The Amendment of the Standardization Rules Concerning Testing of Rolling Stock in Terms of EMC

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Summary
The paper presents the methodology of radiated and conducted disturbance emission measurement in on-board rolling stock power low voltage network in reference to current obligatory normative standard requirements PN-EN 50121-X-X. The article presents in detail the methodology of measurement, permissible levels of radiation disturbance emission during stand and during vehicle ride and the levels of conducted disturbance emission in on-board low voltage power network. In conclusion, the paper outlines the comparison of obligatory, normative standard requirements in this range along with a new edition of rail standards, which will be implemented soon, due to the old editions of current standards documents based on rolling stock should be tested in terms of EMC in order to fulfill normative requirements.

Keywords: rolling stock, methodology of measurement, electromagnetic compatibility, radiation disturbance emission, conducted disturbance emission

1. Introduction

The standardization rules concerning testing of rolling stock in terms of EMC are the subject to modification because the rolling stock and its electrical and electronic equipment are subjected to change due to the implementation of the new solutions. The standardization rules binding in the range of UE standardization system relay on following type of documents:

- The European Council Directive published in the Official Journal of the European Union (OJ),
- The Harmonization Documents, defining as en example the implementation of standardization document (EN) to the set of legally national binding standards or removal of standards which are incompatible with EN,
- The CENELEC EN standard, ENV (European pre-Standard), prEN (the Draft European Standard).

The very first standardization rules binding in Poland and concerning radio-electric disturbance emission generated by mobile rolling stock were implemented in the 70's in the previous century. They included detailed methodology of the measurement, permissible levels and the range of measuring frequency which ranges from 150 kHz to 30 MHz.

When Poland acceded to the EU, the European standards concerning different systems of electric traction began to came into force.

2. Legal conditionality concerning range of the rolling stock testing

The whole range of rolling stock certification is multithreaded and one of its stages covers electromagnetic compatibility testing. That obligation directly results from provisions of 2004/108/EC Directive which concerns electromagnetic compatibility EMC [1]. It includes electrical and electronic devices, stationary and mobile systems of installations located in the railway area and terminal devices. Therefore it includes equipment which can be the source of electromagnetic disturbance.

The rolling stock tests in the range of electromagnetic compatibility requirements have to be performed according to binding normative documents, which are harmonized with the Directive [1]. The harmonized standards include requirements relating to electromagnetic intrusive emission and immunity to natural extraction emission and caused by outside devices. In the case of radio-electric disturbance emission, the harmonized standards include requirements concerning the

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range of measuring frequency, in which tests should be performed, the values of the permissible levels of emission and methodology of the testing. However, in the range of devices immunity to external emission the types of occurred environmental disturbances have been defined, in which rolling stock should be examined, the severity of the tests and the method of their simulation. The work modes for the object during certification tests have been described for both cases mentioned above. At the same time parameters for conformity assessment, which are basis of the evaluation of received measurement results have been presented.

Requirements of the rolling stock certification are also laid down in The Technical Specifications of Interoperability – Train (TSI_Train). In view of complexity of interoperability rail system, the specifications have been divided into dedicated subsystem Moreover in the normative research the rolling stock in Poland has to obtain authorization for placing into service into the railway premises, which according to current regulations of Minister of Infrastructure is issued by the Office of Rail Transport.

In order to meet electromagnetic compatibility requirements the railway rolling stock tests are essential mostly due to the probability of negative influence on the control and command and signalling equipment which may affect traffic safety, as well as public devices and systems whose protection is laid down in relevant standards.

Public objects such as houses, blocks of flats and shopping centers equipped with various electronic devices which are necessary for their proper functioning are often located near railway. The typical examples are Berlin Central Station (Hauptbahnhof) or the main hall in Poznan's Main Station with a shopping mall situated near the railway station.

The main task of the paper is to compare current standards with amended edition of railway standards, which are implemented as they arise, because new modifications are not included in previous editions of binding standardization documents, basing on which rolling stock should be tested for electromagnetic compatibility EMC.

