The Compelled Environmental Risk at Occurrence of the Overall Electromagnetic Field Created by the Mobile and Fixed Radio Equipment

Vladimir Mordachev
EMC R&D laboratory
Belarusian State University of Informatics and Radioelectronics
Minsk, Belarus
emc@bsuir.by

Abstract—**The technique of an estimation of the compelled environmental risk for people health because of the influence of the total electromagnetic field (EMF) created by all fixed transmitters of all radio services and taking into account the contribution to total field intensity of electromagnetic radiations of mobile telephones is submitted. The novel probabilistic criterion of electromagnetic safety of population is used - the criterion of excess by total relative EMF intensity (including totality of quasi-stationary and stochastic components) of the maximum permissible level, with probability no more then one percent. Procedure of application of this technique at estimation of electromagnetic safety in places with intensive use of mobile phones is given.**

Keywords - electromagnetic environment, ecology, safety, compelled risk, radiotelecommunications

I. 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 overall intensity of EMF on urban and suburban territories produced by base stations (BS) of cellular communication (CC) and wireless broadband access (WBA) placed on these territories. For last 20 years total EMF intensity in cities increased approximately for 1-2 orders, 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 mobile radio communication users radio devices (URD) 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.

Peculiarity of estimation of environmental safety of URD is that widely used parameter “Specific absorption rate” (SAR) of URD allows to characterize only voluntary ecological risk for health of its owner, and is unsuitable for the analysis of influence of the contribution of electromagnetic radiation (EMR) of URDs in total electromagnetic background and in an increasing of the compelled ecological risks for health of people in ambient space.

Conception of system ecology of CC developed in [1] has allowed to substantiate the approaches regulating a technique of an estimation of compelled risks for the population’s health, caused by presence of all assemblage of EMF generated by fixed and mobile radio equipment and systems of various radio services and frequency ranges, placed (installed, used) on objects or areas with high population density and/or of increased ecological requirements. In particular, according to requirements of the accepted Regulations [2,3] this estimation should be made in following situations:

- At designing of BS of CC or WBA at a stage of a selection of places and spatial parameters of its allocation in object territory and/or in its vicinity, and
- At modernization of BS radio equipment of CC or WBA, including replacement old or installation new radio transmitting modules and equipment, antennas and feeding lines; changing of height or allocation of antenna masts, etc.

Novelty of results stated in this paper is in following:

- in practical application of the threshold probabilistic criterion for electromagnetic safety of population – an excess of the maximum permissible level (MPL) of EMF by total relative EMF intensity with probability no more then 1%,
- in practical application of the total relative EMF intensity as a sum of two components - the quasi-stationary component formed by EMR of fixed transmitters of different radio services and EMR of URD located in the far terrestrial zone with respect to place of sight, and stochastic components formed by EMF of URD located in the vicinity of this place, and
- in mathematical models and approaches used for estimation the compelled environmental risks at occurrence of the overall EMF created by the fixed and mobile equipment of different radio services.

The paper is organized as follows. The main principles of assessment of compelled electromagnetic risks at occurrence of the overall EMF created by the fixed and mobile EMF sources are briefly summarized in Section II. The basic stages of the analysis of the considered compelled ecological risks for population are described in Section III. The basic mathematical approach to the representation of the total intensity of EMF produced by URDs is presented in Section IV. The technique of estimation of the probability of excess of relative MPL by overall EMF intensity is given in Section V. Finally, advantages and results of practical application of this technique at estimation of electromagnetic safety in places with intensive use of mobile phones are summarized in Conclusion.

II. Principles of Assessment of Compelled Electromagnetic Risks

A. Principle of Total EMF intensity.

This principle provide an estimation of total EMF intensity in the place of sight (on object) and its vicinity produced by all radio services, and the analysis of possible alternative variants of EMF sources allocation or upgrading and the subsequent choice of the best variant at which the minimum level of total EMF intensity will be received.

