PROBLEMY KOLEJNICTWA
RAILWAY REPORTS Zeszyt 181 (December 2018) ISSN 0552-2145 (print) ISSN 2544-9451 (on-line)

Measurements of the Magnetic Fields Generated by Electronic Devices Installed on Railways Rolling Stock

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Summary
This paper covers the measurements of the AC and DC magnetic fields generated by electrical and electronic equipment installed on rolling stock. It discusses the methodology for measuring magnetic fields with the EN 50500 standard. Moreover, it covers measuring equipment used for testing and methods of selecting measurement points inside and outside the rolling stock. The article shows exemplary results of measurements on the example of diesel and electrical railway rolling stock.

Keywords: railway rolling stock, magnetic induction, methodology of measurements, measuring equipment

1. Introduction

The use of numerous electrical and electronic devices installed in workplaces, as well as systems that are part of, for instance, buildings with work rooms, is associated with exposure to electromagnetic fields. The strongest sources of electromagnetic fields in the workplace are electromagnetic systems, devices for the electronic protection of items, such as detection gates, wireless systems for data transfer as well as industrial and medical devices. It is thus necessary to identify the sources of electromagnetic fields and see if their levels are in line with applicable legal provisions.

A similar phenomenon may also occur in the railway environment and, more specifically, in the railway rolling stock which has electrical devices installed.

2. Applicable legal rules in the railway environment

In line with the Regulation of the Minister of Infrastructure and Development [5] on the authorization to commission railway buildings, devices and vehicles subject to special conditions and the procedure of granting type conformity certificates and declarations of type conformity, it is obligatory to audit railway vehicles for exposure to electromagnetic fields. To this end, it is required to test the impact of magnetic fields inside and outside the vehicles. In addition, it is necessary to comply with the appendix to the said Regulation of the Minister of Infrastructure and Development [5], the list of the President of the Polish Office of Rail Transportation regarding applicable technical specifications and standardizing documents, in order to meet the principal requirements for the interoperability of railway systems. Pursuant to Article 25d paragraph 1 of the Law on Railway Transport [6], such tests are required to comply with essential specifications for the electromagnetic compatibility, safety and reliability as well as the technical compliance of the on-board power supply and steering systems, as well as the impact on other vehicles and systems installed in the vicinity of the tracks.

3. Measurements of rolling stock AC and DC magnetic fields

Based on the previously or currently applicable legal documents, AC and DC magnetic fields generated within the railway environment by electronic devices installed on railway rolling stock should be tested in line with the EN 50500 standard [2]. This standard defines the procedures for the measurement of electrical and magnetic fields generated by electrical and

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electronic devices and systems within the railway environment. In addition, the standard specifies the principles and criteria for compliance with permitted limits, the scope of measurements, measuring devices and methods of assessing the results of measurements.

Currently, when conducting measurements, one needs to take into account the provisions of the document [1] and the standard [3] providing the examples of measuring methods, simulation and the evaluation of the tests completed. The railway environment has three basic sources of electromagnetic fields that can affect people: rolling stock, traction power supply and signaling equipment.

4. Measurement methodology according to EN 50500 standard

Conducted according to the standard [2], the measurement of the AC and DC magnetic field levels for rolling stock should be performed under real weather conditions and within the frequency range specified by the standard, i.e. from 0 Hz to 1 Hz for the DC field and from 5 Hz to 20 kHz for the AC field. The measurements are carried out for all of the three axes of the electric field strength, with the assumption that one of the axes is parallel to a rail. The strength of magnetic fields is measured for two working modes of a railway vehicle, namely:

- Static mode – The vehicle is parked and plugged into the traction with all on-board systems turned on, including air-conditioning, heating, internal and external lighting and all electronic devices. In this case, the measurements are conducted both inside the vehicle (the driver's cab and passenger compartments) as well as outside the vehicle, in the vicinity of the installed electric devices, such as traction motors, converters, inverters and power electronic converters etc.
- Dynamic mode – The vehicle moves from a standstill, and then accelerates at the highest possible rate to the maximum speed available for normal operation, keeps this speed for 10s, and then brakes at the maximum rate to a complete stop. All auxiliary circuits should work and all devices should be turned on (e.g. air-conditioning, heating and lighting).

