Journal of
MECHANICAL and ENERGY
ENGINEERING

ISSN: 2544-0780
Vol. 1 | No. 1(41) | June 2017
pp. 87-94

OPERATION OF THE ELECTRONIC TRANSPORT SYSTEMS ON WITHIN VAST RAILWAY AREA

Jacek PAŚ[1*]

[1*] Department of Operation of Electronic Systems, Institute of Electronic Systems, Military University of Technology, Gen. S. Kaliskiego 2, 00-908 Warszawa, Poland, e-mail: jacek.pas@wat.edu.pl

(Received 20 April 2017, Accepted 15 May 2017)

Abstract: The transport safety is a property of the transport process (movement of individuals and/or goods), characterized by absence of danger to life and health of individuals [1,2,10]. This process should represent a high reliability and safety. The measure of safety is certainty that components of the transport process will remain intact during operation, except for natural changes due to ageing and wear. To ensure a sufficient safety level, it is vital to employ the electronic transport systems which aim is to increase the safety of transferred individuals and goods. The electronic transport systems are designed to detect the threats that occur during the transport process (for both stationary and moving objects). This article presents influence of the electromagnetic interferences within vast railway area on the electronic transport systems with one transmission bus. These electromagnetic interferences are able to completely compromise the electronic system, induce the voltage in the transmission buses or in other components of the system and trigger the alarm (higher probability of false alarm). While operating the transport safety system, full spectrum of electromagnetic interferences should be taken into account. Due to complex behavior of the electromagnetic waves during penetration (propagation), influence of the electromagnetic interferences requires separate analyzes for different frequency bands.

Keywords: amplifier, diagnostic system, remote access

1. INTRODUCTION

In the 20th century, due to human activity, artificial factor shaping the electro-climate were introduced. Creation of the numerous radiation sources resulted in serious changes of the Earth's electromagnetic environment. A wide interest in unfavorable effects of the electromagnetic fields from different frequency bands on the human organism and operation of electronic device started when the EU introduced a directive concerning electromagnetic compatibility [1,7,8,10,12,15,19].

In order to quantify the electromagnetic interferences appearing within railway area one should determine parameters of the following circuits:

– high current circuits (traction substations, traction grid, return grid, traction vehicles, supply grid);
– low current circuits (SRK – railway traffic control system, hard-wired communication systems, radio and voice-broadcasting, electronic transport systems).

The interferences generated by substations and traction vehicles are asynchronous (DC traction grid), contrary to the AC traction (synchronous interferences) – see Fig. 1. In case of AC traction, the supply is one-sided (each traction section is supplied from a different phase). The interferences generated in the AC traction grid are synchronized with the basic frequency of a given traction supply system.

The sources of the interferences appearing within railway area can be divided into:

– stationary (e.g. interferences originating from railway traction supply systems);
– mobile (e.g. interferences originating from electric traction vehicles).

The electronic transport systems are operated in various climate conditions and in different electromagnetic environment, what causes interferences – Fig. 2. A proper functioning of the transport supervision system depends on:

– reliability of each component of system [5,10,19];
– internal reliability structure of transport system;

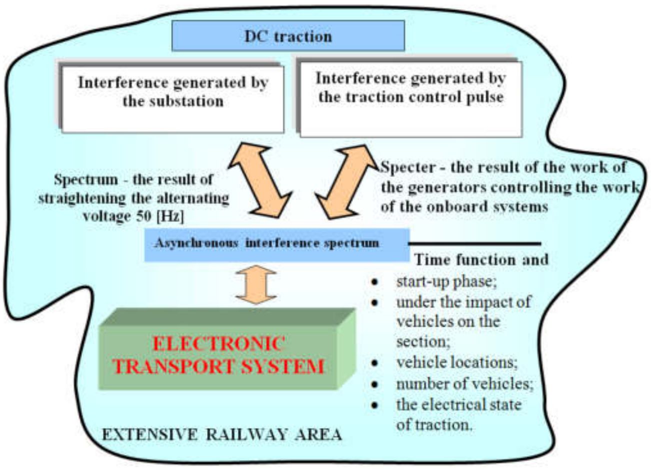

Fig. 1. Interferences generated within vast railway area originating from substations and traction vehicles

