World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:6, No:1, 2012

Developing a Statistical Model for Electromagnetic Environment for Mobile Wireless Networks

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Abstract**—**The analysis of electromagnetic environment using deterministic mathematical models is characterized by the impossibility of analyzing a large number of interacting network stations with a priori unknown parameters, and this is characteristic, for example, of mobile wireless communication networks. One of the tasks of the tools used in designing, planning and optimization of mobile wireless network is to carry out simulation of electromagnetic environment based on mathematical modelling methods, including computer experiment, and to estimate its effect on radio communication devices. This paper proposes the development of a statistical model of electromagnetic environment of a mobile wireless communication network by describing the parameters and factors affecting it including the propagation channel and their statistical models.

Keywords**—**Electromagnetic Environment, Statistical model, Wireless communication network.

I. Introduction

THE electromagnetic environment (EME) is the sum of electromagnetic fields from various radio communication devices and natural electromagnetic processes at a given geographical location in space. The intensive development of radio communication systems has led to a significant concentration of radio communication devices which are sources of electromagnetic radiation, especially in large cities. The consequence of this is the increase of both intra-system and intersystem interferences and the complication of electromagnetic environment. The ability of a radio communication device to adequately function at a given location is completely defined by the EME and its characteristics and specifications. The prospects of radio communication systems development, including mobile wireless communication networks, depend to a considerable degree on correct and rational planning. However, the technological development of radio communication systems planning lags behind the developmental rate of these systems, and this complicates further systems development and consequently leading to accumulation of planning errors.

The available tools for frequency terrestrial planning considerably simplify and increase the effectiveness of mobile wireless network design, planning and optimization processes. One of the tasks of the above tools is to use mathematical models of radio transmitter stations emissions, radio receiver stations receptivity, antenna feeder units, radio wave propagation, and different noise and interference mechanisms to simulate the electromagnetic environment (EME) and to estimate its effect on network stations. In general, it is necessary to evaluate the aggregate action of many independent signals on the network stations characterized by different operational structures and algorithms, and also by the presence of a set of random parameters like their random number, their operating time, the position of mobile stations, random physical processes in the radio channel. The principal unavoidable, drawback in the deterministic approach [1 – 4] to the description of EME is the impossibility of analyzing a large number of interacting network stations with a priori unknown parameters, and this is characteristic, for example, of mobile wireless communication networks.

The statistical approach to the description of EME is given in [5-7]. It is based on defining the statistical distribution of the parameters of network stations (coordinate, frequency, the power of radiations, etc.), the calculation of the statistical characteristics of electromagnetic environment and statistical evaluation by analytical methods of the action of electromagnetic environment on the network stations. The main disadvantage of the above mentioned works is the essential simplification in the models of the distribution of the stations random parameters for the purpose of obtaining their statistical characteristics by analytical methods, which in practice leads to incorrect statistical conclusions.

Therefore, developing a statistical model of EME while adequately accounting for the set of the random parameters of the network stations in practice is impossible without the use of special statistical methods, one, of which is the Monte Carlo method. By describing the parameters and factors affecting the electromagnetic environment, including the propagation channel and their statistical models, the well known Monte-Carlo technique [8] can be used to develop a statistical model of EME according to the steps shown in figure 1 and this is the main focus of this paper.

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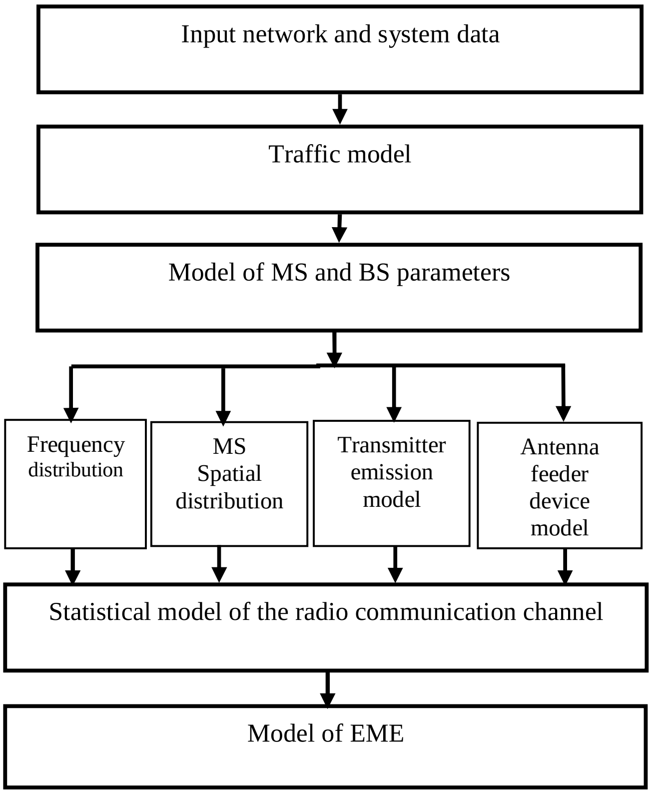

