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Levels of Electromagnetic Fields From Rail Vehicles in the Context of Formal Requirements

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Summary
The article discusses the issue of electromagnetic field levels emitted from rail vehicles with regard to civil protection. The article presents the lack of legal solutions, limits and research methods in the railway industry in Poland. It also depicts the initial results of measurements from rail vehicles. Based on the findings, taking into consideration the measurement results and suppression of electromagnetic waves in free space, electromagnetic fields may reach substantial levels which can affect people's health and life. The authors of the article conclude that the problem should not be ignored and requires further research, bearing in mind the progressing saturation of all rail vehicles with devices and electronic systems which will serve as sources of electromagnetic fields.

Keywords: electromagnetic fields, civil protection, measurements

1. Introduction

The extensive railway environment of the 21st century undeniably benefits from the potential of technological developments in the fields of electrical power engineering, data communication, wired communication and wireless communication. The railway industry is continuously increasing the effectiveness and quality, as well as extending the range, of services rendered and adopted for the purposes of mutual cooperation of complementary entities, acting as part of railway units which work to the benefit of passenger and cargo transport. All these services are associated with the aforesaid technology disciplines which, in turn, are sources of emission of electromagnetic fields. These fields are either generated on purpose or are solely the side effect of the operation of particular devices and systems.

The issue of electromagnetic fields generated by rail vehicles is widely known and described through a series of railway standards, among others in [8, 9] which are enforced through obligatory tests of particular kinds of rail vehicles, in accordance with requirements of the Railway Transport Act [19] and normative requirements included in the List of the Head of the Rail Transport Office assigned to this act [6]. However, this document focuses almost solely on EMC, so by definition the field of interest is not human life and health protection but the correct operation and interplay of devices and systems in the electromagnetic environment.

It turns out that, aside from the PN-EN 50500:2008/A1:2015-10 standard [11] specified in the above-mentioned List and referring to the impact of electromagnetic fields from rail vehicles on people's health and life in the limited scope of the frequency spectrum, there are no requirements for the verification of hazards listed. For this reason, the article shows an analysis of the influence of railway rolling stock as a potential source of electromagnetic fields, with regard to civil protection and natural environment protection in the context of formal requirements applicable in Poland.

2. Research problem and research method

Before they are commissioned, rail vehicles must be granted approval confirmed with the vehicle type approval certificate issued by the Head of the Rail Transport Office (*UTK*). The prerequisite for obtaining approval for use, regardless of whether vehicles comply with the technical specification of interoperability or fail

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to satisfy all requirements listed in TSI [2, 3], is the confirmation of compliance with specific normative requirements regarding electromagnetic compatibility [8, 9, 11]. The 50121-3-1 standard requires testing in the range of 150 kHz – 1 GHz, whereas this scope is divided into the sub-ranges 150 kHz – 30 MHz (magnetic component) and 30 MHz – 1 GHz (electric component).

This demonstrates that requirements of the standard do not assume the verification of interference of frequencies either below 150 kHz (e.g. 50 Hz) or above 1 GHz, that is, in public mobile network operators' bands (1800 MHz, 1900 MHz, 2.1 GHz) or short-range radio systems (e.g. in the band of 2.4 GHz). We need to be aware that the aforesaid standards apply to the scope of EMC tests, which do not aim to verify types of rail vehicles in terms of human hazards, but still demonstrate the lack of standards and guidelines for high-frequency checks.

It was stated at the beginning of the article that the only norm in Poland required by the Head of the Rail Transport Office [6], aimed at human health and life protection from rail vehicles, is currently the PN-EN 50500 standard [11], which includes the measuring range of electromagnetic fields from 0 Hz to 20 kHz of the magnetic component only. This range is therefore substantially limited in relation to requirements imposed on permanent facilities, as referred to in Resolution [16][3]. The limits for levels of particular electromagnetic field components to which the PN-EN 50500 standard applies [11] have been specified in the EU 1999/519/EC recommendation [4] for the entire society and in the 2013/35/EU directive [5] concerning the safety of employees. These limits vary and, despite the fact that the very standard does not express it directly, we can logically assume that they refer to passenger compartments and the engine driver's cab. It is necessary to stress that the boundary values of magnetic and electric component levels also considerably deviate from the limits adopted in Resolution [16].

