A Compact Multiband Planar Antenna for Multiple Wireless Access Standards Applications

Ching-Song Chuang , Tsi-Tsu Ku , Yi-Ting Sie and Wei-Bin Lin

Electronic Engineering, Lunghwa University of Science and Technology
No.300,Sec.1,Wanshou Rd.,Guishan District,Taoyuan City, 33306,Taiwan
Ching-Song Chuang, chuang.cs@mail.lhu.edu.tw

Abstract

This paper presents a compact planar monopole antenna that covers the operating frequency bands of LTE (0.7, 1.5, 1.9 and 2.6 GHz), WiFi (2.4 GHz) and WLAN (4.9-5.8GHz). The proposed antenna is composed of two distinct structures, a tree-type and a multi-loaded meander-line type monopoles, separately situated on the two opposite sides of the substrate; the meander-line type monopole is configured with multiple sectional strip widths in order to create the multiple lower frequency bands; on the other hand, the tree-type monopole is built not only to produce the higher frequency bands, but also to act as a proximity coupling feed for the meander-line type radiator. The originality exhibits in this presented antenna is the combination of shaping meander-line structure and proximity coupled feeding mechanism for constructing a compact multi-band antenna. Both techniques enable us to reduce the antenna size and to simplify the multiband feeding network layout. The proposed antenna accompanied with several attractive characteristics makes itself particularly suitable to the modern integrated mobile wireless access applications.

***Index Terms* —Multiband Antenna, LTE, WLAN, Proximity Coupling.**

1. INTRODUCTION

Recently, the prevalence of mobile wireless radio applications demands the need to integrate the multiple wireless access standards such as LTE, Wireless LANs, and others into a mobile unit. As a result, the emerging requirements in the modern wireless access applications asks for the design of a compact multiband antenna that covers multiple frequency bands ranged from LTE-0.7GHz up to WLAN-5.9GHz. The design of multiband antenna has long been the subject of interest in the antenna advanced studies. Many related researches can be found in the public literatures, and some of them are listed in [1-4] where, the topology in [1] is to use multi-branch structure, each branch is tuned corresponding to the resonant length of each frequency band, and conceivably a multiband antenna can be attained; In [2], they judiciously use the slots on the surface of a patch subtract to form multiple branches to achieve the multiple operating bands requirement; In [3-4], they configure the planar Inverted-F structure to form multiple branches corresponding to the multiple operating frequency bands. Another recognizable design approach has been the use of parasitic elements either to improve the antenna bandwidth or to excite additional frequency bands [4]. However, as the total integrated number of frequency bands increased, the feeding network becomes more complicated to tune or moreover fails to be matched.

In this paper, a compact multiband planar monopole antenna is presented. The antenna is devised by utilizing a line shaping technique and a proximity coupling mechanism to effectively alleviate the degree of complexity in the design of planar multiband antenna and its corresponding broadband feeding network [5]. The architecture of the antenna contains a two-branch tree-type planar monopole and a shaped meander-line type monopole. The two distinct monopoles are located at the two opposite sides of the substrate. The former monopole is built not only to generate the higher frequency bands of 2.4-2.6GHz and 4.8-5.9GHz for LTE and WLAN standards, but also to act as a proximity-coupling feed for the later one. On the other hand, the meander-line type monopole is purposely structured with multiple sectional non-uniform strip widths to form as multiple loads in order to create the triple lower LTE frequency bands of 0.7, 1.5 and 1.9GHz. The antenna prototype was fabricated on the FR4 substrate with 39.5 mm x 15.9 mm in breadth and height. As demonstrated in the completed prototype, the proposed antenna accompanied with several attractive characteristics, including multiple operating frequency bands, simple in structure, small in size and omni-directional radiation pattern, lends itself particularly suitable to the integrated mobile wireless access applications. The antenna structure, the design topologies, the preliminary simulations, the fabricated prototype and the measurement results are given in the following sections respectively.

