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Adjustment of Free Space Propagation Model for 3.3 Ghz Measurements Made in Mexico City

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Abstract

This paper describes a modification of the Free Space model in the frequency of 3.3 GHz for measurements made in Mexico City. Adjustment was made, changing the value of free space model equation exponent, comparing measurements with amplitude and slope of new losses curve. To make this work, we find scenarios with similar characteristics of Mexico City environment validating them in different areas of the City.

Key words: modification of free space attenuation, measurement of urban attenuation, WiMAX.

Resumen (Ajuste del modelo de propagación del espacio libre sobre mediciones en 3.3 GHz hechas en la Ciudad de México)

Presentamos en este trabajo una propuesta de modificación del Modelo de Atenuación del Espacio Libre en la frecuencia de 3.3 GHz para mediciones hechas en la Ciudad de México. El ajuste se realiza cambiando el exponente de la ecuación original, al compararla con curvas de atenuación de las mediciones. Para el desarrollo del trabajo se identifican escenarios con características similares, que son validadas para diferentes zonas de la Ciudad de México.

Palabras clave: atenuación del espacio libre, mediciones de atenuación en zonas urbanas, WIMAX.

1. Introduction

Due to new wireless communication systems are evolving rapidly, it has become important to create new propagation models to meet those needs. Examples of these systems is WiMAX (Worldwide Interoperability for Microwave Access), which is a metropolitan area service used in one or more base stations, within a range of 50 km, for data distribution in large wireless broadband geographical areas at frequencies 2.3 GHz, 2.5 GHz, 3.3 GHz, 3.5 GHz and 5.8 GHz [1,2].

Even models help to predict propagation losses, they were designed using data of specific cities and then generalized to be applied in other environments, but for different cities should be tested to probe its applicability.

We propose to use Free Space model, modifying the equation exponent. As is known, model supposes a free obstacle region between transmitter and receiver; it is given by [3]:

$$PL_{FS} = \left[\frac{4\pi df}{c}\right]^2 \tag{1}$$

where

d: distance between transmitter and receiver,
f: operating frequency,
c: speed of light.

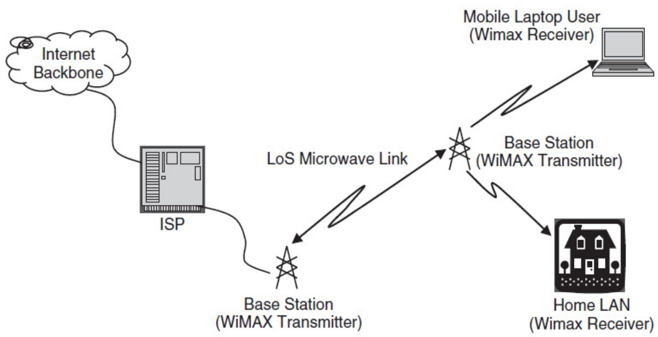

Fig. 1. Operational principle of WiMAX [1].

Equation (1) is often expressed in dB as:

$$LP_{EL} = 20\log\frac{4\pi}{c} + 20\log d + 20\log f \qquad (2)$$

As many Latin American cities, Mexico City has a mobile communication environment, different to those European and US cities, where models were defined. This paper, analyze our own scenarios and adjust the Free Space Model (FSM) trying to find the best relationship between measurements and model modifications.

2. Measurement methodology

Measurements were performed using base stations located in National University (UNAM) with base station in the Humanities Building at the south of the city, in Instituto Politécnico Nacional (IPN) with station located in the Dirección de Cómputo y Comunicaciones (DCyC) at the city's north and the Instituto de Ciencia y Tecnología (ICYT) in downtown. Three scenarios were chosen due their similarities but also by their differences. Table I shows characteristics of communications system, transmitter antenna height is almost the same for all scenarios.

Measurements were made using an analyzer Anritsu Master Spectrum MS2721B, which includes a GPS antenna for referenced positioning. When equipment is mounted on top of a vehicle, saves the received power level and geographic location (latitude and longitude coordinates) at each measurement point.

