Studies of Selected Parameters of Electromagnetic Fields Generated by Diesel-Electric Locomotives

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Summary

The widespread use of counter clear track reporting systems by various railway managements has highlighted the problem of the resistance of these devices to disturbances generated by rolling stock. Equipping rail vehicles with electrical and electronic devices featuring extensive structures is another aspect related to this topic. The experience of many railway managements shows that modern vehicles can cause disturbances in the operation of axle counters. For this reason, standardization work at European level, aiming to harmonize and simplify the procedures related to the authorization of individual types of rolling stock for operation on the European rail network, has been ongoing for many years. The study results presented in the article show the need to perform measurements for both electric and diesel tractions, due to the similar nature of emissions and measured levels. Impact measurement of magnetic fields emitted by traction vehicles is an important component of the electromagnetic compatibility tests of rolling stock moving on rail tracks equipped with train detection devices.

Keywords: electromagnetic compatibility, axle counters, rolling stock

1. Introduction

Widespread use of counter clear track reporting systems can nowadays be observed on rail lines in Poland. The work of these devices may be exposed to the negative effects of electrical and electronic devices featuring extensive structures, such as the equipment of modern rail vehicles moving on rail tracks. The possible interference hazard in the operation of axle counters has highlighted the problem connected with the resistance of these devices to interference generated by rolling stock. For this reason, standardization work at European level, aiming to harmonize and simplify the procedures related to the authorization of individual types of rolling stock for operation on the European rail network, has been ongoing for many years. These efforts are also largely focused on the so-called frequency management process that determines acceptable interference levels for specific frequency ranges.

Legal considerations in the field of rail interoperability require rolling stock manufacturers to meet the requirements set out in the Technical Specifications for Interoperability (TSIs) [15]. The main document, in terms of the subject matter described in this article and specifying the requirements for rolling stock, is ERA/ETRMS/033281 [11], which presents, among others, the limits of magnetic field strengths for AC traction and the method of measuring these fields. It is worth noting that currently there are no uniform European requirements regarding magnetic field limits for DC traction systems – these are the so-called open points defined by national law. Permissible levels of emitted electromagnetic interference within the national requirements are specified in the work of the Railway Research Institute [13] and are binding as an official annex to the List of the President of the Office for Railway Transport [9], while within European law they are included in the CLC/TS 50238-3: 2010 technical specification [12] and in the PN-EN 50592: 2017-04 [12] standard.

The compatibility issues regarding the rolling stock cooperation with train detection devices are also specified in the PN-EN 50238: 2003 standard [11] and the PN-EN 50617-2: 2015-12 [13] standard.

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2. Wheel sensors – types of interference and magnetic field interactions

As mentioned in the Introduction, the counter detection systems for train axles using circuits with wheel sensors (i.e. sensitive components) are exposed to magnetic fields. This is due to the short coverage (the antenna mounted on the rail is about 15 cm long) and the fact that the required response time of wheel sensors to magnetic field changes should be as short as possible. In this case, the probability of exceeding the limit of resistance to interference is the highest due to its short duration.

In DC 3kV traction there are two main types of interference sources in the operation of wheel sensors: direct interference from return current in rails and the magnetic field emitted by traction vehicles moving on the track. In addition, special conditions for the negative impact of a magnetic field on the above-mentioned devices must occur:

- on a railway line, elements sensitive to interfering magnetic fields;
- overlapping of the wheel sensor working frequency band with the interference spectrum lines generated by the vehicle and other elements of the electromagnetic environment, and
- exceeding of the wheel sensor resistance level by some given electromagnetic interference in a given operating band – for a signal with the required amplitude and interference duration.

