A Compact Broadband Planar Antenna for GPS, DCS-1800, IMT-2000, and WLAN Applications

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***Abstract*—A compact broadband planar antenna is developed for global positioning system (GPS), DCS-1800, IMT-2000, and WLAN handsets. The planar antenna consists of an S-strip and a T-strip which are separately printed on the two sides of a thin substrate (no via process is involved in the fabrication). The antenna size is only 18 mm × 7.2 mm × 0.254 mm which is more compact than previously published antenna configurations. The bandwidth of the planar antenna is enhanced by the mutual coupling between the S-strip and the T-strip. It has been demonstrated by simulation and experiment that the compact planar antenna can achieve a bandwidth of more than 50% for return loss< -10 dB with an almost unchanged radiation pattern.**

***Index Terms*—Broadband antenna, compact antenna, global positioning system (GPS), mobile handset, planar antenna, WLAN.**

I. INTRODUCTION

FOR an antenna (usually, linearly polarized) operating at DCS-1800 (1710–1880 MHz), IMT-2000 (1885–2200 MHz), and WLAN-IEEE 802.11b (2400–2483 MHz) bands, it is required to have a bandwidth of ~40%. Recently, it has been found that a linearly polarized antenna can be also used for a global positioning system (GPS) (1570–1580 MHz) receiver [1], [2]. To include the GPS receiver in a mobile handset, the antenna must have a bandwidth of ~50%, while maintaining a compact size. In recent years, a lot of compact broadband antennas have been developed for mobile handsets [3]–[7]. However, most of these antennas have a non-planar configuration which involves shorting metal walls/vias and requires a considerable antenna thickness, thus not suitable for a fully photolithographic fabrication process. In this letter, we present a fully planar antenna which can achieve a bandwidth of more than 50% and has a more compact size (18 mm × 7.2 mm × 0.254 mm) than previous antennas (e.g., 30 mm × 10 mm × 2 mm in [3]). The configuration of the compact planar antenna is described in Section II while simulation and experimental results are presented in Section III.

II. ANTENNA CONFIGURATION

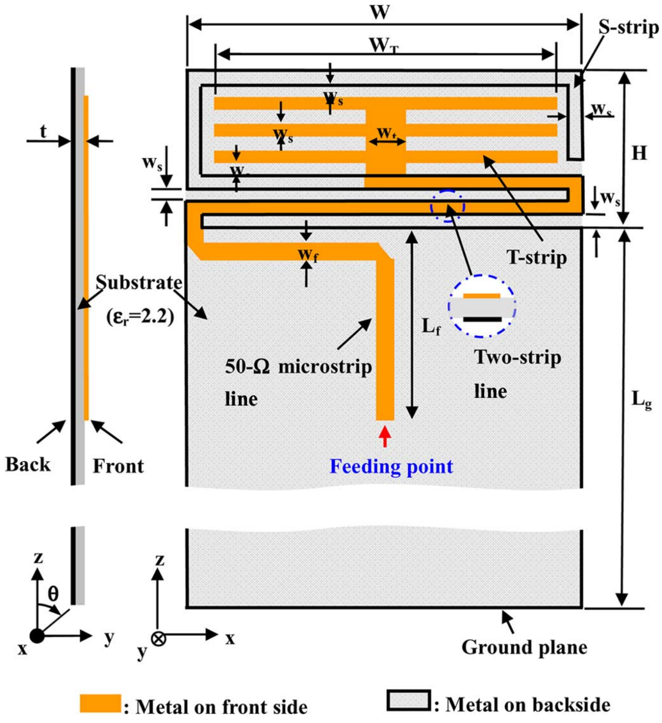

Fig. 1. Configuration of a compact broadband planar antenna ($\mathrm{H} = 7.2$ mm, $\mathrm{W} = 18$ mm, $\mathrm{W_T} = 15.6$ mm, $\mathrm{w_s} = 0.6$ mm, $\mathrm{w_t} = 1.8$ mm, $\mathrm{w_f} = 0.75$ mm, $\mathrm{t} = 0.254$ mm, and $\mathrm{L_f} = 15$ mm).