Measurements were taken every 20 seconds, at that time analyzer updates GPS position. A data base with extension wxme is constructed, extracting measurements from spectrum analyzer, becoming in computer *txt* files containing latitude, longitude, distance and input power.

We develop a Matlab program to construct tables as that shown in Figure 3, extracting only the necessary information from each file; getting relationship charts of power, position and distance where measurements were taken. Database is used to construct linear regression curves, to be compared with adjustments of Free Space model.

Table 1. Communication system features.

Operating frecquency	3,4785 GHz
Bandwidth	3,5 MHz
Transmitter power	-7 dBW
Transmitter antenna height	29 - 70 m
Receiver antenna height	2 m
Transmitter antenna gain	14,8 dBi
Receiverer antenna gain	3,6 dBi

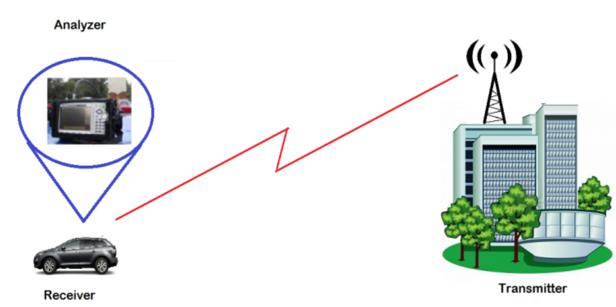

Fig. 2. Measurement scheme.

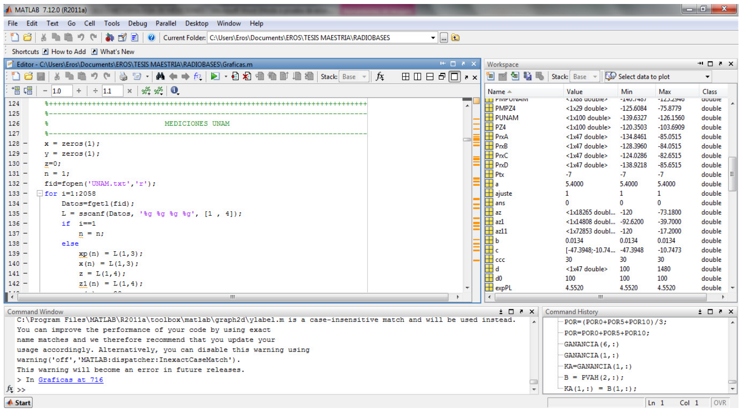

Fig. 3. Information processing using Matlab.

3. Identification of scenarios

We identified 5 scenarios accordingly of existing features of different areas in Mexico City, which are described in following paragraphs:

A. Scenario 1: low buildings with low tree density
This scenario considers an area with a low tree density, and low high buildings, as shown in Figure 4.

B. Scenario 2: low buildings with medium tree density
The scenario considers an area with medium tree density and a low height of the buildings as the one shown in figure 5.

C. Scenario 3: area with a high tree density
Figure 6 shows a scenario with a high tree density.

Fig. 4. Scenario 1.

D. Scenario 4: tall buildings with medium tree density
The scenario considers an area with medium tree density and high height buildings.

E. Scenario 5: colonial city
Scenario 5 is a unique environment of Mexico City (and many Latin American cities), it is located at historic downtown; it has some very unique construction features such as: large width walls, tall buildings, and narrow streets.

Fig. 5. Scenario 2.

Fig. 6. Scenario 3.

Fig. 7. Scenario 4.

Fig. 8. Scenario 5.

Figures 9 and 10 show UNAM and IPN zones where measurements were made for scenarios 1 through 4, each one bounded for different colors. The blue frame define scenario 1, while scenario 2 is red, green is the scenario 3 and scenario 4 orange.

Each scenario was visually distinguished from both base stations photos. As an example, area for scenario 1 is mostly filled by buildings with few green zones. Others can be distinguished in photographs from tree density.

Figure 11 shows the unique scenario 5. Although is not clear from the photo the differences with other scenarios, is possible to distinguish them from Figure 8, specially the narrow background street between the colonial buildings.

Fig. 9. Radio base located in the UNAM.

