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Optimization of Okumura Hata Model in 800MHz based on Newton Second Order algorithm. Case of Yaoundé, Cameroon

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Abstract: *Propagation models are essential tools for planning and optimization in mobile radio networks. In this paper we optimize Okumura Hata model by using an iterative algorithm based on Newton second order method. For that, radio measurements were made on the existing CDMA2000 1X-EVDO network through drive test on 800MHz frequency band. Calculating the root mean squared error (RMSE) between the actual measurement data and radio data from the prediction model developed allows validation of the results. A comparative study is made between the value of the RMSE obtained by the new model and those obtained by the standard model of OKUMURA HATA. We can conclude that the new model is better and more representative of our local environment than that of OKUMURA HATA. The new model obtained can be used for future radio planning when the government will open the market for LTE deployment in 800MHz in the city of Yaoundé, Cameroon.*
Keywords: *Drive test, Newton second order algorithm, propagation models, root mean square error.*

I. Introduction

A propagation model suitable for a given environment is an essential element in the planning and optimization of a mobile network. A proper planning of the coverage will enable the users to enjoy all services everywhere in the coverage area. In 4G network, the subscribers should access internet service with high data rate. The handoff performance should be also high to satisfy subscribers requirements in terms of mobility and service availability. To enable users to access different mobile services, particular emphasis must be made on the size of the radio coverage. Propagation models are widely used in the network planning, in particular for the completion of feasibility studies and initial deployment of the network, for new network deployment like LTE, or when some new extensions are needed especially in the new metropolises. To determine the characteristics of radio propagation channel, tests of the real propagation models and calibration of the existing models are required to obtain a propagation model that accurately reflects the characteristics of radio propagation in a given environment. There are several softwares used for planning that include calibration of models on the market namely: ASSET of the firm AIRCOM in England, PLANET of the MARCONI Company, and ATTOL of the French company FORK etc.

Several authors were also interested in the calibration of the propagation models, we have for example: Chhaya Dalela, and all [1] who worked on 'tuning of Cost231 Hata model for radio wave propagation prediction'; Deussom E. and Tonye E. [2] who work on “New Approach for Determination of Propagation Model Adapted To an Environment Based On Genetic Algorithms: Application to the City Of Yaoundé, Cameroon”; Medeisis and Kajackas [3] presented "the tuned Okumura Hata model in urban and rural areas at Lituania at 160, 450, 900 and 1800 MHz bands; Prasad et al. [4] worked on "tuning of COST-231.
"Hata model based on various data sets generated over various regions of India ', Mardeni & Priya [5] presented optimized COST - 231 Hata model to predict path loss for suburban and open urban environments in the 2360-2390 MHz.

In our study, we use the data collected through drive test in existing CDMA1X EVDO RevB network in the city of Yaoundé. The frequency band of the network is 800MHz.Once getting the optimized model; it could be used for the planning of the future LTE in 800MHz band. To achieve this goal, we use 4 BTS distributed all around the city.
We propose an approach of model optimization based on Newton second order method.
In this document, sometimes will use the abbreviation NSO for Newton Second Order.

This article will be articulated as follows: in section 2, the experimental details will be presented, followed by a description of the methodology adopted in section 3. The results of the implementation of the algorithm, the validation of the results and comments will be provided in section 4 and finally a conclusion will be presented in section 5.

II. Experimental Details

2.1 Propagation environment.

This study is done in the city of Yaoundé, capital of Cameroon. We relied on the existing CDMA 2000 1X-EVDO network for doing drive test in the city. To do this, we divided the city into 2 categories namely: downtown Yaoundé, the downtown to periphery area and finally the outskirts of the city. For each category, we used 2 types of similar environments, and then compared the results obtained between them. We have the table below which shows the categories with the concerned BTS:

Table 1: Types of environment

Categories	A	B
Urban characteristics	Dense urban	Urban
Concerned BTS	Ministere PTT (A1) Bastos (A2)	Hotel du plateau(B1) Biyem Assi(B2)

2.2 Equipments description

2.2.1 Simplified description of BTS used.[6]

BTS that we used for our drive tests are the ones provided by the equipment manufacturer HUAWEI Technologies. We used 2 types of BTS: BTS3606 and DBS3900 all CDMA. The following table shows the specifications of the BTS according to the type.

