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RESEARCH PAPER

Compact ACS-fed antenna with DGS and DMS for WiMAX/WLAN applications

KALIKUZHACKAL ABBAS ANSAL AND THANGAVELU SHANMUGANANTHAM

A novel compact asymmetric coplanar strip fed planar antenna with defected ground structure and defected microstrip structure for dual band application is presented. The proposed antenna is composed of defect in both ground plane and radiating strip. The antenna has an overall dimension of 21 × 15.35 × 1.6 mm^3 when printed on a substrate with dielectric constant of 4.4 and loss tangent of 0.02. The antenna resonating at two different frequencies of 3.5 and 5.5 GHz is covering worldwide interoperability microwave access and wireless local area network bands. The planar design, simple feeding technique, and compactness make it easy for the integration of the antenna into the circuit board. Details of the antenna design, simulated, and experimental results are presented and discussed. Simulation tool, based on the method of moments (Mentor Graphics IE3D version 15.10) has been used to analyze and optimize the antenna.

Keywords: Antennas and propagation for wireless systems, Antenna design, Modeling and measurements

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I. INTRODUCTION

The rapid growth in the development of wireless portable gadgets for high data rate communication has gained more attention toward the development of wireless antennas. Especially for wireless local area network (WLAN, 2.4–2.48, 5.15–5.35, and 5.72–5.85 GHz) and the worldwide interoperability microwave access (WiMAX, 2.5–2.69, 3.40–3.69, and 5.25–5.85 GHz) frequencies. Many types of planar antennas for different user requirements have been reported in the literature [1–21]. An asymmetric coplanar strip (ACS) fed compact monopole antenna for WLAN and mixed band mobile communication application was proposed [1]. An F-strip ACS-fed geometry was proposed for dual-band application [2]. A dual-band design which is embedded by electromagnetic band gap (EBG) for WLAN was reported [3]. Triple-band slot antenna with U-shaped open stub for WLAN and WiMAX was proposed [4]. A compact monopole antenna with double meander line was proposed for WLAN application [5]. These designs however, have complex structures and are difficult to integrate with WLAN systems. Hence, this paper mainly focuses on the design and development of miniaturized and simple structure which operate on WiMAX and WLAN frequencies. Here the proposed antenna is composed of a defected exciting strip and lateral ground plane in addition to that an open ended slit and a half dumbbell-shaped slots by which the defects are realized. The mentor graphics IE3D electromagnetic (EM) solver is used for the simulation, analysis, and optimization of the proposed structure.

In this work, miniaturization is achieved using ACS feeding and defected structure. The feeding mechanism of an antenna is a critical factor as far as the compactness is concerned. Normally in coplanar waveguide (CPW), the feed structure consumes much of the overall antenna dimension. In the proposed antenna design, a compact and effective feeding technique is employed. The ACS feed used here has all the advantages of a uniplanar feed along with compactness. This feeding mechanism analogous to the CPW feed except the ACS feed has a single lateral ground plane compared with the twin lateral ground plane in the CPW feed. The use of discontinuities in ground planes of planar transmission lines was currently employed to improve the performance of different passive circuits, size reduction of amplifiers, the enhancement of filter and antenna characteristics, and applications to suppress harmonics [6–14]. On the other hand, a new proposal called defected ground structure (DGS) and defected microstrip structure (DMS) has been successfully used in reducing the size and tuning the patch antennas to the desired band of operations.

DGS is an etched periodic or non-periodic one-dimensional or two-dimensional cascaded or non-cascaded configurations. It is located on the ground plane of a planar transmission line (e.g. microstrip, coplanar, and conductor-backed CPW), which disturbs the shield current distribution in the ground plane, and this disturbance will change the characteristics of a transmission line such as line capacitance and inductance. In brief, any defect etched on the ground plane of the planar transmission line can give rise to increase in the effective capacitance and inductance. Here DMS and DGS are configured as a spur line and dumbbell, respectively. The configuration of the proposed defect and its equivalent circuit is shown in Fig. 1 which is described by the slot of width (W) and length (L).

