Estimation of Electromagnetic Background Intensity Created by GSM Cellular Networks Base Stations with High Spatial Density on Urban Area

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***Abstract*—Estimation of the total intensity of electromagnetic background created by GSM-1800 cellular network base stations with spatial density of 3-9 base stations per square kilometer taking into account intrasystem electromagnetic compatibility of the cellular network (levels of intranetwork interference) was executed based on computer modeling of functioning of the cellular network fragment with the use of X3D three-dimensional model of radio wave propagation and three-dimensional model of the fragment of urban area of Minsk. The results are presented for base stations antenna height of 25-35 m, equivalent isotropic radiated power of 33-58 dBm per frequency channel, and for various spatial population density of 6000-12000 people per square kilometer**

Keywords—Intrasystem EMC, cellular communication base stations, electromagnetic background, electromagnetic safety

I. Introduction

At present time mass active use of different type of cellular communications services is observed [1]. Thereby spatial density of mobile stations (MS) and base stations (BS) increases especially in densely populated urban areas which in turn contributes to an increase in the total intensity of electromagnetic background (EMB) created by this equipment.

Increase in spatial density of BSs of GSM standard is caused by the need to service high-intensity subscribers traffic at a limited radio frequency resource (the number of radio channels) assigned to a cellular radio network.

Spatial density of BSs of cellular networks can achieve 10 BS/km^2 on urban areas [2].

Electromagnetic radiation (EMR) of cellular networks equipment can negatively impact on health of the population [3]-[6]. It was also found that EMR of cellular networks equipment negatively effects on operation of electronic medical devices of individual use in public places of urban areas with high spatial density of the population [7]. Cellular network BSs installed in the top of or near hospitals, clinics and residential buildings can serve as a main potential source of electromagnetic interference on electronic equipment [8]. A GSM signal of BS may be considered as a highly interfering source for the EGG (electroencephalogram) [9].

Therefore, the following issues becomes relevant: electromagnetic safety of cellular radio networks with high spatial density of BSs for the population, as well as impact of system parameters of cellular networks on the total intensity of EMB generated by BSs and on quality of intrasystem electromagnetic compatibility (EMC) of cellular radio networks.

The goal of this paper is estimation of the total intensity of EMB created by a set of GSM cellular network BSs with various spatial density in densely populated urban area, as well as analysis of quality of intrasystem EMC of the cellular network.

For this goal, computer modeling of functioning of GSM-1800 cellular network fragment (at voice communication mode of cellular system) was made with the use of X3D three-dimensional model of radio wave propagation (RWP) and three-dimensional model of the fragment of urban area of Minsk with buildings heights of 6-20 m, at allocation of MSs over a terrestrial surface. As a result of the computer modeling, estimation of the total intensity of EMB created by BSs with various spatial density, various BS antenna height, and also various BS equivalent isotropic radiated power (EIRP), was executed. The results are presented for various spatial density of subscribers. Estimation of levels of intranetwork interference to the MS receivers of created by BSs operating on the same radio channels was also made. Then the levels of "carrier/ (interference plus noise)" ratio (CNIR) at the inputs of MS receivers and the relative number of MSs, for which intrasystem EMC is not ensured (CNIR level does not increase the performance threshold of MS receivers) was calculated. The calculation was made for various BS EIRP as well as various BS antenna heights.

II. Initial Data and Models

A. The system parameters for simulation

Initial data and models used at behavior simulation of GSM cellular network are given below.

1) The analysis is performed for BS and MS of GSM-1800 standard.

2) Spatial density of BSs ρ_{BS} is approximately 3-9 BS/km^2.

3) BS EIRP P_{BS} value is 33-58 dBm/channel.

4) BS antenna height H_{BS} is 25-35 m.

5) Observation point (OP) height H_{OP} and MS height H_{MS} over the terrestrial surface is 2 m.

6) Type of MS antenna is accepted as isotropic.

7) The type of BS antenna is real antenna (HWX-6516DS1-VTM) with 68° beamwidth of antenna pattern on

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the horizontal plane at –3 dB level and tilt depending on size of site and BS antenna height at estimation of CNIR value (see item B of present section), and isotropic when the total intensity of EMB is analysed (see item C of present section).

