A Compact Tri-Band PIFA with Multiple-Folded Parasitic Elements

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***Abstract* — The application of the multiple folded structure to a compact tri-band PIFA composed of three resonant frequencies, GSM(880-960MHz) / DCS1800(1710-1880MHz) / Satellite DMB (2605-2655MHz), are treated with the optimized parameter values. The proposed antenna has been designed and analyzed by using a commercially available software, CST MWS based on the FDTD algorithm and a simple resonant equation, respectively. In addition, the return loss has been measured and compared between measured and simulated data under the criterion of VSWR less than 3.**

***Index Terms* — Tri-band, PIFA, parasitic elements**

I. Introduction

With the help of the rapid development of wireless communication systems and the increasing requirements for portable characteristics of electronic devices, a compact and light-weighted antenna is continuously introduced in many literatures[1]-[4].

Furthermore, in order to satisfy the various demands for wireless services, multi-band antenna is a good candidate and PIFA concepts is adopted for antenna design. Especially, one of many advantages of PIFA structure is easily to be incorporated into the electronic equipments due to the flexible structures and compactness.

Many researchers have studied the derivation of multiple resonance and low-profile structure by using slit, slot[1], parasitic elements[2], the modification of ground pattern[3]. In this paper basic meander and folded structure has been applied to accomplish the novel and compact antenna. Folding the meander structure vertically leads to a relative volume reduction of 50% by overcoming the problem of low-frequency resonance dependent on the large area of the radiator. This paper deals with the physical insight into the PIFA covering GSM(880~960MHz), DCS(1710~1880MHz), and Satellite DMB(2605~2655MHz) by adjusting and locating two meander-folded structure optimally.

II. Antenna Configuration

Consider the meander-folded PIFA installed on top and bottom line separately as shown in Fig. 1. The heights H1, H2 of meandered structure are set to be 1mm to satisfy the target

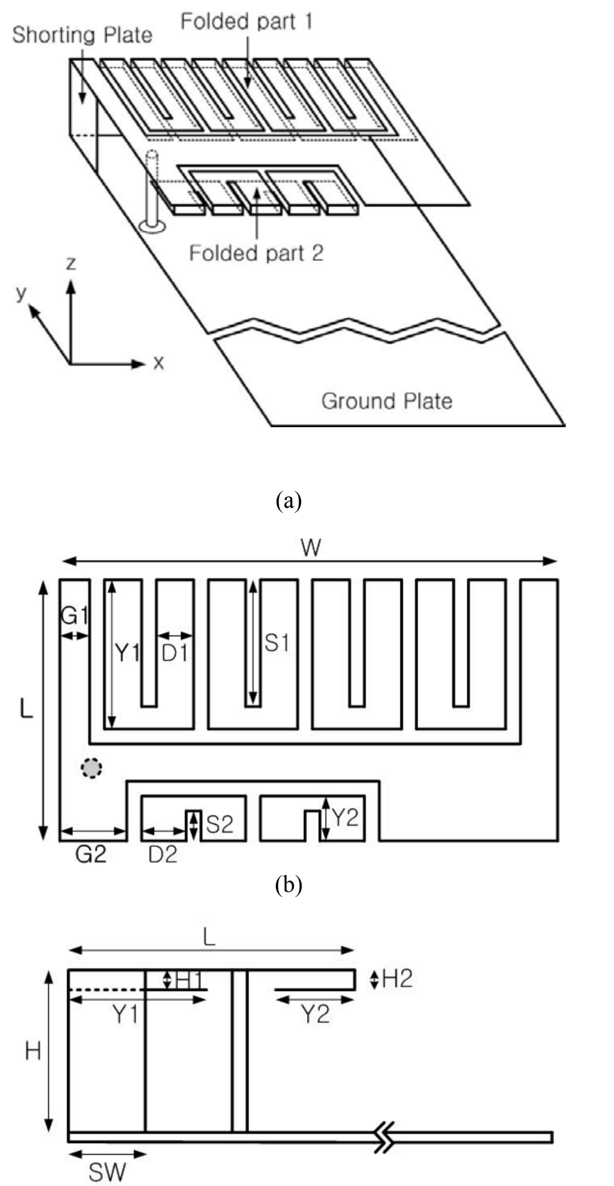


Fig. 1. Geometry of the proposed antenna. (a) 3-D View. (b) Top View. (c) Side View

