A low cost fractal CPW fed antenna for UWB applications with a circular radiating patch

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Article Info

Article history:

Received Mar 13, 2019
Revised Jul 5, 2019
Accepted Jul 23, 2019

Keywords:

CPW
FCC
Fractal geometry
Radiation pattern
Return loss
UWB

ABSTRACT

In this study a validated antenna into simulation and through measurement has been described and analyzed. The coplanar waveguide (CPW) technique has been chosen to feed the radiating patch while the two ground planes have been partially designed in the top side of the substrate. The fractal geometry, applied to the circular radiator, has been obtained by merging the circular and rectangular shapes. The fiberglass FR-4, with a single side of 35µm copper thickness, has been used to achieve the antenna material with a permittivity of 4.4, a thickness of 1.6 mm, a loss tangent of 0.025 and an overall dimension of 34x43 mm^2. The proposed CPW fractal antenna has been configured to operate in the frequency range 3.1-10.6 GHz published by the federal communications commission (FCC) as an ultra-wide band (UWB). To calculate the return loss, the gain, the current density and the radiation pattern of the simulated antenna, two electromagnetic solvers have been involved which are the CST microwave studio and ADS. The series of measurement have been performed by using the network analyzer and the anechoic chamber in order to confirm the computed antenna.

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1. INTRODUCTION

The first definition of the UWB, applied by The Defense Advanced Research Projects Agency (DARPA) as American standard, has been based on the value of the below Taylor expression BF = 2(FH - FL)/(FH + FL), so the signal is considered as UWB when BF is superior than 0.25. Where BF is the fractional Bandwidth of the signal, FH is the higher frequency and FL is the lower frequency in the spectrum. In February 2002, a new definition of UWB has been published by the Federal communication commission (FCC) as the second American standard, based on the signal bandwidth. So according to the FCC a signal can be known as UWB if it frequency spectrum is similar or greater than 500 MHz [1-5].

In the planar technology, the microtrip feed line remains the most popular technique to establish the microwave transmission due to several advantages, however this method suffers from some limitations mainly belong to the reduced bandwidth offered. Therefore the introduction of the coplanar waveguide

(CPW) technique becomes mandatory in the planar devices and especially in the printed antennas, by depositing the transmission feed line between two narrow ground planes on the top side of the substrate, which offers to the antenna a wider signal spectrum, a less dispersion, low radiation loss, an ease integration with passive and active circuits [6-8]. The Fractal is a rough of an original shape that can be fragmented n times with reduced sizes, this technique offers two important behaviors, the first one is the self-similarity to improve the matching of input impedance in the frequency spectrum, while the second is space filling to increase the miniaturization of the devices [9].

2. ANTENNA GEOMETRY

The CPW technique has been applied to the proposed antenna by designing the transmission line and the ground planes on the top side of the substrate, the radiating patch has been circularly chosen with a fractal geometry obtained by the merging of rectangular and circular shapes by using the Boolean add included in the CST solver as shown in Figure 1.The overall dimensions of the achieved antenna is 43x34 mm^2 which are the dimensions of the FR-4 of Epoxy fiberglass used as substrate with the following features; a thickness of h=1.6 mm, a permittivity constant $\varepsilon_r = 4.4$ and a loss tangent $\tan(\delta) = 0.025$. The entire area of the antenna is 43x34 mm^2. The Figure 2 presents the validated antenna with the different parameters which are optimized by the methods of calculation implemented in the electromagnetic solver. The values are shown in the Table 1. Tables and Figures are presented center, as shown below and cited in the manuscript. The Figure 3 presents the fabricated antenna with the SMA connector soldered simultaneously to the feed line and the two ground planes.

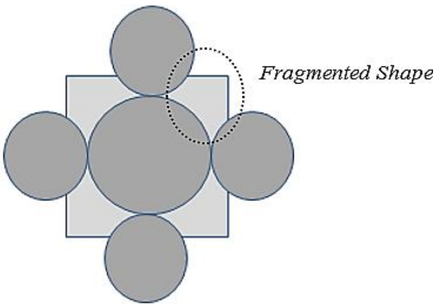

Figure 1. The fragmented shape for the fractal geometry

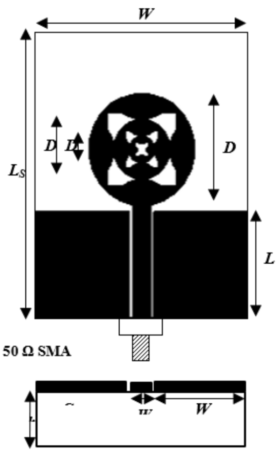

Figure 2. The geometry of the proposed antenna

Figure 3. The fabricated fractal CPW antenna

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

Parameter	Value (mm)	Comment
L_S	43	Length of antenna
W_S	34	Width of antenna
L_G	16	Length of ground
W_G	15	Width of ground
W_F	3	Width of Feed line
D	17	Diameter of radiator
D_1	9.1	Height of 1st Circular shape
D_2	6.125	Height of 2nd Circular shape

