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A New Design of an UWB Circular Fractal Printed Antenna

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Abstract

A Microstrip Antenna (MSA) has been computed and analysed in this study by using CST of Microwave studio as Electromagnetic solver by generating the coefficient of reflection, the Gain, the density of current and the radiation pattern in the frequency range 3.1-10.6 GHz which commercialised by the Federal communication commission (FCC) as an Ultra-wide band (UWB) frequency range. The substrate used to achieve the proposed structure is the FR4-Epoxy with a thickness of 1.6 mm, a constant dielectric of 4.4 and a loss tangent of 0.025. The radiating patch is a circular shape etched with different sizes to create the fractal geometry. The transmission line has been designed by including a tapered section in the part connected to the radiator. The design of the antenna has been verified by using ADS and CST solvers. The fabrication of the antenna has been performed in order to measure the coefficient of reflection and the radiation pattern.

Keywords*: microstrip antenna, coefficient of reflection, gain, density of current, UWB.*

1. Introduction

With the realization of the patch board circuit in the 20th Century, the researchers developed the printed transmission line by adding a ground plane in the bottom of the dielectric substrate in order to create a virtual second conductor called the stripline. This technique replaced the coaxial cable fabricated by two parallel wires. The new transmission line became the famous Microstrip feed line. A mass production in the microwave field appeared by using the technique of Microstrip line.

To promote the exhibition of the electromagnetic radiation by using the Microstrip line it was mandatory to add a compatible conductor radiator to the top of the transmission line, this technique has been started in the 1950s, to be developed in 1952 by Grieg and Engelmann, therefore the first functional connection between the radiating patch conductor and the Microstrip feed line has been designed by Deschamps in the 1953s; the improvement of this technique in order to invent what we called now the Microstrip Antenna has been achieved in 1955 by Gutton and Baissinot

Starting from that time the conception of the Microtrip Antenna or the connection between the radiator and the stripline has been dramatically become the interest of the among designers in the microwave domain. In 1960 Denlinger design the first Rectangular and circular Microstrip antenna radiating with efficiency, the description of the current distribution of those antennas has been explained by Watkins in the 1969s [1-7].

In the time being several geometries of the radiating patch and the Mcrostrip transmission line have developed by using different technique and by merging some mathematical theories in the design of microwave components. The result it was an ease Microstrip antenna which can be achieved by dielectric substrate with ground plane on the bottom and a Microstrip transmission line connected to Radiator conductor which can take several shapes.

Many numerical methods have been involved in order to analysis the Microstrip antenna starting with the Method of Moment (MoM) developed in the 1980s, to use recently, with the improvement of the CPU and Memories of computer, more complicated methods to analysis the

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Micorstrip antenna such as the finite difference time domain (FDTD) and finite element method (FEM) [8-10].

The Microstrip antenna presents many advantages such as the low cost Manufacturing, Low profile, ease to be integrated with circuits using the Micostrip technique, small thickness of Antenna, but the Micostrip antenna suffers also from the narrow bandwidth, the poor efficiency and the influence by the environmental criteria such as the temperature. The circular Microstrip antenna is used to benefit from some radiation patterns which are not offered by the Rectangular Microstrip antenna, with TM_{11} is the fundamental mode [11-12].

2. Anetnna Geometry

The circular Microstrip antenna presented in this study has been achieved by optimizing a partial ground plane in order to create a virtual conductor on the bottom of the dielectric substrate, to be an image of the Microstrip transmission line, by analogy this configuration it looks like an ordinary coaxial cable. To benefit from the smooth distribution of the current from the excitation point to the radiator patch, the transmission feed line has been designed to contain two parts, the lower one is an ordinary feed line matched in 50Ω while the second has been chosen to be tapered section. The conception of the proposed antenna has been fulfilled by using the dielectric substrate Epoxy FR4 with an overall dimension of 20x25 mm^2, the dielectric material has the below features:

a. Metallic thickness: t=35μm.
b. Substrate thickness: h=1.6mm.
c. Relative dielectric permittivity εr=4.4.
d. Dielectric loss: tan(δ)=0.025.

