BROADBAND CONCENTRIC RINGS FRACTAL SLOT ANTENNA

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Abstract: A microstrip fed dual band printed hybrid antenna consisting of an annular slot ring and an inner fractal slot ring placed concentrically with the outer one is proposed. The inner slot ring is in the form of a 2nd order fractal of dimension 1.2619 ring evolved form an equilateral triangle. Perimeters of both the rings are kept nearly equal to make them to resonate closely. Impedance bandwidths for input reflection coefficient of -10 dB are 27% and 11% are achieved at center frequencies of 2.15 GHz and 4.25 GHz respectively. A reasonable match between experimental and simulated results is observed.

INTRODUCTION

Fractals have been applied successfully for miniaturization and multi-band operation of simple antennas mainly dipole, loops and patch antennas. It has been observed that such an approach results in reduction of the input impedance bandwidth [1, 2]. Concentric annular ring slot antennas with narrow slots possess multi-band at distinctly far frequencies due to large differences in their radii and posses fractional bandwidths of the order of less than 10% [3]. Further, the dimensions of annular slot rings, for close resonance frequencies, become indistinguishable and the inner ring gets merged with the outer rings and it becomes difficult to maintain the spacing between inner and outer ring. In this paper, it is shown that with the help of fractals it is possible to enhance the operational bandwidth while multi-band characteristic is preserved which is otherwise not observed with two annular ring slot antennas having narrow slot width. The inner ring is constructed in the form of a Koch curve which makes it possible to resonate at a frequency close to that of the outer ring and by providing suitable coupling between the two rings, broader input impedance bandwidth can be achieved. The resulting hybrid antenna structure consists of a Euclidian ring as well as a fractal ring. The proposed work is to demonstrate the concept of fusion of fractal techniques along-with the conventional antenna structures.

CONSTRUCTION

The proposed concept is demonstrated with the help of an outer slot ring of mean diameter 43 mm having 1 mm slot width and an inner fractal ring having perimeter of length 84 mm and slot width of 0.6 mm. Both the slot rings are etched out in the ground plane of dielectric substrate having a dielectric constant of 2.2 and thickness of 1.58 mm. The inner fractal slot ring of growth order N=2 was evolved from its generator (called 0^{th} order stage), which is an equilateral triangle of side length 28 mm. Affine transformations (scaling S, translation T and rotation θ) are applied to the generator stage to evolve higher order fractal stages [4]. The middle one third of each side of the triangle was removed and replaced with two shifted and rotated copies of itself with 60^o angle of rotation. The concept of fractal growth is depicted in Fig. 1 for one side of the equilateral triangle. The fractal dimension of each side is 1.2619 [4]. The same process is applied to all the three sides of the triangle. Thus, each side of the triangle resembles a Koch curve of order N=2. Both the rings are placed concentrically and fed by a microstrip.

The inner fractal ring (of growth order N=2) appears smaller in size compared to its Euclidian counterpart (i.e. outer slot ring) but its fundamental resonance frequency is 2 GHz while that of the outer slot ring is 2.2 GHz. This shows how fractals can be used to make smaller structures resonate closer to physically larger structures. Coupling between the two rings has been realized with the help of straight slots symmetrically placed at several places. The location and the orientation of these coupling slots greatly influence the input performance of the antenna. The complete layout of the proposed antenna is shown in Fig. 2. The proposed slot structure is etched out on the ground plane of a low loss substrate of size 85mm×60mm, 1.58 mm thickness and dielectric constant of 2.2. The tail end of the feed extending beyond the fed point acts as stub to match the antenna. The optimum length, ℓ_s, of stub tail is 4.25 mm from the inner slot ring. Dimensions of the tapered section and straight slots are shown in Fig. 2. Grayed parts in Fig.2 are metallic layers while darken ones are the slots etched out in the ground plane of the substrate.