Fig. 1 Structure for the formation of statistical model of EME

The remainder of the paper is organized as follows: The next section considers the traffic model developed using the Erlang-B traffic model. Section III outlines how the statistical models used in describing the MS and BS parameters are developed. In section IV, an algorithm of obtaining the statistics of the propagation loss by modeling the slow and fast fading as log-normal and Nakagami distribution respectively is proposed. In section V, the structure for developing the statistical model of EME is presented.

II. Traffic Model

The Erlang-B model probability $P(n, A)$ of occupation of n channels for a given BS load A is given by the expression

$$P(n,A)=\frac{\frac{A^n}{n!}}{\sum_{m=0}^{n}\frac{A^m}{m!}},\quad n\le N_{MS},\qquad (1)$$

Where N_{MS} — Maximum number of MS, providing a specified blocking probability value for a given BS load, A.
When $n = N_{MS}$, the Erlang-B model probability $P(n, A)$ equals the blocking probability.

The recurrent expression (1) can be expressed in the form represented by expression (2) which is used to compute the required number of MS N_{MS} for a given blocking probability.

$$\begin{cases} P(n,A)=\dfrac{\dfrac{A.P(n-1,A)}{n}}{1+\dfrac{A.P(n-1,A)}{n}}, \\ P(0,A)=1 \end{cases}\qquad (2)$$

The distribution of active channels when the maximum number of BS channels $N_{\max} = 16$ and load of $A = 3, 5, 7$ is shown in figure 2.

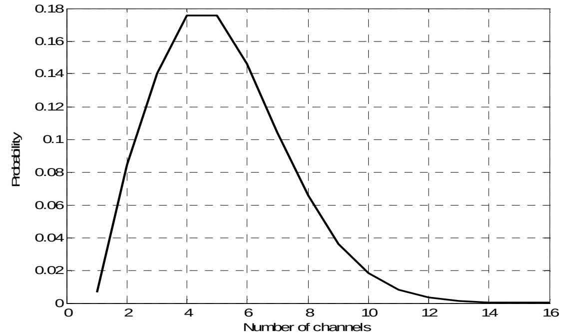

Fig. 2 Distribution of active channels when $N_{\max} = 16$ and $A = 3, 5, 7$

The distribution of active channels for different values of $N_{\max}$ for a given value of A is shown in Fig. 3.

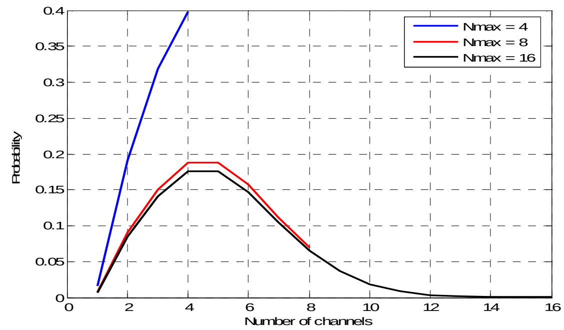

Fig. 3 Distribution of active channels when $A = 5\,Erl$ and $N_{\max} = 4, 8, 16$

The probability of occupying n out of $N_{\max}$ channels for different values of A are shown in Fig. 4.

