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SIMULATION FOR VERTICAL DISTRIBUTION OF THE RADIO WAVES. A COMPARATIVE MEASUREMENT -SIMULATIONS STUDY AT 2600 MHZ.

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Abstract: *In this paper is presented an analysis of the RF signal strength distribution on the vertical, when the receiver antenna modifies its height, in an urban propagation scenario. The study is based on measurements campaigns deployed in Timisoara city, and on a Matlab simulation program developed by the author.*
Key words: *propagation, simulation, measurement*

1. INTRODUCTION

The actual trend in communications standardization, the next generation beyond 3G, mean enable the migrations of Internet applications such as Voice over IP (VoIP), video streaming, music downloading, TV and many others, from fixed to mobile. Long Term Evolution (LTE) technologies are addressed to the growing nomadic wireless broadband market space, with users found not only on the streets, but on inside office, malls, at home in front of TV, etc. – is the idea of convergence of technology and networks into a single applications domain, serving customers across multiple networks and devices. That means that the receiver height is different from the classic antenna height of 2 m, used in the majority of the propagation models, in order to predict the signal strength.

The instantaneous radio-channel quality varies in time, space, and frequency and depends on the detailed structure of propagation paths. This includes relatively rapid variations due to multipath propagation (multiple reflections and diffractions, waves spread). The fading due to the receiver location variability, especially in the NLoS propagation (the most probable propagation scenario) become important because the wavelength at 2600 MHz is small compare to the geometrical dimensions of the obstacles. Therefore, any small displacements from a reference point on the horizontal or the vertical can radically change the received power.

There are propagation models that can predict the electromagnetic field strength for a 3-D distribution. It can be reminded here the ITR or UDP (Hoppe, 2005) models who support that kind of features, but they are deterministic models and calculus is made based on very complex 3-D maps of the signal coverage area, including the placement and structure buildings, and the topographical data. Every building is modeled as a vertical cylinder with polygonal ground plane and an uniform height above street level. Also, the properties of the building walls are taken into account (surfaces thickness, dielectric permittivity, electrical conductivity), data used for the calculation of the reflection and diffraction coefficients and also for the penetration into buildings.

These types of models are interesting and accurate, but there are disadvantages that make them less attractive for many applications. One problem is related to the accuracy, directly proportional to the maps accuracy and sensitive to the map parameters changes, so the performances are affected by the precision of the maps. Additionally, these maps are expensive so the use of the models software becomes expensive.

The empirical models such as Okumura – Hata (Hata, 1980), or Lee model have correction terms for the receiver antenna modification, adding to the propagation median path loss formula. But these corrections are designed for relief changes (effective antenna height modifications), and not take into account the building influences.

Below it present a study of the RF signal strength variations, due to the influences of the buildings and other urban area obstacles, when the receiver antenna height increase from 2 m to 10 m, accomplished using a Matlab program developed by the author starting from experimental data. The goal of this study is to find a correction formula, that can characterize the influence of the receiver antenna height modification, and that can be added to the prediction or measured values done in urban propagation area having a 2 m receiver height.

2. MEASUREMENTS AND SIMULATION

The propagation scenario taken into account for this study is an urban one, with the receiver shadowed by the surrounding buildings, and the buildings are disposed parallel along the street (Fig. 1).

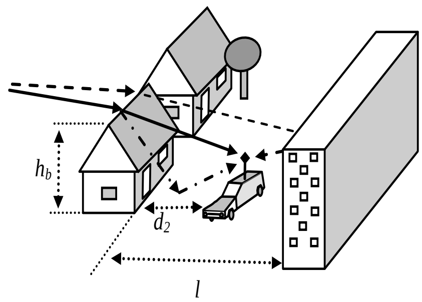

Fig.1. Propagation scenario for the simulation model

From RF signal propagation point of view, a city area can be splited into small clutters that have the same type of buildings, the same type of height regime. Statistically, the signal attenuation follows the same law, if the propagation is made in the same type of clutter (Bertoni et al., 1994).

The measurements were made in two different areas of the Timişoara city: an area, downtown, with buildings around 30 m height and narrow streets, and a residential area, with houses about 5 – 10 m high, and the streets width about 12 – 15 m. According to [clutter type], the two areas can be labeled as ‘high density urban’ and ‘low density urban’. For each measured area, the transmitter was a base – station operating at 2600 MHz. The base – station antenna height was, in both cases, above the roof top. Measurements were carried out along the streets, for every measurement point, a hydraulic mast helped to measure the RF signal at: 2 m, 4 m, 6 m and 10 m.

