PROCEEDINGS OF ISAP2005, SEOUL, KOREA

A Novel Wideband Built-in Antenna with Resonance Frequency Variability for Digital Terrestrial Broadcasting

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1. Introduction

A digital terrestrial broadcasting service for mobile users which is to launch in Japan by 2006 will use the UHF band from 470MHz to 770MHz. From the viewpoint of external appearance of a mobile phone terminal, a built-in antenna has recently become a requirement in Japan and is also expected to apply as the antenna to receive the digital terrestrial broadcasting service. However, it is difficult to realize a built-in antenna for the UHF band because the wavelength of the UHF band is much longer than the length of a mobile phone terminal and a frequency bandwidth of an antenna generally becomes narrow if the antenna is small and built into a mobile phone terminal. Therefore, it is necessary to make the built-in antenna wideband. As a technique for reducing the volume of an antenna, the usage of the boards of the mobile phone terminal has been developed [1].

In this paper, we propose a novel antenna which is small due to the usage of the boards of the mobile phone terminal and the usage of a variable capacitance applied to the antenna element. Applying the variable capacitance, the resonant frequency of this antenna changes, so the antenna is expected to have a wideband performance. We calculated and measured the properties of the proposed antenna, and verified the availability of this antenna.

2. Proposed antenna

Figure 1 shows the overall view of the antenna model used in this work and Fig. 2 shows the enlarged view of this antenna. This antenna is located at the top of the upper board of a clamshell mobile phone, and the antenna element shapes a meander structure for a wideband property and a built-in structure, and the midpoint of the meander structure connects to the upper board through a variable capacitance. This antenna resonates at the frequency corresponding to the total length of the antenna elements and upper and lower boards. The resonant frequency of the antenna changes with the capacity of the variable capacitance.

3. Simulation results

First, we calculated the impedance characteristics of this proposed antenna with the variable capacitance. The calculation model of the antenna is shown in Fig. 3. The upper and lower boards of this antenna are composed of linear elements. The simulation tool is the NEC2 (Numerical Electromagnetic Code 2) based on the moment method. Impedance characteristics of the antenna were calculated in the frequency from 400MHz to 800MHz.

VSWRs of the antenna with the variation of the variable capacitance from 0.55pF to 2.3pF are shown in Fig. 4. Figure 4 shows that the frequency bandwidth of 310MHz (from 450MHz to 760MHz) can be obtained by the changes of the capacity of the variable capacitance although the frequency bandwidth of an antenna with fixed capacity 1.5pF is only 130MHz, where the frequency bandwidth is specified as VSWR<3.

4. Experimental results

Second, the proposed antenna was fabricated and measured in order to verify the properties of this antenna. A diode (Toshiba JDV2S17S) for the variable capacitance of the antenna was used. The experimental model antenna is shown in Fig. 5-(a) and the circuit around the variable capacitance diode is shown in Fig. 5-(b). In Fig. 5-(b), the symbol VD indicates a variable capacitance diode, the

ISBN: 89-86522-77-2 94460©KEES

symbol C1 a capacitor for filtering out the direct current for controlling the capacity of the variable capacitance diode, and the symbols L and C2 an inductor and a capacitor for filtering out the UHF band frequencies, respectively. The capacity of the variable capacitance diode changes from 0.75pF to 2.3pF corresponding to the control voltage from 5.5V to 0.5V.

4.1 Impedance characteristics corresponding to the capacities

The impedance properties of the experimental model antenna were measured with the variation of the capacities of the variable capacitance diode and the measured VSWR of the experimental model antenna are shown in Fig. 6. The comparison of Fig. 6 with Fig. 5 indicates that the property of the experimental model antenna is similar to that of the calculated one. And, it is found from Fig. 6 that the frequency bandwidth of 240MHz is obtained within 455MHz to 695MHz. The frequency bandwidth of the antenna is almost covered the UHF band of the digital terrestrial broadcasting.

