Evaluation on Input Characteristics of MIMO Antenna for Mobile Terminal Gripped by Human Hand

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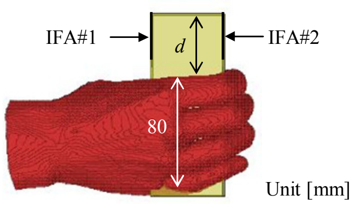
1. Introduction

In recent years, next generation systems have been actively studied to realize high speed and capacity data communication within mobile environments. MIMO (Multiple-Input Multiple-Output) systems are well known as a transmission technology that improves the quality of wireless links and enhances the system capacity within the limitary frequency band. This is because these systems with multiple antennas on the transmitter and receiver can perform parallel transmission at the same time and frequency by taking advantage of multi-path environment [1, 2]. In general, the characteristics of the antenna are influenced by a body of user. Recent studies showed that the presence of the hand in vicinity of mobile phones has more effects on the antenna performances rather than head [3, 4]. In the actual situations, the characteristics of MIMO antennas are also easily affected by the human hand [5]. However, relatively few studies have taken into account the influence of the human hand for evaluating the performance of MIMO antennas.

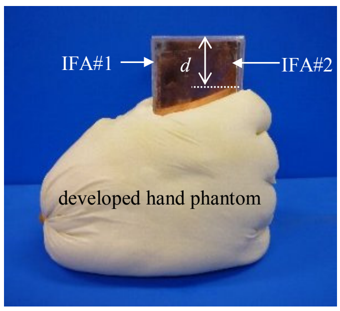
In this report, the interaction between IFA (Inverted F antenna) elements of a MIMO antenna for a MIMO terminal and a human hand is investigated by using an FDTD (Finite Difference Time Domain) calculation and measurement. The input characteristics which are reflection coefficients of the MIMO antenna gripped by hand model are calculated and measured when changing the distance between MIMO antenna and the human hand model.

2. MIMO antenna gripped by the human hand model

Figures 1 show the MIMO antenna model with acrylic case gripped by human hand on the assumption of practical use condition. In the evaluations, the reflection coefficients S_{11} and S_{22} of the IFA elements gripped by human hand model are calculated and measured when the distance d from the up edge of the ground plane to the human hand model changes to 0, 17.5, and 35 mm.



(a) Calculation model



(b) Measurement model

Figures 1: MIMO Antenna model with acrylic case gripped by human hand model.

2.1 Antenna configuration

Figure 2 shows the configuration of 2-branch MIMO antenna consisting of IFA elements for a mobile terminal. The IFA elements are designed to resonate at 2.0 GHz. The two IFA elements are mounted adjacent to the left edge of a rectangular ground plane of size 115 × 45 mm^2. The length and diameter of the IFA elements is 29 and 0.4 mm, respectively, where the length is corresponding to quarter-wavelength in 2.0 GHz. The distance between the short and feeding pins is 3 mm. IFA elements are arranged in parallel rows and the feeding point adjusted appropriately in order to match the input impedance to 50 Ω. The distance between two antennas is 45 mm; corresponding to 0.3-wavelength 2.0 GHz [6]. The whole antenna is in an acrylic case (thickness : 1.0 mm, electrical properties are ε_r= 2.1, σ = 0.0 S/m).

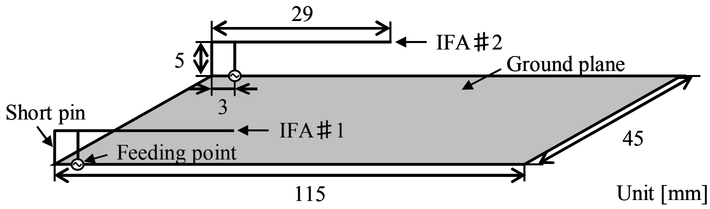


Figure 2: Configuration of 2-branch MIMO antenna consisting of IFA elements.

2.2 Human hand model

The relative permittivity and conductivity of the human hand model are equivalent to 2/3 times those of the real human muscle in 2.0 GHz, where ε_r= 36.0, and σ = 1.0 S/m, respectively [7]. In the calculation, the human hand model was created by employing the Poser® software [8]. The width of the hand is 80 mm. Then, it was converted to 0.5-mm resolution volume data and imported into the finite-difference time-domain (FDTD) program.