It might not be possible to accelerate the vehicle to its maximum speed available for normal operation, or the power supply system might not allow the vehicle to accelerate to the maximum speed available for normal operation during the test. In such a case, the maximum value of the strength of emitted magnetic fields should be calculated based on the results of the conducted measurements and monitoring of the line by means of the method specified within the standard. Examples of such methods are specified in detail in the standard [2] and [3].

5. Measurement method of tested rolling stock

Magnetic fields should be tested for strength at points inside and outside the rolling stock, as specified in detail in Table 1. Figure 1 shows examples of measurement points inside the driver's cab and in passenger compartments marked with red, and marked with blue outside the vehicle (an articulated diesel multiple unit). Figure 2 shows a similar scheme of measurement points for a bi-articulated electric multiple unit.

Table 1

Location of measurement points

Location / Distance	Vertical distance from the floor [m]	Horizontal distance from the walls [m]	Notes
Available only to staff members	0.9 1.5	≥ 0.3	Measuring close to the source of emissions, where staff members work
Available to the public	0.3 0.9 1.5	≥ 0.3	Measuring as close as possible to the source of emissions where passengers are allowed to stay
Available to the staff and the public	0.3 m 1.5 m 2.5 m	0.3	Measuring outdoors in the vicinity of, for example, the inverter

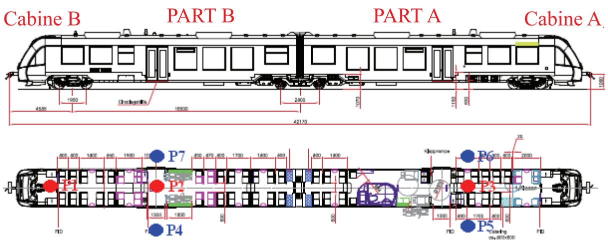

Fig. 1. An example of the location of measurement points inside and outside a diesel multiple unit [author's drawing]

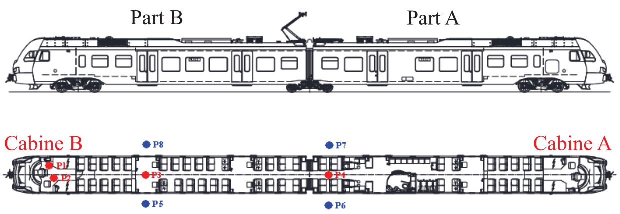

Fig. 2. An example of measurement points inside and outside an electric multiple unit [author's drawing]

The measurement equipment used for measuring magnetic fields consists of the following devices that should meet the requirements of the standard [2]:

- A DC magnetic field meter, such as the Hall effect sensor teslameter;
- An AC electromagnetic field meter with a magnetic field probe with the sectional area of 100 cm^2;
- A weather station to determine the actual weather conditions;
- A computer with software for FFT analysis of measurement results.

6. Results of magnetic fields' measurements of tested rolling stock

The requirements set forth in the standard [2] and the document [1] make up the assessment criteria for estimating the levels of magnetic induction inside and outside railway vehicles. Table 2 shows the results of DC magnetic field measurements carried out inside both rail vehicles for the driver's cabin and the passenger compartment for certain measurement points in order to compare the results.

Figures 3 to 14 show exemplary characteristics of the resultant magnetic field levels (function of the magnetic induction and frequency of AC magnetic field measurements) after the relevant software performed FFT spectral analysis, using the fast Fourier transform, for the driver's cab of both rail vehicles.

