A Multiband Antenna Consisting of One Element for Mobile Phone Applications

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Compactness and multiband operation are usually required for antennas used in mobile phones. In addition, other features such as flexibility, light weight, simple structure, and low cost are also important for practical design. In this paper, we report a new multiband antenna which operates for the Global System for Mobile Communications (GSM:880-960 MHz), Digital Cellar System (DCS:1710-1880 MHz), Personal Communication Service (PCS:1850-1990 MHz), and Universal Mobile Terminal System (UMTS:1920-2170 MHz) bands. This antenna can be made of metal wires, plates, or thin films. From a fabricated antenna, it is shown that the antenna covers the four bands of GSM, DCS, PCS, and UMTS and has almost omni-directional radiation patterns at each band.

1. Introduction

As the use of mobile phones is spreading far and wide, compactness and multiband operation have become the basic requirements for antennas used in mobile devices[1)2)3)]. Figure 1 shows the main frequencies used for mobile phones[4)]. In the beginning, only the GSM band was assigned for mobile phones. However, with the fast spreading use of mobile phones and demand for faster signal transmission, DCS, PCS, and other bands were added to the frequencies, and it became necessary that one mobile phone be available for multiple systems with different frequencies. As a result, it is desirable that a single antenna used in such a terminal should cover multiple frequencies shown in Fig. 1. In addition, other features such as flexibility, light weight, simple structure, and low cost are also important for practical design. In this paper, we present a new multiband antenna which can cover the GSM (880-960 MHz), DCS (1710-1880 MHz), PCS (1850-1990 MHz), and UMTS (1920-2170 MHz) bands at the same time[5)]. This antenna consists of one radiation element with a short-pin. By applying a meander structure to the radiation element, we can not only minimize the size of the antenna but also adjust resonant frequencies. The short-pin is enlarged to broaden the bandwidth of the antenna. The antenna has a planar structure and can be fabricated by metal wires, metal plates, or thin films. We investigate the antenna theoretically by using Poynting™ based on finite-define time-domain (FDTD) method, and also experimentally. A fabricated antenna shows that it can cover the GSM, DCS, PCS, and UMTS bands and has almost omni-directional radiation patterns at each band. The planar structure can also be folded without much variation on radiation properties. With this option, the antenna can be easily installed in a narrow space in a mobile phone.

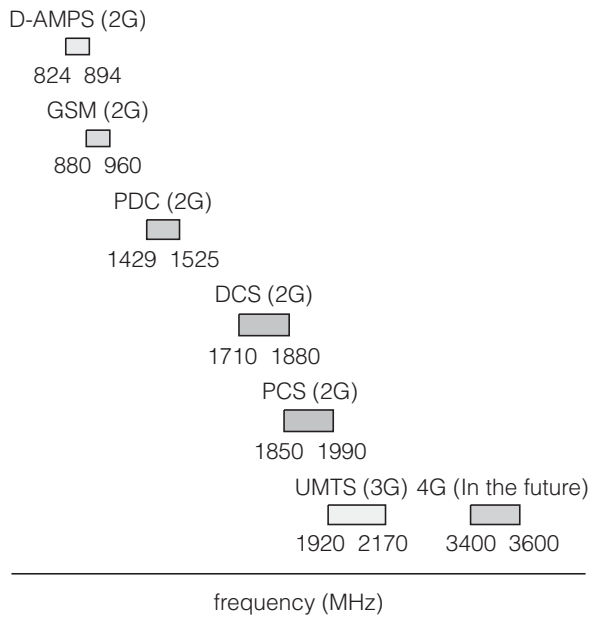

Fig. 1. Assigned frequency bands for mobile phones.

2. Antenna configuration

Figure 2 shows the basic structure of a planar inverted-F antenna (PIFA), which is generally used for mobile phones. It consists of a radiation element, a short-pin, and a ground plane (GND). The antenna generates a fundamental mode and a higher-order mode. When the antenna is used as it is, a gap of frequency between the two modes is too large for the multiple bands of mobile phones.

