A Compact six-band PIFA design for mobile phones

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Ⅰ. Introduction

Modern portable communication systems have experienced very high growth in recent years and the trend is likely to continue. With this rapid development, a single handset must support many services including voice data, video, broadcasting, and digital multimedia contents. These service necessities for the handsets lead to a great demand to develop a small antenna with multi-bands capability in the transceiver. Now, the requirement for quad-bands, five-bands or six-bands antenna is urgent for mobile communication. In additions, low cost, compact size, easy fabrication, and wideband are also important issue for handset antenna design. The planar inverted-F antenna, which is easily embedded in a handset, is a good candidate to meet above-mentioned requirements [1-2].

Many new designs of the multiband antenna based on PIFA concept for achieving operation at traditional quad-band, i.e., GSM900, DCS1800, and PCS1900 and IMTS2000, have been reported in the open literature [3]. Furthermore, some published papers extended the multi-band function to include more bands, such as GPS1700, ISM2450 or WiMAX (2.305-2.69GHz) [4-5]. Various internal antennas which applied many size reduction techniques or bandwidth enhancement approach have been proposed recently. In this paper, a six-bands compact PIFA design that still owns compact size will be presented to cover the operating band of WiMAX (3.5GHz) and WLAN within the 5-6GHz for the applications of the IEEE802.11a and HIPERLAN.

The proposed antenna consist a main patch with two slit-cuts and two parasitic elements. The geometry size of the proposed is shrunken to meet the requirements for a practical handheld. The antenna size was realized within a volume of 40*25*8 mm^3. By varying the meandered slit-cuts, the desired operation at the hexaband frequency bands is able to be implemented. Designed parameters and simulation results will be discussed in this conference. Finally, the prototype antennas are constructed and measurement is performed to verify the simulation results.

Ⅱ. Antenna design

The planar inverted-F antenna is an antenna that can be miniaturized and capable of achieving multiband function if an electrical design is efficiently performed. Now, it has become very attractive in the handheld-phone market as the demand for small handsets with multiband functions increases. Multiband PIFA has an important feature, i.e., its size is almost the same as that of a single band PIFA [3]. Our proposed multiband PIFA is shown in Fig.1. The PIFA is comprised of a main planar radiating element in the first layer and a ground plane in the second. The main quarter-wavelength patch is fed via a metallic strip of 2mm width. The feeding strip parallel to the short strip is connected to the edge of the antenna element at one end. The other end of the feeding strip is connected to the microstrip line on the back of the ground plane.

The main radiating element consists of four parts. The center part functions as the PIFA for the GSM system. The other two side parts are the second and the third resonators for the DCS-1800 and PCS-1900 systems. By vertically folding the strip end of the main patch, capacitive load is formed in order to cover the band for UMT-2000. By introducing proper meandered cuts in the center patch, the impedance bandwidth is expected to include the desired quad-band. Since the parameters that must be tuned or designed are numerous, it can be optimally solved by the full-wave simulator, IE3D, combined with genetic algorithm. The genetic algorithm is more robust. It is able to optimize multiple design parameters simultaneously with a wide-range of initial guesses. Detailed about IE3D+GA can be referred to reference [6].

Final parts in the front side have two parasitic quarter-wavelength shorted strips that are added to create new resonance and thus enlarge the impedance bandwidth. The first parasitic shorted-element is added to the left side of the main patch to enlarge the impedance bandwidth for UMT-2000. Since the resonant frequency of the center part of the PIFA is designed at about 1GHz, its third-harmonics frequency is about 3GHz. So, the addition of the first shorted strip resonator is also used to adjust the resonant frequency to cover the frequency range for the application of the WiMAX system. On the other hand, the third-harmonics is about 6GHz since the fundamental resonant frequency for the other minor PIFAs is between 1.7GHz and 2.1GHz. In order to design this antenna for the application of the WLAN within the 5-6GHz band, the resonant frequency of the third harmonics must be lowered down to 5.5GHz. In like manner, the second parasitic element added to the front side is adjusted to increase capacitive coupling and then the resonant frequency can be decreased to meet the specifications of WLAN.

