# 2020

# Conference Proceedings

## 7th International Conference on Automation, Control Engineering & Computer Science (ACECS)


PET Proceedings

Vol. 64

ISSN : 1737-9934

7th International Conference on Automation, Control Engineering & Computer Science (ACECS)
Proceedings of Engineering & Technology – PET -
Vol.64, pp. 10-18

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ISSN: 1737-9334

7th International Conference on Automation, Control Engineering & Computer Science (ACECS)
Proceedings of Engineering & Technology – PET -
Vol.64, pp. 10-18

# Optimization of Path Loss Models for 3G Mobile by Using Cultural Algorithms

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*Abstract*: **Planning in mobile networks is essential to having a good performance of a BTS. Losses in a physical channel are a big problem in a UMTS network. This effect is defined by a propagation model. The empirical models are based on the analysis of many experimental measurements, that is to say, A statistical analysis of data according to different parameters: frequency, distance, the height of the antennas, and attenuation. The parameters of the empirical models can be adjusted to get a minimum of error between predicted losses and measure them real. It will return the more definite model for the predictions of losses. The objective of our paper is to describe a program that uses the CA algorithm to optimize the empirical model Egli and make it more appropriated to the zone of desired coverage. For optimization, we will calculate the global minimum of a cost function in a direction to reduce the mean square error between the prediction data established by this model to be optimized, so measured reals taken from the Batna region, Algeria. BTS1 covers the suburban area.**

*Keywords*: **UMTS, path loss, empirical models, CA, RMSE**

## I. Introduction

In the study of the mobile channel and given its obvious importance, mastery of the methods of planning and densification of UMTS cellular networks is crucial. The study of the physical behavior of signals in the mobile channel and the measurements of the losses generated is necessary [1,2].

Coverage areas can be obtained, either by measurement or by calculation from a wave propagation model to develop engineering studies and to resolve planning issues [3]. One of the fundamental needs in the design, implementation, and operation of a mobile terrestrial radio system is knowledge of the value of the power of the signal received and its variations at each point of the system's coverage. Such a system is based essentially on one or more models or methods of propagation calculation [4].

The propagation models are then used to mathematically predict the propagation of radio waves between the source and the target service area, giving an idea close to reality to allow a system receiver to find in advance whether the proposed radio communications system will serve the intended service area [5,6].

In this context, our paper consists of studying the physical behavior of signals in the mobile channel and we have been interested in the problem of weakening in a UM interface (mobile user) in the third generation cellular network [7,8].

we have developed an optimization tool to reduce the error between predicted and measured losses in the UMTS network based on CA optimization. To evaluate the performance of our algorithm, we considered the cellular network of the operator MOBILIS for the city of BATNA. Indeed, we have adjusted the parameters of an empirical model to reflect actual measurements in a targeted environment. This made the model more accurate for the weakening prediction.

The rest of this paper is organized as follows. In sections 2 and 3, we review each. empirical model and Experimental setup. Section 3 presents the application, results, and discussion. Finally, in the last area we present our decision and potential future work.

## II. Path Loss Model

The propagation model is an essential process at the beginning of network deployment because it allows precise predictions on coverage. The radio wave propagation model is a mathematical model, a model given by a number of parameters (technical characteristics, geographic environment type) that simulates losses between a transmitter and a


ISSN: 1737-9334

7th International Conference on Automation, Control Engineering & Computer Science (ACECS)
Proceedings of Engineering & Technology – PET -
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receiver. In this paper, we have considered four different Empirical models for our investigation as follows.

*1. A. Egli Model*

Egli prediction model is an empirical model which has been proposed by [9]. The Egli model is a simplistic model to approach radio-wave path-loss of irregular topography. Based on real data the path-loss approaching can be formulated as following:

$$PL(dB) = 20\,log\ (f_c) + 40\,log\ (d) - 20\,log\ (h_{te}) + \begin{cases} 76.3 - 10\,log\ (h_{re}),\ h_{re} \le 10 \\ 85.9 - 10\,log_{10}(h_{re}), h_{re} \ge 10 \end{cases} \quad (1)$$

where

$h_{te}$ = height of the base station antenna. Unit: meter (m)
$h_{re}$ = height of the mobile station antenna. Unit: meter (m)
d = distance from base station antenna. Unit: meter (km)
f = frequency of transmission. Unit: megahertz (MHz)

