Erroneous Practices in Measuring Discontinuous Disturbances

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***Abstract*—CISPR has defined a standard regarding the radio-frequency disturbance level of appliances (CISPR 14-1). The scope of this standard is to worldwide fix disturbance limits and standardise methods of measurement, operating conditions, and interpretation of results. Today, there exist special discontinuous disturbance analysers ("click analysers") that perform both measurements and analysis. However, the analysis performed by some click analysers is not in accordance with the procedure defined in the CISPR 14-1 standard. This leads to appliances on the market being incorrectly declared CISPR 14-1 compliant. The intention of this article is to address and clarify possible misinterpretations of the CISPR 14-1 measuring procedure of discontinuous disturbances.**

Keywords*—CISPR 14-1, Clicks, Switching operation, Click analyser, Quartile method

I. Introduction

CISPR 14-1 standard regulates the conduction and radiation of radio-frequency disturbances from appliances. The scope of this standard is to fix disturbance limits and to standardise measurement methods in order to enable an adequate radio protection with economically sustainable approaches. This standard pays particular attention to discontinuous disturbances, commonly called "clicks". Clicks are broadband disturbances which are usually produced by switching operations. The maximum of their spectral characteristic is below 2 MHz and the disturbance they produce depends on the amplitude, the duration, the spacing and the repetition rate of clicks. For this reason, when performing the CISPR 14-1 compliance test of an appliance, clicks have to be assessed over the frequency range as well as over the time interval. Further, because the amplitude and the duration of a click are not constant, a statistical method (the upper quartile method) has to be applied to guarantee reproducibility of the test results.

The CISPR 14-1 compliant measuring procedure of discontinuous disturbance consists of two measuring runs. The first run is a preliminary investigation and serves to obtain parameters which are then used as reference during the actual test of the appliance (second run). The second run has to be carried out only at four frequencies (150 kHz, 500 kHz, 1.4 MHz and 30 MHz). This procedure differs from the one for measuring continuous disturbances, which has to be carried out over the whole frequency range. This is because clicks are supposed to be less disturbing than continuous disturbances. Hence, the CISPR 14-1 standard contains some relaxations when measuring discontinuous disturbances.

During the first run, depending on the type of appliance, either the number of switching operations has to be counted or the actual clicks have to be measured. In the first case, the clicks must not be measured. In the second case, CISPR 14-1 states that the clicks have to be measured only at 150 kHz and at 500 kHz. The parameters obtained during the first run at 500 kHz have then to be used as reference during the second run also at 1.4 MHz and 30 MHz.

Due to the stochasticity of clicks a minimum amount of clicks must be recorded before being able to evaluate the appliance's compliance with the CISPR 14-1 standard. The less disturbing the appliance (i.e. the fewer clicks it produces) the longer it takes to do the measurements. CISPR 14-1 has defined the observation time as a minimum of 40 registered clicks or a maximum of 120 minutes if fewer clicks are registered.

A frequent mistake when measuring discontinuous disturbances is related to the procedure during the reference (first) run. Often, measurements during the first run are performed at all four frequencies, instead of only at two (in the case of clicks) or none (in the case of switching operations). The consequence is that during the second run, "wrong" parameters are used as reference.[1] This means that some appliances which would have passed the CISPR 14-1 test fail the actual test instead, and vice versa. The ultimate result is that, today, there are appliances on the market that are erroneously declared CISPR 14-1 compliant.

Although the CISPR 14-1 standard is written clearly and no misinterpretations should be possible, the CISPR 14-1 compliant measurement of clicks still remains a rather complex procedure. For this reason, CISPR 14-1 has also released guidance notes (CISPR 14-1, Annex C). The intention of this article is to address and clarify current misinterpretations of the CISPR 14-1 standard. Thus, this article strictly refers to [1] if not otherwise mentioned. In the following, we refer to specific clauses either in the guidance notes (numbers preceded by C, e.g. Clause C.x) or in the standard containing the corresponding normative determinations (only numbers, e.g. Clause x). CISPR 14-1 standard also specifies some exceptions. However, these exceptions are not relevant to this article; we will omit these details in the following.