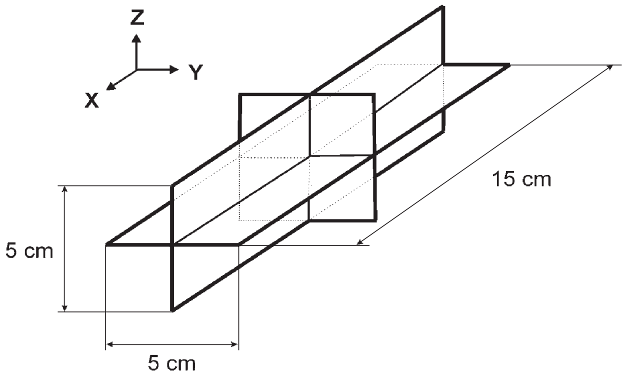

Fig. 1. Standard, recommended dimensions of the measuring antenna [Department archive]

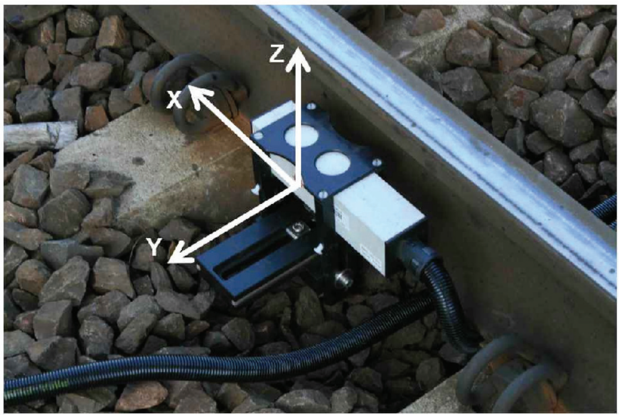

Fig. 2. The measuring antenna installation method with indicated directions of planes [Department archive]

3. Methodology for measuring track magnetic fields generated by rail vehicles

In accordance with the provisions of the ERA/ETRMS/033281document[8],PN-EN50592:2017-04[12] and PN-EN 50617-2: 2015-12 [13] standards, measurements of magnetic fields generated by rolling stock should be performed with an antenna of standardized dimensions (length 15 cm, width 5 cm and height 5 cm – Fig. 1), attached to the rail base and set in a certain position (Fig. 2). This location of the measuring antenna ensures the correct reading of the magnetic field measurement results in three mutually perpendicular measurement planes: X, Y and Z (Fig. 2). The measured values are in the range from 10 kHz to 2 MHz, while allowable magnetic field strength values, the most important for the operation of axle counters, are determined for three frequency ranges: 27–52 kHz, 234–363 kHz and 740–1250 kHz.

The Railway Research Institute has measuring equipment that meets the applicable European requirements for this type of measurement and a team of qualified employees with extensive experience in the described tests. The measuring equipment (Fig. 3) includes:

- a portable laptop with software for data processing and archiving;
- two measuring antennas (in other systems one measuring antenna is used as standard);
- three oscilloscope cards;
- two TNB modules with built-in impedance transformers;
- a USB hub with an external power supply;
- test leads.

The electromagnetic field tests consist of measuring the generated magnetic field strengths during the transit of a specific vehicle over the measuring antennas installed on the track (Fig. 4). The tests are performed in various vehicle operation configurations, such as: different speeds, starting, electrodynamic braking and on-board equipment activated (air conditioning, heating, etc.). Voltage values induced in the antennas during the transit of the tested vehicles are recorded on oscilloscope cards. The registration results are then sent to a measuring computer, where FFT analysis is carried out using specialized software. The results of this analysis are the characteristics of the generated magnetic field strength values as a frequency function. The results are then compared with the limit values specified for each of the measured planes, in accordance with the previously mentioned applicable requirements.