3. Binding methodology of research in range of radiated disturbances

The tests concerning the fulfillment of the requirements in the range of electromagnetic compatibility may be considered in two aspects:

- immunity – defined as an ability of the system and devices to work without deterioration in the place where electromagnetic disturbance occur,
- emission – defined as an influence, which systems or devices have on other systems and devices located in the nearby electromagnetic surroundings, by sending out electromagnetic waves.

The normative requirements do not impose the necessity of conducting tests concerning rolling stock immunity to electromagnetic disturbances as it has been assumed that devices installed in a complete vehicle treated as a whole, are provided with sufficient immunity. In that case a requirement has to be met that a comprehensive plan relating to the fulfillment of EMC requirements with limit values contained in the standard [3] has been prepared and implemented.

The issues concerning the rolling stock radiated emission tests are contained in the following standards based on the established methodology of requirements:

- **PN-EN 50121-1** Railway applications – Electromagnetic compatibility – Part 1: General [2],
- **PN-EN 50121-2** Railway applications – Electromagnetic compatibility – Part 2: Emission of the whole railway system to the outside world [3],
- **PN-EN 50121-3-1** Railway applications – Electromagnetic Compatibility – Part 3-1: Rolling stock – Train and complete vehicle [4].

Radiated disturbance is defined as a disturbance sent as an electromagnetic wave. Considering the specificity of electric traction (high voltage and high consumption of current), the measurement of the radiated disturbance emission level is only performed as a measurement of field strength 10 meters away from the rail axis. The measurement should be made with 3 types of antennas due to the significantly wide range of frequency radiated disturbances emitted by the train, which is illustrated in the Figure 1. Recommendations concerning measurement performed by 2 antennas (active rectangular magnetic loop and log-periodic antenna) are contained in the standard's recommendation [3].

The measurement of radiated disturbance emission are carried out 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 active rectangular magnetic loop antenna,
- 50 kHz÷150 kHz – measurement of magnetic field strength component disturbances using the active rectangular magnetic loop antenna,
- 150 kHz÷1,15 MHz – measurement of magnetic field strength component disturbances using the active rectangular magnetic loop antenna,
- 1 MHz÷11 MHz – measurement of magnetic field strength component disturbances using the active rectangular magnetic loop antenna,
- 10 MHz÷20 MHz – measurement of magnetic field strength component disturbances using the active rectangular magnetic loop antenna,