B. Principle of Total EMF representation.

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

C. Principle of Summation of Relative EMF Levels.

A well-known technique [2,3,4] 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 [2,3] an independent maximum permissible levels (MPL) S_{MPLk} of EMF for the population are determined:

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

where S_{km} - intensity of m-th EMF of k-th frequency sub-range or specialized group of radio systems, $S_{\Sigma Mk}$ is total EMF intensity of k-th frequency sub-range or specialized group of radio systems; values S_{km}, $S_{\Sigma Mk}$ 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 EMF component (background) in analyzed place of sight; in (1) a scalar summation of separate EMF power parameters S_{km} is made.

D. 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 component in considered place, the level of each considered EMF component will be not lower then 1% of corresponding MPL: $S_{km} \ge 0{,}01\ S_{MPLk}$.

E. Criterion of unacceptability of the compelled ecological risk in Severe Electromagnetic Environment.

As criterion of unacceptability of the compelled ecological risks in severe multi-component electromagnetic environment (EME) for people in the place of sight, the criterion of excess by total relative EMF intensity X (including totality of quasi-stationary and stochastic components) of the level equal to 1, with probability more then 1%, is used.

F. 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 URD in considered place of territory the results of [1,5-7] are used. They are based on Poisson model of stochastic spatial distribution of radiating URDs and taking into account existence of adjustment of EMR power of URD according to basic radio wave propagation (RWP) losses between BS and this URD.

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

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

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

Here $\rho_e = N_{URD}/m^2$ is a spatial density of radiated URDs in consiered place, its dimension is [URD/m^2], and N_{URD} is an average number of URDs in one square meter of considered territory; $S_{MPL1} = 0{,}1\ W/m^2$ ($10\ \mu W/cm^2$) for a frequency range of cellular communication (> 300 MHz) according to harmonized requirements [2,3]; $P_{etr\,max}$ - maximal average e.i.r.p. of URDs: $P_{etr\,max} \approx 0{,}4$ W for GSM-900 and IMT-450, $P_{etr\,max} \approx 0{,}2$ W for GSM-1800 and UMTS (in consideration of antenna gain of URDs); X is a total relative EMF background intensity calculated taking into account all frequency sub-ranges and specialized groups of radio systems.

III. THE BASIC STAGES OF THE ANALYSIS OF COMPELLED ECOLOGICAL FISK FOR POPULATION

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

Stage 1: calculation of total EMF intensity produced by all BS of all CC 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 URDs of CC on considered 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 considered territory 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 considered territory by total EMF intensity (sum of cumulative EMF background intensity and intensity of EMF produced by the nearest active URD) (radio transmitter of the fifth group).

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

IV. THE TOTAL EMF INTENSITY FROM MOBILE URDS

Basing on reasons [1,5-8], we shall define a vicinity around of some point of supervision, within of which a random territorial accommodation of URDs - sources of EMR, is occur, and it is possible to use model of RWP in free space. The radius of this vicinity ("Break-point" distance) R_0 and its area S_0 are approximately equal to R_0=0,15-0,3 km and S_0=0,1-0,3 km^2 for GSM-1800, IMT-2000 and to R_0=0,05-0,2 km and S_0=0,01-0,1 km^2 for GSM-900. Taking into account estimations [9,10], and also the practically occurred URDs terrestrial density c in places of a mass congestion of people in various conditions with $c=[10^3\div 2\cdot 10^6]$ URD/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 URD/km^2. Thus, in a considered vicinity of a point of supervision number of simultaneously radiating URDs can be $[10^1\div 10^5]$.

At an estimation of total intensity of the electromagnetic background formed by EMR of URDs at random uniform territorial accommodation of URDs in a vicinity of a point of supervision a following models [1,5,6] of probability distribution 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 URDs, placed randomly with Poisson stochastic mode in a vicinity of radius R_0 of a point of supervision (for the H-th distant radiating URD):

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

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

$$D_P \geq 0,\ N_a \geq 0,\ \nu > 0;\ m > 0;\ H > 0; \qquad (4)$$

$\Gamma(H, N_a D_P^{-m/\nu}) = \int\limits_{N_a D_P^{-m/\nu}}^{\infty} \exp(-x)\cdot x^{H-1} dx$ - incomplete Gamma - function of the second kind. At terrestrial type of URDs spatial distribution and free space RWP it is necessary to use m=2, ν=2.

