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**MIMO Performance Evaluation in a Street Microcell
Using a Spatial Fading Emulator
in Comparison with a Radio Propagation Test**

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MIMO Performance Evaluation in a Street Microcell

Using a Spatial Fading Emulator in Comparison with a Radio Propagation Test

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Abstract

This paper presents effectiveness of a RF-controlled spatial fading emulator on MIMO performance evaluation in a street microcell environment in comparison with a radio propagation test. The fading emulator can produce a radio propagation environment with a uniform and non-uniform angular power spectra (APS) in the horizontal plane. In this paper, we measured MIMO characteristics of four handset arrays in a multipath environment with one cluster by the emulator. From this, good agreement between the results obtained by the emulator and experimental data of a radio propagation test in a street microcell reveals the emulator to be effective in evaluating the handset MIMO performance in a multipath environment. The study presented in this paper was conducted under the collaboration between Tokyo Institute of Technology, Japan and Panasonic Corporation, Japan. The propagation test presented here was performed under the collaboration among Aalborg University, Denmark and Panasonic Corporation and Panasonic Mobile Communications Corporation, Japan.

1. Introduction

The RF-controlled spatial fading emulator [1, 2] has been proposed to be one of the promising candidates for a MIMO over the air (OTA) testing of incoming 3G-LTE and IMT-Advanced. The emulator can directly produce multipath radio propagation environment by radio waves emitted from scattering units arranged around a handset tested. Moreover, the emulator has an advantage of measuring radiation characteristics of a handset antenna for the present OTA testing in 3GPP as well as the multipath testing because of its RF operation [3].

This paper presents effectiveness of the RF-controlled spatial fading emulator on MIMO OTA testing in a street microcell environment in comparison with experimental data of a radio propagation test. Handset arrays tested and their radiation characteristics are shown in section 2. Each handset array has two monopole antennas and thus, we can evaluate 2-by-2 MIMO characteristics. In section 3, the experimental conditions of the propagation test are described. The propagation test was conducted in a central area of a downtown in Aalborg city in Denmark [4]. The experimental parameters of the OTA testing using the emulator are presented in section 4. Finally, section 5 presents the measured results of 2-by-2 MIMO of the propagation test and the OTA testing. From this, the effectiveness of the emulator was confirmed by the propagation experiment.

2. Handset array for 2-by 2 MIMO testing

Fig. 1 shows four handset arrays tested. Each handset has two monopole antennas and a ground plane with a size of 90 mm by 45 mm, and is operated at 2.35 GHz. The handset A, shown in Fig. 1(a), has two planer antennas and their feeding points are set far away from each other. The handset B, shown in Fig. 1(b), has also two planer antennas but their feeding points are set closely to each other. With regard to the handset C, shown in Fig. 1(c), two line-type antennas are set far away from each other. The handset D, see Fig. 1(d), has a set of two line-type antennas with a spacing of 3 mm between centers of the two antennas.

Figs. 2(a) and 2(b) show radiation efficiencies and spatial correlations between the antennas, respectively. It is found from Fig. 2 that the handsets B and C exhibits both good radiation efficiency and low correlation, and that the handset D has the worst radiation efficiency and the highest correlation. It is predicted from these facts that the handsets B and C give a good MIMO performance and the handset D has the worst MIMO characteristics.

3. Experimental condition of MIMO radio propagation test in an urban area

Fig. 3 shows a test site of MIMO propagation test in an urban area of Aalborg city, Denmark [4]. As shown in Fig. 3, the propagation test was performed in four sub routes. Almost buildings have a height of more than 15 m. The base station, shown as a blue circle in Fig. 3, was set near the test route and had a horizontal linear array with two elements set parallel to the sub route II. Fig. 4(a) depicts the radio propagation test. Height of the base-station array was set at 14.5 m. Thus, all the sub routes were under a non-line of sight (NLOS) condition. The antenna element of the base-station array has a half-power beam width of 85 degrees in the horizontal plane and 6 degrees in the vertical plane, and its maximum gain is 16.5 dBi in the 2.3 GHz band. Each base-station element transmitted vertically-polarized wave with power of 33 dBm. The handset was set at a height of 1.5 m from the ground and was inclined at 40 degrees from the vertical, as shown in Fig. 4(b). In the propagation test, the handset was moved on a car trailer at a speed of about 20 kilometers per hour. The sampling frequency was 100 Hz, and the number of the snap shots was 4300 for each sub route. In this paper, we evaluate the experimental data of the sub route I. The sub route I has buildings along the both sides. Thus, in the sub route I, propagation paths mainly came from in the moving direction so that spatial distribution of the propagation paths is modeled as one cluster coming from in the moving direction of the handset.

