DOI: 10.36137/2009E

Research Issues Regarding the Impact of a Rolling Stock on a Trackside Train Detection Systems Devices

Łukasz ZAWADKA[1], Dominik ADAMSKI[2]

Summary

The paper characterises the operation and basic components of track occupancy devices that are currently used on the PKP PLK S.A. network. Furthermore research methods of measurement of railway vehicles impact on track circuits and axle counter systems as well as wheel set axle impedance measurement that are performed in Railway Research Institute were described. Examples of measurement results were presented for each of the described methods.

Keywords: track circuits, axle counters, interference, magnetic fields, EMC

1. Introduction

The increasing number of modern rolling stock in service on the network managed by PKP PLK S.A. has clearly highlighted the need for research on the impact of a rolling stock on a trackside train detection systems devices, especially at the stage of the type-approval test. The components of these devices are largely installed in tracks and are directly exposed to interferences from moving trains. From the perspective of electromagnetic compatibility, differences in the construction of modern vehicles (high-power electric motors, extensive integration of various power and energy processing systems, as well as installations of advanced train control systems) contribute to an increase in potential disruptions in the railway electromagnetic environment, which can affect the safety and smoothness of railway traffic. [1, 7–10] Therefore, aspects related to the cooperation of rolling stock with trackside train detection systems devices should be treated as a priority and comprehensively. Additionally, modern measurement equipment enhances research and analytical capabilities, thereby enabling broader and more precise analysis of obtained results.

2. Impact on Track Circuits

A track circuit can be characterised as a section of track of appropriate length isolated from neighbouring sections. Essentially, there are closed track circuits, open track circuits, and audio frequency track circuits. Depending on the types and applications, track circuits are powered by alternating current at a specific frequency. The length of a track circuit can vary. A typical track circuit consists (excluding railroad tracks) of a transmitter and a receiver, which is connected to a track relay. In the normal state, when the controlled section is unoccupied, the track relay is in the excited state. The entry of rolling stock into the controlled area causes the rail tracks to deviate, which results in a sudden drop in voltage at the receiver, and the subsequent reactivation of the relay. Therefore, the state of the relay is the fundamental parameter determining the occupancy or vacancy of the track circuit.

To assess the interaction of a specific track circuit with the tested rolling stock, it is necessary to empirically verify the correctness of this interaction by examining the stability of voltages at the relay. Such research is conducted at the Railway Research Institute in the closed test track of the RRI in Żmigród [1–3]. The methodology involves simultaneous measurement and recording of voltage at the track relay and traction return current flowing through the rails of the track circuit, as the rolling stock approaches the track circuit and passes through it. This allows assessing the stability of voltage at the track relay when the track circuit is unoccupied and the track is loaded with traction return current. In this case, the voltage value at the track relay should be higher than its

[1] M.Sc. Eng.; Railway Research Institute, Railway Traffic Control and Telecom Department; e-mail: lzawadka@ikolej.pl.
[2] M.Sc. Eng.: Railway Research Institute, Railway Traffic Control and Telecom Department; e-mail: dadamski@ikolej.pl.

reactivation voltage. With the track circuit occupied, the voltage value at the track relay cannot exceed its de-excitation voltage, ensuring safe occupancy control. The recording of traction return current is used additionally to document that during the testing of rolling stock interaction with track circuits, traction current flows through the rails of the track circuit.

Figure 1 shows an example of the recording result of the interaction of a rail vehicle with a jointless track circuit SOT-1, characterised by the following parameters: operating frequency 1580 Hz, signal current in the rail 129 mA, voltage at the track relay 16 V AC. The red colour represents the values of traction current flowing through the rail, and blue represents the voltage value at the track relay.

Figure 2 shows an example of the recording result of the interaction of a rail vehicle with a jointless track circuit SOT-2, characterised by the following parameters: operating frequency 800 Hz, signal current in the rail 90 mA, voltage at the track relay 6.8 V AC. The red colour represents the values of traction current flowing through the rail, and blue represents the voltage value at the track relay.

