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Bandwidth Enhanced Planar Inverted-F Antenna with Modified Ground Structure

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Abstract—**In this paper, we present a wideband design of planar inverted-F antenna (PIFA) using modified ground structure (MGS). The antenna consists of two-layer patches with common feed and modified ground structure. The bandwidth of the designed antenna covers the frequency bands of services such as DCS1800, DCS1900, UMTS (WCDMA), WiBro, WLAN (IEEE 802.11b), satellite DMB, HLAN (IEEE 802.11a) in Korea. The radiation patterns are consistent with frequency change in the bandwidth.**

Keywords-Wideband-PIFA, two-layer patches, modified ground structure, impedance bandwidth enhancement

I. Introduction

Recently, rapid development and growth in wireless communication technology lead to a demand of mobile terminal with multi-band operation for combined use of multiple functions. The antennas with multi-band or wide band operation have been investigated for multi-function mobile terminals. In mobile communications, several types of antenna structure are developed to be installed inside the terminal. The planar inverted-F antenna (PIFA) is a popular type of internal antenna since its small-sized low-profile structure is advantageous in mounting inside the terminal. Also, the flexibility of PIFA structure provides the diverse use in designing internal antennas of mobile terminals. The basic PIFA element, however, has the disadvantage of narrow bandwidth; typically its bandwidth is about 5~10 % with VSWR < 2. To increase the bandwidth, the PIFA structures employing parasitic elements [1], slit and slot [2], or multiple resonances [3] has been investigated.

In this paper, we present a PIFA structure with modified ground structure (MGS) to enhance bandwidth characteristic. The designed antenna employs two-layer patches to provide dual resonance frequencies which are closely located. Wideband characteristic can be achieved by overlapping two resonance bands, and the resonance frequencies are controlled by adjusting the dimensions of slots on the patches. In addition, we use the modification of the ground structure to obtain wider bandwidth and to avoid the degradation of VSWR characterristic which appears in the above procedure. The designed antenna shows wide bandwidth from 1.46 to 3.03 GHz and from 4.97 to 6.14 GHz for VSWR < 2.5, which covers 7 service bands in Korea including DCS 1800, PCS 1900, UMTS (WCDMA), WiBro, WLAN (IEEE 802.11b, Blue Tooth), Satellite DMB, and HLAN (IEEE 802. 11a). The antenna characteristics for different cases were calculated using the commercially available CST MWS (Microwave Studio).

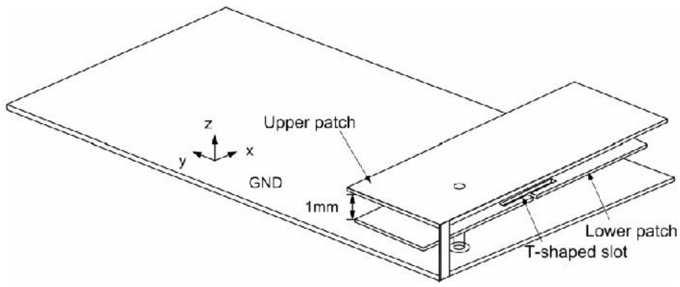

Figure 1. Geometry of proposed basic two-layer PIFA

II. Antenna Design

A. PIFA withTwo-layer Patches

In Fig. 1, a PIFA structure with two patches is illustrated, where the upper- and lower-patches are fed directly from the probe and T-shaped slot is located on the lower patch. The upper patch is connected to the ground via shorting plate; however, the lower plate is not connected to the shorting pin. The resonance frequencies corresponding to the upper- and lower-patches are denoted by f1 and f2, respectively. The upper patch determines f1 from the formula for PIFA by [4]

$$f_1 = \frac{c}{4(W_u + h_u)} \tag{1}$$

where W_u and h_u represent the width and the height of the upper patch, respectively. c is the velocity of the propagating wave. Since the lower patch is floated from the shorting plate, f_2 is determined from the formula for microstrip patch antenna by

