Small Folded Shorted-Patch Antenna

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I. Introduction

In modern mobile and wireless communications systems, there is an increasing demand for small low-cost antennas. This is especially true for handheld wireless applications where a package-integrated antenna may be desirable such as in mobile phone handsets or Bluetooth chips. It is well known that planar structures, e. g. microstrip patch antennas, have a significant number of advantages over conventional antennas, such as low profile, light weight and low production cost. In some practical wireless communications systems such as GSM 1800, PCS 1900, IMT 2000, or Bluetooth ISM, however, their physical sizes may be too large for integration with RF devices.

A number of techniques have been proposed to reduce the size of conventional half-wave ($\lambda_0/2$, λ_0 is the guide wavelength in the substrate) patch. The most straightforward approach is to use high dielectric constant substrate [1], however, it leads to poor efficiency and narrow bandwidth. Shorting posts also have been used in different arrangements to reduce the overall size of the patch antenna. A shorting wall [2] can reduce the patch size to $\lambda_0/4$ while a shorting pin near the feed [3] can reduce the patch size even further. Introducing reactive loads can also reduce the resonant frequency [4]. It was found that the capacitive load reduces the resonant length of a patch from $\lambda_0/4$ to less than $\lambda_0/8$.

In this paper we propose a simple technique for further reducing the size of a conventional shorted-patch antenna. By folding a wall-shorted patch antenna, the antenna length can be reduced to $\lambda_0/8$. The resonant frequency of the folded shorted-patch antenna can be further reduced by more than a half through an adjustment of the width of shorting walls and the height of the folded patch. This means that the overall length ($\lambda_0/16$) of the new folded shorted patch antenna can be eight times shorter than the length of a conventional patch ($\lambda_0/2$).

II. Antenna Structure and Analysis

The structure of a folded shorted-patch (S-P) antenna is shown in Fig. 1. The reason why the above structure is referred as a folded S-P is because we consider this antenna is evolved from a conventional shorted patch, as illustrated in Fig. 2. It is well known that a conventional rectangular patch antenna operating at the fundamental mode has an antenna length of ~$\lambda_0/2$ (see Fig. 2a). Considering the electric field vanishing around the middle of the patch, we can short the patch along its middle line with a metal wall without significantly changing the resonant frequency of the antenna. Thus we get a S-P antenna with an antenna length of ~$\lambda_0/4$, as shown in Fig. 2b. Next we fold the shorted patch together with the ground plane, reaching to Fig. 2c. Note that the total electric length of the folded S-P will not change very much, but the practical antenna length has been reduced by a half (~$\lambda_0/8$). Finally we add a new piece of the ground plane to the right (the original ground plane has become as the upper patch) and press the folded patch together to form the standard folded S-P antenna as shown in Fig. 2d.

To demonstrate the above deduction, a numerical simulation was carried out for a 10 mm × 10 mm folded S-P antenna. To guarantee the correctness of simulated results, two different simulators, the TLM-based *Micro-Stripes* 5.6 and an FDTD code developed *in house*, were employed. Fig. 3 shows the simulated return loss for a 50-Ω impedance match. Good agreement can be seen between the results from TLM and FDTD simulations. For comparison the return loss for a conventional S-P antenna with the same antenna size (except the patch height=1.5 mm) is also plotted in this figure. Note that the resonant frequency of the folded S-P is only about 3.6 GHz, about 57% of that (6.3 GHz) for the conventional S-P antenna. This means that the antenna length of the folded S-P do have only $\lambda_0/8$, ~4 times smaller than a conventional patch antenna.

The resonant frequency of the folded shorted-patch antenna can be further lowered by slightly modifying the shape of the antenna, such as reducing the width of two shorting walls and/or adjusting the height of the folded patch. Fig. 4 shows a variation of the return loss with the height of the lower patch (h_1). We can find that h_1 has a significant impact on the resonant frequency. As the lower patch moves toward the upper patch, the resonant frequency decreases quickly. When the distance between the lower and upper patches is less than 1/5 of the total antenna height, the resonant frequency reduces by more than a half of that for a standard folded S-P. This implies that the generalized folded S-P can achieve a size reduction by more than 8 times compared with a conventional patch antenna. In addition we also can take advantage of the sensitivity of resonant frequency to h_1 for tuning the antenna. The reason for the decrease in resonant frequency as h_1 increases is probably due to a length extension of the lower shorting wall on one hand, and an enhancement of the coupling between the lower and upper patches on the other hand.

III. Application

As an example, we now apply the technique for antenna-size reduction described above to design a practical folded S-P antenna in bluetooth ISM band (2.4-2.483 GHz). We choose the dimension of the folded S-P to be 15 mm × 15 mm. In order to achieve the bandwidth (near 4%) required by the Bluetooth protocol, the total thickness (h_2) of the antenna needs to be at least 6 mm (we simply select h_2=6 mm). By adjusting the height (h_1) of the lower patch to 2.85 mm, we can tune the resonant frequency near 2.44 GHz. Fig. 5 pictures the prototype of the folded S-P. The simulated return loss is compared with measured result in Fig. 6. As seen, there is good agreement between the simulated and measured results. The radiation pattern is also simulated and measured in the xz- and yz-planes at 2.44 GHz, which is shown in Fig. 7. Good agreement is noted. There is a nearly omni-directional pattern for the co-polarized component, which is desirable for Bluetooth applications.

