A Triple-Band Printed Dipole Antenna using Parasitic Elements for Multiple Wireless Services

Ki-Hun Chang · Hyung-Rak Kim · Kwang-Sun Hwang · Ick-Jae Yoon · Young-Joong Yoon

Abstract

In this paper, a triple-band printed dipole antenna using parasitic elements is proposed for the multiple wireless services. The proposed antenna is designed and experimentally analyzed at the bands of PCS, IMT-2000, and ISM services. To achieve triple frequency operation, the proposed antenna contains two parasitic elements, which act as additional resonators by coupling from the driving dipole antenna. From the measured results, the resonant frequencies of this antenna are 1.79 GHz, 2.03 GHz, and 2.41 GHz and the measured impedance bandwidths are 90 MHz(1760~1850 MHz), 210 MHz(1,930~2,130 MHz), and 30 MHz(2,400~2,430 MHz) for VSWR<2. The measured antenna gains are 2.14 dBi, 0.9 dBi, and 0.5 dBi, respectively. Antenna parameters for triple-band operation are investigated and several antenna characteristics are discussed.

Key words : Parasitic Element, Triple-Band, Printed Dipole Antenna.

Ⅰ. Introduction

Various types of printed dipole antenna(PDA) have been actively studied since they provide easy fabrication, simple structure, coplanar integration with solid state devices, and low cost[1]~[3]. In recent years, PDAs using parasitic elements are reported[4],[5]. There are some PDAs using parasitic elements as a director, and then the antennas have directional radiation patterns. Several researches using parasitic elements as a resonator have been carried out for the dual frequency operation. As the related techniques, PDAs using parallel or series extended parasitic elements with a small gap are suggested[6]~[8]. However, by these techniques, it is not able to have the adjacent operating frequencies of the PDA.

In this paper, we propose a novel PDA with parasitic elements to achieve the operation at the adjacent triple service bands for PCS(Personal Communication Service; 1,750~1,870 MHz), IMT-2000(International Mobile Telecommunication-2000; 1,920~2,170 MHz), and ISM(Industrial Scientific and Medical; 2,400~2,483.5 MHz). The optimum antenna parameters for triple-band are investigated and experimental results are discussed.

Ⅱ. Antenna Configurations

Fig. 1 shows the dual-band PDA using the coplanar parasitic element, which lies parallel to the driving dipole antenna on the top of the substrate. To yield resonance on the parasitic element, it is close to the driving dipole antenna. Then it radiates by coupling from the driving dipole antenna. The parasitic element and the driving dipole antenna have the resonant lengths of the PCS and IMT-2000 bands for dual-band operation, respectively[9].

The antenna is fed by the balun which has a microstrip line to coplanar stripline transition with a broadband radial stub[10]. The feeding line, the driving dipole antenna, and parasitic elements of this antenna lie on the top of the dielectric, and ground plane is on the bottom of the dielectric.

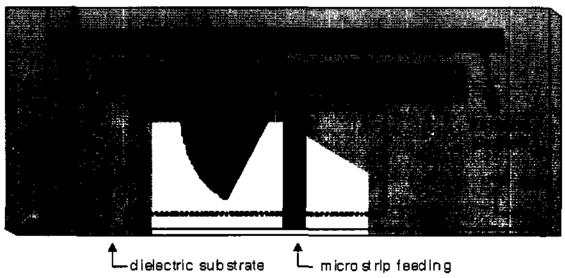

Fig. 1. Configuration of the dual-band printed dipole antenna using a parasitic element.

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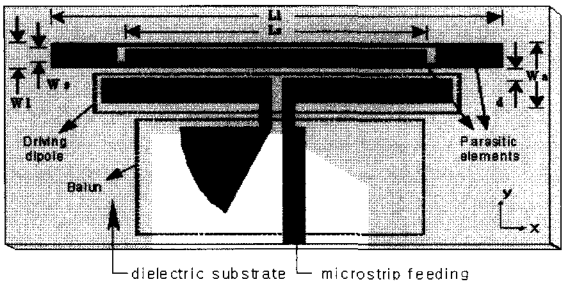


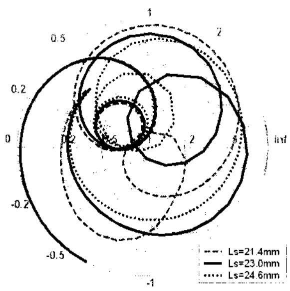
Fig. 2. Configuration of the triple-band printed dipole antenna using two parasitic elements.

Similarly, the triple-band dipole antenna operates under the same mechanism as dual-band PDA. The configuration of the proposed triple-band dipole antenna is shown in Fig. 2. This antenna has a driving dipole and two parasitic elements. One small parasitic element is added inside the existing parasitic element to yield the additional resonance at the ISM band without additional size increase. To operate at triple-bands for PCS, IMT-2000, and ISM, these are designed to have the $\lambda/2$ lengths of the respective resonant frequencies.

