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Application of Hardware-Software Complex for Monitoring of Electromagnetic Environment

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Abstract

The article describes the principles of functioning of the hardware-software complex, which purpose is the estimation of a danger level of the combined electromagnetic field influence on a human organism. The complex consists of the hardware and the software parts. The hardware part is an array of electromagnetic parameter detectors; the software part is an electromagnetic field modelling program based on OpenEMS. The complex creates so-called images of electromagnetic environment danger. The results show practical applicability of the hardware-software complex for the stated purpose.

Keywords: Electromagnetic Environment; Electromagnetic Field Modelling; Electromagnetic Danger Image

Introduction

At present, the electromagnetic field created by anthropogenic electromagnetic field sources is a valuable factor of danger in both domestic and industrial applications [1-30].

The research conducted [31,32] shows that the measured electromagnetic field levels generated by operation of various electrical equipment may drastically exceed the Maximal Permissible Level (MPL) of electromagnetic field on some frequencies. That means that simultaneous influence of multiple electromagnetic field sources should be taken into account when considering electromagnetic field parameters.

The research should solve the problem of estimating the level of the danger of the personnel staying in the zone of the influence of an electromagnetic field caused by multiple sources. The results will help to choose reasonably the measures to protect the personnel; these measures will be based on the new principles of multi-frequency control of the electromagnetic field parameters.

Description

There is a special hardware-software complex designed to automate the electromagnetic field measurement process and to create the images of danger in the zones of influence of multiple electromagnetic field sources on various frequencies. The complex allows to monitor the measurement results in the real time, and to analyze the danger image of electromagnetic field.

The hardware-software complex consists of the following blocks:

- A measurement devices block (one possible variant is ST-01, MTM-01, P3-50, BE-meter AT-004 and P3-41 devices to measure, correspondingly, electrostatic; magnetostatic; alternate electric and magnetic fields on industrial frequency, i.e. 50 Hz; electric and magnetic fields on radiofrequency, i.e. 30 kHz - 30 MHz; energy flow density on 300 MHz - 300 GHz, together with AKS-1201 spectrum analyzer)
- A block of device adapters designed to connect the measurement devices to PC,
- The specialized PC software to gather and analyze the measurement results.

Figure 1 shows the connection of measurement devices (basic configuration) to a PC.

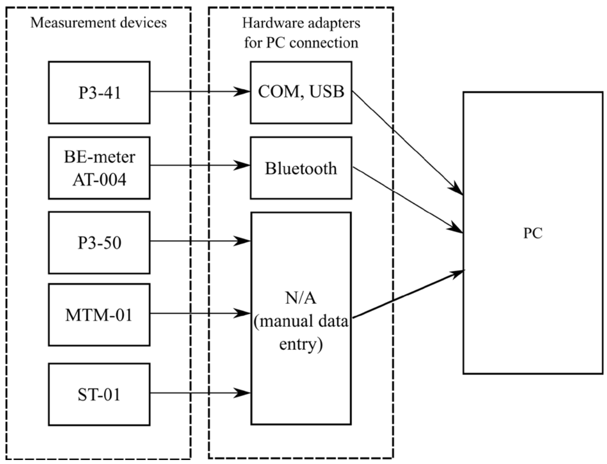

Figure 1: Connection of measurement devices to PC.

Figure 2 is a photo of the typical hardware-software complex configuration for measurement of electric field on frequency of 50 Hz - 330 GHz.

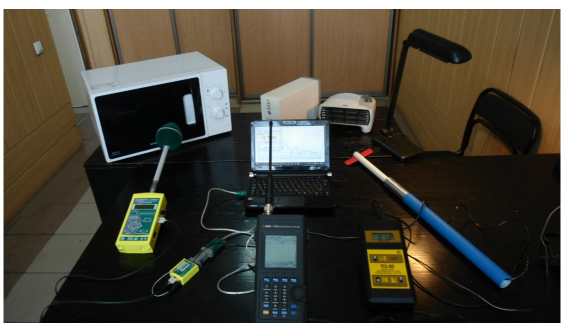

Figure 2: Possible configuration of the hardware-software complex.

