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STOCHASTIC METHOD FOR EVALUATING INTERFERENCE FROM THE IMT MOBILE STATIONS TO THE GROUND STATION OF RADIODETERMINATION SERVICE

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СТОХАСТИЧЕСКИЙ МЕТОД ОЦЕНКИ ПОМЕХ, СОЗДАВАЕМЫХ МОБИЛЬНЫМИ СТАНЦИЯМИ IMT НА НАЗЕМНУЮ СТАНЦИЮ СЛУЖБЫ РАДИООПРЕДЕЛЕНИЯ

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Abstract. *Conservative deterministic method for determining the interference is ineffective in the case of estimating the electromagnetic compatibility with services such as mobile, since in this case are not considered random processes that occur in reality, for example, the movement of mobile stations. This article discusses the technique and the stochastic model for evaluating interference from mobile network mobile stations.*

Аннотация. *Консервативный детерминированный метод определения помех является неэффективным в случае оценки электромагнитной совместимости с такими службами как подвижная, поскольку в этом случае не учитываются случайные процессы, которые имеют место в реальности, например, передвижение абонентов. В данной статье рассматривается методика и модель стохастической оценки помех, создаваемых абонентскими станциями мобильной сети.*

INTRODUCTION

In recent years within the framework of the International Telecommunication Union (ITU) there is the trend of increasing needs of the spectrum on a global basis for such progressive system, as:

– international mobile telecommunications (IMT);

– communication and navigation systems for solving control, telemetry and control of unmanned aerial vehicles;

– system of radiodetermination of global parameters of objects on Earth, water, air and in space [1].

Development and introduction of new technologies and data transmission is not in place. Therefore the question of electromagnetic compatibility of existing systems and technologies with those who are at the implementation stage is still relevant.

In this paper we investigate aspects of electromagnetic compatibility of mobile stations with facilities of radiodetermination service in the frequency band 790-862 MHz, namely the impact of mobile subscriber stations to the ground station radio-determination. As the mobile communication network is considered developing and implementing LTE technology. This frequency range was chosen as one of the most problematic, because it is allocated on a primary basis to the aeronautical radionavigation service, whose main aim is to ensure the safety of aircraft flies.

At this time, some ITU recommendations [2–6] establish protection ratios to ensure compatibility of radar and radio detection corresponding interference-to-noise ratio at minus 6 dB in the case of exposure to radar receiver noise with a pulse type of modulation [2]. This value protection ratio is also used for research of EMC between mobile communications network and the radiodetermination radar [7]. Providing this protection ratio ensures proper functioning of the radar with the specified quality indicators (probability of correct detection, false alarm probability) only when pulsed modulation type interference. However, such an approach ignores the static dynamic functioning of a mobile network, namely its mobile stations, and effects of continuous emission type. Random placement of subscribers on the network, different network load and network configuration may lead to additional levels of interference in a certain percentage of time. Therefore, in this paper the method for calculating such additional reserve due to the dynamics of the mobile network interference continuous type of radiation, and the results of these calculations are considered.

METHODOLOGY OF CALCULATING THE IMPACT OF INTERFERENCE FROM MOBILE STATIONS TO THE GROUND RECEIVER OF RADIODETERMINATION SYSTEM

Typically, the problems of modeling of complex electromagnetic environment, which is characterized by uncertainty in the parameters of the radiation, the location coordinates of stations, signal propagation in space, are solved using the Monte Carlo method [8]. This mathematical approach allows to solve complex problems in various fields, including the field of communication.

The main principle of the Monte Carlo method is to obtain a set of realizations of the same scenario (in this case scenario of electromagnetic environment) with various parameters of elements included in the realization of this scenario (transmission parameters, propagation models, coordinates). Thus, the parameters are not simply a value, but a probability density function corresponding to a particular distribution law. As a result, the required value of many implementations will follow a precise statistical distribution law, and all further inferences are made indicating the probability and confidence intervals.

Figure 1a shows a scenario of interference from the part of the subscriber stations of LTE mobile network to the radar ground station of radiodetermination system that was used in the simulation. In all cases, the main lobe of the radar is directed perpendicularly to the network edge. The mobile network has a hexagonal structure, in which each base station has three sectors in the form of a hexagon [7]. On the territory of the network subscriber stations are posted radiation which cause harmful interference to radar receiver.

