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Ground Slot Application in Microstrip Antenna for Portable Wireless Devices

A.R. Razali*, A.S. Ahmad Yusak* and A. Abu Bakar*

ABSTRACT

An investigation into the effect of ground slot in a microstrip antenna is presented. Initially, a planar inverted-F antenna dedicated for 2.45 GHz WLAN lower band is designed. Its rectangular ground plane is then introduced with slots to excite new magnetic resonance for 5.2/5.8 GHz WLAN upper band. The slots are optimized by tuning their three different configuration parameters which are the length, width and location. As a result, a new antenna design with dual open-ended ground slot with enhanced bandwidth is proposed. The new proposed antenna offers a compact radiator size with wideband coverage between 2.31 and 6.63 GHz bandwidth. It is not only applicable for 2.4/5.2/5.8 GHz WLAN for IEEE 802.11 a/b/g, but also covers other services within this range such as the 2.5/5.5 GHz WiMAX application. With such coverage and nearly omni-directional radiation pattern, the antenna is a promising candidate for multiband application in portable wireless devices.

Keywords: Ground slot, Microstrip antenna, Multiband.

1. INTRODUCTION

Nowadays, Portable Wireless Device (PWD) has become an important gadget in daily life as they are now intensely assimilated into society. The key considerations for Portable Wireless Device are to be robust, flexible, small size, consume a small amount of power, and comfortable to carry. It is important for the device to be as small as possible for easy handling and carrying [1]. In order to realize the wireless connectivity, and to suit the features demand of the device, the selection of antenna is very important. There are several type of common antenna used in small wireless devices, with each of them behave with different characteristics. The two most popular microstrip antennas used are monopole and planar inverted-F antenna or PIFA. Due to their versatility, conformability, low cost and low sensitivity to manufacturing tolerances, planar inverted F antennas or PIFA are well suited for wireless LAN application systems.

There are many literatures that discuss techniques to improve antenna flexibility without sacrificing the antenna performance [2-4]. One of the techniques is through meandering of antenna radiator [4, 5]. In addition to physical consideration of the antenna, a compact antenna which covers a wide operational bandwidth is in demand for high speed data transfer. In order to enhance the bandwidth of a PIFA while maintaining the antenna compactness, the insertion of slots in the ground plane of a single band antenna are proposed [1, 4, 6-13]. This paper presents the investigation on the effect of ground slot to produce a PIFA for multiband operation. Three different ground slot parameters are studied for optimization purpose. The substrate used is FR4 with 0.8 mm thickness. The radiator is fed by 50 Ω microstrip feedline which makes it easy to integrate with other microwave circuitry.

2. ANTENNA DESIGN

First, a single band design of planar inverted-F antenna without ground slot for 2.4 GHz WLAN application is designed and used as a reference antenna (RA). The antenna radiator consists of simple single stacked of

* Researcher, Antenna & Microwave Research Group, Faculty of Electrical Engineering, Universiti Teknologi MARA Caw. Pulau Pinang, Malaysia, *Email: aslina060@ppinang.uitm.edu.my*

inverted-F copper strip. The reference antenna is designed using FR4 substrate material with a dielectric constant of εr = 4.4, and dimension of 31.25 mm (width) x 40 mm (length) x 0.8 mm (thickness). The antenna is then fed by a 50 Ω microstrip feedline having a dimensions of (fh, fw) = (36.5, 1.5) mm as shown in Fig. 1.

The length of the antenna radiating element is set to (Lr1, Lr2) = (5.25, 18.5) mm. The total length of Lr1 and Lr2 is approximately quarter wavelength of the operating frequency and (Sl + Sl2) is typically

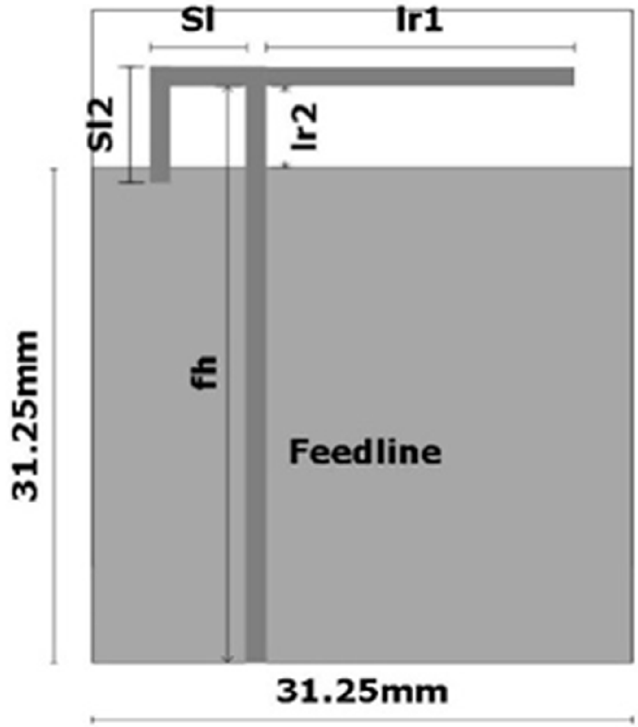


Figure 1: Reference Antenna Structure (RA).