The circular radiating patch chosen with a radius R where R=6mm, the fractal geometry has been applied on the patch by etching three circular shapes with different sizes in the radiating patch. The Diameters of the circular slots are respectively from the high to the low; D1, D2 and D3 where D1=4mm, D2=1.75mm (the circular in the middle of the radiating patch) and D3=1mm. The geometry details of the Micostrip antenna is shown in the Figure 1. The Table 1 contains the values in mm of the optimized dimensions of the designed antenna.

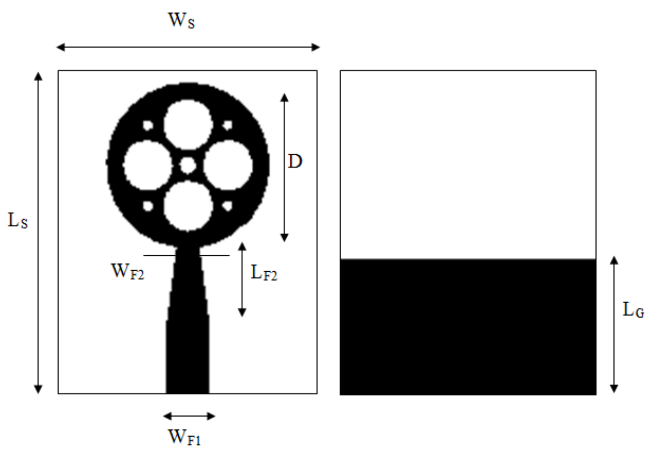

Figure 1. The geometry of the proposed antenna

Table 1. The calculated and optimized dimensions of the proposed antenna

Parameter	Value (mm)
X	25
L_S	20
W_S	10.5
L_G	3
W_{F1}	1.4
W_{F2}	5.5
L_{F1}	6

Table 1. The calculated and optimized dimensions of the proposed antenna

Parameter	Value (mm)
L_{F2}	12
D	4
D_1	1.75
D_2	1
D_2	25

3. Antenna design and simulation

In order to generate the coefficient of reflection in the frequency range 3.1-10.6 GHz called the FCC band, it was necessary to use the electromagnetic solvers, in this study two of them have been chosen which are the CST of Microwave studio and ADS of Agilent. Therefore the two software based on different numerical methods to compute the printed circuits. For the CST, especially its transient tool is based on the FDTD (the finite-difference time domain) method, the suitable technique for the Microstrip antenna based on the gridding the spatial and time with same way for the electric and magnetic fields by aligning the E cell with the boundary of the configuration. While the technique behind ADS is the Method of Moment which is based on the formulating of the unknown current on the Radiating patch, the Microstrip transmission line and their image on the ground plane by an integral equation [13-16].

The graph of coefficient of reflection is generated by using CST and shown in the Figure 2 a, the values of S_{11} are less than -10dB in the whole UWB 3.1-10.6 GHz, the result has been double checked by using ADS in order to obtain the graph of the coefficient of reflection which present a good agreement in terms of input impedance matching at 50Ω in the FCC frequency range.

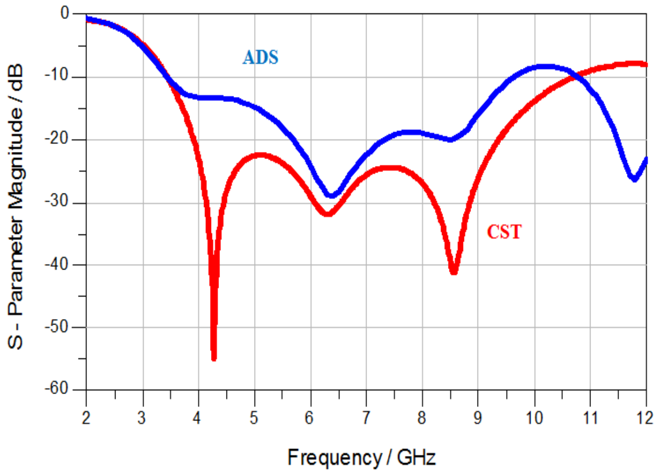

Figure 2. The S_{11} parameter vs Frequency by CST and ADS

The current density has been generated by using CST in order to check the distribution through the different parts of the achieved antenna which are the Microstrip line, the radiating patch and the virtual conductor on the ground plane. The Figure 3 presents the current distribution in four different frequencies to coverage the whole FCC band, the 3 GHz and 5 GHz are chosen as lower frequencies while 7GHz and 10GHz are considered as higher frequencies.