When discussing the issue of rolling stock impact on track circuits, it is also important to mention the measurement of axle impedance. This parameter fundamentally affects the ability of a rail vehicle to shunt a particular circuit [12–14].

For track circuits used on the railway network managed by PKP PLK S.A., specific permissible values for axle impedance are adopted. Therefore, it is necessary to examine this value for each new vehicle during type-approval tests. [12–14] This test is also recommended to be conducted for vehicles immediately after repair

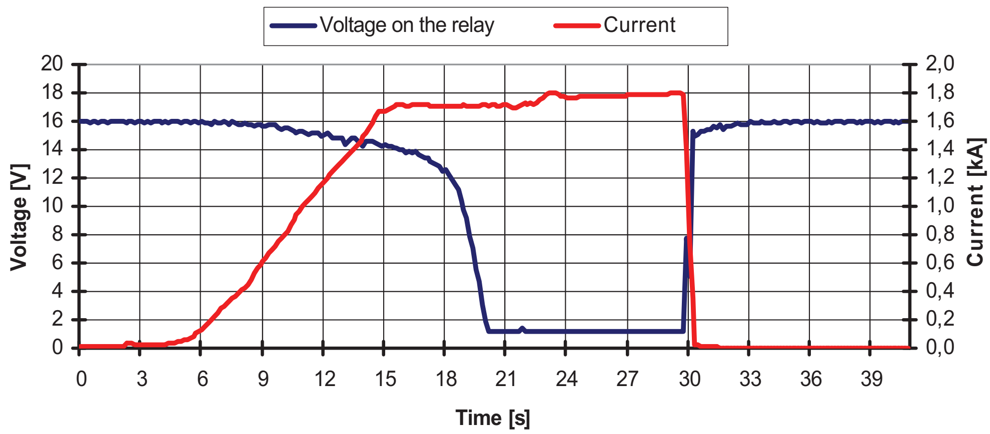

Fig. 1. Result of the recording of the vehicle's impact on the operation of the track circuit equipped with SOT-1 devices (1580 Hz) [own work]

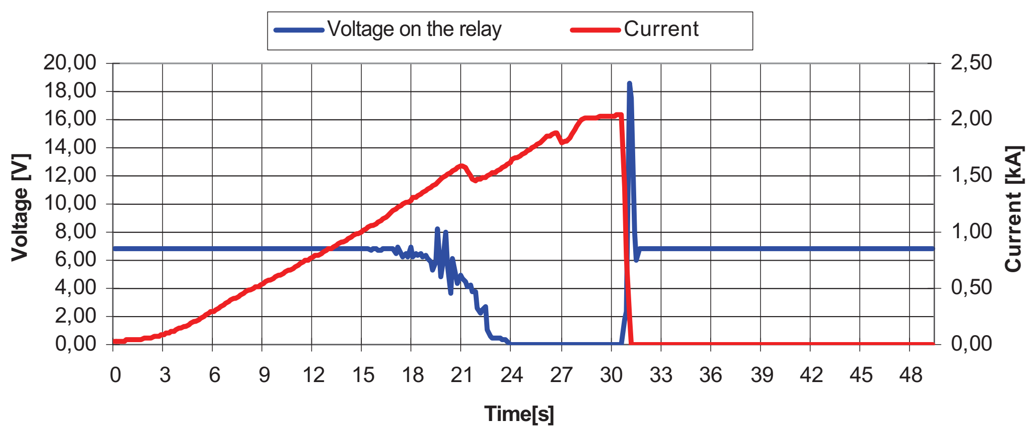

Fig. 2. Result of the recording of the vehicle's impact on the operation of the track circuit equipped with SOT-2 devices (8000 Hz) [own work]

or overhaul, as well as periodically (after wheel reprofiling or replacement, and wheel tread machining). Axle impedance measurements of rail vehicle wheel sets are mainly conducted at the Railway Research Institute in Warsaw and on the test track of the Railway Research Institute in Żmigród. The method of these measurements involves simultaneous measurement of voltage drop between the rails, voltage drop on the wheel set axle of the rolling stock, and the current applied to the circuit. It is worth emphasising that the measured axle should be isolated from other axles of the vehicle. The calculated impedance values for rail-to-rail and wheel-to-wheel, as derived from Ohm's Law, are compared to the permissible values of shunt impedances adopted for track circuits used at PKP Polskie Linie Kolejowe S.A.

