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Statistical Modelling of the Mobile Radio Propagation in Rural Area at Medium Wave

#F.F. Lima[1], H.A. Junior[1], A.J.M. Soares[1], L.M da Silva[1], R.L. Filho[1], A.R Baigorri[2]
[1] Department of Electrical Engineering, University of Brasilia
P.O. Box 04591, Zip Code 70910-900, Brasília-DF, flima@nmi.unb.br
[2] Department of Mathematical, University of Brasilia
Zip Code 70910-900, Brasília-DF, baig@unb.br

1. Introduction

Currently there are two system for digitalization at medium wave band, DRM (Digital Radio Mondiale) and HD Radio (High Definition Radio) [1]. In Brazil, the service of digital Amplitude Modulation broadcasting is under an investigation process. Independently of which standard is going to be adopted, for the planning and management of the system, is it important to know the real variability of signal being propagated in determined condition, aiming that it is important to delimit the covering area of the signal.

Existing analog AM services planning tools in these bands are based on the field strength prediction models which could also be used for digital service [2]. Planning inaccuracies could be more critical for a digital service as field strength values lower than the reception threshold would cause the complete loose of availability of the service. Thus, digital radio systems need conscientious tuning of the existing field strength prediction models so that they can be accurate enough for network.

The systems DRM and HD Radio are very sensitive to variations of the received field strength. Information on the mean values of signal received is not sufficient to characterize the performance of those digital broadcasting systems. The variations in time, space and frequency also have to be taken into consideration.

In this work, measurements of the E-field have been carried in Brazil's central region, around the city of Brasília, with the objective of assisting in the planning of the implantation of the digital radio. With this in mid, the statistical modelling of the mobile radio propagation in rural area at medium wave was done.

3. Measurement Campaign

For the evaluation of the surface wave attenuation, the signal of an AM transmitter station was used, located downtown Brasilia, whose characteristics are summarized in the Table 1. The electric field intensity had been collected throughout six radial routes in the central region of Brazil, uniformly distributed, each one of them with a radius of approximately 180 km. The measures had been collected from a period of 9 am to 5 pm in order to prevent the influence of the ionosphere reflections.

The signal transmitted by the broadcaster was received using a mobile unit for measurements gave by the National Agency of Telecommunications (Anatel), which is responsible for the regulation of the telecommunications services in Brazil. The mobile unit, whose equipment had been mounted and calibrated by the French company Thales, is prepared for the accomplishment of measures such as radio goniometry, evaluation of technical parameters (modulation, frequency and field intensity), spectral analysis and rate of occupation. The acquisition of the AM signal is made by an active monopole antenna. The system also makes use of a GPS for the registry of the space coordinates.

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Table 1: Measurement campaign

Broadcaster		RadioBrás
Transmitter station		Brasilia downtown, Brazil 15°49'31,44" S 47°57'49,89" W
Central frequency		980 kHz
Nominal bandwidth		10 kHz
Transmitter power		50 kW ERP
Characteristic field		319 mV/m
Transmitter antenna	Height	94 m
Receiver antena	Gain	15 dBi vertical monopole
	Heigth	2.5 m
Transmission scheduling		9 am – 5 pm

2. Statistical Analysis Methodology

The process of investigation of statistical distributions to describe experimental data is highly demonstrated in numerous cases [3]. The analysis and interpretation of empirical data is known as statistical inference. However, the inference statistical will be used to generalize the behavior channel through from field intensity measure realized. For to do this, is necessary to estimate all parameters of the probability density function (pdf) and hypothesis testing. The statistical distribution parameters play a crucial role in the inference process. In many situations the family of candidate probability models describing a phenomenon may be assumed, but the particular member of the family that best describes the phenomenon might be unknown [2]. One of the most important methods for estimate of parameter is the MLE (Maximum Likelihood Estimation), defined as:

$$L = \prod_{i=1}^{N} f\left(x_i;\theta_1,\theta_2,\ldots,\theta_k\right); \qquad i = 1,2,\ldots,N \tag{1}$$

where:

$\theta_1,\theta_2,\ldots,\theta_k$ are k parameters constant unknown that to need to be estimate, and x_i are variables with probability density function. Often is more easy to maximize ln(L) of that the proper L, then:

$$\ln(L) = \Lambda = \sum_{i=1}^{N} \ln f\left(x_i;\theta_1,\theta_2,\ldots,\theta_k\right) \tag{2}$$

With the values of the estimate parameters of the samples, it is possible to carry through definitive assumptions regarding the behavior of the population, called of hypothesis test. Chi-square test is one of the tools mathematical used with this purpose. The chi square test is used to test if a sample of data came from a population with a specific distribution. More formally, the chi square can be defined as follows: H_0 when the data follow the specified distribution, H_a when the data do not follow the specified distribution, defined as:

$$\chi^2 = \sum_{i=1}^{m} \frac{\left(O_i - E_i\right)^2}{E_i} \tag{3}$$

where O_i is the observed frequency for bin i and E_i is the expected frequency for bin i. The expected frequency is calculated by

$$E_i = N\left(F\left(Y_u\right) - F\left(Y_l\right)\right) \tag{4}$$

where F is the cumulative distribution function for the distribution being tested, Yu is the upper limit for class I, and Yi is the lower limit for class i.

