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DESIGN MULTIBAND ANTENNA FOR ULTRAWIDE BAND

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Abstract— **Wider bandwidth is required in modern wireless communication. Traditionally each antenna operates in a single frequency band, where a different antenna is required for different application. This will occupy more space. This paper presents a novel comparative study between three multiband antennas – Monopole antenna, PIFA and Fractal antenna. The planar monopole antenna has a simple structure, omni-directional radiation characteristic, low profile, and lightweight internal antenna. PIFA is one of the most promising antenna types because it is small and has a low profile, making it suitable for mounting on portable equipment. Fractals have self similar shapes and space filling properties. This property makes the fractal antenna compact and operating in multiband frequencies. The comparison is done in terms multiband radiation and size.**

Index terms- **Antenna, Monopole, PIFA, Fractal.**

I. INTRODUCTION

In the last few years, the trend of mobile phone technology has dramatically decreased the weight and size. Due to enhancement in this trend, the antennas used for mobile have to be small, light weighted, low profile and have Omni-directional radiation pattern in horizontal plane.

A. PLANAR MONOPOLE ANTENNA

Monopole antenna have been the best whelming choice for use in various automobiles and mobile equipment[4]. The planar monopole antenna is a good candidate for wireless communication because of its simple structure, omni-directional radiation characteristic, low profile, and light weight internal antenna. It is significant that the designed dual or multi band antenna maintained good radiation efficiency value and constant gain at both bands[2].

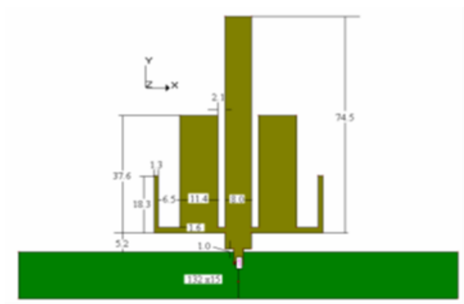


Fig 1.Extended E shape monopole antenna

B. PIFA

The Planar Inverted-F antenna (PIFA) is increasingly used in the mobile phone market. The antenna is resonant at a quarter-wavelength (thus reducing the required space needed on the phone), and also typically has good SAR properties. This antenna resembles an inverted F, which explains the PIFA name. The Planar Inverted-F Antenna is popular because it has a low profile and an omnidirectional pattern. The PIFA is shown from a side view in figure[3].

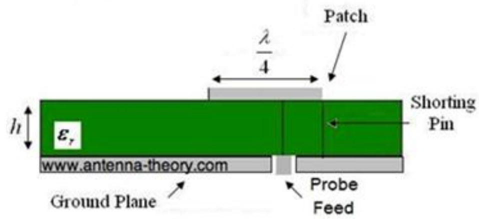


Fig 2. The Planar Inverted-F Antenna (PIFA).

C. FRACTAL

Fractal antennas are reliable and cost-effective. Fractal antennas allow for multiband capabilities, decreased size, and optimum smart antenna technology. Fractals have self similar shapes and space filling properties that can be subdivided into parts. This property makes the fractal antenna compact and operating in wideband frequencies..The presence of discontinuities in the geometry increases the bandwidth and radiation properties of antenna. It also has long electrical lengths that fit into a compact size. There are many mathematical structures that are fractals; e.g. Sierpinski's gasket, Minkowski ,Cantor's comb, von Koch's snowflake, the Mandelbrot set, the Lorenz attractor, etc.

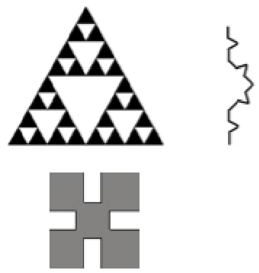


Fig 3. Sierpinski, Koch and Minkowski fractal structures.

II. Overview of Patch Antenna

In its most fundamental form, a Microstrip Patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure 2.1.

