Comparative Study of Propagation Modeling of Tunnel Environments Using Asymptotic and Full-Wave Techniques

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Electromagnetic (EM) modeling of communication signals is becoming increasingly important as communication frequencies increase. In many cases of indoor and outdoor EM propagation structures and systems, modeling and computation of EM fields presents a difficult challenge using traditional full-wave computational EM (CEM) techniques because practical structures and systems being modeled at modern communication frequencies may span thousands of wavelengths. This makes traditional CEM methods practically unfeasible in many problems, which has led to an increase in interest in asymptotic modeling techniques. One such category of techniques is ray tracing (RT), which is developed from the geometrical optics (GO) approximation.

We examine the shooting and bouncing ray (SBR) RT method in EM propagation modeling of tunnel environments. These environments and RT models prove to be a good test for the efficiency and accuracy of simulation methods, because reflections become very important in accurate modeling of the fields. Tunnels can prove problematic for fast and accurate simulation with all methods, including full-wave and other asymptotic techniques. This test case helps to point out the potential strengths and drawbacks of many existing methods. In the case of RT solvers, a very high ray density and reflection count are necessary for accurate simulations.

Here we compare modeling fields in real tunnel environments using the SBR method with full-wave techniques, as well as other existing asymptotic techniques. We focus on computational complexity of the simulations as well as the accuracy of the results in several characteristic tunnel cases. The results show that proper implementation of the SBR method proves to be both fast and accurate when compared to other simulation techniques. This demonstrates that SBR can be a powerful tool when modeling indoor and outdoor EM propagation and communication signals in real world environments, such as 5G communication networks.