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# A study on radiated interference emitted by power tool appliances within 30 MHz to 1 GHz

***Abstract.*** *The paper presents the results of measurements of electromagnetic disturbances of radiated power tools in the frequency range 30 MHz – 1 GHz. Experimental studies were carried out in a GTEM cell. The results obtained were compared with the directive defining the requirements for common devices, electric tools and other similar equipment. The maximum quasi-peak value measured was 65.41 dBμV/m, which exceeds the normative values by 10dB. Using statistical analysis, the following variables were evaluated in the context of characterisation of particular types of devices.*

***Streszczenie.*** *W pracy zaprezentowano wyniki pomiarów emisji elektromagnetycznych zaburzeń promieniowanych elektronarzędzi w zakresie częstotliwości 30 MHz – 1 GHz. Badania eksperymentalne przeprowadzono w komorze GTEM. Uzyskane wyniki porównano z dyrektywą określają wymagania dotyczące przyrządów powszechnego użytku, narzędzi elektrycznych i innych podobnych urządzeń. Maksymalna zmierzona wartość quasi szczytowa wynosi 65,41 dBμV/m, co przekracza wartości normatywne o 10dB. Posługując się analizą statystyczną dokonano wartościowania występujących zmiennych w kontekście scharakteryzowania poszczególnych typów urządzeń.(**Badanie zakłóceń wytwarzanych przez elektronarzędiza zakresie częstotliwości 30MHz do 1 GHz)***

**Keywords:** Gigahertz Transverse Electromagnetic cell (GTEM), electromagnetic field (EMF), electromagnetic compatibility (EMC), radiated EMI, power tools.
**Słowa kluczowe**: komora GTEM, pole elektromagnetyczne, kompatybilność elektromagnetyczna, zaburzenia promieniowane, elektronarzędzia.

## Introduction

When electrical equipment is in operation, it intentionally or unintentionally introduces transmission signals or electromagnetic disturbances into the environment in a measurable manner. Its influence can be analyzed in relation to exposure to humans and the environment [2, 7, 11] or studied in the context of electromagnetic compatibility [3, 4, 5, 6, 8]. Electromagnetic compatibility (EMC) covers two aspects of a system-object's operation: emissivity and immunity. Emission efficiency refers to the level of electromagnetic disturbances generated by a given system (object), which may enter the environment. Immunity defines the susceptibility of the system-object in question to disturbances occurring in the environment.

Electrical and electronic devices should be designed and manufactured in such a way as to be resistant to a certain level of interference in normal electromagnetic environment. Electromagnetic disturbances are divided into radiated EMI and conducted EMI. The permissible levels of emitted disturbances radiated by power tools are strictly defined in the standards for a given type of device (PN-EN 55014) [9, 13]. The PN-EN 55014-1 standard applies to general-purpose devices, electrical tools and similar devices (power tools). It specifies the permissible levels of electromagnetic disturbances and specifies the measurement methods used for quantitative determinations [7, 10, 13].

Disturbance levels are determined by specifying the value of electromagnetic field strength in the vicinity of an object or the power radiated by a given object. One of the directives which should be fulfilled by every electrical or electronic device when it is placed on the market is EMC 2014/30/EU [1]. Conformity assessment of a product with the directive is an action for the certification body, which demonstrates that the manufactured devices comply with the essential requirements for EMC devices in the European Union. According to the 2014/30/EU directive, the manufacturer is responsible for carrying out the EMC assessment of devices, including electromagnetic emission [4, 5]. To confirm that the essential requirements of the directive and harmonized standards are met, the equipment is marked with the CE sign [1, 5, 6, 11].

