New Miniature Planar Microstrip Antenna Using DGS for ISM Applications

R. Er-rebyiy1,2, J. Zbitou2, M. Latrach3, A. Tajmouati4, A. Errkik5, L. EL Abdellaoui6

1,2,4,5,6 LMEET Laboratory FST of Settat, University of Hassan 1st Settat, Morocco
3 Microwave Group ESEO Angers, France
*Corresponding author, e-mail: ridouane1986@gmail.com

Abstract

The aim of this paper is to use defected ground structures (DGS) in order to miniaturize a microstrip patch antenna. The DGS structure is integrated in the ground plane to improve the performance of the planar antenna, and shifted the resonance frequency from 5.8 GHz to 2.5 GHz, with a miniaturization up to 83%. The antenna is designed, optimized, and miniaturized by using the CST MW-studio, mounted on an FR-4 substrate having a dielectric constant 4.4, a loss tangent tan (δ) = 0.025, thickness of 1.6 mm with the whole area of 34 X 34 mm². The proposed antenna is suitable for ISM (Industrial, Scientific and Medical) applications at 2.5 GHz with S11 ≤ (-10) dB. The antenna is fed by 50ohm input impedance and it has good performances in terms of matching input impedance and radiation pattern. The proposed antenna was fabricated and tested. Simulation and measurement results are in good agreement.

Keywords: Defected Ground Structure (DGS), Miniaturisation; Planar Antenna, CST-MW, ISM

1. Introduction

Microwave components such as filters, couplers, antennas play a very important role in today's world of wireless communication systems, but the important constraints for engineers in radio frequency (RF) researches in recent years are to obtain high performance with small size, low cost, and ease of integration. Microstrip planar antennas have been an important candidate for this new progress research.

To miniaturize microstrip antennas several methods are used to achieve this goal, among these techniques we distinguish for instance: In [1] U-shaped slot can be utilized as Fractal shapes for miniaturization of patch antennas, also meta-materials can be utilized for size reduction of patch antenna [2] and in [3] miniaturization is obtained by the complementary split ring resonators. A Combination of the discussed techniques can also be used for getting miniaturized antenna such as: photonic band gap (PBG), electromagnetic band gap (EBG), defected microstrip and ground structures (DMS) and (DGS) [4-6].

DGS is a popular technique, which is used to miniaturize the size of microstrip antenna, this method consists of etching a simple shape in the ground plane or for the best performance we can etch a complicated shape, this last serves to influence the distribution of current in the antenna, also DGS technique can be used in microstrip antenna for many approaches such as, harmonic suppression reduction, mutual coupling reduction, size reduction of antennas array [7, 9].

There are various shapes structures which can be etched in the ground plane such as: fractal, dumb bell, periodic, spiral, circular, and L shaped [10], DGS shape is composed of two defected areas and a connecting slot which are the sources of the equivalent LC elements. In other words, When DGS is inserted in a microstrip antenna, we can have an increase of the effective capacitance and inductance, which influence its input impedance and as a results thus reducing its size with respect to a given resonance frequency [11].

Therefore, in the present paper a new shaped slot are used in the ground plane as a defected ground structure for the size reduction and miniaturization of the patch antenna. Initially the proposed antenna resonates at 5.8 GHz in the ISM band [12-13], and then the integration of DGS permits to shift the resonance frequency to 2.5 GHz having the same...
dimensions of the antenna validated at 5.8 GHz. More details of the proposed antenna design procedures; simulated and measured results are presented and discussed below.

2. Antenna Design
2.1. Antenna without DGS
The idea was to achieve an antenna that functions in a high frequency band in order to have miniature dimensions of the microstrip patch. Figure 1(a) shows the simple antenna structure resonating at 5.8 GHz, this antenna is mounted on an FR4 substrate due to its lowcost and easy fabrication. After many series of optimization by using the different optimization methods integrated in CST-MW solver, the different parameters of the designed antenna are as follows: \( W_p=16 \) mm, \( L_p=10.89 \) mm, \( L_1=7 \) mm, \( L_2=7 \) mm \( W_I=3 \) mm, \( W_I=0.85 \) mm and metallization thickness of \( t=0.035 \) mm. The dimensions of the ground plane are \( W_G=34 \) mm and \( L_G=34 \) mm.

Figure 1(b) presents the simulated return loss obtained for this antenna. As we can see, we have an antenna which functions at 5.8GHz with a reflection coefficient under -30dB.

![Figure 1](image)

Figure 1. (a) Geometry of the proposed antenna (b)The reflection coefficient versus frequency

2.2. Antenna with DGS
Figure 2(a) presents the extracted equivalent circuit for the proposed DGS. By using the equations below (1), (2) and the theoretical part as explained in [14] we can calculate the various value of equivalent circuit illustrated in Figure 2(a).

\[
L = \frac{1}{4\pi^2 f_0^2 c}
\]

(1)

\[
C = \frac{f_c}{2z_0} \cdot \frac{1}{2\pi (f_0^2 - f_c^2)}
\]

(2)

With \( z_0 \) is the characteristic impedance of the microstrip line. \( f_o \) and \( f_c \) are the resonant frequency and the cutoff frequency respectively. Figure 2(b) shown the located place of DGS in the metallic ground plane, the position of DGS plays an important role in shifting the resonance frequency of the microstrip antenna previously presented in Figure 1(a).

