Contribution to The Performance of Mobile Radio Systems by Optimizing The Okumura Hata Model by Linear Regression: Application to The City of Annaba in Algeria

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Abstract: The study of propagation characteristics is a fundamental step in mobile radio engineering; which is intended to achieve maximum performance for a mobile radio system. To do this, the propagation models are essential tools for this study such as the evaluation of the signal strength received by a mobile terminal, the evaluation of coverage radii and deduce the number of cells needed to cover a given area, such as radio planning, which in turn is the step that aims to estimate the necessary equipment and configurations of the radio interface. In this work we adopt the standard K factor model and OKUMURA HATA model to demonstrate a propagation model adapted to the physical environment of the city of Annaba in Algeria using a linear regression algorithm based on the ordinary least squares method. Radio measurements were carried out on the CDMA network of operator Mobilis. The calculation of the square root of the mean square error between the actual data and the radio measurements and the prediction data derived from the model implemented allowing the validation of the results obtained. A comparative study between the value of the RMSE obtained by the new model and those obtained by the models K standard factors and the model of OKUMURA HATA allows us to conclude that the new model is better adapted to our local environment than that of OKUMURA HATA. The new model obtained can help increase the performance of mobile radio systems deployed in our territory.

Keywords: Model K factor, Model of OKUMURA HATA Linear regression.

1. Introduction

To obtain a propagation model that accurately reflects propagation characteristics radio in a given environment. It is necessary to rely on network coverage, the capacity of the network as well as the quality of service of it which are the essential points of a network planning. In order to have access to all the services offered by a network, it is necessary to give particular importance to the dimensioning of the latter. The use of propagation models is very widespread for the planning and installation of networks or also for the extensions of already existing networks, especially in the new towns. Contributing to the improvement of the performance of mobile radio systems. To determine the characteristics of the radio propagation channel, the tests of the concrete propagation modes and the calibration of the existing models are essential to have a propagation models that accurately represent the radio propagation characteristics of the environment being studied. Several types of software allow the improvement of the performance of mobile radio systems through the planning and sizing of mobile networks including prediction models namely: ASSET of AIRCOM company in England, Atoll of the French company FORK ... etc.

Some authors investigate the calibration of propagation models, Like Chhaya Dalila, and Garlic [1] who have studied « tuning of Cost231 Hata model for radio wave propagation prediction », Medeisis and Kajackas [2] who presented « the tuned Okumura Hata model in urban and rural zones at Lithuania at 160, 450, 900 and 1800 MHz bands », Prasad and al [3] have worked on « tuning of COST-231 Hata model based on various data sets generated over various regions of India », Mardeni & Priya [4] have presented « optimized COST-231 Hata model to predict path loss for suburban and open urban environments in the 2360-2390MHz »,

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Some authors have been particularly interested in the use of the least squares method to calibrate or determine the propagation models we have for example: MingjingYang and al [5] In China presented « A Linear Least Square Method of Propagation Model Tuning for 3G Radio Network Planning », Chen, Y.H. and Hsieh, K.L [6] TAIWAN presented « A Dual Least-Square Approach of Tuning Optimal Propagation Model for existing 3G Radio Network », Simi I.S andt ail [7] In Serbia presented « Minimax LS algorithm for automatic propagation model tuning », Allant Mousa, Yousef Dama and Ail [8] In Palestine presented «Optimizing Outdoor Propagation Model based on Measurements for Multiple RF Cell », Deussom Djomadji Eric Michel and Tonye Emmanuel [9] In cameroon have presented « Optimisation du modèle d'Okumura Hata par la régression linéaire. Application à la ville de Yaoundé au Cameroun », Famoriji and Olasoji[10] have presented «Development of a Radiowave Propagation Model for Hilly Areas», V.S. Abhayawardhana, I.J. Wassell, D. Crosby, M.P. Sellars, M.G. Brown[11] Who presented «Comparison of empirical propagation path loss models for fixed wireless access systems».

In our work, we used data collected from the network of operator Mobils. And this in the city of Annaba. To carry out this task we use 6 BTS distributed on both sides in the city. We also use an algorithm based on linear regression to determine a propagation model adapted to the city of Annaba.

This article will be articulated as follows: In the first part, we present the experimental details, followed by a description of the methodology chosen in the second part, the implementation of the algorithm as well as the results, their validations and comments will be addressed In the last part; At the end a conclusion will be presented.

2. Experimental parts

A. Propagation environment

The city on which our study was based is that of Annaba. We have emphasized the existing network to carry out radio measurements in this city. To do this, We subdivided the city into 3 zones: The city center of Annaba, the downtown area towards the outskirts and finally the outskirts of the city. For each type of zone, we used 2 similar types of environment.

