EMC STANDARDS

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On-site and In-situ EMC test methods

Helping you solve your EMC problems

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On-site and In-situ EMC Test Methods

Test methods suitable for testing emissions and immunity at sites other than a proper EMC test laboratory, including close-proximity tests with cellphones and the like

This version dated 10th January 2019

An earlier (2005) version of this document is published by the EMC Test Labs Association, www.emctla.com, as Technical Guidance Note No. 49 ('TGN49'), available from the 'Member's Area' at http://emctla.com/home/memberarea/tgns/

Examples of the use of these methods…

- For pre-compliance or diagnostic testing of equipment that will later be tested at a test laboratory for compliance to the EMC standards listed under the EMC Directive (89/336/EEC or 2004/108/EC).
- For generating test results to support an EMC Technical Construction File for compliance to 89/336/EEC, or when submitting a technical file to a Notified Body under 2004/108/EC.
- As part of the acceptance procedure for purchased equipment, systems, or installations.
- For diagnosing real-life interference problems (and for determining whether the source or the victim is most to blame).

Note: Where equipment or systems need to have high reliability; reliably withstand a variety of environments; or have an impact on legal metrology or safety (including safety-related and safety-critical) – these tests may not be adequate on their own. We can provide assistance on what to test, and how to test, in such situations.

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2. Introductory topics

2.1 Summary

There is, at this time, no EMC harmonised standard which can be used to demonstrate compliance with the EMC Directive 89/336/EC for EMC testing of industrial equipment whose physical parameters will not allow it to be tested on a normal test site or at its final location.

This standard is based on the industrial generic standards EN 61000-6-2 and EN 61000-6-4, and has been created by Cherry Clough Consultants to be used as a *minimum* basis by which industrial equipment whose physical parameters will not allow it to be tested on a normal EMC test site, can be approved using a Technical Construction File (TCF) under article 10.2 of the first edition of the EMC Directive, 89/336/EEC.

It should also be useful when using on-site tests as the basis for compliance with the 2nd edition of the EMC Directive, 2004/108/EC, with or without the involvement of a Notified Body.

When declaring compliance with the EMC Directive on the basis of on-site testing according to this standard (or any other on-site EMC testing methods), the EM phenomena that are tested, and the frequencies and test levels they are tested to, should correspond to the normal EM environment(s) that is(are) present at the intended operational location(s). Our website has a downloadable document on how to assess an EM environment.

Where high reliability, legal metrology or safety are concerned, the EM environment assessment should take account of all of the reasonably foreseeable EM phenomena and their worst-case frequency ranges, amplitudes and other characteristics (e.g. modulation frequencies, multiple interfering sources, etc.). We will be pleased to provide assistance with this.

An on-site test standard that could be used for all the EM phenomena that could possibly occur would be a huge document, so this standard restricts itself to the EM phenomena covered by the generic EMC standards EN 61000-6-2 and EN 61000-6-4. Please note that these will not always be sufficient, and a Competent Body or Notified Body would expect to see some evidence that an EM environment assessment had been carried out and that its results correlated with the on-site EMC tests actually carried out.

Before carrying out any of these tests, check that the EMC Competent Body (TCF route under 89/336/EEC) or EMC Notified Body (optional under 2004/108/EC) that it is intended to use is happy with the use of this standard. It is always best to involve the Competent or Notified Body as early as possible in a project, and follow their guidance, instead of simply presenting them with a finished test report.

This standard is written so that it may be used by people who are not already very familiar with on-site testing for EMC compliance. EMC testing experts might find it a bit wordy.

2.2 Scope

The limits and methods of measurement laid down in this standard apply to equipment may be specified by an EMC Competent Body as suitable for use as part of a Technical Construction File (TCF) under article 10.2 of the EMC Directive 89/336/EC.

These test methods may also be used for other purposes, as discussed above.

2.3 Normative references

EN 61000-6-2	Generic standards – Immunity for industrial environments
EN 61000-6-4	Generic standards – Emission standard for industrial environments
EN 61000-4-2	Electromagnetic compatibility (EMC) Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test
EN 61000-4-3	Electromagnetic compatibility (EMC) Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test
EN 61000-4-4	Electromagnetic compatibility (EMC) Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test
EN 61000-4-5	Electromagnetic compatibility (EMC) Part 4-5: Testing and measurement techniques – Surge immunity test
EN 61000-4-6	Electromagnetic compatibility (EMC) Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields
IEC 61000-4-8	Electromagnetic compatibility (EMC) Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test
EN 61000-4-11	Electromagnetic compatibility (EMC) Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests
EN 55011	Industrial, scientific and medical (ISM) radio-frequency equipment – Radio disturbance characteristics – Limits and methods of measurement
EN 55022	Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement

2.4 Definitions

Definitions related to EMC and to relevant EMC phenomena may be found in the EMC Directive 89/336/EC and CISPR publications. The definitions stated in the EMC Directive 89/336/EC take precedence.

The following definitions are used in this standard:

Port	A particular interface between the specified apparatus and the external EM environment
Enclosure port	The physical boundary of the apparatus through which electromagnetic fields may radiate or impinge
Cable port	A point at which a conductor or cable is connected to the apparatus. Examples are signal, control and power ports
Functional Earth port	Cable port other than signal, control, or power port, intended for connection to earth for purposes other than electrical safety
Signal port	Port at which a conductor or cable carrying information for transferring data is connected to the apparatus. Examples are data buses, communication networks, control networks
Power port	Point at which a conductor or cable carrying the primary electrical power needed for the operation (functioning) of an apparatus or associated apparatus is connected to the apparatus
AM	Amplitude Modulation
AMN	Artificial Mains Network (as defined by EN 55011). Other EMC standards (e.g. EN 55022) might refer to the same device as a LISN (Line Impedance Simulation Network) or as a V-Network

AV	Average, when applied to a detector (a CISPR-16 specified type of detector used in emissions measurements)
BCI	Bulk Current Injection, see EN 61000-4-6 and the Cherry Clough Consultants On-Site EMC Test Standard
CDN	Coupling Decoupling Network (as defined in EN 61000-4-6)
CNE	See CSS (strictly, a CNE emits a broadband noise-type output, unlike many other types of CSS which often have frequency comb-type outputs)
CRT	Cathode Ray Tube
CSS	Comparison Signal Source, used to verify the on-site performance of emissions test equipment and/or to qualify the antenna locations for radiated emissions testing. Alternative names for essentially the same device include: comparison noise emitter (CNE); comparison signal emitter (CSE); emissions reference source (ERS); emissions reference generator (ERG) and Reference Signal Generator (RSG). For on-site work where ambient noise is high, a CSS that has a ‘frequency comb’ type of output is often preferred as it is easier to distinguish between its emissions and the noise.
CW	Continuous Wave (an unmodulated RF waveform)
EM	Electromagnetic (usually assumed to cover the frequency range 0 - 400GHz)
EMC	Electromagnetic Compatibility: the ability of a device, equipment or system, to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment or without it’s operation being affected by adverse radiated or conducted emissions
EMCD	The Electromagnetic Compatibility Directive (89/336/EEC as amended). Full title: "Council Directive 89/336/EEC of 3 May 1989 on the approximation of the laws of the member states relating to electromagnetic compatibility. Published in the Official Journal of the European Community: L139, 23/05/1989 p. 0019 – 0026. Amended by directive 92/31/EEC (Official Journal L126 12.05.92 p.11) and 93/68/EEC (Official Journal L220 30.08.93 p.1) and incorporated by 294A0103(52) (Official Journal L001 03.01.94 p.263)." Also amended by 95/54/EC, 99/5/EC and other product-family directives. The EMC directive has been enacted in UK law by Statutory Instrument 1992 No 2372 EMC “The Electromagnetic Compatibility Regulations” 28 October 1992, and amended by Statutory Instrument 1994 No 3080 EMC “The Electromagnetic Compatibility (Amendment) Regulations 1994”, and also amended by Statutory Instrument 1995 No 3180 “The Electromagnetic Compatibility (Amendment) Regulations 1996”.
Emissions	Any unwanted signal which might possibly have an affect on any electrical or electronic device, equipment, system or installation, or software
ERG, ERS	See CSS
EUT	Equipment Under Test: the product, equipment, apparatus, system or installation that is to be tested, using this standard, at the on-site test site
Immunity	The ability of an electrical or electronic device, equipment, system or installation (or software) to function in the intended electromagnetic environment without unacceptable loss of functional performance
LISN	See AMN
QP	Quasi-peak (a CISPR-16 specified type of detector used in emissions measurements)
RF	Radio Frequency (usually considered to extend upwards in frequency from 150kHz)
RSG	Reference signal generator (another name for a CSS or ERS)
TCF	Technical Construction File, described in Article 10.2 of the EMCD