The track circuits currently in service on Polish Railway Lines are adapted to the following maximum shunting impedance values [12, 13]:

- isolated track circuits powered by 50 Hz voltage – 0,06 Ω,
- jointless track circuits powered by a signal with a frequency of 1500÷3000 Hz – 0,1 Ω,
- jointless track circuits powered by a signal with a frequency of 7÷10 kHz – 0,15 Ω,
- jointless track circuits powered by a signal with a frequency above 10 kHz – 0,2 Ω.

Figure 3 depicts the measurement locations for voltage drops, while Figure 4 presents sample results of axle impedance measurements for various types of rolling stock conducted at the Railway Research Institute.

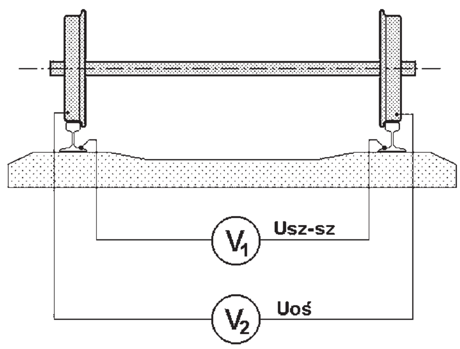

Fig. 3. Measurement locations for voltage drops [own work]

Based on the results presented in Fig. 4 and previous axle impedance tests, it can be concluded that achieving values consistent with normative values under operational conditions poses no problem for wheel set manufacturers.

