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Design of a Multi-Band Internal Antenna Using an Open Stub

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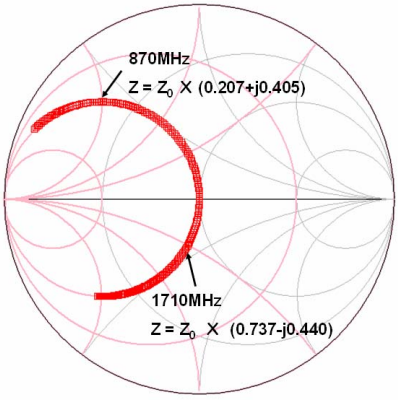
***Abstract*-An internal antenna for GSM (880~920MHz), DCS (1710~1880MHz), and US-PCS (1850~1990MHz) mobile handset is proposed. The antenna is designed to have a multi-band operation and includes feed line, patch and matching stub. It has a single radiating element and operates in multi-band by a matching circuit. The measured peak gain is 0.11dBi, 1.65dBi and 0.13dBi for GSM, DCS, and US-PCS, respectively.**

I. INTRODUCTION

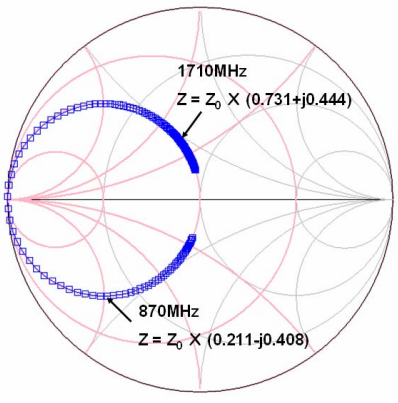
Recently, an internal antenna becomes a matter of concern in design of mobile handset. In many countries, considering a feature of the handset, it is common to use an internal antenna in practical cases. However, the demands for compact antenna, multi-band operation, lower SAR and mitigation of antenna performance degradation due to the human body effect have grown. Especially for multi-band operation, it is necessary to consider more carefully all aspects of the design facts such as size (resonant frequency), impedance matching, gain, and radiation pattern. However, it is very difficult for a multi-band small antenna to achieve all these requirements, because in general two or more radiating elements by using slits or slots, or higher modes are used, and they cause undesired surface currents on radiating elements. In this paper, a multi-band antenna is designed without any slits or slots, and it reduces the undesired effects to each other band. Theory of the design method is verified by ADS circuit simulator and the proposed antenna is simulated by using IE3D simulator based on the full-wave method of moment (MoM). Measured results are also presented.

II. THEORY

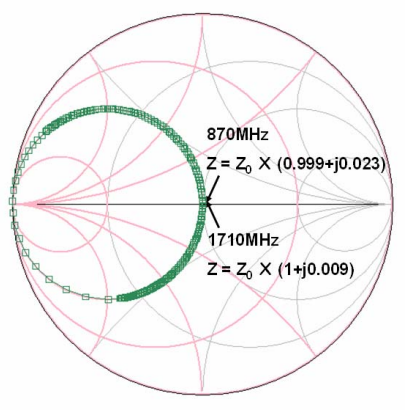
For the multi-band internal antenna design, two or more resonant modes of the single resonant element can be used, and several different resonant elements to generate separate modes can be also applied. For the former case, resonant frequencies can be easily varied with adding slots or slits. But it is difficult to obtain the desired impedance bandwidth in higher frequency band. Each antenna performance can be optimized using the several different radiating elements for the latter case. However, since these elements are not perfectly independent each other, the element resonating at one specific frequency may act as a parasitic load for other resonating elements. Also, tuning of the one element gives a noticeable effect on the others. Therefore, it is difficult for these methods to avoid the undesired currents in each resonant frequency band, and these result in degradation of antenna performances such as bandwidth, gain, or omni-directional radiation pattern.



