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A Miniature Microstrip Patch Antenna Array with Defected Ground Structure

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***Abstract*- The aim of this work is to miniaturize a microstrip patch antenna array resonating at 10 GHz. It presents an improved method of size reduction of a microstrip antenna array with circular polarisation using Defected Ground Structure (DGS) which is used to perform serious LC resonance property in certain frequency. By integrating Defected Ground Structure elements, the resonance frequency was shifted from 10 GHz to 7.5 GHz. The proposed structure of DGS is incorporated in the ground plane of our array antenna. Prototype of the antenna was fabricated with FR4 substrate and tested. The simulation and measurement results were in good agreement.**

***Index Terms*- Circular Polarization, DGS, Microstrip Patch Antenna.**

I. INTRODUCTION

Today, we find many applications which combine a lot of kinds of antennas. For Wireless integrated circuits, we find that the most used technology is the microstrip and coplanar configurations [1-5]. The microstrip technology is used in many applications such as satellite communication, military and civil purposes, and mobiles due to its compact shape, light weight and possibility of integration. The ability to have polarization diversity is an advantage found in patch antennas. Patch antennas can easily be designed to have vertical, horizontal or circular polarizations, using multiple feed-points, or a single feed-point with asymmetric patch structures. This unique property allows patch antennas to be used in many types of communications that may have varied requirements. [2]

Circular polarization is of paramount importance since we can have the same amplitude with phase difference of 90 degrees. This kind of polarization produces two orthogonal components $E\theta$ and $E\varphi$ with 90 degrees out of phase [6-10].

Recently, several methods have been proposed to miniaturize microstrip antennas saving their radiation performances such as DGS technique [11-20]. This method includes the use of high dielectric-constant material [21], the introduction of slots in the resonating patch [22-23], the integration of a single-layer patch into a two-layer structure [24], the inverted-F configuration, the quarter-wave-patch approach [25], the genetic algorithm [26], and the use of photonic band-gap materials [27]. When DGS is introduced in a microstrip antenna, the defect geometry etched in the ground plane disturbs its current distribution. This disturbance affects the transmission line characteristics such as the line capacitance and inductance. In other words, introducing DGS in a microstrip antenna can result in an increase of the effective capacitance and inductance which influences the input impedance and current flow of the antenna ; therefore reducing its size with respect to a given resonance frequency [28]. The military satellite communication uses this frequency in the X-band (8-12 GHz) which can be defined for the uplink from 7.9 to 8.4GHz and for the downlink 7.25 to 7.75 GHz as assigned by the International Telecommunication Union [29-30] and also for C-Band applications.

The aim of this work is to achieve a miniature antenna array with circular polarization by introducing DGS technique that allows us to shift

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the resonance frequency of our array antenna from 10 GHz to 7.5 GHz.

II. ANTENNA ARRAY WITH CIRCULAR POLARIZATION DESIGN

A. Microstrip Patch Antenna

The proposed microstrip patch antenna is shown in Fig. 1. The two truncated corners are used to obtain circular polarization [5]. This antenna is built on an FR4 substrate with 1.6mm height, the dielectric constant is 4.4 and the loss tangent is 0.021. The antenna is designed and optimized by using CST Microwave Studio tool. The simulated return loss obtained for this antenna is shown in Fig. 2. We can see that the adaptation is better than -10 dB in a resonance frequency equal to 10 GHz.

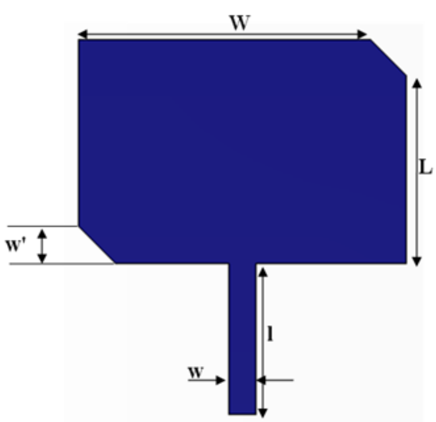

Fig 1. The microstrip patch antenna designed in CST-MW (L=5mm, W=8.13mm, l=4.21mm, w=0.75mm, w'=1mm)

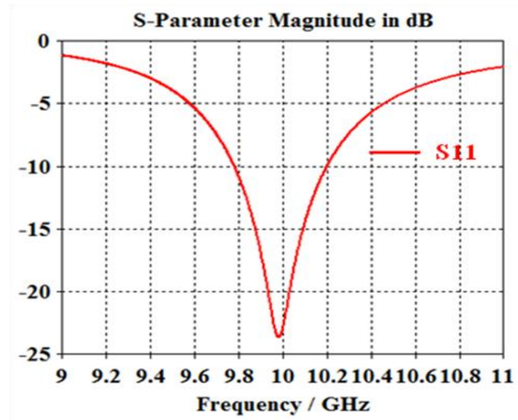

Fig 2. The return loss versus frequency

B. Microstrip Patch Antenna Array

The antenna array based on previous microstrip patch antenna associated with the calculated microstrip lines and power dividers is shown in Fig. 3. Its parameters are shown in table.1.