TABLE I

DESIGNED PARAMETER VALUES OF THE PROPOSED ANTENNA

Parameter	L	W	G1	G2	H	H1	H2
Value(mm)	16	30	2.1	2	9	1	1
Parameter	D1	D2	S1	S2	SW	Y1	Y2
Value(mm)	2.5	3	7.3	2	5	9	3.8

frequency and wide impedance bandwidth around the resonant frequencies. The 50-Ω cable-feeding structure has been adopted to utilize the limited space effectively and avoid microstrip feed line.

Two meander-folded structures (folded part 1 and 2) have been employed to induce multiple resonance at different frequencies. The folded part 1 is related with GSM/DCS bands while the folded part 2 can control the Satellite DMB band. The important parameter that determines the resonant frequencies of GSM and DCS is Y1, D1 and S1 as shown in Fig. 1(b). The optimized parameter values have been obtained from iterative simulation with initial data depending on the relationship between the resonant frequency and the path length of current distribution. In a similar way, the resonant frequency of satellite DMB can be controlled by tuning the parameters Y2, D2 and S2 with additional parameter G2. Therefore the total volume through the optimized process amounts to $30 \times 16 \times 9\text{mm}^3$.

As a controllable parameter related with impedance matching, the position and width of shorting plate play an important role in satisfying the required bandwidth. The length of ground plane also affects the impedance bandwidth. As a basic role, the first maximum bandwidth can be obtained at the length corresponding to 1/3 of the resonant wavelength, λ[4]. According to the basic rule, a simple calculation shows that the length of ground plane to satisfy the maximum bandwidth at GSM band can be represented as $110 + (160 \times n)$ [mm] (n=0,1,2,⋯). In this paper the size of ground plane has been determined as $30 \times 105\text{mm}^2$ focused on the wide impedance bandwidth at GSM band under the criterion of return loss less than -6dB. The designed parameter values are listed in Table 1.

III. MEASUREMENTS AND VERIFICATION

The electrical performances of the proposed antenna have been investigated and measured by using a commercially available software, CST Microwave Studio and E5071B Network Analyzer of Agilent, respectively.

Fig.2 describes the return loss of the proposed antenna. It shows a good agreement between the comparison data under the criterion of VSWR less than 3 with a little derivation at highest resonant frequency. It is seen that the proposed antenna, which covers GSM(878~957MHz, BW=79MHz), DCS1800 (1700~1882MHz, BW=182MHz), Satellite DMB(2560~2660MHz, BW=100MHz) bands can be applied in the three service bands. Fig. 3 shows the independent characteristics of the resonant frequencies according to the changes of the optimized parameters located at the different part. Especially, Fig. 3(a) depicts the effects of parameter,

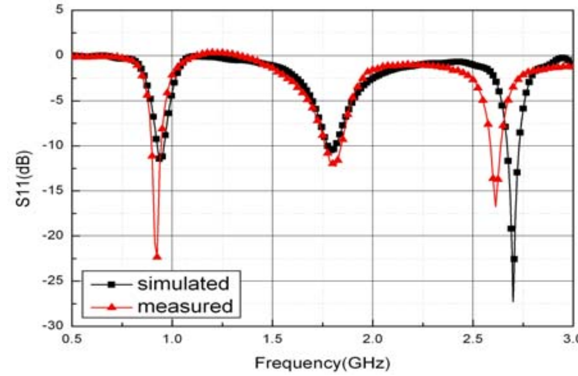
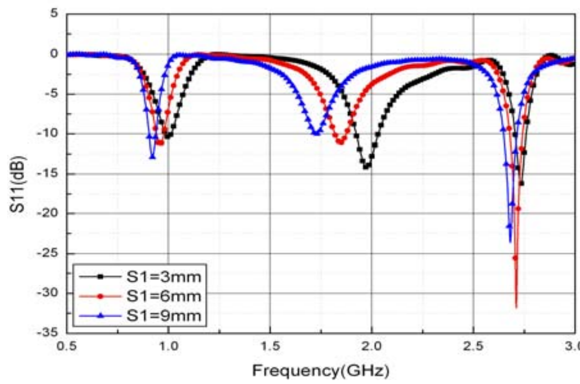


Fig. 2. The comparison between the measured and simulated data.