In order to shorten the frequency gap, we folded the radiation element as shown in Fig. 3. The folded ele-

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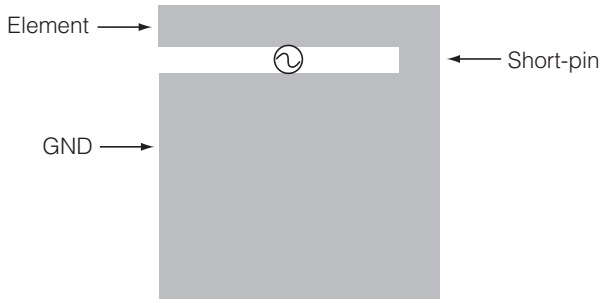

Fig. 2. Typical planar inverted-F antenna.

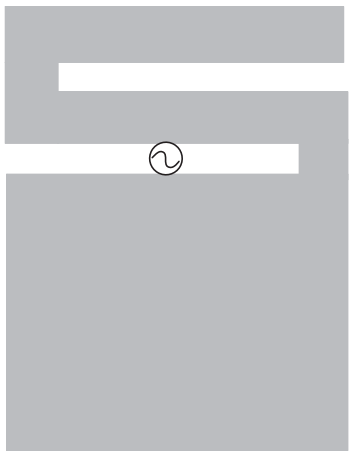

Fig. 3. PIFA with folded radiation element.

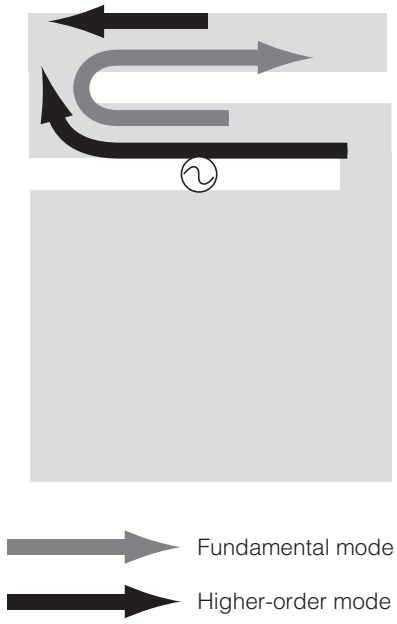

Fig. 4. Schematic current flow in PIFA with folded element.

ment strengthens electromagnetic coupling in the element and then lowers the resonant frequency of the higher order mode. Figure 4 shows schematic current flow for the fundamental and higher order modes. While a multiband antenna is often realized by using multiple radiation elements, we realize the multiband operation by using a single element.

We theoretically investigated the input characteristics by changing the location of meanders to get a guide line for the design of the antenna. Figure 5 shows four different structures with different locations of meanders but the total length of the radiation element is kept constant. Figure 6 shows the simulated input characteristics for these structures. Whereas the resonant frequency of the fundamental mode does not vary much, that of the higher order mode shifts to the lower frequency as the number of meanders in the lower section increases. It is shown that the gap of the resonant frequency between the fundamental and the higher order modes can be accommodated by arranging the location of meanders. Figure 7 shows two antennas with different short-pin structures and Figure 8 shows their simulated input characteristics. As shown in Fig. 8, the bandwidth of the higher order mode can be widened by arranging the short-pin structure.

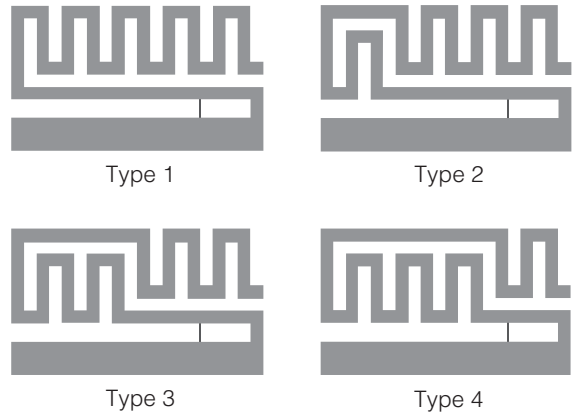

Fig. 5. Antennas with various meander positions.

