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# Signal Propagation Model for Microcells at 900 MHz Frequency Range

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***Abstract*—In this research paper, a signal propagation for microcells, based on building heights and distance from base station, is examined. The tests were carried out in an urban area. There were measured the signals' path losses from two mobile network base stations depending on buildings highs and distances to them. The "Anritsu Cell Master MT8212A" spectrum analyser was used for signal strength measurements. The results are compared with well-known models. Based on experiment results a new propagation model is proposed for the examined area.**

***Index Terms*—Cellular networks, radiowave propagation, mobile communications.**

## I. INTRODUCTION

For the past decade the networks of telecommunications have been expanding at a tremendous speed so older cellular technologies are becoming obsolete and updated by newer ones, for example, the Advanced Long Term Evolution (LTE-A). The demand for newer, more reliable higher capacity and high-speed information access networks is growing exponentially, especially in densely populated city areas [1].

In order to create a reliable, high capacity cellular network with wide coverage, one of the first steps is to predict how radio signals will travel in the selected environment from transmitter (Tx) to receiver (Rx). These predictions are made using different propagation model types: deterministic, empirical or half empirical. The deterministic model is usually the most accurate, but involves very complex calculations for wave propagation phenomenon (diffraction, reflection, scattering and so on). The easiest model type to apply for a selected environment is empirical because it is based on experiments and some simple calculations. However, different frequency signals propagate differently in the same environment, therefore experiments are carried out using a limited frequency range of signals.

The main problem is that the prediction of signal propagation in different environments is hard and many factors need to be included, for example, line of sight (LOS) or non-line of sight (NLOS) conditions, building heights, street widths, etc. On the other hand, existing empirical models have been developed relatively long time ago and require some corrections or confirmation that they are valid.

The aim of this paper is to propose an empirical signal propagation model for microcells at 900 MHz frequency range based on the distance between user equipment (UE) and base station (BS) and different building heights. Hundreds of researches have investigated how signal acts in microcell environments, however, there is a lack of research assessing the influence of building heights. The proposed empirical model is designed for 900 MHz signal frequency range and, therefore, it may be used even with the newest present and sophisticated technologies like LTE-A, if it operates at 900 MHz frequency range.

## II. OTHER EXPERIMENTS

Currently there are dozens of created signal propagation models and much more experiments conducted. Many empirical models were created for only those environments which are similar to those in which signal propagation experiments were made. The most frequently used models are free-space path-loss (FSPL), Clutter Factor, Lee, COST231 Walfisch-Ikegami, COST231 - HATA, Two Slope, Multiple Slope, Log-distance. What model will be used depends on the cell type, frequency, area type and other environment variables.

The analysis of current research papers was a crucial step for creating a new more advanced model for microcells where prediction of signal propagation is more complex than in macrocells.

An improved model based on Walfisch-Bertoni model was analysed for microcells in 900 MHz range in paper [2]. This model estimates the influence of the mean building heights and density for radio frequency signals. The simulation results showed that cellular system signal quality was unaffected if building heights and street widths were based on Gaussian distribution.

However, based on previously mentioned geometric parameters, Rayleigh distribution had a big influence for signal quality.

The purpose of research study [3] was to propose a 3D deterministic signal propagation model at 900 MHz based on COST231 Walfisch Ikegami model. The accuracy of COST231 Walfisch Ikegami model was analysed without defined building height parameters and then a 3D model was

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experimentally examined with defined building heights. In order for the model to work correctly, base station has to be higher than the buildings. The result is an improved propagation model for 900 MHz signal with better prediction accuracy.

Paper [4] proposed Lee model calibration. The final results were then compared with the ones obtained from Hata, Egli models and experiments. The experiments were conducted in a low building density area with heights of maximum 5 meters. The results were processed using MATLAB software. The calibration of Lee model was done by calculating the correction coefficients for frequency and antenna, then calculating and normalizing the distance from the base station and finally calculating the signal loss, difference between sent and received signals. The final results showed that calibrated Lee model is much more accurate than Hata or Egli models.

In paper [5] signal loss in suburbs and countryside for 3G network was investigated based on experiment results and four empirical models: Okomura-Hata, COST231-Hata, Clutter, Lee. The results showed that even if the distance from base station is the same, the signal loss is not the same in different areas. Multipath effect was more noticeable in the countryside. Lee model results were the most inaccurate. Clutter model was the most precise for countryside but Okomura-Hata was overall the more accurate for cities, suburbs and countryside.