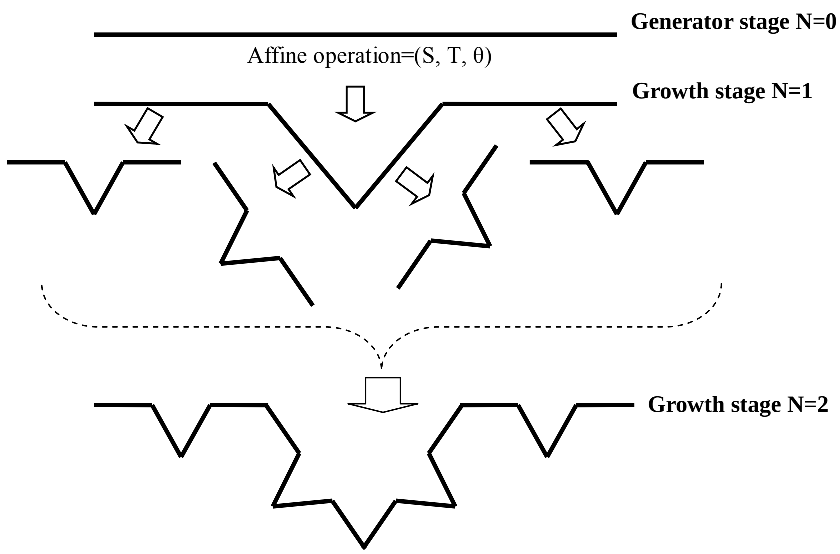


Fig. 1: Growth stages of a Koch curve

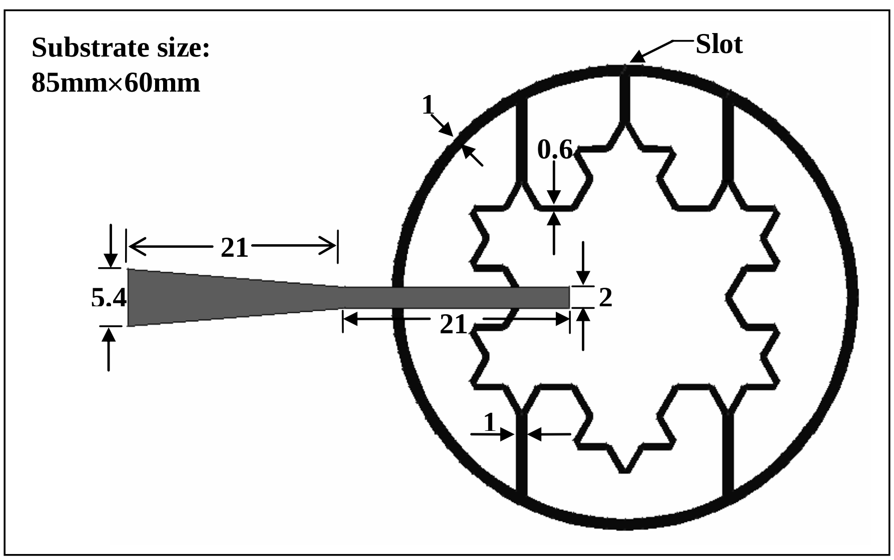
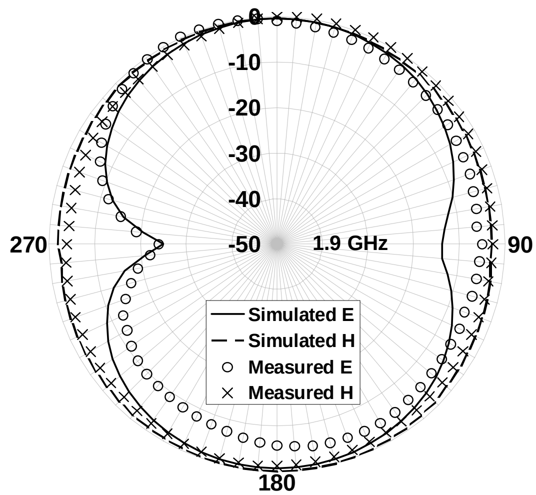