*2. B. Hata's Model*

This model has been acquainted with urban zones; and with some revision factors it could be stretched out to rural and provincial zones. For the urban region, the middle way misfortune Equation is given by

$$L(urbain)(dB) = 69.55 + 26.16\log(f_c) - 13.82\log(h_{te}) - a(h_{re}) + (44.9 - 6.55\log(h_{te}))\log(d) \quad (2)$$

For suburban area, it is expressed as

PL(suburban)(dB) = PL(urban) - 2[log(fc/28)]2 - 5.4 (3)

Finally, for open rural area, it is modified as

PL(open)(dB) = PL(urban) - 4.78(log(fc))2 +18.33log(fc) - 40.94 (4)

In the above Equations, d is the transmitter-receiver antenna separation distance and it is valid for 1km–20km, fc represents the operating frequency from150 MHz to 1500 MHz. The transmit antenna height, $h_{re}$ ranges from 30m to 200m and the receive antenna height, $h_{re}$ ranges from 1m to 10m are considered [10].

*3. C. Cost 231 Hata model*

The COST 231 Hata is an extension of the Hata model but at higher frequencies. This model is used to calculate the weakening on the path in three different environments (urban, suburban and rural) in the range of frequencies 1500 MHz to 2000 MHz [11,12].

$$PL(d)(dB) = 46.3 + 33.9\log(f_c) - 13.82\log(h_{te}) - ah_m + (44.9 - 6.55\log(h_{te}))\log(d) + C_m \quad (5)$$

And Cm=0 dB for medium sized city and suburban area with moderate tree city or Cm =3 dB for metropolitan centers.

*4. D. SUI Model*

The basic SUI model was proposed by the IEEE , for frequencies around 2 GHz, receiver antenna below 2 m. It is suitable for suburban environments. SUI model comes out with three distinct sorts of terrain like terrain A dense urban locality, terrain B has hilly regions and terrain C for rural with moderate vegetation [13,14].
The median path loss is defined as the following expression:

$$PL = A + 10\,\gamma\,log\ \left(\frac{d}{d_0}\right) + X_f + X_h + s \quad (6)$$

where:
$d \ge d_0$ : is the distance between the base station and the receiving antenna, $d_0$=100 m.
Parameter A is defined as:

$$A = 20\,log\ \left(\frac{4\pi d_0}{\lambda}\right) \quad (7)$$

where λ is the wavelength in meters. Path loss exponent γ given by

$$\gamma = \alpha a - b\,h_{te} + \left(\frac{c}{h_{te}}\right) \quad (8)$$

Where $h_{te}$ is the base station antenna height in meters, it must be between 10 m and 80 m, and a, b and c are constants dependent on the terrain type, as given in Table 1.

TABLE I
MODEL PARAMETERS FOR DIFFERENT TERRAINS

| Model Parameter | Terrain A | Terrain B | Terrain C |
|---|---|---|---|
| a | **4.6** | **4.0** | **3.6** |
| b ($m^{-1}$) | **0.0075** | **0.0065** | **0.005** |
| c (m) | **12.6** | **17.5** | **20** |

The correction factors for the operating frequency and for the receiver antenna height for the model are :

$$X_f = 6.0\log_{10}\left(\frac{f_c}{2000}\right) \quad (9)$$

and, for terrain type.

$$X_h = -10.8\log_{10}\left(\frac{h_{re}}{2000}\right) \text{ for the terrain type A and B} \quad (10)$$

$$X_h = -20.0\log_{10}\left(\frac{h_{re}}{2000}\right) \text{ for the terrain type C} \quad (11)$$

Where f, is the frequency in MHz, and h is the receiver antenna height in meters. The SUI model is used for path loss prediction in rural, suburban and urban environments.

## III. MEASUREMENTS AREA

To confirm the propagation models, an experiment is setup to collect and measure received signal power in a deployed 3G network operating at 2.124 GHz. The area is


ISSN: 1737-9334

7th International Conference on Automation, Control Engineering & Computer Science (ACECS)
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located in the Northeast part of Batna from Algeria and can be classified as a low-urban to suburban environment. The test area covers a radius of approximately 2.5 km.