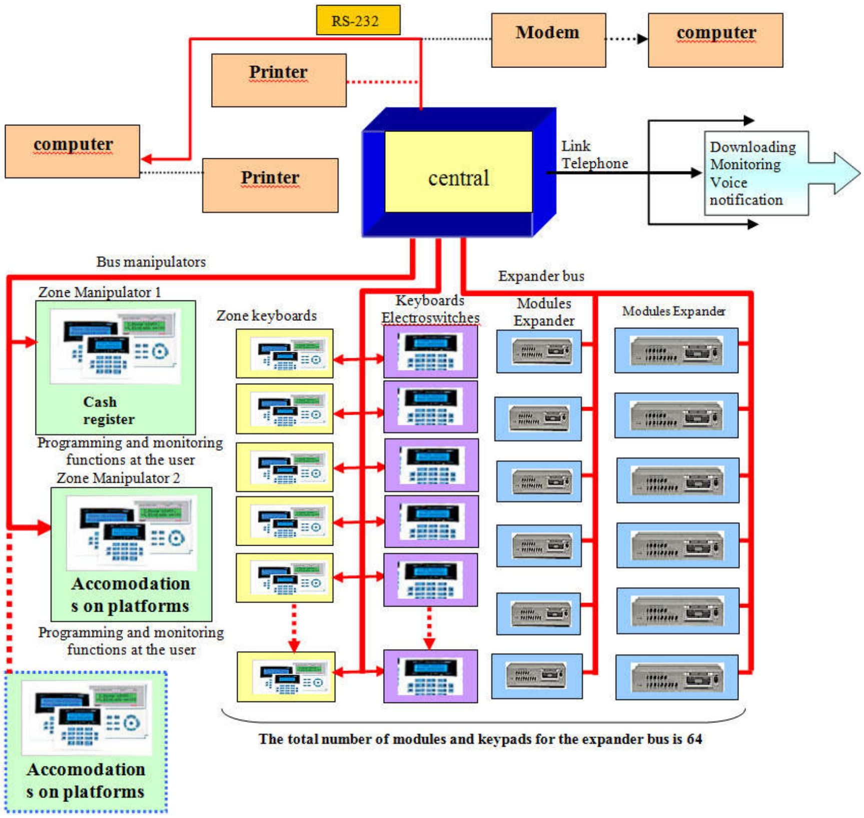

Fig. 2. Block diagram for system with 2 transmission buses and modules with RS-232 inter-face

- assumed strategies for system operation [5,9,10];
- electromagnetic interferences affecting operation of system.

The sources of the interferences that affect the electronic transport systems are as follow:

- traction substations with converters;
- pulse controlled traction vehicles,
- electric and electronic devices installed at railway station (e.g. computer systems, internal power supply lines, electric heating systems, electric power supply for internal and external lighting etc.);
- external electromagnetic interferences (e.g. originating from base station transmitters, tram power supply traction passing near railway station,

high-voltage power supply grid, transformer station supplying railway station, railway traction etc.)[3,10].

The problem of the electromagnetic interferences started in the early ages of radiophony. In many countries, yet before the World War II, there were state services dealing with the interferences, e.g. in England they were founded in 1920. Before the war, around 10% of complaints about the interferences of the radio signal concerned the municipal electric traction. A sudden development of the radiophony and television after 1945 as well as the use of higher and higher frequencies resulted in increase of the number of complaints in England. Within 1947 and 1956 it reached 160,000 per year (compared to 34,000 in 1934). But the number of complaints concerning the electric traction decreased at the same time. The reason for this could be the transition to ultra-short waves and frequency modulation (FM) in broadcasting of radio programs. Before that, more susceptible for interferences amplitude modulation (AM) was used – Fig. 3.

