Evaluation of Inter-cell Interference Suppression Using Tunable Beam-width Microstrip Antenna in Actual Indoor Environment

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***Abstract*—In this paper, we present the improvement method of the achievable rate using tunable beam-width microstrip antenna for the inter-cell interference (ICI) environment. 4x4 Multiple-Input Multiple-Output (MIMO) channels are measured in actual indoor environment by using tunable beam-width antennas at two across points. It is shown that the combination of the transmitting beamforming and beam-width control is effective in enhancing the date rate for the situation suffering from ICI.**

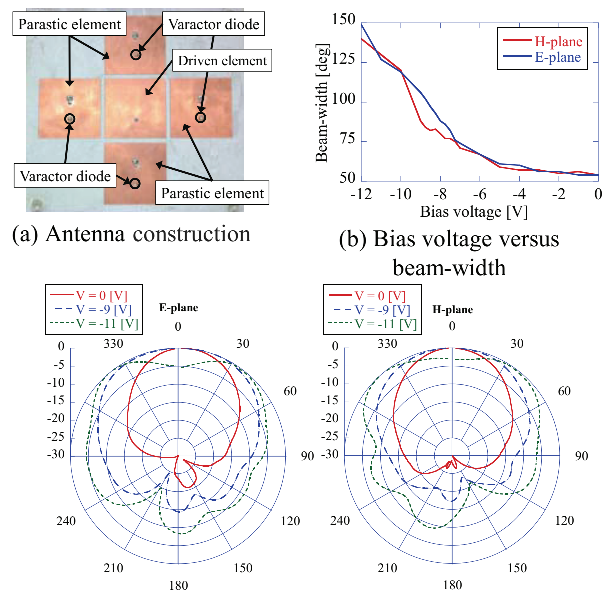
I. Introduction

Due to the spread of wireless LAN, inter-cell interference (ICI) from nearby cells needs to be considered since ICI seriously degrades the spectral utilization efficiency. Inter-cell interference suppression methods, such as, transmitting beamforming method [1] and transmitting power control [2], have been invesgated. Transmitting beamforming improves signal to interference ratio (SIR) by suppressing eigenvalue of interference channel. Although transmitting power control reduces ICI, it reduces received power for desired signals. Also, the transmitting beamforming at access points (AP) can reduce ICI without lowering the desired signal power, yet the number of the streams is reduced and this causes data rate reduction since some degree of freedom is used for interference suppression.

In this paper, we present the new method for improving achievable rate using tunable beam-width microstrip antenna. In order to clarify the proposed method, we measured Multiple-Input Multiple-Output (MIMO) channels between APs with four tunable beam-width antennas and Stations (STA) with four small antennas in actual indoor environment. We measured MIMO channels and evaluated the combination effect of the digital beamforming and analog radiation pattern control.

II. Antenna and Measurement Condition

Figure 1 (a) shows tunable beam-width microstrip antenna with loaded parasitic elements [3]. The parasitic antennas are loaded by varactor diodes, and beam-width is changed by controlling their bias voltage. Fig.1 (b) shows bias voltage versus half power beam-width, and Fig.1 (c) shows measured



(a) Antenna construction

(b) Bias voltage versus beam-width

(c) Radiation pattern

Figure 1. Configuration and characteristics of tunable beam-width antenna.

radiation pattern. It is found that lower bias voltage yields wider beam-width. In this experiment, E-plane beam-width is varied from 54 to 140 deg, and H-plane beam-width is varied from 54 to 150 deg.

Figure 2 shows measurement environment. MIMO channels were measured in the classroom (12x8.5x2.7 m^3). There is line-of-sight (LOS) environment between AP antennas and STA antennas. We measured at 96 position combinations (Positions for the AP: 6 places, and for the STA: 16 places). Two APs are located in the classroom, i.e., the classroom is divided into Cell #1 and Cell #2 at the center.

The AP antenna comprises 4 tunable beam-width antennas in a square arrangement, and their spacing is set to d_1=1.2λ_0. The polarizations of the adjacent antennas are orthogonal to each other. The STA antennas are also square array with 2 horizontally and 2 vertically polarized omni-antennas, where the antenna spacing is d_2=0.25λ_0. The operation frequency is 2.4 GHz.