8) The population density is accepted equal to ρ_N = 6000 people/km^2, that is corresponds to the population density of Minsk. The population density is taken equal to ρ_N = 12000 people/km^2 for densely populated areas. It is also assumed that the population density is equal to spatial density of subscribers.

9) Spatial density of active MSs in telephone mode is ρ_{MS} = 480-960 MS/km^2 taking into account that traffic intensity in cellular radio networks can reach value of E = 0.08 Erl on business hours.

10) The minimum number of GSM duplex radio channels which are necessary for service of subscribers in network sites on business hours is defined taking into account the cluster dimensionality of frequency sharing with the use of the Erlang-B model of the traffic theory (providing of communication channels in system of mass service with blocking of calls [14]) for the level of probability of calls blocking of 0.01, which is typical for high-quality cellular communication, in the following way.

a) The average number of MSs in telephone mode N_{AVRS} (volume of voice traffic) in sector is calculated at first:

$$N_{AVRS} = \frac{S \cdot \rho_N \cdot E}{n}; \quad (1)$$

$$S = \frac{3\sqrt{3}}{2} R^2_{\max}, \quad (2)$$

where S is the square of site, square km; n is the amount of sectors in site (n = 3); $R_{\max}$ is the radius of site, km.

b) Then the number of traffic channels N_t for service of MSs in telephone mode is defined. The number of traffic channels is selected in the tables [14] for the level of probability of calls blocking of 0.01 depending on the average number of MSs in telephone mode per sector of the cellular network.

Taking into account that each GSM frequency channel provides up to 8 time-division traffic channels, the required number of duplex frequency channels N_d per each sector is determined. It is also taken into account that at least one channel should be used as control channel per each four duplex frequency channel. The ceiling function is used in order to calculate integer value N_d of duplex radio channels and N_c of control channels. Thus, the total number of duplex radio channels will be as follows:

$$N_\Sigma = N_d + N_c; \quad (3)$$

$$N_d = ceil(\frac{N_t}{8}); \quad (4)$$

$$N_c = ceil(\frac{N_d}{4}). \quad (5)$$

11) BS EIRP is defined as product of EIRP value per requency channel and the number of frequency channels per sector when the total intensity of EMB is analysed:

$$P_{EIRP\ BS} = N_\Sigma \cdot P_{EIRP\ channel}, \quad (6)$$

where $P_{EIRP\ channel}$ is BS EIRP per frequency channel, Watt.

B. Level of CNIR

It is accepted that quality of intrasystem EMC is defined by CNIR value which assigned by dimensionality Cl of the cluster of network frequency sharing. The CNIR value at the GSM MS receiver input should be more than 9 dB.

The CNIR value at the MS receiver input is defined as follows:

$$CNIR = \frac{P_{signal}}{P_{I1} + \ldots + P_{IM} + P_0}, \quad (7)$$

where P_{signal} is the level of desired signal, Watt; P_I is the level of interference signal, Watt; M is the amount of interference sources and P_0 is the receiver own noise (8).

The level of GSM-1800 MS receiver own noise P_0 resulted to the receiver input is defined by the following equation:

$$P_0 = k \cdot T_0 \cdot \Delta F \cdot K_N, \quad (8)$$

where k is the Boltzmann constant ($1.38 \cdot 10^{-23}$ J/K); T_0 is the temperature of the environment in Kelvin degree (290 K); ΔF is the signal bandwidth, Hz; K_N is the noise figure of the radio receiver.

Thus the level of GSM receiver own noise resulted to the receiver input is equal to P_0 = –114 dBm in the 200 kHz radio band.

C. The total intensity of electromagnetic background

The total intensity of EMB $\Pi_{\Sigma BS}$ (Watt/m^2) [16] time averaged taking into account the independence of signals radiated by different BSs is defined as scalar sum of values of electromagnetic field (EMF) power flux density in OP:

$$\Pi_{\Sigma BS} = \sum_{i=1}^{M} \Pi_{BS_M}, \quad (9)$$

where Π_{BS} is the level of power flux density of BS EMR in OP, Watt/m^2; M is the number of BSs on considered fragment of urban area.

D. The maximum permissible level of electromagnetic field

1) The maximum permissible level (MPL) of EMF created by equipment of the cellular network is 0.1 W/m^2 (–10 dBW/m^2). This permissible level is accepted for the population for example in Belarus [10], Russia [11], in Switzerland for general public [12], in Italy for general public as attention value which cannot be exceeded in residential environment [12], [13].