The results of the measurement of the emission levels of AC magnetic fields inside and outside the vehicle, generated by electrical and electronic equipment, show that the health and safety requirements regarding the exposure of workers to the risks arising from physical agents, including electromagnetic fields, are met. The devices installed on the test vehicle do not exceed the emission limit value for the AC magnetic field as indicated by the grey line in Figure 3–14.

Table 2

DC field measurement results for the vehicles

Vehicle type	Measuring point	Mode of operation	Measuring height [m]	Measurement distance [m]	Measurement result B_{max} [μT]
Diesel multiple unit	P1 Driver's cab	Stop	0.9	0.3	221.7
		Stop	1.5	0.3	196.6
		Travel	0.9	0.3	234.5
		Travel	1.5	0.3	236.5
Electric multiple unit	P1 Driver's cab	Stop	0.9	0.3	220.1
		Stop	1.5	0.3	180.9
		Travel	0.9	0.3	237.4
		Travel	1.5	0.3	245.2
Diesel multiple unit	P2 Passenger compartment, section B	Stop	0.3	1.1	235.7
		Stop	0.9	1.1	210.2
		Stop	1.5	1.1	218.7
		Travel	0.3	1.1	267.5
		Travel	0.9	1.1	294.4
		Travel	1.5	1.1	272.6
Electric multiple unit	P3 Passenger compartment, section B	Stop	0.3	1.1	238.5
		Stop	0.9	1.1	266.6
		Stop	1.5	1.1	256.2
		Travel	0.3	1.1	239.9
		Travel	0.9	1.1	280.1
		Travel	1.5	1.1	276.6

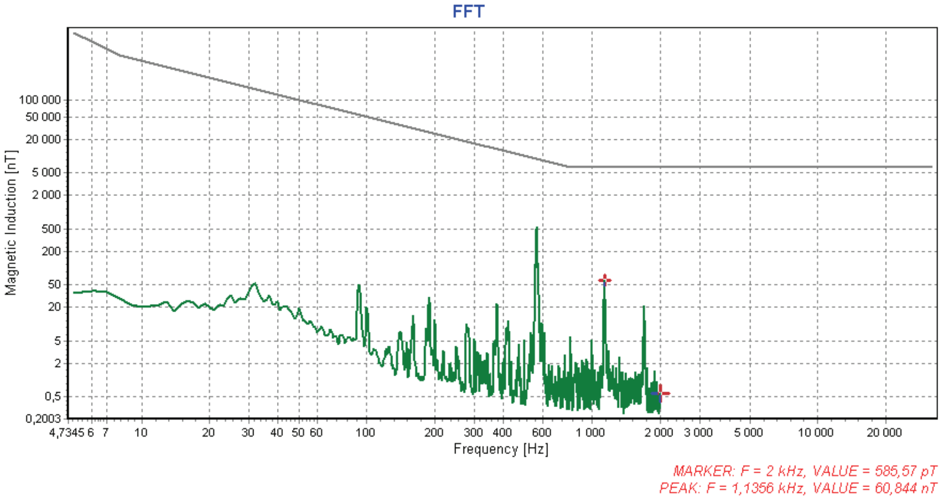

Fig. 3. Characteristics of the magnetic field induction level as a function of the diesel traction unit frequency: measurement point P1, Stop, height 0.9 m, measurement scope 5 Hz–2 kHz [A. Dłużniewski]