Table 2: BTS characteristics

	BTS3606	DBS3900
BTS types	Indoor BTS	Distributed BTS (Outdoor)
Number of sectors	3	3
Frequency Band	Band Class 0 (800 MHz)	Band Class 0 (800 MHz)
Downlink frequency	869 MHz - 894 MHz	869 MHz - 894 MHz
Uplink frequency	824 MHz - 849 MHz	824 MHz - 849 MHz
Max power (mono carrier)	20 W	20 W
BTS Total power (dBm)	43 dBm	43 dBm

The BTS engineering parameters are presented in the table below:

Table 3: BTS engineering parameters

BTS informations									
BTS Type	**BTS name**	**Latitude (degree)**	**Longitude (degree)**	**BTS Altitude (m)**	**Antenna height**	**Mean elevation**	**Antenna effective height**	**Antenna's Gain（dB i)**	**7/8 Feeder Cable(m)**
3606	MinistryPTT_800	3.86587	11.5125	749	40	741.82	47.18	15.5	45
3900	Hotel du plateau	3.87946	11.5503	773	27	753.96	46.04	17	0
3606	Biyem-Assi_800	3.83441	11.4854	721	40	709.54	51.46	15.5	45
3900	Camtel Bastos	3.89719	11.50854	770	28	754.86	43.14	17	0

1.3 Others equipments parameters.

In order to perform the drive tests, we used a Toyota Prado VX vehicle, an ACER ASPIRE laptop, drive test software namely Pilot pioneer of Dingli communication V6.0, a LG CDMA mobile terminal, a GPS terminal, a DC/AC converter to power the PC during the measurement.

The drive test done in the area A1, A2, B1, B2 gave the following results.

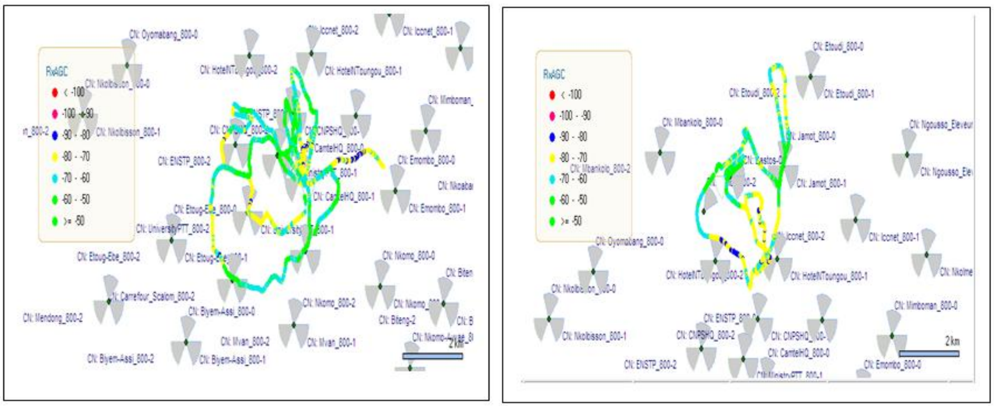

Figure 1: Drive test in centre town (A1 left side image) and in Bastos area (A2 right side image).

