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RESEARCH PAPER

Design analysis and fabrication of novel coplanar waveguide -fed hybrid fractal-based Broadband antenna

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In this paper, a new compact hybrid fractal antenna with ultrawideband (UWB) behavior is proposed. Two merged fractals shapes, i.e. Sierpinski carpet and Sierpinski Gasket fed with coplanar waveguide (CPW) feed make patch as multiband and broadband antenna. The antenna is optimized using particle swarm optimization for side length of Sierpenski Gasket fractal and bandwidth. The overall width of the patch is taken as a parameter for optimizing bandwidth. The total size of presented antenna is 59×29 mm². The antenna resonates at 2–5.2 GHz, so that wideband operation is observed. Antenna with this type of characteristics can be used when UWB response at lower frequencies is required. Sierpenski Gasket performs two functions in the proposed design, i.e. to radiate as well as impedance transformer to Sierpenski carpet. The proposed design presents novelty in design to achieve proper impedance matching to edge of Sierpenski carpet design with CPW feed by making Sierpenski Gasket as impedance transformer.

Keywords: Antennas and Propagation for Wireless Systems, Applications and Standards (Mobile, Wireless, networks)

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I. INTRODUCTION

Nowadays multimedia applications are extended from narrow bandwidth audio application to wide bandwidth application such as video conferencing, online gaming, streaming videos, high-speed data transfer etc. In recent years, next generation wireless devices have been introduced, which support the multimedia applications given above in single device only. As devices are being miniaturized day by day it drives demand for small size of devices. Antenna is said to be a bottleneck in reduction of size and data rate enhancement of these devices. Antenna is a frequency-dependent device because its length is defined in wavelength. Antenna of specific length resonates at specific frequency. Hence, reducing size of the antenna is challenged if the frequency is defined. Another requirement in antenna design is to improve data rates in next generation wireless devices which require large bandwidth support of antenna. Furthermore, nowadays, single wireless devices include more than one technology, for example, cellphone mobiles in use nowadays contain different technologies such as GSM/CDMA, WiFi, WiMAX, Bluetooth, etc. in single device and drives the antenna's ability to operate on multibands. Hence, the major requirements of antennas are broadband and multiband designs to support multimedia applications as well as to support different technologies in a single device.

Microstrip patch antenna was introduced as planar antenna as alternate to high-profile wire antennas that were difficult to mount on any dynamic and moving surfaces as air pressure, etc. can affect reliability of wire antennas. However, microstrip antennas suffer from narrow bandwidth which is again problematic to support high-speed media applications as data rates are directly proportional to bandwidth. In the literature on Wire antennas, Rumsey's principle claims that frequency independence of antenna can be achieved by making dimensions of antenna dependent on angle. There are large numbers of shapes that are proposed in the literature that are following Rumsey's Principle hence Frequency independence. Examples of these types of shapes in Wire antennas are Log Periodic, Biconical Antenna, etc while in context of Planar antennas Fractal shapes are said to be satisfying Rumsey's Principle.

Fractal shapes were introduced to achieve multiband as well as broadband operation. There are large numbers of Fractal shapes that are proposed in the literature such as Sierpenski carpet, Sierpenski Gasket, Koch Monopole, Parany, etc. [1, 2]. In the literature, a large number of designs and analysis are present for Sierpenski Gasket fractals and its variant [3]. Modification in design of Sierpenski Gasket allows uniform current density over metallic patch, which improves radiation property of antenna [4, 5].

II. PROPOSED DESIGN

In this paper, hybrid fractal shape is introduced to achieve optimized broadband operation of antenna while maintaining

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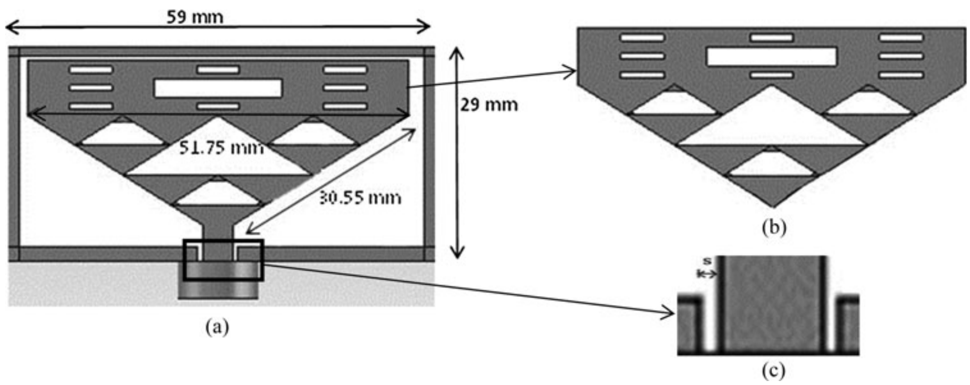

Fig. 1. Proposed antenna for UWB application: (a) front view of antenna, (b) patch of proposed antenna (c) feed for proposed antenna

radiation pattern to be good. Hybrid of Sierpenski Gasket and Sierpenski carpet is considered as patch of antenna. Sierpenski Gasket is used as radiating fractal-shaped patch as well as impedance transformer for Sierpenski carpet. Major problem faced by the Sierpenski carpet shape is its feed. As there is no close-loop expression to find edge impedance of Sierpenski carpet patches, hence, it is difficult to find the length and width of feed to match this type of patch efficiently. Also, edge impedance for Sierpenski carpet comes out to be quite high therefore while feeding it deteriorates radiation pattern.

