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REVIEW

Mathematical methods for the analysis of propagation in multitrajectory in communications move

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Abstract

A study about movable communication using the cellular technology and a mathematical model is presented. The aim of the present paper is to solve the problems of multi-trajectory propagation in the movable communications so that at least a station can have access to a point of the area (Huambo) with a sign, at the level stipulated by the communication companies, depending on the user's need that allows a quality communication The Mathematics methods used have as objective to facilitate the search and selection of the most appropriate alternative to the case under study, and they help to take into account several aspects involved in the decision making. The objective of the methodology presented is to obtain the parameters of quality of the service needed. The introduction of an empiric model allows reducing the values of those parameters to discover the areas of the city that possess potential covering. Besides the potency prediction (through the proposed model), a study of forecast of the parameters of service quality was accomplished, the values limits of those parameters depended on the service that is being used.

Keywords . Movable communications, Empiric model, Propagation, Service Quality.

1. Introduction.

A mobile communication system is the signal of information transmission in order to distance itself and deviate according to the characteristics of the channel computer networks. Communication was used before cell phone networks, AM and FM radio communications, maritime communications, television, two-way communication between vehicles (1930) and the pagination that has existed since the last World War.

The first system of communication was the telegraph in the mid-nineteenth century. The system is the telephone and at the beginning of the 20th century was connected through copper chips. Among the various comprehensive services, mobile communications are included and they played an important role within societies, because people can use this same network at any place, position, and moment. However, data sets will be essential. Deficits mainly derived from population density and climatic factors[1].

The purpose of each model is to re-route through mathematical functions, common phenomena to wireless transmissions and to apply them in a practical way in equipment and services. This is very important for a data set and for the number of network users. The attempt to find a suitable model to represent a spread in several places, especially for mobile applications, has been a great challenge for telecommunication engineers. In this paper some models of coverage prediction are presented with the objective of analyzing propagation losses within the Very High Frequency (VHF) and Ultra High Frequency (UHF) band. The prediction of an area is very important for a Broadcast project intensity of a given signal may have occurred with the quality of a service, in this case, over Long Term Evolution (LTE) networks. Prediction models can be divided into three types: empirical, theoretical, and site-specific models. These propagation models are

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mathematical formulas used to characterize a propagation of radio waves. Usually, it is a function of frequency, distance, antennas, terrain and other conditions. Models are generally sets of test-based equations, usually done in fields for path loss, propagation delay, or other channel characteristics. This information is stored in a database.

The advent of new wireless technologies is becoming a motivator of the growing interest in the study of systems and methods of transmission through radiofrequency. Research problem: Because telecommunications encompass many services and the relative qualitative deficit in remote areas of the city has presented in relation to these services, added to the factors of population density and encourage the development of work on this topic because these services contribute permanently and exponentially to the development of societies, and a detailed and specific scientific study of the factors of mobile communications [1].

In order to arrive at a mathematical model capable of obtaining results with the desired precision and model broadcasting projects, many significant factors are taken into account such as the topography and degree of urbanization of the land. The site-specific models are based on numerical methods applied to the geometry of the site studied, and are therefore more detailed and accurate. The theoretical models are already derived from the physical phenomena assuming some ideal conditions. The models can also be characterized by their applications such as: point-multipoint (or general location), point-to-point and Point-to-multipoint models provide a general estimate of radio propagation rather than using specific path data, and can be used when a good land data is not available. Thus, these models are very useful for the design of proposed cellular networks and are better suited for long-path analysis. Peer-to-peer models, in addition to making estimates of radio links, also make it possible to describe the propagation behavior between the transmitter and receiver. It is also possible, through this, to determine the behavior of the analyzed region and for this, it is necessary to know the topography and the characteristics of the land where the analysis will be done.

General Objectives:

Establish a methodology to solve the problems of multi-trajectory propagation and to understand the mathematical models within the mobile communications. Design and develop in software capable of interacting with the hardware part, collecting the data from the graphical construction of the radiation diagram.

Specific Objectives:

To propose an empirical model to determine the coverage area of our locality from an approach based on measurements and predictions.

To compare the results obtained in the practice, using the software of simulations by the finite difference time domain method (FDTD).

To obtain a final mathematical prototype t o help develop new planar antennas in the different bands.

1.1. Mobile communication systems. Mobile communication systems These systems allow connections between fixed users, from the control centers or through a telephone network with mobile users who have the appropriate equipment, thus making telecommunication links of great versatility [2].

Telecommunications regulation defines the mobile service as the radio communications service between mobile stations and fixed land stations, or only between mobile stations. There are three classes of mobile services, each one can be provided by terrestrial means exclusively and by satellite, namely:
- Land mobile service,
- Maritime mobile service,
- Aircraft mobile service.

There are large subsystems in every mobile system:
- Network Subsystem and
- Subscription Subsystem.

Network Subsystem comprises a set of fixed equipments and installations such as controllers, switching centers, user registration, control centers, operation and maintenance.

