Printed internal antenna for mobile broadcasting (DVB-H/T-DMB) and communications (GSM900)


Department of Electrical and Computer Engineering, Hanyang University, Seoul 133-791, Korea
E-mail: taeyeoul@hanyang.ac.kr

Abstract: This study proposes a printed internal antenna operating in the digital video broadcasting-handheld (DVB-H) band and the terrestrial digital multimedia broadcasting (T-DMB) L-band for mobile broadcasting and the GSM900 band for mobile communications. Owing to the limited physical size of the mobile terminal, the miniature antenna technique is very important for a low-band application. The proposed antenna consists of a printed rectangular monopole with a U-shaped slot, an extended ground stub and a folder-type chassis, which are easily printed on an FR4 substrate. The antenna occupies an area of only 50 × 27 mm², which makes it attractive for use with modern multiband and multifunctional slim handsets. The combined behaviour of the antenna resonant mode and the chassis resonant mode is utilised without any matching circuits or magneto-dielectric materials. In addition, the proposed antenna uses a second higher-order resonance of the extended ground stub and the U-shaped slot.

1 Introduction

Currently, the digital video broadcasting-handheld (DVB-H) service has made it possible to deliver digital broadcasting for a portable device, which operates in the ultra-high-frequency (UHF) band (470–702 MHz, relative bandwidth of 40%) [1]. The wavelength of the UHF band in free space is longer than that of a typical mobile handset. Therefore it is difficult to design a single antenna that can cover all of the above-required bands with good impedance matching while integrating into a mobile handset. In addition, a small mobile-handset antenna size is required because of the miniaturisation trend. Compactness, light weight, slimness and low cost are also significant requirements.

Several studies have been performed to produce an antenna structure able to satisfy the demands of the DVB-H antenna for use in hand-held terminals. Miniaturisation techniques with control circuits were introduced [2–5]; however, they had problems such as low antenna efficiency because of insertion loss in lumped elements, as well as an increased cost. Magneto-dielectric materials have primarily been used for the antenna miniaturisation method [6, 7]; however, they have certain disadvantages that cause high loss as well as low radiation efficiency and high cost in comparison with those of a general dielectric material [8].

The terrestrial digital multimedia broadcasting (T-DMB) L-band (1458–1492 MHz) is also widely used for mobile digital television technologies. In order to operate the T-DMB L-band with the DVB-H [9] and the global system for mobile communication band (GSM900, 880–960 MHz) with the DVB-H [10, 11], additional or larger antennas than that available in the mobile handset are required.

In this study, we design and fabricate an internal antenna for use in a mobile handset performing mobile broadcasting and mobile communications. In order to achieve broadband operation for the DVB-H band, we use a combined wave modes technique of the antenna resonant and chassis resonant modes. In addition, in order to generate the L-band resonance, a U-shaped slot inserted on a rectangular monopole is used. Moreover, we develop the antenna operating in the GSM900 band using the second higher-order resonance generated by the extended ground stub. Unlike previous research [9–11], the proposed printed internal antenna acquires triple bands and provides simultaneous broadcasting and mobile communication bands operation.

2 Antenna design

The geometry of the proposed antenna for a folder-type mobile handset is depicted in Fig. 1a, and an enlarged view is shown in Fig. 1b. The proposed antenna, with a size of 50 × 27 mm², is located at the top of the upper ground of a mobile phone. The upper and lower FR4 substrate dimensions are 90 × 50 × 1.6 mm³ for a mobile handset with a relative permittivity of 4.4. In order to electrically connect both ground planes, two connecting strips, with dimensions of 5 × 8 mm², are located at the corners of each ground plane junction. The antenna consists of a printed rectangular monopole antenna (Fig. 2a), an extended ground stub (Fig. 2b) and a U-shaped slot (Fig. 2c) in order to achieve a broad bandwidth and multiband characteristics. The simple rectangular monopole antenna, shown in Fig. 2a, has a resonant frequency of ~620 MHz but a narrow bandwidth, as shown in Fig. 3.
order to satisfy the required bandwidth for the DVB-H band, we try to obtain dual resonances over the DVB-H band, for which the extended ground stub surrounds the printed rectangular monopole antenna, as shown in Fig. 2b. Adding the extended stub from the ground, and adjusting the length of the extended ground stub, as well as the space between the extended ground stub and the rectangular monopole antenna, allow a supplementary resonance mode to occur close to the rectangular monopole antenna’s fundamental resonance [12, 13].

Furthermore, the GSM900 band is covered by using the second higher-order resonance of the extended ground stub. In order for the antenna to operate in the L-band, a U-shaped slot, generally used to obtain a multiband characteristic, is integrated into the printed rectangular monopole antenna, as shown in Fig. 2c [14]. We consider the U-shaped slot as a half wavelength resonator. As a result of substrate properties, the physical dimension of the U-shaped slot is slightly shorter than half of a wavelength in free space [15]. The parallel slit near the feeding point functions by improving impedance matching by adjusting the input impedance of the antenna. Fig. 3 shows the simulated return loss for each part of the antenna.

