Novel fractal antenna for UWB applications using the coplanar waveguide feed line

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ABSTRACT

In this study an original Coplanar Waveguide (CPW) antenna has been achieved into simulation and manufacturing in order to be an important candidate for the Ultra-wideband applications. The area of the proposed structure is 34mmx43mm operating in the frequency range 3.1–10.6 GHz released as UWB by the Federal Communications Commission (FCC). To perform the design of the proposed CPW antenna two electromagnetic solvers has been adopted which are CST of Microwave Studio and ADS of Agilent. The radiating patch has been chosen circular with fractal geometry based on circular slots with different sizes. The dielectric substrate is an Epoxy FR4 with a Relative permittivity 4.4, a thickness 1.6 and a loss tangent 0.025. To valid the functionality of the antenna two parameters has been computed which are the coefficient of reflection and the radiation pattern and confirmed into measurement by using the Network Analyser and the anechoic chamber.

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1. INTRODUCTION

The microstrip line, based on the transmission line connected to the radiating patch and the ground plane in the bottom of the dielectric substrate, remains the most popular technique to design the antennas operating in the lower and little higher frequencies. The microstrip antenna consists of the focus of the maximum energy in the strip line on the top of the substrate and the virtual conductor created by the ground plane which defines the main electromagnetic radiation. However, the integration of the microstrip antenna in the circuits presents some difficulties related to the ground plane inaccessibility and the difficulty to establish the shunt between the strip line and the ground [1-4].

The coplanar waveguide (CPW) has been invented to avoid the disadvantages of the microstrip by designing the various conductors in the same geometric plane, in order to have the dielectric substrate without any conductor. The first coplanar strip structure has been developed by Seymour Cohn in the 1969s. Over the recent years others structures more developed has been involved in the conception of the antenna due to several advantages such as the low cost of manufacturing, the reduced dispersion, the decreased losses related the radiation and the ease ground plane existing in the same side with the transmission line [5-10].

2. ANTENNA GEOMETRY

The CPW antenna depicted in this study has been chosen with a circular radiating patch connected to a strip line established between two partial ground planes on the top of the dielectric substrate. The fractal geometry applied on the radiator, is based on a circular shape with different diameters respectively from the higher to the lower are D1, D2 and D3 as shown in Figure 1.

The substrate used to design the proposed antenna is an Epoxy FR4 characterized by the below features:

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

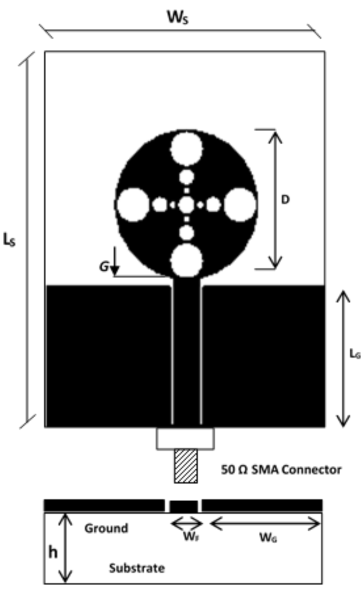

Figure 1. The Geometry of the validated antenna

The different values of the optimized parameters of the simulated antenna have been summarized in the Table 1.

Table 1. Calculated and validated dimensions of the designed antenna

Parameter	Value (mm)
W_S	34
L_S	43
W_G	15
L_G	16
W_F	3
G	1
D	17
D_1	4.05
D_2	1.925
D_3	0.8625

3. ANTENNA DESIGN

The main electromagnetic solver used to design the proposed antenna was CST of Microwave Studio by using it component Transient based on the numerical method called finite-difference time domain (FDTD). Three parameters have been generated by CST which are the coefficient of reflection, the gain and the radiation pattern in order to have a complete idea about the antenna behaviour in the FCC band. The second solver was ADS of Agilent developed by using the Method of Moment (MoM) which is involved to double check the S_{11} parameter and compared with the graph generated by CST [11-14].

