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WOJCIECH CZUCHRA*

THE INFLUENCE OF CONVERTER CABLES SCREENING ATTENUATION ON RADIATED ELECTROMAGNETIC DISTURBANCES FROM CONVERTER DRIVE

WPŁYW TŁUMIENNOŚCI EKRANOWANIA KABLI PRZEKSZTAŁTNIKOWYCH NA EMISJĘ ZABURZEŃ ELEKTROMAGNETYCZNYCH PROMIENIOWANYCH NAPĘDU PRZEKSZTAŁTNIKOWEGO

Abstract

Screening attenuation as a parameter of screened cables used in converter systems is one of the indicators of screen efficiency. Catalogue data rarely considers that parameter, especially with the division on frequency bandwidths. Screening efficiency may be deduced by analysis of the cable's construction and type, but based on this, it may only be roughly estimated. The results of screening attenuation tests in a wide frequency bandwidth for chosen cable types are presented in the article. The methods of cable parameters testing based on standard PN-EN 50289-1-6:2009: Communication cables – Specifications for test methods. Part 1–6: Electrical test methods – Electromagnetic performance, were used. Afterwards, the emission of radiated electromagnetic disturbances of the converter drive was measured. The converter was using chosen cable types, for which screening attenuation was determined. Comparisons of the obtained results were presented and the influence of the screen type and cable parameters on the emission of radiated electromagnetic disturbances was analyzed. The obtained measurement results and presented analysis in the field of electromagnetic compatibility may be useful for designers of converter drive systems.

Keywords: cables attenuation, radiated electromagnetic disturbances, converter drive, electromagnetic compatibility

Streszczenie

Tłumienność ekranowania jako parametr kabli ekranowanych stosowanych w układach przekształtnikowych jest jednym z wyznaczników skuteczności działania ekranu. Dane katalogowe rzadko uwzględniają ten parametr kabli szczególnie z podziałem na pasma częstotliwości. O skuteczności ekranowania można wnioskować analizując budowę i rodzaj zastosowanego ekranu kabla lecz na tej podstawie można ją określić jedynie szacunkowo. W artykule przedstawiono wyniki badań tłumienności ekranowania w szerokim paśmie częstotliwości dla wybranych rodzajów kabli ekranowanych. Zastosowano metody badań parametrów kabli na podstawie normy PN-EN 50289-1-6:2009: Kable telekomunikacyjne – Metody badań – Część 1–6: Metody badań właściwości elektrycznych – Właściwości elektromagnetyczne. Następnie zmierzono emisję zaburzeń elektromagnetycznych promieniowanych falownikowego napędu przekształtnikowego wykorzystującego wybrane wcześniej rodzaje kabli dla których wyznaczone były tłumienności ekranowania. Zaprezentowano zestawione porównania uzyskanych wyników i przeanalizowano wpływ rodzaju ekranu i parametrów kabli na emisję zaburzeń elektromagnetycznych promieniowanych. Uzyskane wyniki pomiarów i przedstawione analizy z zakresu kompatybilności elektromagnetycznej mogą być przydatne dla projektantów przekształtnikowych układów napędowych.

Słowa kluczowe: tłumienność ekranowania kabli, zaburzenia elektromagnetyczne promieniowane, napęd przekształtnikowy, kompatybilność elektromagnetyczna

* Ph.D. Eng. Wojciech Czuchra, Department of Traction and Traffic Control, Faculty of Electrical and Computer Engineering, Cracow University of Technology.

1. Introduction

Electromagnetic compatibility of converter drive systems includes, among others, issues of radiated electromagnetic disturbance emission. Standard PN-EN 61800-3 defines the scope of standard measurements of that emission in the bandwidth from 30 MHz to 1 GHz [1]. A high operating frequency together with high signals' steepness at output of converters used in drive systems may be a reason of the increased levels of radiated electromagnetic disturbances generated by the system. The generated disturbances, which depend on system parameters and the control method, occur in a frequency bandwidth considered in standard [1] for typical power drive systems. In some systems, there are several converter drive systems differing in parameters and purpose. Electrical traction vehicles may be an example, where the considered systems operate as main drives or auxiliary drives. The emission of radiated disturbances for those systems is investigated in a much wider frequency bandwidth – from 9 kHz to 1 GHz [2, 3]. Application of screened cables with low attenuation properties may cause a necessity to reduce emission by additional filtering methods with application of individually designed RFI filters [4].

