# ESTIMATION OF THE COMPELLED ECOLOGICAL RISKS AT INFLUENCE OF THE ELECTROMAGNETIC FIELDS CREATED BY THE RADIOTELECOMMUNICATION EQUIPMENT IN PLACES WITH HIGH POPULATION DENSITY

VLADIMIR MORDACHEV, REPUBLIC OF BELARUS

Belarusian State University of Informatics and Radioelectronics, e-mail: emc@bsuir.by

**Abstract.** The technique of an estimation of compelled ecological risk for people health because of the influence of the electromagnetic fields created by base stations of cellular communication and broadband wireless access in places with its high spatial density, taking into account the contribution to total field intensity of electromagnetic radiations of mobile telephones along with electromagnetic radiations of transmitters of all main radio services (radiolocation, broadcasting, etc.) is submitted. This technique is officially accepted in Belarus in 2010 for an assessment of electromagnetic safety of significant social objects with increased ecological requirements - children's educational, medical and health improvement establishments, etc.

## Introduction

Intensive development of the mobile and fixed radio communication systems and networks in places with high population density is the reason of significant growth of "electromagnetic stress" (EMS) on urban and suburban territories from base stations (BS) of cellular communication and wireless broadband access (WBA) placed on these territories. For last 10 years this EMS in cities of Russian Federations and Republic of Belarus has increased approximately for 2 order, having exceeded essentially a level caused by presence of systems of on-air radio and TV broadcasting, radars, base radio communication transmitters and other services and systems. On a cumulative specific level of equivalent isotropic radiates power (e.i.r.p.) in city areas it can be up to 10 $kW/km^2$ and even more. In these conditions cellular telephones and other radio telecommunication user's devices in places with high population density also creates an appreciable electromagnetic background, however until last time this factor practically was not taken into account at estimations of the compelled electromagnetic risks for the population.

Conception of system ecology of cellular communication developed in [1] has allowed to substantiate the approaches [2,3] regulating a technique of an estimation of compelled risks for the population's health, caused by presence of all assemblage of electromagnetic fields (EMF) generated by radio electronic equipment and systems of various radio services and frequency ranges of frequencies, placed (installed, used) on significant social objects (SSO) of increased ecological requirements - children's educational, medical and educational establishments, boarding schools and houses, rest areas etc. and in their vicinities. In particular, in Belarus according to requirements of the accepted Regulations [3] this estimation should be made in following situations:

– At designing of BS of cellular communication or WBA at a stage of a selection of places and spatial parameters of its allocation in SSO territory and/or in its vicinity, and

– At modernization of BS radio equipment of cellular communication or WBA in SSO territory and/or in its vicinity, including replacement old or installation new radio transmitting modules and equipment, antennas and feeding lines; changing of height or allocation of antenna masts, etc.

Substantive foundations and conditions of regulations [3] accepted in Belarus are stated below.

## Principles of Assessment of Compelled Electromagnetic Risks

Principle of Total EMF intensity.

Regulations [3] provide an estimation of total EMF intensity on SSO and its vicinity produced by all radio services and the analysis of possible alternative variants of BS allocation or upgrading and the subsequent choice of the best variant at which the minimum level of total EMF intensity will be received.

Principle of Total EMF representation.

Representation of total EMF intensity as two components is provided: an intensity $S_Y$ of the electromagnetic background formed by ensemble of EMF of stationary transmitters of all services, including EMF generated by BS of cellular communication and WBA, allocated on SSO territory or in its vicinity within the remoteness of the first line of building or distance of direct visibility, and EMF from cellular telephones in SSO territory and in its vicinity (the first component which is quasi-stationary), and EMF intensity $S_{mob}$ produced by the nearest cellular telephone in an active state (the second component which is stochastic).

Principle of Summation of Relative EMF Levels.

