Radiocommunications Agency
Reference AY4395

Study into how CISPR14 Part 1 (Emissions from household appliances, electric tools and similar apparatus) may be improved to make it more relevant and accessible.

Final Report

by
Richard Marshall
MA, CEng, FIEE

The Dappled House
30 Ox Lane
Harpenden
Herts AL5 4HE

Richard Marshall Limited
Analogue and radio-frequency design
Electromagnetic compatibility

phone: +44 (0) 1582 460815 email: richard.marshall@iee.org website: www.design-emc.co.uk

Registered office as above Registered in England No. 3180455

Contents

Executive summary and recommendations

1.1 Executive summary

The structure and test requirements of CISPR14-1 were well-established by 1975 and so pre-date the philosophy and limits of present-day basic, generic, and product standards. Consequently the standard is not "co-ordinated with the generic EMC standards to the extent possible". Of the many areas of discrepancy that are considered in this report the most important relate to the limited scope of testing that is required. Accordingly it is recommended that radiated field requirements up to 1GHz should be included as a matter of urgency for all products, and that an upgrade path for testing up to 2GHz should be under consideration. Furthermore, the "click" requirement profile that covers impulsive interference from spark sources such as motors and thermostats should be applied to all measurements within the standard, not just those below 30MHz. Suggestions are made as to how these additional requirements may be met at minimum cost to the manufacturer and to the consumer.

CISPR14-1 has long been the definitive standard for emissions from spark sources and so has an importance beyond its product scope. For this reason it is recommended that the relevant parts of the standard be recognised as the *basic* standard for discontinuous disturbances. Work should be put in hand to compare the historic "click" profile with the sensitivities of digital transmission systems to confirm the continuing validity of this approach.

There is inadequate statistical information available to support market-oriented decisions about emission test limits. Availability of data such as this was available in the past, and it is still vital for the development of cost-effective and environmentally sensitive EMC standards. It is strongly recommended that the authorities in each country should recognise the importance of interference that threatens radio spectrum utilisation and should fund interference data collection, analysis and publication.

The standard includes many product-specific test requirements and omissions of test requirements. Whilst it is proper for a product standard to set out test *methods*, any decision about product-specific variation of test *limits* is dependent upon contemporary technology and should be the responsibility of the manufacturer. Accordingly the standard should be made more independent of product technology by substantially reducing the number of such requirements and omissions.

Editorially it is recognised that the document is complex because its requirements are complex. However it would benefit from painstaking review by a native English speaker. Structurally it requires the addition of more explanatory material to allow users to understand the reasons for its requirements. Its accessibility could be greatly improved by the addition of an index.

1.2 Technical recommendations

Note: Throughout this document number references in {curly brackets} *refer to the text of CISPR14-1-1:2001 inc. amendment No. 1. References in* [square brackets] *are to information sources identified in 5.2 of this report .*

1.2.1 IEC Guide107 sets out functional and editorial requirements for a product standard that are summarised in 4.1 below. Editorial aspects are the subject of recommendation 1.3.3 below. Functionally CISPR14-1 is not "co-ordinated with the generic EMC standards to the extent possible". See also 2.2.2 below. Within this report - 3.3 below - the technical arguments that the CISPR14-1 approach of extrapolation from HF and VHF emissions adequately controls UHF interference are discussed and rejected. In 3.4.1 we consider the possible cost impact and in 3.5 the choice of test method. It is recommended that;

*** Radiated field requirements up to 1GHz should be included as a matter of urgency for all products.**

*** The "click" requirement profile should be applied to all measurements within the standard, not just those below 30MHz.**

1.2.2 In the light of the matters discussed here in 3.1, 3.2, 3.3 and 3.5.4, the degree of extrapolation resulting from not testing at above 1GHz appears to be acceptable for the time being, but a **development path needs to be in place for extension to 2.5 GHz to protect mobile radio services.**

1.2.3 In 3.5 we consider the choice of test method above 300MHz, and conclude that **whilst the measurement method should be that of CISPR22 as already required for certain toys, reverberation chamber measurements have special attractions for this class of product and their future introduction should be encouraged.**

1.2.4 Section 2.2.1 below notes that for "clicks" - that is for interference emissions that exceed the recognised steady-state limits - the standard is used as the *basic* standard for the relaxation of limits as well as a *product* standard. It is a *basic* reference in the generic standards EN 61000-6-3 for residential and light industrial limits and in EN 61000-6-4 for industrial environments. Likewise it is referenced in product standard EN55103 for professional audio/video equipment.

It is recommended that sections {4.2} and {7.4.2} of CISPR14-1, together with annexes {B} and {C} and the related definitions and diagrams, be recognised as the basic standard for discontinuous disturbances.

1.2.5 In 3.2 below it is noted that there is inadequate statistical information available to support decisions about standardisation. Availability of data such as this is vital for the development of cost-effective and environmentally sensitive EMC standards. **It is strongly recommended that the authorities in each country should recognise the importance of interference that threatens radio spectrum utilisation and fund interference data collection, analysis and publication.**

1.2.6 CISPR14-1 includes "components" in its scope. In 3.4.2 below it is pointed out that if manufacturers of simple products such as motor-driven toys and extractor fans could buy components tested to the standard then, after reviewing the remaining electric/electronic content and the recommendations of their suppliers, they might quite properly decide to market these products without further testing. Lower overall product cost should result.

Tests for components, particularly small motors, should be added to CISPR14-1.

1.2.7 In many cases - particularly those reviewed here in paras 2.2.3.(c) and 2.4 - the standard makes assumptions about product emission characteristics. The correctness of these assumptions is dependent upon contemporary technology. Transferring responsibility for assumptions of this sort from the standard to the manufacturer is discussed in 3.4.1.

The standard should be made more independent of product technology by reducing the number of product-specific requirements and omission of requirements. See also 1.2.8 below.

1.2.8 The option to observe clicks from EUT operation and correct them for product-specific click characteristics is complex and technology-dependent. See 2.3.2.d below. **As a part of recognising the generic nature of the "click" requirements this option should be allowed with f=1 for all products.**

1.2.9 Difficulties with the classification of processor-based products such as gaming machines are discussed in 2.2.4 below. **Either the scope of CISPR14-1 needs to be narrowed in respect of processor-based products or its requirements above 300MHz need to be extended.**

1.2.10. There is a trend towards digital devices that are less tolerant of short interference events. See 2.3.2.c below. **It is therefore recommended that the match between the existing "click" time profile and digital system requirements be studied.**

1.3 Editorial recommendations

1.3.1 It is noted in 4.2 below that those involved in drafting standards are too close or too stressed to recognise ambiguity or readability problems.

A native English speaker technically knowledgeable but outside the committee should review all committee drafts (CDs) and the committee required to accept the comments or state why they cannot. This may require specific funding.

1.3.2. 4.2 below gives examples of words having specific meanings within the standard that cannot be understood without reference to the "Definitions".

CISPR14-1 should print internally-defined words in a special typeface.

1.3.3 IEC guide 107 states that *justifications* for deviations from generic requirements should be included. If such explanatory material is added to CISPR14-1 it will help the user. See 4.3.1.

CISPR14-1 should be thoroughly revised editorially to bring it in line with the requirements of IEC Guide 107.

1.3.4. In 4.3.1 below it is noted that those who use CISPR14-1 for more than one product category find it very difficult to determine exactly what tests should be applied in a specific case, and that the reasons for that test profile are not then sufficiently clear for comfort.