Deterministic model, called RMC (Radio Microcell), for ultra high frequency (UHF) radio propagation is proposed in research paper [6]. This model is suitable for microcellular environment. The model accounts for environment geometries and obstacles which cause reflection, diffraction and scattering. Also it is suitable for evaluating interference parameters for IMT systems. Experiment measurements of signal strength were carried out in the urban environment in order to compare real-life results with different deterministic models at 1900 MHz frequency. About 20 measurement points were selected with 10 meters to 30 meters distance between two points. The results showed that proposed RMC deterministic model was the most accurate comparing with microcellular WINNER model.

## III. MEASUREMENT PROCEDURE

Two base stations from one of the Lithuanian telecommunications operators have been chosen. Signal strength was measured only in outdoor environment at frequency range of 900 MHz. Main characteristics of base stations are presented in Table I.

TABLE I. MAIN CHARACTERISTICS OF SELECTED BASE STATIONS.

| | **BS1** | **BS2** |
|---|---|---|
| **Frequency, $f_c$ (MHz)** | 945.40 | 956.20 |
| **Tx antenna height, $h_b$ (m)** | 32.00 | 43.00 |
| **Rx antenna height, $h_m$ (m)** | 1.30 | 1.30 |
| **BS power, $P_{tx}$ (dBm)** | 38.82 | 40.01 |

A spectrum analyser "Anritsu Cell Master MT8212A" was chosen to measure the signal strength from the base stations. This spectrum analyser is suitable for analysing the characteristics of cable, antenna and base station. The frequency interval for measuring power is 10 MHz to 3.0 GHz. "Handheld Software Tools (HHST 6.61)" software was selected for processing of results. This software allows to investigate results the same way as in spectrum analyser user interface. If further data analysis is needed, results can be exported to .txt format and processed using other sophisticated software.

Few dozens of points were chosen around BS near Kaunas University of Technology with a radius of 1 km. Coordinates for each point were determined by GPS in order to calculate the distance between BS and user equipment. Using spectrum analyser signal frequency was measured in each point. All measurements were repeated 10 times at each point, two days in a row in order to minimize the error of results.

The correlation coefficient between the different measurements is more than 0.82, which corresponds to a strong correlation. The average standard deviation is 2.06 dBm.

For more detailed analysis buildings of different heights were chosen and the previously stated measurement algorithm was repeated. The height of the buildings varied from 12 m to 41 m. The 10 measurement points were selected behind each building. The distance between two adjacent points was 2 meters.

Based on experiment results from the two base stations and calculations a new propagation model is proposed.

## IV. RESULTS

The results of these experiments are compared with the experiments of other authors [7]–[9] in Fig. 1.

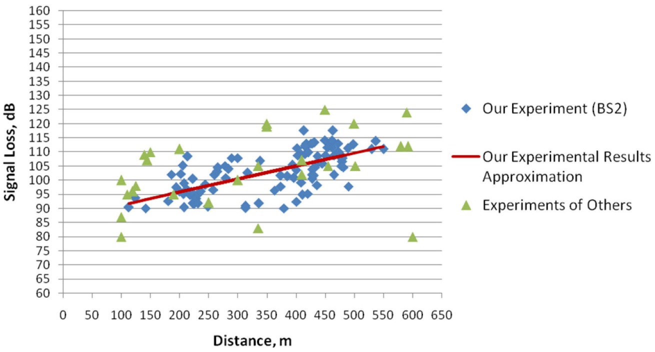

Fig. 1. Comparing signal path losses vs distance with other authors' experiments.

In this part only signal loss based on the distance is evaluated for. The results of this work correspond reasonably well with the results of other works, and can be approximated using the relationship (1)

$$y = 0.046x + 86.60, \tag{1}$$

where y is signal loss (dB) and x is the distance between BS and UE (m).

Form the approximation line (Fig. 1) it can be seen that signal loss is growing when the distance between UE and BS increases. The signal loss fluctuates between 90 dB and 110 dB if the distance is less than 400 m.

The obtained results and results from other papers are quite similar and are scattered through all the distance. These kinds of results do not have a very clear tendency because many propagation parameters were not considered, for example, building heights, NLOS and LOS conditions at specific points during the measurements, street widths, tree influence and so on.

The measurements of signal loss were compared with the different 8 empirical propagation models (Fig. 2, Fig. 3).

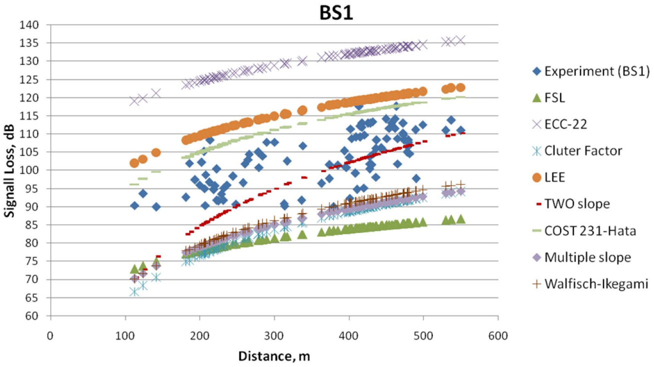

Fig. 2. Comparison of experiment results and propagation models for BS1.