One of the key features of the calculation of electromagnetic compatibility in these scenarios is the uncertainty of the position the source of interference (subscriber stations) in the space, both horizontally and vertically. Thus, by introducing random coordinates for subscriber stations we will get random noise level at the receiver input radar. The basic logic of this process is shown in Figure 1b.

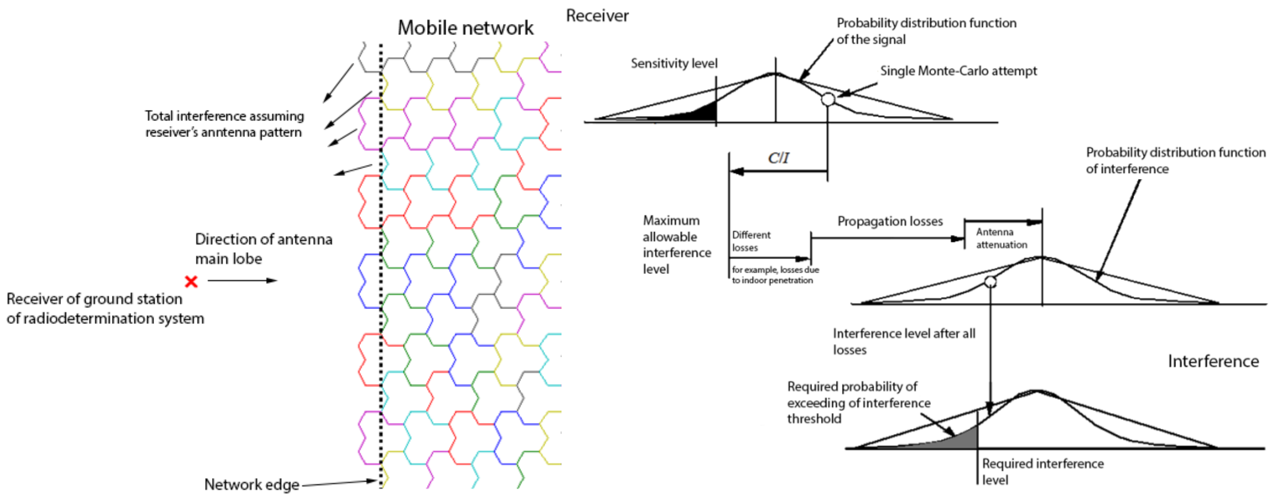

Figure 1 – Monte Carlo method to determine the effect of interference from subscriber stations mobile network

It should be noted that in reality so many parameters of interference, propagation models are random, however, the more it is possible to fully describe the processes occurring in the reality statistically, the more plausible model is, and will be more realistic simulation results. One of the problems of this approach is to set unrealistic probability density functions of the original signals and getting distorted scenario as a result, which may not be in reality. The second problem is the lack of a complete set of experimental data on the move, the functioning of subscriber stations, the network as a whole, other third party factors that affect the electromagnetic environment, which may also underestimate some real factors affecting the level of interference. The following describes an algorithm that has been used in research and solving the problem of electromagnetic compatibility.

According to an algorithm used at first the network of base stations is placed (including the necessary percentage of base stations are below roof level) and the ground radar at the required distance from the network is placed. Then the configuration of the network (in this case - hexagonal structure described above), the type of density scenario (urban, suburban, rural), number of cells are selected. On the type of density scenario many settings of the network depend (base station power, antenna gain, cell size, depth of the antenna, various parameters of the script). Next, the random placement of mobile stations in the network is performed in a uniform law according to the selected users density (depending on the type of density scenario), as well as the random placement of the users in the buildings according to the required percentage of stations located indoor. This further leads to further weakening both interference and desired signal of the mobile station indoor. After random allocation of users it’s needed to assign a specific mobile station to specific base station and sector. This is done on the principle of least attenuation by a modified Hata model [8].

