Outdoor Radio Propagation Model Optimization Using Genetic Algorithm

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Abstract

Path loss which is one of the main issues in wireless communication system and has been studied for long time. With the tremendous increase in demand in wireless technology, this Path loss needs to be optimized. Therefore, it is very important to analyse these different propagation models in order to get some useful information out and develop a system based on it. This is done to get the optimum path loss from different models. These are useful tools which makes the designers capable of designing a wireless system with great efficiency. In pursuit of the same, this paper attempts to optimize free space propagation model and hata model using GA algorithm, and shows a comparison by putting them side by side. This paper gives an insight of comparison between free space and Hata model in wireless communication taking different propagation environments into consideration.

Keywords: Hata model, Free Space Propagation model, Genetic Algorithm.

1 Introduction

Wireless communication is the process of the transmission of data over a long distance with the help of electromagnetic radiations like millimeter waves. From past few decades, wireless communication is growing rapidly with the increasing demand in technology. Since then continuous efforts are done to achieve better efficiency. With the arrival of 4G-LTE, most of the limitations associated with the previous generation in terms of coverage area, spectrum, and data rates are being overcome, resulting in excellent coverage in remote locations.

By choosing the proper antenna height, frequency, transmitting power the system effectiveness can be improved [2]. A rapid increase in mobile data usage forced the engineers to work on Long Term Evolution. The central idea or goal of long term evolution is to provide higher rate of data and low latency supporting flexible bandwidth [2] [3] [3]. As the electromagnetic wave propagates from transmitter to receiver various factors affects its signal quality and results in losses. Path loss is one of the main factors used in analyzing and designing of wireless communication system. Under the application of an optimized model the design will perform in a better way, saves a lot of time and will be cost effective than the actual system deployment [4].

2 Algorithm Used

In this paper genetic algorithm (GA) based optimization technique has been used to get the optimum solution for constrained and unconstrained problems rely on principles of genetics and natural selection process which is same as biological evolution. Genetic algorithm is most widely used to solve optimization problem, in machine learning, research as well as for the problem on which the standard optimization algorithm doesn't perform well. It also includes problem whose main objective function is stochastic discontinuous, non-differentiable or extremely non-linear.

The working of genetic algorithm can be summarized as:

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1) Firstly it starts with generating a batch of random solutions.
2) Then the sequence of new solutions is being created by the algorithm. From the creation of the next solutions the algorithm at every step uses the solutions of the current generation. The GA performs following steps to get to the new solutions-
    a) The values of raw fitness scores are being computed.
    b) The expectation value which is attained from previous scores are converted into more suitable ranges.
    c) Depending on the calculation done in previous step, members are selected which then used to generate new batch of solutions.
    d) The individuals having lesser fitness are chosen and transferred to the next batch.
    e) New solutions are calculated from the batch selected in the above step.
    f) To form the next generation of solution, current solutions are replaced with new solutions which are known as children.

Once the boundary conditions are met, the algorithm stops.

3 Path Loss Models

3.1 Free space path loss model (FSPL)

The FSPL is a theoretical path loss model which is utilized in case of line of sight propagation [4]. To predict path loss it takes the power at receiver station into consideration and then compare it to the transmitted power along with all the variables like antenna gains, distance between stations and transmission frequency. The path loss can be given as:-

$$PL(dB) = Pt(dB) - Pr(dB) \qquad (1)$$

Or

$$PL(dB) = -10log10(\lambda^2/(4\pi)^2 d^2) \qquad (2)$$

Here λ is the carrier wavelength (m) and d depicts distance(m).

3.2 Outdoor Radio Propagation Model

Outdoor Radio Propagation Model also known as Hata model is an outdoor empirical propagation model. Empirical path loss model is basically a collective set of equations which are obtained from field measurements. Frequency range for Hata model is in between 150 MHz and 1500 MHz and the transmitter-receiver distance is about 1 km to 100 kms [4] [5] [6] [7] [8] [9].

For any urban area, the median path loss according to Hata model can be given as:-

$$L50\ (urban)\ (dB) = 69.55 + 26.16\ log10\ fc - 13.82\ log10(Th) - a(Rh) + (44.0 - 6.55\ log10(Th))log10(d) \qquad (3)$$

Where Th and Rh is transmitter and receiver antenna heights (in meters) respectively.