A well-known technique [2,4,5] of summation of relative EMF Levels is used. This technique is provided definition of total intensity of an electromagnetic background using accepted technique of summation of number $M_k$ of relative total EMF levels of each k-th frequency sub-range or specialized group of radio systems for which in [4] an independent maximum permissible levels (MPL) $S_{MPLk}$ of EMF for the population are determined:

$$X = \sum_{k=1}^{K} S_{\Sigma M_k} / S_{MPL\,k} \le 1, \qquad S_{\Sigma M_k} = \sum_{m=1}^{M_k} S_{km} , \tag{1}$$

where $S_{km}$ - intensity of m-th EMF of k-th frequency sub-range or specialized group of radio systems, $S_{YMk}$ is total EMF intensity k-th frequency sub-range or specialized group of radio systems; values $S_{km}$, $S_{YMk}$ and $S_{MPLk}$ are expressed in terms of EMF power flux density or in terms of a square of EMF intensity, depending on frequency sub-range; X - total relative intensity of quasi-stationary (background) EMF component in analyzed point of SSO; in (1) a scalar summation of separate EMF power parameters $S_{km}$ is made.

Principle of Selection of Considered EMF Levels.

The number $M_k$ of taken into account quasi-stationary EMF components of each k-th frequency sub-range or specialized group of radio systems is limited by an ensemble of the most powerful EMF in considered place of an SSO, the level of each considered EMF will be not lower then 1 % of corresponding MPL: $S_{km} \ge 0{,}01\, S_{MPLk}$.

Criterion of unacceptability of the compelled ecological risk in Severe Multi-Component Electromagnetic Environment.

As criterion of unacceptability of the compelled ecological risk for people inside SSO accepted in [3], the criterion of excess by total relative EMF intensity (including totality of quasi-stationary and stochastic components) of the level equal to 1, with probability more then 1 %, is used.

Technique of Estimation of Level of Stochastic Component of Total Relative EMF Intensity.

At definition of statistical characteristics of level of the prevailing EMF of mobile telephone (or other user's device with electromagnetic radiation) in considered point )pace) of SSO results of [1,6-8] are used. They are based on Poisson model of stochastic spatial distribution of radiating user's devices and taking into account existence of adjustment of power of user's device electromagnetic radiation according to basic radio wave propagation losses between BS and this device.

An estimation of probability (risk) of excess of MPL value in any analyzed point of SSO by total relative intensity of quasi-stationary EMF component and intensity of stochastic EMF component produced by the nearest cellular telephone is made with use of graphic representation of probability distribution function (PDF) of total EMF intensity $S_{YY}$ for any moment of time in considered place of SSO with given total EMF background (quasi-stationary EMF component) intensity $S_Y$ and given average spatial density of radiating mobile telephones in this place of SSO:

$$p(S_{\Sigma\Sigma}) = \frac{2\sqrt{S_{\Sigma\Sigma} - S_\Sigma}}{\sqrt{\rho_e P_{etr\,max}}} \int_0^{\sqrt{\frac{\rho_e P_{etr\,max}}{4(S_{\Sigma\Sigma} - S_\Sigma)}}} \exp\left(-t^2\right) dt, \tag{2}$$

$$S_\Sigma = X\, S_{MPL1}; \quad S_{\Sigma\Sigma} = S_\Sigma + S_{mob}$$

Here $c_e$ is a spatial density of radiated mobile telephone or "user's stations" (US) in analyzed place of SSO, its dimension is [US/m$^2$]; $S_{MPL1}$ = 0,1 W/m$^2$ (10 мW/cm$^2$) for a frequency range of cellular communication (> 300 MHz) according to harmonized requirements [2,4]; $P_{etr\,max}$ - maximal average e.i.r.p. of cellular telephones: $P_{etr\,max} \approx 0{,}4$ W for GSM-900 and IMT-450, $P_{etr\,max} \approx 0{,}2$ W for GSM-1800 and UMTS; X is a total relative EMF background intensity calculated taking into account all frequency sub-ranges and specialized groups of radio systems.

