Propagation Modeling of an Open-Trench Drain

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Introduction

Propagation measurement results were reported in a style of open-trench drain that is common in several Asian countries in [1]. In particular, measurement results at three frequencies, namely 900 MHz, 2.4 GHz, and 5.8 GHz were reported in three scenarios, whose findings are beneficial in designing wireless communication systems in environments where such drains are present. In this work, further investigation has been made on the contents inside an open-trench drain. This investigation is expected to contribute to a practically important propagation problem because in reality, the open-trench drains environments are not always dry and empty. On the contrary, they are sometimes filled with different contents, the most common one being water, as one of the primary objectives of a drain is to collect water runoff from the surrounding buildings and houses and convey it to an outfall. In other scenarios, the open-trench drain's floor might be filled with liquids, soil, foliage from the surrounding trees, and even, trash.

Drain Structure and Relative Permittivity

A drainage system is governed by the topography and gradient of the land. It should have adequate capacity so that it can accommodate runoff that enters the system. In this work, we focus on a portion of one open-trench drain that receives runoff from inlets and conveys the runoff to some point where it is subsequently discharged into a channel, water body, or piped system. Fig. 1 presents a cross-section diagram of an open-trench drain with and without water flow.

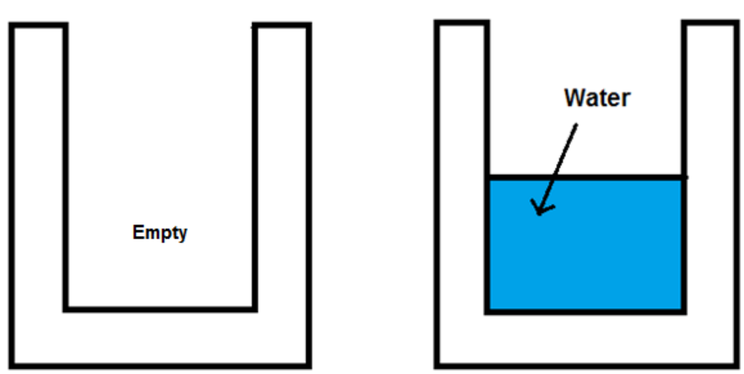

Fig. 1. Open-trench drain with and without water flow.

Three conditions are assumed for an open-trench drain. First, the open-trench drain is in a dry condition whose floor resembles dry earth; second, the open-trench drain is also in a dry condition whose floor resembles typical concrete ground; and third, the open-trench drain is filled with water. The relative permittivity used for the simulation of the ground-reflected ray for the above-mentioned three conditions are ε_r = 7 for dry earth, ε_r = 15 for typical ground, and ε_r = 81 for water [2]-[4]. The permeability value used is μ_r = 1 while the conductivity value is assumed σ = 0.001 S/m. Fig. 2 presents the simulation setup of an ideal open-trench drain with the transmitter (Tx) and receiver (Rx) put in place.