A comprehensive index should be added.

1.3.5 **Minor editorial recommendations are to be found in paragraph 5.3 below.**

2 CISPR14-1 document fundamentals

2.1 History

BS800: 1937. A single set of limits was to be applied for disturbances lasting more than 10 seconds or occurring more often than once in 10 minutes or lasting more than 1 second per hour.

BS800: 1951. Introduced relaxations to continuous limits for conducted and radiated tests from 200kHz to 1.605MHz for "discontinuous mode" disturbances. This was based on the click rate formula 20* Log(30/N) dB as used today {4.2.2.2}.

BS800: 1954. Frequency range Extended to 70MHz.

BS800: 1972. Split into 3 parts for motor/contact/semiconductor product technology classifications. Part 1 (motors) included quasi-peak (only) interference power measurement 30 to 300MHz with ferrite clamp for cabled devices and substitution method in chamber for radiated field testing of battery powered domestic items.

BS800: 1975. Part 2 Contact devices. 26 pages. Measurement of conducted interference from "clicks" was required at 0.16, 0.55, 1.4 and 10MHz, and additionally the interference power of clicks was specified for the whole of the ferrite clamp test range up to 300MHz – actually at spot frequencies near 45, 90, and 220MHz – which corresponded to the then TV Bands I and III and FM radio frequencies.
Discontinuous disturbance requirements included the dual "counting clicks" and "counting switching operations" routes and product test condition, test method, and relaxation structure as today.

CISPR14 1st Edition 1975. 30 pages. Quasi-peak measurements only.
Terminal voltage 66/60/66dBuV 0.15/0.35/5/30 MHz, relaxed in two steps for tools as today.
Interference power limits as today. The "click" requirements were applied on top of ***all*** the above requirements including spot frequencies up to 220MHz.

BS800: 1977. 29 pages. Claimed alignment of limits with CISPR14 1st Edition 1975 -though there remained many differences of text.

BS800: 1983. "Identical with EEC Directive 82/49/EEC" and so *included* motors as components.

CISPR14 2nd Edition 1985 = EN55014:1987 = BS800: 1988. 58 pages. *Average* limits added.
"For the time being no measurements on discontinuous interference are to be made in the frequency range 30 to 300MHz."

CISPR14-1 4th Edition 2000 =EN55014-1:2000 69 pages.
Amendment No. 1 introduced radiated disturbance requirements up to 1GHz for certain toys {4.1.3 & 7.3.6} and removed the requirement for terminal voltage measurements on certain cables integrated into the product {4.1.1.2}.

2.2 Relationship to other standards.

2.2.1 Generic content

For "clicks" - that is for interference emissions that exceed the recognised steady-state limits but for a very limited time - CISPR14-1 has been and is used as the *basic* standard for short-term emissions as well as a *product* standard. It is a quoted as a basic reference in the generic standards IEC 61000-6-3 for residential and light industrial limits and IEC 61000-6-4 for industrial environments. Likewise it is referenced in product standard EN55103 for professional audio/video equipment. There is clearly a need for such a basic standard, and since the "click" requirement {4.2} takes the form of a time-dependent mask of dB relaxation relative to the steady-state limit it can be easily applied to any sort of emission measurement. In principle, therefore it is recommended that sections {4.2} and {7.4.2} of CISPR14-1, together with {annex B}, {annex C}, and the related definitions and diagrams be recognised as the generic standard for discontinuous disturbances. See recommendation 1.2.4.

This might be achieved as a stand-alone part of either CISPR14-1 or CISPR16. One might argue that the application expertise is already within CISPR/F. On the other hand the disturbance analyser requirements are best understood within CISPR/A and the "click" test might benefit from a new look.

2.2.2 Comparison with generic requirements

The objective of emission standards is to define the electromagnetic environment within which other products must be able to operate. Consequently all emission standards for a given environment (Domestic and light industrial in the present case) should quote the same figures for the same phenomena. There are only two reasonable exceptions:

* Items very rarely used in this environment, such as industrial or building tools occasionally used in the home. In such cases the user might reasonably tolerate some difficulties and so some relaxation is reasonable.
* Items inescapably present in the environment – that is, which cannot be switched off - or items continually radiating over a wide bandwidth, such as certain sorts of HF cabled telecommunications. In these cases tighter limits may be justified.

It is possible to challenge the generic emission limits. However these limits establish the transmitted power level required to provide an adequate signal/noise ratio for radio/TV/data reception in the specific environment, and any general increase in environmental noise level must eventually lead to a proportionate increase in transmitter power. This is undesirable on environmental grounds.

Accordingly the objective of CISPR14-1 should be to ensure that products within its scope meet the generic requirements of IEC61000-6-3 at minimum cost. A similar purpose may be deduced from IEC Guide 107 quoted in 4.1 below.

This argument supports recommendation 1.2.1

2.2.3 Test requirement boundaries

No limits at all apply to battery operated tools and appliances with no mains lead {4.1.1.5 & 4.1.2.2}. This exception has become more important as battery technology has improved. Measurements in the UK in 2002 on a sample set of 12 such devices revealed one cordless drill (but only one) that exceeded the CISPR22 radiated emission limit [23]. CISPR22 – the emission standard for information technology equipment - is commonly used as a benchmark for such tests since it is referenced as "basic" in the generic emission standard IEC61000-6-3.

In these particular tests the emission was excessive by 16dB in quasi-peak value in the 233MHz region: capable of causing significant interference to Private Mobile Radio services. The item appeared to contain no suppression components whereas a toy using an identical motor did include effective suppression. It is clear that such tools are capable of emissions above the generic limits and that the manufacturer took advantage of the lack of any requirement for emissions from battery-powered tools.

Products without a convenient cable which may be subjected to a conducted disturbance

power test up to 300MHz are a problem within CISPR14-1, and the most recent amendment has introduced radiation testing from 30 to 1,000MHz only in those cases where such a disturbance power test is impractical {7.3.6.1.B}. In some borderline cases {7.3.6.1.C & E} the manufacturer may choose between disturbance power to 300MHz and radiated field to 1,000MHz - so the objective is the limited one of extending the scope of testing up to 300MHz across a wider product range and has incidentally extended the maximum frequency to 1,000MHz in a few cases.

A committee draft CISPR/F/378/CD proposes to extend this scope to cover all *battery-operated* appliances but falls well short of introducing universal limits to 1GHz as recommended in 1.2.1 above.

No discontinuous disturbance limits apply for any product or emission above 30MHz {4.2.1}.

From the historical notes in 2.1 above this appears to have been a CISPR/F decision in 1985. For the reasons given below in 3.2 and 3.3 this needs urgent review.

The balance between the responsibilities of the standard and of the manufacturer is discussed further in 3.4.1 below.