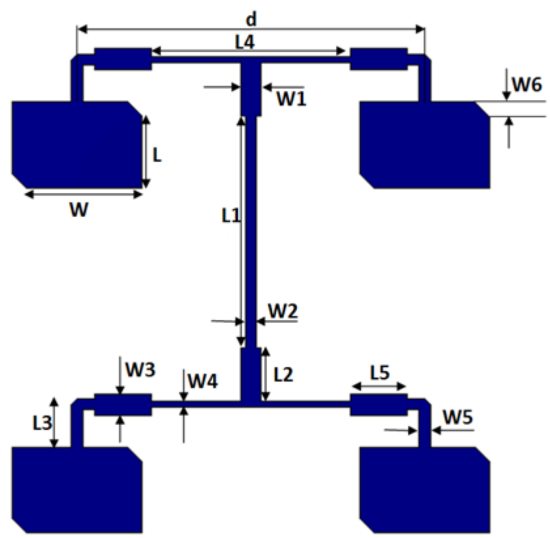

Fig 3. The Patch Antenna Array designed structure

The simulation return loss is illustrated in Fig. 4. As we can see, the resonant frequency is 10 GHz.

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Table 1. Dimensions of the antenna array

Parameter	L	W	L1	L2	L3	L4	L5
Value (mm)	5	8.13	16.2	3.79	3.38	14	4
Parameter	W1	W2	W3	W4	W5	W6	d
Value (mm)	1.47	0.76	1.47	0.42	0.76	1	24.48

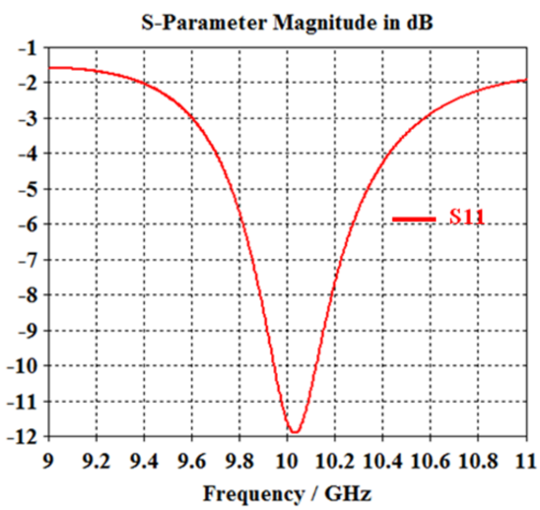
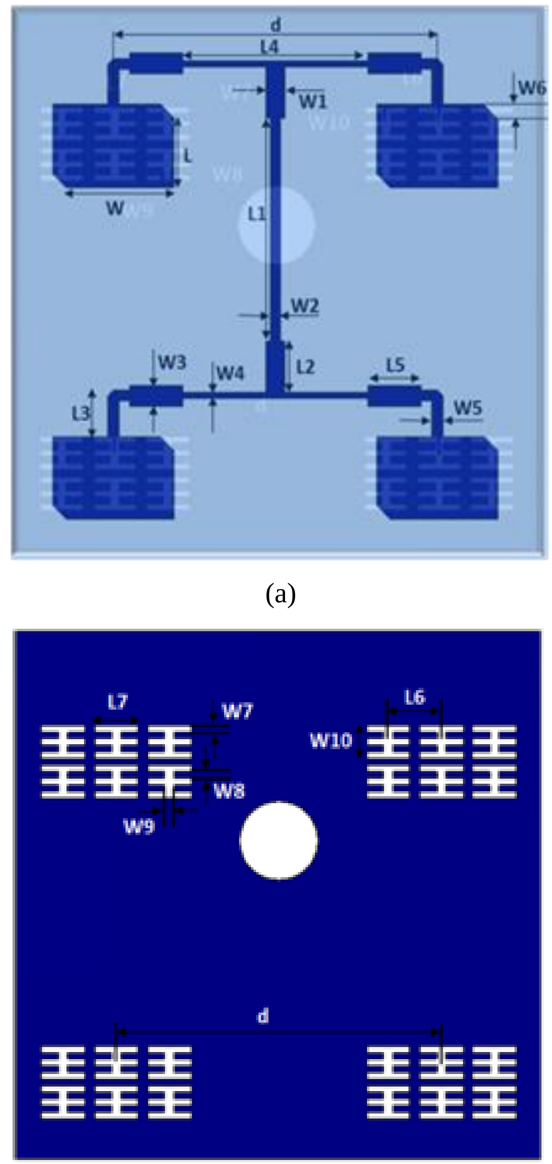


