Low-Profile Broadband and Dual-Frequency Two-Strip Planar Monopole Antennas

B. Pan*, R. L. Li, J. Papapolymerou, J. Laskar, and M. M. Tentzeris
School of Electrical and Computer Engineering
Georgia Institute of Technology, Atlanta, GA 30332-0250, USA

Abstract: A novel type of low-profile broadband and dual-frequency monopole antennas is developed for wireless applications. The broadband monopole consists of an S-strip and a folded T-strip which are separately printed on the two sides of a thin planar substrate. No via process is involved in the fabrication. The two-strip planar monopole can achieve a bandwidth (VSWR<2) of ~35% with a height of $0.056\lambda_0$. The dual-frequency operation of the broadband monopole antenna is realized by adding a short T-strip to the S-strip and a couple of inverted-L strips to the folded T-strip. The dual-frequency monopole can accomplish a bandwidth of ~40% at a lower-frequency band and ~10% at a higher-frequency with a total height of $0.08\lambda_0$.

I. INTRODUCTION

For applications in a portable wireless communication device, such as a mobile phone handset or a notebook computer, the antenna with a low-profile planar structure is essential for low-cost manufacture and easy integration with a printed circuit broad (PCB). On the other hand, the requirement for a dual-frequency operation is becoming a common sense in order to accommodate multi-functional services, such as voice, video, and data transmissions. To cover the DCS-1800, PCS-1900, IMT-2000/UMTS, the 2.4 GHz ISM band, and the 5.8-GHz UNII band, it needs a bandwidth of ~40% at the lower-frequency band (around 2 GHz) and a bandwidth of ~10% at the higher-frequency band.

Monopole antenna is attractive for wireless applications due to its simple structure and omni-directional radiation pattern. However, a straight monopole usually has a height of larger than $~0.15\lambda_0$ [1], [2]. A simple way for reducing the antenna height is to bend or fold the straight monopole into some type of low-profile configuration, such as an inverted L or an inverted F [3], a double S or a double T [4], [5], or a meandered shape [6]. Unfortunately, a bent/folded monopole usually corresponds to a lower impedance bandwidth (typically <10% for a VSWR<2), particularly, at the lower-frequency band of a dual-frequency operation. In general, it is more difficult to achieve a broad bandwidth at a lower frequency band than at a higher-frequency band due to the electrically smaller antenna size at a lower frequency. In recent years, a lot of efforts have been made to increase the impedance bandwidth while keeping a low antenna profile [7]. But most of techniques for bandwidth enhancement involve shorting metal walls and require a considerable antenna thickness ($>0.02\lambda_0$), not suitable for a fully photolithographic fabrication process. It has been found in [8] that electromagnetic coupling and two-strip configuration are two effective methods for increasing the bandwidth of a compact antenna structure. These methods have been demonstrated to be effective for a few three-dimensional structures. In this paper, we combine the electromagnetic coupling and the two-strip configuration into a monopole structure folded on a very thin planar substrate (thickness<$0.002\lambda_0$) for achieving a broadband operation. The dual-frequency operation is realized by adding some parasitic elements into the broadband structure. There is no shorting via involved in the antenna structure.

II. BROADBAND OPERATION

The geometry of a low-profile broadband two-strip planar monopole antenna is illustrated in Fig. 1. This antenna is designed at the 2 GHz band based on an RT/Duroid 5880 planar substrate which has a dielectric constant of ε_r=2.2 and a thickness of t=10 mils (0.254

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 feedline. On the backside of the substrate, there is an S-strip which is terminated at a ground plane. The upper section of the T-strip is fitted into the area surrounded by the upper section of the S-strip. The height (H_T) and width (W_T) of the T-strip are slightly shorter than those (i.e., H and W) of the S-strip. To alleviate the skin effect, the crossbar of the T-strip is divided into some narrow strips whose width and separation are equal to the width (w_s) of the S-strip, which is approximately equal to the width (w_f) of the 50-Ω microstrip feedline. 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 directly electrical connection (e.g., by a shorting via) between the front side and the backside. A prototype of the low-profile broadband antenna is shown in Fig. 2. The total height of the antenna is H=8.4 mm (0.056λ_0, λ_0 is the free-space wavelength at 2 GHz) and the width W=18 mm (0.12λ_0). Other geometrical parameters are attached in the caption of Fig. 1.