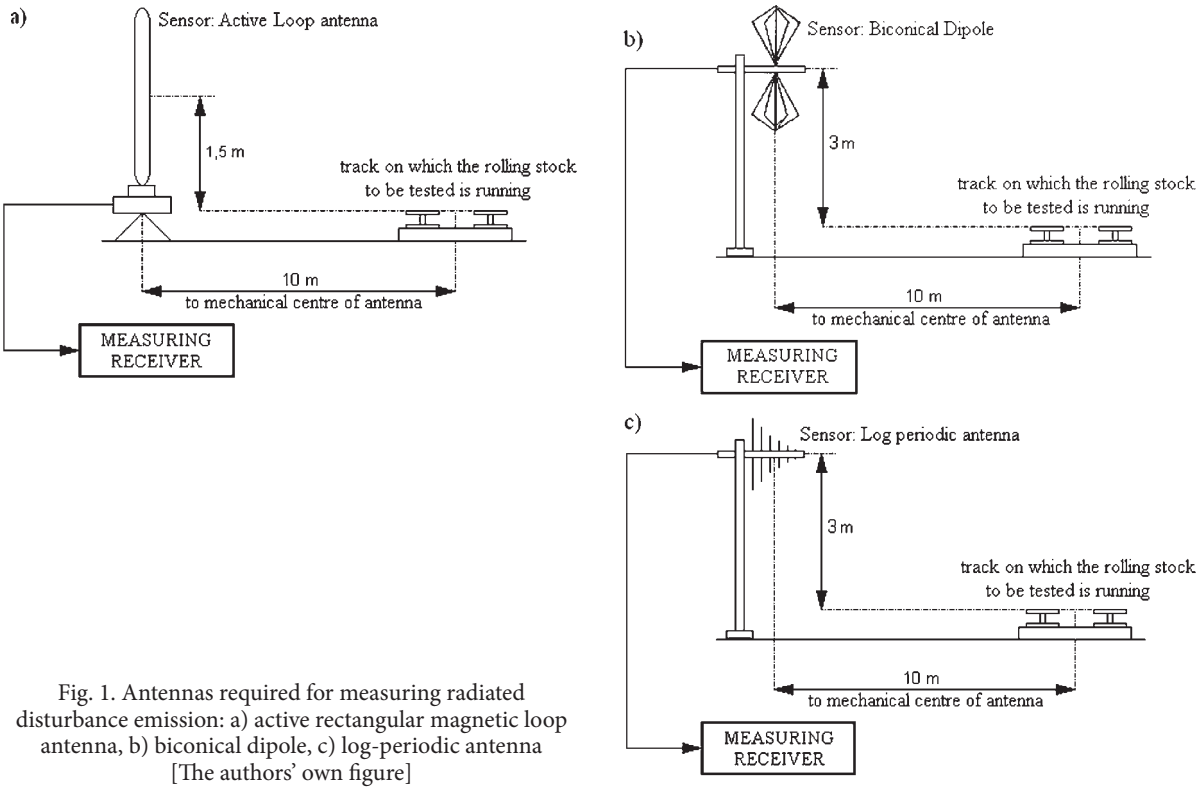

Fig. 1. Antennas required for measuring radiated disturbance emission: a) active rectangular magnetic loop antenna, b) biconical dipole, c) log-periodic antenna [The authors' own figure]

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

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

Before measuring a tested object, it should be checked on every measuring frequency range if excessive outside wireless-electric disturbances (electromagnetic background) do not appear. The level of outside disturbances which make up the background should be smaller at least 6 dB from permissible levels. If detected outside emission (electromagnetic background) has too high level for given frequency or for range frequency, this range is not evaluated.

Permissible levels of radiated disturbance emission for two test modes are contained in the standard's recommendation [4] as graphs (Fig. 2 and Fig. 3).

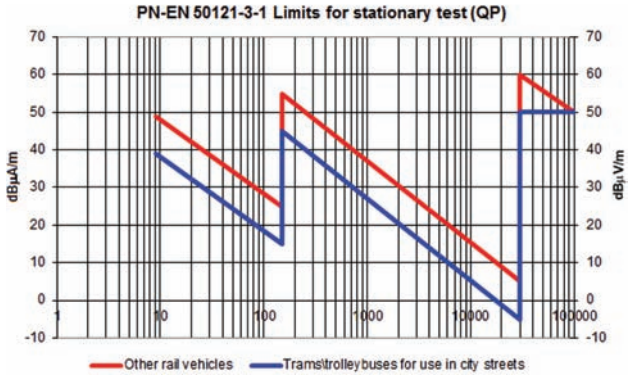

Fig. 2. Permissible levels of radiated disturbance emission for railway rolling stock during the stop [The author's own figure]

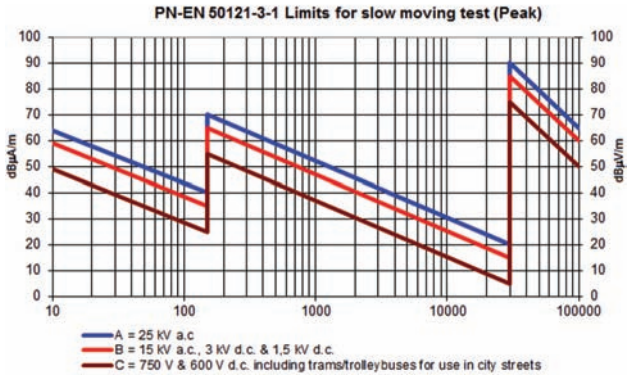

Fig. 3. Permissible levels of radiated disturbance emission for railway rolling stock during the drive [The author's own figure]

4. Binding methodology of the research in the range of conducted disturbances' emission

The emission of conducted disturbances is defined as an electromagnetic disturbance spread out along electric cables or line of signal transmission. The measurement of conducted disturbances' emission in on-board low voltage network are conducted during the stop according to the methodology contained in registration standard [5].

