Multi-frequency Microstrip Antenna Using Defected Ground Structures With Band-Notched Characteristics

Humberto C. C. Fernandes, José L. da Silva and Almir Souza e S. Neto

Abstract— **This paper presents a design of multi-frequency microstrip antenna using defected ground structure (DGS), etched structure on the ground plane, for C band and X band operations, with band-notched characteristics. Rogers RT/ DUROID 3006 substrate is used with dielectric constant 6.15 and loss tangent 0.0025. The proposed antenna resonates at 4.4 GHz, 6.3 GHz , 8.1GHz and 8.8 GHz and has band-notched characteristics at 4.4 - 6.2 GHz for wireless local area network (WLAN) applications (5.18–5.825 GHz), 6.5 - 8.0 GHz for X band satellite communication (7 - 8 GHz), 8.2 - 8.8 GHz for ITU 8 GHz application. A good agreement was observed between the simulated and measured results.**

Keywords*— *Defected Ground Structures; band-notched characteristics; multi-frequency.

I. Introduction

The use of multi-frequency systems has grown to integration of various communication system in a single device to promote the portability of a personal communication. Because of the large number of applications in the frequency range of UWB, the system can generates electromagnetic interference with other existing technologies in the Band, such as: IEEE 802.16 WIMAX (3.3 - 3.7 GHz), IEEE 802.11a WLAN (5.18 - 5.825), satellite communication (7-8 GHz) , ITU 8 GHz. To solve this problem are used some solutions to generate band rejection, multiband and compact structure: resonators, defected ground structures (DGS), electromagnetic band gap structures (EBG) or photonic band gap structures (PBG) and slots [1]-[9].

The DGS is an etched non-periodic or periodic cascaded configuration defect in the ground plane of a planar transmission line. This disturbs the shield current distribution in the ground plane which changes the characteristics of a transmission line such as line capacitance and line inductance. Defect etched on the ground plane can give effective capacitance and inductance, increase bandwidth and introduce band-notched characteristics. There are variety of DGS geometries has been reported in the literature, including circular, square, spiral, rectangular, H-shped, U-shaped, V-shaped etc[5]-[6],[10]-[12].

The antennas in spirals has been subject to investigation, since its use in 1960, the spiral can be single or multiple arms. For radiation and attenuation occurs in an electromagnetic structure, the load must be accelerated and this happens when one conductor is curving for direction in which the load is moving in this way, the curvature of a spiral provides an operating frequency. There is a distributed capacitance between the spiral turns and the interaction between the inductance and capacitance produces a resonant behavior. Usually the resonators structures using spiral loop are placed on the opposite side of the dielectric substrate to obtain frequency rejection [1], [13]-[14].

In order to get multiple resonant frequencies at C Band and X Band and introduce rejection Bands, the antenna proposed operates at multi-frequency using defected ground structure (DGS),spiral shaped, etched structure on the ground plane and presents a structure simple, low weight, low cost and compact for integration into circuits [15]-[21].

II. Antenna Design Parameters

The material used for the substrate is RT DUROID 3006 substrate of 1.27 mm thickness, dielectric constant εr =6.15 and loss tangent tan δ = 0.0025 and dimension of 30 (L) x 30 (W) mm2.

Figure 1 shows the dimension of antenna: lx = 15 mm and ly = 13 mm, coupled to microstrip line of 50Ω with width, lf = wf = 3 mm. The dimension of DGS are: l1 = 12mm, l2= 13 mm, l3 = 13 mm, l4 = 9 mm, l5 = 8 mm, g = 1mm, c = 3 mm, d = 3mm [1].

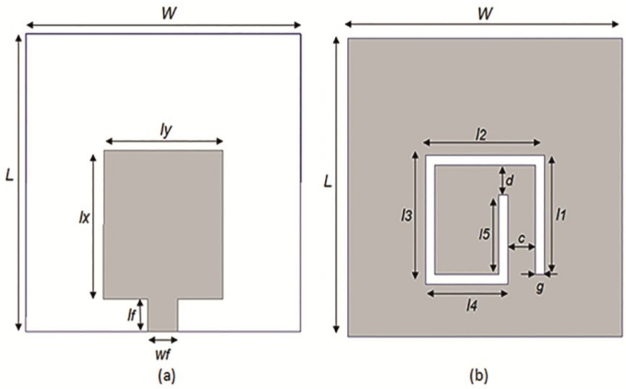


Fig. 1. (a) Front view of proposed antenna. (b) Back view of proposed antenna..

