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Comparative Analysis of Propagation Models in Urban Environments

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Abstract—**This paper shows an analysis about signals propagation in Third Generation Mobile Networks, their access medium is Wideband Code Division Multiple Access. The research includes field measurements and the choice of three propagation models with technological and environment of the test area. With a computer algorithm we select one of three outdoor propagation models for the study area; we compared results of field measurements versus selected models. The study was made in an environment with a high population density and a high demand of data traffic; we selected four Base Stations (Nodes B) in test area with the objective of observe real behavior of signal transmitted versus ideal behavior of an empirical method.**

Keywords-component- ***3G; 3GGP; CPICH; Cost Walfish-Ikegami; Krige; Okumura-Hata; Propagation Models; WCDMA.***

I. Introduction

The set of wireless technologies, especially those related to communication have evolved quickly. Mobile communications have become the best partner of people, helping them to complete daily tasks and making this a better and comfortable experience.

The development of mobile technology in Third Generation (3G) is a global engagement work always focused on improving services quality, all under supervision of work groups, these groups carry out compliance with international standards and protocols, especially created to support 3G technology.

The study showed in this paper was realized into urban environments of Mexico City. In this place the deployment of 3G services still predominate and 4G technologies are in a first stage.

Otherwise, important factors in any kind of wireless communication system are signal propagation and losses through the physical environment from one place to another. Therefore, mobile services providers use this factor for planning and distributing equipment and if this way they can satisfy the minimum conditions for establishing a good communication [1].

In this paper we present a comparison between empirical propagation models against field measurements in a particular area. You can observe power levels in the region and get an overview of the technical specifications for a given project and planning distribution of elements of UMTS architecture, in this case from the Nodes B and User Equipment.[2]

The performance of a propagation model is evaluated by assertiveness or veracity against results obtained in field measurements.

Analyzing signal propagation is realized on Uu interface, ie on downlink between User Equipment and Node B, in this part are where we find medium access with WCDMA, as shown in Figure 1.

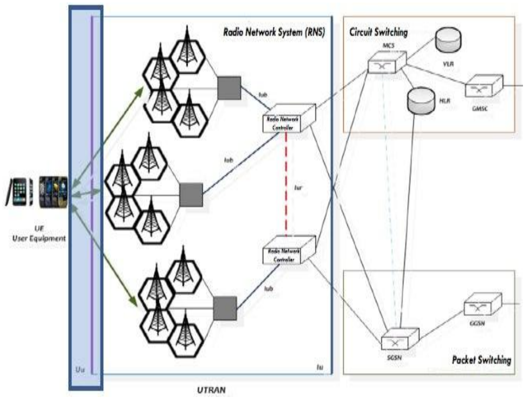

Figure 1. Access Plane Architecture [3]

A. *Theorical fundamentacion*

In 3G systems there are several parameters that allow us to measure performance of network, as Common Pilot Channel (CPICH) which transmits a carrier to estimate channel parameters. It is used for power control, adjacent cells measurement and to determine the Scrambling Code (SC) [4], this channel let us identify a successful coverage area and determine distribution in 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 [5].

The Okumura-Hata model makes a prediction of the signal strength. The model for an urban considers 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, is given by:

$$L_{50(urbano)}(dB) = 69.55 + 26.16 \log f_c - 13.82 \log h_{te} - a(h_{re}) + [(44.9 - 6.55 \log h_{te})] \log d \quad (1)$$

Where:

150 <fc <1500 [MHz]
30 <hte <200 [m]
1 <d <20 [km]
a (hte). Correction Factor

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

800 <f <2000 [MHz]
4 <ht <50 [m]
1 <hr <3 [m]
0.02 <d <5 [km]

The total loss (L) is composed of three values: Free space loss (LF), diffraction loss roof-street/dispersion (LD) and multiscreen loss (LS) [6], thus we have:

$$L = L_F + L_D + L_S \quad (2)$$

$$L_F = 20 \log(f) + 20 \log(d) + 32.44 \quad (3)$$

$$L_D = -16.9 - 10 \log(r_W) + 10 \log(f) + 20 \log(h_B - h_r) + L_\varphi \quad (4)$$

$$L_S = -18 \log(1 + h_t - h_B) - 9 \log(d_B) + k_a + k_d \log(d) + k_f \log(f)' \quad (5)$$

The propagation model 3GPP is applicable to test scenarios in urban and sub-urban and is functional for frequencies up to 2000 MHz [7]. The equation describing the loss of the model is as follows:

$$L = 40(1 - 4 \times 10^{-3} Dhb) \log_{10} R - 18 \log_{10}(Dhb) + 21 \log_{10}(f) + 80 \quad (6)$$

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 many that exist, in this particular case, we choose these three because they are tailored to characteristics of environment and area of study; in addition meet range of operating frequencies used.

