

# A Modified Rectangular Mid-band Microstrip Slot Antenna for WLAN, WiFi and 5G Applications

D.O.I - 10.51201/12527

<https://doi.org/10.51201/12527>

Ajay Thatere<sup>\*1</sup>, Sachin Khade<sup>2</sup>, Vipul S. Lande<sup>3</sup>

<sup>1,2</sup>Yeshwantrao Chavan College of Engineering, Nagpur, India

<sup>3</sup>Shri Ramdeobaba College of Engineering and Management, Nagpur, India

**Abstract-** A modified rectangular Microstrip slot antenna for numerous applications like WLAN, Wi-Fi 5, satellite telecommunication and 5G application is portrayed. The proposed antenna has dimension of  $25 \times 30 \times 1.6 \text{ mm}^3$ . The structure consists of partial ground and DGS. The proposed design is embedded on FR4 lossy substrate having dielectric constant of 4.3 and thickness of 1.6 mm. Two similar inverted L shape CLLR are introduced at left and right edge of the ground plane to improve current distribution and to achieve wide bandwidth. The results like reflection coefficient, surface current, gain, directivity, VSWR, impedance and radiation pattern are found up to the mark.

**Keywords -** DGS, CLLR, slot antenna, Wi-Fi 5, radar, satellite, 5G.

## I. INTRODUCTION

Nowadays Microstrip slot antenna is one of the most used Microstrip antennas. Moreover, slot antennas are adding improvements. Slot antennas are preferable as most of the portion is cut out and compactness increases as size decreases. Mostly, slot antennas are linearly polarized. The size of slot, its shape offers various designs which can be helpful in tuning performance. In addition to all these, slot antenna offers omnidirectional radiation pattern

Slot antennas are very inexpensive to manufacture and design because of cut out sections and decreased size. Advantages like fabrication within metallic bodies, provision for covert communication with smaller transmitter is available.

Microstrip slot antennas are used for wide applications starting from wireless or satellite communication to medical system, as they are miniaturized, simple, inexpensive, conformable, light, low profile, reproducible and easy to integrate with most solid-state device [1-2]. Moreover, slot antenna has wider bandwidth and less conductor loss [3].

The Microstrip antenna has many disadvantages, mainly it has quite small bandwidth and to overcome these numerous methods are implemented [5]. Most antenna structures made for UWB applications face lots of challenges mainly in their radiation stability, impedance matching, and electromagnetic interference (EMI) problems, specifically the packed size design [6].

Etched slots or in other words defects on Microstrip circuit's ground plane are termed as Defected Ground Structure. A single or more than one defect over the ground plane can be referred as DGS. Firstly, DGS was said as filters underneath the Microstrip line. DGS is widely applied under the Microstrip line to achieve EBG characteristics. Moreover, it is used to vanquish higher mode harmonics and also suppress mutual coupling in MIMO antennas. After the successful execution of DGS in the filters field, in this era DGS is in demand as it can be implemented for various applications. The disturbances introduced on the ground plane disturb the current distribution of that plane. This phenomenon improves the characteristics of structures by adding some parameters like slot resistance, slot capacitance, and slot inductance to the line parameters. That means, any defect made in the ground surface under the Microstrip line changes the effective capacitance and inductance of Microstrip line as we add slot resistance, inductance and capacitance [7].

In this article we have designed a rectangular shaped slot antenna which is embedded on FR4 lossy having dielectric constant of 4.3 and thickness of 1.6 mm.

The dimension of the substrate is  $25 \times 30 \text{ mm}$  and thickness of 1.6 mm. Parameters such as  $S_{11}$ , VSWR, impedance, gain, directivity and surface current are studied.

## II. ANTENNA STRUCTURE

### A. Referred Design

The design of antenna is started with the dimensions of referred antenna [4] in the initial stage. The antenna has dimension of  $30 \times 30 \text{ mm}^2$  and thickness of 1 mm. Two Capacitive Loaded Line Resonators (CLLRs) are embedded on the left edge of the ground plane. Partial ground arrangement is made which has height of 9.6 mm and width of 30 mm displayed in the Fig.1b. A rectangular patch on the top surface of the substrate has size of  $15 \times 12 \text{ mm}^2$  and slot in patch has dimension of  $10 \text{ mm} \times 8 \text{ mm}$  as shown in the Fig.1a. The antenna has Microstrip line feeding and impedance is matched at 50 ohms.