4. Experimental parameters in MIMO OTA testing by a spatial fading emulator

In this section, experimental parameters of MIMO OTA testing of the handsets by using the emulator are described. Fig. 5 shows an experimental setup of the spatial fading emulator and arrangement of the scattering units. The emulator contains 31 scattering units that are composed of two half-wavelength dipoles crossing at right angles in order to represent a cross polarization power ratio (XPR). The radius of the circle of the emulator is 1.5 m. The handset was inclined at 40 degrees from the vertical, in the same orientation as the handset in the propagation experiment.

Angular power spectrum (APS) of incoming waves in the horizontal plane is modeled by a Laplacian distribution as following equation in the same manner as the spatial channel model (SCM) of 3GPP [5].

$$\Omega_L(\phi) = \frac{1}{2\sigma} \exp\left\{-\frac{|\phi - \mu_\phi|}{\sigma}\right\} . \quad (1)$$

According to the SCM of the 3GPP, σ was set at 35 degrees. μ_ϕ was set at 0 in the same condition of the propagation test. For the 2-by-2 MIMO evaluation, the waves transmitted from the scattering units have different set of initial phase for different incoming waves transmitted from different base-station antennas so that correlation between the transmitted signals is almost 0. The XPR was set at 9 dB [4]. Radio frequency was 2.35 GHz. Doppler and sampling frequencies were 25 Hz and 500 Hz, respectively. Moving distance of the handset was 1600 wavelength of the radio frequency so that the number of the snap shots was 32,000.

The theoretical open-loop Shannon capacity, C_s , of an M-by-M MIMO system of the s-th snap shot is given as follows [6]:

$$C_s = \log_2 \left| I_M + \frac{SNR}{M} HH^H \right| \quad [\text{bits/sec./Hz}], \quad (2)$$

where $|A|$ denotes the determinant of A, H is a channel matrix that is an $M \times M$ complex matrix, and I_M indicates the identity matrix of dimension $M \times M$. The average channel capacity is given by the following equation:

$$\bar{C} = \frac{1}{S} \sum_{s=1}^S C_s \quad [\text{bits/sec./Hz}], \quad (3)$$

where S is the number of the snap shots.

5. Comparison between measured results of the OTA testing and the propagation experiment

Fig. 6 shows average received powers of the handset arrays in the propagation test and OTA testing using the emulator. The received power in the propagation test was averaged along the sub route I, and the received power of the OTA testing was averaged by all the snap-shot data. Each received power was averaged by two received powers obtained by two antennas of the array. Moreover, the received powers were normalized to a mean value among the four handsets. It is observed from Fig. 6 that the received powers of the OTA testing are in good agreement with those of the propagation test. Furthermore, the handsets B and C have a large received power and the handset D exhibits the smallest one, similarly to the radiation efficiencies shown in Fig. 2(a).

Fig. 7 shows fading correlations between signals received by the handset arrays. In Fig. 7, both the data of the propagation test and the OTA testing are plotted in comparison purpose. As can be seen in Fig. 7, the correlations measured by the emulator agree well with those obtained in the propagation test. Moreover, the correlation of the handset C is the lowest among those of the handsets. This result agrees with the spatial correlations, shown in Fig. 2(b).