2.2.4 Product scope

Whilst the scope of the standard is almost wholly related to the domestic and light industrial environment, there are a number of borderline cases.

a) Limits for tools {Tables 1 & 2} are relaxed by 4dB for ratings above 700 watts and by 10dB above 1,000 watts. This approach pre-dates the customary simple 10dB relaxation for "Class A" heavy industrial apparatus and is entirely sensible in its context; but having introduced class A limits should these not be applied to industrial water heaters and industrial gas-fired boilers?

b) Why are power staplers excluded from the "Class A" concession irrespective of rating? {7.3.2.7}.

c) There are references to apparatus rated at up to 25amps/phase {1.1} and three-phase thermostatically-controlled switches {4.2.3.2 and 7.2.5.2}. Some modern domestic cookers consume 70amps single-phase and should be included within the scope. Many such items may be found in "Light industrial" Catering Establishments where again the "Class B" limit is reasonable.

d) The "Lighting" standard CISPR15 requires conducted emission tests down to 9kHz, but CISPR14-1, whilst covering the spectrum down to 9KHz {1.2} does not require tests below 150KHz {Table 1}. Clarification is needed as to whether the low-frequency test should be performed if such lighting with an electronic ballast is incorporated in a CISPR14-1 product. One test house has noted a cooker hood that would have failed a test at 60kHz had it been required.

e) Several people have identified difficulties with the classification of gaming machines, which some countries regard as within the scope of CISPR22 since they are nowadays computer-based rather than electromechanical.

f) Electric fence energisers are covered by detailed requirements in the standard {7.3.7.2} but there is nothing in the scope {1.1} to suggest this. The scope could be widened accordingly.

These borderline cases arise from sheer complexity and would be best tackled by the simplification of product-specific requirements, and by the extension of test method and frequency coverage.

In the short term either the scope of CISPR14-1 needs to be narrowed in respect of processor-based products or its requirements above 300MHz need to be extended to make the question less important. See recommendation 1.2.9.

2.3 "Click" emission limits in CISPR14-1

2.3.1 Summary of requirements

The CISPR14-1 treatment of "clicks" can be traced back to 1951, and has scarcely been changed since 1975. In summary it allows the relaxation of limits according to the following rules:

a) A "Click" is a disturbance exceeding the continuous limit, the duration of which is not longer than 200mS and which is separated from a subsequent disturbance by at least 200mS {Para. 3.2 and Figs. 3 & 4}.

b) Measurement is only required at 150kHz, 500kHz, 1.4MHz, and 30MHz. {Para. 7.4.2.5}. Nowadays the level of disturbances below 30MHz is interpreted as an indication for the level above 30MHz {Para. 4.2.1}.

c) **No limit is applied** {para. 4.2.3.3 and Fig.9} if there are fewer than 5 clicks/minute *and* all are shorter than 20mSec. *and* 90% are shorter than 10mSec.

d) A **pass** is recorded if less than 25% of clicks exceed a threshold

- 44dB above the continuous quasi-peak limit at a rate of 1 per 5 minutes or less
- a limit tapering down from the above to the continuous limit at 30 clicks/minute.

e) The clicks/minute figure N may be measured at r.f {para. 7.4.2.2 and table A1}. Alternatively for certain domestic appliances {para 7.4.2.3 and Table A2} this N may be observed from EUT "switching operations" and then in some cases corrected downwards. However, if the latter test is failed then the former may be adopted instead {last para. of the *informative* annexe C 4.1}

f) Infrequent Clicks resulting from mains connection or disconnection or programme selection are excluded from the test {Para. 4.2.3.1}.

2.3.2 "Click" specification Issues

a) The test is essentially that introduced internationally in 1975.

b) The rationale "… disturbances below 30MHz …interpreted for the level above 30MHz" {Para. 4.2.1} is not technically valid – see 3.3. below – and nowadays potential victims such as cellular telephones operate at around thirty times 30MHz. Whilst it is acknowledged that this involves undoing a change introduced into the 2nd edition of CISPR14-1 it is recommended at 1.2.1 above the "click" profile be applied to all measurements. It could be that the spot frequency tests at 45, 90 and 220MHZ be re-instated and 300MHz added. However, if it is felt that the added test time is a problem then the existing four spot frequencies should be spread out over the wider range of 150kHz to 300MHz.

CISPR16-1 contains in para. 5.4 a specification for a disturbance analyser to be connected to the i.f. output of a measuring receiver. This specification already covers frequencies above 30MHz - see note 4 to table 13 – so there should not be any instrumentation obstacles to this recommendation.

Modern FFT techniques would allow all frequencies to be measured at the same time. Study and publication of work on FFT analysis of impulsive interference would be of great value to the standards community.

c) New digital radio and TV services using multi-carrier techniques have a different vulnerability to interference to that of traditional narrow-band services. This is being evaluated by standards-makers for repetitive interference that produces a low bit-error rate (see CISPR/A/382/CD). However a single "Click" exercises quite different features of interference rejection by modern digital coding, since it may cause errors in all the individual carrier channels at the same time. The result of this depends in part on the extent that time interleaving has been incorporated in the code. It may cause a total loss of data that defeats the data-storage and error-correction capability of the system resulting in a long recovery time. Of course, poor front-end dynamic range can lead to paralysis by impulsive interference in a digital receiver in just the same way that it would in an analogue one.

Development of digital transmission appears to have concentrated on the ability to reject narrow-band interference rather than wide-band. Interestingly, DTV studies in the UK by BBC [32] and RA [10] have both concluded that real-world domestic impulsive interference events consist of a series of very short spikes between which useful digital transmission may be achieved. This suggests a fundamental mis-match between the existing "click" time profile and digital system requirements.

Further study of this could prove important. However the urgent issues are between real-world interferers and real-world telecommunications service designers. The “click“ standard can only hope to follow behind, changing slowly in response to the totality of interference scenarios, but with the effect of any specification change limited by the long working life of “white goods“ and “brown goods“.

A minimum objective for CISPR14-1 would be to ensure that the environmental situation does not get any worse. In this respect para.{4.2.3.3}is perhaps unfortunate since it allows unrestricted amplitude for “clicks” of duration less than 10/20mS occurring less than 5 times per minute, and product designers have been known to deliberately choose a click rate just below this to avoid the need for suppression components.

One can perceive the trend towards digital devices that are less tolerant of short interference events. If future field data provides evidence of a significant problem, then these two areas would merit attention. At present the possible benefit of any change to the test requirements is unclear, and the upset to industry of such a change is obvious. It is therefore recommended in 1.2.10 that the match between the existing “click” time profile and digital system requirements be studied in more detail, and assessed in relation to better field problem statistics - see 1.2.5 - with a view to revising the basic click limits or time profile at some time in the future.

d) The option to observe clicks from EUT operation and correct them for product-specific click characteristics is complex and technology-dependent. As a part of recognising the generic nature of the “click” requirements this option should be allowed for all products but only with f=1. Tables A1 and A2 would then be eliminated, and para. {7.4.2.6} and the last para. of {informative annexe C 4.1} would be replaced by the following procedure;-

* The tester to determine how many potential click events occur in each “switching operation“.
* Measurements then made to the limit calculated for this value of N
* In the event of failure then the product might be re-assessed against the lower value of N that would be obtained by counting the clicks that exceeded the i.f. threshold as defined in {3.2}.

2.4 Technology dependence

Requirements such as {4.1.2.4} “Regulating controls...which do not contain any internal frequency or clock generator operating at ...higher than 9kHz are not subject to...requirements in the range 30 to300MHz”, and the tabulated click rate correction factors f {Table A2} are examples of the standard making assumptions that are vulnerable to becoming inappropriate as a result of product technology change or poor quality design. In particular frequency is considered but not switching speed or the possibility of oscillation during transitions. Faster switching may result as a chance effect of improved semiconductor manufacturing technique, or deliberately as part of a drive towards improved energy efficiency. Consider, for example, semiconductor power switches. Even though slow switching speeds may be functionally acceptable, technology change may result in slow devices becoming more expensive or even unavailable so that faster devices with greater rf emission are substituted. Poor design can result in the use of transistors that appear to operate satisfactorily as relay drivers whilst actually oscillating in the VHF FM band. Electromechanical thermostats can be replaced by solid-state devices with *lower* emission.