Fig. 10. Base station in IPN.

After each bounded polygon was defined by its geographical position, we created tables for each one with the point

Fig. 11. Base station of scenario 5.

measurements and then, there were constructed regression curves showing attenuation behavoir. These curves were used, in the first place, to validate scenarios 1-4. Comparing regression curves from both base stations, we could see if the selection of scenarios was correct. For scenario 5, there was no other base station to compare similarities of environment, to do so, we have to look for other colonial cities in México or Latin America.

4. Results

Once the scenarios were identified in maps, tables were constructed and obtained linear regression curves from measurements, we were ready to compare, scenarios for stations at UNAM and IPN with Free Space Model (FSM). Following curves show results of our analysis.

As an example, comparison of IPN (DCyC) and UNAM (Humanidades II) stations for scenario 1, is shown in Figure 12. As seen curve behavior is very similar, with differences not greater than 3 dB, then we conclude that scenario selection is adequate.

Next step was to adjust FSM finding a match for slope and attenuation as best as possible with regression curves of base stations. Adjustment is made changing the exponent value (X) for the slope and (Y) for losses magnitude, in equation 3:

$$PL_{FS} = \left[\frac{4\pi df}{c}\right]^{X} \pm Y \quad (3)$$

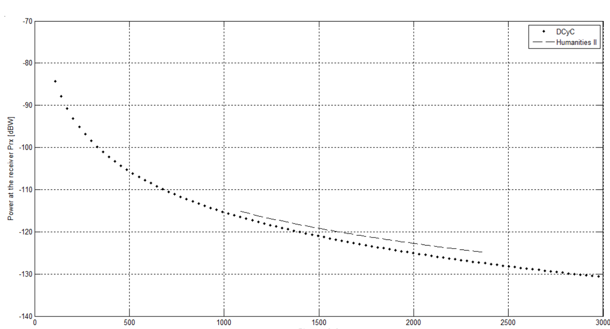

Fig. 12. Comparison of base stations for scenario 1.

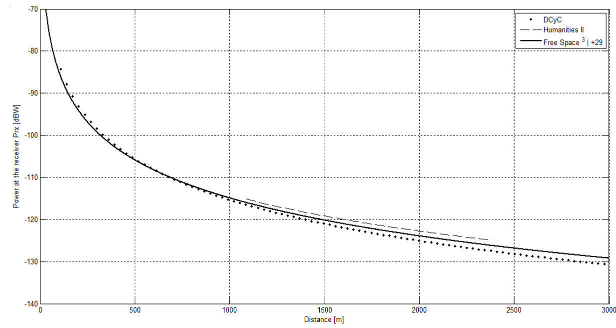

Fig. 13. Adjustment of FSM for scenario 1.

Figure 13 shows adjustments for scenario 1; we found that X=3 and Y=29 then:

$$P_{E1} = EIRP - \left[\frac{4\pi df}{c}\right]^{3} + 29$$

Figure 14 depicts measurements comparison of same base stations, leading to scenario 2 validation, considering the slopes similitud with no higher than 3 dB difference. Figure 14 also shows adjustment of FSM power for scenario 2 leading to:

$$P_{E2} = EIRP - \left[\frac{4\pi df}{c}\right]^{2} - 28$$

We select a FSM adjust curve between both base station regression curves, giving a difference between FSM and measurement no higher than 1.5 dB. As seen the exponent value do not change (X=2); magnitude of attennuation factor is selected as $Y = -28$ for scenario 2.

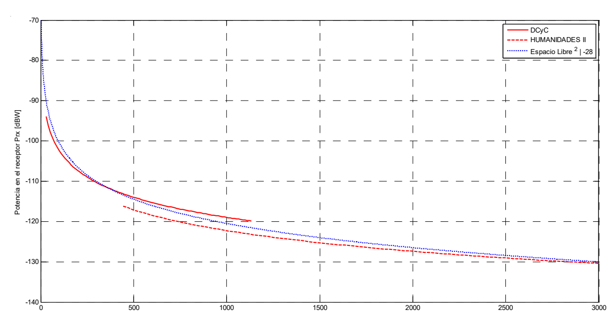

Fig. 14. Comparison of base stations and adjust of FSM for scenario 2.