Access Subsystem is a set of radio stations that spread across the area of coverage of the mobile network between each other and through the network with fixed terminals.

1.2. Classification of radio stations. Radio stations are classified as:
- Fixed Stations (FS)
- Mobile Stations (MS)

1.2.1. Fixed Stations. A fixed station (FS) is an electrical radio station not intended for use on the movements. In the mobile service three types of fixed stations are used:
- Base stations (BS),
- Control stations (CS),
- Repeater stations (RS).

From figure 1.1 it shown that the Base station is a fixed radio station, the operation of which is controlled directly from the control unit at a specific point. The control can be local or remote, via telephone lines or radio links. Base stations have the primary characteristic of being sources and recipients of traffic, both information and signaling. They are made up of transceiver equipment, radiant systems and elements of connection between them.

Figure 1.1: Base station antenna(Global Distributed Antenna Systems Market, Global Distributed Antenna Systems Industry: Ken Research).

Some factors define the extent of coverage of an (Emergency Radio Beacon) ERB [3].

- Output power applied to the antenna;
- Frequency band to be used;
- Antenna height and location;
- Air type;
- Topography of the area;
- Sensitivity of receiver

Figure 1.2: Base station antenna(Label Italy | Log 8 Elements FM Antenna Systems | FM Systems).

Control station is a fixed station whose transmissions are used to automatically govern the operation of another specific radiolocation station. Usually as shown on the figure 1.2 not used for remote control to a base station or a repeater. Repeater stations are fixed stations that relay the received signals. They are used to get large radio coverage, so they can only be used in high places. They are also used to fill or cover shaded areas on the roof of a radio station or to provide coverage in difficult scenarios such as tunnels, underground parking[4].

1.2.2. Mobile Stations. Mobile Stations (MS) is a mobile service radio station intended for use by a person on foot or in a vehicle in motion or with stops at any point in the coverage area. The term includes the equipment mounted on a vehicle, as well as the portable or hand held vehicle that carries the user with it. It can also be called mobile terminals or user equipment[5].

The mobile terminals connect to the network through the base stations (BS) of the access subsystem. On the other hand, it is said that in Base Stations (BS) the traffic originated up to the Mobile Stations (MS) or finished from the Mobile Stations (MS).

The connection of the BS to the network subsystem can be done through a metallic line, optical fiber or also by point-to-point radio-links. The radio stations of these radio links may be called control stations. These stations operate at different frequencies from those of mobile service and in the traffic.

For special environment coverage (underground, tunnels) those not accessing an outdoor base station, RS repeater stations, which receive signal from base station BS and radiate to the area in question where mobile stations MS are located. In the repeaters traffic and mobile service frequencies are used[6].

Mobile communication systems can be classified according to Frequency band used which are:
- VHF band;
- Band III;
- UHF Band and 2 GHz band.

1.3. Quality of mobile communication systems. The mobile systems have certain quality requirements that are quantified by means of characteristic parameters, in which they must be specified in the projects of mobile systems as objectives of design, and it must be demanded their fulfillment to the providers of equipment and system installers.

1.4. Quality characteristics. The main characteristics that define the quality of mobile systems are:
- Roof;
- Resource Availability;
- Connection reliability;
- Security Connection and
- Fidelity.

1.5. Coverage. The primary characteristic of any mobile communication system is its degree of coverage. It should be born in mind that the DL (downlink) and ascending links, UL (Uplink), the magnitudes and radio conditions are distinct. Enough RF power is available in DL and it is also possible to use antennas of adequate size, with sufficient clearance of obstacles (at the top of buildings and towers). Unlike the UL, there is power limitation due to the capacity of the battery of the mobile terminals, the antenna of these must be short, reason why its radiation efficiency is not good and in addition it cannot have an educated disposition. Therefore, the priority, the coverage range of the DL may be higher than that of the UL[7].

Coverage is usually defined for different geographic scenarios and thus covers coverage:
- Urban: Streets and interiors of buildings.
- Rural: Field, roads and railways.
- Special Environments: Tunnels and Underground.

In all these cases, due to the variability of the radio path, one can only speak of coverage in a statistical sense. Two levels of statistical quality of coverage are used, namely: percentage of placement, which indicates the percentage of places within the theoretical coverage area where radio link is expected to exist and the percentage of time in which quality is expected exceed a certain threshold value[8].

2. Propagation Study. The propagation study is obtained with the involvement of propagation aspects through models in conjunction with parameters of performance evaluation of data networks. An event simulation is performed using specific software that simulates propagation phenomena to evaluate the performance of wireless data network with change of the transmission rate (or level of modulation), related to propagation parameters, considering aspects of the environment through attenuation factor and interference between cells, with cellular arrangements for frequency reuse.

The propagation considerations follow the classic definitions through the free space and shadowing models, where only the models with no mobility are studied, and then this variable is introduced. The attenuation in the free space is the most used form due to the simplicity to evaluate the effect of the signal attenuation in the coverage of wireless systems.