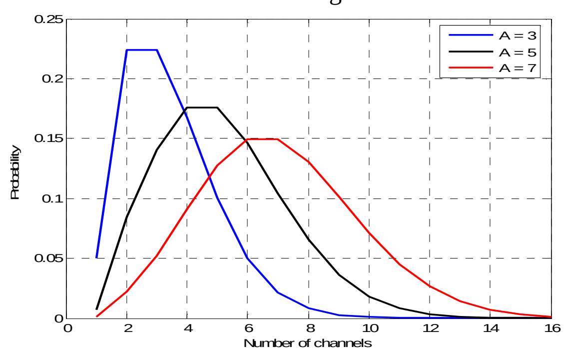

Fig. 4 Distribution of active channels when $N_{\max} = 16$ and $A = 3, 5, 7$

The total number of MS N_{MS} is determined by summing all the maximum allowable number of MS for all the BS or BS sectors in the network as follows:

$$N_{MS} = n_{slots} \sum_{i=1}^{N_{BS}} N_i \ , \tag{3}$$

n_{slots} - number of time slots in each frequency channel (used for TDMA network). For FDMA and CDMA networks, $n_{slots} = 1$. Note that the value of N_{MS} must not be greater than the number of grid points in the region to be analysed.

III. Model Of MS And BS Parameters

A. Frequency Distribution

Cellular network based on FDMA / TDMA technology consists of a collection of BS grouped in clusters. A cluster represents a group of BS, in which any frequency channel is used by only one BS.

The transmission frequency for a given signal or interference transmitter is obtained as a random variable from a set of possible frequencies $\{f_1, f_2, ... f_n\}$ for that transmitter according to a discrete uniform distribution [7].

B. Mobile Stations Spatial Distribution

In any given region of analysis, the spatial coordinates of the location of the MS (latitude, longitude) are defined as pairs of independent random numbers (x_i, y_i) distributed over a uniform distribution with probability density functions:

$$f(x_i) = \begin{cases} 0, & for \ \ x_i < x_{\min}, \ x_i > x_{\max} \\ \dfrac{1}{x_{\max} - x_{\min}} & for \ \ x_{\min} < x_i < x_{\max} \end{cases} ,$$

$$f(y_i) = \begin{cases} 0, & for \ \ y_i < y_{\min}, \ y_i > y_{\max} \\ \dfrac{1}{y_{\max} - y_{\min}} & for \ \ y_{\min} < y_i < y_{\max} \end{cases} \tag{4}$$

In a city, however, there is non-uniform distribution of MS (users) depending on the time of the day. During working hours, the maximum number of users is located at the city business center, while in the evening they are redistributed in the living areas of the city. Therefore, in this case we use the exponential distribution model of MS [9]. The probability density function in this case is express as:

$$f(r) = \begin{cases} \sigma_0, & for \ \ 0 < r < R \\ \sigma_0 e^{-\alpha(r-R)} & for \ \ R < r < R_M \end{cases} , \tag{5}$$

where

σ_0 — user's constant density at the center of the region of analysis;

R — radius of the circular part defining the center of the region of analysis;

α — parameter defining the decrease of the number of users with distance from center.

This model is most appropriate to describe the distribution of MS within a city with radial structure of buildings. As an example, the city of Moscow has the following parameters [9]; $\sigma_0 = 168.5\, Erl/km^2$, $R = 1.45\, km$, $\alpha = 0.48$.

C. Transmitter Model

The transmitter emission's power in practice is not constant but depends on many factors, amongst which includes the frequency dependence of the channels being used to its instability, variations in transmitter supply voltage, the impact on the transmitter output stage of the radiation of other closely located transmitters etc. Some of these factors are random, and this is confirmed by experimental measurements [1].

Therefore, in the description of the transmitter emission's power a statistical distribution of power is used. The statistical model of the BS transmitter's main emission $P_{BS,main}$ is based on the assumption of normal distribution of power

$$f(P_{BS,main}) = \frac{1}{\sqrt{2\pi}\sigma_P} \exp\left(-\frac{\left(P_{BS,main} - \overline{P}_{BS,main}\right)^2}{2\sigma_P^{\ 2}} \right)$$

and is defined as:

$$P_{BS,main} = \overline{P}_{BS,main} + \Delta p \ , \tag{6}$$

where, $\overline{P}_{BS,main}$ — mean value of BS main emission power indicated in the technical documentation of transmitters; Δp — Gaussian variable with zero mean.

The statistical model of the BS side frequency emission at harmonics $P_{BS,side}$ is defined as:

$$P_{BS,side} = P_{BS,main} + X_{BS,side} \ , \tag{7}$$

where, $X_{BS,side}$ — attenuation (relative to carrier's power) of the BS side frequencies emissions at harmonics.

Usually the emissions at the side frequencies at harmonics of the fundamental frequency have the highest power level compared to the emissions of other side frequencies [10]. Therefore, in most cases, the emissions of the other side frequencies can be neglected.