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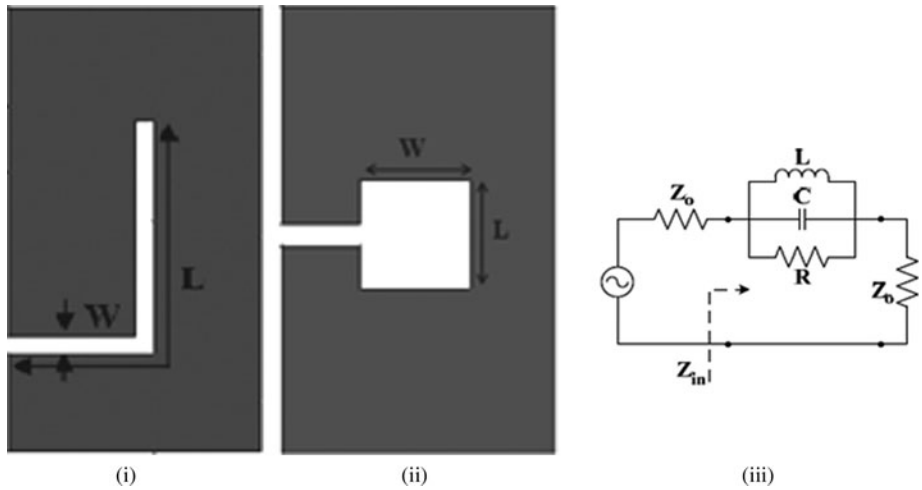

Fig. 1. Proposed defects. (i) Spur line, (ii) dumbbell, (iii) lumped equivalent circuit.

In general, the slot gap provides the capacitive effect (C) and narrow line exhibits an inductive effect (L). The lumped equivalent model of defected resonator is an RLC tank circuit was discussed [15]. The values of L and C are obtained by 3 dB cut off frequency (f_c) and pole frequency (f_p) in GHz is given by the following equations.

$$R = 2Z_0\left(\frac{1}{(S_{11}{}^2 - 1)}\right)\Omega, \quad (1)$$

$$C = \frac{5f_c}{\pi(f_c^2 - f_p^2)}\text{pF}, \quad (2)$$

$$L = \frac{250}{C(\pi f_p^2)}n\text{H}. \quad (3)$$

II. ANTENNA DESIGN AND STRUCTURE

Figure 2 shows that the geometry of the ACS-fed antenna has strip length (L_s) and strip width (W_s) 21 and 3 mm, respectively. The feed of the antenna is designed by using standard design equations of ACS available in the literature [16]. The ground plane dimensions of the antenna are optimized for good impedance matching. The antenna is designed and printed on a FR4 epoxy substrate which has dielectric constant of 4.4 and thickness of 1.6 mm. It has to be noted that the overall antenna dimension in terms of area is greatly reduced in the case of the proposed antenna using the ACS feed as shown in Table 1. Since, it uses only single lateral ground plane, and the size reduction has been achieved about a half of the conventional CPW-fed configuration.

For the desired resonant frequency f_r, guided wavelength λ_g is given by Askarali et al. [17]:

$$\lambda_g = \frac{c}{\sqrt{\varepsilon_{eff}} f_r}, \quad (4)$$

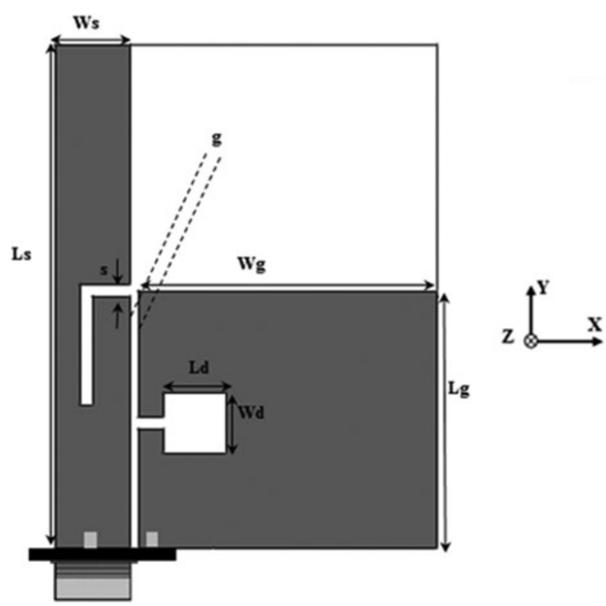

Fig. 2. Geometry of the proposed antenna.

Table 1. Design parameters of the proposed antenna.