In Poland, research on an influence of the interferences on a radio signal were started in 1935. Two years later, a team for elimination of the interferences was created. The Polish Electric Standard PN/E-58 entitled "Wskazówki usuwania zakłóceń w odbiorze radiofonicznym pochodzącym od różnych urządzeń elektrycznych" ("Guidelines for interference of various electric devices removal from a radio signal") was drafted and introduced in 1935. Nowadays, an analog and digital electronic devices (components of SRK, TSN and telecommunication systems), that create the unintended electromagnetic field and are exposed to an external field coming from other devices, are used within railway area.

2. AN INFLUENCE OF THE INTERFERENCES ON OPERATION OF THE TRANSPORT SUPERVISION SYSTEMS

The effects of the interferences on operation of the transport supervision systems can be divided into the independent and cumulative ones [3,8,10,12,13,19]. Basing on their effects it is possible to distinguish the following types of interferences:

- **A –** interferences causing total damage to electronic transport system, independent effects (e.g. system damage caused by atmospheric discharge – direct or indirect influence);
- **B –** interferences causing parametric damage to electronic transport system – cumulative effects. Parametric damages are connected to gradual change of properties of system, therefore type **B** interferences can be divided into:
  - **B1 –** interferences whose effects cumulate in such a way that probability $p(t_i)$, $i = 1,2,...$, for system damage at time t is monotonically rising function of time in strict manner, in other words, if damage criterion is defined as attribute X droping below permissible limit X_{dop} then:

    $$p(t_i) = P_r(X(t_i) \geq x_{dop}),\ i=1, 2, ..., \quad (1)$$

    $$p(t_i) < p(t_{i+1}) \text{ when } t_i < t_{i+1},\ i = 1,2, ..., \quad (2)$$

    where: t_i, t_{i+1} – moments of interferences occurrence;
  - **B2 –** interferences whose effects cumulate in such a way that system damage requires occurance of z number of interferences, in other words, at time t_z – occurance of z-th interference, signal offset exceeds critical value and:

    $$p(t_z) = 1 \Rightarrow [(p(t_z) = Pr(X(t_z) \geq x_{dop})]; \quad (3)$$

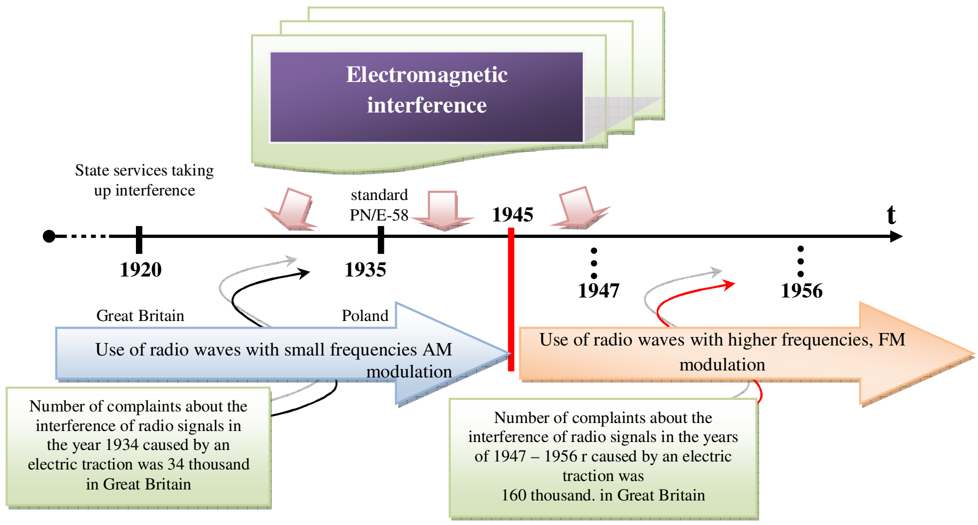

Fig. 3. Electromagnetic interference within railway area

– multiplicative interferences influence electronic transport system whose internal structure consist of electronic components with discontinuous and non-linear characteristics (ex. diode or transistor). Interference signals are therefore are multiplied together with signal coming from supervision system:

$$Y_{wyj\xi}(t) = K(\theta)\cdot X_S(t)\cdot \xi_z(t), \quad (4)$$

where:

