A Compact Proximity-Coupling Multiband Planar Antenna

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Abstract

This paper presents a compact planar monopole antenna that covers the operating frequency bands of GSM (880-960MHz), DCS (1710-1880MHz), WiMAX (3.2-3.6GHz), WLAN and Bluetooth (2.4GHz), and WLAN (5.1-5.35GHz). The proposed antenna is incorporated with two distinct monopoles, a tree-type and a shaped meander-line type monopole, situated on the opposite side of the substrate; the shaped meander-line type monopole is tuned to create the triple lower frequency bands, on the other hand, the tree-type monopole is built not only to produce the two higher frequency bands, but also to act as a proximity coupling feed for the meander-line resonator. The noticeable originalities exhibited in this proposed antenna include the handiwork of shaped multiband meander-line monopole and the use of broadband proximity coupling mechanism. Both of them enable us to simply the tuning process of the broadband matched network and to reduce the antenna size as well. The proposed antenna accompanied with several attractive characteristics makes itself particularly suitable to the modern integrated mobile wireless access applications.

***Index Terms* —Multiband Antenna, GSM, WLAN, Proximity Coupling, Cognitive Radio**

1. INTRODUCTION

Recently, the prevalence of mobile wireless radio access applications demands the need to integrate the popular mobile wireless radio standards such as GSM, Wireless LANs, and others into a portable or a hand-held unit. Hence, the emerging trend in radio communication asks for the design of a compact multiband antenna that can cover the frequency bands of multiple wireless access standards ranging from GSM-900MHz up to WLAN-5.2GHz. The design of multiband antenna has long been the subject of interest in the advanced studies. One of the topologies to construct a compact multiband antenna has been the use of multi-branch structure[1-4], where, each branch is tuned corresponding to the resonant length of each desired frequency band, conceivably an impedance broadband or multiband antenna can be attained; such as in [4], it uses a pentagon shape UWB antenna together with a parasitic meander-line and an edge coupling mechanism to produce the frequency bands of UWB, WiFi and Bluetooth-2.4, DCS-1800 and GSM-900. Another recognizable design approach is applying a parasitic element either to improve the antenna bandwidth or to excite additional frequency bands [4-7]; such as in [7], utilizing a rhomboidal shape UWB antenna and an inverted-L parasitic monopole offer a dual band of UWB and Bluetooth standards. However, as the number of frequency band increased, the feeding network becomes more complicated to tune well or even fail to match, for instant in [4], it uses a very sophisticated feeding network that combines the mechanisms of open slot, beveling ground plane and tapering CPW transmission line together to achieve the multiple broadband impedance match.

In this paper, a multiband planar monopole antenna is presented. The originality of the proposed antenna is that it is constructed judiciously by utilizing a shaping technique and a proximity coupling mechanism to effectively alleviate the degree of complexity in the design of broadband feeding network and to reduce the antenna size as well [8]. The structure of the antenna contains a two-branch tree-type planar monopole and a non-uniform strip width meander-line type monopole. Each of them is built at the opposite side of the substrate individually. The former monopole is primarily designed to the frequency bands of WLAN-5GHz and WiMAX-3GHz, moreover, it also acts as a proximity-coupling feed of the latter monopole. On the other hand, the meander-line type monopole is shaped with a non-uniform line width in order to produce the triple lower frequency bands of Bluetooth-2.4, DCS-1800 and GSM-900 while maintains the antenna in an acceptable size. The antenna prototype was fabricated on the FR4 substrate with a size of 24mmx28mm, and it shows that the antenna height is about one-twentieth of the wavelength of the lowest frequency band. As demonstrated in the 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 over all the frequency bands, lends itself particularly suitable to the modern integrated mobile wireless access applications. The antenna structure, the design topologies, the preliminary simulations, the fabricated prototype and the measurement result are given in the following sections respectively.

