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Evaluation of Noise Immunity of Channels with Rail and Inductive-Rail Lines

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Abstract. Modern train interval control systems contain communication channels between traffic organizers and the train locomotive, using rail and inductive rail as communication lines. The rail threads that make up these lines are an integral part of the traction network and, therefore, the traction current is channeled through them. Bearing this in mind, the signals of these channels operate under the conditions of strong interference from traction current. At present, continuous automatic locomotive signalling systems continue to improve, so it is necessary to have information on the relationship between the immunity of their channels, in particular under conditions of traction current interference, from different signal parameters, such as carrier frequency. This article deals with the method of evaluating the influence of the frequency of the carrier signal on the noise resistance of the channels comprising rail and inductive rail lines.

1 Introduction

The Russian railways are constantly improving their technical base: track superstructure, locomotive control systems, wagon design, traction elements, etc.

One of the main components of the railways is the Train Interval Control Systems (TSDS), which are also constantly being improved. For example, the electromagnetic relay, which implements all the basic control and control functions of SIRWD floor facilities, has been replaced by microelectronics, which has almost completely changed the structure of SIRWD. Microelectronics has made it possible to apply completely new methods and methods of signal and noise processing, methods of logical decision-making, organization and construction of devices, technical diagnostics, etc.

Given that SIRGs operate under strong current distortion signals such as rail lines (RL) and inductive rail lines (IRL), it is necessary to have information on the parameters of these disturbances at all times in order to successfully combat them. According to [1–3], knowledge of the parameters of the interference provides almost complete protection against their influence on the signal reception.

In view of the above, this work is aimed at the development of a machine simulation model allowing the estimation of the immunity of the signals receivers in any communication channel with RL and IRL [4, 5].

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2 Materials and Methods

The immunity of the channels can be investigated in real world operation on real devices. It is possible to carry out research on physical models of channels, but the most advanced method of research is machine modeling, which allows research of almost any type of channel with minimal time and economic investment, subject to any type of interference [6].

In this work, it is proposed to apply machine simulation to the estimation of the immunity of RL and IRL channels using a machine model of interference and signals.

In Figure 1 the functional design of a computer-based machine simulation model is presented, which makes it possible, by means of machine simulation models of interference and signals, to evaluate the immunity of receivers in channels with RL and IRL.

The functional scheme contains the following procedures:

- RL and IRL signal generation (procedure 1);
- interference (procedure 2);
- Mixed signal and interference (procedure 3);
- Reception of a mixture of signal and interference (procedure 4);
- Assessment of immunity (procedure 5);
- Conclusion of the evaluation (procedure 6).

In the first stage, when developing a simulation model of interference, the interference with DC propulsion current was chosen as the level and intensity of these disturbances far exceeds the level and intensity of the AC propulsion current. A preliminary recording was made of interference at the output of the receiving coils (PCs) located on the train locomotives. Interference was recorded on the Moscow Railway (Moscow Section Sortirovochnaya – Cherusti – Rybnoe) and on the Kuibyshev Railway (section Kinel – Oktyabrsk) for 5 years. As a result of the research carried out, the following types of interference have been found in the RL and IRL: spectral-concentrated (harmonic), pulsed and fluctuating [7, 8].