2) The threshold of 3 V/m (–16.2 dBW/m^2) is established in [15] regarding electromedical devices that was mentioned in [7].

E. *RWP model for urban (city) area*

Three-dimensional X3D model [17] of multipath RWP on urban area is used. It is based on the use of three-dimensional SBR (shooting and bouncing ray) algorithm used for determination of RWP rays paths between BS and MS in three-dimensional space. The model has no restrictions on the use in the considered conditions. The parameters of the RWP model are shown in [18]. Multipath X3D model was experimentally tested in [19]. The difference between the results of measurements of EMF levels created by BS of UMTS cellular network on urban area and the results of calculations with the use of X3D RWP model was approximately 6 dB [19]. Three-dimensional RWP model is also recommended for transmitters of wireless systems whose antenna height is comparable with or higher than surrounding buildings of urban area [20]. In most locations, the correct propagation loss predictions were made with a mean error of less than 7 dB and a standard deviation of less than 8 dB [20].

F. *The model of urban (city) area*

The topographical computer model of the fragment city housing of part of Minsk is used with the following characteristics: the considered urban area fragment can be conformed to the territory type of “urban high-rise” [21]; buildings height is mainly 6-20 m; the earth surface is accepted as flat; covering of the earth surface is asphalt; the walls material is brick and the roof material is concrete.

G. *Scenarios of modeling*

The following scenarios for modeling of behavior simulation of the cellular network are used.

1) At estimation of CNIR values at the inputs of MS receivers the scenario with three-sector structure of the network for cluster dimensionality $Cl = 7$ of frequency sharing is used [18]. The scenario is shown in Fig. 1. In this figure the filled sector of BS1 service zone is the area of location of analysed set of MSs. Radio transmitters of BSs (BS2-BS4) are servicing the filled sectors of these BSs service zones. BSs (BS2-BS4) use the same frequency channels which BS1 use and are considered as the sources of intranetwork interference for MSs of considered sector of BS1 site. BSs of other sites use other frequency channels and does not effect on MS served by BS1.

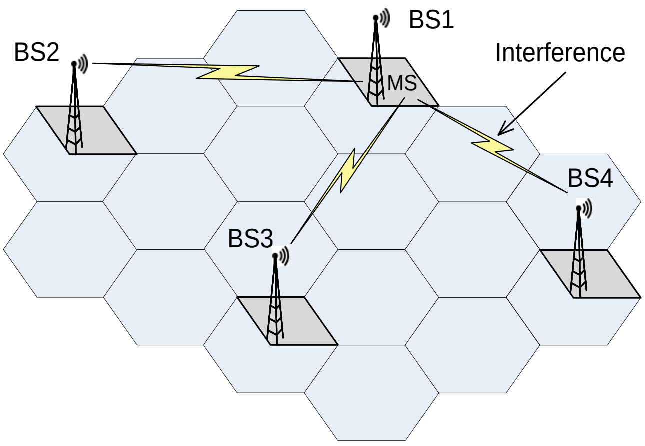

Fig. 1. Scenario of simulation for estimation of CNIR value at the input of MS receivers

2) For estimation of the total intensity of EMB created by BSs the following scenario was considered. This scenario is shown in Fig. 2. In this figure BSs (BS1-BS7) are allocated close to regular placement with different average spatial density of approximately ρ_{BS} = 3-9 BS/km^2 on considered urban area fragment. The total intensity of EMB created by these BSs is analysed in OPs which are allocated uniformly in the vicinity of BS1 coverage area.