At the design and construction stage, there is a possibility for proper selection of converter cables with respect to their attenuation parameters. Screening attenuation parameter is usually provided by telecommunication cables manufacturers. In the case of cables used in converter drive systems, catalogue data rarely provides that parameter. Manufacturers of screened cables used for motor control in converter drives provide data about the screen efficiency in a very limited range. The only reference to the screen effectiveness evaluation is the type of screen and a description of its performance. By taking into consideration the way of screen production, its effectiveness may be only roughly determined. The need of conducting individual and comparative tests of various types of screened converter cables appears, which will allow to evaluate their electromagnetic attributes (screening).

The effectiveness of a cable screen can be determined by conducting suitable measurements. Screen effectiveness can be determined by measurements of transfer impedance or screening attenuation [5, 6]. Numerous publications mainly present the results of transfer impedance measurements of screened cables. Analyses of cables' screening efficiency are most often conducted based on standard methods, but alternative, simplified or modified methods are also proposed [7]. Primary tests regard electromagnetic attributes of screened cables or various cable connections [7]. Theoretical analysis and simulation methods in that scope are proposed as well [5, 6]. The standard PN-EN 50289-1-6: Communication cables – Specifications for test methods. Part 1–6: Electrical test methods – Electromagnetic performance [8] is the basic document, which describes the methods of cable testing. The article presents test results of converter cables' screening attenuation in a wide frequency range of 1 MHz to 1 GHz with the use of the triaxial method. A comparison of the obtained results was conducted for chosen screened cable types with division into frequency subscopes. The frequency range, for which screening attenuation measurements were perfromed, is a typical band for determining that value. The determination of the cables' screening properties for lower frequency ranges about several dozen kHz is an important issue, but it requires the use of measuring methods and determination of another parameter e.g. transfer impedance Z_T.

2. Tested system and research methodology

2.1. Determination of cables screening attenuation

In the triaxial method, a measuring set for screening attenuation consists of three coaxial elements [8]. The tested circuit consists of an outer and an inner circuit, where the inner circuit is the tested cable, while the outer one consists of a screen and coaxial pipe (Fig. 1).

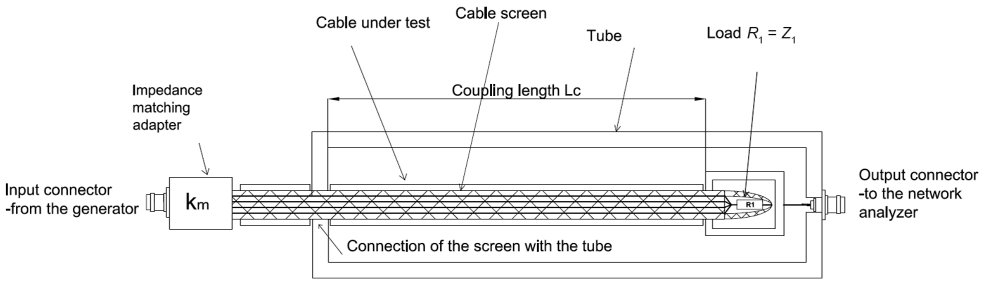

Fig. 1. The arrangement for determining the screening attenuation of screened cables

An aluminum pipe with an inner diameter of 50 mm and length of 2.2 m acts as the outer conductor of the outer circuit and it is connected to the screen at the side of the signal input. The inner diameter of the pipe in relations to cable screen's diameter is matched to ensure characteristic impedance of the outer circuit equal or higher than the receiver input resistance. The pipe must be long enough to wave overlapping in narrow frequency ranges. One end of the cable is loaded with well-screened resistor R_1, of which value equals to the characteristic impedance of coaxial system Z_1. The method of determining the unknown characteristic impedance Z_1 is precisely described in standard PN-EN 50289-1-6. There is a joint on the other end of the circuit, which enables connection with a generator.