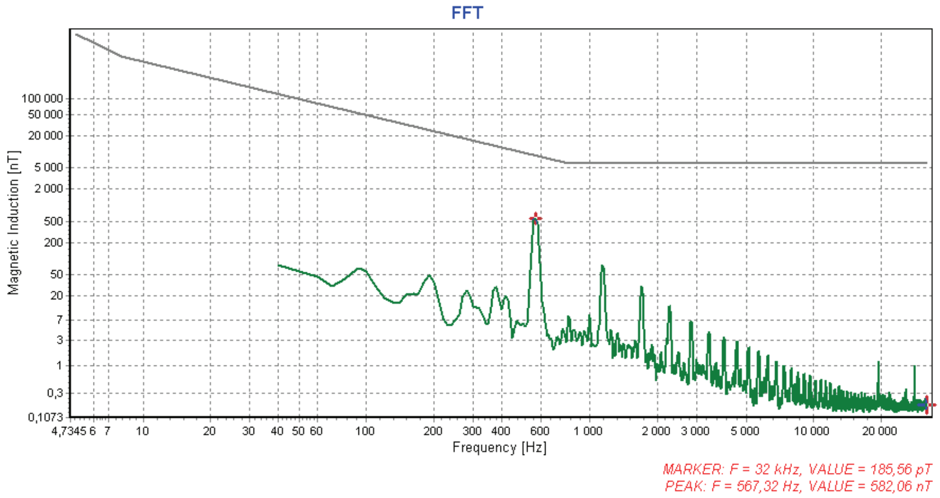

Fig. 4. Characteristics of the magnetic field induction level as a function of the diesel traction unit frequency: measurement point P1, Stop, height 0.9 m, measurement scope 2 kHz–20 kHz [A. Dłużniewski]

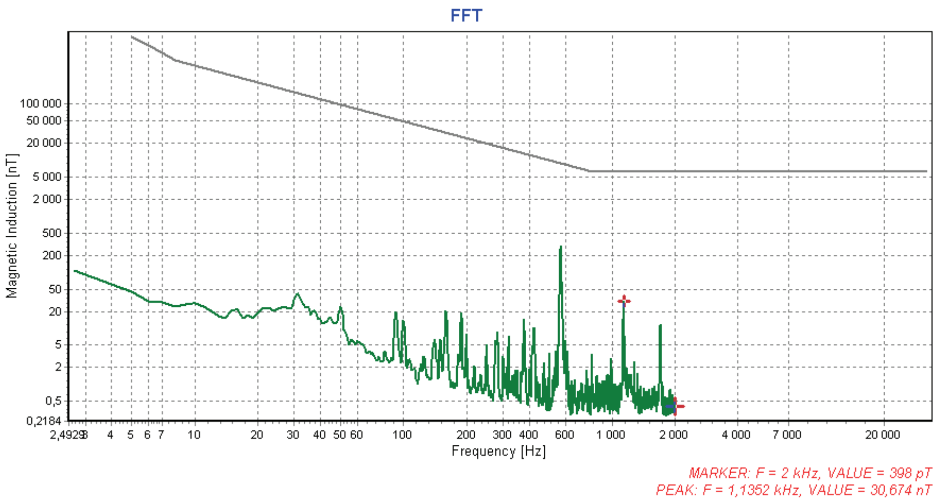

Fig 5. Characteristics of the magnetic field induction level as a function of the diesel traction unit frequency: measurement point P1, Stop, height 1.5 m, measu rement scope 5 Hz–2 kHz [A. Dłużniewski]

