Project Report: Diffraction Effect in Wireless Signal Propagation

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Project Report

Introduction

This project aims to analyze and simulate the diffraction effects in wireless signal propagation within an urban environment. The primary objective is to understand how buildings and other obstacles affect the transmission of electromagnetic waves from a transmitter to a receiver. The study leverages the Uniform Theory of Diffraction (UTD) to model the impact of corners on the signal strength and field distribution.

You can find the full code from link below:

https://github.com/RezaHardMan

Feel free to check out my LinkedIn profile as well:

https://www.linkedin.com/in/reza-aramjou-6a2b56228

METHODOLOGY

The methodology involves two main parts:

1. **Defining the Environment and Propagation Model**

2. **Calculating the Total Diffracted Electric Field at the Receiver**

PART 1: DEFINING THE ENVIRONMENT AND PROPAGATION MODEL

We first establish the environment in which the signal propagates, characterized by a grid representation of an urban area with buildings and other obstacles. Each building is defined by its top-left and bottom-right coordinates. The transmitter and receiver are placed at specific locations within this grid.

To model the propagation, the following parameters are defined:

- **Frequency (f):** The frequency of the signal is set to 60 GHz.
- **Speed of Light (c):** The speed of light is considered to be 299,792,458 m/s.
- **Wavelength (λ):** Calculated as $(\lambda = \frac{c}{f})$.
- **Wavenumber (k): Calculated as $(\boldsymbol{k} = \frac{2\pi}{\lambda})$.**
- **Initial Electric Field Intensity (E0):** Set to 1 for simplicity.

Visibility matrices are constructed to determine the line-of-sight and potential diffraction paths between the transmitter, receiver, and building corners. Each corner of a building is classified based on its position relative to the structure, aiding in the calculation of diffraction coefficients.

PART 2: CALCULATING THE TOTAL ELECTRIC FIELD AT THE RECEIVER

The total electric field at the receiver is calculated using the UTD diffraction coefficients. The process involves:

- **UTD Diffraction Coefficient Calculation:** The Uniform Theory of Diffraction (UTD) provides an efficient method for calculating diffraction coefficients, which are crucial in understanding wave propagation around obstacles. To ensure the accuracy of the UTD diffraction coefficient function implemented in this project, a thorough verification process is conducted.

  The UTD diffraction coefficient for a perfectly conducting π/2 wedge is given by:

  $$D = -1j \times F \times f \times \mathrm{bessel}_{\mathrm{term}} \times \mathrm{phase}_{\mathrm{shift}}$$

  Where:

  $$k = 2\pi/\lambda, \quad F = \sqrt{}(2/\pi k d1 d2|sin\ (diff\_angle)\ |\ ),$$

  $$f = \mathrm{e}^{\frac{j\pi}{4}} \sqrt{k|\sin(diff\_angle)|},$$

  $$phase\ shift = \ \mathrm{e}^{(-jk(d1+d2))}$$

  and the Bessel function terms are:

