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EVALUATION METHOD OF THE PHYSICAL COMPATIBILITY OF EQUIPMENT IN A HYBRID INFORMATION TRANSMISSION NETWORK

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ABSTRACT

The article considers the physical compatibility of equipment (PCE) in a hybrid network of information transmissions. The use of information technology is justified in the scheme of the protection measures applied against disturbances. A method of equipment compatibility research has been developed to describe communication channels in network nodes unambiguously. A correlation matrix of the signals of different physical nature, which are used for information transmission via media, has been developed. The corresponding examples have been given. The dependence of the hybrid network parameter values on the physical nature of the signal and the transmission medium has been revealed. It has been shown that the distribution of the telecommunication network resources into channels with signals of different physical nature in different media increases the physical compatibility of the equipment. A method for assessing the PCE in a hybrid information transmission network is proposed. The method proposed in the paper is based on the distribution of resources of a heterogeneous telecommunication network into channels with signals of different physical natures in different transmission environments, which contributes to increasing the compatibility of communication channels. A device has been developed to implement multi-channel information transmission in a hybrid network, allowing optimizing recommendations for increasing the PCE in a hybrid information transmission network.

Keywords: *Interference, Physical Compatibility, Spurious Emission, Parasitic Channel Weakening*

1. INTRODUCTION

According to Directive 2004/108/EC of the European Parliament and of a Council of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC, the ability of the equipment to function satisfactorily in its electromagnetic environment (EME) without causing unacceptable disturbances to the regular operation of other equipment in such an environment is defined as electromagnetic compatibility (EMC) [1].

Electromagnetic interference protection systems that form EME are designed to simultaneously protect against several destabilizing electromagnetic factors. As a rule, these are information security, protection against electromagnetic pulses, protection against electromagnetic action of powerful radiation sources (radio, television, radar) and lightning strikes, and EMC equipment provision [2].

A comprehensive approach to protection against electromagnetic nature destabilizing factors and the similarity of these tasks is the reason to apply measures of protection against the lightning—extreme interference manifestation. A modified application scheme of the protection measures against interference is shown in Fig. 1.

The proposed scheme is designed to develop a plan of action to prevent hazards of interferences or at least reduce their negative consequences. Short-term hazard forecasting is performed to alert the public and collect data. These data are used in longterm forecasting. It is used in assessing risks and their acceptable levels to declare the safety of facilities, make decisions on their location and operation, develop measures to prevent accidents, and prepare to respond to them. The list of protection measures includes:

- ✓ Use of resistance to specific hazards materials and structures.
- ✓ Interception of danger, which involves shielding the object or its most vulnerable and responsible elements from danger, or shielding danger from the object, as well as counteracting the danger.
- ✓ Maintenance systems replacement (power supply, ventilation, air conditioning, fire alarm, fire extinguishing, notification, etc.).
- ✓ Transmission network reconfiguration is to change the route of transmission of messages [3] or rerouting the call [4].

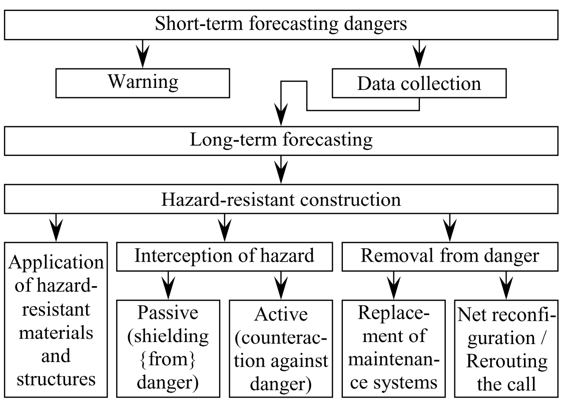

Figure 1: An Application Scheme Of The Protection Measures Against Interferences [5]

It should be noted that reconfiguration, which replaces segments of a hybrid information transmission network that differ from the transmitted signal and/or media, avoids the action of such destabilizing factors that do not physically affect them [5] and [6]. This can be using a radio link instead of an optical FSO line during fog, or an FSO instead of a radio link under adverse electromagnetic conditions, etc. [7].

2. PROBLEM STATEMENT

The article aims to improve the process of evaluating PCE, which is defined as the ability of equipment to function satisfactorily in a hybrid network of information transmission without causing unacceptable violations of the regular operation of other equipment in such an environment.

For that express purpose, it is necessary to solve the following tasks:

- ✓ Determine the list of environments through which signals of different physical nature are transmitted.
- ✓ Determine the list of signals of different physical natures that are used to transmit information.
- ✓ Determine the conformity of the signals of different physical natures used for information transmission to the transmission media.
- ✓ Study the parameters of signals of different physical nature in different transmission media.