Figure 1 illustrates the permissible limits for field emission in accordance with the 50121-3-1 standard [8], and the maximum permissible level of radiated interference from a vehicle powered by 3 kV DC traction is 85 dBμV/m (for 30 MHz when running), whereas for a parked vehicle this value is lower by 25 dB. As a result of calculation into the unit adopted in Resolution [11], this value is 0.02 V/m.

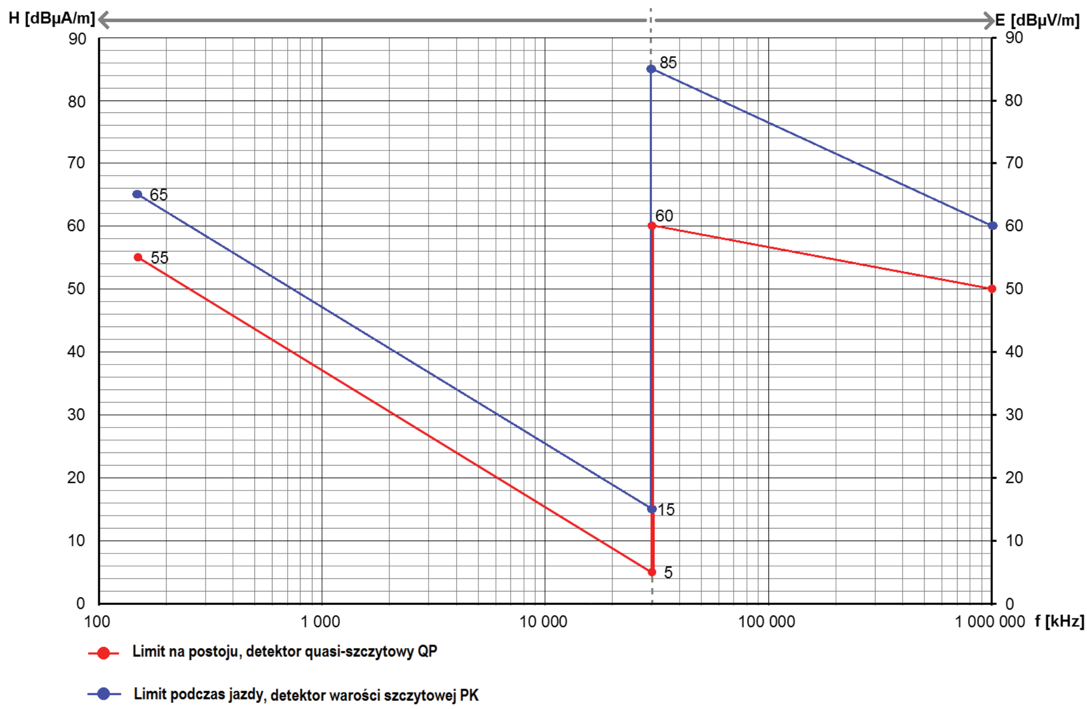

Fig. 1. Permissible values of emission for vehicles powered by 3 kV [1]

[3] The article was created for the conference "Transport of the 21st Century", 09–12.06.2019, Ryn. Resolution [16] was revoked on 1 January 2020 and replaced with the Resolution of the Minister of Health dated 17 December 2019 [17] by way of which permissible levels equivalent to levels specified in Recommendation 1999/519/EC were implemented [4].