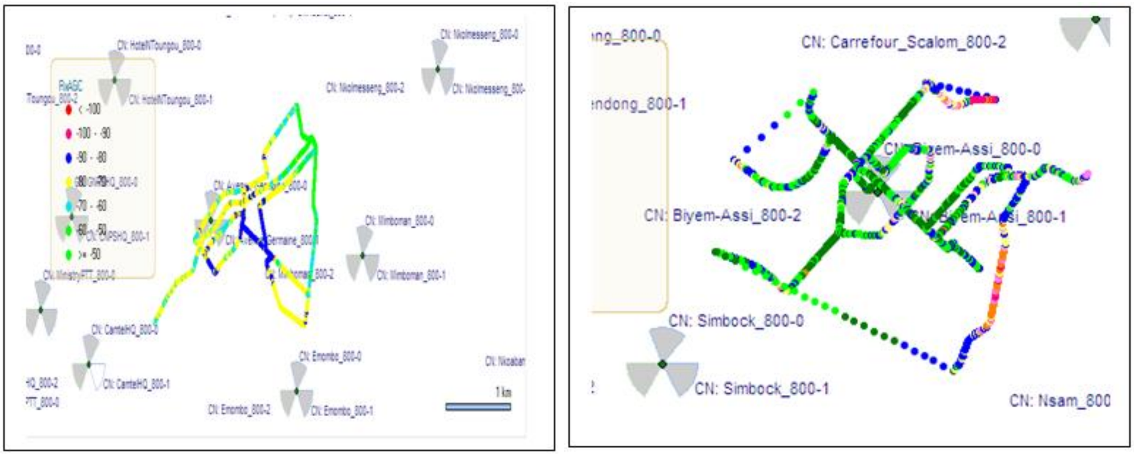

Figure 2: Drive test in Essos (B1 left side image) and Biyem Assi (B2 right side image)

III. Methodology

Many propagation models exist in the scientific literature, we present only the Okumura Hata model on which we relied for this work.

3.1 Okumura-Hata propagation model [7]

The General form of Okumura Hata model is given by the following equation for urban area:

$$L = 69.55 + 26.16\log(f_c) - 13.82\log(h_b) + \left(44.9 - 13.82\log(h_b)\right) * log(d) - E \quad \textbf{(1)}$$

With $E = 3.2(\log(11.75h_m))^2 - 4.97$, for hm=1.5 ; E = $-9.1905 * 10^{-4} \approx 0$, which can be neglected.

Considering the following standard form given by equation (2):

$$\mathrm{L_p} = K_1 + K_2 * \log(d) + K_3 * (H_m) + K_4 * \log(H_m) + K_5 * \log(H_b) + K_6 * \log(H_b) * \log(d) \quad \textbf{(2)}$$

It is possible to determine the corresponding Okumura Hata model coefficients, these coefficients are contained in the table below:

Table 4: Okumura Hata model writen on the form of equation (2)

	K1	K2	K3	K4	K5	K6
Okumura Hata	146,56	44,9	0	0	-13,82	-6,55

Equation (2) can also be written as:

$$\mathrm{L_p} = [K_1 + K_3 * (H_m) + K_4 * \log(H_m) + K_5 * \log(H_b)] + [K_2 + K_6 * \log(H_b)] * \log(d) \quad \textbf{(3)}$$

Assuming $A = K_1 + K_3 * (H_{m)} + K_4 * \log(H_m) + K_5 * \log(H_b)$ and $B = K_2 + K_6 * \log(H_b)$

The equation below is obtained in matrix form: $L_p = [1 \quad \log(d)] * \begin{bmatrix} A \\ B \end{bmatrix}$ **(4)**

It is this last modified form that we will eventually use for our work.

3.2 Determination flowchart

The flowchart below represents the determination of the propagation model using NSO algorithm.

