WIDE BAND FRACTAL ANTENNA WITH INSET FEED ON EBG GP

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ABSTRACT

In this paper, design of a microstrip Fractal antenna with inset feed, for wide band frequency operation is presented. The proposed antenna is excited by a inset feed connected to one side of the fractal antenna. The inset feed strip length and width is modified to obtain the best possible match with the antenna input impedance and to give better radiation properties due to optimized feed strip length. It is demonstrated that with the modified feed strip length, better radiation characteristics can be obtained at the band of frequencies. Iteration of Koch dimensions decides the resonant frequency band values. As the iteration level increases resonance frequency shifts towards lower values. Here a electromagnetic band gap ground plane is used to enhance the band of operation and also improved radiation characteristics i.e. return loss gain directivity etc.

Keywords: Inset feed, Fractal, Koch, EBG

I. INTRODUCTION

Microstrip antennas are versatile candidates for the modern wireless applications because of their numerous advantages [5, 6]. Microstrip patch fractal antennas have been rapidly developed for multi-band and broad band in high data rate systems known as wideband communication systems. The use of microstrip fractal geometry antennas in electromagnetic radiations has been a recent topic of interest in the world. It has been shown that fractal shaped antennas exhibit features that are directly associated with the geometric properties of fractals. One property associated with fractal geometry that is used in the design of super special antennas is self-similarity, which means that some of their parts have the same shape as the whole object but at a different scale [10]. In this work, a design of fractal that uses single layer on dielectric substrate with electromagnetic ground plane and single inset feed which offers a wide band frequency operation is proposed.

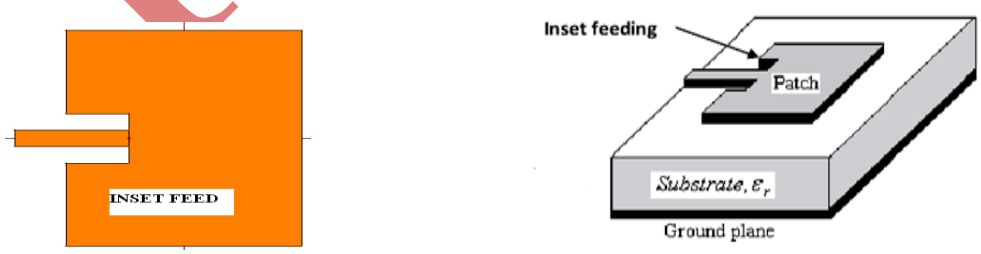
II. FRACTAL GEOMETRY

Fractals are not just complex shapes and pretty pictures generated by computers. Anything that appears random and irregular can be a fractal. Fractals permeate our lives, appearing in places as tiny as the membrane of a cell and as majestic as the solar system. Fractals are the unique, irregular patterns left behind by the unpredictable movements

of the chaotic world at work [8]. A wide variety of applications of fractals can be found in many branches of science and engineering. One such area is fractal electrodynamics. Fractal geometry can be combined with the electromagnetic theory for the purpose of investigating a new class of radiation, propagation and scattering problems. Small antennas are of prime importance because of the available space limitation on devices and the oncoming deployment of diversity and multi-input multi- output (MIMO) systems. The basic antenna miniaturization techniques can be summarized into lumped-element loading, material loading, and use of ground planes, short circuits, the antenna environment and finally the antenna geometry. Fractal geometry provides the solution by designing compact and wideband antennas in a most efficient and sophisticated way [12]. In the miniaturization of wire antennas it has been found that the electromagnetic coupling between wire angles limits the reduction of the resonant frequency with increasing wire length [10].

III. KOCH FRACTAL ANTENNAS OPTIMIZATION WITH INSET FEED

For a rectangular patch, the length L of the patch is usually 0.333 λo , where λo is the free space wavelength. The patch is selected to be very thin, such that the height of the substrate $h << \lambda o$ [3]. Thus, a rectangular patch of dimensions 29.09 × 37.23 mm is positioned on one side of an FR-4 substrate of thickness 1.5 mm, and the ground plane with dimension of 42 × 47 mm is located on the other side of the substrate with electromagnetic band gap structure [2]. There are three essential parameters for the design of an inset fed rectangular patch antenna. They are resonant frequency (f_r), dielectric material of the substrate (ε_r), and the thickness of the substrate. The resonant frequency selected for this design is 2.45 GHz. The dielectric material of the substrate selected for this design is FR-4, which has a dielectric constant of the 4.4 and a loss tangent equal to 0.018. The dielectric constant of the substrate material is an important design parameter. A low dielectric constant of the substrate material is used in the prototype design because it gives better efficiency, a higher bandwidth, and a low quality factor Q. The low value of the dielectric constant increases the radiated power [3]. The design has a patch size independent of the dielectric constant. Therefore, the reduction in the patch size is accomplished by using a higher dielectric constant and FR-4 is good in this agreement. The thickness of the substrate is another important design parameter. The thickness of the substrate increases the fringing field at the patch periphery like the low dielectric constant and increases the radiated power. The height of the dielectric substrate of the inset microstrip patch antenna is h = 1.5 mm.



