

Radiation Power Measurement Method of Mobile Device Using Field Simulator

Mitsuhiro Tsukamoto and Hiroyuki Arai
Graduate School of Engineering, Yokohama National University
79-5, Tokiwadai, Hodogaya-ku, Yokohama-shi, 240-8501 Japan
E-mail: tsukamoto, arai@arailab.dnj.ynu.ac.jp

1. Introduction

It is necessary to evaluate the characteristics of antenna built-in mobile devices because their emission characteristics are changed due to the device size and the antenna mounting position. Several methods have been proposed so far as for measuring the antenna built-in radio equipment, i.e. the pattern integration method inside anechoic chamber [1], the random field method (RFM) measured under real propagation environment [2], Wheeler cap method [3], the method with compact shield box [4] or with the reverberation chamber [5] and the partial spherical scanning method with a reflector [6] etc.

These techniques have the demerit that the measuring frequency and antenna structure are limited. Moreover, there is the demerit that large scale facility is necessary to move the rotator. We propose an electric power measurement method by simple facility to overcome these demerits. We should decrease the influence of the antenna directivity in the measurement to evaluate the radiation power of antenna built-in mobile devices. To decrease the influence of the antenna directivity and to measure with easy equipment without rotators, it is possible to apply the field simulator which has been used to measure the effect of antenna diversity for radiation power measurement [7].

This paper shows the configuration of a proposed measurement system in the next section. Then, we discuss the size of measurement area inside shield box to neglect the influence of antenna directivity of the mobile device. Finally, we carry out the simulation considering the effect of the phantom to simulate the antenna in realistic environment and we conclude in section 4.

2. Basic simulation of Field simulator

In this section, we show the system configuration of the field simulator and simulation results of radiation power measurement to reduce the influence of directivity of mobile device. Figure 1 shows the configuration of the proposed field simulator. We describe a procedure of field simulator in the following. First, E-field generated from mobile device (Tx) with the transmitting frequency of 2GHz is received with multi antennas arranged along the wall inside the shield box. Second, we change phases of received voltage obtained in each receiving antenna with phase shifter at random. Finally, we obtain CPDE (cumulative probability distribution of the electric field) by synthesizing outputs from each receiving antenna at every phase. It is an easy measurement system, because neither rotator nor moving components are used. It is necessary to achieve the measurement environment that the electric power of the coming wave is randomly distributed like outdoor to decrease the influence of the directivity. This is evaluated by the CPDE with the Rayleigh distribution.

Next, we examine the radiation power measurement of the mobile device taking into the influence of the antenna directivity. In this simulation, we use a metallic cube, the length of each side being 5λ . We calculate the excitation voltage of the receiving antenna by using the Ray-trace method. Figure 2 shows the CPDE obtained for the antenna arranged in appropriate locations. From this result, Rayleigh environment is given in the metallic shield box because CPDE is close to the Rayleigh distribution. Figure 3 shows the CPDE obtained when the directivity of the transmission

antenna is changed inside the box and Table 1 shows those median values. We change antenna directivity to cardioid, and dipole. These median values are almost the same each other, which shows the proposed power measurement is provided not depending on the antenna directivity.

At last, we examine how the area where the radiation power can be measured without depending on antenna directivity is distributed inside the shield box. These receiving antennas Rx1, Rx2 and Rx3 are fixed as shown in Fig. 4, only transmission antenna is moved, and we calculate the area where the CPDE similar to Rayleigh distribution in the box. Fig. 4 shows the range that the transmission antenna moves inside the region of $\lambda \leq x \leq 3.9\lambda$, $\lambda \leq y \leq 5\lambda/2$ and $2.5\lambda \leq z \leq 2.7\lambda$, considering about the symmetry of antennas arrangement. The CPDE close to the Rayleigh distribution is obtained in the area inside the cube as shown in Fig. 5 and the maximum area in this result is 7λ in the direction of y axis. The result shows that the enough area to measure the radiation power without depending on antenna directivity inside shield box.