Screening attenuation is a ratio of power inserted into a cable (P_{feed}) and the maximal peak radiated power ($P_{rad,\max}$) [8]:

$$a_s = 10 \cdot \log_{10} \left| \frac{P_{feed}}{P_{rad,\max}} \right| \tag{1}$$

Two types of screened cables were chosen for testing: LiYCY 4 × 2.5 mm^2 (single screen) and 2YSLCY 4 × 2.5 mm^2 (double screen), destined for converter systems. The first one contains a screen made of tinned copper strings with a coverage density of 80%, while the second one contains a screen made of aluminum foil and a screen made of tinned copper wire braiding with a coverage density of 80%. The tested screened cables are considered as a quasi-coaxial circuit and all conductors were connected together at both ends. Double screens also are connected together on both ends along the whole circumference. The tested cable sample was connected to a generator, outer circuit (pipe) and spectrum analyzer. The measurement of the voltage ratio at the output of the outer circuit and at the input of the tested cable was conducted with automatic frequency tuning, in a whole measured range. Spectrum analyzer Rohde&Schwarz type FSL3 with an operating frequency range from 9 kHz to 3 GHz, equipped with a generator with a bandwidth of 1 MHz–1 GHz, was used for carrying out the measurements.

To determine the real value of screening attenuation, the losses introduced by conforming system and connection cords must be taken into account. Connection cord attenuation was included in the calibration process. Screening attenuation of the cable a_s in [dB] at standardized environment impedance was calculated from formula (2):

$$a_s = 20 \cdot \log_{10} \left| \frac{U_1}{U_2} \right|_{\min} + 10 \cdot \log_{10} \left(\frac{2 \cdot Z_s}{Z_1} \right) - a_Z \tag{2}$$

where:

- a_z – conforming system attenuation in [dB],
- Z_1 – characteristic impedance of tested cable in [Ω],
- Z_S – standardized environment impedance in [Ω] (equals 150 Ω),
- U_1 – voltage at generator’s output in [V],
- U_2 – voltage at receiver’s input in [V].

The view of the measuring stand equipped with a system used for testing the screening attenuation of converter cables is shown in Fig. 2. The measuring stand was verified by measurements of coaxial cable with a known value of screening attenuation.

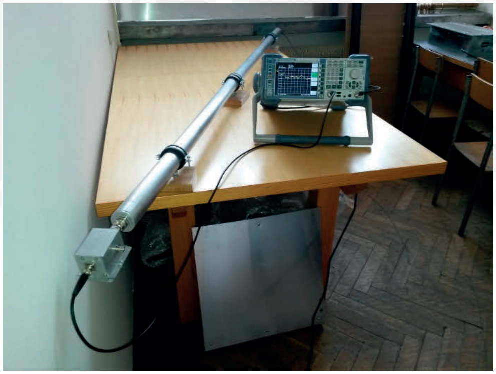

Fig. 2. The view of the measuring stand

2.2. Measurement of radiated electromagnetic disturbances emission

The conducted measurements of radiated electromagnetic disturbances emission had an engineering, comparative character. Measurements were conducted with equipment, which parameters meet standard requirements, for antenna as well as for spectrum analyzer.

During measurements the following measuring devices were used: spectrum analyzer Rohde&Schwarz type FSL3, TRILOG broadband antenna VULB 9168 with measured bandwidth from 30 MHz to 1 GHz. Measurement of the radiated emission carried out at 3 m from investigated converter drive and the measurement results were converted to a standard distance of 10 m by the subtraction of 10 dB. Two measurement rounds were carried out, with a single screened cable between converter and motor, and with a double screened one. The length of both cables was 4 m. The converter was operating with a carrier frequency of 3 kHz, an output frequency of 50 Hz and a phase supply current of 4 A. Despite the fact that the measurement ground did not fulfil standard requirements, the measurement results may be useful at estimating the influence of screened cable types on the emission of radiated disturbances of converter drives. The view of the measuring stand of the tested converter drive system is shown in Fig. 3.

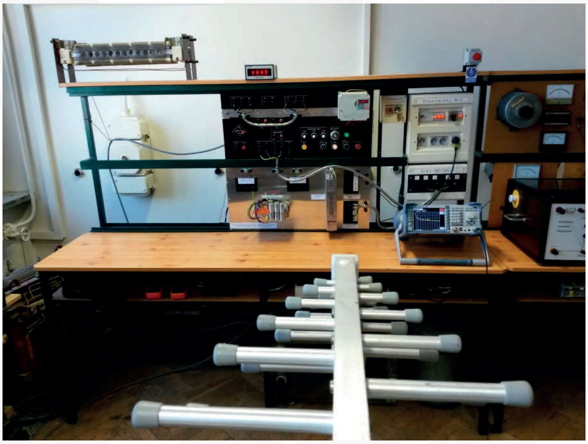

Fig. 3. The view of the measuring stand of the tested converter drive system

3. Results of cables' screening attenuation tests

The measurement of screening attenuation for two types of cable was conducted in frequency range from 1 MHz to 1 GHz with division of given range into subranges: 1–100 MHz, 100–500 MHz, 500 MHz–1 GHz. Owing to the fact, we can gather information about screening attenuation in a particular frequency bandwidth and more precise similarity of the tested parameter than during measurement for the whole range.