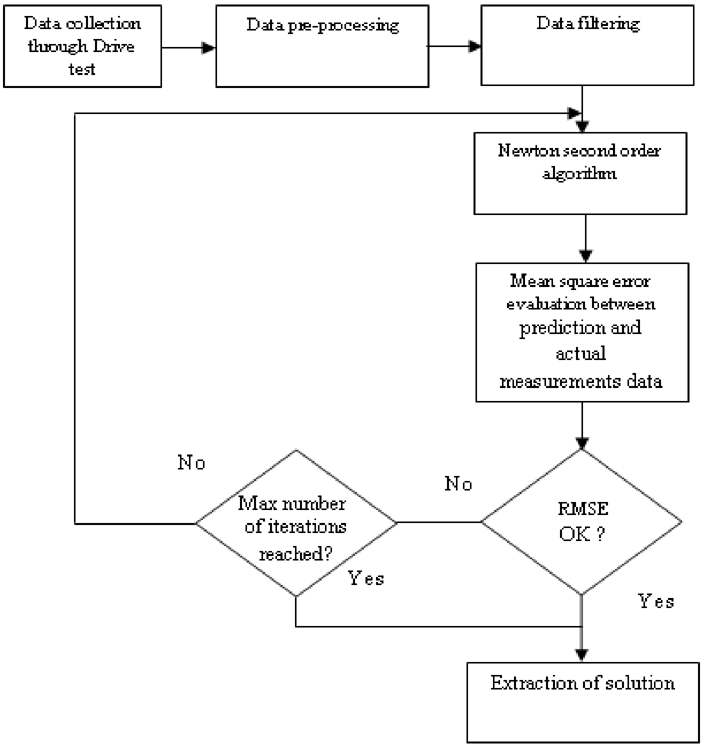

Figure 5: Algorithm implementation flowchart

In this chart, data filtering is made according to the criteria for distance and signal strength received:

Table 5: filtering criteria. [7], [8]

Minimum distance (m)	100
Maximum distance (m)	10 000
Minimum received power (dBm)	-110
Maximum received power (dBm)	-40

3.3 Presentation of Newton second order method. [9]

In calculus, Newton's method is an iterative method for finding the roots of a differentiable function f. Newton second order iterative scheme for a function of several dimensions can be express as:

$$K_n = K_{n-1} + [H(f)^{-1}] * \Delta(f), \quad \textbf{(5)}$$

Where $\Delta(f)$ represents the gradient of the function f and H(f) the hessian matrix of f.
Here it comes to seek a solution of the equation f (K) = 0 by performing successive iterations on the vector K.
We will model our problem in the form of the second order Newton algorithm.
First of all, we will classify the parameters of the equation (2) into two major groups **[10]:**
-The global adjustment parameters.
- Micro adjustment parameters.

The global adjustment parameters here are K_1 and K_2, while the other coefficients are parameters of micro adjustment and as such, their default values in the standard model can be considered constants.
Using equation (5) above for N radio measurement points, for different distances d_i we will obtain the corresponding propagation loss values L_i, then equation (5) will become:

$L_i = A + B * log(d_i)$ This could be also written as:

$$L_i = [1 \quad \log(d_i)] * \begin{bmatrix} A \\ B \end{bmatrix}, \quad \textbf{(6)}$$

And for all the measurements points we will deducted the following:

$$\begin{bmatrix} L_1 \\ L_2 \\ \vdots \\ L_N \end{bmatrix} = \begin{bmatrix} 1 & \log(d_1) \\ 1 & \log(d_2) \\ & \vdots \\ 1 & \log(d_N) \end{bmatrix} * \begin{bmatrix} A \\ B \end{bmatrix} \quad \textbf{(7)}$$

And assuming: $M = \begin{bmatrix} 1 & \log(d_1) \\ 1 & \log(d_2) \\ & \vdots \\ 1 & \log(d_N) \end{bmatrix}$ and $K = \begin{bmatrix} A \\ B \end{bmatrix}$; we will obtain: $L = M * K$ **(8)**

Our target is to minimize the Euclidean distance between the prediction values contained in the vector L and the measured values of the propagation loss L_M [13].

Let $E = \frac{1}{N} \|L_M - M * K\|^2$ **(9),** the mean square error. We are looking for a vector K which minimize E. So E here is our objective function, we can also remark that E is a quadratic function related to the variable K. In other to implement Newton second algorithm according to equation (5), we should find the gradient and Hessian of E. Equation (9) can also be written as $E = \frac{1}{N} * (\|M * K\|^2 - 2(M * K).L_M + \|L_M\|^2)$ where <.> represents the scalar product. Then $N * E = \|M * K\|^2 - 2(M * K).L_M + \|L_M\|^2$;
$N * E = K^T M^T M K - 2K^T M^T L_M + L_M^T L_M$ Where K^T represents the transpose of vector K.
We can then deduct the gradient as following:
$\frac{\partial(NE)}{\partial K} = \frac{\partial(K^T M^T M K - 2K^T M^T L_M + L_M^T L_M)}{\partial K}$ This gives $\frac{\partial(NE)}{\partial K} = 2M^T M K - 2M^T L_M$
And $\frac{\partial(E)}{\partial K} = \Delta(E) = \frac{1}{N} * (2M^T M K - 2M^T L_M)$ **(10)**

