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TITLE: Contact Current Measurement Results of Multimedia products and Office equipment

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SUMMARY: Various EMF exposure limit setting standards also provide limits for contact currents. Limits for contact current are usually set in the frequency range up to 110 MHz in terms of reference levels (table 2). These limits are set to prevent that a metallic or conductive object that is charged by an external nearby EM field is discharged after being touched by a person. Contact current measurements were carried out on a range of multimedia and office equipment using a clamp-on current transformer in order to determine the usefulness of such measurements for this category of products. The measured values of contact current are given in table 4 and table 5. These values lie far below the applicable reference levels. It is therefore most likely that multimedia products can be stated to be inherently compliant against the requirements for contact currents. Hence it is not relevant to include such a test in a future EMF product standard for demonstrating EMF compliance.

Report

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Contact Current Measurement Results of Multimedia products and Office equipment

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List of abbreviations

BCI	Bulk Current Injection
CL	Consumer Lifestyle
EMF	Electromagnetic Fields
EUT	Equipment Under Test
ECMA	European Computer Manufacturer Association
MM	Multimedia

1 Introduction

1.1 Background

Various EMF exposure limit setting standards, like the ICNIRP Guidelines, also provide limits for contact currents [1][3]. Contact current is defined as the current flowing into the body resulting from contact with a conductive object (or surface) in an electromagnetic field. This is the localised current flow into the body (usually the hand) [1]. Contact currents are hence the result of an indirect effect of the exposure to electric or magnetic fields [4].

Limits for contact current are usually set in the frequency range up to 110 MHz in terms of reference levels [1]. These limits are set to prevent that a metallic or conductive object that is charged by an external nearby EM field is discharged after being touched by a person. The generic EMF standard IEC 62311 [2] (and its European equivalent EN 62311) also address contact currents. In this standard [2] it is stated that products are deemed to comply with the limits if the product does not have touchable conductive parts or if the conductive touchable parts are permanently connected to ground. The latter is often, but not always, the case for multimedia equipment.

It is expected (hypothesis), that an excessive contact current is not an issue for multimedia products and for household appliances. This is also due to the fact that these products already comply with current leakage tests (up to 100 kHz) that are performed to comply with safety standards. However, it is very difficult to provide a rigid proof of this hypothesis based on modelling. The contact-current investigation performed by De Santis [4] has been a first step in the process to generate valid models of MM-products for the purpose to determine contact currents.
Another and a relatively quick way to substantiate the hypothesis is simply to perform contact current measurements for a number of typical MM products. Currently, no IEC-standard is available for contact current measurements. However, such measurements can be performed rather easily by measuring the actual contact currents in a person's arm by using a clamp-on current probe. Such a current probe, the Holaday HI-3702, is specifically designed for in-situ contact-current measurements using actual persons. It should be noted that from a standardisation point of view, the use of an actual person as body-under-test does not lead to reproducible measurement results. However as a first step, such an approach is good enough. Furthermore, from a safety and ethics point of view one could also have doubts to use an actual person as body-under-test. However, the MM products to be tested are common products that are compliant with the leakage current requirements for safety. Hence, as stated before, it is unlikely that the health and safety of the person-under-test is jeopardised.

The purpose for demonstrating the hypothesis is to avoid useless and complex contact current measurements as part of the EMF compliance demonstration process for MM products. With these results it can be justified that it is not necessary to specifically perform EMF contact-current measurements of MM products. This approach and substantiation can then be included in the ECMA EMF technical report that is under development specifically for MM products [3].

1.2 Approach

The contact current measurements have been carried out by use of a clamp-on current transformer instrument which is clamped around the arm of a person while the person touches conductive parts of the equipment. The Holaday HI-3702 meter is used for these measurements. This meter carries out a broadband r.m.s. current measurement over the frequency range 9 kHz – 110 MHz. In the ICNIRP guidelines it is specified that a linear summation should be carried out for low frequency induced current densities (1 Hz – 10 MHz). Hence, a slight discrepancy is present in the current method of measuring the contact current.

Measurements were carried out on a range of MM-products classified as unintentional radiators, i.e. products which do not contain an intended antenna. Additional test were done on typical office equipment (some of which do contain intentional radiators).

The obtained results were analysed and compared to the limit stated in [1]. See also 2.2.

