A Miniature Wideband Internal Antenna with Dual Resonant Structures

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***Abstract*-This paper suggests a miniature wideband internal antenna with dual resonant structures for operating at multi-band handset applications. It consists of two radiation monopole elements with parallel connection in the limited handset interior space. The proposed antenna can be easily placed in practical handsets because of the small size of 20 × 17 × 3.5 mm^3. The measured bandwidth of the proposed antenna shows about 1 GHz from 1.71 GHz (DCS band) to 2.71 GHz (Bluetooth band) with VSWR below 2. It also resonates at GPS band of 1.57542 GHz. The electrical and structural characteristics of the proposed antenna make it attractive for use in mobile handset applications.**

I. Introduction

Recently, the development of innovated handset applications with an internal antenna has been entered the spotlight. These internal antennas must be minimized enough to be easily placed in practical mobile handsets while retaining the good performances with respect to impedance bandwidth, radiation patterns, and gains [1]. Moreover, the antennas need to cover multi-bands to accommodate the multi-standard services, due to the difference of available communication bands depending on each area or country.

This paper suggests dual monopole structure by attaching another radiation element of the internal antenna to improve the impedance bandwidth for mobile applications. It uses two branches of additional current paths, and resonates at more frequencies. This results into enhancing the impedance bandwidth. The impedance bandwidth can be further widened by applying the trapezoidal feeding shape and tilting it [2]. As a result, the dual radiation elements achieved a wide bandwidth of about 1 GHz (1.71 GHz ~ 2.71 GHz, VSWR < 2, 45.2%). The proposed antenna is able to cover GPS (1.57542 GHz), DCS (1.71 ~ 1.88 GHz), KPCS (1.75 ~ 1.87 GHz), UPCS (1.85 ~ 1.99 GHz), IMT-2000 (1.885 ~ 2.2 GHz), UMTS (1.92 ~ 2.17 GHz), and Bluetooth (2.4 ~ 2.4835 GHz) bands.

II. The Proposed Antenna Design

Fig. 1 represents the proposed wideband monopole antenna fed by a 50 Ω GCPW (Ground Coplanar Waveguide) line which consists of a metal strip with a width of 1 mm and gap spaces of 0.5 mm. Generally, this type of CPW feeding structure is generally utilized in practical handset applications. The dual structure antenna is installed on a FR4 (ε_r = 4.6) substrate with volume of 40 × 75 × 1 mm^3. On the back side of the printed circuit board (PCB), the ground plane is removed starting from the feeding point to the top of the substrate (17 mm), as shown in Fig. 1. Impedance matching is improved by cutting the copper ground plane [3]. The dual structure consists of two radiation elements with antenna ⓐ and antenna ⓑ, as seen in Fig. 1(a) and (d). The antenna ⓐ is a printed monopole meander line with a width of 1.5 mm, a gap space of 1 mm, and a total length of 54 mm. It is connected directly to the feed line through the trapezoidal shape line for impedance matching and improving bandwidth. As seen in Fig. 2, the antenna ⓐ itself has a narrow bandwidth. If handset system modules or electric circuits are installed on the radiation element of antenna ⓐ, the antenna performances can be deteriorated. However, a small vacant space can be utilized by an additional radiation element. To improve the bandwidth and radiation efficiency, another radiation element of antenna ⓑ is added above antenna ⓐ. The mutual coupling effect between two radiators improves the bandwidth. The antenna ⓑ is composed of two branch lines with a width of 2mm. The antenna ⓑ is connected with antenna ⓐ with a tilted angle of 28.3º through the trapezoidal shape line for impedance matching and improving bandwidth. It is placed on a supporter made of polycarbonate material. Its relative permittivity (ε_r) is 2.6 which was measured by the material measurement system of Damakos, Inc.[11]. The supporter has a height of 3.5 mm and a thickness of 1 mm. To understand the behavior of the antenna model and obtain the optimum parameters, the simulation was performed with the Ansoft High-Frequency Structure Simulator (HFSS) based on the finite element method [12]. The optimized values of each physical dimensions of the proposed antenna are shown in Fig. 1.

III. Result

Fig. 2 shows the simulated return loss of each radiation element and the combination of two elements in the proposed antenna, respectively. As seen in Fig. 2, the printed meander line monopole antenna ⓐ itself has inherently narrow bandwidth. The two branch line monopole antenna ⓑ itself has two resonant points due to the different current paths. By combining antenna ⓐ and antenna ⓑ, an enhanced mutual coupling and more resonant points can be obtained. This results into the improvement of the impedance bandwidth. Fig. 3 shows the simulated return losses of the proposed structure in