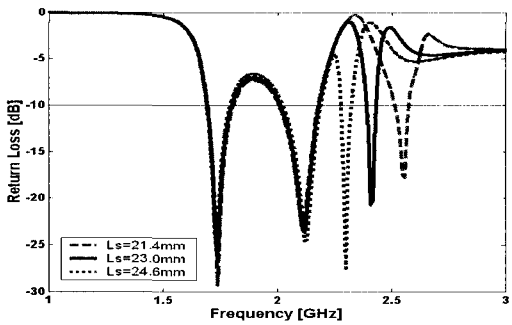
III. Antenna Design and Characteristics

For proper antenna design, the several parameters of the proposed PDA are investigated and the effects of the parameters on the frequency shift or the input impedance are also examined. To optimize antenna characteristics, the IE3D software is used. The proposed PDA is etched on a substrate with a relative dielectric constant of 10.2 and thickness of 50 mil.

It is found in Fig. 3(a) and (b) that the small parasitic element has the resonant frequency depending on its length Ls, which has no relation to a variation in the other operating frequency. Therefore, this is designed to have the length of 23 mm for the operation at the ISM band. The width Ws of this has an effect on the mismatch at the ISM band, as shown in the loop size on the right-side of Fig. 4(a). This does not affect the mismatch at other resonant frequencies. Thus the optimum value of Ws for matching at the ISM band is 1.3 mm. That is, the size Ws x Ls of the small parasitic element determines its own operating frequency and matching. However, in Fig. 4(a), the variation of Ws also has an effect on the size and location, which affect the impedance bandwidth and the operating frequency, of a left-side loop in the input impedance locus. Thus, as shown in Fig. 4(b), the operating frequencies and the

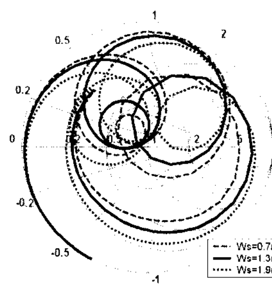


(a) Input impedance

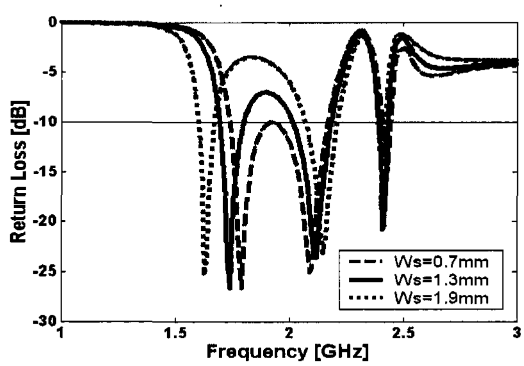


(b) Return loss

Fig. 3. Computed input impedance and return loss of the proposed antenna depending on the small parasitic element length Ls.

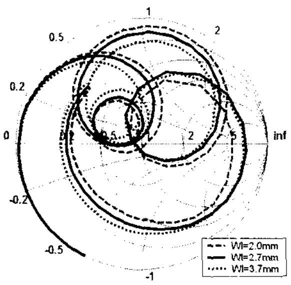


(a) Input impedance

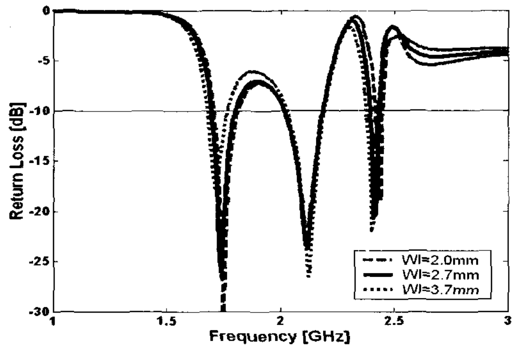


(b) Return loss

Fig. 4. Computed input impedance and return loss at the feeding point with the width Ws of the small parasitic element.

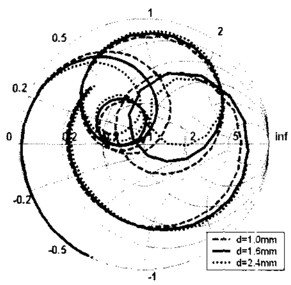


(a) Input impedance

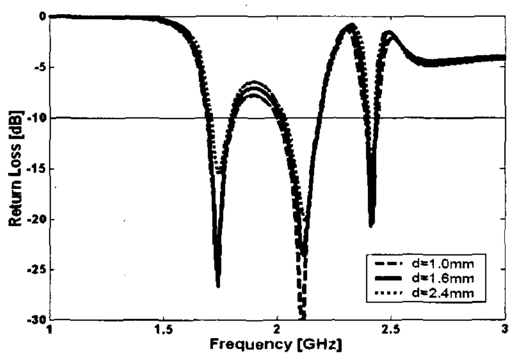


(b) Return loss

Fig. 5. Computed input impedance and return loss at the feeding point with the width Wl of the large parasitic element.