### The Basic Stages of the Analysis of Compelled Ecological Fisk in SSO Territory

Calculation of total EMF intensity produced by various kinds of radio transmitting equipment on SSO territory include the following stages:

Stage 1: calculation of total EMF intensity produced by all BS of all cellular networks and WBA, and also radio transmitters with continuous and pulse radiation (except EMF from radars in a mode of the circular scanning or scanning with frequency no more then 1 Hz and pulse ratio ≥ 20) on frequencies ≥ 300 MHz (radio transmitters of the first group);

Stage 2: calculation of total EMF intensity from US of cellular mobile telecommunication on SSO territory and its vicinity (radio transmitters of the second group);

Stage 3: calculation of total EMF intensity produced by radars in a mode of the circular scanning or scanning with frequency no more then 1 Hz and pulse ratio ≥ 20 on frequencies is higher than 300 MHz if SSO is placed relatively near one of this systems and this partial EMF total level may exceed 1% of MPL for UHF pulse EMF (radio transmitters the third group);

Stage 4: calculation of values of total EMF intensity from all radio transmitters with continuous and pulse radiation for all frequency sub-ranges less 300 MHz for which various MPL are established (radio transmitters of the fourth group);

Stage 5: estimation of probability (risk) of excess of relative MPL in an any place of SSO by total EMF intensity (sum of cumulative EMF background intensity and intensity of EMF produced by the nearest US) (radio transmitter of the fifth group).

Stages 1,3 and 4 of analysis are carried out with use of the traditional technique stated in [2,4]. Novelty of a stated technique is defined by the second and fifth stages described below.

**The Total EMF Intensity From Mobile User's Devices (Cellular Mobile Telephones)**

Basing on reasons [1,6-9], we shall define a vicinity around of some point of supervision, within of which a random territorial accommodation of USs - sources of EMR is occur, and it is possible to use model of radio wave propagation (RWP) in free space. The radius of this vicinity $R_0$ and its area $S_0$ are approximately equal correspondingly $R_0$=0,15-0,3 km and $S_0$=0,1-0,3 $km^2$ for GSM-1800, IMT-2000 and $R_0$=0,05-0,2 km and $S_0$=0,01 - 0,1 $km^2$ for GSM-900. Taking into account estimations [10,11], and also the practically occurred USs terrestrial density c in places of a mass congestion of people in various conditions situations with $c=[10^3\div 2\cdot 10^6]$ US/$km^2$ are of great interest. Taking into account the known data on the average traffic created by one subscriber of a network (0,025 Erl.) with the tendency of increase up to 0,05-0,08 Erl.), we are interested to study situations with $c=[10^2\div 2\cdot 10^5]$ radiating US/$km^2$. Thus, in a considered vicinity of a point of supervision number of simultaneously radiating USs can be $[10^1\div 10^5]$

At an estimation of total intensity of the electromagnetic background formed by EMR of USs at random uniform territorial accommodation of USs in a vicinity of a point of supervision a following models [1,6,7] of probability distributions of a dynamic range of signals in this point can be used:

_1) Model 1:_ Probability density distribution $w(D_P)$ and probability density function $F(D_P)$ of dynamic range $D_P$ of signals radiating by USs, placed randomly with Poisson stochastic mode in a vicinity of radius $R_0$ of a point of supervision:

$$w(D_P) = \frac{N_a^H m}{\nu\Gamma(H)} D_P^{-(Hm+\nu)/\nu} \exp(-N_a D_P^{-m/\nu}) ; \quad (3)$$

$$P(D_P) = \frac{\Gamma(H, N_a D_P^{-m/\nu})}{\Gamma(H)} ;$$

$$D_P \ge 0 ,\ N_a \ge 0 ,\ \nu > 0 ;\ m > 0 ; \quad (4)$$

$$\Gamma(H, N_a D_P^{-m/\nu}) = \int_{N_a D_P^{-m/\nu}}^{\infty} \exp(-x)\cdot x^{H-1} dx \quad -$$

incomplete Gamma - function of the second kind. At terrestrial type of USs spatial distribution and free space RWP it is necessary to use m=2, H=2.