(a) Top view **(b) Front view**

Fig 1: Inset Feeding Technique

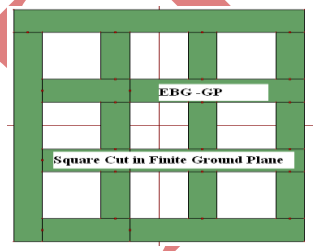
The inset feed introduces a physical notch, which in turn introduces a junction capacitance. The physical notch and its corresponding junction capacitance influence the resonance frequency. As the inset feed-point moves from the edge toward the center of the patch, the resonant input impedance decreases monotonically and reaches zero at the center [15]. When the value of the inset feed point approaches the center of the patch, $\cos^2 (\pi y_0/L)$ where y0 is the inset distance, which varies very rapidly; therefore, the input resistance also changes rapidly with the position of the feed point [3]. In this paper, the value of the inset-fed distance y_0 is 7.8 mm and the length and width of the transmission line at 50 Ω are 14.175 mm and 2.84 mm, respectively. The input resistance for the inset-feed is given approximately by :

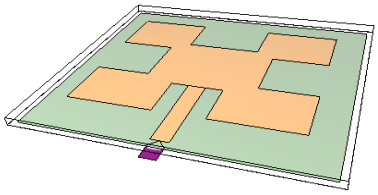
$$R(y = y_0) = R\,(y = 0)\,\cos^2 (\pi y_0/L)$$

Using the above formulas, calculated values of width and length of rectangular microstrip patch for FR4 substrate of dielectric constant 4.4 is optimized and then designed in IE3D simulator.

IV. BASIC ANTENNA GEOMETRY AND ITS WORKING

It should be noted though applying fractal geometry to reduce the size of the wire antenna a reduction in resonant frequency is obtained. The effect can be explained with the help of Koch fractal curve to understand the behavior of the resonant frequency of fractal antennas as a function of the antenna geometry and wire length. It has been found that with increase in number of iterations, n, the effective length increases by a factor of $(4 / 3)^n$. Thus with an increase of the wire length of a Koch fractal there is a decrease in the resonant frequency. The Koch curve has been used to construct a monopole and a dipole in order to reduce antenna size. The miniaturization of the antennas shows a greater degree of effectiveness for the first several iterations [1]. From the properties of the Koch fractal monopole it was shown that the electrical performance of Koch fractal monopoles is superior to that of conventional straight wire monopoles, especially when operated in the small-antenna frequency regime [10]. The basic geometry of the antenna with a inset feed strip is shown in Figure 1. The radiating square koch along with the inset feed strip is located on the same substrate.



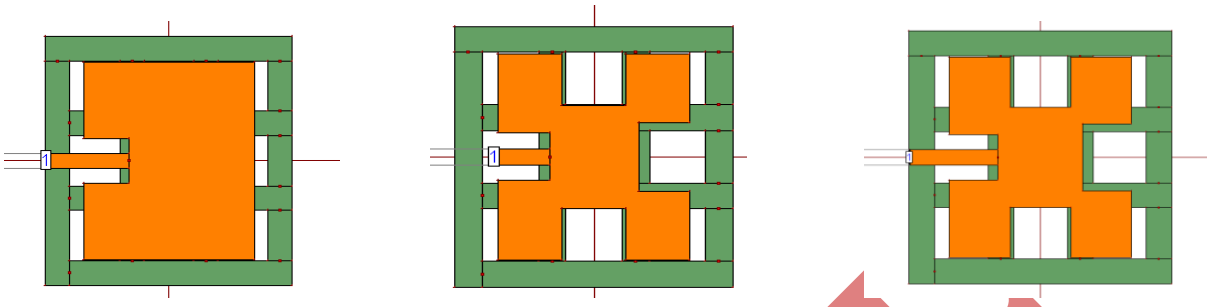


(a) **Top view** **(b) Front view**

Fig 2: (a) EBG ground plane, (b) Proposed antenna geometry on finite plane

The EBG ground plane of the antenna is used to enhance its bandwidth when compare to the same structure with a typical ground plane. Unlike normal conductor ground plane, EBG structure does not conduct AC currents within a

forbidden frequency band, and is characterized by its high surface impedance, which does not support propagation of surface wave [7].