Ⅲ. Results

The configuration and geometry size of the final designed antenna is shown in Fig. 1. For WLAN/802.11a application, the center frequency of the third-harmonics band must be tuned to 5.5GHz. The length of parasitic length in the front side must be accurately designed. Parameter study must be done in advance. Shown in the Fig.2 are simulation results with different parasitic length as parameters. It is found that choosing the length $l=5.25$ mm meets the specification requirement on the 5-6GHz band.

The simulation results must be verified by laboratory measurement. To reduce the cost of manufacture, a prototype of the antenna was fabricated using a circuit board plotter (PC board maker). The measurement was performed on an Agilent-5071B network analyzer based on the open-short-load calibration technique. Fig. 3 shows the measured data compared with the simulation results for the antenna return-loss. Fig. 3(a) shows the magnitude and (b) its phase. The solid line shown in the figure Fig. 3(a) is the measured results. The dashed line shown in this figure is the simulation results after optimization. It shows that a good agreement is obtained. The occupied bandwidths meet the specification requirements for GSM-900, DCS-1800, PCS-1900, UMT-2000, WiMAX3500 and WLAN application.

The patterns of the designed PIFA were also simulated and measured for the frequencies corresponding to the six- bands. The radiation patterns were simulated by using simulator tool, IE3D**.** The simulation results and measurement results of the vertical and horizontal polarization pattern in the YZ-cut are shown in Fig. 4. The nearly omni-direction pattern on the YZ-plane was obtained for the vertical polarization field, which is a desired feature in a hand-held telephone. Figure 5 shows the power gain of this six-band antenna. The simulated and measured peak antenna gains are about 5 dBi, and the gain variations in the desired bands are about 3 dBi.

Ⅳ. Conclusions

Using parasitic elements and meandered cuts, we have presented a compact six-band PIFA. This optimal structure was designed and obtained to achieve low return loss in the GSM band, DCS/PCS/UMTS bands, WiMAX band and WLAN/802.11a band. Since the measured results show a good matching over the covered frequency bands, it makes this antenna suitable for the mobile communication applications.

Reference

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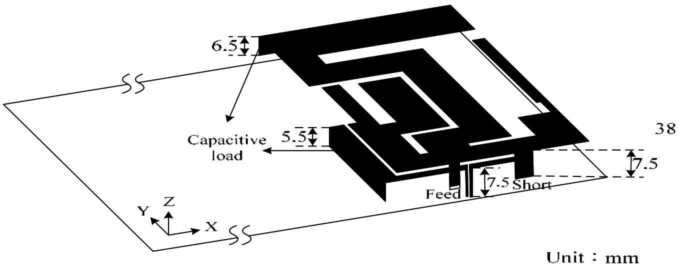
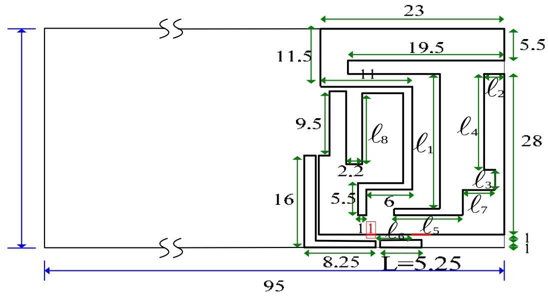
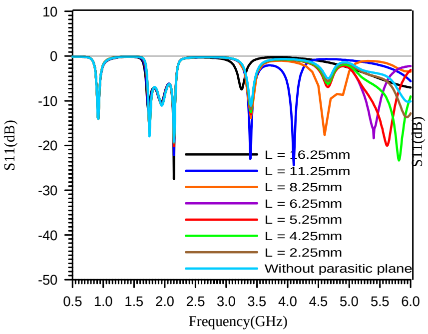