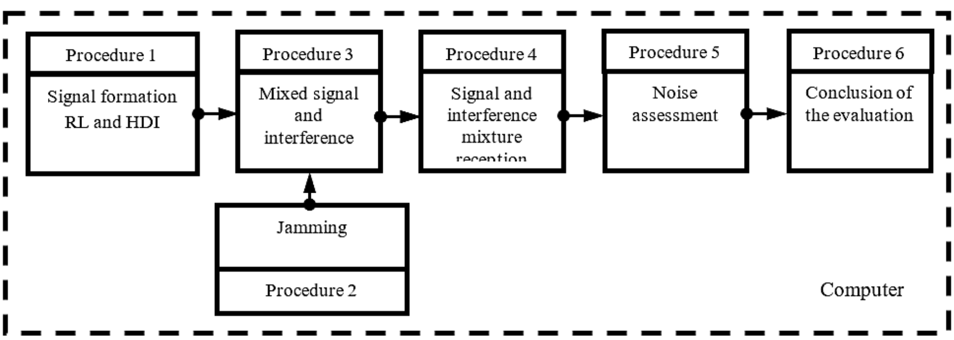


Fig. 1. Functional diagram of a computer-based machine simulation model

The recording and subsequent treatment of DC interference at the RL and IRL outputs revealed that the impulse interference was the most significant, in the sense of signal distortion. In order to assess the immunity of channels with RL and IRL, the Markov model of impulse interference was developed and a mathematical expectation of the amplitude of fluctuation interference was established. At the same time, the spectral concentration of interference was determined. The analysis of DC interference shows that in terms of immunity, impulse and fluctuating additive interference are most significant for RL and IRL signals, as their influence significantly distorts the transmitted signals [9].

Impulse disturbances in the RL and IRL occur mainly during switching of traction engine coupling schemes of the train locomotive. For example, on type VL10U locomotives (Figure 2), traction engines have four possible coupling schemes:

Traction engines switched off — “0”

- Sequential connection (C);
- serial-parallel connection (SP);
- parallel connection (P).

During the movement of a train locomotive, the train operator, depending on local conditions, speed limits and the character of the train movement, constantly switches the coupling circuits of traction engines. There are impulse disturbances in the RL and IRL. When the traction current receiver slides along the contact wire, fluctuating interference occurs.

The results of the research made it possible for the first time to develop mathematical models of additive fluctuation and impulse interference [9], on the basis of which simulation models of the sources of these emissions were developed.

It is widely known that the main source of disturbance from traction current is the train locomotive. The drive control process of the electric locomotive is accompanied by a change in the value of the traction current during start-up, acceleration and electric braking. The start-up of electric locomotive engines and the control of the speed of the locomotive are carried out by changing the voltage supplied to the traction engines and by changing the magnetic flow of the engine.

When touching the traction current, the Id shall be limited to successively inserting the R resistance into the circuit

$$I_d = \frac{U_d}{R_d + R},$$

where Ud — the voltage on the engine clamps;

Rd — the internal resistance of the engine;

R — the resistance of the starter rheostat.

In order to maintain the permanence of the starting current, the value of R is reduced as the speed increases. In practice, step-by-step resistance is widely used by switching off individual sections of the resistance. The reduction of energy losses in start-up reeds as well as in train movements is achieved by changing the voltage of traction engines when switching on them is changed. For example, an eight-axle electric locomotive can have three circuits for activating propulsion engines (see Figure 2).