3. RESULTS AND ANALYSIS

The simulation of the achieved antenna has been performed by using two electromagnetic solvers, CST of Microwave Studio, which uses the finite integration technique (FIT) as numerical method, was the main one while the second solver it was ADS which apply the Method of Moment (MoM) [10-17]. The measurement of the proposed CPW antenna in this article has been fulfilled by using the network analyser PNA-X N5247A from agilent technologies and a SMA connector operating until 12 GHz. The return loss has been computed by the two solvers CST and ADS and presented in the Figure 4 with the measured one, a good agreement between the three graphs appeared in term of input impedance matching in a bandwidth of 120% from 2.99 GHz to 12 GHz which include the FCC band 3.1–10.6 GHz [18-28].

The gain has been calculated in the Figure 5 by using CST only, appears between 1 and 4dB in the lower frequencies, while in higher frequencies the gain reaches the values from 4 to 6dB which means that the validated antenna can be proposed for indoor UWB application in lower frequencies and for outdoor applications in higher frequencies. The current distribution is mainly present in the peripheries between the transmission line and two ground planes in the frequencies 3, 5, 7 and 10 GHz of the FCC band shown respectively in the Figures 6 (a), (b), (c) and (d).

The radiation pattern has been computed by CST in E and H planes for the frequencies 3, 5, 7 and 10 GHz, but has been measured only in H planes in the same frequencies as shown in the Figures 7 (a), (b), (c) and (d). The radiation pattern in E–plane of the simulated antenna is bidirectional in overall frequencies. However in the H–plane the radiations pattern shown unidirectional in the same frequencies into simulation and measurement with some distortions in the measured diagram due to the experience environment.

