A Triple-Band Unidirectional Coplanar Antenna for 2.4/3.5/5-GHz WLAN/WiMax Applications

R. L. Li, T. Wu, and M. M. Tentzeris
School of Electrical and Computer Engineering
Georgia Institute of Technology, Atlanta, GA 30332-0250, USA

Abstract: A triple-band unidirectional coplanar antenna is developed for WLAN/WiMax wireless applications. The triple-band planar antenna consists of a top-loaded dipole for the 2.4-GHz band, two longer dipoles for 3.5-GHz band, and 2 shorter dipoles for the 5-GHz band. The triple-band antenna is printed on a coplanar substrate. The antenna achieves a similar directional radiation pattern at all of the three frequency bands with gains of 7.5 dBi for the lowest band, 8.5 dBi for the middle band, and 9-10 dBi for the highest band.

I. INTRODUCTION

For WLAN/WiMax communications, the operating frequency may be available at different bands, including the 2.4-GHz band (2.4-2.5 GHz), the 3.5-GHz band (3.4-3.6 GHz), and the 5-GHz band (5.1-5.9 GHz). In recent years, a large number of multi-band antennas have been developed for wireless applications [1]-[6]. Most of these multi-band antennas are used for mobile terminals, such as cellular phones or laptop computers. For such applications, the desirable radiation patterns are usually omnidirectional. A unidirectional radiation pattern is sometime required for wireless base station and/or access point applications. For a triple-band antenna, a higher-order mode can be excited at the highest frequency band, which causes a radiation pattern with large ripples. In mobile communications environments, a large ripple may not be a problem. But for base station or access point applications, the large ripples can cause interference and reduce the antenna gain. A lot of techniques have been proposed to suppress the higher-order mode, such as slotted patches [7]-[9] or notched patches [10]. Patch antennas normally have a narrow bandwidth. To enhance the bandwidth, it usually needs a stacked configuration [11]-[13]. A stacked patch antenna has high cross-polarization (>15 dB) and large ripples (>10 dB) at the highest frequency. A printed multi-band dipole antenna was presented in [14]. The total height of the dipole antenna is approximately a quarter wavelength ($\lambda_{Lo}/4$) at the lower band. In this paper, we propose a coplanar triple-band unidirectional dipole antenna. The antenna height is only $0.1\lambda_{Lo}$. There is no ripple in the radiation patterns for all the frequency bands. The antenna gains are 7.5 dBi for the lowest band, 8.5 dBi for the middle band, and 9-10 dBi for the highest band.

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II. ANTENNA CONFIGURATION

The configuration of the proposed triple-band unidirectional antenna is shown in Fig. 1. The triple-band antenna consists of a top-loaded dipole for the 2.4-GHz band (2.4-2.5 GHz), a couple of longer dipoles for the 3.5-GHz band (3.4-3.6 GHz), and a couple of shorter dipoles for the 5-GHz band (5.1-5.9 GHz). The top-loaded (T=10 mm, W_T=2 mm) dipole for the lowest band has a total length of L_{Lo}=52 mm while the couple of the longer dipoles for the middle band has a length of L_{Mi}=42 mm and the couple of shorter dipoles for the highest band has a length of L_{Hi}=30 mm. The two couples of longer and shorter dipoles have a separation of D_{Mi} =7 mm and D_{Hi} =26 mm, respectively. The two couples of dipoles are connected by a slot line with a slot width W_g=1 mm. All dipoles are printed coplanar on the bottom side of a thin RT/Duroid 5880 substrate with a dielectric constant ε_r=2.2 and a thickness t=0.5 mm. The printed dipoles are placed H=12 mm ($\sim 0.1\lambda_{Lo}$)

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above a ground plane (100 mm × 60 mm) and excited by a coupling microstrip line (L_m=10 mm) printed on the top side of the substrate through a 0.084″ semi-rigid coaxial cable. The line widths of the printed dipoles, the slot line, and microstrip line are W_{Lo}=3 mm, W_{Mi}=W_{Hi}=2 mm, W_s=13 mm, and W_m=1.5 mm, respectively.