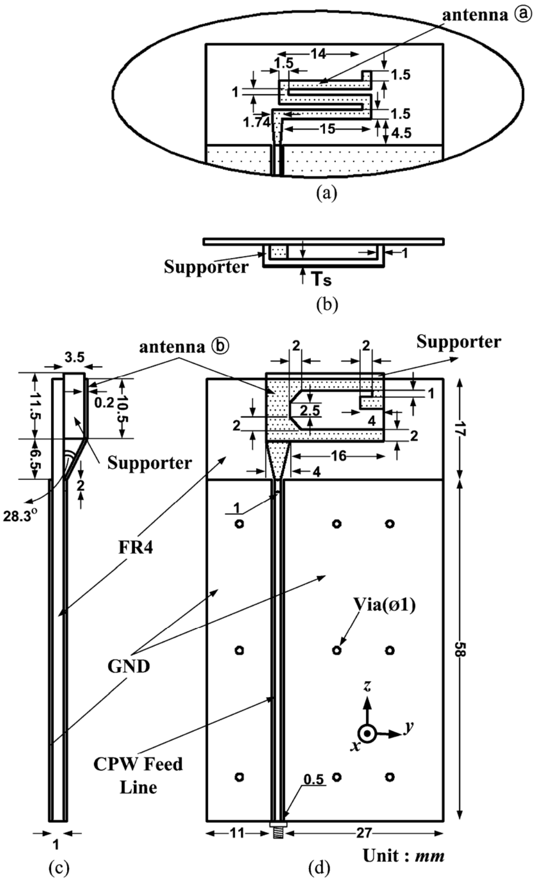

Fig. 1. Geometries and dimensions of the proposed wideband dual structure antenna.
(a) Front view before applying antenna ⓑ and supporter
(b) Top view (c) Side view (d) Front view

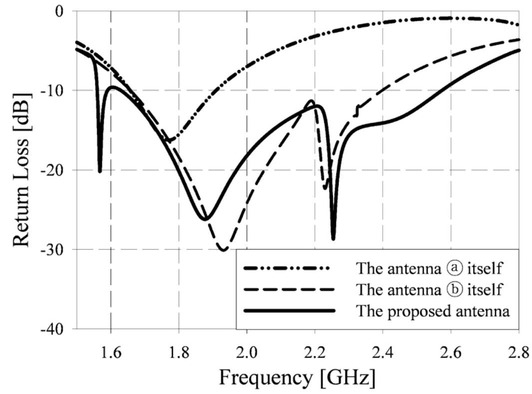

Fig. 2. Simulated return loss for each element.

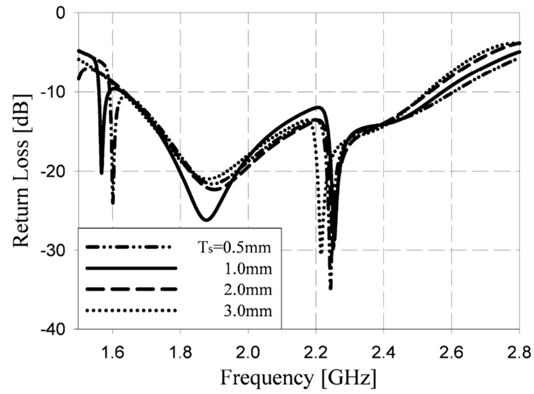

Fig. 3. Simulated return loss in terms of the different supporter's thicknesses (T_s).

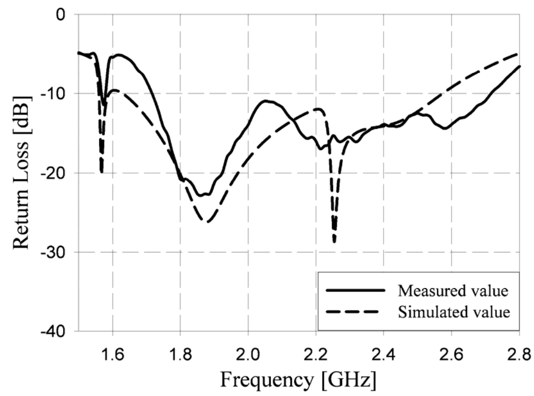

Fig. 4. Simulated and measured return losses for the proposed antenna (T_s = 1 mm)

terms of the four different thicknesses of the supporter, T_s. As shown in Fig. 3, the thickness of the supporter significantly changes the resonant frequency in the vicinity at the GPS band, while relatively retaining others higher resonant frequencies. This reason is due to the fact that the thicker the supporter, the closer it is to antenna ⓐ within the fixed height of 3.5 mm. The radiating E-field of antenna ⓐ is more restricted to the supporter compared to those of antenna ⓑ. Therefore, antenna ⓐ is expected to play a key role at the resonance of the GPS band. From the results shown in Fig. 3, the optimized thickness of the supporter, T_s is determined to be 1 mm. Fig. 4 compares the return loss values between the measured and simulated results. Although there is slightly discrepancy between the simulated and measured impedance bandwidths in Fig. 4, the measured results can cover the GPS, DCS, KPCS, UPCS, IMT-2000, UMTS, and Bluetooth bands. Fig. 5 shows the simulated current distributions. In Fig. 5(a) and (b), the current distributions of the upper and lower branch lines are stronger in the UPCS and the Bluetooth band, respectively. As the operating frequency goes up higher into 2.44 GHz, the stronger the current distributions of lower branch line at antenna ⓑ can be observed. The total lengths of the upper and lower branch line are 42 mm and 26 mm, corresponding to an approximate