These are further cases where responsibility for test relaxations should be with the manufacturer, not the standards body. See 3.4 below.

3 Test frequency ranges, limits and methods

3.1 Electromagnetic environment

In the UK serving a population of 60 million users there were;

	1991	2001
Mobile phones 900MHz	1.1 million	24.2 million
Mobile phones 1.8GHz	-	22.8 million
Colour TV receivers	18.1 million	22.7 million
Short-range devices: mostly 433/868MHz. Annual sales	0.4 million	2.7 million

The number of potential victims is therefore very large and increasing rapidly

3.2 Spectrum user problems

The Radiocommunications Agency [20] has investigated the following interference reports in the 12 months to 31st March 2003 - but no analysis of cause is available.

Analogue TV	2,415
Digital TV	98
Analogue FM radio	214
Digital radio	5
	2,732

It has to be said that it is quite difficult for consumers to complain either to product manufacturers or to the RA, and that there is widespread acceptance that interference is a fact of life. When the writer tried to explain to his hairdresser what an EMC consultant did, the immediate response was “Oh, like hair driers and TV!”

This study has noted anecdotal evidence of problems with central-heating boilers, microwave ovens, “savaplugs”, carving knives, toothbrushes, shavers, gas igniters, cordless drills, refrigerator door switches and toys, - and there is considerable commercial interest in the service area of mobile phones which can be limited by the emissions from domestic items.

In the UK today no-one analyses and publishes problem reports. It has been possible in the past: see below for data [28] from 1972.

TABLE 1
SIMPLIFIED 1972 STATISTICS OF INTERFERENCE COMPLAINTS

Sources	No. of complaints per service					Approximate % of all complaints
	Sound		Television		Private mobile radio	
	l.f./m.f.	v.h.f.	v.h.f.	u.h.f.		
Inadequate signal	57	36	874	1001	6	3.00
Inadequate antenna	637	436	5867	2735	43	14.00
Receiver faults or maladjustments	611	594	6499	3945	208	17.00
Contact devices	1170	250	7528	791	16	14.00
Radio transmitters in U.K.	220	256	2053	979	435	6.00
Broadcast receiver radiation	323	14	1485	1472	23	5.00
Electric motors	275	83	2585	178	15	4.00
Overhead powerlines	86	14	2324	65	15	4.00
Discharge lamps and signs	301	25	1001	63	3	2.00
Industrial and medical r.f. heating equipment	18	10	728	74	22	1.00
Identified sources other than those above	582	154	3294	857	103	7.00
Unidentified	1561	357	9527	2043	324	20.00

Availability of data such as this is vital for the development of cost-effective and environmentally sensitive EMC standards. It is recommended (1.2.5 above) that the authorities in each country should recognise the importance of problem reports and fund interference data analysis and publication, perhaps for limited geographic areas.

A number of report sources have spoken of the need to protect the short-range data communication services now appearing in the 2.4GHz ISM band. This is almost a contradiction of principles and is certainly outside the scope of this report, but has to be recorded.

3.3 Frequency extrapolation of measurements

3.3.1 Introduction

The present situation in the CISPR14-1 standard is that;

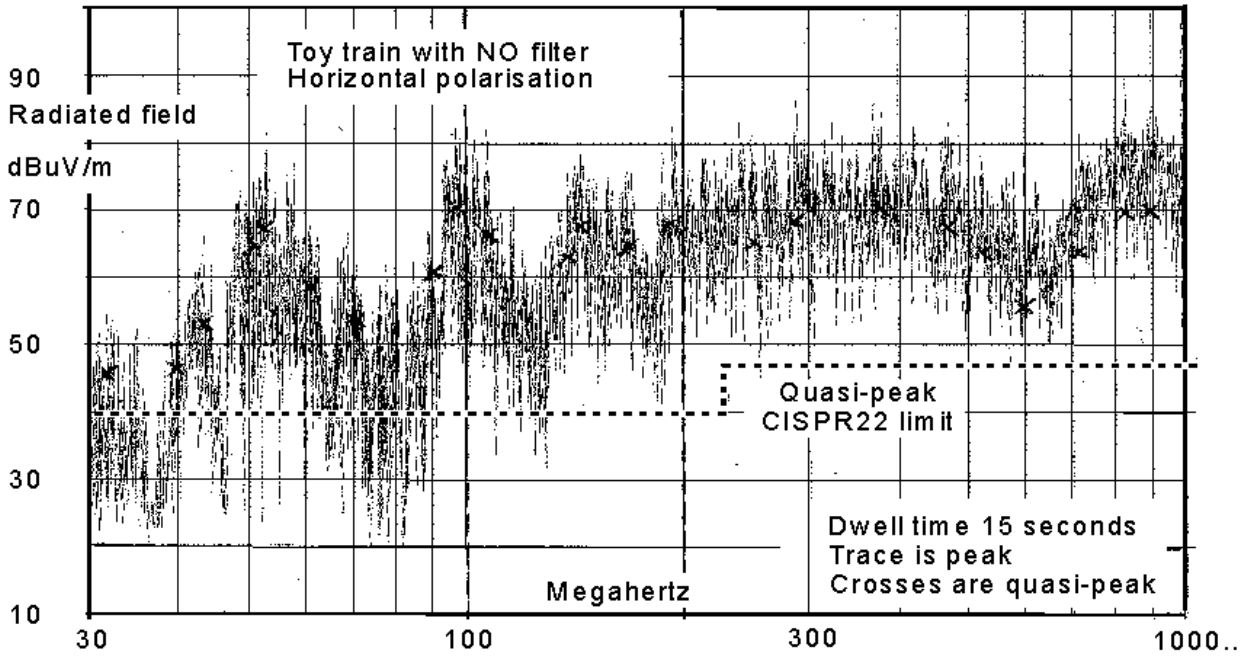
* For mains-powered products other than toys the maximum frequency of the continuous disturbance requirements of the standard is 300MHz {Table 2}.
* For toys running on tracks and certain other categories the manufacturer has the option to test only up to 300MHz {7.3.6.1}.
* No discontinuous disturbance requirements exist above 30MHz {4.2.1}, *and*
* For battery-powered appliances other than Toys, there are at present no requirements *at all* {4.1.1.5}, though a committee draft CISPR/F/378/CD to introduce radiated field testing for these has been circulated.

These general parameters have been unchanged since the second edition of CISPR14-1 in 1985. Since then television has completed its migration from VHF to UHF and a variety of new UHF and microwave services have appeared. These are widely-deployed new users of the radio spectrum that need protection from interference.

The standard's underlying philosophy {spelt out in para. 4.2.1} is to infer UHF emission levels from HF and VHF measurements. This philosophy may be questioned on motivational

grounds because it leads the product designer to believe that there are no UHF requirements, and so must encourage the design of products that pass the lower frequency test specified rather than meet the actual whole-spectrum needs of users.

There can be no doubt that sparks associated with thermostats, switches, motors etc have the potential for serious wide-band interference. The chart below [25] shows an excess of 20dB over the domestic limit across most of the spectrum. The toy train moving round a track has an advantage for a test of this sort since the varying connection length as the train proceeds spreads out any radio-frequency resonance effects.