2.5 Description of locations

On site locations are usually factory-manufacturing areas, often in close proximity to other industrial equipment.

Examples of on-site locations are:

Indoor: manufacturing areas, semiconductor fabrication plants, power stations and other utilities etc.

Outdoor: water treatment plants, cranes, access platforms, airports, docks, etc.

2.6 Performance criteria

2.6.1 Introduction

The Performance Criteria are used in immunity testing to ascertain whether the equipment continues to perform as specified. Large industrial machines will have many different modes and outputs but will in general have only one primary function. (E.g. a steel mill produces rolled steel).

Assessment of the equipment under test will be based on the primary function e.g.

- Equipment under test becomes unsafe
- Primary function is aborted (e.g. steel mill stops making steel)
- Systems shut down
- Fluctuation of displayed control data.

2.6.2 Acceptance criteria

Criterion A: System continues to operate as intended

Examples of Criterion A: Interference signals do not produce any effects. Minor interference such as corrupted displays and or indicators, which do not affect the primary function, are acceptable.

Criterion B: System continues to operate after the test.

Examples of Criterion B: Parameter displays that vary but do not affect primary function are allowed. The primary function may vary but it must be recoverable by the operator, using the normal controls, without the equipment under test becoming unsafe.

2.7 Conditions during testing

The equipment shall be installed and operated as specified in the users installation and operating manuals.

Any deviations from the above must be agreed prior to the test with Cherry Clough Consultants and the deviations recorded in the test plan and test report.

2.8 Documentation

2.8.1 Test Documentation

Each on-site equipment test carried out under this standard must be accompanied by the following documents:

a. The Cherry Clough Consultants On-site EMC standard

b. The Basic Test Method standards (e.g. EN 55011, EN 61000-4-2, -4, -6, etc.)

c. The generic test standards (EN 61000-6-4 and EN 61000-6-2)

d. Calibration data for all the devices used to verify test equipment performance (e.g. comparison signal source, CSS, comparison noise emitter, CNE, or emissions reference source, ERS).

e. The EMC Test Plan for the equipment to be tested, which will detail…

- The boundaries of the equipment to be tested
- Start-up/shut down sequences
- Position of all RF sources
- Power, Control and Signal cables
- For each EMC test…
  - Position of test equipment
  - Test levels
  - Equipment under test operating modes
  - Performance and acceptance criteria

f. Plus any other information relevant to carrying out the test, remembering that the aim of the documentation is to be able to recreate the test exactly, at some time in the future, if required.

2.8.2 Test Report

The report should contain as a minimum the following information:

a. Introduction

- Reasons for carrying out the test
- Unique identification of the equipment under test
- Date of test

b. Details of EMC test equipment

- Calibration data
- Results of on-site equipment verification

c. Details of EMC test personnel

d. Test location

- Plan drawings
- Antenna locations
- Metal structures
- Operator positions

e. Test methods

- For each test carried out there must be enough information provided to allow the test to be repeated
- How the performance criteria were measured

f. Test Results

- Measurement data
- Equipment under test operating modes
- Observations

g. Examples of how the results presented are derived from the basic data in the form of antenna factors, uncertainty etc.

h. Photographs of the test set up

i. Conclusions

j. The EMC Test Report and all its associated documentation and computer data files must be retained at least until a favourable assessment of the TCF has been achieved from the EMC Competent Body. However, it is strongly recommended that the documents and data are stored and protected from damage for at least ten years after the last equipment supplied under that TCF has been delivered to its customer, in case of queries or investigations by EMC compliance enforcement agencies in Europe. Of course, they must be stored in such a way that they can easily be retrieved if the need arises.

2.9 Applicability

In some instances the testing of some ports can be impractical or unrealistic. In such cases the following dispensations will be accepted within the test plan.

2.9.1 Dispensation 1 – Ports that are entirely within the EUT

Where wiring and cabling is entirely enclosed within a metal cabinet, metal conduit or metal trunking, or other enclosed metal structures that are bonded to the site's common bonding network (often imprecisely referred to as 'grounding' or 'earthing') at *all* of their extremities and considered to be part of the equipment under test – then the ports associated with such wiring and cabling will be considered as being within the enclosure of the equipment under test and not tested, either for emissions or immunity.

2.9.2 Dispensation 2 – Mains power from an uninterruptible power supply

Where the equipment under test is supplied from a dedicated uninterruptible power supply (UPS), using screened cables or cables enclosed in dedicated metal conduit bonded to the site's common bonding network (often imprecisely referred to as 'grounding' or 'earthing') at *all* of their extremities – then no testing of the mains power port of the equipment under test (i.e. after conditioning by the UPS) is required, either for emissions or immunity.

However, the incoming mains supply port of the UPS should be EMC tested for both emissions and immunity (regardless of any EMC test evidence provided by the UPS manufacturer), with the UPS powering the equipment, under all operating conditions of both the equipment and of the UPS.

Where there are too many possible combined operating conditions of the UPS and of the EUT to test in a reasonable time, quick tests shall establish which combination of UPS and EUT operation creates the worst-case, and that combination shall be fully tested, for each type of EMC test in turn.

2.9.3 Dispensation 3 – Voltage dips, dropouts and interruptions

Equipment built of subsystems with the required immunity to voltage dips and fluctuations, or supplied from a dedicated uninterruptible power supply, can be excluded from the requirements of testing immunity to voltage dips dropouts and interruptions.

For example, the required immunity can be determined from an assessment of the design, or from the subsystem manufacturers EMC test reports.

2.9.4 Dispensation 4 – Surge protection

Ports for external cables which (according to the manufacturers instructions or actual site installation) can be longer than 30 meters, and all mains power ports, can be excluded from some or all of the requirements for surge immunity testing if the following conditions are met:

a. All ports are on purchased items of equipment which their manufacturers' EMC test reports show already meet all the surge test requirements for these ports.

b. Ports for which the user is required to fit suitable surge suppression to his installation.

c. Ports protected by surge suppression circuits designed to provide suitable protection.

d. For mains ports, where power is supplied by a continuous on-line double-conversion UPS that, when surge tested on its inputs, passes the tests and does not transfer any surge voltages to its outputs (according to its test report).

Whether the above conditions have been met can be determined from an assessment of the schematics for the equipment and design of the surge protection circuits, or from the EMC test reports of the purchased items of equipment.