2. ANTENNA STRUCTURE DESCRIPTION

Figure 1 gives the geometrical structure and the 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 structure of the shaped multiband meander-line type monopole. Each of them is individually built at the opposite side of the substrate. The tree-type radiator is matched to produce the frequency bands of WiMAX-3.5GHz and WLAN-5.2GHz while the meander-line type monopole shaped with non-uniform strip width is structured as a broadband resonator to generate the frequency bands of GSM-900MHz, DCS-1.8GHz, and Bluetooth-2.4GHz respectively. The tree-type monopole also arranged to play the role of the proximity coupling feed for the shaped meander-line type monopole. The coupling gap between two monopoles is 1.66mm which is the thickness of the FR4 substrate.

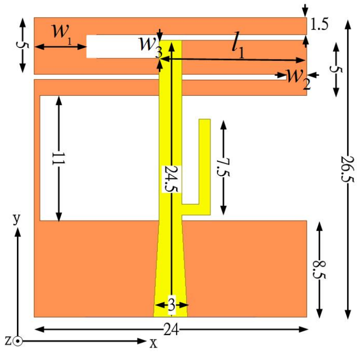


Figure. 1. Antenna geometrical structure and physical dimensions (unit: mm)

3. ANTENNA DESIGN AND SIMULATION

The original design topologies of the proposed planar multiband antenna are described in this section. The preliminary performances with respect to each of the individual monopole prototype have been evaluated by using the Ansoft-HFSS electromagnetic simulation software.

3.1 The planar two-branch tree-type monopole

It has been recognized that the height of a planar monopole antenna built for the frequency bands beyond 3GHz can be acceptable to install on a portable hand-held terminal. As a result, as given in Figure 1, a two-branch tree-type monopole is built for the frequency bands of 3.5GHz and 5.2GHz, and the branch lengths, measured at 16mm and 11mm individually, are approximately equivalent to the effective quarter resonant wavelength of the specified frequency bands respectively on the FR4 substrate, where a typical microstrip feed line is trimmed to match the impedance of the tree-type dual band monopole. The S_{11} of the two-branch tree-type monopole has been simulated and is shown in Figure 2. As shown in the simulation result the dual frequency bands of 3.5GHz and 5.2GHz have been produced based on the -10dB return loss measurement.

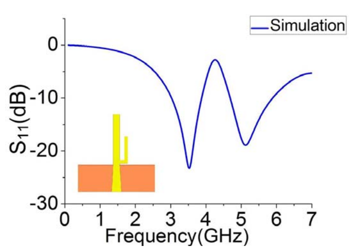
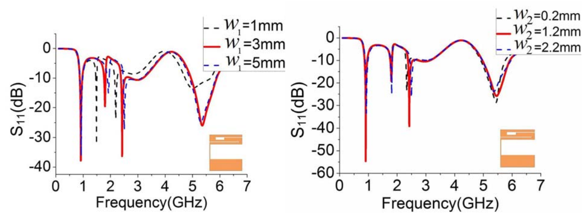


Figure. 2. The simulated S_{11} of the tree-type monopole

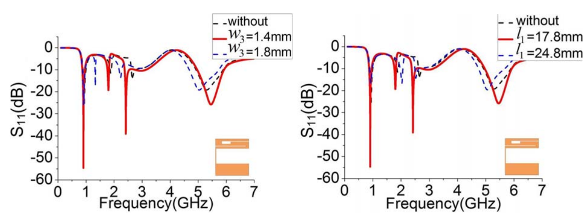
3.2 The shaped multiband meander-line monopole

