

Multiband Reconfigurable Coplanar Inverted-F Antenna With Tunable Ground Slot

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ABSTRACT

In this paper, a coplanar inverted-F antenna with reconfigurable ground slot using PIN diode switches is proposed for GSM1800, DCS1800, PCS1900, UMTS2100, WLAN2450, WiMAX2500, and LTE2300 services. Initially, the antenna radiator is designed at quarter wavelength of 1.8 GHz. A ground slot is then introduced and loaded with two pair of PIN diode switches to create a new tunable magnetic resonator with a broaden bandwidth without affecting the 1.8GHz operation. The antenna configurations and performance results are presented and discussed. From the simulation results, the antenna covers many popular frequency services with nearly omni-directional radiation patterns and low gain.

Keywords: Inverted-F antenna, Ground slot, Reconfigurable.

1. INTRODUCTION

The development of mobile phone has rapidly changed. From text messaging and makes a phone call, nowadays mobile phones are equipped with variety of applications such as WiFi, 4G services and Bluetooth at different frequency bands. As a result, the need for multiband antennas has increased. However, the design for multiband radiators is a challenging task to antenna designers. Some mobile phones require more than one antenna to support different frequencies for different application which is not preferable by manufacturers. For that reason, multiband wireless devices have to cover multiple frequencies with a single antenna. nevertheless, a single-fed multiband antenna has noise problem and to recover their out-of band noise rejection, it needs a complicated filter with inflexible requirements [1]. The filter is usually bulky and causes another complexity to any communications system.

Reconfigurable antenna with better out-of-bands noise rejection capabilities is a solution for the disadvantage of a multiband antenna. Furthermore, modern wireless communication can rely on reconfigurable antenna and it is becoming more popular to serve multiple frequencies with only a single antenna. Therefore, this configuration allows a reduction in the dimensions of the wireless devices and provide more space to integrate other electronic components [2].

Reconfigurable antenna can be classified in three categories: frequency, radiation pattern and polarization reconfigurable. The frequency reconfigurable antenna is about modification of the electrical current path of the antenna to form tunable resonant excitation. There are various techniques to fulfill this concept, including electrical element as switching mechanism. Electrical switch such as RF-MEMS, PIN-diodes and varactors, is frequently adopted in the design of reconfigurable antenna. This switch makes it easier to achieve the reconfigurable functionality. Among these switching devices, PIN diode switches is normally the easiest to use because it is reliable, compact, high speed switching and low resistance or capacitance in its on or off states [3].

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In mobile wireless devices, Planar inverted-F antenna (PIFA) is commonly used in the antenna design. This is due to its advantages which are low-cost, electrically small in size and flexible in its far field performance [4-6]. In order to achieve those criteria, miniaturization of radiating elements is necessary while allowing it to be embedded into a small space. On the other hand, the antenna performance is a narrow operational bandwidth. According to Byndas et al. [7] and Hossa et al. [8], they have reported bandwidth enhancement that can be achieved by inserting the open-ends ground slots using a coaxial-fed PIFA and in [9-11] using a Coplanar Inverted-F antenna (CIFA). Recently, a new approach of reconfigurable CIFA with electronically controlled ground slot is proposed in [12]. According to the work, three pairs of PIN diode switches in the ground slots excited new resonant frequencies at each switching mode without affecting the main resonant frequency. The proposed antenna can cover GSM900, PCS1900 and UMTS2100. This paper extends the idea in [12] with new design of CIFA with bandwidth enhancement and size reduction of about 50%. With the aid of CST Microwave Studio, an extensive study and optimization of the proposed configuration resulted in bandwidth enhancement that can cover popular services such as GSM1800, DCS1800, PCS1900, UMTS2100, WLAN2450, WiMAX2500, and LTE2300 services.