IV. Conclusion

The size of a conventional shorted-patch antenna can be reduced by almost a half via folding the shorted patch together with the ground plane. The resonant frequency of the folded shorted-patch antenna may be further lowered by reducing the width of the shorting walls or by moving the folded patch upward. It is shown that the antenna length of a folded shorted-patch can be reduced by as small as less than 1/8 compared with a conventional patch antenna. A practical folded shorted-patch antenna for the Bluetooth ISM band is designed and measured to demonstrate its potentials of applications. This size-reduced antenna can achieve an impedance bandwidth of 4% and has a nearly omni-directional radiation pattern, which may be suitable for some mobile communications systems. Future works will focus on the bandwidth improvement and the design under practical specifications such as use of different dielectric materials.

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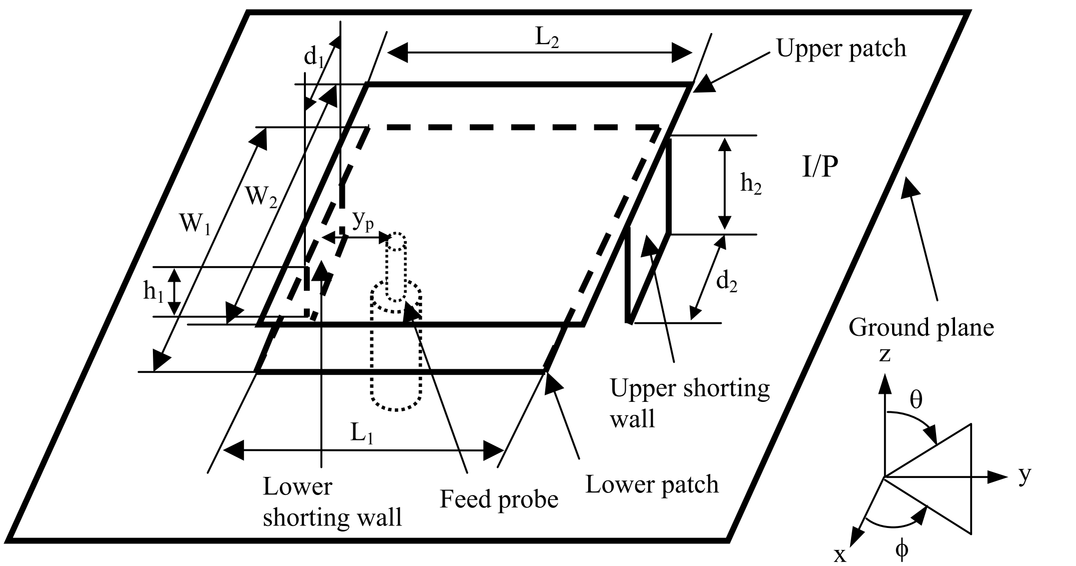

Fig. 1. Folded shorted-patch antenna.

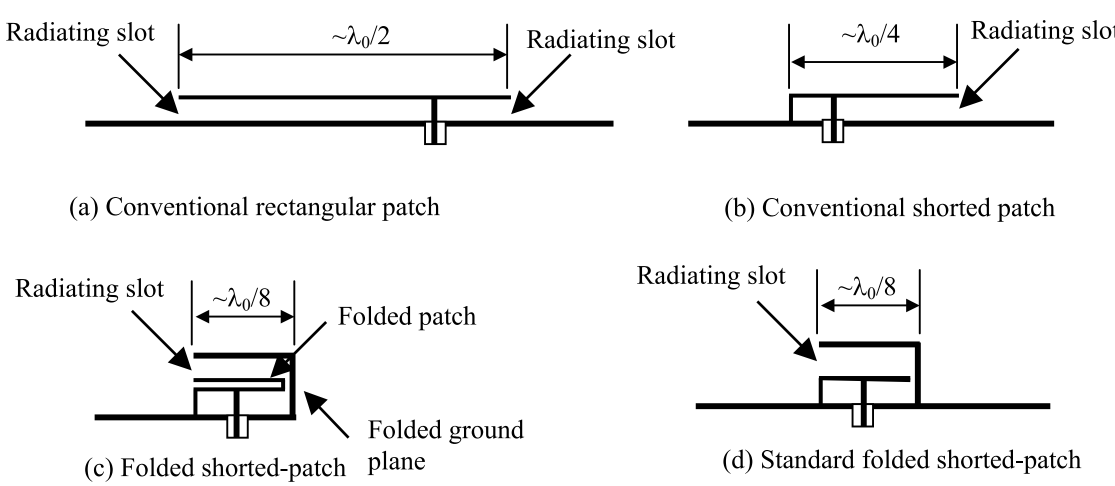

Fig. 2. Evolution of the folded shorted-patch antenna.