Parameter $N_a$ of this distribution is meaningful an average amount of EMR sources in some vicinity of a point of supervision. According to [1,6,7] it can make sense an average amount of EMR sources with equivalent e.i.r.p. $P_{etr}$ in spherical area of potential interfering interaction of radius $R_{max} = (P_{etr}/(4p\Pi_{min}))^{1/2}$, limited by US radio reception sensitivity $\Pi_{min}$ [W/$m^2$] of on the main channel of reception in case the average spatial density of sources in all this area is constant and equal to average density ρ of random spatial accommodation of sources in vicinity of supervision point:

$$N_a = GR_{max}^m = \rho\pi^{m/2} R_{max}^m / \Gamma(1 + m/2) \ge 0 ; \quad (5)$$

In this case dynamic range $D_P$ (level $\Pi_H$ [W/$m^2$] normalized to sensitivity value $\Pi_{min}$) of H-th signal on signal strength range in a point of supervision is defined as ratio $D_P = \Pi_H/\Pi_{min}$.

However in a considered case it is more convenient to normalize dynamic range $D_P$ of signals in a point of supervision to intensity $\Pi_0$ [W/$m^2$] of an US signal in this point if the US it is removed from this point on distance $R_0$. In this case $D_P = \Pi_H/\Pi_0$, and the expression (5) for parameter $N_a$ of distribution (3), (4) gets the following kind: $Na = pcR_0^2$. Thus, distribution (3), (4) appears a distribution of normalized level $D_P$ of H-th on US signal strength in a point of supervision.

Expression for the initial moments of distribution (3), (4) has the following kind:

$$m_n(D_P) = N_a^{n\nu/m} \frac{\Gamma(H - n\nu/m)}{\Gamma(H)} ,\ H - n\nu/m > 0 . \quad (6)$$

_2) Model 2:_ Probability distribution of a dynamic range of signals as distribution of range of sample of values of intensity of N signals distributed under the hyperbolic law [1].

If at a point of supervision N signals are present with hyperbolic distribution on power parameter, that, transforming sample of values $\Pi_1, \Pi_2..., \Pi_N$ in variational series $D_{(1)} = \Pi_{(1)}/\Pi_{min}$, $D_{(2)} = \Pi_{(2)}/\Pi_{min}...$, $D_{(N)} = \Pi_{(N)}/\Pi_{min}$, using known rules it is possible to find probability density distribution of k-th serial statistics $D_{(k)}$ of these series:

$$\begin{aligned} w\left(D_{(k)}\right) &= \frac{m\Gamma(N+1)}{\nu\Gamma(k)\Gamma(N-k+1)} \times \\ &\times \left[1 - D_{(k)}^{-m/\nu}\right]^{k-1} D_{(k)}^{-\frac{m}{\nu}(N-k+1)-1} = \\ &= \frac{m\Gamma(N+1)}{\nu\Gamma(H)\Gamma(N-H+1)} \times \\ &\times \left[1 - D_{(k)}^{-m/\nu}\right]^{N-H} D_{(k)}^{-\frac{m}{\nu}H-1} ,\ k = N - H + 1; \end{aligned} \quad (7)$$

$$F_N\left(D_{(k)}\right) = 1 - I_{\left(D_{(k)}^{-m/\nu}\right)}\left(H, N-H+1\right); \quad (8)$$

$I_{\left(D_{(k)}^{-m/\nu}\right)}\left(H, N-H+1\right)$ - incomplete Beta - function.

Expression for the initial moments of this distribution has the following kind:

$$\begin{aligned} m_n\left(D_{(k)}\right) &= \frac{\Gamma(N+1)\Gamma(H - \nu n/m)}{\Gamma(H)\Gamma(N - \nu N/m + 1)} = \\ &= \prod_{i=1}^{\nu n/m} \frac{N+1-i}{H-i}, \quad H > \nu n/m \end{aligned} , \quad (9)$$

At big $N=N_a$ estimations (6) and (9) practically coincide, however even for the most favorable case corresponding to USs random territorial accommodation (m=2) and free-space RWP (H =2) these estimations exist only for the 2-d, 3-rd and other signals on intensity, and are absent for a highest-level (prevailing) signal in a point of supervision. Estimations of danger of excess in this point of the defined threshold level by intensity of a prevailing signal are given in [1]. Expressions (6), (9) allow to calculate total intensity of all other signals in a point of supervision, summing average values of signals intensity of all others $N_a$-1 (using (6)) or N-1 (using (9)) signals accept prevailing signal intensity.