2. ANTENNA DESIGN

2.1. Original Antenna Configuration

Reconfigurable CIFA is designed with a quarter wavelength at 1.8 GHz to cover WWAN services. With the aid of CST Microwave Studio, a CIFA is designed on an FR4 board with permittivity of 4.3 and 1.6 mm of width with dimension $W \times L$. The radiating element and ground plane are both assigned as 0.0017 mm cooper strip. The ground plane dimension is $W_g \times L_g$. The radiator is fed with a 50 ohm microstrip feedline with dimensions of $W_f \times L_f$. Then, the shorting arm is designed to connect part of the main radiator to the ground slot to improve the mismatch condition of the folded arm, thus create balance between capacitive and inductive element in the antenna. To realize it, a via is created at the end of the main radiating folded arm and short it to the ground plane. The via and shorting arm both have dimensions of $W_s \times L_s$ and $W_v \times L_v$ respectively. For the first modification, the length of the radiating element is reduced from 42 mm to 30 mm to minimize the size of the antenna and to improve the return loss performance. It shifted the

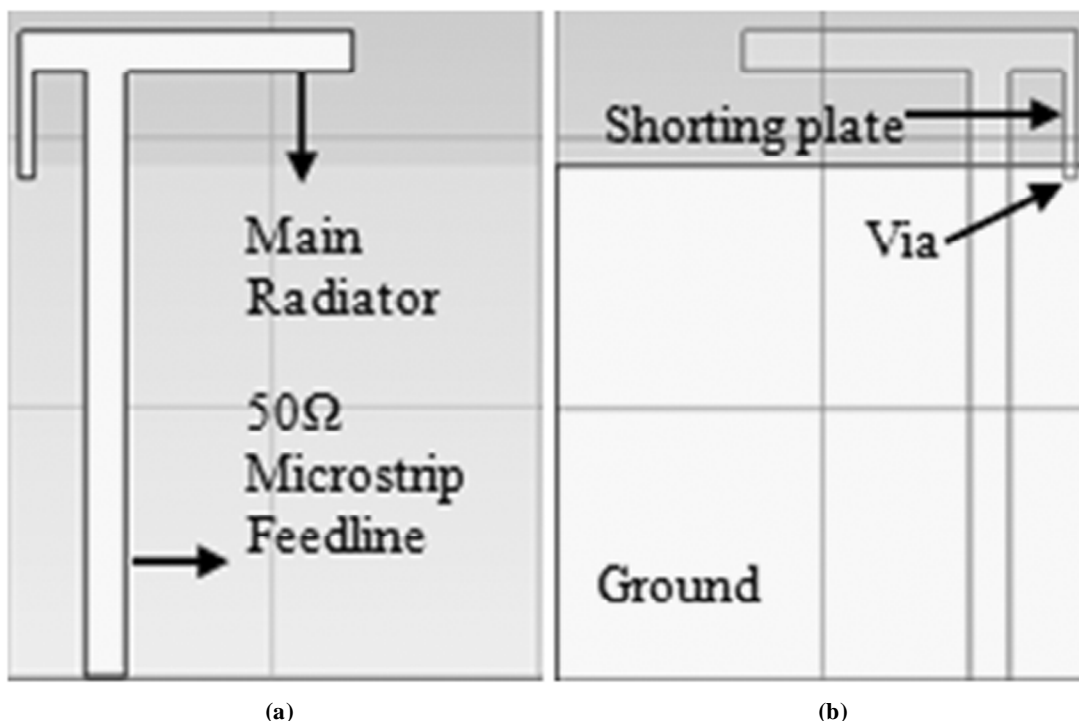


Figure 1: Configuration of proposed antenna. (a) Front view. (b) Back view.

Table 1
Dimension of the Antenna.

<i>Dimensions</i>	<i>Width (mm)</i>	<i>Length (mm)</i>
Ground Plane	40	38
Radiator	3	30
Substrate	40	50
Slot 1	1	27
Slot 2	3	16.6
Slot 3	0.5	12
Shorting plate	2	10
Via	2	1
PIN diode	1	3

lowest resonant at 1.95 GHz with bandwidth only covers PCS and UMTS services. Figure 1 indicates the proposed antenna and Table 1 shows the dimensions of the antenna.

2.2. Insertion of Slots at Ground Plane and Main Radiator

In order to improve return loss performance and to achieve WWAN coverage, the second modification is introduced with two slots at ground plane and one slot at the main radiator with both dimensions as shown in Table 1. The first and second slots are designed closed to the main radiator and shorting arm for coupling purpose [9]. Another slot is designed at the main radiator to increase the electrical length towards its original design as shown in Figure 2.