2. ANTENNA STRUCTURE DESCRIPTION

Fig. 1 and Table 1 give the geometrical layout and the corresponding physical dimensions of the proposed Multiband Planar Monopole Antenna. Where, the element colored in yellow depicts the two-branch dual band tree-type monopole and that colored in tawny gives the shaped multiband meander-line type monopole. The two distinct monopoles are intentionally arranged and situated at the opposite side of the FR4 substrate. The tree-type radiator is fed by a typical microstrip line and is tuned to produce the WiFi frequency bands of 2.4-2.6GHz and WLAN 4.8-5.2GHz, while the meander-line type monopole is purposely constructed with multiple non-uniform strip width in order to generate the multiple LTE frequency bands of 0.7GHz, 1.5GHz, and 1.9GHz respectively. It should be noted that the tree-type monopole also plays the role of the proximity coupling feeding network for the shaped meander-line type monopole. The coupling gap between two monopoles is 1.66 mm which is the thickness of the FR4 substrate.

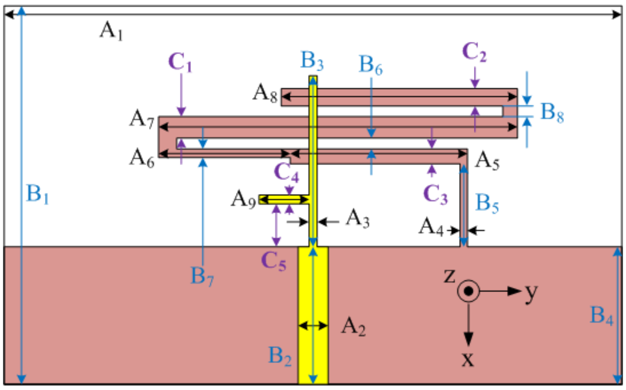


Fig. 1. The antenna geometrical layout and physical parameters

Table 1. The dimensions of the antenna physical parameters

Para-meter	length (mm)	Para-meter	length (mm)	Para-meter	length (mm)
A_1	68	B_1	35.2	C_1	2
A_2	3	B_2	12.8	C_2	1.6
A_3	0.8	B_3	15.9	C_3	1.4
A_4	0.8	B_4	12.8	C_4	0.8
A_5	19.5	B_5	7.7	C_5	4
A_6	14.5	B_6	1		
A_7	39.5	B_7	0.8		
A_8	26	B_8	1		
A_9	5				

3. Antenna Design and Simulation

The initial design of the proposed planar multiband antenna is described in this section. The preliminary performances with respect to each of the individual design parameters marked with indexes C's in the prototype layout (Fig. 1) have been analyzed and evaluated by using the Ansoft-HFSS electromagnetic simulation software.

3.1 The two-branch tree-type monopole

The two-branch tree-type monopole is purposely built for the frequency bands of 2.4GHz and 5.2GHz. Consequently, the corresponding branches can be experimentally lengthened with the lengths equivalent to the effective quarter wavelengths of the two specified frequency bands respectively on the FR4 substrate, However two parameters of C_4 and C_5 are used to tune the frequency band of 5.2GHz. As a result, as shown in Fig. 1 and Table 1, the two respective branch lengths are given by 15.9 mm and 9 mm. In addition, a typical microstrip line is trimmed to match the impedance of the tree-type dual band monopole. The simulated reflection coefficient S_{11} of the ultimate two-branch tree-type monopole is shown in Fig. 2. As indicated in the simulation result the dual broadband of 2.4GHz and 5.2GHz have been achieved based on the -10dB S_{11} measurement.

