A Triband Shunt-Fed Omnidirectional Planar Dipole Array

Kunpeng Wei, Zhijun Zhang, *Senior Member, IEEE*, Wenhua Chen, *Member, IEEE*, Zhenghe Feng, *Senior Member, IEEE*, and Magdy F. Iskander, *Fellow, IEEE*

***Abstract*—A novel shunt-fed triband printed two-element collinear dipole array is presented in this letter. The planar dipole array configuration is designed using two shunt-fed back-to-back dipole elements with omnidirectional pattern. The motivation for this work was to devise a novel feed structure that has an advantage of structural simplicity with good performance. The proposed antenna can provide the required bands of GSM850 (824–894 MHz), DCS (1710–1880 MHz), and PCS (1850–1990 MHz) with $S_{11} < -10$ dB. A prototype array antenna is fabricated and measured. Good omnidirectional radiation with gain variations less than 1.5 dBi in the azimuth plane has been obtained. Enhanced antenna gain about 3.4∼3.8 dBi for GSM850 band and about 3.8∼5.5 dBi for DCS/PCS bands are achieved. It is significant that the designed triband dipole array maintained good radiation efficiency values at all bands.**

***Index Terms*—Array antenna, omnidirectional antenna, printed antenna, triband dipole.**

I. Introduction

DUE TO THE rapid development of modern wireless and mobile communication, the need for novel omnidirectional (in the azimuth plane) antennas with a multiband operation increased considerably. The great progress of multifrequency antenna makes it possible to realize the integration of several services such as GSM/DCS/PCS or 2.4/5.2 GHz WLAN access points into one device [1], [2]. However, it is still a significant challenge to design a multiple-band antenna that is omnidirectional in the azimuth plane and has a narrow beam and low sidelobes in the elevation plane.

In conventional single-band applications, vertical dipole antennas with a half-wavelength resonant structure are the most popular choice [3]. For some applications, half-wavelength dipole antenna gain of about 2.15 dBi may not be sufficient. To enhance the gain of dipole antenna, the coaxial collinear (COCO) antenna [3], [4] employs a collinear arrangement of coaxial cables where the feeding structures are inverted in a half-wavelength step so as to produce in-phase excitations. Recently, a variety of promising omnidirectional printed antennas [5]–[7] suitable for replacing the traditional coaxial antennas [3] have been reported. However, since these dipole array antenna designs are series-fed and needing a 180° phase shift to excite all radiating elements in phase, the distance between two elements of series-fed collinear dipole array [3]–[7] should be half-wavelength. Consequently, to design a multiband array with a series-fed configuration, the array must be segmented to different regions, and each region corresponds to a different band [8]. In a series-fed multiple-band array, the radiating elements are different for each band, which results in large electrical size and great gain variation in the horizontal plane. Moreover, the arrangement of the feeding network is complicated, the impedance bandwidth is limited, and the direction of peak gain drifts with frequency changes.

In this letter, a novel triband printed collinear dipole array antenna using shunt-fed network is fabricated and measured. The planar dipole array antenna comprises two back-to-back dipole elements to enhancing the antenna gain. The shunt-fed planar dipole array antenna has an advantage of structural simplicity with good performance. Shunt-fed structure with symmetric feeding lines is facilely excited in phase. Moreover, without any phase-shifting device, shunt-fed planar dipole array is suitable for multiple-band or wideband services. Details of the proposed planar triband dipole-array antenna are described, and experimental results of a constructed prototype are presented.

II. Antenna Design

To design a triband omnidirectional dipole array, first of all, a triband dipole element covering the required bands is needed. This work employs the design approach presented in [2]. To provide a triband coverage, the dipole antenna works at both half-wavelength mode and one-wavelength mode. As the one-wavelength mode cannot achieve a good matching by itself, a shorted transmission line section of length s is used as a matching component at the high band. Fig. 1 shows a schematic of 45° chamfered printed dipole with a shorted stub. The dipole was printed on a Teflon ($\varepsilon r = 2.65$) substrate. The thickness of the substrate is H, the length is L, and the width is W. Two shaded rectangular sections in Fig. 1 are the copper trace on the bottom layer of the substrate. The gap between the two traces is G. The

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K. Wei, Z. Zhang, W. Chen, and Z. Feng are with State Key Lab of Microwave and Communications, Department of Electronic Engineering, Tsinghua University, Beijing 100084, China (e-mail: zjzh@tsinghua.edu.cn).

