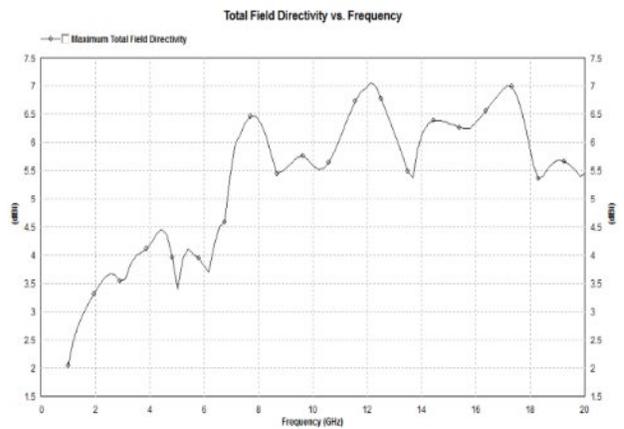
Fig VSWR Plot of Sierpinski Carpet Antenna
Input Impedance Plot of Sierpinski carpet antenna
I expect pure impedance at frequencies where the patch resonates, and see table 5.3 and figure 5.3



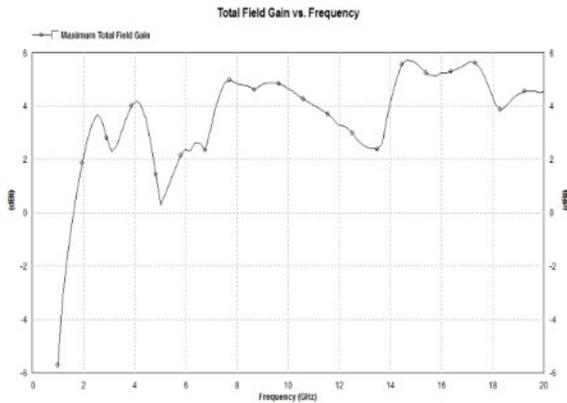
Graph between Frequency and Magnitude Input Impedance of Sierpinski Carpet Antenna
Frequency vs. Various Efficiency Plot of Sierpinski carpet antenna



Directivity and Gain Plot of Sierpinski carpet antenna



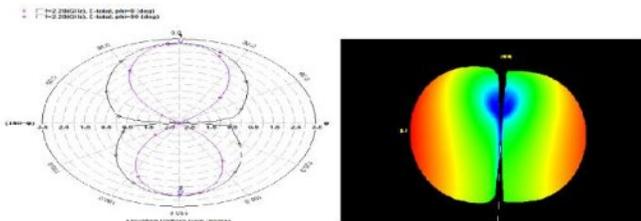
Directivity vs. Frequency Plot of Sierpinski Carpet Antenna



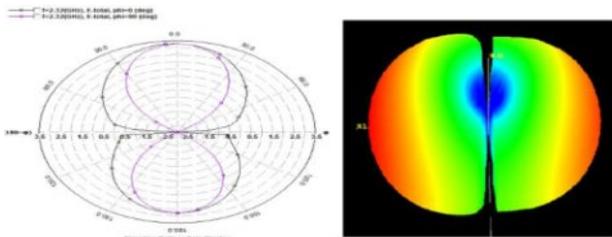
Gain vs. Frequency Plot of SierpinskiCarpet Antenna

Radiation Pattern of carpet antenna

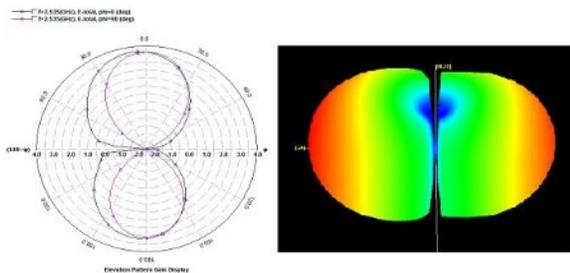
- Radiation pattern for 2.28 GHz



- Radiation pattern for 2.32 GHz



2D & 3D Pattern for 2.32 GHz



2D & 3D Pattern for 2.53 GHz

II. USING THE TEMPLATE

After the text edit has been completed, the paper is ready for the template. Duplicate the template file by using the Save As command, and use the naming convention prescribed by your conference for the name of your paper. In this newly

created file, highlight all of the contents and import your prepared text file. You are now ready to style your paper; use the scroll down window on the left of the MS Word Formatting toolbar.

A. Authors and Affiliations

The template is designed so that author affiliations are not repeated each time for multiple authors of the same affiliation. Please keep your affiliations as succinct as possible (for example, do not differentiate among departments of the same organization). This template was designed for two affiliations.

