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Broadband Roll Monopole

Zhi Ning Chen

***Abstract*—This correspondence presents a roll monopole for broadband applications. The impedance and radiation properties of the proposed monopole are investigated experimentally and numerically. The study shows that the roll monopole features a compact configuration and satisfactory radiation characteristics within a broad impedance bandwidth.**

***Index Terms*—Broadband monopole, impedance matching, planar monopole, radiation patterns.**

I. Introduction

Monopoles having simple structures, but powerful merits, such as pure vertical polarization and horizontal omnidirectional radiation, have extensively been used in a variety of applications. The impedance bandwidths of simple thin-wire monopoles can be increased by modifying their geometry, such as thickening or loading or folding their wire elements. Typical designs include conical or skeletal conical, cage, and various loading monopoles [1]–[4]. However, compared with thin-wire monopoles, conical or rotationally symmetric monopoles are much more bulky. Alternatively, planar elements have been proposed to replace the wire elements for the broad impedance bandwidths [5]–[9]. However, within the broad impedance bandwidths the undesired variation of radiation properties due to the asymmetry of the planar elements significantly sets off the advantage of volume reduction. In particular, the beam-maximum directions in vertical cuts greatly change and the radiation patterns in horizontal planes do not keep omnidirectional as operating frequencies increase. More severely, the gains of the planar monopoles go down [8].

This correspondence describes a novel roll monopole for broadband and compact applications. Essentially, it evolves from the planar monopoles but features the advantage of a symmetrical and compact structure over the latter. Both impedance and radiation characteristics of the roll monopole are examined experimentally and numerically.

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II. Antenna Design

The configuration of the proposed roll monopole and a coordinate system are depicted in Fig. 1. The monopole is formed by uniformly rolling a copper sheet of a width $W = 75$ mm and a height $H = 50$ mm. The trace of its cross section shown in Fig. 1 can be described in $r = r_o + \alpha\phi$, where r_o is the inner radius or minimum radius, α is the constant related to the spacing between two adjacent rolled layers, and ϕ is the angle ranging from 0 to $360^\circ \times \mathrm{N}$. The term N is the number of the roll turns and may be not an integer.

In tests, the parameters of the roll are selected as $r_o = 4$ mm, $\alpha = 0.5/360^\circ$, and $\mathrm{N} = 2.5$. The spacing between the two adjacent rolled layers is 0.5 mm. The monopole is vertically mounted at the center of a 320 × 320-mm ground plane. The bottom of the monopole is parallel to the ground plane with a feed gap $g = 1$ mm and fed by a 50-Ω coaxial probe of a 0.6-mm radius at the point ($r_0, \phi = 0^\circ$) through the ground plane. To reduce the possible distortion of radiation patterns due to the RF feeding cable, the RF feeding cable is kept straight and enclosed by an absorber layer.

III. Measurement and Simulation

The impedance and radiation characteristics of the roll monopole are examined experimentally and numerically. An electromagnetic simulator, Zealand IE3D is used to simulate the monopoles numerically, which based on the method of moment.

A. Impedance Characteristics

Fig. 2 demonstrates the good agreement between the measured and simulated VSWR against the frequency, especially in the well-matched band ranging from 1.25 to 2.25 GHz. The remarkably broad impedance bandwidths of more than 70% for VSWR $<$ 2:1 have been obtained. The measured and simulated frequencies of the lower edge of the bandwidths are 1.12 and 1.21 GHz, respectively. The planar helical structure and the strong electromagnetic coupling between the rolled layers may introduce an additional reactive network into the monopole to produce good impedance matching over a broad bandwidth.

B. Radiation Characteristics

For a broadband antenna, it is important to examine its radiation properties. The measurements and simulations of the radiation patterns