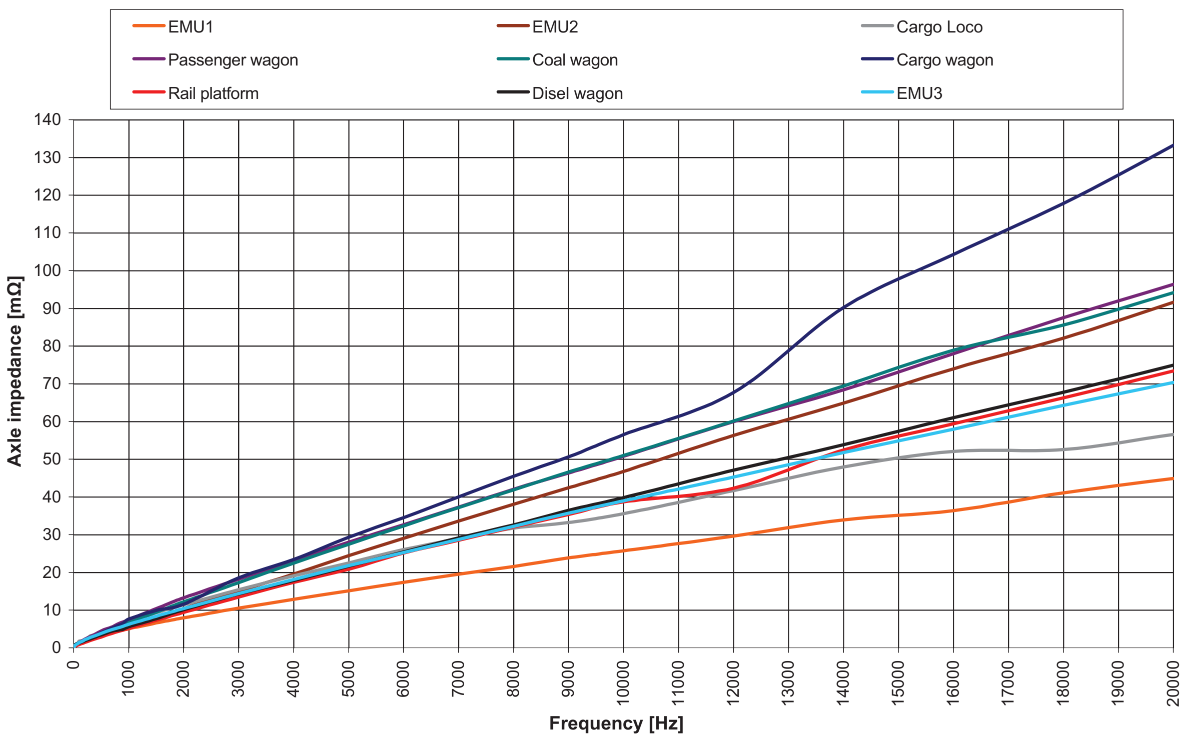

Fig. 4. Results of axle impedance measurement in the 0÷20 kHz frequency band [own work]

3. Impact on Axle Counters

Axle counter systems consist of similar components, which may be differently located depending on the type of counter (manufacturer). The basic components of an axle counter include (Fig. 5):

- wheel sensor,
- analogue circuits and impulse detection circuits of the contact,
- data transmission circuits,
- counting unit.

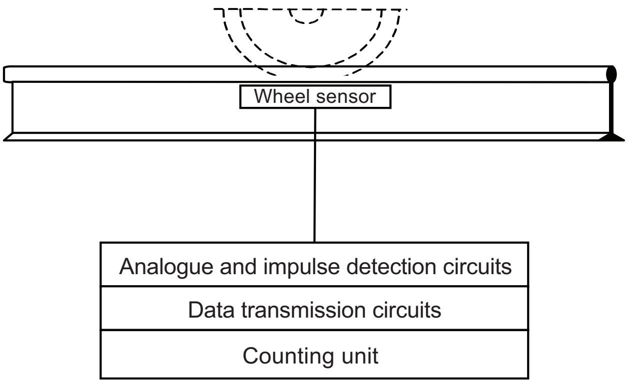

Fig. 5. Diagram of a typical axle counter construction [own work]

The division of the axle counter into components indicates that the rail contact is the element from which the axle counting process begins. The rail contact of the axle counter is mechanically connected to the rail, while its electrical circuit is separated from it. The rail contact of the axle counter system must meet sensitivity requirements to reliably detect the passage of a wheel (axle) of rolling stock through the interaction point. Therefore, the possibility of not detecting the entry of rolling stock onto the section controlled by this axle counter system must be eliminated. However, the sensitivity of the rail contact must also be limited, as it is necessary to ensure a certain resistance of the rail contact to external interference, which may cause erroneous, excessive axle counting despite the absence of passage of rolling stock through the interaction point.

Wheel sensors operate in frequency bands characteristic for the particular types of these devices. The current flowing in the rail at the frequency of operation of the contact or external magnetic field at this frequency strongly affects the operation of the contact. The vector of the magnetic field from the rail currents has a predictable direction, while the vector of the magnetic field from the vehicle depends on the location of the source of the interference in relation to the rail contact. The impact of disturbances will be different for the contact state when there are no axles nearby, and different when there is an axle in the contact's operating zone. Therefore, disturbances can be divided according to their origin into:

- currents flowing in the rail tracks (return traction current and currents resulting from resonances in the traction network),
- magnetic fields (constant and variable) generated by rolling stock components (e.g. rail brakes, eddy-current brakes, electric traction motors, traction converters).

The consequence of the interaction of magnetic fields whose intensity levels exceed permissible values is a negative impact on the operation of axle counters. This can manifest itself in, among other things, axle counters entering emergency states requiring manual restarts, axle imbalances of passing rolling stock, and ultimately incorrect indications of track occupancy. Each of these mentioned risks will have a negative impact on train traffic management and, in extreme cases, may even lead to accidents.

Therefore, it is necessary to conduct research on the levels of magnetic field emissions when introducing new or modernised rolling stock into service. The aim is to eliminate sources of interference from vehicles already at the stage of type-approval tests. Figures 6 and 7 illustrate the example of the effect of interference and its absence on the operation of a wheel detector.