III. RESULTS

The coplanar printed dipole antenna was first simulated using *CST MicroStripes 7.5*. The simulated return loss (RL) is plotted in Fig. 2. Good impedance matching is achieved in the 2.4-GHz (RL>10 dB from 2.4 to 2.5 GHz), in the 3.5-GHz (RL>10 dB from 3.4 to 3.6 GHz), and in the 5-GHz band (RL>10 dB from 5.1 to 5.9 GHz). There is a resonance appearing around 1.4 GHz. This resonance is due to the feeding coaxial cable which introduces a vertical monopole mode. A prototype has been fabricated and measured. The measured return loss is compared with the simulation result and good agreement is observed. The radiation patterns at the 2.45 GHz, 3.5 GHz, and the 5.5 GHz are plotted in Fig. 3. We can see that in all of the three frequency bands the radiation patterns are unidirectional and there are little ripples and side lobes. Note that the radiation pattern at 1.4 GHz is omnidirectional (see the inset of Fig. 2), which confirms the monopole mode. The antenna gain in the 2.4 GHz band is about 7.5 dBi, 1-2.5 dB lower than those in the 3.5-GHz band (8.5 dBi)and in the 5-GHz band (9-10 dBi). The higher gain in the middle band and in the highest band is due to the two-dipole array for the 3.5-GHz band and the 5-GHz band.

IV. CONCLUSION

A triple-band unidirectional antenna has been developed. The triple-band antenna consists of a top-loaded dipole for the lowest frequency band, two dipoles for the middle frequency band, and two dipoles for the highest frequency band. All dipoles are printed coplanar on a thin substrate. The printed dipole antenna is excited by a microstrip line. The higher-order mode in the higher frequency band has been suppressed, leading to a good unidirectional pattern in all of the three frequency bands. This triple-band unidirectional antenna may find applications in base stations and/or access points for 2.4/3.5/5-GHz wireless communications.

Acknowledgement

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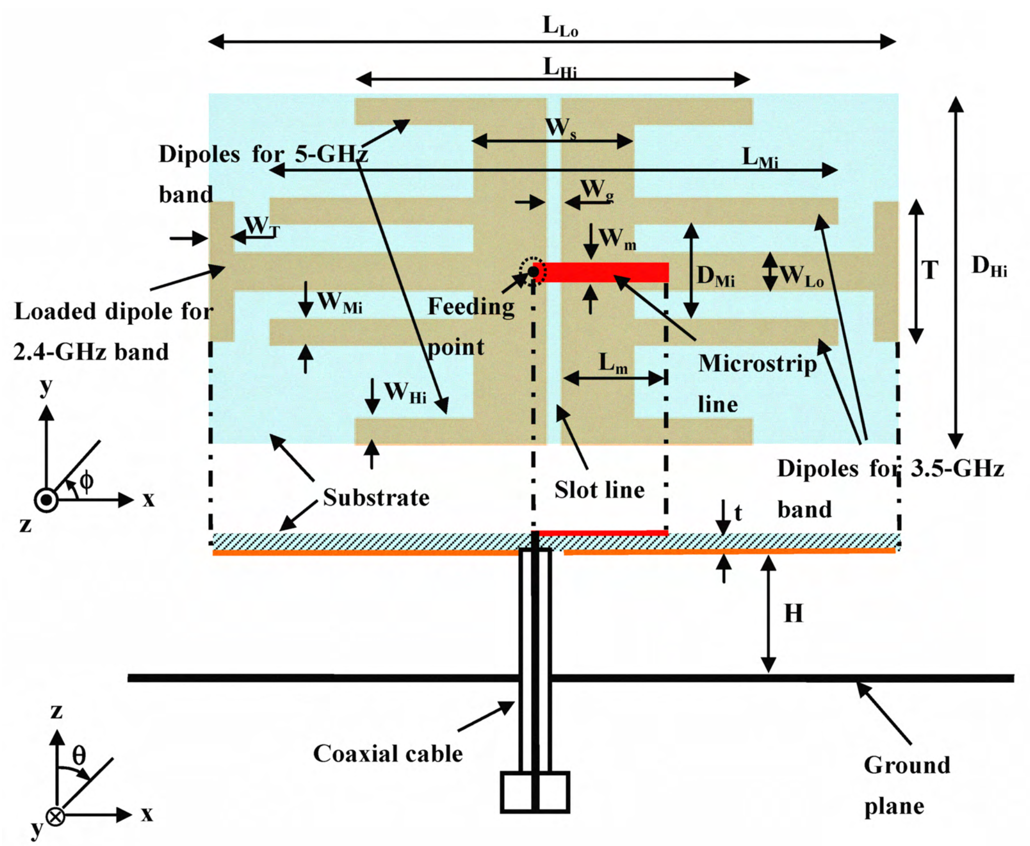


Fig. 1. Configuration of a triple-band unidirectional coplanar antenna.