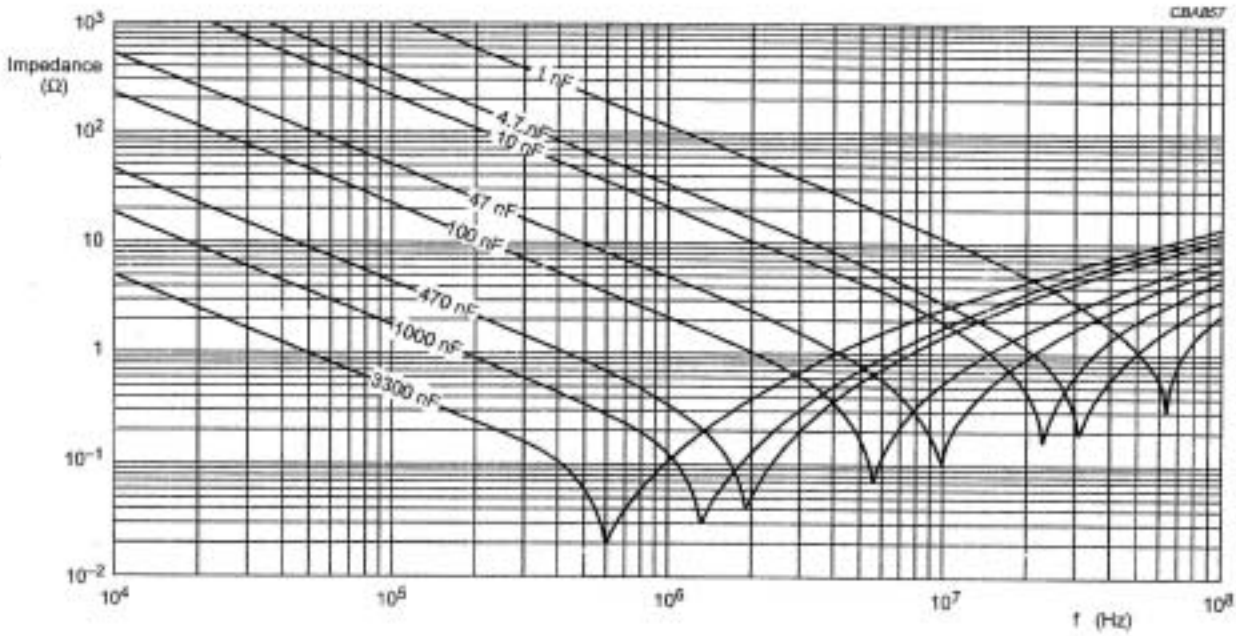


The question of the efficiency with which this emission may be removed by the measures required to conform to CISPR14-1 is discussed below.

3.3.2 Component issues

Technically is should be recognised that filter component choice, connecting lead length, and product structural design have increasing effects at higher frequencies.

For example, capacitors for shunt suppression filter exhibit series resonance with their connecting leads and so are most effective at a specific frequency. Above this frequency it is primarily the lead length that determines the impedance. The graph below shows the impedance vs. frequency characteristics for a commercial range of plastic film suppression capacitors. A natural choice to pass the 150kHz to 30MHz "click" test might be 100nF but in the UHF TV band even with minimal connecting leads this would offer 10dB worse filtering than would a 1nF capacitor.



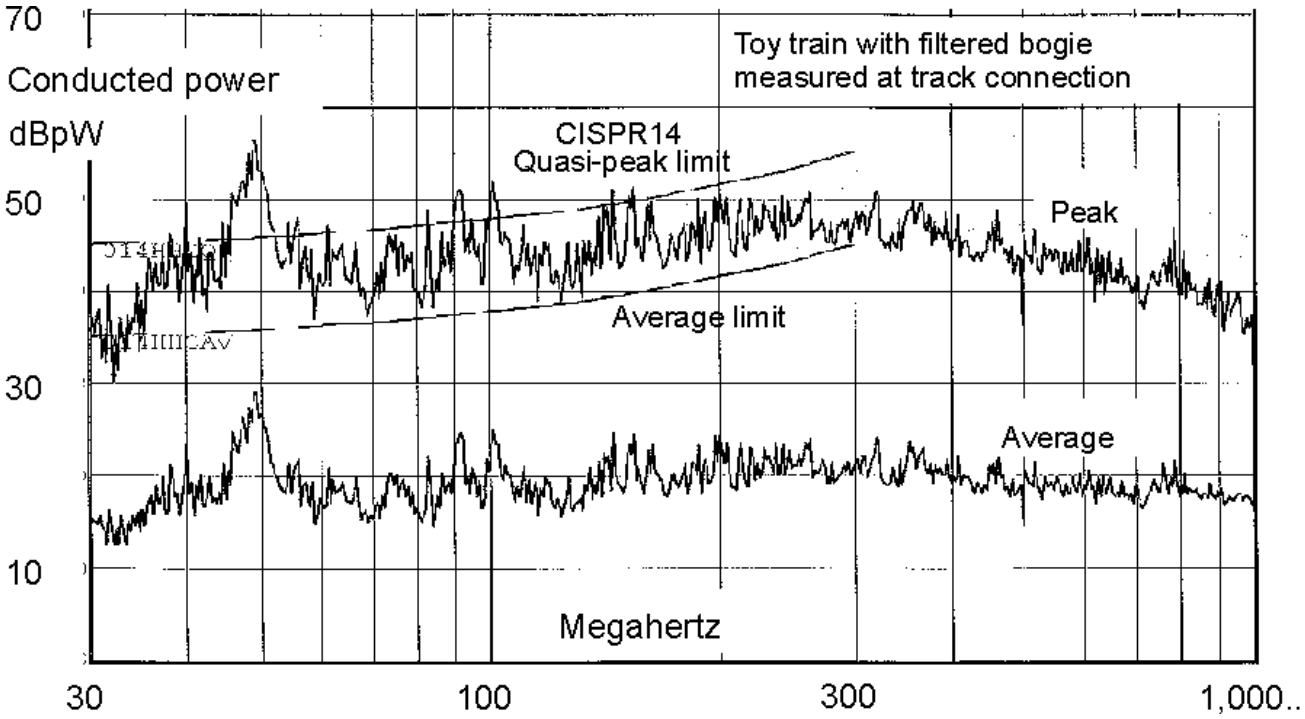
Where products are designed for unregulated markets and have filters added for sale in areas where conformance to standards is essential, it is the invariable practice to fit a filter to the mains lead at its product entry point. This can easily be made to control hf emissions, but will be quite unable to reduce VHF/UHF radiation that comes from within the product.