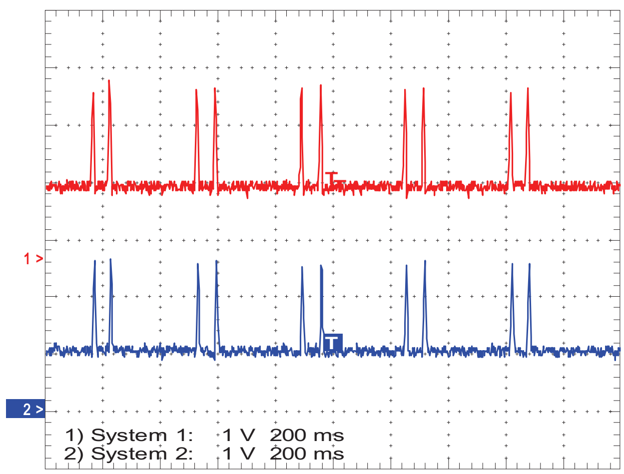

Fig. 6. Correct analogue signal transmitted by the wheel sensor (10 axles, 2 channels) [own work]

Taking this issue into account, a test stand was constructed at the Railway Research Institute to investigate the magnetic fields generated by rolling stock within the frequency band of axle counters. The structure of the test stand complies with current European standards [5, 6] and includes two MFS-3D-100 measurement antennas along with external measurement cards, cabling, and a laptop computer with specialised software. Supplementary equipment for the test stand includes measurement devices for calibration, including an oscilloscope, signal generator, and multimeters.

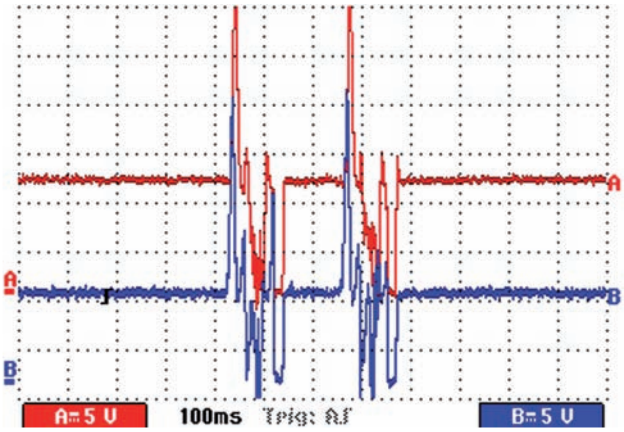

Fig. 7. Distorted analogue signal transmitted by the wheel sensor (2 axles, 2 channels) [own work]

The test takes place during the passage of railway rolling stock and involves measuring the magnetic field intensity values (and recording them) at the mounting location of the measurement antennas. By employing two measurement antennas concurrently, both sides of the test rolling stock can be measured simultaneously. The magnetic field intensity is measured in three planes – X, Y, Z – using special antennas mounted on the rails (Fig. 8), within the frequency range of 10 kHz to 2 MHz [7–11].

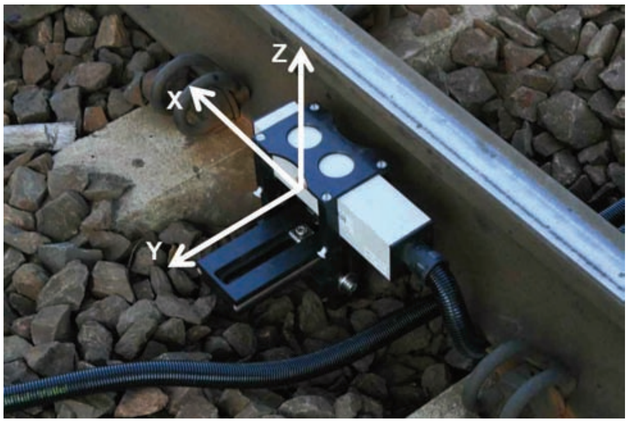

Fig. 8. View of the measurement antenna installed in the track with the indicated directions of the measurement planes [own work]