Fig 4. The return loss of the patch antenna array

III. MICROSTRIP PATCH ANTENNA ARRAY WITH DGS

As shown in Fig. 5. We introduce the DGS in order to shift the resonance frequency of the microstrip antenna array previously presented in Fig. 3. We study its effect on the antenna properties, specially the resonance frequency. CST Microwave Studio has carried out the simulations. In the absence of DGS, we have seen in the previous section that the resonance frequency of our microstrip patch antenna array is at 10 GHz. Now with DGS introduced, the simulation result obtained for the return loss is shown in Fig. 6. The resonant frequency is shifted from 10 GHz to 7.5 GHz with return loss of -17dB.

The DGS dimensions are listed in Table.2.



(a)

(b)

Fig 5. (a) Top view (b) bottom view of the antenna array with DGS

Table 2. Dimensions of the periodic DGS

Parameter	L6	L7	W7	W8	W9	W10	d
Value (mm)	4	3.3	0.5	0.5	0.7	2.5	24.48

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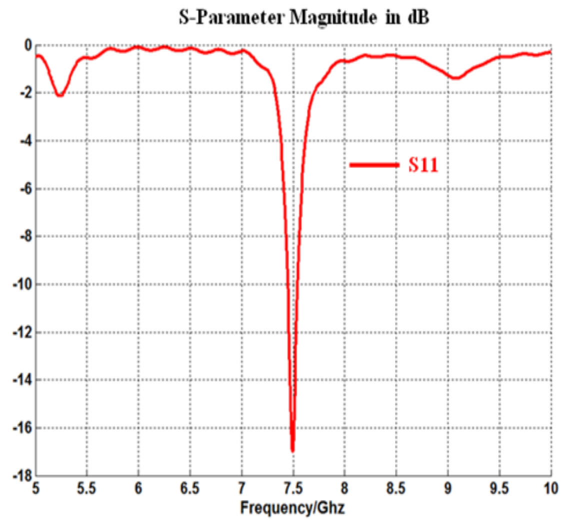
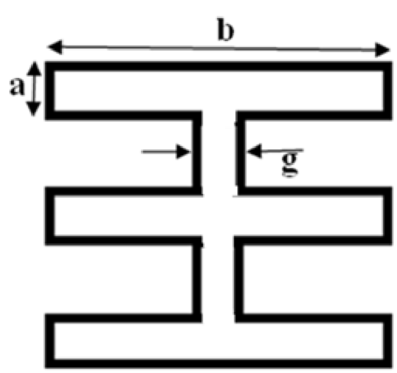
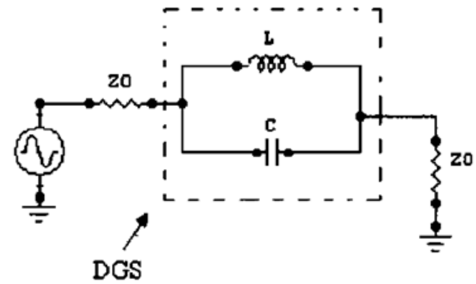


Fig 6. The return loss of the antenna patch array with DGS

The DGS structure used in our antenna is presented in Fig. 7(a), which is the simplest and mostly used dumbbell shaped DGS [11]. It is etched in the ground plane below the microstrip line. In general, the equivalent circuit of a DGS consists of a parallel tuned circuit in series with the transmission line to which it is coupled, as shown in Fig. 7(b). The varieties of attached area shapes have the same role and the same characteristics of miniaturization of size, stop band, slow wave effect and high impedance. And also they all have the same equivalent circuit [28].



(a)



(b)

Fig 7. (a) Dumbbell DGS unit cell, (b) L-C equivalent of DGS

The different elements of the equivalent circuit can be calculated by using the following equations [11] and the theory had been studied in detail in [28]:

$$L = \frac{1}{4\pi^2 f_0^2 C} \quad (1)$$

$$C = \frac{f_c}{2Z_0} \cdot \frac{1}{2\pi(f_0^2 - f_c^2)} \quad (2)$$

Where f0, fc and Z0 denote the resonant frequency, the cutoff frequency and characteristic impedance of microstrip line respectively.