Absence of initial moments for a signal of prevailing level (for the most powerful US signal) at (6) and (9) is the main reason of that stages 2 and 5 in a technique of [3] are made separately: at a stage 2 an expected intensity of EMF background from the USs in a vicinity of a point of supervision is defined, and at a final stage 5 models (3),(4)/(7),(8) in the form of an expression (2) for estimation of probability of exceeding by the sum of an electromagnetic background from all sources are presented in SSO region, including the USs in a vicinity of a considered point, and EMF of the nearest active US (or prevailing US's EMF).

Thus, at constant density c of USs in a vicinity of a point of supervision total intensity of an electromagnetic background in this point as scalar sum $S_{Y2}$ of values of power flux density expressed in W/m$^2$ on the given point from EMR of ambient USs, except for the nearest US (radio transmitters of the second group), is defined by an expressions:

$$S_{\Sigma 2} = \frac{P_{etr}\rho_e}{4}\sum_{H=2}^{int[N_a]}\frac{1}{H-1}, \quad P_{etr} = \frac{P_{etr\,max}}{2+\nu}; \qquad (10)$$

$$S_{\Sigma 2} \approx \frac{P_{etr}}{4R_0^2}N_a^{1,12}, \quad N_a = \pi R_0^2\rho_e; \qquad (11)$$

In these expressions for $S_{Y2}$, given in W/m$^2$, value c should be expressed in US/m$^2$, radius of vicinity $R_0$ - in meters, and average EIRP of US $P_{etr}$ - in watts; for free=space RWP H=2, for RWP with presence of direct and reflected rays H≈4. Dependences (10), (11) are illustrated by curves in Fig. 1, received for $R_0$=300m, $P_{etr}$=0,1W. In this figure the continuous line corresponds (10), a dashed line - to approximation (11). It is easy to notice, that in the given special case at c>0,3 calculated average intensity of an electromagnetic background exceeds size of a maximum permissible level of -20 dBm/sm$^2$ (0,1 W/m$^2$), regulated by effective standards [2,4].

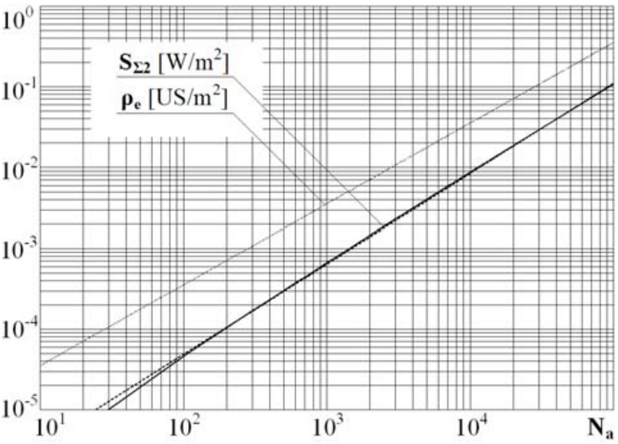


Figure 1.

USs terrestrial density $c_e$≈0,3 is quite real for places of a mass gathering of people (different "waiting rooms", gates of air terminals, stadiums and arenas, etc). And MPL 0,02 W/m$^2$, accepted in Moscow and Paris, are exceeded at $c_e \approx 0{,}07$ (one radiating US on 15 m$^2$) that in conditions of modern city is not a rarity.