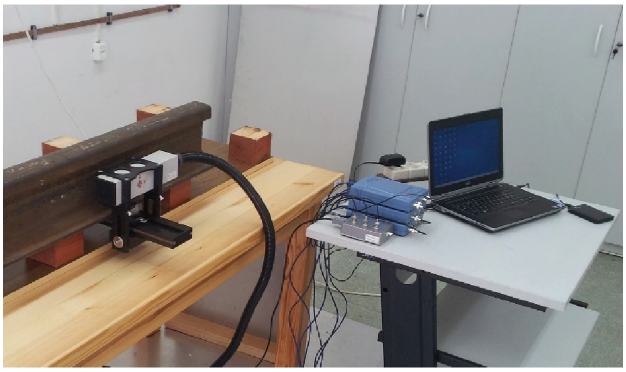

Fig. 3. The magnetic field testing stand view during laboratory tests [Department archive]

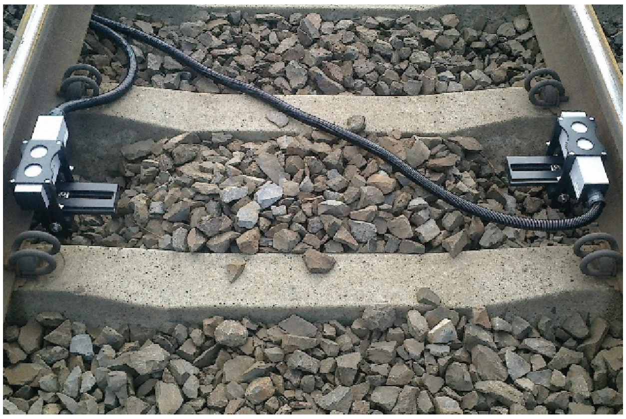

Fig. 4. Measuring antennas mounted on the railway track [Department archive]

Two measuring antennas significantly reduce the number of transits and enable a comprehensive assessment of the tested rolling stock, regardless of the possible asymmetry of the interference source location on a vehicle relative to the track axis, which is of particular importance during tests on a railway route. The presented test method complies with the applicable requirements and allows the precise estimation of the measured values in relation to the applicable limit values.

4. Test results

This section presents the results of exemplary tests performed for a locomotive operated with a 3 kV DC power supply system and diesel traction. These tests concerned the assessment of compliance with the requirements in the vehicle approval process for the network managed by PKP PLK S.A.

The measuring stand was located in the experimental area of the Railway Research Institute in Żmigród. The measurements were carried out for the basic operating conditions of a traction locomotive (start-up, braking, transit at a constant speed) and for the case of no vehicle near the measuring antennas (the so-called background measurement). Figure 5 illustrates the magnetic field strength recorded during the start-up of the tested locomotive with electric and diesel traction. Figure 6 shows the results recorded during the implemented electrodynamic braking of the locomotive with electric and diesel traction. The figures present the magnetic field limits and the measured values in accordance with the requirements of the ERA/ETRMS / 033281 document and PN-EN 50592: 2017-04 standard.

An increased level of interference in the band to about 200 kHz was observed in Figures 5 and 6, decreasing almost linearly (on a logarithmic scale), which may indicate the occurrence of low-frequency interference with high amplitude, which gives a wide signal spectrum during electrodynamic braking. Slightly higher, by about 5dB, interference levels occur with electric traction, which may be caused by the additional effect of the traction current flowing from the pantograph through the tested locomotive to the rail tracks. Such an insignificant difference in interference levels indicates the same nature of electrical and electronic devices used in the locomotive. The difference is only in the way of supplying power: using a pantograph for electric traction and a generator powering a diesel engine for diesel traction.

5. Examples and effects of exceeding limit values

Many years of experience of the entire team prove that the exceeded magnetic field strengths emitted by rolling stock can most often be expected in the Y measuring plane with a vector perpendicular to the rail and parallel. This is conditioned by the mutual compensation of magnetic fields originating from currents flowing in railway tracks and from vehicles. An example of exceeding the permitted values is shown in Figure 7.