The configuration of the compact planar antenna is illustrated in Fig. 1. The design of the antenna is based on an RT/Duroid 5880 planar substrate that has a dielectric constant of $\varepsilon_r = 2.2$ and a thickness of $\mathrm{t} = 10$ mils (0.254 mm). The planar antenna consists of an S-strip and a T-strip which are printed on the two sides (i.e., the front side for T-strip and the backside for the S-strip) of the substrate, respectively. There is no direct electrical connection (e.g., by a shorting via) between the front side and the backside. The T-strip (its strip width $= \mathrm{w_s}$) is fed by a 50-Ω microstrip line while the S-strip (its strip width $= \mathrm{w_s}$) is terminated at a ground plane (its length $= \mathrm{L_g}$). The upper section (its width $= \mathrm{W_T}$) of the T-strip is fitted (leaving a space of $\mathrm{w_s}$) into an area surrounded by the upper section of the S-strip while the lower section of the T-strip overlaps with the lower section of the S-strip, forming a two-strip line. The height (H) of the planar antenna can be adjusted for an optimal performance. The compactness of the planar antenna is attributed to the folded configuration of the S-strip and T-strip (specifically, the folded two-strip line) while the broadband performance is a result of the mutual coupling between the S-strip and the T-strip.

The feeding point is set up at the center of the upper half section of the ground plane. This setup is completely for the purpose of accurate measurement. As will be shown in the next

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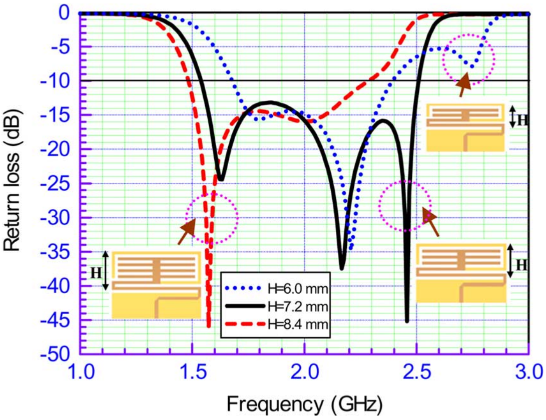

Fig. 2. Simulated results for return loss of the planar antenna with different heights ($\mathrm{H} = 6.0$, 7.2, and 8.4 mm) ($\mathrm{L_g} = 60$ mm).

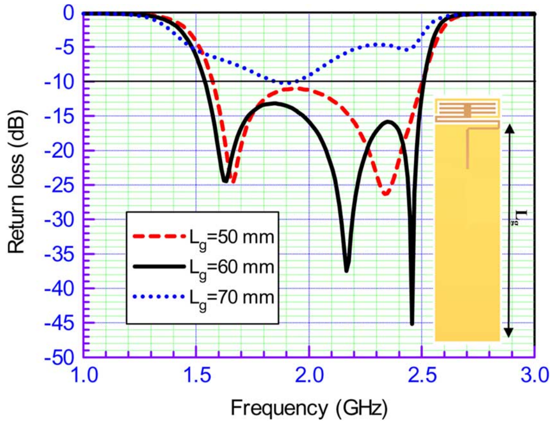

Fig. 3. Effect of the length ($\mathrm{L_g}$) of ground plane on the return loss of the compact broadband planar antenna ($\mathrm{H} = 7.2$ mm).

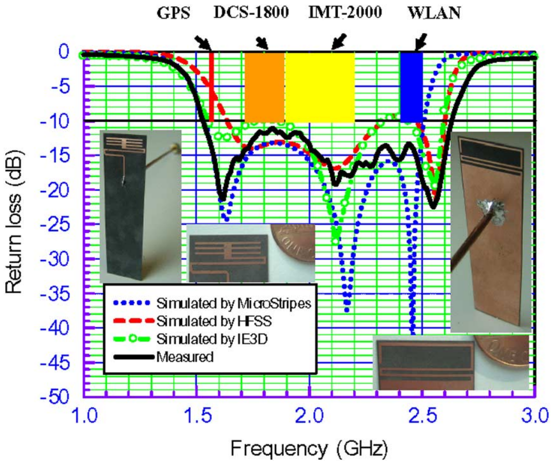

Fig. 4. Measured return loss of the compact broadband planar antenna compared to simulation results. (Inset are four photographs of the antenna prototype, which show the front view and the back view of the planar antenna, respectively.)