Coplanar type of feed is used to feed the proposed antenna. Coplanar waveguide (CPW) feed enhances bandwidth further as well as is advantageous in ease of integration with PCB of receivers or transmitters. In the literature, researchers are using CPW feed extensively due to its advantage over other feeding techniques. In [5], Saluja and Khanna proposed design using CPW-fed antenna with unidirectional radiation. In [6], the author claims design of CPW-fed Microstrip antenna to radiate at triple band of frequencies. In [6], U slot and I notch with CPW feeding are used.

A novel design of Microstrip antenna is presented in this paper. Hybrid fractals are used to enhance bandwidth of Microstrip antenna by tuning both fractals to closely spaced resonances. By Rumsey's principle, fractal shapes can produce wide bandwidth if designed such that every fractal generates closely spaced resonance. In [7], Saikavara presents design of hybrid fractal arrays by combining fractal array by different generators for wide band operations but with a large size. In the proposed design, CPW feed is used to feed the hybrid fractal patch. The proposed design is optimized to work for improved ultrawideband (UWB) operation. Figure 1 shows the design of antenna with dimensions of proposed antenna.

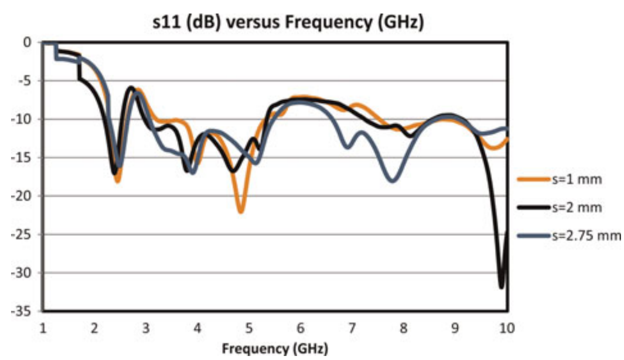

Fig. 2. Parameter s_{11} versus frequency for different values of spacing 's' between feed and ground plane.

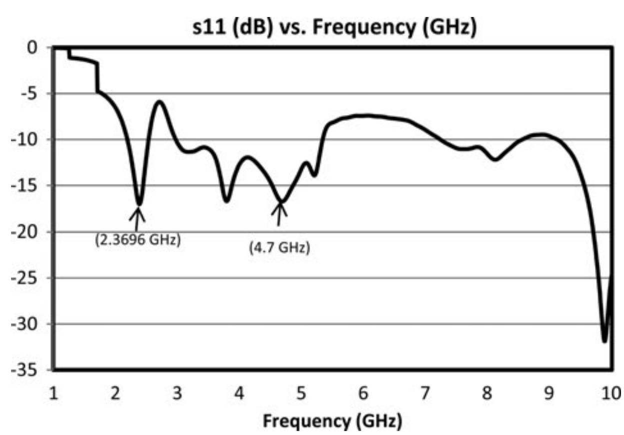

Fig. 3. Parameter s_{11} for proposed antenna at optimum value of spacing (s) = 2 mm.

III. RESULTS AND DISCUSSION

The proposed antenna is optimized with parameter's', i.e. spacing between feed and ground plane. The s_{11} graph for different values of 's' is shown in Fig. 2. Optimum value of '$s = 2$ mm' is selected and corresponding return loss is given in Fig. 3. As can be seen from Fig. 3 that antenna is properly matched in frequency range 2.1684 to 5.3287 GHz with notch at 2.74 GHz. It is evident from the literature that UWB support to antenna deteriorates gain performance of antenna. The proposed antenna presents good bandwidth gain product therefore that antenna performs well in terms of gain as well as bandwidth. In this novel design, Sierpenski Gasket is used as impedance transformer design to match feed with edge of Sierpenski carpet and also Sierpenski Gasket is radiating in close frequency bands to Sierpesnki Gasket bands. In Figs 4 and 5, current density at frequencies 2.38 and 4.925 GHz is shown, which depicts that at lower frequency, i.e. at GHz, larger part of patch is radiating. At higher frequencies, current density depicts that radiation is due to smaller slot of patch. Since both Sierpenski carpet

