

Measurement of Electric Fields Emitted by Household Appliances

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Abstract: Each electric device emits electromagnetic (EM) energy. If the radiated energy exceeds the safety level, it may affect the performance of other electrical devices. This influence of the device whose radiation is observed manifests in a way that degrades or even disables the operation of other devices. It is important to note that the radiated energy can be harmful to the health of living organisms near the radiating devices. In order to have such values of electric field strength controlled, the field amounts must be standardized. The radiation of household appliances is standardized by HRN EN 55014, which defines the limit values for different groups of devices. When measuring the EMI of a device, it is necessary to define the measurement requirements, identify the device, check the feasibility of the measurement, define the activity, and plan the measurement. Several types of household appliances have been reported in the paper, the application of the rules, regulations and instructions contained in the standard is presented. Measurements included the strength of the electric field of household appliances most commonly used in households: hair dryers, air styler, handheld blenders, hand mixers, cordless drill and hammer drill. The purpose of this paper is to determine the amount of electric field strengths that radiate frequently used home appliances and to check whether radiation is within the limits permitted by HRN EN 55014. The results of the measurement from the point of view of the prescribed boundary levels were analyzed at the end of the paper.

Keywords: EM radiation; Household Appliances; Standard; Electric Field Limits

1 Introduction

Each electric device radiates EM energy and in this way is interacting with other electrical devices. If the values of the radiated energy are high, signal degradation of the surrounding devices may be possible or functioning of the devices could be disabled. This is not the only manifestation of electrical devices radiation. For the same reason, the effects on the health of living organisms are also possible. From all of the above and preventive, the amount of energy emitted by such devices must be standardized [1].

Electromagnetic Interference (EMI) is an electromagnetic radiation from a device or system that interacts with other devices and systems in a normal (daily) operation. Radio-frequency Interference (RFI) is often referred to EMI in the texts as well.

Since each Device Under Test (DUT) is different, it is crucial to have good and quality EMI signal detection devices. Spectral Analyzer is a measuring device that measures the amplitude of the signal in the frequency domain within the defined frequency band and as such is one of the most commonly used EMI measurement devices.

The Croatian standard, which prescribes the limits of the permitted calculated strengths of the electric field of household appliances (and refers to the emission) is HRN EN 55014:1 [1]. If the immunity of a particular household appliance to radiation from the environment is observed, the standard for which measurements are made and the results are analyzed is HRN EN 55014: 2 [2].

The standard HRN EN 55014:1 is described below, a complete EM radiation measurement system has been analyzed - EM devices, antenna, cables, and home appliances whose radiation is important are used.

One of the most commonly used household appliances is a hair dryer, and this paper shows how significant contributions of the radiated EM energy are. This paper analyzes more hair dryers (different manufacturers and features), air styler, handheld blenders, hand mixer, cordless drill and hammer drill. The same chapter presents and analyze the measurement results achieved in a partially EM isolated room. Those results are compared with the permitted values of the electric field strengths specified in [1].

1.1 Croatian Standard HRN EN 55014:1 and Standards for Measurement EM Radiation of Household Appliances

The Croatian Standards Institute (at the proposal of the Technical Committee HZN / TO E500) has accepted the European standard EN 55014-1:2017 as the Croatian standard in the original English language, so the European standard EN 55014-1:2017 has the status of Croatian standard. The Croatian standard HRN EN 55014-1 refers to electromagnetic compatibility - requirements for household appliances, electrical tools and similar devices - Part 1: Emission [1]. The standard specifies (by the International Special Committee on Radio Interference CISPR 14-1: 2016) the requirements applicable to RF emissions in the frequency range of

9 kHz to 400 GHz of household appliances, electrical tools and similar devices. The International Standard CISPR 14-1 was prepared by the International Electrotechnical Commission (IEC). Also, IEC 61000-4-22:2010 defines Electromagnetic Compatibility (EMC): device emission and immunity measurement in Fully Anechoic Room (FAR) [3]. According to the above standard, Table 1 shows the limits of the permitted values of the radiated strengths electrical fields in the frequency range of 30 MHz to 1000 MHz.