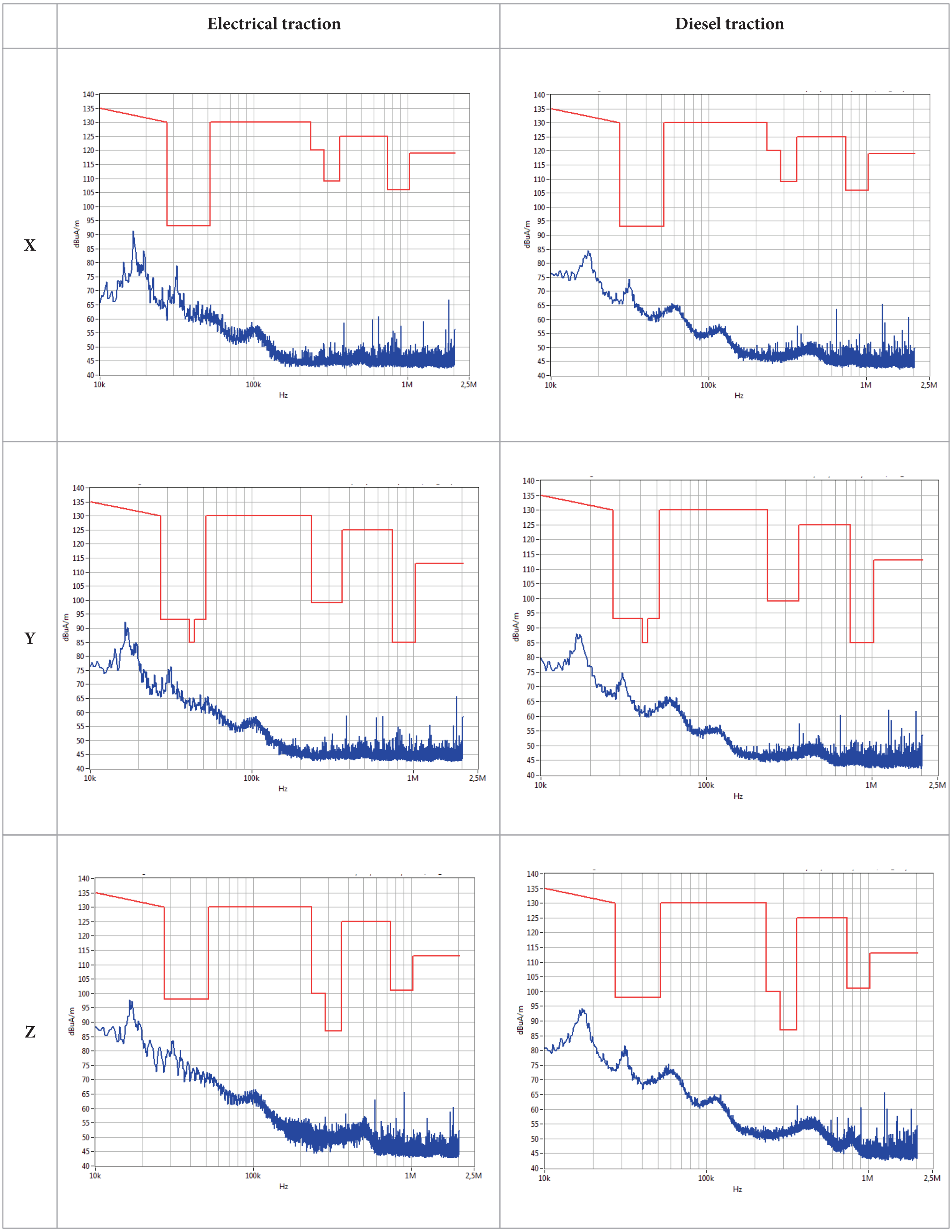

Fig. 5. Magnetic field strength in the X, Y and Z planes recorded on the track during the start-up of a diesel-electric locomotive [authors' report]