For the development of the Matlab simulation program, the receiver is considered shadowed by the buildings along the street, and there are three waves that were taken into account: a direct, diffracted ray, a diffracted ray and further reflected by the ground and a ray diffracted and then reflected by the walls of the building opposite to the diffraction building (Fig. 1). This approach is not new, in (Walfisch & Bertoni, 1988), (Ikegami et al., 1994) is described a similar approach of the propagation, based on the observation that in an urban area, the received signal is a sum of many rays arriving from different paths. Yet, most of the received mean power is the contribution of two or three single diffracted and reflected rays, not transmitted through building or arrived as a consequence of other propagation mechanisms.

The model is based on the equation (1), calculating the received electric field E_{tot} as a sum of the three rays:

$$\overline{E}_{tot} = \frac{E_0}{d_1^{\,p}} \cdot F(\nu_1) \cdot e^{-jkd_1} + R_{gnd} \cdot \frac{E_0}{d_2^{\,p}} \cdot F(\nu_2) \cdot e^{-jkd_2} + R_{wall} \cdot \frac{E_0}{d_3^{\,p}} \cdot F(\nu_3) \cdot e^{-jkd_3} \qquad (1)$$

$E_0 = \sqrt{30 \cdot P_t \cdot G_t}$ – the r.m.s of the electric field of the transmitted wave;

$F(\nu_i)$ – is the Fresnel function for diffraction calculus;

d_i – propagation path distances for the four rays;

p – the path loss exponent;

R_{gnd}, R_{wall} – are the reflection coefficients for the ground and wall reflection.

The simulation program is designed to take into account the specific parameters of the propagation clutter: average building height, the width of the street, the distance of the receiver to the diffraction building and the "street angle" – angle made by the street with the imaginary line that make the receiver collinear with geographic north. Also, the program admits as input data the geographic coordinates of the transmitter and receiver (UTM datum, WGS84), and transmitter antenna, vertical and horizontal gain characteristics. The user needs to specify the electrical parameters (conductivity, permeability) of the ground and the walls. The diffraction parameters, distances, reflection angles are then calculated by the program. For diffraction, the Fresnel 'knife edge' model is used.

In the equation (1) appears a path loss exponent. According to (Seidel, 1991), the path loss is directly proportional to d^{-p}, where p depends on the propagation environment. For the electrical field free space propagation, the path loss exponent is 1 (for received power is 2). Due to the imperfections of the model used in simulation (the exact height of the obstructing building is not known, the diffraction due to the building roof is far from 'knife edge' model, the real loss from reflection can be different from the theoretical values due to the reflecting surfaces roughness), this path loss exponent can be used as a calibration parameter of the simulation, starting from experimental data prior collected.

3. EXPERIMENTAL RESULTS & CONCLUSIONS

In the Fig. 2 and Fig. 3 are presented two cases coming from two measurement points, one from 'high density urban' clutter and the other from 'low density urban' clutter, and the corresponding simulation data. In the 'high density urban' clutter, the path loss exponent was found to be *p = 0.8*, and for 'low density urban' clutter, *p = 1*. That shows that, in the areas where the shadowing is not so deep, the model can evaluate with good results the vertical distribution of the field strength.

For the other case, where the obstructing buildings height is large compare to the receiver antenna height, the model become pessimistic, the received field above 10 dB higher than the prediction values. In (Seidel, 1991) a similar situation is reminded in the cases where the street canyon effect appears. For the streets arrangement on the measured area in the 'high density urban' clutter, it is possible to appear this kind of propagation mechanism.

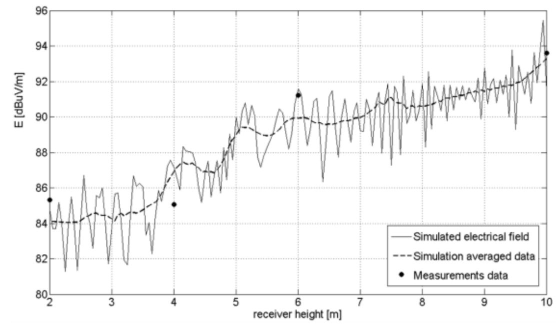

Fig.2. Experimental results for a measurement point from 'high density urban' clutter

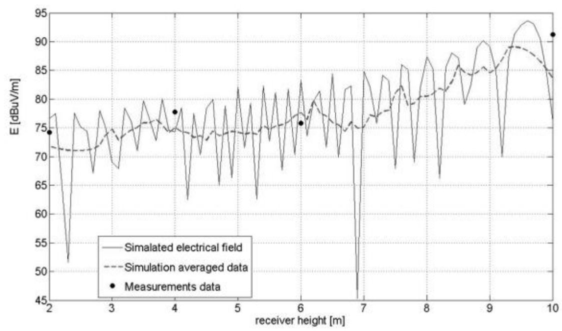

Fig.3. Experimental results for a measurement point from 'low density urban' clutter

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