Low-Profile Broadband Planar Antennas for DVB-H, DCS-1800, and IMT-2000 Applications

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Abstract: A new type of low-profile broadband planar antenna is developed for DVB-H, DCS-1800, and IMT-2000 handsets. The planar antenna for UHF-band DVB-H terminals has a height of 8 mm while the antenna height for DCS-1800 and IMT-2000 applications is only 4.8 mm which is much lower than previously published antenna configurations. The broadband planar antennas consist of an S-strip and a folded T-strip which are separately printed on the two sides of a thin planar substrate. The bandwidth enhancement is realized by the mutual coupling between the S-strip and the T-strip. It has been demonstrated that the antenna for DVB-H terminals can achieve a gain of -2 to -4 dBi (3-7 dB higher than the standard specification) over the DVB-H band (470-702 MHz) while the antenna for the DCS-1800 and IMT-2000 handsets can achieve a bandwidth of ~30% for return loss <-10 dB.

I. INTRODUCTION

DVB-H (Digital Video Broadcasting – Handheld) is the emerging digital broadcast technology developed for the transmission of video broadcast content to handheld terminal devices, overcoming the limitations that hinder the use of DVB-T (Terrestrial) television in a mobile environment [1]. Therefore, the operating frequency for DVB-H terminals should be compatible with a DVB-T system, which has been allocated the UHF frequency band from 470 MHz (channel 21) to 862 MHz (channel 69) [2]. Due to the interoperability considerations with a GSM-900 system, the upper usable frequency for DVB-H terminals is limited to channel 49 (702 MHz) to relax the requirements on the GSM reject filters [3]. For the reception of DVB-T signals on a DVB-H terminal, the antenna must cover the whole frequency range 470-702 MHz (about 40% in relative bandwidth). To integrate with a DVB-H terminal, the antenna has to keep a low profile and preferably a planar configuration. Due to the long wavelengths (42-64 cm) in the DVB-H band (470-702 MHz), an antenna integrated inside DVB-H terminals will be electrically small. It is a challenging task to design such a wideband antenna with a low profile and a small size. To achieve a wideband operation, the requirement for the antenna gain is usually relaxed. In the EICTA MBRAI specification, it is indicated that a gain of -10 dBi (at 470 MHz) to -7 dBi (at 702 MHz) is acceptable [4]. This specification is based on a theoretical estimation of the achievable gain for an integrated antenna in a reasonable size terminal. It is still challenging but should be achievable. An internal low-profile (antenna height=5 mm) antenna was presented in [5] for a terminal size of 135 mm $\times$ 75 mm. The return loss (RL) is around -1.5 dB over the DVB-H band and the antenna gain is about 4 dB higher than the specification. There are two drawbacks for the antenna in [5]: 1) it needs a matching circuit and 2) it has a non-planar configuration. The mismatch of input impedance has been improved (RL<-5 dB) in [6] by making use of an earpiece cord with an RF choke and two matching components. Obviously, the earpiece cord antenna cannot be considered as an internal antenna. For antennas operating at DCS-1800 (1710-1880 MHz) and IMT-2000 (1885-2200 MHz) bands, a bandwidth of ~25% and a low profile are required for all mobile handset topologies. In recent years, a lot of low-profile antennas have been developed for mobile handsets [7]-[12]. However, these previously published antennas either have a narrow bandwidth (e.g., those in [7], [8]) or have a non-planar configuration (e.g., those in [9]-[12]) which involves shorting metal walls/vias and requires a considerable antenna thickness, making them unsuitable for a fully photolithographic fabrication process. In this paper we present a new type of low-profile planar antenna which can be easily integrated with commonly used printed circuit broads (PCB). The antenna height for DVB-H terminals is 8 mm and the terminal size is 128 mm $\times$ 78 mm. The return loss realized is lower than -2 dB and the gain achieved is 3-7 dB above the specification. The planar antenna for DCS-1800 and IMT-2000 applications has a height of 4.8 mm and can achieve a bandwidth of ~30%.