Human hand phantom has developed by authors [9]. As a first step of fabrication, we grounded the 2/3-muscle solid phantom into like a clay. Then, we packed the ground 2/3-muscle solid phantom in a latex glove. As for the dimension of the glove, its length of each finger from thumb to little finger is 50.0, 70.0, 85.0, 75.0 and 55.0 mm, respectively. The thickness of the rubber is 0.06 mm. The hand phantom incorporates plastic joints to achieve the flexibility of the fingers and the palm. The target values of the dielectric properties are set to be 2/3-muscle equivalent at 2.0 GHz. Table 1 shows the composition of the 2/3-muscle equivalent solid phantom employed in this research [10]. The measured electrical properties of the 2/3-muscle model are shown in Figure 3. According to Figure 3, the electrical properties of the fabricated phantom are ε_r= 36.0 and σ = 1.04 S/m. The target value of electrical properties of the phantom are ε_r= 36.0 and σ = 1.00 S/m. It is clear that the measured relative permittivity and conductivity are within ± 5 % difference of the target values. There is no influence on the antenna performances with such different errors.

Table 1 Composition of the 2/3-muscle model.

Material	Amount[g]
Deionized Water	3,375.0
Agar	104.6
Polyethylene Powder	1,012.6
Sodium Chloride	7.0
TX-151	30.1
Dehydoroacetic Acid Sodium Salt	2.0

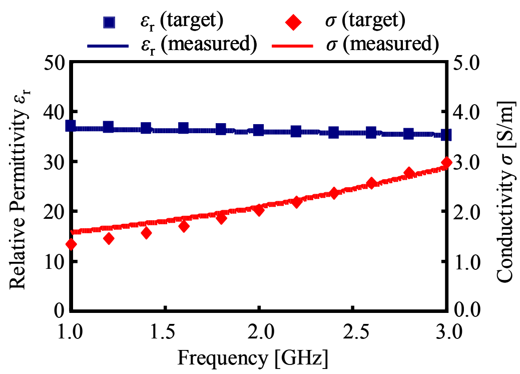
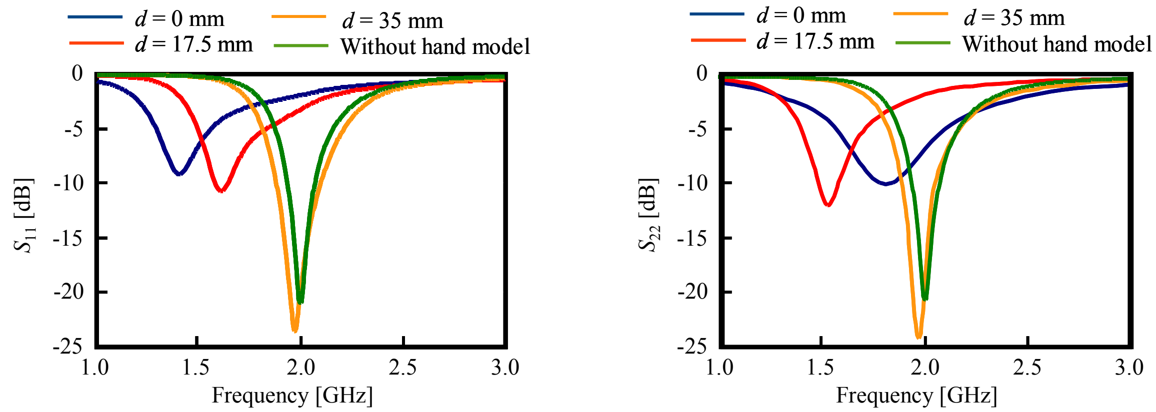


Figure 3: Electrical Properties of 2/3-muscle model.

3. Analytical method and results

Figures 4 (a) and (b) show the calculated reflection coefficient of the IFA element #1 and #2 of the MIMO antenna, S_{11} and S_{22} gripped by the human hand model, respectively. As the hand model locates so close to the antenna, that the both resonant frequencies of IFA element shift to low frequency and the reflection coefficients S_{11} and S_{22} at the resonant frequency are degraded. As the distance d becomes smaller, the resonant frequency of the IFA element #1 got lower, but the resonant frequency of the IFA element #2 got lower except when the d is 17.5 mm. About the reason why S_{11} is different from S_{22}, we consider that an affected finger is different from IFA element #1with IFA element #2. Figure 5 shows the change of resonant frequency by the distance from the up edge of the ground plane to the human hand model. According to figure 5, it's also confirmed an affected hand model is different from IFA element #1with IFA element #2.