Moreover, following the methodology specified in the PN-EN 50121-3-1 standard [8], during the measurement, antennas are positioned at a distance of 10 m from the track axis, and therefore the methodology stipulated in the 50121-3-1 standard [8] does not allow the electromagnetic field levels to be verified in the immediate proximity of the rail vehicles (0.3–3 m from the side walls of the vehicle). The distance from the vehicle is typical of travelers getting on the train. After considering the suppression of signals in free space (see Table 3) as acceptable to people near the vehicle and by stating permissible values at a distance of 10 m from the track axis, the PN-EN 50121-3-1 standard [8] treats values of electromagnetic fields as a few dozen decibels higher than those presented in Figure 1.

The limit for electric components as per the EU 1999/519/EC recommendation [4]to which the PN-EN 50500 standard [11] refers for the sample frequency of 1800 MHz used by public mobile network operators is about 58 V/m. This value is a few times higher than the limits specified through the resolution [16]. Certainly, the PN-EN 50500 standard [11] does not encompass the sample range of frequencies, but this example was used to show the general differences. After all, we need to emphasize that this dependency applies to many frequencies covered by the PN-EN 50500 standard [11] and Resolution [16]. We need to highlight that the methods of measurements as per the 50500 standard [11] outside the vehicle are concurrent in the aspect of distance of the first measuring point from the vehicle with the general rule of measuring as per Resolution [16]. Analyzing the issue of emission of electromagnetic fields from rail vehicles, the following can be stated:

1. Monitoring electromagnetic field levels in the general environment does not embrace railway stations. Analysis of GIOS reports [7, 21] leads to the conclusion that none of the points monitored in the last couple of years were located at any railway station.
2. There are no specific requirements concerning the supervision of railway stations which gather a number of people.
3. Resolution 1883 [16] refers to permanent systems, and therefore cannot be directly used for rail vehicles.
4. The PN-EN 50121-3-1 standard [8] involves the examination of the vehicle with all electric and electronic systems activated, but these tests are performed at a distance of 10m from the vehicle and with the frequency of up to 1000 MHz, which means certain bands (e.g. mobile phone public operators' bands) are excluded and the signal which is a dozen decibels lower than in the immediate vicinity of the vehicle is measured.
5. Aside from the general requirement to maintain compliance with the PN-EN 50155 standard [10] imposed by rail carriers, the Internet access systems for rail vehicle passengers are currently not subject to any regulations regarding railway law. In practice, the modernized trains equipped with such systems do not undergo any tests for the PN-EN 50121-3-1 standard [8]. Pursuant to the act [18] and resolution [13], the systems of this sort do not require any additional radio broadcasting licenses.
6. The only currently applicable tests in the railway environment which consider human health protection are magnetic component tests in accordance with the PN-EN 50500 standard [11] in the frequency band up to 20 kHz.

Table 1 below presents a list of the most important intentional sources of electromagnetic field emission,

Table 1

Examples of devices which emit electromagnetic waves on the rail vehicle [own elaboration]

Selected sources of electromagnetic fields on vehicle	Frequency	Power [W]
Static converters	20 kHz	Most frequently < 0.2 MW
Asynchronous motors	0–200 Hz	Most frequently < 0.5MW
Air conditioning system	0–50 Hz	Most frequently < 10 kW
Analog Cab radio	Band 150 MHz	<10*
GSM-R Cab radio	Band 900 MHz	≤ 8*
EDOR	Band 900 MHz	≤ 8*
Radar	e.g. 24 GHz	5 mW
Power meter	Most frequently 50 Hz	2 W
Internet access systems (Wi-Fi), antennas, internal cables, routers, outside antennas	2.4 GHz, 5 GHz	100 mW for 2.4 GHz < 1 for 5 GHz
Passenger information systems	GSM 900 MHz and higher, GPRS	≤ 2 W*
Ticket machines	GSM 900 and higher, GPRS	≤ 2 W*

* The values apply to transmitters and do not include EIRP power arising from antenna track budget.

as well as the ones being the side effect of operation of particular systems or devices, and therefore there are real grounds leading us to assume that the problem must not be underestimated. However, there is a certain discord between the testing requirements of rail vehicles with regard to EMC tests and EMF tests (*Electromagnetic Fields*).