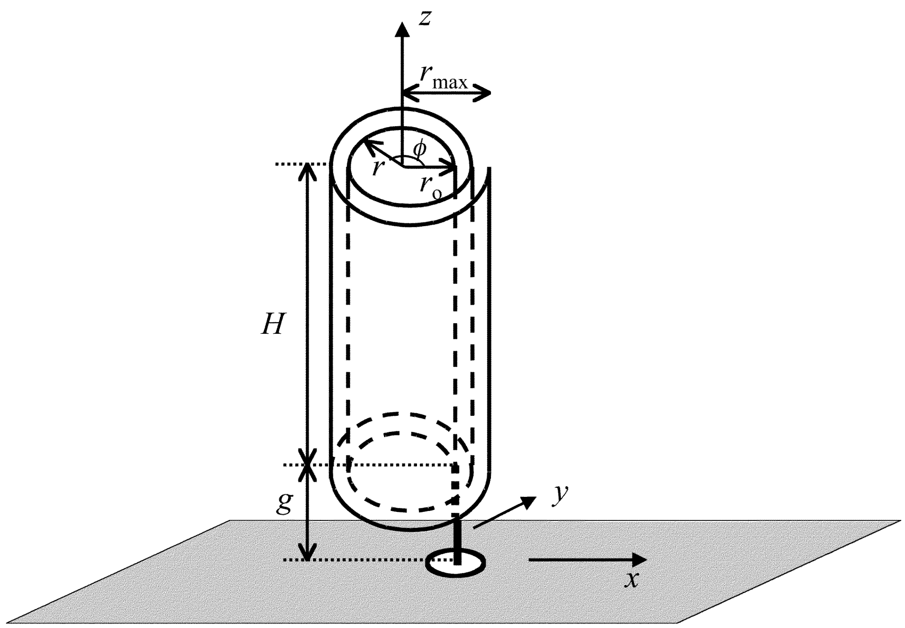

Fig. 1. Geometry of the monopole under consideration and a coordinate system.

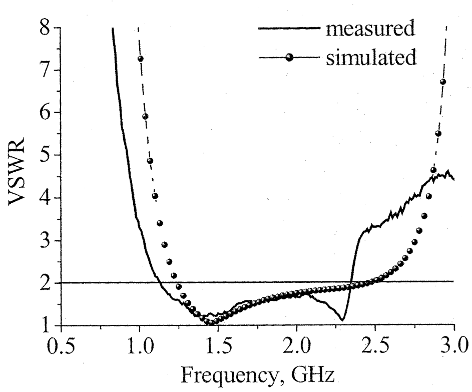

Fig. 2. Measured and simulated VSWR against frequency.

and gains for the roll monopole are carried out in $\phi = 0^\circ$, 90° and $\theta = 90^\circ$ planes.

The radiation patterns are measured and simulated within the band ranging from 1.0 to 2.4 GHz although for brevity, only are the patterns at 1.4 and 2.2 GHz shown in Figs. 3 and 4. The results show the very similar radiation patterns within the frequency range. It should be noted that in the simulations, an infinite ground plane is used as against the finite-size ground plane in the measurements. So, the radiation patterns are just simulated above the ground plane in the ϕ-cuts and the resultant gains will be slightly higher than measured ones.

Figs. 3 and 4 demonstrate the good agreement between the measured and simulated radiation patterns for E_θ components (or co-pol components) in the above half space. There are larger differences between the simulated and measured results for E_ϕ components also due to the use of the different ground planes.

Furthermore, Fig. 4 exhibits that due to the almost symmetrical structure of the roll monopole the measured radiation patterns for the E_θ-components are quite omni-directional across the entire impedance bandwidth. Obviously, the radiation performance of a roll monopole is superior to that of a planar monopole across a broad impedance bandwidth.

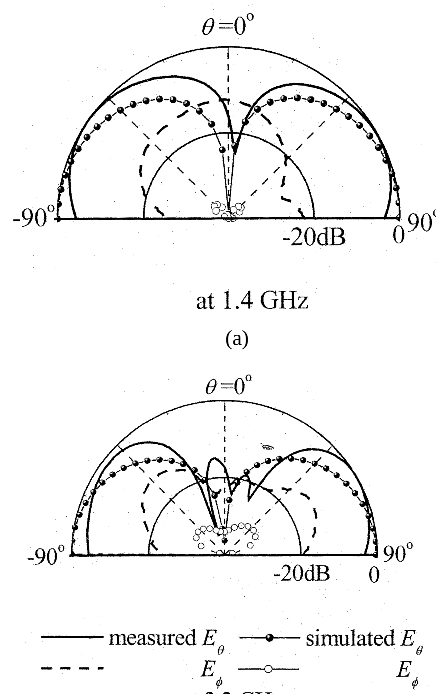

Fig. 3. Measured and simulated radiation patterns at 1.4 and 2.2 GHz in $\phi = 0^\circ$.

