Analysis and Design of Broadside-Coupled Striplines-Fed Bow-Tie Antennas

Yu-De Lin and Syh-Nan Tsai

***Abstract*—The design of a bow-tie antenna fed by broadside-coupled striplines (BCS) for the 2.4-GHz ISM band is described in this letter. The two fins of the bow tie are, respectively, on the two sides of the substrate. The feeding balanced lines adopted are the BCS. A quarter-wave transformer is used to transform the microtrip line input to the BCS feed. Analysis method based on the mixed-potential integral equation method is used to characterize the input characteristics of the bow-tie antenna. Obtained numerical results are in good agreement with experimental data. Through experiments with bow-tie antennas of various extended angles, the bow-tie antenna with a 90° extended angle exhibits the widest bandwidth in the desired frequency band, which has a bandwidth of 19% for VSWR $< 1.5:1$.**

***Index Terms*—Microstrip antennas.**

I. Introduction

Printed bow-tie antennas have been known for decades due to their advantages such as wide bandwidth and easy fabrication [1], [2]. In [3], we reported the design results of a coplanar waveguide fed uniplanar bow-tie antenna as an improvement in bandwidth over the uniplanar printed dipole reported in [4]. In this letter, the two fins of the bowtie antenna are fabricated on the two sides of the substrate. Accordingly, another feeding approach is used; namely, the printed bow-tie is now fed by broadside-coupled striplines (BCS). Similar to the uniplanar bow-tie antenna in [3], this antenna is designed for the mobile station antenna for the 2.4-GHz ISM band. The substrate used is the FR-4 substrate, which is commonly used in printed circuits and is much more inexpensive than the microwave substrates such as Duroid. This feature, combined with its omnidirectional radiation patterns, makes this antenna suitable as a low-cost mobile station antenna in the mobile communication system.

II. Analysis and Design of the Broadside-Coupled Striplines-Fed Bow-Tie Antenna

The BCS-fed printed bow-tie antenna is shown in Fig. 1. A quarter transformer is used to transform the input 50-Ω microstrip line to the BCS feed line. Two back-to-back microstrip-to-BCS transitions provide an insertion loss of less than 1.5 dB from dc to 3 GHz and a return loss of almost 30 dB at the operational frequency 2.44 GHz. Most of the insertion loss in the frequency band comes from the dielectric loss of the FR-4 substrate, which is not as low loss as the microwave substrate. The entire circuit is fabricated on an FR-4 substrate $(\varepsilon_r = 4.8)$. The substrate thickness is 1.6 mm. The bandwidth of bow-tie antennas with various extended angles (θ in Fig. 1) of 0° (dipole), 30, 60, 90, and 120° is investigated. We find that the printed BCS-fed bow tie with 90° extended angle results in the widest bandwidth. For the printed bow tie of 90° extended angle, the length of the bow tie (WA in Fig. 1) is 22.4 mm for the 2.44-GHz band.

Manuscript received May 28, 1997; revised October 21, 1997. This work was supported in part by National Science Council under Grant NSC 85-2221-E-009-030.

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Publisher Item Identifier S 0018-926X(98)02254-6.

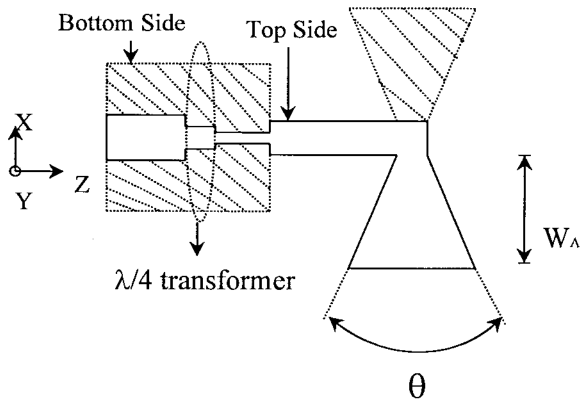

Fig. 1. Circuit configuration of the broadside-coupled striplines-fed bow-tie antenna.

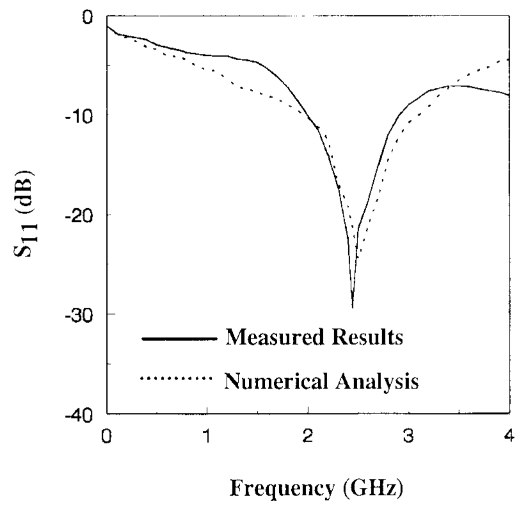

Fig. 2. Measured and calculated return loss of the broadside-coupled strip-lines-fed bow-tie antenna.