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II. ANTENNA FOR DVB-H TERMINALS

The geometry of a low-profile planar antenna for DVB-H terminals is illustrated in Fig. 1. The antenna was designed on a RT/Duroid 5880 planar substrate with a dielectric constant of ε_r=2.2 and a thickness of t=20 mils (0.508 mm). The antenna is printed on both sides (i.e., the front side and the backside) of the substrate. On the front side, there is a T-strip whose lower section is folded and extended to a 50-Ω microstrip line. The feeding point is set up at the center of a 120 mm (length) × 78 mm (width) ground plane. On the backside of the substrate, there is an S-strip which is terminated at the ground plane. The upper section of the T-strip is fitted into the area surrounded by the upper section of the S-strip. The folded lower section of the T-strip on the front side overlaps with the lower section of the S-strip on the backside, forming a two-strip line. There is no direct electrical connection (e.g., by a shorting via) between the front side and the backside. The electromagnetic coupling between the T-strip and the S-strip helps in the radiation enhancement of the antenna. The strip width of the T-strip and the S-strip is equal to the spacing between the T-strip and the S-strip, which is chosen to be 1 mm, leading to an antenna height of 8 mm. The total width of the antenna is equal to the width of the ground plane. Therefore, the antenna can fit a terminal (or chassis) with a size of 128 mm × 78 mm.

The simulated and measured results for return loss are compared in Fig. 2 and good agreement is observed. Over the DVB-H band, the return loss is less than -2 dB, which corresponds to a mismatch of ~4 dB. Fig. 3 shows the directivity, material loss, mismatch, and gain over the DVB-H band. The calculated gain agrees well with the measurement result which is the peak gain observed in the horizontal plane. There is a 3-7 dB margin between the measured gain and the specification. Fig. 4 shows the radiation pattern of the low-profile planar antenna at the centre frequency (590 MHz). Good agreement between the measured and simulated results is observed for the dominant vertical component (E_θ). It is seen that the radiation pattern is omni-directional on the horizontal plane, similar to the pattern for a dipole antenna. Also, it is observed that there is only a small variation for the radiation pattern over the DVB-H band.

III. ANTENNA FOR DCS-1800 and IMT-2000 APPLICATIONS

The configuration (see Fig. 5) of the planar antenna for DCS-1800 and IMT-2000 applications is similar to that for the DVB-H terminals. The optimal performance is achieved by adjusting the height (H) of the antenna. It is observed by simulation that the planar antenna has the best performance at H=4.8 mm. The bandwidth of the optimal planar antenna is found to be close to 30% for return loss <-10 dB, completely covering the frequency bands for the DCS-1800 and IMT-2000 systems. The antenna height H=4.8 mm is much lower than previously published antennas, e.g., H=10 mm in [9], H=12.5 mm in [10], H=22 mm in [11], and H=17 mm in [12].

The measured return loss is presented in Fig. 6, which shows good agreement with the simulation results. The radiation patterns simulated and measured at 1.8 GHz for DCS-1800 and 2.1 GHz for IMT-2000 are plotted in Fig. 7. Good agreement is observed between the simulated and measured results. The radiation patterns have a figure-eight configuration in the E-plane, and an omni-directional shape in the H-plane, similar to the radiation pattern of a dipole. The configuration of the radiation pattern has no significant change over the whole frequency band (i.e., 1.65-2.25 GHz). The simulated and measured gains in the H-plane are found to be 2.05 and 1.4 dBi at 1.8 GHz, 2.06 and 1.2 dBi at 2.1 GHz, respectively. The slight differences come from the coaxial cable and the calibration errors.

IV. CONCLUSION

A new type of low-profile planar antenna has been developed for the reception of digital television signals on DVB-H terminals (which operate at the UHF band 470-702 MHz) and for mobile hand sets of the DCS-1800 and IMT-2000 applications. The antenna for the DVB-H terminals has a height of 8 mm and can fit in a terminal (or chassis) with a size of 128 mm × 78 mm. The gain achieved by this antenna is more than -4 dBi, 3-7 dB higher than the specification. The planar antenna for the DCS-1800 and IMT-2000 applications can achieve a bandwidth of ~30% with an antenna height of 4.8 mm which is much lower than previously published antenna configurations. This type of broadband planar antenna can be realized on a thin substrate without via process, thus easy to integrate with RF front-end circuits.