Table 1 describes the technical characteristics of the hardware-software complex.

Characteristic title	Characteristic value
Measurement device types	ST-01, MTM-01, P3-50, BE-meter AT-004, P3-41, AKS-1201
Controlled frequency diapasons of the electrical field	0 Hz (electrostatic field), 48-52 Hz, 10 kHz - 300 MHz
Controlled frequency diapasons of the magnetic field	0 Hz (magnetostatic field), 48 - 52 Hz, 10 kHz - 50 MHz
Controlled frequency diapasons of the energy flow density	300 MHz - 40 GHz
Electric power	Embedded notebook batteries and the batteries included into measurement devices; powering from the standard power network is possible
Battery life	From 2 hours (depends on the state of the batteries)

Table 1: The technical characteristics of the hardware-software complex.

PC saves the incoming measurement data into a separate database for every examination. Figure 3 shows the data flow diagram for the experimental data that's written into the hardware-software complex database, and also shows the possible data sources.

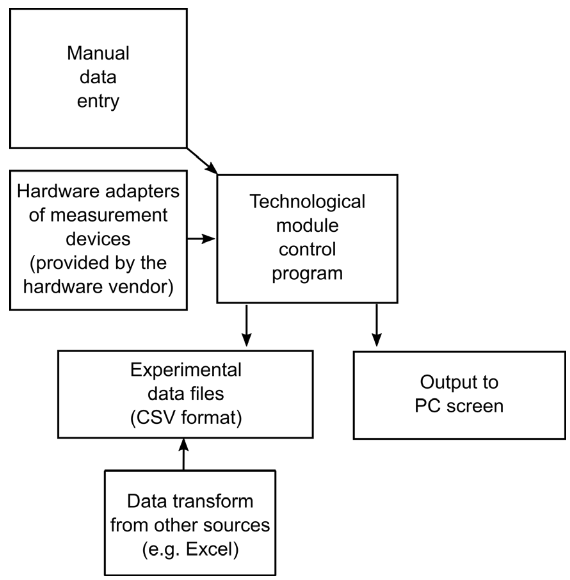

Figure 3: Experimental data flow diagram.

If the measurement device has the adapter that allows connecting it to the PC, then it sends the experimental data directly through the adapter. In case of some older devices, there is no such adapter, and in that case the hardware-software complex allows entering the data manually from the PC keyboard. There's also a possibility to convert existing data into the format compatible with the complex. After the measurement stage, the data is processed using the analytical software included into the hardware-software complex. Figure 4 shows the data processing diagram.

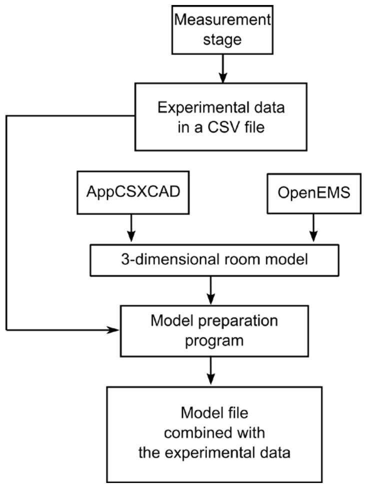

Figure 4: Experimental data processing diagram.

The functioning of the hardware-software complex is based on the following principles.

The digital model of the studied room (including all the electromagnetic field sources) is produced based on the geometric parameters of the facility, and the relative positions of the electromagnetic field sources. Every source is modelled as a 3D box; the model resolution should be 5 cm.

The measurement or every controlled electromagnetic field parameter (i.e. electrical and magnetic field values, energy flow density) is performed in every of the standardized frequency diapasons (i.e. 0 Hz, 50 Hz, 30 kHz - 300 GHz), including the sub-diapasons (30 kHz - 3 MHz, 3 MHz - 30 MHz, 30 MHz - 50 MHz, 50 MHz - 300 MHz) and possibly higher frequencies. The measurement should be performed on the standard distance from every face of every electromagnetic field source in question; the standard distance should be determined by local sanitary rules and norms for every case. The main data collected on this stage is the maximal value of every measured parameter for every accessible face of every electromagnetic field source in the room.