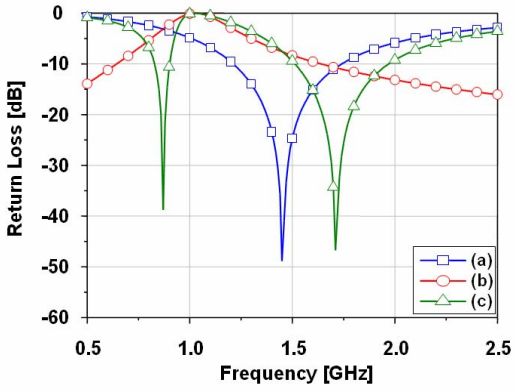
(a) PIFA as an RLC parallel resonator.



(b) BRF (LC series resonator) parallel to load.



(c) Combined circuit.



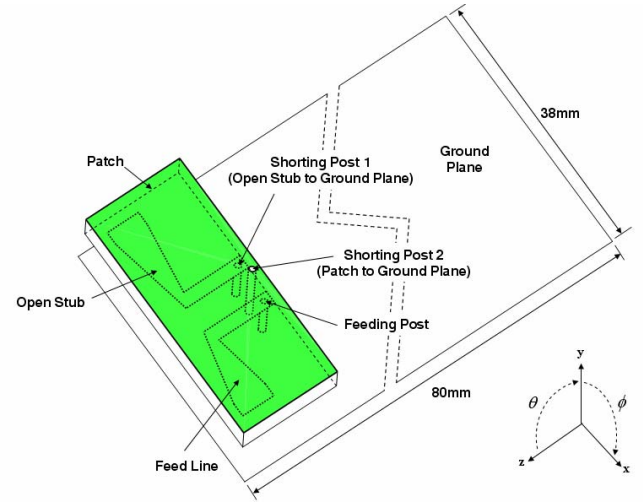
(d) Return loss of each case.

Fig.1. Impedance behavior and return loss.

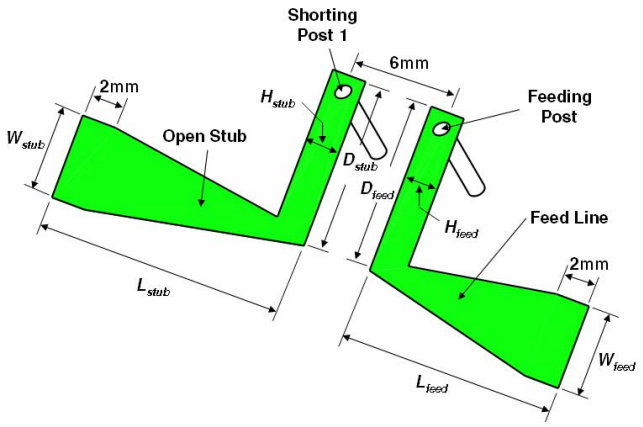
The multi-band operation in this work is realized by the only matching network without any modification of the radiating patch. Thus, the antenna can reduce such problems. In general, the PIFA (Planar Inverted-F Antenna) has the same impedance characteristics of the RLC parallel resonator. Although the inductive reactance due to the feed probe is dominant, in this case, it is not included. As shown in Fig. 1 (a) the real part of admittance remains 50 mhos, and the imaginary part is symmetric around the center of its resonant frequency. The imaginary part of the impedance is positive in lower frequency band and negative in higher frequency band. Therefore if the matching network with opposite impedance characteristics compared with that of the antenna is used, dual-frequency resonance can be achieved. Fig. 1 (b) shows the impedance characteristics of the band rejection filter as an LC series resonant circuit parallel to load. When this network is combined with the antenna, the combined antenna can be resonated in dual frequency band as shown in Fig.1 (c) and (d).