Due the DGS to etching in the ground plane, the current distribution in the ground plane changes resulting in an equivalent inductance (Ls) and capacitance (Cs).The DGS structure functions as a resonant circuit coupled to microstrip line, the defect produced in the ground plane provides Band rejection characteristics. The equivalent circuit of DGS structure is shows in Figure 2 [6], [22]-[26]:

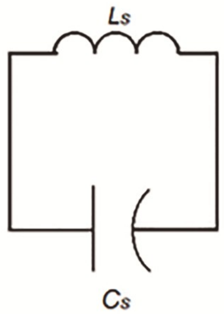


Fig. 2. Equivalent circuit of DGS structure [23].

The etched slot of the DGS structure is related with the rejection frequency of resonant circuit and the inductance (Ls) and capacitance (Cs) is given by equation (7) [6],[22]-[26]:

$$f_r = \frac{1}{2\pi\sqrt{L_s C_s}} \tag{1}$$

The S parameters extracted from HFSS are used to calculate the curve of permeability [27]. Figure 3 show the permeability curve. From that curve is showed that the permeability is negative in the frequencies 4.2 GHz, 7.3 GHz and 8.9 GHz, showing metamaterial characteristics [28].

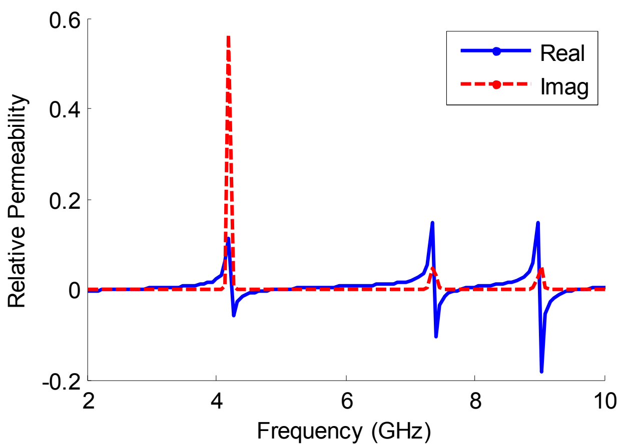


Fig. 3. Imaginary and real values of relative permeability.

III. RESULTS AND DISCUSSIONS

The antenna simulation was developed by ANSOFT HFSS® software [27]. Figure 4 shows the comparison between simulated antenna with DGS and without DGS.

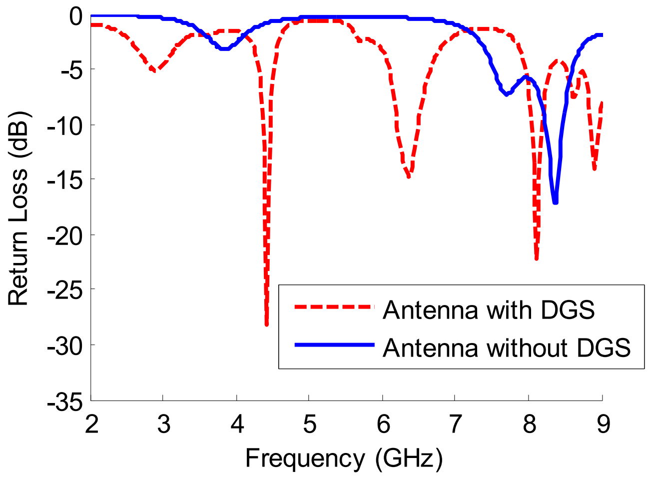
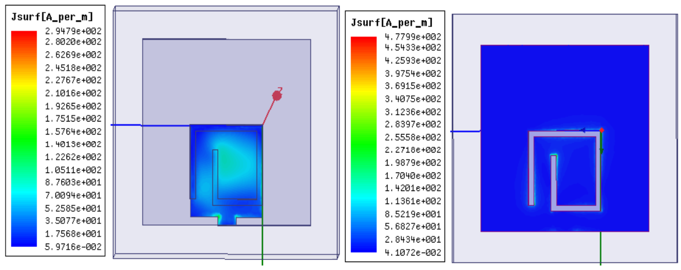