A method of optimizing measures to protect the telecommunications network from natural disasters has been developed. It includes the step-by-step collection of information on their impact on telecommunication network resources, analysis of actions, and development and systematization of appropriate countermeasures. The versatility of this method made it possible to adopt it for developing telecommunication network protection measures.

3. METHODOLOGY

Regarding the theory of reliability, EMC can be defined as the resistance of telecommunications network equipment to the effects of an electromagnetic interference signal. Stability is ensured by preventing the onset of the boundary state [8]:

$$S \le I \quad (1)$$

where I is the magnitude of the undesirable effects of electromagnetic interference on the equipment (*Impact*); S is the resistance of the equipment to the action of electromagnetic noise (*Stability*).

Given the uncertainty of the list of unwanted interference signals in a changing natural and anthropogenic environment of the hybrid network, we rewrite the condition of the PCE as follows:

$$\forall i_I \in I,\ I_{i_I} < S_{i_S},\ i_S \in S,$$
$$i_I = \overline{1, n_I},\ i_S = \overline{1, n_S}, \quad (2)$$

where $\forall$ is generic quantifier; i_I, i_S are identifiers of destructive effects on equipment and relevant indicators of equipment stability, respectively; I, n_I is the set and number of the interference effects on the equipment, which in this case include any destructive effects on the equipment (destabilizing factors); S, n_S is the set and number of the resistance indicators of the equipment to the action of these disturbances; I_{iI}, I_{iS} is the magnitudes of the interference effects on the equipment and the resistance of the equipment to them, respectively.

Reconfiguration of the performance systems is provided by their redundancy and is estimated by the formula [25]:

$$P_{\Sigma} = 1 - \prod_{i=1}^{n} \left(1 - P_i\right), \quad i = \overline{1,n} \qquad (3)$$

where P_{Σ} is the probability of connectivity of the path formed by parallel connected chains-systems, P_i is the probability of the operability of each of the systems.

Reconfiguration of the transmission network is provided by the redundancy of nodes and communication lines and is estimated by the formula [26]:

$$\chi(G) \geq 2, \; \lambda(G) \geq 2, \; P_{ij}(t) \geq P_{ij}^{normalized},$$
$$i \neq j, \; i,j = \overline{1,n}, \qquad (4)$$

where $\chi(G)$ is a number of vertex connectivity (the smallest number of vertices (nodes), the extraction of which together with the incident edges (communication lines) leads to a disconnected or single-vertex graph); $\lambda(G)$ is a number of edge connectivity (the smallest number of the edges that remove a disconnected graph); $P_{ij}(t)$ is the probability of the connectivity (the probability that the message from node i to node j will be transmitted in a time not exceeding t).

The telecommunication network is given by a graph $G(V,E)$, the set of vertices of which V are stations and nodes i_V of dimension n_V, and the set of arcs E are lines (channels) of communication e_{ij} between them. The graph is described by an adjacency matrix [9]:

$$A = \left\| a_{i_V j_V} \right\|, \; i_V, j_V = \overline{1, n_V},$$
$$a_{i_V j_V} = \begin{cases} 1, \forall e_{i_V j_V} \in E; \\ 0, \forall e_{i_V j_V} \notin E \end{cases} \qquad (5)$$

The scheme of a full-fledged hybrid network of information transmission is a three-level hierarchical sequence of multiplexers, as shown in Fig. 2.

According to the functional scheme, communication channels are described by the dependence as follows

$$e_{ij} = \left(i_f, i_t, i_{\varepsilon}, i_m\right), \; i_f = \overline{1, n_f}, \; i_t = \overline{1, n_t},$$
$$i_{\varepsilon} = \overline{1, n_{\varepsilon}}, \; i_m = \overline{1, n_m}, \qquad (6)$$

where i_f, i_t, i_{ε}, i_m are channels identifiers of multiplexing systems with frequency f and time t channel divisions, with channel divisions according to the physical nature of signals ε and by transmission media m, respectively; n_f, n_t, n_{ε}, n_m is the number of channels n of multiplexing systems with frequency f, time t channel divisions, with channel divisions by the physical nature of the signals ε and by the transmission media m, respectively.