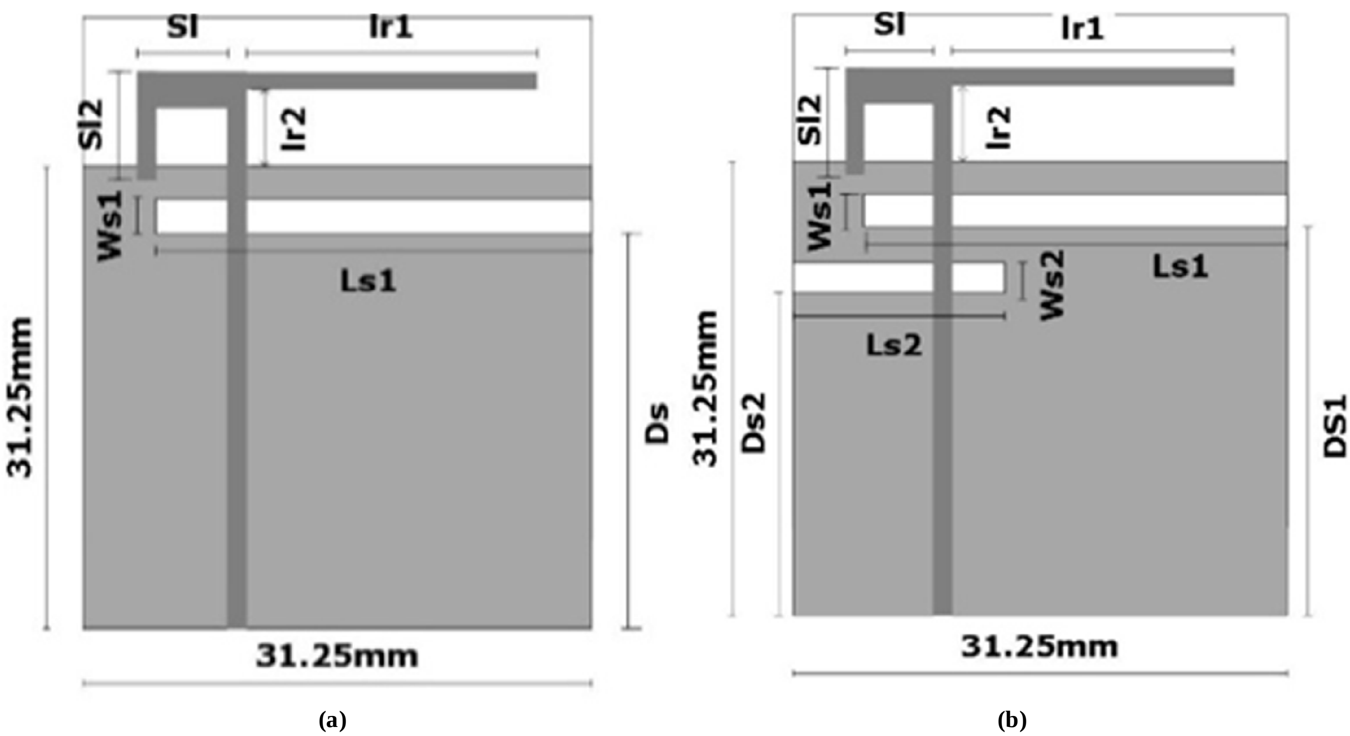


Figure 2: PIFA with open ended ground slot (a) Single open-ended Slot (b) Dual open-ended slot.

smaller this length. The shorting strip (Sl) is short circuited to the ground plane printed on the side of the dielectric substrate through a via. The addition of the shorting strip (Sl) to the radiator permits an impedance matching by compensating the capacitive loading created at the radiator arm to the top edge of the ground plane.

