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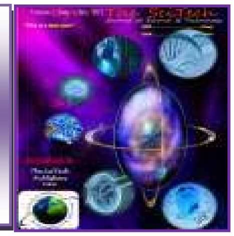

Research Article

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OKUMURA-HATA, WALFISH-IKEGAMI AND 3GPP PROPAGATION MODELS IN URBAN ENVIRONMENTS FOR UMTS NETWORKS

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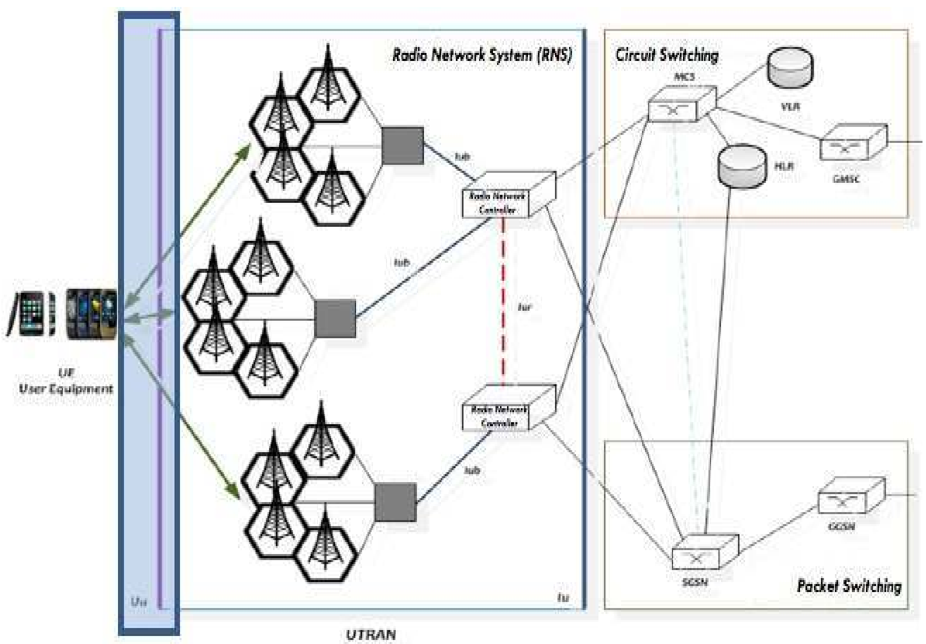
Abstract:

This paper describes an analysis based on the study of signal propagation in third-generation mobile networks. We chose three propagation outdoor models. Field measurements were used as input in an algorithm created for these models. The results were compared with theoretical results of models and then we chose the best model for testing. The selected environment was an urban area highly populated within Mexico city.

Key words: 3GGP; Cost Walfish-Ikegami; Krige; Okumura-Hata.

Graphical abstract:



Introduction:

Wireless technologies, especially those related to communication, have advanced quickly. Mobile communications are an everyday necessity, helping people to complete tasks and making this a better and more comfortable experience. The development of third generation (3G) mobile technology is a global endeavor focused on improving service quality, all under the supervision of working groups who ensure compliance with international standards and protocols, especially those created to support 3G technology.

Mobile service providers must plan the distribution of their equipment carefully and guarantee good quality of service. Important factors in any type of wireless communication system are signal propagation and losses owed to the physical environment. That is why in this paper we present a comparison of empirical propagation models and field study in a particular area. This allows one to appreciate the power levels in the region while also enjoying an overview of the technical specifications for a given project and planning distribution of elements of UMTS architecture, in this case Nodes B and User Equipment.

Analyzing signal propagation is realized through the Uu interface, i.e., on a downlink between User Equipment and Node B. This is where we find medium access with WCDMA, as shown in Figure 1.

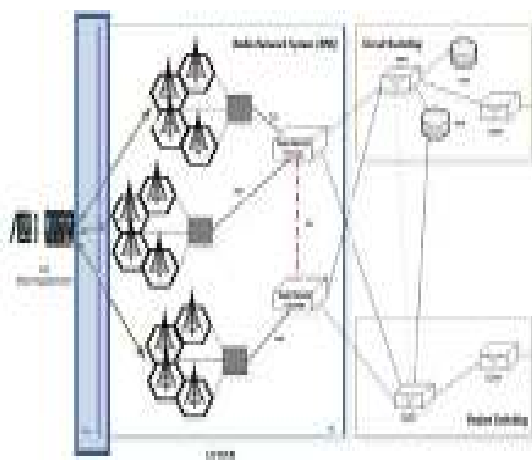


Fig 1: Access Plane Architecture

Theoretical Foundations:

In 3G systems there are several parameters that allow us to measure the performance of a network such as the common pilot channel (CPICH) which transmits a carrier to estimate channel parameters. It is used for power control, adjacent cell measurement and to determine the scrambling code (SC) [1, 2]. This channel let us identify a successful coverage area and determine distribution of power levels.