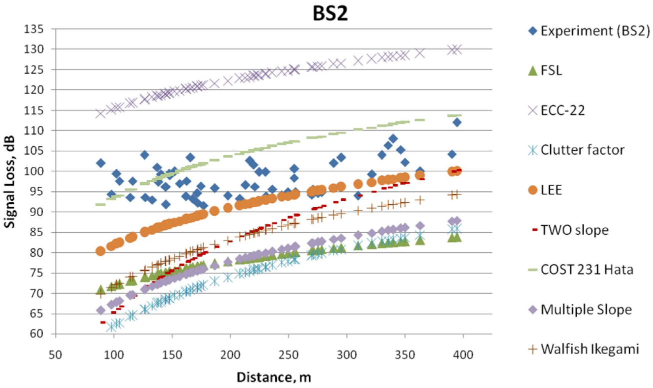

Fig. 3. Comparison of experiment results and propagation models for BS2.

Based on Fig. 1 and Fig. 2 it is evident that the results of selected propagation models are quite different to the experimental ones. The results of all models have higher line slope and are distributed only higher or lower compared to the experiment results.

Propagation models for BS1 and BS2 present different results. It is because of differences between BS power and Tx antenna height for both base stations.

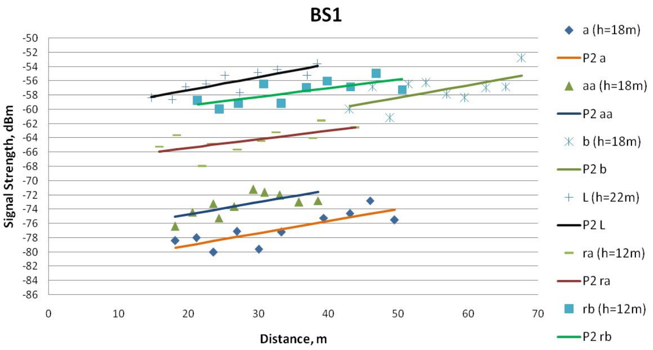

Fig. 4. The influence of different building heights for signal strength (BS1).

As we can see in Fig. 2 and Fig. 3, none of the selected propagation models are accurate for selected base stations and would produce a non-correct results. In order to predict signal loss for selected BS it is crucial to propose a new model based on the results of the experiment and the environment variables.

The evaluations of the impact of building height and distance for signal loss are presented at Fig. 4 and Fig. 5.

The height of the buildings were from 12 to 22 meters for BS1 (Fig. 4) and from 15 to 41 meters for BS2 (Fig. 5). The measured signal strength values behind every building were approximated by the equation of straight line: $y = ax + b$. The line slope of all approximated lines is almost identical.

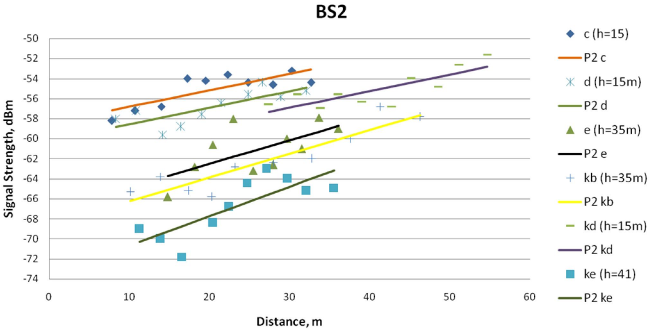

Fig. 5. The influence of different building heights for signal strength (BS2).

The coefficient *a* in linear equation estimates the influence of the building heights (Fig. 6). The higher the building, the higher the coefficient.

From Fig. 4 and Fig. 5 it is obvious that the same height buildings have the same *a* value in different BS.

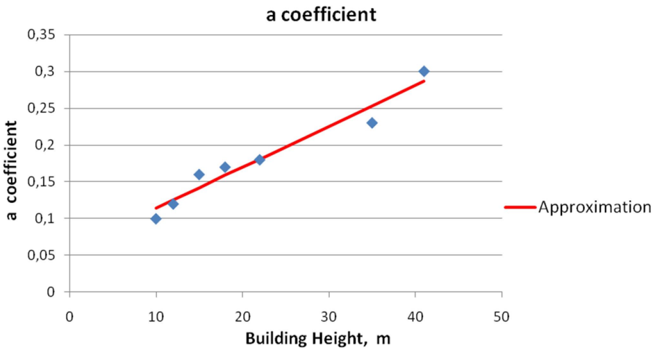

Fig. 6. The influence of different building heights for *a* coefficient.