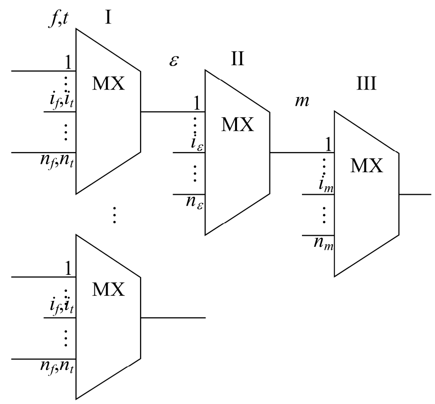

*Figure 2: Functional Diagram Of The Transmitter Of The Hybrid Information Transmission Network: **I** Is The Level Of Channels Multiplexing With The Frequency-Time Division Of Signals; **II** Is The Level Of Channels Multiplexing With The Separation Of Signals By Physical Nature; **III** Is The Level Of Channels Multiplexing With Signal Separation By Transmission Media [6]*

III-level hybrid information transmission network combines the available resources of the signal propagation medium, signals of different physical natures, frequency bands, and signal time intervals. High bandwidth is described by the formula [10]:

$$C_{res} = \sum_{i=1}^{n_f} \sum_{i=1}^{n_t} \sum_{i=1}^{n_{\varepsilon}} \sum_{i=1}^{n_m} C\left(i_f, i_t, i_{\varepsilon}, i_m\right). \qquad (7)$$

At the first level of multiplexing, the separation of transmission channels by frequency and time is used:

$$C_I = \sum_{f_{i_f}}^{f_{n_f}} C(f_{i_f}) \sum_{t_{i_f}}^{t_{n_f}} C(t_{i_t}) = \sum_{f_{i_f}}^{f_{n_f}} \sum_{t_{i_f}}^{t_{n_f}} C(f_{i_f}, t_{i_t}),$$
$$i_f = \overline{1_f, n_f}, \; i_t = \overline{1_t, n_t} \qquad (8)$$

where C is the bandwidth of the multiplexing system; i is the communication channel identifier; f_i is the frequency interval identifier; t_i is the identifier of the time interval.

The second level includes signals of different physical nature:

$$C_{II} = \sum_{\varepsilon_{i_{\varepsilon}}}^{\varepsilon_{n_{\varepsilon}}} C(\varepsilon_{i_{\varepsilon}}), \; i_{\varepsilon} = \overline{1_{\varepsilon}, n_{\varepsilon}}, \qquad (9)$$

where ε_i is the channel identifier according to the physical nature of the signals.

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At the third level of multiplexing, spatial separation of channels is used:

$$C_{III} = \sum_{m_{i_m}}^{m_{n_m}} C(m_{i_m}), \quad i_m = \overline{1_m, n_m}, \tag{10}$$

where m_i is the channel identifier for the signal transmission medium.

4. CORRELATION MATRIX

According to the scheme shown in Fig. 2, the hybrid information transmission network, in addition to frequency (i.e., spectral, wavelength division multiplexing) and time division multiplexing, supports multiplexing of communication channels with physical and media separation. Table 1 presents the matrix of their correspondence for the case $n_\varepsilon = 5$, $n_m = 5$. Communication channels are represented by dependence, as in equation (6).

Table 1: The Correlation Matrix Of The Signals Of Different Physical Nature Is Used For Information Transmission Via Media.

Trans-mission medi-um	The physical nature of the signal $e_{ij}(i_f,i_t,i_\varepsilon,i_m)$				
	Acous-tic (i_ε=1)	Electro-magne-tic (i_ε=2)	Optical (i_ε=3)	Quan-tum (i_ε=4)	Neu-trino (i_ε=5)
Atmos-phere (i_m=1)	$(i_f,i_t,1,1)$	$(i_f,i_t,2,1)$	$(i_f,i_t,3,1)$	$(i_f,i_t,4,1)$	$(i_f,i_t,5,1)$
Space (i_m=2)	**$(i_f,i_t,1,2)$**	$(i_f,i_t,2,2)$	$(i_f,i_t,3,2)$	$(i_f,i_t,4,2)$	$(i_f,i_t,5,2)$
Under-water (i_m=3)	$(i_f,i_t,1,3)$	$(i_f,i_t,2,3)$	$(i_f,i_t,3,3)$	**$(i_f,i_t,4,3)$**	$(i_f,i_t,5,3)$
Under-ground (i_m=4)	$(i_f,i_t,1,4)$	$(i_f,i_t,2,4)$	**$(i_f,i_t,3,4)$**	**$(i_f,i_t,4,4)$**	$(i_f,i_t,5,4)$
Artifici-al guides (i_m=5)	$(i_f,i_t,1,5)$	$(i_f,i_t,2,5)$	$(i_f,i_t,3,5)$	$(i_f,i_t,4,5)$	**$(i_f,i_t,5,5)$**

The examples of the information signals of different physical nature in different transmission media usage, by the elements of the matrix of Table 1, are presented in Table 2. It should be noted that in space, no acoustic signal is transmitted. The underground environment can not propagate an optical signal. However, data are currently missing regarding the propagation of the quantum signal under the ground and underwater and the neutrino signal in artificial guides. However, active research is being conducted in this direction.