The remaining of the article is structured as follows: we first explain in detail the CISPR 14-1 compliant measuring procedure of discontinuous disturbances (Sect. II), then we discuss often-performed mistakes regarding this procedure and

[1] We define as "wrong" those parameters that would not result from a CISPR 14-1 compliant reference run.

its implications (Sect. III), and finally we close the article with some concluding remarks.

II. CISPR 14-1 Compliant Measuring Procedure of Discontinuous Disturbances

To measure the parameters of a discontinuous disturbance (amplitude, duration and spacing) a quasi-peak measuring receiver and an oscilloscope are needed. CISPR 14-1 recommends using a special discontinuous disturbance analyser (usually called click analyser or click meter) which incorporates both instruments (Clause C.2-C.3). As mentioned in the Introduction, the measuring procedure consists of two measuring runs. The first run is a preliminary investigation and only serves to obtain the click limit, L_q, and the maximum allowed number of clicks, in this article called n_{max}, registered during the observation time, T. The second run is the actual measurement, which evaluates whether the amplitude of every single click is above or below the click limit L_q and thus counts the number of clicks above the click limit. These measurements must be carried out at the four frequencies 150 kHz, 500 kHz, 1.4 MHz and 30 MHz. If for all four frequencies the number of clicks above the click limit is below or equal to n_{max} , the equipment under test has passed the test, otherwise it has failed it.

Depending on the type of appliance, CISPR 14-1 considers two different ways to make the preliminary assessment: (i) count the number of switching operations or (ii) count the number of clicks above the limit for continuous disturbance. In the following, we discuss in detail the two options for the preliminary assessment (first run) and the resulting parameters that are used as reference during the second run.

A. Counting switching operations

A switching operation is defined as one opening or closing of a switch or contact, *independently of whether clicks are actually observed or not* (Clause 3.4). Hence, in the case of switching operations, a simple switching operation counter has to be used; no click analysers are needed. Let us consider the example of a toaster: a complete cycle of a toaster, i.e. starting from when the lever is pushed down to start the heater until the lever flashes back up and stops the heater, consists of two switching operations, on and off. To count the number of switching operations no sophisticated devices are needed; a person could simply count the number of "on" and "off". From the number of switching operations n_2 registered during the minimum observation time T, i.e. time elapsed to produce 40 switching operations or a maximum of 120 minutes, the rate N is calculated as (Clauses 7.4.2.3 and C.4.1) $N = n_2 \cdot f/T$, where f is an appliance dependent factor given in CISPR 14-1, Annex A, Table A.2. The level offset can then be calculated according to Clauses 4.2.2.2 and C.4.3 as $\Delta L = 20\log(30/N)$ for $0.2 \leq N \geq 30$. Finally, we can calculate the click limit L_q according to Clauses 4.2.2.2 and C.4.3 as $L_q = L{+}\Delta L$, where L is the relevant limit for continuous disturbance, as given in Clause 4.1.1. The maximum number of clicks allowed above the click limit L_q is calculated according to the upper quartile method as $n_{\text{max}} = n_2 \cdot 0.25$ (Clauses 3.8 and C.4.3).

At this point, the actual measurement run can be started. In this run, obviously, a click analyser is necessary to measure the amplitude of every single click and to evaluate if the number of registered clicks above the click limit L_q is less or equal to n_{max}. These measurements must be carried out at the four frequencies: 150 kHz, 500 kHz, 1.4 MHz and 30 MHz (Clauses 7.4.2.5 and C.4.3). Since the number of counted switching operations is frequency-independent, n_{max} is the same for all four frequencies. Conversely, L_q might differ from frequency to frequency; although N and thus also ΔL have the same value for all frequencies, L may vary according to the frequency.