The propagation phenomenon to be analyzed is the attenuation of the signal in the free space. The best analogy is to imagine a sphere that is expanding and thereby decreasing power per square meter. This model is called free space because there is no influence of any obstacle or surface in the propagation process. The free space model assumes an ideal propagation condition, where there is only one path between the transmitter and the receiver [8].

As the wave moves away from the isotropic antenna (which radiates equally in all directions), in the form of a sphere that expands, there is a decrease in power per unit area as mentioned above. Considering a transmission system with transmission power P_t in Watts and gains of the transmission and reception antennas G_t and G_r respectively, the power received can be determined by the expression:

$$P_r(d) = \frac{P_t G_t \lambda^2}{(4\pi)^2 d^2}. \tag{2.1}$$

Where P_t is the transmission power in Watts, G_t is the transmission antenna gain, G_r is the gain of the receiving antenna, λ is the wavelength and d is the distance between the transmitter and the receiver.

By expression (2.2) it is possible to observe that the only factor that affects the attenuation, besides the distance in which the receiver is, is the frequency. That is, the higher the frequency the greater the attenuation. However, with the increase of the frequency it is possible to construct antennas with greater gains due to the shorter wavelength, which is the factor used for sizing the antennas.

For the sake of ease, the attenuation in free space is defined as the expression:

$$L = \frac{(4\pi)^2 d^2}{\lambda^2}. \tag{2.2}$$

Due to the large attenuations of the signal, the most common is to calculate the attenuation L in dB by the expression:

$$L_{dB} = 10log\left[\frac{(4\pi)^2 d^2}{\lambda^2}\right]. \tag{2.3}$$

In practice, a ratio between the power received from a reference point at a distance from and the power received at the distance d of interest is used. In this way the calculation of the attenuation can be done through the relation between the distance of interest and the reference distance, considering the attenuation factor β that specifies the environment. For attenuation in the free space $\beta = 2$ is considered.

This model is interesting, since it allows a characterization of environments with the change of the attenuation factor β. The expression below shows this relation:

$$\frac{P_r(d)}{P_r(d_0)} = \left(\frac{d}{d_o}\right)^{\beta}. \tag{2.4}$$

Where β is the attenuation factor, determining the model that reflects the environment; expression (2.4) shows that the relation between the power received at the reference distance and the power received at the distance of interest is proportional to the relation between the distance from the reference point to the receiver and the reference distance. Note that the attenuation factor β establishes the severity of the attenuation to be imposed on the signal[9].

With the parameter β it is possible to present different scenarios tested from the most stable to the very severe one. The values of β vary between 2 and 6 as shown in Table 2.1 and table 2.2, where LOS= loss of path.

Environment		β
Outdoor	Free space	2
	Urban Area	2,7 to 5
Indoor	LOS	1,6 to 1,8
	Obstructed	4 to 6

Table 2.1: Attenuation Factor β.

In general, an average of the measurements received in distance d in Watt and converted to dB as in the expression:

$$\frac{P_r(d)}{P_r(d_0)} = -10\beta log\left(\frac{d}{d_o}\right). \tag{2.5}$$

This model is interesting, since it allows a characterization of environments with the change of the attenuation factor β.

Note the inversion between the power received at the reference point and the power received at the point of interest.

In order to arrive at the model of Shadowing it is necessary to include a random variable that shows the uncertainty of the power received. For both expressions (2.6) a random variable representing the uncertainty of the received signal is included. The expression to represent this uncertainty is as follows:

$$\frac{P_r(d)}{P_r(d_0)} = -10\beta log\left(\frac{d}{d_o}\right) + X_{dB}. \tag{2.6}$$

Propagation environment	n
Free space	2
Mobile phone in urban area	2,7 to 3,5
Mobile phone in urban area with shade	3 to 5
Constructions with line of sight	1,6 to 1,8
Obstruction in buildings	4 to 6
Obstructions in factories	2 to 3

Table 2.2: Absorbent exponent for different environments.

Where X is a Gaussian log-normal random variable and X_{dB} is a Gaussian random variable with mean zero and standard deviation σdB. The value of the standard deviation represents the characterization of different environments[10].

2.1. Prediction Modeling Concepts.

2.1.1. Prediction models. According to modeling, prediction models can be divided into three types: empirical, theoretical, and site-specific models. These propagation models are mathematical formulas used to characterize propagation of radio waves. Usually, depending on frequency, distance, antenna heights, terrain and other conditions.

Empirical models are generally sets of test-based equations, usually field-made for path loss measurements, propagation delay, or other channel characteristics. This information is stored in a database in order to arrive at a mathematical model capable of obtaining results with the desired precision.

To model broadcasting projects are taken into account many significant factors such as the topography and degree ofurbanization of the land. The site-specific models are based on numerical methods applied to the geometry of the studied site, and are therefore more detailed and accurate.