D. Antenna Model

Considering that there are no perfect matching feeders with the antenna, and also that the antenna radiation pattern is affected by various surrounding objects, the BS transmitter antenna gain G_{BS} is defined as a random variable with normal distribution express as:

$$G_{BS} = \overline{G}_{BS} + \Delta g \ , \tag{8}$$

were, Δg — Gaussian variable with zero mean and standard deviation — σ_a , numerically equal to the value the spread, which is contained in the technical characteristics of antennae; $\overline{G}_{BS}$ — average gain of BS transmitter antenna and can be expressed by the formula:

$$\overline{G}_{BS} = G_0 + C + H \ , \tag{9}$$

G_0 — Receiver antenna gain for the working frequency range and given polarization with radiation pattern taken into account;

C — correction for the frequency dependence of antenna pattern (for the frequencies of side emissions and receiver spurious channel); H – correction for different polarizations of the transmitting (interference) and receiving antennae.

IV. Channel Model

The well known propagation models such as Hata model, ITU-R P.529-3 and ERC Report 68 with sufficient certainty predict the median loss for mobile communications systems in urban areas, but do not give the statistics, due to the effects of slow and fast fading. We propose a technique of obtaining the statistics of propagation losses in the channel by numerical simulation, taking into account the effects of both slow (lognormal distribution) and fast (Rayleigh, Rice) fading thus improving the accuracy of the estimated losses.

For the case when the lognormal distribution, the Nakagami distribution characterizes the slow and fast fading respectively, the loss statistics is obtained by the generation of the instantaneous value of propagation loss L_{ij} from the j-th BS to the location of the i-th MS is as follows:

1. Calculate the median value of the loss L_{mij} from BS with index j to the location of MS with index i.
2. Generate the slowly varying local mean value of the loss L_s according to normal distribution with mean L_{mij} and given standard deviation σ_{L_s}.
3. Generate the instantaneous value of propagation loss L_g according to gamma distribution with fading parameter m and scale parameter $\Omega/m = \left[\left(\Gamma(m)/\Gamma(m+1/2)\right)\cdot 10^{L_s/10}\right]^2$.
4. Calculate the instantaneous loss by the formula:

$$L_{ij} = 10\log_{10}\left(\sqrt{L_g}\right) \tag{10}$$

V. Conclusion

The proposed procedure for developing a statistical model for EME can be used in the algorithm for the statistical estimation of electromagnetic compatibility of a communication network and also in organisations ranging from telecommunication authorities and network planners carrying out services requiring computation in software tools for Radio Network Planning, Optimisation of Radio Networks and Spectrum Management.

References

[1] Donald R. J. White. Electromagnetic compatibility of radio electronic equipment and unwanted interference. Moscow: Soviet Radio, 1977.

[2] Knyazev A.D. Elements of the theory and practice for electromagnetic compatibility of radio electronic equipment. - M.: Radio and Communications, 1984.

[3] Vladimirov V.I, Doctorov A.L, Elizarov F. V. et al. Electromagnetic compatibility of radio electronic equipment and systems. Edited by N.M. Tsarkova. - M.: Radio and Communications, 1985.

[4] Petrovsky, V. I., Sedelnikov U.E. Electromagnetic compatibility of radio electronic equipment: A manual for higher institutions. M.: Radio and Communications, 1986.

[5] ITU-R M.1634.

[6] Alter L.S. The probability of intermodulation interference in mobile radio communication systems receivers. Mobile systems. 2003. 12. pp.55-58.

[7] Aporovich A.F. The statistical theory of electromagnetic compatibility of radio electronic equipment, Edited by V.Y. Averyanova. - Mn.: Science and Technology, 1984.

[8] Nyah C. Temaneh. Monte-Carlo technique estimation of a probability of intermodulation interference in a cellular wireless communication network. Proceedings from the IEEE Region 8 International Conference on Computational Technologies in Electrical and Electronics Engineering SIBIRCON-2010, Irkutsk – Russia, Volume 1, pp. 329-33.

[9] A. Dementiev. Reliable methods of estimating the spatial distribution of the load in cellular networks. Telecommunication journal № 2 in 2002.

[10] Petrovsky V.I., Sedelnikov U.E. Electromagnetic compatibility of radio electronic devices. Moscow: Radio and communication, 1986.

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