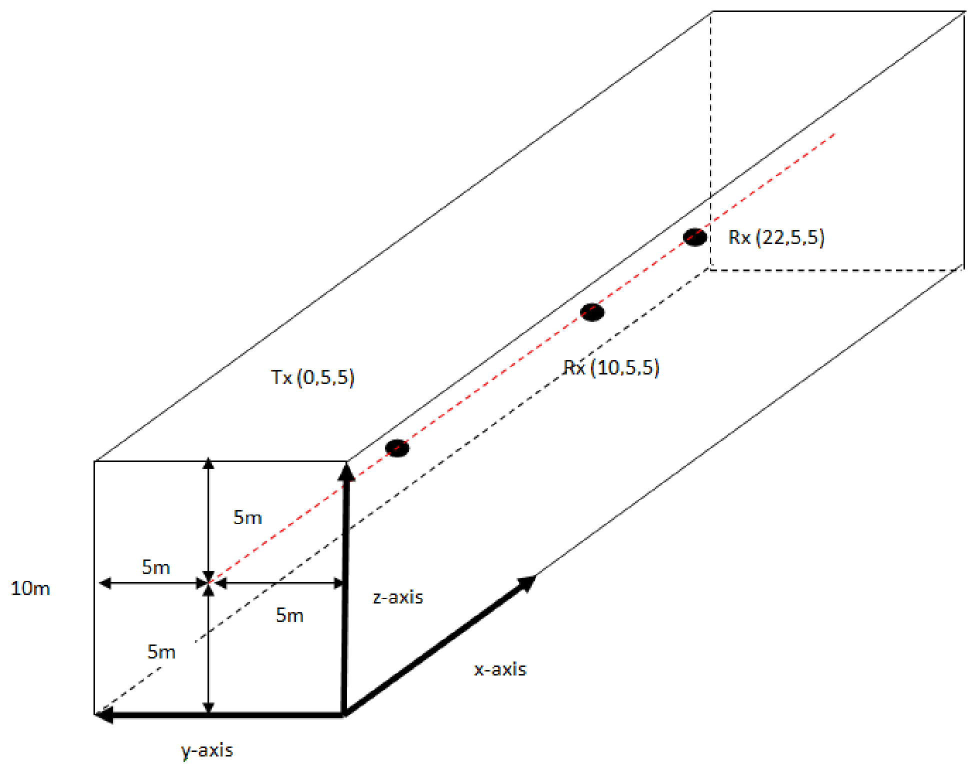

Fig. 2. Simulation setup of the Tx and Rx positions inside an ideal open-trench drain.

Results and Discussion

Ray tracing of image method was utilized for the simulations of this work. Specifically, the rays that are taken into consideration are the direct ray (LOS), the reflected ray from the left wall of the open-trench drain, the reflected ray from the right wall of the open-trench drain, and the reflected ray from the open-trench drain's floor. The frequency of operation is 2.4 GHz. Fresnel reflection coefficient for perpendicular polarization is used for the simulation of the wall-reflected ray while Fresnel reflection coefficient for parallel polarization is considered for the ground-reflected ray. Fig. 3 shows the simulation results of the total rays inside the open-trench drain under the three conditions stated earlier. We can observe from Fig. 3 that when the value of the relative permittivity increases, from 7 for dry earth to 15 for typical ground and further to 81 for water, the variation of the signal is on a milder scale.

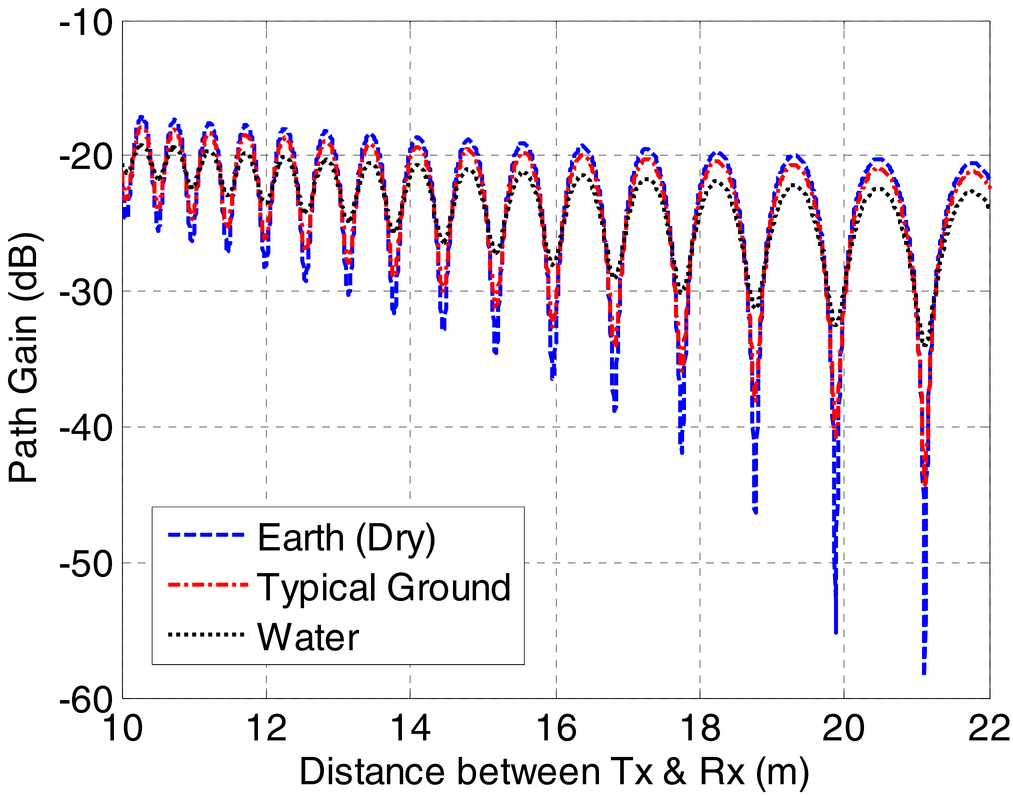

Fig. 3. Simulation results of the direct and reflection rays from the drain's walls and ground.