$Y_{wyj\xi}(t)$ – amplitude of input signal of system (device) affected by interference signal;

$K(\theta)$ – function describing characteristic of non-linear element;

$X_S(t)$ – amplitude of supervision system signal;

$\xi_z(t)$ – amplitude of interference signal.

The classification of the interferences affecting the electronic transport system with respect to consequences is shown on Fig. 4.

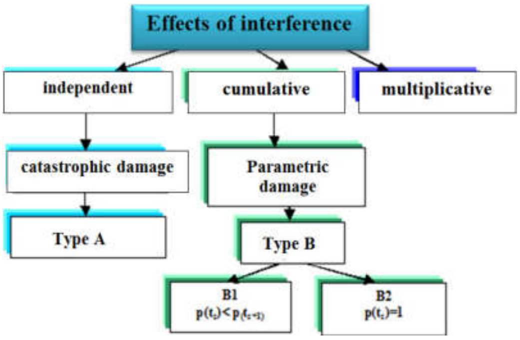

Fig. 4. Classification of interferences affecting electronic transport system

3. MODELS FOR OPERATION OF THE ELECTRONIC TRANSPORT SYSTEM

The problem of an optimal operation of the electronic transport systems affected by the interferences is of prime importance. They require high reliability of the operational parameters. During a reliability analysis, it is possible to develop a method for determining the reliability structures. Such an approach guarantees a high reliability level in designed and operated systems that work in various electromagnetic environments. In order to achieve sufficient readiness, it is necessary to take into account the operational parameters of the electronic systems (e.g. damage intensity, interference indicators). It allows to suggest a method for selecting a strategy of electronic transport system operation.

The modeling part involves two actions:

– construction of model of selected system under interferences;
– experiments with model.

Creation of a model requires knowledge concerning principles of designing and operation of the electronic transport systems as well as values of reliability-exploitation parameters. With this data, it is possible to create the model that allows to formulate a problem, and to solve this problem. The scheme for the place of the model in the method is shown on Fig. 5.

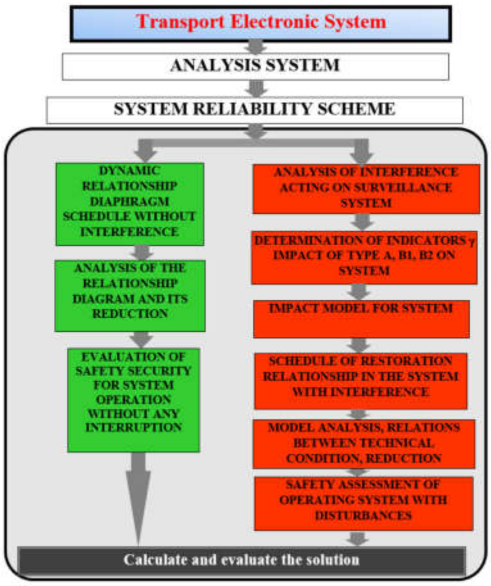

Fig. 5. Scheme for safety evaluation method of electronic transport system operation