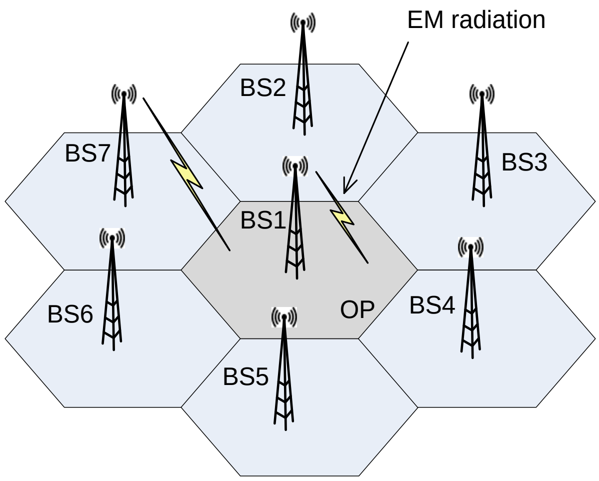

Fig. 2. Scenario for estimation of the total intensity of EMB created by set of BSs

III. Results of Behaviour Simulation and Discussion

A. *CNIR levels at MS radio reception*

The results of estimation of CNIR values at the MS receivers input at various levels of BS EIRP and at various BS antenna height H_{BS} with various spatial density of BSs ρ_{BS} and cluster dimensionality $Cl = 7$ of frequency sharing are given below in Tables 1-3.

TABLE I. Relative number of MSs for which the intrasystem EMC is not ensured, at various BS EIRP P_{BS}, various BS antenna height H_{BS}, BS spatial density of 3 BS/km^2 and cluster dimensionality $Cl = 7$

P_{BS}, dBm/channel	**Relative number of MSs, for which CNIR < 9 dB, %**	
	H_{BS} = 25 m	***H_{BS} = 35 m***
33	4.0-7.2	1.0-2.9
40	1.9-3.8	0.1-2.3
43	1.1-3.0	0.1-2.1
47	0.6-2.6	0.1-2.1
53	0.5-2.3	0.1-2.1
58	0.5-2.1	0.1-2.1

TABLE II. Relative number of MSs for which the intrasystem EMC is not ensured, at various BS EIRP P_{BS}, various BS antenna height H_{BS}, BS spatial density of 6 BS/km^2 and cluster dimensionality $Cl = 7$

P_{BS}, dBm/channel	**Relative number of MSs, for which CNIR < 9 dB, %**	
	H_{BS} = 25 m	***H_{BS} = 35 m***
33	1.7-7.5	0.2-2.3
40	0.6-5.8	0.1-2.3
43	0.3-5.8	0.1-1.5

P_{BS}, dBm/channel	Relative number of MSs, for which CNIR < 9 dB, %	
	H_{BS} = 25 m	H_{BS} = 35 m
47	0.3-5.8	0.1-1.5
53	0.3-5.8	0.1-1.5
58	0.3-5.8	0.1-1.5

TABLE III. RELATIVE NUMBER OF MSS FOR WHICH THE INTRASYSTEM EMC IS NOT ENSURED, AT VARIOUS BS EIRP P_{BS}, VARIOUS BS ANTENNA HEIGHT H_{BS}, BS SPATIAL DENSITY OF 9 BS/KM^2 AND CLUSTER DIMENSIONALITY C_L = 7

P_{BS}, dBm/channel	Relative number of MSs, for which CNIR < 9 dB, %	
	H_{BS} = 25 m	H_{BS} = 35 m
33	0.2-3.6	0.2-1.2
40	0.2-3.3	0.1-1.0
43	0.1-3.3	0.1-1.0
47	0.1-3.1	0.1-1.0
53	0.1-3.1	0.1-1.0
58	0.1-3.1	0.1-1.0

The analysis of estimation of CNIR values at the inputs of MS receivers testifies to the following:

1) Relative number of MSs, for which intrasystem EMC is not ensured, comes to 0.5-2.6 % at spatial density of BSs ρ_{BS} = 3 BS/km^2 on considered urban area, BS EIRP P_{BS} = 47-58 dBm/channel, and antenna height H_{BS} = 25 m. At decrease in BS EIRP down to 33-43 dBm/channel this number increases up to 3.0-7.2%. Increasing in BS antenna height up to 35 m improves intrasystem EMC of the cellular network. And relative number of MS, for which intrasystem EMC is not ensured, is 0.1-2.1% that is acceptable for high quality of service, at BS EIRP P_{BS} = 40-58 dBm/channel, and can achieve 2.9 % with decrease in BS EIRP down to 33 dBm/channel. Deterioration of intrasystem EMC of the cellular network is observed with decrease in BS EIRP because of increase of dependence of the level of the receiver own noise on CNIR value.