For every frequency analyzed, prepare a computer model of the whole room, to derive the so-called electromagnetic field image for the whole room on this frequency. AppCSXCAD program [11] used to create the 3D models allows to enter some of the electromagnetic parameters of the room on the room plan. Every electromagnetic field source and communication line in the room should be registered as a solid metal object.

See Figure 5 for the sample of 3D room model.

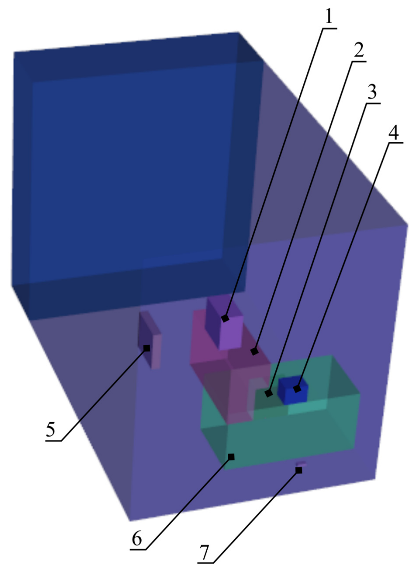

Figure 5: 3D model of a studied room with electromagnetic field sources: 1 - LCD display, 2 - table, 3 - PC system block, 4 - notebook, 5 - electric heating device, 6 - table, 7 - notebook power adapter.

The modeling of the electromagnetic field using the FDTD method [12-14] is performed to estimate the electromagnetic environment based on the measurement data. The core of the method is the partition of the studied space onto pieces of simple form (e.g. cubic mesh) and further modeling of electromagnetic signal propagation through these pieces according to the well-known Maxwell laws in the finite-differential form [13].

The hardware-software complex uses the open-source Open EMS modeling library [15] to perform the calculations. The library provides efficient ways of calculation using the modern CPUs, and allows to dramatically improving the modeling times.

Open EMS library is written in a C^{++} programming language and may be integrated with either MATLAB or GNU Octave modeling environments. The hardware-software complex includes a subroutine written in GNU Octave to invoke Open EMS routines.

Open EMS requires the following inputs to perform the modeling stage:

- 3-dimensional model of the room.
- Known disposition of electromagnetic field sources.
- Frequency of the electromagnetic field.

- Known boundary condition types.

Results and Discussion

The generated electromagnetic field spatial images are used to prepare the so-called electromagnetic field danger image. The hardware-software complex achieves that by transforming the axe of the electromagnetic parameter (e.g. electric field, magnetic field, energy flow density) to the so-called allowed staying time (determined according to the local sanitary norms) axis in every image node.

The zones of the room where multiple danger zones are overlaying may be determined based on the analysis of the images of danger created by controlled components of electromagnetic field. Analysis of the complex case involving multiple electromagnetic field sources operating on different frequencies with overlaying danger zones is a complex task that can have multiple solutions.

One possible solution of gathering the objective danger image is the so-called overlay model. The overlay model takes into account the effect of amplification of danger under the influence of multiple electromagnetic field sources and frequencies. The model is based on processing of the overlay regions of the cylindrical zones of influence of the electromagnetic field sources. The sample of the model applied to the simple electromagnetic environment is shown on Figure 6.