B. Counting clicks

If the preliminary assessment (first run) has to be done by counting clicks, a click analyser is necessary. As before for switching operations, from the number of clicks n_1, registered during the minimum observation time T, the rate N is calculated as (Clauses 7.4.2.3 and C.4.1) $N = n_1/T$. The first run has to be performed at 150 kHz for the frequency range 148.5 kHz to 500 kHz and at 500 kHz for the frequency range 500 kHz to 30 MHz (Clause 7.4.2.2). Hence, the measurements of the number of clicks for determining the click rate N (and thus also the click limit L_q) shall be carried out only at the two frequencies 150 kHz and 500 kHz (see also Clause C.4.1). This means that after the first run we have two n_1 parameters: $n_{1@150}$ related to 150 kHz and $n_{1@500}$ related to 500 kHz (valid for 500 kHz, 1.4 MHz, and 30 MHz) as well as two T parameters: $T_{@150}$ related to 150 kHz and $T_{@500}$ related to 500 kHz (valid for 500 kHz, 1.4 MHz, and 30 MHz), which in turn produce two click rates N: $N_{@150}$ related to 150 kHz and $N_{@500}$ related to 500 kHz (valid for 500 kHz, 1.4 MHz, and 30 MHz). Following, one will obtain also two n_{max} parameters: $n_{max@150} = n_{1@150} \cdot 0.25$ valid for the measurement at 150 kHz and $n_{max@500} = n_{1@500} * 0.25$ valid for the measurements at 500 kHz, 1.4 MHz and 30 MHz. Once the relevant parameters have been obtained, the actual measurement run can be started and evaluated identically as for switching operations. The measurement run must be carried out at the four frequencies (150 kHz, 500 kHz, 1.4 MHz and 30 MHz; Clauses 7.4.2.5 and C.4.3).

III. Common Mistakes During the Measurement of Discontinuous Disturbances

A frequent mistake made during the measurement of discontinuous disturbances arises because of the complex measuring procedure during the first run defined by CISPR 14-1. In the following, although the principle of the mistake remains the same, we separately discuss the two different options during the first run, i.e. counting switching operations or counting clicks.

A. Mistakes related to the counting of switching operations

During the first run, for appliances where the number of switching operations has to be counted, only a switching operation counter has to be used. It is wrong (misleading) to use also a click analyser since the number of switching operations is frequency-independent. If clicks are actually caused or not by the switching operations is completely irrelevant during the first run; clicks should not be measured at all. Hence, the only correct value of n_{max} (valid during the second run for all four frequencies) derives from the number of observed switching

Reference: EN 55014-1

Discontinuous Interference Tests

Apparatus Code: XXX
Model: XXX

Tested by: XXX

RUN A: June 11, 2014: 03.01 PM
Run Duration: 6 mins 48 secs

Duration limit: 120 mins
Continuous limit: 0.600 secs
Sw Ops limit: 40 A
Switching Operations: 40 Rate: 5.88

C

Channel no:	1	2	3	4	5	6
	150kHz	500kHz	1.4MHz	30MHz		
Sensitivity (dBuV):	66	56	56	60		
Short Clicks:	27	19	13	1		
Long Clicks:	11	22	22	0		
Total:	38	41	35	1 (D)		
Click Rate:	5.59	6.18	5.29	0.15		
Continuous(s):	0.00	0.27	0.29	0.00		

Count limit reached

RUN B: June 11, 2014: 03.09 PM
Run Duration: 6 mins 48 secs

Max Duration: 6 mins 48 secs
Max Continuous: 0.600 secs
Max Clicks: 10 B
Sensitivity = Run A + 20*log(30/Run A SwitchOpsRate*0.66)
Switching Operations: 40 Rate: 5.88

Channel no:	1	2	3	4	5	6
Click Rate used:	3.88r	3.88r	3.88r	3.88r		
	150kHz	500kHz	1.4MHz	30MHz		
Sensitivity (dBuV):	84	74	74	78		
Short Clicks:	11	11	1	0		
Long Clicks:	4	5	1	0		
Total:	15	16	2	0		
Limit = RunA/4:	9	10	8	0 (E)		
Click Rate:	2.21	2.35	0.29	0.00		
Continuous(s):	0.00	0.00	0.00	0.00		

r=Click rate adjusted
Apparatus Fails (subject to exceptions):
Count exceeds limit
Run time limit reached