2) Relative number of MSs, for which intrasystem EMC is not ensured, can be changed significantly in some cases and comes to 0.3-5.8 % at BS EIRP P_{BS} = 40-58 dBm/channel, at spatial density of BSs ρ_{BS} = 6 BS/km^2 with antenna height H_{BS} = 25 m on considered urban area. At decrease in BS EIRP down to 33 dBm/channel this number increases up to 7.5%. Increase in BS antenna height up to 35 m also improves intrasystem EMC at this spatial density of BSs. And number of MSs, for which intrasystem EMC is not ensured, comes to 0.1-1.5% at BS EIRP P_{BS} = 43-58 dBm/channel and can achieve the value of 2.3% with decrease in BS EIRP down to 33-40 dBm/channel.

3) Relative number of MSs, for which intrasystem EMC is not ensured, decreases essentially down to 0.1-3.6 %, at spatial density of BS ρ_{BS} = 9 BS/km^2 with antenna height H_{BS} = 25 m on considered urban area, at BS EIRP P_{BS} = 33-58 dBm/channel. This number is decreased down to 1.2 % with increase in BS antenna height up to 35 m.

B. Estimation of electromagnetic background

The arithmetic mean and maximum values of the total intensity of EMB created by GSM cellular network BSs with various spatial density ρ_{BS}, various BS antenna height H_{BS}, and various BS EIRP P_{BS} are given in Tables 4-9. The estimations of the total intensity of EMB are made for various spatial density of active subscribers (in telephone mode) ρ_{MS} for which the necessary amount of duplex radio channel N_Σ to provide radio communication was calculated.

TABLE IV. ESTIMATIONS OF THE TOTAL INTENSITY OF EMB CREATED BY BSS WITH SPATIAL DENSITY OF 3 BS/KM^2 AT BS ANTENNA HEIGHT H_{BS} = 25 M AND VARIOUS BS EIRP P_{BS}

P_{BS}, dBm/channel	The total intensity of EMB $\Pi_{\Sigma BS}$, dBW/m^2			
	Max	*Mean*	*Max*	*Mean*
	ρ_{MS} = 480 MS/km^2; N_Σ=9 frequency channels		ρ_{MS} = 960 MS/km^2; N_Σ =15 frequency channels	
33	–36.5	–50.6	–34.2	–48.3
43	–26.5	–40.6	–24.2	–38.3
53	–16.5	–30.6	–14.2	–28.3
58	–11.5	–25.6	–9.2	–23.3

TABLE V. ESTIMATIONS OF THE TOTAL INTENSITY OF EMB CREATED BY BSS WITH SPATIAL DENSITY OF 3 BS/KM^2 AT BS ANTENNA HEIGHT H_{BS} = 35 M AND VARIOUS BS EIRP P_{BS}

P_{BS}, dBm/channel	The total intensity of EMB $\Pi_{\Sigma BS}$, dBW/m^2			
	Max	*Mean*	*Max*	*Mean*
	ρ_{MS} = 480 MS/km^2; N_Σ=9 frequency channels		ρ_{MS} = 960 MS/km^2; N_Σ=15 frequency channels	
33	–31.0	–44.8	–28.8	–42.6
43	–21.0	–34.8	–18.8	–32.6
53	–11.0	–24.8	–8.8	–22.6
58	–6.0	–19.8	–3.8	–17.6

TABLE VI. ESTIMATIONS OF THE TOTAL INTENSITY OF EMB CREATED BY BSS WITH SPATIAL DENSITY OF 6 BS/KM^2 AT BS ANTENNA HEIGHT H_{BS} = 25 M AND VARIOUS BS EIRP P_{BS}

P_{BS}, dBm/channel	The total intensity of EMB $\Pi_{\Sigma BS}$, dBW/m^2			
	Max	*Mean*	*Max*	*Mean*
	ρ_{MS} = 480 MS/km^2, N_Σ =5 frequency channels		ρ_{MS} = 960 MS/km^2, N_Σ =9 frequency channels	
33	–40.2	–51.7	–37.6	–49.2
43	–30.2	–41.7	–27.6	–39.2
53	–20.2	–31.7	–17.6	–29.2
58	–15.2	–26.7	–12.6	–24.2

TABLE VII. ESTIMATIONS OF THE TOTAL INTENSITY OF EMB CREATED BY BSS WITH SPATIAL DENSITY OF 6 BS/KM^2 AT BS ANTENNA HEIGHT H_{BS} = 35 M AND VARIOUS BS EIRP P_{BS}

