Folded Meandered-Patch Monopole Antenna for Triple-Band Operation

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Introduction

The meandered patch is generally formed by cutting several linear slits in a planar conducting patch to meander the excited patch surface current path, and has been utilized in microstrip antennas for achieving compact operation [1] and in planar inverted-F antennas (PIFAs) for compact [2], dual-band [3], or triple-band [4] operations. The meandered patches in these designs are all in planar structures. In this paper, we demonstrate a novel antenna design utilizing a meandered patch folded into a compact three-dimensional structure. The proposed antenna is suitable for applications in mobile phones for GSM (Global system for mobile communication, 890–960 MHz), DCS (Digital communication system, 1710–1880 MHz) and PCS (Personal communication system, 1850–1990 MHz) triple-band operations. In addition, owing to the proposed folding design, the antenna height of the proposed antenna is greatly reduced to be 8 mm and can be mounted on top of a grounded substrate with a distance of 7 mm, leading to a low profile of 16 mm only (about 4.2% of the wavelength at 900 MHz) from the ground plane. This characteristic makes it very promising for the proposed antenna to be placed within the mobile phone housing, leading to a concealed mobile phone antenna.

Antenna Design

Figure 1(a) shows the geometry of the proposed monopole mounted on a grounded FR4 substrate of dimensions 70 × 100 mm^2, which can be considered as a PDA (Personal digital assistant) equipment circuit board. The FR4 substrate used in the experiment had a thickness of 0.8 mm and a relative permittivity of 4.4. The proposed monopole was easily constructed by folding a planar meandered patch shown in Figure 1(b) (the dashed lines shown in the figure are the folding lines), and was 8 mm in height, 35 mm in width and 8 mm in thickness. The width (35 mm) of the constructed monopole was chosen to be less than that (70 mm) of the grounded substrate such that it is possible that the proposed monopole be placed within the PDA equipment housing. As for the thickness of the proposed monopole, a reasonable thickness of 8 mm was chosen, which is less than that of most of the present-day PDA equipment. Also notice that the planar meandered patch shown in Figure 1(b) was made of a copper plate of thickness 0.1 mm in the experiment. For feeding the proposed monopole, a triangle copper plate of a length 10 mm was connected between the feed point

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(point A) of the proposed monopole to the 50 Ω microstrip feed line printed on the grounded substrate. In this case, the total height of the proposed monopole from the ground is 18 mm or only about 5.5% of the wavelength at 900 MHz.

As seen in Figure 1(b), there are two resonant paths (paths 1 and 2) in the proposed monopole. First path has a length of about 110 mm, which is mainly used for generating the 900 MHz resonant mode. With the inclusion of the 10 mm connecting copper plate, the length of first patch corresponds to about 35.7% of the wavelength at 900 MHz. Note that this resonant length is larger than one-quarter wavelength of the resonant frequency, and this behavior is largely owing to the coupling effect between two meandered sections, which reduces the effective length of the resonant path. On the other hand, second path is for generating the 1800 and 1900 MHz resonant mode, and has a length of about 37 mm, which corresponds to about 22.2% of the wavelength at 1800 MHz by including the length of the connecting copper line. Note that, probably because there is no meandering in second path, its resonant length is close to one-quarter wavelength at 1800 MHz.

Experimental Results and Conclusions

A prototype of the proposed monopole antenna was constructed and tested. Figure 2 shows the measured and simulated return loss of the constructed prototype. From the measured data, two resonant modes are clearly excited. The lower mode is at about 900 MHz, as designed, and has a bandwidth (10 dB return loss) of 135 MHz (826–961 MHz), which satisfies the operating bandwidth of the GSM system. For the upper resonant mode, a much wider bandwidth of 386 MHz (1650–2036 MHz) is obtained, which also covers the required bandwidth of the DCS/PCS system.