M. F. Iskander is with the Hawaii Center for Advanced Communications (HCAC), University of Hawaii at Manoa, Honolulu, HI 96822 USA (e-mail: Magdy.iskander@gmail.com).

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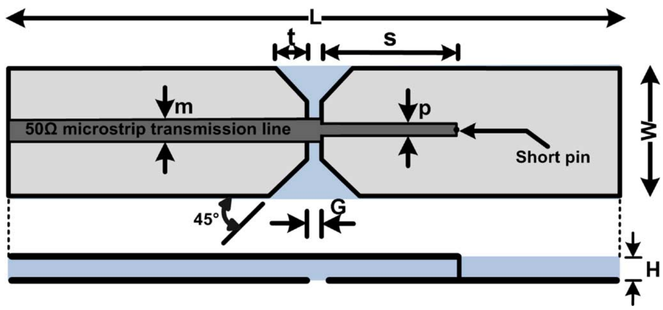

Fig. 1. Diagram of 45° chamfered printed dipole with a shorted stub.

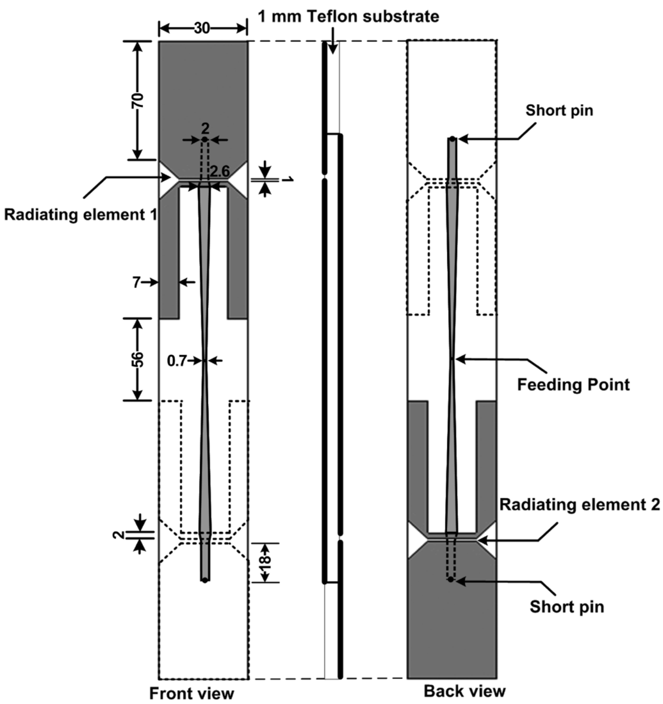

Fig. 2. Geometry of the proposed triband omnidirectional planar dipole array antenna (units: millimeters).

TABLE I
DIMENSIONS OF THE 45° CHAMFERED PRINTED DIPOLE (MILLIMETERS)

Parameter	L	W	G	H	t	s	p	m
Value	145	30	1	1	7	18	2	2.6

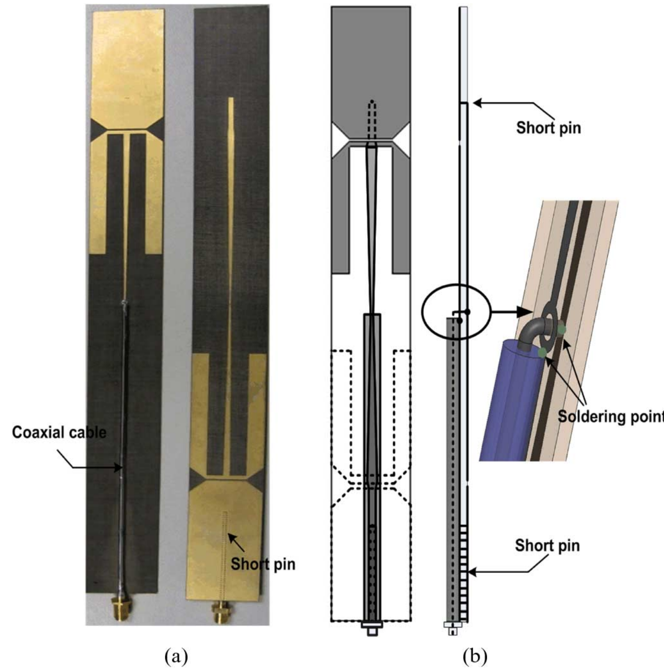

Fig. 3. Fabrication of antenna. (a) Photograph of the fabricated prototype. (b) Schematic of the feeding network.