P_{BS}, dBm/channel	The total intensity of EMB $\Pi_{\Sigma BS}$, dBW/m^2			
	Max	*Mean*	*Max*	*Mean*
	ρ_{MS} = 480 MS/km^2, N_Σ =5 frequency channels		ρ_{MS} = 960 MS/km^2, N_Σ =9 frequency channels	
33	–32.9	–44.4	–30.4	–41.8

P_{BS}, dBm/channel	The total intensity of EMB $\Pi_{\Sigma BS}$, dBW/m^2			
	Max	*Mean*	*Max*	*Mean*
43	–22.9	–34.4	–20.4	–31.8
53	–12.9	–24.4	–10.4	–21.8
58	–7.9	–19.4	–5.4	–16.8

TABLE VIII. ESTIMATIONS OF THE TOTAL INTENSITY OF EMB CREATED BY BSS WITH SPATIAL DENSITY OF 9 BS/KM^2 AT BS ANTENNA HEIGHT H_{BS} = 25 M AND VARIOUS BS EIRP P_{BS}

P_{BS}, dBm/channel	The total intensity of EMB $\Pi_{\Sigma BS}$, dBW/m^2			
	Max	*Mean*	*Max*	*Mean*
	ρ_{MS} = 480 MS/km^2, N_Σ =4 frequency channels		ρ_{MS} = 960 MS/km^2, N_Σ =7 frequency channels	
33	–39.8	–50.1	–37.4	–47.4
43	–29.8	–40.1	–27.4	–37.4
53	–19.8	–30.1	–17.4	–27.4
58	–14.8	–25.1	–12.4	–22.7

TABLE IX. ESTIMATIONS OF THE TOTAL INTENSITY OF EMB CREATED BY BSS WITH SPATIAL DENSITY OF 9 BS/KM^2 AT BS ANTENNA HEIGHT H_{BS} = 35 M AND VARIOUS BS EIRP P_{BS}

P_{BS}, dBm/channel	The total intensity of EMB $\Pi_{\Sigma BS}$, dBW/m^2			
	Max	*Mean*	*Max*	*Mean*
	ρ_{MS} = 480 MS/km^2, N_Σ =4 frequency channels		ρ_{MS} = 960 MS/km^2, N_Σ =7 frequency channels	
33	–34.1	–43.8	–31.1	–41.4
43	–24.1	–33.8	–21.1	–31.4
53	–14.1	–23.8	–11.1	–21.4
58	–9.1	–18.8	–6.1	–16.4

The analysis of estimation of the total intensity of EMB created by BSs of GSM cellular network testifies to the following:

1) Maximum value of the total intensity of EMB created by BSs achieves –11.5 dBW/m^2 and does not overrate MPL, 0.1 W/m^2 (–10 dBW/m^2), set for the population [10]-[13], at spatial density of BSs ρ_{BS} = 3 BS/km^2 on considered urban area, BS EIRP P_{BS} = 58 dBm/channel, BS antenna height H_{BS} = 25 m, and spatial density of subscribers ρ_{MS} = 480 MS/km^2 in telephone mode. In case of ρ_{MS} = 960 MS/km^2 the total intensity of EMB increases up to –9.2 dBW/m^2, overrating MPL, that is dangerous for the population. This total intensity does not overrate MPL at BS EIRP less than 56 dBm/channel. With increase in BS antenna height up to H_{BS} = 35 m the maximum value of the total intensity of EMB can achive level of –3.8 dBW/m^2 which overrates the MPL. In this case BS EIRP has to be less than 51 dBm/channel in order to ensure electromagnetic safety of the cellular network for the population.

2) Maximum value of the total intensity of EMB created by BSs does not overrate MPL set for the population, at spatial density of BSs ρ_{BS} = 6 BS/km^2 on considered urban area, BS antenna height H_{BS} = 25 m, and spatial density of subscribers ρ_{MS} = 480-960 MS/km^2 in telephone mode. With increase in BS antenna height up to H_{BS} = 35 m this intensity can achieve level of –5.4 dBW/m^2 at BS EIRP P_{BS} = 58 dBm/channel and overrate MPL. In this case BS EIRP has to be less than 53 dBm/channel in order to ensure electromagnetic safety of the cellular network for the population.

