x3 Scale-Model Experiments on a Slot-Based Directivity Control Built-In Antenna Sytem for Mobile Terminals

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1. Introduction

In the field of mobile communication, the used of Multiple-input Multiple-output (MIMO) systems to increase channel capacity has received increasing attention in recent years. In these systems, antennas play an important role, since antenna's radiation characteristics are inherently included in the communication channel between the transmitter and the receiver. Especially, the increased mutual coupling between built-in antennas will affect the radiation efficiency and correlation of the antennas. To reduce mutual coupling and correlation between antennas, element-separation of more than half wavelength is required [1]. However, small sized terminals will often be required in real applications and limited space makes element-separation difficult to achieve.

Therefore, the authors proposed a new configuration adding switch-able slots on a ground plane for a mobile built-in antenna [2]. A switch is placed at the end of each slot to control the radiation pattern of the antenna system while maintaining the stable impedance characteristics of the antenna. Also, a human hand is assumed to be placed in the vicinity of the proposed mobile built-in antenna; thus, the effects of the human hand on the antenna's radiation characteristics need to be investigated.

In this paper, a validation of the antenna's radiation characteristics by measurements of both impedance and radiation pattern is presented. The measurement results for the antenna radiation efficiency including the human hand phantom are also shown at the end of this paper.

2. Antenna structure

Figure 1 shows the physical structure of the proposed antenna system. The physical dimensions of the ground plane are modeled by the general size of mobile terminals. The antenna system is assumed for 2x2 MIMO usage. Thus, two Planar Inverted F Antenna (PIFA) are placed on the ground plane with a resonant frequency of 2.6 GHz considering the use in the LTE band(2.5-2.7 GHz). A slot is cut at the edge of the ground plane to control the radiation pattern of the antenna. The length of each slot is set to quarter wavelength (to simulate stab function) and each slot serves to control the current distribution of the RF current on the ground plane in order to change the radiation patterns of the antenna sytem. The locations of the slots are chosen to be where a higher level of RF current is flowing in contrast to a lesser one in order to realize the effective alternation in the radiation patterns of the antenna system.

3. Radiation pattern and VSWR measurements

Figure 2 shows the fabricated antenna used during the radiation pattern and impedance measurements. To increase the accuracy of the measurements, the x3 scale model from existing literature [2] is used. Furthermore, since there is a known problem with the interconnection between the feeding point and the coaxial cable when measuring small built-in antenna [3], a SMA receptacle is used at the bottom of each feeding point to realize a firm and stable connection to a coaxial cable, which is disconnected during the calibration procedure for the vector network analyzer. All measurements were done in an anechoic chamber and the results are compared with the calculated results obtain by the Finite-Difference Time-Domain (FDTD) method.

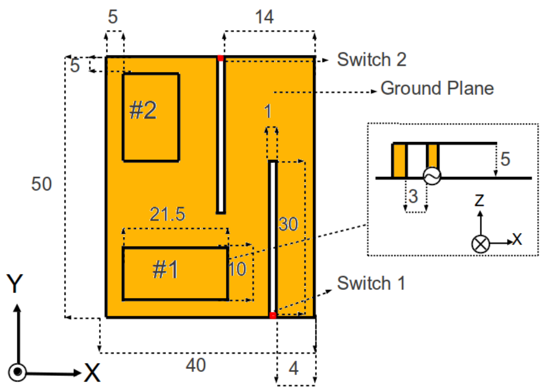

Figure 1: Structure of antenna system

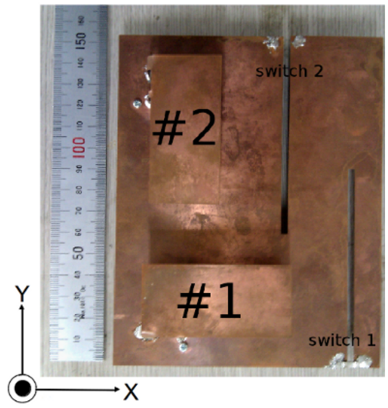

Figure 2: x3 scale model of antenna system

Measurement results for the antenna radiation patterns for all switch conditions are shown in figure 3 and 4. VSWR measurement results for all switch conditions are also shown in figure 5 and 6 respectively. As shown in these figures, the radiation patterns are altered effectively depending upon each switch condition, whereas the resonant frequencies of both antenna #1 and antenna #2 in VSWR are maintained stably for all switch conditions.