$$f_2 = 0.49 \frac{c}{L_{eff}} \tag{2}$$

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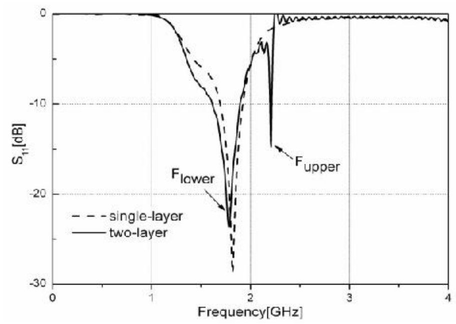
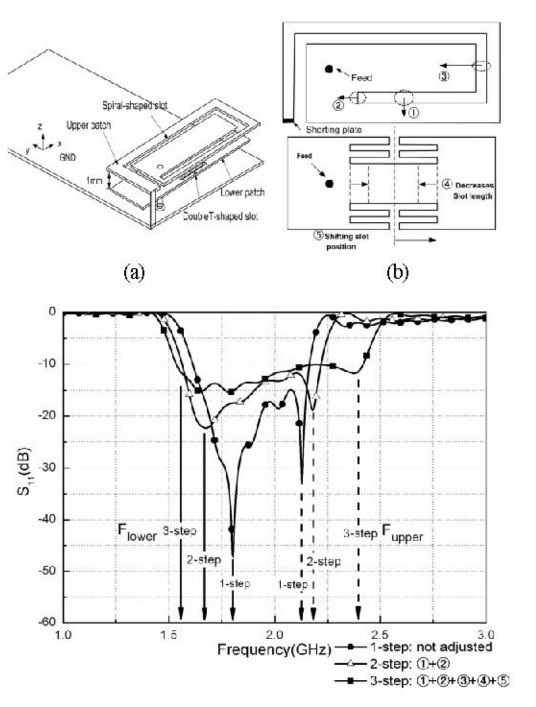


Figure 2. Return loss of single-layer and two-layer patch PIFA.



(c)

Figure 3. Geometry of proposed two-layer PIFA: (a) 3-D view, (b) 2-D view and (c) expansion of bandwidth versus adjustment of slot.

where L_{eff} is the effective patch length of the lower patch. The effective length of the lower patch is reduced from the actual size due to the T-slot. In Fig. 2, the return loss of the two patch PIFA is plotted, where the sizes of the upper- and lower-patches are 30×12 mm^2 and 30×10 mm^2, respectively, and h_u = 7 mm. The characteristic of the single patch PIFA, where the lower-patch is removed from the two-layer PIFA, is plotted to compare the resonance frequency. The resonance frequencies of the two-patch PIFA in Fig. 2 are lower than the calculated frequencies from Eqs. (1) and (2), 2.0 and 2.4 GHz, since the effective electric lengths are increased due to the mutual coupling between two patches.

B. Control of Bandwidth

The F_{lower}, F_{upper} can be controlled by adjusting the dimensions of slots on the patches. In Fig. 3, spiral-shaped slot is adapted to upper patch and double T-shaped slot is adapted to lower patch. Then adjusting the dimensions of slots, it can be achieved F_{lower} to much lower, F_{upper} to much higher. As a result of that, PIFA has widened bandwidth. But VSWR is depredated. So the increase of bandwidth (VSWR < 2) is limited.

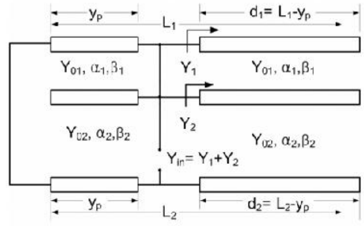


Figure 4. Simple transmission line model for two-layer PIFA.

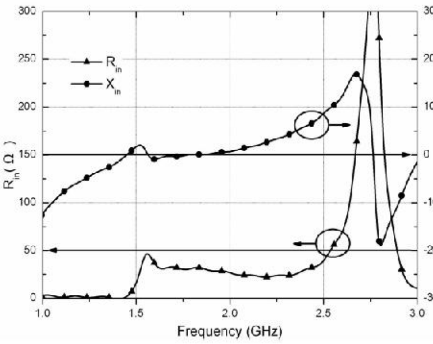


Figure 5. Input impedance when antenna has maximum impedance matching in limited condition.