The current in 3GHz reaches the circular radiator especially around the peripheries with high density, therefore in 5GHz the current appeared mainly in the lower part of the radiating patch and in the transmission line, the current distribution in 7 GHz is slightly similar to the current behaviour in 5 GHz with small surface in the radiator, while in 10GHz the current exist with high density in the Microstrip feed line.

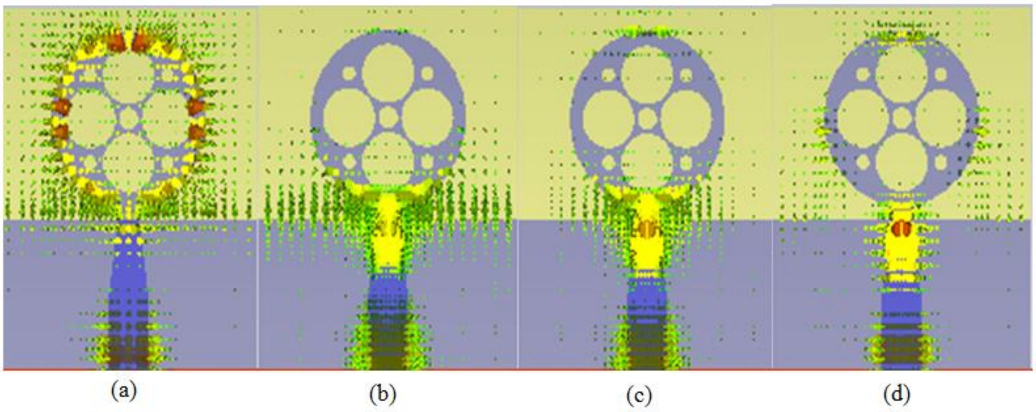

Figure 3. The current distribution in the simulated antenna by CST
(a) @ 3GHz, (b) @ 5GHz, (c) @ 7 GHz and (d) @ 10GHz

The current density has been generated by using CST in order to check the distribution through the different parts of the achieved antenna which are the Microstrip line, the radiating patch and the virtual conductor on the ground plane. The Figure 3 presents the current distribution in four different frequencies to coverage the whole FCC band, the 3 GHz and 5 GHz are chosen as lower frequencies while 7GHz and 10GHz are considered as higher frequencies. The current in 3GHz reaches the circular radiator especially around the peripheries with high density, therefore in 5GHz the current appeared mainly in the lower part of the radiating patch and in the transmission line, the current distribution in 7 GHz is slightly similar to the current behaviour in 5 GHz with small surface in the radiator, while in 10GHz the current exist with high density in the Microstrip feed line.

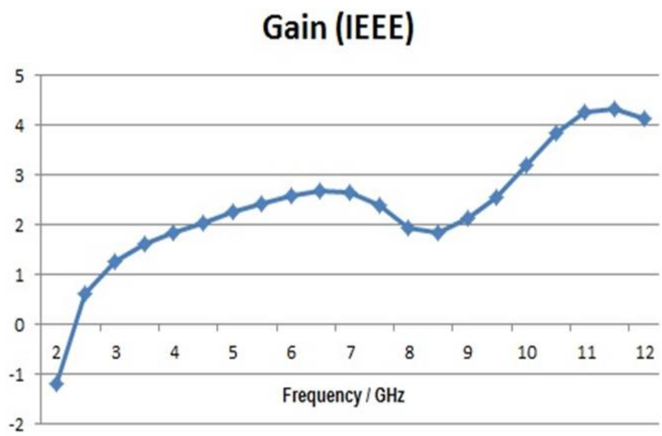

Figure 4. The Gain IEEE vs Frequency generated by CST

The simulated radiation pattern of the proposed MSA has been done by using CST in the E-plane and H-plane shown in the Figure 5 for the following frequencies; 3, 5, 7 and 10GHz. In different frequencies the radiation pattern in H-plane of the computed antenna presents an unidirectional form, while the Microstrip antenna in E-plane is bidirectional.