## Methods and Materials

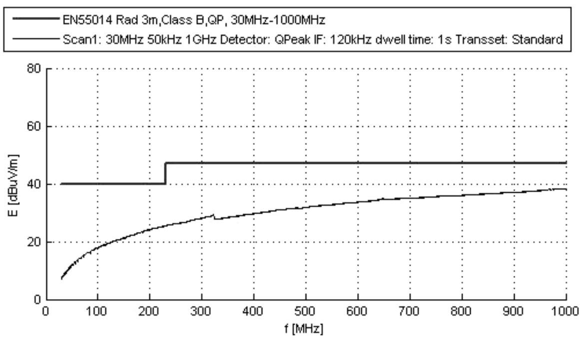
Investigations of the emission of radiated disturbances were performed on a measuring stand equipped in a Teseq GTEM 1000 cell (Fig. 1) with a Gauss Instruments TDEMI 1G measuring receiver (Fig. 2) [14, 15]. The testing methodology is described in IEC 61000-4-20:2010 [12]. According to norm CISPR 22, the standard environment for radiated emission tests between 0,03 and 1 GHz is the Open Area Test Site (OATS) with 10 m separation between the receiving antenna and the equipment under test (EUT). A 3 m separation is also allowed. In most cases, the results from alternative test methods have to be correlated with the OATS.

The GTEM cell is a TEM waveguide with the upper frequency limit extended to the GHz range. The setup for emission measurements in a GTEM cell is simple. The EUT is placed inside the GTEM and its radiation is measured with a receiver (a spectrum analyser). The receiver can be software-controlled, and some software that includes the GTEM to OATS correlation is commercially available. The “three orientation method” is the one used in IEC 61000-4-20. Detailed methodology of measurements using the cell has been described e.g. in article [8].

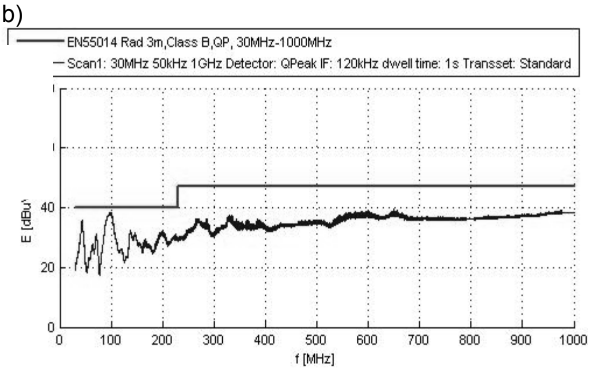

Fig.1. A TESEQ GTEM 1000 cell for emission and immunity testing of electromagnetic disturbances

The tests were carried out in accordance with the guidelines contained in the PN-EN55014-1 standard, in the measurement range covering the band from 30 MHz to 1 GHz, using a QP detector and 120 kHz resolution bandwidth [3, 13]. The following power tools were selected for the analysis: 1) impact drill, 2) impact wrench, 3) angle grinder, 4) chiseller, 5) screwdriver. The tests were performed with the use of a cell and a waveguide with a transverse electromagnetic wave TEM. Domestic appliances are Class B. Devices in this class are subject to stricter regulations than those in class A (commercial use). The difference between the levels of the limits of tests performed at a distance of 3 m and 10 m is 10 dB for the tested device. The article specifies the type of device without indicating the type and the name of the manufacturer. All devices are driven by commutator motors. They differ in power and speed control method. During the measurements, all power tools operated in idle mode at a constant speed. All receivers tested were CE marked.
The diagrams below show the results of tests of selected power tools made in the GTEM cell. Fig. 2a shows the results of tests carried out in the GTEM cell without the object being tested (cell background).

