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A Mechanism to Enhance Antenna Performance using Notch and Defected Ground Structure

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Abstract

Objectives: This paper has proposed the mechanism to enhance antenna performance. The antennas are designed to be applied in communication devices. **Methods/Statistical analysis:** The proposed antenna characteristics had been analyzed by means of Finite Difference Time Domain (FDTD) method and had been fabricated by photolithography method on FR-4 Printed Circuit Board (PCB). Both simulation and measurement result show that the proposed antenna had three resonant frequencies 2.45GHz, 3.75GHz, and 5GHz with Return Loss (RL) are -40dB, -25dB and -20dB, respectively. **Findings:** All four antenna designs show characteristics of the mechanism. The antenna 1 is the reference design, after the first mechanism of antenna 2 which is to give the notch line on the both side of the antenna 2. The improvement of this first mechanism shows the RL. The second mechanism is rotated 60 degrees of the resonator of the antenna 2, show that the surface current adds more significant and give better RL. The third mechanism adds the defected ground structure on the both ground plane, the result gives the antenna a better RL from all the mechanism. The mechanism steps that applied on proposed antenna give enhance on such as RL, bandwidth, and radiation pattern. **Application/Improvements:** The radiation patterns show the omni direction in frequency 2.45 GHz and bi-direction in both 3.75 and 5 GHz with HPBW around 80 degrees. The proposed antenna was suitable for communication devices.

Keywords: Communication, Defected Ground Structure (DGS), Finite Different Time Domain (FDTD), Microstrip Antenna, Return Loss, Radiation Patterns

1. Introduction

In recent years, the wireless communication system has been more complex, a multiband resonance is needed to fulfill that requirement. There are many electronics device which is needed a complex communication system such as a lap top, mobile phone et al. Because of can be used for many applications, a compact antenna design becoming very popular day by day. Using different geometry and passive element to enhance the performance are more likely. With that thing, the antenna is expected to gain more resonance frequency (multiband)[1–3]

A similar method is also expected to simultaneously enhance the antenna performance. Range frequency WLAN, WiMax, and LTE are widely used today. All this frequency area is designed to be achieved in this paper. The method has ever done to achieved this requirement is fractal structure, notch, and slit to the radiator or ground plane[4–6]

In this research, an antenna designed to gain frequency resonance in the area WLAN, WiMAX and LTE 2500.The radiator of antenna shaped the hexagonal that is connected with a coplanar a waveguide strip line as a link between connectors and antenna. On both sides, strip line is ground plane antenna system, whereby on the

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ground plane was appended a pair of a gap or Defected Ground Plane (DGP) and with the radiator is notch line that used to direct the electromagnetic fields before being released into the air so that power loss becomes smaller[7].

The hexagonal antenna also modified to obtain a better result on current distribution with rotation 30°. In this ground plane of the antenna are applied a U-shaped DGS element. Accordance to the current distribution which is through the ground plane generated the electromagnetic interfering that radiated to space. The particles warm optimization used to get the compact size for the antenna[8]

Fabricated the antenna in this paper is using an FR-4 material which has relative permittivity 4.4 and loss tangent 0.02, the thickness of the material is 1.6 mm. The substrate size of this antenna is 60 mm x 80 mm x 1.6 mm. To get matched characteristic impedance 50-Ohm, the antenna is used a CPW-fed with the width 3 mm.