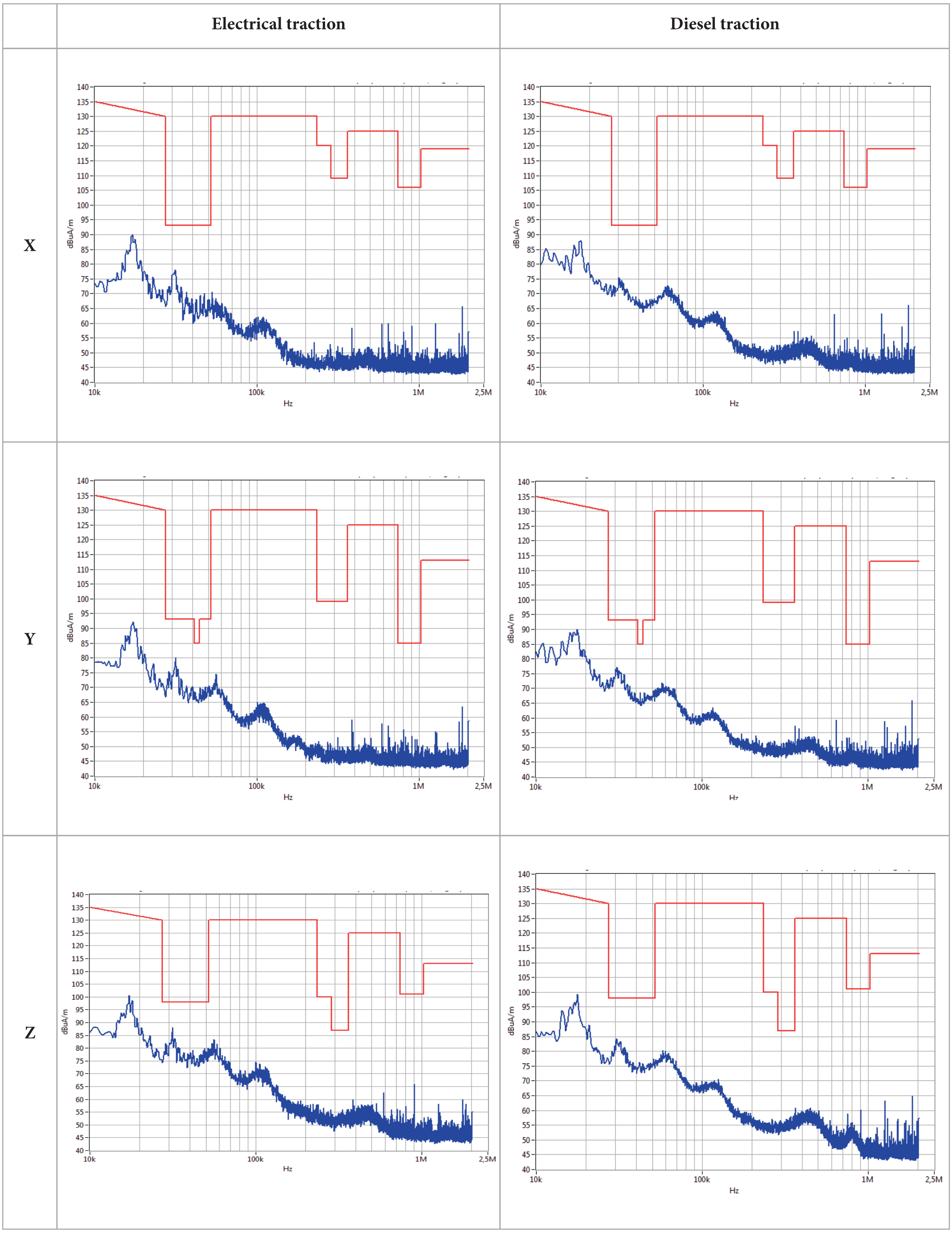

Fig. 6. Magnetic field strength in the X, Y and Z planes recorded on the track during electrodynamic braking of a diesel-electric locomotive [authors' report]

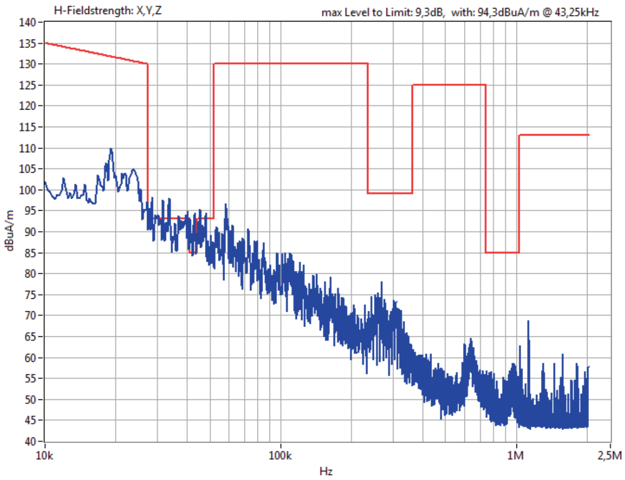

Fig. 7. Exceeding the permitted value of the magnetic field strength in the Y measuring plane [authors' report]