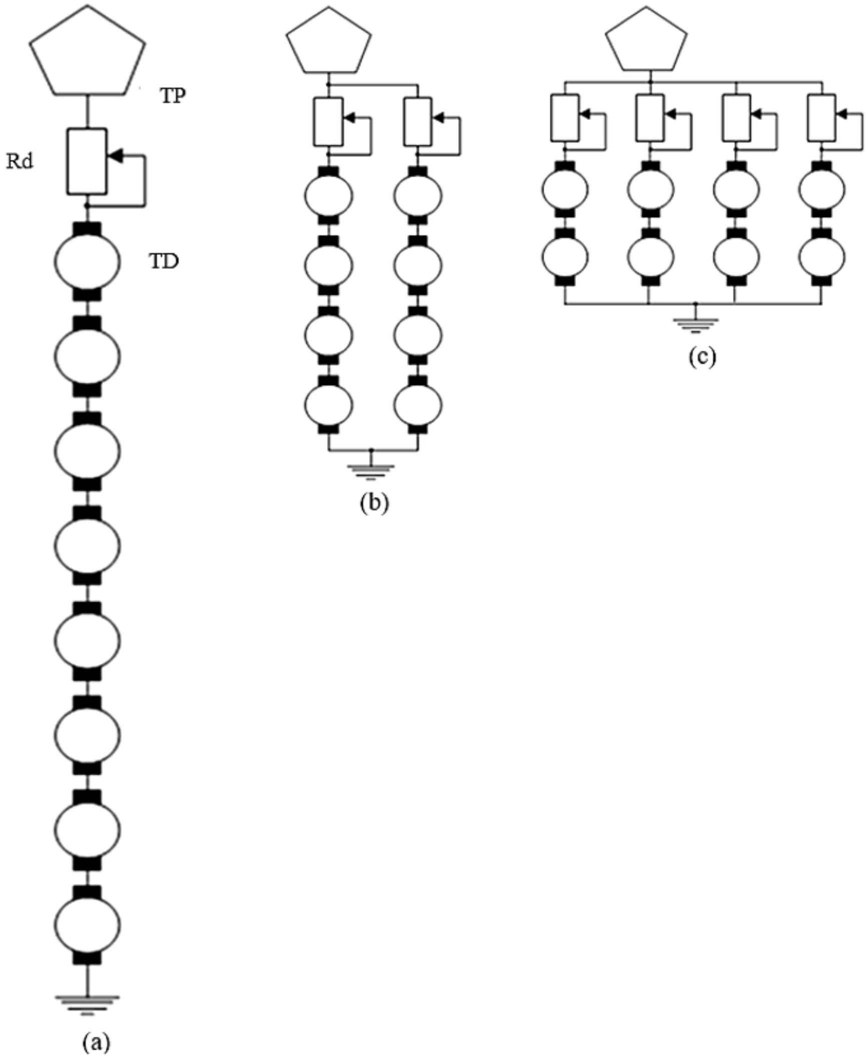


Fig. 2. Connection diagrams of traction motors of an eight-axle electric locomotive: (a) — sequential (C); (b) — serial-parallel (SP); (c) — parallel (P)

The authors developed a simulation model of the source of interference from direct traction current in the RL and IRL in the simulation environment Simulink of the mathematical package MATLAB [10, 11]. A block diagram of the simulation model of this emission source is presented in Figure 3.

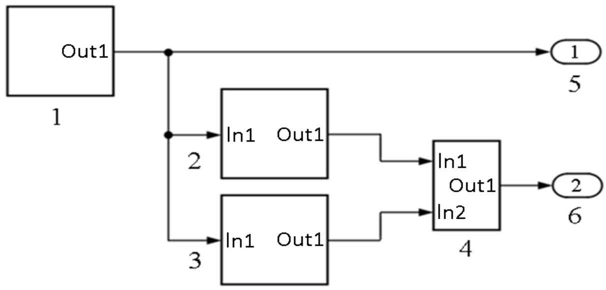
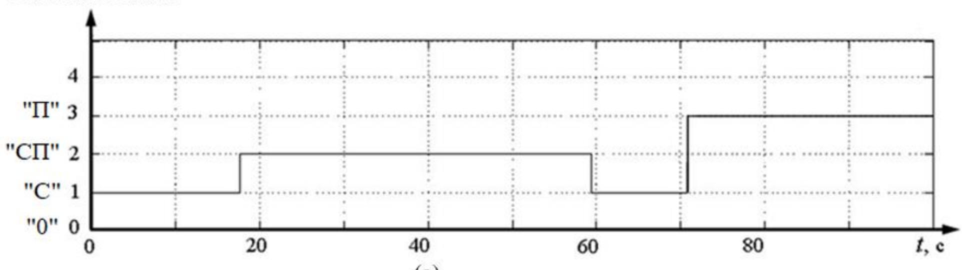


Fig. 3. Block diagram of a simulation model of DC traction current interference in Simulink

The block diagram comprises the following units: 1 — a model of switching of circuits for connecting traction electric motors of an electric locomotive; 2 and 3 — models of impulse and fluctuation interference, respectively; 4 — an aggregator of interference from the output of blocks 2 and 3; 5 — a signal output block, The inventive method for switching electric traction motors is characterized by an electric locomotive; 6 — a block for discharging formed disturbances from the output of blocks 1 and 4, respectively.