Table 1

Permitted values of the electrical field intensity and the test methods in the 30 MHz – 1000 MHz frequency range (by the standard HRN EN 55014:1 [1])

Test method	Standard	Frequency, MHz	Permitted values, dB μ V/m	Comment
OATS or SAC	CISPR 16-2-3	30 to 230 230 to 1000	30 37	10 m distance measurement
FAR	CISPR 16-2-3	30 to 230 230 to 1000	42 to 35 42	3 m distance measurement
FAR	IEC 61000-4-22	30 to 230 230 to 1000	42 to 35 42	3 m distance measurement
TEM Waveguide	IEC 61000-4-22	30 to 230 230 to 1000	30 37	-

Where test methods are:

OATS: Open Area Test Site

SAC: Semi Anechoic Chamber

FAR: Fully Anechoic Room

TEM: Transferzal EM Waveguide

This paper describes the measurement of EM radiation of six different hair dryers (different characteristics and manufacturers), one air styler, two handheld blender, one hand mixer, one cordless drill and one hammer drill according to [1], in Open Area (OATS), but at a distance of 3 m (the explanation below).

2 Measurement Settings and Measurement Results

2.1 Defining of the Household Appliances

Selected household devices (DUT) that were tested - are six different hair dryers (Figures 1 - 6); one air styler (Figure 7), two handheld blenders (Figure 8 and 9), one hand mixer (Figure 10), one cordless drill (Figure 11) and one hammer drill (Figure 12) of the following manufacturers and power characteristics:

- DUT 1: hair dryer Remington ac 8000 (max 2200 W);
- DUT 2: hair dryer Grundig hd 6080 (max 2200 W);
- DUT 3: hair dryer Rowenta cv 1220 (max 1400 W);
- DUT 4: hair dryer Rowenta cv 5062 (max 2300 W);
- DUT 5: hair dryer Grundig hd 6760 (max 2000 W);
- DUT 6: hair dryer Sencor shd 108 vt (max 2000 W);
- DUT 7: air styler Remington as 8090 (max 700 W);
- DUT 8: handheld blender Clatronic sms 3190 (max 200 W);
- DUT 9: handheld blender Tefal dd 1000 (max 350 W);
- DUT 10: hand mixer Severin hm 3817 (max 250 W);
- DUT 11: cordless drill Einhell th-cd 12-2 li (max 1.3 W);
- DUT 12: hammer drill Bosch psb 500 re (max 500W).



Figure 1

Hair dryer Remington ac 8000



Figure 2

Hair dryer Grundig hd 6080



Figure 3

Hair dryer Rowenta cv 1220



Figure 4

Hair dryer Rowenta cv 5062



Figure 5

Hair dryer Grundig hd 6760



Figure 6

Hair dryer Sencor shd 108 vt



Figure 7

Air styler Remington as 8090



Figure 8

Handheld blender Clatronic sms 3190



Figure 9

Handheld blender Tefal dd 1000



Figure 10

Hand mixer Severin hm 3817



Figure 11

Cordless drill Einhell th-cd 12-2 li



Figure 12

Hammer drill Bosch psb 500 re

Most hair dryers work in three temperature modes (1 – cold, 2 – semi hot and 3 - hot) and two speed modes (except hair dryer Rowenta cv 1220 which has one temperature mode and two speed modes). handheld blender Clatronic sms 3190 works in one mode, cordless drill Einhell th-cd 12-2 li has two speed modes, handheld blender Tefal dd 1000 works in one mode, Remington as 8090 works in two temperature modes, hand hand mixer Severin hm 3817 can work in five speed modes and finally, hammer drill Bosch psb 500 re works in one mode.

All listed devices emit the EM field in their environment and could be able to affect operation others electrical devices.

2.2 Measurement Procedure and Plan for Measurement Measurement of Electric Fields Emitted by Household Appliances

The HRN EN 55014-1 standard prescribes the measurement settings as follows:

- The measurement should be performed in the range of frequencies between 30 MHz and 1000 MHz;
- Measurements should be carried out at a distance of 10 m;
- Setting up a device that measures DUT on nonconductive substrate 0.8 m from the ground (in a laboratory where there is an EM echo);
- To set RX antenna to measure the electrical field strength at a certain height from the ground;
- The RX antenna is connected to the device that measures electrical field strength;
- To set the selected mode of operation of the DUT (with the selection of maximum heat and speed).