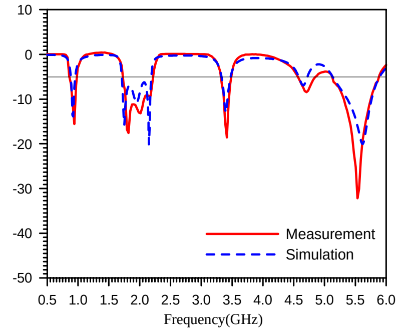


$\ell_1=24$ $\ell_2=1.7$ $\ell_3=3.1$ $\ell_4=17.7$ $\ell_5=9.2$ $\ell_6=5.2$ $\ell_7=3.9$ $\ell_8=10.8$

(a) (b)

Fig. 1. Geometry of the proposed PIFA, all dimensions are in mm.





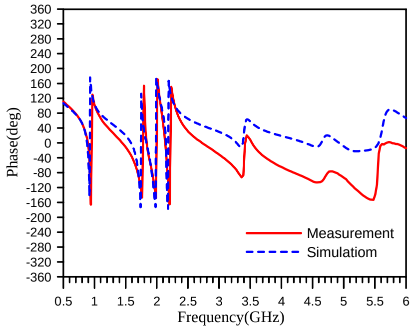


Fig2. Simulation results with L as a design parameter.

(a) Magnitude (b) phase.

Fig. 3. Measured and simulated S_{11} of the six-band PIFA.

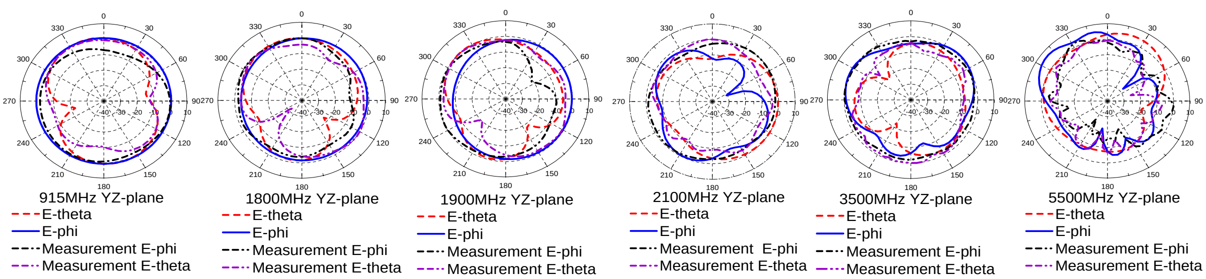


Fig. 4. Simulated and measured radiation patterns for the six-band PIFA.

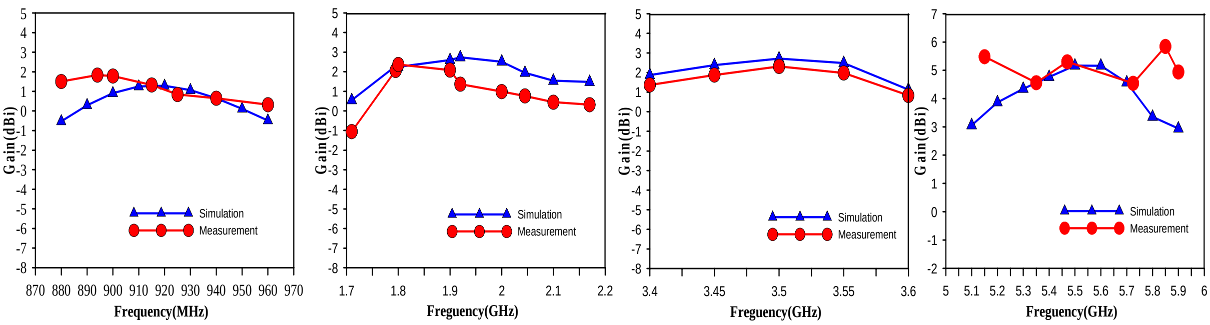


Fig. 5. Simulated and measured peak gains for the six-band PIFA.