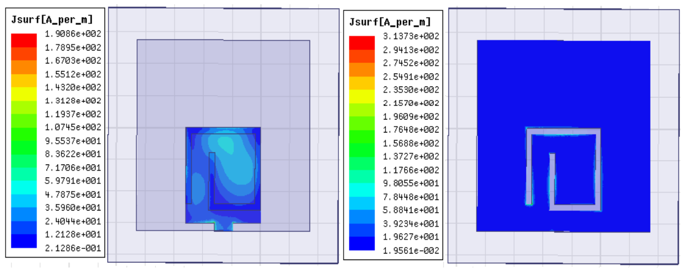
Fig. 4. Return Loss (S11) with DGS and without DGS.

According to the result simulated the antenna without DGS has a resonant frequencies at 8.3 GHz and the proposed antenna with DGS resonates has a resonant frequencies at 4.4 GHz, 6.3 GHz, 8.1GHz and 8.8 GHz and band-notched characteristics from 4.4 - 6.2 GHz for WLAN applications, from 6.5 - 8.0 GHz for uplink and downlink satellite applications and from 8.2 - 8.8 GHz for applications in ITU 8 GHz.

The simulated current distribution of the proposed antenna is shows in figure 5 at: (a) 4.4 GHz, (b) 6.3 GHz, (c) 8.1 GHz and (d) 8.8 GHz.



(a)



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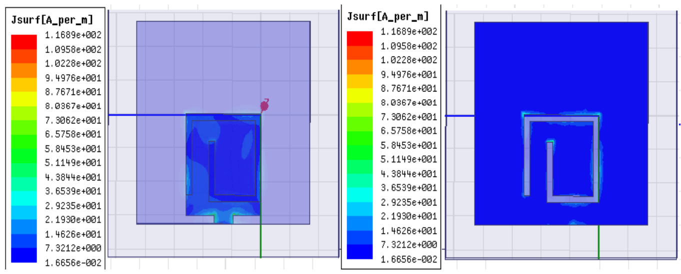
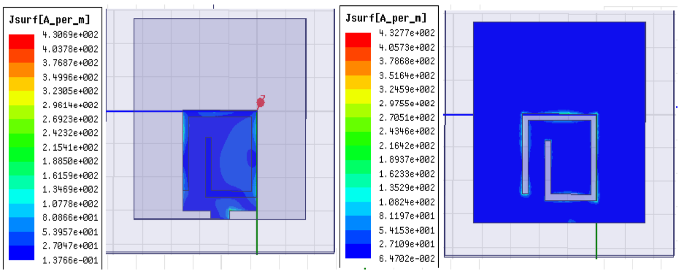


(c)

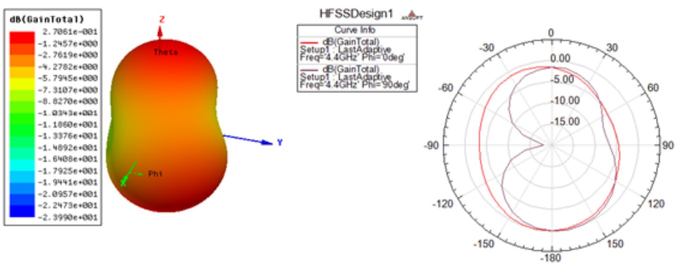


(d)

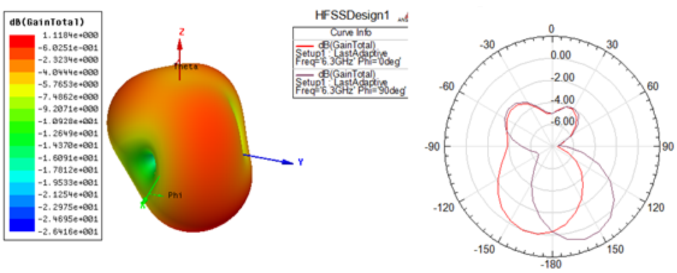
Fig. 5. Simulated current distribution of the proposed antenna at: (a) 4.4 GHz, (b) 6.3 GHz, (c) 8.1 GHz and (d) 8.8 GHz.