### The Probability of Excess of Relative MPL by Tolal EMF intensity

The estimation of probability (risk) of exceeding of MPL value in an any point of SSO by the total relative EMF intensity formed as a cumulative EMF intensity of radio transmitters of the first, second, third and fourth groups, and relative EMF intensity of the strongest US signal (as a rule, from nearest cellular US) for GSM 900/1800 networks (radio transmitters the fifth group) is made in [3] with use of the curve in Fig. 2. This curve is constructed in the following coordinates:

– abscissa corresponds to values of total relative EMF intensity produced by transmitters of the first, second, third and fourth groups which is defined by (12):

$$X = \frac{S_{\Sigma 1} + S_{\Sigma 2}}{S_{MPL1}} + \sum_{k=1}^{2}\frac{S_{\Sigma 3k}}{S_{MPL3k}} + \sum_{j=1}^{4+M}\left(\frac{E_{\Sigma 4j}}{E_{MPL4j}}\right)^2 \le 1; \qquad (12)$$

where $S_{Y1}$ and $S_{Y2}$ are total values of EMF intensity for first and second groups of radio transmitters correspondingly, $S_{Y31}$ and $S_{Y32}$ are total values of EMF intensity for first and second kinds of radio transmitters of the third groups (radars) for which the different MPL levels $S_{MPL31}$ = 1 W/m$^2$ and $S_{MPL32}$ = 0.25 W/m$^2$ correspondingly [2,4] are defined; $(E_{Y41})^2$ – $(E_{Y44})^2$ are total EMF intensity of radio transmitters of the fourth group for each of considered four frequency sub-ranges less 300 MHz for which various MPL $E_{MPL41}$ - $E_{MPL44}$ [V/m] are established (radio transmitters of the fourth group); M is a number of taking into account EMF produced by TV transmitters of frequency range up to 300 MHz for which an MPL dependence on number of TV channel in [2,4] is established;

– ordinate axis corresponds to values of territorial density ce [US/m2] of radiating US in a considered part of SSO.

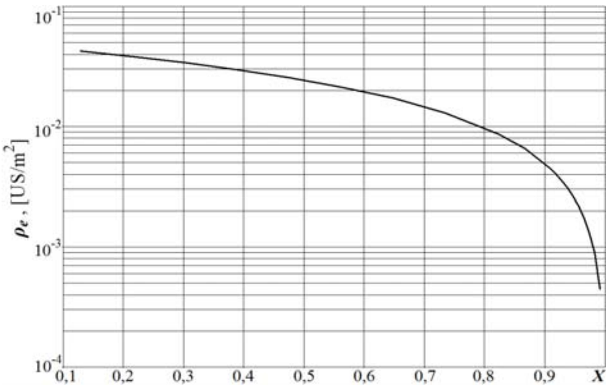


Figure 2.

On the final stage of the estimation of compelled ecological risk on SSO territory for people health because of the influence of the EMF created by BS of cellular communications and WBA in places with its high spatial density (and, of course, taking into account EMF created by all other essential sources) it is stipulated to make the following:

– To find the value of total relative EMF intensity produced by transmitters of the first, second, third and fourth groups using (12) and mark this X value on X axis of Fig. 2 by imaginary vertical line,

– To find on this imagined vertical line a point corresponding to predicted value of territorial density ce of US of GSM 900/1800 and to define, where this point is: above or below a curve in Fig. 2.

The area above a curve in Fig. 2 is area of the inadmissible compelled ecological risk and corresponds to values of $c_e$ at which probability of non-exceeding of MPL in a considered place of SSO by the total EMF intensity formed by EMF of radio transmitters of all five groups are lower than 0,99.

The area below a curve in Fig. 2 is area of the acceptable compelled risk and corresponds to values of $c_e$ at which probability of non-exceeding of MPL in a considered place of SSO by the total EMF intensity formed by EMF of radio transmitters of all five groups are greater than 0,99.

Additionally it is necessary to take into consideration the following:

– At definition of the EMF levels of components used at calculation of relative EMF intensity (12), can be used both the rated data, and the data received by measurements, for example, as a result of EME monitoring on SSO territory.

– If a result of an estimation of total relative EMF intensity produced by radio transmitters of 1, 2, 3 and 4 groups in any point of SSO territory using the equation (12) X>1 is obtained then the analyzed variant of BS allocation or upgrading admits unacceptable as not satisfying conditions of electromagnetic safety of the population.