Fig. 8 shows the 2-by-2 MIMO channel capacities of the handset arrays. Average input signal to noise power ratio (SNR) was defined as a ratio of average signal power received by all the four handset antennas to noise power for each measurement. In the calculation, the input SNR was set at 30 dB. From Fig. 8, the emulator is effective in evaluating the MIMO channel capacity by the agreement between the capacities obtained from the emulator and the propagation test. It is concluded from this that the emulator can evaluate MIMO performance of handset array under a multipath condition with one cluster in the same way as a radio propagation test.

6. Conclusion

Comparison between MIMO performances in a radio propagation test and an OTA testing using the RF-controlled spatial fading emulator was presented. Evaluation of handset MIMO antennas was

conducted under a multipath environment with one cluster. From the agreement between MIMO characteristics in the both cases, the emulator is effective in evaluating handset MIMO arrays in the case of a multipath fading environment with one cluster.

References:

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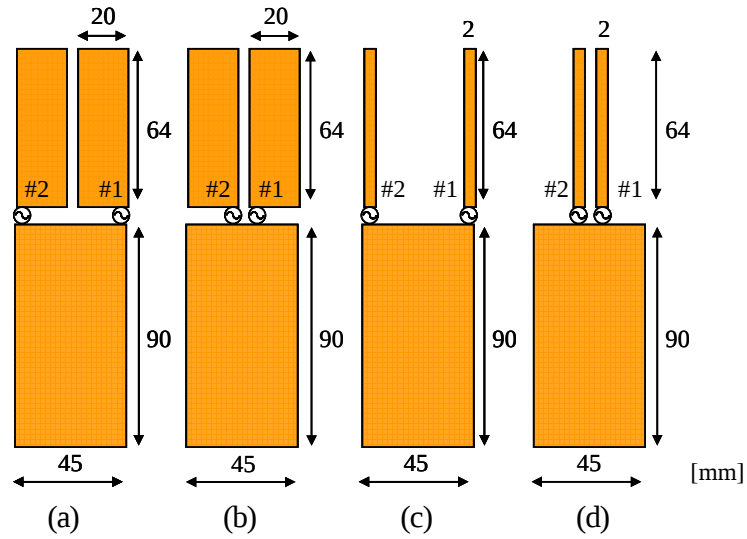


Fig. 1 Handset arrays with two monopole elements.

(a) Handset A. (b) Handset B. (c) Handset C. (d) Handset D.

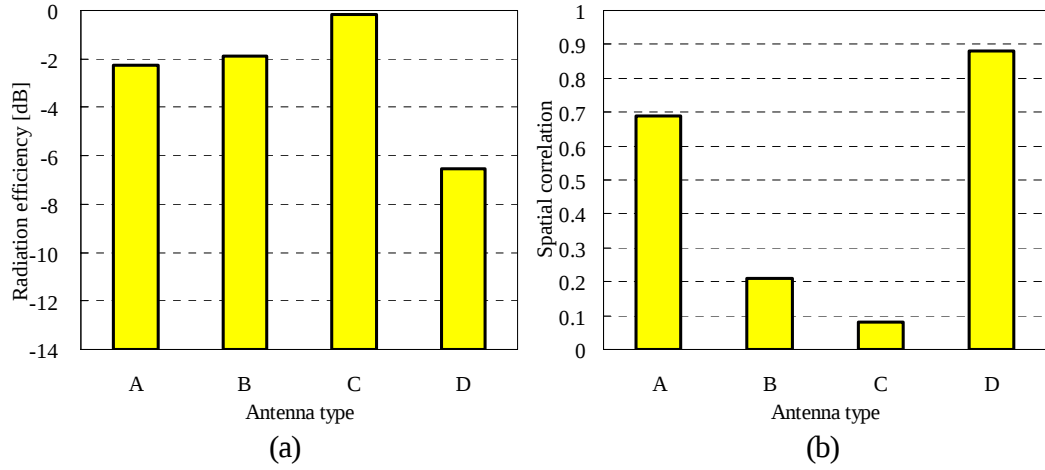


Fig. 2 Radiation efficiencies and spatial correlations of the four handset arrays at 2.35 GHz.

(a) Radiation efficiencies. (b) Spatial correlations.