Table 1. The zone

Zone	Z1	Z2	Z3
Type of zone	Urbain	Suburbain	Rurel
BTS planted	Annaba center et Post office befor Harbor	Sidi Ammar et Sidi Ammar center	Airport Rabeh BETATE Annaba

B. Simplified description of the BTS used

The BTS we used for our radio measurements are those of the state operator Mobils, We used 3 types of BTS namely the BTS types 3900 and 2206. The radio parameters of the BTS used are shown in the table below [12]:

Table 2. Characteristics of the BTS used

	BTS3900	BTS2206
Type of BTS	Outdoor Distributed	Outdoor Distributed
Number of Sectors	3	3
Frequency band	806–960MHz	806–960MHz
Fréquency download	880 – 960 MHz	880 – 960 MHz
Fréquency upload	806 – 880 MHz	806 – 880 MHz
Total power of the BTS	600 Watt (at 50 °C ambient temperature)	600 Watt (at 50 °C ambient temperature)
Impedance	50Ω	50Ω

Table 3: Radio BTS parameters used.

BTS Type	Site code	Site Name	Wilaya	Région	Longitude	Latitude	Antenna	HBA Toit (m)	HBA Sol (m)	Feed Len (m)	Feed Type
3900	23626	Aéroport	Annaba	Annaba	7,8135	36,82081	739623		18	22	7/8"
3900	23611	Sidi Ammar	Annaba	Annaba	7,72140	36,81419	739623	7	16	18	7/8"
2206	23648	Sidi Ammar center	Annaba	Annaba	7,71843	36,82214	739623	10	22	12	7/8"
3900	23106	Annaba center	Annaba	Annaba	7,75967	36,90239	ATR 451703	10m	22m	2*70	7/8"
2206	23627	Post office before harbor	Annaba	Annaba	7,76256	36,89777	739634	4	29	26	7/8"
2206	36694	Ben Ammar	El Taref	Annaba	7,81509	36,79176	ADU454801	10	19	15	7/8"

3. Methodology

We have relied in this work only on the K factor model. Knowing that several propagation models exist in the scientific literature on propagation.

A. Propagation model K factors [13]

The general form of the model K factor is given by the relation below:

$$L_p = K_1 + K_2 \log(d) + K_3 h_m + K_4 \log(h_m) + K_5 \log(h_b) + K_6 \log(h_b) \log(d) + K_{7diff} + K_{clutter} \quad (1)$$

The values of the parameters K change according to the nature of the zone and the characteristics of the propagation environment of the cities, the table below gives values of K and of the factor of attenuation of the congestion for an average city.

Table 4. Parameter values K .

Parameter Name K	K_1	K_2	K_3	K_4	K_5	K_6	K_{7diff}	$K_{clutter}$
Value	149	44.9	-2.49	0.00	-13.82	-6.55	-0.8	0

Equation (1) can be written in this form:

$$L_p = (K_1 + K_{7diff} + K_{clutter}) + K_2 \log(d) + K_3 h_m + K_4 \log(h_m) + K_5 \log(h_b) + K_6 \log(h_b) \log(d)$$

The:

$$K'_1 = (K_1 + K_{7diff} + K_{clutter})$$

Equation (1) becomes:

$$L_p = K'_1 + K_2 \log(d) + K_3 h_m + K_4 \log(h_m) + K_5 \log(h_b) + K_6 \log(h_b) \log(d) \quad (2)$$

$$L_p = (K'_1 + K_3 h_m + K_4 \log(h_m) + K_5 \log(h_b)) + (K_6 \log(h_b) + K_2) \log(d) \quad (3)$$

Let:

$$A = K'_1 + K_3 h_m + K_4 \log(h_m) + K_5 \log(h_b)$$

Equation (3) then becomes of the form :

$$L_p = A + B \log(d) \quad (4)$$

Equation (4) can also be put in vector form as follows:

$$L_p = [1 \quad \log(d)] \begin{bmatrix} A \\ B \end{bmatrix} \quad (5)$$

Equation (5) will be used hereinafter.

B. Organizational chart

The flow chart below generates the new propagation model using linear regression.

In this flowchart, the data was filtered according to the criteria below for the distance and signal strength received.

Table 5. Filter settings. [13][14]

Minimum distance(m)	100
Maximum Distance(m)	10.000
Minimum Received Power (dBm)	-110
Minimum Received Power (dBm)	-40

C. Linear regression method

This method is based on equation (3) presented previously. In the beginning, We will classify the parameters of equation (2) into two major groups [15]:

- The global adjustment parameters.
- Micro Adjustment Settings.