III. STRUCTURE

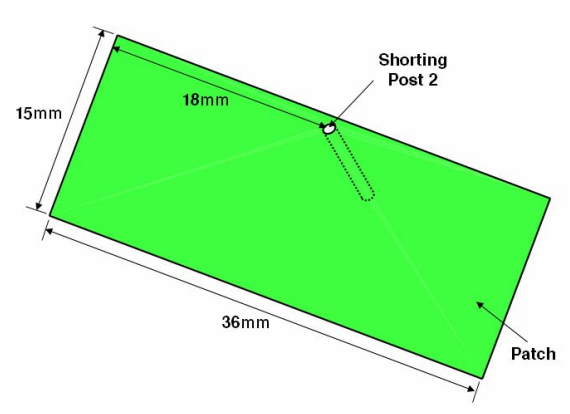
The structure of the proposed antenna is shown in Fig. 2. The antenna mainly consists of three parts: radiating patch, feed line, and open stub. 6mm height of the antenna includes 4mm of air layer (ε_r=1) and 2mm of FR4 (ε_r =4.7).



(a) Structure.



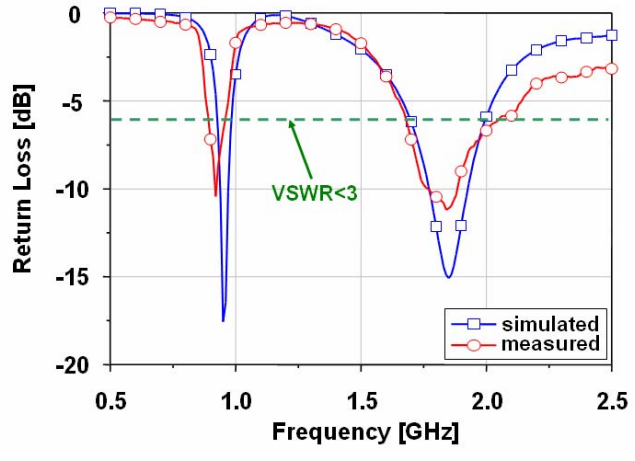
(b) Feed line and open stub ($D_{shorting}$=18mm, H_{feed}, H_{stub}=2mm, D_{feed}, D_{stub}=10mm, W_{feed}=4mm, L_{feed}=12mm, W_{stub}=6mm and L_{stub}=14mm).



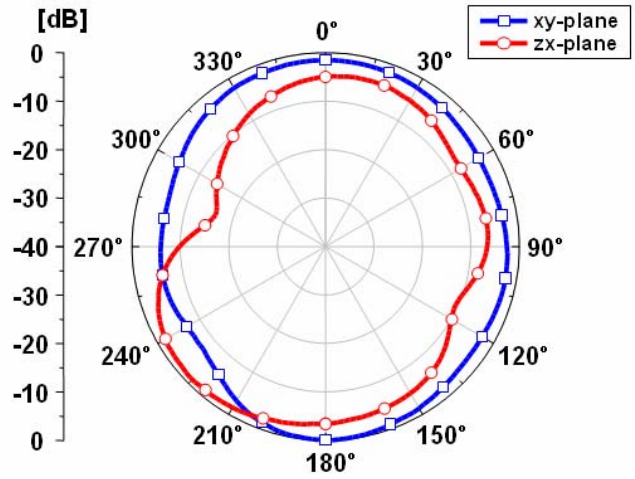
(c) Patch

Fig.2. Structure of the proposed antenna.

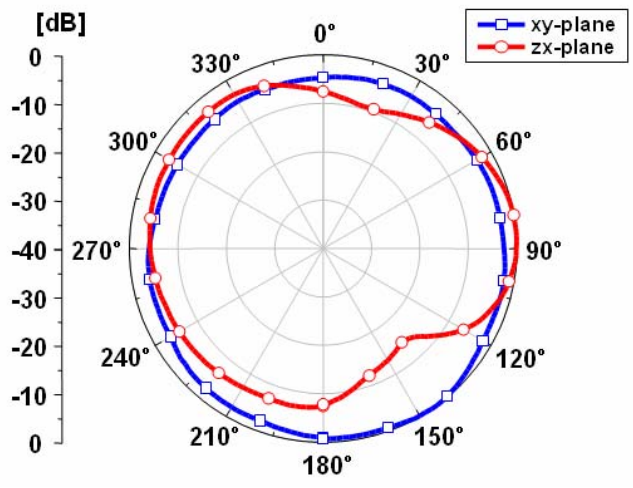
Basically the proposed antenna can be considered as PIFA because of shorting pin on radiator and its impedance characteristics. Although the indirect feeding is different from a conventional PIFA fed by a probe, it still has the same impedance behavior as the RLC parallel circuit. An open circuited line that is a quarter-wavelength long at a specific resonant frequency may be used to approximate the series resonant circuit [1]. And LC series resonator parallel to load has the same impedance characteristics of a band reject filter as shown in Fig. 1 (b). Therefore when this circuit called as an open stub in this paper is combined with the antenna, dual resonance can be created. As, in general, the conventional internal antennas have inherently a problem of high unloaded quality factor in lower frequency band because of its limited sizes, the proposed antenna does too. Therefore, the problem of the narrow bandwidth at the lower frequency band still remains in the case of the proposed antenna. This drawback will be considered in future work.