(a) S0: Square Patch **(b) P1: Koch Fractal** **(c) G2: Proposed Antenna**

Fig 3: Antenna's basic geometry without fractal and with fractal

This type of metallic electromagnetic structure has attracted considerable attention in improving antennas performances, such as radiation patterns improvement, bandwidth and gain enhancement, and mutual coupling reduction between radiating. EBGs make possible to intensively suppress surface waves [13].

V. EXPERIMENTAL RESULTS AND DISCUSSIONS

Design procedure and simulation of the proposed antenna is carried out by IE3D, which is method of moment based tool. The proposed antenna is optimized in the length and the width of the inset feed line. As shown in Table 1 the proposed antenna geometry G2 has inset feed line length 14.175 mm and width is 2.84 mm which has improved return loss (as shown in fig) as well as the gain (as shown in fig). The Table 2 shows all the results of the proposed antenna with and without electromagnetic band gap ground plane. As we can clearly see that either without EBG-GP the proposed geometry has better return loss (-21.09 dB) and gain 2.28 dB. These results are further improved using EBG-GP. The quasi Koch structure improves the radiation characteristics of the antenna.

Antenna Parameter	P1(mm)	G1(mm)	G2(mm)	G3(mm)
Length of 50 feed line	8.38	14.125	14.125	14.125
Width of 50 feed line	2.84	2.87	2.84	2.89
Length of Inset feed	7.84	7.84	7.80	7.84
Patch Length	29.09	29.09	29.09	29.09
Patch Width	37.23	37.23	37.23	37.23

