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METHODOLOGY AND PROBLEMS DURING TESTING ELECTROMAGNETIC COMPATIBILITY OF ROLLING STOCK

1. Legal conditionality of railroad train research

The range of certification railway rolling stock includes electromagnetic compatibility research. They result from EMC 2004/108/WE European directive registrations. This directive replaced directive 89/336/EEC and its major task was to standarized regulations concerning electromagnetic compatibility in Member States to the European Union. The new directive had been published on 31st of January 2004, however it had been in force on 20 of July, 2007. Its scope includes devices, stationary and mobile installation systems, terminal equipment, which can be a source of electromagnetic disturbances, if its actions have influence on generating electromagnetic disturbances. The directive regulations define the rules to launch or brig in for use the new devices and fundamental procedures conformity control and marking of conformity signed by CE.

The railway rolling stock electromagnetic compatibility research also has to be done according to valid normative documents, which are harmonized with directive 2004/108/WE. The harmonized standards disclose required concerning immunity and emission.

In immunity emission case the harmonized standards disclose required frequency range in which the research should be done, legal emission level and specify the research methodology.

The standards which are harmonized with directive 2004/108/WE in range immunity disclose variety environmental immunity, which railroad train should be exposured and the sharpness of attempts exposing and also method of its simulation.

Both case have defined curse of work for object during the time of certification research and criteria of conformity assessment which help during the evaluation of the research results.

The electromagnetic compatibility research of railway rolling stock are very important not because of possibility occurred wrong effect on device interlocking, which can influenced on security, but also can influenced on device useful in public system. It is connected with railway rolling stock influence range, where more often public objects are situated including detached houses and huge shopping center full of electronic systems and device. For example: Hauptbahnhof Railway Station in Berlin or Wileński Railway Station in Warsaw.

2. Methodology of measurements

The railway rolling stock electromagnetic compatibility research are realized according to revealed methodology and valid normative requirement including above-mentioned standards:

- EN 55011 Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement
- EN 50121-1 Railway applications – Electromagnetic compatibility – Part 1: General
- EN 50121-2 Railway applications – Electromagnetic compatibility - Part 2: Emission of the whole railway system to the outsider world
- EN 50121-3-1 Railway applications – Electromagnetic compatibility – Part 3- 1: Rolling stock – Train and complete vehicle
- EN 50121-3-2 Railway applications – Electromagnetic compatibility – Part 3-2: Rolling stock – Apparatus

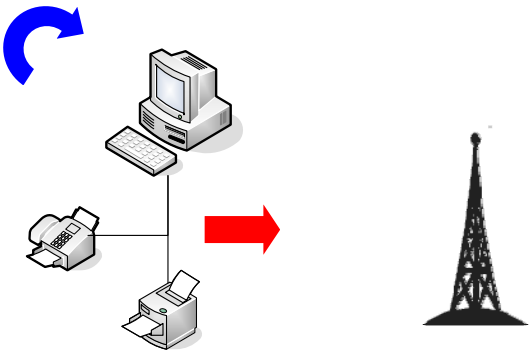
This standards has defined compatibility as an ability electric or electronic device to correct work in given electromagnetic environment and to do not emitted electromagnetic filed which could disturb correct work of other device which are working order in this environment.

The electromagnetic compatibility research can be considered in two aspects:

- emission is defined as a system or device influence because of electromagnetic waves influenced on the other system or device situated in the nearest electromagnetic environment;
- immunity is defined as a system or device work ability without getting worse quality of action in a place, where occur electromagnetic disturbances.

The railway rolling stock research of electromagnetic immunity normative registration reveal lack of necessity of research. That norm includes [5] requirement immunity to level 20V/m in range frequency from 0,15 MHz to 2

GHz. On the assumption that in complete vehicle devices are installed as a whole, sufficiently immunity on condition that plan EMC was prepared and implemented, and was taken into account border values included in this norm.