For a small to medium sized city (urban), the mobile antenna correction factor is [4]:

$$a(Rh) = (1.1\ log10\ fc - 0.7)\ Rh - (1.56\ log10\ fc - 0.8)\ dB \qquad (4)$$

For a large city:-

For fc ≥ 300MHz:-

$a(Rh) = 3.2(log1011.75Rh)2 - 4.97\ dB$ (5)

For fc ≤ 300MHz

$a(Rh) = 8.29(log10\ 1.54\ Rh)\ 2 - 1.1\ dB$ (6)

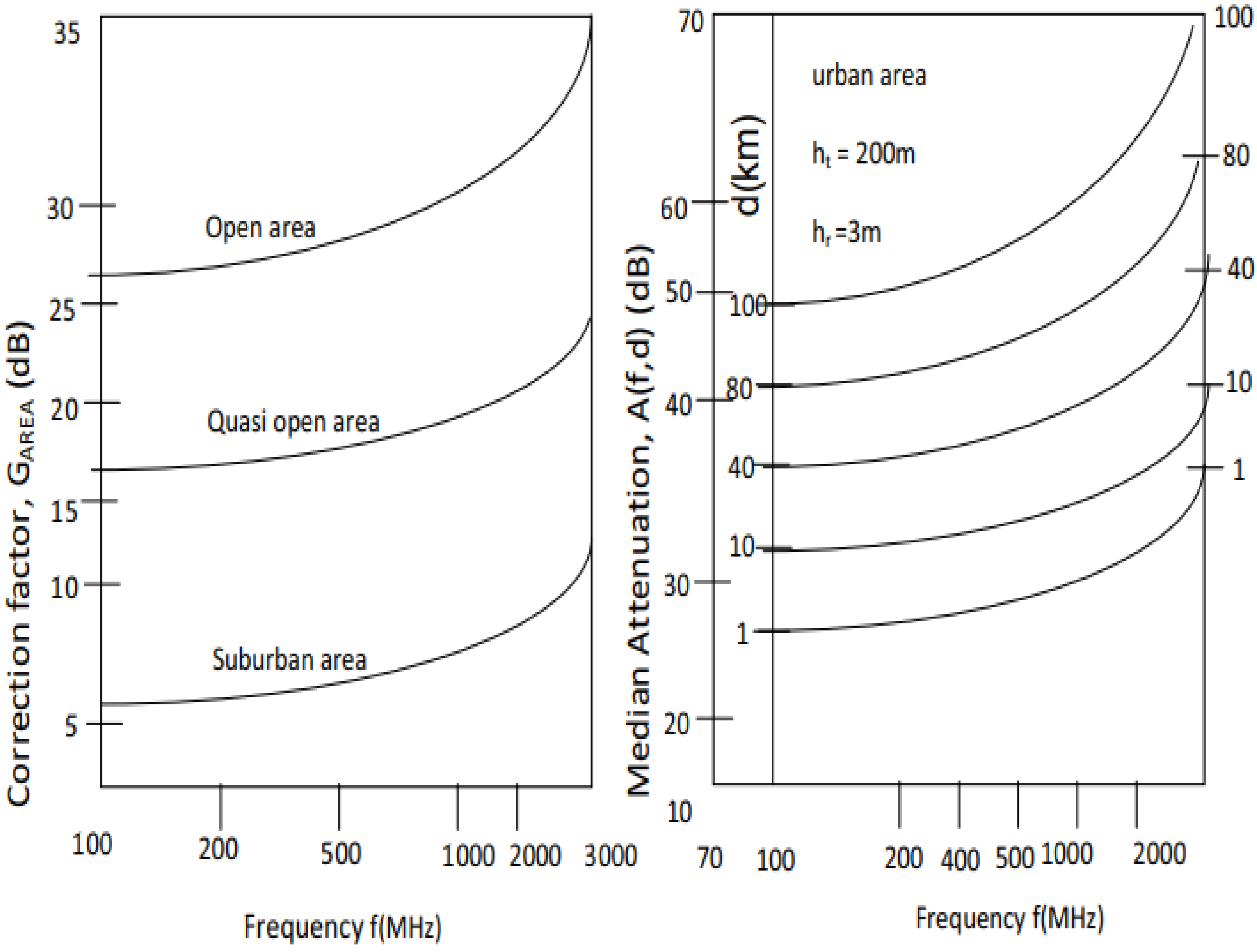

Fig. 1: The correction factor GAREA for terrains of different type and the median over a quasi-smooth terrain relative to free space.

4 Results

TABLE I: Numerical Path Loss (dB) for various path loss prediction models. [7] [9]

Distance (km)	Free Space Model (dB)	Hata Model (dB)	Measured Values(dB)
1.00	91.58	117.90	125.71
2.00	97.60	127.48	132.50
3.00	101.12	133.07	136.63
4.00	103.57	137.05	140.02
5.00	105.56	140.13	145.81

The collected measurements after applying GA algorithm when fc = 870.52MHz, Th =50m and Rh=2m

TABLE II: Numerical Path loss (dB) using GA algorithm for different path loss prediction models

Distance (km)	Free Space Model (dB)	Hata Model (dB)	Measured Values(dB)
1.00	91.2373	121.6934	125.71
2.00	97.2573	131.8957	132.50
3.00	100.7798	137.8066	136.63
4.00	102.2785	142.0260	140.02
5.00	105.2167	145.2988	145.81