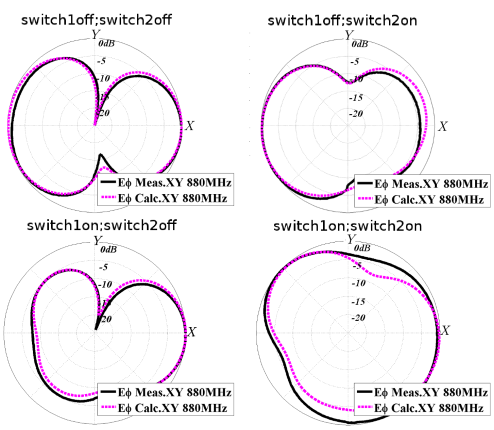

Figure 3: Radiation Patterns: Antenna #1.

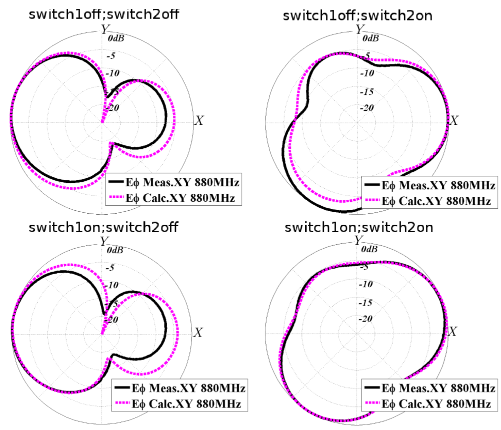

Figure 4: Radiation Patterns: Antenna #2.

4. Human hand phantom and radiation efficiency measurement

In this section, a human equivalent phantom with 2/3 of the electrical parameters of human muscle was modeled in the FDTD simulation in order to assess the effects of a human hand on the antenna radiation characteristics. Figure 7 shows three models of a human hand holding the proposed antenna system: 1) Model 1 represents a holding position for data mode usage, 2) Model 2 corresponds to a case where the index finger is closer to antenna, and 3) Model 3 has more space between fingers in comparison to Model 1. Table 1 summarizes the calculated results for antenna #1's radiation efficiency for all switch conditions.

To confirm the calculated results for antenna #1 of the proposed antenna system, measurements were performed with a non-metallic spherical scanner placed in an anechoic chamber. Considering the size of the phantom and limited space on the azimuth table, a unit scale (x1) antenna system was used combined with a unit scale (x1) human hand phantom for these measurements, as shown in figure 8. Also, the entire measurement set-up is shown in figure 9.

The measured results for antenna #1 are summarized in table 2. The calculated and measured results for antenna #1's radiation efficiency show a difference of around 10-20%. Model 2 exhibits the lowest radiation efficiency no matter what the switch conditions are. One of the possible causes for this is that

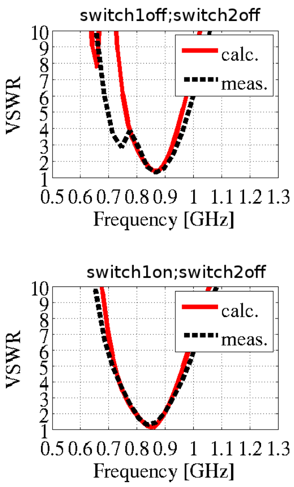

Figure 5: VSWRs: Antenna #1.