To assist the design of the printed bow-tie antenna, the input characteristics of the antenna is analyzed by the mixed-potential integral equation method [5]. Triangular bases are used to model the currents on the feed lines and on the bow-tie antenna [6]. Both numerical and experimental results of the return loss of the bow-tie antenna with a 90° extended angle are shown in Fig. 2. As shown, they are in good agreement. This confirmed the validity of the analysis program. The return loss of the bow-tie antenna was measured with an HP8720 network analyzer, with the antenna immersed in a box filled with absorbers to simulate the anechoic environment. The results show that the antenna circuit has a return loss of 29 dB at 2.44 GHz and a bandwidth of 19% for VSWR $< 1.5:1$ and a bandwidth of 40% for VSWR $< 2.0:1$. These results show some improvement over those reported for the uniplanar bow tie on the same substrate in [3]. For comparison, a printed resonant half-wavelength dipole (with the extended angle θ in Fig. 1 being 0°) built on the same substrate shows a bandwidth of only 11% for VSWR $< 1.5:1$ and 20% for VSWR $< 2.0:1$.

Radiation patterns of the antenna were measured with an HP85301 antenna measurement system in an anechoic chamber. E-plane (xy-plane in Fig. 1) radiation patterns of both copolarization and cross

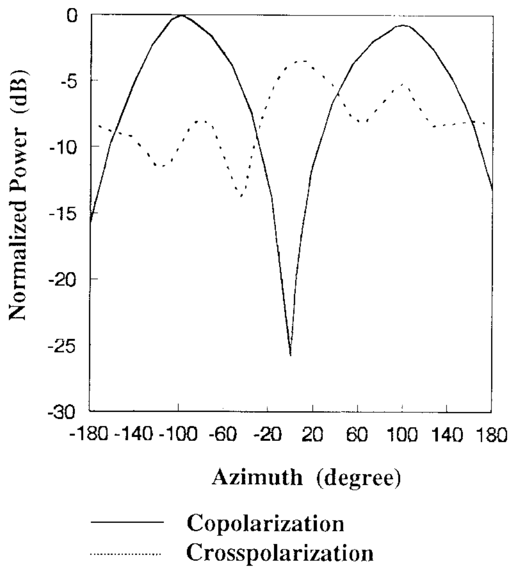

Fig. 3. E-plane radiation patterns of the broadside-coupled striplines-fed bow-tie antenna.

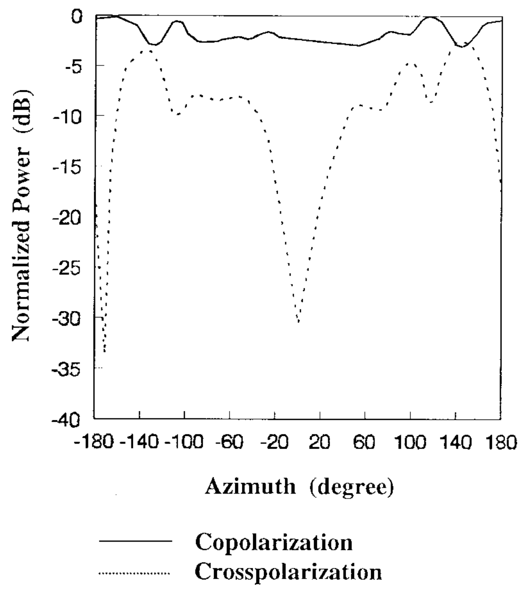

Fig. 4. H-plane patterns of the broadside-coupled striplines-fed bow-tie antenna.

polarization are shown in Fig. 3. Typical sine pattern of dipole antenna is observed. H-plane (yz-plane in Fig. 1) radiation patterns of both copolarization and cross polarization are shown in Fig. 4. Typical omnidirectional pattern of the dipole antenna is observed.

Compared with the uniplanar bow tie reported in [3], the BCS-fed bow tie has better bandwidth performance. Yet the gain variation is smaller in the uniplanar bow-tie case. Also, the cross polarization is higher in the BCS-fed bow tie.

III. Conclusions

Analysis and design of a BCS-fed bow-tie antenna on an inexpensive PC substrate for the 2.4-GHz ISM band is described in this letter. Numerical results based on the mixed-potential integral equation method were validated by measurement. By comparing the properties of bow-tie antennas with various extended angles, we found that the antenna with 90° extended angle exhibits the widest bandwidth. With its features of low-cost, wide bandwidth, and dipole-like radiation patterns, the proposed BCS-fed bow-tie antenna is suitable as the mobile station (handset) antenna in the personal mobile communication.

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