3. Simulation result with the effect of phantom

We showed in preceding section that the Rayleigh distributions are obtained by the field simulator. In this section, we simulate the field simulator with phantom arranged in the box because we want to simulate in realistic propagation environment. Figure 6 shows the configuration of a proposed measurement system. We increase the number of the receiving antenna from three to four and arrange these antennas to four sides of the cube to simplify the power dividers used at experiment and to improve uniformity of the reception E-field. The phantom is arranged in a metallic shield box and the dipole antenna (Tx) as a radiation source is arranged in the vicinity of the hand of phantom. The E-field radiated from the dipole antenna is received with multi monopole antennas arranged along the wall. The model of the lightweight phantom for the simulation uses low density wave absorber [8]. HFSS and MATLAB are used for this calculation and the frequency in the simulation is 1.85GHz.

In this simulation, we decide the arrangement of receiving antennas at first, because the CPDE changes most depending on these parameters, then we change the size of box to decide its optimum size. It has already described in section 2 to obtain Rayleigh environment for the cube, the length of each side being 5λ . We design the box length being smaller than 5λ because the existence of phantom disturbs the electric field distributions. Transmission and receiving antennas are arranged inside the box as shown in Fig. 6, where the receiving antennas are fixed to Rx1, Rx2, Rx3 and Rx4, respectively. The width y and height z of the box is fixed to be 50 cm, and only depth parameter d is changed. Table 2 shows the RMS (root mean square error) of the electric power probability distribution compared with the theory of Rayleigh distribution for d being 40 to 100 cm in every 10 cm. The threshold of RMS is set to 0.001, and if the value obtained by the calculation is smaller than this threshold, the CPDE is considered equal to Rayleigh distribution. The value of d is decided as 50 cm to satisfy this threshold from the results in Table 2, and Fig. 7 shows this distribution which is very close to the Rayleigh one.

At last we examine the relation between the number of antenna and simulation result and show that four antennas or more are necessary to achieve the Rayleigh distribution. The shield box is a cube with the 50 cm each side length, and we use the receiving antenna arrangement as shown in Fig. 6. Table 3 shows the RMS of CPDEs calculated for two antennas. The obtained CPDE as shown in Fig. 8 shows that two antennas are not enough to obtain Rayleigh distribution.

4. Conclusion

We proposed radiation power measurement method of mobile device with field simulator which is easier equipment compared with conventional techniques. In the basic simulation, we obtained the Rayleigh distribution with a field simulator using the small shield box. In addition, we simulated the performance with phantom arranged inside the box to show that the Rayleigh distribution was also obtained by this measurement.

References

- [1] K.S.Yee, IEEE Trans. Ant. Prop., 14(3), pp. 302-307, May 1966
- [2] J.Andersen and F.Hansen, IEEE Trans. Vehicular Technology, vol.26, pp.349-357, 1977-11
- [3] O. Litschke, et al., International ITG Conference on Antennas, Berlin, September 2003
- [4] H.Arai, et al., IEICE Trans., J81-B-2(7), pp.691-698, July 1998 (Japanese)
- [5] P. S. Kildal, iWAT 2007, Cambridge, UK, 2007
- [6] T.Yamada, et al., ISAP 2007, Niigata, Japan, 2007
- [7] N.Igi and H.Arai, AP, pp.1-8, Japan, 1994 (Japanese)
- [8] H.Yamaguchi, et al., APMC, G2-3, Hong Kong, Dec. 2008

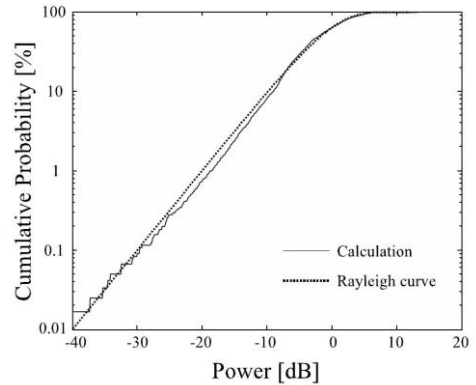
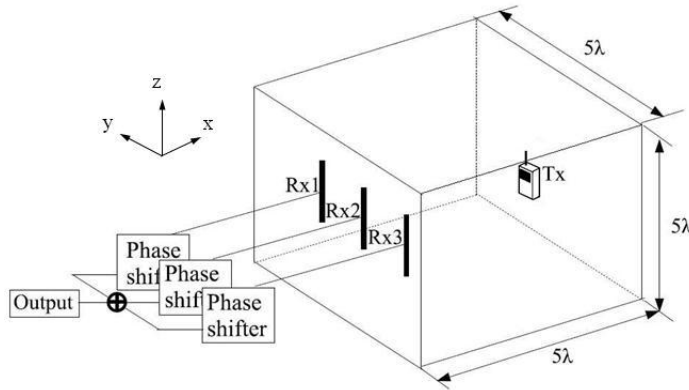