2.3. Reconfigurable using PIN diode switches

Two identical $1\text{ mm} \times 1\text{ mm}$ conducting pads (P1 and P2) are designed at the second lower slot with a PEC material to achieve an electronically to tune the length of the slot. PIN diode switch is used rather than other

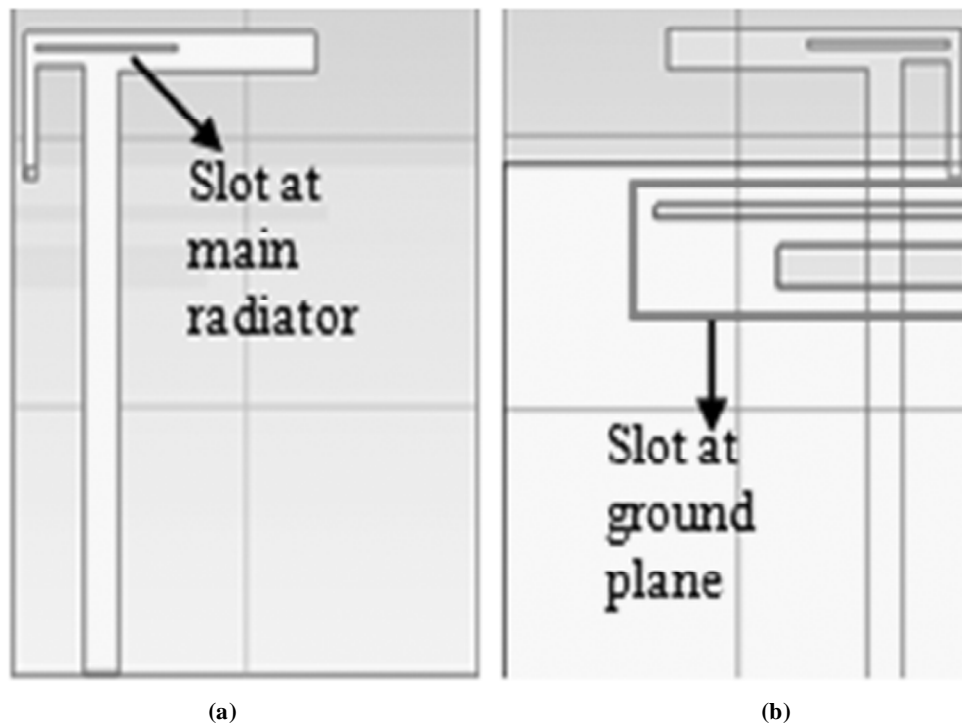


Figure 2: Second modification with insertion of slots. (a) Slot at the main radiator. (b) Slots at the ground plane.

Table 2
Dimension of the Antenna.

<i>Diode Combination</i>	<i>Diode States</i>		
	<i>Mode 1</i>	<i>Mode 2</i>	<i>Mode 3</i>
D1 & D2(P1)	OFF	ON	OFF
D3 & D4(P2)	OFF	OFF	ON

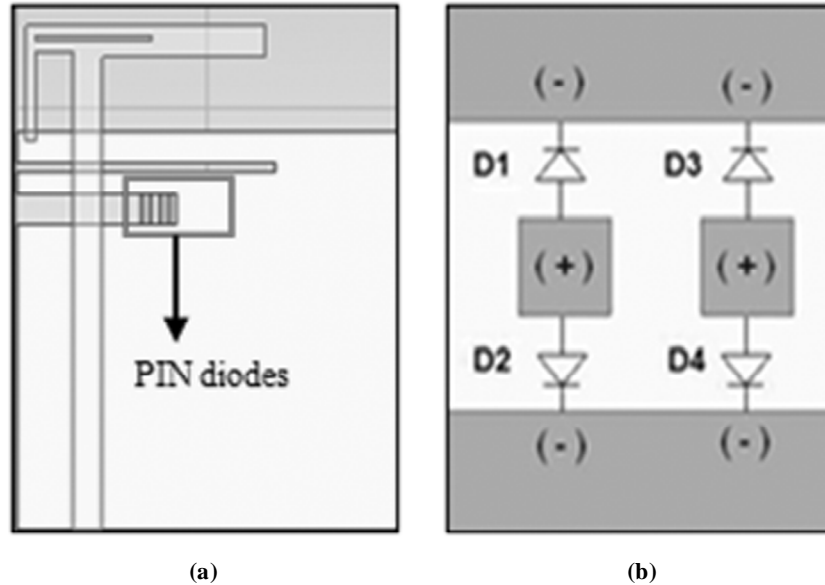


Figure 3. Final configuration of the proposed antenna. (a) Reconfigurable with two pair of PIN diodes. (b) Configuration of the PIN diode switches bias network.