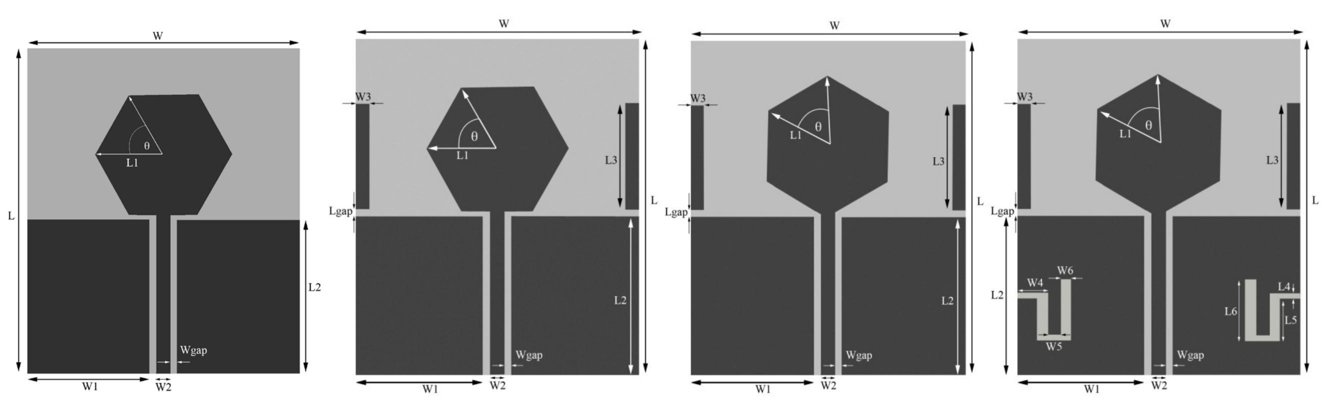
2. Antenna Design

There are four antennas in this paper, antenna 1 is designed as hexagonal shaped with monopole characteristics,this is called reference antenna[9]. Antenna 2 – 4 is a modification of the antenna 1 to obtain a better result. Figure 1 shows all proposed antenna[10].The fixed parameter structures of the antenna with the coordinate as in Figure 1 can be seen in Table 1.

Figure 1 illustrates the difference between antennas 1 to 4; the first mechanism to obtain a better result in this paper is putting some notch beside the radiator element (antenna 2). The basic idea of this notch is to guide the electromagnetic field from the antenna into space, so that the antenna can radiate power more effectively. The second mechanism is rotating the radiator element with 30º, to get a better current distribution on that area of radiator and transmission line. The third mechanism in this paper is placed on the ground plane of the antenna, a full discussion about this will be placed on the result and discussion results[11–13].

Table 1. Antennas parameter

Parameters	Value (mm)	Parameters	Value (mm)
w_1	27	L_{gap}	1.5
w_2	3	L_1	14.4
w_3	3	L_2	33
w_4	6.8	L_3	10
w_5	5	L_4	1
w_6	2.2	L_5	16.7
w_{gap}	1.5	L_6	11.7
w	60	L	80



a) Antenna 1 b) Antenna 2 c) Antenna 3 d) Antenna 4

Figure 1. The proposed antenna.

3. Antenna Analysis and Simulation

All proposed antenna were simulated by means of Finite Difference Time Domain (FDTD) method to analysis and characterize all aspect of the antenna. Comparison between antenna 1 and 2 after addition of the parasite element can be seen in Figure 2; the parasite element on antenna 2 guides the radiated power to space, but also absorbs some power into it.

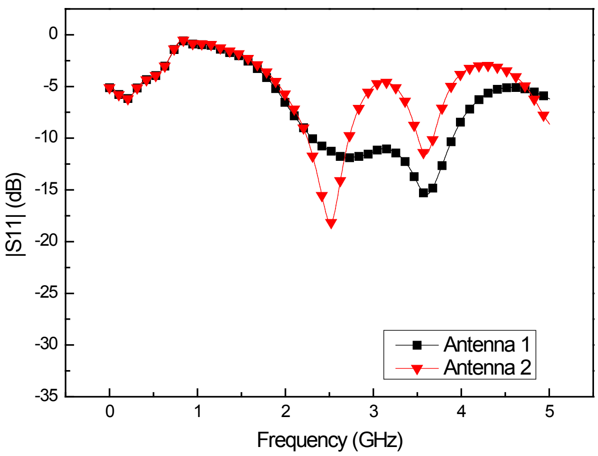
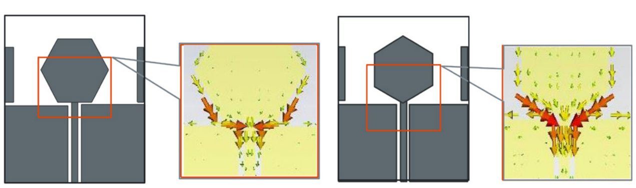


Figure 2. RL of the antenna 1 and 2.

The next step of this mechanism is rotating the radiator of the antenna. Comparison between antenna 2 and 3 after rotating the radiator, can be seen that antenna 3 has quite different in current distribution as we can see in Figure 3.