4.2 Total losses of the experimental model antenna

For the experimental model antenna, we investigated the losses of the variable capacitance diode including the circuit around it by the method proposed in [2]. The total losses composed of the matching loss and the loss caused by the degradation of the radiation efficiency of the experimental model antenna were measured in the case that the capacity of the variable capacitance diode is 1.6pF, 1.2pF and 0.84pF, respectively. These values of the variable capacitance diode are corresponding to the control voltage of 1.5V, 3.0V and 4.5V, respectively. VSWRs of these cases are shown in Fig. 8-(a), and these measured total losses of the proposed antenna and the matching loss of a dipole antenna are shown in Fig. 8-(b). These measured total losses of the proposed antenna were compared with the matching loss of a dipole antenna, assuming that the radiation efficiency of a dipole antenna is 100% and the loss of a dipole antenna is only a matching loss. It is found from Fig. 8-(b) that the bandwidth of the proposed antenna of which the total loss is less than 2dB is wider than that of a dipole antenna.

5. Conclusion

We have shown the wideband property of the proposed antenna. Firstly, the impedance characteristics of the antenna by calculation were compared with that by measurement. It is found from the result that the impedance property of the experimental model antenna is similar to that obtained by calculation. Secondly, the impedance properties of the antenna were measured with the variation of the capacity of the variable capacitance diode. The result shows that the frequency bandwidth (VSWR < 3) is 240MHz (from 455MHz to 695MHz). Finally, the total losses composed of the matching loss and the loss caused by the degradation of the radiation efficiency of the experimental model antenna were measured. It is found from the result that the bandwidth of the proposed antenna of which the total loss is less than 2dB is wider than that of a dipole antenna.

The frequency bandwidth of the experimental model antenna can’t be covered the entire UHF range for the digital terrestrial broadcasting. It will be necessary to optimize the shape of the antenna element and to expand the variation width of the capacity of the variable capacitance.

In this paper, the control voltage was used from 0.5V to 5.5V. But the available voltage on a mobile phone is generally less than 3V. Therefore, it is necessary to examine this problem. Also, the losses of the proposed antenna need to be reduced. By using MEMS (Micro Electro Mechanical System) for the variable capacitance of the proposed antenna, the losses can be expected to reduce.

Reference

[1] Y. Nishioka et al., “One-Branch Diversity Antenna Construction Using Reactance Switching Circuit for Portable Telephones”, Proc. of the 2004 ISAP, Sendai, Japan, pp.1169-1172, Aug. 2004

[2] T. Maeda and T. Morooka, “Radiation efficiency measurement for small antennas using a new radiation characteristic measurement equipment”, Proc. of ISAP’89 JAPAN 4B2-2, pp.921-924

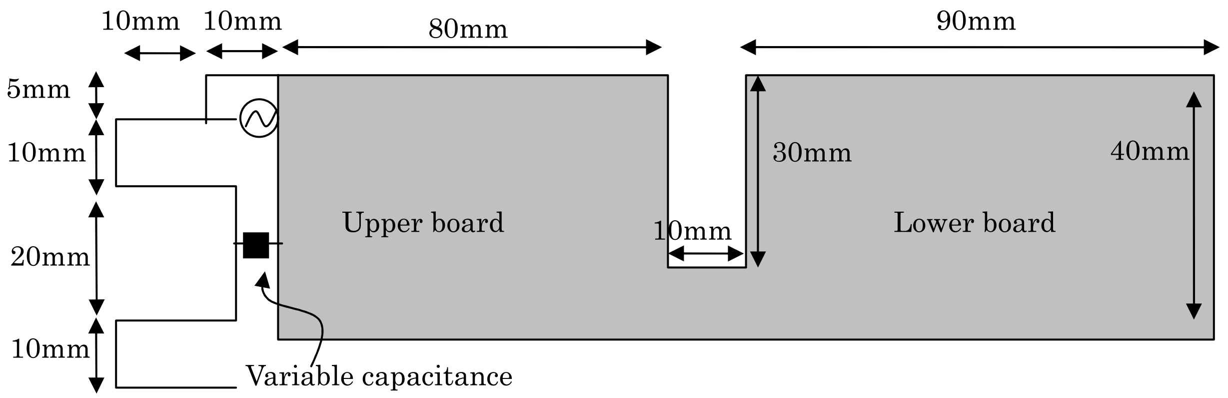
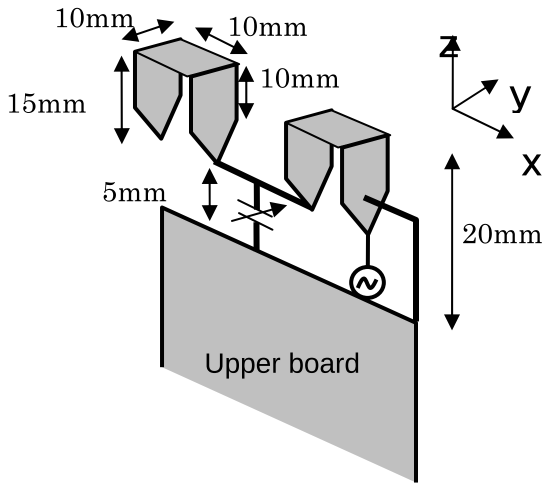