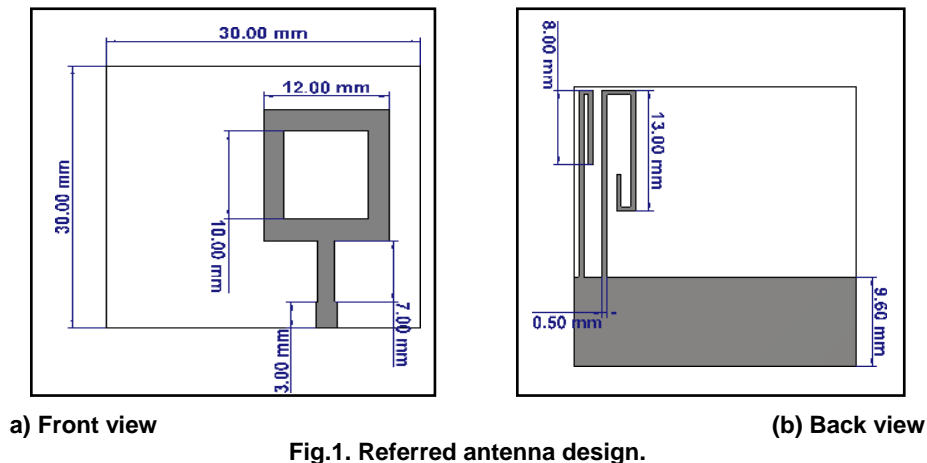


Fig.1. Referred antenna design.

The CLLRs possesses the width and gap of 0.5 mm. The length of CLLR 1 is  $20 + 1.5 + 8 = 29.5 \text{ mm}$ . The lengths tend to be nearby the value of  $\lambda_g/4$  for the corresponding resonance [14].  $\lambda_g$  can be determine by

$$\lambda_{gg} = \frac{cc}{ff \epsilon_{eff}}$$

$$\epsilon_{eff} = \frac{(\epsilon_r + 1)}{2}$$

Where,

$\epsilon_r$  and  $\epsilon_{eff}$  are relative and effective permittivity of Substrate,  
 $c$  is velocity of light and  $f$  is the resonance frequency.

### B. Proposed Design

The proposed design in this paper is highly miniaturized and covers a wide bandwidth. The structure has few modifications, the dimension of substrate is reduced to  $25 \text{ mm} \times 30 \text{ mm}$ , the thickness of dielectric is changed to 1.6 mm, the rectangular patch is at the middle of the substrate, in the ground plane the DGS structure is introduced which has a dimension of  $3.9 \text{ mm} \times 3.4 \text{ mm}$  just behind the Microstrip line and two symmetric CLLRs like stub are attested on the partial ground plane as shown in the Fig.2a and Fig.2b.

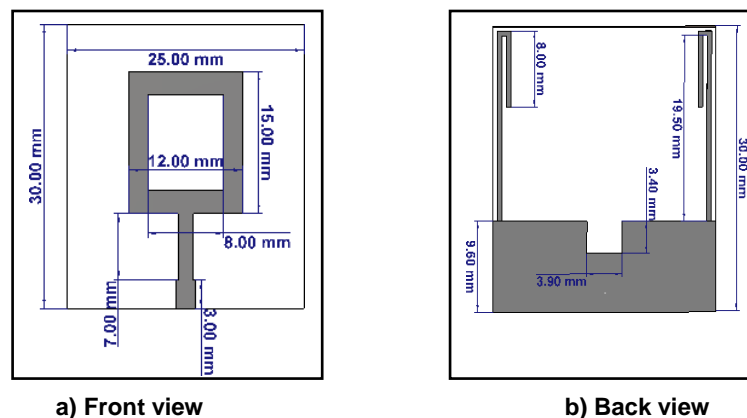


Fig.2. Proposed Antenna Design.

