Reconfigurable Ground-Slotted Patch Antenna Using PIN Diode Switching

Seung-Bok Byun, Jeong-An Lee, Jong-Hyuk Lim, and Tae-Yeoul Yun

ABSTRACT—This letter presents a reconfigurable ground-slotted patch antenna using a PIN diode connection in slots to achieve dual-frequency operation. Slots in the ground plane increase the electrical length and thereby reduce antenna size by 53%. By controlling PIN diode conduction, we achieved band hopping while still satisfying the bandwidth requirements for K-PCS and WiBro bands.

Keywords—Frequency-reconfigurable, K-PCS, PIN diode, WiBro.

I. Introduction

Development of reconfigurable antennas has received a great deal of attention in recent years as functional diversity is integrated in small antennas to accommodate the demanding requirements of modern wireless communication systems. There are four types of reconfigurable antennas: frequency reconfigurable, radiation pattern diversity, polarization diversity, and combined antennas. Reconfigurable antennas and conventional antennas have similar radiation performance, but reconfigurable antennas are more compact and experience less co-site interference [1], [2].

Switching components, such as PIN diodes, varactor diodes, and micro-electromechanical system (MEMS) switches, are frequently adopted in the design of reconfigurable antennas to electronically change the operating frequency band, the radiation pattern, and/or the polarization [3]-[5]. Among these switching devices, PIN diodes are very reliable and compact because they have high switching speeds and low resistance and capacitance in the on and off states, respectively.

Korean personal communications service (K-PCS) technology, referred to as digital cellular, operates in a range from 1,750 to 1,870 MHz. In addition, Korean wireless broadband Internet (WiBro), which provides high data rate wireless Internet access for stationary or mobile environments, operates in a range from 2,300 to 2,400 MHz. However, there is a demand from customers to merge these technologies so that mobile communications and wireless Internet services operate from the same terminal but in a separate mode.

In this letter, a reconfigurable ground-slotted patch antenna using PIN diodes is presented to provide dual-frequency operation for K-PCS and WiBro bands. Added slots on the ground plane decrease the patch size by increasing the electrical length.

II. Antenna Design

A new reconfigurable ground-slotted patch antenna structure is presented in Fig. 1. The proposed antenna is printed on an FR4 substrate with a dielectric constant of εr=4.4 and a thickness of h=1.6 mm. Ansoft's High Frequency Structure Simulator (HFSS) was used to simulate and optimize the antenna. The antenna has the dimensions of W_1=50 mm, L_1=57 mm, W_2=26 mm, L_2=26 mm, W_3=8.9 mm, W_4=23 mm, W_5=11.75 mm, W_6=3.5 mm, W_7=1.5 mm, W_8=6 mm, W_9=2 mm, L_3=5.75 mm, L_4=19.8 mm, and L_5=8.5 mm, L_6=1.8 mm, and L_7=0.5 mm. An input-impedance matching network consists of a quarter wavelength transformer with dimensions 19 mm long and 0.5 mm wide, which is

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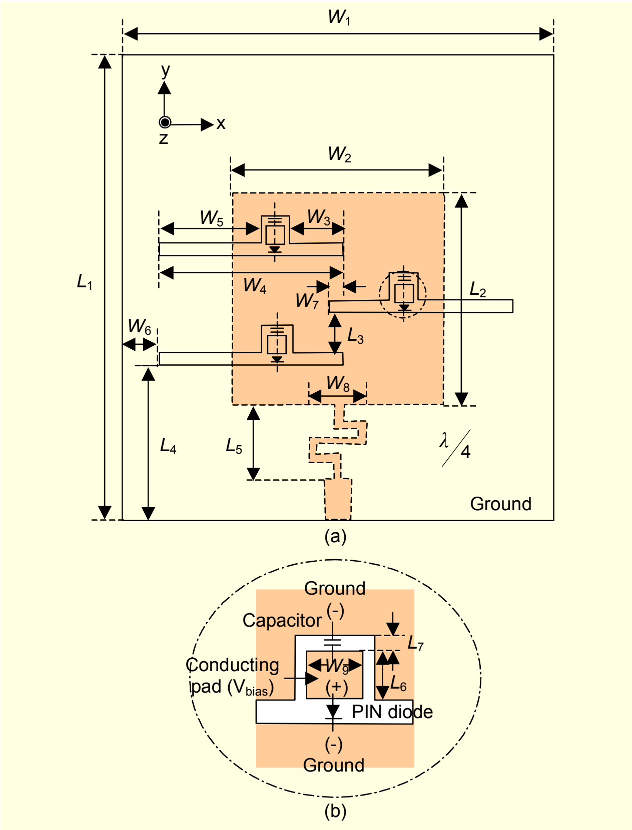

