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Research Article

Multiband Printed Asymmetric Dipole Antenna for LTE/WLAN Applications

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The ability of a single layer strip fed printed asymmetric dipole antenna, which is composed of top-loading, asymmetric coplanar waveguide (ACPW) and stepped-feeding structure, to operate at three wide frequency bands (698~960 MHz, 1710~2620 MHz, and 5150~5850 MHz) to cover WLAN and LTE operation has been demonstrated. A prototype of the proposed antenna with 57.5 mm in length, 0.4 mm in thickness, and 5 mm in width is fabricated and experimentally investigated. The experimental results indicate that the VSWR 2.5 : 1 bandwidths achieved were 74.3%, 40.8%, and 18.2% at 700 MHz, 2450 MHz, and 5500 MHz, respectively. Experimental results are shown to verify the validity of theoretical work.

1. Introduction

Recently, the antennas desired features include multiband, broad bandwidth, simple impedance matching to the feed line, and low profile, to be used in various wireless communication applications, such as the IEEE 802.11 wireless local area network (WLAN) standards, and the pre-4G technologies such as long term evolution (LTE) standards. A variety of printed monopole antennas for covering multibands have been reported in the published articles [1–5], those types of printed monopole antenna designs occupy a relatively larger space and they are difficult to meet the size-limitation of the external antenna. In industrial applications involving external antennas with tapered streamline radome covers, the space limitations are an important issue. In this paper, we present a single layer multiband printed asymmetric dipole antenna for LTE/WLAN external antenna applications. The arm-lengths of dipole are designed to response two different resonant frequencies, respectively. It is beneficial to enhance antenna performance by letting the length of the ground-arm of dipole antenna be larger than the signal-arm [6]. In other words, the signal-arm of dipole antenna is designed for upper-operating band, and the ground-arm is designed for lower-operating band. The proposed antenna is consisted of top loading, asymmetric coplanar waveguide (ACPW) and stepped-feeding structure, which was developed by modifying the structure of printed sleeve monopole antenna [7]. The feasibility of wide bandwidth operation has been proven by the design of ACPW feeding structure and ground-trace structure that operates in the WLAN and LTE bands. Details of the design considerations of the proposed antenna and the experimental results of constructed prototypes are presented and discussed.

2. Antenna Structure and Design

As for the specification requirement of wireless products, the multiband antenna is required to enable operations at the two WLAN and the LTE bands, whose bandwidths and list of the corresponding bands are detailed in Table 1. The operating frequency rangeis divided into three bands: 700 MHz

Table 1: Considered WLAN and LTE bands.

Allocated bands	Frequency range (MHz)
LTE	
FDD	
#5, #6, #8, #12, #13, #14, #17, #18, #19, #20	698–960
#1, #2, #3, #4, #9, #10	1900–2620
TDD	
#33, #34, #35, #36, #37, #38, #39, #40, #41	1850–2690
WLAN	
2.4 GHz	2400–2500
5 GHz	5150–5850