The hessian matrix of (N*E) can also be deducted by $\frac{\partial^2(N*E)}{\partial K^2} = \frac{\partial(2M^T M K - 2M^T L_M)}{\partial K} = 2M^T M$
Finally, the Hessian of E will then be: $H(E) = \frac{2}{N} M^T M$ **(11)**

The final iterative scheme is then: $K_n = K_{n-1} + [H(f)^{-1}] * \Delta(f)$ this gives

$K_n = K_{n-1} + \frac{1}{N} * [\frac{2}{N} M^T M]^{-1} (2M^T M K - 2M^T L_M)$, This can be rearranged as:

$\boldsymbol{K_n = K_{n-1} + inv(M^T M) * (M^T M K - M^T L_M)}$; n≥1, where inv(X) refer to the inverse of the matrix X. **(12)**

The equation (12) is the key point of this study, the following algorithm presents is based on it.
According to [10] we know that a propagation model is précised and feat a local environment if it's Root Mean Square Error (RMSE) is less than 8dB. In fact $RMSE = \sqrt{E}$, then we can define a stopping criteria of our iterations which is: $\boldsymbol{E \leq 64}$. But for complex environments and in some special cases, it could be found that E is always greater than 64, so another stopping criteria based on the maximum number of iterations should be also added, otherwise we could be dropped inside an infinite loop.
We will therefore have the implementation algorithm below:

```
Begin
    D ;              % The vector that contains the distances between BTS and MS gotten through  drive test
    K= [0 ; 0] ;   % initialization of   K .
    Eseuil=64 ;  % We fix the mean square threshold to 64
    It=20 ;          % We fix the maximum iterations number to 20
                     %Generation of matrix M
    For i=1 : N
          M (i, 1)=1 ; M (i, 2)=log (D(i)) ;
    End
    Iteration=0 ;
    e = L-M*K;                    % e ERROR function
    Fit_new=1/N*(e^T*e);         % Fit: mean square error
    O=M^T*M;                    % Temporal vector to make the iteration easy
    While (Fit_new >Eseuil)
          iteration=iteration+1;
           if iteration < 20
                 G=2*1/N*(-M^T*L + O*K);     %Gradient calculation
                 H=2*1/N*O;                    % H=2/N*O; Hessian calculation
                 K=K-inv(H)*G;                 % Newton iteration
                 e =L-M*K;                    % updating e for next iteration
```

```
                Fit_new=1/N*(e^T*e));
        else
                Break           % We break the while loop
        End
    End
End
```

After running the algorithm, we will have the solution which is a vector $\mathbf{K}^* = \begin{bmatrix}\mathbf{A}\\ \mathbf{B}\end{bmatrix}$ for our optimization problem.

Through this we can deduct that for K_3, K_4, K_5 and K_6 constants, we can have:

$$\mathbf{K_1 = A - (K_3 * (H_{m)} + K_4 * \log(H_m) + K_5 * \log(H_b))} \qquad \textbf{(13)}$$

$$\mathbf{K_2 = B - K_6 * \log(H_b)} \qquad \textbf{(14)}$$

Now we have clearly defined our determination procedure. The next step is to present what we got as result after implementing our algorithm on data sets collected.

IV. Results and comments

Having implemented the method presented above on radio measurements data obtained in the city of Yaoundé, we have obtained the results as presented below.

4.1 Results per area

We obtained the representatives curves below, the actual measurements are in blue, Okumura Hata model in black, the optimized model obtained via Newton second order method in red**.**

For the implementation we have considered the following value: $\mathbf{K_3=-2.49, K_4=0; K_5=-13.82; K_6=-6.55}$;

a) AreaA1 : Yaoundé centre town.