III. Review of the Interference Suppression Method

Figure 3 shows downlink model in this investigation. The MIMO channel $\boldsymbol{H}_{11}$ and $\boldsymbol{H}_{22}$ are desired channels for Cell #1 and #2, respectively, and $\boldsymbol{H}_{21}$ and $\boldsymbol{H}_{12}$ are interference channels from Cell #1 to #2 and from Cell #2 to #1, respectively. AP1 estimates the right singular matrix, $[\boldsymbol{v}_1^{(21)}, \boldsymbol{v}_2^{(21)}, \ldots, \boldsymbol{v}_N^{(21)}]$ by singular value decomposition (SVD) of $\boldsymbol{H}_{21}$, and AP2 also estimates the right singular matrix, $[\boldsymbol{v}_1^{(12)}, \boldsymbol{v}_2^{(12)}, \ldots, \boldsymbol{v}_N^{(12)}]$ of $\boldsymbol{H}_{12}$. The interference can be suppressed by excluding the singular vectors corresponding to N_{null} largest eigenvalues, and the equivalent MIMO channels become

$$\boldsymbol{H}'_{11} = \boldsymbol{H}_{11}[\boldsymbol{v}_{\mathrm{Nnull+1}}^{(21)}, \ldots, \boldsymbol{v}_{\mathrm{N}}^{(21)}], \quad (1)$$

$$\boldsymbol{H}'_{12} = \boldsymbol{H}_{12}[\boldsymbol{v}_{\mathrm{Nnull+1}}^{(12)}, \ldots, \boldsymbol{v}_{\mathrm{N}}^{(12)}]. \quad (2)$$

Therefore, achievable rate in Cell #1 is calculated by

$$C_1 = \log_2 \left| \boldsymbol{I}_{\mathrm{N}} + \frac{\boldsymbol{H}'_{11}\boldsymbol{H}'^{H}_{11} / \sigma^2 N}{\boldsymbol{I}_{\mathrm{N}} + \boldsymbol{H}'_{12}\boldsymbol{H}'^{H}_{12} / \sigma^2 N} \right|, \quad (3)$$

where $(\bullet)^H$ represents Hermitian transpose, and σ^2 is noise power [1]. Also, that in Cell #2 can be calculated in the same manner.

IV. Result

Figure 4 shows cumulative distribution function (CDF) of achievable rate. The experimental results shows that suppressing ICI (N_{null}=1) without pattern control improves 50 % rate by 3.43 Bits/s/Hz compare to N_{null}=0 with no pattern control. Furthermore, N_{null}=1 with pattern control improves the rate by 2.78 Bits/s/Hz compare to N_{null}=1 with no pattern control. From this result, it is found that the tunable radiation pattern antenna can improve the achievable rate of multi-cell environment greatly especially when it is jointly used with transmitting beamfoming scheme.

V. Conclusion

This paper has proposed the improvement method of the achievable rate using transmitting beamforming and tunable beam-width microstrip antennas for an ICI, and presented its effectiveness based on the experimental result. It is found that the achievable rate is improved by 6.21 Bits/s/Hz, and shown that transmitting beamforming with analog radiation pattern control is effective in improving achievable rate in the ICI environment.

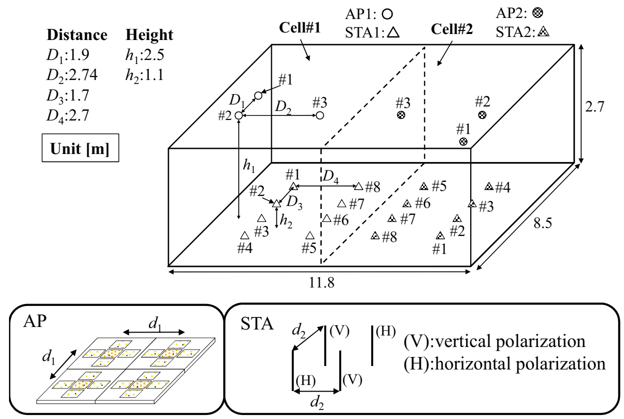


Figure 2. Measurement environment.

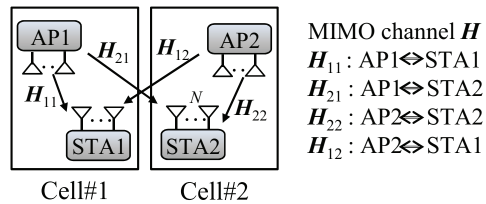


Figure 3. Downlink model.

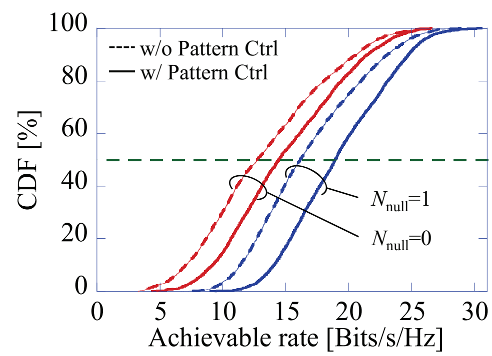


Figure 4. Cumulative distribution function of achievable rate.

References

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