Data were collected when driving a vehicle, having the experimental configuration. It consists of a Special Mobile Phone (Huawei U6100) GPS receiver (NMEA), a receiving antenna, and a laptop with a key and a drive test software (Huawei GENEX Probe). The vehicle was driven within the base station coverage area while continuously recording the received signal. At every moment of the collected measurements, GPS data are also recorded simultaneously.

The information of the base station such that the frequency of transmission or reception, transmitted power, and antenna heights are obtained from the operator "Mobilis" of the Batna city for analysis. With the help of GPS data, and the location of base stations, the radial distances from the base station at any point along the route can be calculated.

TABLE II
BTS PARAMETERS

| Parameters | | BTS1 | BTS2 |
|---|---|---|---|
| Region type | | **Rural** | **Suburbain** |
| Transmit power (dBm) | | 46 | 43 |
| Cable Loss + Body loss | | 10.5 | 9.7 |
| Transmitting antenna gain (dBi) | | 17.5 | 16.7 |
| Receive antenna gain (dBi) | | 0 | 0 |
| Transmit antenna height (m) | | 25 | 35 |
| Mobile station antenna height (m) | | 1.5 | 1.5 |
| Operating frequencies (MHz) | Uplink frequency | 908 | 912,4 |
| | Dn-link frequency | 953 | 957.4 |
| Geographic coordinates | Latitude | 35,2524 | 35,62437 |
| | Longitude | 6,13074 | 6,36984 |

IV. SIMULATION RESULT AND ANALYSIS

### 5. A. *Comparison with Prediction Models*

To examine the prediction models, a comparison between predicted path loss and measured path loss have been performed for two base stations BTS1 and BTS2. The performance of the empirical models is then compared with the path loss data analyzed as shown in Figure 1and 2 .

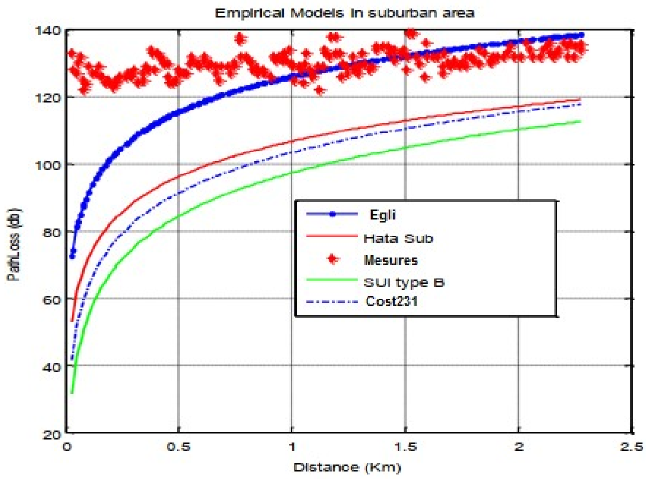



Fig 1. Comparison between predicted and measured path loss for BTS1

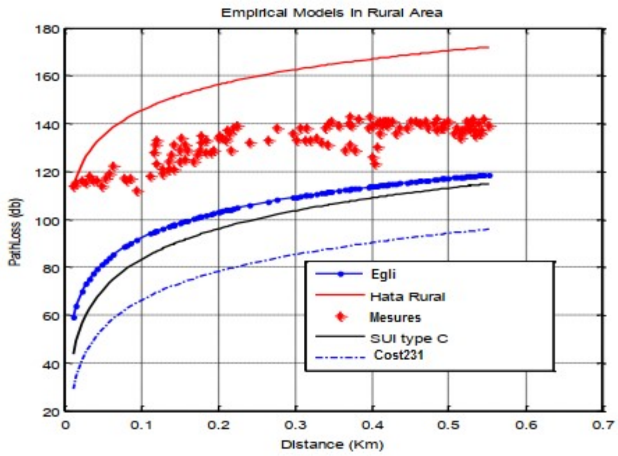



Fig 2. Comparison between Predicted and Measured Path Loss for BTS2

For both open area and suburban environments, the path loss exponent estimated by the Egli model is in closest agreement with the measured path loss, which shows the actual path loss characteristics in Batna. Based on this, the Egli model is selected as the best model for optimization to develop a new model for the path loss prediction in Batna for UMTS system. The next section of the paper describes how the Egli model is first optimized by CA to match the measured path loss and then a comparison analysis of the performance of the new optimized model is made against the measured path loss and the path loss estimated by the Egli model.