The following table presents the result obtain in area A1 using Newton second order algorithm:

Table 6: result in centre town.

Area	Results	K1	K2	K3	K4	K5	K6	RMSE
A1	Newton 2nd order	134.89	37.29	-2.49	0	-13.82	-6.55	**6.7137**
	Okumura Hata	146.56	44.9	0	0	-13.82	-6.55	14.9345

We can remark that the RMSE obtained by the algorithm is less than 8dB and better than that of Okumura Hata. The following figure presents the actual data gotten from field, the curves of Okumura Hata and the optimized model.

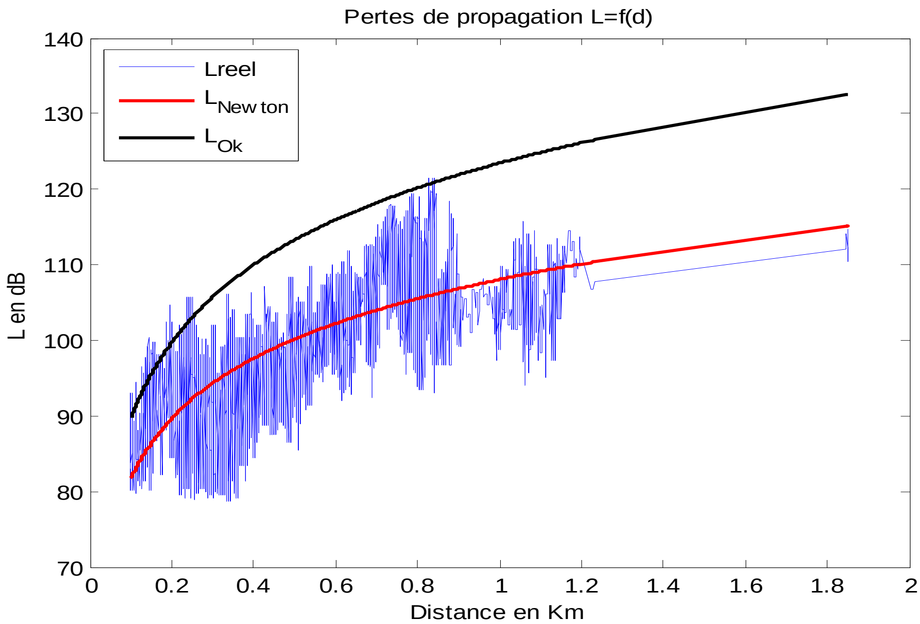

Figure 6: Actual data in Centre town VS predicted measurements.

b) Area A2 : Bastos area (Ambassy quaters)

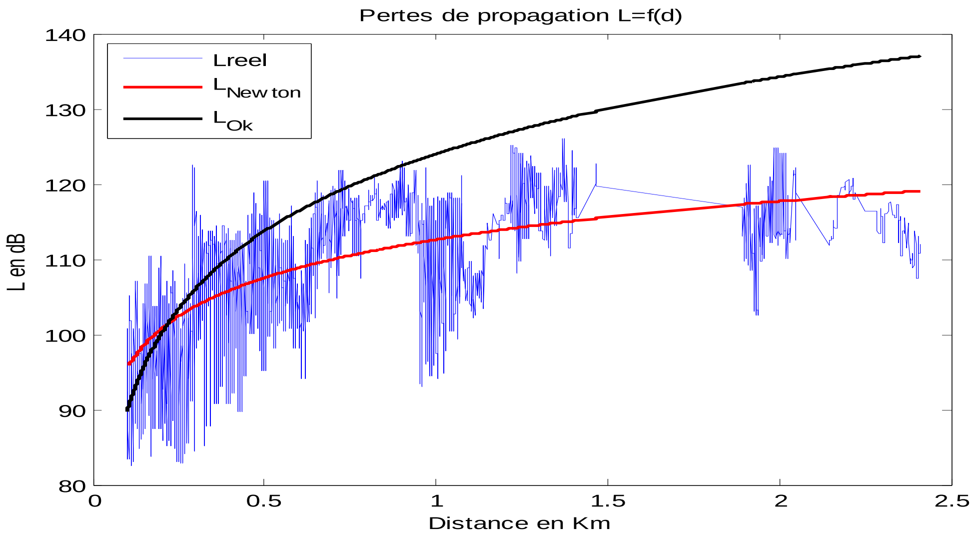

Figure 7: Actual data in Bastos VS predicted measurements.