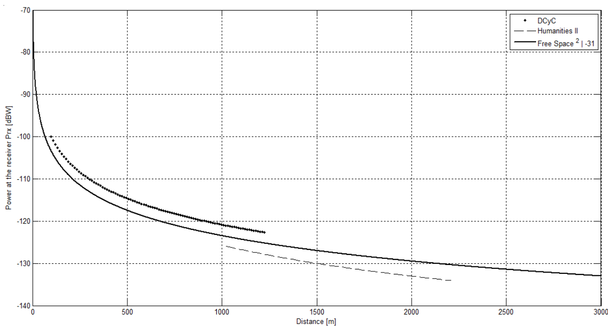

Fig. 15. Base station comparison and adjust of FSM for scenario 3.

In the same way we compare curves for scenario 3, as shown in Figure 15; again the slope of regression curves are similar, with a difference of power no greater than 5 dB, which validates the environment. After adjustment, we select a curve for FSM between both regression curves; power equation is expressed as:

$$P_{E3} = EIRP - \left[\frac{4\pi df}{c}\right]^2 - 31$$

Following same procedure, we compare results for scenario 4. Regression curves are shown in Figure 16. As seen slopes of both curves are different, although no more than 1.5 dB between 100 m and 1200 m. Differences are greater for larger distances, meaning scenario 4 needs further analysis.

Although two power slopes are different, a good FSM adjustment was found as:

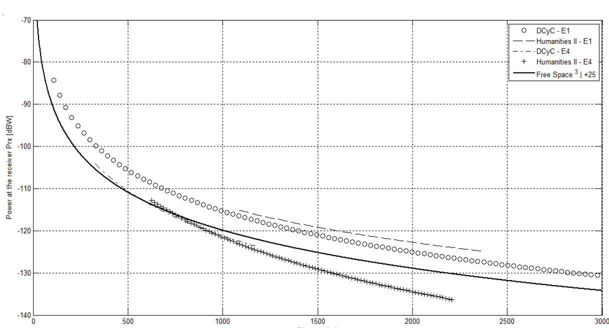

Fig. 16. Base station comparison and FSM adjust for scenario 4.

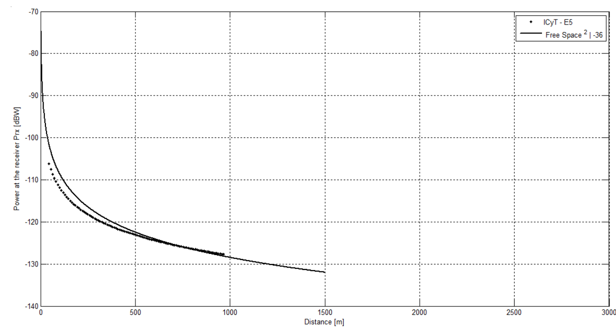

Fig. 17. Adjust of FSM for scenario 5.

$$P_{E4} = EIRP - \left[\frac{4\pi df}{c}\right]^3 + 21$$

As scenario 5 is unique, is not possible to compare with any other curve. Figure 17 shows FSM adjustment, fitting measurement regression curve. As can be seen from Figure 17, there is a sharp slope fall, similar to that of scenario 3, meaning a zone of high attenuation, due the tall buildings very dense walls and narrow streets. Adjustment for FSM is:

$$P_{E5} = EIRP - \left[\frac{4\pi df}{c}\right]^2 - 36$$

Table 2 shows a summary of adjustments for all scenarios.

As seen in Table 2, scenarios 1 and 4 have similar slopes, with an exponent of 3. Furthermore the loss adjustment for FSM is increased with 29 and 21 dB respectively.

Table 2. Summary of FSM adjustment.