Fig. 1. Geometry of the proposed antenna: (a) antenna and (b) PIN-diode bias network.

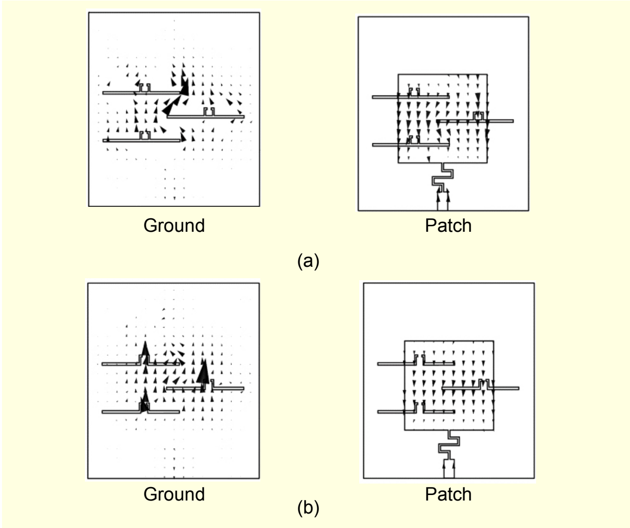

Fig. 2. Current distribution on the ground surface and the patch: (a) K-PCS (1.85 GHz) with diodes off and (b) WiBro (2.35 GHz) with diodes on.

meandered to miniaturize the antenna.

For the initial design, a patch size of W_2=38 mm and L_2=38 mm was chosen for the K-PCS band at 1.85 GHz. To reduce the patch size, three slots on the ground plane were asymmetrically arranged with the same interval L_3 and overlapped W_7 to increase the current path length, as shown in Fig. 1(a). When we optimize the antenna structure, if the length of slot W_4 decreases or the length of W_6 increases, the resonant frequency increases. The resonant frequency also depends on the overlap length of W_7. The patch size was finally reduced to W_2=26 mm and L_2=26 mm by optimizing the dimensions of the slots to 1.0 mm wide and 23 mm long.

Because the slots are used on the finite ground plane, we also simulated a different ground size (W_1 and L_1) and confirmed that there was no significant effect on antenna performance. Insertion of the three slots resulted in a size reduction of 53% compared to a regular square-patch antenna for the K-PCS band. Of course, the conventional method of etching slots on the patch can only slightly reduce the antenna size by 22.8 to 32.6% [6], [7], but this method deeply degrades the performance of the radiation pattern and antenna gain. Therefore, the proposed antenna with slots on the ground has much better spatial efficiency than an antenna with slots on the patch.

The electrical length is effectively controlled by three PIN diodes located between the conducting pads and slots. The PIN diode MA4P274-1279T (MA-COM) is forward-biased with 0.7 V and 10 mA and has a size of 1 mm×0.7 mm. The PIN diode exhibits an ohmic resistance of 3.0 Ω and an intrinsic capacitance of 0.1 pF for the forward bias, but 2.7 kΩ and 9.0 pF at 0 V. Three 10-pF capacitors are soldered at the slots to maintain the RF connection of the PIN diodes and also to isolate the RF signal from the DC. The control DC voltage is supplied to three conducting pads, as illustrated in Fig. 1(b).

Figure 2(a) shows the current distribution on the ground surface and patch for the K-PCS band with all the diodes turned off. Figure 2(b) shows the current distribution of the WiBro band with all the diodes turned on. When the switch is in the off-mode, the electric current travels along a longer path in both the ground and the patch because the current flows around the slots. This causes the antenna to resonate at the lower frequency band of the K-PCS. In contrast, when the switch is in the on-mode, some of the electrical currents can go directly through the switch, thereby shortening the average length of the current path, which enables the antenna to resonate at the higher frequency band of WiBro.