The next step is to implement the control algorithm of power control of the actual variation of the radiation power of the subscriber station depending on the location. In this study the control of power is carried out by providing the maximum possible bandwidth. If the level of the signal / (noise + interference) at the receiver base station exceeds the required for maximum throughput, it is possible to reduce the radiation power of the transmitter subscriber station. The [9] provides an empirical expression that calculate bandwidth for LTE (both “up” and “down”) at a given signal / (noise + interference), which simplifies the process of recording all possible modulation and coding schemes:

$$Thr = \begin{cases} 0 & SNIR < SNIR_{\min} \\ \alpha S(SNIR) & SNIR_{\min} < SNIR < SNIR_{\max} \\ Thr_{\max} & SNIR > SNIR_{\max} \end{cases}, \quad (1)$$

where $S(SNIR) = \log_2(1 + SNIR)$;

$\alpha = 0.4$ – attenuation factor representing the loss of implementing;

$SNIR_{\min} = -10\ dB$ – minimum signal / (noise + interference), based on the modulation of QPSK, code rate 1/5;

$Thr_{\max} = 2.0\ \ b/Hz$ – maximum capacity based on QAM-16 modulation, code rate 3 / 4.

Thus, we have all the necessary parts – its model parameters, some of which are fixed, and some have a value in accordance with a certain probability distribution. With all the parameters it’s necessary to calculate the field strength at the receiving radar from each subscriber unit (should be deleted devices that are out of sight) and then – total field strength at this point from all sources of interference by the formula [7]:

$$E_{multi} = \sum_{i=1}^{N} E_i \quad (2)$$

The resulting field strength can be converted into power at the radar receiver according to the formula [10]:

$$P = E - 77.2 - 20\log(f) \quad (3)$$

However, in fact, this transfer does not make sense on the basis of the task, since variation of values due to the resulting dynamic mobile network is the same as in the case of expressing the result as the field intensity, and a power at the receiver input. The calculated statistic (range, variance, and the distribution type, etc.) for the field strength or power of the signal from the formulas (2) and (3) represents a simulation result of interference between a mobile station of the LTE network to the ground station of the radiodetermination system and has interest to further analyze the results.

Direct impact on the functioning of the results of radar can be estimated using the classical dependence of the probability of correct detection, false alarm probability and the signal / (noise + interference) at the output of the optimal filter for the signal with random phase and amplitude [11]:

$$P_D = P_F^{\frac{1}{1+\frac{1}{2}q_{sn}^2}} \quad (4)$$

where P_D – detection probability, a typical value of 0.5;

P_F – probability of false alarm, the typical value 10^{-4};

$q_{сш}$ – signal / (noise + interference) ratio.

All the data used in the modeling were taken from the reports and recommendations of the ITU, as well as documents of the organization 3GPP. Table 1 below shows the basic parameters of the model for different types of density scenario, and hence the density of the network.

Table 1 – Common parameters of the model

Parameter	Value for different scenario		
	Urban	Suburban	Rural
Cell radius, km	1	2	8
Density of mobile stations, person / sq.km	6	4.32	0.34
Indoor propagation loss, dB	20	20	15
Percent of mobile stations indoor, %	70	70	50
Percent of base stations below roof, %	30	0	0
Typical body loss, dB	4		
Average activity of base station, %	50		
Number of cells	25		

Table 2 shows the characteristics of the base stations of mobile communication networks, subscriber stations, as well as some parameters of the system ground station radio-determination.

Table 2 – Specifications of source and receptor of the interference

Parameter	Value
Base station parameters	
Maximum transmitter power, dBW	16 [12]
Cannel bandwidth, MHz	10
Antenna attenuation, dBi	16 (urban, suburban), 18 (rural) [12]
Antenna pattern	[9]
Antenna height, m	25 (urban), 30 (suburban, rural) [12]
Feeder loss, dB	3 [12]
Receiver noise figure, dB	5 [13]
Mobile stations parameters	
Maximum transmitter power, dBW	–7 [12]
Minimum transmitter power, dBW	–67 [13]
Cannel bandwidth, MHz	10
Antenna attenuation, dBi	–3 [12]
Antenna pattern	omni
Receiver noise figure, dB	9 [9]
Parameters of ground station of radiodetermination system	
Antenna height, m	10 [14]
Antenna pattern	[15]

Figure 2 shows a flowchart of the calculations described in which the key points are displayed, showing the logic of the model and obtain the simulation results based on their task.