– The curve in Fig. 2 is calculated for two-band network GSM 900/1800 for which it is accepted, that intensity of connections in sub-band 1800 MHz is three times higher than intensity of connections in sub-band 900 MHz because number of GSM frequency channels in sub-band GSM-900 is 3 times less than in sub-band GSM-1800; for this case it is accepted $P_{etr\ max} = 0{,}25$W taking into account that US antenna gain is 2.0-2,2 dB and therefore $P_{etr\ max} \approx 0{,}2$W for GSM-1800 and $P_{etr\ max} \approx 0{,}4$W for GSM-900.

– For US of 3G networks $P_{etr\ max} = 0.4$W for IMT-MC-450, $P_{etr\ max} = 0.4$W for UMTS in a mode of voice messaging and taking into account that US antenna gain. In a mode of data transmission both in 2G networks GSM 900/1800, and in 3G/4G networks (IMT/UMTS, LTE, etc.) level of $P_{etr\ max}$ can considerably exceed values used in a mode of voice messaging. Therefore values of $P_{etr\ max}$ in these networks must be defined more exactly in each concrete case in view of used versions, settings and options of these radio networks.

In equations (2), (10) variable $P_{etr\ max}$ is a factor of product $c_eP_{etr\ max}$. Therefore in real cases when simultaneous functioning of cellular networks of various frequency ranges, standards and generations with various values of $P_{etr\ max}$ and different modes (of voice messaging and data transmission) takes place, equations (2), (10) and the curve in Fig. 2 can be used only after corresponding equivalent updating of predicted values of $c_e$. In similar situations the estimation of probability (compelled risk) of excess of MPL value in an any point of SSO by total relative EMF level produced by all number of EMF of radio transmitters of all groups (including all different transmitters of the fifth group) can be made with use of the curve in Fig. 3. This curve is received as the generalization of curve in Fig. 2 and is given in coordinates {X, Y=$c_eP_{etr\ max}$}. The technique of use of the curve given in Fig. 3 is similar to a technique stated above for the curve on Fig. 2.

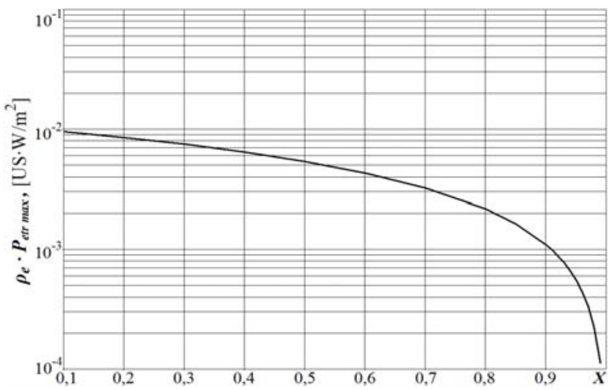


Figure 3

At the forecast of the expected average US territorial density in critical places or points of SSO in [3] a number of typical values of $c_e$ are recommended. These typical values are calculated for situations when the population territorial density is equal to US (on radiating and sleeping modes) territorial density; these values are placed below in table.

| Situations | Terrestrial density, US/m$^2$ |
|---|---|
| Places of local very high people density in urban area | 0,01-0.1 |
| SSO, insight buildings | 0,01-0,05 |
| SSO, on territory and in a vicinity | 0,001-0,01 |

In whole, the technique [3] assumes an attentive attitude to the forecast values of $c_e$ which must be carried out for the period of the maximal traffic intensity in cellular networks. In disputable situations application of the data concerned network statistics of cellular companies for the corresponding service zones is supposed.

## Conclusiion

The approach realized in [3] and presented above, is used in Republic of Belarus at an estimation of compelled risk for health of the population under the influence of EMF, created by systems of cellular communication and WBA in conditions of presence of EMF background produced by radio transmitters of all radio services. This analysis is provided in social - significant objects - in preschools and general educational establishments, children's boarding schools and boarding houses, the areas of public health services for children, health improvement camps and on its territories. Application of presented technique is possible also in all other cases where the profound estimation of conformity of electromagnetic environment to requirements of electromagnetic ecology and electromagnetic safety in places with high population density is necessary to perform.

