Efficient Technique for propagation prediction in

Indoor wireless communications

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I. Introduction

Wireless radio networks operating at millimeter-wave frequencies (20-60 GHz) offer large information transport capacity and more sharply defined cell boundaries than lower frequency systems. The knowledge of the signal coverage must therefore be as accurate as possible. For these systems, the analysis of channel temporal variations as well as the radio-propagation prediction for indoor environments has become important research topics. To adequately estimate the performance of high speed data or other wireless services between large buildings, knowledge of space and time varying channel conditions is essential. A theoretical model capable of predicting the temporal channel variations for specified propagation conditions appears to be an essential tool to establish a level of confidence on the system performance predictions analysis.

Using experimental data obtained with an indoor impulse measuring system in the EHF band, a three-dimensional (3-D) propagation model, based on ray-tracing techniques combining Image Theory method with Binary Space Partitioning algorithms has been developed. It is shown to predict the propagation losses and delay spreads in an indoor environment with reasonable accuracy. The validation of the model is illustrated using experimental results obtained at 37.2 GHz.

II. Deterministic modeling

Propagation tools require site-specific information for the particular environment. In indoor scenario, the received signal is composed of energy reflected, transmitted or diffracted by walls, floor, ceiling and intervening obstacles. These kinds of phenomena can be treated by using an efficient ray-tracing method, in combination with several electromagnetic models of the environment. The model is used in conjunction with a high-frequency approach (Geometrical optics and Uniform theory of diffraction GO/UTD) for a three-dimensional implementation.

Many modifications have been proposed to speed up the ray tracing procedure, particularly the use of visibility, image theory method [1], the Binary Space Partitioning (BSP) [2], the angular z-buffer (AZB) [3] and the space division method [4]. In our approach, the characterization of the wideband indoor channel uses a ray tracing procedure based on a combination of image theory method and the Binary Space Partitioning (BSP) algorithm [2]. The BSP algorithm [5] is an efficient method for calculating and storing the visibility relationships among a group of facet in a 3D space. This information is stored in a binary tree structure called the BSP tree.

In this algorithm [5], the first task is to generate a BSP tree of the scene. It depends exclusively on the geometry of the scene. The BSP tree is recursively built by selecting a plate of the scenario as its root. The root polygon is used to partition the environment into two half-spaces. One half-space contains all remaining polygons in front of the root polygon, relative to its normal surface; the other contains all polygons behind the root polygon. The two sub trees are recursively built in the same way, using the plates that have not been included in the tree at this moment. The process ends when the new sub trees

contain a single plate. The tree can be optimized by selecting as the root a plate that splits the scenario into two half-spaces with a similar number of plates.

The tree contains the information about the relative positions of the facets and it is independent of the source and observer locations. Once the building process is completed, the tree is used to establish which plates are intercepted by the ray joining the source and the observation points. Depending on the effect analyzed and on the ray path considered, the source can be a transmitter antenna, a point of reflection, a point of diffraction, or a point of transmission.

Fig 1. shows the situation for a typical scene and its associated BSP tree. The visibility tree in this situation (Fig 1.b) shows that only the facet on the left branch of the tree need to be interrogated, in order to analyze the visibility of the receiver antenna, Rx, from the transmitter, Tx. (Tx and Rx are on the other side of the root node).

In the application of the brute force method, all facets are tested. So, in complex scenes the computation time is significantly lower than that needed for the conventional analysis.

III. Validation of the simulation procedure

To validate our approach, consider the modeling of a field distribution inside a given room. The impulse response and the multipath spread of wireless indoor channel are computed for specified position of the receiving and transmitting antennas, with a chosen source. Application takes a configuration file as input which contains information about position and dielectric parameters of materials.

Indoor channel characterization

Available experiments that have been conducted on a site of engineering building at Laval University, Québec City, Canada [6] were taken to validate our simulator. These measurements were made in one room for different combinations of transmitter-receiver locations and more details are readily available in [6]. These experimental results are used for the validation of the used to characterize wideband radio channel.
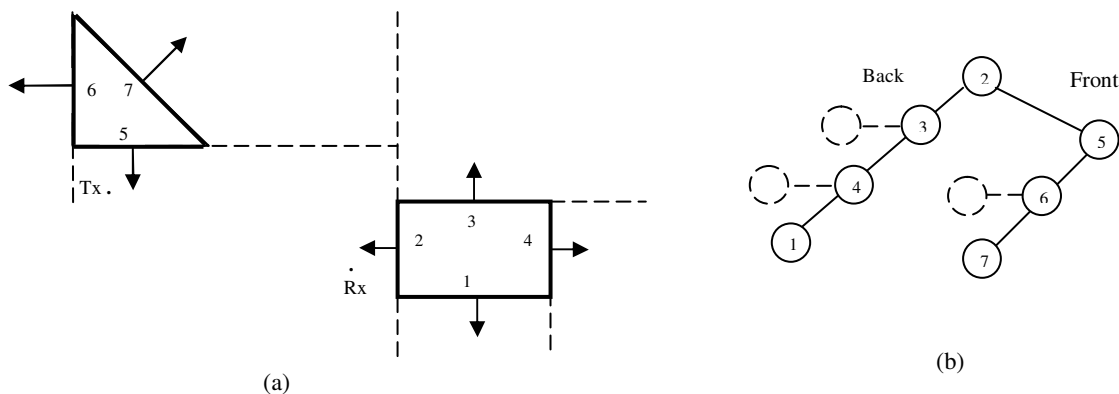

Fig. 1. Example of a typical scene (a) and its associated tree (b).