Table1

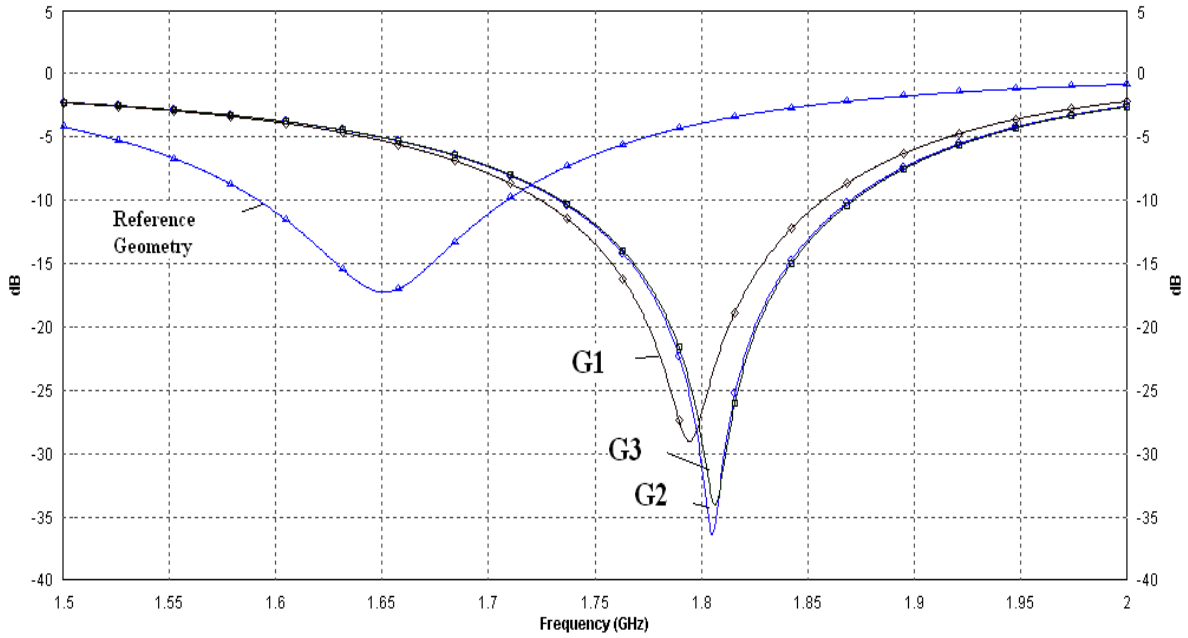


Fig 4: Comparison of Return Loss of different geometries

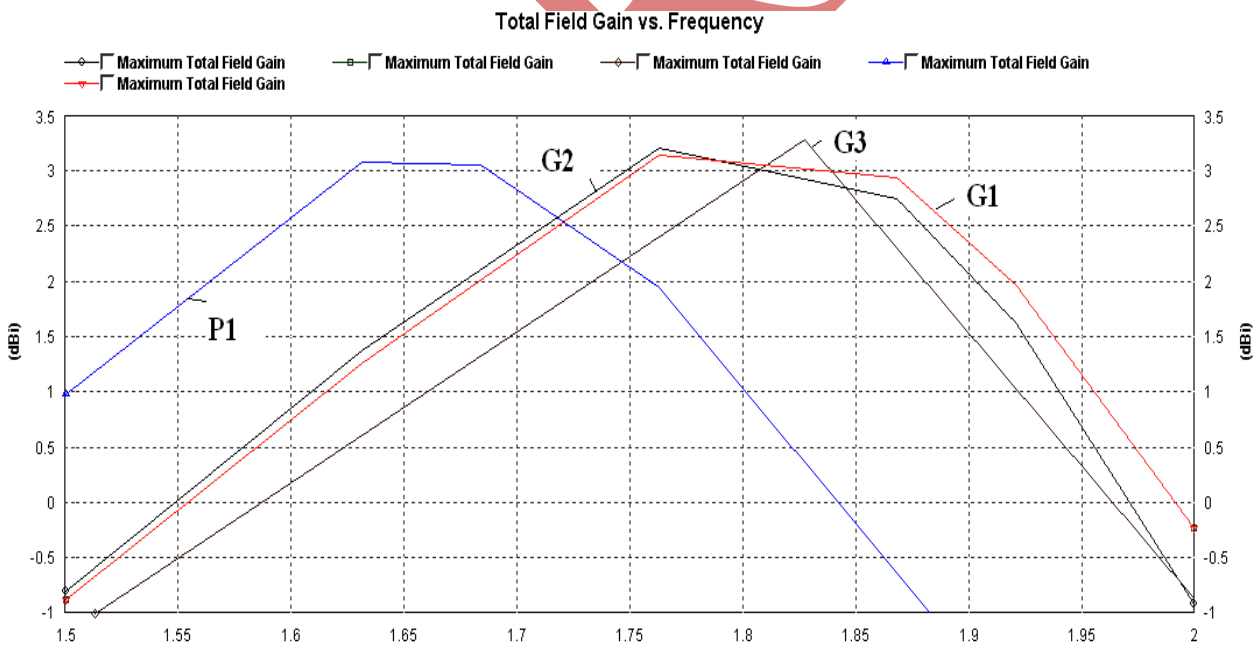
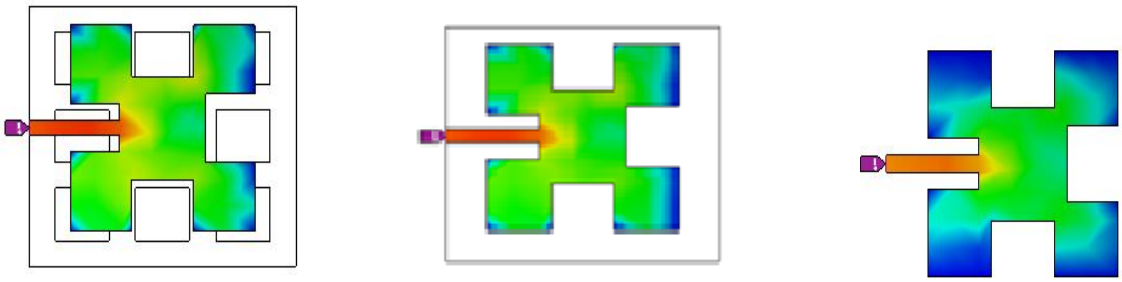


Fig 5: Comparison of Gain of different geometries



(a) (b) (c)

Fig 6: (a) Proposed geometry on EBG-GP (b) Proposed geometry on finite plane (c) Proposed geometry on infinite ground plane

	Without EBG						With EBG					
Patch	**Fr (GHz)**	**BW**	**Return Loss**	**Gain dBi**	**Directivity**	**Efficiency**	**Fr (GHz)**	**BW**	**Return Loss**	**Gain dBi**	**Directivity**	**Efficiency**
P1	**2.426**	**0.27**	**-12.77**	**1.56**	**6.36**	**59.92**	**1.6**	**0.853**	**-17.4**	**2.123**	**3.3**	**78.28**
G2	**1.72**	**0.018**	**-21.09**	**2.8**	**3.27**	**63.5**	**1.8**	**0.135**	**-34.55**	**3.289**	**3.33**	**94.45**

Table 2

VI. CONCLUSIONS

The antenna is simulated on a FR4 substrate. The performance characteristics of the proposed antenna is analyzed on the simulating tool IE3D. An EBG-GP was used in P1 (Square Koch fractal of the first level) antenna to reduce the resonant frequency and, consequently its dimensions and to improve the bandwidth when compare to a typical P1 Antenna geometry with infinite ground plane and also finite ground plane. The antenna has a BW greater than 80% compared to same antenna without EBG in the ground plane. The length of the inset feed is optimized in the proposed geometry G2 for better resonance frequency as well as return loss and the gain as well. The relevant antenna performance parameters such as return loss, radiation efficiency, bandwidth and gain of the proposed design, are reported and discussed. The antenna is compact, simple to design and easy to fabricate and applicable in multi communication systems viz. military telemetry, GPS, mobile phones (GSM), amateur radio.

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