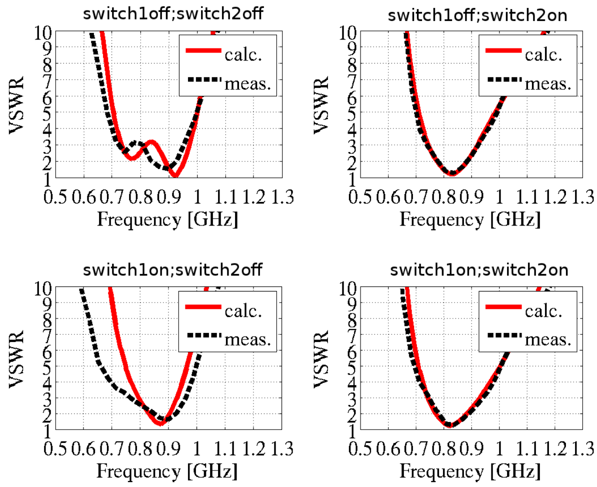

Figure 6: VSWRs: Antenna #2.

the index finger in model 2 is placed closer to the antenna in comparison to the other models. Radiation efficiencies for Model 1 and 3 fluctuate but show minor difference between the two.

Table 1: Radiation efficiencies: Antenna #1 (calculated).

Switch Condition	Model 1 Eff.	Model 2 Eff.	Model 3 Eff.
switch1on;switch2on	64.0	58.5	64.8
switch1off;switch2on	72.7	67.9	71.2
switch1on;switch2off	64.6	56.8	65.2
switch1off;switch2off	73.4	66.7	72.4

Table 2: Radiation efficiencies: Antenna #1 (measured).

Switch Condition	Model 1 Eff.	Model 2 Eff.	Model 3 Eff.
switch1on;switch2on	68.1	62.2	68.6
switch1off;switch2on	59.6	50.3	55.3
switch1on;switch2off	53.4	51.2	56.4
switch1off;switch2off	58.4	51.2	56.4

5. Conclusion

A x3 experimental scale model is used to assess the effectiveness of the proposed slot-based directivity control built-in antenna system. Both the radiation pattern and VSWR measurements for the antenna system show good agreement with the simulated results. It was confirmed that the proposed antenna system has switch-able radiation patterns while maintaining stable impedance characteristics. Also, radiation efficiency of the proposed antenna system was assessed for Antenna #1 including the effects of a human hand phantom.

Acknowledgments

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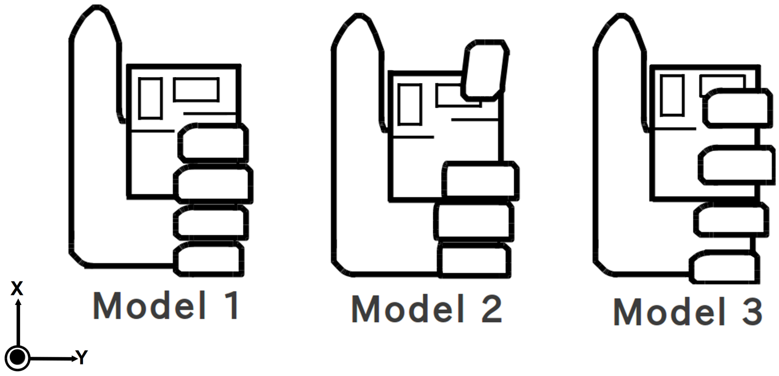

Figure 7: Three models for the human hand.

Figure 8: Antenna system with a phantom.

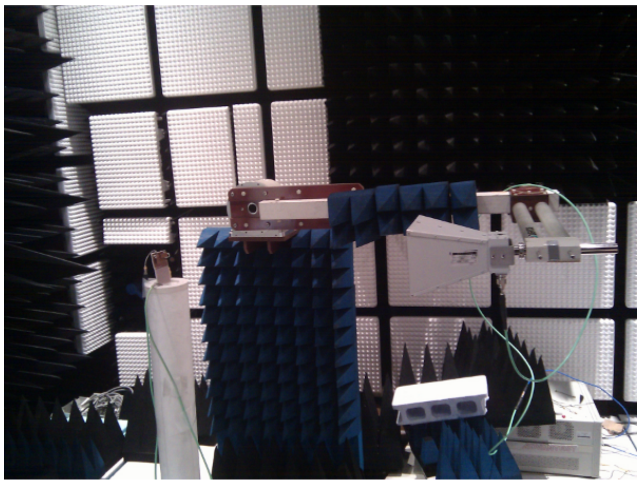

Figure 9: Measurement set-up.

References

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