According to recommendation contained in the above-mentioned standard the measurements of asymmetrical storage voltage of radio-electric disturbances are made from 150 kHz to 30 MHz frequency with two sub-ranges:

- 150 kHz–500 kHz,
- 500 kHz–30 MHz.

The measurement of conducted disturbances' emissions are carried out on all ports of on-board low voltage a.c. and d.c. networks. It includes:

- ports of auxiliary power unit of sinusoidal current a.c. or d.c.,
- ports relating to battery,
- measuring and controlling ports used to power electronic devices.

Typical values of on-board supply power in vehicles are defined in standard[6] and amount to 24 V DC, 36 V DC, 48 V DC, 110 V DC and 230 V AC.

The measurements of conducted disturbances' emission are made by high voltage line measurement probe. The EMI measurement receiver is connected, by coaxial cable to the high voltage line measurement probe, which is illustrated in Figure 4. The level of incidental disturbances described in conditions for disconnecting the power supply as a background, should be evaluated before each measurement. The gained results are compared to the earlier measuring of incidental disturbances (background) occurring in low voltage supply board network when the power supply is disconnected.

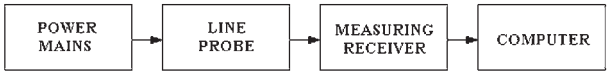

Fig. 4. Block diagram of measuring system to measure radio-electric disturbances in onboard low voltage supply network [The authors' own figure]

All test equipment which is part of measuring track should fulfill the requirements of standard [7]. Permissible levels of conducted disturbances' emission are contained in standard [8] and amount to:

- for frequency band 150÷500 kHz – 99 dBμV,
- for frequency band 0,5÷30 MHz – 93 dBμV.

5. Current standarization amendment implemented in new edition of railway standard in the range of rolling stock testing

At the FINAL DRAFT stage in September 2014, CENELEC published drafts of new editions of normative acts series EN-50121-X-X, which are to replace previous, quite obsolete editions of current normative requirements in the range of rolling stock electromagnetic compatibility testing.

In the range of the most important changes in the above mentioned standards they concern testing grounds as well as the methodology of measurement. The changes relate to the range of radiated disturbances' emission and the testing ground measurement.

In the range of requirements concerning the testing grounds, where rolling stock tests should be performed, the proposed changes are defined in little detail and precision, for example in case of measuring distance. The following issues are defined in detail:

- the lack of specified distance from trees, walls, bridges, tunnels and other vehicles,
- the lack of specified distance from traction substation, high voltage power line or electric cables,
- lack of barriers between a tested vehicle and measuring antenna,
- measuring point should be located between construction of the overhead contact line,
- the incidental (background) disturbances' measurement should be performed before and after a series of normative measurements when the deactivated vehicle stands in front of the measuring antenna,
- the distance from traction network discontinuity has been reduced from 3 km to 200 m.

Another change has been implemented in standard [2] concerning radiated disturbances' emission and it consists in reducing the number of the sub-ranges of rolling stock test frequency from 9 to 7. Measurements are performed in this way in the range of frequency from 150 kHz do 1 GHz, which is different from previous frequency value of 9 kHz. Additionally, despite many considerations, it has not been decided to expand the measuring frequency band to 3 GHz. It would be compatible with the current trend in the range of radiated emission and it would allow verification of devices working in 3 GHz frequency band, which are installed on traction vehicles. Moreover, in the case of application measuring antennas (biconical dipole and periodic antennas) the change consists in the increase of antenna hang-up height.

However, as regards measurements of conducted disturbances' emission in onboard low voltage supply net-

work there occurred a quite radical change concerning a.c. power connection ports. According to standard [10] a new criterion of evaluation has appeared in the output a.c. power connection ports 230V AC for public devices, which are connected to them. The measurement methods and interpretation of obtained results of current quality measurement in a.c. supply network 50/60 Hz frequency (interharmonic factor THD) have been defined. The measurement methods are described for every mentioned meaningful parameter in conditions of reliable and repeatable results regardless of the method used. That standard concerns measuring method under *in situ* conditions.