It is proposed to lay them underground to protect line and cable structures from threats. Fig. 3 presents enhanced precautions for underground cable structures' protection.

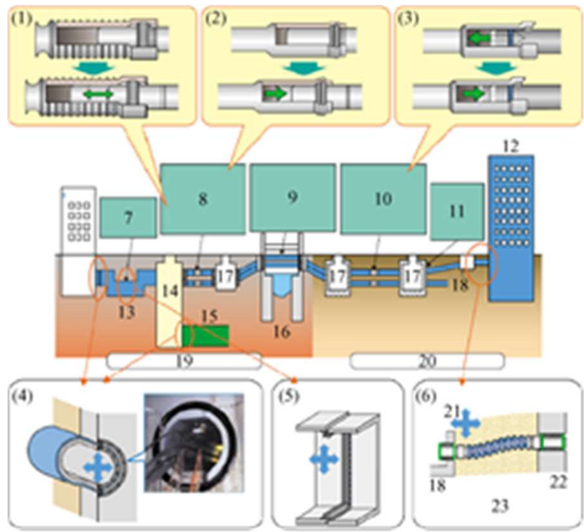

Figure 3: Examples Of Precautionary Measures For The Protection Of The Underground Line And Cable Structures From The Experience Of Japanese Telecommunications Specialists: (1) Sliding Connection For Inspection Wells—Connecting Pipeline Coupling; (2) Sliding Connection For Gas Pipelines; (3) Sliding Connection With Stopper; (4) Flexible Connection For Penetrating The Wall Of The Cable Shaft; (5) Flexible Connection Of Cable Channels; (6) Flexible Connection Of Sections Of The Gas Pipeline For Penetration Into The Building; (7) Flexible Connection; (8) Sliding Connection And Coupling; (9) Sliding Connection With Stopper And Concrete Cable Tray; (10) Sliding Connection With Stopper And Coupling; (11) Reinforced Concrete Manhole Cover; (12) Building Of The User Of Services; (13) Cable Channel; (14) Cable Mine; (15) Cable Sewerage; (16) Penetration Of The Bridge Crossing; (17) Inspection Well; (18) Inspection Well; (19) Regular Soil; (20) Water-Saturated Soil; (21) Directions Of Displacements; (22) The Wall Of The Building; (23) Flexible Corrugated Gas Pipeline [27]

Table 3: Comparative Characteristics Of Signals Of Different Physical Nature Used In Underwater Communication [19].

Signal characteristi cs	The physical nature of the signal		
	Acousti c	Electromagnet ic radio	Optical
Transmission (range), km	< 20	< 0.1	0.1–0.2
Propagation (speed), m/s	1500	2,25×10^8	2,25×10^8
Data transfer rate	< 10 Kbps	< 0,1 Gbps	< 10 Gbps

Table 4: The Radio Spectrum And Some Of Its Applications [20].

Band	Applications
Extremely High (30–300 GHz)	Radar, advanced communication systems, remote sensing, radio astronomy.
Super High (3–30 GHz)	Radar, satellite communication systems, aircraft navigation, radio astronomy, remote sensing.
Ultra High (0.3–3 GHz)	TV broadcasting, radar, radio astronomy, microwave ovens, cellular telephone.
Very High (30–300 MHz)	TV and FM broadcasting, mobile radio communication, air traffic control.
High (3–30 MHz)	Shortwave broadcasting.
Medium (0.3–3 MHz)	AM broadcasting.
Low Frequency (30–300 kHz)	Radio beacons, weather broadcast stations for air navigation.
Very Low (3–30 kHz)	Navigation and position location.
Ultra Low (0.3–3 kHz)	Audio signals on telephone.
Super Low (30–300 Hz)	Ionospheric sensing, electric power distribution, submarine communication.
Extremely Low (3–30 Hz)	Detection of buried metal objects.
Less than 3 Hz	Magnetotelluric sensing of the Earth's structure.

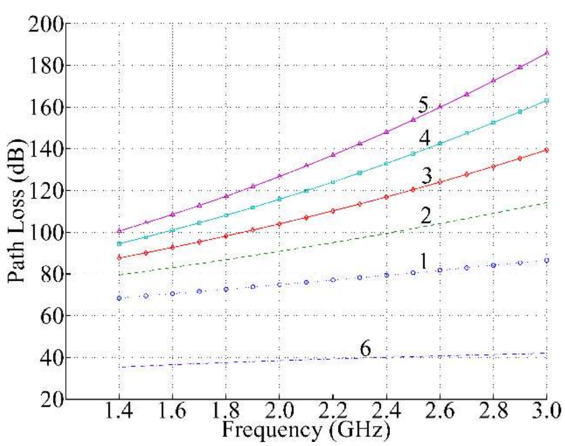

Figure 4: Dependence Of The Attenuation Of The Path On The Frequency Of The Electromagnetic Wave [21]