IV. STUDY OF THE ANTENNA AT 10 GHZ AND THE DGS ANTENNA AT 7.5 GHZ:

A. *Radiation Pattern*

The radiation patterns presented in Figures 8 and 9 are obtained for the antenna without DGS at 10 GHz ; the gain obtained is about 11.1 dB and for our DGS antenna at 7.5GHz which the simulated gain is about 8.99 dB. This gain decrease is explained by the increase of lateral and longitudinal radiations due to the propagation of surface waves. Namely, these radiations adversely affect the main lobe power, and therefore a reduction of the gain is produced.

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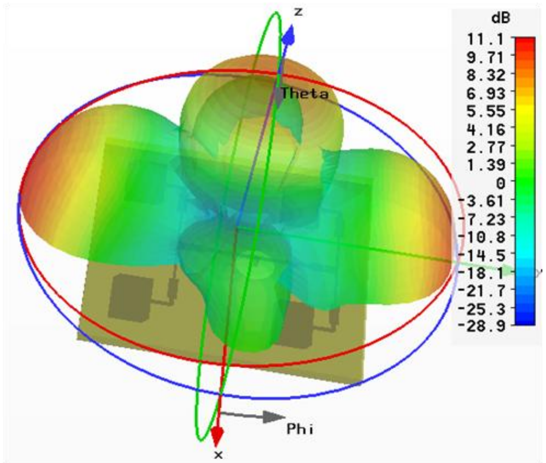

Fig 8. The radiation pattern at 10 GHz of the patch antenna array without DGS structure

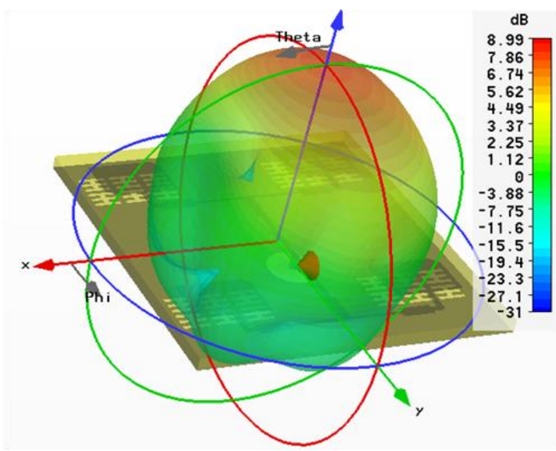

Fig 9. The radiation pattern at 7.5 GHz of the patch antenna array with DGS structure

B. Current Distribution

Figures 10 and 11, shows the current distribution of patch antenna with and without DGS respectively at 10 GHz and 7.5 GHz which present the density level of current at the surface of the patch array antenna. In conventional patch array antenna without DGS, a large surface current density was observed over the structure (Fig. 10). However, in patch array antenna with DGS, the current density was more concentrated along the DGS on the ground plane and the structure array elements on the top face (Fig. 11).