Note that some surge protection measures may only protect against line-to-line surges, whilst others may only protect against line-to-earth surges. Where a surge suppression measure only controls one type of surge – only this type is covered by this dispensation.

3. Emissions test requirements

3.1 Introduction

The relevant harmonised standard, used as a guide, is EN 61000-6-4.

The test method and limits will not be followed exactly as specified in the standard, due to the environment in which the testing is taking place.

Section 4 describes how to apply these tests given the limitations of the test environment.

3.2 Acceptance criteria:

3.2.1 Line conducted emissions (AC mains)

Emission levels less than those detailed in EN 61000-6-4 (Table 1) when measured using the application criteria detailed in Section 4 or as agreed with Cherry Clough Consultants.

3.2.2 Radiated Emissions (Enclosure port)

Emission levels less than those detailed in EN 61000-6-4 (Table 1) when measured using the application criteria detailed in Section 4, or as agreed by Cherry Clough Consultants.

4. Application Notes for Emissions Measurements

Where an equipment cannot be tested at a test site specified in the basic standard, due to physical restrictions (size, power, services requirements etc), then the only available way to collect EMC performance data to present to an EMC Competent Body for evaluation against the protection requirements of the EMC environment – is to test the equipment in a non-standard test environment.

Where it is possible to test the equipment in its final location, then it is possible to use IEC/EN 55011 to test the equipment for emissions and for many products this may be a viable option.

However, the majority of industrial products are designed, manufactured, assembled and commissioned at their site of manufacture, before being dismantled and shipped to their final destination.

In practice, in order to ensure the equipment has the required performance for contractual and legal reasons, manufacturers require to verify the EMC emission performance of their equipment prior to shipment.

This appendix identifies the major issues associated with testing a equipment to the requirements of the basic standard EN 55011 (alternatively: IEC 55011; CISPR11) at a non-ideal location.

4.1 The personnel performing the tests

The non-standard nature of on-site testing and the subsequent requirement to make changes to the test plan, test levels and test methods, in order to resolve difficulties associated with the physical location of the test and operating requirements of the product under test, require the EMC engineer carrying out the test to have a high level of understanding of the test methods involved and the principles behind the test methods.

This kind of knowledge would normally be found in an EMC engineer having greater than five years experience of testing within a laboratory environment together with greater than one year's experience of testing products in a non-standard or development environment.

4.2 Test Plan and Test Report

It is likely that due to commercial and other considerations the EMC testing will be programmed to take place either alongside or on completion of the commissioning of the equipment.

In order to ensure that the equipment to be tested, test location, test equipment are available for the test to take place as scheduled, a test plan should be constructed that addresses all the following issues:

a. Scope of the document
b. Terms, definitions and references
c. Equipment description
d. General testing strategy
e. Worst-case measurements
f. Special EMC tests required by the contract
g. Variances from the standard test method
h. Emissions testing
i. Immunity testing
j. EMC testing criteria
k. Configuration of Equipment
l. Method of exercising the equipment under test
m. Monitoring the functional performance of the equipment under test
n. EMC tests to be performed
o. Reporting requirements

Where necessary the test plan or test report requirements for individual tests will be highlighted in the text below.

4.3 Verification of EMC test equipment prior to emission testing

By definition, on-site testing is not carried out in a test laboratory and the test equipment will have to be transported to the test site.

During transportation the equipment may become damaged and it is a requirement that the operation of the equipment be verified prior to each test.

The verification must have two parts:

- A visual check for damage during transport

  When the emissions test equipment has been delivered to the on-site test site and set-up ready for testing the equipment, a visual inspection of all the test equipment and their transport packaging should be carried out to verify that they have not been damaged in transit.

- A performance check using a calibrated signal source (CSS)

  The performance check of the emissions measuring equipment is best carried out using a comparison signal source, CSS, (or a comparison noise emitter, CNE, or emissions reference source, ERS) that has been measured on a test site meeting the requirements of EN 55011 immediately prior to the on-site test. The results of the CSS's calibration must be available at the on-site test site.

Further details of on-site performance checking methods are given below.

Descriptions of each of the on-site verifications carried out, including a judgement on whether the test equipment is verified to be functioning correctly, must be included in the EMC Test Report.

Equipment that is found to be damaged, or found not to perform as well as is required, must not be used for on-site tests – even if this means delaying the tests while the equipment is replaced, or repaired and recalibrated.

4.3.1 Verifying the conducted emissions equipment

Verifying the CSS and the spectrum analyser

The conducted emissions from the CSS (or CNE or ERS) to be used to verify the on-site conducted emissions test equipment should first be calibrated by measurement with the spectrum analyser to be used for the on-site tests, at a test site which fully meets the requirements of EN 55011 for conducted emissions. A short BNC-BNC cable should be used to connect the CSS to the analyser. The CSS used need not be the same unit as the one used to verify the radiated emissions equipment.

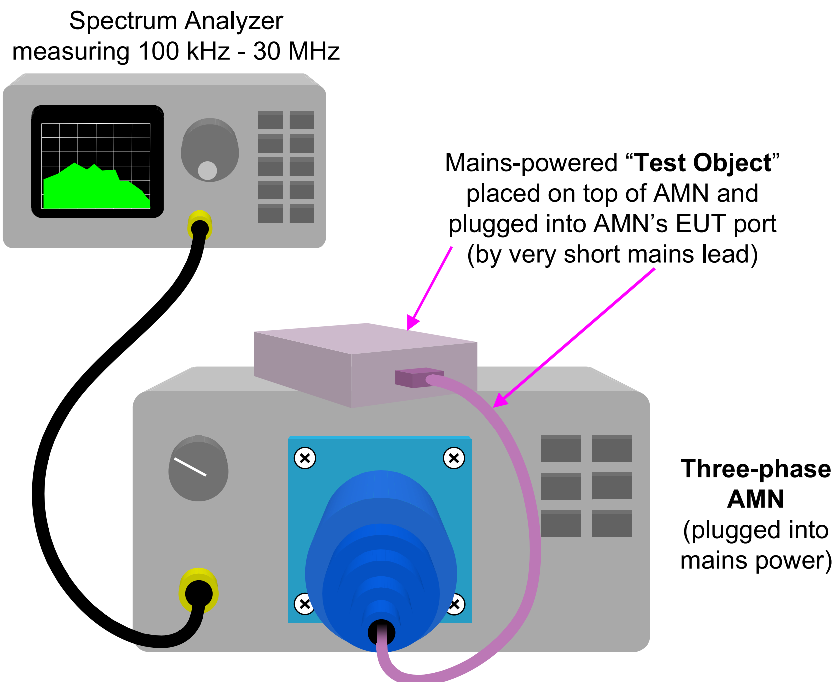
During the CSS's calibration, a peak detector must be used to measure the CSS's output voltage over the frequency range 150 kHz to 100 MHz. In addition: single calibrated measurements must be made with a Quasi-peak detector, and with an Average detector, at 5.000 MHz.

After the receiver or spectrum analyser has been unpacked at the on-site test site the output of the CSS must be measured directly by the receiver or spectrum analyser, using the same short BNC-BNC cable as for the original calibration. The measured levels must then be compared with the levels obtained from the CSS's most recent calibration at an EN 55011 test site to check that the spectrum analyser is working correctly.

If the result is the same (within ±2dB) as was originally measured at the EN 55011 test site, both the CSS and the spectrum analyser can be considered to be working correctly. However, if there is a problem it may be either the CSS or the spectrum analyser or the cable that is at fault. In this case, connect the RF signal generator's output to the input of the spectrum analyser with a different short cable and check to see if the analyser reads the same voltages and frequencies as output by the generator (within ±3dB and ±2% frequency). With these items and a process of elimination it will be possible to discover which equipment (or cable) is faulty.