The above plots present a comparison of the screening attenuation measurement results for a single screened cable and a double screened cable. Through an analysis of particular bandwidths, the obtained results show that, in all frequency bandwidths, the double screened cable has a higher level of screening attenuation. An evident difference of the tested parameter can be noticed for the compared cables. Both cables reach maximal attenuation value in the frequency range from 500 MHz to 1 GHz (Fig. 6). Minimal attenuation value for both tested cables occurs in the frequency range from 100 MHz to 500 MHz (Fig. 5). Taking into consideration the whole frequency range from 1 MHz to 1 GHz, the minimal value from all subranges (obtained for bandwidth 100 MHz to 500 MHz) was assumed as resultant screening attenuation for both cables. Screening attenuation for the single screened cable amounts to 30 dB and 40.5 dB for the double screened one. It needs to be mentioned that, besides applying a double screen to cable, other parameters, e.g. screen thickness, coverage density and conductance of screen's material, have a significant impact on screening effectiveness.

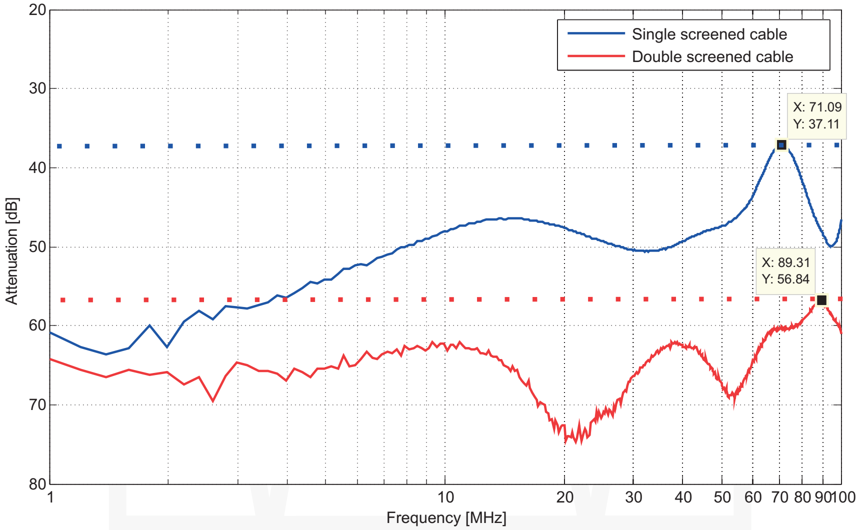

Fig. 4. Screening attenuation in frequency range 1–100 MHz

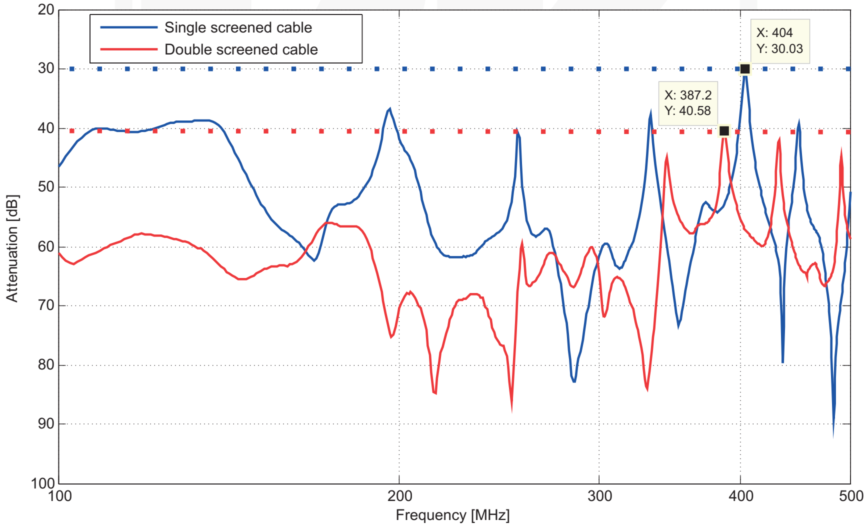

Fig. 5. Screening attenuation in frequency range 100–500 MHz

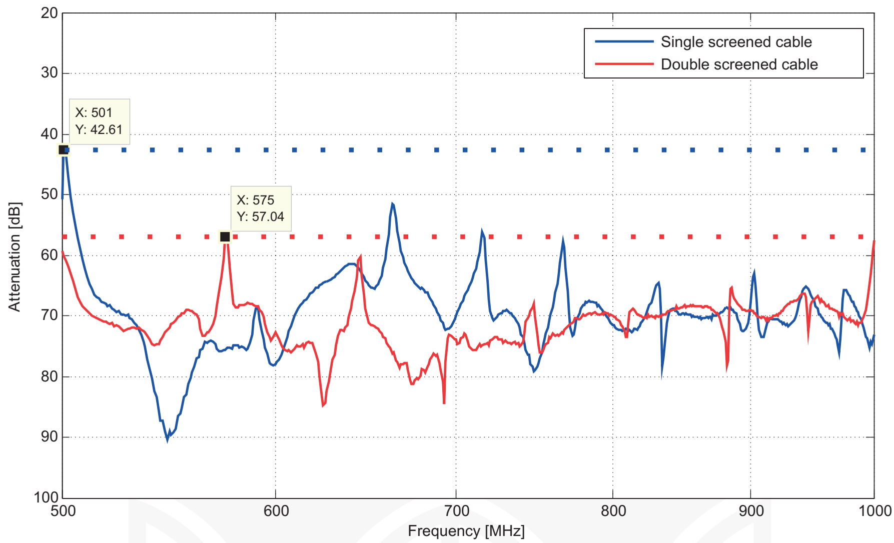

Fig. 6. Screening attenuation in frequency range 500–1000 MHz

4. Results of radiated electromagnetic disturbances tests

