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Measurement-Based Ray-Tracing Models Calibration in Urban Environments

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Abstract**—This paper investigates the effect produced on the accuracy of the estimate of path loss in an outdoor environment in order to adjust the permittivity values for building wall, building roof and street floor by using a full 3D ray-tracing system. Due to the complexity of a real situation, estimation of path loss using the ray-tracing method is generally assumed one or three large classes of homogeneous materials to represent the building walls, building roofs and street floors in order have a viable model of the 3D environment. However, in a real case, an outdoor environment consists of many buildings and streets made of heterogeneous materials. We analyze the behavior of the statistical variation of standard deviation, correlation coefficient and the average error between the values of estimated and measured path loss data when considering various values of permittivity of these three classes. Finally we adjust the values of permittivity obtaining a reasonable improvement of ray tracing to estimate the path-loss.**

I. INTRODUCTION

Path-loss characterization of a wireless communication channel is very important to predict radio coverage. The ray-tracing method in conjunction with UTD (Uniform theory of Diffraction) has been intensively studied. But the inhomogeneity of materials and lack of such parameters like permitivity may reduce the accuracy of estimated propagation loss in a real outdoor situation.

The propagation loss using ray-tracing methods based in UTD depends of the electromagnetic material parameters. Conventional ray-tracing methods typically assume a class of material[1] for all buildings and street floor and other methods assume three classes of materials[2] for building wall, building roof and street floor. However, material parameters remain of approximate values and are difficult to define accurately for each building wall, building roof and street floor, especially when the materials are a heterogeneous mixture of unknown components, for which no electromagnetic measurement values are available and is not satisfied for all frequency bands [3]. Consequently, blind prediction, based on a priori approximate knowledge of material parameters, often shows an obvious mismatch with the measurements. Therefore, a study over sensitiveness of path loss for these material parameters in outdoor environment is required.

It is well known that ray tracing models are deterministic and therefore a very precise prediction models for radio propagation. However, such models require information of material's constitutive parameters, increasing the difficult of use because the absence of such parameters. This is especially true in outdoor environments, because the diversity and quantity of building blocks typically found in outdoor environments. Although some works have been done trying to obtain constitutive parameters for different materials and building blocks [3], the diversity is such that it is almost impossible to characterize all possible environments.

The idea behind this paper is to adjust ray-tracing model parameters (i.e. constitutive parameters) using field measurements. In this case, we use power loss measurements, just because this is a simpler way for measure than wideband measurements.

II. ANALYSIS AND OPTIMIZATION OF PERMITTIVITY PARAMETERS

This section compares simulation results using the 3D ray-tracing tool mentioned above with path loss measurements in an outdoor scenario.

A. Path Loss Measurements campaign

Measurement campaign was carried out by the iTEAM research institute inside University main campus. Measurements were taken using the iTEAM DVB-H test

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network. The test network has one transmitter placed inside the campus at 24 m height. The transmitter antenna used is a vertical polarized omni-directional antenna, with 12.15 dBi gain. The receiver antenna is a mobile vertically polarized antenna, with 2 dBi gain; the operation frequency was 594 MHz.

We store and manipulate the constitutive parameters information as an attribute within the 3D Model (i.e. permittivity, permeability and rugosity). According to their electromagnetic material properties, the structures of the building and street were classified into 3 different classes with common dielectric material parameters for building wall, building roof and street floor. Initially, we assumed that the buildings and objects in the selected area in the city have the same constitutive parameters (i.e. permittivity and permeability) for brick (εr=7-j0.3, μr=1), street floor and building roof for dry concrete (εr=5.3-j0.25, μr=1); brick and dry concrete have similar rugosity (σr=1 mm.) [1].

B. Simulation

The predicted results agree well with the measurement data, with a mean absolute error of 4.64 dB before the adjustments. In Table 1 we show the final values of permittivity for the minimum value of standard deviation obtained.

Table I permittivity values for the global minimum standard desviation.

Class	Permittivity initial	Permittivity optimized
Building Wall	7-j0.3	7-j0.3
Building Roof	5.3-j0.25	0.5-j0.25
Street Floor	5.3-j0.25	7-j0.25

Table II Statistical summary of path loss prediction for permittivity values for the global minimum standard deviation.

Condition	Mean absolute error (dB)	Mean error (dB)	Standard Deviation (dB)	Correlation
Initial	4.64	-1.05	6.89	0.58
Optimized	4.27	0	5.04	0.63

C. Analysis and Calibration of Permittivity Parameters

In order to analyze how the predictions are affected by the simulated building wall, building roof and street floor characteristics, all the simulated objects are characterized by three classes (building wall, building roof and street floor). We assumed a set of values for each of the classes and by changing one of these values at a time, the model's sensitivity to that parameter is evaluated.

First, power results are examined for the varying values of permittivity for one class within range from 0.5 to 10, in steps of 0.5 at processing time. Second, using this method, we obtain the global minimum standard deviation for best values of each class for all the above predictions, respect to the measurements.

Table I show the initial permittivity values and the values obtained for the global minimum standard deviation. Real permittivity values of 7 for the building wall correspond to the initially assumed value before optimization, for brick. Real permittivity values of 7 for the street floor are greater than the initially assumed before adjust, and it is similar to the building wall values. Real permittivity values of 0.5 for the Building roof are less than the initially assumed before optimization.

Table II shows also the values for the global minimum standard deviation of path loss prediction for calibrated real permittivity. The Mean error of 0.0 dB, standard deviation of 5.04 dB and coefficient correlation of 0.63, corresponds to improved results compared with the initial results.

The optimization results are shown in Figure 1 and summarized in Table **I**. Predicted results agree well with the measurement data, with a mean error of 0.0 dB.

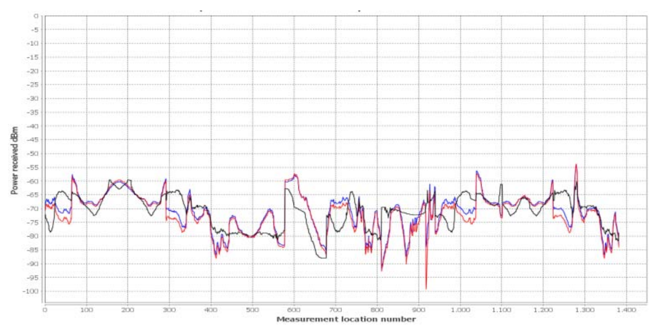

Figure 1 Power prediction comparison of the ray tracing output (red line) and optimized (blue line) with measurement (black line).

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