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Results of measurement and determination of threshold electric field component for transport security systems

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ABSTRACT

For determining the effect of individual field components on systems is required making measurements i.e. drawing up of the radiation characteristics of interference sources. On the basis on the measurements and model chosen of operation process of the transport security system it is possible to determine the limit values of the electric field components for the two sub-bands to 5 Hz to 100 kHz. The steering system is responsible for the security of the PRT transport: the process of people transferring and/or freight. Any disruption of the basic functions of the steering system can be the cause of the occurrence of human life and health hazards. The presented article discusses the impact of electromagnetic interference: the electric component of the field on the process of the operation of the security system.

Keywords: electromagnetic interference, security systems, electric field

1. Introduction

For a range of low-frequency electromagnetic interference effects process for transport security systems are considered severalty for two components of the field: electric field and magnetic field. Determine the threshold for the impact of the transport security systems (resistance of the device or system) needs to measure the field component E according to the standards. The permissible values of the electric fields was performed on the standard (Fig. 1). Transmission bus safety system was for away from away from the power cable at a distance D_{min} - no interferences packet bus. Those electromagnetic interferences that occur over a vast rail area are the cause of the occurrence of false alarms in transport supervision systems, whose objective is to detect hazards in the transport process (e.g. a fire signaling system). The problem of the influence of electromagnetic interferences in the ELF frequency range of (0-2)kHz and the VLF frequency range of (2-100)kHz on the operation process of supervision systems is not addressed in the world literature.

2. Impact of interference - the electric field component on the transport security systems

When examining the propagation of electromagnetic waves from a lightning discharge in a railway area, one needs to consider two centers where a wave can propagate:

- a free space: propagation of an electromagnetic wave is dependent from the frequency and the components of the signal spectrum;

- inside buildings located in a railway area: attenuation (screening): dependent from e.g. the frequency and power of the signal.

Screening of an electromagnetic field by walls, structural partitions is the effect which is known particularly in the range of higher frequencies and the components of field intensity E for a small frequency range [9, 10]. The cables of a lightning protection installation, which are arranged considerably more rarely than reinforcing bars, cause a reduction of the field inside a railway station: the E component of the field. The effect of screening achieved can be characterized by a parameter known as the screening effectiveness. Denoting the intensity of the field that exists at a given place with no lightning protection installation as E0 and denoting the field intensity in the same place yet with a lightning protection installation as E1, one can define the screening effectiveness as:

$$S_E = 20\log\frac{E_{0\max}}{E_{1\max}} \tag{1}$$

The calculations of the effectiveness of screening for a point located inside the building of a railway station for the different dimensions of the eye of the lightning protection grid are presented in Table 1.

Table 1. Assessment of the effectiveness of screening in the function of the grid eye dimensions [12]

Grid eye [m]	E_{0max}/E_{1mam}	S_E[dB]
20x20	2.16	6.7
10x10	3.22	10.2
5x5	6.19	15.8

When taking into consideration the total spectrum of the lightning discharge signal (up to 100 kHz, 99.6% of the energy of lightning is included): the indexes γ of the impact of interference to the steering and security system will be as follows - for field intensity E γ_E = 1. When taking into consideration the values of the discharge energy included in the frequency range up to 1000 Hz, the indexes γ of the impact on the systems will be as follows respectively:

- γ_{Ed} = 0,8 (the spectrum of the discharge signal was taken into account: field E);
- When taking into consideration the values of the discharge energy included in the frequency range above 1000 Hz to 100 kHz, the indexes γ of impact on the systems will be as follows respectively:
- γ_{Eg} = 0,196 (spectrum of the discharge signal was taken into account: field E);

Above the frequency of 100 kHz, the indexes γ of the impact on the systems will be as follows respectively:

- γ_{Eg} = 0,004 (the spectrum of the discharge signal was taken into consideration: field E).

The indexes γ of the impact of interference on the systems calculated in this manner should be accepted in the case of a system installed in an open area: platforms and railway routes. If the systems are installed in building facilities (a central railway station concourse, a signal-box, built-over rail platforms), the screening activity of the grid eye in a lightning protection installation should be taken into account.

