A printed inverted-F antenna for wideband operation

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Abstract: In this letter, a wideband printed inverted-F antenna is proposed. A rectangular element is loaded at the feeding line perpendicularly. A new additional resonance is produced by the loaded rectangular element. Also, the wideband impedance matching and the stable gain can be achieved. The simulated and measured impedance bandwidths with the 10dB-return loss of the proposed inverted-F antenna are approximately 96.1\% (2.33GHz-6.64GHz) and 100.5\% (2.39GHz-7.22GHz), respectively. The dimension of the fabricated antenna is $0.31\lambda_L \times 0.20\lambda_L$ ($\lambda_L$ is a wavelength at the lowest frequency in the frequency range with the 10dB-return loss). The proposed antenna is small in size.

Keywords: Printed inverted-F antenna (Printed IFA), Wideband operation, Wi-Fi, WiMAX

Classification: Antennas and propagation

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1 Introduction

A printed inverted-F antenna (printed IFA) [1] has some good advantages, such as a low profile, easy fabrication, and easy impedance matching. For the last two decades, some wireless applications such as WiFi (IEEE.802.11 standard), WiMAX (IEEE.802.16e-2005 standard) and LTE (Long Term Evolution) have become popular. Due to this, many printed IFAs for multiband operation have been proposed [2]-[7]. Wideband antennas as well as multiband antennas are effective for use of some wireless applications at one terminal. However, printed IFAs for wideband operation have not been reported, to the best of the authors’ knowledge.

In this letter, a printed IFA for wideband operation is proposed. A rectangular element is installed at the feeding line perpendicularly. The shape of the proposed antenna is very simple. Printed monopole antenna (PMA) is useful as a planar antenna for wideband operation. The length of the radiation patch of the PMAs is approximately a quarter wavelength. The length of the radiation element in the printed IFA is also approximately a quarter wavelength. However, as the radiation element of the printed IFA is bent, the size of the printed IFA is smaller than that of the PMA. Moreover, the shapes of the PMA with 100% impedance bandwidth are relatively complex [8]-[10].

For the calculations in this letter, the simulation software package Altair HyperWorks FEKO, which is based on the method of moment, is used. In order to ascertain the accuracy of the simulated results, the simulated return loss and gain are compared to experimental data.
2 Antenna design

Figure 1 shows a printed IFA for wideband operation. A rectangular element is loaded at the feeding line of the conventional printed IFA perpendicularly. The length and width of the rectangular elements are $L_S$ and $W_S$, respectively. The distance between the rectangular element and the horizontal radiation element is $P_S$. The relative dielectric constant, the thickness and the loss tangent of the dielectric substrate are $\epsilon_r=2.6$, $h=1.6\text{mm}$ and $\tan\delta=0.001$, respectively. The size of the dielectric substrate is fixed at $L_a \times W_a=40\text{mm} \times 26\text{mm}$. The widths of the horizontal radiation element and the vertical shorting plate are also fixed at $W_e=L_e=1.5\text{mm}$. An SMA receptacle is connected to the coplanar waveguide at the side edge of the dielectric substrate. In order not to connect the feeding line of the coplanar waveguide with the outside conductor (ground) of the SMA connector, the notches are inserted at the front edge of the feeding line. The size of the front edge of the feeding line is set at $L_c \times W_c=2.0\text{mm} \times 1.0\text{mm}$.

Generally, the impedance matching of the conventional printed IFA can be tuned by adjusting the width of the feeding line $L_f$. In the proposed IFA, not only the width of the feeding line $L_f$, but also the geometric parameters of the loaded rectangular element $W_S$, $L_S$, and $P_S$, are used to tune the impedance matching in the wide frequency range. The geometric parameters of the designed antenna are as follows: $L_g=16$, $W_g=13$, $L_f=6$, $L_s=10$, $W_s=4$, and $P_s=5$ (unit:mm).

![Fig. 1. Geometry of a printed IFA for wideband operation](image)

3 Antenna characteristics

Figure 2(a) shows the simulated return loss of the proposed and the conventional printed IFAs. The measured return loss of the proposed printed IFA is also shown for comparison. In the conventional printed IFA, the bandwidth with 10dB-return loss is approximately 25.3% (2.35GHz-3.03GHz).
In the proposed printed IFA, however, the simulated bandwidth is 96.4% (2.33GHz-6.64GHz). By only loading the rectangular element at the feeding line perpendicularly, the impedance bandwidth is improved significantly. The measured impedance bandwidth is 100.5% (2.39GHz-7.22GHz), and this measured impedance bandwidth, agrees with the simulated one.

Figure 2(b) shows the simulated input impedances of the proposed and conventional printed IFAs. The conventional printed IFA has two resonant frequencies 2.97GHz and 5.63GHz in a frequency range from 2.0GHz to 7.0GHz. On the other hand, in the proposed printed IFA, there are three resonant frequencies, 2.54GHz, 4.09GHz, and 6.32GHz in the same frequency range. In this letter, the frequency, where the input reactance is zero, is defined as the resonant frequency. The input impedance around the first resonance and the first resonant frequency of the proposed antenna are similar to those of the conventional printed IFA. Therefore, the return loss around the first resonant frequency of the proposed antenna is also similar to that of the conventional antenna. However, the second and third resonant frequencies of the proposed printed IFA significantly shift compared to that of the second
Fig. 3. Radiation characteristics

resonant frequency of the conventional printed IFA. It can be confirmed that the second and third resonances are due to the loaded rectangular.
Figures 3(a)-(c) show the radiation patterns at the resonant frequencies in the conventional and the proposed printed IFAs, respectively. The radiation patterns at the first resonant frequency in both antennas are very similar. It can be confirmed that the rectangular element doesn’t contribute to the radiation pattern at the first resonant frequency. In the radiation pattern at the second resonant frequency in the conventional printed IFA, a null is produced in the $+z$ direction. This is due to the fact that the electric current distribution at this frequency, is that of the second order mode ($L_a/2 + W_d = \lambda/2$). In the proposed antenna, however, the main radiation direction of the second and third resonant frequencies are in the $\pm z$-direction, which is caused by the loaded rectangular element.

Figure 3(d) shows the absolute gains in the $+z$ direction of the proposed and conventional IFAs. The simulated gain of the proposed printed IFA is stable in the frequency range with the 10dB-return loss (2.33GHz-6.64GHz). The gain of the proposed IFA is improved significantly around 6GHz compared to that of the conventional printed IFA. In fig. 3(d), the measured gain is also shown for comparison. Although the measured gain is approximately 4dB lower than the simulated result around 2.4GHz, the measured gain agrees with the simulated gain in the frequency range higher than 2.6GHz.

4 Conclusion

A wideband printed inverted-F antenna has been proposed. A rectangular element was loaded at the feeding line of the conventional IFA. The wideband impedance matching and the stable gain were achieved by the loaded rectangular element. The return loss and gain were calculated by simulation software and compared with the measured results. The good agreement between the calculations and measurements confirms the results of this work.