Verifying the AMN

Figure A The test set-up for verifying the AMN



The AMN used for the conducted emissions measurements must first be calibrated at the EN 55011 test site, using a standard 'test object' as shown in Figure A. The test object can be anything suitable as long as it is always the same object, but usually a small switch-mode power supply with a fixed load is used.

Small switching power converters (e.g. 230Vac input, 12v 1A output driving a 12V lamp) can be purchased at low cost, but some testers use the battery charger of their CSS (with the CSS plugged in and charging at constant current). To improve repeatability the mains lead to the test object should be as short as possible (usually <200mm) and the test object should be placed on top of and in the middle of the AMN during its measurement.

The spectrum analyzer is set to measure from 100kHz to 30MHz using a 9 or 10kHz RBW and the peak detector only. For a single-phase AMN the emissions onto the Phase and Neutral leads are measured, but in the case of a three-phase AMN it is sufficient to measure just one of the Phases plus the Neutral.

When the test equipment has been unpacked at the on-site test site, and after the spectrum analyser has been verified to be working correctly, the same test object is measured by the AMN in exactly the same way as before. Differences of more than ±3dB indicate a problem with the AMN.

Verifying the voltage and current probes

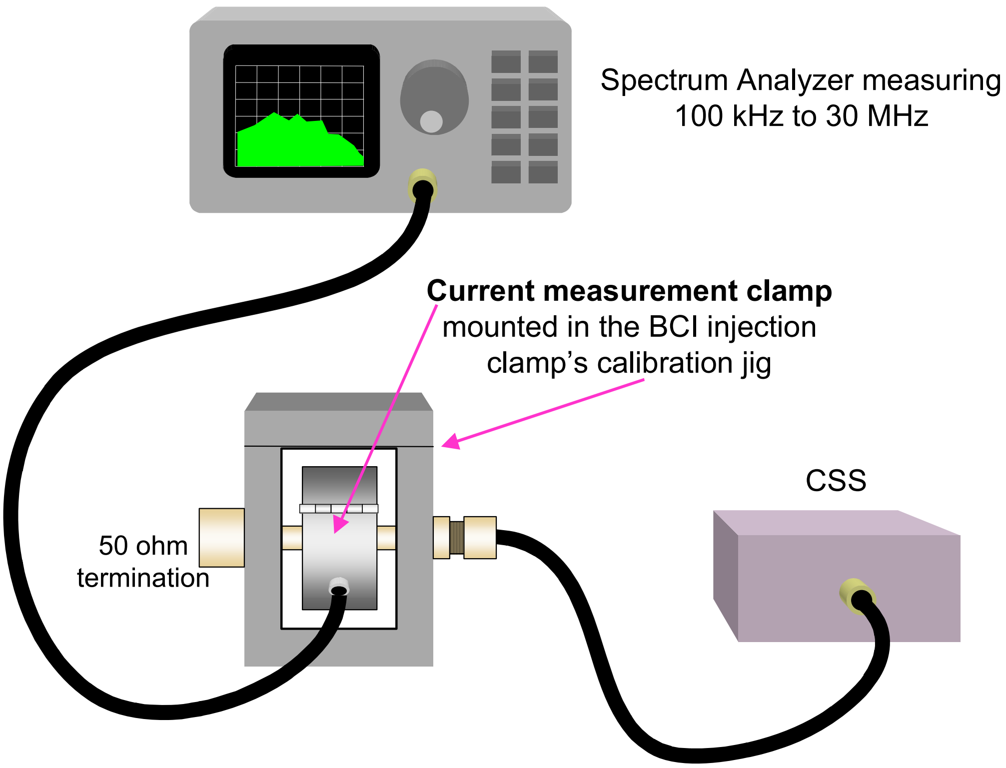
If voltage and/or current probes are to be used for conducted measurements, these should also be verified using the CSS, firstly at an EN 55011 conducted emissions test site and then at the on-site test site.

The voltage probe is used to measure the BNC output of the CSS directly, with the probe's output measured by the spectrum analyser over the 100kHz to 30MHz frequency range. No figure is given here for this set-up.

A current probe (usually called a current measurement clamp) is also used in BCI testing (see section 15). Although they will often be the same clamp, they could be different units.

The current measurement clamp is installed in the calibration jig which is used for verifying BCI current injection clamp. The calibration jig is supplied with a reference signal from the BNC output of the CSS, and the output of the current measurement clamp is measured by the spectrum analyser over the 150kHz to 30MHz frequency range, as shown by Figure B.

Figure B Verifying the current measurement clamp



The output from an RF signal generator could be used instead of a CSS to generate the reference signal for the calibration jig. In this case verification at one frequency point per decade is sufficient as long as the minimum (150kHz) and maximum (30MHz) frequencies are also verified.

If the current measurement clamp is also to be used for immunity testing (see 15.3.8), time will be saved by measuring it and verifying its performance over the range 150kHz to 400MHz (or whatever is the highest frequency to be used in the immunity testing) and also including 30MHz as one of the measured frequencies.

For both clamps, the measurement made in a test laboratory (ideally when the equipment has recently returned from calibration and has not yet been used for testing) is compared with exactly the same measurement made the on-site test site, prior to testing the equipment to be tested. Errors of less than ±3dB are acceptable when verifying either probe.

Documenting the verifications

The EMC Test Report must record whether the verifications showed that the conducted emissions test equipment was judged to be working correctly after shipment to the on-site test site.

All the results (including copies of the spectrum analyser's displays) from these verifications must be saved, with unique identifications which are recorded in the Test Report so they can be referred to later on, if necessary.

4.3.2 Verifying the radiated emissions equipment

The radiated emissions from the CSS (or CNE or ERS) to be used to verify the on-site radiated emissions test equipment must first have been calibrated by measurement with a peak detector at a test site which fully meets the requirements of EN 55011 for radiated emissions, at a distance of 3 m, with one antenna polarisation.

The CSS used need not be the same unit as is used for verifying the conducted emissions test equipment.

During the CSS's calibration, a peak detector must be used to measure the CSS's radiated emissions over the full frequency range (30 MHz to 1000 MHz). In addition a single calibrated measurement must be made with a Quasi-peak detector at 100.0 MHz.

The results of this process will be a graph of calibrated CSS emissions versus frequency plus one spot frequency Quasi-peak measurement, for one antenna polarisation.

After the receiver or spectrum analyser and antennas have been unpacked at the on-site test site the CSS's radiated emissions must be measured by setting up an antenna 3 m away from the CSS and measuring using the receiver or spectrum analyser. Care must be taken to set up the CSS and antenna as far from walls and metal objects as possible, to get as close to an EN 55011 test site as possible. Use the same antenna polarisation as for the original CSS calibration.

The graph of the measured peak detector levels over the whole frequency range (30 to 1000 MHz) must then be compared with the graph from the CSS's recent calibration on the EN 55011 test site.

The Quasi-peak detector result at 100.0 MHz must be compared with the same measurement from the CSS's recent calibration on the EN 55011 test site.

The results of these comparisons must be recorded in the EMC Test Report, including a judgement as to whether the radiated emissions test equipment has been verified to be working correctly.

4.3.3 Verifying leads and cables

Leads and cables are easily damaged and should be visually inspected when unpacked on-site. Look especially for crushed or bent cables, damaged or loosened connectors, etc. Suspect cables should not be used.