Fig. 1. Final test report on switching operations of an appliance. The report is divided in "RUN A" (=first run) and RUN B (=second run). In RUN A, the number of switching operations (n_2) is reported, i.e. 40, highlighted with a green box, letter A. The maximum allowed number of clicks (n_{max}) during RUN B is therefore $n_2/4 = 10$, which is also written in the report, highlighted with a green box, letter B. In RUN A, the numbers of clicks registered at the four different frequencies should not have been measured (highlighted with a blue box, letter C). What is worse, in RUN B instead of using n_{max}, four different parameters are wrongly used as limit at the different frequencies (highlighted with a red box, letter E), derived from the number of clicks measured during the first run (highlighted with a red box, letter D).

operations, n_2, during the first run. Instead, frequently the clicks are also measured during the first run. While possibly the rate N, ΔL and thus the click limit L_q are calculated correctly (based on the observed number of switching operations, n_2), the maximum allowed number of clicks above the click limit n_{max} is then calculated incorrectly. More specifically, four different n_{max} parameters are calculated, derived from the four different values of registered clicks at the four frequencies that have wrongly been obtained during the first run. This mistake can easily be spotted by looking at the CISPR 14-1 compliance declaration of appliances: in the final test report, if the maximum allowed number of clicks is different from frequency to frequency, the adopted measurement procedure was incorrect and thus the appliance cannot be declared CISPR 14-1 compliant. The only correct value is the number of counted switching operations divided by four, identical for all four frequencies. In Fig. 1 we show an example of a wrong test report.

B. *Mistakes related to the counting of clicks*

For appliances where real clicks must be counted during the first run, obviously a click analyser has to be used also during

Reference: EN55014-1

Discontinuous Interference Tests

Apparatus Code: XXX
Manufacturer: XXX
Model: XXX
Dishwasher

RUN A: February 12, 2014: 09.05 AM
Run Duration: 120 mins 0 secs

Duration limit: 120 mins
Continuous limit: 0.600 secs
Click limit: 40 (reference frequencies)

Channel no:	1	2	3 (A)	4
	150kHz	500kHz	1.4MHz	30MHz
Sensitivity (dBuV):	66	56	56	60
Short Clicks:	4	14	13	24
Long Clicks:	3	3	2	1
Total:	7	17 (B)	15	25 (D)
Click Rate:	0.06	0.14	0.12	0.21
Continuous(s):	0.00	0.00	0.00	0.00

Run time limit reached

RUN B: February 12, 2014: 11.24 AM
Run Duration: 120 mins 0 secs

Max Duration: 120 mins 0 secs
Max Continuous: 0.600 secs
Max Clicks: 6
Sensitivity = Run A + 20*log(30/ Click rate)

Channel no:	1	2	3	4	5	6
Click Rate used:	0.06	0.14	0.14	0.14		
	150kHz	500kHz	1.4MHz	30MHz		
Sensitivity (dBuV):	110b	100b	100b	104b		
Short Clicks:	0	0	0	0		
Long Clicks:	0	0	0	0		
Total:	0	0	0	0		
Limit = RunA/4:	1	4* (C)	3	6 (E)		
Click Rate:	0.00	0.00	0.00	0.00		
Continuous(s):	0.00	0.00	0.00	0.00		

b=Click rate < 0.2; Sensitivity = Run A + 44db.
Apparatus Passes (subject to exceptions)
Run time limit reached
strong washing mode

Fig. 2. Final test report on clicks of a dishwasher. The report is divided in "RUN A" (=first run) and "RUN B" (=second run). In RUN A, instead of measuring the clicks only at 150 kHz and 500 kHz, the clicks were erroneously measured also at 1.4 MHz and 30 MHz (highlighted with a blue box, letter A). For the frequencies 150 kHz and 500 kHz, the correct values were used as limit (highlighted with a green box, letter C) derived from the number of clicks measured during RUN A (highlighted with a green box, letter B). However, for the frequencies 1.4 MHz and 30 MHz wrong values were used as limit (highlighted with a red box, letter E) derived from the number of clicks erroneously measured during RUN A (highlighted with a red box, letter D). The correct limit for 1.4 MHz and 30 MHz would have been the same as for 500 kHz (i.e., value 4, highlighted with a green asterisk).