(a) Input impedance



(b) Return loss

Fig. 6. Computed input impedance and return loss at the feeding point with the distance d between the parasitic elements.

Table 1. Parameter values.

Parameter	Value [mm]
Ll	40
Wa	6.1
Ls	23
Ws	1.3
Wl	2.7
d	1.6

bandwidths of lower two bands vary as Ws.

Fig. 5(a) shows the variation of the input impedance according to the width increase of the large parasitic element. This indicates that the width Wl has slightly effect on the mismatch at the PCS and IMT-2000 band, as depicted in Fig. 5(b). Thus the optimal value of Wl is 2.7 mm. In Fig. 6(a), the variation of the distance d between the driving dipole antenna and the parasitic element has an effect on the size of loops in the input impedance locus. The size increase of loops means an increase of the coupling from the driving dipole antenna to the parasitic elements, since they become close to each other. Though the decrease of d provides an increase in coupling quantity, it can also derive a mismatch in the input impedance as shown in Fig. 6(b). Thus the distance d results in the optimum impedance matching over the triple-bands at 1.6 mm.

Considering all of these characteristics, the optimum values for Ls, Ws, Wl, and d are 23 mm, 1.3 mm, 2.7 mm, and 1.6 mm, respectively. All the design parameters are summarized in Table 1.

Ⅳ. Experimental Results

Fig. 7 shows the simulated and measured return losses of the proposed triple-band printed dipole antenna. This indicates that the antenna provides triple operating frequencies of 1790 MHz(1760~1850 MHz), 2030 MHz(1930~2130 MHz), and 2410 MHz(2400~2430 MHz) for VSWR<2. The impedance matching and bandwidth of the measured return loss are similar to those of the simulated return loss. But a frequency shift from the simulation is shown in the PCS and IMT-2000 bands, which is considered to be due to the finite ground plane and a fabrication error.

Fig. 8 shows the measured radiation pattern in E-plane and H-plane. As depicted in Fig. 8 (a), this antenna has the E-plane radiation pattern similar with the conventional dipole antenna pattern. However, it

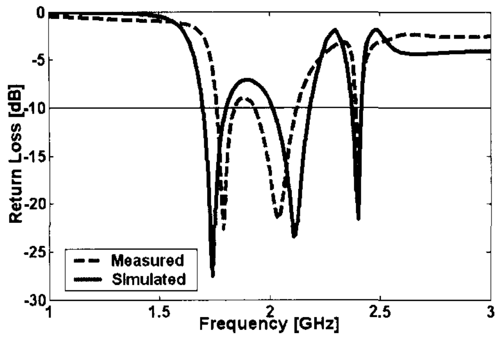
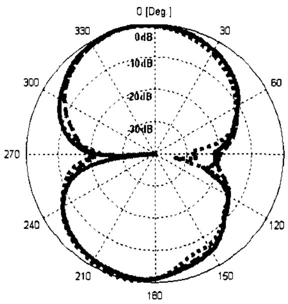
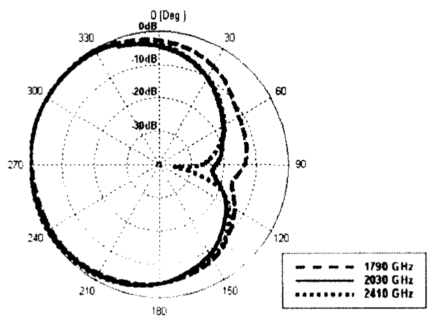


Fig. 7. Simulated and measured return losses of the proposed PDA.



(a) E-plane



(b) H-plane

Fig. 8. Measured radiation patterns in E-plane and H-plane.

has the directional radiation pattern in H-plane by ground plane effect. As at the higher frequency the antenna operates, the ground plane seems larger. Therefore, the back radiation intensity decreases at higher frequency as shown in Fig. 8(b). The measured antenna gains at 1790 MHz, 2030 MHz, and 2410 MHz are given in 2.14 dBi, 0.9 dBi, and 0.5 dBi, respectively.

Ⅴ. Conclusion

In this paper, a triple-band printed dipole antenna for PCS, IMT-2000, and ISM services is proposed. To obtain the triple frequency operation, parasitic elements are used in dipole antenna. In addition, to reduce the antenna size, the smaller parasitic element is located inside the larger parasitic element. As shown in the measured results, the proposed antenna shows a good triple band operation over PCS, IMT-2000, and ISM bands. The antenna parameters for triple-band operation have been investigated. Therefore, this antenna can be used in PCS, IMT-2000, and ISM wireless applications with a simple structure and the reduced size.

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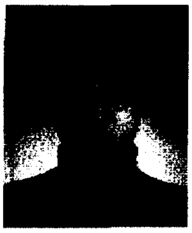

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