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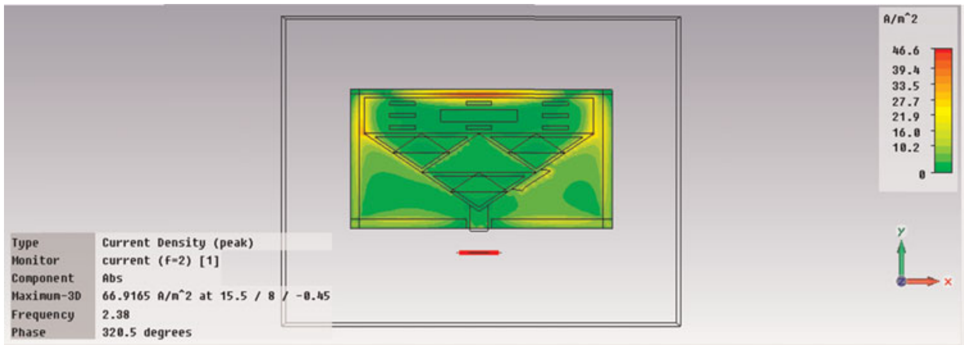

Fig. 4. Current density of proposed wideband antenna at $f = 2.38$ GHz.

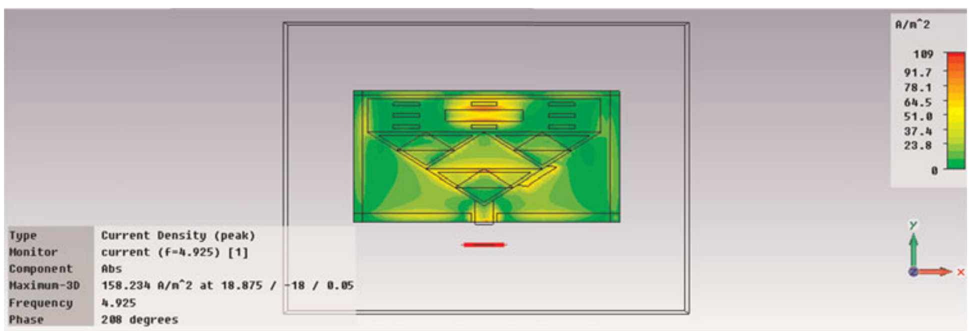

Fig. 5. Current density of proposed wideband antenna at $f = 4.925$ GHz.

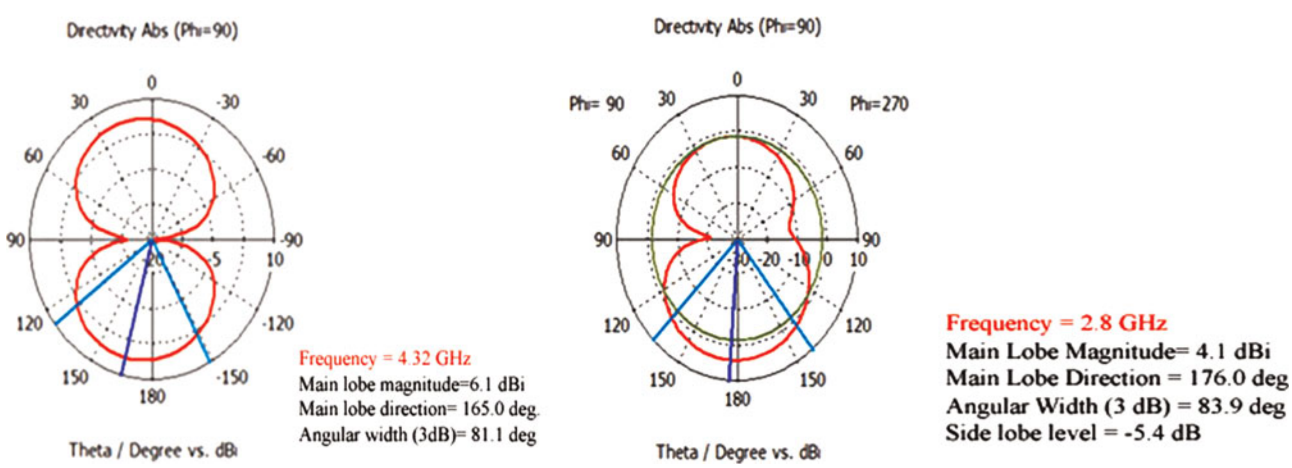

Fig. 6. Radiation pattern of the proposed antenna at 4.32 and 2.8 GHz.

and Sierpenski Gasket patches are resonating in close proximity in frequency results in merging of two bands, so that UWB is obtained while maintaining good gain bandwidth product (Fig. 6).

IV. CONCLUSION

A CPW-fed hybrid fractal-based antenna is considered for broadband applications. Two fractals are resonating in close proximity, therefore, overall broadband response of antenna is observed. The antenna works well in terms of s_{11} in ranges 2–5 GHz and 7–9 GHz. The proposed design shows good response in terms of gain as well. The antenna can be efficiently used for UWB applications as well as WiFi and WiMAX applications as the gain provided by the antenna is quite good. Hybrid fractal approach increases the bandwidth of the antenna. The Sierpenski carpet type of antenna suffers from edge impedance matching problem while feeding and non-uniform density over its surface. The proposed antenna design offers solution to both the problems by using hybrid fractal given in this paper. Sierpenski Gasket is used as impedance transformer to Sierpenski carpet type of antenna.

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