The coefficient of reflection computed by CST and ADS shown the Figure 2 presents a good matching in terms of input impedance at 50Ω in the frequency range 3.1GHz – 10.6GHz, with the values of S_{11} less than -10dB in the UWB. The gain of the antenna has been simulated by using CST in the Figure 3 in the frequency 2GHz-12GHz which include the FCC band chosen in this study. According to the graph the gain is between 2dB and 3dB in the lower frequencies which mean that the CPW antenna can be used in indoor applications in UWB, however the gain reaches the value between 4dB and 6dB in higher frequencies in this case the proposed antenna can be a good candidate for outdoor application in the FCC band.

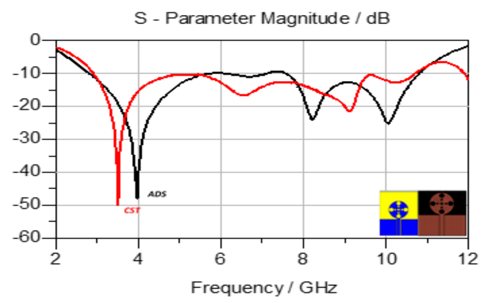

Figure 2. S_{11} vs frequency of the designed CPW antenna

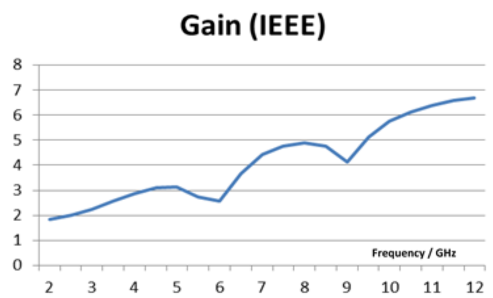

Figure 3. Gain vs frequency of the designed CPW antenna

The radiation pattern in the frequencies 3GHz, 5GHz, 7GHz and 10GHz has been simulated by CST in E-plane and H-plane shown in the Figure 4 (a), (b), (c) and (d). The diagram of radiation is unidirectional in H-plane in different frequencies with some slight variation in higher frequencies such as 10GHz. While in E-plane the radiation pattern keep the directionality behaviour in all frequencies. The graph of S_{11} it's not a sufficient parameter to conclude that the antenna will radiate even the input impedance matching, because the antenna can be analogue to pure resistance, so the radiation pattern is mandatory criteria to confirm the radiation od the antenna.

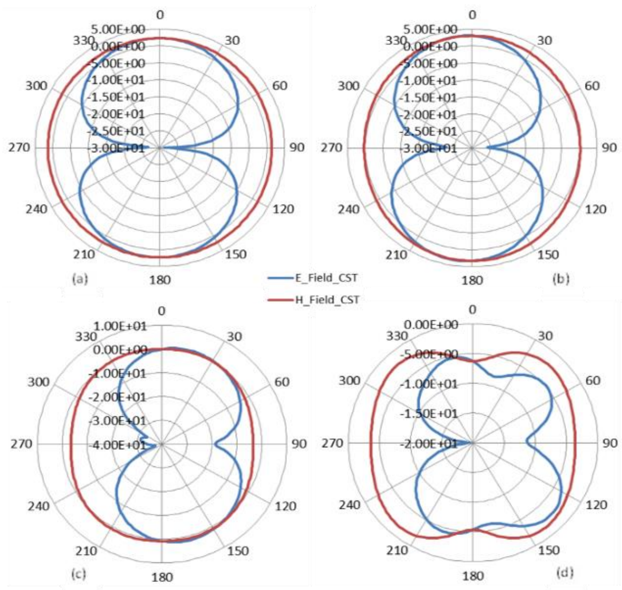

Figure 4. The Radiation Pattern in E-Plane and H-Plane by CST; (a)@3GHz, (b)@5GHz, (c)@7GHz and (d)@10GHz

4. EXPERIMENTAL RESULTS AND DISCUSSION

The photolithographic method has been used to fabricate the antenna, in order to perform the measurement series based on the Network Analyser and the Anechoic chamber, the Figure 5 present the manufactured antenna. The PNA-X Network Analyzer N5247A from Agilent Technologies coefficient has been used to measure the coefficient of reflection. The Figure 6 presents the two graphs of S_{11} generated by ADS and CST and the one validated into measurement. A good agreement in terms of form and matching of input impedance at 50Ω has been confirmed. The Figure 6 presents the two graphs of S_{11} generated by ADS and CST and the one validated into measurement. A good agreement in terms of form and matching of input impedance at 50Ω has been confirmed.