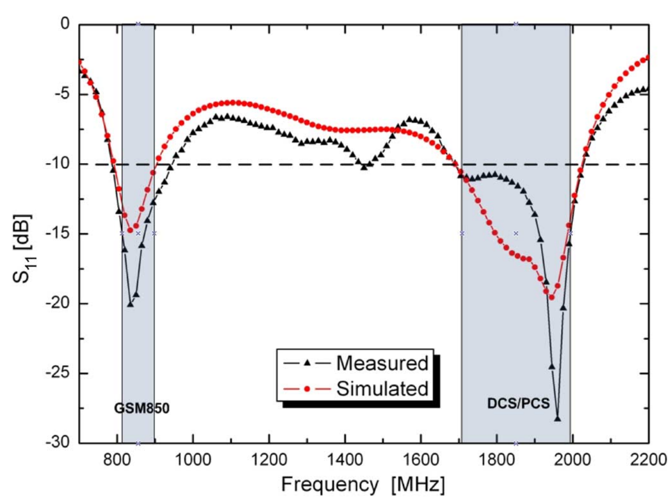

Fig. 4. Measured and simulated reflection coefficient S_{11}.

printed dipole was fed by a 50-Ω microstrip transmission line and a shorted stub on the top layer.

The printed antenna was first designed and well-matching in GSM850 band. However, the printed dipole displayed large capacitive input impedance in DCS/PCS bands. It was possible to broaden the bandwidth by increasing the width of the dipole arms. Another technique used for impedance matching is by chamfering the feeding point of a dipole. Only a 45° chamfered was used in this letter, and the chamfered length t was selected to achieve good impedance matching. In order to counteract the large capacitance in DCS/PCS bands, a shorted transmission line is used as a series inductor. With properly chosen values for the length s and width p, the 45° chamfered printed dipole can achieve good matching at DCS/PCS bands. To minimize the antenna dimensions, the antenna parameters have been optimized. The geometrical parameters of the 45° chamfered printed dipole are given in Table I.

The main problem of omnidirectional array antennas is the difficulty in arranging the elements. This is because the excitation is physically on the symmetry axis, which blocks the way of the feeding network. In this letter, a new shunt-fed structure is proposed to solve this problem. Fig. 2 shows the geometry and specific dimensions of the triband omnidirectional planar dipole array antenna. The antenna mainly consists of two printed dipole elements of identical dimensions, which are mounted on the opposite surfaces of the substrate. Two printed chamfered dipoles with shorted stubs as described in Fig. 1 are arranged symmetrically with a 56-mm distance between them. Each dipole element is shunt-fed by two parallel-strip lines, and a gradual