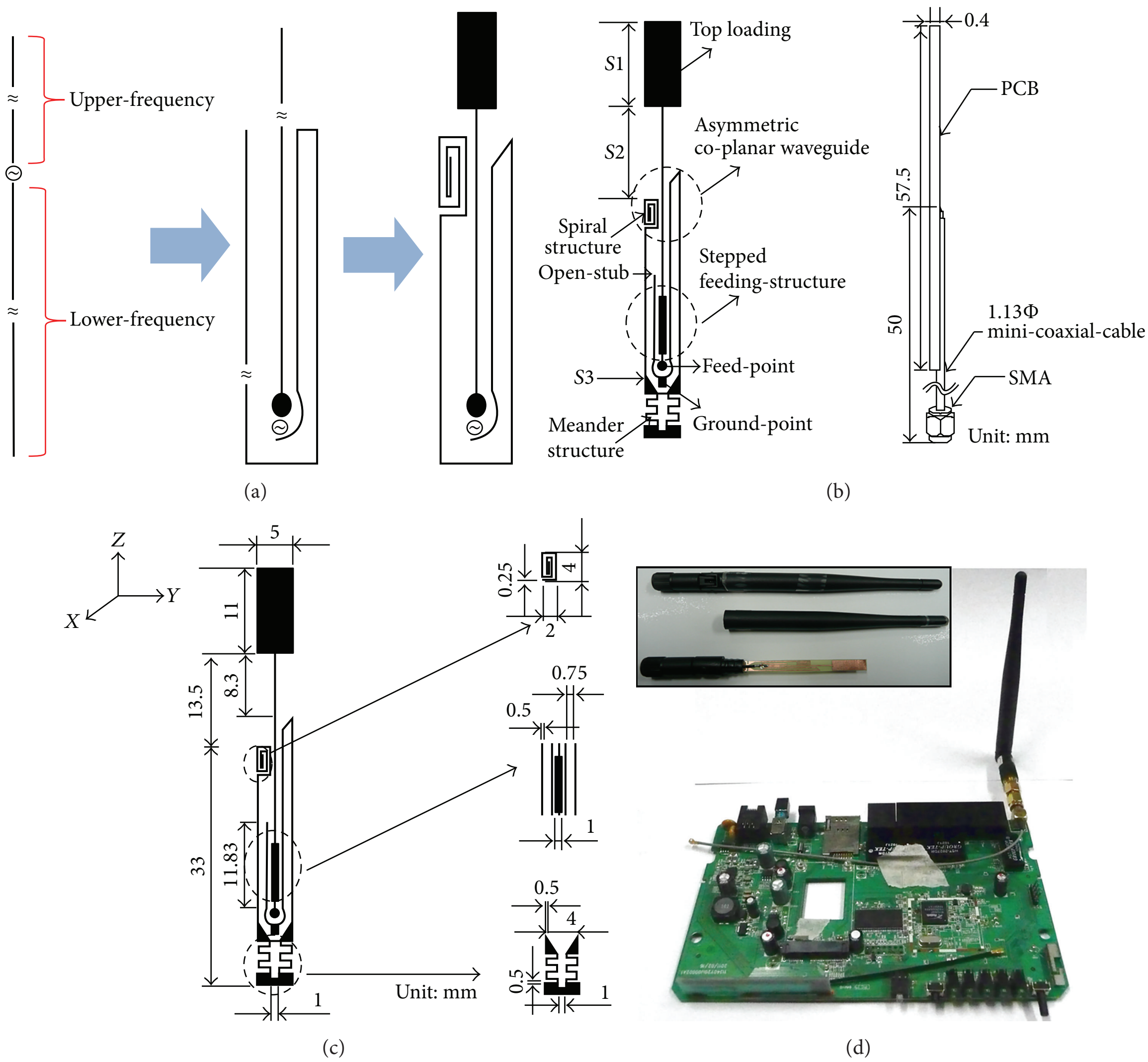

Figure 1: (a) The original geometry structure of the proposed antenna. (b) Profile and side view of the proposed antenna. (c) Configuration and dimensions of the proposed antenna. (d) The tapered streamline radome cover of antenna.

band (698 MHz–960 MHz), 2450 MHz band (1710 MHz–2620 MHz), and 5500 MHz band (5150 MHz–5850 MHz); in which the 700 MHz band was denoted as lower-operating band, and 2450 MHz and 550 MHz bands were denoted as upper-operating band.

Accordingly, a good impedance matching in those operating ranges is needed. Such a requirement has been conveniently expressed in terms of VSWR by imposing a suitable threshold on the magnitude values of the VSWR ≤2.5. Figure 1(a) shows the original geometry asymmetric dipole

Table 2: Measured results of the antenna bandwidth as a function of varying antenna structure.

Antenna structure	Lower band Bandwidth, $f_L \sim f_U$ (MHz)	Upper band (I) Bandwidth, $f_L \sim f_U$ (MHz)	Upper band (II) Bandwidth, $f_L \sim f_U$ (MHz)
Case I	300, 950~1250	650, 2000~2650	400, 5100~5500
Case II	250, 880~1130	1000, 2000~3000	600, 4900~5500
Case III	300, 700~1000	600, 2000~2600	800, 4500~5300
Proposed antenna	520, 680~1200	1000, 1700~2700	1000, 4700~5700

Table 3: The measured antenna gains and efficiencies within the operating bandwidth of the proposed antenna.

Frequency	Gain (dBi) *xy*-plane Max. gain	Gain (dBi) *yz*-plane Max. gain	Gain (dBi) *zx*-plane Max. gain	Efficiency (%)
700 MHz	0.08	1.62	1.77	58.57
960 MHz	0.81	1.41	1.81	63.47
1710 MHz	0.65	0.57	0.8	54.91
2170 MHz	0.44	0.83	0.71	55.6
2450 MHz	0.98	1.09	1.17	62.3
2700 MHz	1.18	1.44	1.21	60.7
5150 MHz	1.01	1.22	1.31	62.1
5500 MHz	0.54	0.88	1.15	56.8
5850 MHz	0.35	0.48	0.77	51.6

"Max.: maximum."

