Compact Printed Quasi-Self Complementary Ultra Wideband (UWB) Antenna

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Abstract— In this paper, a compact ultra wideband antenna has been realized. The compact size stem from the usage of a quasi-self-complementary structure with triangular notch and stub in the ground plane. The quasi-self-complementary structure is constructed using fractal shape technique with a stepped feedline. The antenna has a small physical dimension of 25 x 16 mm^2 with a 10 dB return loss bandwidth from 2.7 to 11.3 GHz. The antenna is designed using FR-4 substrate with dielectric constant $\varepsilon_r = 4.5$. It has been found that the dielectric constant of the substrate material have the most sensitive impact on antenna performance. The antenna has an average gain of 2.2 dB and effieciency of 97%.The antenna is fabricated and tested where a good results is obtained.

Index Terms— UWB, SCA, SMA Connector, VNA, CST studio.

1. Introduction

Ultra wideband communication is an exciting technology which has become a very promising candidate for future short-range indoor high speed data communication [1-4].

In February 2002, FCC amended part 15 which covers unlicensed radio devices to include the operation of the UWB deices.

Ultra wideband technology is defined as a radio transmission technology that occupies a bandwidth over 500 MHz or a fractional bandwidth which has at least 20% of the centre frequency or the range from 3.1 to 10.6 GHz [5].

In this research, it is desirable for UWB antennas to cover a wide bandwidth spanning the entire range of 3.1 to 10.6 GHz to produce an omnidirectional radiation pattern and to have a compact size as well as simple configuration.

The advantages of ultra wideband antennas are [6-7]: Low cost, provides high secure and reliable communication solutions. According to Shannon-Hartley theorem, channel capacity is in proportion to bandwidth (it can achieve a capacity as hundreds of Mbps or Gbps with distance 1 to 10 meters).

In order to introduce an UWB antenna using Microstrip antennas, several techniques was introduced in literatures to enhance the microstrip antenna bandwidth, such as low substrate dielectric constant [8], application of slot antenna configurations [9], increasing the substrate height [10], application of special feeding systems [10], implementation of impedance matching techniques [11], use of parasitic elements [12], and employment of fractal geometries [12].

In this work, the concept of quasi-self complementary antenna with fractal geometries is chosen for our design in conjunction with implementing impedance matching technique to increase the antenna bandwidth.

The use of fractal geometries has impacted many areas of science and engineering; one of which is antennas. One of the methods for decreasing size and increasing bandwidth is the use of fractal geometries.

Fractals were first defined by Benoit Mandelbort in 1975 as a way of classifying structures whose dimensions were not whole numbers. Fractals are shapes or geometries that if you zoom in or zoom out, the structure is always the same. They are constructed through iterative mathematical rule but very complicated. There is some degree of self-similarity in fractals. Using self-similarity is to maximize the length of the material in a total surface area. This makes fractal antennas compact and wideband.

The fractal concept can be used to reduce antenna size, such as the Koch dipole, Koch monopole, Koch loop and Minkowski loop. Or, it can be used to achieve multiple bandwidth and to increase bandwidth of each single band due to the self-similrity in geometry such as Sierpiniski dipole, Cantor slot patch and fractal tree dipole [13].

Guo, et al. introduced a printed quasi-self-complementary antenna with dimensions of 40 x 51.5 mm^2 [14].

UWB microstrip antenna based on circular patch topology with both partial ground and stepped impedance is introduced [15]. The dimensions of this antenna is 31.7 x 40 mm^2 with a gain that varies from 1.4 to 3.6 dB from 3 to 8 GHz.

A small printed quasi-self-complementary ultra wideband antenna with size 25 x 16 mm^2 is introduced in [2]. The gain varies between 3.19 to 4.75 dBi at frequencies between 3 GHz to 9 GHz.

Nagalingam et al. [16] introduces a time domain analysis for a circular patch UWB antenna with dimensions of 34.2 x 34.2 mm^2 and average gain of 2 dB.

Jianxin Liang et al. [17] introduces a study of a printed circular disc monopole antenna with dimensions 50 x 42 mm^2. The gain ranges from 3.5 to 6.7 dBi.

Z.Ul Abedin et. al. [18], introduced a design of a microstrip patch antenna with high bandwidth and high gain for UWB and different Wireless Applications is introduced. The proposed antenna is designed using FR-4 substrate with dimensions of 40 x 43 mm^2.