Figure 1: Configuration of proposed measurement system

Figure 2: CPDE

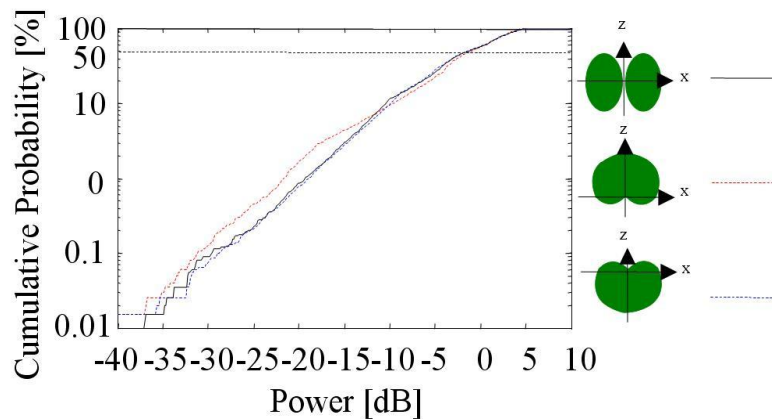


Figure 3: Probability for different antenna directivity

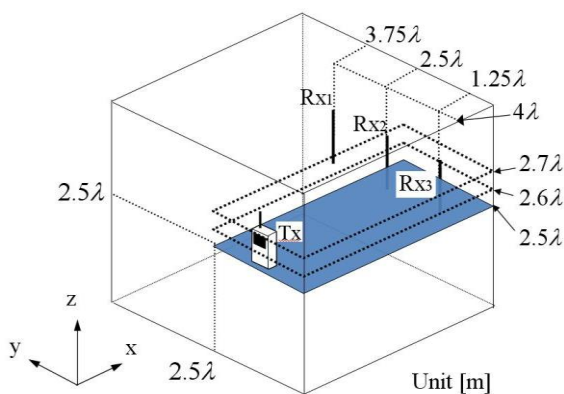


Figure 4: Observation area of Tx

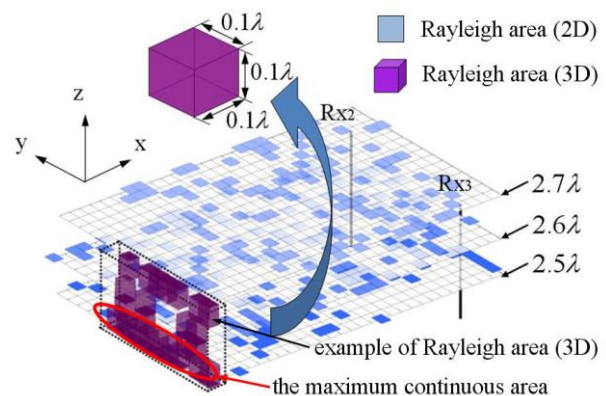


Figure 5: Rayleigh fading area

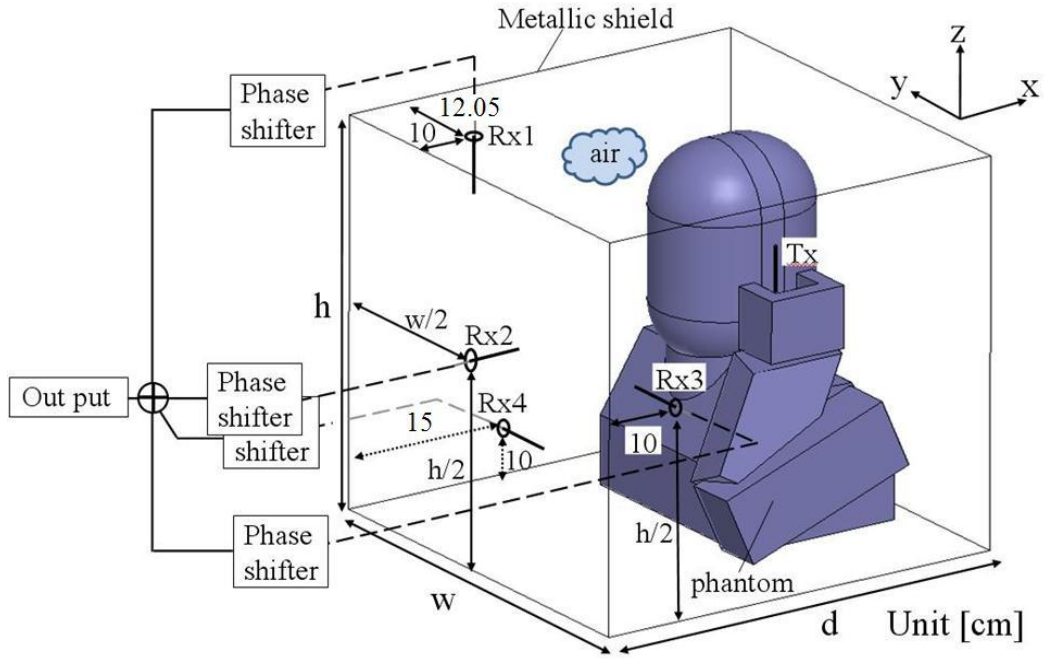


Figure 6: Configuration of proposed measurement system with phantom

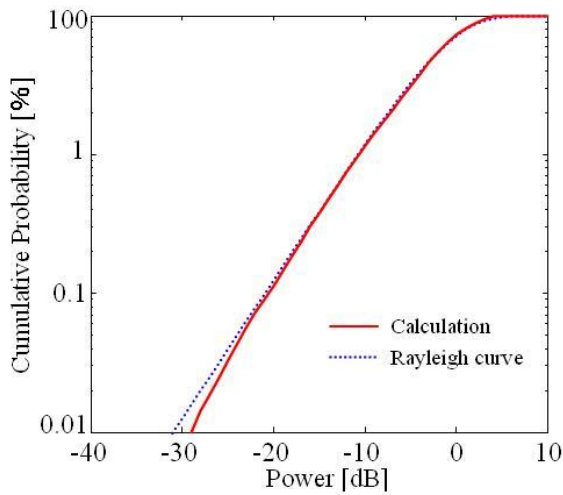


Figure 7: CPDE (four antennas)