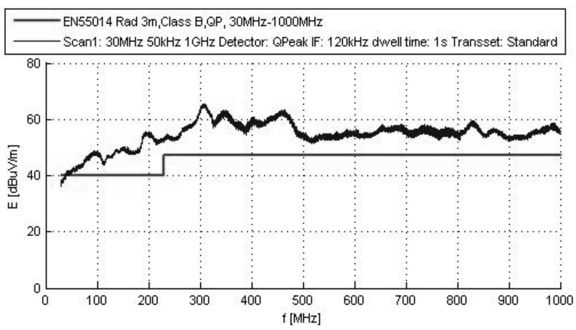
a)



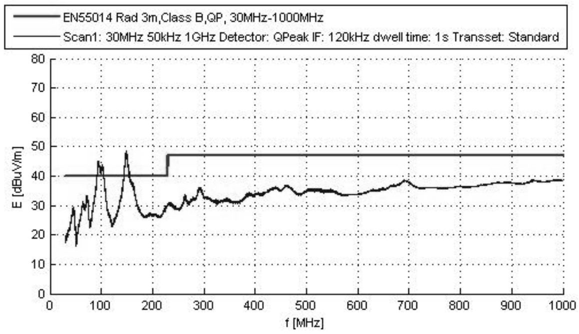

b)




c)




d)

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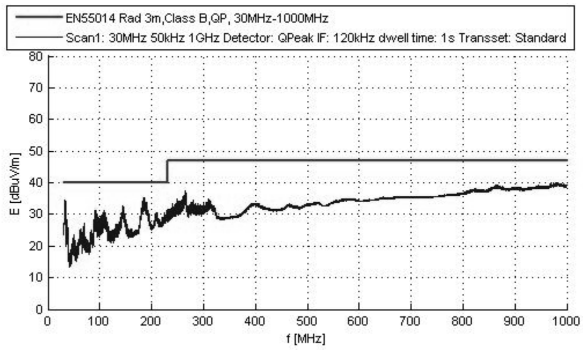


f)

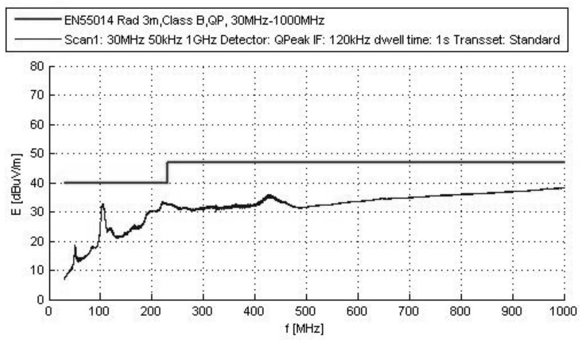


Fig. 2. Measurement of radiated emission with regard to the standards (PN-EN55014): a) background, b) impact drill, c) impact wrench, d) angle grinder, e) chiseller, f) screw driver.

The characteristics obtained by measurement show that the impact wrench exceeded the acceptable levels of disturbances of radiated emission in the whole frequency spectrum. The exceedances in the frequency range of 80-150 MHz were also recorded for an angle grinder.

**Statistical analysis**

The data obtained in the course of radiated emission measurements were registered with the Gauss Instruments TDEMI 1G and analysed by mean of the Statistica 13.3 software. A total of 24 636 measurements for each variable was qualified for the statistical analysis. The values of the analysed variables are defined by mean, median, standard deviation and range of variability. The researchers assumed a 5% error of inference and a level of significance of $p<0.05$. The characteristics of radiated interferences for selected groups of power tools are presented in Table 1, with the average, median, range of variation and standard deviation.

Table 1. Characteristics of radiated emissions of power tools

| Variable | Mean | Min | Max | SD | Median | Lower quartile | Upper quartile |
|---|---|---|---|---|---|---|---|
| *background* | 30,234 | 7,034 | 38,306 | 6,825 | 32,177 | 26,965 | 35,648 |
| Drill | 34,088 | 17,422 | 39,417 | 3,986 | 35,631 | 32,881 | 36,826 |
| Impact wrench | 54,540 | 36,355 | 65,414 | 4,739 | 54,975 | 53,407 | 57,015 |
| Grinder | 34,091 | 16,336 | 48,405 | 4,203 | 35,085 | 31,892 | 36,739 |
| Mortiser | 32,537 | 13,369 | 39,908 | 4,885 | 33,293 | 30,100 | 35,821 |
| Screwdriver | 30,324 | 7,992 | 38,326 | 6,749 | 32,245 | 27,030 | 35,703 |

The average emission value for the analyzed devices ranges from 30.32 dBµV/m to 54.540 dBµV/m. The variability of the tested feature is very high, ranging from 7.99 dBµV/m to 65.41 dBµV/m.