Figures 3 plot the measured and simulated radiation patterns at 900,1800 and 1900 MHz for the constructed prototype. It is seen that the radiation pattern is more omnidirectional in the elevation plane (*x*–*y* plane) at 900 MHz than at 1800 and 1900 MHz, and the radiation patterns in the principal planes are also more monopole-like for the 900 MHz operation. Radiation patterns for other operating frequencies across the GSM and DCS bands were also measured, and the obtained patterns are stable across their respective operating band and similar as shown in Figures 3. Figure 4 shows the measured antenna gain for operating frequencies in the GSM, DCS and PCS bands. The antenna gain across the GSM, DCS and PCS bands are about 1.5–2.1 dBi and 3.5–4.2 dBi, respectively.

The monopole design of using a meandered patch folded into a rectangular-tube-like structure for providing 900,1800 and 1900 MHz dual-band operations. The proposed antenna can be easily constructed with low cost, and two separate wide impedance bandwidths at about 900, 1800 and 1900 MHz are obtained, which cover the required bandwidths of the GSM, DCS and PCS systems. The proposed antenna also shows a low profile, and is very promising to be concealed within the PDA equipment housing.

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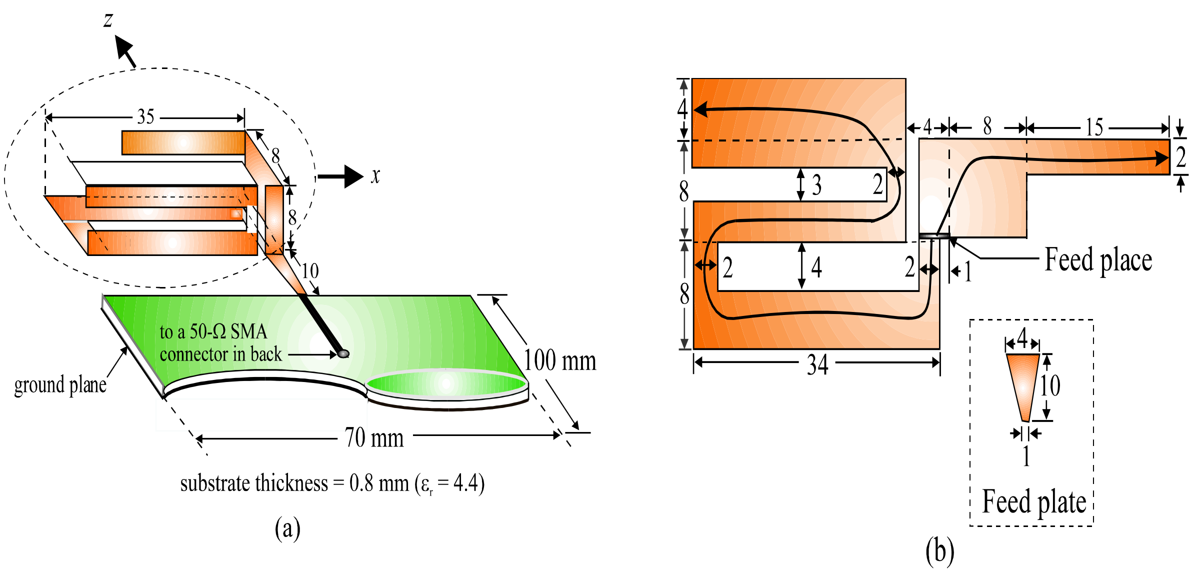

Figure 1. (a) Geometry of the proposed folded meandered-patch monopole mounted on top of a grounded substrate of dimensions 70 × 100 mm^2.(b) Dimensions of the proposed monopole unfolded into a planar structure.

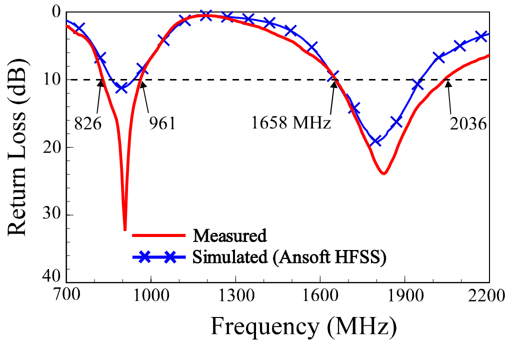

Figure 2. Measured and simulated return loss for the proposed antenna.