Pic. 1. Electromagnetic emissions and immunity of equipment and systems

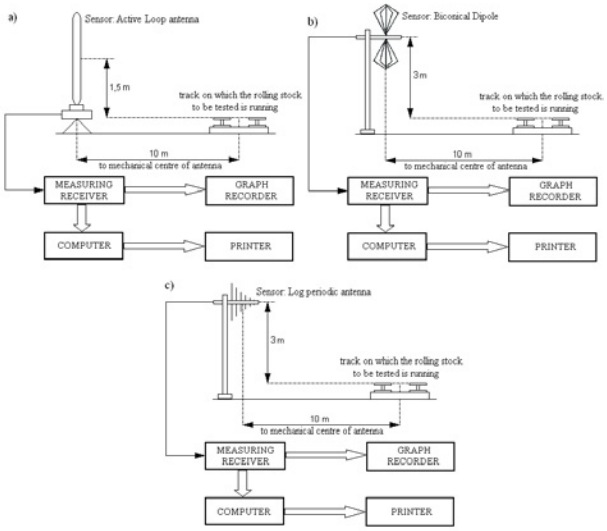
The research of emission of electromagnetic disturbances railroad train are made for emission disturbances of radiation and conduction.

2.1. The measurement of emission radiation disturbances

The emission of radiation disturbances is a disturbance send as a electromagnetic waves. On account of specificity devices electric traction (high voltage and high consumption of current), measurement of the level of radiation disturbance emission are made as a measurement of filed amplification 10 m away from rail axel. On account of wide range of frequency the measurement of radiation disturbances railroad train should be made by the 3 types of antennas, which is illustrated in 2. From now on recommendation included in that norm [4] allow to make a measurement with 2 antennas (active loop and log periodic).

The measurement of emission radiation disturbances are made in 9 kHz ÷ 1 GHz with nine range division according to registrations in norm [4]

- 9 kHz ÷ 59 kHz - measurement of magnetic field strength component disturbances using the loop antenna,
- 50 kHz ÷ 150 kHz - measurement of magnetic field strength component disturbances using the loop antenna,
- 150 kHz ÷ 1,15 MHz - measurement of magnetic field strength component disturbances using the loop antenna,
- 1 MHz ÷ 11 MHz - measurement of magnetic field strength component disturbances using the loop antenna,
- 10 MHz ÷ 20 MHz - measurement of magnetic field strength component disturbances using the loop antenna,



Pic. 2. Antennas required for measuring radiated disturbance electromagnetic emission

- 20 MHz ÷ 30 MHz - measurement of magnetic field strength component disturbances using the loop antenna
- 30 MHz ÷ 230 MHz - measuring the vertical component of electric field strength using the biconical antenna,
- 200 MHz ÷ 500 MHz - measuring the vertical component of electric field intensity using the log periodic antenna,
- 500 MHz ÷ 1 GHz - measuring the vertical component of electric field intensity using the log periodic antenna.

Antenna should be situated 10 m axel from rail axel. During the measurement magnetic storage in 9 kHz ÷ 30 MHz the aerial should be situated from 1 to 2 m high, counted above the track head level, but for 30 MHz ÷ 1 GHz the antenna should be situated 3m high.

Before we started measurement the object which is researched, we should check if on every measurement frequency which we choose included in required frequency range, we won't find excessive outside wireless-electric disturbances (electromagnetic background). The level of outside disturbances which are making background should be smaller at least 6 dB from permissible levels. In case of statement that outside emission (electromagnetic background) has too high level for given frequency or for range frequency, this range is not evaluated.

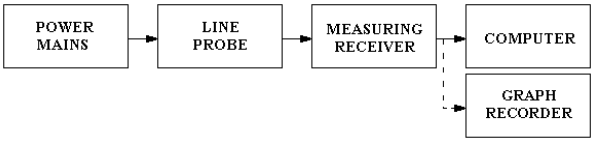
2.2 The measurement of radioelectric disturbances in deck net supply low voltage

The emission of conduct disturbances is defined as a electromagnetic disturbances spread out in

length electric line or in length line of signal transmission. The measurement of emission of conduct disturbances in on-board the low voltage network are made during stop according to methodology registration in norm [6]

According to norm recommendation the measurement of asymmetrical storage voltage of disturbances radioelectric are made from 9 kHz to 30 MHz frequency range.