To demonstrate the performance of the low-profile two-strip monopole, the antenna structure was simulated using *MicroStripes 6.5* and *HFSS 9.1*. Fig. 3 shows the return loss of the low-profile two-strip monopole. The bandwidth for VSWR<2 is found to be ~35%. The measured result confirms the broadband performance. The effect of the monopole width (W) on the operating frequency is displayed in Fig. 4. As expected, the operating frequency shifts up when W decreases; therefore, the width W can be used for tuning the operating frequency to a specified frequency band. The low-profile two-strip antenna has an omni-directional pattern in the x-y plane with a peak gain of ~2 dBi.

III. DUAL-FREQUENCY OPERATION

In order to cover the 5.8 GHz UNII band for WLAN applications (e.g., IEEE 802.11a), three parasitic elements are added to the two-strip monopole for achieving a dual-frequency operation. Fig. 5 shows the configuration of the dual-frequency monopole antenna. A short T-strip is attached to the lower section of the S-strip while a couple of inverted-L strips are branched from the lower section of the T-strip. The dominant radiating element in the 5.8 GHz band is the short T-strip which is electromagnetically coupled with the inverted-L strips. The addition of the parasitic elements can increase the level of return loss in the 2 GHz band. To alleviate this effect, the height (H_{T2}) of the short T-strip should keep as low as possible and it is necessary to keep a certain separation distance (i.e., D) between the upper and lower parts of the S-strip/T-strip. Numerical simulation shows that H_{T2} should be less than 1.5 mm while D should be more than 4 mm to keep the return loss in the 2 GHz band is lower than -10 dB. The level of return loss in the 5.8 GHz band can be optimized by adjusting the widths (W_{L1} and W_{L2}) and the height (H_L) of the inverted-L strips. The optimal values for W_{L1}, W_{L2}, and H_L are found to be 6.0 mm, 6.0mm, and 0.75 mm, respectively. The total height (H) of the dual-frequency monopole is 12 mm (0.08λ_0). A prototype of the dual-frequency antenna is shown in Fig. 6. The simulated and measured results for return loss are compared in Fig. 7. The bandwidth in the 5.8 GHz band is found to be ~10% while the bandwidth in the 2GHz band remains ~40%.

IV. CONCLUSION

The profile of a monopole antenna can be lowered by making use of an S-strip and a folded T-strip. By combining the S-strip and the T-strip into a planer substrate, the bandwidth of the two-strip monopole is significantly increased. A broadband dual-frequency operation is realized by adding more parasitic elements into the two-strip monopole structure. A bandwidth of ~35% is achieved for the two-strip monopole with a

height of $0.056\lambda_0$ while the dual-frequency antenna realizes a bandwidth of ~40% in the 2 GHz band and ~10% in the 5.8 GHz band. The low-profile two-strip monopole antennas are easy to fabricate with possible integration with RF front-end circuits. This type of broadband and dual-frequency antennas may find applications in 2G/3G cellular phones and WLAN devices.

Acknowledgement

References

[1] H.-D. Chen and H.-T. Chen, "A CPW-fed dual-frequency monopole antenna," *IEEE Trans. Antennas Propagat.,* vol. 52, no. 4, pp. 978-982, April 2004.

[2] W.-C. Liu, "Design of multiband CPW-fed monopole antenna using a particle swarm optimization approach," *IEEE Trans. Antennas Propagat.,* vol. 53, no. 10, pp. 3273-3279, Oct. 2005.

[3] H. Nakano, Y. Sato, H. Mimak, and J. Yamauchi, "An Inverted FL antenna for dual-frequency operation," *IEEE Trans. Antennas Propagat.,* vol. 53, no. 8, pp. 2417-2421, Aug. 2005.

[4] W.-C. Liu, W.-R. Chen, and C.-M. Wu, "Printed double S-shaped monopole antenna for wideband and multiband operation of wireless communications," *IEE Proc.-Microw. Antennas Propag.* vo1. 151, no. 6, pp. 473-476, Dec 2004.