1.3 EUTs

For these measurements, a number of TV-sets/monitors and typical office equipment have been selected. These products are deemed to be compliant with the EMC- and safety requirements[1)]. Most of these EUTs do not include intentional radiators. It is noted that no big differences are expected for products that do include intentional radiators, because the associated frequency ranges of intentional radiators are always well above the frequency range where the body-current requirements apply, i.e. 0 - 110 MHz.

[1)] Strictly speaking there is no 100% certainty about the compliance of the equipment for EMC and safety. EMC tests are performed in the EMC center testlab for these products. No formal information on compliance testing for safety (leakage current tests) is available. The nature and technologies used in the products however is such that the risk for non-compliance is considered negligible.

2 Contact current measurements

2.1 Measuring instrument

The contact current measurements are carried out using a clamp-on current transformer instrument comprising of the Holaday HI-3702 clamp-on current meter and the Holaday HI-4416 read-out system (Figure 1).

Figure 1 The Holaday clamp-on current probe HI-3702 and read-out system HI-4416

Table 1 Specifications Holaday current transformer instrument

Ranges:

Auto range	1 mA – 1 A
Range 1	1 mA – 10 mA
Range 2	3.1 mA – 31.6 mA
Range 3	10 mA – 100 mA
Range 4	0.031 A – 0.316 A
Range 5	0.1 A – 1 A

Frequency response:

Frequency response	9 kHz – 110 MHz (± 2 dB)

The HI-3702 can be used for measurements in accordance with the requirements of the IEEE standard C95.1-2005 (safety levels with respect to human exposure to RF electromagnetic fields) for the frequency range 3 kHz-100 MHz [5]. Measured contact currents are r.m.s. values.

2.2 ICNIRP reference levels

The contact current reference levels as specified in the ICNIRP guidelines are given in table 2. Separate exposure levels are specified for occupational and general public. For MM products, the contact current limits for general public apply.

Table 2 Contact currents reference levels

Exposure characteristics	Frequency range	Maximum contact current (mA)
Occupational exposure	Up to 2.5 kHz	1.0
	2.5 to 100 kHz	0.4f *
	100 kHz to 110 MHz	40
General public exposure	Up to 2.5 kHz	0.5
	2.5 to 100 kHz	0.2f*
	100 kHz to 110 MHz	20

*f is the frequency in kHz

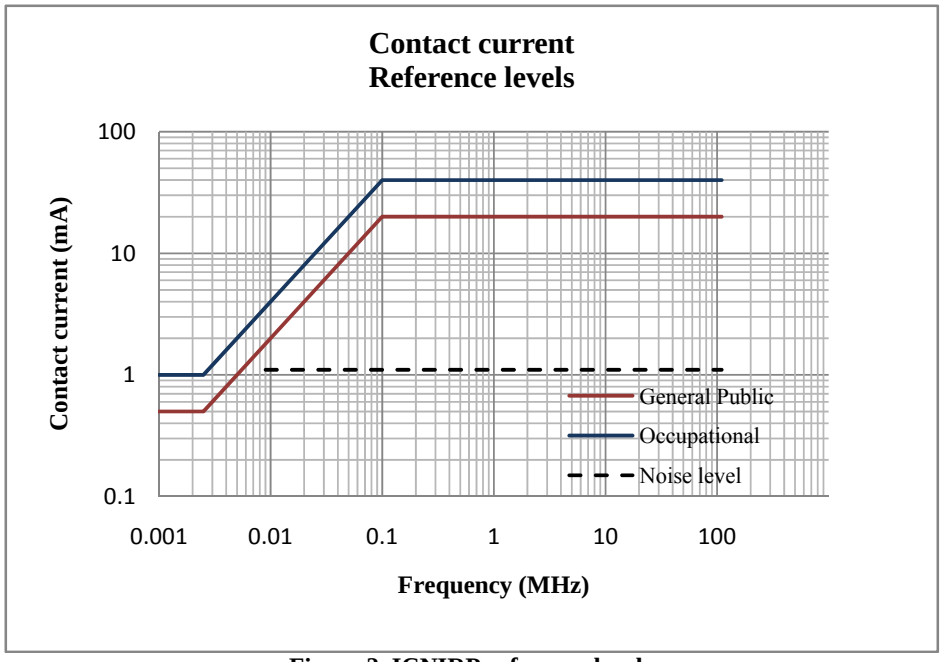


Figure 2 ICNIRP reference levels

The ICNIRP reference levels (Occupational and General Public exposure limits) are shown in figure 2. Alongside these values, the noise level of the Holaday clamp-on current transformer is also shown (black dashed line). The noise level of the current transformer was determined by clamping the current transformer around the arm but *not* touching the equipment under test (EUT), i.e. the hand was kept in the air. The current measured by the Holaday clamp-on current meter is a broadband r.m.s. measurement over the frequency range 9 kHz – 110 MHz, while the reference levels are specified per discrete frequency point. When the measured broadband values of current lie below 1.8 mA (General public exposure level at 9 kHz), then one can be certain that the reference levels are not exceeded in this frequency range. This is a very conservative measurement limit.