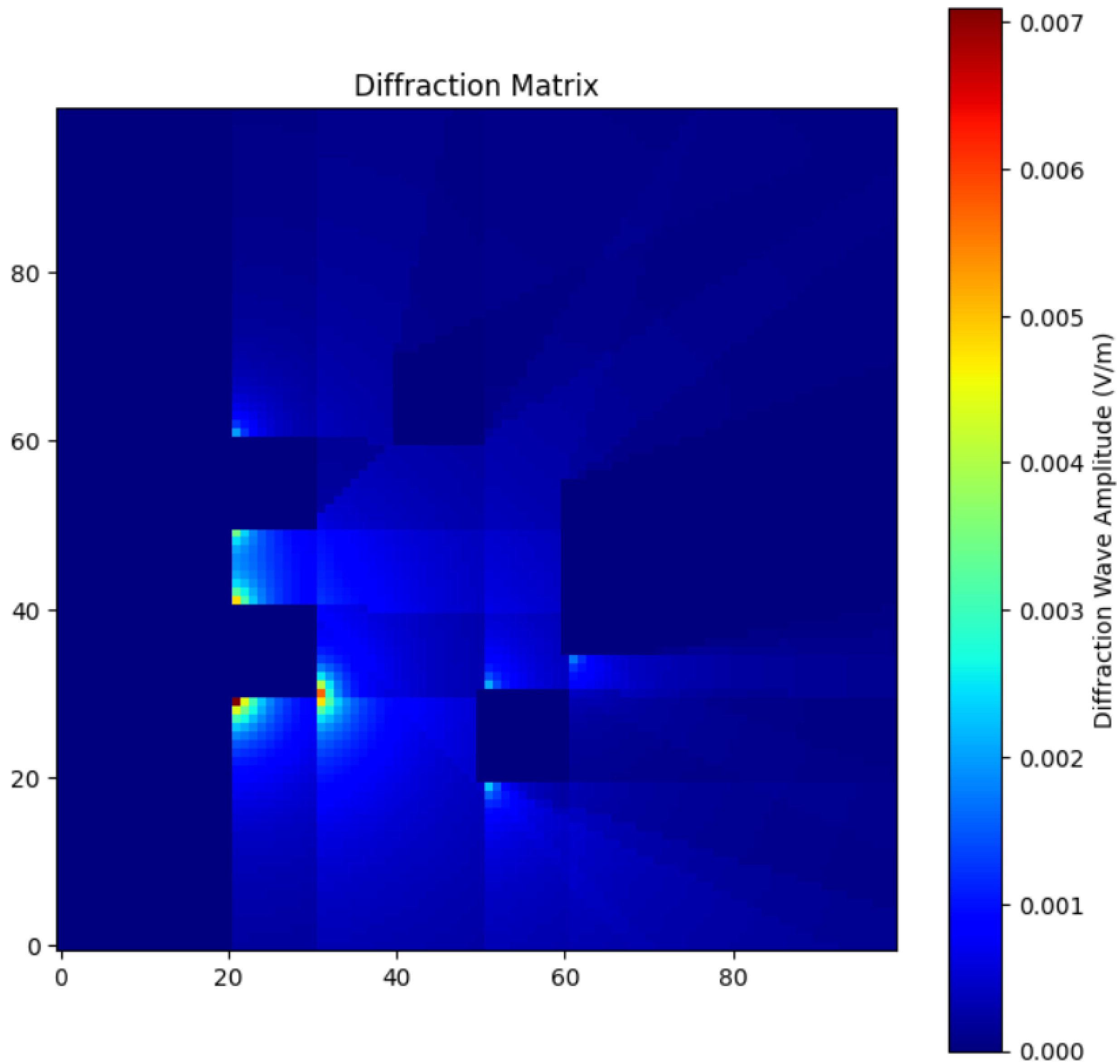
  $$\mathrm{bessel\_term\_0} = J_0(k \sin(\mathrm{sum\_angle}/2)),$$

  $$\mathrm{bessel\_term\_1} = J_1(k \sin(\mathrm{sum\_angle}/2)),$$

  $$\mathrm{bessel\_term} = \mathrm{bessel\_term\_0} + j \times \mathrm{bessel\_term\_1}$$

  This coefficient depends on the incident and diffraction angles, as well as the distances from the transmitter to the corner and from the corner to the receiver.

- **Pathfinding:** All possible paths from the transmitter to the receiver are identified using depth-first search (DFS), considering visibility constraints and corner classifications.
- **Electric Field Calculation:** For each path, the electric field contribution is calculated iteratively from the transmitter to the receiver, taking into account the diffraction effects at each corner encountered along the path.



The analysis provides a detailed understanding of how the urban environment, particularly building corners, affects wireless signal propagation. The calculated total diffracted electric field at the receiver gives insight into the impact of diffraction and helps in optimizing the placement of transmitters and receivers in urban settings to ensure better signal coverage and quality.

As we are aware, overshoot predominantly occurs in proximity to corners, a phenomenon clearly depicted in the accompanying image. The image further illustrates Shadow Regions and Interference Patterns, subjects that are comprehensively explored in my latest article.

CONCLUSION

This project successfully demonstrates the use of UTD in modeling diffraction effects in urban wireless communication. By defining a structured environment and using precise mathematical models, the study offers valuable insights into improving wireless network design and performance in complex urban landscapes. Future work can extend this model to include more complex scenarios and dynamic elements such as moving obstacles.