The measurement emission of conduct disturbances are made on every ports the low voltage network low voltage A.C and D.C. The line probe measurement is used to measurement of conduct disturbances. The concentric cable connects the receiver measurement and line probe measurement, which is illustrated in picture 3. The measurement are made during stop with maximum load. The gained results are compare to the earliest measurement background for the power mains.



Pic. 3. Scheme of measuring the emission of conducted disturbances

3. The examplary results of measurement

3.1. The results of the measurement of emission radiation disturbances

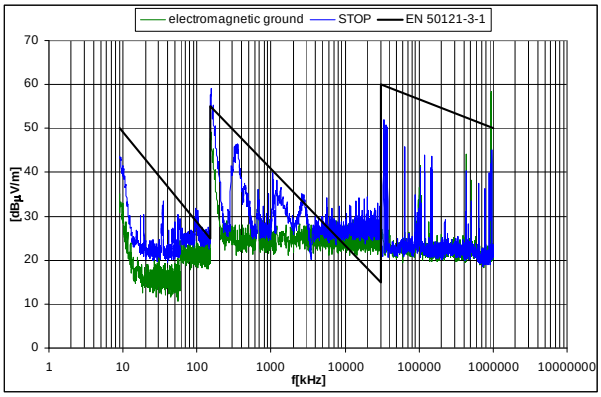
In the picture 4 was shown exemplary results of the measurement of emission radiation disturbances which originated from electric traction set EMU 22 WE type, but we took account of requirement of outside disturbances which are included in norm.

The measurement of emission radiation disturbances were made in this circumstances:

- during stop – the picture 4;
- during driving – the picture 5.
- During stop the train was situated straight the antennas and all deck devices which could be the potential source of radio-electric disturbances were switched on.

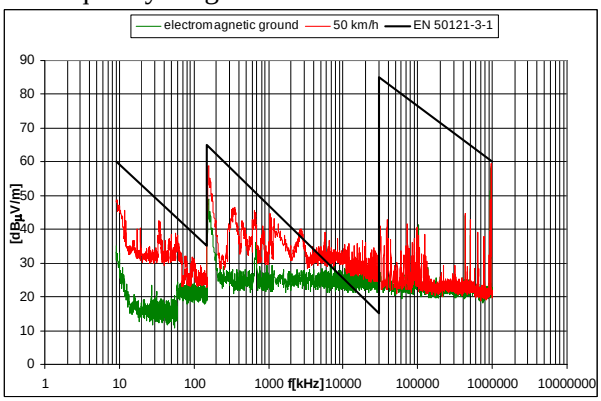
During drive the measurement was made in measurement position and locomotive's speed was 50km/h ± 10km/h and the power trial was 30 %.

In the pictures 4 and 5 we put the results of the measurement of emission radiation disturbances which originated from EMU 22WE during stop and also during drive ahead of antennas with required speed.



Pic. 4. Disorders of radiated emissions of railway rolling stock during the stop

The results of measurement depends on outside disturbances and it should be 6dB of permissible value. According to norm's recommendation [4] on frequency where the level of permissible value were exceed, the measurement result weren't evaluated because of high level of outside disturbances. In the case of the test vehicle, such situation was in the frequency range 10 MHz – 200 MHz.



Pic. 5. Disorders of the rolling stock radiated emissions during drive

3.2. The results of measurement radioelectric disturbances in low voltage power circuit in electric locomotive

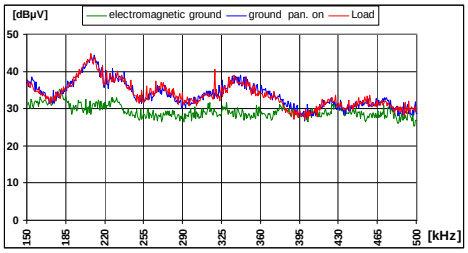
The railway mobile objects like a locomotive, we can treat as a specific and complex electromagnetic environment. The device which work in this environment shouldn't have an influence on each other, and especially electric devices powered 3 kV voltage shouldn't bring in excessive levels of radio-electric disturbances to a deck circuit which sends a signal in electric deck devices.