The table below gives the results of newton second order algorithm.

Table 7: Results from bastos area.

Area	Results	K1	K2	K3	K4	K5	K6	RMSE
A2	Newton 2nd order	138.93	27.71	-2.49	0	-13.82	-6.55	**6.1059**
	Okumura Hata	146.56	44.9	0	0	-13.82	-6.55	11.2924

Note that we have a RMSE <8dB which confirms the reliability of the result.

c) Area B1 : Biyem Assi area

We have the figure below.

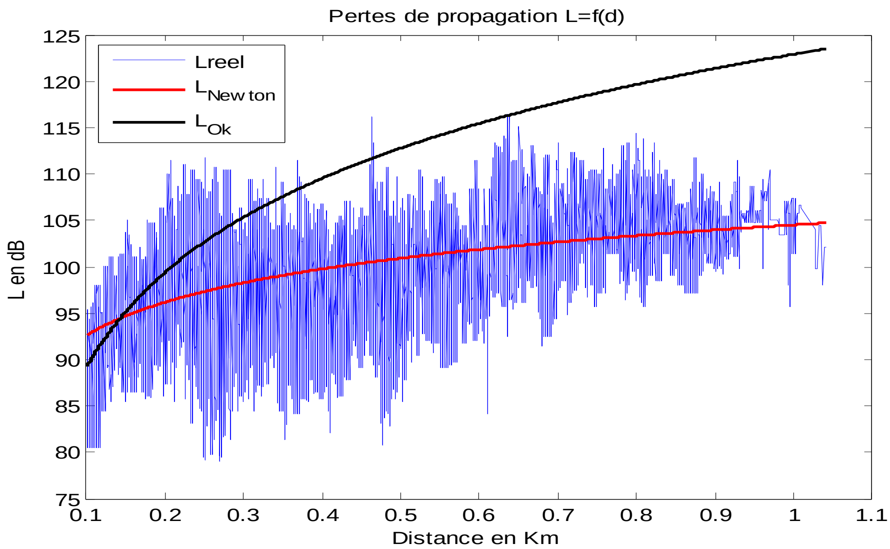

Figure 8: Actual data in Biyem Assi VS predicted measurements.

The table below gives the results of NSO algorithm.

Table 8: Results from Biyem Assi area.

Zone	Résultats	K1	K2	K3	K4	K5	K6	RMSE
B1	Newton 2nd order	131.90	23.17	-2.49	0	-13.82	-6.55	**5.3883**
	Okumura Hata	146.56	44.9	0	0	-13.82	-6.55	12.3604

Note that we have a RMSE <8dB which confirms the reliability of the result and which is better than the one of Okumura Hata.