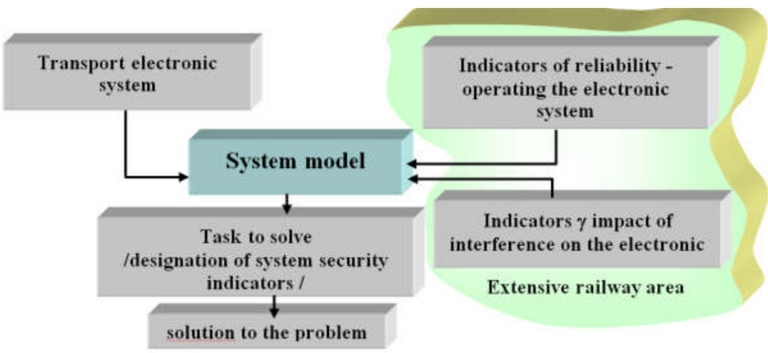

Fig. 6. Scheme for place of model in method

After solving the problem (formulated for model), one obtains results that require a further analysis. Assuming proper criteria of evaluation, it is possible to confirm whether the assumed conditions are met (solutions is accepted), or not (in this case it is necessary to modify data or to create new model) – Fig. 6.

4. A SYSTEM WITH ONE TRANSMISSION BUS AND MODULES

The electronic system with one transmission bus and modules (central unit, power module, extension module) of parallel structure is presented below. A damage of module or an effect of the interferences on operation of a particular component of the system causes transition from the complete usability state $R_0(t)$ into the safety unreliability state $Q_B(t)$ – Fig. 7.

A system consisting of 3 components can be analyzed as shown on Fig. 7, but it is possible to simplify the system and obtain a diagram with a smaller number of the transitions (Fig. 8).

Knowing the damage intensities $\lambda(t)$ and indicators of the various interferences on the particular modules of the supervision system $\gamma(t)$, it is possible to determine the probability of complete usability state $R_0(t)$ and the probability of damage $Q_0(t)$ (Tab. 1).

5. CONCLUSIONS

Above paper presented issues connected with a propagation of the electromagnetic interferences within vast railway area and how they affect the electronic transport systems. In the 21st century, there is a constant increase of risks during transport of people and goods. It has a significant influence on the reliability-exploitation requirements of the installed electronic transport systems [4,6,8,10,17,19]. Apart from the requirements, the systems should be also immune to the electromagnetic interferences generated in both intended and unintended manner. Therefore all safety systems installed in the transport supervision systems should have a certificate for the electromagnetic compatibility specified by the EN 50130-4 standard. Compliance with the standard guarantees that during operation of the electronic transport system, devices are immune to interferences.

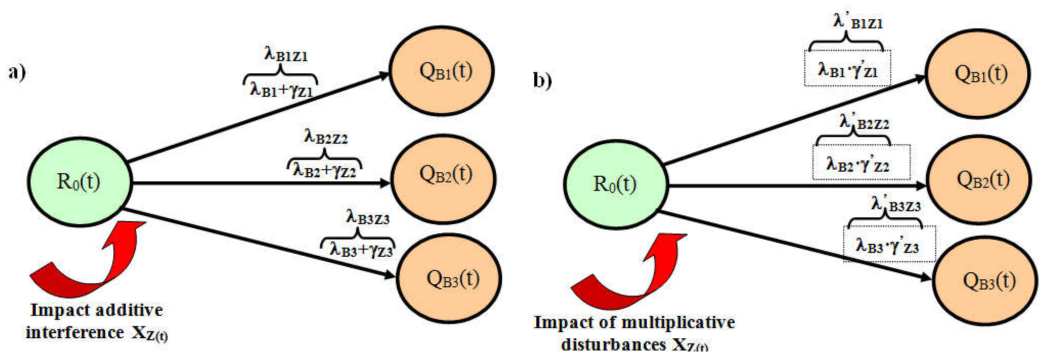

Fig. 7. Relations of supervision system with one transmission bus: a) diagram for additive interferences; b) diagram for multiplicative interferences