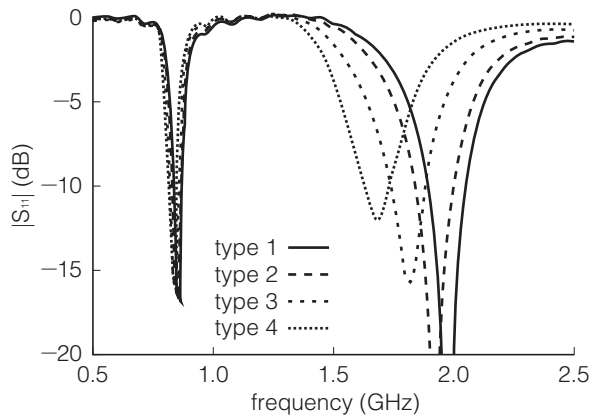

Fig. 6. Simulated input characteristics of antennas with different meander positions.

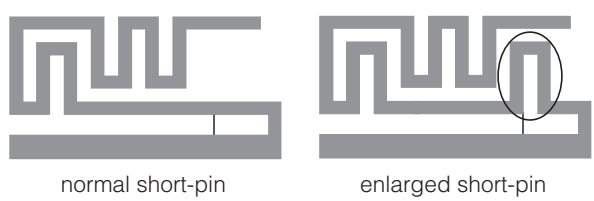

Fig. 7. Antennas with different short-pin structures.

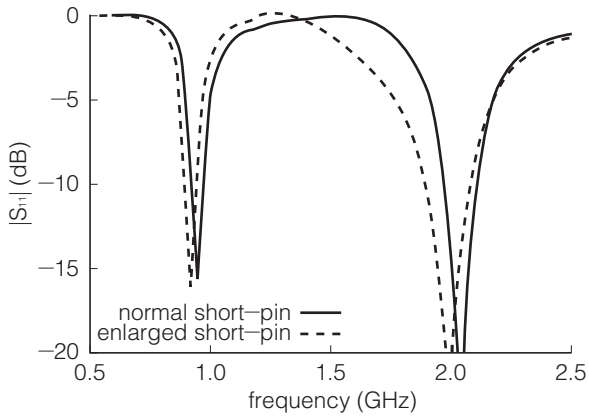

Fig. 8. Simulated input characteristics for antennas with different short-pin structures.

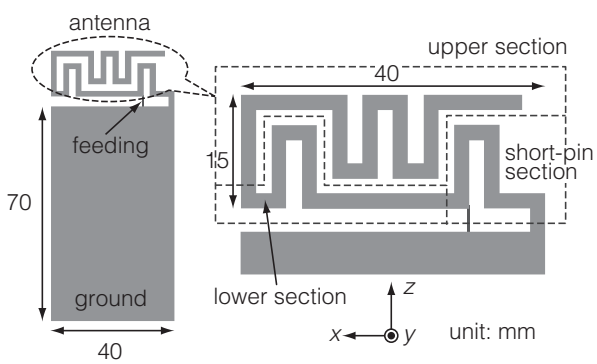

Fig. 9. Configuration of antenna.