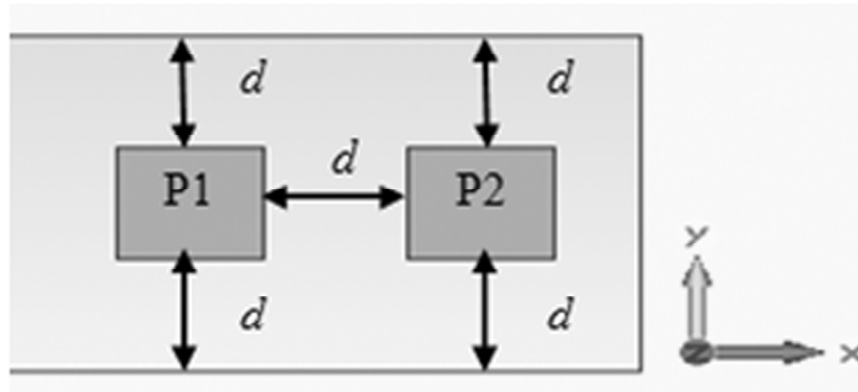


Figure 4. Close view of short-end section of ground slot (marked as red box in Figure 3(a), P1 is PIN diode 1 and P2 is PIN diode 2.

electrical switches because it is cheaper and requires a simpler biasing circuit. The two operational modes of PIN diode are the ON and OFF states. The ON state indicates the diode in a forward biased while OFF state indicates in reversed biased. In the simulation, the ON state is represented by a 1 mm × 3 mm copper pad. Both configurations are presented in Figure 3. Table 2 indicates the mode of operations for both switches. The gap between both switches in the ground slots is $d = 1$ mm as shown in Figure 4.

3. RESULT AND DISCUSSION

In the simulation, the S11 performance optimization is made for each modification using CST Microwave Studio. CST simulation can compute the electromagnetic properties of radiating elements using Maxwell

parameters thus providing a reliable analysis acceptable worldwide. The simulated S11 results of the modifications are shown in Figure 5. The first modification is miniaturization made at the main radiator by reducing the radiator's length from 42 mm to 30 mm. Even though the bandwidth is observed to increase at the higher band, it reduces the bandwidth at the lower 1800 MHz band at 6dB return loss. The second modification is made by inserting slots in the main radiator to recover the lower 1800 MHz service band. The ground plane slots is then introduce to recover the reducing bandwidth due to the insertion of slot at the main radiator. With these design procedures, the CIFA has obtained resonances that cover GSM, DCS and PCS services by achieving bandwidth from 1.71 GHz to 2.04 GHz at 6dB return loss. Further study has been performed to recover more bandwidth at the higher band without scarifying the lower 1800 MHz service band. As a result, the lower ground slot length has been made tunable as mentioned in the previous section. In the simulation analyses, when P2 is in ON state and P1 is in OFF state, the bandwidth at the higher band has increased almost double. The achievable bandwidth has increased from 320MHz up to 610MHz. Finally, when P1 is in ON state and P2 is in OFF state, the bandwidth increases to 1.05 GHz, which starts from 1.70 GHz up to 2.75GHz at 6 dB return loss. The final antenna enhanced bandwidth covers GSM1800, DCS1800, PCS1900, UMTS2100, WLAN2450, WiMAX2500, and LTE2300 services as shown in Figure 6.

Figure 7 presented the simulated radiation pattern at the center of each popular wireless services that are covered by the antenna. Based on the result, all radiation are nearly omni-directional pattern which is suitable for mobile application. The antenna gain tabulated in Table 3 shows a low gain of 1.19 dB to 2.73 dB across the resonant frequencies that confirms their omni-directional features.