Fig. 1　Proposed antenna



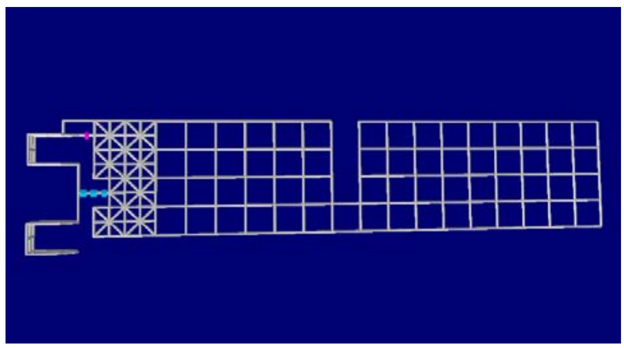


Fig. 2　Enlarged view of the proposed antenna　　　Fig. 3　Calculation model

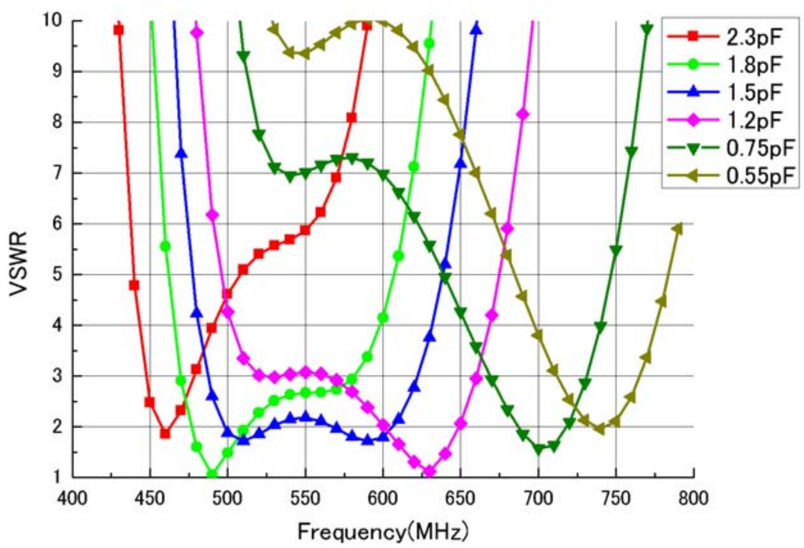
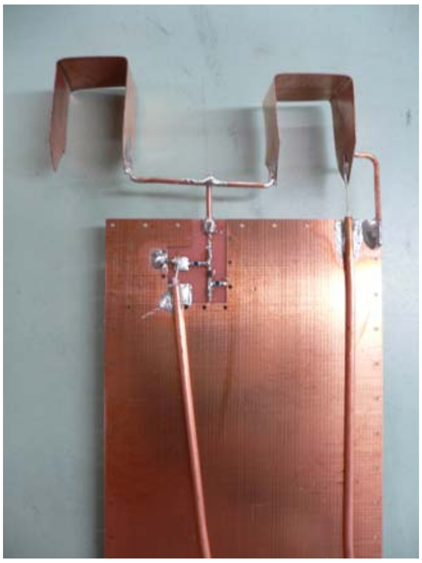
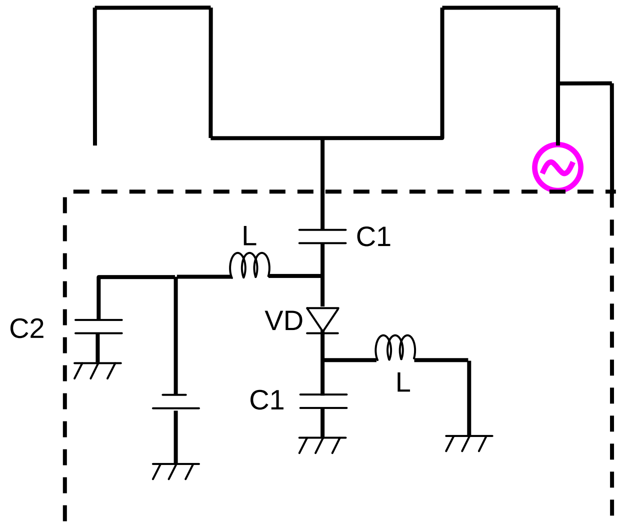


