Methods for Controlling Levels of Electromagnetic Radiation in Indoor Spaces

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Abstract - **We propose a model of a system for control of resistance levels of electronic systems with regard to electromagnetic noise in indoor spaces, which allows analyzing cumulative averages of electromagnetic fields of concentrated sets of radiation sources.**

Keywords - **electromagnetic radiation, simulation model, tension, control, protection.**

The rapid development of wireless telecommunication systems, such as mobile telephony, satellite radio, wireless local networks and Internet technologies of Wi-Fi and Wi-MAX poses significant problems for ensuring electromagnetic compatibility and stability of electronic equipment [1]. Concentrated sets of low-power electronic devices operating indoors create a complex spatial-temporal structure of electromagnetic field. We have previously proposed a simulation technique for predicting possible negative impact of concentrated sets of electronic devices on their environment. [2, 3].

The overall result of simultaneous operation of any number of electronic devices at some point in space can be formalized as

$$Y = F(X_1; X_2; ...; X_n), \quad (1)$$

where Y is a response function that which depends on a number of factors X_n. (Fig. 1).

These factors include environment properties at the location, overirradiation and screening barriers, presence of secondary radiation sources, the heterogeneity of landscape and plants, soil conditions, etc.

These factors are random in nature and affect the character of propagation of radio waves substantially. Under these conditions, the intensity of electromagnetic radiation is a random variable, which can be represented as a generalized sum of a set of random arguments E_i**:**

$$E = F(E_1; E_2; ...; E_n) \approx E_i, \quad (2)$$

The indoor space under real conditions serves as a medium for propagation of radio waves and the level of an electric component of electromagnetic radiation at an arbitrary point of this environment has random value.

Thus the task of predicting and controlling electromagnetic field of a concentrated set of electronic devices in a random place of some indoor space can be solved with a simulation model which allows obtaining qualitative and quantitative values of parameters of electromagnetic radiation.

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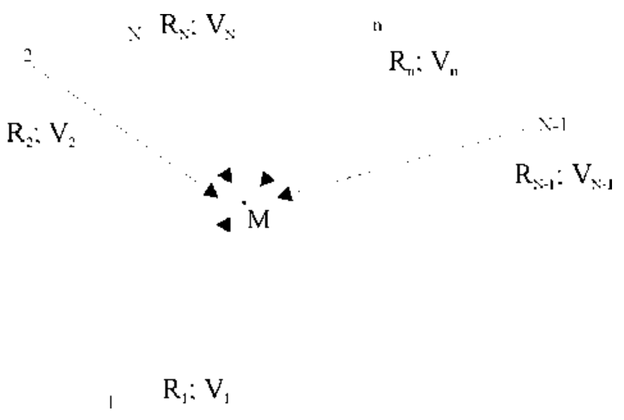

Fig. 1 Definition of the average level of electromagnetic radiation

Let’s assume that **N**>>1 sources of electromagnetic radiation are located in certain indoor space. Each of the sources emits electromagnetic radiation of certain level to the ambient space and the intensity of the electric field can be defined by the following equation:

$$E = (30 \cdot P_A \cdot G_A \cdot \eta_\delta)^{0,5} V / R, \quad (3)$$

where P_A is the power of a radiation source; G_A is an amplification factor of an antenna relative to isotropic radiator; η_ϕ is efficiency of the antenna-feed system; V is a decay factor for field intensity in free space; and R is the distance between the radiation source and the point chosen.

Since the chosen point has a random location, all distances R and factors V are random variables. In addition, in further calculations we assume that the efficiency of antenna-feed system is 1 **(**$\eta_\phi \approx 1$**).** In general, the distance between a radiation source and a selected point is calculated relative to the geometric center of the radiation source antenna.

According to the effective regulations, for evaluation of electromagnetic environment safety, the magnitude of electromagnetic energy flow is compared to the maximum allowable level, defined therein. Changing from field intensity to the magnitude of electromagnetic energy flow we use the following formula for a remote zone:

$$\Pi = E^2 / Z_c, \quad (4)$$

where Z_c is the environment impedance.

Then a period average of Poynting vector for the n-th radiation source is determined by the following formula:

$$\Pi_n = P_{An} \cdot G_{An} \cdot V_n^2 / 4\pi R_n^2, \quad (5)$$

The total average level of electromagnetic field induced by concentrated radiation sources in an arbitrary, randomly chosen point will be

$$\Pi_{cp} = \Sigma \Pi_n, \quad (6)$$

It should be noted that in reality, only some random subset of $z \leq N$ radiation sources operates at the chosen moment. So more precise form of the previous equation is

$$\Pi_{cp} = \Sigma p_n \Pi_n \, , \qquad (7)$$

where p_n is the probability that n-th radiation source operates at the moment.

The values of P_{An} and G_{An} are deterministic and can be calculated from the characteristics of the radiation sources, while V_n and R_n are stochastic variables. This is the final formula (7) to simulate an average level of electromagnetic radiation induced by a concentrated set of radiation sources in an arbitrary chosen point.

We have developed an expert system [4, 5] for determining the power of radiation sources that occur in indoor spaces of buildings due to strong external electromagnetic influences. In this case, the characteristics of the environment include density distribution of lightning charges for the region, topographic qualities and geometric characteristics of the location.

Using the knowledgebase, we created a number of templates for configurations of buildings and structures, protection schemes, equipment placement and layout of communication lines. Each template has its properties, theoretical level of safety, a set of the most vulnerable areas and an integrated assessment, which is used a weight of the template when comparing it to the others. The developed technique employs panoramic images of a location or existing architectural plans of a plot created in ArchiCAD along with the layouts of underground communications systems, lightning protection, grounding and electric transmission lines. Prior to the analysis, these data are preprocessed with SierraPhoto Home, SolidWorks and a special COM add-in module for SolidWorks. The preprocessing consists in formalization of the image, its conversion to an analyzable format, building 3D models, detecting the most vulnerable areas and their mapping to the available templates. Here we use methods from class libraries swpublished.tlb, swvba.tlb registered in Windows system registry. The software module has a user interface in the form of a modeless dialog box (Fig. 2) displayed as a topmost window on the screen. This allows working with SolidWorks [6] and the developed software module simultaneously.

The proposed methods for controlling electromagnetic radiation levels in indoor spaces allow design-stage development of well-grounded recommendations for placement of electronic equipment in buildings taking into account topology of communications, external safety systems and overall electromagnetic conditions.

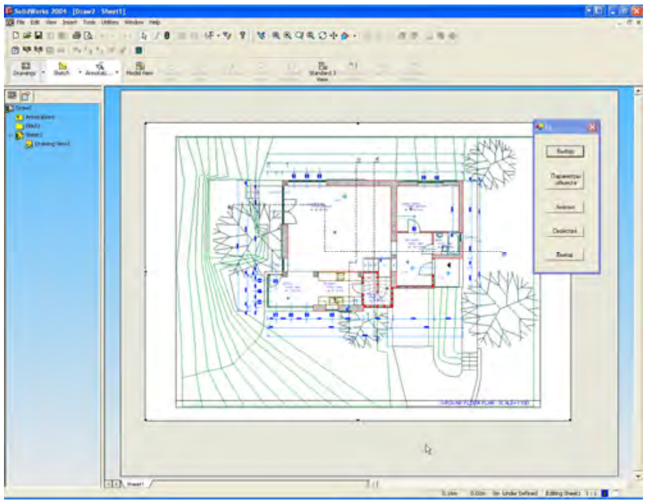

Fig. 2 Working with SolidWorks software module

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