Urban radio channel insight and GTD interpretation.

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Abstract: A ray theory using a local description of an urban area is investigated to predict wideband decimetric radiowave propagation between a transmitter located on an elevated point and a mobile moving in the street in cellular environment. In this paper we clearly show that most steady delayed paths are incoming in the direction of the street where the mobile is moving, and that some of them are generated by vertical wedge diffraction of buildings lying in the same street. A better fit of the total received power was found by the use of the Luebbers diffraction formula instead of perfectly conducting UTD formula.

I. Introduction

The radio telephone development has generated an increasing need in electromagnetic wave propagation prediction model in urban area. The first models developed and most used up to date are based on empirical expressions [1], where the different coefficients are fitted from measurements. A recent success was obtained with a second type of model by the work of Bertoni & Walfish [2], who used a physical model to predict mean field attenuation dependence with distance between transmitter and receiver.

The model presented hereafter belong to a third type actually emerging that can be entitled deterministic physical method [3-9]. These studies are based on physical process to obtain not only tendency or mean values, but complete solution from modelled urban data. The advantages of such methods is to give promising accurate prediction models, but also to provide a powerful mean of investigation on propagation mechanisms involved. Two reasons favoured this evolution: on the one hand transition to microcells networks for which statistic field description become insufficient and where less environment information is necessary for modelling, and on the other hand the availability of digital data.

Even in simple cases, often a rigorous solution can't be given, and some simplification of the environment is necessary. The main one was to disregard small construction irregularities typically represented by chimneys and windows. A high frequency method like ray theory can then be applied. Most authors adopted this solution [3,4,6-9], and ray theory was also chosen here for its adaptation to three dimensional problems.

In this work, only a restricted part of the environment surrounding the receiver was taken into account. This approximation seem to be relevant in the case of cellular environment, when the base station is located on an elevated point over mean building height, and for old city types where only few buildings stand out a regular roof height [7,9]. This configuration permitted the computation of a relative complete set of diffracted and multiply reflected ray paths in a way explained in the next section and then obtain complex impulse response for any transmitter and receiver location.

In the last section, simulated results are compared with measurements performed in Paris. A new type of analyse of impulse response permitted to identify a clear structure on evolution of medium and long delay paths, and to compare the measured structure with the simulated one. The 3 dB received power bias found in a previous version [9] of the model was cancelled by the use of Luebbers diffraction formula instead of perfectly conducting metal UTD.

II The model

In cellular environment, when the base station is located on an elevated point, and cover a distance of the order of several kilometers, one can consider that the propagation is decomposed in two main parts: the first one is attenuation due to propagation over roofs tops typically represented by Bertoni & Walfish model, and a second term highly dependant on the close environment of the mobile. This second term was the only one considered by this work.

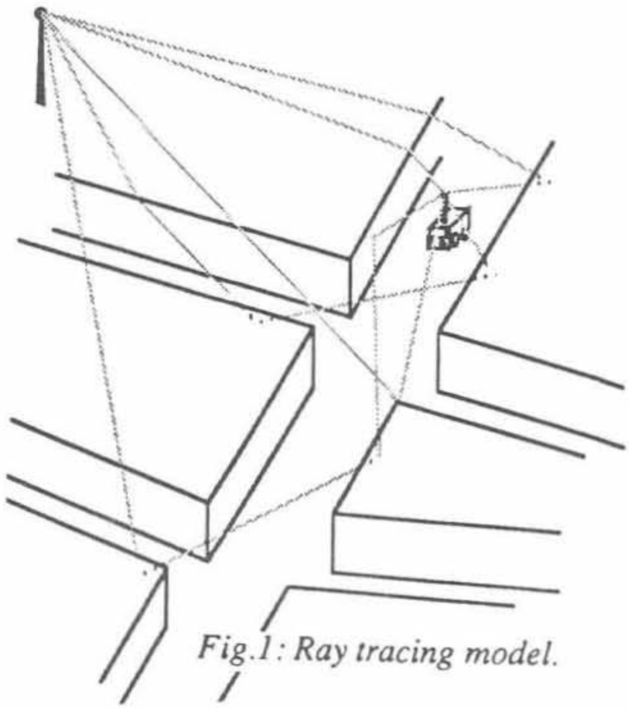

Fig.1: Ray tracing model.

The environment of the mobile is described here by the buildings lining the street where the mobile is moving and the streets crossing this first one (fig.1). Radiowave is assumed to have a free space propagation over roof top not given in this description. Building walls are considered to be flat and opaque, roughness plays here only a role in reflection attenuation and is gathered with effects of material permitivity in a constant reflection factor, since diffraction term was given by the UTD expression modified empirically by Luebbers [10]. We then neglect waves generated by scattering on walls and roofs irregularities, and transmission through buildings. The only phenomenon involved are thus diffraction and specular reflection [3].

