An Analysis of the Performance of a Handset PIFA Influenced by an Operator's Finger Effect and its Mitigation Method

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1. INTRODUCTION

Because handset terminals operate in proximity to the human body, of particular interest involves the interaction of radiant electromagnetic (EM) fields with nearby biological tissue. The operator's influence on antenna performance, which includes a head, a hand, and a left shoulder effect, has been investigated theoretically [1]. The study indicates that significant gain reduction occurs when the antenna is used close to the human body, and approximately half of the transmission power is absorbed in the human body.

The effect of the human body depends on the type of antenna used; the effect of a head is dominant for an external whip antenna [2], whereas the effect of a hand holding the terminal becomes significantly large for a built-in antenna such as a planar inverted F-antenna (PIFA) [3] when the antenna approaches the hand. As for a built-in antenna, an operator's finger is a part of the human body that can affect the antenna characteristics since the finger may be placed directly on the top surface of the built-in antenna. This situation is illustrated in Fig. 1.

In such a situation, the finger could provide a different effect compared to the hand because the size of the hand (palm) is comparable to that of the antenna, resulting in the whole EM interaction between them, whereas the finger touches a part of the antenna element and thus makes the localized EM interaction, giving various different characteristics when a touching position is changed.

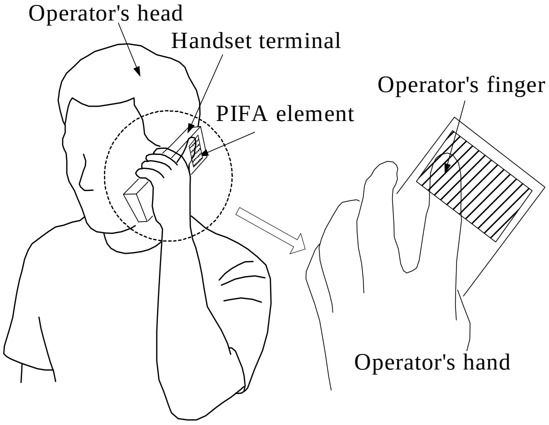

Fig.1 Finger is placed directly on the top surface of the built-in antenna

The purpose of this paper is to make a FDTD analysis of a built-in PIFA that includes the EM interaction of a finger of an operator. The analysis is carried out with regard to three different positions of a finger, and shows that a considerable change in the antenna performance is exhibited with regard to the touching positions of the finger. The results indicate that a significant improvement in the antenna gain can be expected by choosing a proper geometrical relationship between a PIFA and the finger. According to these analytical results, a noble method for mitigation of the gain reduction due to the finger will be presented.

2. PIFA AND FINGER MODELING

The PIFA model illustrated in Fig.2 is used in the FDTD calculation. In Fig.2, a ground plane is a cupper plate with the dimension of 110 mm x 40 mm. The PIFA element is placed to the top edge of the ground plane. The dimension of the PIFA element is designed so that the PIFA resonates at 900 MHz in free space. In that case, it is set to be 20 mm x 40 mm with some slits, and 6 mm height. A short-circuit element connects the PIFA element to the ground plane at their right corners of the top edges. The distance between a feed point and the short-circuit element is 5 mm. The impedance at the feed point is matched to 50 ohm at 900 MHz.

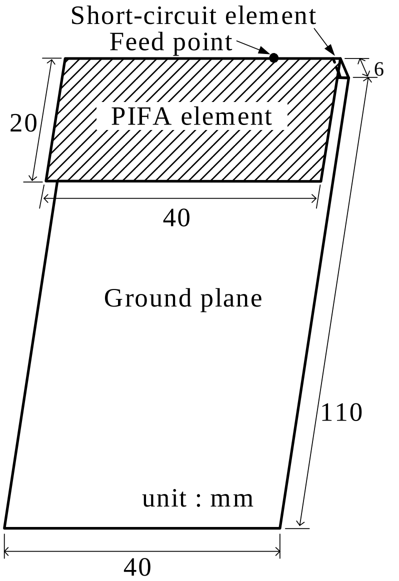

Fig. 2 PIFA model.

Figure 3 shows the calculation model of the PIFA with the finger. The finger consists of a rectangular dielectric with the dimension of 30 mm x 13 mm x 8 mm. The dielectric properties are set to be ε_r = 45, σ = 0.9 [S/m] [1].