(a) Antenna 2 (b) Antenna 3

Figure 3. A distribution current of the antenna 2 and 3

Figure 3 had shown the distribution current that flows in antenna 2 and 3.The different path of surface current distribution on radiator element is quite significant. On the edge side between thetransmission lineand radiators, show the current on antenna 2 which flow in x-axis will cancel out and it will reduce the signal from radiators to a transmission line. On the antenna 3, the surface current has two axis component x and y and will give a better signal received than antenna 2. Figure 4 shows the rotational effect that caused from the third mechanism. After rotating, the antenna 3 are indicated has a better result on Return Loss (RL) from antenna 2 and it has a value about -33dB.

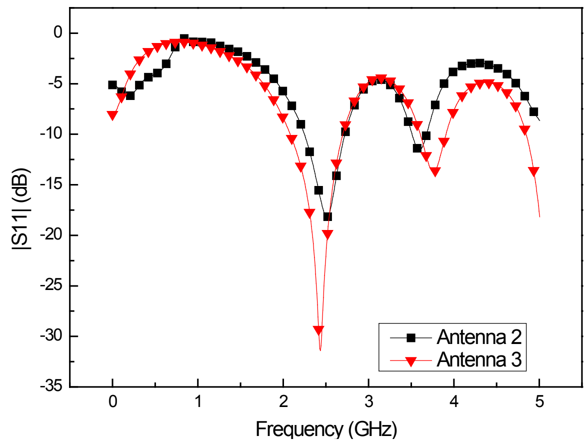


Figure 4. Rotational effect on proposed antenna.

To complete the mechanism on this proposed antenna, U-shaped DGS has been added to the design and called antenna 4.The detailed geometry of the antenna 4 is present in Figure 1. The DGS structure are applied on both ground plane of the antenna and already mentioned at the beginning that is, with the addition of these DGS forms, through which current distribution will be transformed into harmony between the time that the signal antenna radiated into the air with the signal that return after the antenna radiates the signal, the effect is the loss of power is becoming increasingly small between with the three other antenna types. Loss of power that is increasing can be seen in Figure 5. Figure 6 is seen that antenna 4 changes the characteristic impedance at the frequency of 1.5-2 GHz14,15.

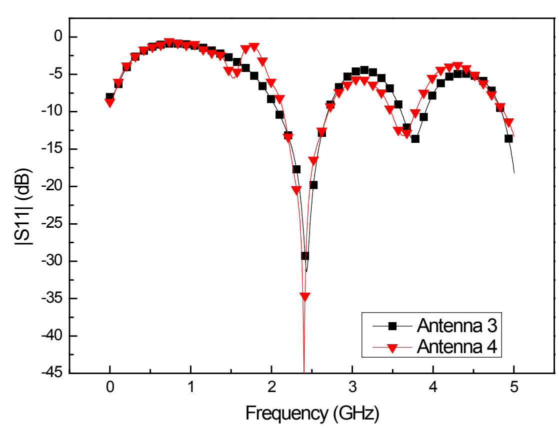


Figure 5. U-shaped DGS effect on the proposed antenna

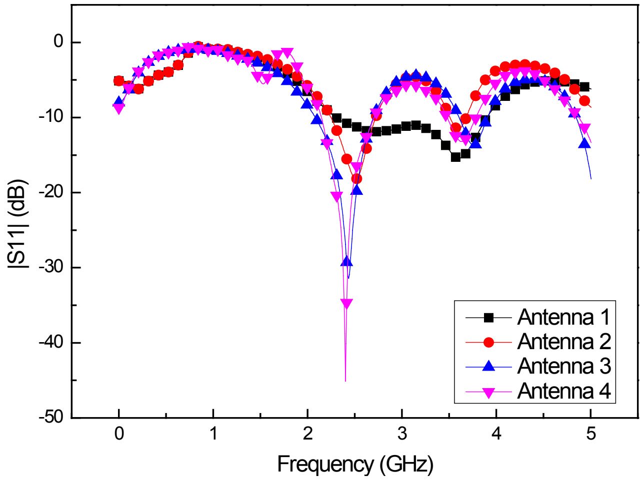


Figure 6. Comparison result of the all antennas.