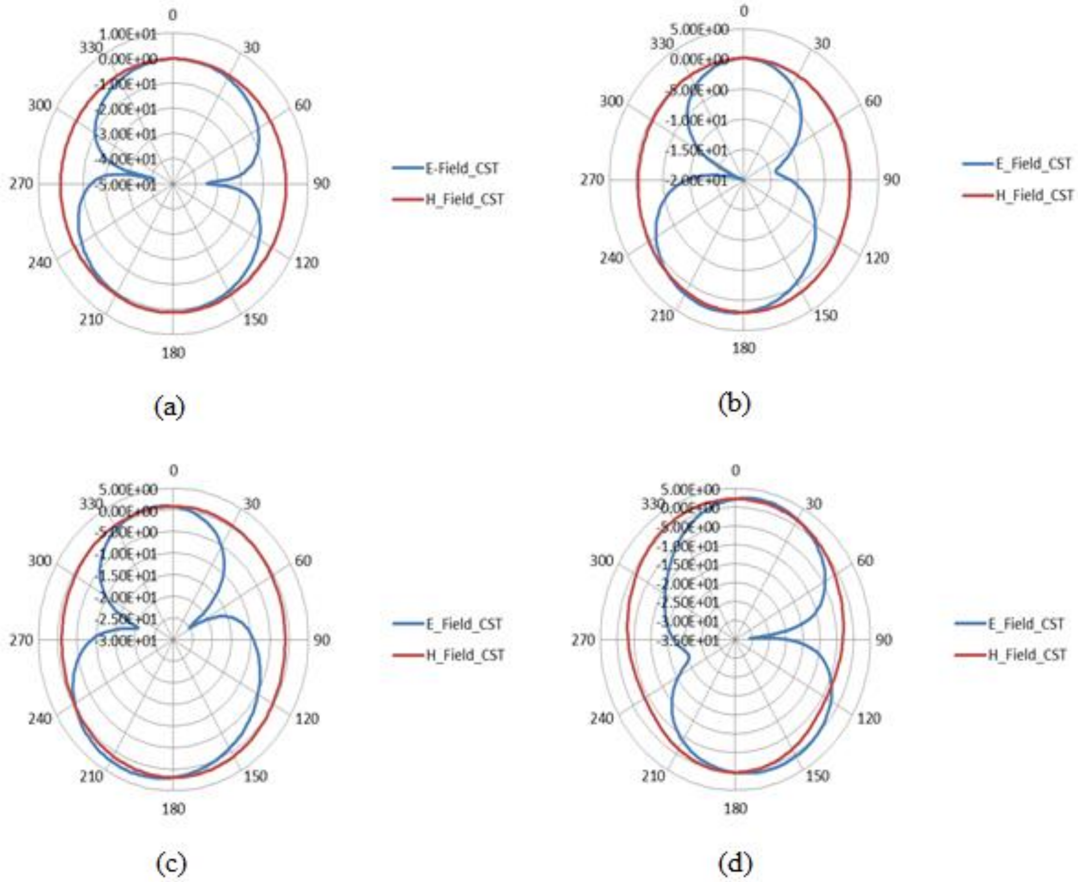

Figure 5. The Radiation Pattern in E-Plane and H-Plane by CST; (a)@3GHz, (b)@5GHz, (c)@7GHz and (d)@10GHz

4. Eperimental Results and discussion

The antenna has been manufactured based on the optimized parameters and the described dielectric substrate by using CST and ADS as solvers of design. The Figure 6 presents fabricated antenna.

