A Fading Generator Using Rotated Scattering Slots

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Abstract

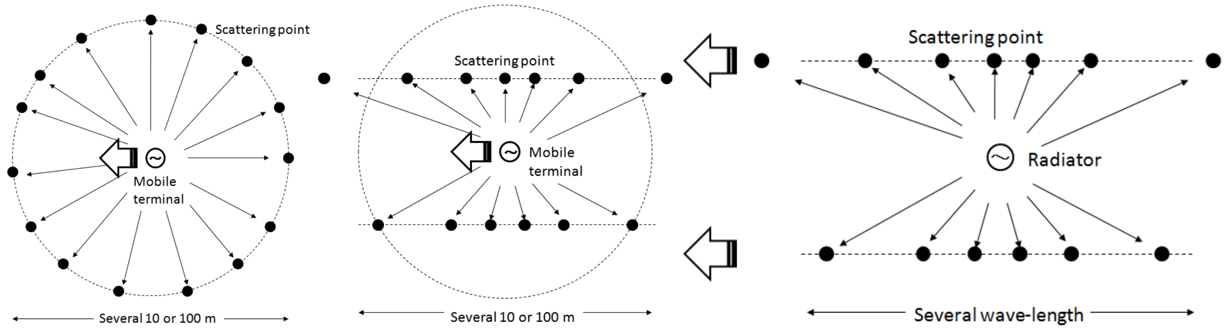
MIMO-OTA (Over-the-air) measurement methods of mobile terminals have been recently studied and developed for mobile communications. However, the methods like these for base station antenna have not been often reported. A fading generator using rotated scattering objects has been proposed in my previous study in order to establish an OTA measurement method for MIMO base station emulating radio environment around the base station. This fading generator is based on a near-field Jakes scattering model that is modified from the conventional Jakes model. Although metal patches on the dielectric disc as scattering objects is used to obtain fading waves in the study, slots on the metal disc are newly adopted as scattering objects in order to get the same waves. In this paper, the validity of the proposed generator is clarified by experiments using a prototype.

1. Introduction

Some antenna measurement methods by using random field have been proposed [1][2]. Especially, MIMO-OTA measurement methods of handy terminals have been recently studied and developed for mobile communications [3]. On the other hand, the methods like these for base station antenna have been rarely reported because it is difficult to measure any radiation properties due to its length and specific radiation patterns [4]. If the above methods with conventional fading simulators are employed for the base station measurement, too many fading simulators are needed to emulate the angle spread of coming waves. Therefore, it is impossible to emulate a measurement environment easily. A fading generator using scattering objects has been proposed to generate many fading waves in my previous study in order to overcome this problem. In this paper, another fading generator using scattering slots is newly proposed to establish an OTA measurement method for MIMO base station emulating radio environment around the base station.

2. Scattering Model and Principle

A scattering environment around a mobile terminal is often expressed by the Jakes model like Figure 1(a). This model can be modified to Figure 1(b) when the mobile terminal moves through the street. Rayleigh fading can be also obtained using this model. Figure 1(c) indicates a modified near-field Jakes model that is the principle of the proposed fading generator. This is similar to the modified Jakes model of Figure 1(b). However, the arrangement of scattering points and the distance between radiator and scattering points are quite different from the modified Jakes model. This can be recognized as near-field scattering problem although the modified Jakes model is treated as far-field. Scattering points move to the left side on each straight line. The interval of scattering points is set at random. Each scattering wave has different phase, different Doppler shift and different angle to the radiator. Therefore, the sum of all the scattering waves becomes Rayleigh fading if a direct wave from the radiator does not exist. On the other hand, Nakagami-Rice fading is realized if a direct wave is large.



(a)Jakes model (far-field) (b) Modified Jakes model (far-field) (c) Modified near-field Jakes model

Fig.1: Principle of the proposed fading generator that scattering objects are located at very near from radiator.