Thus, the simulation model of DC interference generates an additive mixture of impulse and fluctuation disturbances occurring in the RL and IRL during the movement of electric locomotives [12–14]. The functioning of the model is as follows: block 1 generates a random Markov' process — a model of the switching process of control circuits for traction electric motors of an electric locomotive (a signal appears at the output of the block containing information about the current connection scheme of traction motors of the locomotive and commutations at random times); block 2 generates impulse noise that occurs at the moments of switching control circuits for traction motors of an electric locomotive and is characterized by the values of parameters specific to each type of switching (impulse noise appears at the output of the block, which is a burst of pulses of a certain duration, amplitude and their number in a packet); block 3 generates a constant traction current fluctuation noise, acting continuously, the power of which depends on the current traction motor connection scheme; block 4 implements the process of summing up the interference from the output of blocks 2 and 3.

As an example, Figure 4 shows the oscillograms of the signals at the outputs of blocks 1 and 4 obtained using the simulation model (see Figure 3), showing respectively the accidental switching of traction motor coupling schemes in schemes “C”, “SP”, “C”, and “P” and the resulting voltage U of the additive mixture of impulse and fluctuating interference.



(a)

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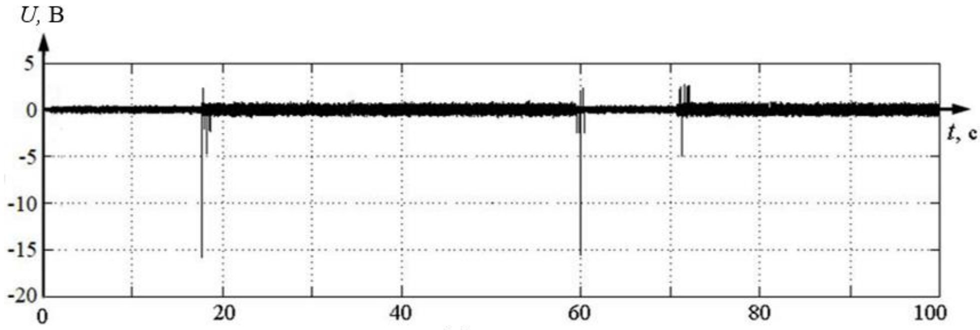

Fig. 4. Oscillograms of signals at the outputs of blocks 1 and 4 (see Figure 3): (a) — signal at the output of block 1; (b) — signal at the output of block 4

A preliminary analysis of the immunity of the channel with IRL, performed by means of a machine simulation model, showed a correlation between the probability of errors in the channel and the frequency of the carrier signal f.

The noise resistance of the channel with the IRL was evaluated when receiving a signal with amplitude manipulation of harmonic carrier single-polar rectangular pulses of low frequency with a borehole of two [15, 16].

In Figure 5 shows the graphs of the dependence of the attenuation a of the signal at the output of the RL, IL and IRL on the carrier frequency f.