It can be noted that the maximum values are comparable for three power tools (drill, mortising, screwdriver) and are comparable to the background values. It can be observed that values exceeding the radiation emission limit occur in the case of both the impact wrench and the grinder.

In order to verify this hypothesis, the differences between the averages for power tools were examined. Fig. 3 presents a frame-moustache graph with marked averages and standard deviation.

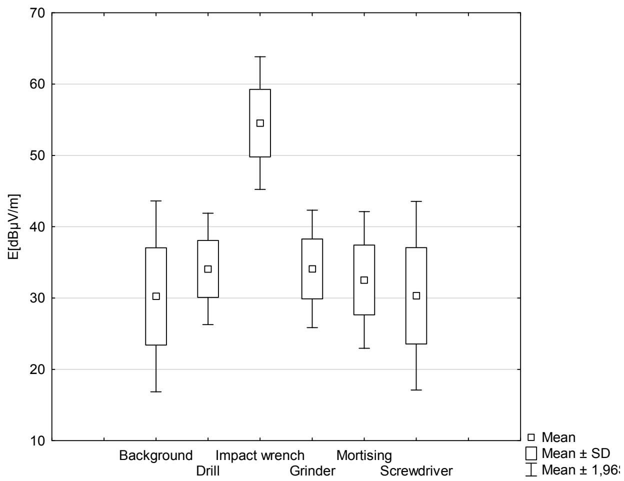


Fig.3. Box plots of the measurement of power tool radiation emission mean / standard deviation value

From Fig. 3 it can be observed that there are differences in average radiated emission between the background and power tools such as: drill, impact wrench, grinder or mortiser.

In order to determine whether there are statistically significant differences between the radiation emission values for particular types of power tools and the background measurement, the Student's t-test (Table 2) was performed.

Table 2. Test results for individual comparisons

| Test results for individual comparisons | | Statistical significance |
|---|---|---|
| Background vs. Drill | p=0,000 | relevant |
| Background vs. Impact wrench | p=0,000 | relevant |
| Background vs. Grinder | p=0,000 | relevant |
| Background vs. Mortising | p=0,000 | relevant |
| Background vs. Screwdriver | p=0,319 | irrelevant |

Comparing the levels of radiated emission at different types of tools, statistically significant differences were found for drill, impact wrench, grinder and mortiser. Statistically insignificant differences were observed for screwdriver.

## Conclusion

The article is a continuation of a research series devoted to emission measurements of popular electrical devices, admitted to market trading and exploitation. The measurements were carried out with the use of a GTEM1000 cell. It was assumed that the emission level recorded inside the cell should reach at most the value of min. 6 dB lower than the permissible values specified in the standard. Conducted tests showed that the tested power tools mostly meet the requirements related to electromagnetic compatibility in terms of radiated emission. The levels contained in the indicated standard were not met for the impact wrench power tool in the whole frequency spectrum. The maximum measured quasi-peak value of the instrument is 65.41 dBµV/m and the exceedance level is 10 dB. Exceeding 9 dB in the 150 MHz frequency range has been observed for an angle grinder. These are significant differences that deviate from the permissible normative values.

The analysis shows that the manufacturers of power tools mostly take care to maintain the allowed emission levels. These tools are often used for a long time, and both the user and the existing infrastructure of electrical facilities in the local environment remain in long-term exposure. If products do not comply with the acceptable levels of standards, the operator may be adversely affected and the radiated electromagnetic disturbance may be propagated. It can be assumed that the tested equipment met the acceptable requirements at the time of market entry. Each device tested was an operating tool (not a new one). Emission levels of radiated disturbances vary with wear and tear, and is a common case for tools with commutator engines. Existing disturbances at an elevated level can affect the life of the equipment and most often affect the quality of the mains power supply.