### 6. B. *Optimization Process by CA*

Cultural algorithms are evolutionary techniques modeling the cultural evolution of populations [15]. These algorithms support the basic mechanisms of cultural change [16].

So these algorithms work in two spaces: the population space that contains a set of individuals that evolve


ISSN: 1737-9334

through an evolutionary model, and the knowledge space that contains the information and knowledge used to guide and influence the evolution of individuals of populations over generations[17].

*1) Algorithme Culturel*

{
t=0;
Initialiser la population P(t);
Initialiser l'espace de connaissances B(t);
**Répéter**
{
Evaluer P(t);
Ajuster (B(t), acceptance (P(t));
Evoluer (P(t), influence(B(t));
t=t+1;
} Jusqu'à (condition d'arrêt valide);
}

In this study The Egli model is selected. Formulating the problem to be solved as a single mathematical Equation has five variables as shown in Table 4, assessed by a cost function to a stopping criteria depends on the performance thereof. And in general, this cost function is defined as RMSE (Root Mean Square Error).

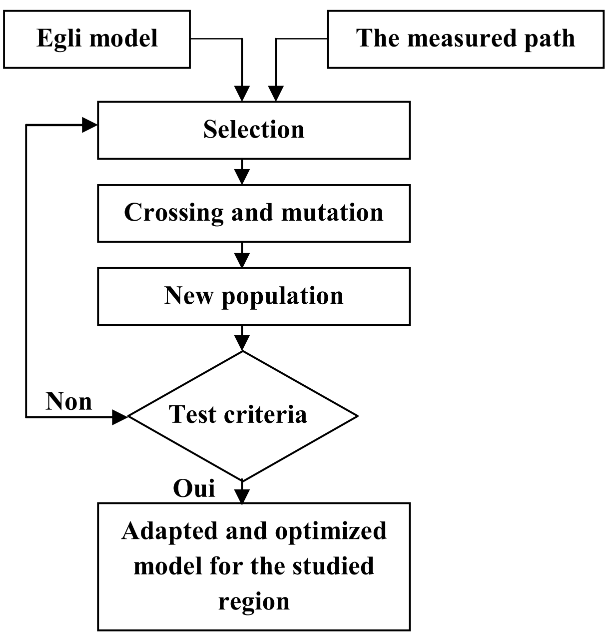
Egli (rural/sub) model is defined as:

$$PL(dB) = 20\,log\ \ (f_c) + 40\,log\ \ (d) - 20\,log\ \ (h_{te}) + 85.9 - 10\,log\ \ (h_{re}),\ \ h_{re} \le 10 \qquad (12)$$

TABLE III.
THE OPTIMIZED PARAMETERS

| | | | | |
|---|---|---|---|---|
| K1=20 | K2=40 | K3=-20 | K4=-85.9 | K5=-10 |

The diagram for optimization identified as follows:




Figu 3. Flow Chart of the Optimization Process

*2) Root Mean Square Error(RMSE)*

The RMSE which measures the difference between the signal power predicted by a model and the actual measured signal was implemented in MATLAB. It served as a measure of accuracy to compare forecasting errors of the different propagation models given the drive test measurement data. It is defined mathematically by equation:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} |PL_{m,i} - PL_{e,i}|^2}{n}} \qquad (13)$$

Where represents the measured path loss in dB, is the predicted path loss in dB, and is the number of the measured data points.

We will probably minimize RMSE to get the best arrangement in the population to guarantee the exactness and accuracy of the considered model (Egli). For the implementation of the GA technique, selected parameters are listed in Table IV.