The meander-line is a well known structure that can be used to shorten the upright height of a resonant monopole antenna. In general, not the upright height but the total length of the line determines the resonant frequency. Accordingly, in order to reduce the size of the planar antenna, a multi-winding meander-line monopole with 18mm in its upright height and 80mm in its total winding line length is constructed, where the total line length is given approximately to be the effective quarter resonant wavelength of 900MHz on the FR4 substrate. Furthermore, as shown in Figure 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 1.8GHz and 2.4GHz, and the creative shaping technique makes it possible to produce multiple discontinuities along the meander line, and consequently to produce multiple frequency bands in single line. There four effective shaping parameters, including the strip widths w_1, w_2, w_3 and the strip length l_1, have been created after a tedious optimization process. The tuning results with respect to the four parameters are simulated and shown in Figure 3 to 4, and the ultimate strip widths and length are given by 3mm, 1.2mm, 1.4mm and 17.8mm respectively. It should be noted that the tree-type monopole in opposite side has been judiciously used as an excitation feed to the meander-line monopole and the proximity coupling mechanism does alleviate the degree of complexity in the broadband matching network design.



(a) (b)

Figure. 3. The simulated S_{11} of meander-line monopole with parameters (a) w_1 and (b) w_2

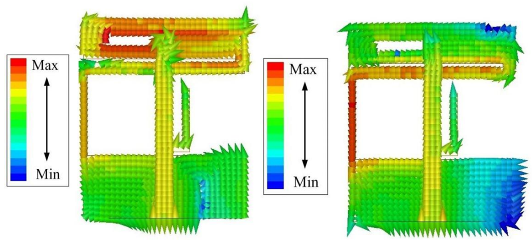


(a) (b)

Figure. 4. The simulated S_{11} of meander-line monopole with parameters (a) w_3 and (b) l_1

3.3 Surface current distribution

It is meaningful to further investigate the efficiency of the proximity coupling mechanism by examining the surface current induced on the shaped meander-line monopole. The simulated surface current distributions with respective to 900MHz, 1.8 GHz and 2.4 GHz bands respectively are given in Figure 5, 6, and the surface current distributions of the tree-type monopole at 3.5Ghz and 5.2GHz bands are also given in Figure 7 for reference. As shown in Figure 5, and 6, a noticeable surface current has been induced at the shaped meander-line monopole via the proximity coupling mechanism. However, the current distributions along the meander-line are different among the three frequency bands. It is worthwhile to be noted that the current distribution along the meander-line can also give the intelligence to estimate the radiation efficiency of the monopole antenna. Experimentally, by comparing the current distributions in Figure 5(a), 5(b) and 6, it can be accessed that the meander-line type monopole gives better radiation efficiency at 900MHz band than other two bands. This is because the crest of the surface current standing wave is located at the upright portion of the meander-line at 900MHz band. On the other hand, the peaks of the surface waves in other two bands are occurred at the folded portion of the line where the currents are in a reversal direction in upper and lower strips that cause a mutual cancellation effect in radiation.



(a) (b)

Figure. 5. The simulated surface current distribution at (a) 900MHz, (b) 1.8GHz

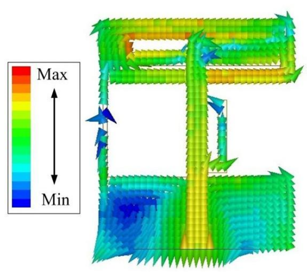
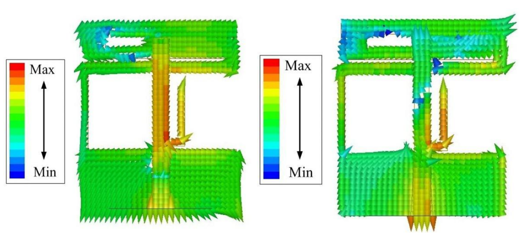


Figure. 6. The simulated surface current distribution at 2.4GHz

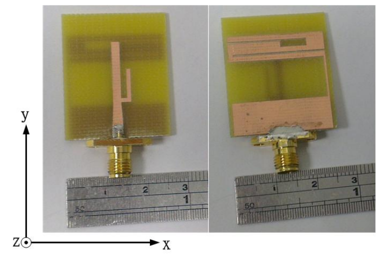


(a) (b)