Later, two parallel slots are added to the reference antenna ground plane as shown in Fig. 2 (b). The introduced slots are open-ended at the side edge and opposite to each other. In order to excite the new desired magnetic resonance, the closed-end of the slot arm is used as a tuning stub. Through several parametric optimization and analysis using CST Microwave Studio, the final dimension of the slots are obtained. For the first configuration in Fig. 2 (a), a single open-ended slot is first introduced and studied. The dimension of the slot is Ws1 × Ls1 = 4 × 27.5 mm with the distance of the slot to ground bottom edge is Ds = 29 mm. In the second configuration, another open-circuited ground slot is added as shown in Fig. 2 (b). The second slot dimension is Ws2 × Ls2 = 1.5 × 12 mm while Ws1 is reduced to 2.8 mm for tuning purpose. The second slot is placed at a distance Ds2 = 22 mm from the bottom edge of the ground plane. Both of the slot locations are adjusted as close as possible towards the upper edge of the ground plane to minimize the utilized area. The slot insertion reduces the area of the ground plane by only 21.32% or 208.21 mm2. The slots are also located in such a way that they can couple with the feedline for excitation purpose.

Next, the arm of the main radiator is folded twice (second order folding) to miniature the main radiator's area while maintaining its performance [10]. The slot dimension Ws1 is reduced to 2.2 mm for tuning purpose. Through radiator folding, the useful area at the radiator vicinity is improved to 32.8% or 64.06 mm2 from the original reference antenna (RA) radiator's area.

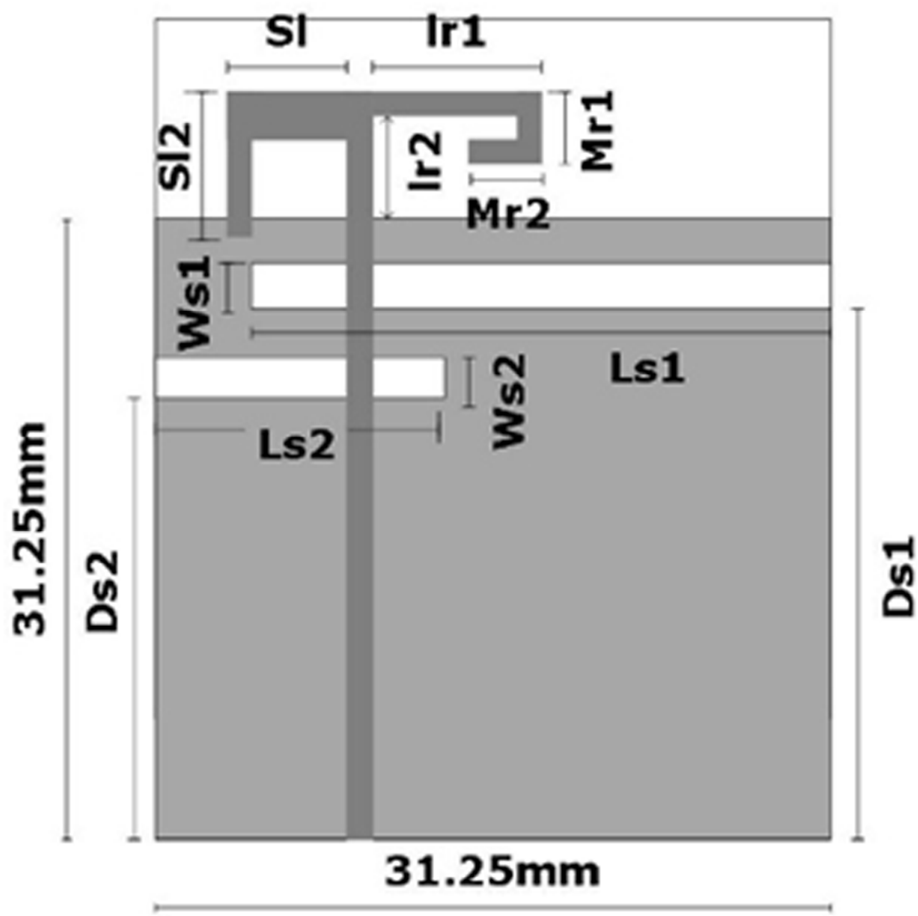


Figure 3: Folded proposed antenna with dual open-ended ground slot.

3. RESULT AND DISCUSSION

The performances of both PIFA are assessed in terms of return loss, radiation pattern and gain. Fig. 4 shows the simulated S11 of the original RA as compared to the single slot configuration. The result validates the hypothesis of inserting a ground slot would generate an extra resonance. Apart from the original 2.4 GHz resonant by the main radiator, a resonant located at 5.2 GHz (175-MHz impedance bandwidth at S11 = –10dB) and 7.2 GHz (658-MHz impedance bandwidth at S11 = –10dB) are achieved. Fig. 5 shows that the S11 of three slot parameter variation that are the width (w), length (l) and distance (d). In addition to the variation studies to achieve optimized dimensions, the analyses also prove that the dimension variation does not have major effect to the original resonance at 2.4 GHz.