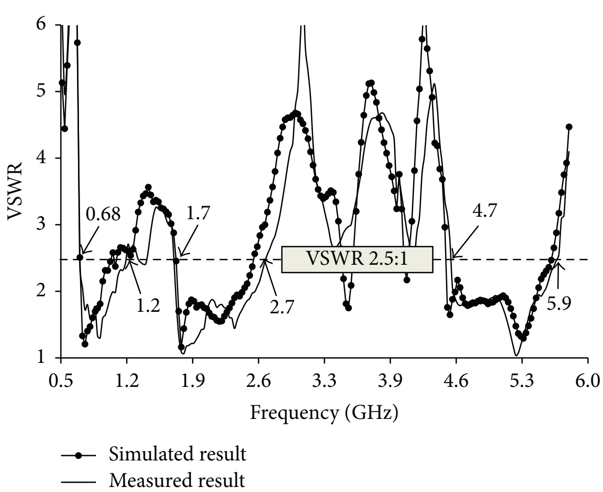

Figure 2: Measured and Simulated VSWR against frequency.

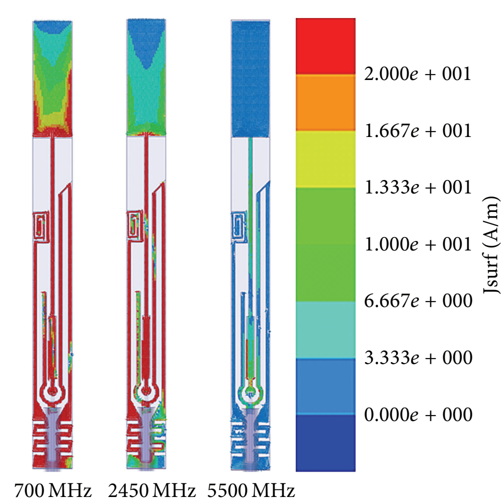

Figure 3: The simulated current distribution of the proposed antenna at 700 MHz, 2450 MHz, and 5500 MHz.

antenna for multiband applications. The lengths of signal arm and ground-arm are related to the upper- and lower-frequency, respectively. The presented antenna structure is composed of an upper-element section of length $S1$, and the lower-element section of length $S2$, and the ground-trace section of electrical length $S3$. These sections are all printed on a 1.6 mm-thick FR4 glass epoxy substrate (the relative permittivity is 4.3, and the loss tangent is 0.022) at the same layer and the profile and side view of the proposed antenna are shown in Figure 1(b). The resonant mode of total shape ($S1+S2$) is designed to occur at 2450 MHz, the lower-element ($S2$) is designed to resonate at 5500 MHz, and the ground-trace ($S3$) is designed to resonate at 700 MHz. The length of radiating elements can be determined from about quarter-wave length at the resonant frequencies. Note that the widths of these sections are not identical. By selecting appropriate dimensions ($S1, S2, S3$) of the antenna structure, good impedance matching of the printed asymmetric dipole can be obtained across an extended bandwidth. The corresponding characteristics of resonant frequency, input impedance and bandwidth are a function of the geometrical parameters of

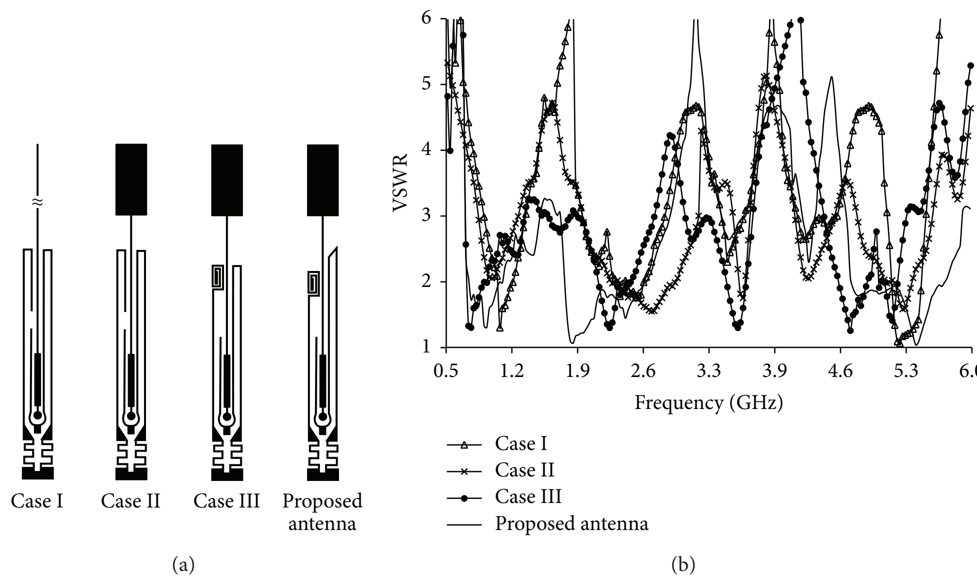

Figure 4: (a) The configuration of varying antenna structure. (b) Measured VSWR against frequency of the corresponding antenna structure.

the top-loading and ACPW structure, the configuration and dimensions of the proposed antenna are shown in Figure 1(c).

