Slot Antenna for Dual-Frequency Operation

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Abstract

A slot bowtie antenna is analyzed to obtain dual-frequency operation at wireless LAN system frequencies (2.45 GHz and 5.2 GHz). The slot bowtie has a layered structure composed of a slot bowtie on a dielectric substrate backed by a conducting reflector. It is found that dual-frequency operation is obtained by offsetting the feed point from the center of the bowtie. The radiation is unidirectional and the cross polarization component is low (less than –18 dB). The slot bowtie has a 4.8% VSWR bandwidth around 2.45 GHz and a 6.2% VSWR bandwidth around 5.2 GHz.

Introduction

This paper presents a slot bowtie antenna for dual-frequency operation at 2.45 GHz and 5.2 GHz. The slot bowtie is intended to satisfy three conditions: unidirectional radiation, low cross polarization, and low profile. For satisfying these conditions, a layered structure is used, as shown in Fig. 1. The slot bowtie is cut in a conducting plate on a dielectric substrate. Another conducting plate below the dielectric is used as a reflector, which changes the inherent bi-directional radiation from the slot bowtie to unidirectional radiation. Note that the radiation from the slot bowtie is generated by the magnetic current within the slot bowtie; the magnetic current and its image generated by a conducting reflector are in phase, and hence one can make the antenna height (above the reflector) small. In this paper, the antenna height is chosen to be very small: 7 mm = 0.057 wavelength at 2.45 GHz.

Analysis and discussion

The slot bowtie in Fig. 1 is cut in a finite conducting plate of $S_{GP,x} \times S_{GP,y}$ (backed by a reflector) with a finite slot arm length, and hence it cannot be a self-complementary antenna [1]. This means that the slot angle is not necessarily restricted to $\phi_{BW} = 90$ degrees. In this paper, the slot angle is arbitrarily chosen to be $\phi_{BW} = 56$ degrees.

For analysis [2], the reflector is assumed to be of infinite extent; the dielectric below the slot bowtie has thickness B = 1mm and relative permittivity $\varepsilon_r = 4.8$ (corresponding to a commercially available material), with side lengths $S_{GP,x} = 42$ mm (= $0.343\lambda_{2.45} = 0.728\lambda_{5.2}$) and $S_{GP,y} = 43$ mm (= $0.351\lambda_{2.45} = 0.745\lambda_{5.2}$); the slot bowtie height h is chosen to be small to make a low-profile antenna: h = 7 mm (= $0.057\lambda_{2.45} = 0.12\lambda_{5.2}$); and the feed probe width is fixed to be $w_{pro} = 1$mm, where λ_f is the wavelength at frequency f.

Based on the abovementioned choices, the structural parameters to be determined are the slot arm length $2L_{arm}$ and the distance from the bowtie center to the feed probe, d_{pro}. These unknowns are optimized through a step-by-step investigation.

The first step is to determine the slot arm length $2L_{arm}$. This is performed by holding the feed probe distance at $d_{pro} = 0$ (center feed). Analysis reveals that there is an optimum slot arm length that leads to resonance at 2.45 GHz ($\equiv f_{2.45}$). When $2L_{arm} = 26$ mm, the bowtie shows the lowest VSWR at $f_{2.45}$. This slot arm length is less than one-half of the guide wavelength: $2L_{arm} = 0.36\lambda_g$, where the guide wavelength λ_g is roughly estimated using $\lambda_g = \lambda_{2.45} / [(1+\varepsilon_r)/2]^{1/2}$.

The second step is to obtain resonance at 5.2 GHz ($\equiv f_{5.2}$), where the slot arm length is held at $2L_{arm} = 26$ mm, determined in the first step. This is realized by appropriately choosing the feed probe distance d_{pro}. Fig. 2 shows the VSWR as a function of frequency for three representative values of d_{pro}. It is found that the VSWR at $f_{5.2}$ can be controlled by the feed probe distance d_{pro}. It is also found that the VSWR around $f_{2.45}$ is not significantly affected by the feed probe distance d_{pro}. This phenomenon helps facilitate the dual-frequency antenna design.

From the investigations in the first and second steps, the slot arm length and the feed probe distance are determined to be $2L_{arm} = 26$ mm and $d_{pro} = 5.5$ mm, respectively. In this case, the frequency band width for a VSWR = 2 criterion is 4.8% around $f_{2.45}$ and 6.2% around $f_{5.2}$.

