Performance Evaluation of Propagation Control Devices for Active Propagation Control

Ryo Araki, Kenichiro Kamohara, Hisato Iwai, and Hideichi Sasaoka
Graduate School of Science and Engineering, Doshisha University
1-3 Tatara Miyako-dani, Kyotanabe, Kyoto, 610-0321 Japan

Abstract – **The authors have proposed "Active Propagation Control" (APC) as a method to improve receiving transmission performance of a wireless communication channel. By APC, we can obtain better transmission performance by changing propagation characteristics actively in some ways, such as moving, rotating or transforming objects in the surrounding environment. In this paper, we evaluate the variation performance of the propagation characteristics of propagation control devices by indoor experiments to show the fundamental effectiveness of APC quantitatively.**

Index Terms — **Radio propagation, Active propagation control, Propagation characteristics, Indoor experiment**

1. Introduction

In wireless communication environments, there are some positions where the transmission performance is severely degraded by multipath fading. In general, it is difficult to realize a high quality transmission such as high speed and large capacity at these positions. As one of the improvement methods for such cases, we have proposed "Active Propagation Control "(APC) [1], where the radio propagation characteristics are controlled to improve the transmission performance of wireless communications. In the previous research, the improvement of the path loss of a Single-Input Single-Output (SISO) channel by APC was shown by using the three-dimensional Finite Difference Time Domain (FDTD) method [2]. The analysis was done assuming an empty room where a metal plate is rotated as a device to change the propagation characteristics. In this paper, we evaluate the performance of changing propagation characteristics by propagation control devices to present the effectiveness of APC. In the evaluation, we perform experiments at an indoor environment and show the improvement of the receiving performance by APC quantitatively.

2. Active Propagation Control

Fig. 1 schematically shows the basic concept of APC. The configuration of APC is relatively simple as shown in Fig. 1. In APC, the propagation characteristics at the receivers are changed to be better by some devices which can change the propagation characteristics. Some related techniques having similar idea to that of APC were presented. For example, in [3] it is reported that the blind spots between the buildings can be eliminated by using a reflect array antenna installed on the roof of a tall building. Also, it is shown that the Multiple-Input Multiple-Output (MIMO) channel capacity can be improved by changing the propagation characteristic to "multipath-rich" by using a reflect array antenna in an indoor line-of-sight environment [4]. In addition, the Electrically-Steerable Parasitic Array Radiator (ESPAR) antenna has close principle to APC. The ESPAR antenna can control the directivity of the antenna by changing the reactances of the parasitic elements loaded with variable reactor [5]. The ESPAR antenna thus adjusts the directivity to a situation of the receiving point and improves the transmission performance without using a radiating element. However, the ESPAR antenna cannot change the propagation characteristics beyond the range of the antenna system. We assume that APC improves the transmission performance in larger-scale.

Also, we assume using the feedback control in APC as shown in Fig. 1. If it is possible to calculate all of the propagation characteristics at any positions in the range where APC is applied, we can optimize the characteristics at the receiver without the feedback control. In order to realize the control without the feedback, highly-precise predictions of the propagation characteristics are required but it is impossible by current technologies for electromagnetic analysis. Therefore, in this paper, we assume the feedback control for APC.

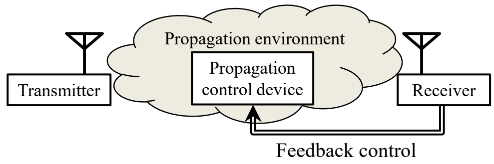
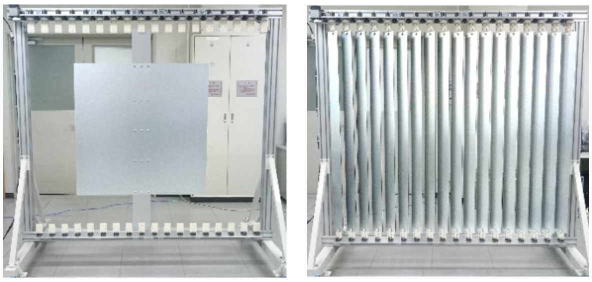


Fig. 1. Basic concept of APC

3. Evaluation of improvement by propagation control devices

Fig. 2 shows the propagation control devices which we use in this paper. Fig. 2 (a) is the single square plate type. It has a large rotatable square metal plate at the center of the unit. We use 1.0 m and 0.5 m square plates. Fig. 2 (b) is the blind type device developed considering safety for human bodies. The device has narrow 18 rotatable metal plates. All metal plates rotate at the same angles at the same time. The height of the center point of these metal plates is 1.1 m. The material of the all metal plates are aluminum. The thickness of the plates is 2.5 mm.