C. Input Impedance Matching

To reduce the VSWR characteristic, it is necessary to maintain the input impedance about 50 Ω in wide range of frequency. As the resonant antennas are analyzed by employing an open transmission line model [5], the two-layer patches PIFA can be modeled as shown in Fig. 4. Assuming the upper- and lower-patches are independently operating, two transmission lines are connected parallel from the source, and each transmission line has its characteristic impedance, attenuation coefficient, propagation constant, and effective electric length, respectively. By moving the feeding position, the input impedance can be controlled. However the smooth control of input impedance is difficult because the choice of feeding position is limited due to the slots spread on the patches. Fig. 5 shows the resistance and the reactance components of input impedance when the most impedance matching is performed under limited condition. Input resistance is smaller than 50 Ω in band, and a rapid increase is observed at 2.7 GHz. Also, input reactance remains around zero in band and rapidly changes at 2.7 GHz. The impedance response at 2.7 GHz represents the resonance characteristic for one- or two-wavelength dipole. Due to the rapid change of impedance at 2.7 GHz, the impedance matching in wide frequency region is not easy.

D. Bandwidth Enhanced PIFA with MGS

The impedance matching characteristic can be improved by employing the modified ground structure (MGS), in which some part of the ground conductor under the patch is removed

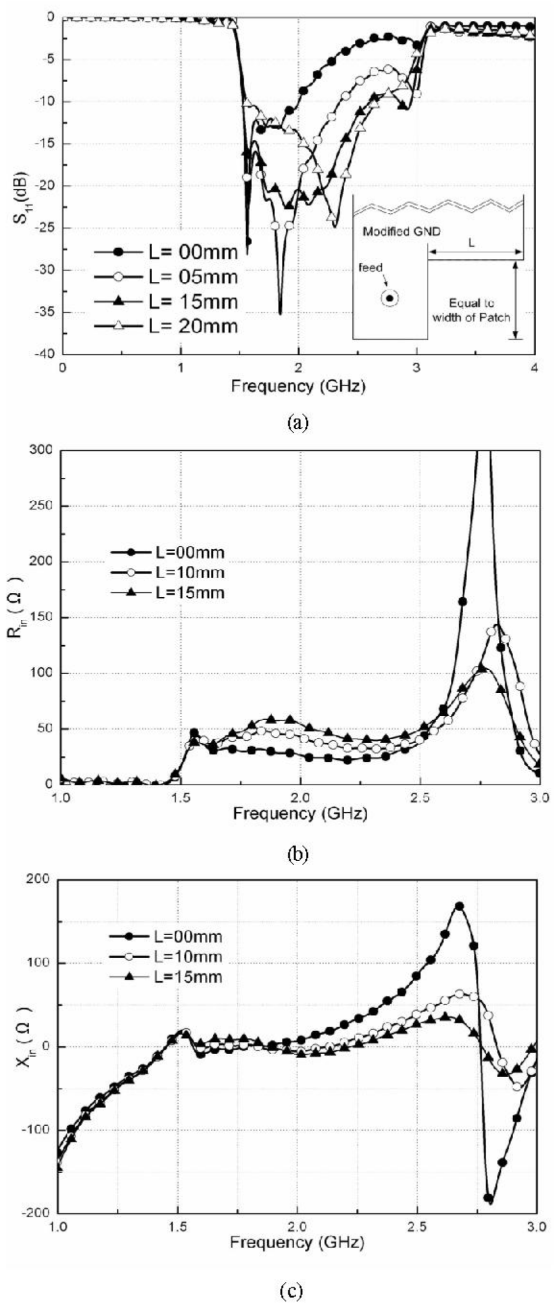


Figure 6. (a) Return loss (b) input resistance, and (c) input reactance as a function of MGS.

as shown in Fig. 6(a). In the mobile terminal, the connection of circuit elements on the printed circuit board (PCB) uses the signal line and the ground conductor. Because the circuit elements are not installed on the ground conductor under the patches to avoid the electromagnetic interferences, the part of the ground conductor can be removed under the patches. Fig. 6(a) shows the return losses with the change of the length L on the ground. In Figs. 6(b) and (c), the input reactance and the resistance characteristics are plotted respectively for different L. When the MGS is employed, the impedance matching of the two-patch PIFA is improved with fixed flower and fupper. The changes of resistance and reactance at 2.7 GHz become slow with the MGS.