RF cables can be tested by connecting between the signal generator or CSS and the spectrum analyser, as described for the attenuator verification above. Cables used at radio frequencies are all lossy, especially at high frequencies and especially if they are long. But all such cables will have been calibrated and any which attenuate more than 3dB more than expected at any frequency should not be used.

4.4 Conducted Emission Testing

4.4.1 Requirements for Test Plan and Test Report

a. The power cables to be measured

b. Choice of measurement method (with justification):

    Artificial Mains Network (AMN)

    Voltage probe

    Current measurement clamp

c. Choice of measurement receiver (if not using the instrument detailed in basic standard with justification for use in this test).

Post processing requirements to refer measured results to limit in basic standard (e.g. AMN calibration factors; compensation for the losses in any transient limiting device between the AMN and the receiver or spectrum analyzer; cable factors; calculations on the results from the voltage probe or current measurement clamp).

Note that, in general, sufficient information must be provided in the EMC Test Report and its associated documentation and computer data files to:

i. Be able to repeat the test on the equipment exactly, at any date in the future

ii. Show that the equipment's worst-case emissions were below the limit set by EN 61000-6-4.

4.4.2 Detector types

EN 55011 requires measurements to be carried out with a receiver and quasi peak and average detectors meeting the requirements of CISPR 16-1.

Issue	The equipment's operation and other factors may constrain the time available for measurement. In such cases the use of a CISPR receiver with quasi peak and average detectors may be unrealistic due to the time taken by the measurement.
Guidance	Other measuring instruments (spectrum analysers) can be used provided the measurements can be correlated with a CISPR receiver and the quasi-peak and average detectors. A peak detector always measures greater than or equal to a quasi-peak detector. So if the quasi-peak emissions specification is met when using a peak detector, it may be claimed that the quasi-peak specification was met. Peak and quasi-peak detectors always measures greater than or equal to an average detector. So if the average emissions specification is met when using a peak or quasi-peak detector, it may be claimed that the average specification was met.

Note: Spectrum analysers without a pre-selector can sometimes be overloaded in the high signal environments found in some on-site environments, making their measurements inaccurate. This can happen even when the high signals are outside the measuring range of the spectrum analyser.

Care must be exercised in ensuring the accurate measurement of signals in the presence of high-energy signals.

Connecting an external 10 dB attenuator (sometimes known as a 'pad') to the RF input of a spectrum analyser is a good way to check for overload. If RF overload is affecting the measurements, some or all of the measured signals will be reduced by significantly more than 10dB (e.g. 30dB) when the 10dB external attenuator is applied. But if overload is not happening the measured signals will reduce by 10dB.

4.4.3 Ambient noise

EN 55011 requires measurements to use an artificial mains network (AMN) to provide defined impedance at RF frequencies across the mains supply at the point of measurement, and also to help provide isolation from ambient noise on the power lines.

Issue: In practice the level of interference present on the power lines is likely to be considerably higher than that found in a typical EMC test laboratory.

Guidance. Switch off any equipment using the same power supply and verify ambient levels are below limits. Alternatively (or as well) fit an RF filter to bring the ambient levels below the limits.

Where the ambient noise is narrowband, vary the frequency span (and the resolution and video bandwidths too, if necessary) on the Spectrum Analyser 'zoom in' closer to the noise signals. The purpose of this is to make it easier to see if emissions from the equipment under test are being masked by ambient noise when using the normal span (150 kHz to 30 MHz).

Note: The intention of the test is to demonstrate that the conducted emissions are below the limits set out in this standard. This is demonstrated if the ambient levels are below the limit and the levels remain below the limit when the equipment under test is operating.

4.4.4 Using the Voltage Probe instead of an AMN

EN 55011 requires measurement of the mains terminal to be made using an artificial mains network (AMN) consisting of a 50 ohms / 50 µH artificial mains network as specified in CISPR 16-1.

The artificial mains network is required to provide a defined impedance at RF frequencies across the mains supply at the point of measurement and also to provide isolation from ambient noise on the power lines.

The voltage probe shown in Figure 4 of EN 55011 shall be used when the artificial mains network cannot be used.

Issue: In practice, artificial 50 ohms / 50 µH mains networks as specified in CISPR 16-1, with current ratings up to 100 amps, are expensive and difficult to transport.

Guidance: Whilst it is preferred that the conducted voltage measurement is done with an artificial mains network, the use of a voltage probe shown in Figure 4 of EN 55011 is acceptable.

Note 1: The measured result obtained with a voltage probe will depend upon the impedance of the mains power supply. It is acceptable to verify the mains power supply impedance by measuring the RF currents in the power supply by using a calibrated RF current measurement clamp, before referring the voltage probe measurements to 50 ohms by calculation.

Note 2: Where it is not possible to connect directly to the power supply, the RF currents can be measured with a calibrated RF current measurement clamp and converted to RF voltages by assuming 50-ohm supply impedance.

In practice, the power supply impedance will fluctuate over a wide range of impedances, leading to inaccuracies in the results that must be accounted for in any assessment of the equipment's performance.

Note 3: Voltage probes and current measurement clamps can give readings much higher than would be obtained from an AMN on the same equipment. Sometimes it is acceptable to note that the ambient is typical for the type of application of the equipment, and that the equipment does not appear to produce conducted emissions that noticeably worsen the ambient.

4.4.5 Identifying the worst-case modes of operation

Issue	EN 55011 requires the equipment under test to be operated in the normal operating modes which will cause the worst-case emissions, when its emissions are tested.
Guidance	Perform 'quick tests' using the peak detector to identify which mode of operation (or reasonable combinations of operational modes) create the worst-case conducted emissions, for each of the mains cables to be tested.
	When the worst-case modes of normal operation have been identified, for each mains cable to be tested, these must be the modes that are used for the final conducted emissions testing.

4.5 Radiated Emission Testing

4.5.1 Requirements for the Test Plan and Test Report

Detail the location of major sources of RF energy associated with the equipment under test in terms of frequencies and power levels.

Detail initial choice of emissions measuring antenna locations.

Describe how the worst-case emissions locations for the measuring antenna were identified.

Record the choice of measurement receiver and antenna (if not the instruments detailed in basic standard) with justification for use in this test.

Detail the post processing requirements to refer the measured results to the limits (e.g. antenna factors, cable factors, correction for distance, correction for non-ideal site, etc.).

Note that, in general, sufficient information must be provided in the EMC Test Report and its associated documentation and computer data files to:

i. Be able to repeat the test on the equipment exactly, at any date in the future

ii. Show that the equipment's worst-case emissions were below the limits in EN 61000-6-4.

4.5.2 Detector types

EN 55011 requires measurements to be carried out with a receiver and quasi peak detector which meet the requirements of CISPR 16-1

Issue	The equipment's operation and other factors may constrain the time available for measurement. In such cases the use of a CISPR receiver and quasi peak detector may be unrealistic due to the time taken to perform the measurements.
Guidance	Other measuring instruments (spectrum analysers) can be used provided the measurements can be correlated with a CISPR receiver and the quasi-peak detector.
	A peak detector always measures greater than or equal to a quasi-peak detector. So if the quasi-peak emissions specification is met when using a peak detector, it may be claimed that the quasi-peak specification was met..
Notes:	Spectrum analysers without a pre-selector can sometimes be overloaded in the high signal environments found in some on-site environments, making their measurements inaccurate.
	This can happen even when the high signals are outside the measuring range of the spectrum analyser.
	Care must be exercised in ensuring the accurate measurement of signals in the presence of other high-energy signals.