II. Development of Research Paper

3G systems as all wireless communication systems using free space how propagation path of signal, thus present problems with degradation signal, which is why importance of good planning on distribution of system architecture, taking into account particularities of testing region.

In this matter is important a study of different models of propagation that can be used for planning and deployment of these mobile providers and that require accurate analysis and reliable.

A. *Measurement Methodology*

Field measurements were obtained using a spectrum analyzer capable of working in frequencies between 9 kHz and 7.1 GHz [8]. The equipment is able to demodulate WCDMA signal allowing to obtain information from various performance factors, in our case, the power of CPICH channel.

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

TABLE I. CONFIGURATION PARAMETERS AND FEATURES ANTENNA

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

For a correct analysis of experimental results was necessary having georeference information. To obtain this information, the equipment has a GPS and generates position information of (Latitude, Longitude, Altitude and Time) these GPS information requires at least 4 satellites.

The stage of analysis is shown in **Figure 2**. Note demarcation of area with an outline in red, also showing the location of Node Bs in this zone of analysis. Testing area has different architectural characteristics and environment. The analysis was made with information of four Node Bs.

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Figure 2. Test Scenario

B. 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 measurement display and export it to a *. cvs for further processing [9]. **Figure 3** shows us working environment and displays measurements

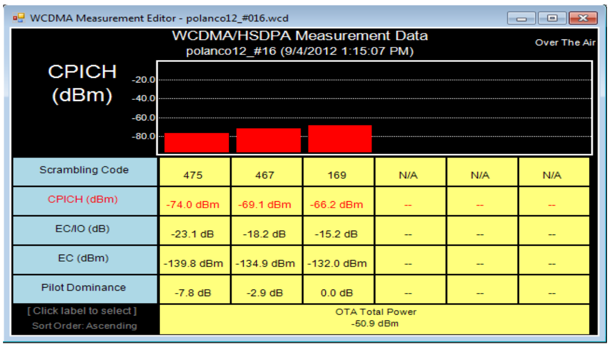


Figure 3. Master Software Tools

Once information is into a single file, we can obtain measurements of each Scrambling Code and its parametres, with this file it is possible to determine occurrence of each SC. Finally, we can identify different Scrambling Codes in measurement area.

Subsequently, analysis was performed based on propagation models, this requires a set of input values for calculating each of them, and these values refer to values as:

1. Type's area.
2. Type's city.
3. Height of transmitting and receiving antennas.
4. Base Station Location or Node B.

Performing this analysis we proposed a data entry environment, it will take measurement information and conditions in structure of analysis area, later to execute and get results of each propagation model. Figure 4 shows that work environment.

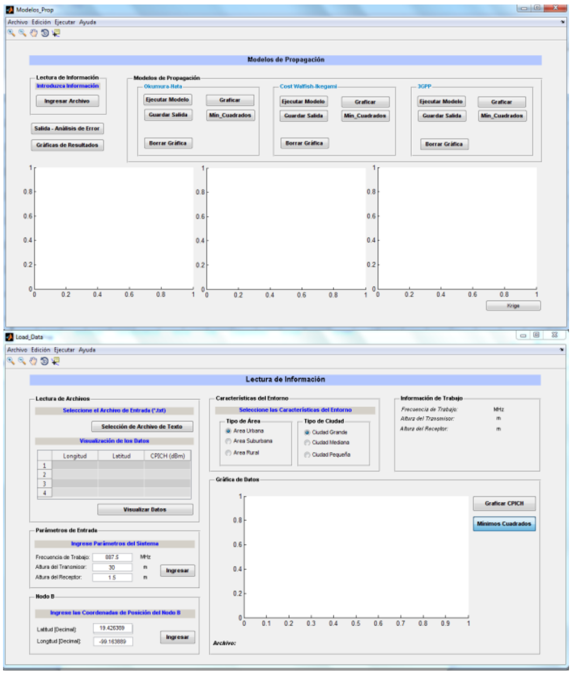


Figure 4. Plataform GUI in MatLAb

Figure 5 shows block diagram of proposed algorithm.