Figure. 7. The simulated surface current distribution at (a) 3.5GHz, (b) 5.2GHz

4. ANTENNA MANUFACTURE AND MEASUREMENT

The prototype of the proposed Multiband Planar Antenna was fabricated on a FR4 substrate and is shown in Figure 8, where, the substrate has 24mm×28mm in dimension, 1.6 mm in thickness, 4.4 in dielectric constant and 0.02 in loss tangent. The measured antenna S_{11}, the accomplished operating bandwidth with respective to various mobile wireless access standards, and the radiation patterns with respective to each of the frequency bands are given in Figure 9, Table 1 and Figure 10 to 12 respectively.



(a) (b)

Figure. 8. The fabricated prototype antenna shown in two opposite sides

4.1 Antenna S_{11} Measurement and Comparison

The measured antenna S_{11} and the frequency bands corresponding to each of the distinct wireless communication standards is given in Figure 9, It is noted that there exists a noticeable difference between simulation and measurement result at the band of 3.5GH. The difference is believed to be caused by the proximity coupling structure. This is because the 3.5GHz monopole in tree-type structure is treated as a feed of the meander line monopole in simulation; however, it can be a radiator in reality. The quantified operating bandwidths that work for the corresponding distinct wireless communication standards are summarized at Table 1, where, the bandwidth is calculated based on the -10dB S_{11} measurement result.

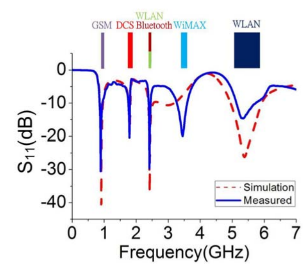


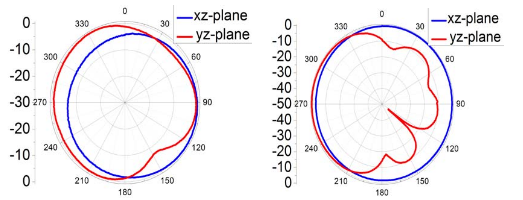
Figure. 9. The antenna S_{11} (measurement and simulation)

Table1. Operating bandwidth of prototype antenna

standards	bandwidth
GSM	858-940MHZ
DCS	1760-1820MHz
WLAN(2.4)	2.4-2.48GHz
Bluetooth	2.4-2.48GHz
WiMAX	3.28-3.6GHz
WLAN(5.2)	5.11-5.72GHz

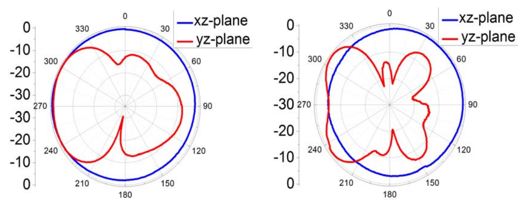
4.2. Radiation Pattern Measurement

The measured antenna radiation patterns with respect to the frequency bands of 900MHz, 1.8GHz, 2.4GHz, 3,5GHz and 5.2GHz are shown in Figure 10 to 12 respectively; where both X-Z and Y-Z planes are included. It is observed that the radiation patterns in X-Z plane exhibit the characteristic of nearly omnidirectional in all frequency bands and, thus it is compatible to the requirement of the mobile wireless radio access applications.



(a) (b)

Figure 10. The radiation pattern at (a) 900MHz and (b)1800Mhz



(a) (b)

Figure 11. The radiation pattern at (a) 2.4GHz and (b)3.5GHz

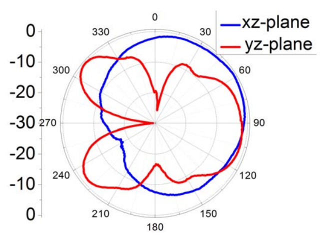


Figure 12. The radiation pattern at 5.2GHz

5. CONCLUSION

A compact proximity-coupling Multiband Planar Antenna has been successfully constructed for the 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.

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