TABLE IV
CA PARAMETERS USED

| CA parameters | Values |
|---|---|
| The population size | 20 |
| Selection | Stochastic Uniform |
| Crossover | Heuristic (Crossover rate = 1.5) |
| Mutation | Adaptive feasible |

*3) Optimization Results by CA*

The results of simulation using CA parameters are presented in the tables and figures below:

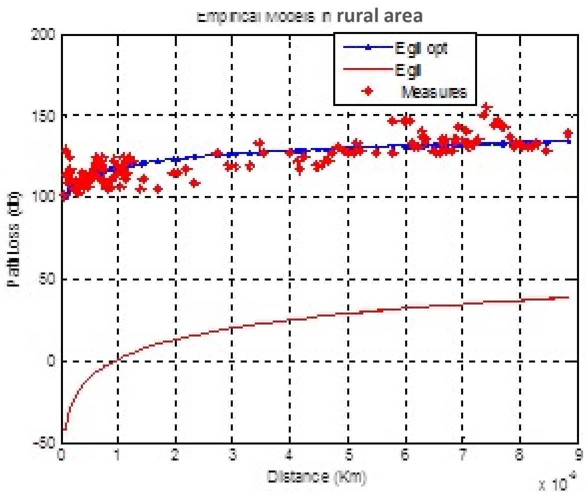



Fig 4. Comparison between Egli and Egli-Opt (rural)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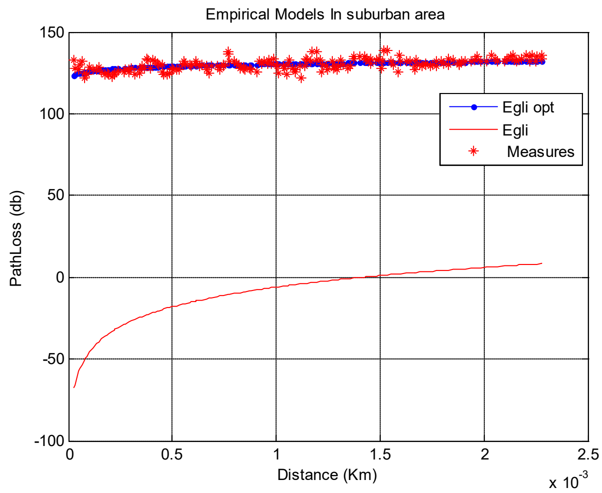


Fig 5. Comparison between Egli and Egli-Opt (suburban)

TABLE V
RESULTS OF THE OPTIMIZATION PROCESS FOR EGLI MODEL (SUBURBAN)

| Parametres | Opt- Egli | Egli |
|---|---|---|
| K1 | 28.0876 | 46 .3 |
| K2 | 16.6776 | 33.9 |
| K3 | -68.4566 | 13.82 |
| K4 | -28.0050 | 44.9 |
| K5 | -43.0732 | 6.55 |
| RMSE | 7.7884 | 16.1158 |
| Time of calculation (s) | 12.259798 | / |

TABLE VI
RESULTS OF THE OPTIMIZATION PROCESS FOR EGLI MODEL (RURAL)

| Parametres | Opt- Egli | Egli |
|---|---|---|
| K1 | 24.2195 | 46 .3 |
| K2 | 16.6776 | 33.9 |
| K3 | 36.5166 | 13.82 |
| K4 | 141.4910 | 44.9 |
| K5 | -17.2163 | 6.55 |
| RMSE | 6.8894 | 16.1158 |
| Time of calculation (s) | 36.165859 | / |

Starting with the results of Table V and Table VI, and going through both Figures 4 and 5, We observed that both Rural and Suburban optimized models exceed other models in terms of global performance.

## V. CONCLUSION

In this paper, We have developed an optimization tool to minimize the error between predicted and measured losses in the UMTS Network based on particle swarm optimization. In order to evaluate the performance of our algorithm, we considered the mobile network of the operator MOBILIS for the city of Batna,Algeria. Indeed, we have adjusted the parameters of an empirical model to real measurements in a targeted environment.

From the numerical model, other estimations of parameters are proposed for Egli model dependent on estimated information. Clearly the balanced Egli model shows the nearest concurrence with the estimation result. Therefore Egli model with proposed modification is recommended for Batna City rural and suburban areas.

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ISSN: 1737-9334