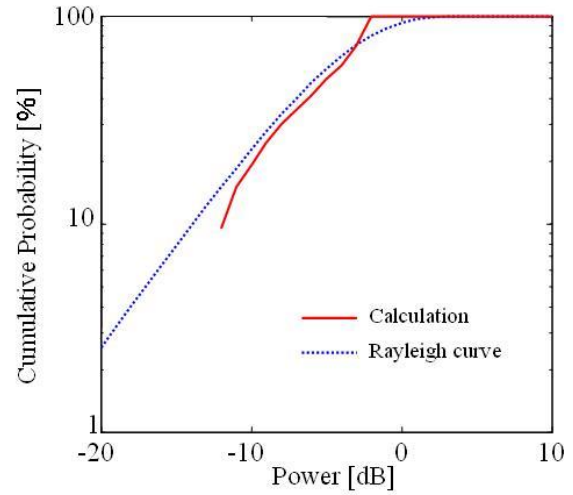


Figure 8: CPDE (two antennas)

Table 1: Median values of results in Fig.3

antenna pattern	dipole	cardioid (z+)	cardioid (z-)
median value [dB]	-1.23	-1.03	-1.23

Table 2: RMS for various box depths

d [cm]	40	50	60	70	80	90	100
RMS	0.0118	0.0098	0.0537	0.0476	0.0144	0.0260	0.0181

RMS: root mean square error

Table 3: RMS by the combination of two antenna positions

combination	Rx1,Rx2	Rx1,Rx3	Rx1,Rx4	Rx2,Rx3	Rx2,Rx4	Rx3,Rx4
RMS	0.0501	0.0452	0.0490	0.0468	0.0494	0.0478

RMS: root mean square error