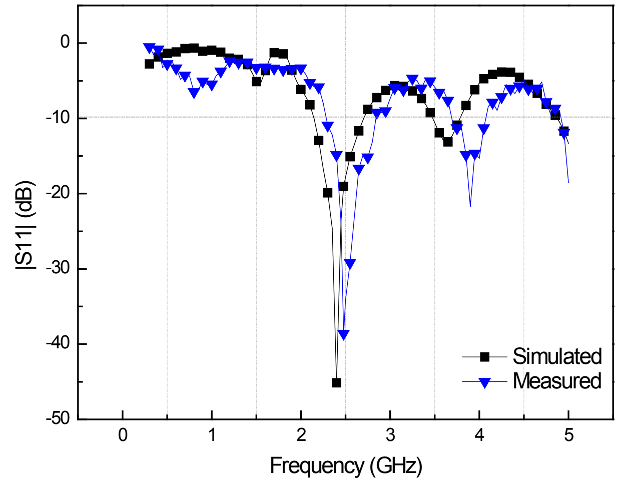


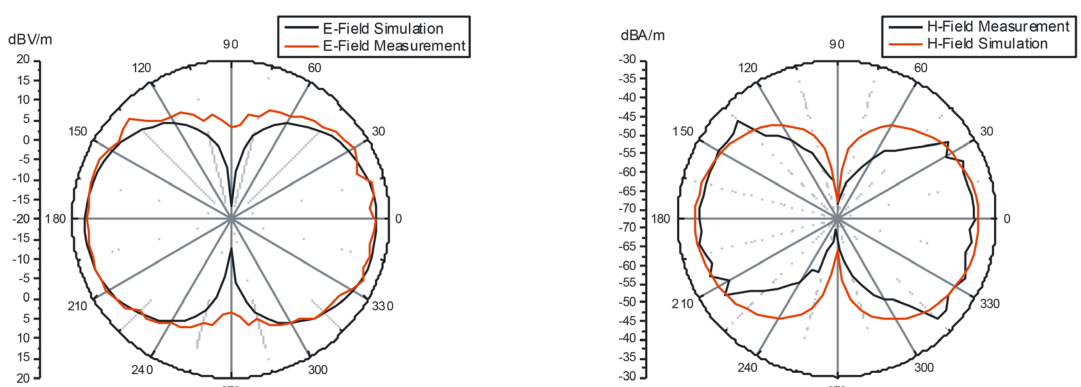
Figure 7. Comparison result of the proposed antenna.

4. Result and Discussion

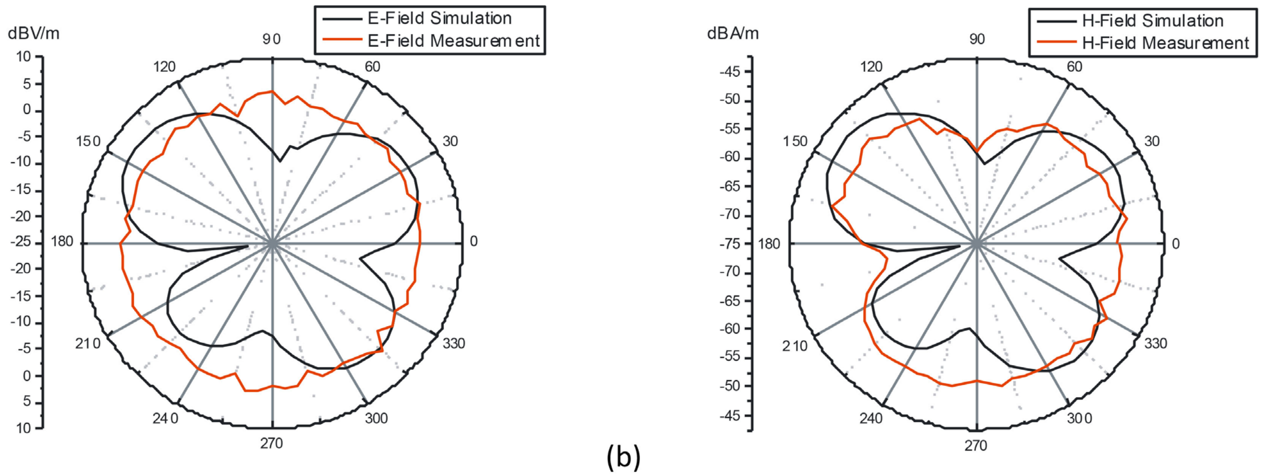
The proposed antennas are designed with anFR-4 substrate which has permittivity 4.4 and to obtain a low-cost antenna fabrication. From the structure has been added on antenna 4, the surface current flow is more stable and it gives a significant result for it. The U-Shaped DGS structure also generated to guiding signal from radiator to the feeding point. On Figure 6, can be seen the comparison of all proposed antenna. All of them have a three basic resonance frequency in that range. The resonant frequencies of the antenna are at 2.4 GHz, 3.5 GHz, and 5 GHz. The first resonance shows that U-Shape DGS give an effect on RL just like discussed before. This impact is generated from current distribution on the vertical shape of the DGS because it's designed to give and effect on 2.4 GHz range. The second impact after DGS addition is on range 5 GHz. However, these impacts not only affect The RL and impedance of the antenna but also their bandwidth.