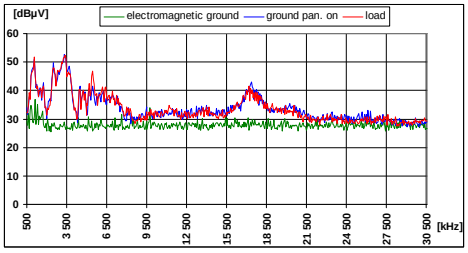
In circuit of high voltage occur potential sources of radio-electric disturbances: traction engines, fan engine powered direct current generator, contacts line and group contactor, contact current collector with trolley wire.

In circuit of low voltage occur relevant source of radio-electric disturbances and electromagnetic impulse disturbances: direct current generator, low

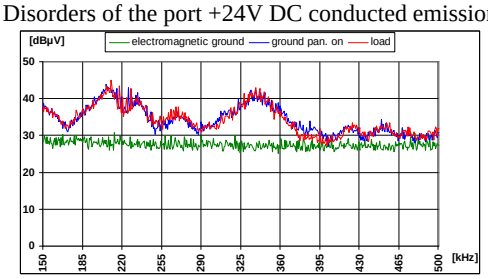
voltage contacts contactor, engines of auxiliary drive.

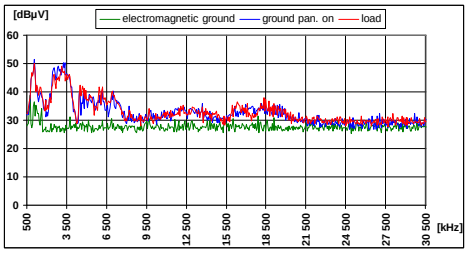
In the picture 6 are presented the results of the measurement which were made.



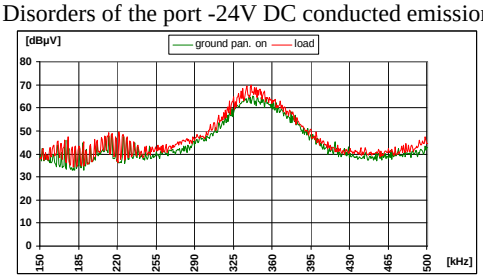


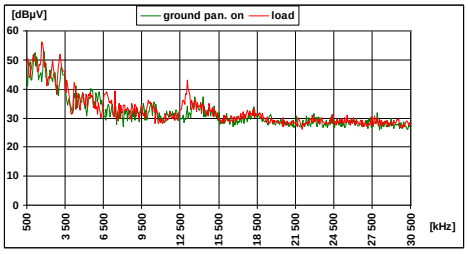
Disorders of the port +24V DC conducted emission



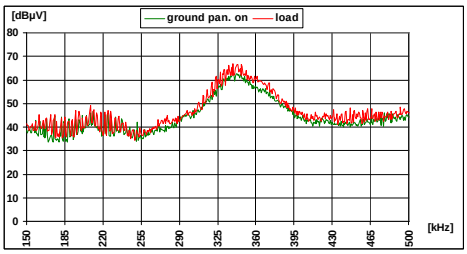


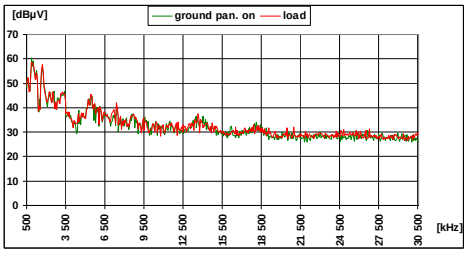
Disorders of the port -24V DC conducted emission





Disorders of the port L 230V AC conducted emission





Disorders of the port N 230V AC conducted emission

Pic. 6. Disorders conducted emission 22WE EMU

In the picture 6 we presented the results of the measurement emission conduction disturbances. The measurement was made in on-board the low voltage network 24 V DC and port 230 V AC electric multiple unit type 22 WE. During measurement's we don't certify any exceed permissible level of the emission conduction disturbances.