This paper presents our study on a compact fractal shape printed quasi-self-complementary antenna fed by a microstrip line with SMA connector using FR-4 substrate. FR-4 is considered the best substrate due to its better utilization of bandwidth, resonant frequency and return loss. A triangular slot is notched on the ground plane in order to improve the impedance matching of the antenna. Furthermore, a partial ground technique is utilized in order to achieve good impedance matching characteristics. The proposed

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antenna dimensions are 25x16 mm^2 which is considered compact compared to those in literatures.

The self-complementary antenna (SCA), firstly proposed by Mushiake [19-22] has claimed a broad impedance bandwidth. Theoretically, a perfect self-complementary antenna possesses constant input impedance 188.5 Ω. However in practice, a self-complementary antenna has truncated on a finite plane, which limits its bandwidth. Furthermore, an impedance matching circuit is required to transform 188.5 Ω to 50 Ω.

2. ULTRA WIDEBAND ANTENNA

The compact quasi-self-complementary antenna is fed by a microstrip stepped feedline using the fractal shape technique. The antenna is fabricated on FR-4 substrate with thickness of h=1.6 mm and relative permittivity of $\varepsilon_r = 4.5$. The total size of the antenna is 25x16 mm^2. Figure (1) shows the geometry of the proposed quasi-self-complementary compact antenna using fractal shape technique. A triangular slot is cut on the ground plane in order to improve the impedance matching of the antenna [2]. There is a partial ground, a stub and two slits at the back of the self-complementary compact antenna.

3. RESULTS AND DISCUSSION

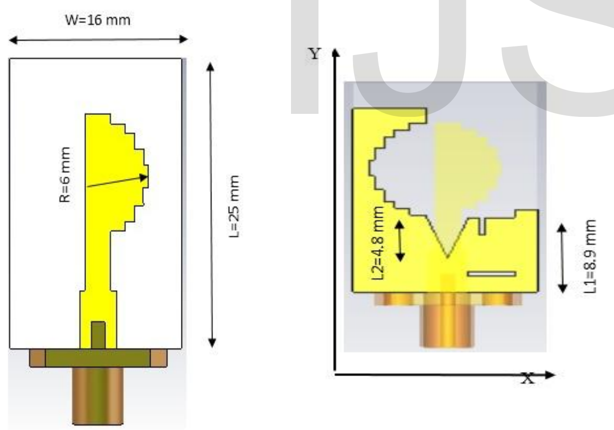

Fig. 1 (a) Dimensions of Quasi self-complementary Antenna with front view (b) Design of Fractal Shape proposed Antenna fed by SMA Connector with back view

A) ANTENNA GEOMETRY AND PERFORMANCE

The compact quasi-self-complementary ultra wideband antenna described in this paper is displayed in Figure (1). A fractal shape and its complementary magnetic counter part are printed on the different side of the dielectric substrate (in this study, the FR-4 substrate of thickness h=1.6 mm and relative permittivity $\varepsilon_r = 4.5$ was used). Furthermore, in order to increase the impedance matching, a triangular notch is etched on the ground plane. The simulations are performed using the CST Microwave Studio package. The microstrip line fed quasi-self-complementary antenna described has the following data, i.e r=6 mm, W=16 mm, L=25 mm, L_1=8.9 mm, L_2=4.8 mm as shown in Figure (1). The return losses are measured using the N9928A FieldFox Handheld Microwave Vector Network analyzer. The radiation pattern was measured in the Science and Technology Centre of Excellence (STCE), Egypt, using compact multi-probe antenna test station (STARLAB-18), VNA model: Agilent E8363B (10 MHz–40 GHz). The practical proposed quasi-self-complementary antenna using fractal shape is illustrated in Figure (2). The return loss versus frequency for the practical antenna is shown in Figure (3).