Connecting an external 10 dB attenuator (sometimes known as a 'pad') to the RF input of a spectrum analyser is a good way to check for overload. If RF overload is affecting the measurements some or all of the measured signals will reduce by significantly more than 10dB (e.g. 30dB) when the external 10dB attenuator is applied. But if overload is not happening the measured signals will reduce by 10dB.

4.5.3 Measurement distance

EN 55011 requires measurements to be carried out with 30m distance from the measuring antenna to the equipment under test.

Issue — Physical constraints or high ambient levels on the site are unlikely to allow measurements at 30 m

Guidance — If the field-strength measurement at 30 m cannot be made because of high ambient noise levels, or for other reasons, measurement may be made at a closer distance, for example 10 m or 3 m.

An inverse proportionality factor of 20 dB per decade of distance should be used to normalise the measured data to the specified distance for determining compliance. (For example, reducing the antenna distance from 30 m to 10 m means an increase of 10 dB in the emissions limits set by EN 61000-6-4. Reducing from 30 m to 3 m means in increase of 20dB in the emissions limits set by EN 61000-6-4.)

Care should be taken in the measurement of large apparatus at 3 m distance at frequencies near 30 MHz, due to near field effects which will tend to increase the measured result.

4.5.4 Measurement frequency span and bandwidth

Issue — Sometimes emissions from the equipment under test are masked by ambient signals which are higher than the emission limits (modified to suit the antenna distance, where necessary) for the equipment under test. This is often the case for licensed analogue radio or TV transmitters, when the spectrum analyser display is set to the normal span (30 MHz - 1000 MHz) and the resolution bandwidth is set to 120 kHz.

Guidance 1 — Where the above problem exists and a Spectrum Analyser is being used for the measurement, it is often possible to use its span and bandwidth controls to 'zoom in' closer to the ambient signals to determine whether there are emissions from the equipment under test in close proximity to the ambient signals.

Where an emission from the equipment under test is so close to an ambient signal that automated quasi-peak measurement routines do not correctly measure the equipment's emission manual quasi-peak measurement using 'zero-span' mode may help.

Refer to the spectrum analyser's User Manual for more instructions on the above.

Guidance 2 — Sometimes a narrowband emission from the equipment under test coincides exactly with a narrowband ambient signal and is impossible to detect or measure. But it is sometimes possible to infer its existence from the presence of other narrowband emissions.

For example: if narrowband emissions are detected from the equipment at 25.0, 50.0, 75.0, 125.0, 150.0, and 175.0 MHz, and there is an FM radio broadcast station located at 100.0 MHz it is very likely that the equipment also has an emission at 100.0 MHz.

In such cases it is usually reasonable to conclude that if every one of the 25.0, 50.0, 75.0, 125.0, 150.0 and 175.0 MHz emissions are underneath the limit line, the 100.0 MHz emission must be too.

4.5.5 Assessing non-ideal test sites

EN 55011 requires on-site measurements to be carried out with the centre of the antenna set at 2.0 m +/- 0.2 m height above a conducting ground plane.

It also requires the test site to be flat, free of overhead wires and nearby reflecting structures, and sufficiently large to permit adequate separation between the equipment under test and the measuring antenna locations.

Issue 1 — Often, the on-site location will not meet the above test site requirements. Although the antenna height is usually achievable, the rest of the above requirements are often not met.

Guidance 1 — A comparison noise emitter (CNE), comparison signal source (CSS), or emissions reference source (ERS) must first have been measured in both horizontal and vertical polarisations, at distances of 3 m and 10 m, over the frequency range 30 to 1000 MHz on a test site fully meeting the requirements of EN 55011.

Before each final on-site measurement at each antenna location, the CNE, CSS or ERS shall be placed on the equipment under test at its nearest point to the antenna and the output of the CNE recorded over the frequency 30 to 1000 MHz in both horizontal and vertical polarisations. (The equipment under test must be switched off during this measurement, but otherwise it and its cables must be set up exactly as it will be for the final test.)Comparison of the data from the above two measurements (the EN 55011 site and the equipment on-site) will allow a qualitative assessment of each measurement antenna location.

Assessment of the above results could indicate that correction factors (which depend on frequency) should be applied to the measurement so that the emissions from the equipment can be sensibly compared with the radiated emissions limits set by EN 61000-6-4.

If the equipment under test is moveable or mobile (e.g. if it is a vehicle), the test site's performance should be measured at each of the antenna locations to be used on the final test, measuring the test site with the CNE, CSS or ERS without the equipment to be tested or its cables anywhere nearby (ideally more than 30 meters away).

In such cases the antenna locations and directions must be accurately marked by durable paint or tape on the floor, so that they can be recreated exactly when the equipment under test has been moved into its final testing position.

Note 1 — If the equipment under test is mobile or moveable (e.g. if it is a vehicle, or can be transported on one) it may be able to move it to a location where the reflections from metal objects and surfaces create less error in the measurement. If possible, any metal walls should be at least 10 m away from the boundaries of the equipment under test and from the measuring antennas.

Issue 2 — How should the EN 55011 measurement of the CNE, CSS or ERS be compared with the measurement of the same CNE, CSS or ERS at each on-site antenna location?

Guidance 2 — Ideally, the CNE, CSS or ERS results from an antenna location are keyed into a spreadsheet and subjected to a curve-fitting program (e.g. the 'Polynomial' program in Excel). This curve should then be compared with the EN 55011 test site results and a judgment made about whether the antenna location gives results which are useable.

But it is often possible to visually compare the on-site results from the CNE, CSS or ERS at an antenna location with its results from the EN 55011 test site, and make a quick qualitative assessment of the suitability of that location, for both vertical and horizontal polarisations.

Sharp peaks or troughs with heights or depths of more than 20dB when compared to the EN 55011 site results; troughs that go down to the noise floor of the measuring system; or ambient noise levels that prevent emissions at the level of the EN 61000-6-4 limits from being measured are indications of an unusable antenna location. (Refer to other parts of section 4.5 for measures for dealing with high levels of ambient noise.)

Where an antenna location is judged to be useable, frequency-dependant correction factors can be derived for that location (one for horizontal polarization and a different one for vertical) and used to correct the measurements of the equipment at that location. Such 'antenna location' correction factors must be applied in the same way as the correction factors for the antenna and for its RF cable.

Note 2a — CNE emits broadband noise which is often difficult to work with on typical on-site testing sites. It is generally easier to use CSS or ERS devices which emit a comb of narrowband frequencies.

Note 2b — Where the peak detector emissions measurements from the equipment under test, at a given antenna location, are lower than the limit set by EN 61000-6-4 (when any correction factors for the antenna location are taken into account) – there is no need to show detailed calculations in the final Test Report. Sufficient information to record the fact that such low levels of emissions were observed is all that is required.

4.5.6 Identifying antenna locations for the worst-case emissions

For an equipment under test that is not located on a turntable, the measurement antenna shall be positioned at various points in azimuth (i.e. various angles in the horizontal plane) and measurements made using both horizontal and vertical antenna polarisations.

Care shall be taken that measurements be taken in the direction of maximum radiation and the highest level at each frequency recorded.

Issue — How to determine the worst-case measurements with respect to azimuth from a large stationary equipment and hence determine the antenna placements for final measurements?

Guidance — Prior to the testing taking place the position of all interference producing electrical and electronic equipment within the equipment should be classified in terms of frequency and potential for producing emissions.

This data should be used to produce a test plan that locates the antenna positions at the most likely sites to receive the identified potential emissions. The presence of interfering signals can be confirmed by near field measurements using simple probes prior to antenna placement if required.