The measured and recorded values are compared with permissible values [4–6]. Based on this comparison, an assessment of the electromagnetic field's impact on the wheel detectors is made. Depending on the characteristics of the electromagnetic fields generated by the rolling stock, suitable types of wheel detectors are selected, and then the impact of the rolling stock is examined. Figures 9–11 present exemplary results of magnetic field intensity measurements recorded on the experimental track at the Railway Research Institute in Żmigród. The red colour represents permissible interference values according to the technical specification TS 50238-3 and document ERA/

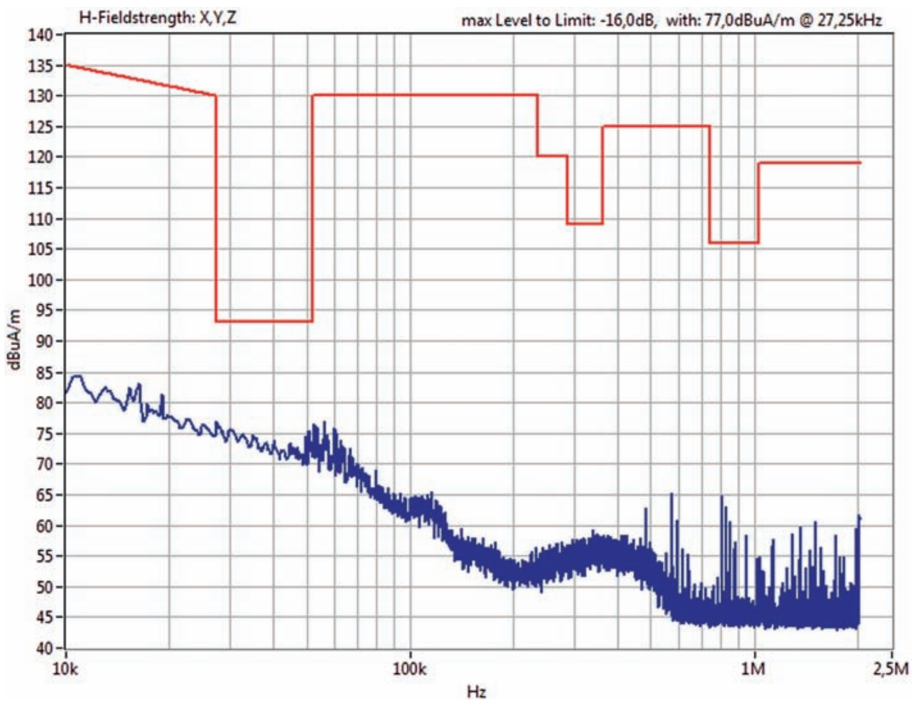

Fig. 9. Magnetic field intensity generated by the electric multiple unit in the X-plane [own work]