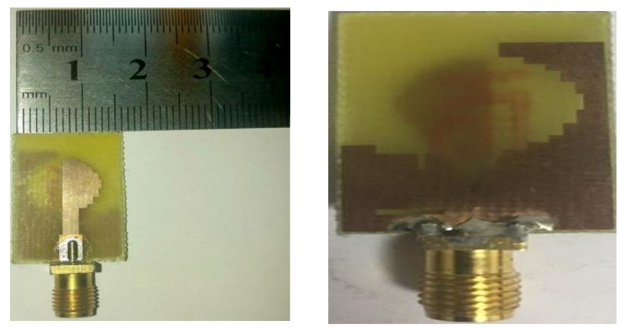

Fig. 2 The fabricated quasi-self complementary antenna using fractal shape design

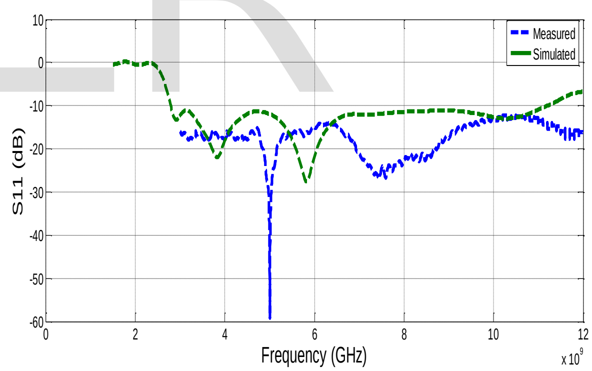

Fig .3 Return Loss Vs. Frequency

B) GAIN AND QUASI-SELF COMPLEMENTARY ULTRA WIDEBAND ANTENNA

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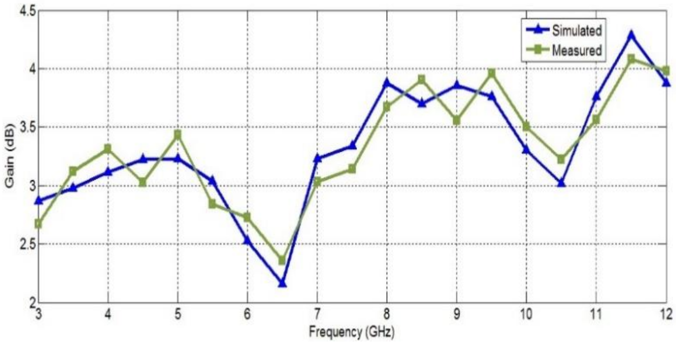
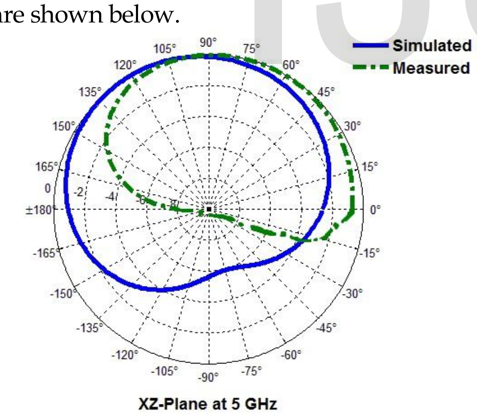


Fig. 4 The measured and simulated antenna gain

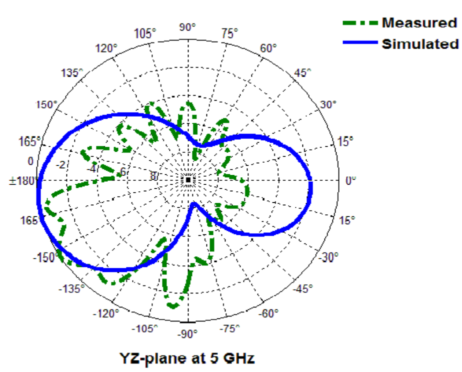
Figure (4) illustrates the measured and simulated gain. It is noticed that the measured and simulated curves are very close to each other. The curve shows that the average gain in the frequency between 2.7 GHz to 11.3 GHz is about 2.2 dB.