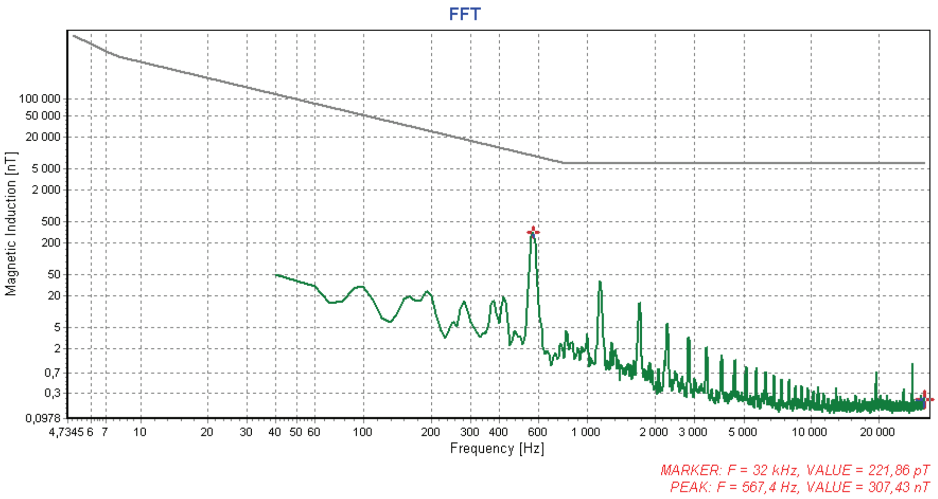

Fig. 6. Characteristics of the magnetic field induction level as a function of the diesel traction unit frequency: measurement point P1, Stop, height 1.5 m, measurement scope 2 kHz–20 kHz [A. Dłużniewski]

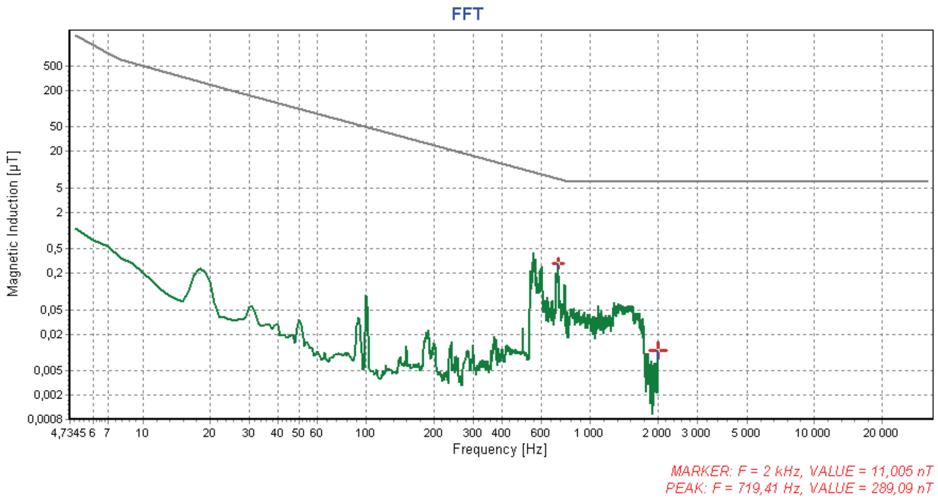

Fig. 7. Characteristics of the magnetic field induction level as a function of the diesel traction unit frequency: measurement point P1, Drive, height 0.9 m, measurement scope 5 Hz–2 kHz [A. Dłużniewski]

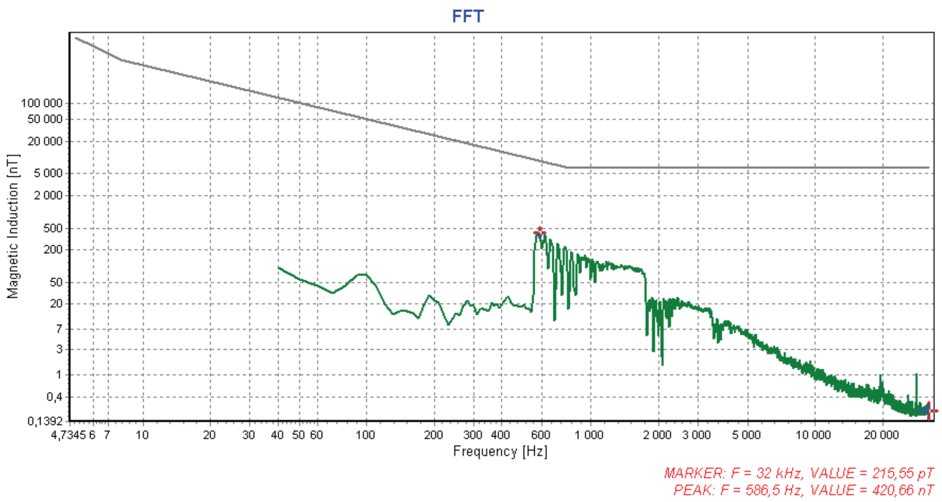

Fig. 8. Characteristics of the magnetic field induction level as a function of the diesel traction unit frequency: measurement point P1, Drive, height 0.9 m, measurement scope 2 kHz–20 kHz [A. Dłużniewski]