Fig. 4　VSWR of the proposed antenna (Calculation)



(a) Antenna element and circuit



(b) Circuit around the variable capacitance diode

Fig. 5 Experimental model antenna

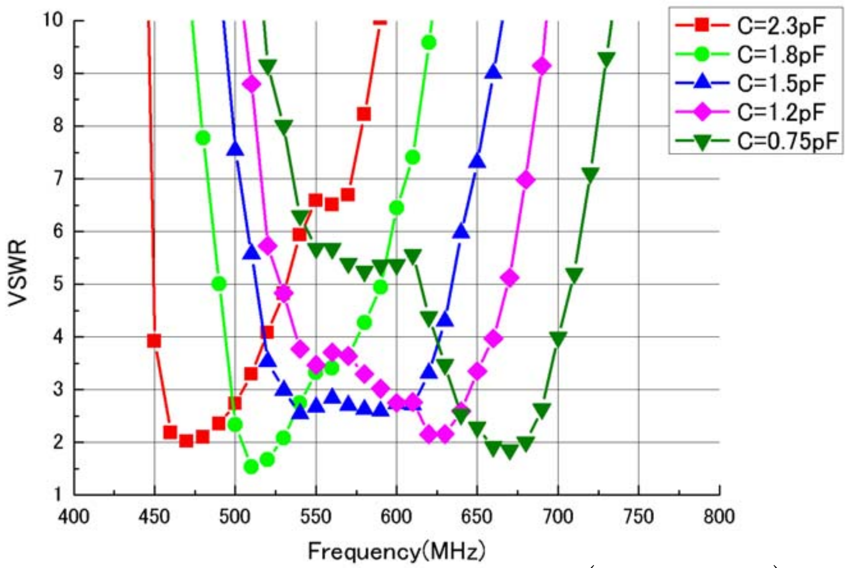
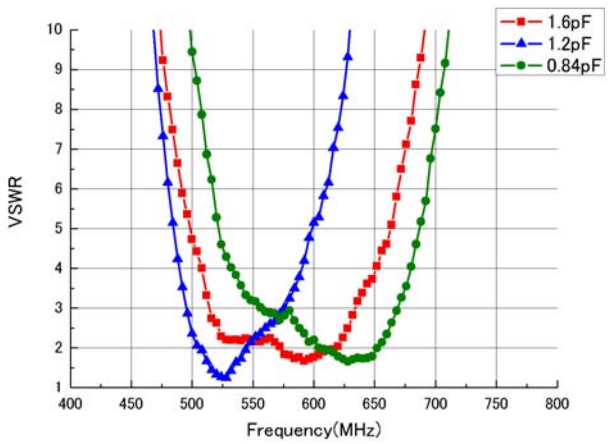
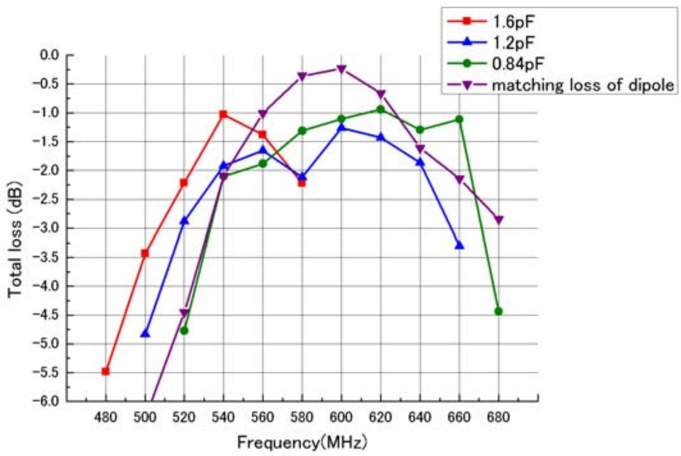


Fig. 6 VSWR corresponding to the capacities (Measurement)



(a) VSWR



(b) Total loss

Fig. 7 VSWR and total loss of the proposed antenna (Measurement)