Parameters	L_s	W_s	L_g	W_g	L_d	W_d	s	g
Values (mm)	21	3	10	12	2.5	2.5	0.5	0.35

where

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2}.$$

Total length and width of the planar antenna are given by

$$W = L = \frac{\lambda_g}{2}. \quad (5)$$

III. RESULTS AND DISCUSSION

A prototype of the proposed dual-band antenna is fabricated and measured as shown in Fig. 3(a). The return loss of the

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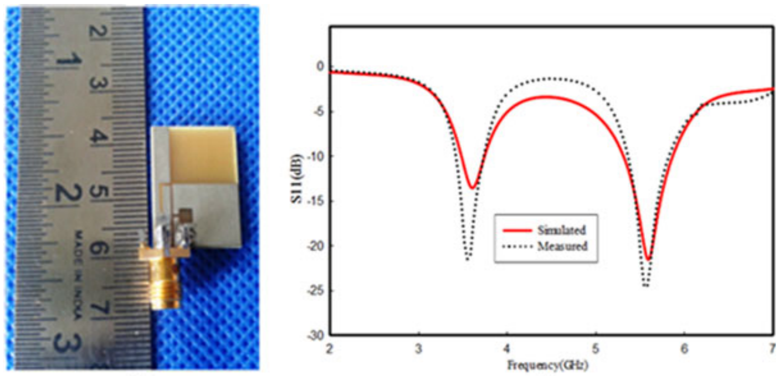

(a) (b)

Fig. 3. (a) Prototype of the proposed antenna, (b) comparison between the simulated and measured return loss characteristics.

antenna is measured by Agilent E8363B vector network analyzer. The comparison between the simulated and measured results is shown in Fig. 3(b). Here it can be seen that good agreement between the simulated and measured results at 3.5 (3.4–3.75 GHz) and 5.5 GHz (5.38–5.85 GHz) resonant frequencies. The parametric analysis of the proposed antenna with and without slow wave structures (DGS and DMS) is carried out and compared with proposed results is shown in Fig. 4. Here it can be noticed that with the application of DGS and DMS the proposed antenna yields resonance at 3.5 and 5.5 GHz which meets the existing standards of WiMAX and WLAN.

The parametric study of the proposed antenna by varying the dimension of DGS is shown in Fig. 5. Here defect in the shape of a half dumbbell of dimension 2.5 × 2.5 mm^2. From the results, it can be found that the proposed dimensions of dumbbell yield optimum results comparing with other dimensions. The other dimensions of resonance have a tendency to die out from the desired band of response. The parametric study of the antenna by varying the dimension of DMS is also carried out which is shown in Fig. 6, while the proposed DMS is in the shape of spur line. The width of the spur line is designated as "**s**". From the comparison, it can be seen that the resonance has a small shift in the lower or upper band of resonance when the spur line dimension varies and any one of

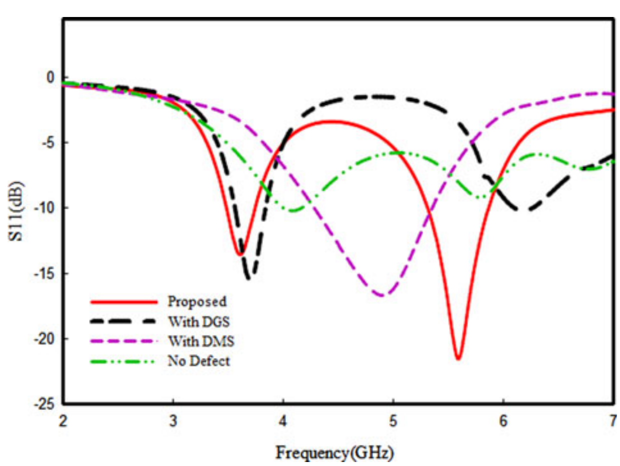

Fig. 4. Comparison of return loss characteristics of the proposed antenna with and without DGS and DMS.

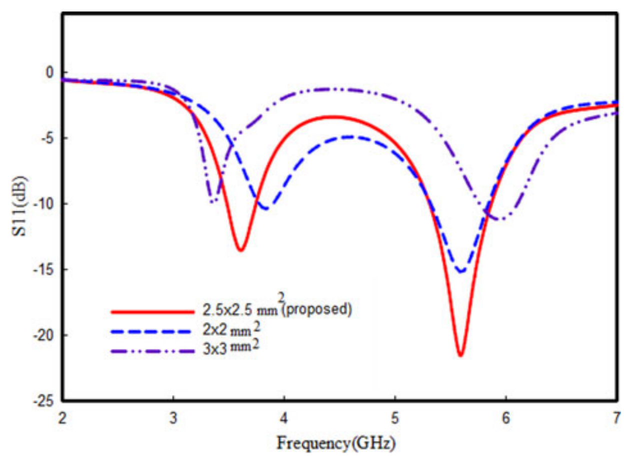

Fig. 5. Comparison of return loss characteristics by varying dimensions of DGS.