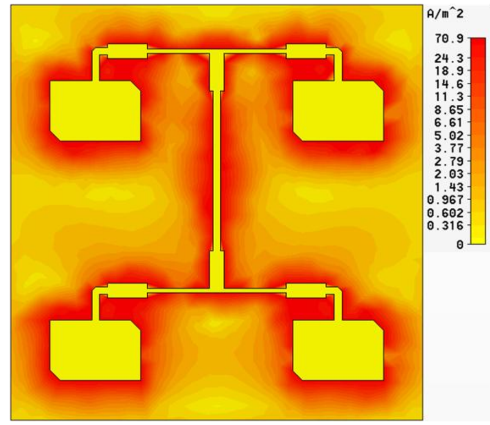

Fig10. The current density of patch array antenna without DGSs at 10 GHz

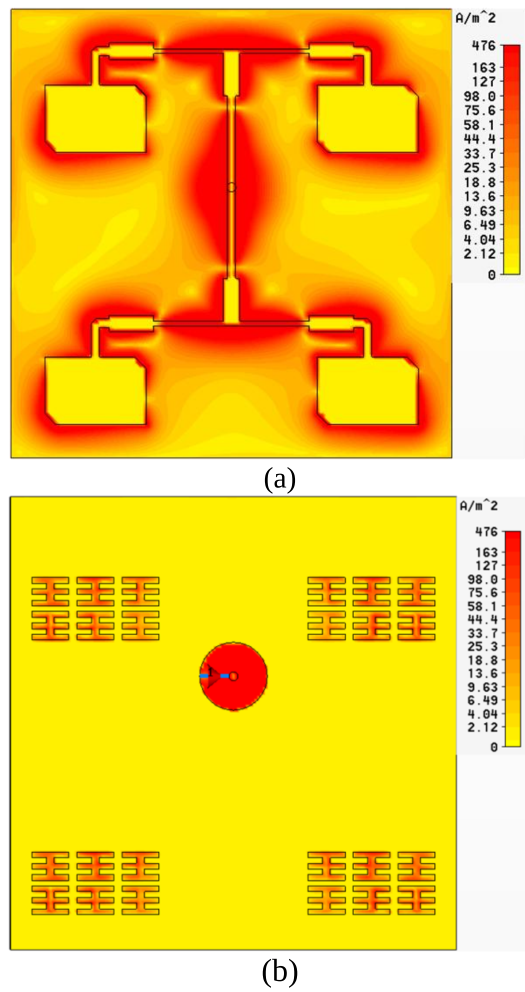

Fig 11. The current density of patch array antenna with DGS at 7.5 GHz: (a) top view, (b) back view

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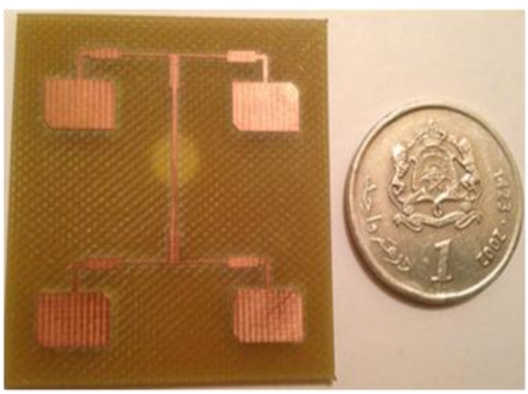
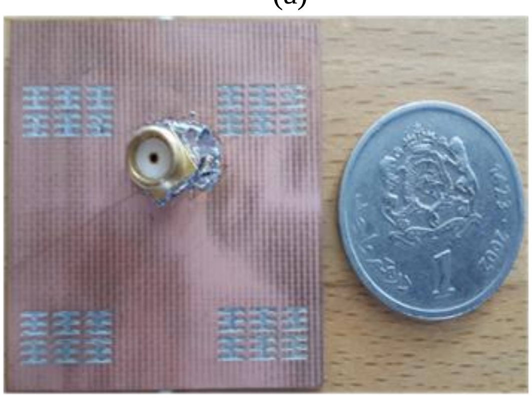
The defects on ground structure disturbs the current density resulting in a concentrated energy around the array antenna elements, Which decrease the resonance frequency from 10 GHz to 7.5GHz.

V. ACHIEVEMENT AND TEST

Shown in Fig. 12 is the size of the fabricated DGS microstrip antenna array that operates at 7.5 GHz. In order to measure the scattering parameters of the proposed antenna, we have been employing a Rohde and Schwarz ZVB 20 vector network analyzer whose frequency range is limited to 20 GHz.



(a)



(b)

Fig 12. Prototype of DGS antenna array (a) top view (b) bottom view

The designed antenna structure is fabricated and tested; the measurement and simulation results are in good agreement as shown in Fig. 13. The final circuit has a return loss of -17dB at resonance frequency equal to 7.5GHz.

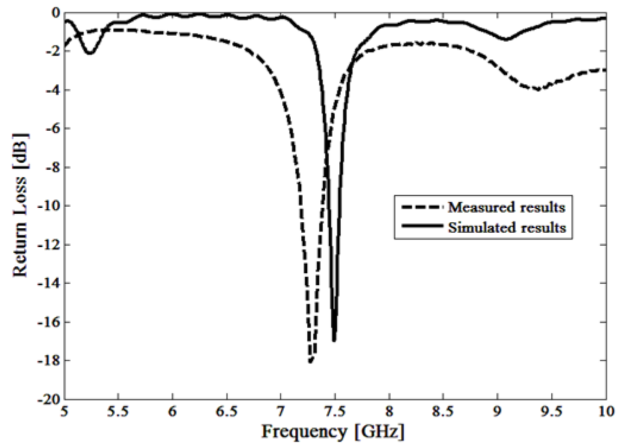


Fig 13. Measurement and simulation results for the antenna array with DGS resonating at 7.5 GHz

VI. CONCLUSION

In this paper we have carried out the design of a miniaturized antenna array with DGS structure. This antenna has good performances in terms of matching input impedance with radiation pattern. The resonance frequency of the initial antenna (without DGS) has been shifted from 10 GHz to 7.5 GHz after introducing DGS. Thus, by introducing DGS we have been able to reduce the antenna size up to 43.75 % as compared with the antenna without DGS.

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