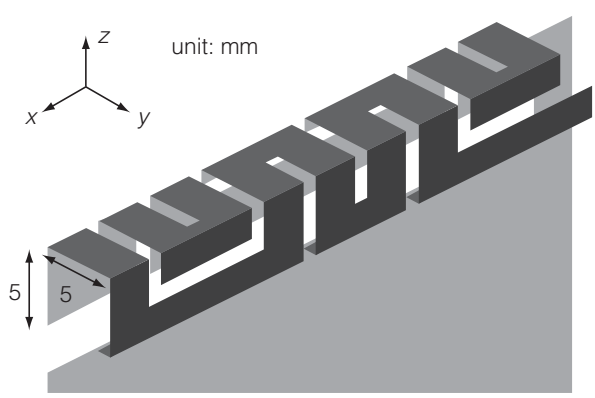

Fig. 10. U-shaped folded antenna.

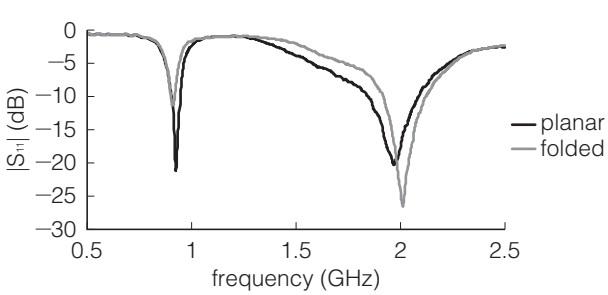

Fig. 11. Simulated input characteristics of antennas in planar and folded structures.

Figure 9 shows the configuration of the multiband antenna based on the previous investigation. The antenna has a planar structure, with its radiation element stretched parallelly to the short edge of the ground and folded once. The size of the antenna is 15 × 40 mm^2. By folding the radiation element, the resonant frequency of the higher order mode shifts to the lower frequency. We minimized the size of the antenna by using the meandering structure in the middle of the element and widened the bandwidth by enlarging the short-pin section.

For antennas used in mobile phones, the size should be minimized so that the mobile phone might be compact. If necessary, our planar antenna can be folded so that it can be installed in a narrow space in a mobile phone. Figure 10 shows a U-shape folded structure, where the volume of the antenna becomes 5 × 5 × 40 mm^3. Figure 11 shows the simulated input characteristics of the folded antenna along with that of the planar antenna. We can see that the input characteristics do not vary much when the antenna is folded. There is no significant variation on the radiation patterns either.

3. Experimental results

Figure 12 shows a picture of a fabricated antenna

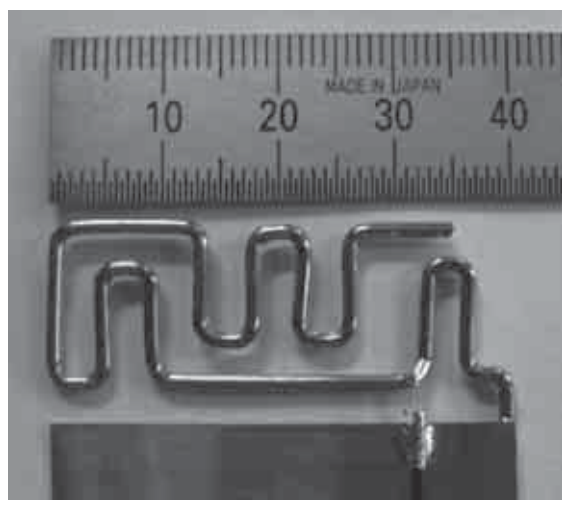

Fig. 12. Fabricated antenna.

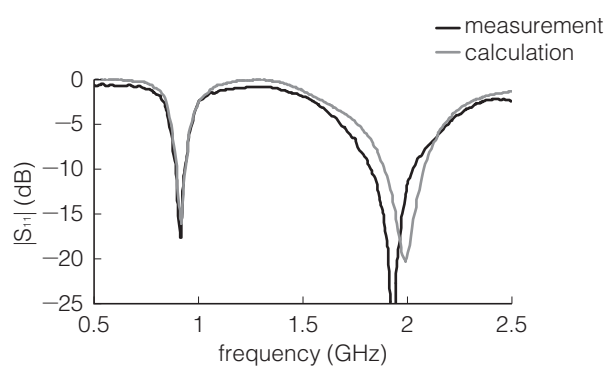

Fig. 13. Measured and simulated input characteristics of fabricated antenna.