[5] Y.-L. Kuo and K.-L. Wong, "Printed double-T monopole antenna for 2.4/5.2 GHz dual-band WLAN operations," *IEEE Trans. Antennas Propagat.,* vol. 51, no. 9, pp. 2187-2192, Sept. 2003.

[6] N. T. Pham, G.-A. Lee, and F. D. Flaviis, "Minimized dual-band coupled line meander antenna for system-in-a-package applications," *IEEE AP-S International Symposium*, vol. 2, pp. 1451-1454, June 2004.

[7] L. Zaid, G. Kossiavas, J.-Y. Dauvignac, J. Cazajous, and A. Papiernik, "Dual-Frequency and broad-band antennas with stacked quarter wavelength elements," *IEEE Trans. Antennas Propagat.,* vol. 47, no. 4, pp. 654-660, April 1999.

[8] H. D. Foltz, J. S. Mclean, and G. Crook, "Disk-loaded monopoles with parallel strip elements," *IEEE Trans. Antennas Propagat.,* vol. 44, no. 5, pp. 672-676, May 1996.

: Metal on front side   : Metal on backside
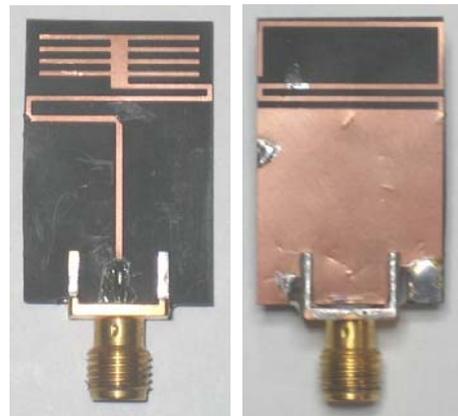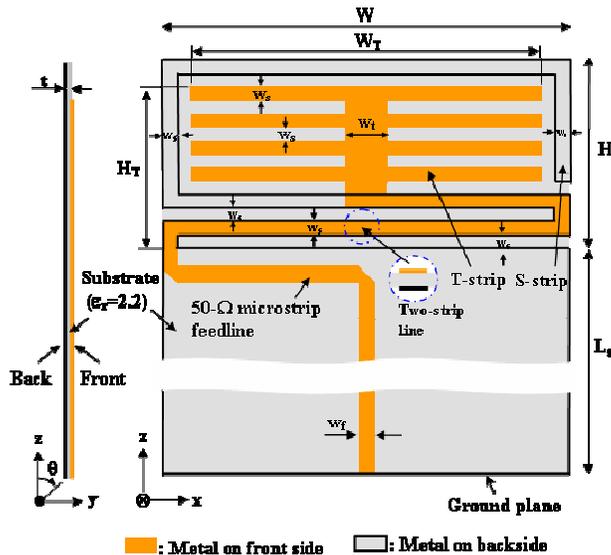
(a) Front view   (b) Back view

Fig. 1. Geometry of a broadband two-strip planar monopole antenna, which includes an S-strip on the front side and a T-strip on the backside of a planar substrate. [Geometrical parameters: H=8.4 mm ($0.056\lambda_0$), W=18 mm ($0.12\lambda_0$), H_T=7.2 mm, W_T=15.6 mm, W_t=1.8 mm, w_f=0.76 mm, t=0.254 mm, and L_g=20 mm.]

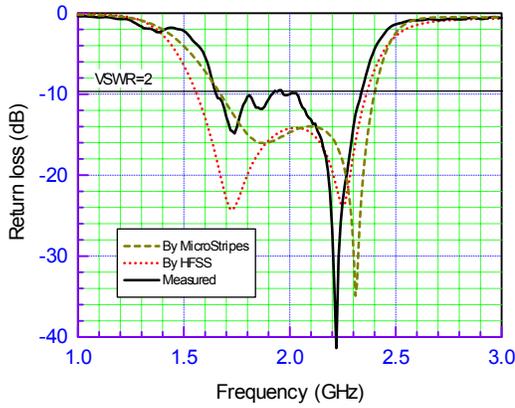Fig. 2. Photo of a prototype of the low-profile broadband two-strip monopole antenna.