Fig.2: Layout of the proposed antenna. All dimensions are in mm. Grayed

SIMULATIONS AND MEASUREMENTS

The proposed structure was simulated using IE3D, a commercial EM simulator based on integral equation and Method of Moment [5], which solves for the magnetic current in the slot. The inbuilt optimizer based on genetic algorithm was used to get optimum dimensions of the stub and tapered section. The comparison of simulated and measured input reflection coefficient is shown in Fig. 3. A reasonable match between the simulation and measurements is seen. The prominent dip at 2.925 GHz in measured data can be avoided by slight adjustment in stub length and tapered section but it that will cause S_{11} of the first to go higher to -10 dB while that of second band comes down to -15 dB. Measurements up to 3 GHz only are shown and beyond 3 GHz these are expected to be similar to the simulated results.



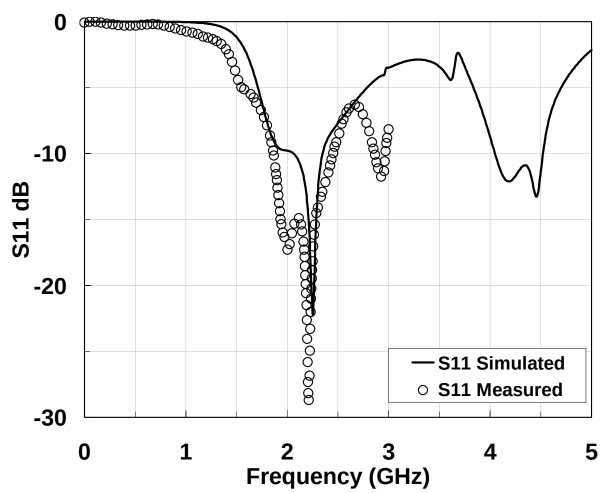
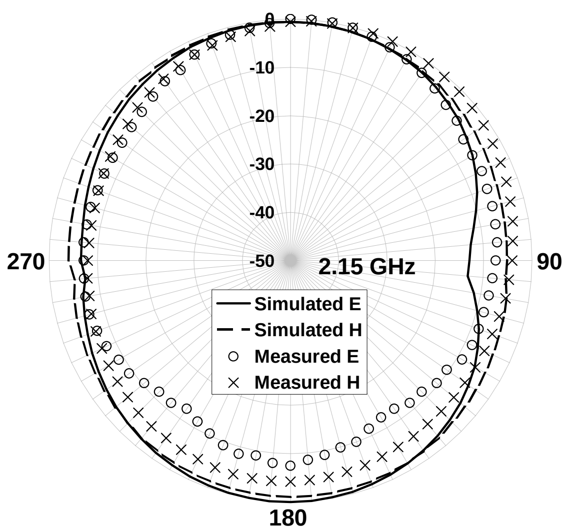


Fig.3: Simulated and measured input reflection coefficient

Fig.4(a): Simulated and measured Electric (E) and Magnetic filed (H) patterns at 1.9 GHz.



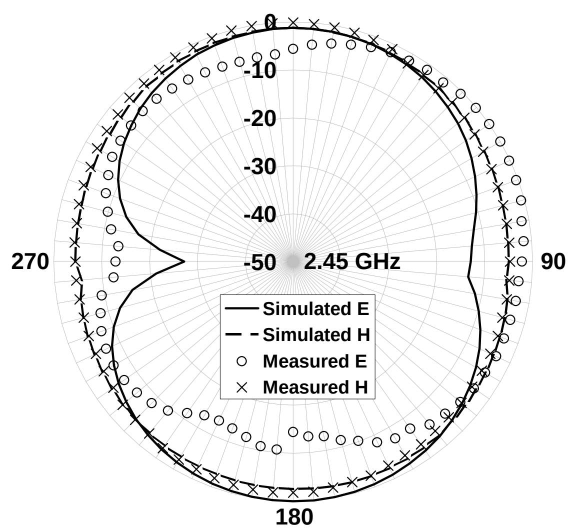


Fig. 4(b): Electric (E) and Magnetic filed (H) patterns at 2.15 GHz

Fig. 4(b): Electric (E) and Magnetic filed (H) patterns at 2.45 GHz.