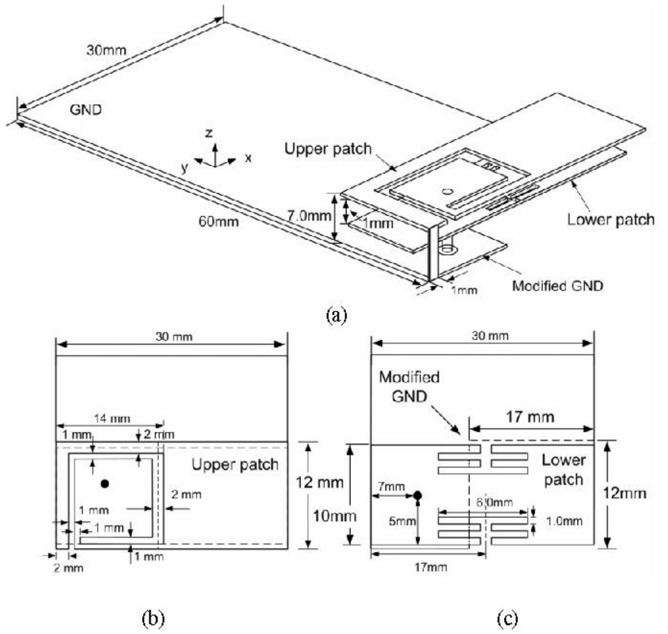


Figure 7. Geometry of proposed antenna: (a) 3-D, (b) upper patch, (c) lower patch, and MGS.

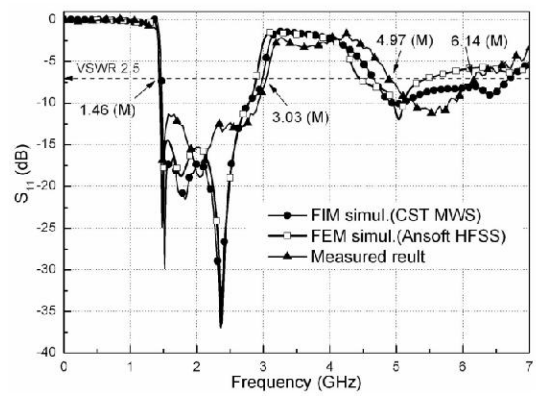


Figure 8. Measured and simulated results.

The input resistance is more close to 50 Ω and the magnitude of the input reactance is reduced in band.

The PIFA with modified ground can be interpreted as an asymmetric dipole antenna in which the feeding point is shifted from the center. For the symmetric dipole, the input impedance diverges for one-wavelength dipole and the impedance changes rapidly at the frequency corresponding to the one wavelength; the impedance fluctuation occurs in band. For an asymmetric dipole, the impedance does not diverge and the impedance fluctuation is reduced. The unbalanced current for the asymmetric structure causes an unwanted polarization characteristic in radiation pattern. For mobile terminal applications, the polarization purity is not an important factor.