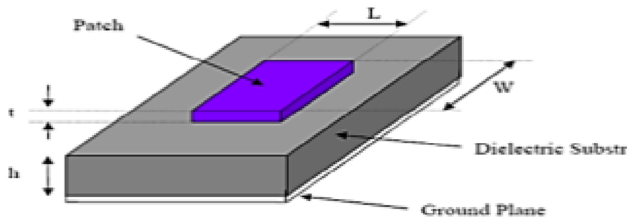


Figure 2.1: Patch Antenna Basics

The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common shape as shown in Figure. For a rectangular patch, the length L of the patch is usually $0.3333\lambda o < L < 0.5\lambda o$, where λo is the free-space wavelength. The patch is selected to be very thin such that $t \ll \lambda o$ (where t is the patch thickness). The height h of the dielectric substrate is usually $0.003\lambda o \leq h \leq 0.05\lambda o$. The dielectric constant of the substrate (εr) is typically in the range $2.2 \leq \varepsilon r \leq 12$.

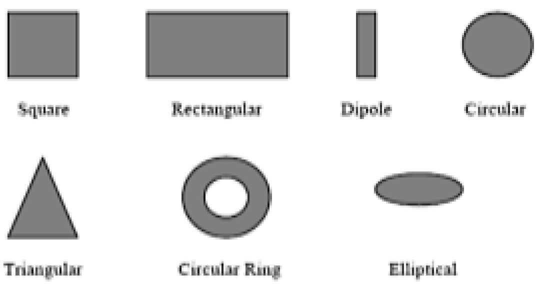


Figure 2.2 Types of Patch Antennas

Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation.

2.1.2. Feed Techniques

Microstrip patch antennas can be fed by a variety of methods[7]. These methods can be classified into two categories- contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch. The four most popular feed techniques used are the microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes).

A. Microstrip Line Feed

In this type of feed technique, a conducting strip is connected directly to the edge of the Microstrip patch as shown in Figure 2.3. The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure.

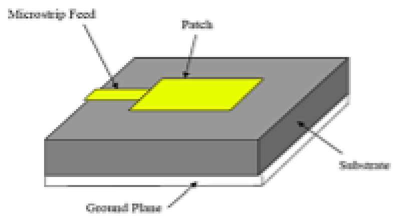


Figure 2.3 Microstrip Feed Line

The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element. This is achieved by properly controlling the inset position. Hence this is an easy feeding scheme, since it provides ease of fabrication and simplicity in modeling as well as impedance matching.

However as the thickness of the dielectric substrate being used, increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna. The feed radiation also leads to undesired cross polarized radiation.

B. Coaxial Feed

The Coaxial feed or probe feed is a very common technique used for feeding Microstrip patch antennas. As seen from Figure 2.4, the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane.

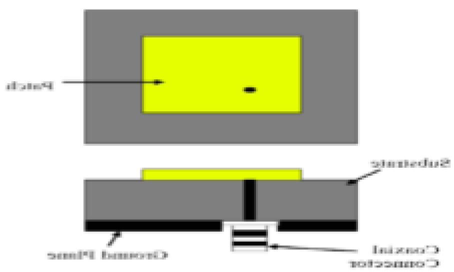


Figure 2.4 Co-axial Feed Line

The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance.

C. Aperture Coupled Feed

In this type of feed technique, the radiating patch and the microstrip feed line are separated by the ground plane as shown in Figure. Coupling be-tween the patch and the feed line is made through a slot or an aperture in the ground plane.

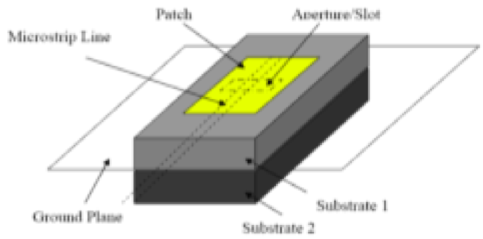
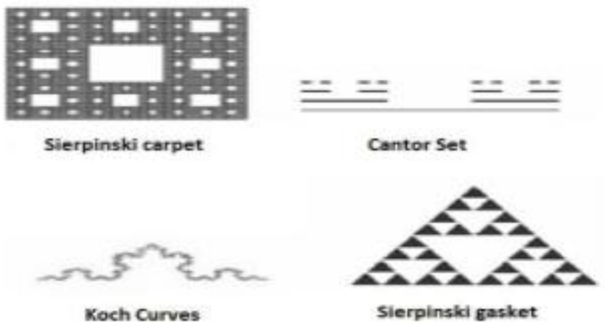