4. Uncertainty of measurement in radioelectric emission disturbances research

The measurement of emission radiated and conducted disturbances is always a measurement mistake ensuing from measurement specificity and precision test equipment which was used. Correct evaluation of this results forced to estimate the uncertainty of measurement. The most important element of conformity and unconformity with permissible level of radioelectric disturbance is to take into account the uncertainty of measurement of test equipment. Uncertainty of the test equipment which was used to radioelectric disturbances research, should be evaluated by included all dimensions named in the norm EN 55016-4-2 [7].

The standard uncertainty $u(x_i)$ in dB and indicator of sensitivity c_i is evaluated for estimation x_i every dimension. The standard uncertainty $u(y_i)$ for estimation u dimension should be calculated by using dependence (1).

$$u_c(y) = \sqrt{\sum_i c_i^2 \cdot u^2(x_i)} \qquad (1)$$

where: $u_c(y)$ – (composed) standard uncertainty of the size y; c_i – sensitivity coefficient; $u(x_i)$ – standard uncertainty estimation x_i.

The widen uncertainty which was brought in by measurement equipment U_{lab} calculates using dependence (2).

$$U_{lab} = 2 \cdot u_c(y) \qquad (2)$$

where: U_{lab} – expanded uncertainty of the sizei y; $u_c(y)$ – (composed) standard uncertainty of the size y.

According to requirement of Polish Centre for Accreditation documents the estimated uncertainty of measurement radioelectric radiated and conducted disturbances should be annouced in report of test.

Conclusions

The results of the measurements of radioelectric disturbances radiated by train had shown, that the offence of permissible level, occurs in 10 MHz – 200 MHz. We take outside disturbances level of disturbances into account which occurred measuring range we can suppose that the offences of permissible level doesn't occur.

The measurements result has definitive influence on condition of electromagnetic environment, where significant levels of radioelectric disturbances occurs and they originate from unidentified sources. The examination which had been conducted, showed that tested EMU, didn't exceed permissible levels.

Before choosing measuring range the condition of electromagnetic environment should be examined very precisely. If there are any excessive levels outside sources it's source and time of the highest levels of emission have to be examine.

If the research is examine on measuring range which was chosen incorrectly and by inexperienced staff the interpretation of the measurements results may be wrong.

During the conducted electromagnetic disturbances researches occurred in the deck net supply low voltage, significant space between measured level of disturbances and permissible norm requirement's were noticed.

The analysis which had been made, had shown that in train EMU 22 WE higher level of generated, conducted disturbances occurred in on-board the low voltage network 230V AC power supply port.

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6. EN 55011: Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement

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Prof. *P. D. Andrienko*, D. Sc. (Tech.) recommended this article to be published.

The electromagnetic compatibility research can be considered in two aspects - emission and immunity. The harmonized standards disclose required concerning immunity and emission. In immunity emission case the harmonized standards disclose required frequency range in which the research should be done, legal emission level and specify the research methodology. Both cases have defined curse of work for object during the time of certification research and criteria of conformity assessment which help during the evaluation of the research results.

The paper studies the evaluation of electromagnetic compatibility of railway rolling stock, the emissions generated by rolling disorders in relation to acceptable levels recorded in the dedicated standards. The paper presents results of measurements of emissions radiated by train EMU type 22WE 4 x 500 kW. Presented results of measurements conducted emission in the on-board low voltage network. The paper also describes a method for estimating the uncertainty in the emissions testing problems of rolling stock. The measurement of radiated and conducted emission disturbances is always a measurement a mistake ensuing from measurement specificity and precision test equipment which was used. It's shown that a correct evaluation of these results forced to estimate the uncertainty of measurement. The most important element of conformity and unconformity with permissible level of radio electric disturbance is to take into account the uncertainty of measurement of test equipment (according to requirement of Polish Centre for Accreditation documents). The examination which had been conducted, showed that tested EMU, didn't exceed permissible levels.

