Calculation Model of the Effectiveness of Electromagnetic Field Protection: Using the Example of a Train Dispatcher's Workplace

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Abstract: An increase in the number and increase in the power of various artificial sources (radio communication, VDT and personal computer, uninterruptible power supply, etc.) lead to a significant increase in the level of electromagnetic radiation in the workplace, which create an additional artificial electromagnetic field that adversely affects human health. One of the most reliable ways to protect against the electromagnetic field is to shield these equipment. The article develops a computational model for calculating the effectiveness of the screen from the effects of electromagnetic fields at the workplace of a train dispatcher.

1 INTRODUCTION

The emission of harmful and dangerous factors at the workplace of a train dispatcher is formed in connection with the indicators of technical means. The electromagnetic field at the workplace of a train dispatcher is mainly created by VDT and personal computers that dispatchers regularly use in their work, as well as electromagnetic waves emitted by an uninterruptible power supply (Eliseeva, 2005; Kudryashov, 2005).

The measurements that were carried out during the certification of workplaces for working conditions showed that the voltage of the electromagnetic field in the workplace of the train dispatcher mainly creates an uninterruptible power supply that provides power to the VDT and personal computers at the workplace. The uninterruptible power supply is located inside the desktop cabinet, and the chair on which the dispatcher sits is placed next to it, due to the need for constant monitoring of data from monitors (Sulaymanov, 2019).

One of the most reliable ways to protect against the electromagnetic field is to shield these equipment. When creating structures that protect against the intensity of the electromagnetic field, various materials (metal or dielectric) are used, which have the property of absorbing or repelling the electromagnetic field in a certain frequency range (Lynkov, 2004; Rakhimbekov, 2017; Odinaev, 2015; Gichev, 1999).

The absorption efficiency of the electromagnetic field is determined by the electrical, dielectric and magnetic properties of the material used for shielding. Due to such properties of the material, electromagnetic energy is absorbed due to dielectric, magnetic and conduction losses. Shielding allows to reduce the level of electromagnetic field intensity to a safe level (Bespalova, 2015).

2 MAIN PART

The shielding is divided into magnetic, electric and electromagnetic fields. Almost always the same dielectric medium is placed on both sides of the screen, and in this case the efficiency of the screen is written as follows (Ovcharenko, 2008):

$$e = 20lg|chkh| + 20lg\left|1 + 0{,}5\left(\frac{z_2}{z_1} + \frac{z_1}{z_2}\right)thkh\right|, \quad (1)$$

where $h -$ screen thickness, mm; $k -$propagation coefficient, mm^{-1};

$z_1 -$ resistance of the medium to the electromagnetic field, Ohms;

$z_2 -$ the resistance of the screen material to the electromagnetic field, Ohms.

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However, the resistance $z_1$in the induction zone depends not only on the type of the main component of the electromagnetic field, but also on the shape of the screen structure.

Taking into account the shape of the screen, the resistancez_1 is written as follows (Ovcharenko, 2008):

When shielding an electric field (Ovcharenko, 2008):

$$|z_1| = \frac{1}{\omega\varepsilon_1 r_* m} \tag{2}$$

When shielding a magnetic field (Ovcharenko, 2008):

$$|z_1| = \omega\mu_1 r_* m, \tag{3}$$

Where m=2 at $r_* = \frac{L}{2}$for a flat screen, m=1 at $r_* = \rho$ for a cylindrical screen, and $m = \frac{1}{\sqrt{2}}$at $r_* = r$for a spherical screen (Ovcharenko, 2008).

When shielding a magnetic field, it is necessary to take into account the individuality of the material from which the screen is made. Usually for magnetic materials (steel, permalloy, ferrite) $\frac{z_2}{z_1} > \frac{z_1}{z_2}$, and for non-magnetic materials (copper, aluminum, lead) $\frac{z_2}{z_1} < \frac{z_1}{z_2}$. In the case that at relatively low frequencies of the electromagnetic field $(f < 10^4 Hz) kh << 1, chkh \approx 1, thkh \approx kh$for protective devices made of magnetic metals, the shielding efficiency is calculated by the formula (Ovcharenko, 2008):

$$e = 20lg\left[1 + \frac{1}{2m}\cdot\frac{\mu_2}{\mu_1}\cdot\frac{h}{r_*}\right] \tag{3}$$

It does not depend on the frequency of the field.

For protective devices made of non-magnetic metals, the shielding efficiency is calculated by the formula (Ovcharenko, 2008):

$$e = 10lg\left[1 + \frac{m}{2}\cdot\omega\mu_1\sigma_1 r_* h\right] \tag{4}$$

This efficiency depends on the frequency and at the frequency $\omega \to 0$ also tends to zero.

