A Dual-Band Unidirectional Coplanar Antenna for 2.4-5-GHz Wireless Applications

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Introduction

In recent years, a large number of dual-band antennas have been developed for wireless applications [1]-[6]. Most of these dual-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 dual-band antenna, a higher-order mode can be excited at the upper 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 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 dual-band patch antenna has high cross-polarization (>15 dB) and large ripples (>10 dB) at a higher frequency of the upper band. A printed dual-band dipole antenna was presented in [14]. The dipoles for the lower band and for the upper band have different heights above a ground plane and the total height of dual-band antenna is approximately a quarter wavelength ($\lambda_{Lo}/4$) of the lower band. In this paper, we propose a coplanar dual-band unidirectional dipole antenna. The antenna height is only $0.1\lambda_{Lo}$. There is no ripple in the radiation patterns for the low band and fro the upper band. The antenna gain is about 9-10 dBi in the upper band and 7.5 dBi in the lower band.

Antenna Configuration

The configuration of the proposed dual-band unidirectional antenna is shown in Fig. 1. The dual-band antenna consists of a long dipole and two short dipoles, which were designed for operation at the 2.4-GHz ISM band (2.4-2.5 GHz) and the 5-GHz UNII band (5.1-5.9 GHz), respectively. The dipole for the lower band has a longer length L_{Lo}=60 mm (~$\lambda_{Lo}/2$,, where λ_{Lo} is the free-space wavelength at the center frequency of the 2.4-GHz band) while two dipoles for the upper band have a shorter length L_{Up}=30 mm. The two short dipoles have a separation D=26 mm and 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 (~$0.1\lambda_{Lo}$) above a ground plane (100 mm × 60 mm) and excited by a coupling microstrip line 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}=5 mm, W_{Up}=2 mm, W_s=13 mm, and W_m=1.5 mm, respectively.

Results

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The coplanar printed dipole antenna was first simulated using *Microstripes 7.5*. The simulated return loss (RL) is plotted in Fig. 2. Good impedance match is achieved in the 2.4-GHz (RL>10 dB from 2.39 to 2.53 GHz) and in the 5-GHz band (RL>10 dB from 5.04 to 6.0 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. We have demonstrated by simulation that the 1.4-GHz resonance would disappear if without the coaxial cable. A prototype has been fabricated and measured. The measured return loss is compared with the simulation result in Fig. 3 and good agreement is observed. The measured bandwidths for 10-dB return loss are 2.39-2.52 GHz for the 2.4-GHz band and 4.93-6.13 GHz for the 5-GHz band, which covers the 2.4-GHz ISM band and the 5-GHz UNII band. The radiation patterns at the 2.45 GHz and the 5.5 GHz are plotted in Fig. 4. We can see that in both 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, 1.5-2.5 dB lower than that in the 5-GHz band (9-10 dBi). The higher gain in the upper band is due to the array configuration for the 5-GHz band. The current distributions on the printed dipoles are displayed in Fig. 5. At the lower band, the current concentrates on the long dipole for the lower band while at the upper band the current is distributed on the short dipoles for the upper band. The higher-order mode is not excited on the long dipole for the lower band, which effectively avoids ripples and reduces side lobes in the upper band. More results and analysis will be presented in the final paper.

Conclusion

A dual-band unidirectional antenna has been developed. The dual-band antenna consists of a long dipole for the lower frequency band and two short dipoles for the higher 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 the both frequency bands. This dual-band unidirectional antenna may find application in base stations and/or access points for 2.4/5-GHz wireless communications.

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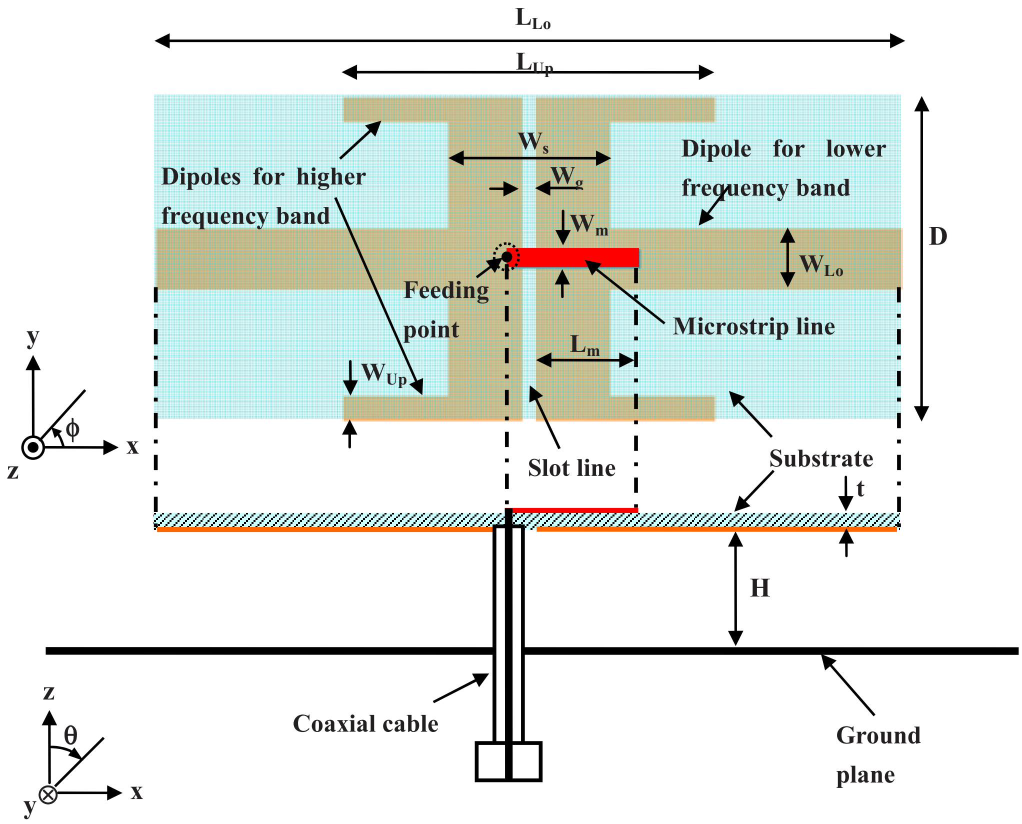