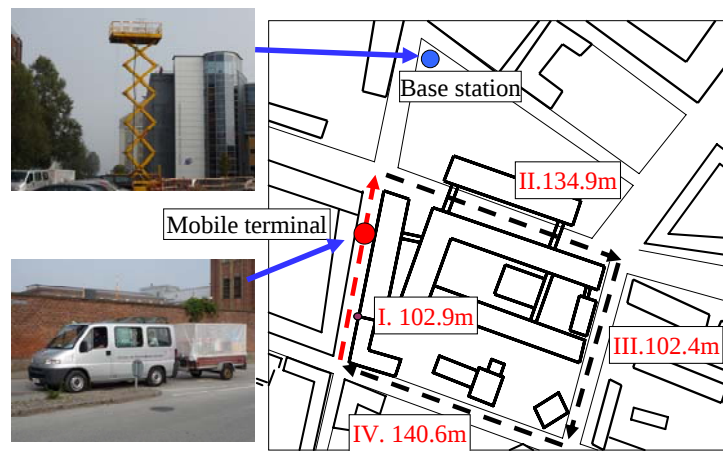


Fig. 3 Test site of MIMO propagation test in urban area of Aalborg city, Denmark.

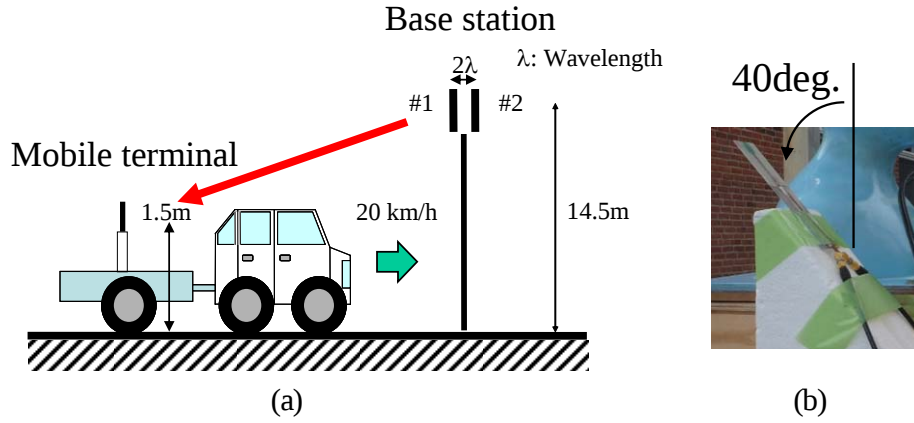


Fig. 4 Outdoor MIMO propagation test. (a) Propagation test. (b) Handset situation.

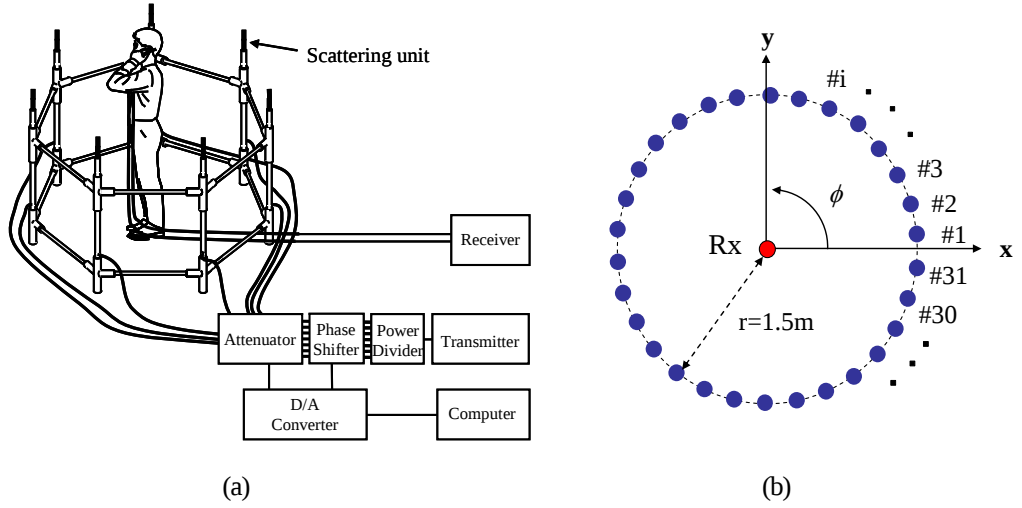


Fig. 5 Experimental setup of the spatial fading emulator.