(a) IFA element #1 (b) IFA element #2

Figures 4: Reflection coefficient when the distance between the antenna and the hand model changes.

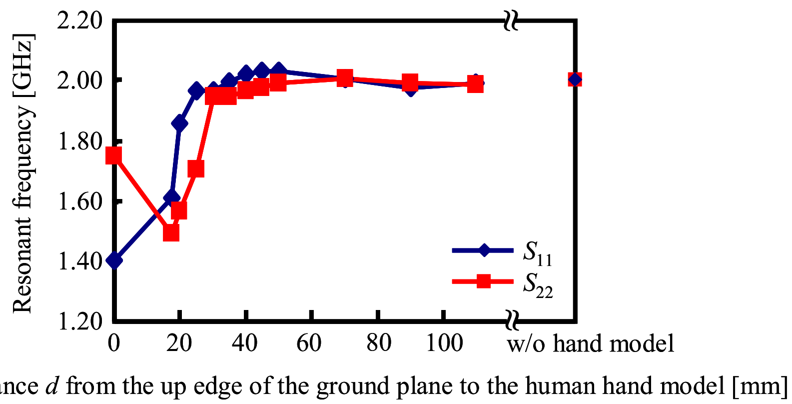
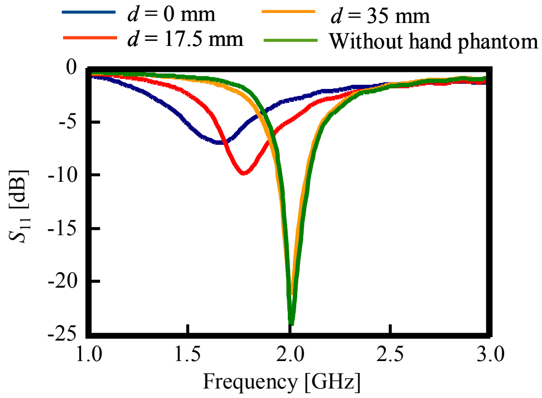


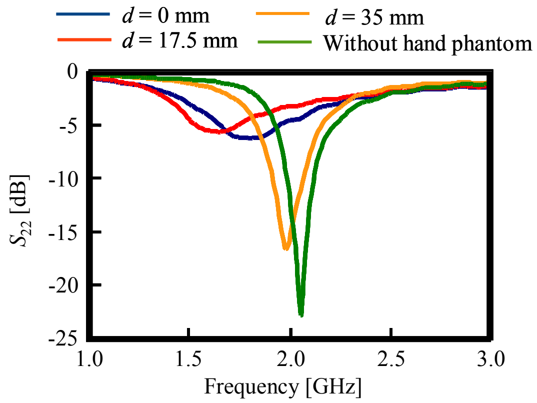
Figure 5: Resonant frequency when the distance between the antenna and hand model changes.

4. Measurement model and results

In order to verify the analytical method, the measurement of the developed MIMO antenna and hand phantom [8] was carried out. The shape of hand phantom is uniformed the human hand model. Figure 6 shows the measured reflection coefficient S_{11} and S_{22} of the IFA gripped by the developed hand phantom. It is compared measurement result of S-parameter of the antenna gripped by developed hand phantom and calculated result. As a result, good agreement is observed between the measured and calculated results of both of the reflection coefficients.



(a) IFA element #1



(b) IFA element #2

Figure 6: Reflection coefficient when the distance between the antenna and the hand phantom changes.

4. Conclusion

In this report, the interaction between the MIMO antenna and the human hand was investigated and the influence of the antenna characteristics was evaluated by calculation and measurement when the antenna was gripped by the human hand model. As a result, MIMO antenna input characteristics are influenced by human hand. Moreover, the influence of the antenna characteristics by human hand is varied by human hand is positioned.

As a further study, channel capacity of MIMO antenna close to human hand model including radio propagation will be evaluated in the near future.

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