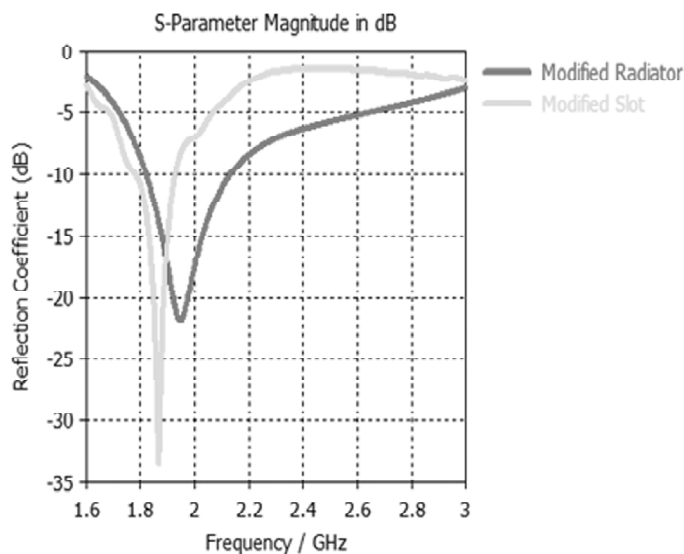


Figure 5: The S11 of the antenna modification.
(a) Modified radiator for the first modification and
(b) modified slot for the second modification.

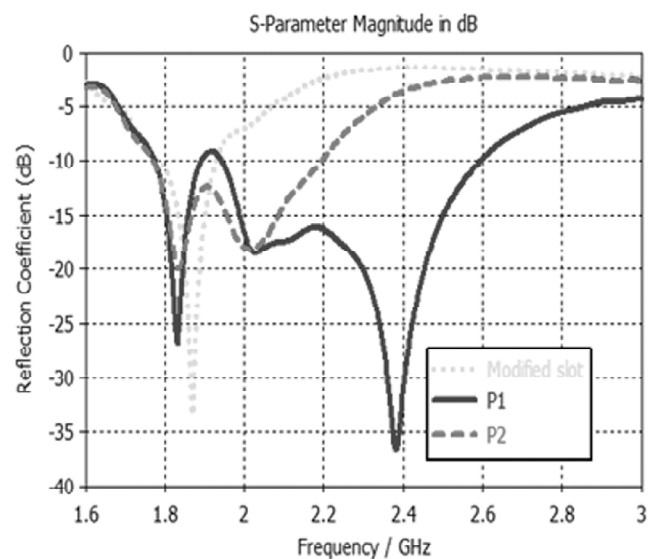


Figure 6: The simulated S11 result.

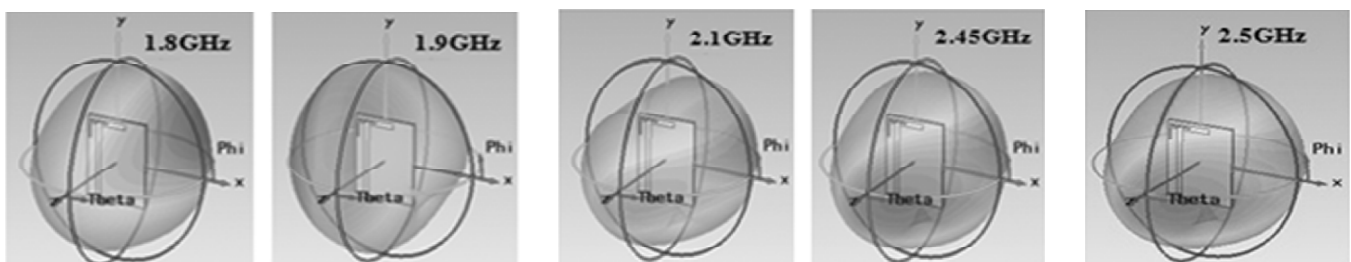


Figure 7: Simulated 3D far field radiation pattern of several popular services covered by the proposed antenna.

Table 3
Dimension of the Antenna.

<i>Frequency (GHz)</i>	<i>Antenna Gain (dB)</i>
1.8	2.46
1.9	1.19
2.1	2.73
2.45	2.26
2.5	2.22

4. CONCLUSION

In this paper, a new configuration of CIFA with a reconfigurable ground slots using two pair of PIN diodes is proposed. The techniques used in the proposed designed has increased the bandwidth enhancement and provide a better performance of the antenna. This antenna is a good candidate in mobile application that covers GSM1800, DCS1800, PCS1900, UMTS2100, WLAN2450, WiMAX2500, and LTE2300 services. For future work, this PIN diode switch can be replaced by RF-MEM electrical switch and use different design of the tunable ground slot.

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