The authors of the article suggest a research methodology which allows limitations arising from normative requirements to be eliminated [8, 9, 10], which is partly based on the methodology specified for permanent radio communication facilities in Resolution 1883 [16], although it is devoid of a search for measuring points in risers, by adopting the representative point at the height of 1.75 m. Bearing the above in mind, 4 measuring distances (10 m, 5 m, 3 m from the center of the track and 0.3 from the vehicle side wall, where the distance of up to 5m is treated as space available to people »platforms«) were adopted. For each measuring distance, at measuring points located at the height of 1.75, it is advisable to measure electromagnetic field levels without the presence of the train (background) along the entire platform length in risers separated from one another by 20 m. Next, at the same measuring points, it would be necessary to measure electromagnetic field levels in the presence of the vehicle by the platform with all devices and systems activated. The broad-band measurement is suggested as a basic type of measurement. The suggested place of measurements is the test track of the Railway Research Institute in Żmigród.

3. Findings

For the purposes of measurement, an SRM 3006 electromagnetic field meter was used to make both broadband measurements and selective measurements, as well as an isotopic measurement probe with the frequency range 27 MHz – 3 GHz. The measurements were made on the basis of the broadband frequency range. The characteristics of the meter used for measurements and the measuring probe are presented in Table 2. Please note that the measuring probe of the measuring set limited its possibilities at the low limit of the measuring band. In order to make measurements in the range 9 kHz – 30 MHz, it would be necessary to use another probe (e.g. 3531/04 type by NARDA). Table 3 provides theoretical values of signal attenuation in free space for selected frequencies.

Table 2

Measuring equipment specification

Parameter	Measurer	Probe
Frequency range	9 kHz – 6 GHz	27 MHz – 3000 MHz
Measuring range	–30 dBm to 20 dBm (max 27 dBm)	0.2 mV/m – 200 V/m

Table 3

Theoretical values of signal suppression in free space for selected frequencies

Frequency [MHz]	Value of suppression in free space [dB]						
	10 m	9 m	8 m	5 m	4 m	2 m	1 m
30	22.0	21.1	20.1	16	14.0	8	2
100	32.4	31.5	30.5	26.4	24.5	18.5	12.4
150	36	35.1	34	29.9	28	22	16
300	42	41.1	40.1	36	34	28	22
450	45.5	44.6	43.6	39.5	37.6	31.5	25.5
900	51.5	50.6	49.6	45.5	43.6	37.6	31.5
925	51.8	50.9	49.8	45.8	43.8	37.8	31.8
960	52.1	51.2	50.2	46.1	44.1	38.1	32.1
1000	52.4	51.5	50.5	46.4	44.5	38.5	32.4
1800	57.6	56.6	55.6	51.5	49.6	43.6	37.6
1900	58	57.1	56.1	52	50.1	44	38
2100	58.9	58	57	52.9	50.9	44.9	38.9
2400	60.1	59.1	58.1	54	52.1	46.1	40.1
2700	61.1	60.2	59.1	55.1	53.1	47.1	41.1

Table 4 presents a list of electromagnetic field level measurement results for the electric component for random passenger trains and Electric Motor Units, both longdistance and suburban units. The measurements were performed in Warsaw on one of the main railway lines, in a suburban area, in order to avoid the potential high background level, where the measurement results are expressed as the maximum value of electric field level in the entire measuring range. The equipment of vehicles and systems active during measurements were unknown. Due to the limited capability of performing controlled measurements in accordance with the above-stated methodology, for the purposes of the article, the decision was made to limit measurements to a single measuring point located in the immediate vicinity of the passenger train stop. The measuring probe was situated 4 m from the head of the nearest rail for the track directed towards Warsaw and about 19 m for the direction from Warsaw.

As Figures 2–5 demonstrate, the growth in electromagnetic field levels corresponds to public operators' mobile network bands[4].