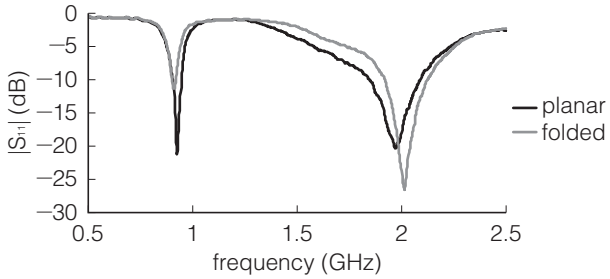

Fig. 15. Measured input characteristics for fabricated antenna in planar and folded structures.

made by a wire with a diameter of 1.13 mm. Figure 13 shows the measured and simulated input characteristics of the fabricated antenna. We can see that the antenna covers the GSM, DCS, PCS, and UMTS bands for Voltage Standing Wave Ratio (VSWR) < 3.5. Figure 14 shows the radiation patterns at 920 MHz. Almost omni-directional radiation patterns are observed in the *xy*-plane. Similar radiation patterns can be observed at other frequencies. Average gain of the planar antenna in *xy*-plane is 0.2, 0.1, 0.6, and 0.4 dBi at 920, 1795, 1920, and 2045 MHz, respectively. Figure 15 shows the measured input characteristics of the fabricated antenna in

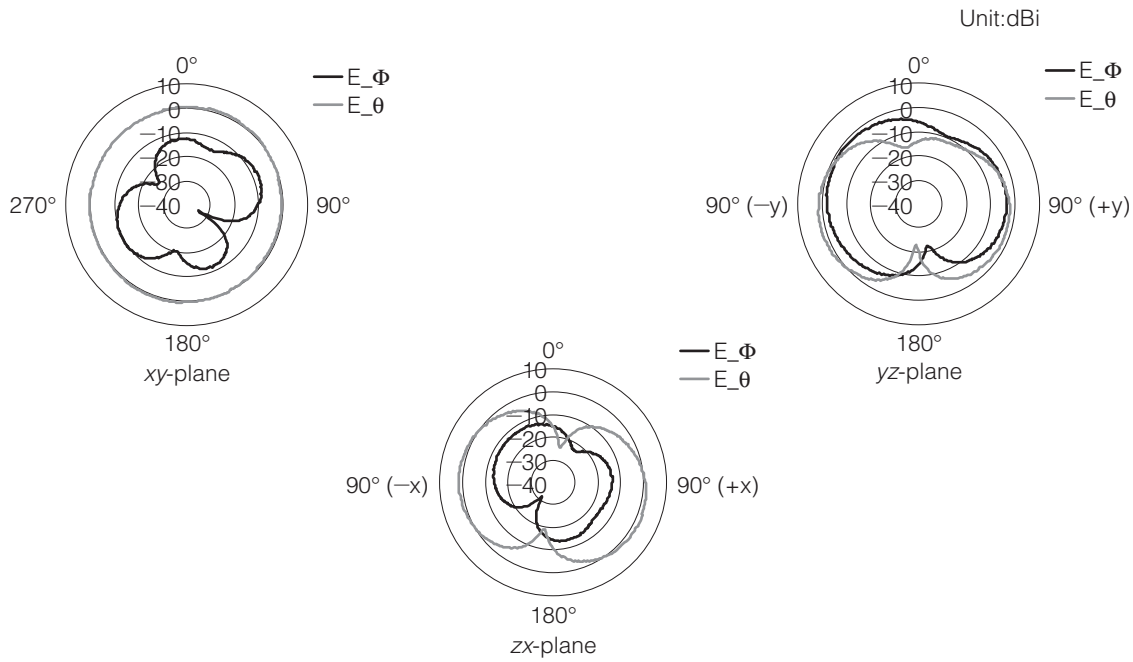

Fig. 14. Radiation patterns at 920 MHz for fabricated antenna.