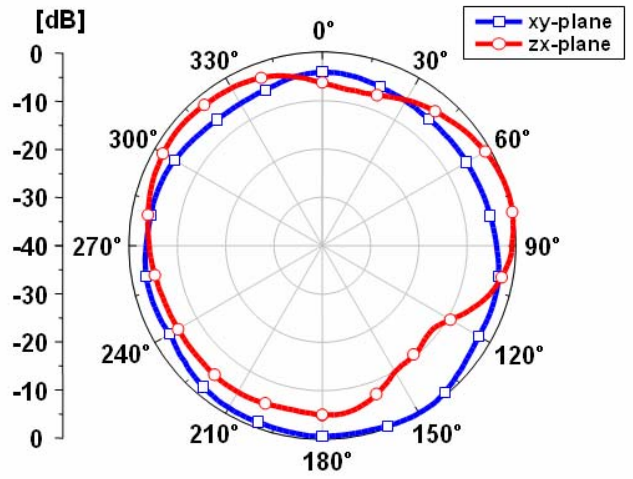
(a) Return loss.



(b) Radiation pattern at 925MHz.



(c) Radiation pattern at 1795MHz



(d) Radiation pattern at 1920MHz.

Fig. 3. Simulated and measured results.

IV. DESIGN AND RESULTS

In practical cases, the length (L_{feed}+D_{feed}) and the width (W_{feed}) of total feed line are set to 22mm and 4mm, respectively, for impedance matching. The length (L_{stub}) and width (W_{stub}) of open stub are set to 14mm and 6mm, respectively, for tuning resonant frequencies.

Fig. 3 (a) shows the simulated and measured return loss. Calculated impedance bandwidth (VSWR<3) is about 6.3% in GSM band (center frequency of 925MHz), and over 14% in DCS/US-PCS band (center frequency of 1850MHz). Measured impedance bandwidth of the antenna (VSWR<3) is 7.6% and 22.2% in GSM band and DCS/US-PCS band, respectively. Fig. 3 (b)-(d) show the measured radiation patterns. Measured peak gain is 0.11dBi at 925MHz (GSM band), 1.65dBi at 1795MHz (DCS band), and 0.13dBi at 1920MHz (US-PCS band). The measured average gain is –2.8dBi, -2dBi and –3.3dBi at each frequency, respectively. It

is noticed that the proposed antenna is very effective to mitigate degradation of its performances and gives the wide bandwidth in high band, maintained gains, and omni-directional radiation patterns for all operating bands.

V. CONCLUSIONS

Design of multi-band internal antenna is proposed and analyzed. Theory and performances of the proposed antenna are confirmed by simulations and measurements. The proposed antenna realizes a multi-band operation with a simple matching circuit so that its performances degradation for all operating frequency bands can be avoided. However there is still in difficulty to realize the wide bandwidth in lower frequency band. If the matching network with the lower quality factor can be achieved in lower frequency band, a broad bandwidth would be obtained. In next works, this will be reflected.

REFERENCES

[1] P. A. Rizzi, *Microwave Engineering Passive Circuits,* Prentice Hall, New Jersey, 1988, pp. 454.