Ray path construction was performed by the well known virtual image technique explained in details in [9]. This permitted to compute the complete set of rays, direct, multireflected, diffracted one time by the roof tops and diffracted one time by vertical wedges (fig.1).

We obtain complex amplitude and delay of any path reaching the receiver, and then the complex impulse response of the channel.

III Comparison of simulated results with measurements

Simulated results are compared to measurements performed in Paris in dense urban area. Impulse responses of the channel, between the base antenna 42 m above the ground and the mobile moving in the street, was recorded every 50 cm on runs several hundred meters long.

The only parameter of simulation is the reflection coefficient fixed here to be R=-.7 (loss=3dB/ref.). Simulated impulse responses were convolved by a theoretical measurement device filter [9]. However, because of the multiple imprecision in environment data and mobile location, and the sensitivity of coherent contributions to errors of the order of few centimeters, a direct comparison between measured and simulated impulse responses is not feasible. To observe evolution of the impulse response on several hundreds of meters a new long delay path representation mean was used: for each mobile location represented by the abscissa, any peak of the impulse response over a fixed threshold was detected and a dot was drawn for the abscissa representing his absolute delay. A threshold of 20dB under the maximum of any response was chosen on fig.2 for 2000 successive impulse responses recorded in a street (rue Parmentier) located more than 1km far from the transmitter.

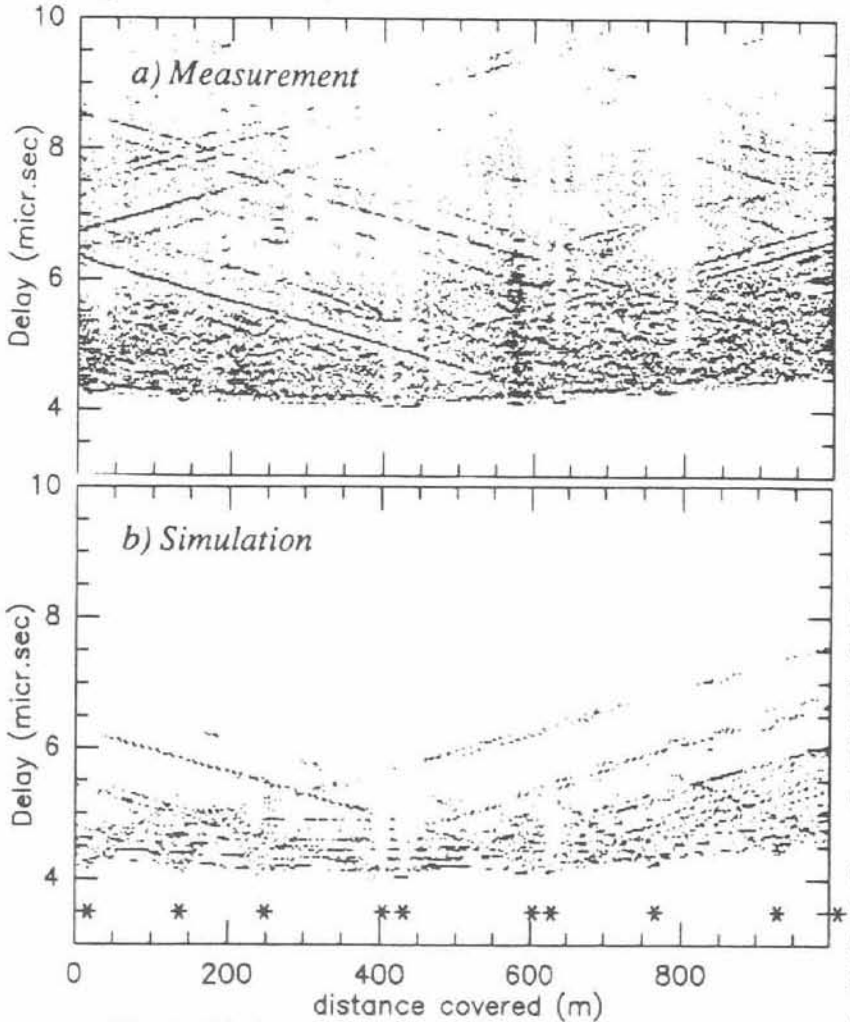

Fig.2: Main peak delays of impulse responses

We can observe that dots often stand on lines, and that these line lie on large part of the the run. This phenomenon means that main peaks of the response are not randomly distributed but most of them belong to steady path lasting on several hundred meters. Note that the slope of the line is related with the direction of arrival of the wave. In our case we can observe that these steady paths have a direction, close to, or in opposition to the direction of the mobile. The same behaviour was found on all observed runs.