The finite element method electromagnetic software, HFSS, has been utilised to simulate and optimise antenna performance [16]. Fig. 4 shows the parametric studies of the return loss according to the lengths of the extended ground stub (W), upper and lower grounds (L) and the slot line (SL). As W increases, the lower resonance (~450 MHz) is shifted down, as shown in Fig. 4a. In addition, the GSM900 band, using the second higher-order resonance of the lower resonance, is significantly affected by variations of W. As L increases, the upper resonance (~700 MHz) shifts down, as shown in Fig. 4b. Optimisation of both parameters transforms the proposed antenna into a broadband antenna. Fig. 4c shows the effects of the U-shaped slot, which creates resonance in the L-band with small variations in the DVB-H and GSM900 bands. In order to provide a 6-dB return loss bandwidth for all bands, the optimised parameter values of W, L and SL are 50, 90 and 11 mm, respectively.

The proposed antenna generates two adjacent resonance wave modes, that is, antenna and chassis resonance modes, in order to satisfy the broadband DVB-H band. For the case of antenna resonant mode, electromagnetic fields radiate in both the rectangular radiator and the extended ground stub at the lower resonance (470 MHz). For the case of the chassis resonant mode, radiation occurs in both the system ground and the rectangular radiator at the upper resonance (700 MHz). Figs. 5a, b and c show surface current distributions at 470 (DVB-H), 920 (GSM900) and 1470 MHz (L-band), respectively. The extended ground stub is approximately one quarter of the wavelength of the lower resonance frequency, and wraps the rectangular radiator in order to reduce the antenna size, as shown in

Fig. 1 Geometry of the proposed printed internal antenna for a folder-type mobile handset
a Three-dimensional view
b Enlarged view

Fig. 2 Progress of antenna design
a Rectangular monopole
b Extended ground stub
c U-shaped slot

Fig. 3 Simulated return loss for each part of the antenna
The second higher-order resonance, 920 MHz, is generated with a half-wavelength resonance mode and phase reversal at a centre of the line, as shown in Fig. 5a. Therefore this antenna with the extended ground stub operates in both bands (DVB-H and GSM900). In order to generate the T-DMB (L-band) without an additional antenna, additional resonance is excited by inserting a U-shaped slot at the rectangular radiator. The L-band resonance of 1470 MHz is introduced by the excited strong currents surrounding the U-shaped slot, as shown in Fig. 5c.

3 Measurement results

Fig. 6 shows both the simulated and measured return loss characteristics for the suggested antenna, which are in strong
agreement with one another. The measured bandwidth of the proposed antenna covers a frequency range of 460–785 MHz (~52% in relative bandwidth) with a 6-dB bandwidth for the DVB-H band. In addition, the GSM900 and L-band are satisfied from 880 to 980 MHz and 1450 to 1492 MHz, respectively.

Fig. 7 shows the simulated and measured peak gains of the proposed antenna in comparison to the European Telecommunications Standards Institute (ETSI) gains over the DVB-H frequency band [1]. It is clear that the antenna meets the ETSI antenna gains even though the differences between the simulated and measured gains are not clearly explained. The measured peak gains (efficiencies) are 1.63 (69), 1.39 (51) and −1.76 dBi (26%) at 690 (DVB-H), 920 (GSM900) and 1490 MHz (L-band), respectively. Fig. 8 shows the measured radiation patterns for each service band, illustrating the E- and H-plane radiation patterns over the DVB-H band at 470, 550 and 702 MHz, respectively. Good radiation patterns that are similar to those of the monopole antenna are produced. Figs. 8d and e show E- and H-plane radiation patterns at centre frequencies (920 and 1490 MHz) of the GSM900 and L-band, respectively. A couple of radiation lobes in Fig. 8d are caused by the second higher-order resonance. In addition, a somewhat distorted radiation pattern in Fig. 8e is partly caused by a leakage of surface current through the ground extended stub, as shown in Fig. 5c. Therefore its gain and efficiency are not as good as the other bands. Nevertheless, the proposed antenna primarily maintains omni-directional radiation patterns in all service bands. Fig. 9 shows the fabricated printed antenna using a 50-Ω coaxial cable to feed the antenna along the extended line from the ground.

Fig. 7 Simulated and measured peak gains over the DVB-H, GSM900 and L-band

Fig. 8 Measured radiation patterns for the proposed antenna [solid: E-plane (x–z), dotted: H-plane (y–z)]

- a 470 MHz
- b 550 MHz
- c 702 MHz
- d 920 MHz
- e 1490 MHz
4 Conclusion

This study proposed a printed internal antenna simultaneously operating in mobile communication and broadcasting bands. In order to achieve the wide bandwidth required for DVB-H service, the proposed antenna was designed using the combined wave mode technique of the antenna resonant and chassis resonant modes. When a U-shaped slot was inserted into a rectangular monopole, the antenna operated in the L-band for T-DMB service. Moreover, the proposed antenna extended the ground, with a long meandered line, in order to allow GSM900 band operation. According to the measurement results, the proposed antenna provided excellent return loss performances at three service bands and omni-directional radiation patterns. Therefore the proposed internal antenna is a good candidate for use in mobile broadcasting and communication handsets.

5 Acknowledgment

This work was supported by the Korea Science and Engineering Foundation (KOSEF) Grant funded by the Korea government (MOST) (No. R01-2007-000-11475-0).

6 References

1 DVB-H Implementation Guidelines, ETSI TR 102 377 V1.4.1 (2009–04), European Telecommunications Standards Institute