2.3 Clamp-on current transformer verification

The functioning of the clamp-on current transformer was verified by measuring its response to a fixed current level (10 mA) over the frequency range 10 kHz – 110 MHz. During the actual contact current measurements it was observed that the measured current levels were very near to the noise level of the clamp. In order to determine the correct functioning of the clamp, this verification test was performed.
The verification test has been based on the method of calibrating a Bulk Current Injection (BCI) clamp. Further details can be found in Annex A of [6]. A fixed level of current (10 mA) was created in the BCI calibration jig by connecting a signal generator at one end of the jig, and an attenuator and 50 Ω termination at the other end of the jig. The current level was verified using a current clamp with a known transfer impedance (see figure 3a).

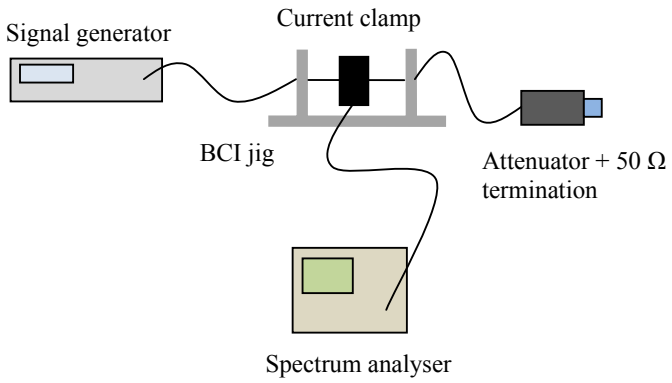


Figure 3a **Determination of fixed current level (10 mA)**

Next, the Holaday HI-3702 current transformer was clamped around the jig and the current level was measured using the HI-4416 read-out unit over the frequency range 10 kHz – 110 MHz (see figure 3b). Measurement results are given in table 3. All values lie within the specified margin of ± 2 dB (7.9 – 12.5 mA).

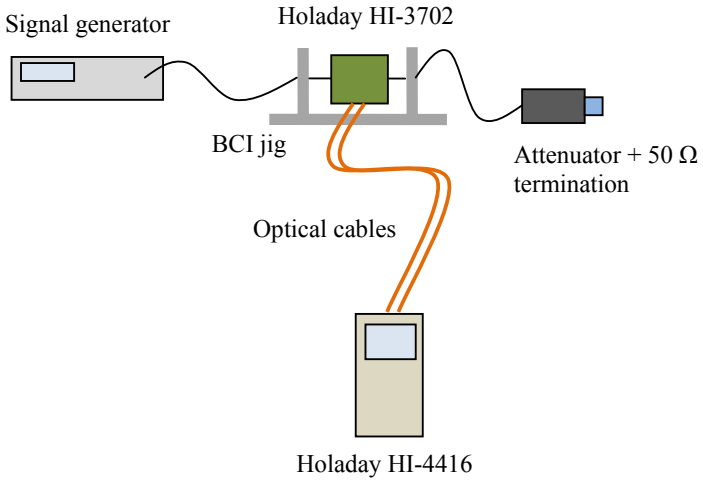
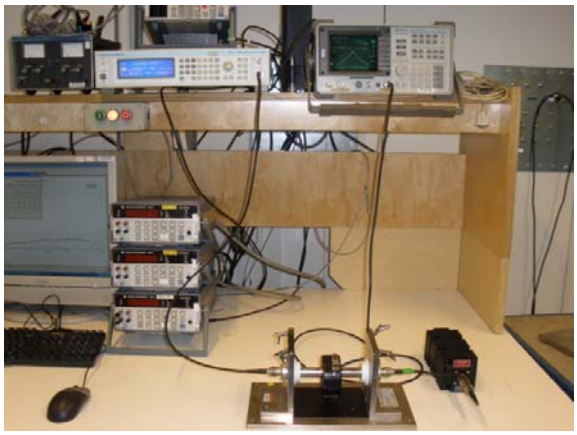