When the dimension of the top-loading is varied, the impedance bandwidth and resonant frequency will change in the 2450 MHz band. An ACPW feeding structure excites the end of $S2$-segment as shown in Figure 1(b). The impedance matching at 2450 MHz and 5500 MHz bands can be tuned by this structure, which was found to be effective in obtaining a wider impedance bandwidth in the antenna's upper-operating band. In addition, it should be noted that the ground-trace length ($S3$) and configuration could also affect the resonant frequency and operating bandwidth of 700 MHz band; when the printed ground-trace was curled a meander-structure and spiral-structure, the operating bandwidth will increase. The bended ground-trace is designed for the lower-operating band, which is also act as a sleeve balun for the upper-operating band, a complete radiation pattern-shape can be obtained. The bandwidth enhancement results are demonstrated in the following section. Furthermore, the impedance matching at 700 MHz, 2450 MHz, and 5500 MHz bands can be tuned by the stepped-feeding of signal-trace and the open-stub of the ground-trace, which was found to be effective in securing triple band. The access point (AP) is the intended platform of antenna integration. The proposed antenna's size is based on the size of tapered streamline radome cover, as shown in Figure 1(d).

3. Experimental Results and Discussion

In the experiment, the feeding-point and ground-point are connected to a 1.13Ø 3 cm mini-coaxial cable with 50 Ω SMA connector. By utilizing the above-mentioned design procedure, a wide band antenna was constructed to operate at the ranges of WLAN and LTE system (698~960 MHz, 1710~2690 MHz and 5150~5850 MHz). Figure 2 shows the simulated (by Ansoft HFSS) and measured VSWR plot of the wideband antenna as a result of this geometry. The measured VSWR ≤2.5 bandwidths are 74.3% at 700 MHz, 40.8% at 2450 MHz and 18.2% at 5500 MHz. There is good agreement between the measured and simulated results. Figure 3 presents the simulated current distribution of the proposed antenna at 700 MHz, 2450 MHz, and 5500 MHz which are corresponding to the resonant lengths of the $S3$, $S1 + S2$ and $S2$, respectively; simulation results are shown to verify the validity of theoretical work.

The effect of varying the top-loading, feeding structure and the ground-trace structure on the antenna performance has been studied. The configuration of varied antenna structure is shown in Figure 4(a), and the measured VSWR plot of the corresponding structure is shown in Figure 4(b). From Figure 4(b), it is obviously that the tuning of the 2450 MHz band was acquired by adjusting the size of top-loading to produce the required frequency response characteristic. The top-loading width increase will lead to an increase of impedance bandwidth and a decrease resonant frequency in the 2450 MHz band, as shown in Figure 4(b). In addition, to let the co-planar waveguide feeding structure to be an asymmetric structure, it was observed that the resonant frequency and impedance bandwidth will increase in 2450 MHz and 5500 MHz bands and nevertheless, the effect in 700 MHz band is very small. Furthermore, when the printed ground-trace was curled a meander-structure and spiral-structure, the operating bandwidth will increase. The ground-trace length ($S3$) and configuration could also affect the resonant frequency and operating bandwidth of the 700 MHz band. The quantitative comparisons of the effects of varying antenna structure on the antenna's resonant frequency and impedance bandwidth were studied experimentally, as shown in Table 2 (the configuration of