Figure 2(c) illustrates the details of the DGS parameters in terms of values: the length and the width of ground plane where \( L_G=34 \) mm, \( W_G=34 \) mm, the separation between the inner and outer ring of the concentric rings shaped and different parameter of the rectangular slot are as follows: \( a=6.4 \) mm, \( b=3 \) mm, \( c=6 \) mm, \( d=5.9 \) mm, \( e=2.4 \) mm, \( f=1 \) mm, \( g=0.4 \) mm, \( h=0.8 \) mm.
3. Simulation Results

After the integration of DGS structure, as illustrated in Figure 3 the simulation result permits to obtain a good matching input impedance at 2.5 GHz with a value less than -30dB. We can see that the effect of the DGS technique allows to shift the resonant frequency from 5.8 GHz to 2.5 GHz, which permits to have at the end a miniature antenna.

3.1. The Surface Current

Figure 4 shows the distributions of the surface current of the proposed antenna associating with DGS elements at 2.5 GHz. As seen in Figure 4, the current density is more concentrated along the finally the DGS structure; however a large surface current density was observed over the structure without DGS.
3.2. Radiation Pattern and Gain results

Figure 5 illustrates the simulated radiation patterns of the proposed antenna with DGS at 2.5 GHz in H-plane and E-plane. Into simulation; we obtain a gain value equal to 1.75dBi of the proposed antenna at 2.5 GHz.

4. Fabrication and Measurement

After the validation of the proposed antenna into simulation, we have passed to fabrication. Figure 6 presents the photo of the achieved antenna with DGS having a volume of 34x34x1.6 mm$^3$. The proposed antenna structure with DGS is fabricated by using LPKF machine and tested by using Vector Network Analyzer (VNA) from Rohde & Schwarz.

The $S_{11}$ parameter was measured and compared to the simulated results. As we can see in Figure 7 the simulated and measured results are in agreement. The result presented in Figure 7 shows that the proposed antenna can be suitable for ISM applications at 2.5 GHz.
New Miniature Planar Microstrip Antenna Using DGS for ISM Applications (R. Er-rebyi)

5. Conclusion

In this paper, we have presented the miniaturization of a microstrip patch antenna by using DGS technique. The proposed antenna firstly was validated at 5.8GHz and after that shifted by integrating DGS structures to a frequency of 2.5 GHz which permits to reach at the end small dimensions. After the achievement and the test of the final miniature patch antenna we have obtained good agreement between simulation and measurement results. The final circuit is suitable for ISM applications.
Acknowledgements
We thank Mr. Mohamed Latrach Professor in ESEO, engineering institute in Angers, France, for allowing us to use all the equipment and solvers available in his laboratory.

References
[1] M Koohestani, M Golpour. U-shaped microstrip patch antennawith novel parasitic tuning stubs for ultra wide band applications. Microw. Antennas Propag. 2010; 4: 938-946.
[2] Homayoon Oraizi, Shahram Hedayati. Miniaturization Of Microstrip Antennas By The Novel Application Of The Giuseppe Peano Fractal Geometries. IEEE Transactions on Antennas and Propagation. 2012; 60(8): 3559.
[3] JP Gianvittori, Y Rahmat-Samii. Fractal antenna: A novel antenna miniaturization technique, and applications. IEEE Antenna Propagat. Mag. 2002; 44(1): 20-36.
[4] Dewan R, Rahim SKA, Ausordin SF, Purnamirza T. The improvement of array antenna performancewith the implementation of an artificial magnetic conductor (AMC) ground plane and in-phasesuperstrate. Progress in Electromagnetics Research. 2013; 140: 147-167.
[5] H Jiang, H Arai. Optimization of circular polarized patch antennawith cross-shaped slit. IEEE Antennas and Propagation SocietyInternational Symposium. 2002; 1: 418-421.
[6] Ningsih YK, Hadinegoro R. Low Mutual Coupling Dualband MIMO Microstrip Antenna Parasitic with AirGap. TELKOMNIKA Indonesian Journal of Electrical Engineering. 2014; 12(2): 405-410.
[7] Darsono M, Wijaya E. Circularly Polarized Proximity-Fed Microstrip Array Antenna for Micro Satellite. TELKOMNIKA Indonesian Journal of Electrical Engineering. 2013; 11(4): 803-810.
[8] Rahmadani, A Munir. Microstrip patch antennameasurements using artificial magnetic conductor. 2011 6th International Conference on Telecommunication Systems, Services, and Applications (TSSA). 2011: 219-223.
[9] H Oraizi, S Hedayati. Miniaturization of Microstrip Antennas by the Novel Application of the Giuseppe Peano Fractal Geometries. Antennas and Propagation, IEEE Transactions on. 2012; 60: 3559-3567.
[10] Arya AK, A Patnaik, MV Kartikeyan. Microstrip patch antenna with skew-F shapedDGS for dual band operation. Progress In Electromagnetics Research M. 2011; 19: 147-160.
[11] Kapoor S, D Parkash. Miniaturized triple band microstrip patch antenna with defectedground structure for wireless communication applications. International Journal of Computer Applications. 2012; 57(7).
[12] P Rocca, AF Morabito. Optimal synthesis of reconfigurable planar arrays with simplified architectures for monopulse radar applications. IEEE Trans. Antennas Propag. 2015; 63(3): 1048-1058.
[13] T Isernia, A Massa, AF Morabito, P Rocca. On the optimal synthesis of phase-only reconfigurable antenna arrays. Proceedings of the 5th European Conference on Antennas and Propagation (EuCAP 2011). Rome, Italy. 2011: 2074-2077.
[14] IJ Bahl, PBhartia. Microstrip Antennas. Dedham, MA: Artech House. 1980.