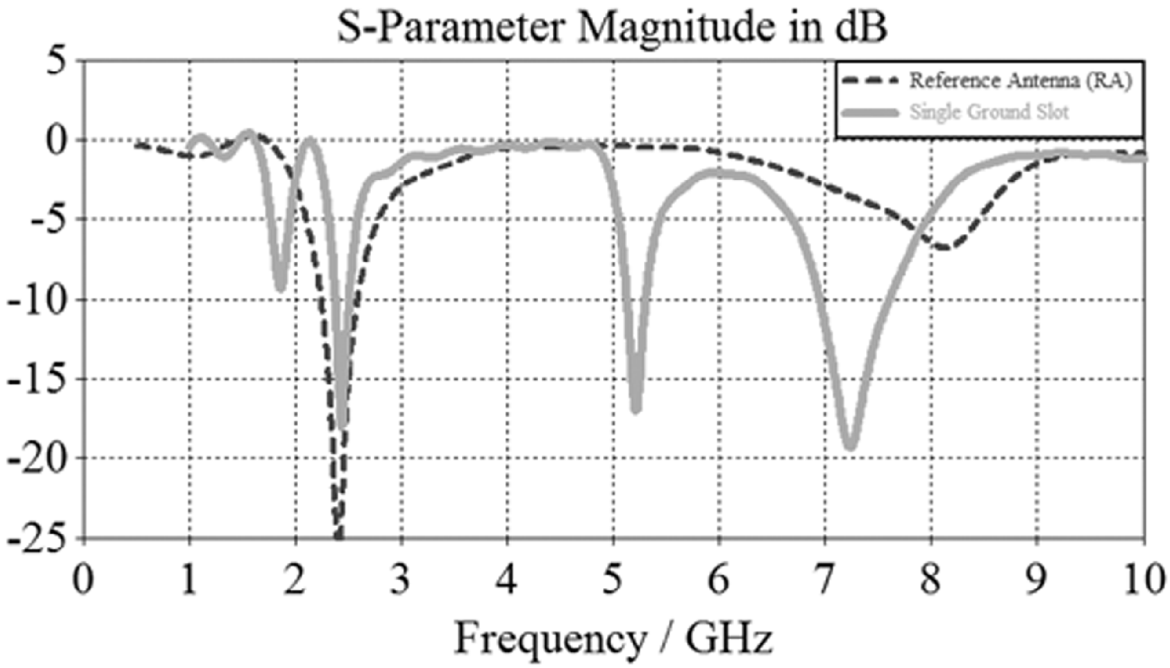
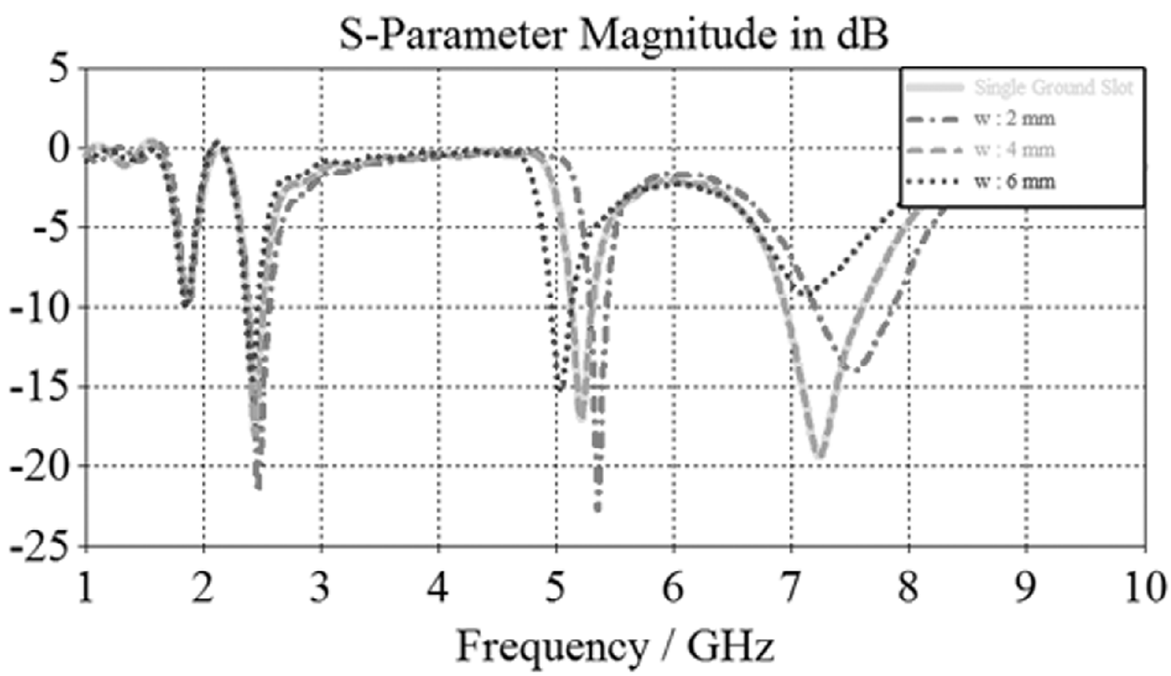