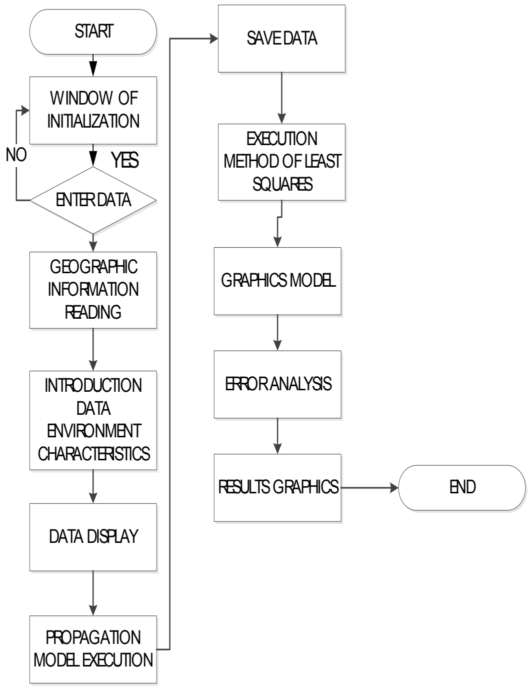


Figure 5. Algorithm Blocks Diagram

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

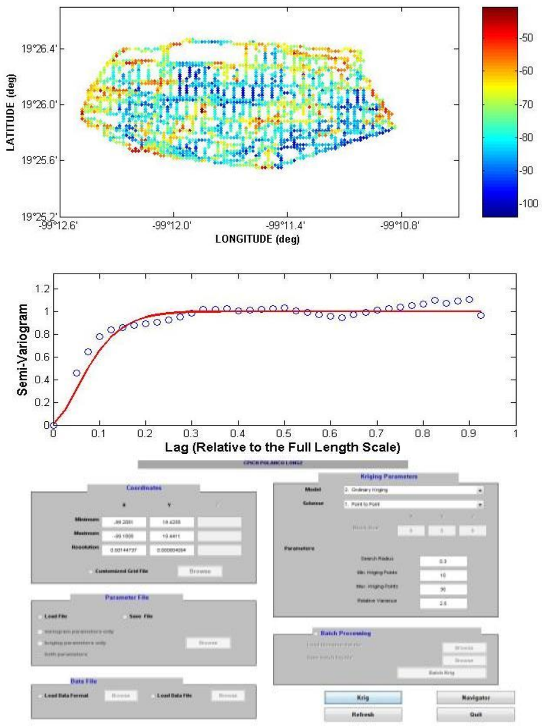
C. Building Coverage Maps

With the points measured, it was possible to generate coverage maps. The data were processed using software called Easy Krigig to implement kriging geostatistical method, that was initially developed by Daniel G. Krige based on interpolation algorithms by least squares regression. The method takes the point values and generates continuous graphic, performing an interpolation of them. Krige [10].

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

1. Data reading. Longitude, Latitude and performance indicator.
2. Generate a theoretical variogram based on one experimental. Predicting behavior of signal transmitted by node B
3. Running the Kriging process.
4. Validation and map display. Ensure effectiveness of prediction is needed validation process; included in application of "EasyKrig" in which approximation error is within acceptance region determined by variability of measurement power.

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



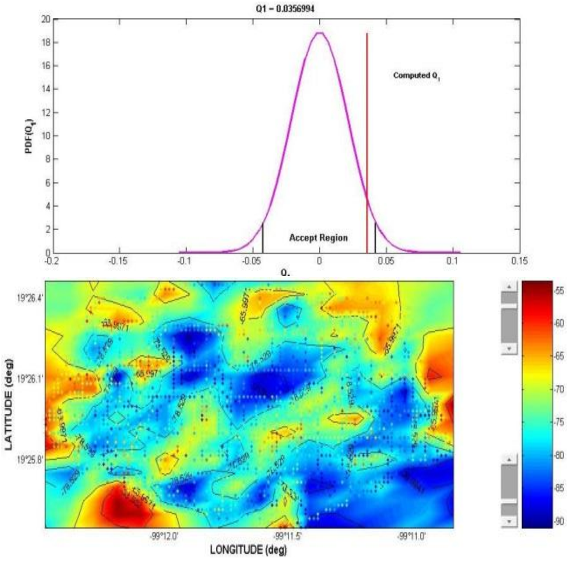


Figure 6. Procedure for Creating Coverage Maps

III. RESULTS

A. CPICH Power Levels vs. Experimetnal Propagation Models

As mentioned earlier, the study is based in 4 Nodes B and their coverage analysis. Table 2 shows the corresponding Scrambling Codes, as well as its appearance and impact on area.