Fig. 1. Configuration of a dual-band unidirectional coplanar antenna.

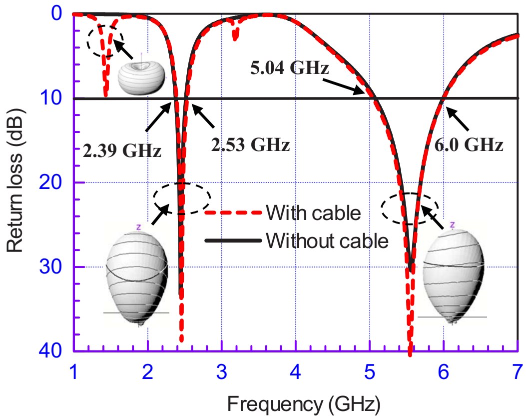


Fig. 2. Simulated return loss for the dual-band unidirectional antenna.

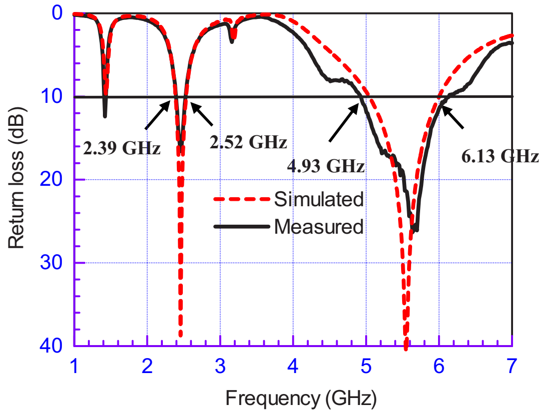
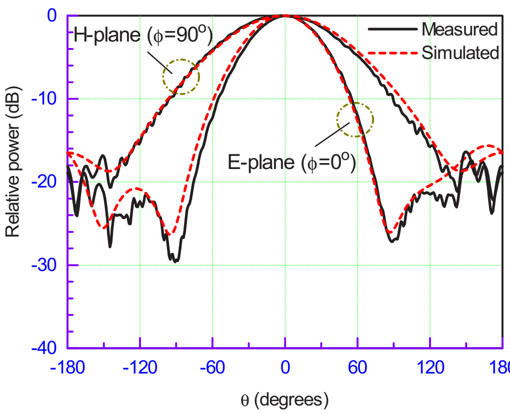
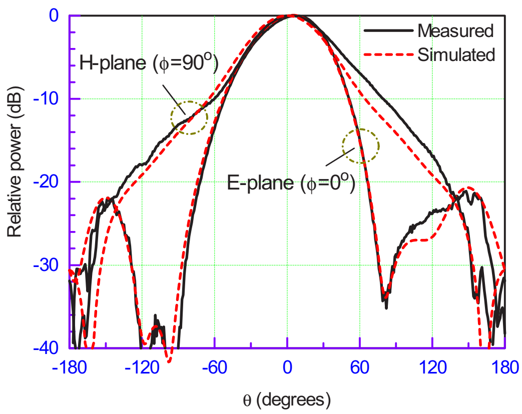


Fig. 3. Measured return loss for the dual-band unidirectional antenna.

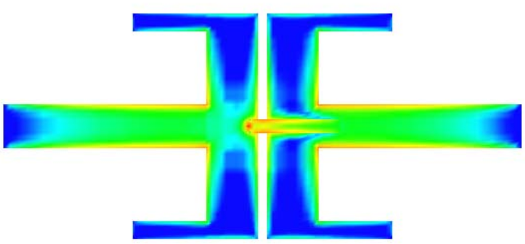


(a) At 2.45 GHz.

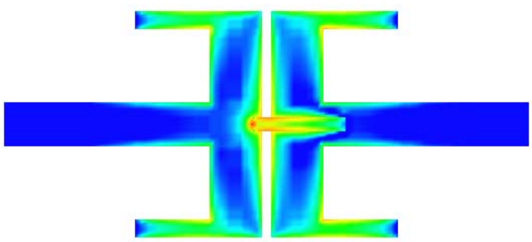


(b) At 5.5 GHz.

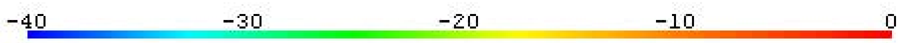
Fig. 4. Radiation patterns of the dual-band unidirectional antenna.



(a) At 2.45 GHz.



(b) At 5.5 GHz.



Surface current (dB)

Fig. 5. Current distributions on the printed dipoles for the dual-band unidirectional antenna.