Fig. 3 schematically shows the room for the experiment. We perform measurement in two 1.1m square areas. In each area, receiving antenna is moved every 0.05 m. Therefore, each area contains 529 receiving points. Also, we change the height of the receiving antenna from 0.6m to 1.6m. Therefore we assume 2645 receiving points in total at each area. We measure the transmission coefficient S_{21} using a network analyzer as the propagation characteristics between transmitter and receiver antennas. The measured values of S_{21} the cable loss. The RF frequency was 2.4 GHz and we used dipole antennas at vertical polarization (*z*-axis direction).



(a) Square plate type (b) Blind type

Fig. 2. Propagation control devices

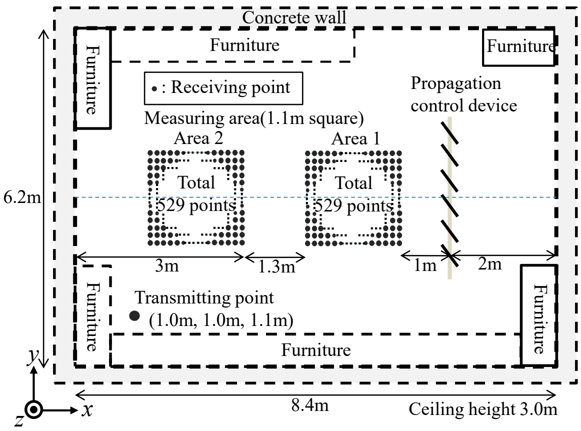


Fig. 3. Experiment environment

4. Improvement of propagation characteristics

We define "maximum improvement" (MI) as the evaluation index of the improvement by APC to quantitatively show the performance of changing propagation characteristics. MI is the difference between the maximum and 50 % values of the S_{21} distribution while the metal plates are rotating. MI shows the quantity of the improvement which can be expected at a receiving point.

Fig. 4 shows the examples of variations of S_{21} at two receiving points when the square plate type device is used. The measured S_{21} at two receiving points in Area 1, A and B, is shown in the figure where the variations of S_{21} were relatively small or large, respectively. We can find the propagation characteristics can be changed significantly by the rotation of the metal plates. Fig. 5 shows Cumulative Distribution Function (CDF) of MI over all receiving point. We compare the square plate type and the blind type. In this figure, we can find that the improvement at the 10 % receiving points more than 5 dB and 3 dB of MI are obtained by APC in Area 1 and 2, respectively. In addition, MI in Area 1 is larger than that in Area 2. Also, we can expect the improvement by the blind type is smaller than that of the square type having the same size plate.

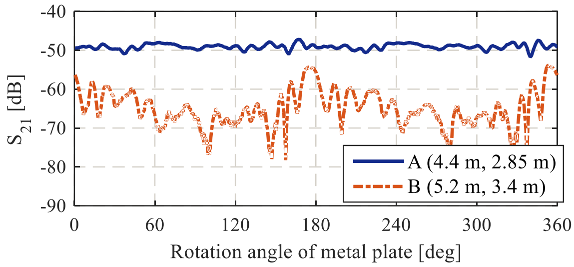


Fig. 4. Variation of S_{21} by rotated metal plate.

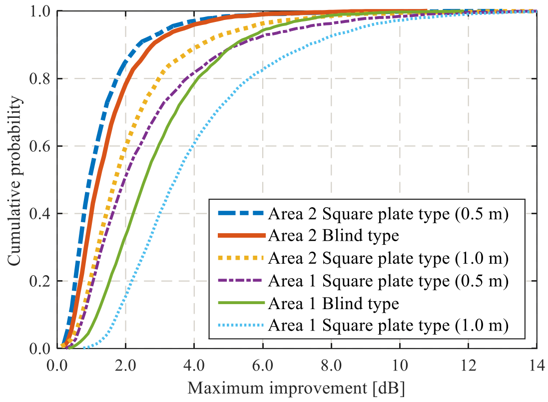


Fig. 5. CDF of MI.

5. Conclusion

We performed the experiments and evaluated the performance of changing propagation characteristics by APC by using the propagation control devices in an indoor environment. As the result, it was found that we can change and improve the propagation characteristics of receiving points by APC effectively. Also, we showed the blind type is one of the effective devices to improve the transmission performance safely for human bodies. We plan evaluations by FDTD analysis to show more accurate performance of APC of the blind type propagation control device.

Acknowledgment

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