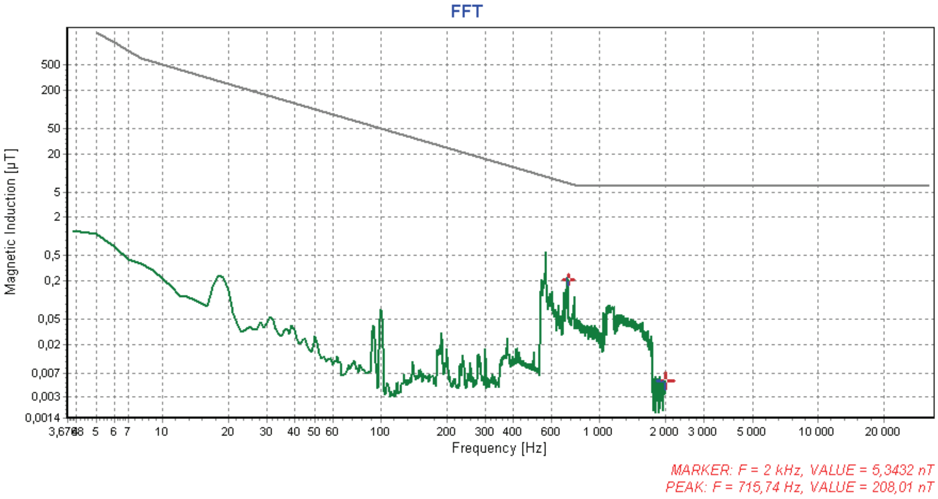

Fig. 9. Characteristics of the magnetic field induction level as a function of the diesel traction unit frequency: measurement point P1, Drive, height 1.5 m, measurement scope 5 Hz–2 kHz [A. Dłużniewski]

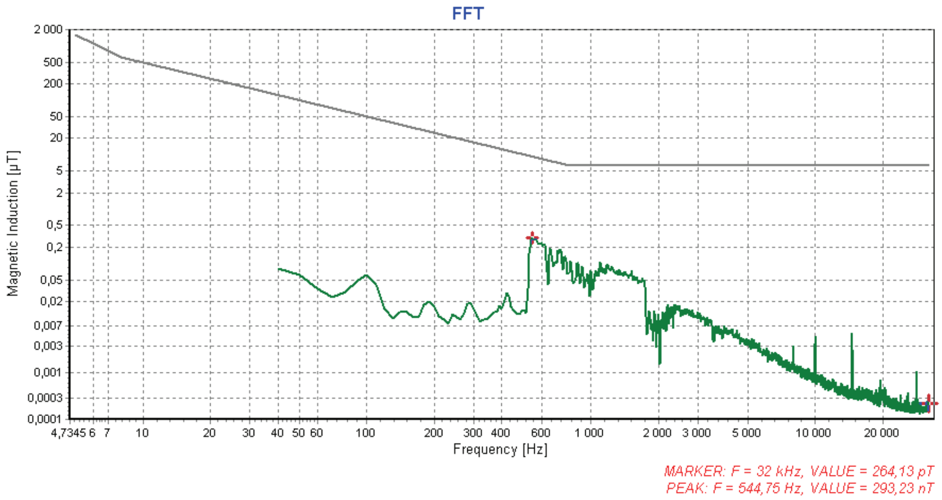

Fig. 10. Characteristics of the magnetic field induction level as a function of the diesel traction unit frequency: measurement point P1, Drive, height 1.5 m, measurement scope 2 kHz–20 kHz [A. Dłużniewski]