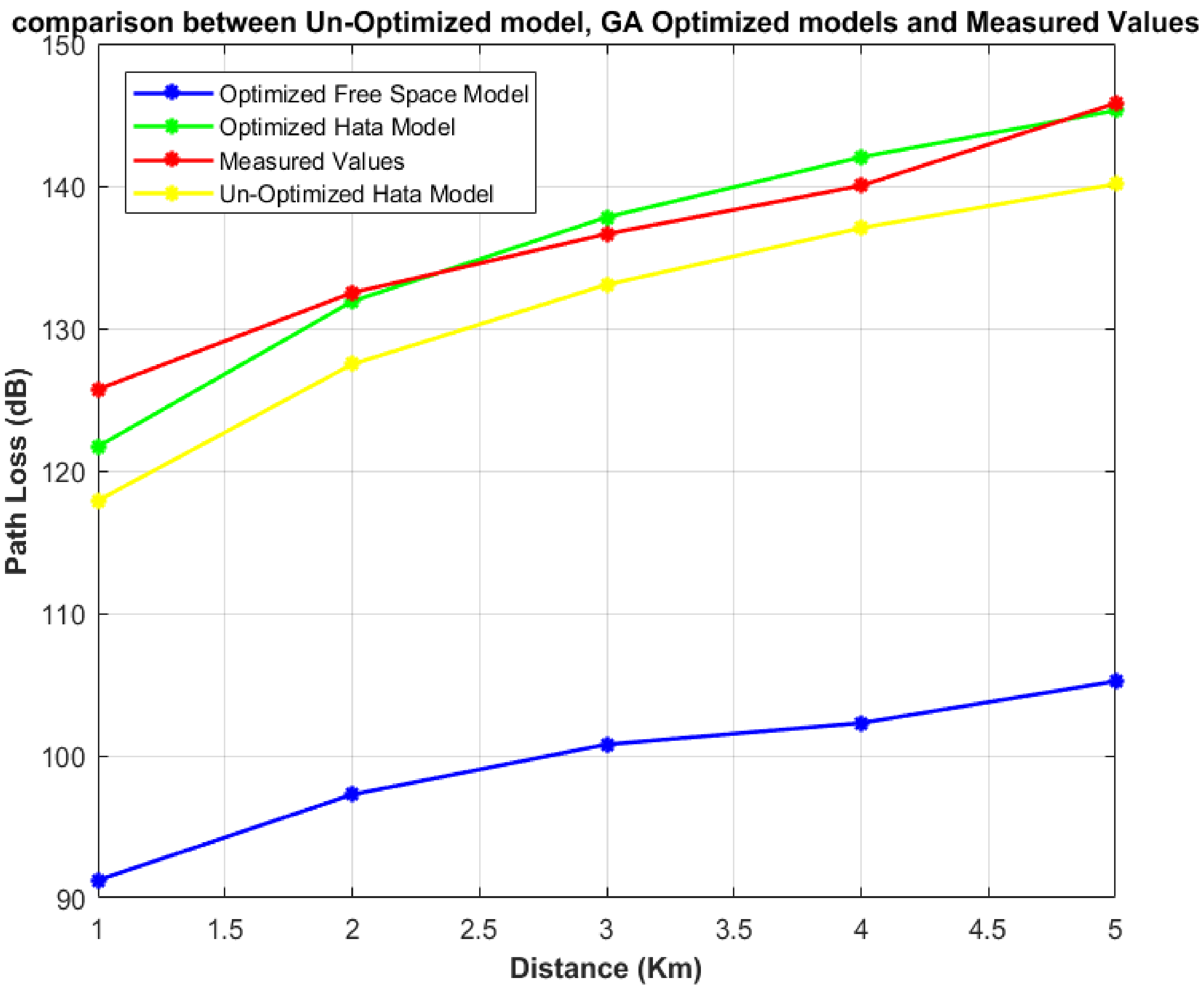

Fig.2: Comparison between Un-Optimized model, GA Optimized models and Measured Values

Taking upper bound and lower bound condition and distance between transmitter and receiver into consideration

Fc=> Upper bound = 1500 MHz

Lower bound = 150 MHz

d=> Upper bound = 60 km

Lower bound= 40 km

For Free Space Path Loss Model

Minimum at Lower bound i.e. fc= 150 MHz

d= 40 km

Min value = 108.0048 dB

For Hata Model

For large city:-

Th = 30 m; Rh = 1m

Min. at lower bound

Min. value = 163.3036 dB

Th = 50 m; Rh = 4m

Min. at lower bound

Min. value = 153.0328 dB

Th = 70 m; Rh = 7m

Min. at lower bound

Min. value = 145.8086 dB

Th = 100 m; Rh = 10m

Min. at lower bound

Min. value = 139.1915 dB

5 Conclusion

The paper shows a comparative study of propagation models. It shows that values computed from free space path loss model are farthest from the actual measured values. Path loss calculated using Hata model are closer to the measured values which due to which the error will be lesser than the free space path loss model. This difference between the values of path loss further decreases when these are compared with the values calculated using GA optimization algorithm, which results in further reduction of error between designed system and implemented system. Further the paper also contains the variation of path loss with different transmitter and receiver station antenna heights. From the results it is clear that the optimized Hata model should be used to calculate path loss for a system that is being designed.

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