Figures 8 and 9 show oscillograms of voltage characteristic waveforms at the wheel sensor inputs during vehicle axle transits. Figure 8 shows the transit of four axes of a given vehicle and the uninterrupted signal at the output, and Figure 9 shows the interrupted signal resulting from exceeding the permissible values (as in Figure 7).

Wheel sensor interruption (Fig. 9) with an external magnetic field may lead to:

- an additional axle being counted,
- not all the vehicle axles being counted,
- the sensor switching into emergency (meter reset required),
- service intervention being needed,
- transit being controlled (speed limit),
- train delays.

6. Conclusions

The research method presented in the article and the described problem show the validity of magnetic field measurements on vehicles with both electric and diesel traction, because the method and type of energy supplied to the electric devices mounted on the vehicle do not have a significant impact on the difference in the values of the measured electromagnetic fields. It is justified to carry out magnetic field strength tests when new and upgraded rolling stock is put into service as an important testing point on railway lines equipped with train detection systems. The measurement method described in the article is in accordance with the applicable requirements and enables the precise estimation of the measured magnetic field values in relation to the limit values. It facilitates the elimination of the generated source of interference exceeding the admissible values from vehicles already at the stage of approval tests.

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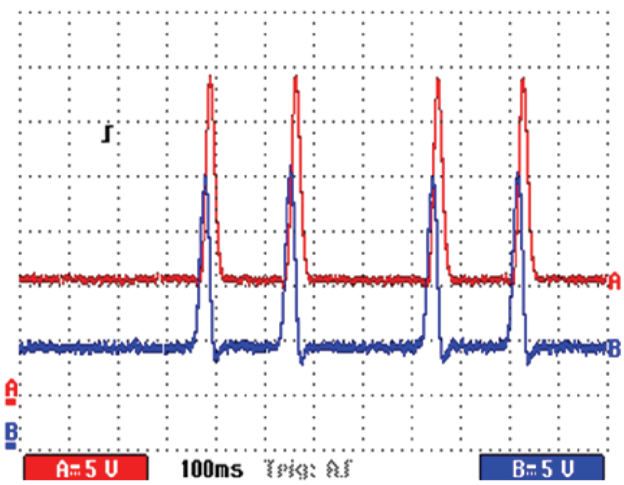

Fig. 8. Voltage characteristics (including reaction to vehicle axles) at the wheel sensor outputs during transit – correct signal [authors' report]

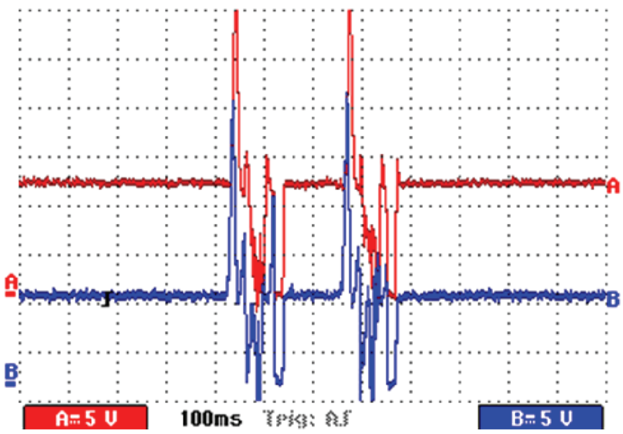

Fig. 9. Voltage characteristics taking into account the reaction on the vehicle axles) at the wheel sensor outputs during transit – interrupted signal [authors' report]

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