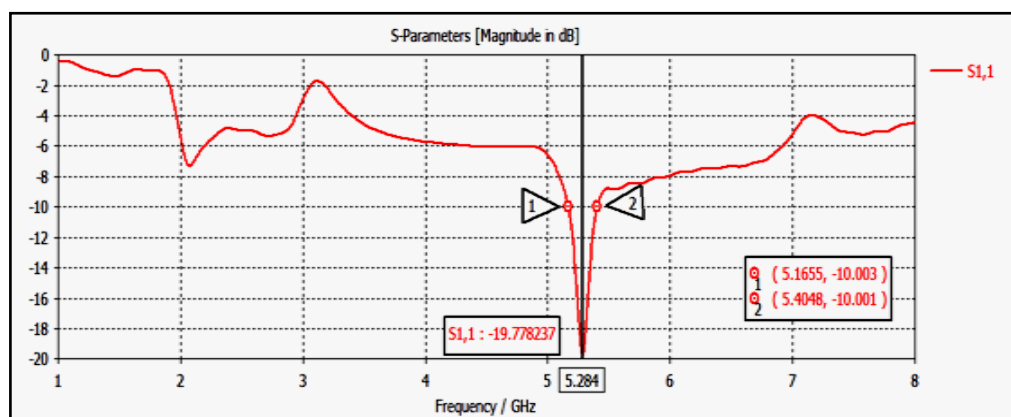
**Table 1.1. Size Comparison**

Parameters	Referred Design	Proposed Design
Substrate Dimesnsions	30 mm × 30 mm	25 mm × 30 mm
Ground Dimesnsions	30 mm × 9.6 mm	30 mm × 9.6 mm
Dielectric height	1 mm	1.6 mm
CLLR	0.5 mm × 20 mm	2 × 0.5 mm × 20 mm
DGS	-	3.9 mm × 3.4 mm
Length of Feed line	21 mm	17.5 mm

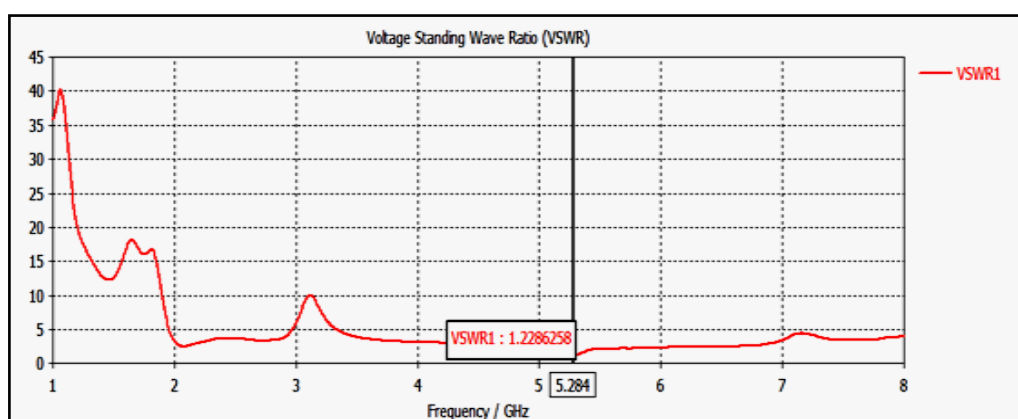
### III. SIMULATION RESULTS

#### A. Referred Design simulation

Antenna referred is designed on simulation software name Computer Simulation Technology (CST) Microwave Studios. Simulation results consisting of various antenna parameters like-  $S_{11}$ , VSWR, Gain, Directivity, etc.

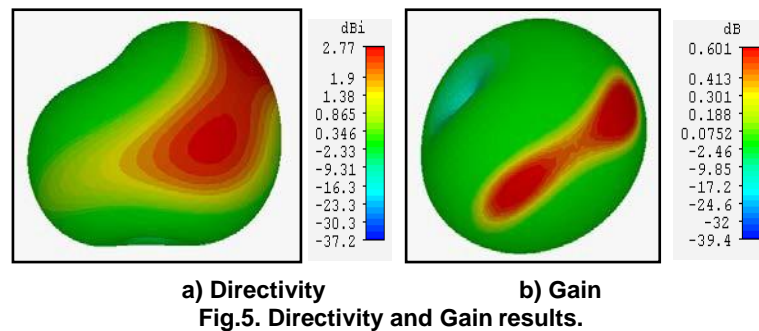
**Fig.3. S-parameter results.**

The above Fig.3, shows the s-parameter graph in which we can observe frequency band pattern. The observed frequency band range from 5.16-5.40 GHz with resonance at 5.284 GHz. The bandwidth is around 0.3 GHz. This narrow frequency band is used in various applications like 5G communication, mobile communication and WiFi.