Figure 2.5 Aperture Couple Feed

The coupling aperture is usually centered under the patch, leading to lower cross-polarization due to symmetry of the configuration. The amount of coupling from the feed line to the patch is determined by the shape, size and location of the aperture. Since the ground plane separates the patch and the feed line, spurious radiation is minimized. Generally, a high dielectric material is used for bottom substrate and a thick, low dielectric constant material is used for the top substrate to optimize radiation from the patch. The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness. This feeding scheme also provides narrow bandwidth.



D. Sierpinski Gasket Geometry

Sierpinski gasket geometry [4]is the most widely studied fractal geometry for antenna applications. The steps for constructing this fractal are described.1st a triangle is taken in a plane. Then in next step a central triangle is removed with vertices that are located at the midpoint of the sides of the triangle as shown in the figure. The process is then repeated for remaining triangles as shown in figure. The Sierpinski gasket fractal is formed by doing this iterative process infinite number of times. Black triangular areas represent a metallic conductor and the white triangular areas represent the region from where metals are removed.

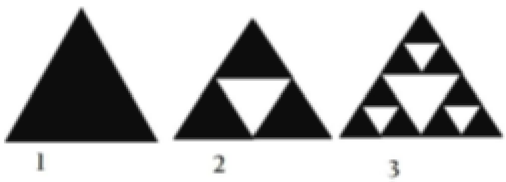


Figure 2.7: Steps of construction for Gasket geometry

E. Sierpinski Carpet

The Sierpinski carpet [4] is constructed similar to the Sierpinski gasket, but it use squares instead of triangles. 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.

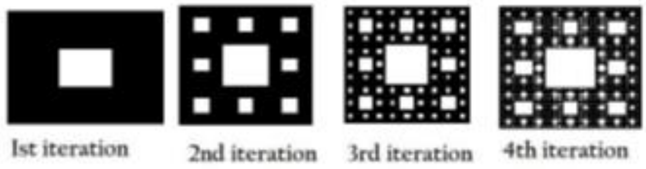


Figure 2.8: Steps of Iteration to get Carpet geometry

F. Koch Curves

The geometric construction of the standard Koch curve is fairly 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.

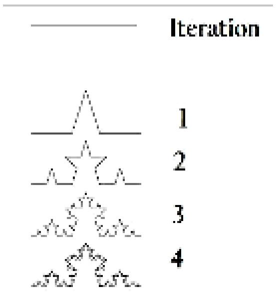


Figure 2.9: Steps of construction for Koch curve geometry

The Cantor Set Geometry

The Cantor Set is created by the following algorithm. It starts with the closed interval.

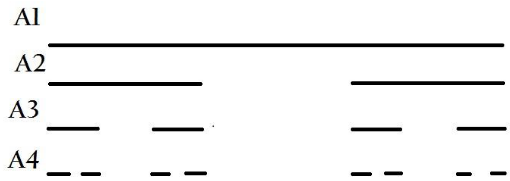


Figure 2.10: Steps for the Cantor Set geometry

Say it as set A1 or the 0th (initial) set. Delete the middle open third. This leaves a new set, called A2 .Each iteration through the algorithm removes the open middle third from each segment of the previous iteration. Thus, the next two sets would be A3 and according to the previous one A4 set will be A4. We can see that the set becomes sparser as the number of iteration increases. The Cantor Set is defined to be the set of the points that remain as the number of iterations tends to infinity.