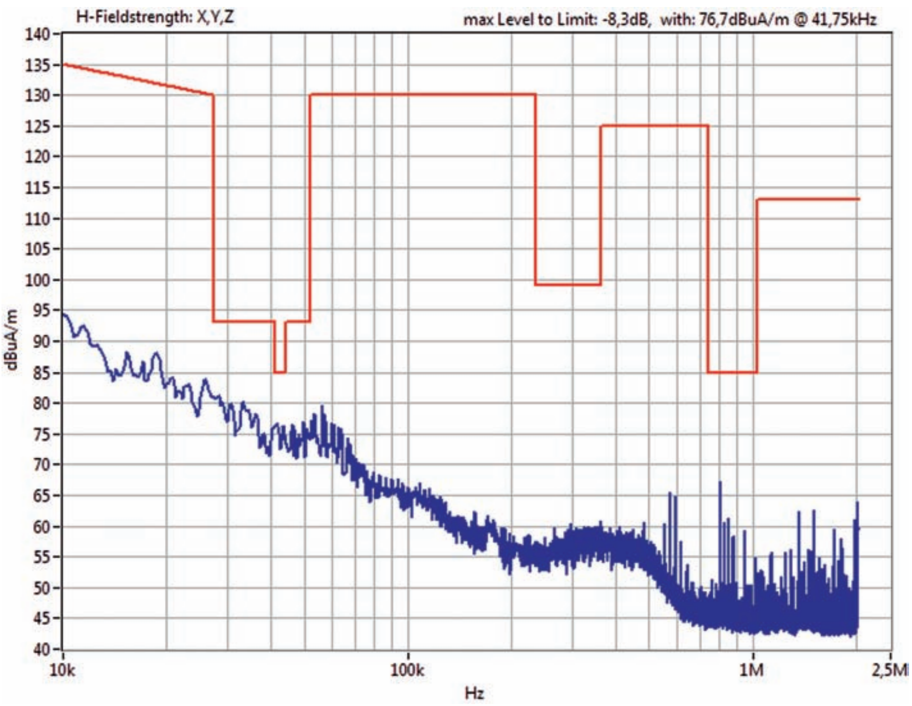

Fig. 10. Magnetic field intensity generated by the electric multiple unit in the Y-plane [own work]

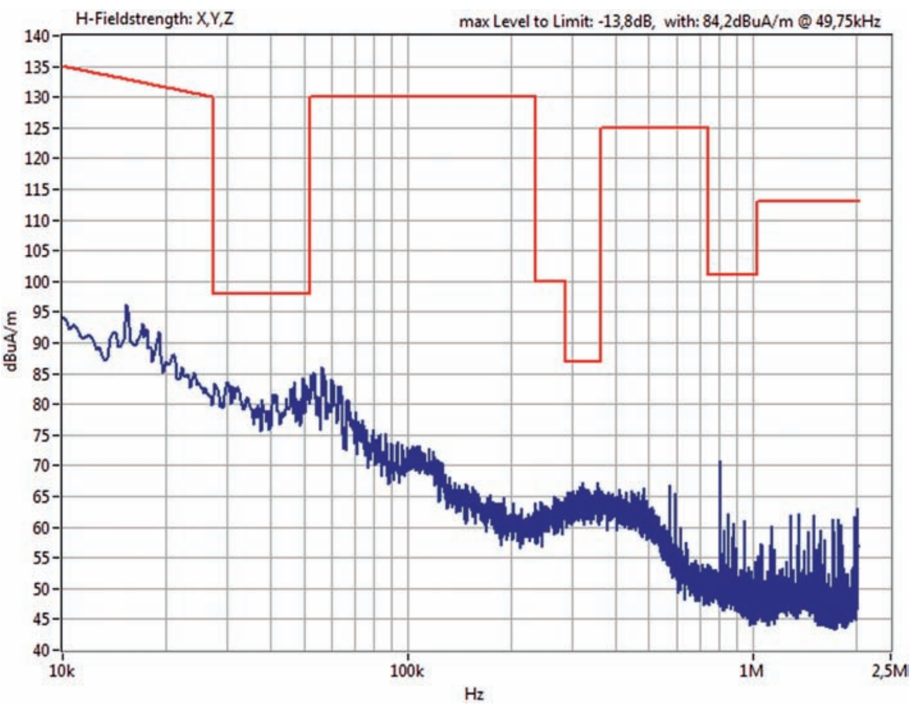

Fig. 11. Magnetic field intensity generated by the electric multiple unit in the Z-plane [own work]

ERTMS/033281 [5, 6], while the blue represents the intensity of fields generated by the tested vehicle.

In the event of exceeding the permissible value of the electromagnetic field of the tested rolling stock, it is necessary to record impulses at the output of the wheel detector operating in this frequency range to assess their distortions, which may affect the operation of the devices controlled by the wheel detector.

4. Conclusions

In the general trend of increasingly introducing axle counters and a large number of track circuits, studies on the impact of a rolling stock on a trackside train detection systems devices are a key issue and should be conducted for all rolling stock operating on the Polish railway network. Such studies will eliminate from operation rolling stock that may negatively affect the operation of these devices, and thus reduce disruptions in train traffic, making it easier to manage railway traffic and, above all, maintain safety at an appropriate level.

The presented method of studying magnetic field intensities meets the latest European standards and enables unambiguous determination of whether the tested vehicle may adversely affect the operation of wheel detectors and, consequently, the axle counters themselves.