Fig. 3 shows the radiation patterns at $f_{2.45}$ and $f_{5.2}$. Each radiation is unidirectional; the maximum beam direction is normal to the antenna plane with the help of the conducting reflector. The average value of the half-power beam widths (HPBWs) in the x-z and y-z planes is approximately 70 degrees at $f_{2.45}$ and 54 degrees at $f_{5.2}$. The cross polarization component is less than –30 dB at $f_{2.45}$ and –18 dB at $f_{5.2}$. Note that the gain within each VSWR bandwidth is almost constant: 9.2 dBi at $f_{2.45}$ and 10.1 dBi at $f_{5.2}$.

Conclusions

The slot bowtie antenna, having a layered structure composed of a slot, a dielectric substrate, and a conducting reflector, is investigated for operation at two frequencies, 2.45 GHz and 5.2 GHz. The radiation is generated from the magnetic current within the slot bowtie and hence the antenna height above the conducting reflector can be made small: h = 7 mm = 0.057 wavelength at 2.45 GHz. Investigation shows that operation at 2.45 GHz is obtained by appropriately choosing the slot arm length, while operation at 5.2 GHz is obtained by offsetting the feed point from the bowtie center. It is found that the feed probe offset for the 5.2 GHz operation does not significantly affect the 2.45 GHz operation. It is also revealed that the slot bowtie radiates a unidirectional beam at 2.45 GHz, as well as at 5.2 GHz. A frequency bandwidth of 4.8% for a VSWR = 2 criterion is obtained around 2.45 GHz, and a frequency bandwidth of 6.2% is obtained around 5.2 GHz.

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Reference

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[2] A. Taflove, Computational Electrodynamics: The Finite-Difference Time Domain Method, Norwood, MA, Artech House, 1995.

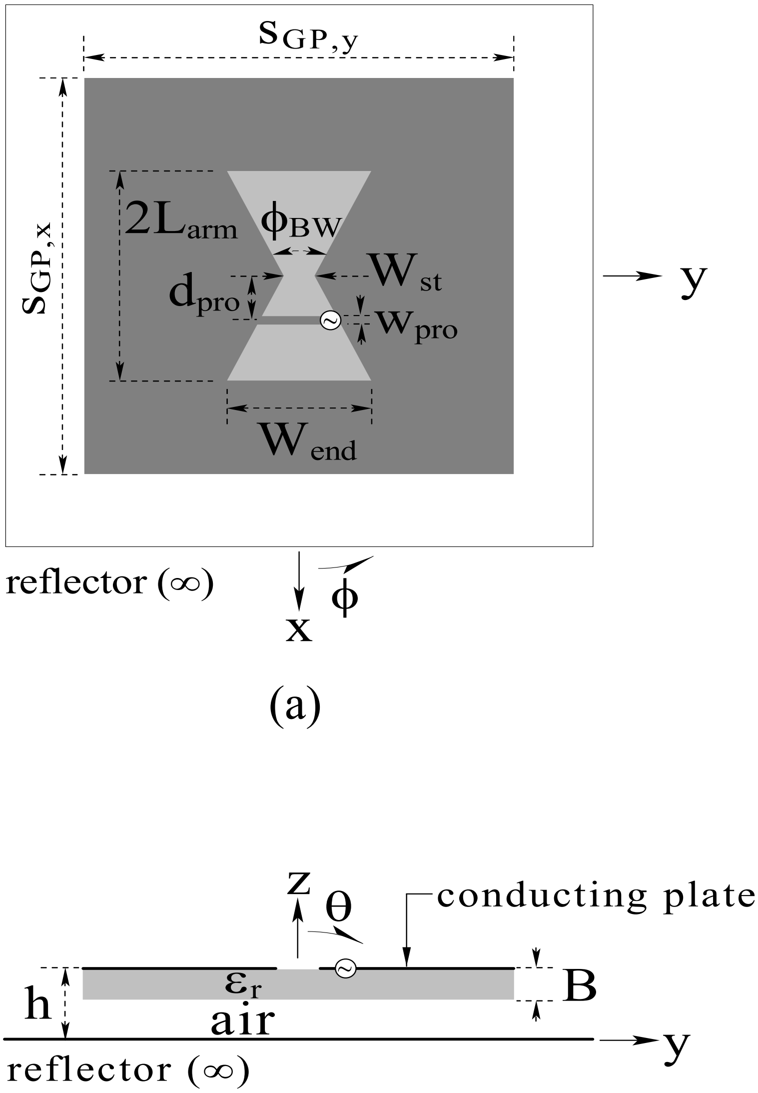


Fig. 1. A slot bowtie antenna: (a) Top view. (b) Side view.

