

USING 3D GAME ENGINES AND GPU FOR RAY LAUNCHING BASED CHANNEL MODELING IN INDOOR

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Abstract

This paper investigates the use of a full 3D ray-launching system based on Game Engine and GPU for the prediction of channel parameters in indoor. We explore the behavior of the materials and the possible influence of objects external to the room where measurements were performed. We explore the modeling of indoor channel for Digital TV frequencies and analyze the behavior of material on such low frequencies and how the frequencies affect the constitutive parameters of materials in the scenario. Because of the environment used for experimentation, the number of rays is very high and the number of interactions is higher than usual. We show results of the ray tracing model compared with measurements of delay spread at 594MHz in a meeting room.

1. Introduction

Channel 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 information about such parameters like permittivity or conductivity may reduce the accuracy of estimated propagation loss in a real indoor situation.

It is well known that ray launching models are deterministic and therefore a very precise prediction models for radio propagation and channel modeling. However, such models require information of material's constitutive parameters, increasing the difficult of use because the absence of such parameters. This is true in indoor environments, because the diversity and quantity of building blocks typically found in indoor environments, such as furniture, walls, windows, etc.. 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 very difficult to characterize all possible environments. Additionally, constitutive parameters vary with frequency, increasing the complexity of the problem.

Another issue related with ray launching techniques deals with the complexity of the algorithms and the computing time required obtaining confident results. This computing time is typically related with the complexity of the scenario and the number of the interactions considered in the model; most interactions (i.e. combinations of reflection-diffraction) require more computing time. In recent years, some authors have used GPU power in order to improve the computation capacity for propagation calculations and channel modeling [6]. The authors of this paper have proposed the use of Game Engines to improve computation time and to use the efficient ray tracing techniques implemented in such engines [7-9], which have been well tested in the games area. Game Engines combines the power of GPU with efficient ray tracing algorithms and new graphics technologies for channel estimation in current and future wireless technologies.

The idea behind this paper is to compare a Game Engine based ray-launching model with a set of measurements in a meeting room. In this case, we use delay spread measurements, using a VNA. Because of the complexity of the environment, we have found that some materials do not behave as dielectrics and is necessary to consider the conductivity of the material, as well as some external elements to the tested area. We also have to consider up to ten different interactions for each launched ray, increasing considerably the number of rays launched and processed. This paper includes improved results to previous work

2. Some Comments about Game Engines

A Game engine is a system designed for the creation and development of video games. It includes a rendering engine, a physics engine for collision detection, and an efficient memory management system. One of the characteristics

of the game engines is the efficient implementation of ray tracing algorithms and the use of GPU power for rendering, independent of the manufacturer of the GPU. The physics engine is intended to optimally implement effects like optical physics as reflections, refractions and diffusion. It is possible to combine different physics engines with game engines in order to obtain optimal results and reduce computation time.

New technologies like CUDA, allows exploiting the GPU graphics computational power to improve channel characterization computation time, in order to obtain coverage and channel results in affordable time comparable to semi-deterministic propagation models. At this time, CUDA is a technology independent of Game Engines and is not been implemented in Game Engines; however, it is possible to implement such technology in most Open Source Game Engines increasing computing capabilities for real time gaming and visualization.

We used the 3D Game Engine Ray Launching techniques in combination with our indoor 3D model to derive multipath channel parameters [7,8]. The identified propagation parameters between the transmitter and the receiver are: time delay of arrival (TDoA), full polarimetric transmission matrix, direction of departure (DoD), direction of arrival (DoA), Delay Spread, among others. Introducing the gains of the transmitting and receiving antenna and their complex directional pattern, we estimated the parameters of: attenuation, depolarization, phase shift, delay, angle of arrival and angle of departure.

3. Measurement and Simulations

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

3.1 Measurement Scenario

Measurement campaign was executed in a meeting room with 10m by 6m with typical furniture: Table, chairs, carpet and walls of soft materials. Outside the windows, above the ceiling and below the floor, we found steel, quite common in the constructive techniques used in the last 15 years. Ceiling and floor use the system know as steel deck. Outside the windows, we found some steel bars and metalized glass.

These characteristics of the constructive elements cause reflection effects that can increase the number of reflections to be considered in the model. In Figure 1 we show the measurement scenario modeled in 3D tool, indicating the walls, ceiling, floor, table and chairs.

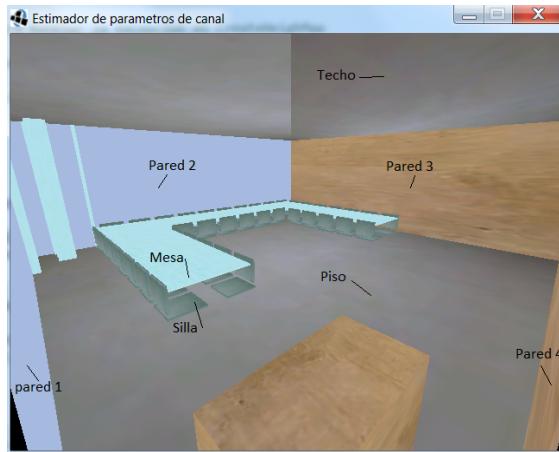


Figure 1 Measurement Scenario, indicating the elements.