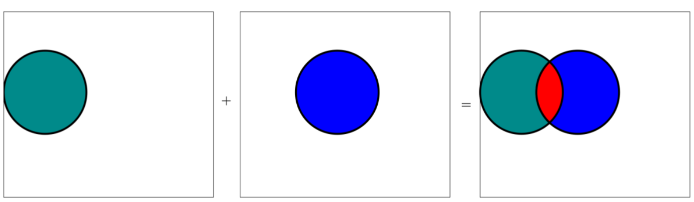

Figure 6: The principle of overlaying the cylindrical danger zones. Red shows the zone of maximal danger, green and blue shows the zones of lesser danger

For industrial conditions, the resulting intersection zone itself may generate the derivative cylinder danger image with the radius based on the size of the local personnel working zone. The resulting electromagnetic danger image (see Figure 7) is a colored image, where the color of every pixel means a value of the allowed staying time. The time scale is usually drawn to right of the image. The scale allows to visually identifying the danger zones of the room.

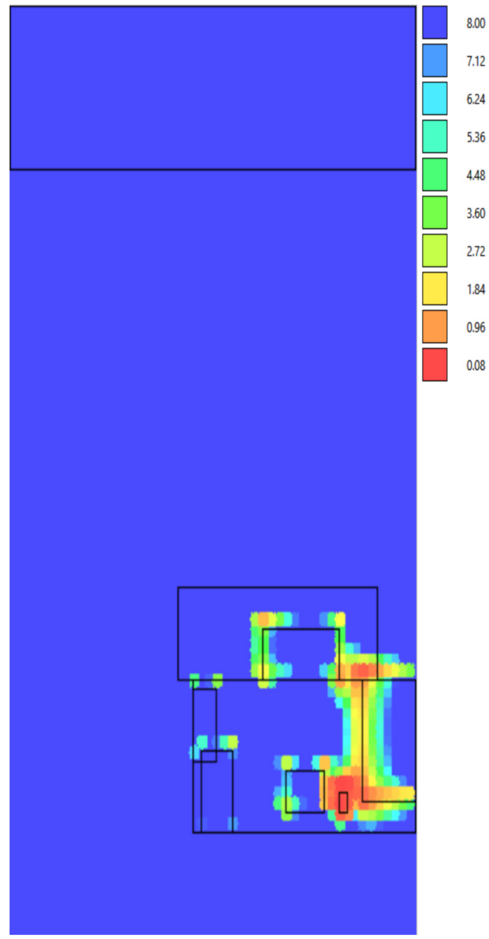

Figure 7: Combined point image of the electromagnetic field (hours of allowed staying time).

When evaluating the electromagnetic field danger inside of the industrial rooms, so-called cylindrical danger image may be used. The main difference between the point and cylindrical picture is the projection method used to prepare the picture. Every pixel of the cylindrical picture accounts the parameters of the electromagnetic field inside of the cylindrical zone (with some predetermined radius based on the industrial requirements) around the pixel. It helps to better consider the working zones of the personnel inside of the industrial room. The sample cylindrical picture of the room is presented on Figure 8.

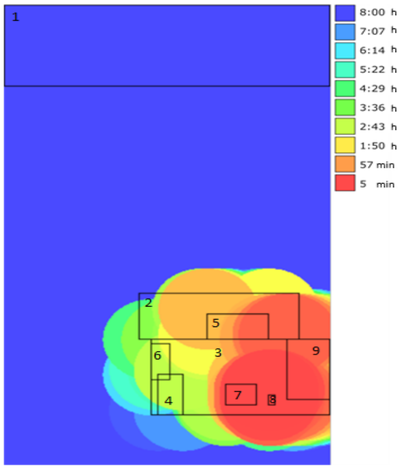

Figure 8: Combined cylindric image of the electrolagnetic field (hours of allowed staying time).

Conclusion

The produced hardware-software complex allows to control the danger levels in the electromagnetic environments that include multiple electromagnetic field sources. For the zones of the rooms with no overlays between the danger zones, the generated images are used to prepare the protective measures based on the values of the controlled electromagnetic field components in the controlled frequency diapasons. For the zones with intersections of multiple frequencies, a complex danger combining algorithm should be used; one perspective model for that is the danger overlay model.

The resulting danger images with refined personnel stay time with the zones of complex electromagnetic field influence are used to derive the protection measures for personnel with respect to frequency diapason for every frequency in the studied room.

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