3.3.3 Toy train tests

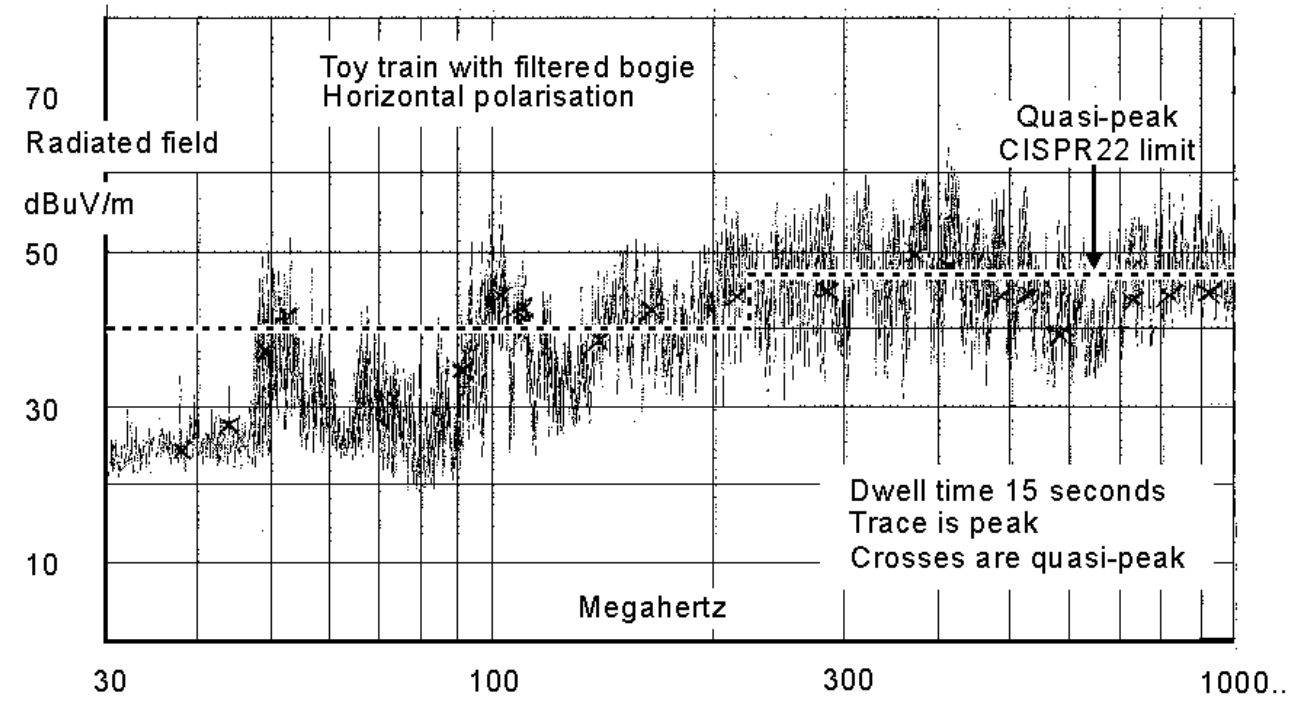
Practical evidence has been obtained of emission in excess of CISPR22 domestic limits from a product conforming to CISPR14-1. The engine of the toy train set used without filtering for the test in 3.3.1 was fitted with the test engineer's choice of a high-quality wideband filter with very short leads for these tests [25].

It is important to note that the spark sources of the engine are representative in spectral content not only of commutator motors but also of *discontinuous* "click" spark sources; they are just conveniently repeated for ease of study.

The following graph shows the peak and average disturbance power produced. Additional spot-frequency checks using a quasi-peak detector showed that with the developmental filter on the engine the CISPR14-1 requirements were just met, and the trend of conducted power as the frequency approaches and passes 300MHz suggested a large safety margin in the UHF range.



The radiated field from the same train with the same filter was then measured in a 3metre semi-anechoic chamber according to CISPR22. The results were a test failure despite the fact that the filter had been carefully chosen for good UHF performance. The quasi-peak measurements (shown by the crosses just visible among the peak recording) were out of specification not only at the known borderline region at 48MHz, but also at 100, 170, 210 MHz and at the CISPR22-only test frequencies of 380 and 410 MHz. See the chart below.



It may be concluded from these tests that for an EUT of significant size the conducted power test under-estimates the emission at and above 100MHz.

These results are not surprising in view of the possibility for radiation from the track.

Many larger domestic items have significant internal wiring with the same possibility to

radiate as has the track of this train.

There are also domestic products comprising a number of units linked by cables that can radiate in the same manner as does the train track. CISPR14-1 excludes from measurement cables of less than 2 metres {4.1.1.2, 4.1.1.4, 4.1.1.5 and 5.2.1.2}. These may be effective antennas at frequencies where they are more than a quarter-wave long - that is above about 35 MHz. This provides another argument for introducing radiated field testing - see 3.5. below and recommendation 1.2.1 - or for reducing this exclusion length.

3.4 Risk, responsibility and cost

3.4.1 Assignment of responsibility

The cost of compliance, that is the cost of adequate *product design for EMC*, is not open for discussion here since it is a requirement of 21st century society as is evidenced by the multitude of national and regional regulations.

However, the cost of *demonstrating* compliance is a serious issue, particularly for lower-priced items that are made in relatively small quantities. It is important that standards minimise the cost burden on the manufacturer, since this eventually falls upon the consumer.

The generic emission standard IEC61000-6-3 states in its clause 8;

> "It may be determined from consideration of the electrical characteristics and usage of a particular apparatus that some of the measurements are inappropriate and therefore unnecessary. In such a case it is required that the decision not to measure is recorded in the test report."

Addition of a clause such as this to CISPR14-1 forms part of recommendation 1.2.7 above since it removes the cost impact of additional tests for those products for which such tests are arguably unnecessary. The clause would have the effect of transferring responsibility for choosing a test profile (but not responsibility for the test method or test conditions) from the standards-maker to the manufacturer. This would allow the standard to adopt a user-oriented test profile with many fewer qualifications and exceptions, whilst at the same time helping to stabilise the standard in the face of technological change.

There are products which fall within the scope of CISPR14-1 but for which there are no requirements stated. This of course has the effect that these may be marketed without *any* EMC design or test measures. Battery-powered tools {4.1.1.5 or 4.1.2.2 plus 4.2.2.3} are examples – but see committee draft CISPR/F/378/CD.

In other cases relating to testing over a restricted frequency range, or by methods that infer radiated field characteristics by measuring conducted power on a cable, the standard takes decisions about emission characteristics and about what is or is not worthy of testing that should be the responsibility of the product manufacturer. Moreover the correctness of these decisions may be dependent upon the characteristics of the components used and the method of construction of the product. For example {4.2.1} states "The level of disturbances below 30 MHz is interpreted as an indication for the level above 30MHz". The truth of this depends upon the type and lead-length of the suppression components used and on the product design and packaging. Such details cannot be known to the standards-writers - at least not throughout the life of the document.

Removing decisions of this sort from the standard would simplify the document and make it more immune to technology change (for example a manufacturer of a product whose only potentially emitting electronic content was zero-crossing semiconductor power switches might reasonably decide that neither radiated field or click testing was justified.) Some test houses already take on this decision by deciding that it is in their customer's interest to apply radiated-field testing up to 1GHz.

3.4.2 Approved components

In many Toys, tools, and appliances the only source of emission is a single motor. Such motors are made in larger quantities than the products and could well incorporate more cost-effective filtering than can the product. Therefore it ought to be possible for product manufacturers to source motors conforming to CISPR14-1 and incorporate them into products that might then be self-certified

and sold without further testing. Clearly this step would only be appropriate for products using standard motors, which would exclude those handheld tools and domestic appliances that use custom-designed and moulded parts. However, large numbers of items such as extractor fans and toys would benefit. CISPR14-1 includes in its scope the words "…separate parts…such as motors…however no emission requirements apply unless formulated in this standard". Unfortunately there appear to be no emission requirements formulated for any components except thermostats {7.2.4 and 7.2.6}. If requirements for motors as components were included as recommended in 1.2.6 above then overall product approval cost would be reduced - and there is a good chance that overall product manufacturing cost would be reduced and design quality improved.