2.3 Measurement and Measurement Results of EM Radiation of Household Appliances

Most of the settings and measurement parameters were met as stated and prescribed in standard, with the addition of measurements – the electric field strength without the DUT included and the included DUT was measured. These two values have been subtracted in order to achieve the value of electric field strength of the each DUT. Then, the radiation of all DUTs was measured in all possible combinations of modes - heat and speed (this is difference from the standard). The antenna distance and the DUT measured was 3 m.

The decision on the measurement at 3 m from the DUT was made because the measurers were limited by the space in which the measurement was performed and the equipment could not be set at 10 m distance. For this reason, the values in

Tables 2 – 5 are values of electrical fields obtained after computation for a distance of 3 m to 10 m. The conversion principle of dBμV/m at 3 m to dBμV/m at 10 m is based on the basic formula that links the strength of the electric field and the power of the transmitter antenna:

$$E = \frac{\sqrt{30 \cdot P \cdot G}}{r} \quad (2-1)$$

where:

P – is power of the transmitter antenna,

E – electrical field strength emitted by antenna,

r – measurement distance (3 m),

G – antenna gain.

The conversion procedure is as follows:

$$E, dB\mu V / m_{10m} = 20 \log \left(10^{\frac{E, dB\mu V / m_{3m}}{20}} \cdot \frac{3}{10} \right) \quad (2-2)$$

This approach to electrical field strength measurements is the result of many years of engineering practice in the area of measuring high frequency fields. Standard HRN EN 55014-1 prescribes the measurements of the activated DUT - a combination of maximum heat and speed mode. Therefore, measurements of all possible combinations of the modes of operation of the certain device is an additional decision and procedure of the accredited Laboratory for HF Measurements at the Faculty of Electrical Engineering, Computer Science and Information Technology Osijek, and provides a more detailed approach to the stated norms and measurements in general.

Instruments and devices used in radiated electrical field measurements DUT 1 - 12 (Figure 13) are:

- RX antenna: conical dipole PCD 8250;
- Rotator and tripod (1.5 m height) to which the antenna is mounted;
- Spectrum Analyzer (SA HMS-X Rhode Schwarz) connected to RX antenna;
- The coaxial cables used to connect the antenna and rotator, as well as rotator and spectrum analyzer are RG 178 and RG 400, respectively.

Figure 13 shows all the instruments, antenna, cables and DUT involved in measuring procedure.

Since measurement is performed in an EMI (Electromagnetic Interference) area, the signals from three groups of radio systems will appear in the defined range of 30 MHz to 1000 MHz (Figure 14) [4]:

- 88 MHz - 108 MHz → FM broadcasting;
- 470 - 821 MHz → TV Broadcasting and LTE;
- 880 - 915 and 925 - 960 MHz → GSM900 (GSM) and UMTS900,

and those amplitudes is desirable to eliminate as much as possible in order to obtain information on the DUT itself [5]. All measurement results are shown in Tables 2 - 5.

Measurement method used for HF fields measurements is ADD3D method. This method uses an omnidirectional broadband antenna – conical dipole PCD 8250 of

a frequency range of 80 MHz to 2500 MHz. Using this antenna – effective field strength can be determined by three orthogonal orientation (x, y and z) voltage measurements. Effective field strength is obtained by using the relation:

$$E_{eff} = \sqrt{E_x^2 + E_y^2 + E_z^2} = \sqrt{U_x^2 + U_y^2 + U_z^2} \cdot AF \quad (2-3)$$

Spectrum Analyzer (SA HMS-X Rhode Schwarz) measures the voltage V_{emi} and it is proportional to the permissible E of Table 1:

$$V_{emi}(dB\mu V) = E(dB\mu V/m) - AF(dB/m) + Gain(dB) - Loss(dB) \quad (2-4)$$

Assuming that the antenna gain equals the sum of antenna factor AF and losses in cables $Loss$, equation (2-4) can be written:

$$V_{emi}(dB\mu V) = E(dB\mu V/m) \quad (2-5)$$

and E (dB μ V/m) is the measured value in Tables 2 – 5 (2-5).