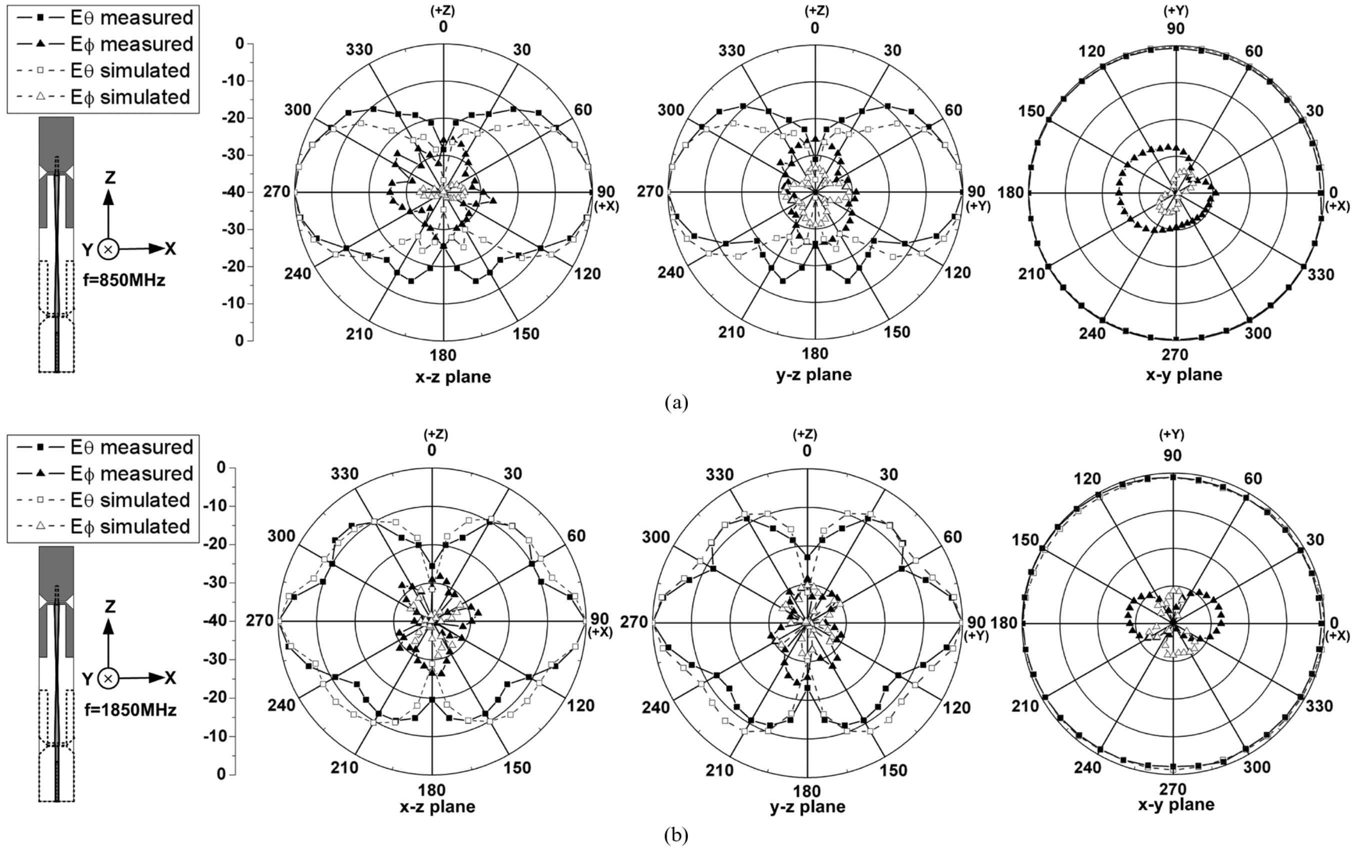

Fig. 5. Measured radiation patterns. (a) 850 MHz. (b) 1850 MHz.

50–100-Ω broadband impedance transformation is achieved by tapering the width of the parallel-strip lines. The lower arms of two dipole elements are fed by the microstrip feeding line on the top layer, while the upper arms are fed by feeding line on the bottom layer.

The feeding point is at the center of the antenna array. These balanced feeding lines with identical length ensure that the two radiating elements have the same phase, which leads to constructive omnidirectional radiation. Moreover, without any phase-shifting device, shunt-fed planar dipole array has no limitation to cover multiple-band or wideband. This characteristic is very attractive in modern communication systems. Therefore, the shunt-fed planar dipole array is a better candidate for a multiple-band omnidirectional antenna.

III. Measurement Results

To verify the design, a prototype of the proposed antenna has been fabricated and measured. The dimensions of the antenna are given in Fig. 2. As shown in Fig. 3(a), the antenna is constructed by printing on both sides of a printed circuit board (PCB) (Teflon, $\varepsilon r = 2.65$) with a thickness of 1 mm. Fig. 3(b) shows a schematic of the feeding network. Since the omnidirectional antenna should be fed from the bottom in some practical applications such as base station or WLAN access points, the shorted stub on the top layer is extended to the end of the board, and a semirigid coaxial feed cable (0.085 in) is used to feed the antenna. The outer conductor of coaxial cable is soldered to the feeding strip line on the top layer, and the inner conductor is connected to the other feeding line through a hole at the center of the board. The coaxial feed cable is connected to a 50-Ω SMA connector. Because the shorted stub is connected to the lower arm of radiating element 2, little interaction effect would be caused by the semirigid coaxial feed cable.

Fig. 4 shows the measured and simulated return loss of the constructed prototype. The measured data in general agrees with the simulated results obtained from Ansoft simulation software High Frequency Structure Simulator (HFSS). Note that a resonant mode is excited with good impedance matching at about 850 MHz, and the VSWR 2:1 ($\text{S11} < -10$ dB) impedance bandwidth is about 130 MHz (800–930 MHz), which covers GSM850 band. At about 1850 MHz, a wide impedance bandwidth of about 350 MHz (1700–2050 MHz) is also obtained, which satisfies the required bandwidth of DCS and PCS bands.