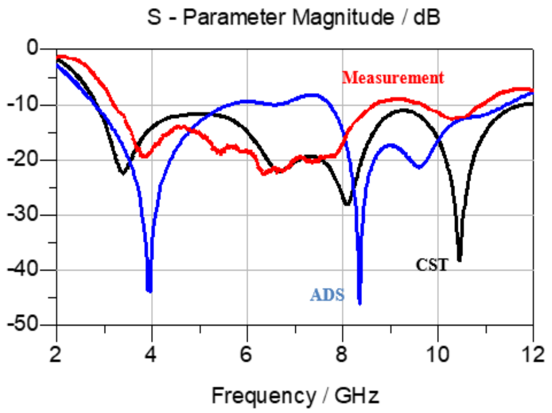

Figure 4. The S_{11} vs frequency of the CPW antenna by CST and ADS

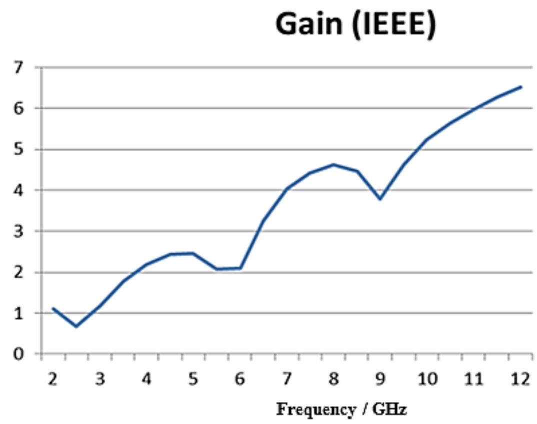

Figure 5. The gain vs frequency of the CPW antenna

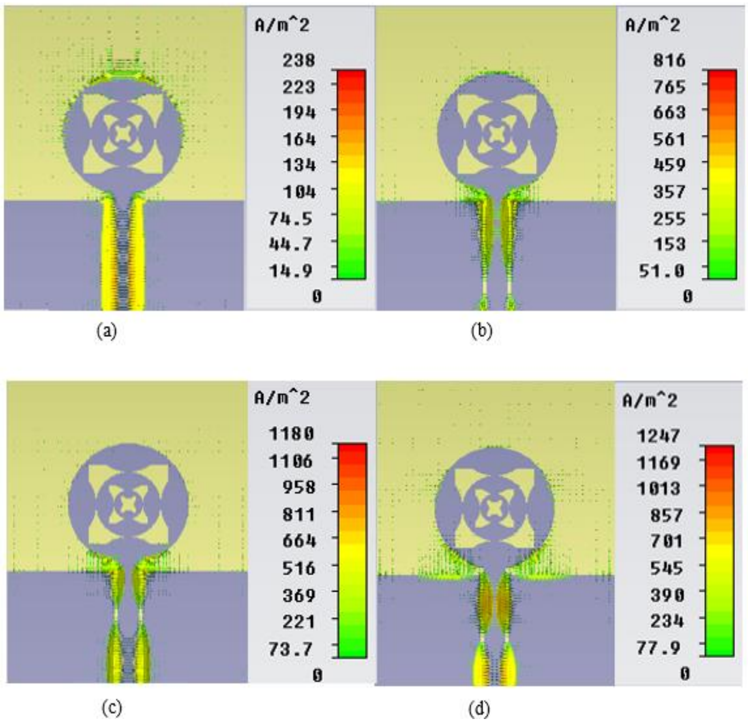

Figure 6. The current density of CPW antenna with slots: (a) @3 GHz, (b) @5 GHz, (c) @7 GHz and (d) @10 GHz

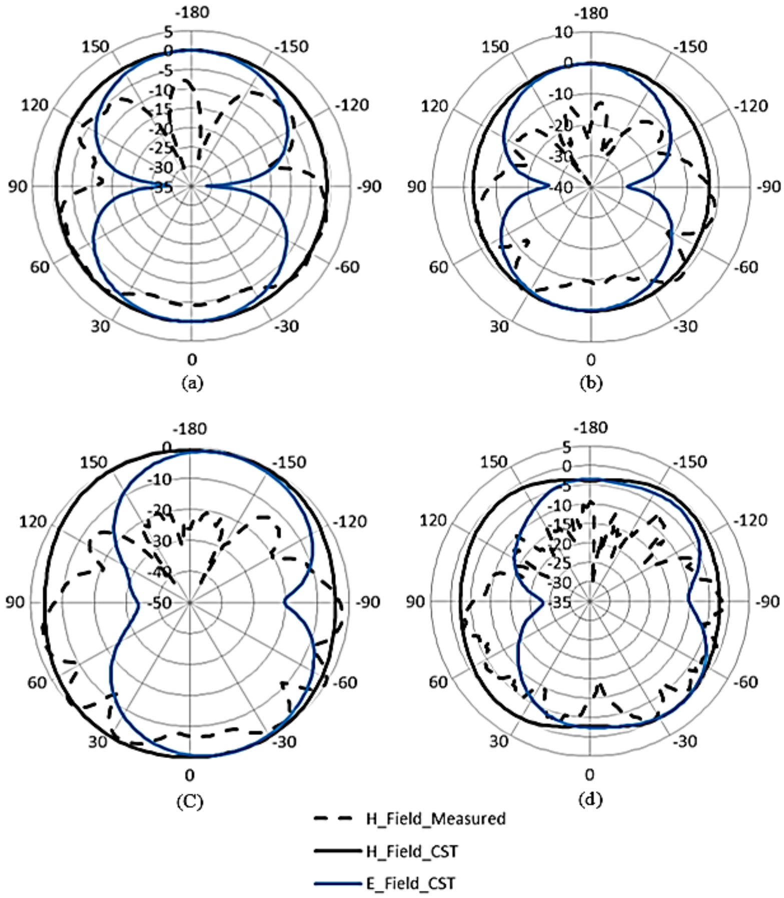

Figure 7. The radiation pattern in E&H-planes by CST and measured in H-plane only:
(a) @3 GHz, (b) @5 GHz, (c) @7 GHz and (d) @10 GHz

4. CONCLUSION

A novel fractal and CPW fed antenna has been validated into simulation and by manufacturing in order to operate in the UWB. So, the structure has been computed and optimized by using two electromagnetic solvers ADS and CST-MW. The simulated parameters present an important result, in terms of return loss, gain, current distribution and radiation pattern, in the FCC frequency range 3.1–10.6 GHz with a bandwidth of 120%. A good agreement between the computed and measured parameters has been appeared which permit to achieve a printed antenna with an acceptable performances, a low cost, a low profile and an ease integration with passive and active circuits.

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