The theoretical models are derived from the physical phenomena assuming some ideal conditions. The models can also be characterized for their applications as: point-multipoint (or general place) and point-to-point[**?**].

Point-to-multipoint models provide a general estimate of radio propagation rather than using specific path data, and can be used when good terrain and clutter data is not available. Thus, these models are very useful for the design of proposed cellular networks and are more suitable for the analysis of long journeys.

Peer-to-peer models, in addition to making estimates of radio links, also make it possible to describe the behavior of propagation between the transmitter and the receiver. It is also possible, through this, to determine the behavior of the analyzed region and for this it is necessary to know the topography and the characteristics of the terrain where the analysis will be done.

Based on this, it is shown below the most common models used in the market and the most appropriate for the new generation of networks. The empirical models that are used to size the coverage area in mobile systems are presented:
- the Okumura-Hata model,
- the Ikegami-Walfisch model and the Erceg model.
- Hata model.

2.1.2. Model of Okumura-Hata. The empirical model that currently serves as a standard was proposed by Okumura in 1968, based on measurements in the band [150, 2000] MHz Okumura presents the results in the form of curves, later Hata in 1980 established expressions that approximate some of these curves.

Two large-scale tests were conducted between 1962 and 1965 with several broadcast stations transmitting in various bands in a wide variety of propagation environments, trying to explore the fundamental factors that influence the propagation from the morphology of the terrain to the existence of buildings, street orientation, existence of open surfaces, water surfaces, etc.

- Propagation models based on field measurements between Tx and Rx.
- Most of the effects depend on the site and prevent generalization of the Formulas for path attenuation.
- Depend on frequency.
- They depend on the heights of the Tx and Rx antennas.

Okumura-Hata model based on different regions among others

- region,
- suburban region and
- region open

The Hata Model is valid only within the following parameters:

$$150MHz \leq f \leq 1500MHz,$$
$$30m \leq h_b \leq 200, \tag{2.7}$$
$$1m \leq h_m \leq 10m,$$
$$1KM \leq d \leq 20Km.$$

The Hata model is an empirical formulation of the Okumura graph model. Mitigation in urban areas can be calculated by:

$$L_{Urban} = 69.55 + 26.16logf - 13.82logh_t - a(h_r) + (44.9 - 6.55logh_t)logd. \tag{2.8}$$

where:
$L =$ attenuation in dB,
$f =$ frequency (MHz) $-150MHz \leq f \geq 1500MHz$,
$d =$ distance in (Km) $-1km \leq d \geq 20MHz$,
$h_t =$ transmitter height in meters $-30km \leq ht \geq 200MHz$,
$a(h_r) =$ correction factor in dB,
$h_r =$ receiver height in meters - $1m \leq ht \geq 10m$.

Correction factor for small and medium-sized cities:

$$A(h_{re}) = (1, 1logf - 0, 7)h_{re} - (1, 56logf - 0, 8), \tag{2.9}$$

here h_{re} is the same as h_r one for medium another for large.

Correction factor for large cities:

$$h_r = 8.29((log1.54h_{re}) - 1.1)h_{re}forf \leq 300MHz. \tag{2.10}$$

$$h_r = 3.2((log1.75h_{re}) - 4.97)h_{re}forf = 300MHz. \tag{2.11}$$

The Okumura-Hata model is very similar to the model used by the ITU-R for digital TV broadcasting. Since it is a widely used model, it will serve as a basis for the locally adjusted model developed in this paper. The method recommended by the ITU-R for the VHF and UHF digital TV bands, through Recommendation P-1546, provides very similar results to the Okumura method . This method was modeled through curves that allow determining the variation of the field intensity with the distance for a given percentage in the time and frequency for several values of the height of the transmitting antenna h_1.

The figure 2.1 shows that the curves were raised to an effective radiated power of 1 kW at nominal frequencies of 100, 600 and 2000 MHz some curves refer to terrestrial environments and others to marine environments. The curves are based on data collection in regions with climatic variations of hot and icy environments such as the North Sea and the Mediterranean. They were drawn from Europe and North America.

The basic equivalent loss of transmission for a given field strength is as follows:

$$L_b = 139 - E + 20logfdb. \tag{2.12}$$

At where:
Lb: Basic transmission loss (dB).

E: Field strength $(dB(mV/m))$ to $1kW$ e.r.p.

f: frequency (MHz).

The actual height of the base station H1, for small paths, is equivalent to the actual height of the antenna. The height of the transmitting antenna h_1 used in this recommendation is above the height of the clutter. Assuming that the Okumura-Hata scores apply to a representative clutter height at the base station of 20 m, in the Hata equations, H_1 = 30 m is equivalent to h_1 = 10 m (for $d \leq 3km$) in this recommendation.