The preliminary measurements of the electric field intensity at a distance of 4 m and about 19 m from the external rail of the railway track show that passenger trains undoubtedly raise the electric field in-

Table 4

The list of electromagnetic field measurement results in the presence of vehicles

Vehicle no.	Frequency range [MHz]	Distance from rail [m]	Background level E [V/m]	Level E [V/m]
1	26-3000	4	1.85	3.41
2	26-3000	4	1.85	2.65
3	26-3000	19	1.85	2.94
4	26-3000	19	1.85	2.63
5	925-3000	4	1.99	3.19
6	925-3000	4	1.99	2.88
7	925-3000	19	1.99	2.9
8	925-3000	19	1.99	3.54
9	1000-3000	4	1.69	2.72

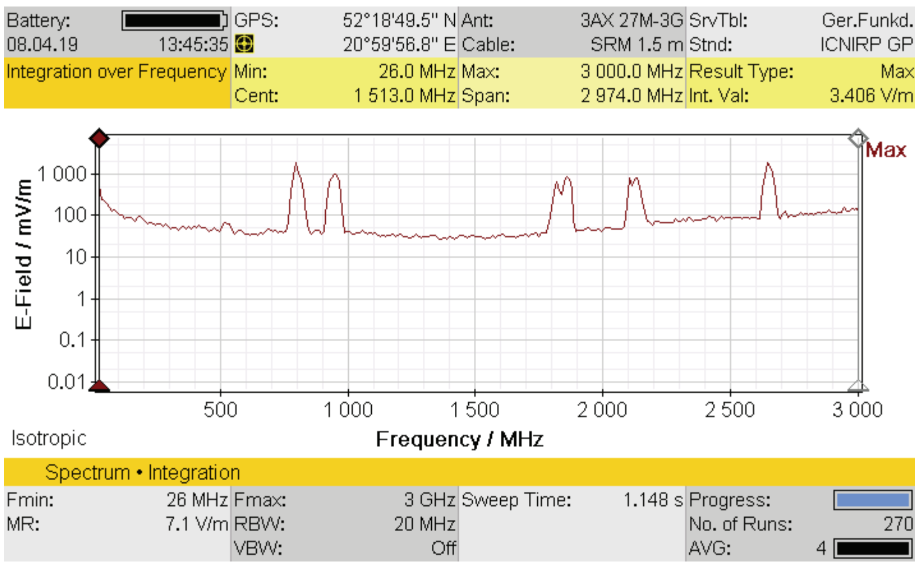

Fig. 2. Example of electric field intensity measurement results for the frequency range 26 MHz – 3000 MHz at a distance of 4m from the vehicle [screen shot from own measurements]

[4] Simplification (also used hereafter). As mentioned earlier, the measuring distance was measured from the railhead.