In Fig. 3, (a), (b) and (c) correspond to the three positions of the finger. In the case of the position (a), the distance between the right edge of the finger and the short-circuit element is 27 mm. The distance is 13.5 mm in (b), and the finger is placed along the right edge of the PIFA in (c). In each case, the gap between the finger and the PIFA element is 1 mm.

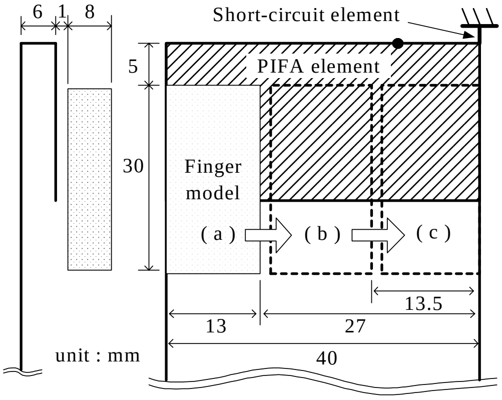

Fig. 3 Calculation model of the finger and the PIFA.

The model of the Fig.3 comprises about 270,000 cells in the FDTD calculation. The minimum size of the cubical cell is 1 mm. The antenna efficiency, the mismatch loss and the power absorbed by the finger are calculated in each position of the finger. The calculation is carried out by using the Fidelity software package [4].

3. RESULT

Figure 4 shows VSWR characteristics calculated by the FDTD method. In Fig.4, the resonant frequency of the PIFA is 900 MHz in free space (without finger). In the case of position (a), the resonant frequency is shifted to 810 MHz and VSWR at 900 MHz is 9.8. In (b) and (c), the resonant frequency is shifted to 870 MHz, and VSWR at 900 MHz is 2.4 to 2.0.

The relationship between the radiation efficiency, power absorbed by the finger and mismatch loss in each position is shown in Fig.5. In the case of position (a), the radiation efficiency is 23.5 % and the absorbed power is 10.5 %. The mismatch loss is very high value of 66 %, and this is caused by variation of the resonant frequency in Fig.4 (a). In the case of position (b), the absorbed power is extremely low, and the mismatch loss is 17 %. The high radiation efficiency of 80 % can be obtained in this position (b).

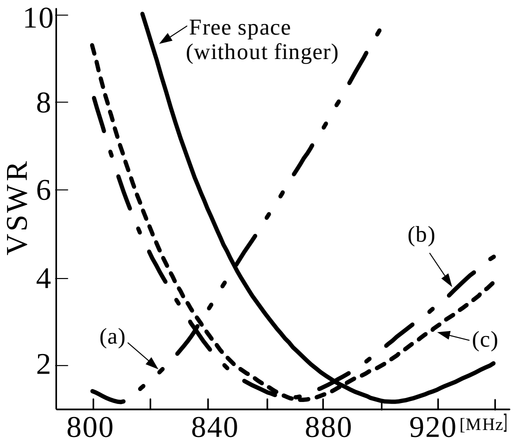

Fig. 4 VSWR characteristics (Calculation).

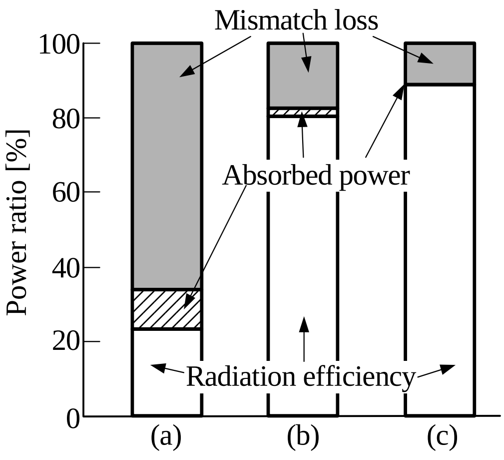

Fig. 5 Power ratio (Calculation).

Figure 6 shows the VSWR characteristics measured by using a finger phantom. Although there are some discrepancies in the measured and calculated VSWR a variation in the resonant frequencies for both cases agrees very well. From this, the effect of the finger on the resonant frequency has been confirmed by the experiment.

The variation mentioned above is related to distribution of electric field near the PIFA, which is illustrated in Fig.7. The broken line in Fig.7 is the relative distribution calculated by the FDTD method, and comprises the three components, E_x, E_y and E_z.