Figure 3b **Verification of functioning of Holaday current transformer**

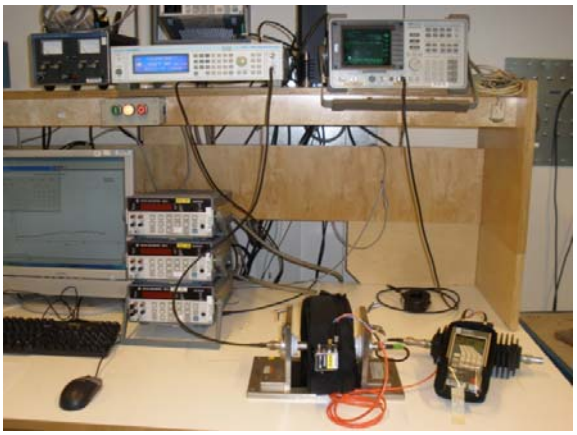
Table 3 Measurement results verification Holaday current transformer

No.	Frequency (kHz)	Current level (mA)
1.	10	9.0
2.	20	10.1
3.	30	10.1
4.	40	10.3
5.	50	10.3
6.	100	10.4
7.	200	10.4
8.	300	10.4
9.	400	10.3
10.	500	10.4

No.	Frequency (MHz)	Current level (mA)
11.	1	10.2
12.	5	9.8
13.	10	10.6
14.	20	9.6
15.	30	9.3
16.	40	9.0
17.	50	8.9
18.	60	8.9
19.	70	9.3
20.	80	8.5
21.	90	8.4
22.	100	9.3
23.	110	10.2



Current probe with known transfer impedance in jig. Current level derived from spectrum analyser



Holaday HI-3702 clamped in jig. Current level noted down from read-out unit (HI-4416)

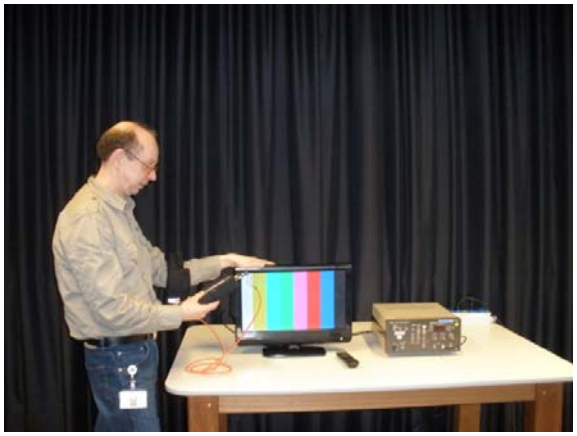
Figure 4 Test set-up verification measurements Holaday current transformer

2.4 Measuring procedure

The Holaday current transformer (HI-3702) is clamped around the arm of a person while the person touches accessible (conductive) parts of the equipment. The contact current value is displayed on the HI-4416 read-out unit. A range of multimedia equipment (TV sets and monitors) and typical office equipment (PCs, printers, etc) were measured using this procedure. Several sections of the equipment which are accessible during normal use (e.g. four corners, connectors at the back, push-buttons, etc) were touched and the maximum value of current was noted down.

a)Front of TV set

b) Rear of TV set



Current transformer clamped around arm of test person

Figure 5 Photographs of application of the clamp-on current probe and typical touch locations of a TV-set

2.5 Measurement results

Initially, measurements were carried out on a range of TV sets and monitors. The mode of operation was chosen according to the mode in which EMC measurements were carried out.
Prior to performing the actual measurements, the noise level of the current transformer was determined by clamping the current transformer around the arm but *not* touching the equipment under test (EUT), i.e. the hand was kept in the air. The measured noise level was 1.10 mA.

When the measured broadband values of current lie below 1.8 mA (General public exposure level at 9 kHz), then one can be certain that the reference levels are not exceeded in this frequency range (see § 2.2 for explanation).

From the results given in table 4, it can be seen that contact current levels of typical multimedia product (unintentional radiators) lie far below the specified reference levels (table 2).