Propagation models are a set of mathematical expressions, diagrams and algorithms used to represent the features in certain environments characterized by factors such as the frequency of operation, physical dimensions of the elements and the modulation scheme used [3]. The Okumura-Hata model makes a prediction of the signal strength. The model for an urban area considers the characteristics of an urbanized city or big city with big buildings and houses or large villages with nearby houses and trees. This model provides a fundamental formula for the calculation of urban losses and is given by:

$$L_{50(urbano)}(dB) = 69.55 + 26.16\,log f_c - 13.82\,log h_{te} - a(h_{re}) + [(44.9 - 6.55\,log h_{te})]\,log d$$

where:
$150 < f_c < 1500$ [MHz]
$30 < h_{te} < 200$ [m]
$1 < d < 20$ [km]

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a (h_{te}). Correction factor

The COST Walfish-Ikegami model is applicable to large, small and micro cells for frequencies (f), base station antenna height (h_t), mobile antenna height (h_r) and distance (d), within the range:

$800 < f < 2000$ [MHz]
$4 < h_t < 50$ [m]
$1 < h_r < 3$ [m]
$0.02 < d < 5$ [km]

The total loss (L) is composed of three values: free space loss (L_F), diffraction loss roof-street/dispersion (L_D) and multiscreen loss (L_S) [4], and thus we have:

$$L = L_F + L_D + L_S$$
$$L_F = 20\log(f) + 20\log(d) + 32.44$$
$$L_D = -16.9 - 10\log(r_W) + 10\log(f) + 20\log(h_B - h_r) + L_\varphi$$
$$L_S = -18\log(1 + h_t - h_B) - 9\log(d_B) + k_a + k_d\log(d) + k_f\log(f)$$

The propagation model 3GPP is suitable for testing scenarios in urban and sub-urban areas and is functional for frequencies up to 2000 MHz [5]. The equation describing the loss of the model is as follows:

$$\boldsymbol{L = 40(1 - 4\times10^{-3}Dhb)\log_{10}R - 18\log_{10}(Dhb) + 21\log_{10}(f) + 80}$$

where:
R: Distance between base station (Node B) and user equipment [km]
f: Frequency of carrier [MHz]
Dhb: Antenna height of base station (Node B) [m]
The three propagation models described above are just some of the many that exist. In this particular case, we have chosen these three because they are tailored to the characteristics of the environment and area of study, in addition to meeting a range of operating frequencies.

Measurement Methodology:

It is important in this context to study different models of propagation that can be used for the planning and deployment of these mobile providers which require accurate and reliable analysis. Field measurements were obtained using a spectrum analyzer capable of working in frequencies between 9 kHz and 7.1 GHz [6-7]. The equipment is able to demodulate WCDMA signals to obtain information from various performance factors, in our case the power of the CPICH channel.

Table 1 shows the configuration of equipment and antenna characteristics, values that allow us to work on the characteristics of the service provider under review.

Table 1. Configuration Parameters

Parameter	Value/Features
Carrier Frequency	887.5 MHz
Operating Band	Band V - Additional Channel Systems UMTS for Downlink
Operating Frequency/ Antenna	870 a 960 MHz
Antenna	Omnidirectional

For a correct analysis of experimental results georeference information is required. To obtain this information, the equipment has a GPS and generates position information on latitude, longitude, altitude and time. At least four satellites are required for this purpose.

The area under analysis is shown in Figure 2. Note the area outlined in red, which shows the location of Node Bs in this zone. The test area has different architectural characteristics and environments. The analysis was based on information of four Node Bs.

Fig 2 : Test Scenario

Information Processing and Information System:

All the measurements were downloaded to a computer, to be interpreted by means of a software tool called Master Software Tools (MST). This tool allows the display of measurements and exports them to a *. cvs for further processing [8]. Figure 3 shows the working environment and measurements.

Fig. 3: Master Software Tools

Once information is collected in a single file, we can obtain measurements of each scrambling code and its parameters. With this file it is possible to determine the occurrence of each SC. Finally, we can identify different scrambling codes in the measurement area.

Subsequent analysis was based on propagation models, which required a set of input values for calculating each of them:

- Type of area.
- Type of city.
- Height of transmitting and receiving antennas.
- Base station location or Node B.

In performing this analysis we used a data entry environment, which took into account measurement information and conditions. Figure 4 shows that work environment.