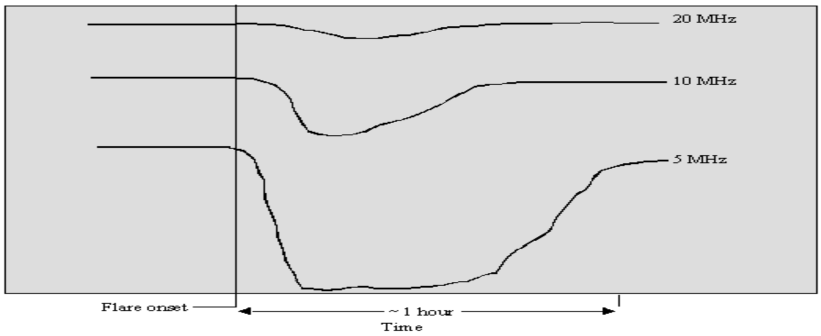

Figure 2.1: Shortwave loss (Asia-Pacific Microwave and ieeexplore.ieee.org, 2007).

For transmitter antenna heights, the Hata range of $30m \leq H_1 \geq 200km(10m \leq h_1 \geq 180km)$ is valid. The two methods provide essentially the same results for paths of up to 20 km. Among all the methods discussed here and observing the characteristics of digital TV broadcasting.

There are limitations in terms of frequency, height and distance. Being that for the use of the proposed model in urban environments we must follow the expression:

$$PL_{Urban} = 69.55 + 26.16log_{10}f - 13.82log_{10}h_b + (44.9 - 6.55h_b)log_{10}d - a(h_m). \tag{2.13}$$

Since h_m is the height of the antenna of the mobile terminal and for this we must calculate its correlation, it is frequency in MHz used, hb is the height of the antenna in the base radio station and d is the distance in relation of the terminal to the radiating system.

$$a(h_m) = (1.11log_{10}f - 0.7)h_m - (1.56log_{10}f - 0.8). \tag{2.14}$$

Already to calculate in relation to the suburban environments we must decrease the calculated value in the urban environment, through the following expression:

$$PL_{surban} = PL_{Urban} - 2\left[log_{10}(\frac{f}{28})\right]^2 - 5.4. \tag{2.15}$$

In the same way we have the expression for rural environments:

$$PL_{Rural} = PL_{Urban} - 4.78(log_{10}f)^2 - 18.33log_{10}f - 40.98. \tag{2.16}$$

This model is widely used for cellular networks in the 800 MHz / 900 MHz band. As other networks start operating at 1800 MHz / 1900 MHz, the Hata model has been modified by the European COST to adapt to these new frequency bands, often referred to as the COST-231 Hata Model.

In Figure 2.2 they follow the Path loss curves of the Okumura-Hata model, using simulation software developed to analyze the characteristics of each of these models.

This statistical model is applicable to both macro cells and microcells, flat and urban,

Where:

$hroof =$ height of buildings, in meters.
$hmovel =$ height of the mobile antenna, in meters.
$w =$ width of the streets, in meters.
$b =$ separation between buildings, in meters.
$j =$ orientation of the road with respect to the link, in degrees.

2.1.3. Model of Ikegami-Walfisch. If there is a direct view between the mobile and the base radio the loss model is summed up to the equation.

$$L(logd)(logf)LOS = 426 + 26logd + 20logf. \tag{2.17}$$

Where:

f = frequency, in MHz, 800 MHz £ f £ 2000 MHz.
d = distance from the ERB to the mobile, in km, d^3 20 m

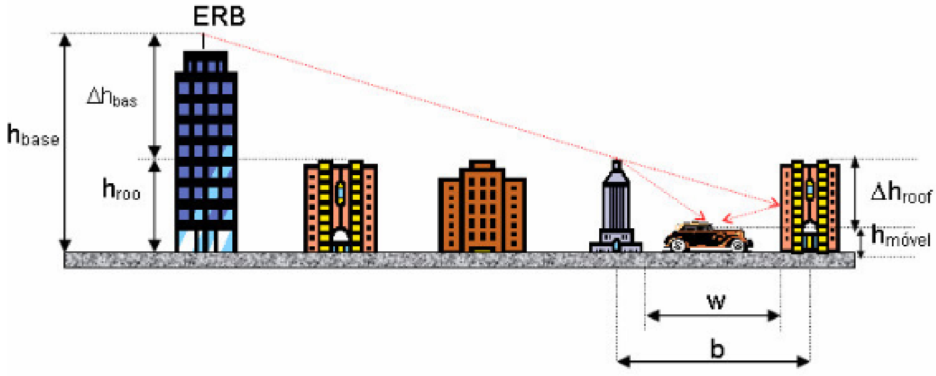

Figure 2.2: Propagation in urban and flat terrain (models Walfisch Ikegami. Scientific Diagram researchgate.net).

COST 231 also developed a model that combines the Ikegami and Walfisch-Bertoni models with the results of measures taken in the city of Stockholm [14]. The model assumes that there is only the urban environment.

