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種別(和文)	論文要旨
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（博士課程）
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	国際開発工学　　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　(Engineering)
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Chapter 1, "Introduction", begins with the major functions, applications and standardizations of multiple input multiple output (MIMO) technology. The performance of a MIMO system is strongly dependent on the radio channel performance, and the first step to study a radio channel is to measure it. Section 1.2 reviews the scenarios and the techniques of radio channel measurement. Furthermore, channel modeling is needed to interpret the measured radio channel, and the popular physical and analytical models are reviewed in Section 1.3. A typical radio channel contains antennas at link ends and a propagation channel. While the antennas are designable, the propagation channel is uncontrollable natural phenomenon. Section 1.4 reviews the antenna de-embedding techniques which enable to characterize propagation channel from the measurable radio channel and antennas. The current problems of antenna de-embedding are also stated. In Section 1.5, the outline and the contributions of this thesis are illustrated.

Chapter 2, "Antenna Radiation Pattern Modeling by Using Spherical Vector Waves", starts with the basics of spherical vector wave (SVW) functions and SVW expansion, as well as the methods of calculating SVW coefficients. Section 2.2 introduces the interpolation of antenna radiation pattern in frequency domain, which is implemented by separating the SVW expansion into frequency-dependent and frequency-independent parts. Section 2.3 introduces the extrapolation of the incompletely scanned radiation pattern in spherical measurement. In particular, under severe sampling condition, the limitations of pattern reconstruction of the deviated antenna (especially the array element) in angular domain by the conventional iterative algorithms were established. An algorithm utilizing the re-sampling techniques in global and local coordinates was proposed. The re-sampling utilizes the simple phase shift for the far-field pattern, and the rotation and translation of SVW functions for the near-field pattern. The proposed algorithm was validated for both the simulated and the measured data. Section 2.4 introduces the approaches to obtain radiation pattern of translated and rotated antenna. Section 2.5 summarizes this chapter.

Chapter 3, "Antenna De-embedding of MIMO Radio Channel with Truncated Spherical Vector Wave Modes", begins with the review of MIMO channel representations in plane wave and SVW domains, as well as the conversion formula between the two domains. In Section 3.2, the antenna de-embedding approach utilizing the dedicated spherical array with practical consideration of the array configuration is proposed. The proposed approach provided the criterion to determine the array radius and the optimized spacing, and is instructive for practical measurement. An ideal spherical array whose elements are θ and φ polarized tangential dipoles was introduced for configuration parameter investigation. A virtual spherical dielectric resonator antenna (DRA) array was introduced as a practical implementation. In Section 3.3, the proposed approach was validated by simulations under ideal condition and under uncertainty. It was found that the lower modes part of the de-embedded $\boldsymbol{M}$ is perfectly reliable, and the major discrepancies happen at the higher modes part. The results indicated that the number of the dominant modes within the limited volume of the spherical array should be larger than that of the target antennas to be applied at link ends in performance prediction. Section 3.4 summarizes this chapter

Chapter 4, "Analytical Modeling of Propagation Channel in Spherical Vector Wave Domain",

the statistical behaviors of entries of mode-to-mode mapping matrix, namely the big-scale gain, the Rician K-factor, and the inter-mode correlation of the scattered part, were investigated in Section 4.1. The analysis showed that entries of $\boldsymbol{M}$ can have different large-scale statistics and can also have different small-scale statistics. Furthermore, an analytical model of $\boldsymbol{M}$ was proposed and validated in Section 4.2. The proposed model of the antenna-independent $\boldsymbol{M}$ was extended from the model of the antenna-specific $\boldsymbol{H}$ in PAN channel, due to their statistical similarity. The proposed model was evaluated by checking the reproducibility of the channel transfer function obtained from the proposed stochastic $\boldsymbol{M}$ given specific antennas at link ends. In order to illustrate the necessity of the proposed model, the advantage of the spherical vector wave channel modeling over the plane wave channel modeling in the environment with a large portion of diffuse scattering was demonstrated in Section 4.3. The results showed that the former outperformed the latter as to the channel reproducibility. Finally, Section 4.4 summarizes this chapter.

Chapter 5, “Preliminary Radio Channel Measurement”, commence with the semi-automatic spherical antenna measurement conducted in Tokyo Tech anechoic chamber in Section 5.1. The measured pattern was compared with the CST simulated pattern in terms of the expanded SVW coefficients. Both agreements and discrepancies were discussed. In Section 5.2, a semi-automatic spherical mold was designed to achieve the virtual spherical DRA array at transmit antenna side. A square patch antenna was allocated at receive antenna side. Besides, in the referenced measurements, a vertical DRA, a horizontal DRA, and a patch antenna, replaced the spherical DRA array at the transmit antenna side respectively. The de-embedding of the virtual spherical DRA array from the measured channel transfer function was conducted first, then the de-embedded one-side mode matrix was used to predict the channel transfer function given target transmit antennas at the same location as the spherical array. The predicted channel transfer function was compared with the measured reference. The results showed the non-negligible discrepancies between the estimated channel transfer function and the measured reference, which mainly due to the impact of fixtures loading antennas and the connected cables. The preliminary measurements indicated that a careful design of the virtual spherical array mold, a smart way of placing cables, and a reliable antenna calibration are necessary for future measurements. Section 5.3 summarizes the chapter.

Finally, Chapter 6 concludes the thesis with future directions.