**Fig.4. VSWR results at various resonance frequency.**

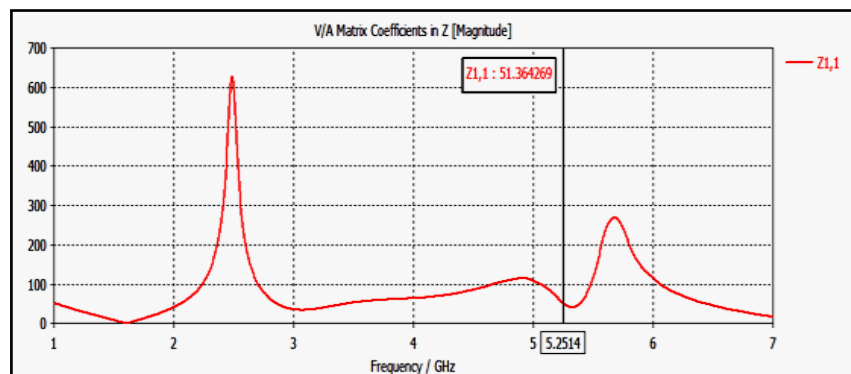
The above Fig.4 depicts the Voltage Standing Wave Ratio (VSWR) at the resonant frequencies. The observed value is around 1.2. The maximum allowed VSWR is 2 and ideally its value is 1.

Fig.5a depicts the directivity at 5.284 GHz resonant frequency and Fig.5b portrays the gain at same frequency. Directivity observed is around 2.77 dBi and gain is 0.6 dB.

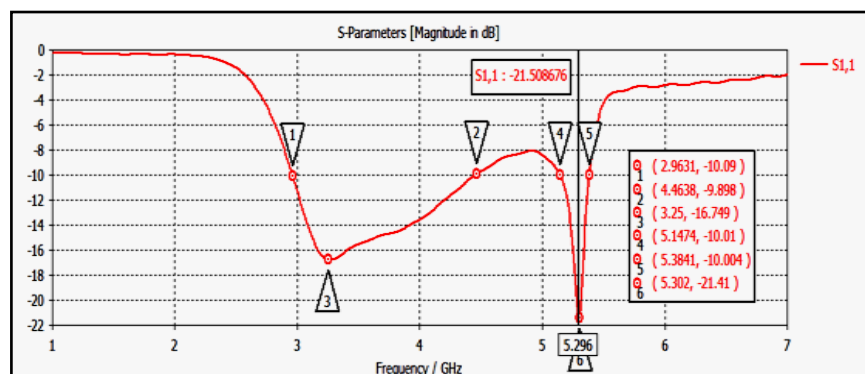


## B. Proposed Antenna simulation

The Fig.6, shows the s-parameter graph in which we can observe frequency band pattern. The obtained dual frequency band range from 2.96-4.5 GHz with resonance at 3.25 GHz and 5.14-5.38 GHz with resonance at 5.29 GHz i.e same resonant point as that of referred design. The bandwidth is around 1.5 GHz and 200 MHz respectively. This dual frequency band is used in various applications like 5G communication, mobile communication, WiFi, WLAN, etc.



The impedance at 5.3 GHz frequency is 51  $\Omega$  which is approximately equal to the ideal 50  $\Omega$  impedance. Impedance matching is essential for power handling and low loss and beneficial for the antenna to work properly practically.



Surface current simulation result at 5.3 GHz is shown in the Fig.8. We can observe the flow of current from the input depicted by arrows and the density of current is very high up to 378 A/m due to CLLRs. The most of the current is rush around the CLLR which is responsible of generation of first band and also the band width is enlarge and hence covers middle band applications like - 5G communication, mobile communication, WiFi, WLAN.

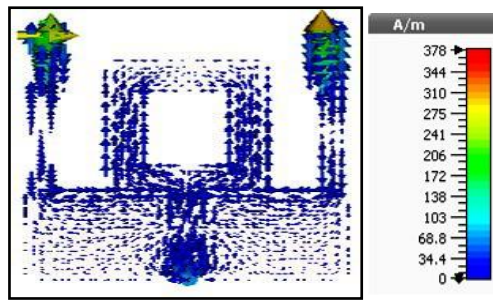


Fig.8. Surface current at 5.3 GHz.

The below Fig.9 depicts the Voltage Standing Wave Ratio (VSWR) at the resonant frequencies. The observed value is around 1.18. The maximum allowed VSWR is 2 and ideally its value is 1.