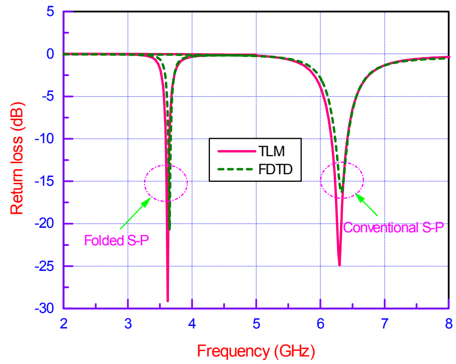

Fig. 3. Return loss for a folded S-P compared with a conventional S-P (parameters: L_1=9.5 mm, W_1=10 mm, L_2=W_2=10 mm, h_1=1.5 mm, h_2=3 mm, y_p=2.25 mm, radius of the feed probe=0.1 mm, ground plane=20 mm × 20 mm).

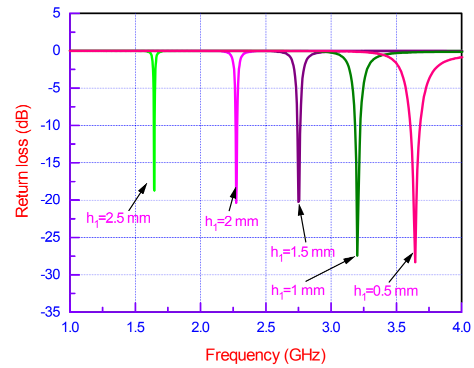

Fig. 4. Return loss of a folded S-P with different height of the lower patch (parameters: L_1=9.5 mm, W_1=10 mm, L_2=W_2=10 mm, h_2=3 mm, d_1=d_2=2 mm, radius of the feed probe=0.1 mm, ground plane=20 mm × 20 mm).

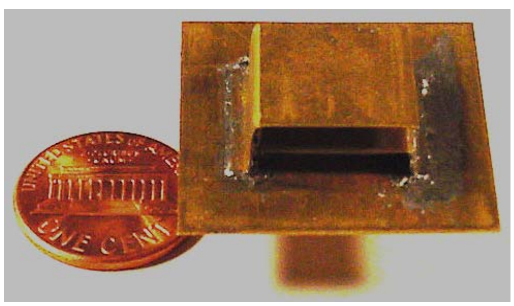

Fig. 5. Prototype of a folded S-P for Bluetooth applications.

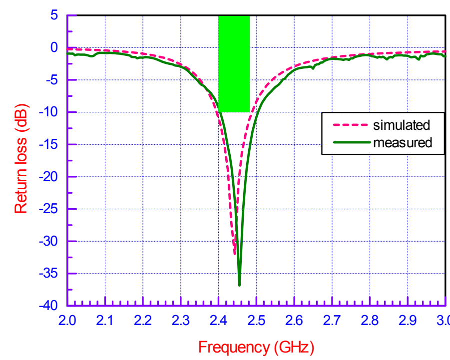

Fig. 6. Return loss of a folded S-P for Bluetooth applications (parameters: L_1=14 mm, L_2=15 mm, W_1=W_2=15 mm, h_1=2.85 mm, h_2=6 mm, d_1=d_2=15 mm, y_p=5 mm radius of the feed probe=0.325 mm, ground plane=30 mm × 30 mm).

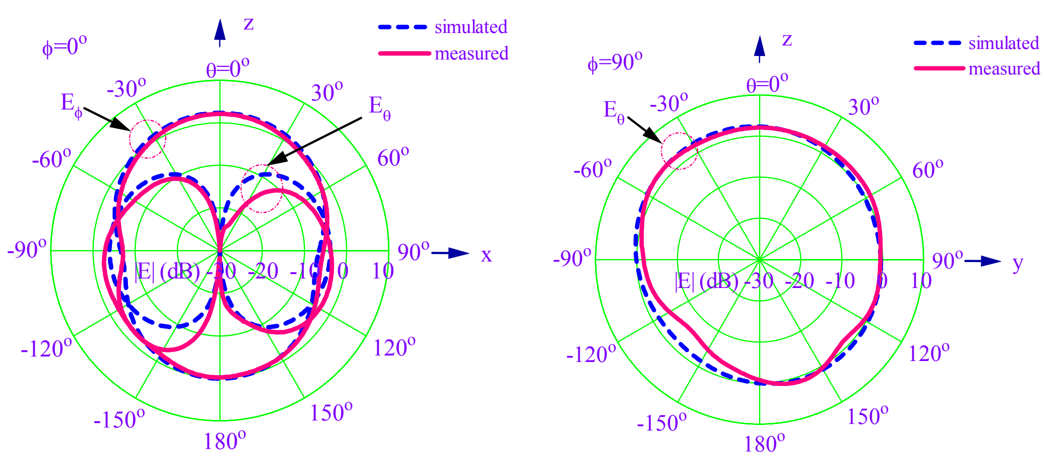

Fig. 7. Radiation pattern of a folded S-P for Bluetooth applications at 2.44 GHz.