The comparisons of the simulated and measured gains are shown in Fig. 5, where the maximum gains are measured in $\phi = 0$ and 90° planes and the simulated gains are the maxima in the two planes. Within the band ranging from 1.2 to 2.2 GHz, the roll monopole has achieved quite stable and high gains of 3.2–4.6 dBi. The measured gains are about 0.5 dBi lower than simulated ones because of the use of the finite-size ground plane in the tests. The beam-maximum directions are also examined, which vary between 56° and 63° within the bandwidth of 1.2–2.2 GHz.

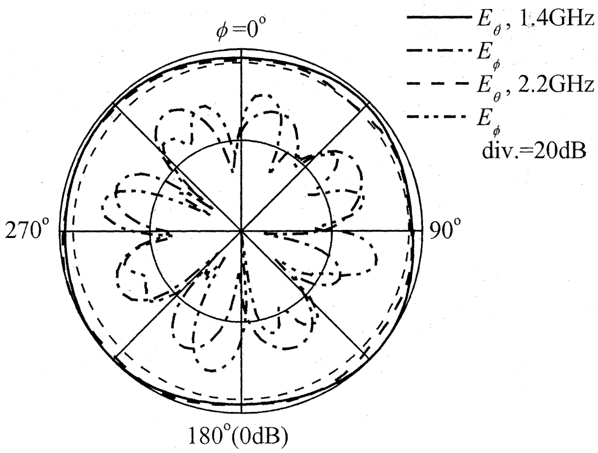

Fig. 4. Measured and simulated radiation patterns at 1.4 and 2.2 GHz in $\phi = 90°$.

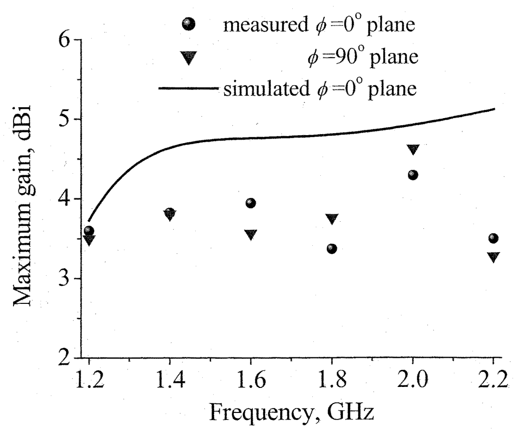

Fig. 5. A comparison of measured and simulated maximum gains.

IV. Conclusion

A new roll monopole antenna has been presented for broadband applications experimentally and numerically. As known, a planar monopole usually features a broad impedance bandwidth due to the larger size of its radiator and the coupling between the ground plane and the bottom edge of the radiator. The almost symmetrical structure of the roll monopole has significantly improved the radiation performances of the broadband monopole within a remarkably broad bandwidth.

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Figure of Merit for Multiband Antennas

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***Abstract*—This communication defines a figure of merit for multiband antennas that gives an objective quantification of the similarities between radiation patterns at the different antenna operating bands.**

***Index Terms*—Antenna radiation pattern, multiband antennas.**

I. Introduction

In recent years, great interest has arisen in multiband prefractal antennas [1]–[3], whose multiband behavior with respect to the similarity of radiation patterns at the different resonant bands apparently outperforms that of classical multiband antennas [4]. However, very often the radiation patterns at the different operating frequency bands are compared only by mere visual inspection of planar cuts over the principal planes. A more rigorous and objective means of comparison between radiation patterns in the whole three–dimensional (3-D) space is found of interest.

In this communication, we propose an objective criterion to establish if two radiation patterns can, or cannot, be considered similar. The key is a reference tolerance table, which sets the maximum radiation level difference in decibels (dB) between the two patterns that is acceptable for each radiation pattern level. Simple surface integrals over the unity radius sphere produce a numerical value, which constitutes a measure of the similarity between the two patterns in the whole 3-D space. The figure of merit thus defined can be easily matched to the specific requirements of different applications by the definition of reference tolerance tables tailored to each application. This procedure should provide a framework of reference to compare patterns at different bands and assess the behavior of multiband antennas.

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