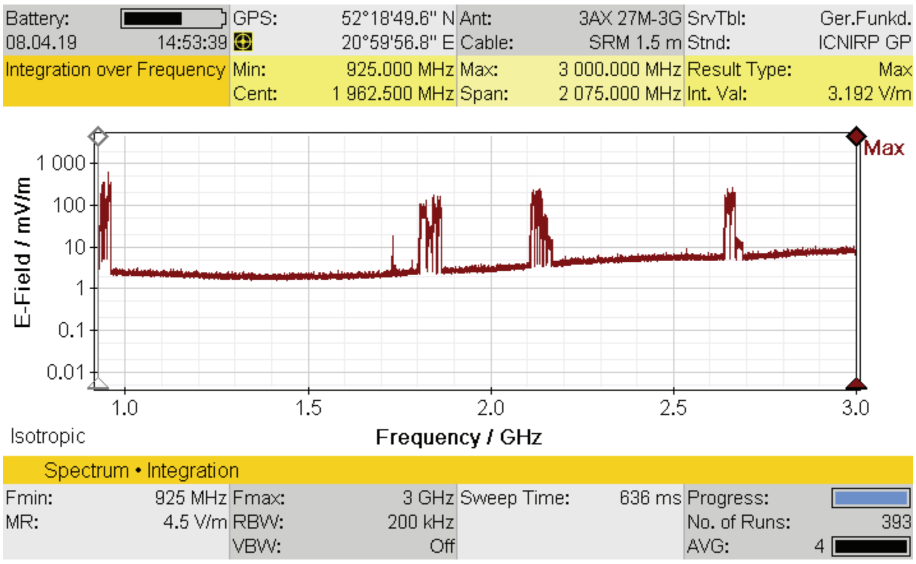

Fig. 3. Example of electric field intensity measurement results for the frequency range 925 MHz – 3000 MHz at a distance of 4 m [screen shot from own measurements]

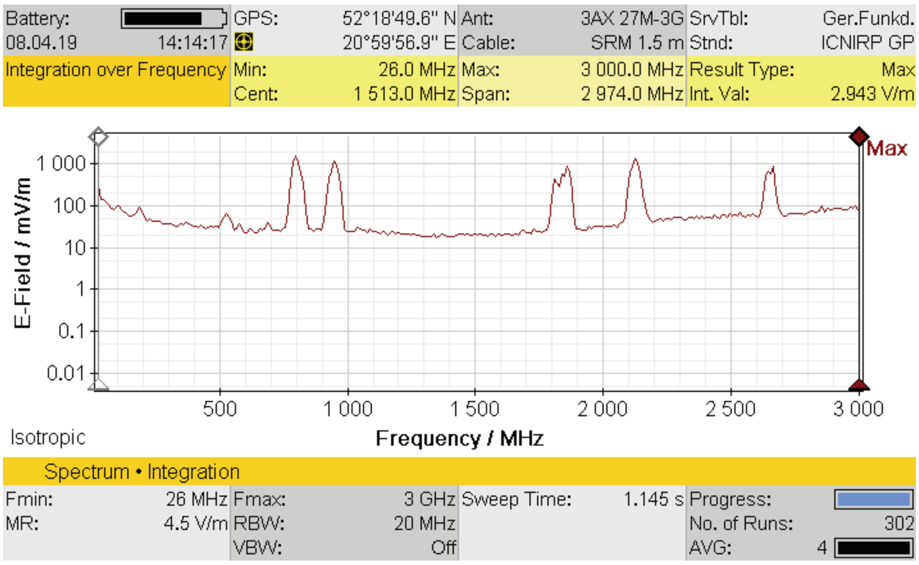

Fig. 4. Example of electric field intensity measurement results for the frequency range 26 MHz – 3000 MHz at a distance of 19 m [screen shot from own measurements]