section, the length ($\mathrm{L_g}$) of the ground plane can affect the performance of the antenna. If the feeding point is set up in the lower section of the ground plane, a coaxial cable attached to the ground plane tends to increase the length of the ground plane, hence changing the antenna performance. In realistic topologies of mobile handsets, the ground plane can be a part of a printed circuit board (PCB) and the planar antenna can be directly connected to the output of an RF front end (or an RF chip). Therefore this setup reflects a practical scenario where there is no coaxial cable attachment.

III. RESULTS

The planar antenna was designed by simulation using the TLM (transmission line matrix) based design tool—*MicroStripes 7.0*. In the simulation, the 50-Ω microstrip line was excited at the feeding point by a wire-port (i.e., a lumped voltage source) instead of a microstrip-port (i.e., a wave-port). (Note that the microstrip-port which is terminated at an absorbing boundary is not suitable for the situation where the length of the ground plane affects the simulation results.) We began the design by adjusting the height (H) of the planar antenna. Fig. 2 shows the simulation results for return loss at three different heights, namely, $\mathrm{H} = 6.0$, 7.2, and 8.4 mm. Note that the height H is adjusted by changing the number of the equidistant crossbars of the T-strip, e.g., 2, 3, and 4 crossbars for $\mathrm{H} = 6.0$, 7.2, and 8.4 mm, respectively. It is observed from Fig. 2 that the planar antenna has a maximum bandwidth at $\mathrm{H} = 7.2$ mm. The maximum bandwidth is close to 50%. The total size of the planar antenna is 18 mm × 7.2 mm × 0.254 mm, which is more compact than the previously published antennas, e.g., 30 mm × 10 mm × 2 mm in [3], 62 mm × 10 mm × 6 mm in [4], 27 mm × 12.5 mm × 3.5 mm in [5], 22 mm × 5 mm × 5 mm in [6], and 20 mm × 17 mm × 4.7 mm in [7].

The effect of the length ($\mathrm{L_g}$) of the ground plane on the return loss of the planar antenna is exhibited in Fig. 3. We can see that there is an optimum value for $\mathrm{L_g}$ where the planar antenna has the best performance for return loss. The reason for the length dependence is that the ground plane also serves as a radiating element. The optimum value for $\mathrm{L_g}$ is found to be around 60 mm. (Probably, around $\mathrm{L_g} = 60$ mm, the ground plane, the S-strip, and the T-strip form a resonant radiator.) Therefore, the planar antenna is suitable for compact mobile handsets.

To verify the performance of the compact broadband planar antenna, a prototype was fabricated and measured. The antenna was fabricated on a 10-mil RT/Duroid 5880 substrate with 0.5 oz copper on both sides by wet etching process. This process is based on a standard double-side lithography using Karl Suss MA-6 Mask Aligner which is capable of backside alignment. Some alignment markers were printed on both sides to aid the backside alignment. After the photoresist was patterned and developed on both sides, the unwanted copper was removed by the 30% $\mathrm{FeCl_3}$ saturated solution. Four photographs of the antenna prototype are inset in Fig. 4 to show the front view and the back view of the planar antenna. For the purpose of measurement, the antenna is connected to a 0.085″ semi-rigid coaxial cable in the upper section of the ground plane. After using this feeding structure, we found that the effect of the coaxial cable on the measurement results could be significantly alleviated. The measured return loss (RL) is presented in Fig. 4, which shows a bandwidth of more than 50% for $\mathrm{RL} < -10$ dB, covering the frequency bands for GPS (1570–1580 MHz), DCS-1800