TABLE 2. NODES B AND APPARITIONS

Node B	SC	Number of Measurements
1	169	47
	177	58
	185	57
2	338	61
	346	40
	354	29
3	386	38
	394	84
	402	97
4	459	6
	467	65
	475	36

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

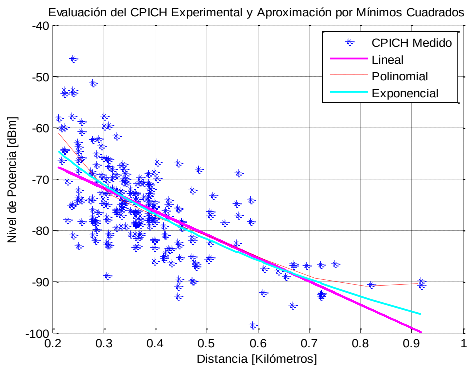
TABLE 3. ERROR ANALYSIS

Errores	MOH[1]	MCWI[2]	M3GPP[3]
Nodo_1			
Average Relative Error	33.3488106	15.4529092	22.5490518
Average Absolute Error	0.33569183	**0.19423429**	0.25518318
Nodo_2			
Average Relative Error	25.8150969	12.7296216	16.2745603
Average Absolute Error	0.26927593	**0.16785949**	0.19176663
Nodo_3			
Average Relative Error	32.040266	16.9823331	22.7363215
Average Absolute Error	0.31778727	**0.21257951**	0.254166216
Nodo_4			
Average Relative Error	32.0156263	14.9359825	21.7830579
Average Absolute Error	0.31648985	**0.18305803**	0.24139559

As shown in above table, propagation model that has the lowest error compared with information obtained from measures is COST Walfish-Ikegami model, followed by 3GPP model.

Graphic 1 shows power levels from measurement procedure, power levels show a random behavior. This behavior does not let us evaluate and compare these results with propagation models.

Therefore, comparison is an approximation performed by least squares approximation function, generating the behavior of measured data.



GRAPHIC 1. Behavior and Least Squares Approximation

Then, Figure 7 shows estimation maps generated for Node_A coverage and result for each model. Power levels in model-Ikegami COST Walfish approximate values obtained from field measurements.

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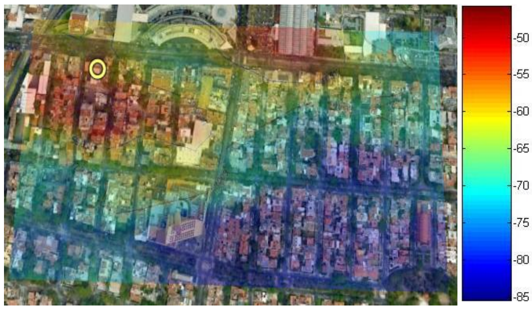
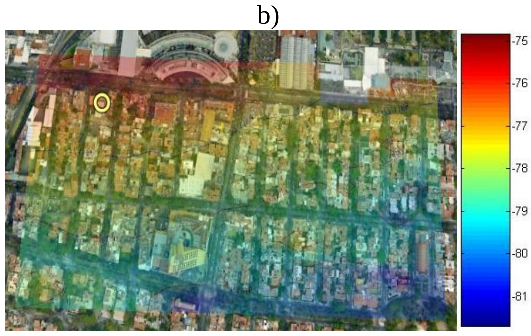
[1] Model Okumura-Hata
[2] Model COST Walfish-Ikegami
[3] Model del 3GPP

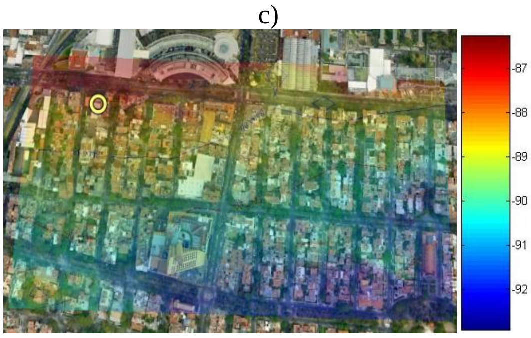


a)

b)



c)



d)

Figure 7. Coverage Maps. a) Experimental b) Okumura-Hata model c) Model COST Walfish-Ikegami d) Model 3GPPP

We can observe that COST Walfish-Ikegami model has the best performance and levels power are approximated to values in field measurements.

IV. CONCLUSIONS

Because propagation models discussed in this article are based on studies realized in different cities to Mexico City its necessary choose a specific model for this city.

The purpose of making a theoretical and experimental study is finding the best features for chosen environment and then develops a suitable propagation for Mexico City scenarios.

The COST Walfish-Ikegami model has the best performance for each Node B analyzed, making the best prediction considering environment features, especially for dispersion caused by roof/width of streets.

This study will be used as precedent in analyzing propagation models.

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