Acknowledgement

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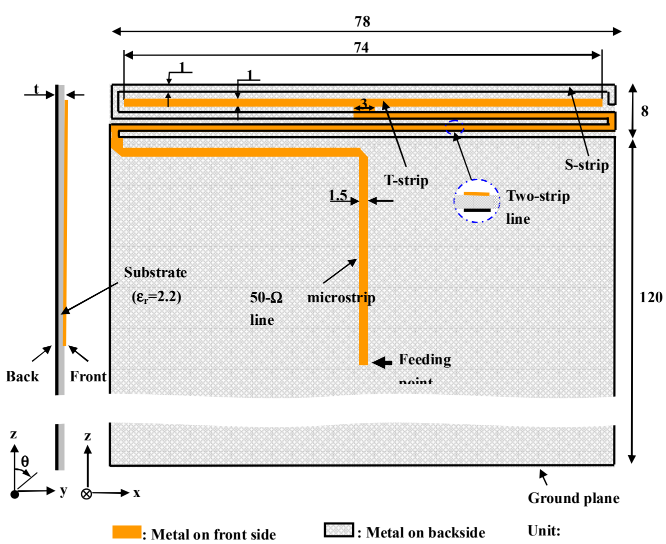


Fig. 1. Geometry of a low-profile planar antenna for DVB-H terminals.

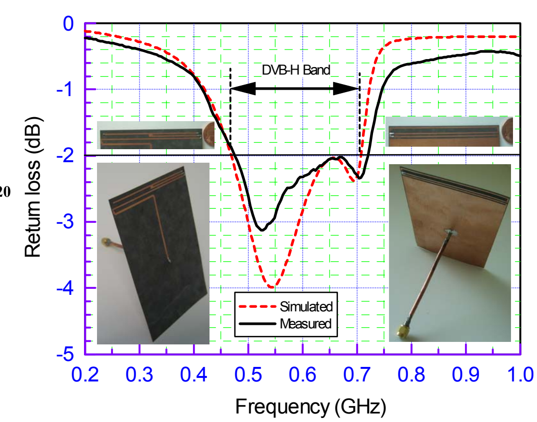


Fig. 2. Return loss of the low-profile planar antenna for DVB-H (Inset are four pictures of the antenna prototype.)

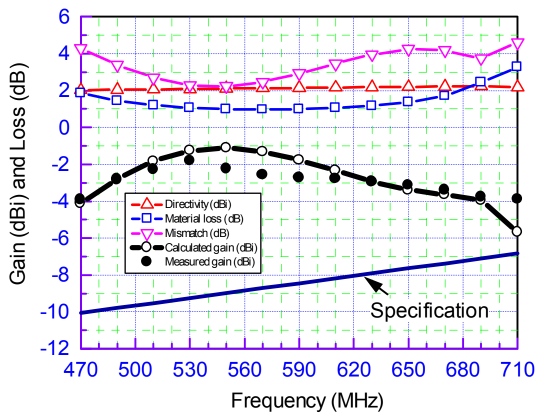


Fig. 3. Directivity, material loss, mismatch, and gain of the low-profile planar antenna for DVB-H.

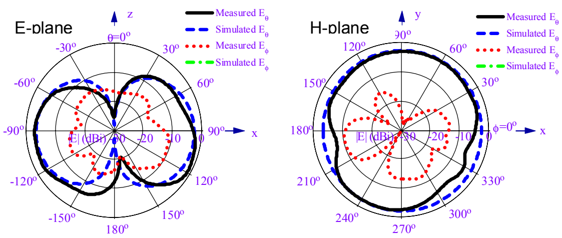


Fig. 4. Radiation pattern of the low-profile planar antenna for DVB-H at 590 MHz.