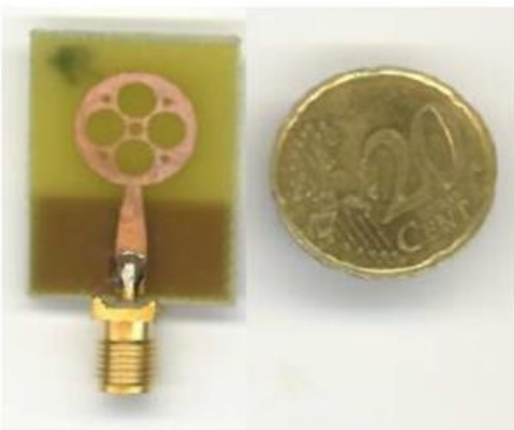

Figure 6. The fabricated MSA Antenna

The measurement of the candidate circuit has been perfomed by using the Network Analyzer PNA-X N5247A from Agilent Technologies in order to plot the graph of S_{11}. For the radiation pattern it measured inside the anechoic chamber to avoid the reflections of the electromagnetic waves, as shown in the Figure 7.

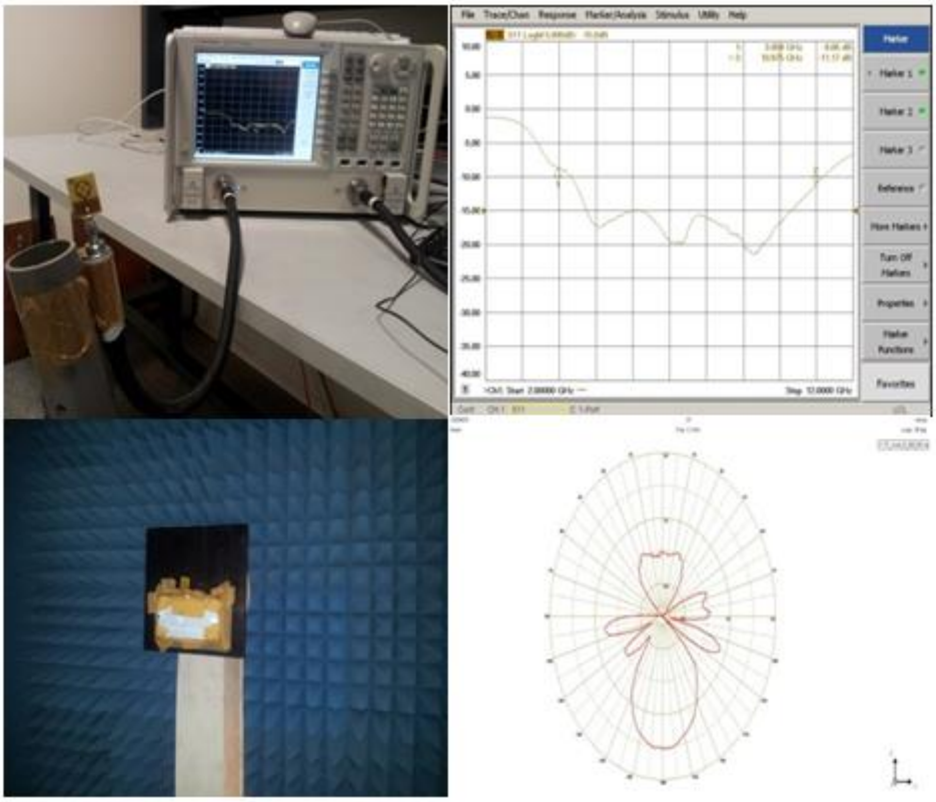

Figure 7. The different Measurements of the fabricated Antenna

The measured and simulated S_{11} are shown in the Figure 8, the two graphs are more and less similar and present a good agreement in terms of input impedance matching at 50Ω in the FCC band.