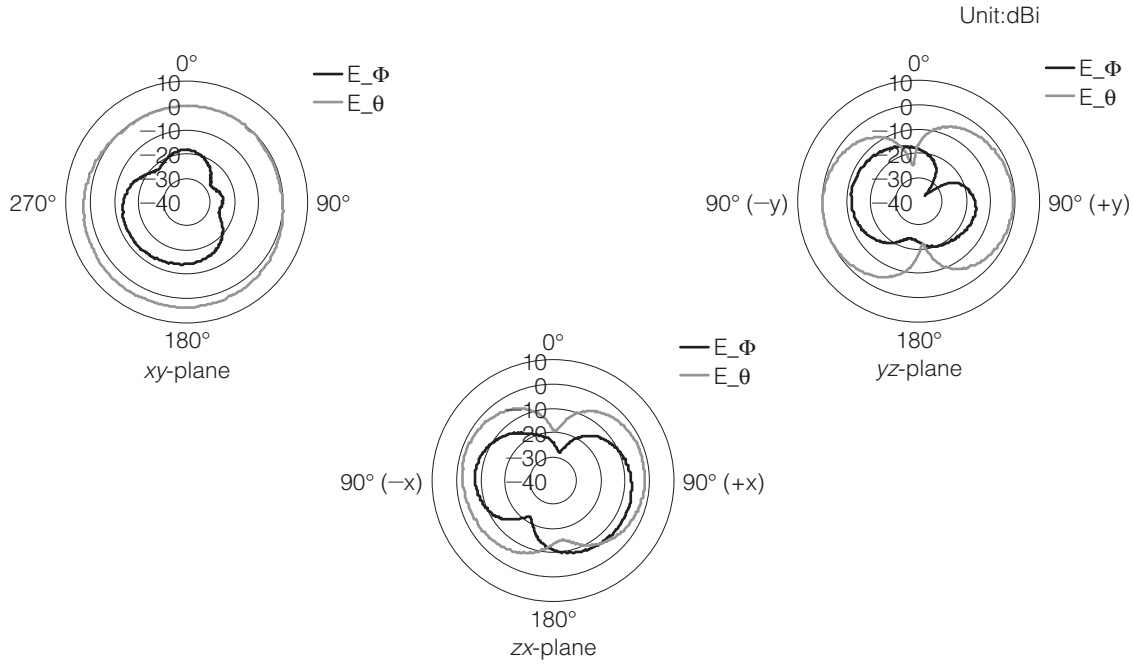

Fig. 16. Radiation patterns at 920 MHz for fabricated antenna in folded structure.

planar and folded structures. The bandwidth of the folded antenna is narrower than that of the planar antenna, but its performance can be improved by arranging short-pin section and feeding point. Figure 16 shows the folded antenna at 920 MHz. It shows an almost omni-directional radiation pattern in the *xy*-plane and is similar at other frequencies. Average gain of the folded antenna is 1.8, 0.0, 0.6, and 0.6 dBi at 920, 1795, 1920, and 2045 MHz, respectively.

4. Conclusion

We have developed a new multiband antenna which consists of only one radiation element. The antenna can cover the GSM, DCS, PCS, and UMTS bands. It has almost omni-directional radiation patterns and average gains are over 0 dBi in the *xy*-plane in all the bands. This antenna can be used in its planar or folded form. This makes the size of the antenna to be 15×40 mm^2 or $5 \times 5 \times 40$ mm^3. The antenna can be cost effectively fabricated by means of wires, plates, or thin films. It is expected that the antenna can be used in mobile phones as a compact, high performance, and low cost antenna.

References

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