MODELING RESULTS

Simulations were implemented according to the algorithm shown in Figure 2. In each of the experiments thousand trials (realizations) were performed. By experiment meant carrying out calculations for a fixed distance from the boundary of the ground radar mobile network. These experiments were performed with several different distances to determine the dependence of the total variance of the interfering signal from subscriber stations on the distance to the boundary of the radar network. Experiments with changes in other factors (e.g., multiple destinations main lobe of the radar antenna) were not carried out. Considered three types of scenario: urban, suburban and rural.

Figure 3 shows the simulation result of two experiments: a) urban development, placement radar within the network at a distance of 4.5 km from the border, b) urban development, placing the radar at a distance of 0.75 km from the border of the network.

As seen in Figure 3 the probability density function for the case of locating the radar within the network has an asymmetrical look, and there are cases of large voltage. In turn, the density distribution of the interference, when the radar is out of the network, has a symmetric form and subject to the normal distribution law. The main observation is the presence of noise variance about the mean. Distribution law of interference out of the network is unchanged, as well as the distribution law of interference within the network is unchanged. This dispersion value varies depending on the scenario and the distance to the boundary of the mobile network.

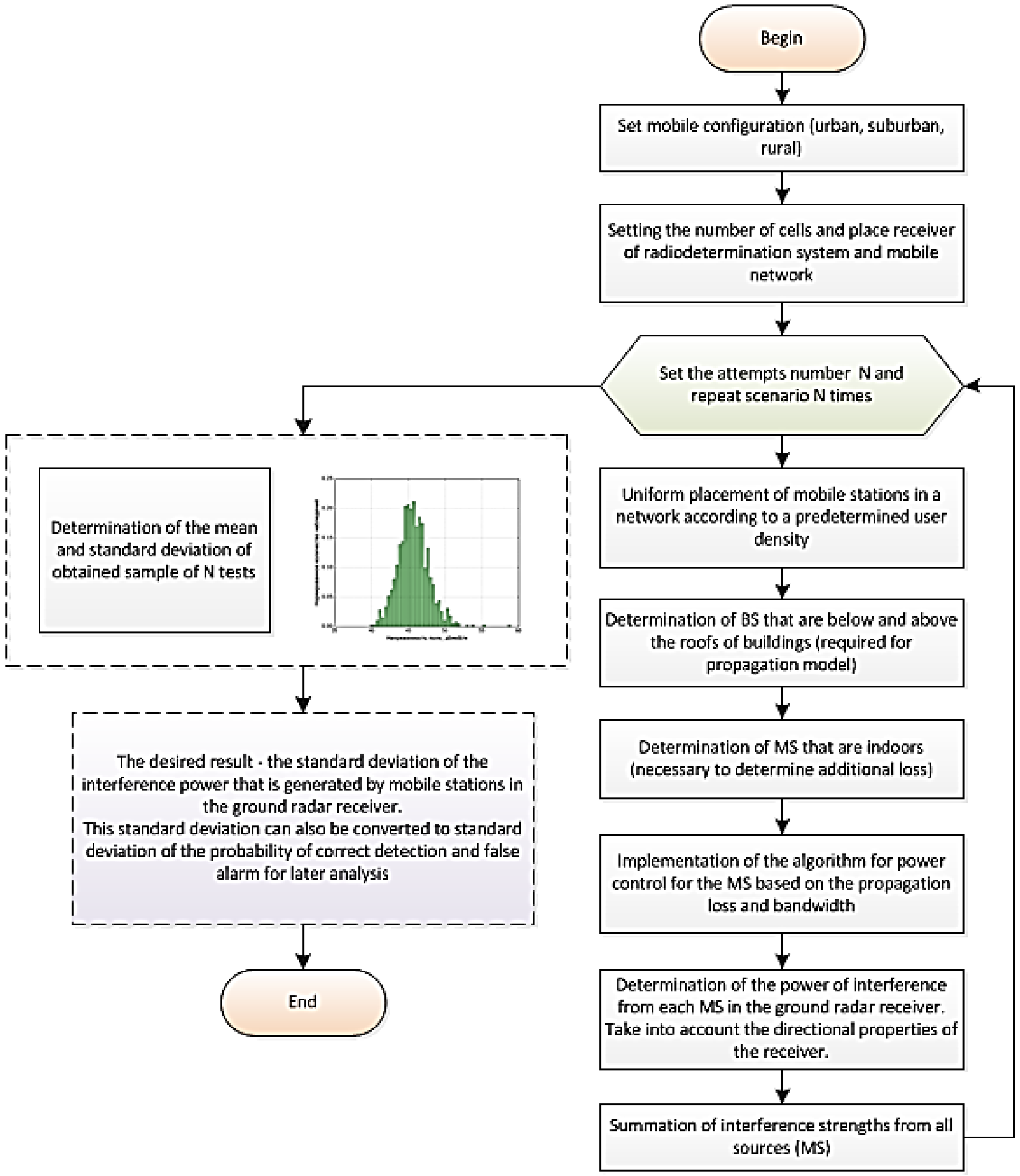

Figure 2 – Algorithm flowchart

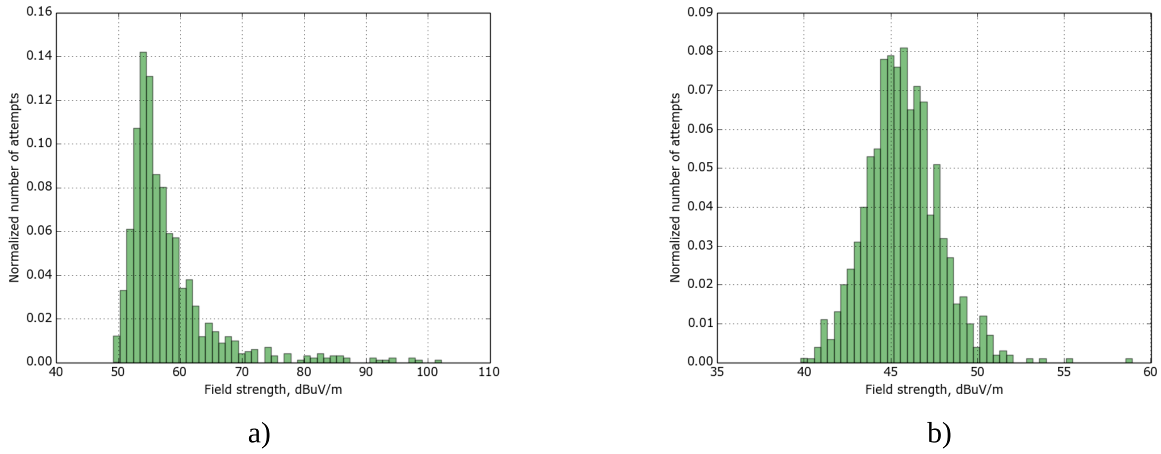

Figure 3 – Interference field strength at the receiver for different scenarios

Figure 4 shows the result of such a dynamic impact of the interference on the fundamental parameters of the radar (using Equation 4). In this case we consider the variation detection probability for three cases: a) urban, the false alarm probability of 10^{-4}, the average value of the signal/noise ratio of 10 dB, placing the radar within the network (green), outside (red) network; b) urban, placing radar outside the network network, the average value of the signal/noise ratio of 10 dB, the various probabilities of false alarm, 10^{-4} (green), 10^{-3} (red), 10^{-2} (blue); c) urban, placing radar outside the network, the false alarm probability of 10^{-4}, different average signal/noise ratio at the output of the optimal filter of radar 10 dB (green), 7 dB (red), 4 dB (blue).