The attenuation of the path (decrease in the power density of the electromagnetic wave during its propagation) depends on the absorption of the material. It takes into account the spherical propagation of the wavefront. Sample transmission medium—soil consisting of 50% sand, 35% silt and 15% clay with different volumetric moisture content (curve 1 is 5%, 2 is 10%, 3 is 15%, 4 is 20%, 5 is 25%). For comparison, curve 6 shows the attenuation during wave propagation in the atmosphere. The bulk density of the soil is 1.3 g/cm^3. The specific density is 2.66 g/cm^3 [21].

It is proposed to lay them underground to protect line and cable structures from threats. Fig. 5 presents enhanced precautions for underground cable structures' protection.

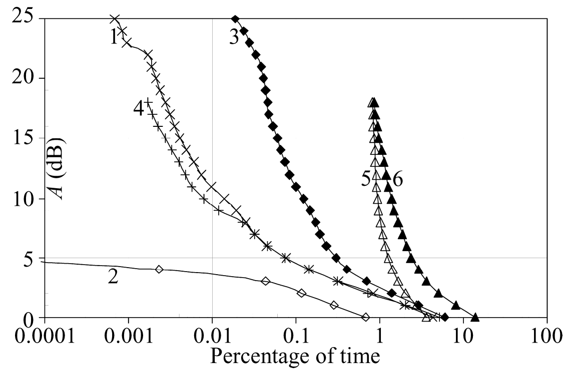

Figure 5: Attenuation A During Time Intervals T In Radio And Optical Communication Lines: 1 Is 58 GHz, Rain; 2 Is 58 GHz, Fog; 3 Is 58 GHz, All; 4 Is FSO, Rain; 5 Is FSO, Fog; 6 Is FSO, All [7]

5. DISCUSSION

5.1. Signal Parameters of Transmission Channels

The study revealed the dependence of the values of the parameters of the hybrid network on the physical nature of the signal; from the transmission medium.

First, the values of the signal parameters of different physical nature may differ in one specific transmission medium. For example, the attenuation A of electromagnetic and optical signals in the atmosphere ($A(i_f,i_t,2,1)$; $A(i_f,i_t,3,1)$), the range L and the maximum transmission rate V of acoustic, electromagnetic and optical signals in an underwater environment ($L(i_f,i_t,1,3)$; $V(i_f,i_t,1,3)$; $L(i_f,i_t,2,3)$; $V(i_f,i_t,2,3)$; $L(i_f,i_t,3,3)$; $V(i_f,i_t,3,3)$).

This suggests that inequality is true in many cases:

$$X\left[e_{ij}=\left(i_f,i_t,i_\varepsilon,i_m\right)\right]\neq X\left[e_{ij}=\left(i_f,i_t,i_{\varepsilon'},i_m\right)\right], \quad (11)$$

where X is some signal parameter in the hybrid network; ε, ε' are signals of different physical nature.

Secondly, unequal values of signal parameters of one definite physical nature in different transmission media have been revealed. The electromagnetic signal propagates with a low level of attenuation in free space $\beta(i_f,i_t,2,1)$, $\beta(i_f,i_t,2,2)$), and on artificial guides ($\beta(i_f,i_t,2,5)$; with high level—in underwater $\beta(i_f,i_t,2,3)$; and underground $\beta(i_f,i_t,2,4)$ environments. The optical signal propagates with a low level of attenuation in space $\beta(i_f,i_t,3,2)$ and on artificial guides $\beta(i_f,i_t,3,5)$, with a higher level in the atmosphere $\beta(i_f,i_t,3,1)$, with even greater level—in water β $(i_f,i_t,3,3)$, does not spread underground $\beta(i_f,i_t,3,4)$.

This suggests that inequality is true in many cases:

$$X\left[e_{ij}=\left(i_f,i_t,i_\varepsilon,i_m\right)\right]\neq X\left[e_{ij}=\left(i_f,i_t,i_\varepsilon,i_{m'}\right)\right] \quad (12)$$

where m, m' are different transmission medium.