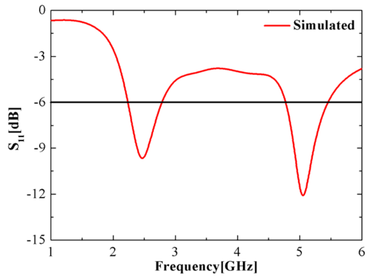


Fig. 2. The simulated S_{11} of tree-type monopole

3.2 The shaped multiband meander-line monopole

The meander-line structure is a well known approach to shorten the upright height of a resonant monopole antenna. Accordingly, in order to reduce the size of the planar antenna, a multi-winding meander-line monopole with 15 mm in upright height and 39.5 mm in width is constructed. However the total winding line length is given approximately to the effective quarter resonant wavelength of 0.7GHz on the FR4 substrate. Furthermore, as shown in Fig. 1, the constituent strip of the meander-line monopole has been shaped with different strip width so as to produce the additional resonant bands at 1.5GHz and 1.9GHz. Where, the combination of shaping and the proximity coupling techniques make it possible to create multiple discontinuities along the meander line, so as to produce multiple frequency bands in single line structure. The shaping parameters used in the meandering line in order to tune the desirable frequency bands include the strip widths C_1 through C_3; where C_1 for band of 1.5GHz, C_2 for band of 1.9GHz, C_3 for band of 0.7GHz respectively. By the aid of software simulation, after a tedious optimization process, the tuning results with respect to the physical parameters are given in Fig. 3 (a), (b) and (c), and the ultimate strip widths are given by 2 mm, 1.6 mm, 1.4 mm respectively. It is noted that the tree-type monopole in opposite side has been used as an excitation feed to the meander-line monopole and the proximity coupling mechanism does alleviate the degree of complexity in the broadband feeding network design.

3.3 Antenna surface current distribution

In order to evaluate the antenna radiation efficiency by using the proximity coupling mechanism, the surface current distributions on the shaping meander-line monopole with respective to the specified frequency bands have been further investigated. The simulated surface current distributions with respective to 0.7GHz, 1.5GHz, 1.9GHz, 2.4 GHz and 5.2GHz are demonstrated in Fig. 4 and 5. As indicated in Fig. 4 (a), (b) and (c), a noticeable surface current has been induced on the shaped meander-line monopole, that is, a reasonable radiation efficiency has been achieve by using the proximity coupling mechanism. However, the current distributions along the meander-line are different among the three frequency bands. Meanwhile, the simulated surface current distributions with respective to 2.4GHz and 5.2GHz are shown in Fig. 5 (a) and (b) respectively. By viewing the simulated current distributions at each of operating frequency bands, it can be stated that the proposed antenna structures could provide good performance in radiation efficiency and radiation gain as well.

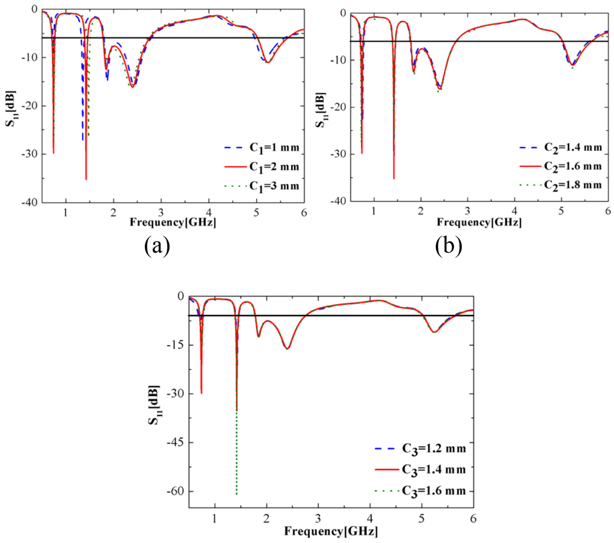


Fig. 3. The simulated S_{11} of meander-line monopole with parameters (a) C_1 (1.5GHz), (b) C_2 (1.9GHz) and (c) C_3 (0.7GHz)

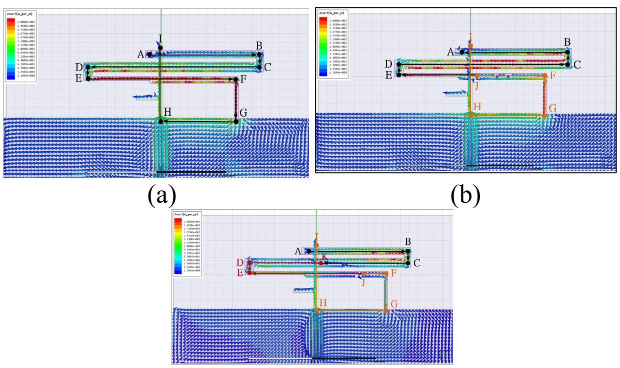


Fig. 4. The simulated surface current distribution at (a) 0.7GHz, (b) 1.5GHz, (c) 1.9GHz

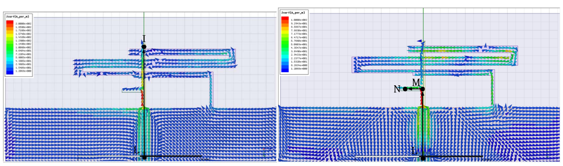


Fig. 5. The simulated surface current distribution at (a) 2.4GHz, (b) 5.2GHz

4. ANTENNA MANUFACTURE AND MEASUREMENT

The prototype of Multiband Planar Monopole Antenna has been fabricated on a FR4 substrate and the complete is shown in Fig. 6, where, the substrate has 35 mm×68 mm in dimension, 1.6 mm in thickness, 4.4 in dielectric constant and 0.02 in loss tangent. The measurements of reflection coefficient, radiation pattern and radiation gain of the complete monopole antenna are given in the following subsections.