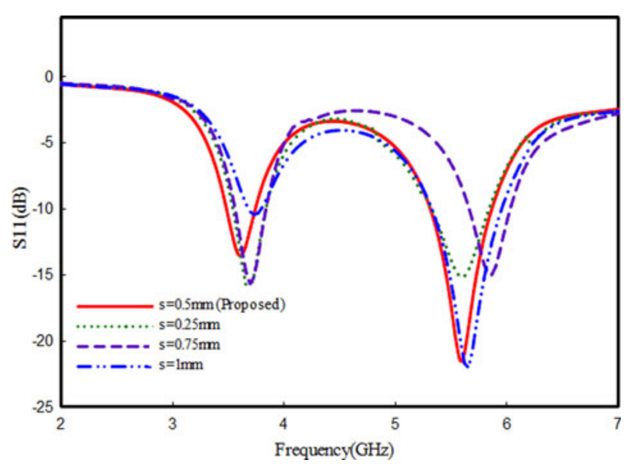

Fig. 6. Comparison of return loss characteristics by varying dimensions of DMS.

the band tends to be died out. In the proposed structure, the slot dimension is taken as $s = 0.5$ mm.

The simulated surface current distribution of the proposed antenna is shown in Fig. 7. It shows that in the lower band of resonance the surface current density is more concentrated around the spur defect in the exciting strip, whereas the

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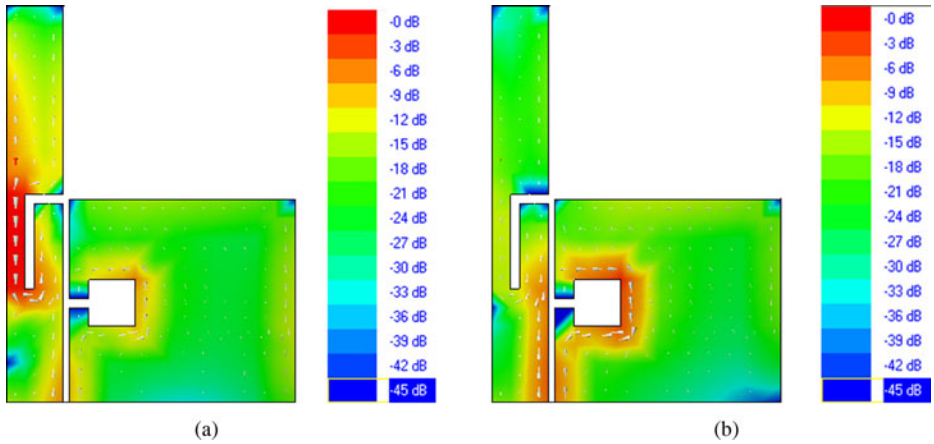

Fig. 7. Current distribution of the proposed antenna for (a) 3.5 GHz and (b) 5.5 GHz.

upper band of resonance current perturbed around the dumbell defect is in the lateral ground plane. Figure 8 shows measured *E*- and *H*-plane radiation patterns are at 3.5 and 5.5 GHz, respectively. The radiation patterns are almost omnidirectional at lower and upper resonances in the *H*-plane. Similarly the *E*-plane radiation patterns are bidirectional. The cross-polarization levels are minimum compared with co-polarization levels for both the *E*- and *H*-planes.