3.5 Test methods above 300MHz

There appear to be three possibilities that have to be considered for the whole range of EUT dimensions and frequency spectrum

3.5.1 Cable power measurement.

The validity of any extension above 300MHz would rely on the cable being the dominant source, which the EMC community could only support for a small EUT. It was demonstrated in 3.3 above that this technique is inappropriate for a toy train: such an EUT is much too large. Accordingly this could only be unreservedly recommended for EUTs less than, say, a quarter-wavelength long (that is 75mm at 1GHz). Perhaps with more study it might be decided that the method is adequate for the numerically large class of small hand-held mains-powered tools and appliances for which the economy of this solution might justify its adoption. There is a precedent in the method of clause 5.6 of CISPR13 (Sound and TV broadcast receivers etc.) - though at present that standard only specifies limits up to 300MHz.

The power limit would also need review. The calculation annexed as 5.4 is subject to a number of assumptions but does indicate that the conducted disturbance power test is 13dB less stringent than the corresponding radiated field test at 300MHz. This conclusion is supported by the toy train measurement data in 3.3.3 above.

3.5.2 CISPR22 radiated test

Testing to CISPR22 has already introduced into CISPR14-1 for certain toys {4.1.3}. This is the most convenient solution for already-equipped test houses, and has the advantage of being well-understood and using readily-available test equipment.

3.5.3 Reverberation chamber

The reverberation chamber as described in 61000-4-21 FDIS should provide an economical solution for the manufacturer who wants to do in-house testing once a sufficient base of suppliers and know-how appears. If a reverberation chamber were only to be used above 300MHz then [1] it could be of dimensions 2.5m x 3 x 4 metres - capable of easy accommodation in a business environment. Such a chamber could also be used for immunity testing.

There are special advantages of a reverberation chamber for CISPR14-1:

* It solves the problem of testing extended sources and integral cables (eg Vacuum cleaners with powered brushes) and so would avoid special cases in the document
* CISPR14-1 already has a "power" based limit rather than a "radiated field" based limit

3.5.4 Development path

In the light of the matters discussed in 3.1, 3.2 and 3.3 the degree of extrapolation resulting from not testing at above 1GHz appears to be acceptable for the time being. In view of the rapid growth in the cellular telephone usage of the 1.8GHz band it is recommended in 1.2.2 that **a development path needs to be in place for extension to 2.5 GHz as soon as practical test methods are in place.** This need is a further argument against the extension of cable power measurement as discussed in 3.5.1 above.

4 Editorial Review

Editorial quality is concerned with the structure and content of a document and its use of language. Both aspects are of prime importance to its user-friendliness and freedom from ambiguity.

Furthermore it must be remembered that English will be a foreign language to many of the creators and users of a Standard

.

4.1 Conformance of Standards to Standards

The following are extracts from IEC Guide 107;

"6.3 Product family EMC standards…….
Product family EMC standards define specific electromagnetic (EM) requirements and test procedures dedicated to particular product families. They should indicate the relevant installation and operating conditions. They should also give precise performance criteria, taking into account the purpose of the equipment where possible. They should apply the basic EMC standards and be coordinated with the generic EMC standards to the extent practicable.
…….
Product family EMC standards…….
b) should not include detailed measurements, test methods, test set-up, etc. but should refer to the basic EMC standards where possible;
c) should not deviate from the basic EMC standards or only in exceptional cases and a justification should be given in the product family EMC standard.
…….
6.5 Comments on the application of the different types of EMC publications …….
c) Product family/product EMC standards take precedence over generic EMC standards. Product EMC standards take precedence over product family EMC standards. However, where neither product nor product family EMC standards exist for a particular group of products, the relevant generic standard should apply.
d) Product family/product EMC standards should be coordinated with the relevant generic EMC standards for the selection of test values. Where a product family standard specifies less stringent values than those specified in the generic standard, a justification should be given in the product family standard."

CISPR14-1 was first published in 1975 and so its structure and content pre-date the distinction between basic, generic and product standards. Whilst generally regarded as a "product standard" it does not conform to several of the above requirements for such a standard. It is not "co-ordinated with the generic EMC standards to the extent possible" and it does not include justifications for deviations. This is not too surprising since it pre-dates the structure, but standards should "practice what they preach" and themselves conform to standards just as they expect their users to conform. This is especially true when, as in this case, conformity would lead to substantial improvement in the ease of understanding the requirements.

CISPR14-1-1 should be thoroughly revised to bring it in line with the requirements of IEC Guide 107. See recommendation 1.3.3 above.

4.2 Aspects common to many Standards

There are a number of editorial steps that would lead to quicker understanding of the standard.

There are words having specific meanings within the standard that cannot be understood without reference to the "Definitions". For example "i.f. reference level" {3.2} sounds like a general purpose term but is impossible to understand in this context until one reads on to its definition {3.3}. All IEC and CISPR standards should print internally-defined words in a special typeface. In such

cases IEC60601 (safety of medical electrical equipment) already uses a special typeface. This is something that should be added in a co-ordinated way to all standards. See recommendation 1.3.2.

A general problem with the language of Standards is that at an early stage of drafting those involved are too close to recognise ambiguity or readability problems, and at a late stage nothing can be changed because reaching agreement to it is then too time-consuming and can raise issues about deliberate ambiguity. A number of people have commented that the process of translation int a second language is a good way to identify ambiguities, but this is not always carried out at a convenient time.

It should be a universal rule for IEC and CISPR standards that some native English speaker technically knowledgeable but outside the committee should review all committee drafts (CDs) and the committee required to accept the comments or state why they cannot. This may require specific funding. See recommendation 1.3.1 above.

4.3 Unique features of CISPR14-1

4.3.1 Navigation and understanding

Those who have to use CISPR14-1 for more than one product category - Company approvals managers, Trading Standards Officers, Test Houses - find it very difficult to determine exactly what tests should be applied in a specific case, and the reasons for that test profile are not then sufficiently clear for comfort. As an example of this the reader might like to work out from the standard the tests required for a full-size but inanimate Santa Claus figure, mains operated and including a ROM-based audio device that responded to a handshake.

Recommendation 1.3.4 is that an index is required, not only for general assistance but also specifically as a guide to verifying the scope {1} and the product-specific requirements {7}. There are at least 70 specific product types mentioned, and for some of these there are different requirements according to configuration or rating. Whilst the standard may be purchased as a computer-searchable .pdf file this is not sufficient since many words need to be found in their context.

IEC guide 107 states that *justifications* for deviations from generic requirements should be included. If such explanatory material is added to CISPR14-1 it will help the user, and may perhaps in some cases lead to the revision of the requirement. What is the justification for the various values of ***f*** given in Table A2? Does that justification apply to all technological variants of products of that type?

Standards should “practice what they preach” and themselves conform to standards just as they expect their users to conform.

CISPR14-1-1 should be thoroughly revised to bring it in line with the requirements of IEC Guide 107. See recommendation 1.3.3 above.

4.3.2 Editorial construction

The standard cannot be comprehended by simply reading it through line-by-line, since many definitions and prescriptions cannot be understood until a later definition or explanation is read. For example the paragraph “Individual switching operations” {4.2.3.1} contains 7 lines of definition before the statement “...is to be disregarded....”

The usage of “and“ and “or“ is rather loose; for example in the *normative* annexe **A** the counting of clicks from three-phase switches is subject to two conditions without use of either word to clarify which meaning is intended.

