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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

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要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words)

Chapter 1, "Introduction", introduces the necessity of forward scattering prediction and the main motivation of this study. Nowadays, millimeter wave bands (mmWaves) have been used for 5G wireless communication system. At mmWaves, attenuation caused by human blockage greatly impact cellphone link performance, and hence the prediction method is needed. However, the previous studies have a drawback to predict the forward scattering for a thick conductor object accurately and quickly. Therefore, this study aims to develop an accurate and fast 2-dimensional mirror Kirchhoff approximation (MKA) to predict the shadowing effect of a thick conductor object.

Chapter 2, "Current Predicting Method", provides the detailed explanations of the traditional methods and their issues. Conventionally, full-wave electromagnetic approach, such as method of moment (MoM), has been used to predict the shadowing effect accurately. However, an unreasonable computational cost is a significant drawback for large-scale problems such as a human-size scatterer, especially at mmWave. Therefore, high-frequency asymptotic approximation is expected to reduce the computational complexity. High-frequency asymptotic approximation can be divided into ray-based and source-based approximations. The former, such as uniform theory of diffraction (UTD), is widely used for predicting diffraction. UTD has the closed-form analytic solutions resulting in the less computational cost. The latter, such as Kirchhoff approximation (KA), numerically calculate the scattering field. Since KA has good balance between accuracy and computational cost, KA is expected for further development. The drawback of KA is it only considers the single diffraction by modelling the scatterer as a single plane without thickness, which causes prediction error for a thick object. Therefore, the extension of KA for a thick object is needed.

Chapter 3, "Concept of Mirror Kirchhoff Approximation (MKA)", explains the concept of the proposal for a rectangular cylinder. Two planes expanded by object surfaces facing transmitter (Tx) and receiver (Rx) are used to deal with the double edge diffraction. The fields distributed on the next plane can be obtained by the secondary Huygens' source generated from the previous plane. The angular spectrum method (ASM) by applying fast Fourier transformation (FFT) is used for a fast calculation speed. The region far away from edge, where the oscillating integral does not contribute to the final integral, is truncated. For avoiding the discontinuity at truncation boundary, the windowing function based on the Fresnel zone number is chosen. The proposal introduces the reflection effect between two planes into the double edge diffraction. The proposal is validated for a PEC rectangular cylinder, by comparing with MoM as the reference. The results imply that the proposed method presents a good accuracy.

Chapter 4, "Design of Simulation Parameters for MKA", proposes the formulations of FFT parameters for a lower computational cost. In section 4.2, the spatial interval considering the Nyquist sampling criterion for the evanescent wave, which is important for the short distance propagation between two planes, is proposed. In section 4.3, using Fresnel region approximation in space domain, we find the region far away the stationary phase point has a huge discretization error. Therefore, it is better to truncate rather than to numerically integrate the region inaccurately. Then, the spatial windowing size is proposed. In section 4.4, using Fresnel region approximation in angular spectrum domain, similar discretization error is observed. The poles in angular spectrum domain, which make a significant contribution for the integral, should be sufficient sampled. That idea proposes the angular spectrum interval. In section 4.5, the windowing function and its size in angular spectrum domain are proposed for better accuracy. With those proposals, the computational cost can be extremely lower than before.

Chapter 5, "Application of MKA for An Arbitrarily Shaped Object", extends the application of MKA to

an arbitrary shaped object. The arbitrary shaped cylinder is approximated to the combination of several rectangular cylinders. Those rectangular cylinders can be seen as the slices of the arbitrary shaped cylinder by multiple planes. By applying MKA repeatedly among those planes, the scattered fields can be calculated for the evaluation of the shadowing gain. The new finding is that only the space domain of the zeroth plane or the angular spectrum domain of the last plane needs their respective windowing functions, other planes or domains do not. The computational cost of the proposal is provided. The author validates the proposed method for an elliptical conductor cylinder with the size of the human body at mmWave. Simulations by changing the object's location, direction, and frequencies are conducted. The results show that the proposed method presents good accuracy with a low root-mean-square error of less than 0.5 dB, compared with the MoM as the reference. Furthermore, the calculation time is improved by 1.4 - 67.2 times compared with the UTD using special functions.

Chapter 6, "Conclusion", summarizes this thesis as well as the important contributions. Future applicability based on this study is prospected. The possible research topics for future work are also provided.