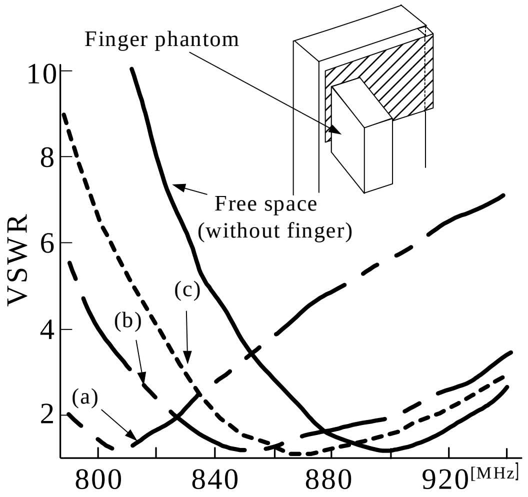

Fig. 6 VSWR characteristics (Measurement).

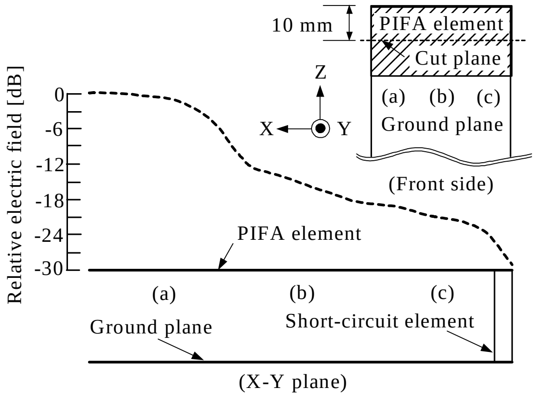

Fig. 7 Electric field distribution.

This result shows that the electric field is concentrated at the position (a), which is the high impedance edge of the PIFA element. When the finger is close to the position (a), the concentrated electric field is influenced by the finger, and the resonant frequency is shifted. The predominant factor of efficiency deterioration is the mismatch loss of 66 % in the position (a).

4. PROPOSAL FOR A MITIGATION METHOD

The results mentioned in the previous section suggest that tuning of the resonant frequency of the PIFA near the finger is an effective means to improve the efficiency. In this case, variable reactance devices with low loss are required for variable tuning of the resonant frequency.

Another means with switching of the short-circuit elements and feed points is shown in Fig.8. When the finger is close to the position (a), the SW2 should be shorted. On the other hand, the SW1 should be shorted when the finger is close to the position (c). If the finger is close to the position (b), whichever the SW1 or SW2 can be selected. The efficiency higher than 80 % can be obtained by this method.

5. CONCLUSION

The characteristics of the PIFA near the finger are calculated by using the FDTD method. When the finger is close to the high impedance edge of the PIFA, the efficiency deteriorates to 23.5 %. The predominant factor of efficiency deterioration is the mismatch loss of 66 %. An effective means to improve the efficiency, which comprises the switches of the short-circuit elements and feed points is proposed.

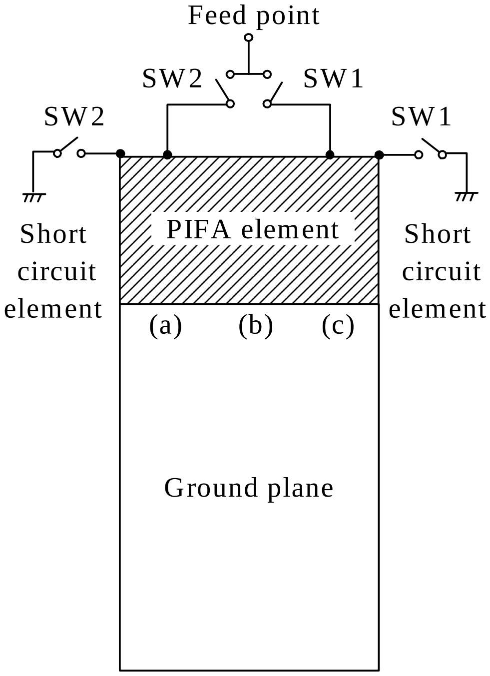

Fig. 8 Proposed structure with switches of the short-circuit elements and feed points.

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