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REFERENCES

[1] European Commission, EMC Directive 2014/30/EU.
[2] Gas P., Kurgan E., Cooling effects inside water-cooled inductors for Magnetic Fluid Hyperthermia, Progress in Applied Electrical Engineering, IEEE Xplore, 2017, art. no. 8008997, pp. 1–4, DOI: 10.1109/PAEE.2017.8008997
[3] Hegarty T., “The engineer’s guide to EMI in DC/DC converters (part 4): *radiated emissions,” How2Power Today,* April 2018 issue.
[4] Han-Nien Lin ; Tai-jung Cheng ; Chih-Min Liao, Radiated EMI prediction and mechanism modeling from measured noise of microcontroller, *2010 Asia-Pacific International Symposium on Electromagnetic Compatibility, IEEE Xplore*: 03 June 2010, DOI: 10.1109/APEMC.2010.5475791
[5] Mazurek P., Selected aspects of electrical equipment operation with respect to power quality and EMC, *Przegląd Elektrotechniczny.- 2017,* vol. 93, nr 1, s. 21-24
[6] Mazurek ., Wpływ przepływu gazu roboczego na zaburzenia przewodzone w torze zapłonu trójfazowego reaktora plazmowego typu GlidArc, *Przegląd Elektrotechniczny.-* 2019, vol. 95, nr 3, s. 37-40
[7] Mazurek A. , Michalowska J , Koziel J. , Gad R. , Wdowiak A., The intensity of electromagnetic fields in the range of GSM 900, GSM 1800 DECT, UMTS, WLAN in built-up areas, *Przegląd Elektrotechniczny*, ISSN 0033-2097, R. 94 NR 12/2018, pp. 102-1.05, doi:10.15199/48.2018.12.45
[8] Michałowska J.,Tofil A., Jóźwik, Analysis of the radiated interferences emission of small household appliances, *2019 Applications of Electromagnetics in Modern Engineering and*

*Medicine (PTZE)*, *IEEE Xplore*: DOI: 10.23919/PTZE.2019.8781730
[9] Michalowska J. , Józwik J., Prediction of the parameters of magnetic field of CNC machine tools, *Przegląd Elektrotechniczny* , ISSN 0033-2097, R. 95 NR 1/2019 pp. 134-136 doi:10.15199/48.2019.01.34,
[10] Michałowska J.,Tofil A., Józwik J.,Pytka J, Budzyński P., Korzeniewska E., Measurement of high-frequency electromagnetic fields in CNC machine tools area, *The 4th IEEE International Symposium on Wireless Systems within the International Conferences on Intelligent Data Acquisition and Advanced Computing Systems, 20-21 September, 2018, Lviv, Ukraine IEEE Xplore:* 08 November 2018, DOI: 10.1109/IDAACS-SWS.2018.8525605
[11] Przesmycki .,Nowosielski L., Bugaj M, Piwowarczyk K., Analiza emisji promieniowanej współczesnych urządzeń informatycznych, *Przegląd Elektrotechniczny*, ISSN 0033-2097, R. 88 NR 2/2012
[12] IEC 61000-4-20:2010 Electromagnetic compatibility (EMC) - Part 4-20: Testing and measurement techniques - Emission and immunity testing in transverse electromagnetic (TEM) waveguides
[13] PN-EN 55014-1:2012 Kompatybilność elektromagnetyczna - Wymagania dotyczące przyrządów powszechnego użytku, narzędzi elektrycznych i podobnych urządzeń -- Część 1: Emisja
[14] www.teseq.com/products/GTEM-1000
[15] www.gauss-instruments.com