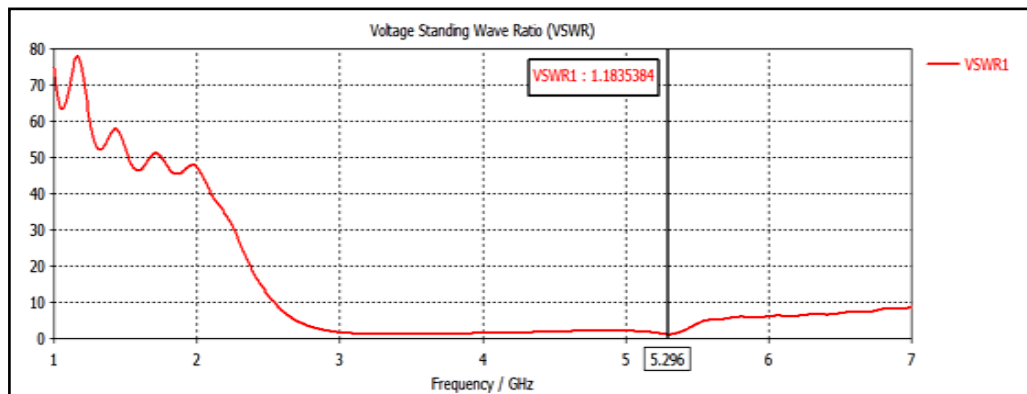


Fig.9. VSWR results of proposed antenna.

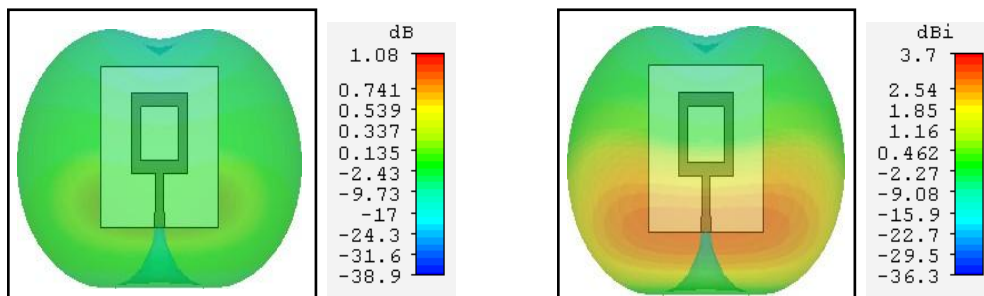


Fig.10. Simulated Gain & Directivity at 5.3 GHz.

A 3D view of simulated gain at 5.3 GHz is portrayed in the Fig.10. At this frequency the gain and directivity of around 1.08dB and 3.7 dBi respectively is achieved. Gain and directivity is medium at this resonance frequency because of the radiation pattern as shown in Fig.11 below.

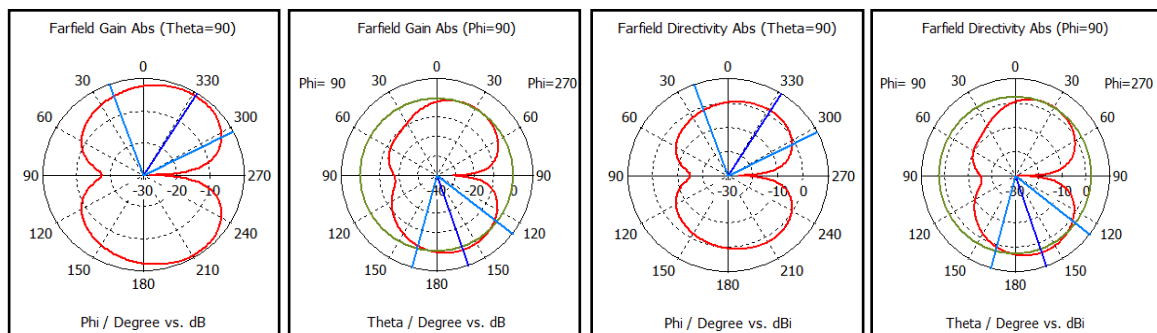


Fig.11. Radiation pattern at constant phi and theta.