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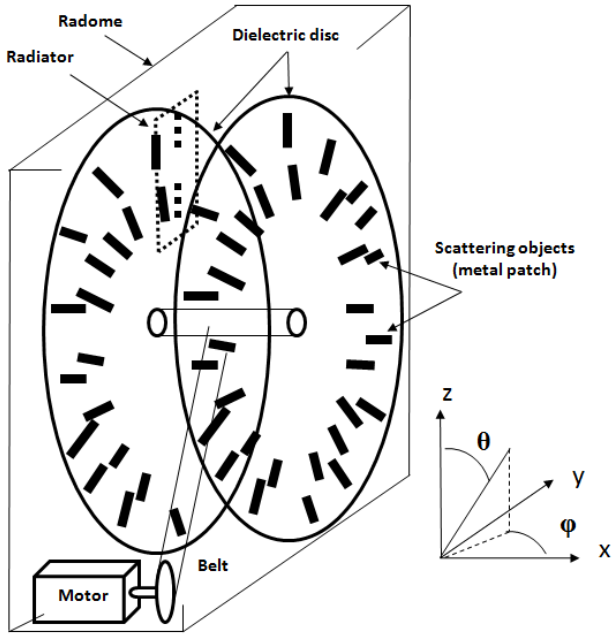
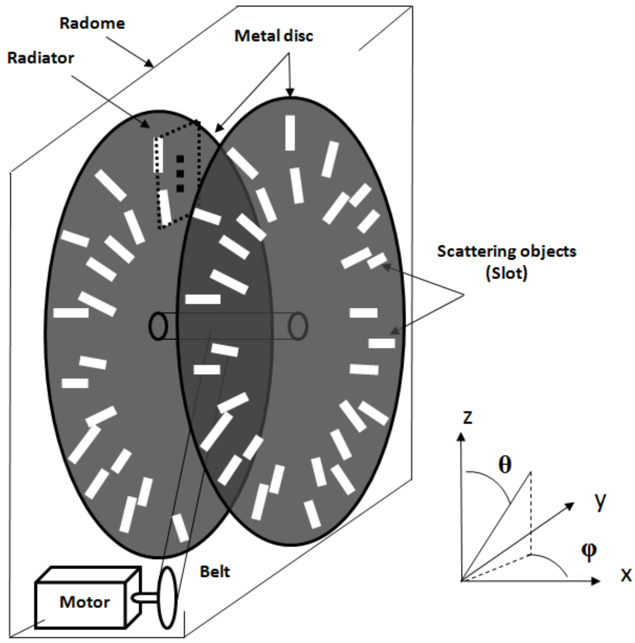
3. Configuration of Fading Generator

Configuration of the fading generator to materialize the principle is illustrated in Figure 2. Figure 2(a) and Figure 2(b) indicate the conventional fading generator and a proposed fading generator, respectively. Each fading generator consists of a radiator, scattering objects on two discs, and a electric motor driving the discs. The conventional has metal patches on the dielectric discs as scattering objects and 2-element dipole array antenna as a radiator. On the other hand, the proposed has slots on the metal discs as scattering objects and a dipole antenna as a radiator. These two generators have different polarization properties if the shapes of scattering objects are same. Since all the components do not have directional properties, these generators can be used for both transmission and reception experiments.



(a)



(b)

Fig.2: Configuration of fading generators rotated scattering patches on the dielectric discs. (a) Generator of patch type (Conventional). Scattering objects are metal patches. (b) Generator of slot type (Proposed). Scattering objects are slots on the metal discs.

3.1 Scattering Patch and Slot

Scattering objects must move near the radiator at high speed in order to materialize the principle of generator. Rotatable dielectric discs having metal patches are set in the conventional generator (Figure 2(a)). The length of each patch is approximately half-wavelength at operating frequency. The patches are located randomly like a double ring on the disc as shown in the figure. The discs are rotated in order to move scattering patches at high speed. Even if the discs are rotated, several scattering patches always exist and move near the radiator. Therefore, scattering waves are continuously radiated from the patches. When the directivity of scattering patches is omni-directional, scattering waves propagate to all the directions. On the other hand, we replace the metal patches on the dielectric discs to the slots on the metal discs to realize the proposed generator. Although a direct wave can easily propagate through the dielectric discs between the patches in the conventional generator, a wave from the radiator is blocked by the metal discs in the proposed generator. This blocking effect creates the environment that the scattered waves from many slots are dominant against the direct wave. Therefore, a Rayleigh fading wave can be received in the x direction especially.