During the testing the antenna should be moved in azimuth about these positions to identify the worst-case emissions.

Also see below on identifying the worst-case modes of operation.

4.5.7 Identifying the worst-case modes of operation

Issue

EN 55011 requires the equipment under test to be operated in the modes which will cause the worst-case emissions, when its emissions are tested.

Guidance

Perform ‘quick tests’ at each of the likely antenna locations (see 14.5.5) using the peak detector to identify which mode of operation (or reasonable combinations of operational modes) create the worst-case radiated emissions.

The operational modes and antenna locations that are used for the final radiated emissions testing must be the ones that have been identified as producing the worst-case measurements.

The Test Report for a compliant equipment need only show how the worst-cases were identified, and that when the worst-cases were measured they were found to be under the EN 61000-6-4 limits.

4.5.8 Reducing test site ambients

Issue 1

The ambient noise levels of the test site should be at least 10dB lower than the limits to be measured to. But this is often not achievable when testing on-site.

Guidance 1

If the equipment under test is mobile or moveable (e.g. if it is a vehicle, or can be transported on one) it may be moved it to a location where the ambient noise levels are lower. Portable generators may be used to provide mains power at the new location.

Lower ambient noise levels will make it easier and quicker to perform emissions testing, and give more confidence in the results obtained.

Locations in the country, far from road traffic, railways, industrial or agricultural buildings, overhead telephone or power lines, airports, harbours, broadcast transmitters, military bases and cellphone base-stations are usually the best. Deserts, islands, or valleys (partially or totally surrounded by hills) are often the quietest locations.

5. Immunity test requirements

5.1 Introduction

The relevant harmonised standard, used as a guide, is EN 61000-6-2.

The test methods and limits will not be followed exactly as specified in the standard, due to the environment in which the testing is taking place.

Section 6 describes how to apply these tests given the limitations of the test environment.

Where the basic standards are listed as EN 61000-4-x, these can in all cases be replaced by the equivalent in the IEC series: IEC 61000-4-x

5.2 Enclosure port

Where practicable small assemblies, sub-assemblies and safety critical equipment should be removed to an ISO 17025 EMC test centre and tested in accordance with the basic standard.

5.2.1 Power-frequency magnetic field

Basic Standard	EN 61000-4-8 (always use the latest version of the standard)
Frequency	50 or 60 Hz as appropriate
Level	30 Amps/metre (A/M)

The test shall be carried out at the frequencies appropriate to the power supply frequency. Equipment intended for use in areas supplied only at one of these frequencies need only be tested at that frequency

Note: This test is only applicable to devices that are susceptible to magnetic fields, as described in EN 61000-6-2.

5.2.2 Electromagnetic fields

Basic Standard	EN 61000-4-3 (always use the latest version of the standard)
Frequency Range	80 MHz to1000 MHz
Level	10 V/m (prior to the application of modulation)
Modulation	AM, 1 kHz, 80%

Note: This test cannot be carried out on-site without breaking national law.

Alternative test methods are described in Section 6 of this standard.

5.2.3 Electrostatic Discharge

Basic Standard	EN 61000-4-2 (always use the latest version)
Level	±1 kV, ±2 kV, ±3 kV, ±4 kV Contact Discharge,
	±2 kV, ±4 kV, ±6 kV, ±8 kV Air Discharge, or as agreed by Cherry Clough Consultants

Note: Some alarm and security systems may require testing with up to ±6 kV contact discharge. This will be covered by the EMC Test Plan.

5.3 Signal, Data and Control Ports

5.3.1 Introduction

These tests include extended frequency tests to cover immunity of enclosure to radiated fields.

Note: Dispensations 1 and/or 2 (see section 3 of this standard) should be applied where practical and noted in the Test Report.

5.3.2 Frequency range 150kHz to 80 MHz

Basic Standard	EN 61000-4-6 (always use the latest version)
Level	10V rms (when unmodulated) common mode into 150 ohms, or as agreed with Cherry Clough Consultants
Modulation	Amplitude modulation, 1 kHz, 80%
Test Method	Bulk Current Injection, EM-Clamp, or CDN

5.3.3 Frequency Range 80MHz to 400 MHz

Spot frequencies or frequency bands between 400 MHz to 1000 MHz identified in test plan as representing practical threats on the present and future sites (e.g. fixed or mobile radio or radar transmitters or ISM equipment) – see section 6.5.

Basic Standard	EN 61000-4-6 (always use the latest version)
Level	10 V/m
Modulation	As identified in test plan.
Test Method	Bulk Current Injection, EM-Clamp, or CDN

Alternatively, test the immunity using radio transmitters or ISM equipment identified as being representative of the electromagnetic environment at the intended operational suite (see Section 6.5).

5.3.4 Fast Transients / Burst

Basic Standard	EN 61000-4-4 (always use the latest version)
Level	±0.5 kV and ±1 kV, or as agreed with Cherry Clough Consultants
Method	Capacitive clamp

5.3.5 Surge

Limitations	Only applied to cables that can, according to the manufacturer's specifications, be longer than 30 m
Basic Standard	EN 61000-4-5 (always use the latest version)
Level	±0.5 kV and ±1 kV line-to-earth, or as agreed with Cherry Clough Consultants
Method	Signal line to earth direct injection

5.4 Input and Output DC ports

5.4.1 Introduction

These tests include extended frequency tests to cover the immunity of the equipment's enclosure to radiated electromagnetic fields.

Notes: Dispensations 1, 2 and/or 4 should be applied (see section 3 of this standard) where practical and noted in the Test Report.

Section 6 gives guidance on application of the tests.

5.4.2 Frequency range 150kHz to 80 MHz

Basic Standard	EN 61000-4-6 (always use the latest version)
Level	10V rms (when unmodulated) common mode into 150 ohms, or as agreed with Cherry Clough Consultants
Modulation	Amplitude modulation, 1 kHz, 80%
Test Method	Bulk Current Injection, EM-Clamp, or CDN

5.4.3 Frequency Range 80MHz to 400 MHz

Spot frequencies or frequency bands between 400 MHz to 1000 MHz identified in test plan as representing practical threats on the present and future sites (e.g. fixed or mobile radio or radar transmitters or ISM equipment) – see section 6.5.

Basic Standard	EN 61000-4-6 (always use the latest version)
Level	10 V/m
Modulation	As identified in test plan.
Test Method	Bulk Current Injection, EM-Clamp, or CDN

Alternatively, test the immunity using radio transmitters or ISM equipment identified as being representative of the electromagnetic environment at the intended operational suite (see Section 6.5).

5.4.4 Fast Transients/ Burst

Basic Standard	EN 61000-4-4 (always use the latest version)
Level	±0.5 kV, ±1 kV, ±1.5 kV and ±2 kV, or as agreed with Cherry Clough Consultants
Method	Direct Injection

5.4.5 Surge

Basic Standard	EN 61000-4-5 (always use the latest version)
Level	±0.25 kV and ±0.5 kV, both line-to-line and line-to-earth, or as agreed with Cherry Clough Consultants
Method	Direct injection

5.5 Input and Output AC Power Ports

5.5.1 Introduction

This test includes extended frequency tests to cover immunity of enclosure to radiated fields.

Note: Dispensations 1, 2, 3 or 4 (see section 3 of this standard) should be applied where practical and noted in the Test Report.