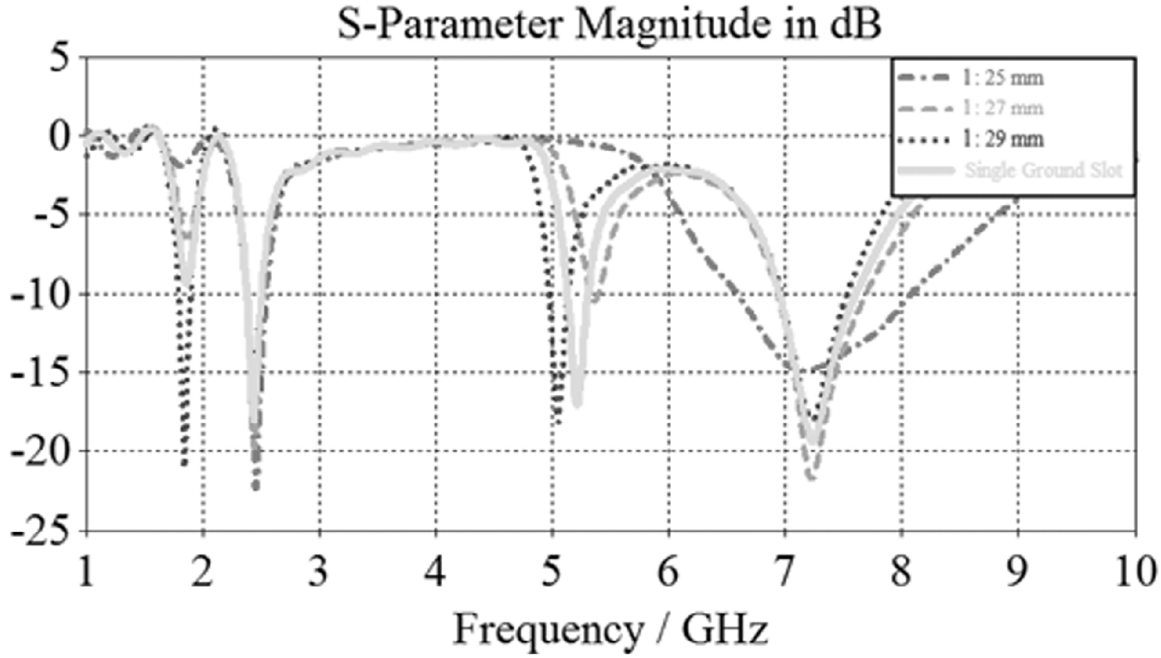