1) For author/s of only one affiliation (Heading 3): To change the default, adjust the template as follows.

a) Selection (Heading 4): Highlight all author and affiliation lines.

b) Change number of columns: Select the Columns icon from the MS Word Standard toolbar and then select “1 Column” from the selection palette.

c) Deletion: Delete the author and affiliation lines for the second affiliation.

d) For author/s of more than two affiliations: To change the default, adjust the template as follows.

e) Selection: Highlight all author and affiliation lines.

f) Change number of columns: Select the “Columns” icon from the MS Word Standard toolbar and then select “1 Column” from the selection palette.

g) Highlight author and affiliation lines of affiliation 1 and copy this selection.

h) Formatting: Insert one hard return immediately after the last character of the last affiliation line. Then paste down the copy of affiliation 1. Repeat as necessary for each additional affiliation.

i) Reassign number of columns: Place your cursor to the right of the last character of the last affiliation line of an even numbered affiliation (e.g., if there are five affiliations, place your cursor at end of fourth affiliation). Drag the cursor up to highlight all of the above author and affiliation lines. Go to Column icon and select “2 Columns”. If you have an odd number of affiliations, the final affiliation will be centered on the page; all previous will be in two columns.

B. Identify the Headings

Headings, or heads, are organizational devices that guide the reader through your paper. There are two types: component heads and text heads.

Component heads identify the different components of your paper and are not topically subordinate to each other. Examples include Acknowledgments and References and, for these, the correct style to use is “Heading 5”. Use “figure caption” for your Figure captions, and “table head” for your table title. Run-in heads, such as “Abstract”, will require you to apply a style (in this case, italic) in addition to the style provided by the drop down menu to differentiate the head from the text.

Text heads organize the topics on a relational, hierarchical basis. For example, the paper title is the primary text head because all subsequent material relates and elaborates on this one topic. If there are two or more sub-topics, the next level head (uppercase Roman numerals) should be used and,

conversely, if there are not at least two sub-topics, then no subheads should be introduced. Styles named “Heading 1”, “Heading 2”, “Heading 3”, and “Heading 4” are prescribed.

C. Figures and Tables

1) *Positioning Figures and Tables:* Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table heads should appear above the tables. Insert figures and tables after they are cited in the text. Use the abbreviation “Fig. 1”, even at the beginning of a sentence.

TABLE I. TABLE TYPE STYLES

Table Head	Table Column Head		
	<i>Table column subhead</i>	<i>Subhead</i>	<i>Subhead</i>
copy	More table copy ^a		

a. Sample of a Table footnote. (Table footnote)

We suggest that you use a text box to insert a graphic (which is ideally a 300 dpi TIFF or EPS file, with all fonts embedded) because, in an MSW document, this method is somewhat more stable than directly inserting a picture.

To have non-visible rules on your frame, use the MSWord “Format” pull-down menu, select Text Box > Colors and Lines to choose No Fill and No Line.

Figure 1. Example of a figure caption. (*figure caption*)

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity “Magnetization”, or “Magnetization, M”, not just “M”. If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write “Magnetization (A/m)” or “Magnetization {A[m(1)]}”, not just “A/m”. Do not label axes with a ratio of quantities and units. For example, write “Temperature (K)”, not “Temperature/K”.

ACKNOWLEDGMENT (HEADING 5)

The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g”. Avoid the stilted expression, “One of us (R. B. G.) thanks . . .” Instead, try “R. B. G. thanks”. Put sponsor acknowledgments in the unnumbered footnote on the first page.

REFERENCES

The template will number citations consecutively within brackets [1]. The sentence punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]—do not use “Ref. [3]” or “reference [3]” except at the beginning of a sentence: “Reference [3] was the first . . .”

Number footnotes separately in superscripts. Place the actual footnote at the bottom of the column in which it was cited. Do not put footnotes in the reference list. Use letters for table footnotes.

Unless there are six authors or more give all authors' names; do not use “et al.”. Papers that have not been published, even if they have been submitted for publication, should be cited as “unpublished” [4]. Papers that have been accepted for publication should be cited as “in press” [5]. Capitalize only the first word in a paper title, except for proper nouns and element symbols.

For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation [6].

- [1] G. Eason, B. Noble, and I. N. Sneddon, “On certain integrals of Lipschitz-Hankel type involving products of Bessel functions,” *Phil. Trans. Roy. Soc. London*, vol. A247, pp. 529–551, April 1955. (*references*)
- [2] J. Clerk Maxwell, *A Treatise on Electricity and Magnetism*, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.
- [3] I. S. Jacobs and C. P. Bean, “Fine particles, thin films and exchange anisotropy,” in *Magnetism*, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.
- [4] K. Elissa, “Title of paper if known,” unpublished.
- [5] R. Nicole, “Title of paper with only first word capitalized,” *J. Name Stand. Abbrev.*, in press.
- [6] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, “Electron spectroscopy studies on magneto-optical media and plastic substrate interface,” *IEEE Transl. J. Magn. Japan*, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetism Japan, p. 301, 1982].
- [7] M. Young, *The Technical Writer's Handbook*. Mill Valley, CA: University Science, 1989.