III. Experimental Results

To confirm the frequency reconfigurable characteristics, the proposed antenna was simulated with two different modes of diodes. The on-state diode was considered as the ideal connection, and the off-state diode was simulated with the ideal disconnection for simplicity.

Figure 3 illustrates the excellent agreement between the

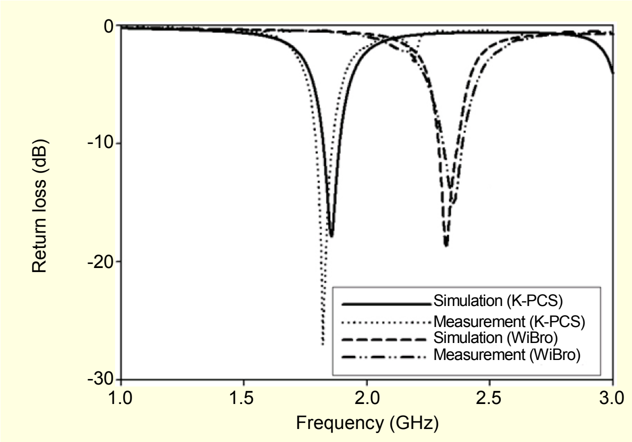

Fig. 3. Measurement and simulated return loss.

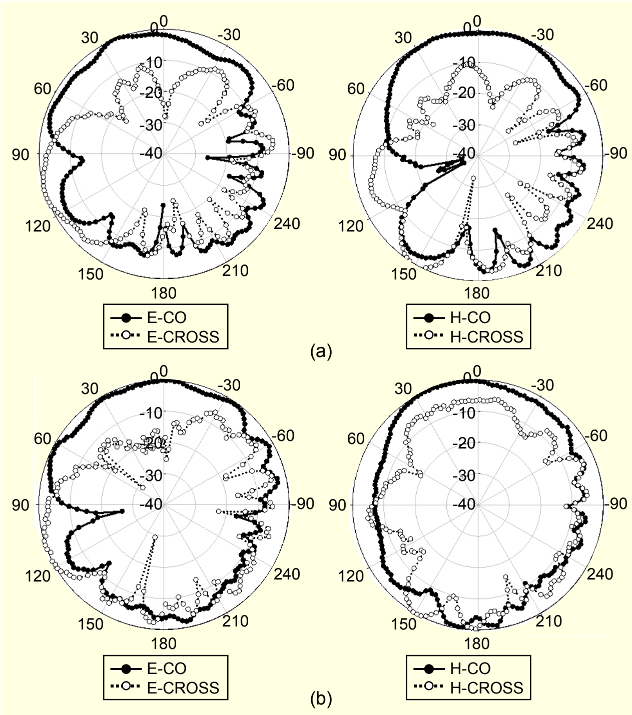

Fig. 4. Measured radiation patterns: (a) K-PCS with diodes off and (b) WiBro with diodes on.

simulated and measured return losses for both bands. With the diodes in the off-state, near 1.85 GHz for K-PCS, the simulated and measured bandwidth of –10 dB return loss is approximately 60 MHz. In the on-state, near 2.35 GHz for WiBro, both bandwidths show a return loss of about 100 MHz.

Figure 4 plots measured E- and H-plane radiation patterns for K-PCS at 1.85 GHz and for WiBro at 2.35 GHz. All patterns display similar omni-directional radiation characteristics. Large amounts of back lobe in the radiation patterns occur due to field leakage through the slots on the ground. Measured gains of 2 and –3 dBi were achieved for the K-PCS and WiBro bands, respectively.

Because of the insertion loss of the diode, the peak gain for WiBro was smaller than that for K-PCS. The loss of antenna gain could be improved if the diode was replaced with a smaller on-resistance diode or MEMS.

IV. Conclusion

A reconfigurable patch antenna using PIN diodes for dual-band operation using K-PCS and WiBro bands was demonstrated. Moreover, slots on the ground plane greatly reduced the antenna size. The proposed frequency reconfigurable antenna should be suitable for service-merged wireless communication systems.

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