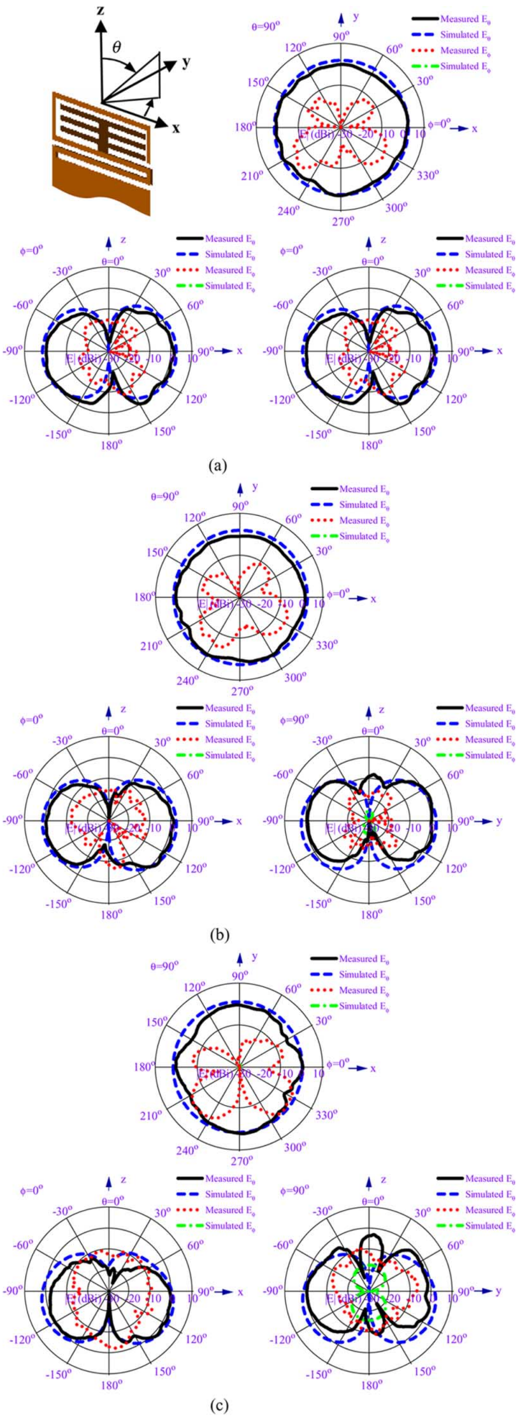

Fig. 5. Radiation patterns of the compact broadband planar antenna: (a) at 1.6 GHz, (b) at 2.0 GHz, (c) at 2.5 GHz.

(1710–1880 MHz), IMT-2000 (1885–2200 MHz), and WLAN-IEEE 802.11b (2400–2483 MHz). To further verify the measurement result, we also simulated the antenna by using *HFSS 10.0* and *IE3D 9.0*. These simulations confirm the measurement result.

The radiation patterns simulated and measured at 1.6, 2.0, and 2.5 GHz are plotted in Fig. 5, demonstrating a good agreement. The radiation patterns have a figure-eight configuration in the x-z and y-z planes, and an omni-directional shape in the x-y plane, similar to the radiation pattern of a dipole. From this point of view, we verify that the ground plane also serves as a part of the radiator. The shape of the radiation pattern has no significant change over the whole frequency band (i.e., 1.52–2.62 GHz). The simulated and measured gains in the x-y plane are found to be 2.05 and 2.45 dBi at 1.6 GHz, 2.07 and 1.53 dBi at 2.0 GHz, and 1.48 and 1.74 dBi at 2.5 GHz, respectively. The slight differences come from the coaxial cable and the calibration errors. The simulated radiation efficiency is higher than 90%, which means that the planar antenna is a highly efficient radiator. (A conductivity of $\sigma = 5.8 \times 10^7$ S/m for the metal and a loss tangent of tan $\delta = 0.0009$ for the dielectric substrate were used in the simulation.)

IV. CONCLUSION

A compact broadband planar antenna has been developed for GPS, DCS-1800, IMT-2000, and WLAN applications. The antenna size is reduced by introducing folded configurations of an S-strip and a T-strip which are printed on the two sides of a thin planar substrate, respectively. The bandwidth is enhanced by the mutual coupling between the S-strip and the T-strip. It is found that the planar antenna can achieve a bandwidth of more than 50% with an antenna size of 18 mm × 7.2 mm × 0.254 mm. The broadband performance of the compact planar has been demonstrated by simulation and experiment. The compact planar antenna can be realized on thin substrates without the need for vias, thus facilitating its integration with RF front-end circuits.

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