Table 4 Contact current measurement results MM products

No.	EUT type	Contact current (mA)	Mode of operation
1.	19PFL3404D/xx	1.12	In CISPR 13 set-up Colour bar at 863.25 MHz using TV pattern generator
2.	22PFL5604D/xx	1.16	In CISPR 13 set-up Colour bar at 863.25 MHz using TV pattern generator
3.	26PFL3404H/xx	1.13	In CISPR 13 set-up Colour bar at 863.25 MHz using TV pattern generator
4.	32PFL5404	1.14	In CISPR 13 set-up Colour bar at 863.25 MHz using TV pattern generator
5.	32PFL5604H/xx	1.12	In CISPR 13 set-up Colour bar at 863.25 MHz using TV pattern generator
6.	32PFL8404H/xx	1.12	In CISPR 13 set-up Colour bar at 863.25 MHz using TV pattern generator
7.	37PFL5604H/12	1.14	In CISPR 13 set-up Colour bar at 863.25 MHz using TV pattern generator
8.	42PFL3604D/xx	1.22	In CISPR 13 set-up Colour bar at 863.25 MHz using TV pattern generator
9.	42PFL5604H	1.18	In CISPR 13 set-up Colour bar at 863.25 MHz using TV pattern generator
10.	42PFL5604H	1.10	In CISPR 22 set-up Connected to PC, keyboard, mouse Scrolling H pattern
11.	47PFL5604H/12	1.17	In CISPR 13 set-up Colour bar at 863.25 MHz using TV pattern generator
12.	52 inch 3D monitor	1.28	In CISPR 22 set-up Connected to PC, keyboard, mouse Scrolling H pattern

Additional measurements were carried out on typical office equipment. Equipment was operated in a typical user mode. Results are given in table 5.

Table 5 Contact current measurement results typical office equipment

No.	PCs and accessories	Contact current (mA)
1.	Desktop PC Dell GX 280	1.17
2.	Tower PC Dell GX 180	1.16
3.	Laptop Dell latitude d630	1.16
4.	Monitor Philips brilliance 190p	1.17
5.	Monitor Philips brilliance 200p	1.16
6.	Monitor Philips 150MT2	1.15
No.	**Kitchen appliances**	**Contact current (mA)**
7.	Coffee machine Douwe Egberts	1.16
8.	Water cooker Philips	1.17
9.	Microwave oven ATAG	1.17
No.	**Printers**	**Contact current (mA)**
10.	Hewlett Packard Color LaserJet 5550dtn	1.16
11.	Hewlett Packard LaserJet M5025mfp	1.17
No.	**Telephones**	**Contact current (mA)**
12.	DECT telephone Philips	1.16
13.	GSM telephone Nokia	1.14
No.	**Test equipment**	**Contact current (mA)**
14.	Signal generator Marconi 2023	1.18
15.	Spectrum analyser Hewlett Packard 8591EM	1.19
16.	Amplifier AR 100W1000M1	1.16
17.	EMI receiver Hewlett Packard 8546A	1.16
18.	Multi Device Controller EMCO 2090	1.18
19.	Signal generator Rohde & Schwarz SMR40	1.16
20.	Spectrum analyser Rohde & Schwarz FSP	1.16

Here again it can be observed that the contact current levels stay well below the specified reference levels.

3 Conclusion

Various EMF exposure limit setting standards also provide limits for contact currents. Limits for contact current are usually set in the frequency range up to 110 MHz in terms of reference levels (table 2). These limits are set to prevent that a metallic or conductive object that is charged by an external nearby EM field is discharged after being touched by a person. Contact current measurements were carried out on a range of multimedia and office equipment using a clamp-on current transformer in order to determine the usefulness of such measurements for this category of products. The measured values of contact current are given in table 4 and table 5. These values lie far below the applicable reference levels. It is therefore most likely that multimedia products can be stated to be inherently compliant against the requirements for contact currents. Hence it is not relevant to include such a test in a future EMF product standard for demonstrating EMF compliance.

4 References

[1] ICNIRP Guidelines – *Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fileds (up to 300 GHz)* – International commission on non-ionizing radiation protection

[2] IEC 62311 – International Standard – *Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields* (0 Hz – 300 GHz).

[3] ECMA International Technical Report – ECMA TC20 2008 054 – *Guide for assessment of human exposure to electromagnetic fields from multimedia products in accordance with IEC/EN 62311*.

[4] *Induced and contact current concerns produced by multimedia equipment* – EMC center Philips Applied Technologies – Valerio de Santis – dated, 30-07-08.

[5] C95.1-2005 – *IEEE standard for safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 kHz to 300 GHz* - IEEE international commission on electromagnetic safety (SCC39).

[6] ISO 11452-4 – *Road vehicles – component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 4 – Bulk Current Injection (BCI)* - ISO International Standard.