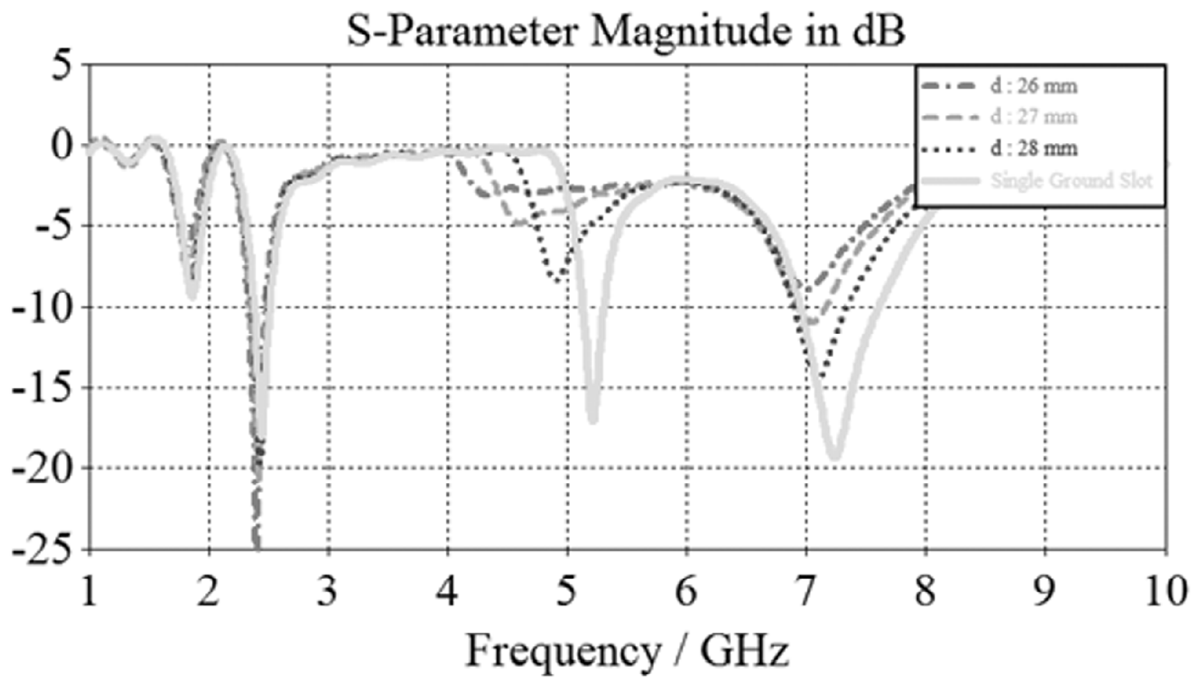
Figure 4: Simulated S11 for single open-ended ground slot as compared to the original RA.