C) EFFICIENCY OF THE ANTENNA ANTENNA

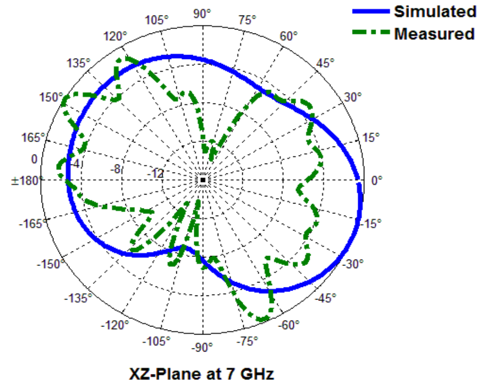
The antenna gain and efficiency also present how good the design antenna is. The radiation efficiency is used to relate the gain and directivity. Larger the efficiency lesser the heat loss, which mean most power is radiated from antenna. The radiation efficiency of the designed antenna approaches 97% at 3 GHz as shown in Figure (6). Figure (5) illustrates the radiation pattern at different planes and frequencies. The measured and simulated radiation patterns in the xz and yz-planes at the center frequencies, 5, 7 and 9 GHz are shown below.



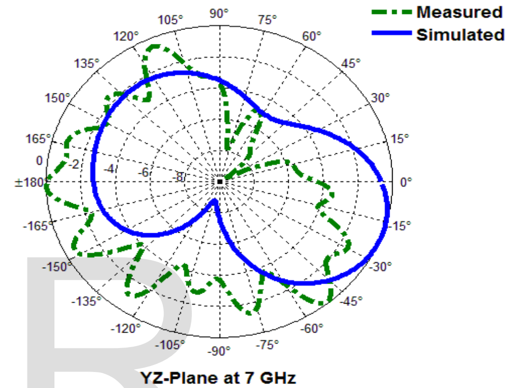
(a)



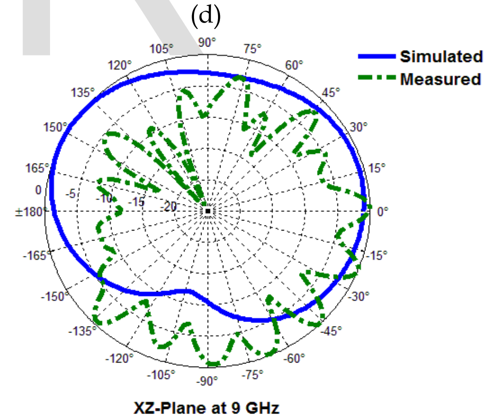
(b)



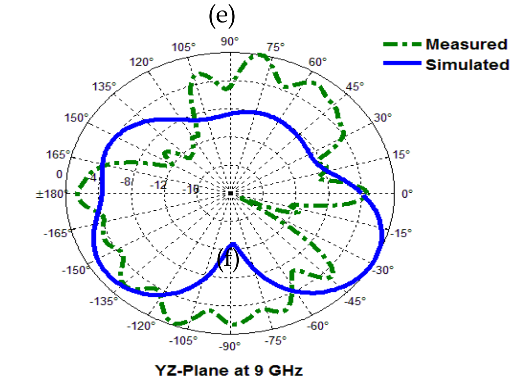
(c)



(d)



(e)



(f)

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Fig. 5 Radiation pattern at different planes and frequencies

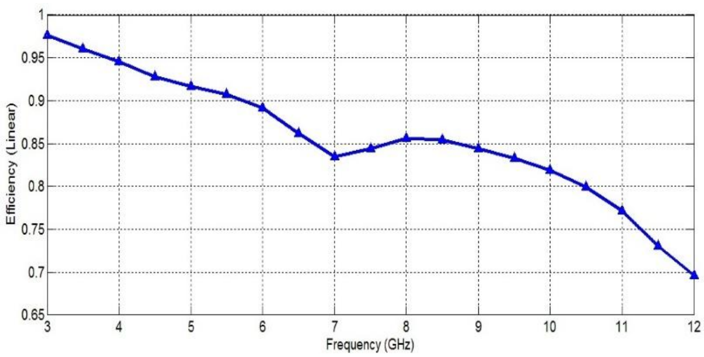

Fig. 6 The antenna radiation efficiencies versus frequencies

4. CONCLUSION

In this paper, a compact quasi-self-complementary ultra wideband antenna using the fractal shape technique was investigated and compared with a half circular disc quasi-self complementary antenna. The antenna designed exhibits compact dimensions of 16 mm x 25 mm in physical size. It is demonstrated that the proposed printed quasi-self-complementary antenna can achieve an ultra wideband impedance bandwidth from 2.7 GHz to 11.3 GHz. The antenna achieved a good agreement between the simulated and the measured antenna characteristics with better efficiency. The results show that this antenna is a good candidate for the ultra wideband applications.

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