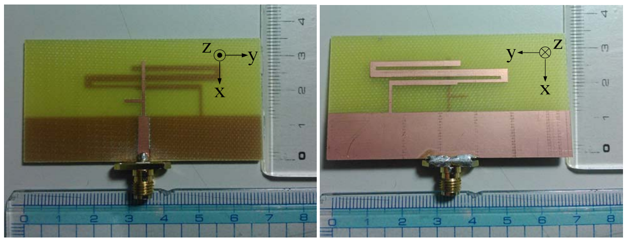


Fig. 6. The fabricated prototype antenna shown in two opposite sides, (a) front view, (b) back view

4.1 Antenna S_{11} and Measurement and Comparison

The measured antenna reflection coefficient S_{11}, and the corresponding operating frequency bands with respective to various mobile wireless access standards are shown in Fig. 7. It is noted that there exists an acceptable agreement between simulation and measurement results at the antenna S_{11} performance. Furthermore, the measured antenna radiation gains with respect to various operating frequencies are summarized in Table 2. The results are compatible to the various mobile wireless access standard requirements.

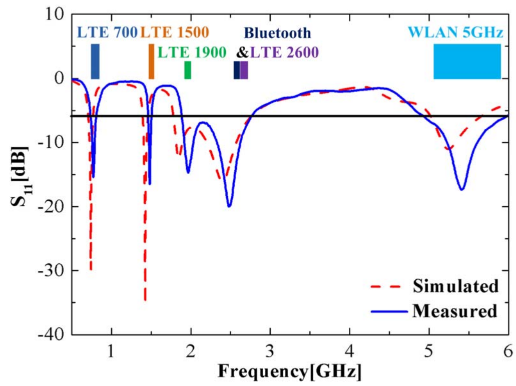


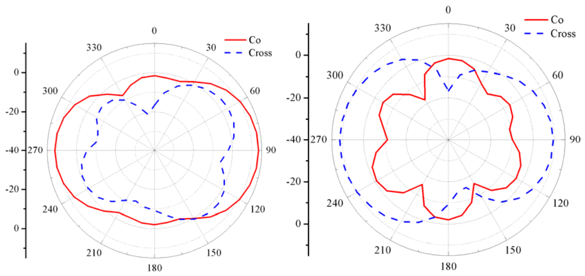
Fig. 7. The measured and simulated antenna S_{11} and the corresponding wireless access standards

Table 2. The measured antenna radiation gain

Frequency	Peak Gain
0.7GHz	1.873dBi
1.5GHz	1.746dBi
1.9GHz	2.914dBi
2.4GHz	1.014dBi
5.2GHz	2.592dBi

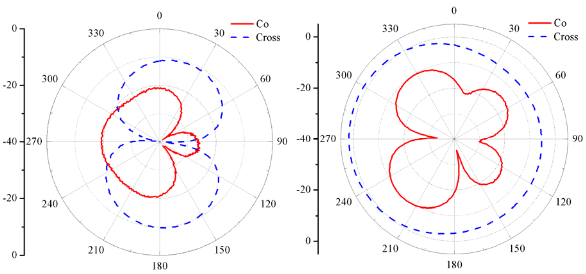
4.2. Radiation Pattern Measurement

The measured antenna radiation patterns with respective to each of the frequency bands of 0.7GHz, 1.5GHz, 1.9GHz, 2.4GHz and 5.2GHz are given in Fig. 8, 9, 10, 11 and 12 respectively; where both y-z and x-z planes are included. By observing from the antenna pattern measurement results, it indicated that the radiation patterns in y-z plane exhibit the characteristic of nearly omni-directional in most of the frequency bands and, that are compatible to the requirement of the mobile wireless radio access applications. However, it should be noted that the radiation pattern at frequency band of 1.5GHz exhibits undesirable notch at rightward direction. By analyzing the corresponding current distribution, it found that the consequence has been resulted from the blockage caused by the tree-type monopole. As a result, it is believed that the defect of the radiation pattern at 1.5GHz can be improved by further adjusting the structure of the tree-type radiator.