In the region of relatively high frequencies$10^4 < f, Гц < 10^9$, it is convenient to determine the screening efficiency by the formula (Ovcharenko, 2008):

$$e = 8{,}686\sqrt{\frac{\omega\mu_2\sigma_2}{2}}h + 20lg\left[\frac{1}{4}\sqrt{\frac{\sigma_2}{\omega\mu_2}}|z_1|\right] \tag{5}$$

In the microwave region covering decimeter, centimeter and millimeter waves ($f \geq 10^9...10^{10}$ Hz), the wavelength λ is commensurate with the diameter of d screen, i.e.$\lambda \geq d$, and the shielding efficiency is oscillatory (Ovcharenko, 2008).

If there are holes or cracks in the screen, which arise as a result of imperfections in its design and production technology, the screening efficiency decreases. In this case, it can be determined by the formula (Ovcharenko, 2008):

$$e = 10lg\left|\frac{\sqrt{2z_1}}{z_2}\right| + A + 8{,}686B \tag{6}$$

where the resistance Z_1 is determined by the formulas (2) (Ovcharenko, 2008):

$$|z_1| = \left|\sqrt{\frac{\omega\mu_2}{\sigma_2}}\right| \tag{7}$$

The summand A and the multiplier B take into account the leakiness of the screen (Ovcharenko, 2008):

$$A = 20lg\left[\left(\frac{2\pi}{k_1 r_*}\right)^{\frac{1}{3}}\cdot(1 - 0{,}5k_1 l)^6\right] \tag{8}$$

$$B = \frac{2\pi h}{l}, \tag{9}$$

where $r_* \approx 0{,}62v^{\frac{1}{3}}$ the equivalent radius of the screen of any geometric shape (v is the internal volume of the screen, mm ^{3}), mm; l is the largest size of the hole (crack) in the screen, mm;

$$k_1 = \omega\sqrt{\mu_0\varepsilon_0} \tag{10}$$

When developing a scheme for calculating the effectiveness of the protective shield, it was based on a convenient technical layout of the dispatcher's workplace and theoretical formulas for calculating the effectiveness of the above-mentioned means of protection against electromagnetic fields (Sulaymonov, 2021).

The working surface of the train dispatcher's workplace consists of two parts, one of which is equipped with a work desk with train schedules. Monitors are installed on the rest of the desktop to track information. An uninterruptible power supply is placed inside the desktop cabinet, consisting of a mini-transformer and a rectifier, which regularly supplies power to VDT and personal computers. Despite the low power of the uninterruptible power supply, it is very close to the place where the dispatcher is located. Therefore, it should be noted that the voltage of the electromagnetic field propagating from it is much higher than the permissible voltage level of the electromagnetic field. It is known that the shielding of an uninterruptible power supply as a means of protection against the effects of electromagnetic field strength is a simple and inexpensive uncomplicated device (Sulaymonov, 2021).

The reduction of the electromagnetic field strength of the uninterruptible power supply can be achieved by covering its body with protective casings and shielding the inner surfaces of the walls of the desktop cabinet (Sulaymonov, 2021).

The efficiency of the screen and casing in shielding was evaluated according to the formula (4) given above.

The developed computational model is two-dimensional, and the shape of the casing and the screen differs from each other. The casing has a semi-cylindrical shape. The inner surfaces of the walls of the table stand are flat. When mathematically expressing the effectiveness of the calculation model, it is necessary to take into account the design parameters, the shape of the protective equipment (cylindrical casing and flat screen). Taking into account the logarithmic expression of efficiency, it is recommended to use the following mathematical expression based on formula (4) to evaluate the overall effectiveness of the protective casing and screen:

$$e_{gen} = 10lg\left[1 + \frac{m_c}{2}\omega\mu_1\sigma_1 r_* h\right] + 10lg\left[1 + \frac{m_п}{2}\omega\mu_1\sigma_1 r_* h\right], (11)$$

where m_c– sphere shape coefficient; $\omega = 2\pi f$– circular frequency, s^{-1}; μ– absolute magnetic permeability, Gn/m; σ– specific conductivity of the medium, Cm/m; r_*– equivalent radius of the screen of any geometric shape, mm; h– screen thickness, mm; $m_п$– flat shape coefficient.

3 CONCLUSION

Thus, the use of screens (cylindrical casing and flat screen) to reduce the level of electromagnetic field intensity, i.e., the opening of the source provides an increase in the effectiveness of the means of protection.

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