From figure 5, it is observed that the surface current is perceived around the DGS structure (Defected Ground strutures), spiral, which means that a large part of the electromagnetic energy has been stored around the slots.

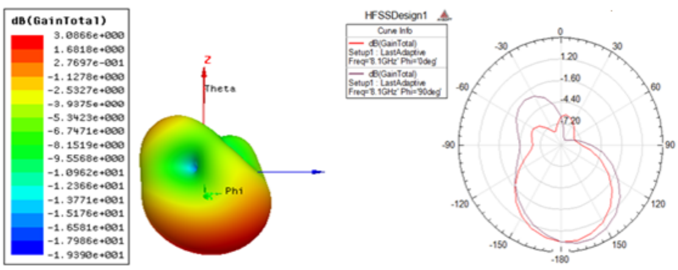
The figure 6 shows the radiation patterns in 2D and 3D on the E-plane (φ = 0°) and H- plane (φ =90°) for: (a) 4.4 GHz, (b) 6.3 GHz, (c) 8.1 GHz, and (d) 8.8 GHz .



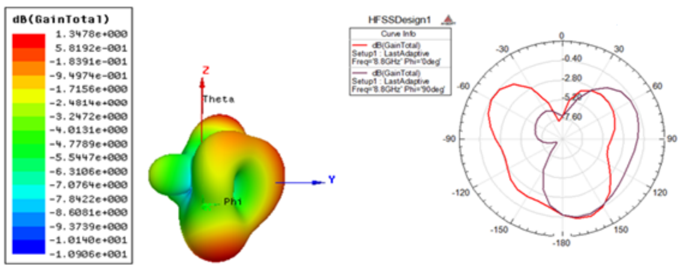
(a)



(b)



(c)



(d)

Fig. 6. Simulated results of radiation patterns in 2D and 3D gain total for: (a) 4.4 GHz, (b) 6.3 GHz, (c) 8.1 GHz and (d) 8.8 GHz.

Table I shows frequency, return loss, gain, bandwidth at 4,4 GHz, 6,3 GHz, 8,1 GHz and 8,8 GHz .

TABLE I. *RETURN LOSS COMPARISONS*

Frequency (GHz)	Return Loss (dB)	Gain (dBi)	Bandwidth (S_{11} <-10 dB) (MHz)
4,4	-28	2,70	100
6,3	-14	1,11	200
8,1	-22	3,08	200
8,8	-14	1,34	100

Figure 7 shows front and back view of fabricated antenna, with the measured result of S11, using a Network Analyzer, E5071C (300 KHz - 20 GHz).

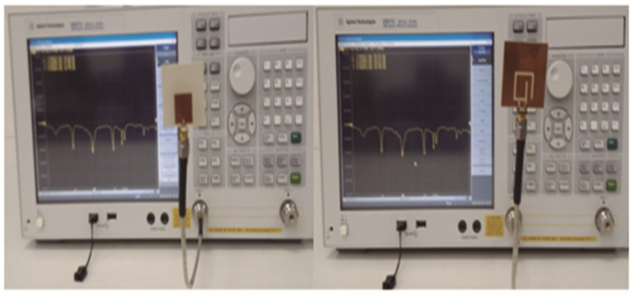


Fig. 7. Front and back view of fabricated antenna using Network Analyzer.

The VSWR simulated and measured performance is shown in Figure 8.

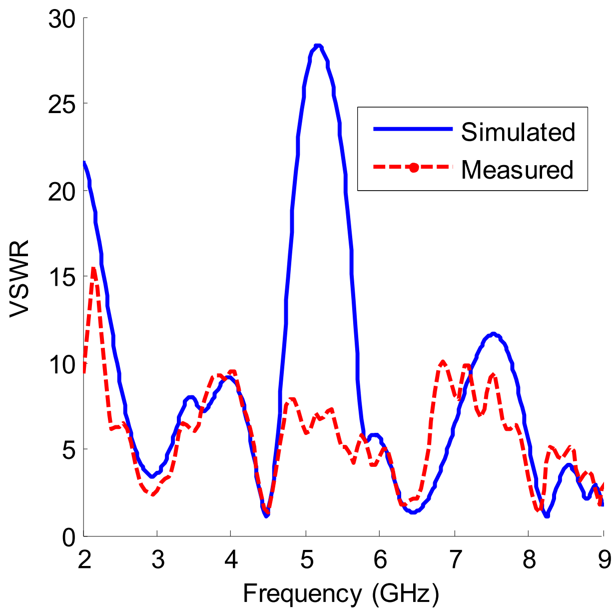


Fig. 8. Plot of VSWR.