Comparisons of simulated and measured radiation patterns in two principal planes at frequencies 1.9 GHz, 2.15 GHz and 2.45 GHz for first band and 4 GHz, 4.25 GHz and 4.5 GHz for the second band are shown in Fig. 4(a)-(c) and 5(a)-(c) respectively. The measured data matches reasonably with simulated radiation patterns.

RESULTS AND DISCUSSION

A conventional ring slot antenna of mean diameter of 43 mm and 1 mm slot width resonates at a frequency of 1.53 GHz with 4.5% fractional bandwidth (FBW) while the FBW obtained with the proposed antenna is 27% with the center frequency 2.15 GHz for the first band of operation and nearly 11% 4.25 GHz center frequency. Deviations in measured simulated radiation patterns are due to the fact that measurements were performed in an anechoic chamber which had an opening on one side. Another reason for deviations might be due to the fact that IE3D performs simulations for slot antenna with the assumption of an infinite ground plane.

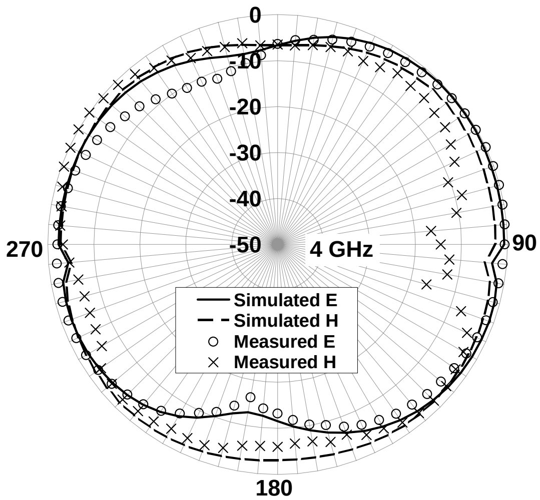


Fig. 4(b): Electric (E) and Magnetic filed (H) patterns at 4 GHz

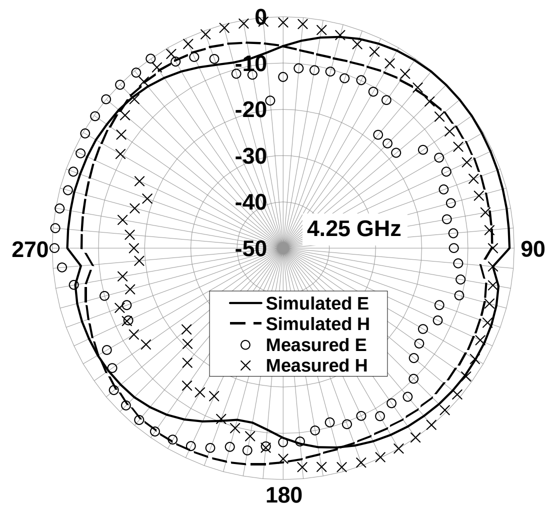


Fig. 4(b): Electric (E) and Magnetic filed (H) patterns at 4.25 GHz.

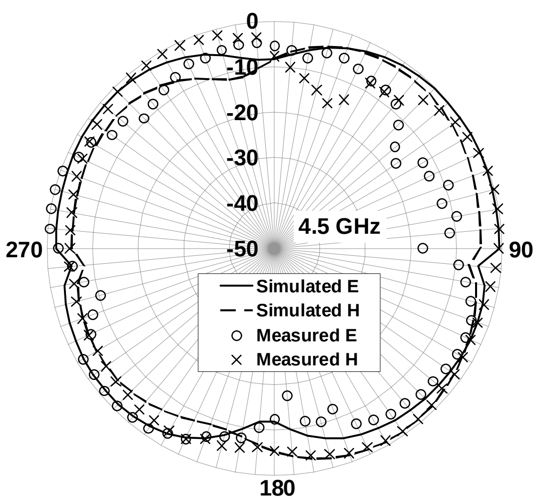


Fig. 4(b): Electric (E) and Magnetic filed (H) patterns at 4 GHz

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