2.1.4 Planar Inverted F Antenna

Basically, a PIFA can be considered as a modification of a monopole or a microstrip patch antenna, as shown in Figure 4.8[15]. Figure 4.8(a) shows the development of a thin-wire monopole into a low profile PIFA. More directly, a PIFA can originate from a planar monopole by bending the planar radiator for a low profile and introducing a shorting pin for good impedance matching, as shown in (b). Alternatively, the PIFA can be a variation of a shorted patch antenna, where the radiating patch of the antenna is halved at its midline by a short-circuiting wall. If the width of the shorting wall is further reduced to a narrow shorting strip, the PIFA is formed, as in (c). Therefore, the PIFA can be regarded asthe variation of either a thin-wire transmission-line ILA or a short-circuit microstrip patch antenna.

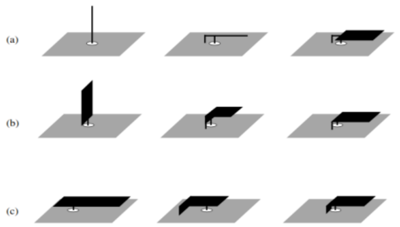


Figure 2.11: Development of PIFA from monopole, planar monopole and microstrip patch antennas.

Figure below shows a typical PIFA above a finite ground plane. The performance of thisPIFA can be expressed in terms of the following parameters:

- The geometric shape of the radiating plate – L W
- The height of the radiating plate – H
- The size and shape of the ground plane – L
- The location and structure of the feeding stem
- The location and size of the shorting strip – H wgWg
- The material used to support or load the radiating plate, if any
- Lump loading (such as an LCR) or a distributed loading (such as a slot or a notch at the radiating plate, if any)

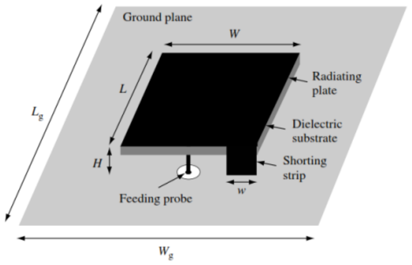


Fig PIFA antenna

I, Equations

$$f = \frac{1}{4}\left(\frac{c}{L_1 + L_2}\right)$$

where,

$$c = \text{free space velocity of light,}$$
$$f = \text{frequency of operation}$$
$$(L_1 + L_2) = x \qquad x = \text{total length}$$
$$x = \frac{c}{4f}$$

III. SIMULATIVE RESULTS OF MONOPOLE, PIFA AND FRACTAL ANTENNA

Monopole, PIFA and Fractal structures are simulated using HFSS(High frequency structure simulator) software. The antenna structures are designed and simulated using FR4 substrate. The relative permittivity and loss tangent thickness of 1.59 mm thick substrate are 4.4 and 0.02 respectively. The structure is fabricated on the one side of the substrate and ground is on the other side of the substrate. The antenna is fed through a 50 F probe feed at the centre of a 50 F microstrip line. Simulated structures are given in figures below.

Monopole antenna has a substrate dimension of 150x105mm2 and microstrip line of width 3 mm and a length of 4 mm.

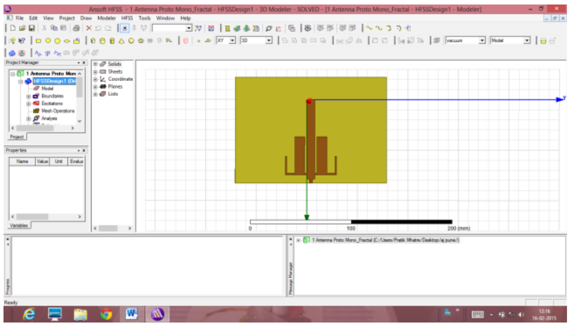


Fig 4.Implemented Monopole structure.

Monopole is resonating in dual band i.e at 2GHz & 3.25GHz frequency.

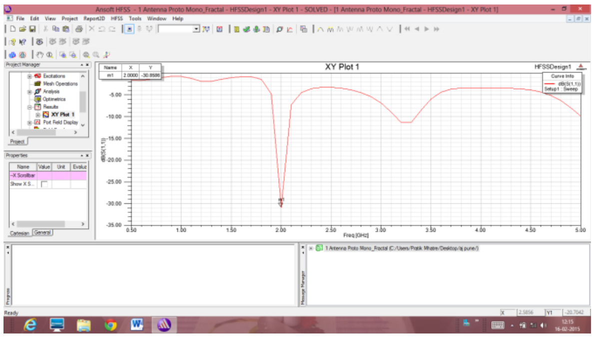


Fig 5. Monopole antenna's Rectangular plot.