In figure 2.3 was demostrate the great innovation of the COST 231 model is related to the consideration of guided propagation phenomena when there is a line of sight between the base station and the mobile in the direction of a street surrounded by buildings differently from free space propagation[12].

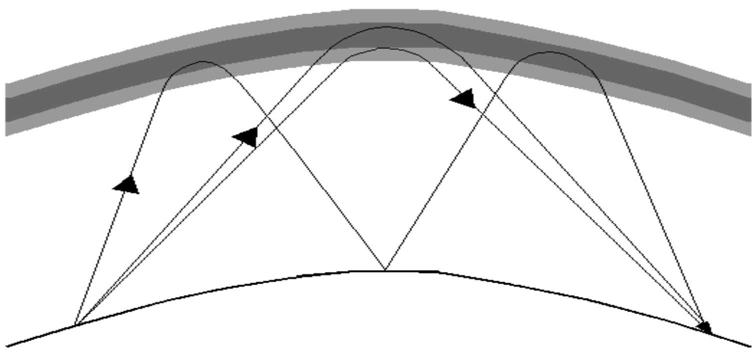

Figure 2.3: Wave multipath (Multipath Fading Electriciantraining.Tpub.Com).

In the other cases, the COST 231 Walfisch-Ikegami model is composed of three terms and restricted by free space attenuation: the first term represents free space attenuation, the second term diffraction attenuation and roof- top-to-street diffraction and scatter loss) and the third the attenuation already at street level due to the multiple diffractions and reflections that occur (multi-screendiffractionloss).

Pathloss attenuation is given by:

$$PL = L_{fs} + L_{rfs} + L_{msd} \tag{2.18}$$

Where, L_{fs} is the loss of free space, L_{rts} is the diffraction loss from the top floor to the street, and L_{msd} is the multipath loss.

For typical parameters such as Base Station antenna (ERB) height=12.5 m, average build height=12 m, average build width = 25 m, Mobile Station antenna height = 1.5 m and antenna aperture = 30º, and in a metropolitan center, we can simplify the equation:

$$PL = -65.9 + 38log_{10}d \left(24.5 + \frac{1.5f}{925}\right) log_{10}f. \tag{2.19}$$

In this model, the diffraction is assumed to be in the main propagation model, and it is only valid for the following parameter ranges:

$$\begin{aligned} &800MHz \leq f \leq 2000MHz, \\ &4m \leq h_b \leq 50m, \\ &1m \leq h_m \leq 3m, \\ &0.2KM \leq d \leq 5Km. \end{aligned} \tag{2.20}$$

This model has been verified in practice in the bands comprising the bands of the cellular telephony, between $900MHz$ and $1800MHz$ and distances between $100m$ and $3km$. The Walfish-Ikegami model applies to small cells being recommended by the WiMAX Forum.

2.1.4. Erceg model. The Erceg model relies on experimentally collected field data in the 1.9 GHz range on 95 macro cells across the United States. Measurements were made mostly in suburban areas of New Jersey, Seattle, Chicago, Atlanta and Dallas.

The IEEE 802.16 model adopted by the group as recommended for broadband applications has three variants, based on the type of terrain:

- Erceg A is applicable to mountainous terrain with a high urban density;
- Erceg B is applicable to mountainous terrain with low urban density or flat terrain;
- Erceg C is applicable to flat land with low urban density.

The Erceg Model is a slope-intercept model given by:

$$PL = PL + X = A + 10\alpha log_{10}(\frac{d}{d_0}) + X. \tag{2.21}$$

Where, PL is the instantaneous attenuation, and X is the multipath attenuation. The d_0 should be greater than or equal to 100m. In addition, the value of A is given by:

$$A = 20log_{10}(\frac{4\pi l_0 f}{C}). \tag{2.22}$$

It is also noticed that in this model the characteristics of the environment are given by:

$$\alpha = (A - Bh_0 + \frac{C}{h_b}) + X\sigma_a. \tag{2.23}$$

The extended version of the Erceg template is valid for all of the following parameters:

$$\begin{aligned} &1900MHz \leq f \leq 3500MHz, \\ &10m \leq h_b \leq 80m, \\ &2m \leq h_m \leq 10m, \\ &0.1KM \leq d \leq 8Km. \end{aligned} \tag{2.24}$$

$$PL = A + 10\gamma log\left(\frac{d}{d_0}\right) + \Delta PL_f + \Delta PL_{lMS}. \tag{2.25}$$

$$\begin{aligned} &\Delta PL_f = 6log\tfrac{f}{1900}, \\ &\Delta PL_{hMS}(A,B) = -10.8log\tfrac{h_m}{2}, \\ &\Delta PL_{hMS}(C) = -20log\tfrac{h_m}{2}, \\ &\Delta PL_{tMS} = 0.64ln\tfrac{\theta}{360} + 0.54ln\tfrac{\theta}{360}. \end{aligned} \tag{2.26}$$

2.1.5. Hata Model. This model is also called the Okumura-Hata model. Hata developed mathematical formulas describing the Okumura model. The formulas make it possible to use the computation to perform the analyzes and necessary calculations to describe the loss of propagation of a network, in this case, the mobile network. These formulas are limited to a frequency range of 150 MHz to 1500 MHz and for almost flat terrain. To determine the attenuation for urban environment and this limitation we want to find out through mathematical methods and models.