The global adjustment parameters here are K_1 and K_2 , while the other coefficients are micro-adjustment parameters and thus, their default values in the standard model can be assumed to be constant. Starting from equation (5) already presented for one point of radio measurements for different distances d , we will obtain values of losses L , for $i = 1: N$ and (5) will become:

$$L_i = A + B \log(d_i) \quad (6)$$

Where we can also write equation (6) in the following form:

$$L_i = [1 \quad \log(d_i)] \begin{bmatrix} A \\ B \end{bmatrix} \quad (7)$$

And for several measures, we will have:

$$\begin{bmatrix} L_1 \\ L_2 \\ \vdots \\ L_N \end{bmatrix} = \begin{bmatrix} 1 & \log(d_1) \\ 1 & \log(d_2) \\ \vdots & \vdots \\ 1 & \log(d_N) \end{bmatrix} \begin{bmatrix} A \\ B \end{bmatrix} \quad (8)$$

Let :

$$M = \begin{bmatrix} 1 & \log(d_1) \\ 1 & \log(d_2) \\ \vdots & \vdots \\ 1 & \log(d_N) \end{bmatrix} \text{ et } K = \begin{bmatrix} A \\ B \end{bmatrix} \quad (9)$$

From where can we get:

$$L = M.K \quad (10)$$

We aim in our work to minimize the Euclidean distance between the values of the vectors L which contains the prediction values and the values of the vector L_M representing the measured values of the loss of propagation [16].

Is

$$E = \|L_M - M.K\|^2$$

, The square error function.

To have the minimum searched distance it is necessary that:

$$\frac{dE}{dK} = 0$$

From where:

$$E = \|M.K\|^2 - 2(MK)L_M + \|L_M\|^2 \text{ Where the } (.) \text{ Represents the scalar product.}$$

$$E = K^T M^T M K - 2K^T M^T L_M + L_M^T L_M$$

With K^T is the transpose of K .

$$\frac{dE}{dK} = 0 \Rightarrow \frac{d(K^T M^T M K - 2K^T M^T L_M + L_M^T L_M)}{dK} = 0$$

Is :

$$2M^T M K - 2M^T L_M^T = 0 \Rightarrow M^T M K = M^T L_M^T$$

From this comes the solution K^* :

$$K^* = (M^T M)^{-1} M^T L_M = \begin{bmatrix} A^* \\ B^* \end{bmatrix} \quad (11)$$

This equation (11) translates the existence of a vector K^* which would minimize the euclidean distance between the predicted and the measured values.

From this it follows that for constant K_3, K_4, K_5, K_6 we get:

$$K_1^* = A^* - (K_3 h_m + K_4 \log(h_m) + K_5 \log(h_b)) \quad (12)$$

$$K_2^* = B^* - K_6 \log(h_b) \quad (13)$$

4. Results and discussions

After applying the linear regression model to the data collected at the city of Annaba, we obtained the results below.

A. The results by zone

We had the curve below representing, the real measures, the Okumura Hata model, The model K factors the result obtained by implementing the linear regression. The model will be seen as accurate if the RMSE between the prediction and measured values is less than 8 dB; (RMSE < 8dB)[17].

a-Zone Z1: Downtown of Annaba.

Figure 1. Weakening Real and predicted measurements of the downtown Annaba.

From this curve on the way the green regression model is closest to the reality of signal weakening at the city of Annaba. The table below gives the results obtained by the linear regression of different values of the coefficients K as well as the RSME:

Table 6. Values of K and RMSE coefficients obtained in downtown of Annaba

Zone	Results	K_1	K_2	K_3	K_4	K_5	K_6	RMSE
Z1	K factors	149	44,9	-2,49	0	-13,82	-6,55	28.0960
	Okumura Hata	146,56	44,9	0	0	-13,82	-6,55	26.4858
	Regression	144.19	-28.80	-2,49	0	-13,82	-6,55	1.677

According to the table, we clearly see that we have an RMSE <8dB for the model resulting from the regression, which confirms the credibility of the result, contrary to the K factor and Okumura Hata model.

b-Zone Z1: The post office after harbor.

Figure 2. Weakening Real and predicted measurements of the post office before harbor.

From this curve in a clear way that the green regression model is closest to the reality of signal weakening at the downtown of Annaba. The table below gives the results obtained by the linear regression of different values of the coefficients K as well as the RSME:

Table 7. Values of the coefficients K and RMSE obtained in the area of the post office before harbor.

Zone	Results	K_1	K_2	K_3	K_4	K_5	K_6	RMSE
Z1	K factors	149	44,9	-2,49	0	-13,82	-6,55	27.64
	Okumura Hata	146,56	44,9	0	0	-13,82	-6,55	25.8455
	Regression	197.52	72.77	-2,49	0	-13,82	-6,55	4.4491

This faith also is according to the table it is clear that we have an RMSE <8dB for the model resulting from the regression; which confirms the credibility of the result, unlike the K factor model and Okumura Hata.

c-Zone Z2: Sidi Amar University.