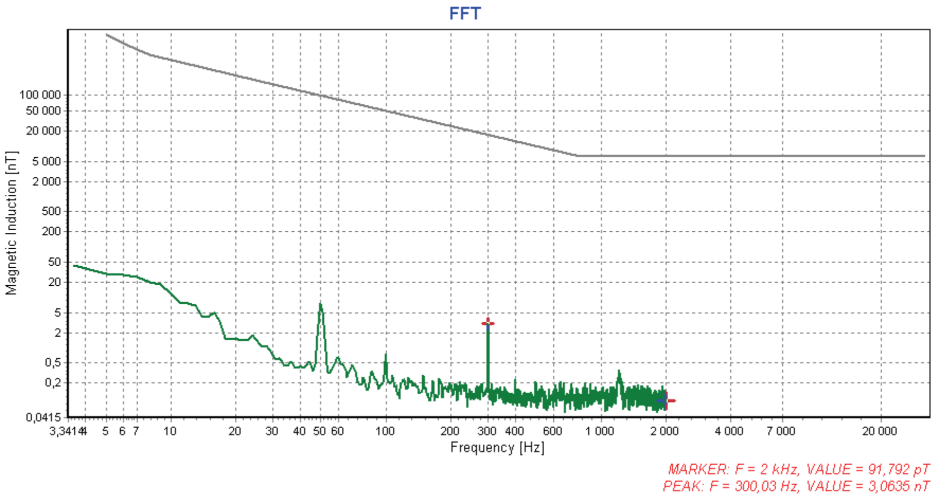

Fig. 11. Characteristics of the magnetic field induction level as a function of the diesel traction unit frequency: measurement point P1, Stop, height 0.9 m, measurement scope 5 Hz–2 kHz [A. Dłużniewski]

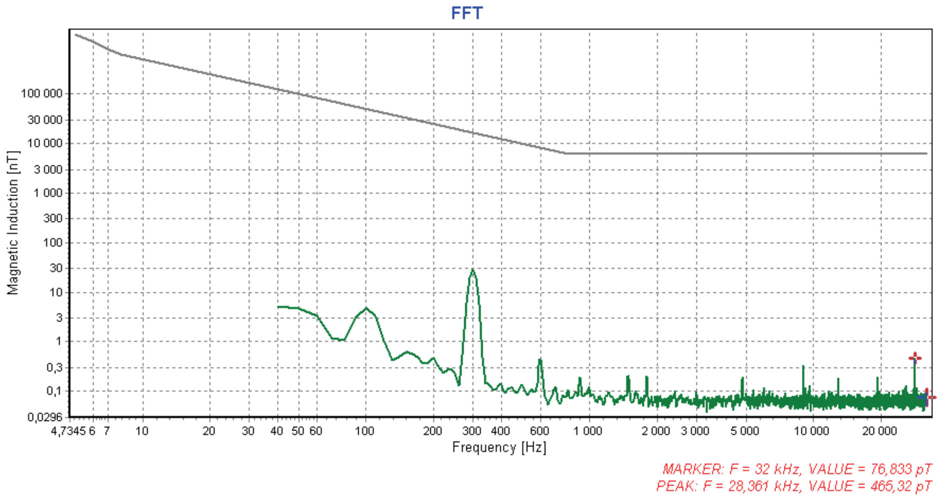

Fig. 12. Characteristics of the magnetic field induction level as a function of the diesel traction unit frequency: measurement point P1, Stop, height 0.9 m, measurement scope 2 kHz–20 kHz [A. Dłużniewski]