	Exponent	Loss (dB)
Scenario 1	3	+29
Scenario 2	2	–28
Scenario 3	2	–31
Scenario 4	3	+21
Scenario 5	2	–36

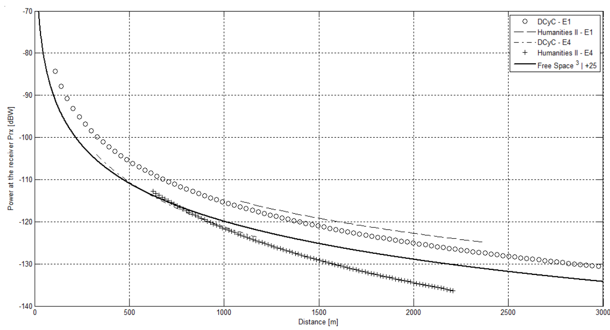

Fig. 18. Adjustment of FSM for scenario A.

For scenarios 2 and 3, the slope has the same exponent of 2, and loss requires an adjustment of –28 and –31 dB respectively, only a 3 dB difference.

Analyzing former numbers, is possible to define only 3 scenarios, besides 5, because the main difference between scenarios 1-4 and 2-3 is in the exponent 3 and 2 respectively; attenuation amplitude varies only 8 dB for 1-4 and 3 dB for 2-3, then we can define scenarios by the power of FSM reducing them from four to two scenarios. As we do not have comparison for scenario 5, we can leave it as a third one.

Then scenarios 1 and 4 form a new scenario A, as the difference in loss adjustment seen in Table 2 is 8 dB, we can take the average of both leading to an adjustment of +25 dB. Figure 18 shows the new overall scenario A, with a ±4 dB losses margin.

In the same way, scenarios 2 and 3 define a new scenario B. Adjusting FSM losses by +30 dB, curves fit with a difference

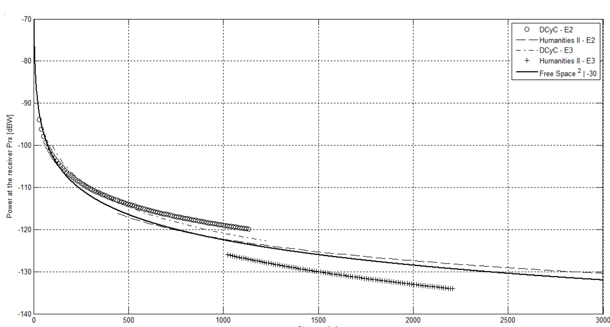

Fig. 19. FSM Adjustment for scenario B.

Tabla 3. Reduction of scenarios.

	Exponent	Loss (dB)	Error (dB)
Scenario A	3	+25	±5
Scenario B	2	–30	±4
Scenario 5	2	–36	–

of only ± 4 dB. Figure 19 shows curves comparison with new FSM adjustment.

Former reduction from 5 to 3 scenarios, could be an Academic procedure, but we think that must be found other scenarios, not only in Mexico Metropolitan area, but in suburban and rural areas, that is our actual work. Table 3 shows the final reduced scenarios and adjustment values.

5. Conclusions

After identification of some common scenarios in Mexico City as: low buildings-low tree density; low buildings-medium tree density; high tree density zone; tall buildings-medium tree density; Colonial City, we compare measurements over city streets with FSM, to find a relationship between them.

Considering similarities for two base stations, we validate scenarios selection, at least for 4 of them, leaving scenario 5 as unique.

Comparing measurements for each scenario with adjusts of exponent and amplitude of FSM losses, we conclude that model can predict path loss for WiMAX or similar communication standard. Further more we find that, for a no more than 5 dB difference, we can define only three scenarios, besides five. We think that 5 dB differences is a good margin, to predict propagation of mobile communication systems over an environment as Mexico City. Probably we have to define an accepted margin, but accordingly with our experience a 10 dB could be a good number.

References

[1] S. Y. Tang, *WiMAX Security and Quality of Service*, Ed. Wiley, 2010.

[2] D. Pareek, *WiMAX Taking Wireless to the MAX*, Ed. Taylor & Francis Group, 2006.

[3] W.A Shittu, "Prediction of Received Signal Power and Propagation Path Loss in Open/Rural Environments using modified Free-Space Loss and Hata Models", 2008