(a)

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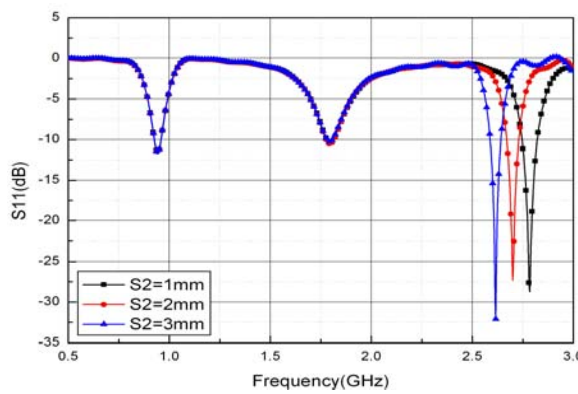
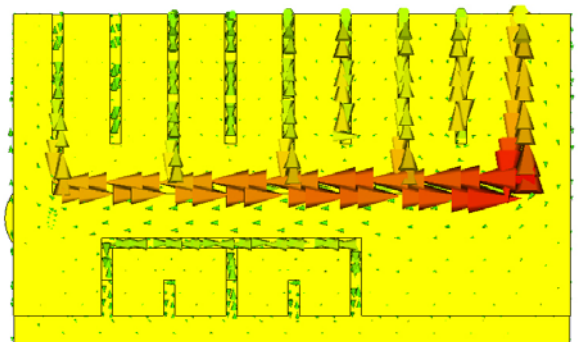


(b)

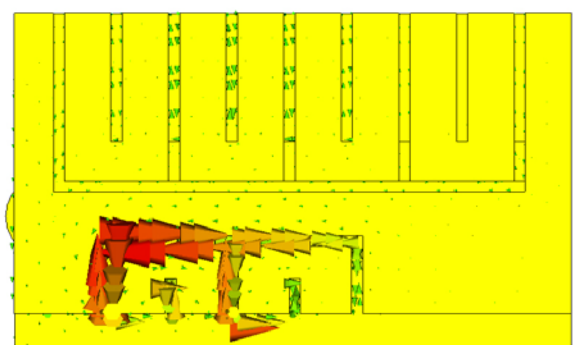
Fig. 3. The return loss as a function of slit (a) according to the changes of parameter S1(b) according to the changes of parameter S_2

TABLE II
THE GAIN AND EFFICIENCY OF THE PROPOSED ANTENNA.

Frequency	GSM	DCS1800	Satellite DMB
Max. Gain(dBi)	2.3	3.8	3.0
Radiation Efficiency(%)	81.5	89.5	86.5

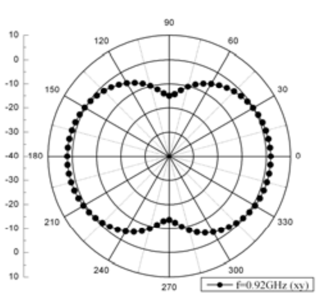


(a)

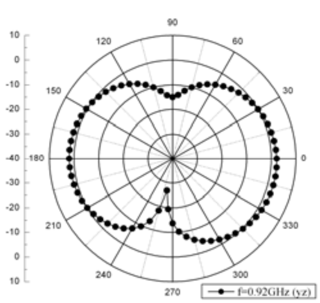


(b)

Fig. 4. Current distributions (a) at GSM band (b) at satellite DMB band



(a)



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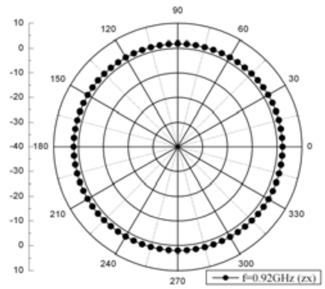