3) Maximum level of the total intensity of EMB created by BSs does not also overrate MPL set for the population, at spatial density of BSs ρ_{BS} = 9 BS/km^2 on considered urban area, BS antenna height H_{BS} = 25 m, spatial density of subscribers ρ_{MS} = 480-960 MS/km^2 in telephone mode. With increase in BS antenna height up to H_{BS} = 35 m this intensity can achieve level of –6.1 dBW/m^2 at BS EIRP P_{BS} = 58 dBm/channel and overrate MPL. In this case BS EIRP has to be less than 54 dBm/channel in order to ensure electromagnetic safety of the cellular network for the populatuion.

4) In order to ensure electromagnetic safety of GSM cellular network for the medical electronic devices of individual use in terms of not exceeding of the EMB total intensity of MPL set in [15] BS EIRP has to be:

a) Less than 45-51 dBm/channel at BSs spatial density ρ_{BS} = 3 BS/km^2 depending on BS antenna height;

b) Less than 46-52 dBm/channel at BSs spatial density ρ_{BS} = 6 BS/km^2 depending on BS antenna height;

c) Less than 47-52 dBm/channel at BSs spatial density ρ_{BS} = 9 BS/km^2 depending on BS antenna height.

IV. CONCLUSION

Estimation of the total intensity of EMB created by GSM-1800 cellular network BSs with various spatial density in places with high spatial density of the subscribers for various BS EIRP, and various BS antenna height was made. Analysis of intrasystem EMC quality of the cellular network was also executed. The results were obtained based on computer modeling of functioning of the cellular network fragment with the use of three-dimensional model of considered fragment of urban area of Minsk and three-dimensional RWP model.

The results of estimations testify to the following:

1) In order to ensure electromagnetic safety of the cellular network for the population on considered urban area BS EIRP has to be not more than 51-54 dBm/channel depending on considered spatial density of BSs and BS antenna height.

2) BS EIRP has to be not more than 45-52 dBm/channel depending on considered spatial density of BSs and BS antenna height in order to ensure electromagnetic safety of the cellular network regarding to medical electronic wearable devices of individual use in terms of not exceeding of the total EMB intensity of MPL set for these devices.

3) Increase in BS EIRP up to 58 dBm/channel will lead to exceeding of MPL set for the population on approximately 6 dB, and will lead to exceeding of MPL set for medical electronic wearable devices of individual use on approximately 12 dB.

4) It should be taken into account that a set of MSs can make essential contribution to the total intensity of EMB created by equipment of GSM cellular network in places of subscribers gathering [22].

5) The results of calculation of relative number of MSs, for which intrasystem EMC is not ensured, indicates that increase in spatial density of BSs from 3 to 9 BS/km^2 can improve as well as degrade quality of intrasystem EMC at BS antenna height of 25 m on considered urban area. Intrasystem EMC is insured with increase in spatial density of BSs at antenna height of 35 m. Increase in BS EIRP more than 43-47 dBm/channel is inexpediently because increase in BS EIRP up to 58 dBm/channel improves insignificantly intrasystem EMC at spatial density of BSs ρ_{BS} = 3 BS/km^2, and does not impact on changes in quality of intrasystem EMC at spatial density of BSs ρ_{BS} = 6-9 BS/km^2 on considered urban area. The relative number of MSs, for which intrasystem EMC is not ensured, comes to 0.1-5.8 % at BS EIRP of 43-58 dBm/channel for all considered values of BSs spatial density and cluster dimensionality Cl = 7 of frequency sharing.

The results of estimation of the total EMB intensity created by BS of the cellular network, and estimation of intrasystem EMC quality of the cellular network are presented for GSM-1800 network because this technology prevails at providing of telephone communication services. The situation will be changed possibly during implementation of technological neutrality of radiofrequency bands assigned for cellular network functionality and implementation of cellular network systems of new generations (4G/5G), but no significant changes should be expected.

The presented results do not fully characterize the current situation concerned EMB created by equipment of cellular network because the volume of voice traffic is reduced compared to the volume of traffic in 3G/4G networks. Therefore further studies will be aimed to analysis of intensity of EMB created by the equipment of new generation of cellular radio networks.

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