To present the LTE Networks through a view of the evolution of cellular networks and development in the World. Its basic characteristics dealing with the protocols used and the access network are also presented together with concepts of propagation models.

This model is also called the Okumura-Hata model. Hata developed mathematical formulas describing the Okumura model, making it possible to use the computations to make the analyses and necessary calculations to describe the loss of propagation of a network, in this case, the mobile network.

These formulas are limited to a frequency range of 150 MHz to 1500 MHz and for almost flat terrain. In order to determine the attenuation for urban environment, we have the Equation:

$$E = 69.82 - 6.16log_{10}f + 13.82logh_1 - a(h_2) + (44.9 - 6.55logh_1(logd)^d). \tag{2.27}$$

where:

- E is the electric field strength in dB (V / m); v f is the frequency in MHz being limited in the range of 150 MHz to 1500 MHz;
- h_1 is the eNodeB antenna height in meters and its value is within the range of 30 to 200 m;
- h_2 is the height of the mobile antenna given in meters and its range varies from 1 to 10 m;
- d is the distance of the given link in km and can reach up to 20 km,
- a(h_2) is a correction factor given in dB used to correct the mobile antenna height in urban environments.

It can be calculated from equations:

$$a(h_m) = 1.1logf - 0.7)h_2 - (1.56logf - 0.8). \tag{2.28}$$

$$b = 1 \longrightarrow d \leq 20. \tag{2.29}$$

$$b = 1 - (0.14 - 0.000187f - 0.00107H_1)\,(log(0.05d))^{0.8} \longrightarrow d \leq 20. \tag{2.30}$$

$$H_1 = \frac{h_1}{\sqrt{1 + 0.000007h_1^2}}. \tag{2.31}$$

This procedure is taken from ITU-R Recommendation P.1546-4 and results in values similar to the recommendation method for d up to 10 km

In this article the main and most appropriate models for 4G network planning, including in this list the Wimax Mobile system are presented[13].

This view shows that the right model must be used for each application, under penalty of under sizing or over sizing the number of base stations. Professionals who master these concepts will have a competitive advantage to better match their reality. Whenever it is thought about a cellular system or even a data network, the system must be sized in line with the simulation through propagation models.

2.1.6. Model of Okumura. The Okumura model is an empirical model based on tests made in Japan covering various types of environments in the frequencies of 150-1920 MHz, or in extreme cases of 3000 MHz. This model was published in 1968 and developed for cells with a radius of 1 to 100 km and for transmitting and receiving antenna heights between 30 - 1000 m. The Okumura model takes into account parameters such as the type of environment and the irregularity of the terrain. This model covers several types of environments: urban and suburban areas, rural areas and terrain features, such as sloped path, irregular relief and mixed paths (land-sea) This calculation method is obtained through graphs and some correction factors are used to obtain a better result. This method of calculation is obtained through graphs and some correction factors are used to obtain a better result.

The basic expression of loss of propagation given by Okumura is represented by Equation:

$$L = L_0 + A(f, d) - G_{Area} - G(h_t) - G(h_r). \tag{2.32}$$

Where L_0 is the free space propagation loss, defined as the ratio between the received power W_r and the transmitted power W_t, as shown by the Equations (2.32) and (2.33)

$$L_0 = \frac{W_r}{W_t}. \tag{2.33}$$

3. Application of different radiation diagrams . Knowing the radiation pattern of an antenna, or controlling this behavior may be of extreme importance for a particular project, the distribution of electromagnetic energy in an ineffective manner may affect the operation or performance of certain systems, ie as an example in a system point-to-point link is desired to establish a point-to-point communication between two regions of space, it is not desired to radiate electromagnetic energy at other points, as suggested in figure 3.1. The diagram that would best meet the profile of the point-to-point link would be well[13].

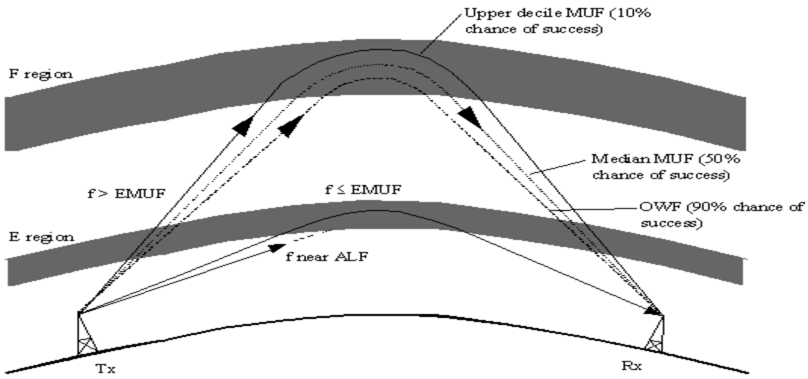

Figure 3.1: Wave multipath(Multipath Fading Electriciantraining.Tpub.Com).