Fig 4: Platform GUI in MatLab

Figure 5 shows a block diagram of the proposed algorithm.

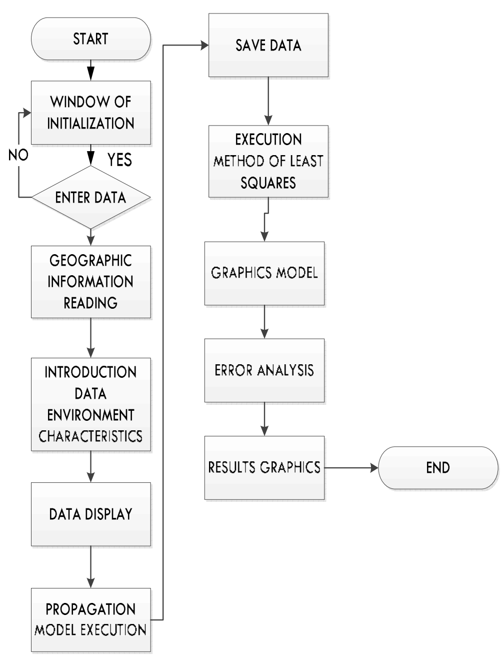

Fig 5: Algorithm. Block Diagram

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With this system it was possible to compare different models and generate an error analysis for each of them based on information obtained from field measurements. Thus, the best model was obtained for each node propagation analysis.

Building Coverage Maps:

With the points measured it was possible to generate coverage maps. The data were processed with EasyKrig software to implement the geostatistical method initially developed by Daniel G. Krige, which was based on interpolation of algorithms by least squares regression. The method takes the point values and generates continuous graphic, performing an interpolation of them.

The process of generating coverage maps consists mainly of four steps:

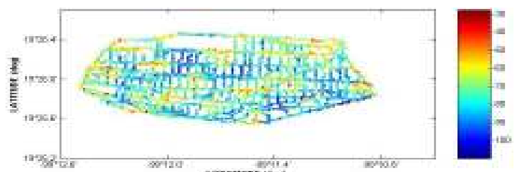
Step 1. Data reading. Longitude, latitude and performance indicator.

Step 2. Generation of a theoretical variogram based on one experiment. Predicting behavior of signal transmitted by Node B.

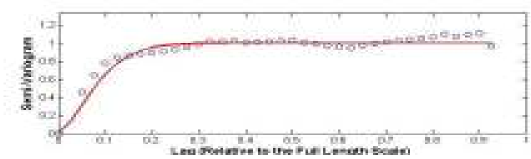
Step 3. Running the kriging process.

Step 4. Validation and map display.

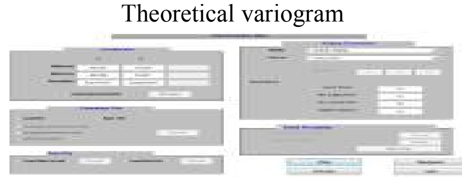
Figure 6 illustrates the steps, allowing us to visualize the process of creating maps.



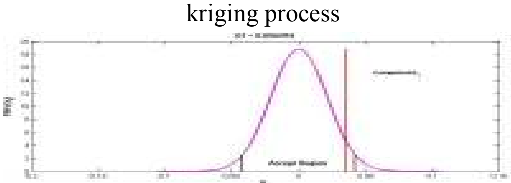
Data reading



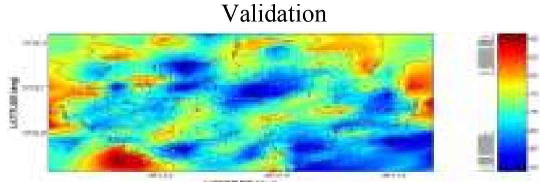
Theoretical variogram



kriging process



Validation



Map Display

Results:

CPICH Power Levels vs. Experimental Propagation Models:

As mentioned earlier, the study is based on four Node Bs and their coverage analysis. Table 2 shows the corresponding scrambling codes, as well as their location in and impact on the area.

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Table 2. Node Bs, Incidents and Appearances

Node B	SC	Number of Measurements	Incidences Pilot Dominance
Node_A	169	47	24
	177	58	18
	185	57	26
Node_B	338	61	16
	346	40	13
	354	29	20
Node_C	386	38	42
	394	84	46
	402	97	43
Node_D	459	6	0
	467	65	34
	475	36	8

Analysis was performed for each Node B using the algorithm developed in MatLab. Processed based on field data were implemented to execute each propagation model, generating an output for error analysis and obtaining the best model for each Node B. Table 3 presents a summary of the errors found for each model and Node B.