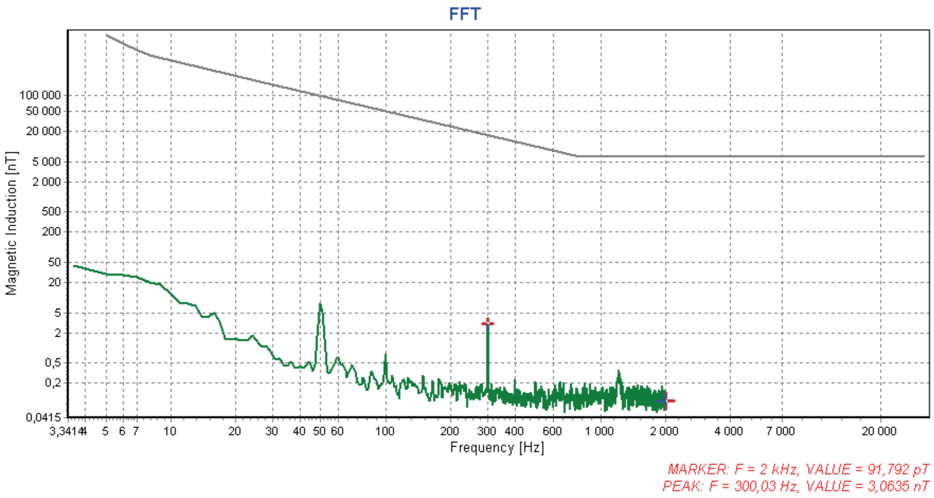

Fig. 13. Characteristics of the magnetic field induction level as a function of the diesel traction unit frequency: measurement point P1, Stop, height 1.5 m, measurement scope 5 Hz–2 kHz [A. Dłużniewski]

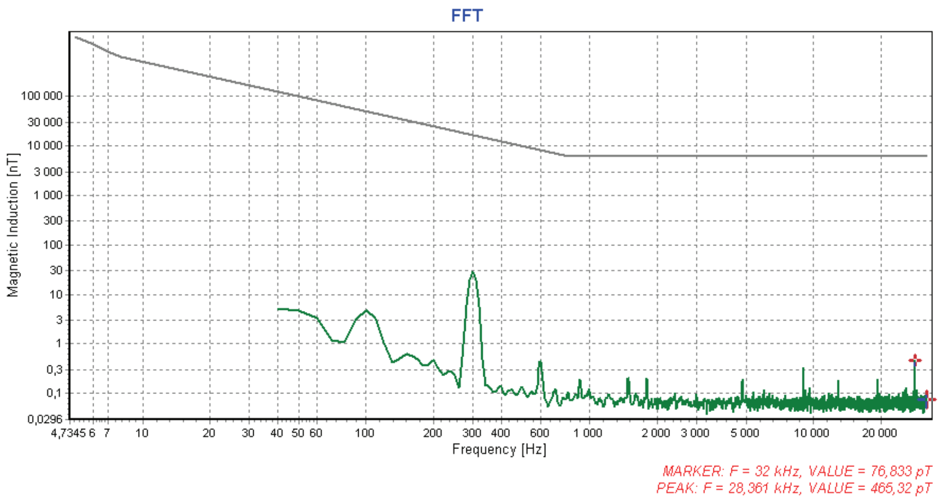

Fig. 14. Characteristics of the magnetic field induction level as a function of the diesel traction unit frequency: measurement point P1, Stop, height 1.5 m, measurement scope 2 kHz–20 kHz [A. Dłużniewski]

7. Conclusions

In measuring the induction of the DC magnetic field, one usually takes measurements right from the measurement device in a numerical or graphic form, depending on the mode of operation of the tested vehicle and the detector used in the measuring measurement device. During measurements of the induction of the AC magnetic field, measurement results are derived by adding up the 3 components at different time intervals, after filtering all of the recorded samples. To this end, a field strength meter is used with relevant parameters or following an FFT spectral analysis of the measured field strength components, the latter derived by using relevant software. The results obtained from AC and DC magnetic field measurements are then compared with permitted levels. It is verified whether a given vehicle meets requirements defined within relevant standards and national regulations and if it can be used in rail transport.

Literature

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