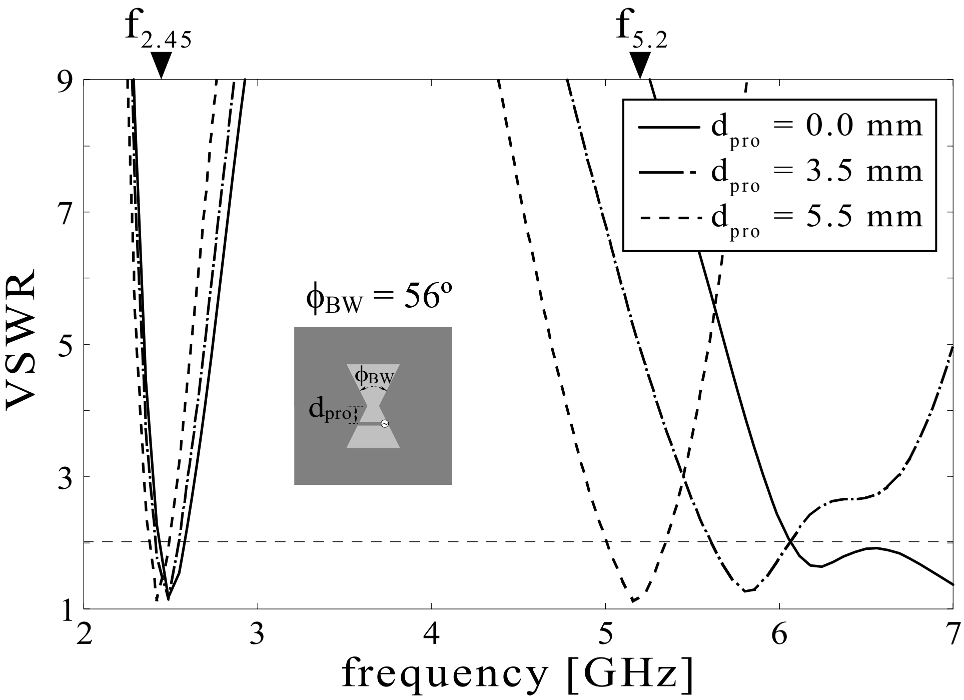
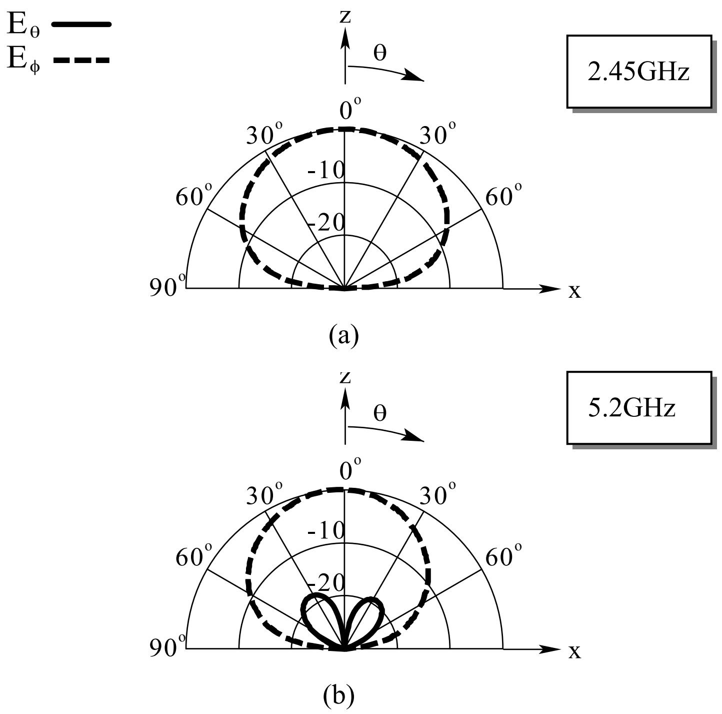


Fig. 2. Effects of feed probe distance d_{pro} on the VSWR of a slot bowtie antenna.



(a)

(b)

Fig. 3. Radiation patterns of a slot bowtie antenna. (a) At 2.45 GHz. (b) At 5.2 GHz.