Figure 8 shows VSWR and rejection Band from 4.4 - 6.2 GHz and 6.5 - 8.0 GHz in the C Band and from 8.2 - 8.8 GHz in the X Band.

Figure 9 shows the comparison between simulated and measured results using defected ground structure (DGS), spiral shaped, etched structure on the ground plane.

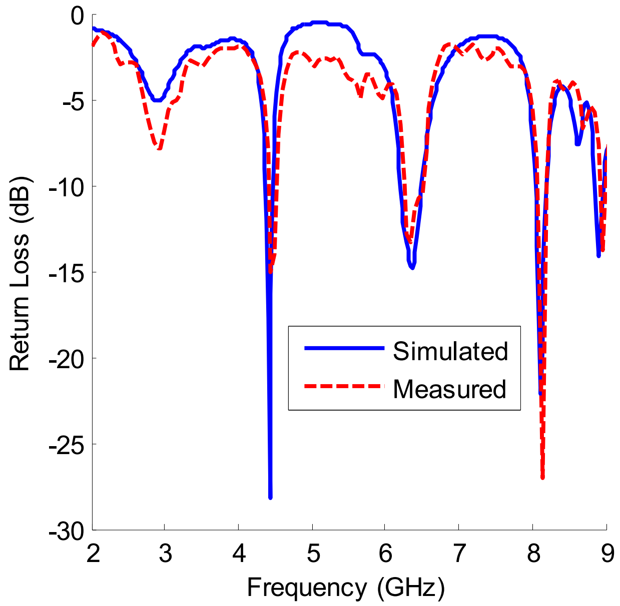


Fig. 9. S11 plot of the antenna simulated and measured.

This comparison shows a good agreement between measured and simulated values. This comparison shows a good agreement between measured and simulation return losses. Differences between these two curves are probably due to misalignment of the two sides during realization.

In the figure 10 shows the measured input impedance in the Smith Chart.

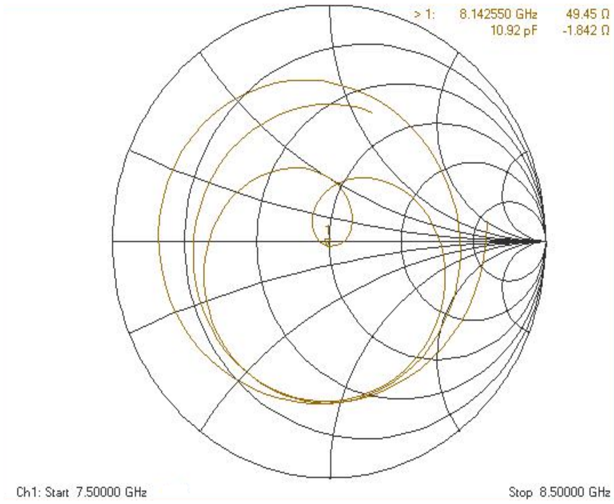


Fig. 10. Smith Chart plot of the antenna measured.

The input impedance for frequency 4.4 GHz is 44 Ω, for 6.3 GHz is 51 Ω, for 8.1 GHz is 54 Ω and for 8.9 GHz is 38 Ω. The measured value are very close to 50 Ω, showing a good impedance matching to the resonant frequencies.

III. Conclusions

In this paper it was proposed, analyzed and fabricated a microstrip antenna with DGS structure, spiral shaped, etched on the ground plane, for operation in the C Band and X Band with Band rejection. Because of the use of DGS the antenna produced resonant frequencies at 4.4 GHz, 6.3 GHz, 8.1GHz and 8.8 GHz and rejection Band 4.4 - 6.2 GHz for WLAN applications, 6.5 - 8.0 for satellite downlink and uplink application, 8.2 - 8.8 GHz for ITU 8 GHz in X Band. There are a good agreement between the simulation result and the measured result.

Acknowledgements

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