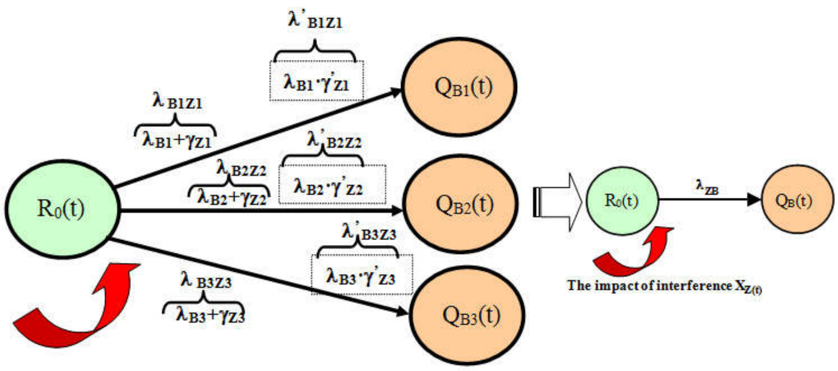

Fig. 8. Simplified system with one transmission bus

Tab. 1. Example of calculation for completely usable supervision system $R_0(t)$ and probability of system damage $Q_0(t)$ for selected operational situations

Type of interference	Reliability of system	Probability of system damage
none	$R_0(t) = \exp[-\int_0^t \lambda_B(\tau)d\tau]$	$Q_0(t) = 1 - R_0(t)$
A	$R_{0A}(t) = \exp[-\int_0^t (\lambda_{B1} + \gamma_{Z1})(\tau)d\tau]$	$Q_{0A}(t) = 1 - R_{0A}(t)$
A	$R'_{0A}(t) = \exp[-\int_0^t (\lambda_{B1} \cdot \gamma'_{Z1})(\tau)d\tau]$	$Q'_{0A}(t) = 1 - R'_{0A}(t)$
B1	$R_{0B1}(t) = \exp[-\int_0^t (\lambda_{B1} + \gamma_{Z1} + \lambda_{B2} + \gamma_{Z2})(\tau)d\tau]$	$Q_{0B1}(t) = 1 - R_{0B1}(t)$
B1	$R'_{0B1}(t) = \exp[-\int_0^t [(\lambda_{B1} \cdot \gamma'_{Z1}) + (\lambda_{B2} \cdot \gamma'_{Z2})](\tau)d\tau]$	$Q'_{0B1}(t) = 1 - R'_{0B1}(t)$
B2	$R_{0B2}(t) = \exp[-\int_0^t (\lambda_{B1} + \gamma_{Z1} + \lambda_{B2} + \gamma_{Z2} + \lambda_{B3} + \gamma_{Z3})(\tau)d\tau]$ $R'_{0B2}(t) = \exp[-\int_0^t [(\lambda_{B1} \cdot \gamma'_{Z1}) + (\lambda_{B2} \cdot \gamma'_{Z2}) + (\lambda_{B3} \cdot \gamma'_{Z3})](\tau)d\tau]$	$Q_{0B2}(t) = 1 - R_{0B2}(t)$ $Q'_{0B2}(t) = 1 - R'_{0B2}(t)$

Only type A interferences (e.g. atmospheric discharge, supply line short-circuit) can result in system damage [10,11]. In case of the electromagnetic interferences of the electronic transport systems there are four different technical states of the system. The electronic system is immune to the external and internal interferences (intended or unintended) – the interference level is too small – state $R_0(t)$. Interference amplitude is high enough to damage the system, but system components automatically eliminate the distortions by using passive and active filters, shielding etc. – state $R_0(t)$. The electromagnetic interferences cause the transition from the complete usability state into the unreliability of safety state – the interferences cause a system damage – total or partial, system safety is compromised – state $Q_B(t)$ – Fig. 7. Safety level of electronic transport system (immunity to electromagnetic interferences) depends on system placement – open area (platform) or restricted area (building situated within vast railway area). Values of the specific probabilities of system being in states $R_0(t)$ or $Q_B(t)$ depend on properties of a source of the electromagnetic interferences – frequency band, dominant vector of electromagnetic field in the vicinity of the system – magnetic or electric, type of signal – continuous, pulse, modulate etc. – Fig. 3.