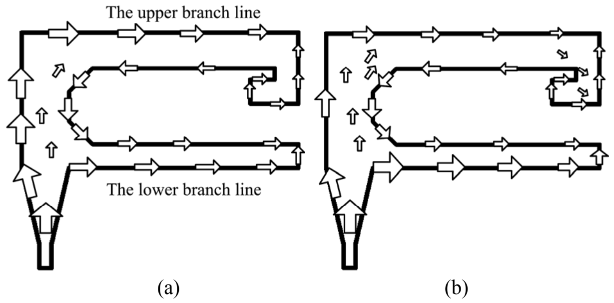

Fig. 5. Simulated current distributions on the antenna ⓑ
(a) 1.91 GHz (UPCS) (b) 2.44 GHz (Bluetooth)

quarter-wavelength at 1.91 GHz and 2.44 GHz, respectively. The measured and simulated radiation patterns of the proposed antenna at 1.91 GHz and 2.44 GHz are plotted in Fig. 6 and 7, respectively. They show that the measured and simulated results agree well with each other. The measured and simulated maximum radiation gain is about 3.13 dBi and 3.38 dBi at 2.44 GHz. This is a good agreement with each other. All the measured results are performed with an Agilent 8722ES network analyzer.

IV. Conclusion

The proposed dual monopole antenna has wideband characteristics. The measured bandwidth is about 1 GHz (1.71 GHz – 2.71 GHz, VSWR < 2) enough to cover GPS, DCS, KPCS, UPCS, IMT-2000, UMTS, and Bluetooth bands. The simulated and measured results are presented to show the validity of the proposed antenna. The total volume of the proposed antenna, $20 \times 17 \times 3.5$ mm^3, makes it suitable for mobile internal handset applications. The supporter plays a role in not only placing antenna ⓑ, but also changes a resonant frequency of GPS Band with the variation of the thickness. The measured maximum gain is 3.13 dBi at the frequency of 2.44 GHz. The proposed antenna is an attractive feature for mobile handset applications because of their antenna performances.

Acknowledgment

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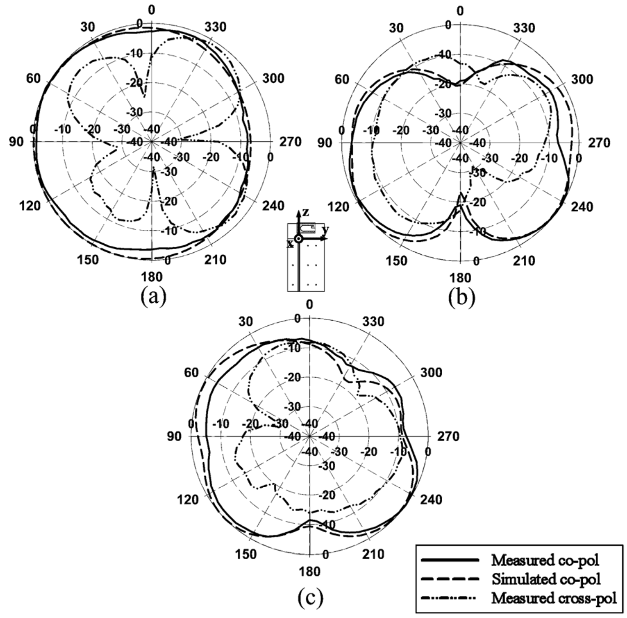

Fig. 6. Simulated and measured radiation patterns for the proposed antenna at 1.91 GHz.
(a) *x*-*y* plane (b) *x*-*z* plane (c) *y*-*z* plane

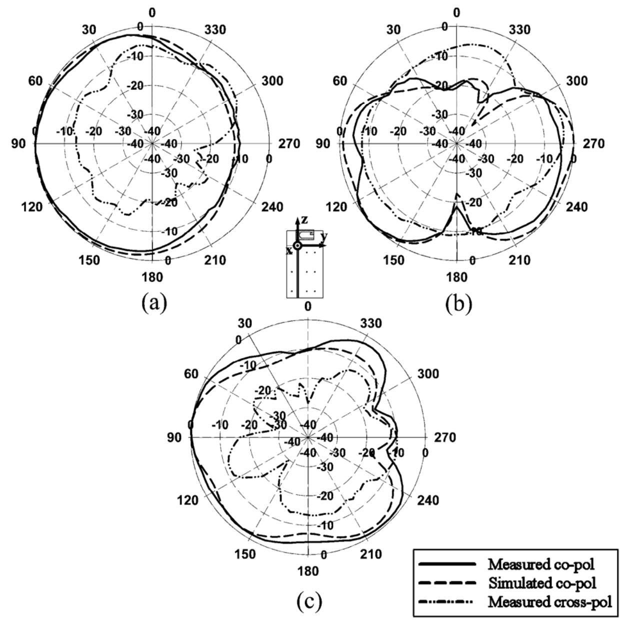

Fig. 7. Simulated and measured radiation patterns for the proposed antenna at 2.44 GHz.
(a) *x*-*y* plane (b) *x*-*z* plane (c) *y*-*z* plane