PIFA's patch dimension is 15.3x15.3mm and shoting pin of 1mm.

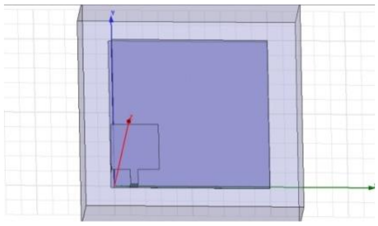


Fig 6. Implemented PIFA antenna

PIFA is resonating in dual band i.e in 2.2GHz & 8GHz frequency.

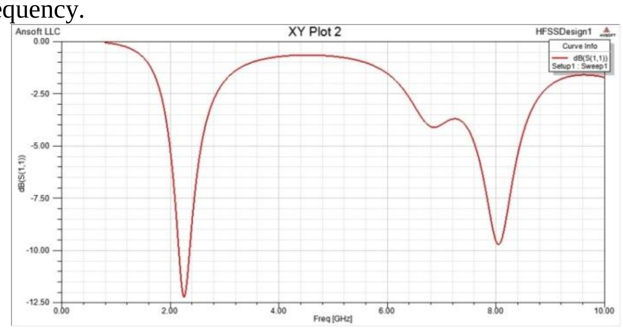


Fig 7. PIFA and its Rectangular plot.

Minkowski Fractal antenna has substrate dimension of 50x50mm, Gnd dimension of 50x9mm and patch of 39x28mm.

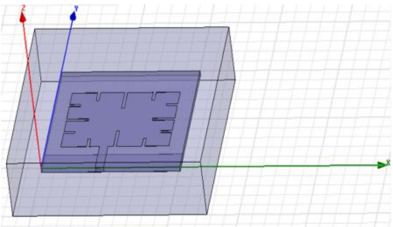


Fig 8.Minkowski fractal antenna.

Minkowski fractal resonate in dual band i.e at 2.2GH & 8.2GHz.

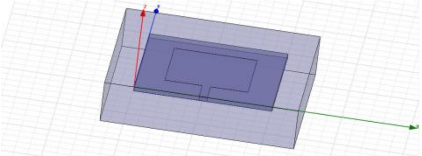


Fig 9 :-Implement Normal Patch antenna

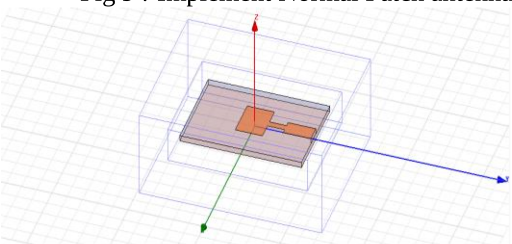


Fig 10- Implement PIFA antenna

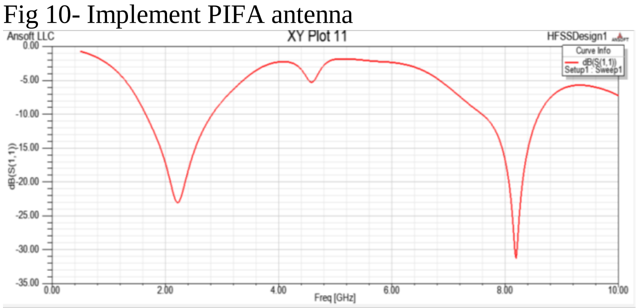


Fig 11 PIFA antenna's plot.

III Table

Parameter	***Monopole***	***PIFA***	***Fractal***
Size	Large	Small	Medium
Height	Medium	Medium	Small
Radiation	Multiband	UWBl	Multiband
Bandwidth	Small	Large	Wide

Table 1. Comparison between Monopole, PIFA and Fractal

IV. Acknowledgements

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