The Railway Research Institute, as the first research unit, had qualified personnel and appropriate technical facilities enabling comprehensive implementation and evaluation of the results of railway rolling stock studies in terms of its impact on a trackside train detection systems devices. The research methods developed and implemented by the employees of the Railway Research Institute have repeatedly contributed to the detection of design and assembly errors at the stage of type-approval tests, as well as in the rolling stock in service.

References

1. Massel A. et.al.: *Rola okręgu doświadczalnego Instytutu Kolejnictwa w badaniach taboru i infrastruktury kolejowej* [The role of the Railway Institute's experimental district in research on rolling stock and railway infrastructure], Warszawa, Żmigród, 2021.
2. Białoń A., Furman J., Ortel K.: *Badania zgodności taboru kolejowego i systemów wykrywania pociągu wykonywane przez Instytut Kolejnictwa na podstawie wymagań krajowych* [Compliance tests of rolling stock and train detection systems performed by the Railway Institute based on national requirements], XXV Konferencja Naukowa Pojazdy Szynowe 2023, 10–13.09.2023.
3. Białoń A., Furman J., Ortel K.: *Charakterystyka badań EMC realizowanych na Okręgu Doświadczalnym Instytutu Kolejnictwa w Żmigrodzie* [Characteristics of EMC tests carried out at the Experimental District of the Railway Institute in Żmigród], XXV Konferencja Naukowa Pojazdy Szynowe 2023, 10–13.09.2023.
4. Lista Prezesa Urzędu Transportu Kolejowego w sprawie właściwych krajowych specyfikacji technicznych i dokumentów normalizacyjnych, których zastosowanie umożliwia spełnienie zasadniczych wymagań dotyczących interoperacyjności systemu kolei z dnia 05 listopada 2021 r.
5. Techniczna specyfikacja CLC/TS 50238-3:2022: Zastosowania kolejowe – Kompatybilność taboru kolejowego z systemami detekcji pociągów – Część 3: Kompatybilność z licznikami osi.
6. Dokument ERA/ERTMS/033281 wersja 4.0.
7. Adamski D., Ortel K., Zawadka Ł.: *Jednolita metoda badania kompatybilności elektromagnetycznej pomiędzy taborem a systemami detekcji* [Unified verification method of electromagnetic compbility between rolling stock and train detection], Prace Instytutu Kolejnictwa, 2019, z. 161.
8. Adamski D. et.al.: *Influence of magnetic field sof a rolling stock onaxle-counters used on Polish railway lines*, Infrastruktura Transportu, 2014 nr 4.
9. Adamski D. et.al.: *Wpływ pola magnetycznego generowanego przez pojazdy trakcyjne na urządzenia srk w odniesieniu do obowiązujących standardów* [Influence of magnetic Field generated by rolling stock on trackside signalin devices in according with applicable standards], Problemy Kolejnictwa, 2015, z. 168.
10. Adamski D. et.al.: *Wpływ pojazdów różnej generacji na poziomy emisji pól magnetycznych* [The impact of vehicles of different generations on the emission levels of magnetic fields], Logistyka, 2015, nr 4.
11. Adamski D., Ortel K., Zawadka Ł.: *Unified verification method of electromagnetic compatibility between rolling stock and train detection system*, Konferencja UIC, Global Debate on Mobility Challenges for the Future Society, Warsaw 15–16.11.2018.
12. Adamski D. et.al.: *Impedancja osi zestawu kołowego a bezpieczeństwo ruchu kolejowego*, cz. I [Wheel set axle impedance and railway traffic safety, part I], Infrastruktura Transportu, 2013, nr 4.
13. Białoń A. et.al.: *Rezystancja osi zestawu kołowego pojazdu trakcyjnego jako jeden z czynników decydujących o bezpieczeństwie ruchu kolejowego* [Axle resistance of a traction vehicle wheel set as one of the factors determining the safety of railway traffic], Autobusy, 2013, nr 3.
14. Adamski D. et.al.: *Impedancja osi zestawu kołowego a bezpieczeństwo ruchu kolejowego*, cz. II [Wheel set axle impedance and railway traffic safety, part II], Infrastruktura Transportu, 2013, nr 5.