3.2 Measurements

Measurement campaign was carried out by the iTEAM research institute inside Building. Measurements were taken using the iTEAM VNA. Receiver antenna is a PROCOM vertically polarized, 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). According to their electromagnetic material properties, the structures of the walls, floor, table, windows and chairs were classified into 5 different classes with dielectric material parameters shown in Table I. Values for conductivity are shown in Table I. We assume initially the same values for conductivity, assuming dielectric behaviour and later we adjust conductivity parameters, according to simulation results.

3.3 Simulation results

Initially, the predicted results does not agree quite well with the measurement data, with a mean absolute error of 10.28ns before adjustments, indicating differences of 70% in the mean values. After adjustments, we reduce the mean absolute error of delay spread to 1.0ns. In Table I we show the final values of relative permittivity for the minimum value of standard deviation obtained. It is important to observe the dependency of the permittivity values to the simulation results respect the measurements, as indicated in Table III. After the modification of some values, we cannot observe relevant changes in simulation results, indicating low dependency.

First, delay spread results are examined for the varying values of permittivity for one class within range from 0.5 to 100, in steps of 1 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 Relative permittivity values for the initial simulations.

INITIAL CONDITIONS	MATERIAL	RELATIVE PERMITTIVITIES	CONDUCTIVITY
Floor and ceiling	Concrete/steel	6.9	0.001
Wall 1 and 2	Unknown material	2.4	0.001
Central Table	Glass	2.4	0.001
Wall 3 and 4	Unknown material	3.81	0.001
Chairs	Fiber	3.0	0.001

For the conductivity, only the modification of the value of walls 1 and 2 affect the results, with a new value of 0.145. In Table III we show the values for the initial simulation and after the adjustment of relative permittivity and conductivity. For the permittivity values, it is observed in Table II that walls 3 and 4 as well as chairs permittivity values have a high dependency and affect simulation results, improving the results with measurements.

Table II Final values of Permitivity and Conductivity

FINAL CONDITIONS (ADJUSTED)	MATERIAL	RELATIVE PERMITTIVITIES	CONDUCTIVITY
Floor and ceiling (low dependency)	Concrete/steel	6.9	0.001
Walls 1 and 2 (low dependency in permitivity)	Unknown material	2.4	0.145
Central Table (low dependency)	Glass	2.4	0.001
Walls 3 and 4 (high dependency)	Unknown material	60.0	0.001
Chairs (high dependency)	Fiber	70.0f	0.001

In Table III we show the error results for the simulation before parameters calibration and after the calibration. An important improvement was obtained after adjust walls 3 and 4 and chairs permittivity, as well as walls 1 and 2 conductivity. It is important to remark that the highest improvement was obtained after the adjustment of the walls conductivity.

Table III Statistical summary delay spread prediction for permittivity values before and after adjustment.

Condition	Mean absolute error (ns)	Mean error (ns)	Standard Deviation (ns)
Initial	10.28	12.09	20.87
Adjusted	0.99	1.0	2.84

4 Analysis and Calibration of Permittivity and Conductivity Parameters

Observing Figure 2, which shows simulation and measurement results before and after adjustments, some important differences are shown in points 16, 17, 26 and 27. These differences are related with external objects not considered in our simulation because of the low frequency.

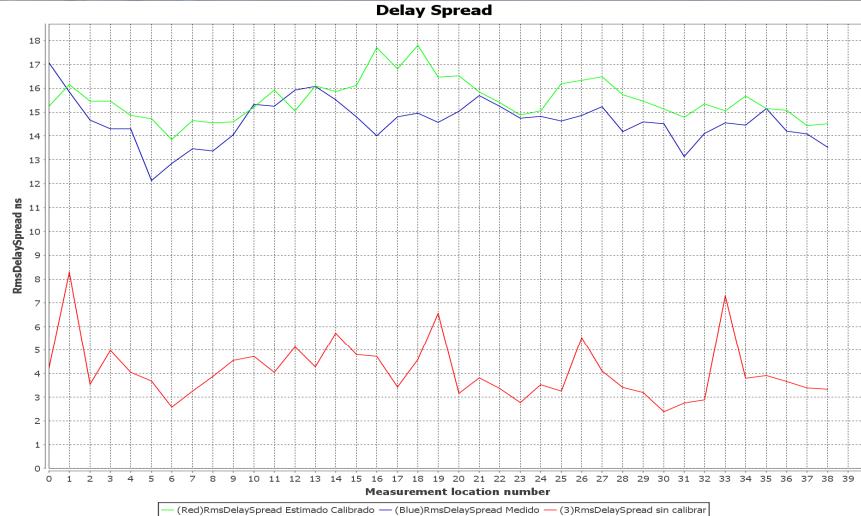


Figure 2 Delay Spread prediction comparison of the ray tracing output (red line) and adjusted (green line) with measurement (blue line).

5 Conclusions and further work

We have shown results of a 3D Ray launching model using Game Engines for indoor channel estimation and compared with measurements, obtaining good results.

Most differences observed between simulations and measurements was related with the presence of steel in the outdoor of walls 1 and 2 and permittivity values of walls 1 and 2 and chairs in the room, showing the importance of constitutive parameters in deterministic ray launching algorithms.

Computation time can be improved using additional gaming technologies like NVIDIA Optix and NVIDIA Physix. We expect to improve the model using the mentioned technologies.

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