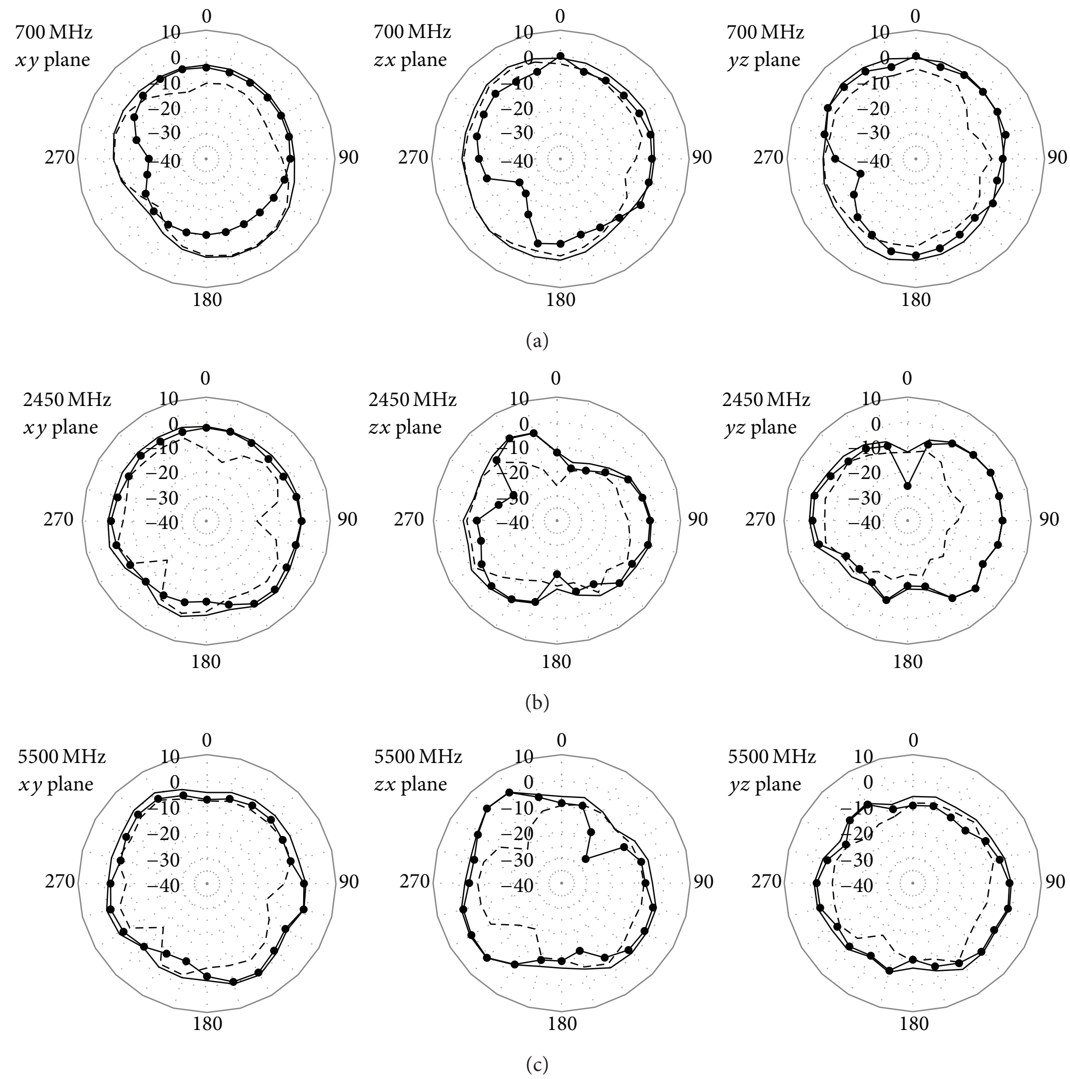

Figure 5: Measured radiation patterns for the proposed antenna. "— Total", "•—• co-pol.", "- - - cross-pol." (a) 700 MHz. (b) 2450 MHz. (c) 5500 MHz.

varying antenna structure with 57.5 mm in length, 0.4 mm in thickness, and 5 mm in width, VSWR ≤ 2.5). The impedance matching was also achieved by optimizing the stepped-feeding trace and open-stub. The measured radiation patterns for free space at 700 MHz, 2450 MHz, and 5500 MHz in the xy-plane, yz-plane, and zx-plane are shown in Figure 5, respectively. Table 3 shows the measured antenna gains and 3D pattern efficiency within the operating bands of the proposed antenna. Stable radiation patterns are observed. The total 3D pattern efficiency is defined as (gain/directivity) × 100%, which was done by using pattern integration employing the ETS-Lindgren anechoic chamber. Acceptable radiation characteristic for the practical applications is obtained for the proposed antenna. The omnidirectional feature of the proposed antenna can also be observed from the xy-plane, where the gain variation between maximum and minimum levels is less than 3 dB. The overall signal trace length is about one wavelength long and there are normally four lobes at the 5500 MHz band, but, due to the ground trace is also acts as a sleeve balun, a close to complete radiation shape (there are a few variations in the radiation pattern-shapes) was obtained.

4. Conclusion

In this paper, a dual-band wideband printed asymmetric dipole antenna suitable for WLAN and LTE applications has been proposed. The antenna is characterized by reduced dimensions and suitable impedance matching over the presented operating band. The performances of the synthesized antenna have been numerically and experimentally verified. The proposed antenna can be easily fabricated and modified to various AP and router as a compact external antenna.

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