Title

Radiowave Propagation Studies In Tunnels Using ADI-PE Technique

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Abstract

Due to the growth of mobile communication systems, there is an increasing demand for numerical techniques capable of predicting signal strength in subway, railway and underground road tunnels. In this dissertation, we study radio wave propagation in tunnels using the alternating direction implicit (ADI) method and the parabolic equation (PE). The PE models waves that travel predominantly in one direction and corresponds to the low order modes in real tunnels. It has been well documented that tunnels are characterized by these low order modes at large distances. The Crank-Nicolson method is the traditional finite difference method used to solve the PE. However, one of the limitations of the Crank-Nicolson method is that it involves the inversion of large matrices that result from discretizing the tunnel cross-section. We explore the use of the ADI scheme as a computationally efficient alternative to the Crank Nicolson method. In the ADI scheme, smaller matrices are used by solving the fields in the transverse plane line by line along one dimension in one half step, and then line by line along the other dimension in the next half step. However, one of the trade-offs is that the ordering of the line by line decomposition becomes important when dealing with circular cross-sections. Also, the boundary conditions at the half step plane are not necessarily the same as the physical boundary conditions and this can effect the overall accuracy of the sheme. We formulate the ADI scheme for use in tunnels with rectangular, circular and arched cross-sections with lossy walls. We also study various realistic tunnel variations, such as curved, branched and rough-walled tunnels. A full vector-PE is used and the wall loss is characterized by the impedance boundary condition. To validate the ADI-PE, we show simulation results for tunnel test cases with known analytical solutions. Furthermore, the ADI-PE is used to simulate real tunnels in order to compare with experimental data. There is good agreement with the ADI-PE and theoretical tunnels where the initial field and wall electrical parameters are completely known. Disagreement with the PE solution is observed when compared to experimental data for tunnels whose electrical parameters and initial fields are not completely defined. The ADI-PE models the electric fields most accurately in real tunnels at large distances and at high frequencies.

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