Laboratory tests of radiated electromagnetic disturbances for a standard frequency bandwidth from 30 MHz to 1 GHz were carried out due to the significant contribution of the investigated system in the disturbance emission in that frequency bandwidth [1]. The frequency subrange was chosen for analysis after considering the whole bandwidth. In the chosen range, the radiated disturbances definitely exceeded background signals (investigated drive switched off). The analyzed emission levels concern the standard subrange from 30 MHz to 80 MHz.

The results obtained for that bandwidth show noticeable difference in the emission of radiated electromagnetic disturbances. Higher levels of disturbance emission for the analyzed frequency bandwidth occur for the converter drive system working with a single screened cable. It shows the influence of the cable screen's parameters on the radiated emission. Investigation of the converter system with double screened cable showed disturbance emission decrease of maximally 14 dB (peak detector) and 9 dB (quasi-peak detector) for the frequency range 61 MHz to 77 MHz (Fig. 7 and 8). Limit quasi-peak values for measuring distance of 10 m according to standard PN-EN 61800-3 have been marked on standard bandwidth disturbance charts with green. The measured emission levels of radiated disturbances for the quasi-peak detector exceeded the limit values, especially for PDS (power drive system) category C1 (Limit 1). It speaks in favour of using double screened cables, especially in a situation, when radiated emission of the tested system may be reduced only with outer methods. It will allow thereafter to fulfil the requirements of the system's electromagnetic compatibility.