Then it is logical to assume that the values of some signal parameters of different physical nature in different transmission media are different:

$$\left\{\begin{matrix} X\left[e_{ij}=\left(i_f,i_t,i_\varepsilon,i_m\right)\right]\neq \\ \neq X\left[e_{ij}=\left(i_f,i_t,i_{\varepsilon'},i_m\right)\right]\end{matrix}\right\}\vee$$
$$\vee\left\{\begin{matrix} X\left[e_{ij}=\left(i_f,i_t,i_\varepsilon,i_m\right)\right]\neq \\ \neq X\left[e_{ij}=\left(i_f,i_t,i_\varepsilon,i_{m'}\right)\right]\end{matrix}\right\}\vee \quad (13)$$
$$\vee\left\{\begin{matrix} X\left[e_{ij}=\left(i_f,i_t,i_\varepsilon,i_m\right)\right]\neq \\ \neq X\left[e_{ij}=\left(i_f,i_t,i_{\varepsilon'},i_{m'}\right)\right]\end{matrix}\right\}$$

where $\vee$ is symbol of disjunction (logical OR).

Also, the discrepancy in parameters of signals from weather conditions frequency of an electromagnetic wave is revealed. All of this determines the feasibility of using signals of different physical nature in different transmission media, mainly depending on weather conditions and the frequency of the electromagnetic wave.

5.2. Improving the Physical Compatibility

Signals of different physical nature can initiate the conversion of some types of energy into others:

- ✓ When passing through the layers of earth's elastic waves, the earth is electrified [22].
- ✓ Due to the irradiation of the matter with light, ionizing radiation, the passage of electric current through it, during chemical reactions, and mechanical impact, there is fluorescence—the emission of light by exciting matter [23].
- ✓ When the substance absorbs the energy of radio waves and radiates heat—there is infrared radiation (absorption and infrared radiation) [23].
- ✓ Under a resonant electromagnetic wave, the photon is emitted by an excited quantum mechanical system (laser) [23].

Taking this into account and providing that the mechanisms for converting some types of energy into others are either negligible or non-existent,

$$X\left[e_{ij}=\left(i_f,i_t,1,i_m\right)\right]\cap\ldots\cap$$
$$\cap X\left[e_{ij}=\left(i_f,i_t,i_\varepsilon,i_m\right)\right]\cap\ldots\cap$$
$$\cap X\left[e_{ij}=\left(i_f,i_t,n_\varepsilon,i_m\right)\right]\approx 0. \quad (14)$$

The isolation of the signal transmission media mi from each other and the interaction of signals in the transmission channels are excluded:

$$X\left[e_{ij}=\left(i_f,i_t,i_\varepsilon,1\right)\right]\cap\ldots\cap$$
$$\cap X\left[e_{ij}=\left(i_f,i_t,i_\varepsilon,i_m\right)\right]\cap\ldots\cap$$
$$\cap X\left[e_{ij}=\left(i_f,i_t,i_\varepsilon,n_m\right)\right]=\varnothing. \quad (15)$$

Then it is logical to assume the absence of the mechanisms of interaction between signals of different physical nature in the different transmission mediums:

$$\left\{\begin{matrix} X\left[e_{ij}=\left(i_f,i_t,i_\varepsilon,i_m\right)\right]\cap\ldots \\ \ldots\cap X\left[e_{ij}=\left(i_f,i_t,i_{\varepsilon'},i_m\right)\right]\end{matrix}\right\}\vee$$
$$\vee\left\{\begin{matrix} X\left[e_{ij}=\left(i_f,i_t,i_\varepsilon,i_m\right)\right]\cap\ldots \\ \ldots\cap X\left[e_{ij}=\left(i_f,i_t,i_\varepsilon,i_{m'}\right)\right]\end{matrix}\right\}\vee \quad (16)$$
$$\vee\left\{\begin{matrix} X\left[e_{ij}=\left(i_f,i_t,i_\varepsilon,i_m\right)\right]\cap\ldots \\ \ldots\cap X\left[e_{ij}=\left(i_f,i_t,i_{\varepsilon'},i_{m'}\right)\right]\end{matrix}\right\}\approx 0$$

Thus, allocating hybrid telecommunications network resources into channels with signals of different physical nature in different transmission media helps to increase the compatibility of communication channels.

6. RECOMMENDATIONS FOR INCREASING THE PHYSICAL COMPATIBILITY OF EQUIPMENT IN A HYBRID NETWORK

Fig. 6 shows a diagram of a flexible device for implementing multi-channel information transmission in a hybrid network, which allows choosing the best performing channel for transmitting the information.

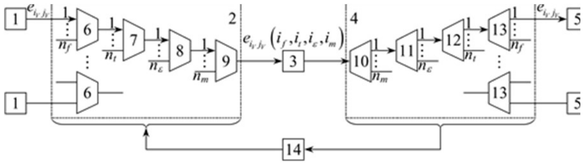

Figure. 6. Block Diagram Of A Device For Multi-Channel Information Transmission On A Section Of The Information Transmission Network, In Simplex Mode [26]

Lettering in Fig. 6: e_{ij} is communication lines (channels) between stations and network nodes; i_f, $i_f = \overline{1, n_f}$, i_t, $i_t = \overline{1, n_t}$, i_ε, $i_\varepsilon = \overline{1, n_\varepsilon}$, i_m, $i_m = \overline{1, n_m}$ are channel identifiers of frequency multiplexing systems with frequency f, with time t channel divisions, with channel divisions according to the physical nature of signals ε, with channel divisions by transmission media m, respectively; n_f, n_t, n_ε, n_m are the number of channels n of multiplexing systems with frequency f, time t channel divisions, with channel division by the physical nature of the signals ε, and by the transmission media m, respectively.