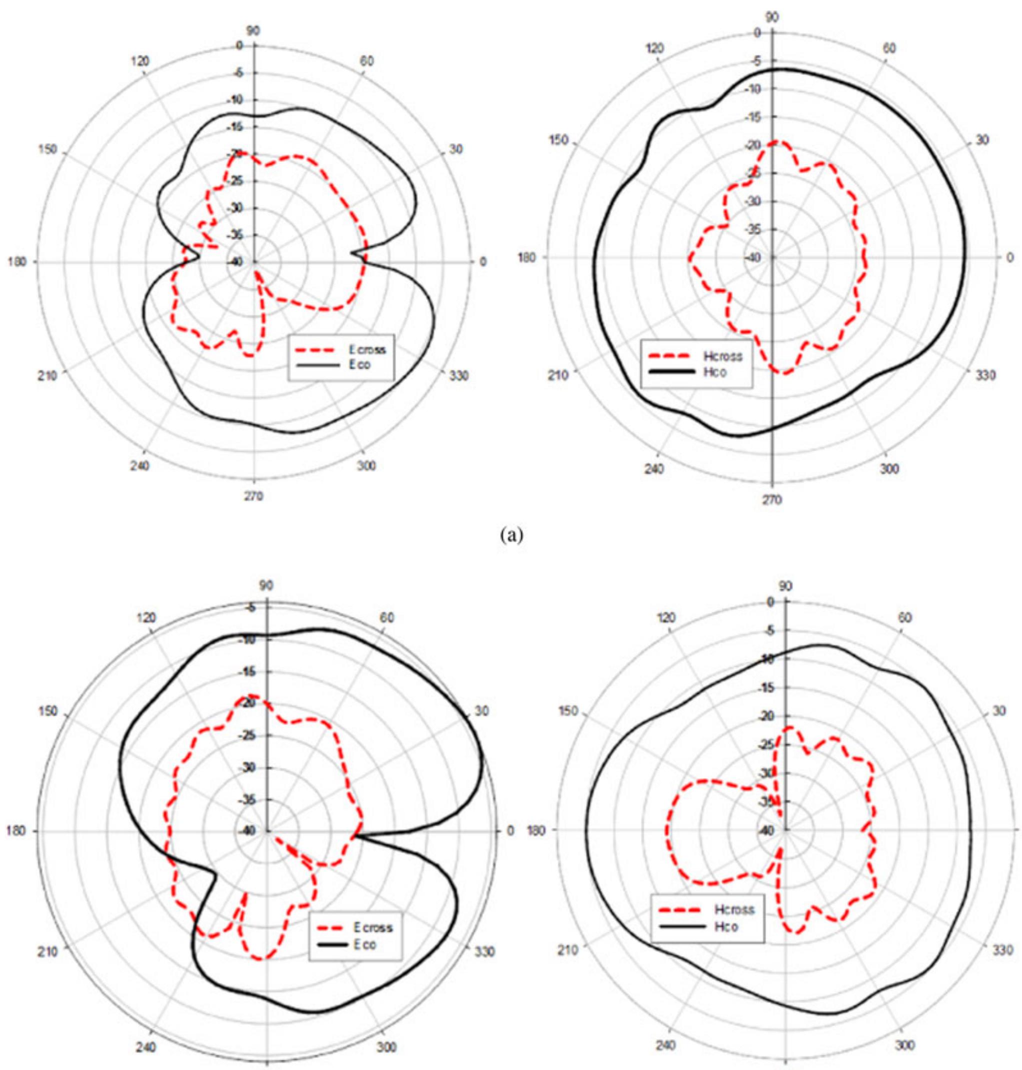

Fig. 8. Measured radiation patterns: (a) *E*- and *H*-planes at 3.5 GHz and (b) *E*- and *H*-planes at 5.5 GHz.

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Table 2. Comparison of gain and area of proposed antenna with existing literatures.

Published literature	Antenna purpose	Peak gain (dBi)	Size (mm²)
Proposed	Dual	3.5	21 × 15.35
[1]	Dual	2.2	30 × 28
[2]	Dual	1.9	21 × 19
[17]	Dual	1.21	37.5 × 24
[18]	Dual	3.5	35 × 15

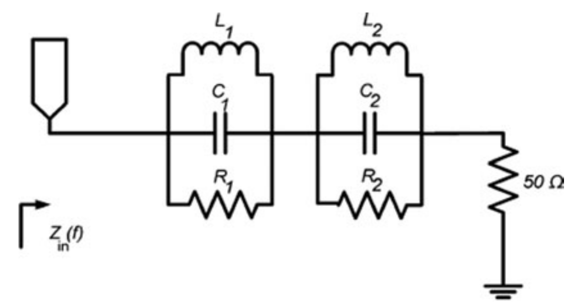

Fig. 9. Lumped equivalent model of the proposed antenna.

Table 3. Equivalent circuit parameters of the proposed antenna.

Circuit/ parameters	Resistance R (Ω)	Inductance L (nH)	Capacitance C (pF)
1	47.3	0.31	7.02
2	48.08	0.14	5.36

The patterns are slightly asymmetric in the *E*- and *H*-planes toward the right side because of the asymmetry in the proposed antenna structure and its feeding configuration. The polarization of the antenna is also experimentally determined and found that the antenna is polarized along with the *X*-axis for dual band of operation.