E. *Fabricated and Measured Antenna*

The configuration of the designed two-patch PIFA with MGS id illustrated in Fig. 7 with the optimized dimensions. For verification of the accuracy and validity of simulation, we com-

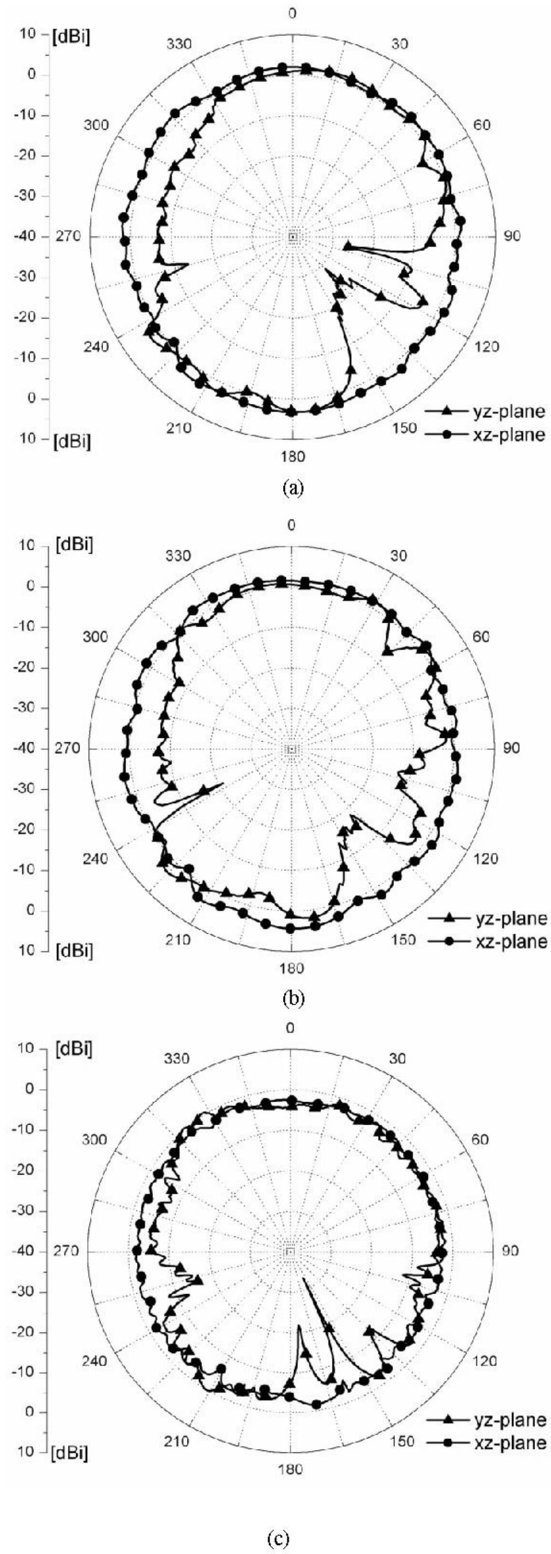


Figure 9. Measured radiation patterns at (a) 1.8 GHz, (b) 2.2 GHz, and (c) 5.5 GHz.

pare the measured data with two simulation results based on different algorithm, based on FIM (Finite Integration Method) based Microwave Studio and FEM based HFSS. The characteristic of the fabricated PIFA is measured by network analyzer Agilent E5071B. In Fig. 8, the measured result shows a wide bandwidth from 1.46 to 3.03 GHz and from 4.97 to 6.14 GHz for VSWR < 2.5, which covers 7 service bands including DCS 1800, PCS 1900, UMTS (WCDMA), WiBro, WLAN (IEEE 802.11b, Blue Tooth), Satellite DMB, and HLAN (IEEE 802. 11a) in Korea. The measured bandwidth agrees well with the simulation results. The measured radiation patterns in the E- and H-plain are shown in Fig. 9 for the frequencies of 1.8, 2.2, and 5.5 GHz. The radiation patterns are omni-directional and the patterns does not change for different frequencies.

III. Conclusion

The PIFA has generally narrow band characteristic. The PIFA with two patches is designed to obtain wideband characteristic by overlapping two resonance frequency bands. The bandwidth is controlled by adjusting slot on patches. The modified ground under the patches provides asymmetric characteristic and wideband performance is achieved. The performance of proposed antenna shows wideband characteristic of 67.7 %. It covers 7-service bands for mobile communication at same time in Korea. The developed antenna structure can be widely used in the design of the wideband internal antennas for the mobile terminals.

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