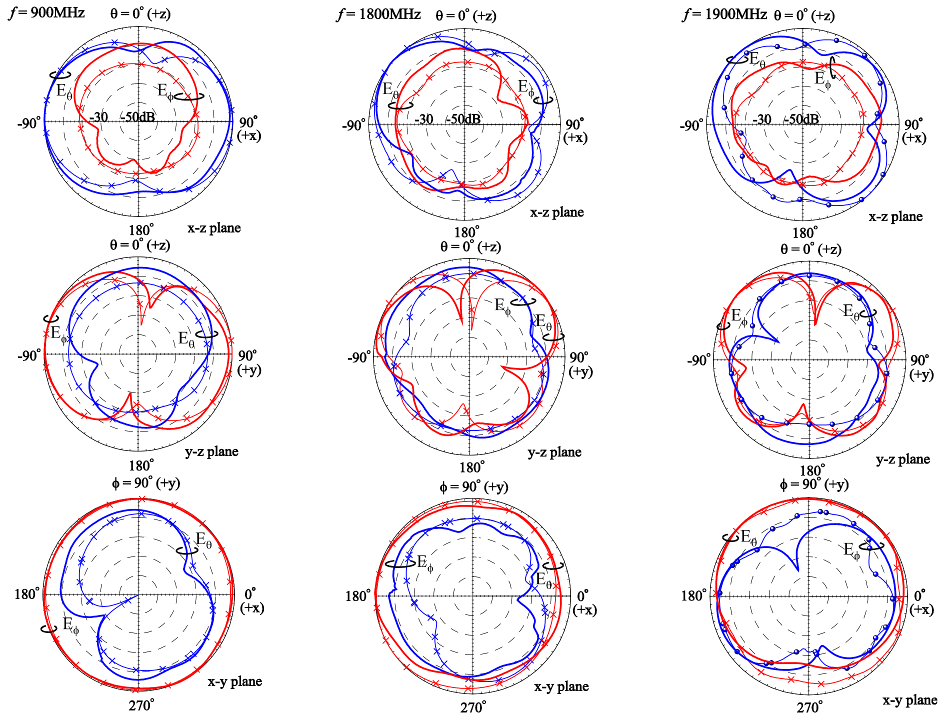

Figure 3.Measured and simulated radiation patterns at 900, 1800 and 1900 MHz for the proposed antenna.

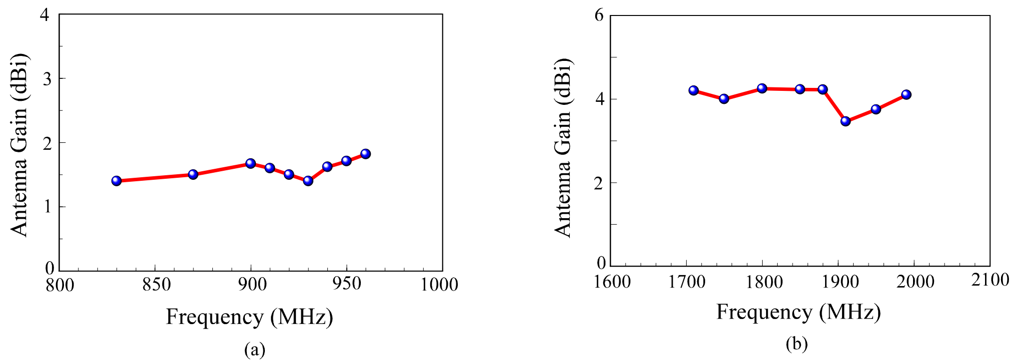

Figure 4. Measured antenna gain for the proposed antenna. (a) The GSM band; (b) the DCS/PCS band.