The comparison between the overall size and gain of the proposed antenna with already exisiting literatures is given in Table 2. Here it can be found that the proposed antenna has achieved a noticeable reduction in the area about more than 30% compared with the available literature. The gain of the proposed structure is also moderate and good which is almost equal to the asymmetrical ground plane antenna and was proposed in [18], but still it is larger in size than our current proposal.

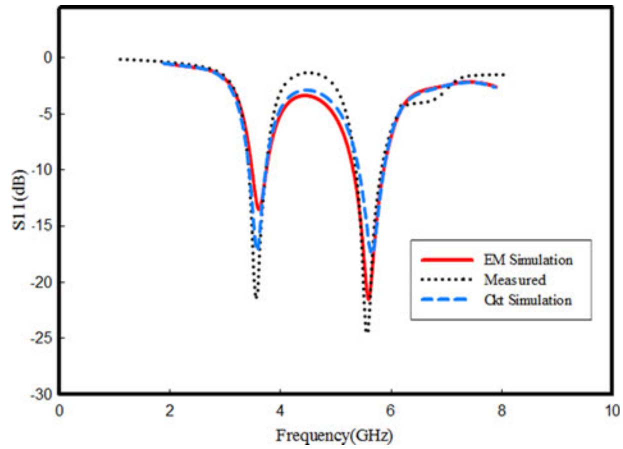

Fig. 10. Comparison between return loss characteristics by circuit simulation, EM simulation, and measurement.

The lumped equivalent model of the proposed design using resistance inductance and capacitance (RLC) tank circuit which is connected in series is given in Figure 9. The circuit parameters are extracted, calculated, and simulated by mentor graphics IE3D modua and the design equations are given in (1), (2), and (3). The optimized values are obtained by after a large number of iterations and data fitting are given in Table 3. Figure 10 shows the comparison of the return loss characteristics of the proposed structure with measured and circuit-simulated results. It can be found that the results showed good conformity between the measurement and simulation.

The measured gain of the proposed antenna shows a good agreement with the simulated gain which is given in Fig. 11. Here it is clear that the lower band shows the peak gain about 2.3 dBi and consistent throughout the band of operation. The upper band peak gain is about 3.5 dBi, which is moderate and sufficient for the present wireless communication standards such as WiMAX and WLAN. Hence, the proposed structure is a useful candidate for the present wireless portable gadgets.

IV. CONCLUSION

The proposed antenna shows that there is no much significant variation in radiation characteristics over the dual band of operation. A good return loss of −22 dB for the 3.5 GHz and −25 dB for the 5.5 GHz band along with a good voltage standing wave ratio (VSWR) (2:1) and better impedance matching at 50 Ω with ACS structure can be achieved by

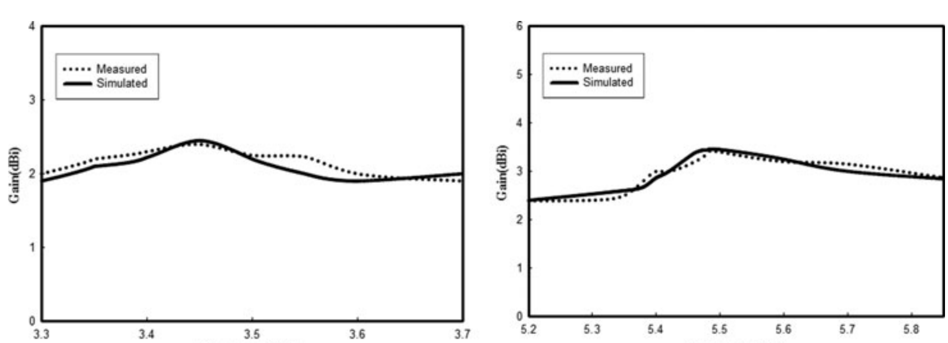

Fig. 11. Comparison between measured and simulated gain characteristics in lower band of resonance and upper band of resonance.

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creating a defect in the ground plane and the strip; therefore the proposed antenna is the most suitable candidate for WiMAX and WLAN applications. Moreover, the simple and uniplanar structures make it easier for the design and mass production. Hence, by changing the length, width, and position of the defect in the antenna can be made to work for multiple bands of operation. It can be predicted that the proposed technique will be useful for other planar antenna structures also.

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