Now we will have a look at gain and directivity measurements at 3.8 GHz frequency. Here we can see in Fig.12 that gain and directivity achieved is approximately around 2.6 dB and 2.89 dBi respectively. This frequency has application in 5G n78 band with 3.3-3.8 GHz as uplink and downlink frequency covering around 500 MHz bandwidth.

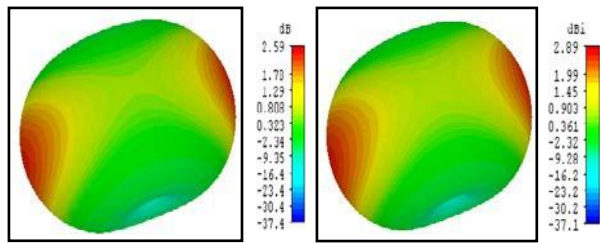


Fig.12. Gain & Directivity at 3.8 GHz.

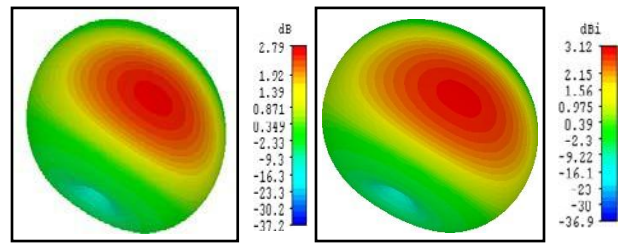


Fig.13. Gain and Directivity at 4.4 GHz.

Another frequency of 4.4 GHz has attained gain of 2.79 dB and directivity of 3.12 dBi, depicted in the Fig.13. Gain and Directivity is higher as compared to previous frequencies. This frequency is allotted for 5G in various Asian countries like China and Japan. The 5G n79 having uplink frequency of 4.4 GHz and downlink frequency 5 GHz.

#### IV. CONCLUSION

The behavior of proposed rectangular slot antenna is studied on the basis of miniaturization and insertion of various defects as well as parasitic elements like EBG and symmetric CLLRs. In the referred antenna a frequency band range of 5.16-5.4 GHz is observed in the reflection coefficient results with resonance at 5.284 GHz. Where as in proposed structure, we got dual frequency bands of range 2.96-4.5 GHz and 5.14-5.38 GHz. Two similar inverted L shapes CLLR are introduced at left and right edge of the ground plane which improves current distribution and provide wide bandwidth. The antenna results are analyzed on the basis of reflection coefficient, surface current, gain, directivity, VSWR, impedance and radiation pattern. The gain and directivity were near about same as per referred one, but most of the communication applications is covered in the proposed antenna. The Proposed antenna is useful for WLAN, WiFi and 5G applications.

#### REFERENCES

- [1] C.A.Balanis, *Antenna Theory Analysis And Design*, 2<sup>nd</sup> Edition, Wiley India (P.)Ltd.2007.
- [2] A.Lozada and S. Donglish, "Microstrip antenna for satellite communication", In *International symposium on Antennas, propagation and EM theory* (2008), pp. 1-3
- [3] A. Chinchole and S. Khade, "A Wideband Slot Antenna with Simple Structure," *2020 International Conference on Emerging Trends in Information Technology and Engineering (ic-ETITE)*, Vellore, India, 2020, pp. 1-5, doi: 10.1109/ic-ETITE47903.2020.338.
- [4] Sharma, Ritu & Shah, Dharti. (2016). *Design A Dual Band Rectangular Slot Microstrip Patch Antenna For Bluetooth and WLAN Applications Using CLLR Technique*.
- [5] S. A. Schelkunoff, H.T.Friss, *Antennas: Theory and Practice*, New York: John Willy & Sons, 1952.
- [6] Lizzi, L., G. Oliveri, and A. Massa, "A time-domain approach to the synthesis of UWB antenna systems," *Progress In Electromagnetics Research*, Vol. 122, 557-575, 2012.
- [7] Mukesh Kumar Khandelwal, Binod Kumar Kanaujia, Sachin Kumar, "Defected Ground Structure: Fundamentals, Analysis, and Applications in Modern Wireless Trends", *International Journal of Antennas and Propagation*, vol. 2017, Article ID 2018527, 22 pages, 2017.
- [8] Guihong Li, Huiqing Zhai, Tong Li, Xiaoyan Ma, and Changhong Liang, "Design of a compact UWB antenna integrated with GSM/WCDMA/WLAN bands," *Progress In Electromagnetics Research*, Vol. 136, 409-419, 2013.