However, there are cases where the spreading of this energy in space is of paramount importance for the correct functioning, we can cite as an example the mobile communication systems, be it cellular, or even the traditional WIFI, as a system where the directivity in the antennas are not very viable due to the constant mobility of the devices, as suggested in figure 6. The diagram in this case tends to be less directional, or even directional Omni.

3.1. Methods of obtaining the radiation diagram . The radiation pattern can be estimated basically by two methods:

Computational simulation: This method is based on predicting the behavior of radiant structures through the mathematical development of radiated electromagnetic field sources and the current distribution in the structure. With the improvement of these methods it was possible to further study the behavior of a radiant system and the current evolution of planar antennas that make up a range of telecommunications equipment.With this evolution some software like ADS (Advanced Design System), have become important tools in the design of new antennas and radiant structures, making the time and cost of development more efficient. But even so, the operator is still very demanding, since the correct configuration of the software still depends on a deep physical and structural knowledge, so that the calculations can correctly shape the behavior that is intended to be achieved in a simulation.

The present paper should act as an auxiliary tool to the computational methods, showing physically the behavior of the electromagnetic field effectively radiated by a planar antenna, projected within the ISM 2.4GHz frequency band power measurement by mechanical antenna displacement: This method consists of a receiver transmitter system where the radiation pattern of the antenna of interest can be obtained either by moving a test antenna around the antenna under test or by rotating the antenna under test around its axis, this due to the characteristic of reciprocity of the antennas, thus making possible to verify the power variation in the system in function of this movement, as suggested by the basic structure So, when we know the characteristics of one of the antennas (reference antenna), we can stipulate several aspects related to the antenna under test, as radiation pattern, among other important characteristics[13].

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So, when we know the characteristics of one of the antennas (reference antenna), we can stipulate several aspects related to the antenna under test, as radiation pattern, among other important characteristics[13].

4. General Conclusions. Radio waves propagate in a straight line. It occurs that the propagation of waves below a certain frequency, such as ”short waves”, accompanies the terrestrial curvature because of

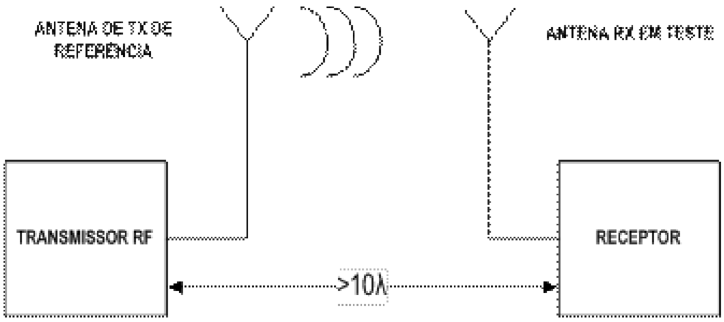

Figure 3.2: Basic metering system(from Smart metering system components and interfaces research-gate.net).

refraction in the ionosphere, thus reaching beyond the horizon. VHF waves do not refract. Instead, they cross the ionosphere, allowing contact with satellites. Very interesting in VHF is the use of repeaters placed in high places, which greatly increases reliable communication. Several channels operate in duplex (the equipment transmits on one frequency and receives on another), and they are thus exact for operation with repeater. The wave that propagates near the surface undergoes some curving, for two factors:

a) Diffraction due to the curvature of the earth,

b) refraction due to the variation of the index of refraction of the atmosphere with the altitude.

Therefore, the reach of a VHF communication link is generally a little higher than the direct line of sight (provided that the radiated power is sufficient to overcome the path losses). The power level is related to the possibility of network connection and the quality of service parameters.

In order to achieve the objectives proposed in this paper it is highlighted some procedures considered as the fundamental aid of this work; measurement procedures were established to obtain the power level received in an open area; it was proposed an empirical model based on measurements of loss of propagation including the polarization effect using the described procedure along with the presented model. The parameters of quality of service required to have a connection with good performance of the network defined and measured with the described measurement procedure. The polarization effect was evaluated with the presence of materials between the transmitter and receiver and for some materials (used in the construction of buildings) was highlighted how much they affect the loss of the signal when crossing them, depending on the polarization. In short what the user wants is to have enough power for the good connection and that it is of the same quality this is the base of this future work, it will be focused on the quality of Communication with Mathematics applications in electronics and telecommunication.

Recommendation

With this view shows that we must use the right model for each application, under penalty of under sizing or oversize the number of base stations. Professionals who master these concepts will have a competitive advantage to better match their reality. Whenever we think of a cellular system or even a data network, the system must be sized in line with the simulation through propagation models for the future quality of communication.

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