6. Conclusion

The paper describes the requirements for issueing the emission measurement of radio disturbance by rolling stock in accordance with applicable standards to date.

It also presents the assumptions of the proposed changes in this area. These proposals can be understood as a simplification of the procedures already in use, which may be by some experts considered as too labor-intensive. Procedures used in the previously existing standards, as well as in their previous editions were created within the CISPR committee as a set of experiences in this field. The standard used in Poland is based on rules contained within the standards applicable in the countries of the Council for Mutual Economic Assistance. The then existing standard contained several recommendations for performing measurements. The recommendations have not been confirmed by the impact on the result. Then gained experience in carrying out their research at the Railway Research Institute was sent to CISPR as members of the appropriate technical subcommittee.

The existing rules of to date standards have been developed by CENELEC on the basis of the experience gained in many countries. The adopted method of measurements as well as the criteria for the allowable level of emissions of electromagnetic field rolling stock and the level of allowable conducted radio disturbance in the power network rolling stock completely met the required criteria for the railway electromagnetic environment.

The authors expressed their opinion on changes simplifying the measurement procedures proposed by CENELEC in 2014. It should taken into account that there is now a trend in the railway rolling stock to saturate it with more complex electronics. It can be an additional source of radio disturbance while being more exposed by unauthorized sources disorders with high energy and natural electromagnetic processes.

Too simplistic method of measurement proposed by the new standard will not always be able to assess properly the state of the electromagnetic environment inside and outside of the rolling stock.

Too hasty decisions, such as the elimination of the measuring range 9 kHz–150 kHz could have a negative influence on the electromagnetic environment. Not extending the scope of measuring the minimum to 3 GHz or 6 GHz raises concerns due to the fact that there are devices working to this frequency on rolling stock rail.

The amendment to the current legislation, standardization is an inevitable process because of systematically rising requirements for rolling stock and ongoing developments in the field of electronics. All work in this area through CENELEC should be preceded by consultations in a wider range of labs specializing in this subject.

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Nowelizacja przepisów normalizacyjnych dotyczących badań taboru kolejowego w zakresie EMC

Streszczenie

W artykule przedstawiono metodykę pomiarów emisji zaburzeń promieniowanych i przewodzonych w pokładowej sieci zasilającej niskiego napięcia taboru kolejowego na przykładzie obecnie obowiązujących wymagań norm serii PN-EN 50121-X-X. Szczegółowo przedstawiono metodykę pomiarów, dopuszczalne poziomy emisji zaburzeń promieniowanych na postoju i w trakcie jazdy pojazdu oraz emisji zaburzeń przewodzonych w pokładowej sieci zasilającej niskiego napięcia. Porównano obowiązujące wymagania normatywne w tym zakresie, z nowym planowanym wydaniem norm kolejowych, które niedługo zastąpią obecne normy.

Słowa kluczowe: tabor kolejowy, metodyka pomiarów, kompatybilność elektromagnetyczna, emisja zaburzeń promieniowana, emisja zaburzeń przewodzona

Поправки в законодательстве по стандартизации исследований железнодорожного подвижного состава в области электромагнитной совместимости

Резюме

В статье представлена методика измерений эмиссии разлучвемых помехов и наведенных помехов в сети бортового энергоснабжения низкого напряжения подвижного состава на примере действующих требований норм серии PN-EN 50121-X-X. Представлена подробнее методика измерений, допускаемые уровни эмиссии излучаемых помехов во время стоянки и движения поезда а также эмиссии наведенных помехов в сети бортогого энергоснабжения низкого напряжения. В конце статьи были сравнены действующие нормативные требования в этой области с новыми изданиями железнодорожных норм, которые скоро должны быть введены из-за совершенно старых изданий действующих документов по стандаризации, на основании которых надо вести исследования подвижного состава на предмет электромагнитной совместимости с целью выполнения нормативных требований.

Ключевые слова: подвижной состав, методика исследований, электромагнитная совместимость, эмиссия излучаемых помехов, эмиссия наведенных помехов