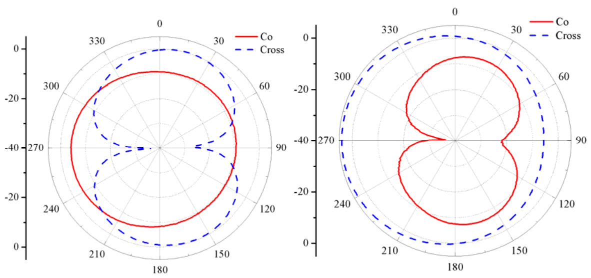
(a) (b)

Fig. 8. The measured radiation pattern at 0.7GHz (a) y-z plane and (b) x-z plane



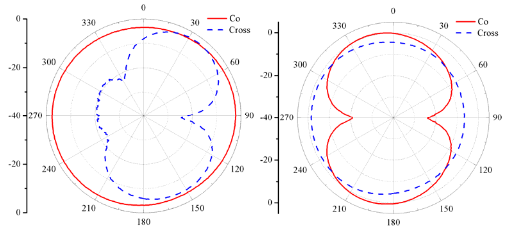
(a) (b)

Fig. 9. The measured radiation pattern at 1.5GHz (a) y-z plane and (b) x-z plane



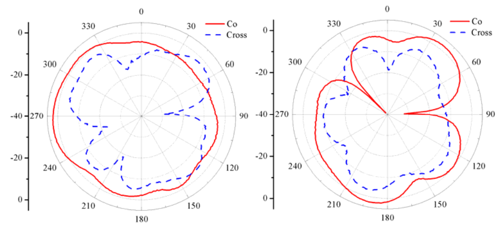
(a) (b)

Fig. 10. The simulated radiation pattern at 1.9GHz (a) y-z plane and (b) x-z plane



(a) (b)

Fig. 11. The measured radiation pattern at 2.4GHz (a) y-z plane and (b) x-z plane



(a) (b)

Fig. 12. The measured radiation pattern at 5.2GHz (a) yz plane and (b) xz plane

5. CONCLUSION

A compact proximity-coupling Multiband Planar Antenna has been successfully constructed for modern integrated mobile broadband wireless access applications. Several astute design approaches have been exploited and applied, where, the creative shaping technique that enables us to produce multiple resonant frequencies in single line can be valuable. The prospective study that follows after this creation is to implement an isolation mechanism between the multiband meander-line monopole to form a Multiple-In-Multiple-Out (MIMO) antenna for the upcoming radio access system applications.

6. REFERENCES

[1] E. Ebrahimi, J. R. Kelly, and P. Hall, "Integrated wide-narrowband antenna for multi-standard radio," *IEEE Trans. Antennas Propag.*, vol. 59, no. 7, pp. 2628–2635, Jul. 2011.

[2] Elamin, N. I. M., Rahman, T. A. and Abdulrahman, A. Y., "New Adjustable Slot Meander Patch Antenna for 4G Handheld Devices," *Antennas and Wireless Propagation Letters, IEEE*, vol. 12, pp. 1077–1080, 2013.

[3] Li, W. Y., Wu, C. Y., Wong, K. L. and Tu, M. F., "Internal small-size PIFA for LTE/GSM/UMTS operation in the mobile phone," *Antennas and Propagation Society International Symposium (APSURSI), 2010 IEEE,* pp. 1-4, 2010.

[4] Redzwan, F. N. M., Ali, M. T., Md Tan, M. N. and Miswadi, N. F., "Dual-band Planar Inverted F Antenna with parasitic element for LTE and WiMAX mobile communication,"*Technology Management and Emerging Technologies (ISTMET), 2014 International Symposium on,* pp. 62-67, 2014.

[5] D. M. Pozar and B. Kaufman, "Increasing the Bandwidth of a Microstrip Antenna by Proximity Coupling," *Electronic Letters*, vol. 23, pp. 368–369, Apr. 1987.