A Wideband Mobile Terminal Antenna Using the Resonance of a Slide Structure

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1. Introduction

With recent progress in mobile communication systems, the design of small and wideband antennas for mobile terminals is becoming very important. To reduce the antenna's size without deteriorating the antenna's performance, it is efficacious to use the case of a mobile terminal as a part of a radiator[1]. When a mobile terminal in slide form is equipped with a monopole-type antenna, it is known that the antenna becomes wideband on a certain condition[2]. However, the mechanism of the wideband behavior has not been revealed.

In this paper, a novel method of obtaining a wideband antenna for a slide mobile terminal by optimizing the conditions of the terminal case is proposed, and this method uses the resonance of a slide structure. The slide structure has two ground planes which overlap each other, and the upper and lower ground planes are connected by FPC (Flexible Printed Circuit). When a monopole-type antenna is used, the antenna can be treated as a series resonator. In addition, the slide structure can be treated as a shunt resonator. Therefore, a double resonance appears in the input impedance of the antenna, and the wideband characteristic is attained. The resonance frequency of the slide structure can be adjusted by changing the length of FPC and the capacitance between the upper and lower ground planes. This is verified by FDTD simulations.

2. The mechanism of the antenna using the resonance of a slide structure

Fig. 1 illustrates an antenna for a slide mobile terminal. GND 1 and GND 2 are connected by FPC to transmit electric signals. An antenna element (monopole) is put at the top of GND 1. Here, we treat the case where GND 1 is drawn from GND 2. Fig. 2 shows the input impedance which are calculated by the FDTD method. When \(l_f\) (the length of FPC) is 44mm, the relative bandwidth for VSWR \(\leq 3\) is 13.0%. On the other hand, at \(l_f = 59\)mm, a double resonance appears and the relative bandwidth for VSWR \(\leq 3\) is 23.6%. When a shunt resonance frequency \(f_r\) is defined as the frequency where the real part of the input impedance becomes a local maximum, \(f_r\) is 2.13GHz. In brief, by using the shunt resonance in addition to the series resonance of the monopole antenna, the wideband characteristic can be attained.

For searching the mechanism of the wideband behavior, consider the case where the antenna element is removed and the impedance between GND 1 and GND 2 is observed at port A (see Fig. 1). Since the antenna element electro-magnetically couples with GND 2, port A is placed just under the antenna feeding point. The calculated impedance between GND 1 and GND2 at \(l_f = 59\)mm is shown in Fig. 3. We define \(f_{r2}\) as the shunt resonance frequency of the impedance between GND 1 and GND 2. At \(l_f = 59\)mm, \(f_{r2}\) is 2.145GHz, thus \(f_r\) is almost equal to \(f_{r2}\). Therefore, it is found that a double resonance appears in the input impedance of the antenna and the wideband characteristic is attained because the slide structure consisted by GND 1, GND 2 and FPC resonates. Since GND 1 and GND 2 overlap each other in a slide mobile terminal, parasitic capacitance \(C_p\) is caused between two ground planes. Also, FPC causes inductance \(L_s\) between two ground planes, and the inductance increases with an increase in the length of FPC. Therefore, the resonance of the slide structure can be considered as a shunt resonator. The equivalent circuit of the proposed
antenna is shown in Fig. 4. Since the antenna element electro-magnetically couples with GND 2, we can consider that the shunt resonator (the resonance of the slide structure) and the series resonator (the resonance of the antenna element) are connected by a coupling coefficient $k$. The resonance frequency of the slide structure is expressed as

$$f_r = 1/(2\pi \sqrt{L_s C_s})$$

(1)

Hence, $f_r$ decreases with an increase in $L_s$ or $C_s$.

3. Calculated results

The above mechanism is validated by the FDTD simulations. Fig. 5 shows the dependence of the shunt resonance frequency on $l_f$. It is confirmed that $f_r$ is almost equal to $f_{r2}$ and the wideband characteristic is attained by the resonance of the slide structure. Moreover, the shunt resonance frequency decreases when $l_f$ increases, namely $L_s$ increases. Practically, a slide mobile terminal is not a simple structure as shown in Fig. 1, and other components such as a slide rail or shielding metals are put between GND 1 and GND 2. Since $C_s$ increases by adding these components, consider the case that a capacitor $C_1$ is put between GND 1 and GND 2 (see Fig. 1). Fig. 6 shows the dependence of the shunt resonance frequency on $C_1$ at $l_f = 49$mm. It is confirmed that $f_r$ is almost equal to $f_{r2}$ and the shunt resonance frequency decreases when $C_1$ increases, namely $C_s$ increases. In summary, the resonance frequency of the slide structure can be adjusted to a required frequency by changing $l_f$ or $C_1$.

4. Conclusions

We have proposed a novel method of obtaining a wideband antenna for a slide mobile terminal by optimizing the conditions of the terminal case. When a monopole-type antenna is used, the antenna can be treated as a series resonator. In addition, the slide structure can be treated as a shunt resonator. Therefore, a double resonance appears in the input impedance of the antenna, and the wideband characteristic is obtained. The resonance frequency of the slide structure can be adjusted by changing the length of FPC and the capacitance between GND 1 and GND 2. This has been verified by FDTD simulations.

![Figure 1: An antenna for a slide mobile terminal.](image-url)
Figure 2: Calculated input impedance of the antenna. (a) Smith chart ($Z_0=50\Omega$ at the center). (b) Return loss.

Figure 3: Calculated impedance at port A ($l_f=59\text{mm}$). (a) Smith chart ($Z_0=50\Omega$ at the center). (b) Resistance.

Figure 4: Equivalent circuit of the proposed antenna.
References