d) Area B2 : Essos-Mvog Ada area

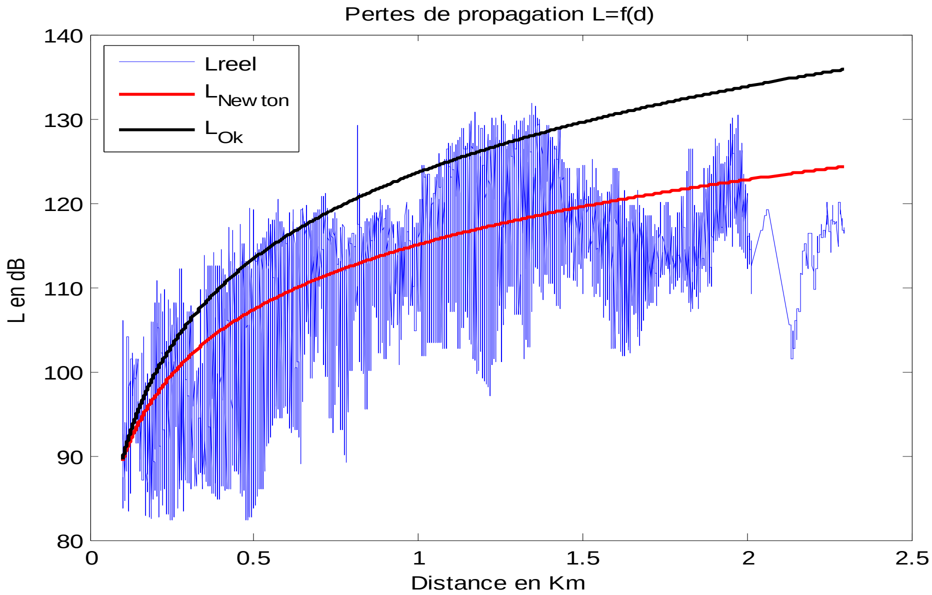

Figure 9: Actual data in Essos Camp Sonel area VS predicted measurements.

The table below gives the results of NSO algorithm.

Table 9: Results from Essos Mvog Ada area.

Zone	Résultats	K1	K2	K3	K4	K5	K6	RMSE
B2	Newton 2nd order	141.75	36.53	-2.49	0	-13.82	-6.55	**7.3907**
	Okumura Hata	146.56	44.9	0	0	-13.82	-6.55	11.5989

Note that we have a RMSE <8dB which confirms the reliability of the result

4.2 Summary of results

In all the area A1, A2, B1, B2 above, the RMSE obtain through the new model made up using NSO is better than the one calculate using Okumura Hata model. After testing, we find that the solution is gotten with only one iteration. This can be explained by the fact that our objective function is a quadratic one. For the whole town of Yaoundé, given that we always got a RMSE < 8dB, we can deduce the final solution as the average of the solution gotten in each area. The final result and the corresponding formula are given below.

Table 12: Optimized propagation model retained

Zone	Method	K1	K2	K3	K4	K5	K6
Final solution	NSO	136.86	31.17	-2.49	0	-13.82	-6.55

Before retaining the result of table 12 as our optimized propagation model, let check that it is accurate for all area A1, A2, B1 and B2. The table below presents the RMSE obtained using the new model in all the considered area.

Table 13: RMSE evaluation for the optimized model per area.

Area	A1	A2	B1	B2
RMSE(Optimized model)	**7.8791**	**6.8575**	**6.0403**	**8.9573**
RMSE(Okumura Hata)	14.9345	11.2924	12.3604	11.5989

We clearly see that the optimized RMSE is always better than the one of Okumura Hata.
The final model equation is

$$\mathbf{L = 136.86 + 31.17\log(d) - 2.49 * h_m - 13.82 * \log(H_{eff}) - 6.55 * \log(H_{eff}) * \log(d)} \quad \textbf{(15)}$$

This final formula can be seen as the propagation model adapted to the environment of Yaoundé.

V. Conclusion

This paper presents the use of a Newton second order algorithm (see equation 12) to optimize existing Okumura Hata model in the frequency band of 800MHz relatively to a given environment. The method described here gave us a very good result and could very well be used to design or calibrate propagation models. This method is relatively simple to implement and the result can be quickly be obtained. 2 stopping criteria were defined for the implementation of the algorithm, one based on the maximum number of iterations and another based on the RMSE threshold that we which to satisfied. Measurements made on the city of Yaoundé as application gave us very good results with an RMSE less than 8dB for all the selected areas in the city. Compare to Okumura Hata RMSE obtained, the new model gives a better result .This means that it is accurate. Despite the fact that we presented the algorithm using Okumura Hata model in a specific band, it doesn't restrict its utilization. This method can then be applied to optimize propagation model for deployment of LTE network in any frequency anywhere.

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