Based on experiment results the cofficient *a* values can be approximated as follows

$$a = 0.0056h_n + 0.0583, \tag{2}$$

where $h_n$ is the height of the building (m).

The equation of straight line has a coefficient *b* which could be the function of BS transmitter and antenna characteristics (*ERP* - effective radiated power, antenna height, distance from BS). In the conducted experiment only the influence of distance from BS for coefficient *b* was analysed. All other function parameters were disregarded, because both BS had a little different ERP and UE antenna height was the same all the time.

The results are presented in Fig. 7.

The approximated lines (Fig. 7) are all parallel and the line slope for each line is the same. Based on experiment results, the coefficient *b* can be approximated as follows

$$b = 0.185 y_{BS} + n\,, \tag{3}$$

where $y_{BS}$ is the distance from the base station (m), *n* is experimentally determined value (dBm), which depends on *ERP* of base station.

By observing the influence of building heights and distance from the BS it was found that the received signal level is a linear function. A new model is proposed based on functions of coefficients *a* and *b*. However, the diffraction effect is not included in the new model.

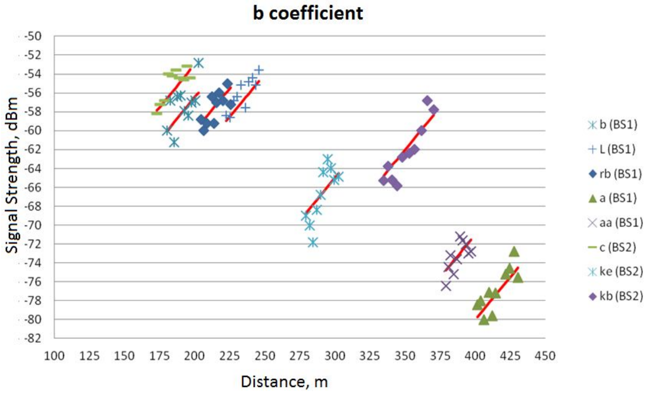

Fig. 7. The influence of distance from BS to UE for *b* coefficient.

The new model can be expressed by the following equations:

$$P_{rx} = (0.0056 h_n + 0.0583)x + 0.185 y_{BS} + n, \tag{4}$$

$$L = P_{tx} - (0.0056 h_n + 0.0583)x - 0.185 y_{BS} - n, \tag{5}$$

where $y_{BS}$ is the distance from the base station (m), *x* is the distance from the building (m), $h_n$ is height of the building (m), *L* is signal loss (dB), $P_{rx}$ is UE received signal power (dBm), $P_{tx}$ is BS transmitting power, *n* is experimentally determined value (dBm).

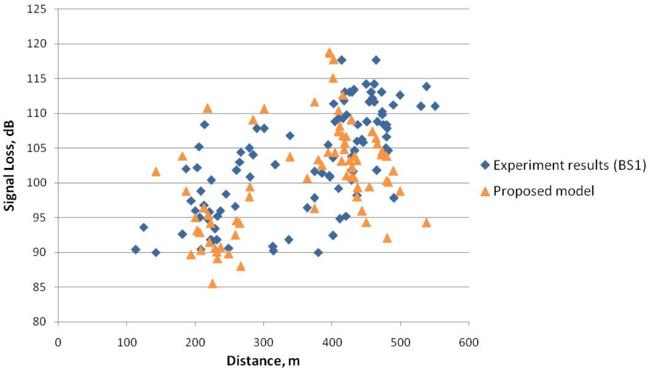

Fig. 8. Comparison of new propagation model and experiment results.

The comparison of proposed model and experiment results is showed in Fig. 8.

The results of new model are very close to the experiment ones (Fig. 8). The scatter of results closely depends on the specific outdoor environment parameters, where experiment was conducted (in our case: heights of the buildings, distance from BS, and distance from the building).

The accuracy of proposed model is ~97.8 %. It means that the difference between new model and experiment results is only 2.2 %, therefore the new model can be used to evaluate the signal loss in similar microcell environment area at 900 MHz frequency range.

## V. CONCLUSIONS

1. It has been found that there is a large discrepancy between the results of the most popular models (Lee, Walfish-Ikegami and so on.) and the results of these experiments. The closest results to experiment results give COST231 Hata model despite the fact that it is intended for macrocells.

2. A new model (formula 5) for path losses evaluation in microcells at 900 MHz range is proposed.

3. The results of this work can be used to develop new path losses prediction models or improve the existing ones.

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