When taking into consideration the impact of a lightning protection installation in a building on the value of the field intensity E for a discharge with a current pulse with the parameters of 20 kA, 2/25μs, the attenuation will be as follows respectively:

- for the component of electric field intensity E:
- eye of grid 20x20 m–E_1=60KV/m – attenuation of the field is σ_{Ed1}=E/E_1= 2,08;
- eye of grid 10x10 m–E_2=40 KV/m – attenuation of the field is σ_{Ed2} = E/E_2=3,13;
- eye of grid 5x5 m – E_3=20 KV/m – attenuation of the field is σ_{Ed3} = /E_3 = 6,25.

Taking into consideration the above attenuation of the components E of the field intensity for the devices of the systems installed in the building, the indexes of the impact γ_{Ed}, $\gamma_{Eg,}$ on the systems will be as follows respectively:

$$\gamma_{Ed12X2} = \frac{\gamma_{Ed}}{\sigma_{Ed1}} = \frac{0.8}{2.08} = 0.39 \quad \gamma_{Ed21X1} = \frac{\gamma_{Ed}}{\sigma_{Ed2}} = \frac{0.8}{3.13} = 0.256 \quad \gamma_{Ed35X5} = \frac{\gamma_{Ed}}{\sigma_{Ed3}} = \frac{0.8}{6.25} = 0.128 \tag{2}$$

where:

- γ_{Ed12x2} – index γ of the impact of interference for field intensity E for the ELF frequency range for the eye of a 20x20 m screening grid;
- γ_{Ed21x1} – index γ of the impact of interference for field intensity E for the ELF frequency range for the eye of a 10x10 m screening grid;
- γ_{Ed35x5} – index γ of the impact of interference for field intensity E for the ELF frequency range for the eye of a 5x5 m screening grid.

In order to determine the indexes γ of the impact of interference on the security and steering systems for the ELF and VLF frequency range, one needs to do the following:

- identify the location of interference in the railway area;
- diagnose the parameters of the sources of interference (power, frequency range, time of activity, frequency of repetitions, permanent, impulse ones, etc.);
- define the range of the impact of the sources of interference on the systems;
- define the parameters of all the interference occurring at a railway station, i.e. the field intensity E and the induction B of the magnetic field;
- determine the values of the electric and magnetic field for the impulse of a lightning discharge for the individual frequency sub-ranges [11].

In order to define the permissible margin of an undisturbed work of the systems, measurements were made of the electric field emitted by power cables which provide electricity to the railway station. Depending on the cable type (single-multi-core, screened, unscreened) and the power consumed by the powering devices, conditions should be met that define the minimum distance for the undisturbed work of the systems [8]. The conditions and method of the measurements are presented in Fig. 1. The values obtained of the field intensity E for the ELF and VLF frequency ranges are presented in Table 2. The measurements were made with the relative harmonic content h of alternating voltage grids 230 V, 50 Hz being equal to 2.5 ÷ 3 %.

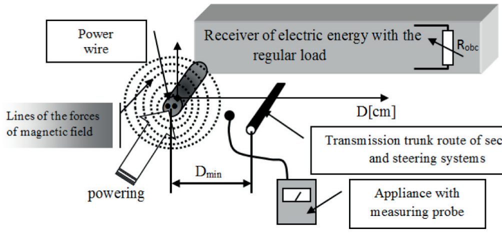

Fig. 1. Diagram of the stand to the measurements of the electric field to determine the margin of the undisturbed work of steering and security systems [own study]

Fig. 2 presents the values of index γ for the considered cases of the impact of power cables on the elements, devices and transmission trunk routes (structural cables) of security and steering systems: denotations in relation to Fig. 3 are presented in Table 3.

Table 2. Parameters of the electric field for the ELF and VLF frequency range in the function of the power consumed by an electric energy receiver [own study]

Parameter of electric field defined during the measurements			Power consumed by the receiver		
			S < 2kVA	5kVA > S > 2kVA	S > 5 kVA
Frequency range ELF	Field intensity E[V/m]	*	270	285	350
		**	31.5	33.3	43.1
Frequency range VLF	Field intensity E[V/m]	*	2.3	2.4	2.6
		**	1.7	1.8	2.1

* - value of the electromagnetic field for electric power cables with no screens; ** - value of the electromagnetic field for electric power cables put in earthed channels, pipes etc.

3. Electric field and the safety states of the operation process of security systems

Security systems can remain in a group of various sets. The set of the states of the system can be divided into specific subsets of states from the perspective of a given criterion.