The device for multi-channel transmission of information on the network includes an information source 1, transmitter switch 2, and communication line 3, the resources of which are sets of transmission media, signals of different physical nature, frequency bands and signal time intervals, receiver switch 4, user server 5, channel condition monitoring selector and transmission channel selection 14. The transmitter switch 2 comprises flexible multiplexers 6, which provide information with channel separation by n_f units ($n_f \geq 1$) by frequency, flexible multiplexers 7, which provide information with channel separation by n_t units ($n_t \geq 1$) by time, flexible multiplexers 8, which provide transmission of information with channel separation by the number of n_ε units ($n_\varepsilon \geq 1$) by the physical nature of the signal, flexible multiplexers 9, which provide transmission of information with channel separation by the number of n_m units ($n_m \geq 1$) by media. The switch of the receiver 4 includes flexible demultiplexers 10, 11, 12, 13, which provide reception of information with the division of channels by media, the physical nature of the signal, time, and frequency, respectively.

The device for multi-channel information transmission is implemented as follows. The information signal on the channel (communication line) e_{ij} from information source 1 is fed to the transmitter switch 2. In switch 2 by successive transformations in the multiplexers 6–9, the information signal is assigned a unique resource for independent transmission over the communication line 3: in the flexible multiplexers 6, 7, 8, 9 signal is assigned the frequency resource i_f, time resource i_t, resource belonging to the set of signals of different physical nature i_ε, the environmental resource i_m, respectively. The information signal transmitted from the switch transmitter 2, using the hybrid communication line 3, on the channel $e_{ij}(i_f,i_t,i_\varepsilon,i_m)$, is received by the switch of the receiver 4. In switch 4 by successive inverse transformations in demultiplexers 10–13, the information signal is converted in the format $e_{i'j'}$, acceptable for transmission to the switch of the receiver 5. The selector for monitoring the state of the channels and the selection of the transmission channels 14 monitors the status of resources in the receiver 4, which, when transmitted over the communication line 3, are subject to destabilizing factors and generates commands to exclude network resources in the transmitter 2 that do not meet the accepted requirements for the quality of signal transmission and the inclusion of network resources in the switch transmitter 2, which meet the accepted requirements for the quality of signal transmission.

It should be noted that the proposed method of assessing PCE can be strengthened by combining it with methods of building forecasts of emergencies in telecommunication networks based on machine learning. Thus, it becomes possible to develop an action plan for the obstacles that have arisen and prevent their occurrence.

7. CONCLUSIONS

The main goal of the conducted research was to improve the process of assessing the physical compatibility of equipment. This will allow optimizing the method of protecting telecommunication networks from preventing the danger of interference or at least reducing their negative consequences.

The article proposes using information technology to assess PCE in a hybrid information transmission network. The application scheme of the protection measures against disturbances in a hybrid network of information transmission for which construction of the application scheme of the lightning protection measures is used has been shown.

A method for studying the compatibility of the equipment, which uses the elements of the reliability theories and graphs, has been developed. The method allowed for unambiguously describing the communication channels, which determines the possible purpose of the description for use, as a required field, in the databases of network structures.

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A study of the PCE has been conducted. The following tasks have been solved:

- ✓ The list of the environments by which signals of various physical nature are transferred has been defined.
- ✓ The list of the signals of different physical nature which are used for information transmission has been defined.
- ✓ The correspondence of the signals of different physical nature used for information transmission to the transmission media has been determined.
- ✓ The parameters of signals of different physical nature in different transmission media have been studied.

By mathematical modeling, the discrepancy of the signal parameters of different physical nature in different transmission environments that can define the expediency of their use in information transmission networks has been revealed.

It is established that the distribution of telecommunication network resources on channels with signals of different physical nature in different transmission media helps increase equipment's physical compatibility.

Based on the conducted research and the developed method of assessing the PCE in a hybrid telecommunication network, a device for multi-channel information transmission in the network has been developed, which allows you to choose the most effective channel for information transmission. Which, in turn, will allow optimizing the method of protecting the telecommunications network from natural disasters. The proposed method will make it possible to develop an action plan to prevent the danger of obstacles or reduce their negative consequences.