Nomenclature

Symbols

QB(t) – probability function of unreliability of safety state at time, t

RO(t) – probability function of complete usability state at time, t

Greek symbols

γ – interference indicator,

γ_E, γ_H – interference indicator system for electric field intensity *E* and magnetic field intensity *H*, respectively

γ_{Ed}, γ_{Hd} – interference indicator for electric field intensity *E* and magnetic field intensity *H* for frequencies below 1000 Hz, respectively

γ_{Eg}, γ_{Hg} – interference indicator for electric field intensity *E* and magnetic field intensity *H* for frequencies between 1000 Hz and 100 kHz, respectively

$\gamma_{Eg'}, \gamma_{Hg'}$ – rat interference indicator for electric field intensity *E* and magnetic field intensity *H* for frequencies above 100 kHz, respectively

λ – damage intensity

λ_{BxZx} – damage intensity for additive interferences

λ'_{BxZx} – damage intensity for multiplicative interferences

λ_B – transition intensity for serial-branch elements of reliability structure

λ_{ZB} – transition intensity for parallel-branch elements of reliability structure

λ_{xy} – transition intensity between *x* and *y* system states

λ_{B1} – transition intensity for central unit

λ_{B2} – transition intensity for power module

λ_{B3} – transition intensity for expansion modules

$\gamma_{Z1}; \gamma_{Z2}; \gamma_{Z3}$ – indicators of type *A*, *B1* and *B2* interferences on central unit, power module and expansion module respectively

$\lambda_{B1Z1}=\lambda_{B1}+\gamma_{Z1}$ – transition intensity for central unit, additive interferences case

$\lambda_{B2Z2}=\lambda_{B2}+\gamma_{Z2}$ – transition intensity for power modules, additive interferences case

$\lambda_{B3Z3}=\lambda_{B3}+\gamma_{Z3}$ – transition intensity for expansion modules, additive interferences case

$\lambda'_{B1Z1}=\lambda_{B1}\cdot\gamma'_{Z1}$ – transition intensity for central unit, multiplicative interferences case

$\lambda'_{B2Z2}=\lambda_{B2}\cdot\gamma'_{Z2}$ – transition intensity for power modules, multiplicative interferences case

$\lambda'_{B3Z3}=\lambda_{B3}\cdot\gamma'_{Z3}$ – transition intensity for expansion modules, multiplicative interferences case

Acronyms

RS-232C – voltage-based data transmission standard
RS-485 – current-based data transmission standard
SA – acoustic indicator
SO – optical indicator
SSNiW – intrusion and hold-up systems
TSE – electronic transport system