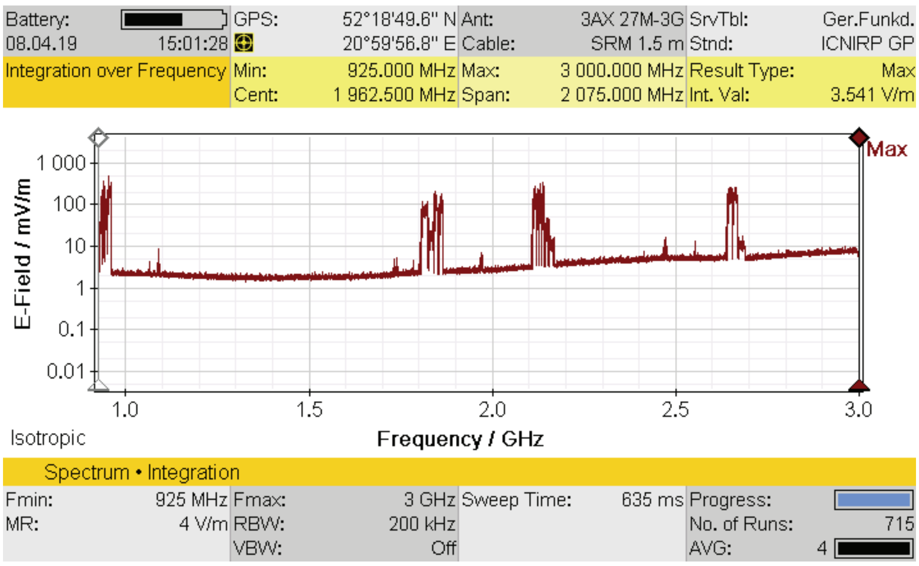

Fig. 5. Example of electric field intensity measurement results for the frequency range 925 MHz – 3000 MHz at a distance of 19 m [screen shot from own measurements]

tensity level in the distant area of the field. Specification of the measurements of electromagnetic fields for distant fields states the value of 20–50% of the total uncertainty of measurements with the trust level of 95%. This means that, in the frequency range covered by the measurement, the results which include ILAC guidelines [22] are below the limit of 7 V/m in accordance with the resolution [16]. Similarly, the results satisfy the criterion by including the growth in level by uncertainty in accordance with the provisions of the PN-EN 62 311 standard [12].

Special attention must be paid to Vehicle no. 8 for which the top level of E = 3.54 [V/m] was measured at a distance of about 19 meters. Considering the theoretical values of suppression in the free space from Table 3, we can assume that the electric field intensity level in the range 26 MHz – 3000 MHz at a distance of 1m from the side wall of the vehicle may grow by about 25 dB. The value of theoretical growth of electric field intensity level determines the question of satisfaction of the limit arising from the resolution [16] and EU directives [4] and [5].

4. Conclusions and summary

Power systems, electronic systems, ICT systems, wired communication systems and wireless communication systems used in the railway rolling stock serve as a source of intentionally generated electromagnetic fields and the fields which are the side effect of operating systems. The issue in question concerned with the potential impact of electromagnetic field levels generated from the railway rolling stock on the general environment and, above all, on human health with regard to radio waves shows a lack of legal regulations in this respect (in the railway industry). Analysis of the legislative status concerning the issue in question leads to the conclusion that there are no requirements nor code of conduct, including the measuring method, aimed at identifying the safety of particular types or single items of rail vehicles with respect to the influence of electromagnetic fields on human health and life.

The railway industry takes into consideration the issue related to EMC, yet almost entirely ignores EMF in relation to human health. So far, the resistance and impact on other devices in a wide electromagnetic environment have been the center of attention. We can notice a clear asymmetry between the care for the proper operation of devices and systems, and the impact of their operation on human health. The current situation presented emphasizes the scope of the List of the Head of the Rail Transport Office, which includes a wide range of EMC standards, with one item referring to the exposure of people to electromagnetic fields, that is PN-EN 50500:2008 + A1:2015-10 [11], taking into account solely the influence of magnetic components for the frequency up to 20 kHz.

The authors of the article made initial measurements and presented the results of a few random vehicles under regular conditions of operation. This operation helped to demonstrate that the level of electric field intensity in the distant field was explicitly higher than the background level. It is necessary to highlight that the results of measurements of vehicles of unknown equipment showed an acceptable level of electromagnetic fields by referring to the "non-rail" resolution [16]. The measurements suggest that, in the presence of the rail vehicle, the electromagnetic field level rises at selected measuring points. The electromagnetic field level measurement presented in Fig. 5 is higher than others despite the fact that it was made at a distance of about 19 m. This leads us to the assumption that, in this case, the source of fields may not be the vehicle itself but mobile communications base stations, which emit towards the devices located in the vehicle. The measuring methodology which has been adopted tentatively does not let us confirm whether this growth is affected by emission from the vehicle or to the vehicle and this may be the basis for further research.

Bearing in mind the above-stated conclusions, the authors of the article suggest conducting a series of controlled tests in selected and prepared rail vehicles in the urban environment at best and in the test track of the Railway Research Institute in Żmigród.

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