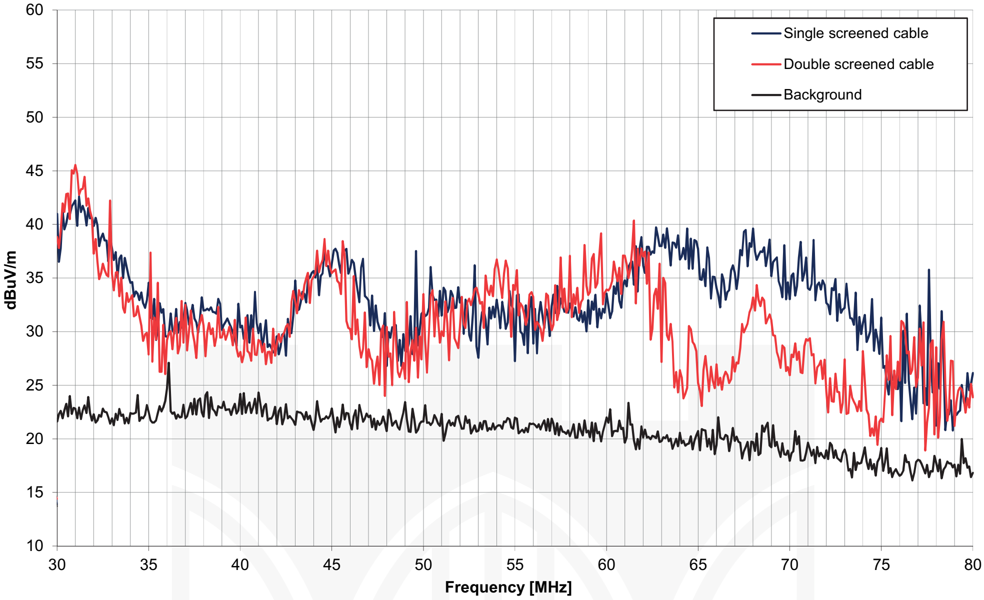

Fig. 7. Comparison of radiated electromagnetic disturbances for single and double screened cable (peak detector)

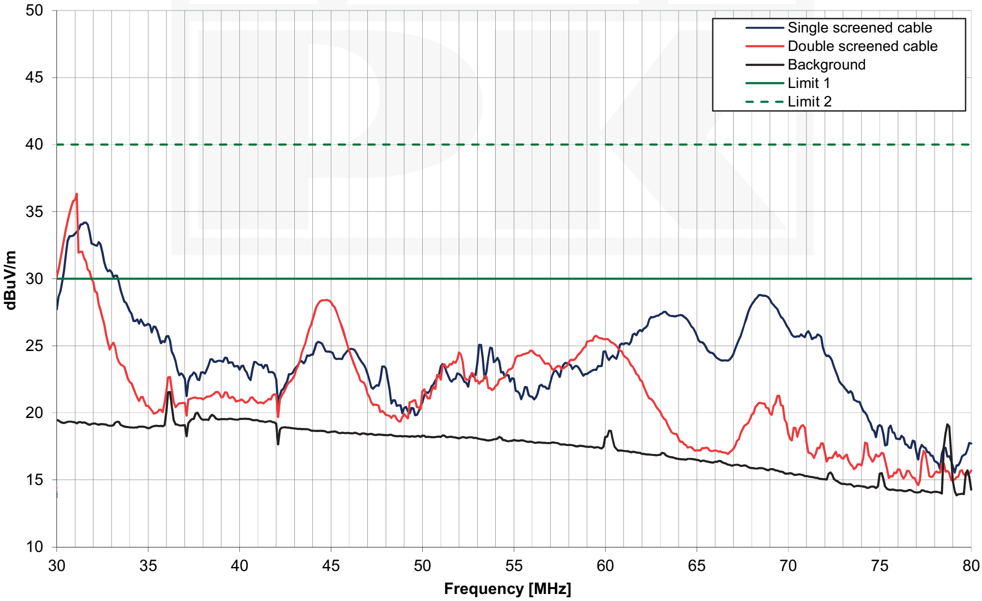

Fig. 8. Comparison of radiated electromagnetic disturbances for single and double screened cable (quasi-peak detector, Limit 1 – category C1, Limit 2 – category C2 to PN-EN 61800-3)

5. Summary

The conducted research on converter cables' screening attenuation and emission of radiated electromagnetic disturbances of laboratory converter drive may be a basis for evaluating the influence of screened cables' parameters on system's electromagnetic compatibility. The article presents the methodology and exemplary results for determining one of the parameters defining the electromagnetic properties of cables applied in converter drive systems. Screening attenuation of cables was determined and analyzed. The stand was made according to measuring method description and advices included in the standard. The stand was also verified through measurements. The obtained screening attenuation results for two cable types with a different screen construction allowed us to determine the level of this parameter for converter cables. The division of the conducted tests into subranges allows us to indicate frequency bandwidths where screening effectiveness is the highest and where it is the lowest.

The conducted measurements of radiated electromagnetic disturbances' emission had an engineering and comparative character. Despite the fact that the obtained differences in the emission levels were not significant, they confirmed a positive influence of double screened cable's higher attenuation on the radiated emission of the tested system. It should be noted that laboratory measurements were carried out for relatively short cables (4 m). The influence of the screened cable's attenuation may be by far more evident for considerably longer cables used in real systems.

When comparing the obtained results, we can notice a significant advantage of screening attenuation for cables with double screen in all the frequency bandwidths. On the basis of the conducted measurement and analysis, we can confirm the correctness of applying double screened cables in converter systems. It will result in the limitation of the emitted electromagnetic disturbances and provide an electromagnetic compatibility of a system.

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