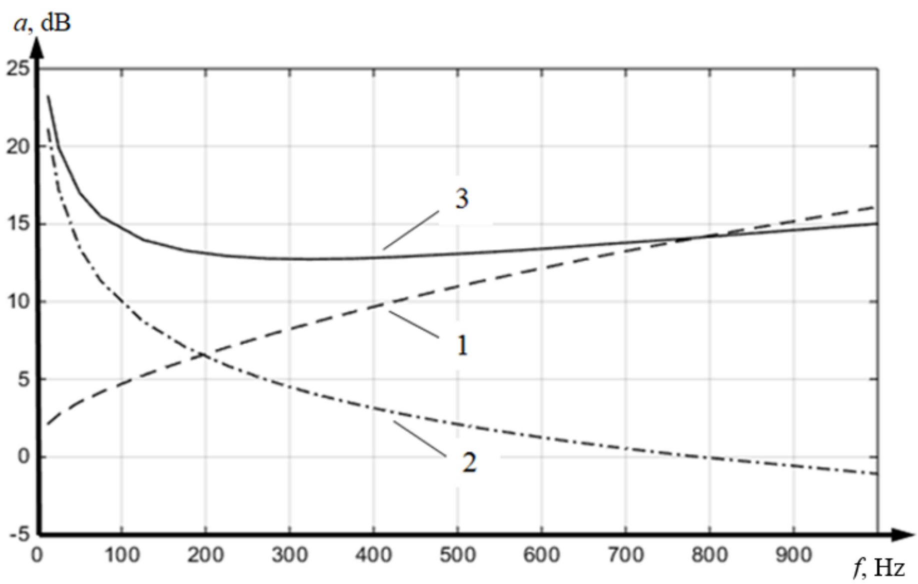

Fig. 5. Signal attenuation versus carrier frequency plots: 1 — attenuation in the RL; 2 — attenuation in IL; 3 — weakening in the IRL

The graphs show that signal attenuation in the RL increases almost linearly with carrier frequency growth, that in IL decreases nonlinearly, and that in IRL attenuation depends on two components: signal attenuation in the RL and signal attenuation in the IL. So on Graph 3, you can see a characteristic inflection: from zero carrier frequency the attenuation in IRL decreases, and from 375 Hz increases.

3 Results

Figure 6 shows the graph of the dependence of the average probability of errors Roch in the automatic locomotive signaling channel of continuous type ALSN with IRL on the frequency of carrier signal f. At 375 and 725 Hz there is an increase in immunity, which can be explained by the properties of impulse interference from direct propulsion current: at carrier signal current frequencies in the range 175–375 Hz and at frequencies above 725 Hz, there is a sharp decrease in the power of interference.

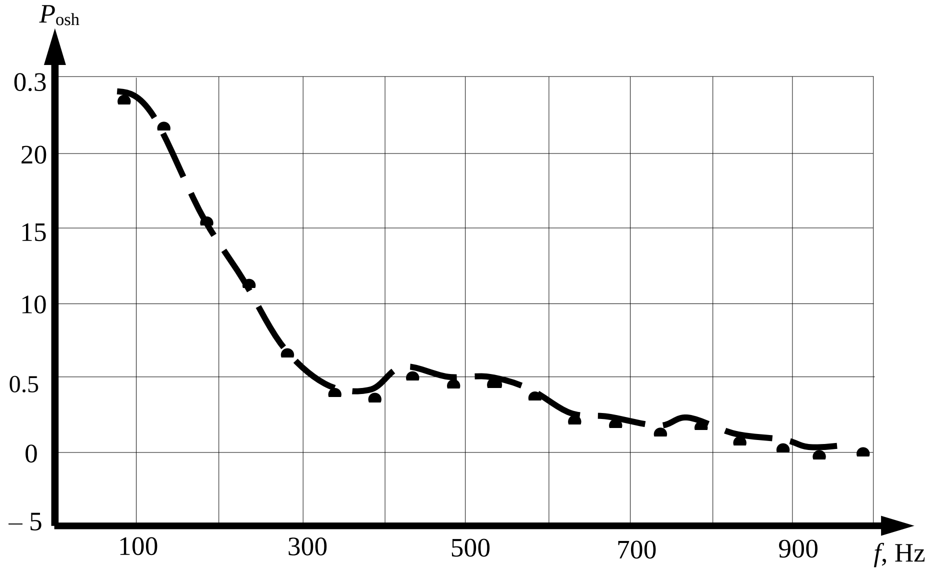

Fig 6. The graph of the dependence of the average probability of error when receiving an AM signal from carrier frequency

4 Conclusions

The use of the proposed machine model for evaluating the immunity of channels with RL and IRL, provided that data are available on the parameters of interference of any kind, makes it possible to determine the immunity of the automatic locomotive signaling channels, which means, in the future, to organize a stable communication between auto-locking devices on distances or electrical centralization at stations and locomotive safety devices.

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