The same phenomenon could be observed on simulated values, where some paths can be clearly identified. On figures of simulated results, stars represent crossroad occurrence. The long delay path was not present in simulated results where diffraction was generated only by building roofs. Most long delay paths missing in our simulation were clearly generated by obstacle not present in our data. A better agreement observed on several exemples by lowering threshold for simulated results was probably due to underestimation of long delay paths.

In previous simulations [7,9], where UTD diffraction formula for perfectly conducting metal was used, a good correlation was found with measured results, but a 3dB overestimation was always observed. Evolution of the total received power when the mobile is moving in the same conditions as in fig.2, was drawn for measured values (fig.3a) and for simulation by using Luebbers diffraction formula. We can observe that the mean received power is now correctly retrieved including short range fluctuations due to interferences. Note that long delay paths generated by diffraction on vertical edges don't participate significantly to the total received signal.

In previous works [7,9] it was clearly shown that a good representation of the received field cannot be obtained by simulating only multiple reflection (without diffraction terms). We show here on fig.3c that the first path, often considered as the

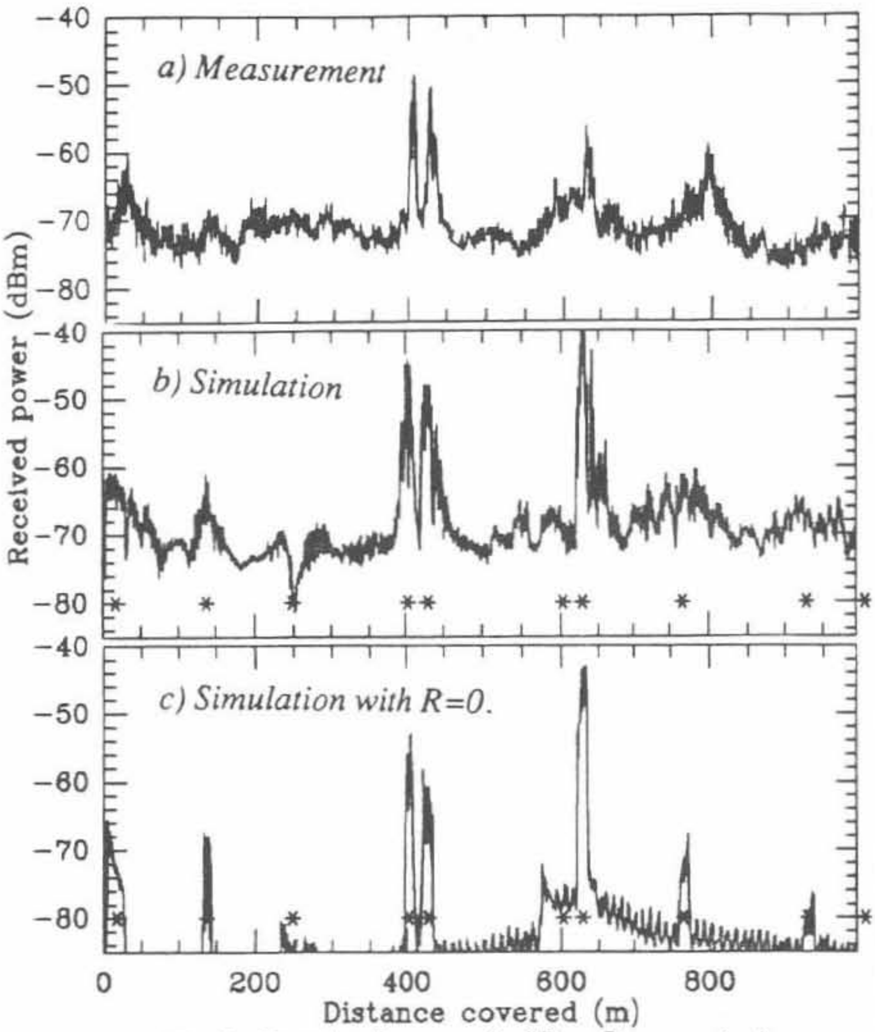

Fig.3: Received power in "Rue Parmentier".

only one in most prediction model, often don't play a significant role in received power.

IV Conclusion

A ray model propagation in cellular environment using a description of the urban area restricted to the vicinity of the mobile was developed. The results were compared to measurements performed in Paris. A good correspondence was found for the received power by using Luebbers diffraction formula. The structure observed on evolution of the impulse response on several hundred meters was partially retrieved by simulation, and some long delay path could be interpreted to be generated by vertical wedges of building lining the street where the mobile is moving.

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