The wideband case will include a part from the coverage the possibility of obtaining the impulse response at any point of interest, in the environment under study. Path loss and delay spread predictions are compared against data from wideband radio channel measurements.

Wideband results

This section reports simulations conducted near 37.2 GHz to characterize an indoor radio channel. The wideband channel characterization is achieved from the impulse response. A significant understanding of the indoor channel behavior can be obtained from the results shown in Fig.2 and 3. The impulse responses are computed using 5ns width Gaussian pulses source of unity amplitude.

Fig. 2 and 3 show the predicted and measured impulse responses for LOS and NLOS scenarios respectively. The validity of the prediction is thus appreciated by comparing the others peaks. The path loss corresponding to a trajectory along the line is compared with the measured results obtained in [6]. Comparing these results, the agreement between simulated results and measurements can be considered good.

For NLOS scenario (Fig.3), the direct path is followed by series of multiple signals delayed mainly by different propagation paths by various reflections and diffractions of obstacles. It is clear for path obtained at this position, that the received signal is dominated by reflected signals. It is, therefore, likely that a suitable interpretation of these results must accept the fact that the diffraction around an obstruction is small compared to multiple reflections arising from NLOS propagation. These reflections can be expected to contribute very significantly to the total amount of power received at a given location.

The inaccuracies in amplitude between prediction and measurements may be attributed to the lack of precise information about materials properties, and the errors consecutives to the averaging over many measured responses. It is because some small metallic objects are neglected. The objects may have larger effects on the 37.2 GHz radio wave since their size is comparable to the wavelength. The inaccuracies may also be attributed to the fact that the numerical model does not consider all the contributing factors that are present in reality and are observed in the experimental results.
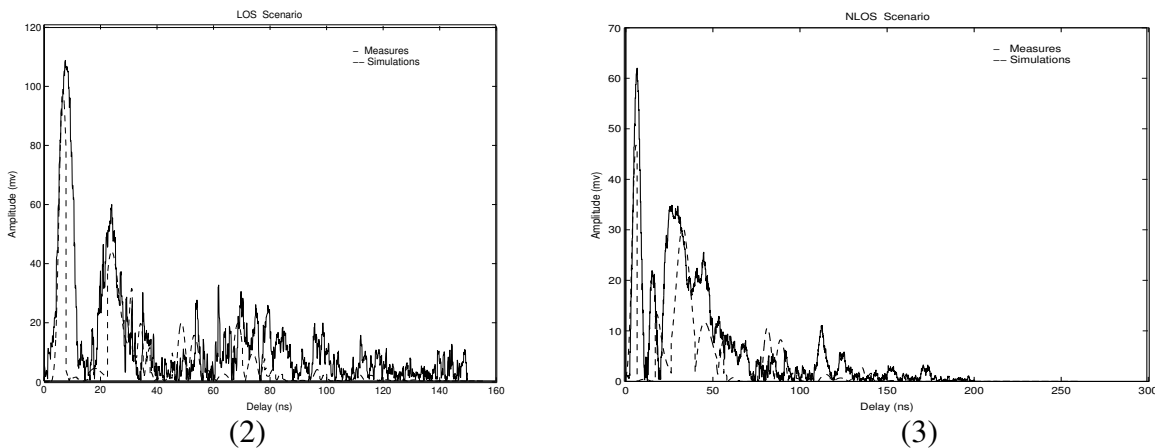

(2)   (3)

Fig. 2, 3. Comparison of experimental and simulated results obtained for LOS (Fig.2), and NLOS (Fig.3) scenarios.

IV. Conclusion

In the context of the radio propagation prediction, an accurate and efficient prediction tool for the characterization of the indoor wireless mm wave channel has been described. With the 3-D Simulator model, path loss and delay spread predictions in indoor propagation environments give reasonable accuracy. The model can predict the coverage for a given position of the transmitter and the impulse responses for given positions of the receiving antennas in a user-specified environment.

Reflection and diffraction phenomena are taken into account. The needed input data are : geometry and dimensions, frequency of operation, electrical parameters of each surface and location of transmitter and receiver.

The validation of the proposed technique has been done for wideband case. A comparison between simulated and experimental results shows a satisfactory agreement for the general behavior of the wave propagation and demonstrates the validity of the model. The impulse responses obtained can also be used to asses the RMS delay spread. In LOS and NLOS conditions, reliable results are achieved for wideband parameters, taking into account many details of the propagation channels.

The rigorous technique is more flexible and very fast to modeling complex structures at millimeter waves than conventional and numerical methods [7-8].

The main feature of the method is the possibility of the simultaneous analyzing outdoor and indoor environments as well as the interactions between them.

Acknowledgement

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