References

1. Dyduch J., Moczarski J. (2007). *Podstawy eksploatacji systemów sterowania ruchem kolejowym*. Oficyna Wydawnicza Politechniki Radomskiej, Radom. (in Polish)
2. Wawrzyński W. (2004). *Bezpieczeństwo systemów sterownia w transporcie*. Instytut Technologii Eksploatacji, Radom. (in Polish)
3. Dyduch J., Paś J. (2008). Optymalizacja procesu eksploatacji w transportowych systemach nadzoru. W: Materiały konferencyjne XII Międzynarodowej Konferencji Naukowej TransComp – 2008 Zakopane, Polska. (in Polish)
4. Dyduch J., Paś J.: (2008). Optymalizacja procesu eksploatacji w transportowych systemach nadzoru. *Logistyka*, No. 6, pp. 105-110. (in Polish)
5. Dyduch J., Paś J., Rosiński A. (2011*). Podstawy eksploatacji transportowych systemów elektronicznych*. Wydawnictwo Politechniki Radomskiej. (in Polish)
6. Paś J., Duer S. (2003). Determination of the impact indicators of electromagnetic interferences on computer information systems. *Neural Computing and Applications*, Vol. 23, No. 7-8, pp. 2143-2157.
7. PN-EN 55016-2-1:2014-09 (2014). *Wymagania dotyczące aparatury pomiarowej i metod pomiaru zaburzeń radioelektrycznych oraz odporności na zaburzenia – Część 2-1: Metody pomiaru zaburzeń i badania odporności - Pomiary zaburzeń przewodzonych.* Polski Komitet Normalizacyjny. (in Polish)
8. Siergiejczyk M., Paś J., Rosiński A. (2016). Issue of reliability–exploitation evaluation of electronic transport systems used in the railway environment with consideration of electromagnetic interference. *IET Intelligent Transport Systems*, Vol. 10, No. 9, pp. 587-593.
9. Paś J. (2016). Shock a disposable time in electronic security systems. *Journal of KONBiN,* Vol. 38, No. 1, pp. 5-31
10. Paś J. (2015). *Eksploatacja elektronicznych systemów transportowych*. Wydawnictwo Uniwersytetu Technologiczno- Humanistycznego, Radom. (in Polish)
11. Paś J., Choromański W. (2015). Results of measurement and determination of threshold electric field component for transport security systems. *Archives of Transport Systems Telematics,* Vol. 8, No. 1, pp. 24-29.
12. Stawowy M. (2014). Model for information quality determination of teleinformation systems of transport. In: Proceedings of the European Safety and Reliability Conference ESREL 2014, Wroclaw, Poland, 14-18 September, (Nowakowski T., Młyńczak M., Jodejko-Pietruczuk A., Werbińska-Wojciechowska S., Eds.), CRC Press, pp. 1909-1914.
13. Siergiejczyk M., Paś J., Rosiński A. (2015). Modeling of process of exploitation of transport telematics systems with regard to electromagnetic interferences. In: Tools of transport telematics (Mikulski J., Ed.) – *Communications in computer and information science*, Vol 531. Springer, Berlin, pp. 99-107.
14. Siergiejczyk M., Rosiński A., Paś J. (2016). Analysis of unintended electromagnetic fields generated by safety system control panels. *Diagnostyka*, Vol. 17, No. 3, pp. 35-46.
15. Paś J., Siergiejczyk M. (2016). Interference impact on the electronic safety system with a parallel structure. *Diagnostyk*a, Vol. 17, No. 1, pp. 49-55.
16. Duer S., Zajkowski K., Duer R., Paś J. (2013). Designing of an effective structure of system for the maintenance of a technical object with the using information from an artificial neural network. *Neural Computing and Applications*, Vol. 23, No. 3-4, pp. 913-925.
17. Charoy A. (2000). *Zakłócenia w urządzeniach elektronicznych (Tom 2).* Wydawnictwa Naukowo-Techniczne, Warszawa. (in Polish)
18. Duer S., Duer R. (2010). Diagnostic system with an artificial neural network which determines a diagnostic information for the servicing of a reparable technical object. *Neural Computing and Applications*, Vol. 19, No. 5, pp. 755-766.
19. Zajkowski K. (2014). The method of solution of equations with coefficients that contain measurement errors, using artificial neural network, *Neural computing and applications,* Vol. 24, Issue 2, pp. 431-439.

Biographical note

Jacek Paś, Ph.D., D.Sc., Eng., professor of Military University of Technology – faculty of Electronic, Division of Electronic Systems Exploitations Manager, scientific interests: electromagnetic compatibility, analogy circuits, reliability, low frequency noise, exploitation, diagnostics, projecting, connected with comprehended wide of the safety both for stationary as well as for movable objects. The author of three books. Additional research interests: environmental studies of electromagnetic the range at low frequencies at (electro smog). He has participated in 1 international and 10 national research projects, presenting results of his work at 30 international and 68 national conferences, published more than 200 scientific papers in international and national journals, book chapters, as well as conference proceedings. He is also the author of 4 monographs.