Parameter N_a of this distribution is meaningful an average amount of radiated URDs in some vicinity of a point of supervision. According to [1,5,6] 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 BS/URD radio reception sensitivity Π_{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:

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

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

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

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

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:

$$w(D_{(k)}) = \frac{m\Gamma(N+1)}{\nu\Gamma(H)\Gamma(N-H+1)} \times$$

$$\times\left[1 - D_{(k)}^{-m/\nu}\right]^{N-H} D_{(k)}^{-\frac{m}{\nu}H-1}, k = N - H + 1; \qquad (7)$$

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

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

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

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

At big $N=N_a$ estimations (6) and (9) practically coincide, however even for the most favorable case corresponding to URDs random territorial accommodation (m=2) and free-space RWP (н =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 URD signal) at (6) and (9) is the main reason of that stages 2 and 5 in a given technique are made separately: at a stage 2 an expected intensity of EMF background from the URDs 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 a considered point, including the URDs in a vicinity of this point, and EMF of the nearest active URD (or prevailing URD's EMF).

Thus, at constant density c of URDs in a vicinity of a point of supervision total intensity of an electromagnetic background in this point as scalar sum $S_{\Sigma 2}$ of values of power flux density expressed in W/m^2 on the given point from EMR of ambient URDs, except for the nearest URD (transmitters of the second group), is defined by the following 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 $S_{\Sigma 2}$, given in W/m^2, value c should be expressed in URD/m^2, radius of vicinity R_0 - in meters, and average e.i.r.p. of URDs P_{etr} is in watts; for free-space RWP ν=2, for RWP with presence of direct and reflected rays (RWP models of Vvedensky, of Okumura-Hata, etc.) ν≈4.

Dependences (10), (11) are illustrated by curves in figure 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 $\rho_e > 0{,}3$ 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 [2,3].

URDs terrestrial density $\rho_e \approx 0{,}3$ 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 $\rho_e \approx 0{,}07$ (one radiating URD on 15 m^2) that in conditions of modern city is not a rarity.

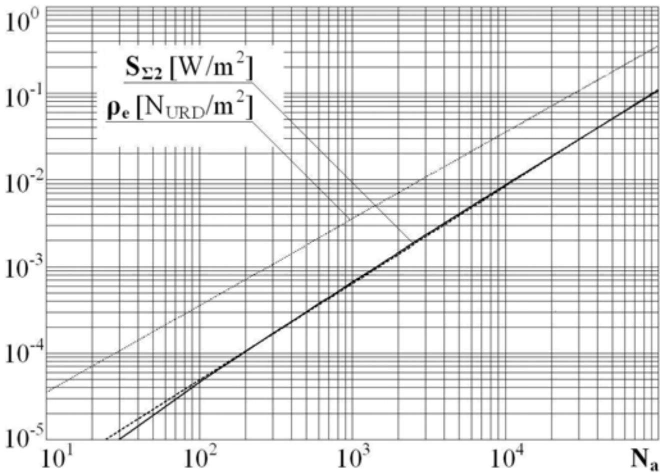

Figure 1. Dependence of the background intensity ($S_{\Sigma 2}$) on the average number of radiating URDs (Na) in vicinity of the supervision place

Urgency of account of URDs EMR at an estimation of the compelled ecological risks is confirmed by experimental data.

On figure 2 the EME spectrograms in the frequency bands of URDs and BS of CC GSM-1800, inside a lecture room - a usual lecture room (the area of 80 sq.m.) of the Belarus state university of informatics and radioelectronics, located in the center of Minsk, are resulted. Measurements are carried out in a verification mode of the relative root-mean-square value of EMF intensity (EAV CISPR).

The first spectrogram corresponds to a situation when URDs of all people present here are switched - off. On the right part of the spectrogram an intensive cumulative EMR of BS of all GSM-1800 networks (3 operators of GSM-900/1800 & UMTS) is observed. The EMR founded in the left half of spectrogram and with levels on 15-25 dB lower than levels of EMR of BS, belong to URDs, located outside of a lecture room in territory of university and in affiliated city areas (in GSM-1800 networks the frequency band of URD's EMR is 1710 … 1785 MHz, for BS's EMR - 1805 … 1880 MHz).