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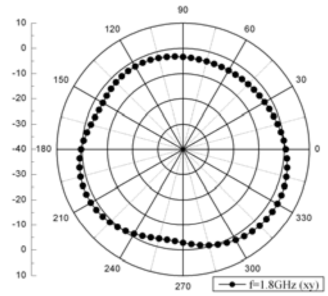

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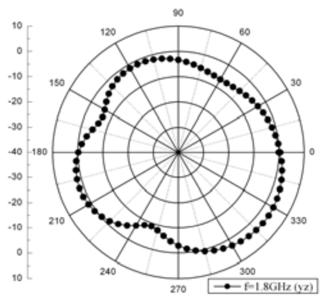

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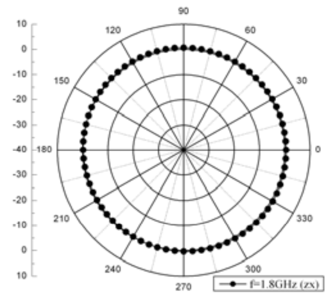

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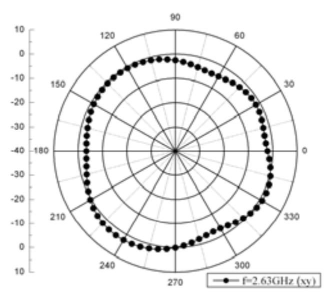

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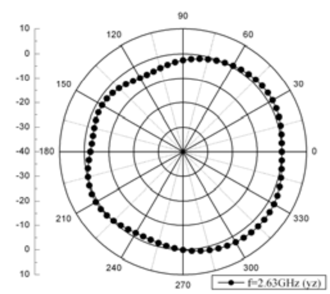
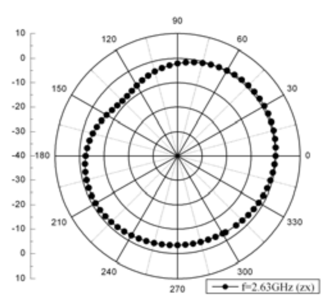


(h)



(i)

Fig. 5. The radiation patterns at three frequencies(f=0.92GHz, f=1.8GHz, f=2.63GHz) (a) at xy-plane(f=0.92GHz) (b) at yz-plane (f=0.92GHz) (c) at zx-plane (f=0.92GHz) (d) at xy-plane(f=1.8GHz) (e) at yz-plane(f=1.8GHz) (f) at zx-plane (f=1.8GHz) (g) at xy-

plane(f=2.63GHz) (h) at yz-plane(f=2.63GHz) (i) at zx-plane (f=2.63GHz).

S1 on the resonant frequency of GSM band. It is expected that the electrical length corresponding to the resonant frequency becomes longer and the resonant frequencies of GSM/DCS bands moves to the lower as the length of slit, S1 occupying at the folded meander part 1 increases. In a similar phenomenon, Fig. 3(b) shows that the resonant frequency of satellite DMB band can be controlled independently by changing the electrical length, S2 of the folded-meander part 2 without the effects of the folded-meander part 1. It is also checked out that other parameters affecting total electrical length at folded-meander part can be used to control the resonant frequencies independently. Fig. 4 plots the current distributions showing that the electrical lengths correspond to the resonant frequencies, respectively and the resonance occurs, independently.

In addition, the radiation patterns according to the cutting planes and frequencies are plotted in Fig.5. As shown in Fig.5, the proposed antenna has omni-directional radiation pattern at zx-plane and more than 2.3dBi as a maximum antenna gain at three bands.

IV. Conclusion

In this paper, a compact and low-profile antenna covering three service bands consisting of GSM900, DCS1800, Satellite DMB has been proposed. By employing the meander and multiple folded structures, it is seen that a lower resonant frequency can be generated with a very small radiator. This feasibility study indicates that the efficiency of the limited space inside the portable device can maximized. The function of multi-band operation can be achieved easily by isolating and locating two meander-folded structures separately on the different lines. The simulation results is based on the FDTD algorithm. In addition, bandwidths under the criterion of VSWR less than 3 of the proposed antenna are approximately 8.6% (878~957MHz), 10.2%(1700~1882MHz), 3.8%(2560~2660MHz), respectively.

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