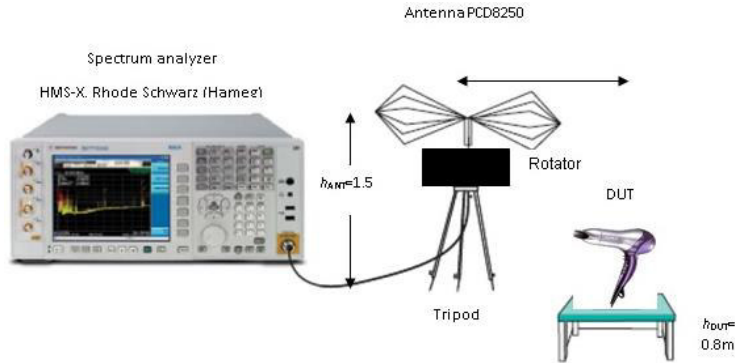


Figure 13

Measurement scheme of the household appliance radiation according to HRN EN 55014-1

After setting all the parameters of EM radiation measurement of DUT and done measurements, all results are processed and presented in Tables 2 - 5. The values of measured and calculated fields are compared with the permissible values in Table 1 and prescribed by the Croatian standard HRN EN 55014:1. The reference values used for comparison are in the first row of Table 1.

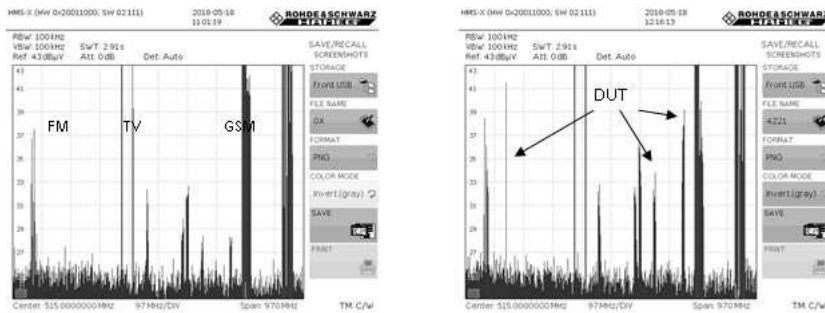


Figure 14

RF spectrum without and with activated DUT (measured at 3m distance from RX antenna)

Table 2
The measured electric field strength of the DUT (different types of hair dryer) at a distance of 3 m, and after the conversion to the value at a distance of 10 m

Mode DUT	Heat 1	Speed 1	Heat 1	Speed 2	Heat 2	Speed 1	Heat 2	Speed 2
	$E_{uk\ max,}$ $dB\mu V/$ $m <$ 230 MHz	$E_{uk\ max,}$ $dB\mu V/$ $m >$ 230 MHz	$E_{uk\ max,}$ $dB\mu V/$ $m <$ 230 MHz	$E_{uk\ max,}$ $dB\mu V/$ $m >$ 230 MHz	$E_{uk\ max,}$ $dB\mu V/$ $m <$ 230 MHz	$E_{uk\ max,}$ $dB\mu V/$ $m >$ 230 MHz	$E_{uk\ max,}$ $dB\mu V/$ $m <$ 230 MHz	$E_{uk\ max,}$ $dB\mu V/$ $m >$ 230 MHz
Remington AC 8000	-0.26	18.85	3.79	23.46	2.58	30.68	22.22	18.82
Grundig hd 6080	-1.25	28.66	5.34	11.54	-2.12	28.70	-0.72	26.99
Rowenta cv 1220	5.51	9.47	-0.43	13.04	No mode	No mode	No mode	No mode
Rowenta cv 5062	1.70	24.95	-1.77	9.94	-1.29	10.82	-1.02	4.24
Grundig hd 6760	4.14	23.46	3.52	18.44	0.36	16.71	0.26	18.65
Sencor shd 108vt	6.41	23.69	11.52	17.54	1.17	12.63	11.39	25.78

Table 2 - continued

Mode DUT	Heat 3	Speed 1	Heat 3	Speed 2
	$E_{uk \max}$, dB μ V/ m< 230 MHz	$E_{uk \max}$, dB μ V/ m> 230 MHz	$E_{uk \max}$, dB μ V/ m< 230 MHz	$E_{uk \max}$, dB μ V/ m> 230 MHz
Remington AC 8000	-0.58	9.23	-1.75	27.01
Grundig hd 6080	-1.74	29.13	8.42	19.09
Rowenta cv 1220	No mode	No mode	No mode	No mode
Rowenta cv 5062	-1.14	-1.14	-1.14	-1.14
Grundig hd 6760	-0.08	17.17	3.22	30.77
Sencor shd 108vt	1.02	17.86	7.43	24.88