The second spectrogram corresponds to a situation when in this lecture room simultaneously 14 URD owners talk by URD or try to communicate with CC network. And although not all of them received a resource in a frequency band of GSM-1800, EMF levels in this room produced by URDs inside the lecture room are comparable and even exceed on 10-15 dB levels of

EMF produced by BS located on university area and in its vicinity.

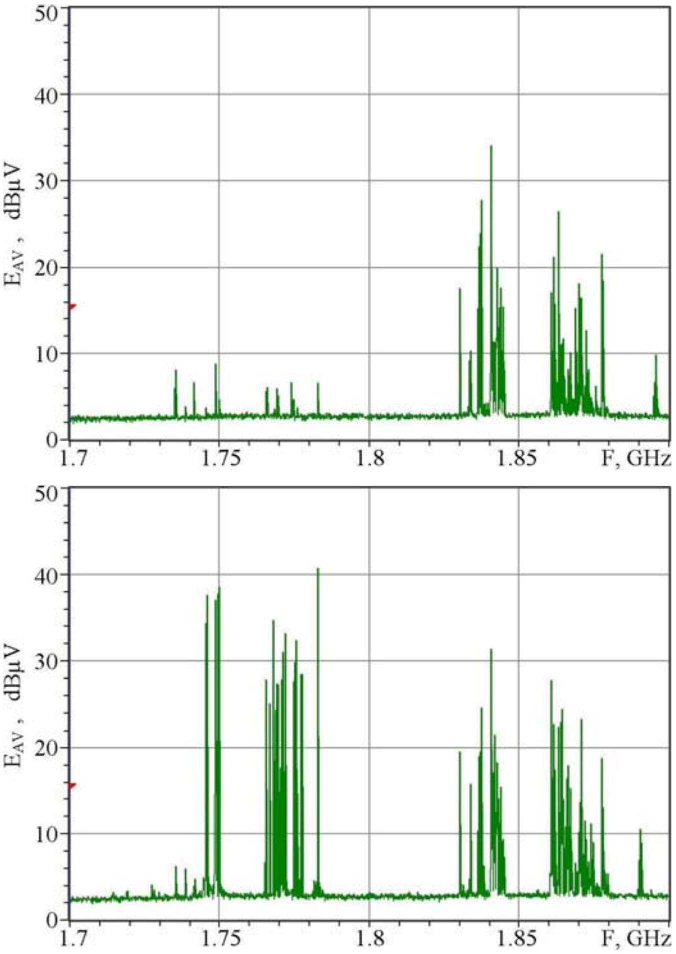

Figure 2. Relative mean-square values (E_{AV}) of EMR of URDs (1710-1785 MHz) and BS (1805-1880 MHz) in GSM-1800 band

V. 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 considered place 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 URD's signal (as a rule, from nearest URD) of CC (radio transmitters the fifth group) can be made with use of the curve in figure 3. 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):

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

  where $S_{\Sigma 1}$ and $S_{\Sigma 2}$ are total values of EMF intensity for first and second groups of radio transmitters correspondingly, $S_{\Sigma 31}$ and $S_{\Sigma 32}$ 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 [2,3] 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 [2,3] is established;

- ordinate axis corresponds to values of product of terrestrial density ρ_e [N_{URD}/m^2] of radiating URDs in a considered place and of the maximal average e.i.r.p. of URD $P_{etr\ max}$.