3.2 Radiator

There are 2 types of radiator according to the scattering objects. One is 2-element dipole array antenna type with a phase shifter for the metal patch generator. Another is dipole antenna type for the slot generator. The 2-element array is used to control the direct wave strength in the horizontal direction to vary the fading properties by using the phase shifter. If the array antenna is fed in co-phase, the direct wave from the array radiator is dominant against scattering waves. On the contrary, the scattering waves become larger than the direct wave if the phase difference between two elements is 180 deg. Thus, the array radiator is able to vary the direct wave easily by changing radiation pattern in the horizontal plane. In other words, the patch type of generator using 2-element array radiator is able to control the fading properties by varying phase shifter. On the other hand, the array antenna as a radiator is not needed for the slot type of generator because of the blocking mentioned above to obtain a Rayleigh fading wave. Thus, a simple dipole antenna is employed to the slot type of generator. If necessary, the slot type of generator can have different fading properties by shifting the position of the radiator.

3.3 Driving Equipment

The period of generated fading waves is very short if these 2 discs of the generator rotate at the same speed. For example, the period of fading waves is only 27 ms when rotating speed is 20 m/s near the radiator. In order to overcome this problem, the speed of one disc is set to be slightly different from that of another disc. In this paper, one disc speed is set to 1.04 times against another one in order to avoid short fading period. Employing different speed, the fading period becomes 0.7 sec that is 25 times against conventional structure.

4. Prototype and Experiments

Specifications and a photograph of prototype fading generator are shown in Table 1 and Figure 3, respectively. Experiments to confirm the validity of the proposed method were carried out by using the prototypes in anechoic chamber. An 8 GHz band horn antenna connected to a receiver was employed and the prototype connected to signal generator was used as a transmission antenna. Figure 4 indicates results of received power on both types of prototype. Horizontal axis is receiving time. Vertical axis means received power normalized by each maximum power. Green line and red line indicate the data of the patch type and that of the slot type, respectively. The phase difference of array radiator on the patch type of generator is set to 180 deg. It is found that some deep fading points are observed on both generators from this figure. Figure 5 indicates Doppler shift frequency of above observed waves on the slot type. It is found that received spectrum spreads when the scattering slots rotate although a transmitting signal is CW. From these figures, it is confirmed that the proposed method is valid for a fading generator.

Table 1: Specifications of Prototype Fading Generator

Type of generator	Patch type	Slot type
Scattering element	Metal patch	Slot
Disc material	Dielectric	Metal
Radiator	2-element dipole array	Dipole
Phase shifter	Yes	No
Frequency and signal	8.45 GHz, Continuous wave	
Length of element	18 mm (λ/2)	
Width of element	2 mm	
Number of elements	64	
Speed of element	20 m/s (72 km/h)	
Diameter of dielectric disc	200 mm	
Period of fading wave	0.7 sec	