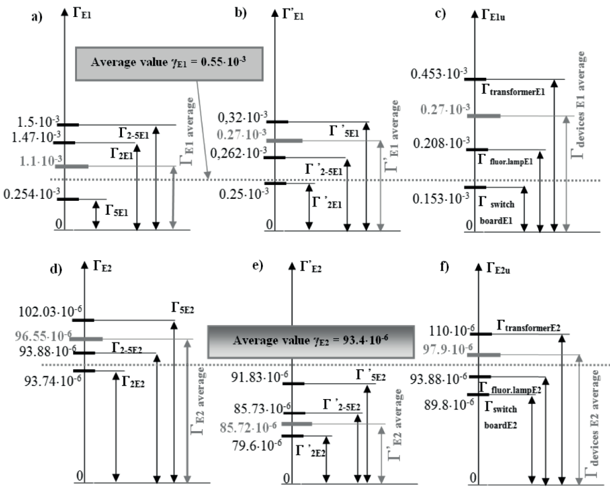

Fig. 2. Determination of the margin of safety Γ of the operation of systems in the case of the impact of electromagnetic interference for the ELF and VLF frequency range of the field intensity E [own study]

Table 3. List of denotations in Fig. 2 [own study]

Fig no.	Name of figure and denotation in the figure	
a)	Margin of safety Γ of the impact of field intensity E - $Γ_{E1}$ on the system for the ELF frequency range in the function of power consumed by a receiver for electric power cables with no screens.	
	Margin of safety Γ	Margin of safety Γ for the power of receiver
	$Γ_{2E1}$,	P < 2kVA
	$Γ_{2-5E1}$	5kVA > P > 2kVA
	$_{5E1}$	P > 5 kVA
	$_{E1\ average}$	Average value $Γ_{E1\ average} = (_{2E1}+Γ_{2-5E1}+Γ_{5E1})/3$
b)	The margin of safety of the impact of field intensity E - $Γ_{E1}$ on the system for the ELF frequency range in the function of power consumed by the receiver for electric power cables with screens.	
	Margin of safety Γ	Margin of safety Γ for the power of receiver
	$Γ'_{2E1}$	P < 2kVA
	$'_{2-5E1}$	5kVA > P > 2kVA
	$Γ'_{5E1}$	P > 5 kVA
	$'_{E1\ average}$	Average value $Γ'_{E1\ average} = (Γ'_{2E1}+Γ'_{2-5E1}+Γ'_{5E1})/3$
c)	Margin of safety Γ for the impact of field intensity E - $Γ_{E1}$ on the system for the ELF frequency range in the function of electric devices for the sources of interference for systems	
	Margin of safety Γ	Margin of safety Γ for the sources of interference
	$Γ_{trafo\ E1}$	Source of interference: transformer station
	$Γ_{elsw\ E1}$	Source of interference: electrical switchboard
	$Γ_{lgtn\ E1}$	Source of interference: high-voltage lighting
	$Γ_{devices\ E1\ average}$	Average value $Γ_{devicesE1\ average} = (Γ_{trafoE1}+Γ_{elswE1}+Γ_{lgtnE1})/3$
d)	Margin of safety Γ of the impact of field intensity E - $Γ_{E1}$ on the system for the VLF frequency range in the function of power consumed by the receiver for electric power cables with no screens	
	Margin of safety Γ	Margin of safety Γ for the power of receiver
	$Γ_{2E2}$,	P < 2kVA
	$_{2-5E2}$	5kVA > P > 2kVA
	$Γ_{5E2}$	P > 5 kVA
	$Γ_{E2\ average}$	Average value $Γ_{E2\ acerage} = (Γ_{2E2}+Γ_{2-5E2}+Γ_{5E2})/3$
e)	Margin of safety Γ of the impact of field intensity E - $Γ_{E1}$ on the system for the VLF frequency range in the function of power consumed by the receiver for electric power cables with screens.	
	Margin of safety Γ	Margin of safety Γ for the power of receiver
	$Γ'_{2E2}$	P < 2kVA
	$'_{2-5E2}$	5kVA > P > 2kVA
	$Γ'_{5E2}$	P > 5 kVA
	$'_{E2\ average}$	Average value $Γ'_{E2\ average} = (Γ'_{2E2}+Γ'_{2-5E2}+Γ'_{5E2})/3$
f)	Margin of safety Γ for the impact of field intensity E - $Γ_{E1}$ on the system for the VLF frequency range in the function of electric devices for the sources of interference for systems	
	Margin of safety Γ	Margin of safety Γ for the sources of interference
	$Γ_{trafo\ E2}$	Source of interference: transformer station
	$Γ_{elsw\ E2}$	Source of interference: electrical switchboard
	$Γ_{lgtn\ E2}$	Source of interference: high-voltage lighting
	$Γ_{E2\ average}$	Average value $Γ_{devicesE2\ average}=(Γ_{trafoE2}+Γel_{swE2}+Γ_{lgtn\ E2})/3$