(a) Experimental setup. (b) Arrangement of the scattering units.

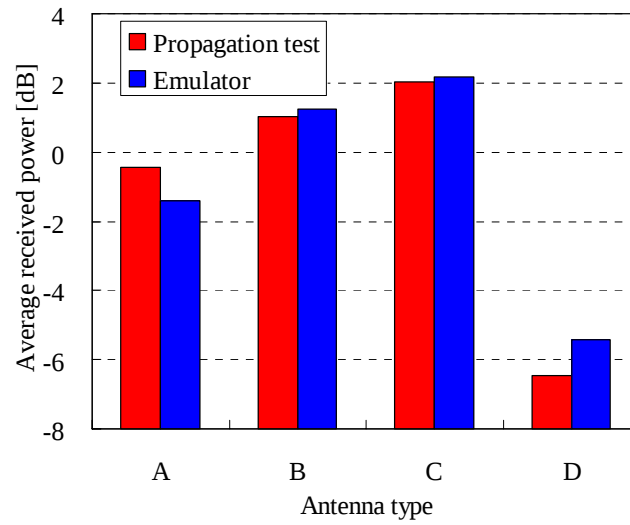


Fig. 6 Average received powers of the handset arrays in the propagation test and OTA testing using the emulator.

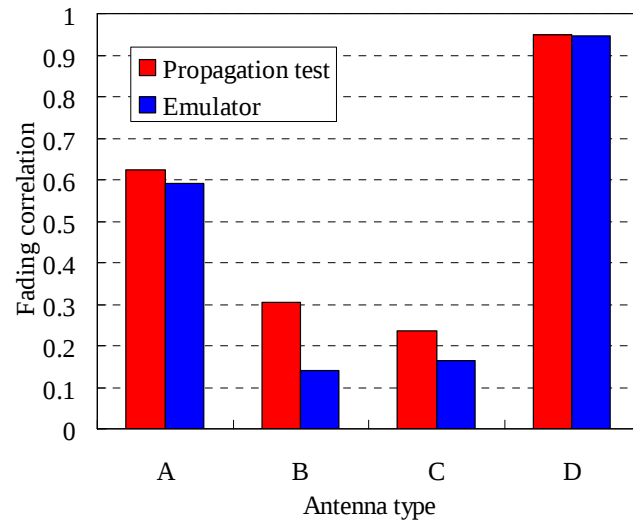


Fig. 7 Fading correlations between signals received by the handset arrays.

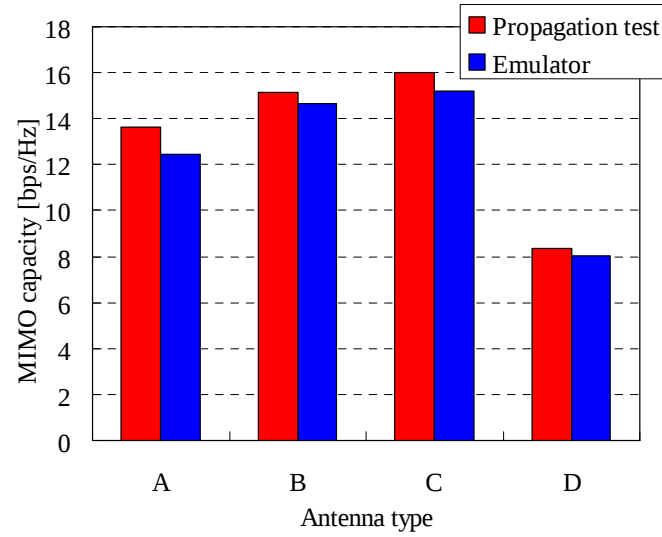


Fig. 8 2-by-2 MIMO channel capacities of the handset arrays.