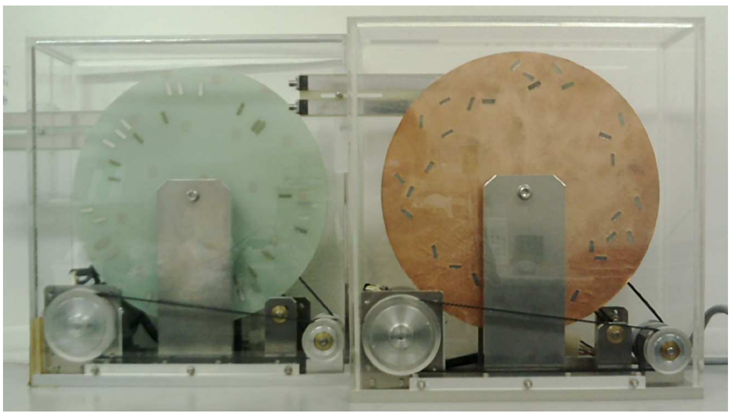


Fig. 3: Photograph of prototype fading generators at 8.45 GHz

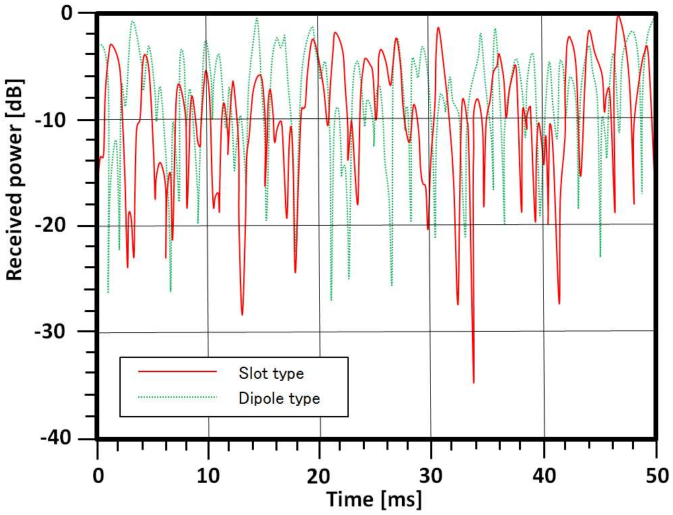


Fig. 4: Received wave from both fading generators.

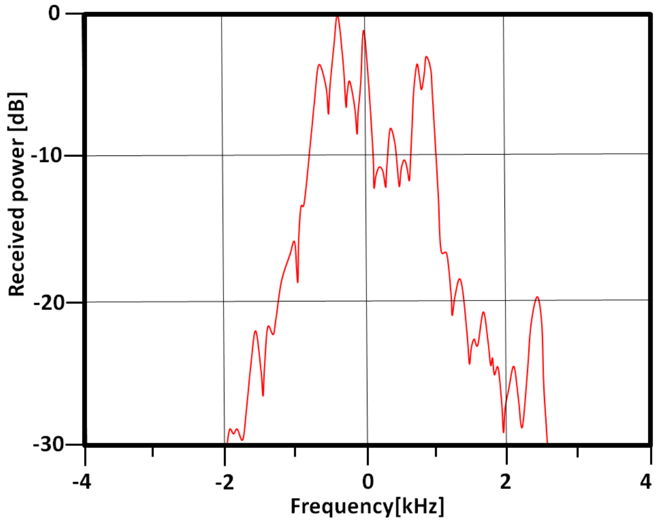


Fig. 5: Doppler shift frequency of received wave.

5. Conclusion

A novel fading generator with rotated scattering slots on the metal discs was proposed in this paper. It was found that not only the patch type of generator but also the slot type can create Rayleigh fading waves. The Doppler shift effect was observed by experiments using the prototype.

6. References

[1] J.B. Andersen, “Antennas for VHF/UHF personal radio : A theoretical and experimental study of characteristics and performance,” IEEE Trans. Veh. Technol., VT-26,4,pp.349-357 (Nov.1977)

[2] T. Sugiyama, T. Shinozuka, Y. Makita, K. Iwasaki, “Estimation of Radiated Power Transmitters Using a Reverberation Chamber”, EMC’04 Sendai, 3C4-3,(2004-6)

[3] P. S. Kildal, “Overview of 6 Years R&D on Characterizing Wireless Devices in Rayleigh Fading Using Reverberation Chambers,” iWAT2007, Cambridge, UK, 2007.

[4] K. Sakaguchi, A.L.S. Neves, J. Takada, K. Araki, and T. Ohira, “Spatial fading emulator using an ESPAR antenna structure,” Proc. International Symposium on Wireless Personal Multimedia Communications (WPMC’01), vil.2, pp.489-492, Sept. 2001.

[5] R. Yamaguchi, “Radiation Characteristics of Fading Generator Using Scattering Objects,” Proc. European Conference on Antennas and Propagation 2011 (EuCAP2011), April 2011.