Mathematical models presented above are not empirical, they are received on the basis of rigorous mathematical modeling of statistical characteristics of electromagnetic environment with use of the initial data adequate to the basic properties and mechanisms of functioning of modern mobile communications of second and third generations and WBA systems. Therefore they can be used at various peculiarities and variants of realization of these networks and systems. As it has been shown above, in equations (2), (10) parameter of US spatial density and parameter of maximal power of US electromagnetic radiation are present in composition $c_e \cdot P_{etr}$ that provides practical invariance of the stated technique in relation to the used standard of cellular communication.

Results of estimation of compelled risk for people health under the influence of EMF, created by systems of cellular communication and WBA in conditions of presence of EMF background produced by all radio services are used at decision-making on an opportunity of suggested variant of BS allocation or modernization on SSO or in its vicinity:

– If result of analysis by a technique [3] is that total relative EMF intensity exceed of MPL value with probability more than 0,01, the offered variant of BS allocation or upgrading is rejected, and
– this result also may be the reason of restriction of use of mobile telephones and Wi-Fi / WiMax equipment in SSO territory, and also the reason of more wide using of alternative technologies (traditional wire telecommunication, optical fiber channels, etc.) in this object.
– If result of analysis by a technique [3] is that total relative EMF intensity exceed of MPL value with probability less than 0,01, the offered variant of BS allocation or upgrading is approved.

## References


1. V.Mordachev, "System Ecology of Cellular Communications", Belarus State University Publishers, 2009, 319 p. (in Russian).
2. "Hygienic requirements to installation and operation of systems of cellular communication", Sanitary Norms, Rules and Hygienic Specifications authorized by the Decision of Ministry of Health of Belarus №14 dt. 01.02.2010 (in Russian).
3. "Estimation of Risk for Health of the Population from the Electromagnetic Fields Created by Base Stations of Cellular Mobile Telecommunications and Broadband Wireless Access. Application Instructions", Authorized by the Ministry of Health of Belarus 28.06.2010, Registr. No. 093-0610 (in Russian).
4. "Electromagnetic Radiations of a Radio-Frequency Range (EMR RF)", Sanitary Rules and Norms 2.2.4/2.1.8.9-36-2002, (The Russian Federation).
5. "Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)", "Health Physics", April 1998, Vol.74, No.4, pp.494-522.
6. V.Mordachev, "Mathematical Models for Radiosignals Dynamic Range Prediction in Space-Scattered Mobile Radiocommunication Networks", IEEE VTC Fall, Boston, Sept. 24-28, 2000.
7. V.Mordachev, S.Loyka, "On Node Density – Outage Probability Tradeoff in Wireless Networks", IEEE Journal on Selected Areas in Communications (Special Issue on Stochastic Geometry and Random Graphs for the Analysis and Design of Wireless Networks), v.27, No.7, p.1120-1131, Sept. 2009, pp.1120-1131.
8. V.Mordachev and S.Loyka, "Statistical Properties of Electromagnetic Environment in Wireless Networks, Intra-Network Electromagnetic Compatibility and Safety", Proc. of the 9-th Int. Symp. on EMC "EMC Europe 2010" joint with 20-th Int. Wroclaw Symp. on EMC, Poland, Wroclaw, Sept. 13-17, 2010, pp.619-624.
9. V.I.Mordachev, "Estimation of the Level of the Electromagnetic Background Formed By Mass Use of Cellular Communications", Proc. of the VIII-th Int. Symp. on Electromagnetic Compatibility and Electromagnetic Ecology, Saint-Petersburg, Russia, June 16-19, 2009, pp.249-252.
10. "Methodology For The Calculation of IMT-2000 Terrestrial Spectrum Requirements", Rec. ITU-R M.1390.
11. Report UMTS Forum N6 UMTS/IMT-2000 Spectrum.