(a)



(b)



(c)

Figure 5: The effect of slot dimensions and location variation of the proposed antenna. (a) width, (b) length and (c) distance.

The simulated S11 for double open-ended ground slot are presented in Fig. 6. From the figure, the bandwidth of the antenna has been enhanced. It introduces a more promising resonant frequencies compared to the single slot configuration. The enhanced coverage includes ranges between 3.2 and 4.6 GHz (1439-MHz impedance bandwidth at 10dB return loss) and between 5 and 6.8 GHz (1684-MHz impedance bandwidth at 10dB return loss). It is capable of providing coverage for 2.4/5.2/5.8 GHz WLAN IEEE 802.11 a/b/g and also the 2.5/5.5 GHz WiMAX application.

The S11 comparison presented in Fig. 7 validates that folding the antenna radiator to reduce its size does not affect the original performance of the dual slots antenna. With this observation, it demonstrates

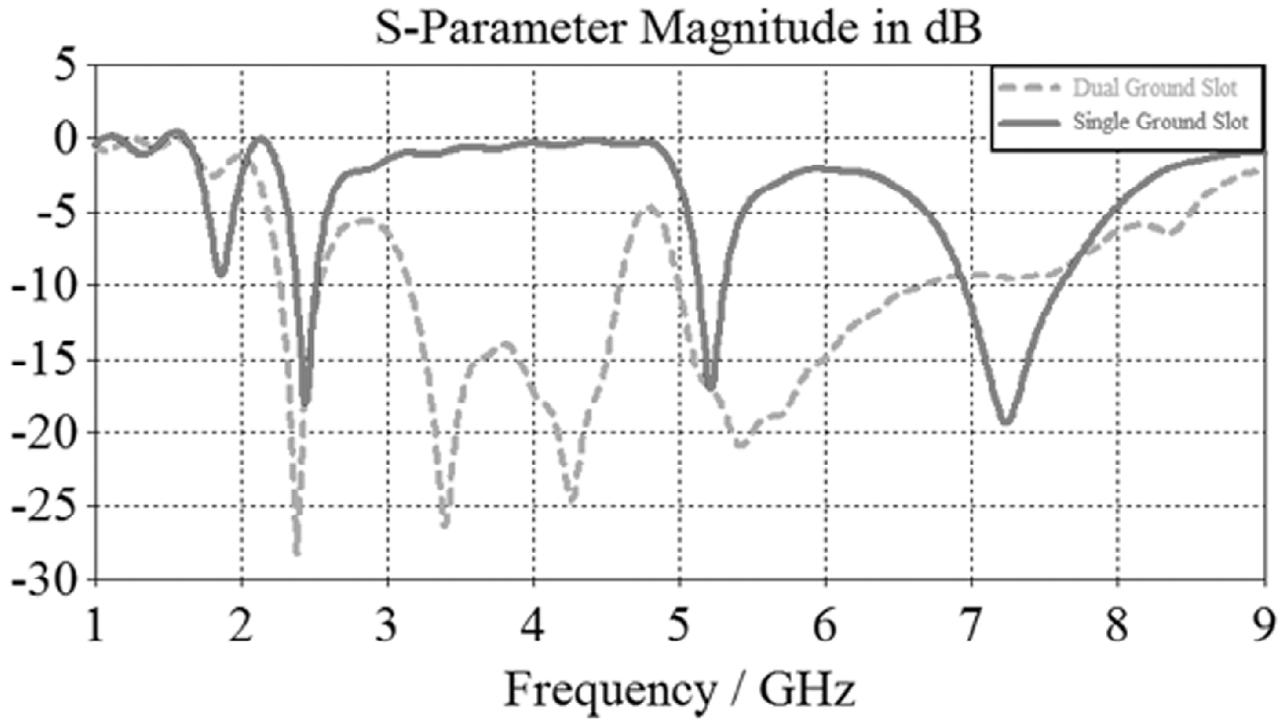


Figure 6: Simulated S11 comparison between the single (solid line) and dual open-ended (dotted line) ground slot.

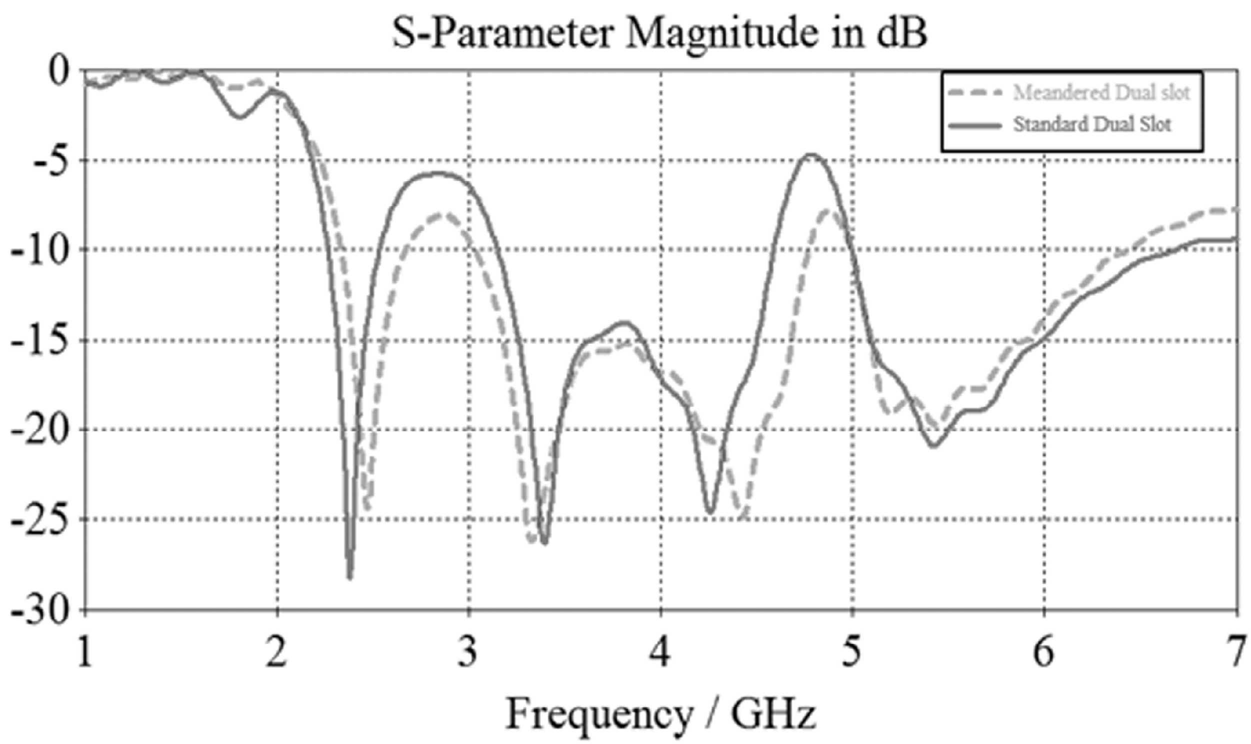


Figure 7: Simulated S11 comparison between unfolded (solid line) and folded (dotted line) radiator for the proposed dual open-ended ground slot antenna.

that ground slot insertion technique is one of the promising approach to allow radiator's miniaturization without scarifying the radiator's performance. Furthermore, the presented result shows bandwidth improvement at the lower band (2.45 GHz) of up to 335 MHz, which is about 55.8% increased from its original. The proposed antenna also offers more promising multiband services as compared to reference work in [4].