Radiation characteristics of the proposed antenna were also studied. An ETS 3-D chamber was used to measure the pattern of the planar dipole array antenna. The coaxial feed cables run out perpendicular to the plane of the antenna (z-direction). Ferrite beads were used to cover the part of test cable that is close to antenna. The length of the ferrite-bead-covered section of the feed cable is about 80 mm. Measured radiation patterns at center operating frequencies (850 and 1850 MHz) of the GSM850 and DCS/PCS band are presented in Fig. 5(a) and (b), respectively. From the results, good omnidirectional radiation in the azimuth plane (xy plane) with small gain variation less than 1.5 dBi is obtained. In the elevation planes (xz and yz planes), half-power beamwidth (HBPW) of the proposed two-element dipole array

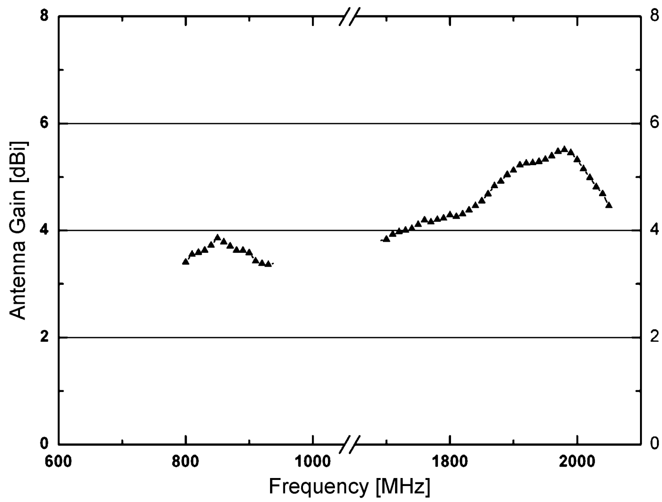

Fig. 6. Measured antenna gain.

is 40° at 850 MHz and 28° at 1850 MHz, compared to 78° HBPW for conventional half-wavelength dipole. A significant improvement of the elevational beamwidth is obtained as a result of having this shunt-fed two-element dipole array. Other operating frequencies across the GSM850 and DCS/PCS bands were also measured, and the obtained results are similar to those shown in Fig. 5.

The measured antenna gain for operating frequencies within the impedance bandwidth is presented in Fig. 6. Across GSM850 band, the measured antenna gain is in a range of about 3.4$\sim$3.8 dBi. At DCS/PCS bands, the measured antenna gain is 3.8$\sim$5.5 dBi. The ETS 3-D chamber can also provide an estimated value of the radiation efficiency of the measured antenna. The radiation efficiency is defined as the ratio of radiated power versus total available power from the source. Thus, the radiation efficiency value includes all impacts from mismatch loss, dielectric loss, conductor loss, and matching component loss. The radiation efficiency of the planar dipole array antenna was found to vary from 74% to 80% in GSM850 band, while it is from 73% to 93% in DCS/PCS bands. The measured antenna gain is about 1 dB lower than simulated antenna gain because of decreased efficiency, which is mainly due to the metallic loss and additional loss of the SMA connectors and cables during the prototype fabrication and measurement.

IV. Conclusion

The design of a novel triband printed two-element collinear dipole array antenna using shunt-fed network was described in this letter. The constructed prototype can provide the required bands of GSM850 (824–894 MHz), DCS (1710–1880 MHz), and PCS (1850–1990 MHz) with S11 < -10 dB. It shows a good omnidirectional radiation in the azimuth plane with small gain variation less than 1.5 dBi. Compared to 78° HBPW for conventional half-wavelength dipole, HBPW of the proposed two-element dipole array is 40° at 850 MHz and 28° at 1850 MHz in the elevation planes. A significant improvement of the elevational beamwidth is obtained as a result of having this shunt-fed two-element dipole array. Enhanced antenna gains about 3.4$\sim$3.8 dBi for GSM850 band and about 3.8$\sim$5.5 dBi for DCS/PCS bands are achieved. Radiation efficiencies were also estimated using the ETS 3-D chamber calculator and values in the range 74%$\sim$80% in GSM850 band and 73%$\sim$93% in the DCS/PCS bands were reported. The antenna has an advantage of structural simplicity due to a novel use of shunt-fed structure for the radiating element. Without any phase-shifting device, shunt-fed planar dipole array is suitable for multiple-band or wideband services. Therefore, the shunt-fed planar dipole array is an inexpensive solution for an omnidirectional antenna for a base station or WLAN access point.

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