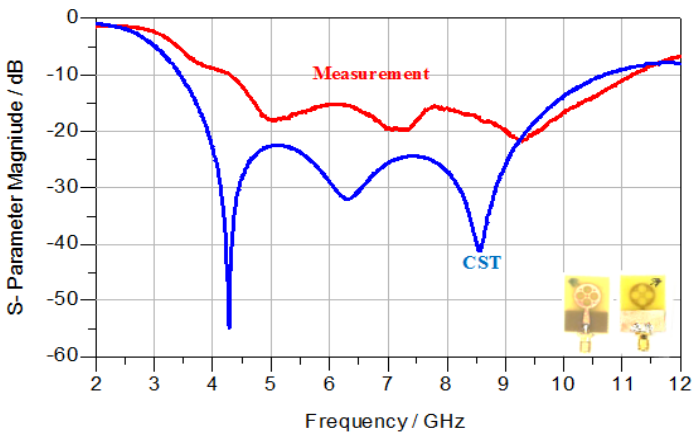

Figure 8. The Measured and Simulated S11

The software ANT-32 Analysis has been used to measure the radiation pattern in H-Plane of the fabricated antenna in the anechoic chamber by creating a Microwave hop of 3m with transmit antenna is an horn in the frequencies 3, 5, 7 and 10GHz, the measured and computed diagrams are shown in the Figure 9.

The Radiation diagram in the H-plane of the proposed antenna is unidirectional in the whole frequency range chosen as UWB. There is an agreement in terms of behavior between the compupted and measured radiation pattern in H-plane, but also the difference is exist reagrding many parameters during the measurement.

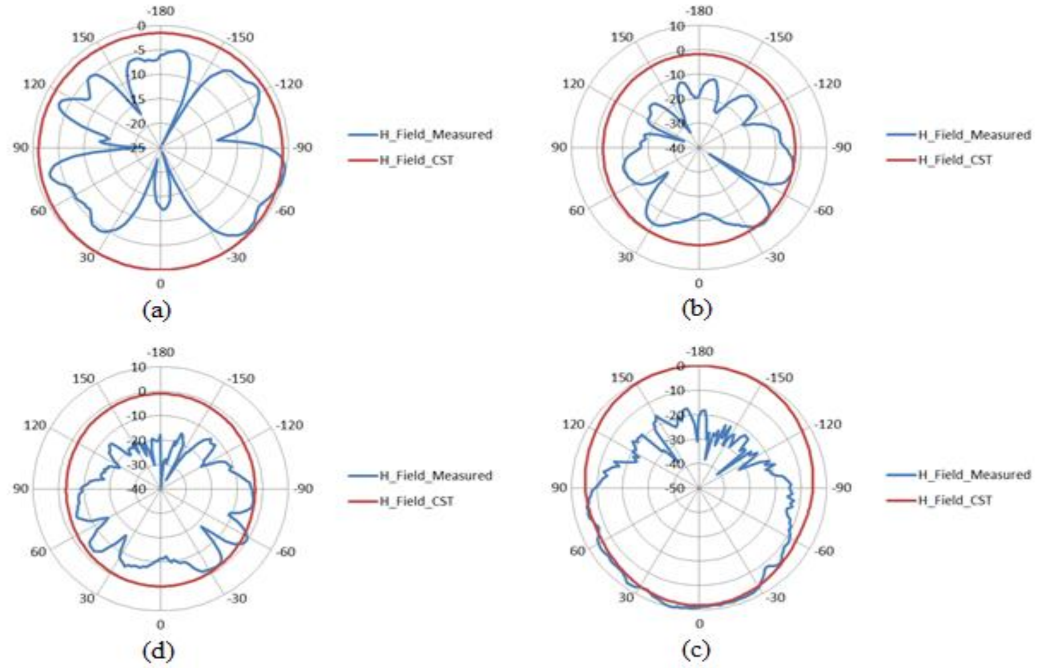

Figure 9. The Radiation Pattern in H-Plane by CST and Measurement; (a)@3GHz, (b)@5GHz, (c)@7GHz and (d)@10GHz

4. Conclusion

The Microstrip antenna achieved into simulation by the two solvers CST and ADS, Manufactured by using the photolithographic method, can be proposed as a low cost and miniaturized candidate for indoor and outdoor applications. The proposed structure etched on FR4-epoxy presents a good matching of the input impedance at 50Ω in the FCC band 3.1-10.6 GHz. The fractal geometry has been chosen to design the radiating patch element while the transmission feed line has been configured with a tapered section with a virtual conductor obtained by the partial ground plane. The radiation pattern of the Microtrip antenna proposed in this study is bidirectional in the in E-plane and unidirectional in H-plane in the UWB.

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