Fig. 3. Measured and simulated results for return loss of the low profile broadband two-strip monopole antenna.
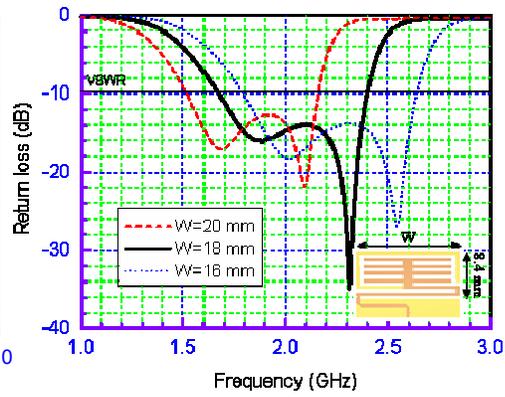

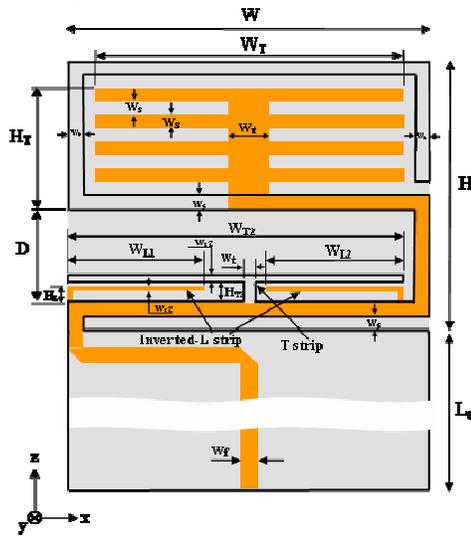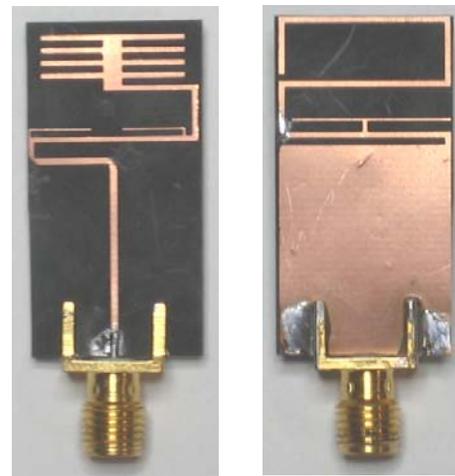Fig. 4. Effect of the width (W) on the operating frequency of a two-strip monopole antenna.

Fig. 5. Configuration of a broadband and dual-frequency two-strip monopole antenna. [Geometrical parameters: H=12 mm (0.08λ_0), W=16 mm (~0.11λ_0), H_T=10.8 mm, W_T=13.9 mm, D=4.2 mm, W_t=1.8 mm, H_{T2}=1.0mm, W_{T2}=14.8 mm, H_L=0.75mm, W_{L1}= W_{L2}=6.0mm, w_s=0.6 mm, w_{s2}=0.25 mm, w_t=0.5mm, w_f=0.76 mm, t=0.254 mm, and L_g=20 mm.]

(a) Front view   (b) Back view

Fig. 6. Photo of a prototype of the broadband and dual-frequency two-strip monopole antenna.
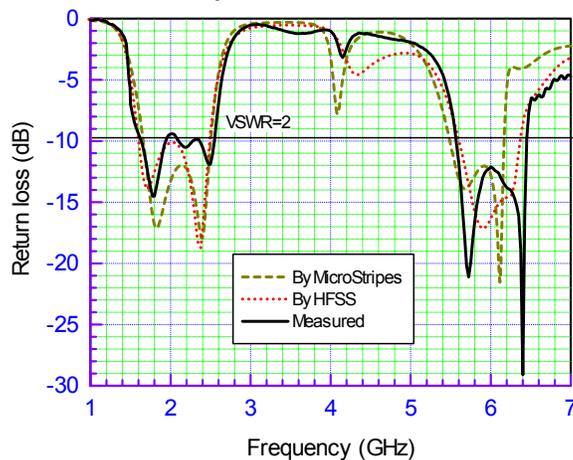

Fig. 7. Measured and simulated results for return loss of the dual-frequency two-strip antenna.