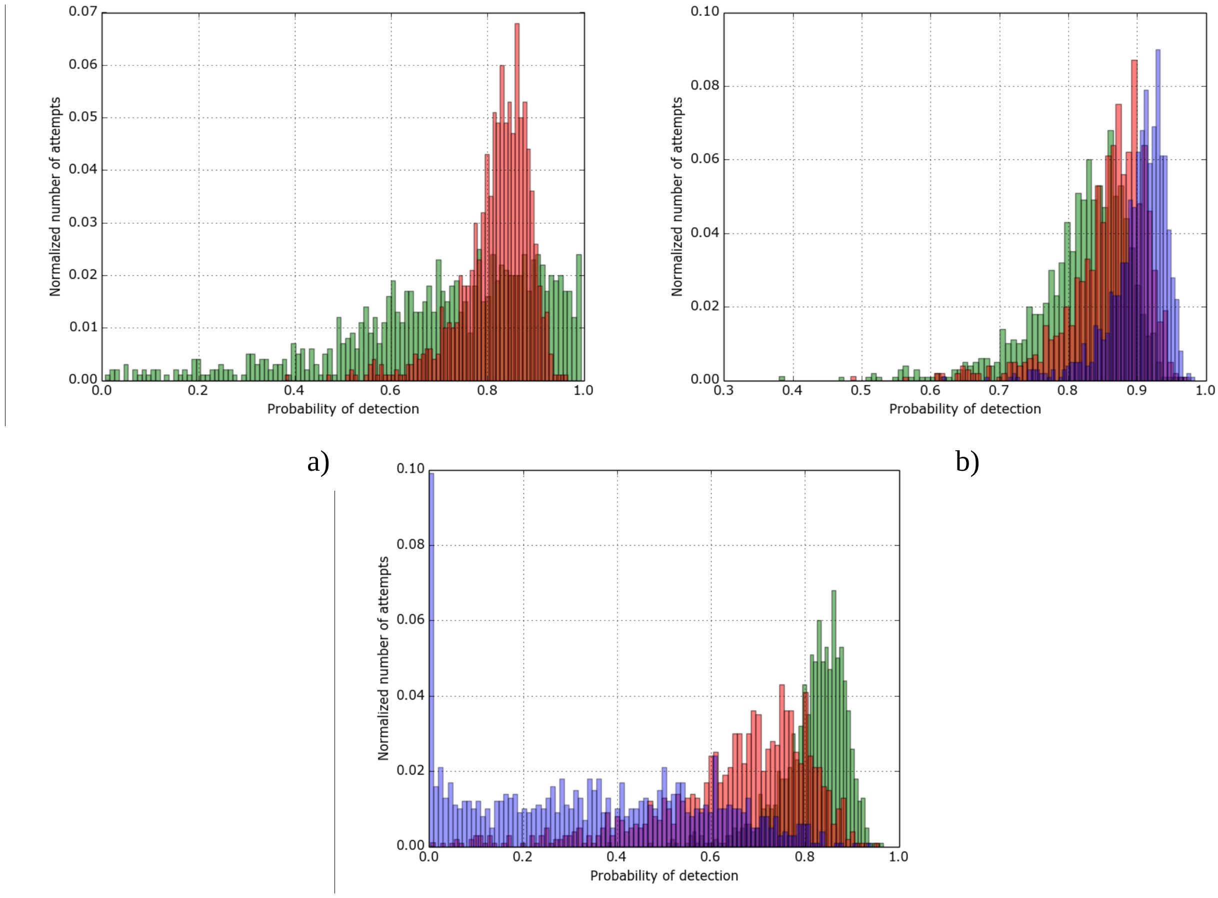

Figure 4 – Detection probability for different scenarios

Figure 4a shows that the other constant parameters, radar location inside or outside the network has a strong impact on the spread of the parameters of the radar detection. This changes not only the values of the statistical parameters, but also the shape of the distribution law, which further affect the calculation of the percentage of time the execution of certain conditions. On the Figure 4b there's also noticeable dependence on the chosen probability of false alarm. That is equal for all kinds of parameters chosen probability of false alarm leads to a different percentage of time providing the required detection probability. The presence of this is caused by the dynamics of the percentage of time the mobile network LTE. Similar conclusions can be drawn also by analyzing figure 4c. However, in this case, the percentage of time affects the level of the average value of the ratio of signal / noise ratio.

Studies were also carried out according to the standard deviation (SD) of the total interference from subscriber stations on the radar receiver input from placing radar relative to mobile network. Figure 5 shows this relationship for different types of scenario (and the density of the network, respectively). There is almost the same low interference standard deviation away from the network for different types of buildings. However, in proximity to the network SD rapidly increases and reaches its maximum at the edge of the network. Later in the recess in the radar network SD is different for different types of buildings and stabilized at a certain level. As expected, the greatest deviation is observed in urban areas, the lowest - in the rural. This dependence can be used to calculate the required distance when planning placement of a mobile network, or radar, or in determining the necessary reserve for the operation of the radar with the specified quality indicators.