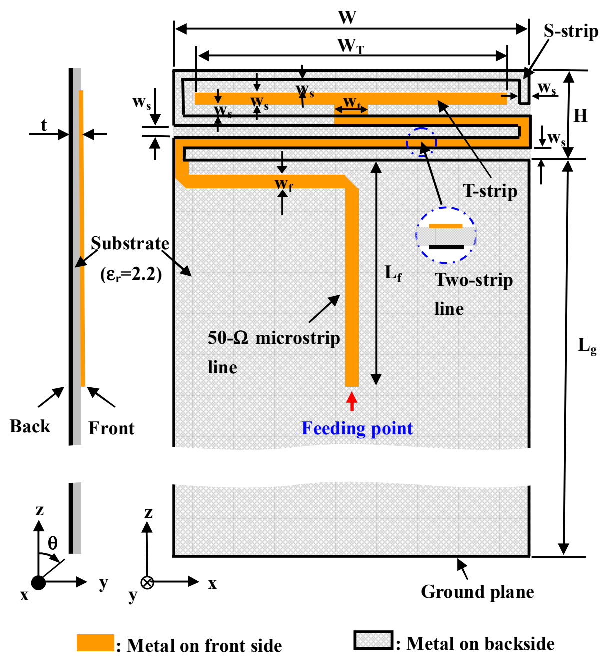


Fig. 5. Configuration of a low-profile planar antenna for DCS-1800 and IMT-2000 applications (H=4.8 mm, W=19 mm, W_T=16.6 mm, w_s=0.6 mm, w_t=1.8 mm, w_f=0.75 mm, L_f=15 mm, and t=0.254 mm).

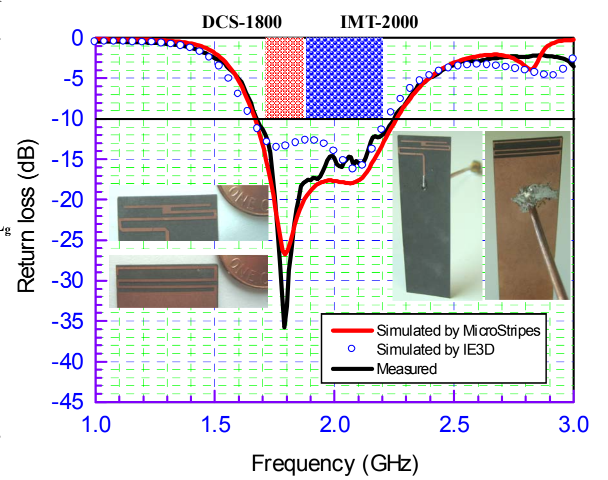
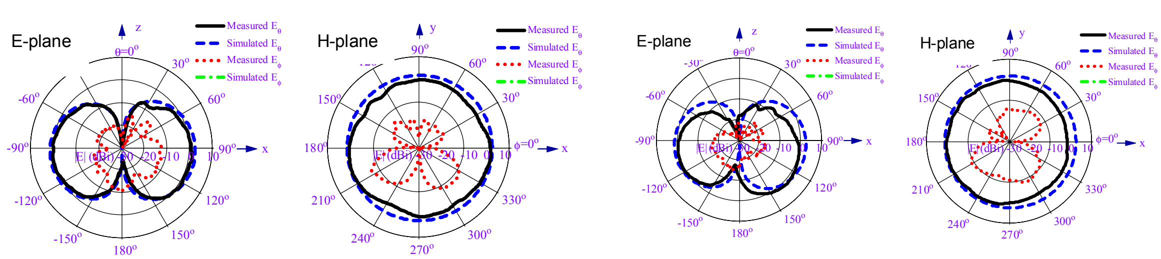


Fig. 6. Measured return loss of the planar antenna for DCS-1800 and IMT-2000 compared with simulation results. (Inset are four photographs of the antenna prototype, which show the front view and the back view of the planar antenna, respectively.)



(a) At 1.8 GHz

(b) At 2.1 GHz

Fig. 7. Radiation patterns of the low-profile planar antenna for DCS-1800 and IMT-2000.