Table 3. Error Analysis

Errors	MOH[1]	MCWI[2]	M3GPP[3]
Node_A			
Average Relative Error	33.3488106	15.4529092	22.5490518
Average Absolute Error	0.33569183	**0.19423429**	0.25518318
Node_B			
Average Relative Error	25.8150969	12.7296216	16.2745603
Average Absolute Error	0.26927593	**0.16785949**	0.19176663
Node_C			
Average Relative Error	32.040266	16.9823331	22.7363215
Average Absolute Error	0.31778727	**0.21257951**	0.254166216
Node_D			
Average Relative Error	32.0156263	14.9359825	21.7830579
Average Absolute Error	0.31648985	**0.18305803**	0.24139559

[1] Okumura-Hata model
[2] COST Walfish-Ikegami model
[3] 3GPP model

As shown in the above table, the propagation model that has the lowest error compared with information obtained from measurements is the COST Walfish-Ikegami model, followed by the 3GPP model.
Figure 7 shows power levels in the measurement procedure. They show a random behavior, however, which means we cannot evaluate these results and compare them with the propagation models.
Therefore, comparison is performed by the least squares approximation function to generate the behavior of the measured data.

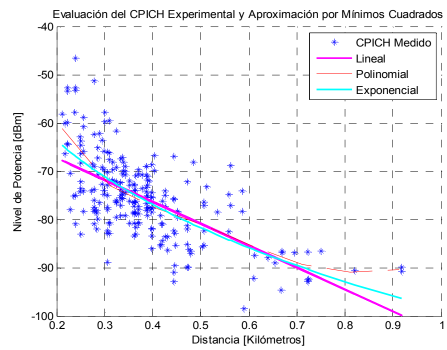
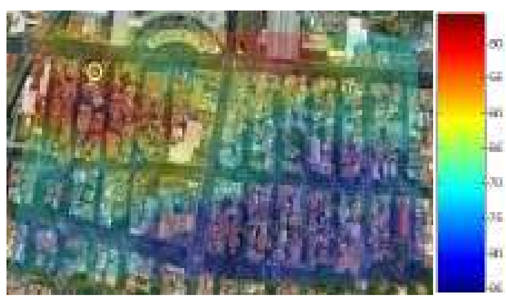
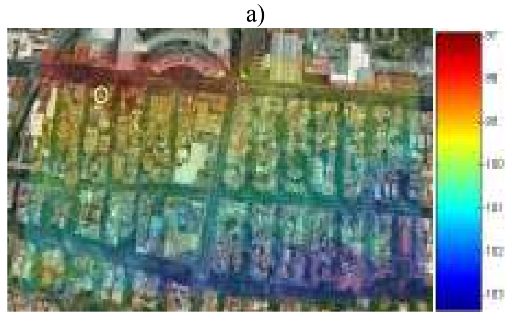


Fig7 : Behavior and Least Squares Approximation

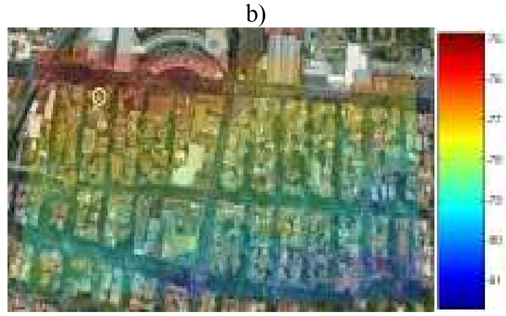
Figure 8 shows estimation maps generated for Node_A coverage and the results for each model. Power levels in the COST Walfish-Ikegami model are approximate values obtained from field measurements.



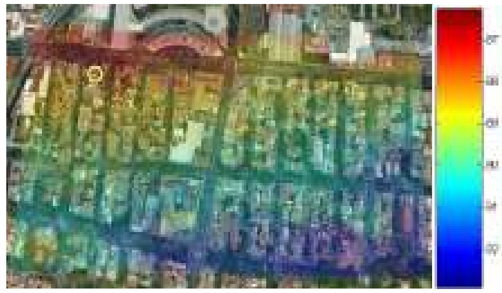
a)



b)



c)



d)

Fig. 8 Coverage Maps. a) Experimental b) Okumura-Hata model c) COST Walfish-Ikegami model d) Model 3GPPP

Conclusions:

As we can observe, according to the area under analysis, The COST Walfish-Ikegami model gives the best performance in each Node B analyzed, making the best prediction by considering characteristics of the environment, especially dispersion caused by the roof/width of streets.

Based on the data measured, it is possible to recommend that the COST Walfish-Ikegami model, could be used in Mexico city in order to improve the celular radio network planning.

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