In security systems, the following subsets of states can be distinguished:

- a subset of operational states, which includes among others the states of serviceability, partial serviceability and unserviceability etc.;
- a subset of readiness states, which includes among others states of constant readiness, complete readiness, non-readiness etc.;
- states of safety, which includes among others states of "sensing of safety hazard", safety hazard, safety unreliability, operational unreliability.

The abovementioned subsets are inseparable. In security systems, there may occur many various unserviceability states and many different states of safety and states of safety unreliability. The abovementioned states may be of a transitory type (e.g. state of testing) or of an absorbing type (e.g. state of damage). A system passes from a transitory state with a probability being different from zero to other states. The system does not pass from absorbing states to any other states. As a rule, such states as serviceability and safety states are transitory, whereas such states as unserviceability and safety unreliability states are frequently treated as absorbing states. Security systems possess various reliability structures which are realized depending on the guarantee level of the safe operation of the system, e.g. reliability.

The reliability of steering and security systems is understood as their ability of a correct operation that is not stopped by a damage. In a quantitative sense, reliability can be expressed e.g. as the probability that an object will be functioning with no damage in a specific manner, in specific conditions and in a specific time interval.

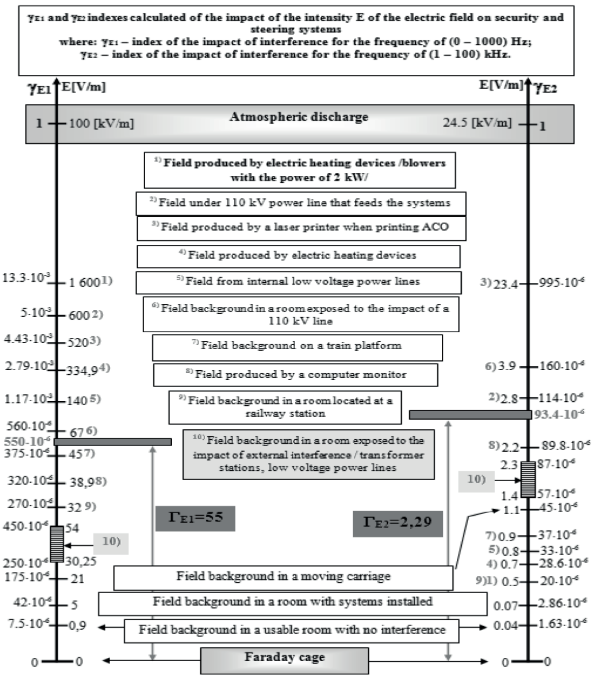

Fig. 3. Determination of γ_{E1}, γ_{E2} indexes and determination of the margin of safety Γ_{E1}, Γ_{E2} for the systems with the impact of the electric field intensity in ELF and VLF frequency ranges [own study]

The probability related to steering and security systems for various reliability structures of these systems with various amplitudes of interfering signals that have an impact on these systems is presented in Table 4. A simulation of the behavior for security and steering systems was conducted for interference that is produced in an extensive railway area: from the value of the electromagnetic field that exists in a usable room, through the values of the field generated at a train platform, to an atmospheric discharge (the range of changes to the γ value: cf. Fig. 4). For the abovementioned γ values, the indexes were determined: $R_0(t)$, $Q_{ZB1}(t)$ and $Q_B(t)$ of the safety of the operation of security and steering systems; cf. Fig. 4.

When analyzing Fig. 4, one can find that for the small values of the indexes γ of interference, the system practically maintains a constant value of the $R_0(t_b)_Z$ parameter: the security and steering system is insensitive to interference with small amplitudes ($\approx \gamma = 10 \cdot 10^{-6}$). If a security system is installed in the buildings of a railway station, the screening impact is to be taken into account of the lightning protection installation with various dimensions of the lightning protection installation eye. The level of the safety Γ of the work of security and steering systems depends on the location of their installation: an open area (a train platform), a closed area (buildings located in a vast railway area). The values of the individual probabilities of the system remaining in states depend from the properties of the interfering electromagnetic field (the vector of the magnetic or electric field).