the first run. As explained in Sect. II-B, the first run has to be performed only at two frequencies, namely 150 kHz and 500 kHz, resulting in two sets of parameters: one set of T, N, ΔL, n_1 and n_{max} measured at 150 kHz, to be used during the second run at 150 kHz, and a second set of T, N, ΔL, n_1 and n_{max} measured at 500 kHz, to be used during the second run at 500 kHz, 1.4 MHz and 30 MHz. However, similarly as for counting switching operations, often the measurements during the first run are performed at all four frequencies (instead of only at two). This again leads to possibly correctly calculated N, ΔL and thus click limit L_q (based on the two different n_1 and T_1 obtained at the two frequencies 150 kHz and 500 kHz), whereas the maximum allowed number of clicks is again calculated improperly. More specifically, again four different n_{max} are calculated, derived from the four different values of registered clicks at the four frequencies, wrongly obtained during the first run. Again, this mistake is easily visible in the CISPR 14-1 compliance declaration of appliances: in the final test report, if the maximum allowed number of clicks at 1.4 MHz and at 30 MHz are not the same as for 500 kHz, the adopted measuring procedure was not CISPR 14-1 compliant. In Clause C.4.3, CISPR 14-1 rules out any misinterpretations on how n_{max} has to be obtained: It is clearly stated that "the number n of clicks exceeding Lq has to be compared with the number n_1 [...], obtained during the determination of the click rate" (CISPR 14-1, Clause C.4.3). Nowhere is it mentioned that there are specific n_1 measured at frequencies other than 150 kHz or 500 kHz. In Fig. 2 we show an example of a wrong test report.

C. Implications of mistakes

The principle behind the mistakes for both switching operations and clicks is exactly the same: during the first run wrong n_1 and n_2 parameters are obtained, from frequencies that should not have been assessed. Then, these wrong parameters are used as reference during the second run to define n_{max}. The parameter n_{max} represents a threshold that defines whether an appliance has passed or failed the test. Unfortunately, it is not possible to predict in which direction the wrong n_{max} is pushed due to the measuring mistake. This leads to completely random test passing or failing and hence, test results are not comparable anymore. Today, there exist many appliances on the market being declared CISPR 14-1 compliant although they are assessed not following CISPR 14-1 rules and procedures.

D. Role of Discontinuous Disturbance Analysers

To assess the CISPR 14-1 compliance of appliances, usually discontinuous disturbance analysers (commonly called click analysers) are used. Modern click analysers do not only measure the clicks but they also make the full CISPR 14-1 analysis procedure. Click analysers must be CISPR 16-1-1 [2] compliant. However, this standard defines the tests for checking the compliance of click analysers as far as click capability is concerned but not for the whole analysis procedure (refer to Tables 17 and F.1 in CISPR 16-1-1). Thus, it may happen that an unaware user performs the CISPR 14-1 compliance test of appliances with a CISPR 16-1-1 compliant click analyser but the test result may still be wrong (not CISPR 14-1 compliant), if the click analyser adopts a wrong analysis procedure.

IV. Conclusion

The CISPR 14-1 compliant measuring procedure of discontinuous disturbance is a rather complex procedure. However, every clause in the CISPR 14-1 standard is clear and never conflicts with referenced points. Further, CISPR 14-1 has released also very helpful guidance notes (Annex C), with references to clauses in the standard in order to double check every statement. Unfortunately, mistakes are still made during the measuring procedure or click analysers that adopt a wrong analysis procedure are used. This leads to appliances on the market being erroneously declared CISPR 14-1 compliant. With this article we hope to clarify these misinterpretations of the CISPR 14-1 standard, in order to unify measuring procedures worldwide according to the CISPR 14-1 standard.

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References

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[2] CISPR 16-1-1 Ed. 3.0 *"Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus",* International Electrotechnical Commission, Jan 2010.