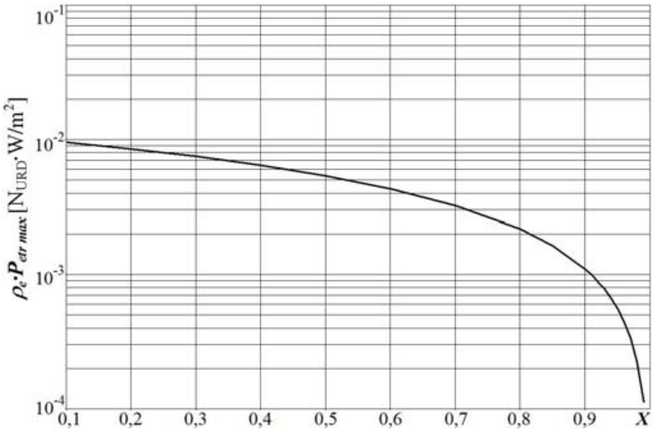

Figure 3. Dependence of the maximum permissible level of the relative EMF intensity produced by the nearest URD, on the average terrestrial density of radiating URDs (ρ_e) and maximal average e.i.r.p. of URDs ($P_{etr\ max}$)

On the final stage of the estimation of the compelled ecological risk on considered territory for people health because of the influence of the EMF created by BS of CC 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 figure 3 by imaginary vertical line,

- To find on this imagined vertical line a point corresponding to predicted value of territorial density ρ_e of URDs of CC and to define, where this point is: above or below a curve in figure 3.

The area above a curve in figure 3 is area of the inadmissible compelled ecological risk and corresponds to values of ρ_e at which probability of non-exceeding of MPL in a considered place 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 figure 3 is area of the acceptable compelled risk and corresponds to values of ρ_e at which probability of non-exceeding of MPL in a considered place 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 considered 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 considered territory using the equation (12) the X>1 is obtained then the analyzed variant of BS or other radio equipment allocation or upgrading admits unacceptable as not satisfying conditions of electromagnetic safety of the population.
- If curve in figure 3 is used for two-band network GSM 900/1800 in which the 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); then for this case it is necessary to accept $P_{etr\ max} = 0{,}25$W taking into account that URD's 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 URDs 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 URD 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 $P_{etr\ max}$ and ρ_e in these networks must be defined more exactly in each concrete case in view of used versions, settings, options and maturity of these radio networks.

In equations (2), (10) variable $P_{etr\ max}$ is a factor of product $\rho_e P_{etr\ max}$. 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 figure 3 can be used only after corresponding equivalent updating of predicted values of ρ_e.

At the forecast of the expected average URDs terrestrial density in critical places or points of considered area a number of typical values of ρ_e are recommended. These typical values are calculated for situations when the population and the URDs (both on radiating and sleeping modes) terrestrial densities are equal; these values are placed below in Table 1.

In whole, the technique given above assumes an attentive attitude to the forecast values of ρ_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.

TABLE I. TOTAL TERRESTRIAL DENSITY OF RADIATING URDS IN CC

Situations	**Terrestrial density, N_{URD}/m^2**
Places of local very high people density in urban area	0,01-0,1
Object territory, insight buildings	0,01-0,05
Object vicinity, on urban territory	0,0001-0,01

VI. CONCLUSIION

The approach presented above are appropriated for estimation of the compelled risk for health of the population under the influence of EMF, created by fixed and mobile radio equipment of CC and WBA networks in conditions of presence of EMF background produced by radio transmitters of all radio services.

Mathematical models presented above are not empirical, they are received on the basis of rigorous mathematical modeling of statistical characteristics of EME with use of the initial data adequate to the basic properties and mechanisms of functioning of modern CC of 2G, 3G and 4G, 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 URDs spatial density and parameter of maximal power of URD's EMR are present in composition $\rho_e \cdot P_{etr}$ that provides practical invariance of the stated technique in relation to the used CC standard or generation.

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", authorized by the Decision of Ministry of Health of Belarus №14 dt. 01.02.2010 (in Russian).

[3] "Electromagnetic Radiations of a Radio-Frequency Range", Sanitary Rules and Norms 2.2.4/2.1.8.9-36-2002, (The Russian Federation).

[4] "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.

[5] V.Mordachev, "Mathematical Models for Radiosignals Dynamic Range Prediction in Space-Scattered Mobile Radiocommunication Networks", IEEE VTC Fall, Boston, Sept. 24-28, 2000.

[6] 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.

[7] 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.

[8] 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.

[9] "Methodology For The Calculation of IMT-2000 Terrestrial Spectrum Requirements", Rec. ITU-R M.1390.

[10] Report UMTS Forum N6 UMTS/IMT-2000 Spectrum.