The comparison returns loss between simulated and measurement results of antenna 4 shown in Figure 7. It can be seen by calculating the comparison that the antenna has difference results or error of about 1.4% of the simulation. Triple band antenna also obtained in accordance with the simulation that is located at a frequency of WLAN with RL -38 dB, LTE 2500 with a value of -30 dB and WiMax -20 dB.

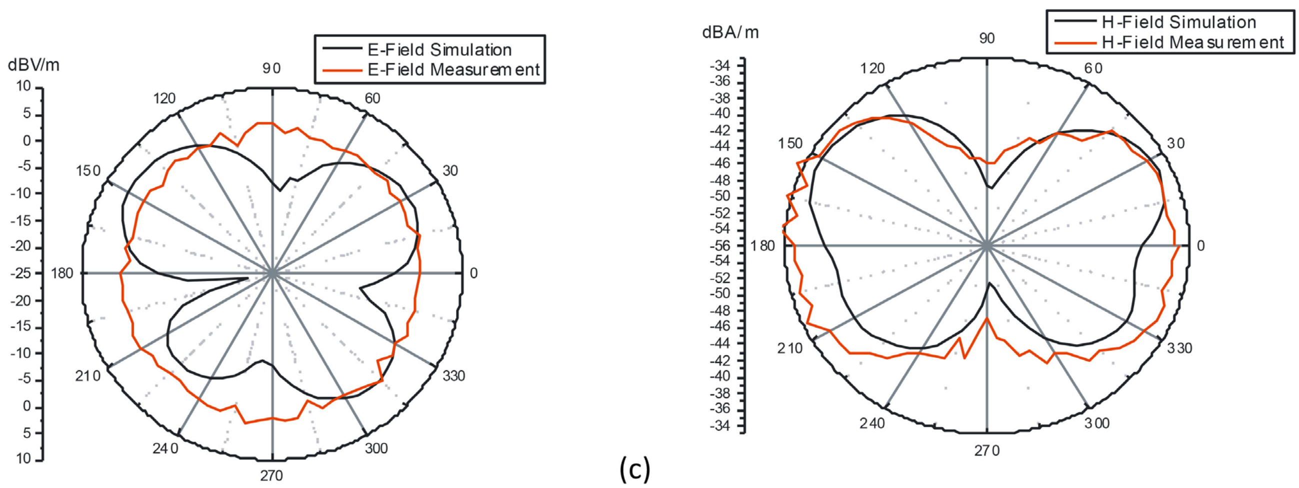
From the result of the antenna 4 can be analyzed that the efficiency on WLAN range is obtained a good result and have a value 85%, for LTE 2500 range has a value 95% and for WiMax range has a value about 84%. Now, we analyzed the radiation pattern characteristics of antenna 4. The CPW-fed design gives the antenna a bi-directional radiation pattern and has been plotted in a different frequency range. Figure 8 is a simulated and measurement result from radiation pattern on frequency 2.4 GHz, 3.5GHz,and 5GHz.The radiation patterns show omni direction in frequency 2.45GHz and bi-direction in both 3.5 and 5 GHz with HPBW around 80 degrees.



(a)



(b)



(c)

Figure 8. E-Field and H-Field pattern (a) 2.4 GHz; (b) 3.5 GHz; (c) 5 GHz.

5. Conclusion

A mechanism to enhance antenna performance has been proposed. The result from the measurement of the antenna has a good comparison with the simulation. The final mechanism gives the antenna to operate in triple band frequency which is WLAN, LTE 2500 and WiMax.

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