Table 4. Probability of the security systems under examination remaining in the following states: R_O – state of the system's complete serviceability; Q_{ZE1} – state of safety hazard; Q_B – state of safety unreliability in the case of an impact of interference for a component of the intensity E of an electric field in the VLF frequency range [own study]

Name of index		Reliability structure of security systems			
		Series-parallel structure		Parallel structure	
		System working with no interference γ=0	System working in a railway area γ≠0	System working with no interference γ=0	System working in a railway area γ≠0
a)	R_O	0.68	0.6667	0.9	0.882357
	Q_{ZE1}	0.127556	0.140886	0.0947435	0.113474
	Q_B	0.192444	0.193041	0.002565	0.004168
b)	R_O	0.68	0.458469	0.9	0.606797
	Q_{ZE1}	0.127556	0.349087	0.0947435	0.311476
	Q_B	0.192444	0.24693	0.002565	0.081726

a) security system installed in a usable room at a railway station: electromagnetic field background: impact of the intensity E of an electric field in the VLF frequency range $\gamma=2{,}26 \cdot 10^{-6}$; b) security system installed in a carriage: measurement of the electromagnetic field while the train is moving: impact of the intensity E of an electric field in the VLF frequency range $\gamma=45 \cdot 10^{-6}$, **Denotations:** R_0 – state of the system's complete serviceability; Q_{ZE1} – state of safety hazard; Q_B - state of safety unreliability.

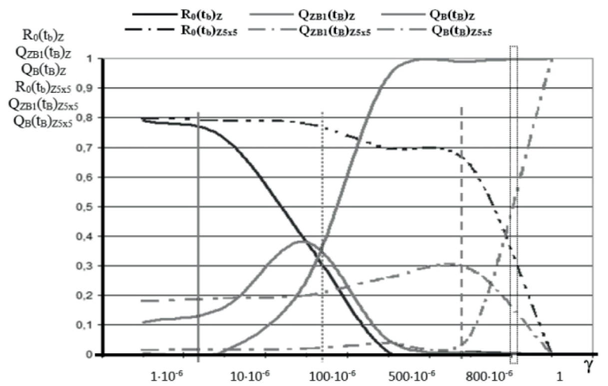

Fig. 4. Course of the probability of the security system with a series-parallel structure remaining in various states in the function of γ index of interference [own study]

Notes to Fig. 15: Systems in the following states: $R_0(t)_Z$, $Q_{ZB1}(t)_Z$, $Q_B(t)_Z$: installed at train platforms; $R_0(t_b)_{Z5x5}$, $Q_{ZB1}(t_B)_{Z5x5}$, $Q_B(t_B)_{Z5x5}$: a security and steering system installed in a railway station building with a lightning protection installation with eye dimensions of 5x5 m; $R_O(t_b)_Z$ – function of the probability of the system remaining in the complete serviceability state; $Q_{ZB1}(t_b)_Z$ – function of the probability of the system remaining in the safety hazard state; $Q_B(t_b)_Z$ – function of the probability of the system remaining in the safety unreliability state.

4. Conclusion

To determine of the impact thresholds component of the electric field on the transport security systems in the first place should be identify sources of the interferences. Ddeterminers value of distortions that are introduced electromagnetic enticement. Permissible level is shown in Fig. 2. For the range of frequencies of ELF that level is $\gamma = 0{,}55 \cdot 10^{-3}$ and for frequencies of VLF is on $\gamma = 93{,}4 \cdot 10^{-6}$. The component of the electric field higher frequencies VLF has very low value. This means that the device ruggedness on interferences with higher amplitudes and frequencies. To ddetermine effects of electromagnetic interference on the transport security systems it is necessary to determine:

- engine power rating P_{max};
- type of engine (s) that is used (power supply with AC or DC, pulse);
- the supply voltage motors (fixed, variable, variable 3-phase);
- the value of current / voltage in different states of engine operation (for example, sterile, fixed, short-circuit - the characteristics of the engine speed);
- the value of current drawn by motors (fixed, variable, variable 3-phase);
- how to enable / disable the engine (start / stop - transients);
- the way the engine power - for example, shielded cable, power rails, cable diameter, cable length, cross-sectional area, laying of cables);
- sources of electromagnetic radiation in the immediate vicinity of the planned investment (electro climate).

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