4. Results

The processing of the data was done after conversion of the value field intensity in logarithmic scale (dBμV/m) for linear scale (μV/m). Once the measured data were converted, the statistical processing was performed using R Statistic, a powerful tool statistics and freeware [5]. To determine the best pdf that represents the behavior of the field strength measured values, estimated data calculation was carried out using most common statistical distributions proposals by ITU which model radioelectric wave propagation. Those distributions are Gaussian, Log-Normal, Nakagami, Weibull, Rayleigh, Rice and Exponential [4].

The Chi-square test with level of significance of 0.05 was implemented for the accomplishment of the tests of hypotheses. This test is sensitive to the choice of bins, however an algorithm was implemented, in way to choose the width of bins automatically preventing frequency of inferior occurrence the ten samples for bin and superior amount of three bins for each processed register. In this way, the Chi-Square becomes very efficient, presenting resulted highly reliable. In the accomplishment of the measures, the maximum speed developed by vehicle it was of 80 Km/h.

Table 2 shows the result of some stretches of mobile measures in rural environment. Some samples of data better had been represented by the distributions Log-Normal, Gaussian and Nakagami, with bigger predominance of the Log-Normal distribution. The Weibull distribution was validated by the Chi square, shown in the last line of Table 2, however was a rare occurrence during all the samples gotten in the process of measures. Figures 1 and 2 show a typical example of the behavior of the signal in this environment of measure. Finally, for the statistical distributions Rice, Exponential or Rayleigh, the values found for p-value are well inferior to the level of significance.

Table 2: PDF more appropriate in rural environment.

Distribution	Log-Normal	Nakagami	Weibull
p-value	0.0519	0.0464	0.0004
	0.2093	0.0193	0.0005
	0.6216	0.5362	0.2013
Total of registers - segments		72	
Distribution		Log-Normal	Weibull
(%)Better accepted registers		93,7	6,3
Completely number of accepted registers for the Chi Square test		58	2

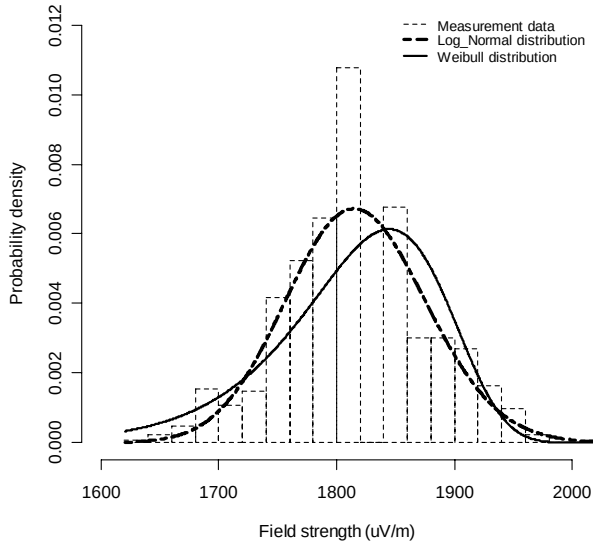

Figure 1: Rural environment record and population

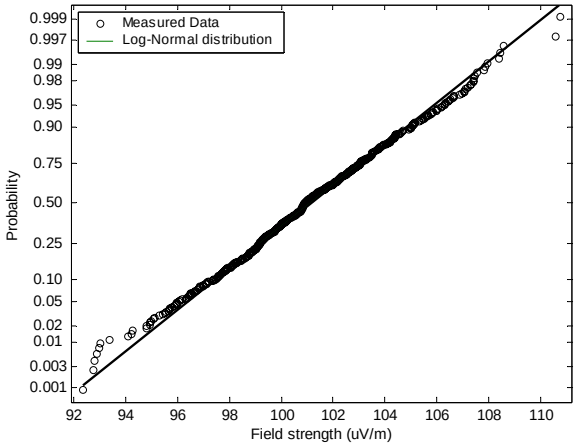

Figure 2: Rural environment record and population on Log Normal paper

5. Conclusions

In Recommendation ITU-R P.1057 [4], during in the daytime hours the ground wave is essentially constant and does not exhibit significant changes with time or atmospheric variability. The signal amplitude depends on range and on the electrical characteristics of the ground. However, ground wave mode may be assumed to be unfading. Only the effects of any ionospheric component on the variability of the signal of medium wave digital service are described in ITU-R Recommendation P.1321 [6].

In this work, measured values of the E-field in mobile have been shown big variation around the mean, mainly when the different height profile along the path is abrupt, and tower over of wavelength. The Log Normal function has been found as the best fitting statistical distribution for rural environments in mobile reception, in the daytime.

With the digitalization this service, the mobile reception will be many used at the road, and space variability characterization is important to be considered. Also, this information must be considered when the mode operation of the simulcast broadcasting system, because in this mode the analogical and digital signals can occupy the bands already destined to the sound broadcasting. Thus, digital radio systems need conscientious tuning of the existing field strength prediction models so that they can be accurate enough for network planning.

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