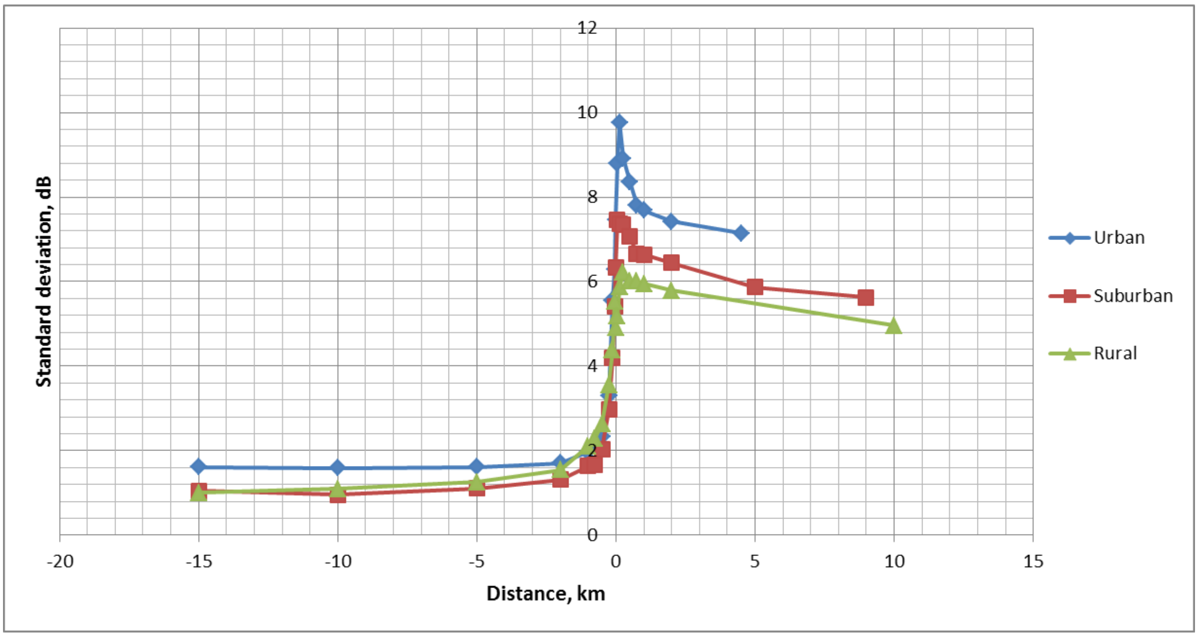

Figure 5 – Dependence of total interference SD from distance

CONCLUSIONS

The constructed model allows to solve many problems related to estimation of interference and influence of it on the receptor under conditions of dynamic changes of the model parameters, different scenarios. The model was used to determine the variability of the interference created by the mobile stations of LTE network to a receiver of ground station of radiodetermination system. Probability density functions of noise for different conditions were obtained. It was found that the total deviation from the mean interference can lead to a marked deterioration in the normal functioning of the radar performance. That is the dynamic nature of the mobile network (the movement of subscribers, their network activity) leads to uncertainty of interference in the receiver of the radar that affects the signal / (noise + interference) and the percentage of time in which the required conditions are fulfilled for normal radar operation (probability of correct detection, probability of false alarm).

The resulting dependence of the total interference SD by the distance to the boundary of the radar network demonstrates the importance of taking into account the additional reserve to used protection ratios to achieve the desired percentage of time for the conditions of the normal functioning of the radar.

The aim of further studies of the effect of mobile stations LTE network to the receiver of ground station of radiodetermination systems is to create an analytical expression for engineering calculations required with respect to the safety margin. The initial data for this regression analysis will be the results of simulation for different scenarios. Analytical expression must take into account the distance to the boundary of the radar network, the required detection probability, the required probability of false alarm, the percentage of time in which these probabilities must be maintained. This analytical expression will display the obtained in the article simulation results and have practical significance when planning placement of radiodetermination systems or mobile network, or when determining the required additional attenuation of interference to ensure the functioning of radiodetermination system.

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