Figure 5. The fabricated antenna

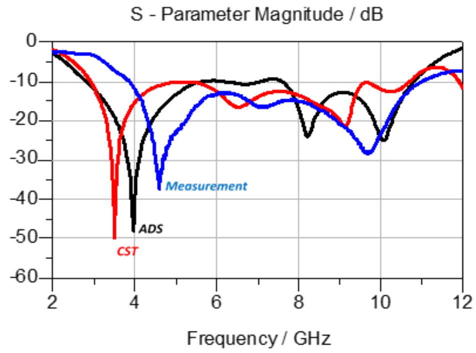

Figure 6. S_{11} vs frequency into simulation and measurement

The radiation pattern has been measured in H-plane only in the four frequencies 3GHz, 5GHz, 7GHz and 10GHz shown in the Figure 7 with the simulated diagrams by CST also in H-Plane. The radiation pattern of the proposed antenna has been performed by establishing a Microwave link of 3m inside the anechoic chamber to avoid the diffraction of the electromagnetic waves. The transmitter antenna is an horn with known output power and gain. So to calculate the gain of the proposed antenna in 360° it was necessary to use the link budget formula, with the receive level measured by the Network analyser and the software ANT-32 Analysis. According to the diagram of radiation an agreement between the simulated and measured graphs in terms of radiation behaviour which unidirectional in all the frequencies chosen the coverage the FCC band.

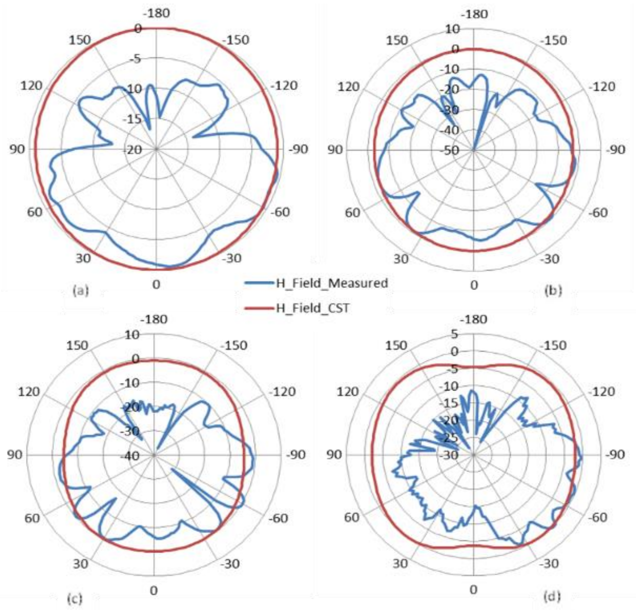

Figure 7. The Radiation Pattern in H-Plane by CST and into Measurement; (a) @3GHz, (b) @5GHz, (c) @7GHz and (d)@10GHz

5. CONCLUSION

The achieved CPW antenna into simulation and measurement in order to operate in the frequency range 3.1GHz – 10.6 GHz with a fractal radiating patch, can be used as good candidate for UWB applications in outdoor and indoor due to several features related to the CPW technique and the parameters of the antenna itself. The proposed structure can be considered as original antenna with low cost, ease of fabrication and facility of integration with MMICs. The coefficient of reflection measured and computed is matched in terms of input impedance at 50 Ω, the radiation pattern is unidirectional in all frequencies of the FCC band. The gain subdivide the operational frequency range to two bands according to its value, in the lower frequencies the antenna can be operating in indoor UWB applications while in the higher frequencies the antenna can be used in the outdoor circuits.

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