Recommendations for increasing the PCE in a hybrid network of information transmissions have been developed.

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Table 2: The Examples Of The Information Signal Different Physical Nature In Different Transmission Media Usage.

Matrix	Examples of the information signals usage
$e_{ij}(i_f,i_t,1,1)$	Telephone communication technology consists in converting the acoustic signals of a voice message into electrical signals transmitted over a telecommunication network and inversely converting the terminal equipment of the oncoming subscriber [11].
$e_{ij}(i_f,i_t,1,2)$	Sound cannot propagate in airless space.
$e_{ij}(i_f,i_t,1,3)$, $e_{ij}(i_f,i_t,2,3)$, $e_{ij}(i_f,i_t,3,3)$	Table 3 shows the comparative characteristics of signals of different physical nature, which are used in underwater communication.
$e_{ij}(i_f,i_t,1,4)$	Soil and the surface of the earth's crust are media for the propagation of the acoustic field and are, in particular, channels for information leakage [12].
$e_{ij}(i_f,i_t,1,5)$	An acoustic waveguide is used to transmit acoustic signals. It is a part of the atmosphere bounded in one or two directions by walls. As a result, the waves' divergence to the sides is eliminated, and the sound propagates with less attenuation than in an unlimited homogeneous medium. Artificial acoustic waveguides are usually pipes bounded by soundproof walls. Used, in particular, in courts [13].
$e_{ij}(i_f,i_t,2,1)$, $e_{ij}(i_f,i_t,2,2)$	Table 4 shows the radio spectrum and some of its applications [11].
$e_{ij}(i_f,i_t,2,4)$	Underground sensor radio networks are organized to monitor soil conditions in agriculture, landslides, earthquakes, navigation needs, etc. Fig. 3 shows the dependence of the attenuation of the signal path α on the frequency of the electromagnetic wave f.
$e_{ij}(i_f,i_t,2,5)$	To transmit electromagnetic signals, artificial guides are used—overhead lines, symmetrical and coaxial cables, electromagnetic waveguide (radio waveguide) [14].
$e_{ij}(i_f,i_t,3,1)$	Wireless optical technologies use a spectrum of 1.4–2.5 THz (wavelengths from 400 to 700 nm). In particular, FSO technology (from Free-Space Optics) is positioned for transport networks, and Li-Fi technology is for access networks (last mile communication lines) [15]. Visibility, depending on weather conditions (from clear skies to dense fog) and rainfall, is from 50 m to 50 km [7]. Fig. 4 for comparison shows the dependence of the attenuation of the signal A on time intervals in the radio (RF from Radio Frequency) and optical FSO communication lines in fog and rain.
$e_{ij}(i_f,i_t,3,2)$	In 2001, Optical Wireless Communication (OWC) was established between the European Space Agency's ARTEMIS geostationary communications satellite and the French 50-Mbps SPOT-4 Earth observation satellite. Later, thanks to the introduction of coherent methods, the speed was increased to about 1 Gbps. A European EDRS data exchange system is being developed to transmit information to non-geostationary satellites, spacecraft, and stationary earth stations. It includes three GEO communications satellites connected by OWC lines. The K_a is frequency spectrum of centimeter and millimeter wavelengths (electromagnetic spectrum from 26.5 to 40 GHz, corresponding to wavelengths from 1.13 to 0.75 cm) are used to communicate with ground stations [16].
$e_{ij}(i_f,i_t,3,4)$	Optical signals are not propagated underground.
$e_{ij}(i_f,i_t,3,5)$	An optical fiber (optical cable) is used to transmit optical signals [14].
$e_{ij}(i_f,i_t,4,1)$, $e_{ij}(i_f,i_t,4,2)$, $e_{ij}(i_f,i_t,4,5)$	Under the guidance of scientists from the University of Science and Technology of China, the world's first integrated quantum communication network has been deployed in China. The total length of more than 700 fiber-optic segments and two space stations with data transmission over satellite channels of the network reaches 4,600 km [17].
$e_{ij}(i_f,i_t,4,3)$, $e_{ij}(i_f,i_t,4,4)$	No data available.
$e_{ij}(i_f,i_t,5,1)$, $e_{ij}(i_f,i_t,5,2)$, $e_{ij}(i_f,i_t,5,3)$, $e_{ij}(i_f,i_t,5,4)$	Experiments are currently being conducted to transmit data through interference to communication facilities located in hard-to-reach underwater and underground facilities. In 2012, a session of wireless neutrino communication was demonstrated at a distance of 1,035 km, including through 240 m of rock. The data transfer rate was 0.1 bit/s, and the bit error rate was 1% [18].
$e_{ij}(i_f,i_t,5,5)$	No data available