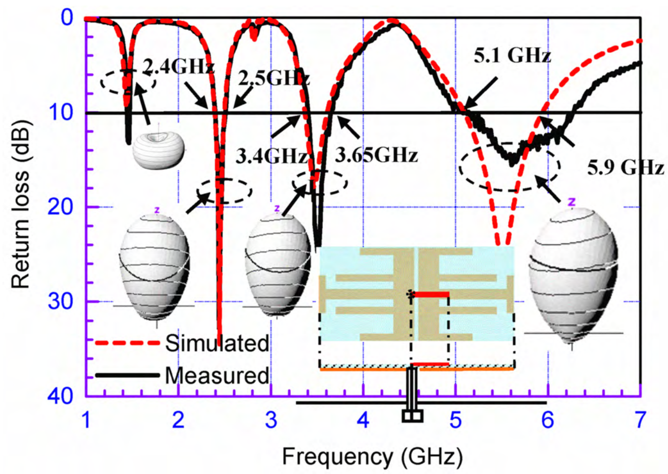
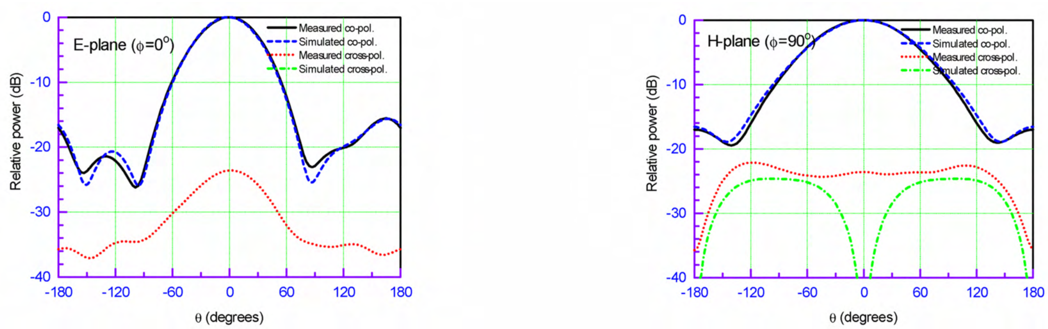
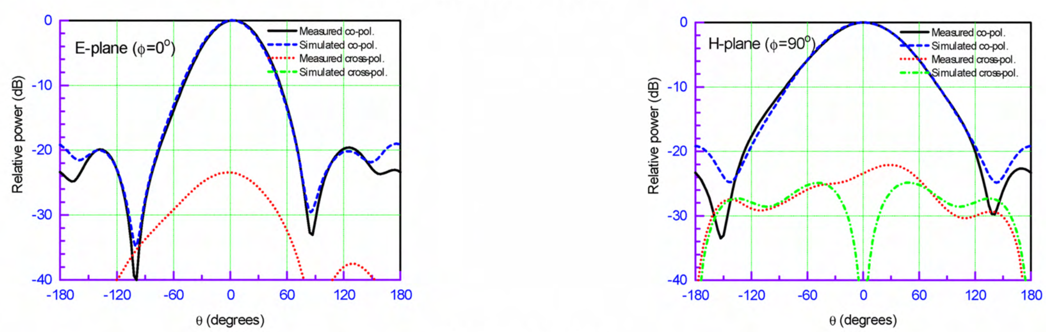


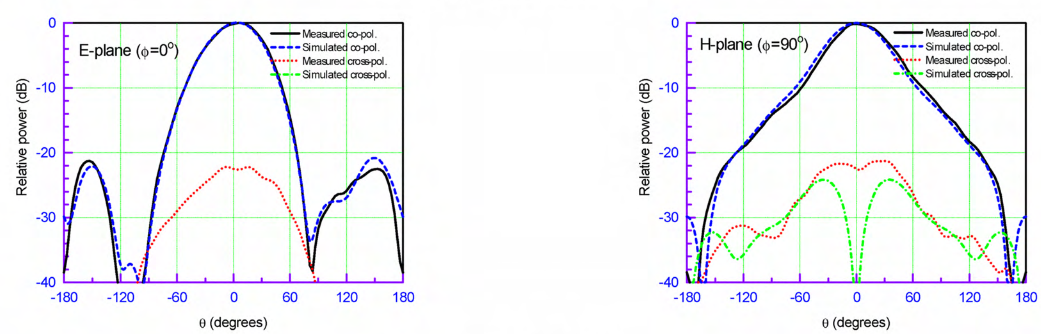
Fig. 2. Simulated and measured results for return loss of the triple-band unidirectional antenna.



(a) At 2.45 GHz.



(b) At 3.5 GHz.



(c) At 5.5 GHz.

Fig. 3. Radiation patterns of the triple-band unidirectional antenna.