Figure 3. Weakening real and predicted measurements Sidi Ammar university.

From this curve on the way, the green regression model is closest to the reality of signal weakening at the downtown of Annaba. The table below gives the results obtained by the linear regression of different values of the coefficients K as well as the RSME:

Table 8. Values of K and RMSE coefficients obtained in Sidi Ammar university area.

Zone	Results	K_1	K_2	K_3	K_4	K_5	K_6	RMSE
Z2	K factors	149	44,9	-2,49	0	-13,82	-6,55	16.8562
	Okumura Hata	146,56	44,9	0	0	-13,82	-6,55	17.0430
	Regression	204.7	115.73	-2,49	0	-13,82	-6,55	3.9707

This faith also is according to the table it is clear that we have an RMSE <8dB for the model resulting from the regression; which confirms the credibility of the result, unlike the K factor model and Okumura Hata.

d-Zone Z2: Sidi Ammar downtown.

Figure 4. Weakening real and predicted measurements downtown of Sidi Ammar

According to this curve on the way, the green regression model is closest to the reality of the weakening of the signal at the city center of Sidi Ammar. The table below gives the results obtained by the linear regression of different values of the coefficients K as well as the RSME:

Table 9. Values of the coefficients K and RMSE obtained in the zone of the town center of sidi Ammar.

Zone	Results	K_1	K_2	K_3	K_4	K_5	K_6	RMSE
Z2	K factors	149	44,9	-2,49	0	-13,82	-6,55	8.4522
	Okumura Hata	146,56	44,9	0	0	-13,82	-6,55	9.1672
	Regression	148.9	18.29	-2,49	0	-13,82	-6,55	8.8107

This faith is according to the table it is clear that we have an $RMSE > 8$ dB for the model resulting from the regression; which explains the non-uniform and complex urban planning of Sidi Ammar, and in spite of this the result obtained is of better quality than the models of Okumura Hata and K factors.

e-Zone Z3: Airport Rabeh BETATE Annaba.

Figure 5. Weakening real and predicted measurements of airport Rabeh BETATE Annaba.

Following this curve on the way, the green regression model is closest to the reality of the signal weakening at the Rabeh BETATE airport zone in Annaba. The table below gives the results obtained by the linear regression of different values of the coefficients K as well as the RSME:

Table 10. Values of the coefficients K and RMSE obtained in airport Rabeh BETATE area.

Zone	Résultats	K_1	K_2	K_3	K_4	K_5	K_6	RMSE
Z1	K facteurs	149	44,9	-2,49	0	-13,82	-6,55	10.1441
	Okumura Hata	146,56	44,9	0	0	-13,82	-6,55	12.5130
	Régression	101.42	153.26	-2,49	0	-13,82	-6,55	6.5139

This faith also is according to the table it is clear that we have an RMSE <8dB for the model resulting from the regression; Which also confirms the credibility of the result.

B. Results Summary

In this part, it was retained that the results giving an RMSE <8dB, Namely those of zones Z1 (Downtown Annaba, La poste Avant Port), Z2(Sidi Ammar University), Z3(Airport Rabeh BETATE Annaba) Which gave us the mean vector recorded in the table below:

Table 11. Evaluation of regression model

Zone	K_1	K_2	K_3	K_4	K_5	K_6
Ville d'Annaba	571.77	78.24	-2,49	0	-13,82	-6,55

By evaluating the RMSE of this vector per zone we had the results indicated in Table 12.

Table 12. Evaluation RMSE of the model by zone.

Zone	Z1		Z2		Z3
	Downtown Annaba	Poste office after harbor	Sidi Ammar University	Downtown Sidi Ammar	Airport Rabeh BETATE Annaba
RMSE	1.677	4.4491	3.9707	8.8107	6.514

The resulting final expression of our propagation model will be:

$$L = 571.77 + 78.24 \log(d) - 2,49 h_m - 13,82 \log(h_{eff}) - 6,55 \log(h_{eff}) \log(d) \quad (14)$$

With; h_{eff} : The average height of buildings

5. Conclusion

These works, Present the results obtained by the implementation of the linear regression method on the data of radio measurements made in various zones of the city of Annaba. As a result, standard propagation models such as Okumura Hata and the K model are not adapted to our urban planning, So it is essential to optimize the said models to obtain models adapted to our environment. The linear regression method used allowed us to obtain a propagation model of the city of Annaba with an RMSE value between 1.677dB and 6.514dB while that of the OKUMURA HATA model varies from 9.167dB to 25.845dB And that of the model K factor of 8.452 dB and 27.64 dB. We hold that the new model is more accurate and better represents the spread in the city of Annaba than the standardized models of OKUMURA HATA and K factor. The present aspect could be applied for the determination of the propagation model for each of the large cities Algeria in particular with the deployment of 4th generation mobile services.

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