The simulated 3-dimensional far-field radiation pattern in Fig. 8 shows an omni-directional radiation pattern for various popular frequencies services. The radiation pattern of the proposed antenna confirms that it is suitable for Personal Communication System (PCS) and mobile application with its nearly omni-directional features. The proposed antenna exhibits gain which ranges between 2.4 to 4.2 dBi

Finally, the photograph in Fig. 9 shows the fabricated prototype of the proposed antenna with dual ground slot configuration. The fabricated antenna confirms the compactness of the proposed design with modest manufacturing structure. The measured S11 presented in Fig. 10 for the fabricated antenna shows a relatively good agreement with the simulated S11 in Fig. 7.

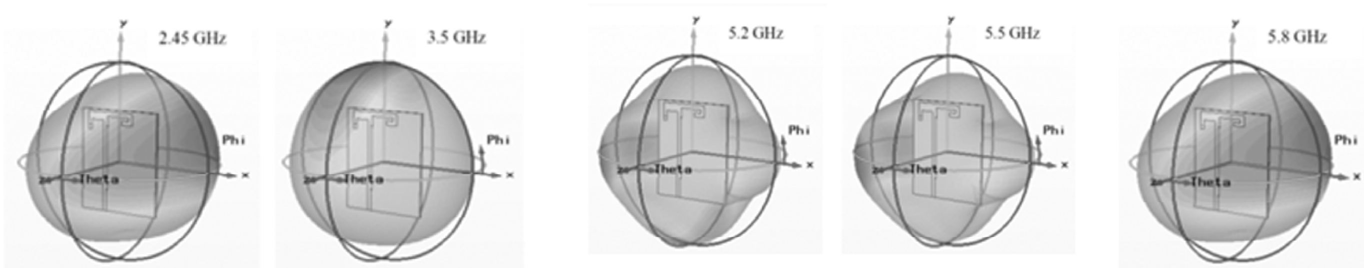


Figure 8: Simulated 3-dimensional radiation pattern

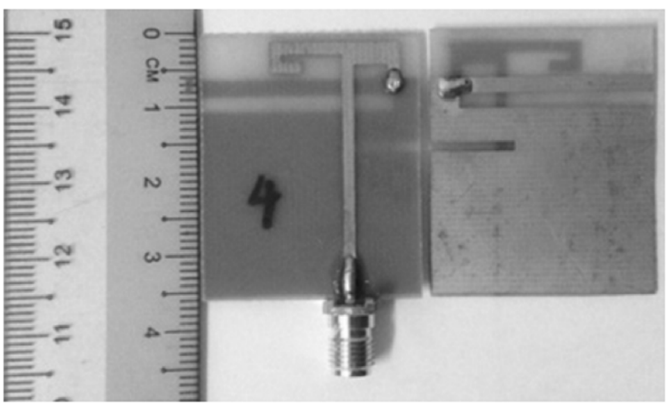


Figure 9: Photograph of the fabricated proposed antenna.

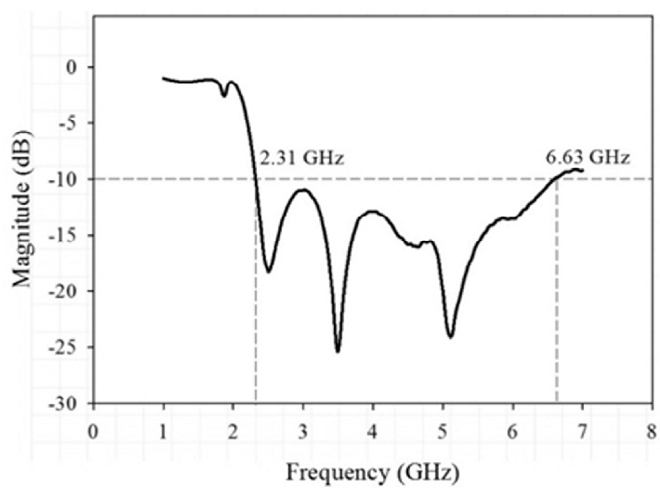


Figure 10: S11 measurement of folded dual slot PIFA using Vector Network Analyzer (VNA).

4. CONCLUSION

This paper presented an investigation into the effect of ground slot technique to produce a microstrip antenna for multiband application. It has been demonstrated that the idea of inserting dual slot in the ground plane can generate an extra resonance with many design advantages. The new proposed PIFA is capable to launch multiband operation at 2.4/5.8-GHz WLAN IEEE 802.11 a/b/g and 2.5/5.5-GHz for WiMAX application. The achieved bandwidth enhancement and size reduction can be promising approaches in the design of antenna intended for multiband application.

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