Table 3

The measured electric field strength of the DUT (two handheld blenders, cordless drill and hammer drill) at a distance of 3 m, and after the conversion to the value at a distance of 10 m

Mode: On DUT	$E_{uk \max}$, dB μ V/m< 230 MHz	$E_{uk \max}$, dB μ V/m> 230 MHz
Clatronic sms 3190	3.02	28.27
Tefal HB100138	-0.38	31.44
Einhell th- cd 12-2 li	6.74	8.90
Bosch psb 500 re	0.13	23.37

Table 4

The measured electric field strength of the DUT (air styler) at a distance of 3 m, and after the conversion to the value at a distance of 10 m

Mode DUT	Cold		Heat 1		Heat 2	
	$E_{uk \max}$, dB μ V/ m< 230 MHz	$E_{uk \max}$, dB μ V/ m> 230 MHz	$E_{uk \max}$, dB μ V/ m< 230 MHz	$E_{uk \max}$, dB μ V/ m> 230 MHz	$E_{uk \max}$, dB μ V/ m< 230 MHz	$E_{uk \max}$, dB μ V/ m> 230 MHz
Remington AS 8090	4.67	2.77	3.34	23.95	3.25	30.52

Table 5

The measured electric field strength of the DUT (hand mixer) at a distance of 3 m, and after the conversion to the value at a distance of 10 m

Mode DUT	Speed 1		Speed 2		Speed 3		Speed 4	
	$E_{uk \max}$, dB μ V/ m< 230 MHz	$E_{uk \max}$, dB μ V/ m> 230 MHz	$E_{uk \max}$, dB μ V/ m< 230 MHz	$E_{uk \max}$, dB μ V/ m> 230 MHz	$E_{uk \max}$, dB μ V/ m< 230 MHz	$E_{uk \max}$, dB μ V/ m> 230 MHz	$E_{uk \max}$, dB μ V/ m< 230 MHz	$E_{uk \max}$, dB μ V/ m> 230 MHz
Severin hm 3817	1.04	33.72	2.59	23.71	0.47	11.88	0.86	3.71

Table 5 - continued

Mode DUT	Speed 5	
	$E_{uk \max}$, dB μ V/m <230 MHz	$E_{uk \max}$, dB μ V/m >230 MHz
Severin hm 3817	0.47	26.48

Conclusions

The testing of electromagnetic compatibility of each device (DUT) is necessary for the purpose of its safe operation in the environment where other devices are present. Testing refers to the measurement and verification of the calculated electrical field strength of the DUT, to make sure that the el. fields are in the prescribed permissible limits.

Regulatory bodies such as IEC and CISPR, and the norm HRN EN 55014-1 under their jurisdiction, prescribe the maximum values that can be emitted by household appliances.

This paper describes the procedure for measuring and processing the EM radiation results of several different hair dryers, air styler, handheld blenders, hand mixer, cordless drill and hammer drill. Thus, DUT emits a certain amount of EM energy in the spectrum of interest (30 MHz to 1000 MHz). The HRN EN 55014-1 standard prescribes the measurement method and permitted electric field values. Measurements have shown (Tables 2 to 5) a significant contribution of these type of devices in the range of 30 MHz to 1000 MHz (up to several dozen dB μ V/m).

The measured values of the electric field strength radiated by all DUTs ranges from:

- In the area below 230 MHz the minimum value is -2.12 dB μ V/m and the maximum value is 28.27 dB μ V/m,
- In the area above 230 MHz the minimum value is 2.77 dB μ V/m and the maximum value is 34.57 dB μ V/m.

After comparing all measured values with OATS condition (30 dB μ V/m up to 230 MHz and 37 dB μ V/m above 230 MHz), it can be concluded that none of the devices exceeds permitted values of the electric field strengths set by HRN EN 55014-1, but all measured DUTs contributes significantly to the total EM power spectrum. Devices are safe to use.

References

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