In Fig. 4, the ground-reflected rays from the open-trench drain's floors are plotted together for the three pre-defined scenarios, namely, dry earth, typical ground, and water. We can observe from this figure that within a distance of 12 m, the signal strength drops from -26 dB to -33 dB for water, a total of 7 dB drop in strength. As for the typical ground, the signal strength drops from -29 dB to -40 dB, a total of 11 dB drop in strength. Finally, for dry earth, whose relative permittivity value is the smallest in this comparison, the signal strength drops from -33 dB to -50 dB, a total of 17 dB drop in signal strength.

Conclusion

In this work, ray tracing (image method) simulation results were reported inside an ideal open-trench environment at 2.4 GHz. Understanding the propagation environments in this drain under various conditions such as dry or with water flow is a practical approach that can contribute to accurate propagation prediction, which is helpful for the design of wireless communication systems in environments where such open-trench drains exist. When water is present inside the open-trench drain, the ground-reflected ray from the water surface is relatively stronger compared to when the drain is dry.

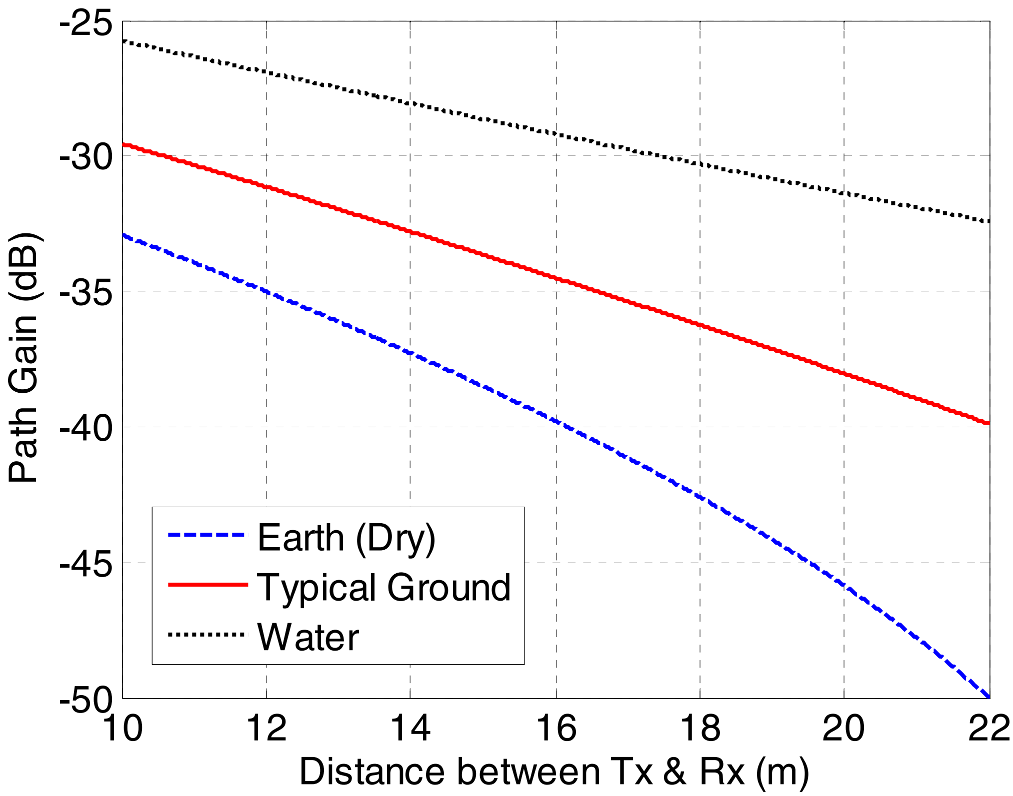

Fig. 4. A comparison of the ground-reflected rays from different contents.

Acknowledgement:

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References:

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