Keywords: electromagnetic compatibility, emission of electromagnetic disturbance, rolling stock.

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МЕТОДОЛОГІЯ ТА ПРОБЛЕМИ ДОСЛІДЖЕННЯ ЕЛЕКТРОМАГНІТНОЇ СУМІСНОСТІ РУХОМОГО СКЛАДУ

Дослідження в області електромагнітної сумісності можна розглядати у двох аспектах - випромінювання і захист. Існують стандарти, що стосуються цих двох аспектів. У разі дослідження захисту об'єктів від електромагнітного випромінювання стандарти встановлюють необхідний діапазон частот, в якому повинні виконуватись дослідження, нормований рівень електромагнітного випромінювання і визначають методологію дослідження. В обох випадках визначаються принципи проведення випробувань на об'єкті під час сертифікації та критерії оцінки відповідності, які використовуються при оцінці результатів випробувань.

У статті представлена оцінка електромагнітної сумісності залізничного рухомого складу, випромінювання, що утворюються при цьому по відношенню до нормованого рівня, встановленого в стандартах. Представлені результати вимірювання емісії, яка випромінюється при русі поїзда EMU типу 22WE 4 x 500 кВт. Представлено результати вимірювань випромінювання в бортовій мережі низької напруги. У статті також описується метод оцінки невизначеності при тестування рухомого складу. Вимірювання такого роду завжди мають помилку, яка обумовлюється специфікою вимірювань і точністю вимірювальної апаратури, яка використовувалась. Показано, що правильна оцінка цих результатів вимагає оцінки невизначеності вимірювань. Найбільш важливими елементами в оцінці невизначеності вимірювань є оцінка відповідності із допустимим рівнем радіоперешкод, оцінка невизначеності вимірювання випробувального обладнання (у відповідності з вимогами Польського центру з акредитації). Експертизи, які були проведені, показали, що випромінювання перевірених EMU не перевищували допустимих рівнів.

Ключові слова: електромагнітна сумісність, емісія електромагнітних спотворень, рухомий склад.

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МЕТОДОЛОГИЯ И ПРОБЛЕМЫ ИССЛЕДОВАНИЯ ЭЛЕКТРОМАГНИТНОЙ СОВМЕСТИМОСТИ ПОДВИЖНОГО СОСТАВА

Исследования в области электромагнитной совместимости можно рассматривать в двух аспектах - излучение и защита. Существуют стандарты, касающиеся этих двух аспектов. В случае исследования защиты объектов от электромагнитного излучения стандарты устанавливают необходимый диапазон частот, в котором исследование должно быть сделано, нормированный уровень электромагнитного излучения и определяют методологию исследования. В обоих случаях определяются принципы проведения испытаний на объекте во время сертификации и критерии оценки соответствия, которые используются при оценке результатов испытаний.

В статье представлена оценка электромагнитной совместимости железнодорожного подвижного состава, излучения, образующегося при этом по отношению к нормированному уровню, установленному в стандартах. В статье представлены результаты измерения эмиссии, которая излучается при движении поезда EMU типа 22WE 4 x 500 кВт. Представлены результаты измерений излучения в бортовой сети низкого напряжения. В статье также описывается метод оценки неопределенности при тестирования подвижного состава. Измерения такого рода всегда имеют ошибку, которая обуславливается спецификой измерений и точностью измерительной аппаратуры, которая использовалась. Показано, что правильная оценка этих результатов требует оценки неопределенности измерений. Наиболее важными элементами в оценке неопределённости измерений являются оценка соответствия с допустимым уровнем радиопомех, оценка неопределенности измерения испытательного оборудования (в соответствии с требованиями Польского центра по аккредитации). Экспертизы, которые были проведены, показали, что излучения проверенных EMU не превышали допустимых уровней.

Ключевые слова: электромагнитная совместимость, эмиссия электромагнитных искажений, подвижной состав**.**

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