5 Annexes

5.1 Task programme

This report is based on consultations within the UK during January-April 2003. Some 50 people were chosen as representative of consumers, manufacturers, test houses and administrators. 25 of these participated in face-to-face discussions, and the remainder contributed by email or extended telephone interviews.

The names and affiliations of those involved are listed in the next section. The numbers in square brackets refer to the author's files, some of which are referenced in this report. Others are to be held confidential at the request of the contributor.

This report draws on the views of everyone concerned but its conclusions are those of the author.

5.2 Listing of sources consulted

Organisation	Name	Notes
Product users/retail		
Consumers Association	Malcolm Bassett [4], Roy Brooker ITS-RTC [12]	
Whirlpool Service	[24]	
Harpenden Domestic Appliances	[24]	
Cardiff Trading Standards	D Holland [6]	
- and many of the following in their personal capacities		
Radio users		
British Broadcasting Corp.	J Stott R&D [32]	
Radiocommunications Agency	N Waby [1], [22], [31]. M Lipscomb, Doug Raynes [20] W Martin, S Green (3G Services), B Bond, R Stanley, Ruzanna Jonck (PMR services), M Low (Spectrum Alloc) [5], Bharat Dudhia (Digital TV) [10]	
Radio Society of Great Britain	John Pink [26] D Lauder [26] R Page-Jones [31]	ex-Anritsu Univ. of Hertfordshire
Low Power Radio Association	Mike Brookes [33]	
Industry		
Lighting Industry Fed.,Thorn Lighting	Peter Archer	GEL210/11 [30]
Alstrom	G Conway	GEL210/11 [30]
EMC Ind. Assoc., Samsung	S Collough	GEL210/11 [30]
Marconi	D Eardley	GEL210/11 [30]
Assoc. Mfgs. Domestic Equip.	S MacConnacher [8]	GEL210/11 [30]
Electrolux	A Blades [8]	
Maytag	C Watson [8]	
Intellect	B Jones	GEL210/11 [30]
BEAMA	D Tyler	GEL210/11 [30]
Prof. Light & Sound Assoc.	J Woodgate [2]	GEL210/11 [30]
IABM	Simon Auty	GEL210/12 [31]
Burco Dean Appliances	Colin Tattersall [15]	
SMT-Seagoe Tech. Ltd. N Ireland	Ardar Bhabra [17]	
Rangemaster Ltd	David Reynolds [16]	
Brit. Nat. Com. Electroheat	A Koral [9]	GEL210/11
BEAMA-TACMA	K Tu [13]	
British Toy & Hobby Assoc.	AH McKenzie [18], Keith Lister [19]	
Hornby Hobbies	D Letley [21]	
Brit. Security Ind. Assoc.	A Carmichael	
Test Laboratories		
BSI Test, Hemel Hempstead	Daniel Griffin, Glen Wallis,Tim Hitch [3],[25]	EMCTLA
RA Whyteleaf Laboratory	P Burton [22], J Mellish, A Cook [23]	GEL210/11
Consultants		
ERA Technology	Tony Maddocks [1]	GEL210/12 [31]
Former CISPR Chairman	Gerry Jackson [28]	
Cherry Clough Consultants	Keith Armstrong [7]	EMCTLA
Elmac Services	Tim Williams [34]	
NPL	Luk Arno [1]	IEE Prof. Net EMC
BSI	J Childs [11]	GEL210/11
York Electronic Services	Chris Marshman [1]	IEE Prof. Net EMC
US Navy	Michael Hatfield [1]	
Literature		
BBC *White paper WH056* [32]	"Co-channel , echoes & impulsive interference"	
IEE Library Statistics [29]	*UK Telecommunications 2002.* Government Transport and comms. statistics	
"Radio Interference - a review" [28]	AS McLachlan et al. *Wireless World* June/July 1974	
BSI Library [14]	Early editions of BS800	
British Library	CISPR14-1 first edition	

5.3 Detailed editorial comments

It should be noted that these comments are not a planned part of the study, but have arisen and are therefore recorded. It is suggested that they be addressed during the next maintenance cycle.

1.1 ...whose main functions are performed by motors and switching...devices
should read
...whose main functions are performed by motors **or** switching...devices

2 *These normative references are duplicated in Annexe ZA and so one instance should be deleted*

3.15 "safety" *is miss-spelt at the third usage*

Table 1 *The terminal voltage of* 59 dB(uV) Average *given here in two places and in* Figures 1 and 2 *for 150kHz only was introduced in the 1985 second edition of CISPR14-1. This figure is 3dB more relaxed than that in the generic standard despite the quasi-peak figures being the same, and therefore deserves a clarifying justification.*

4.1.3 "..dispute ...measurements..are verified" *is very unclear. Does the text mean the close-in test is accepted, that it must be repeated, or that the test must be re-done at 10metres?*

4.2.3.3 *To ease the reader's task the three hyphened paragraphs should be clarified as* "and" *when first written, rather than by the subsequent paragraph* "If one of these..."

5.2.2.1 and 5.2.2.3 *The paragraph break between* "...provisions as above" *and* "However,..." *should be removed since it makes the meaning difficult to understand.*

5.3 *The use of* "shall" *implies that this is an essential requirement - which it is not in view of the alternative possibility in the second paragraph.*

7.2.6 "According to 4.1.2.4 these controls..." *should read*
"According to 4.1.2.4 **certain of** these controls..." *since 4.1.2.4 is not all-embracing*

7.3.1.19 7.3.1.20 *should be a new paragraph*

7.3.7.7 The note "limits...are not applicable" *should say* "limits...**may not be** applicable" *since 4.1.2.4 is not all-embracing*

7.3.7.8 and 7.3.7.9 *It is probably the intent that these paragraphs apply only to 50/60Hz devices: if so this should be stated.*

7.4.2.1 "Minimum observation time" *ought to be in the definitions*

7.4.2.3 "...switching operations (see 3.3)..." *should read* "...switching operations (see 3.**4**)..."

Annexe A *There should be* "and" *or* "or" *between sub-paragraphs* a) *and* b). *The present writer cannot decide which is intended.*

5.4 Comparison of radiated field and conducted power limits

The generic emission standard EN61000-6-3 specifies a quasi-peak field strength of 37 dBµV/metre at 300MHz at 10 metres distance for domestic and light industrial environment.

The following calculation takes the CISPR14-1 conducted quasi-peak power limit of 55dBpW at 300MHz for "household and similar equipment" and for "tools not exceeding 700 watts" and converts this into field strength for comparison with EN61000-6-3.

From *Electronic Engineers Reference Book* 6th Edition Page 49/3 the electric field **E** volts/metre at a distance **r** metres (in the far field) from an antenna of gain **G** fed with power **P** watts is

E = ((30*P*G)^0.5)/r

The parameters for the CISPR14-1 case are as follows;

- Assuming that the conducted power is perfectly matched into the cable as antenna then **P** = 55dBpW = 3.16*10^-7 watts. In practice there may be only 2 or 3 dB loss at those few frequencies where the cable and EUT system is near resonance.
- Assuming that the emission from the cable omni-directional, then **G** = 1. This is a best case; directivity is bound to *increase* emission by 1 to 3dB in some directions.
- **r** = 10 metres.

Hence **E** = 310 µV/m, that is 50dBµV/m

This is 13dB *above* the generic limit of 37 dBµV/m.

END