5.5.2 Frequency range 150kHz to 80 MHz

Basic Standard	EN 61000-4-6 (always use the latest version)
Level	10V rms (when unmodulated) common mode into 150 ohms, or as agreed with Cherry Clough Consultants
Modulation	Amplitude modulation, 1 kHz, 80%
Test Method	Bulk Current Injection, EM-Clamp, or CDN

5.5.3 Frequency Range 80MHz to 400 MHz

Spot frequencies or frequency bands between 400 MHz to 1000 MHz identified in test plan as representing practical threats on the present and future sites (e.g. fixed or mobile radio or radar transmitters or ISM equipment) – see section 6.5.

Basic Standard	EN 61000-4-6 (always use the latest version)
Level	10 V/m
Modulation	As identified in test plan.
Test Method	Bulk Current Injection, EM-Clamp, or CDN

Alternatively, test the immunity using radio transmitters or ISM equipment identified as being representative of the electromagnetic environment at the intended operational suite (see Section 6.5).

5.5.4 Fast Transients/ Burst

Basic Standard	EN 61000-4-4 (always use the latest version)
Level	±0.5 kV, ±1 kV, ±1.5 kV and ±2 kV, or as agreed with Cherry Clough Consultants
Method	Direct Injection

5.5.5 Surge

Basic Standard	EN 61000-4-5 (always use the latest version)
Level	±0.5 kV, ±1 kV, ±1.5 kV and ±2 kV line-to-earth and ±0.5 kV and ±1 kV line-to-line, each at 0°, 90°, 270° of the mains cycle, or as agreed with Cherry Clough Consultants
Method	Direct injection

5.5.6 Voltage Dips / Voltage Interruptions

Basic Standard	EN 61000-4-11 (always use the latest version)
Level	Defined in test plan
Method	Defined in test plan

5.6 Functional Earth Ports

5.6.1 Introduction

This test includes extended frequency tests to cover immunity of the enclosure port to radiated fields.

Note: Dispensations 1, 2, 3 and/or 4 (see section 3 of this standard) should be applied where practical and noted in the Test Report.

5.6.2 Frequency range 150kHz to 80 MHz

Basic Standard	EN 61000-4-6 (always use the latest version)
Level	10V rms (when unmodulated) common mode into 150 ohms, or as agreed with Cherry Clough Consultants
Modulation	Amplitude modulation, 1 kHz, 80%
Test Method	Bulk Current Injection, EM-Clamp, or CDN

5.6.3 Frequency Range 80MHz to 400 MHz

Spot frequencies or frequency bands between 400 MHz to 1000 MHz identified in test plan as representing practical threats on the present and future sites (e.g. fixed or mobile radio or radar transmitters or ISM equipment) – see section 6.5.

Basic Standard	EN 61000-4-6 (always use the latest version)
Level	10 V/m
Modulation	As identified in test plan.
Test Method	Bulk Current Injection, EM-Clamp, or CDN

Alternatively, test the immunity using radio transmitters or ISM equipment identified as being representative of the electromagnetic environment at the intended operational suite (see Section 6.5).

5.6.4 Fast Transients/ Burst

Basic Standard	EN 61000-4-4 (always use the latest version)
Level	±0.5 kV and ±1 kV, or as agreed with Cherry Clough Consultants
Method	Direct injection

6. Application Notes for Immunity Measurements

Where a equipment can not be tested at a test site specified in the basic standard due to physical restrictions (size, power, services requirements etc), then the only available way to collect EMC performance data to present to a competent body for evaluation against the protection requirements of the EMC environment, is to test the equipment in a non-standard test environment.

Where it is possible to test the equipment as individual subsystems to the requirements of EN 61000-6-2 and then building the system using good EMC manufacturing practice, this option should be considered.

However, most industrial equipment is manufactured from components and subsystems integrated into the final equipment at their site of manufacture before being dismantled and shipped to their final destination.

In practice, in order to ensure the equipment has the required performance for contractual and legal reasons, manufacturers should verify the EMC immunity performance of their equipment prior to its shipment.

This appendix identifies the major issues associated with testing an equipment to the requirements of the generic EMC standards at a non-ideal test site.

6.1 The personnel performing the testing

The non-standard nature of on-site testing and the subsequent requirement to make changes to the test plan, test levels and test methods in order to resolve difficulties associated with the physical location of the test and operating requirements of the equipment under test, require the EMC engineer carrying out the test to have a high level of understanding of the test methods involved and the principles behind the test methods.

This kind of knowledge would normally be found in an EMC engineer having greater than five years experience of testing within a laboratory environment together with greater than one year's experience of testing products in non-standard or development environment.

6.2 The Test Plan

It is likely that due to commercial and other considerations the EMC testing will be programmed to take place either alongside, or on completion of, the commissioning of the equipment.

In order to ensure that the equipment under test, test location and test equipment are available for the test to take place as scheduled, a test plan should be constructed that addresses all the following issues:

a. Scope of the document
b. Terms, definitions and references
c. Equipment description
d. General testing strategy
e. Worst-case measurements
f. Special EMC tests required by the contract
g. Variances from the standard test method
h. Immunity testing:
    - Equipment performance criteria
    - Configuration of the equipment
    - Method of exercising the equipment under test
    - Monitoring the performance of the equipment under test
    - EMC tests to be performed
i. Reporting requirements

Where necessary the test plan or test report requirements for individual tests will be highlighted in the text below.

6.3 Verification of immunity test equipment

By definition the testing is not carried out in a test laboratory and the test equipment will have to be transported to the test site.

During transportation the test equipment may become damaged, so it is a requirement that the correct operation of the test equipment be verified prior to each on-site test. For a full set of on-site immunity tests, verifying the performance of the test equipment on-site before starting the testing can take up to two hours.

The verification of an item of test equipment, or of a complete test system, consists of two main parts:

i. A visual check for any damage during transport.

   When the immunity test equipment has been delivered to the on-site test site, a visual inspection of all the test equipment and their transport packaging should be carried out to verify that they have not been damaged in transit.

ii. A performance check using an appropriate method, as described in the subsections below.

Verification of the test equipment may require the construction of fixtures and the purchase or calibration of test equipment before travelling to the on-site test location. So always read the verification methods carefully right through at least one month before the final on-site tests are to be carried out, to leave time for any preparations or purchases to be made.

Descriptions of each of the on-site verifications carried out, including a judgement on whether the test equipment is verified to be functioning correctly, must be included in the EMC Test Report.

Equipment that is found to be damaged, or found not to perform as well as is required, must not be used for on-site tests – even if this means delaying the tests while the equipment is replaced, or repaired and recalibrated.

6.3.1 Verifying power-frequency magnetic field test equipment

Providing no damage or distortion has been done to the coils generating the field during handling and transport, it is enough to monitor the current flowing in them.

If the current is the correct value known to achieve the correct field with that coil construction, and the coil structure is not damaged or distorted, the magnetic fields are almost certain to be correct.

It is also possible to verify the magnetic field by using a magnetic field measuring device (a number are available commercially) or a test coil and AC voltmeter, oscilloscope, or low-frequency spectrum analyser. The magnetic field generating equipment should first have been measured prior to transport to the test site, and the measured field correlated with the mathematically-predicted field to confirm that both the generator and measuring device are functioning correctly. For added confidence, use a field measuring device that has been recently calibrated.

Include details of the on-site verification and a judgement on whether the test equipment is functioning correctly in the EMC Test Report for the equipment.

6.3.2 Verifying radiated immunity test equipment >400MHz

This test equipment will either be BCI, EM-Clamp, individual hand-held or mobile transmitters, or special equipment to simulate broadcast transmitters, base-stations, or ISM equipment (as defined in EN 55011).

To verify BCI test equipment, see the next section.

To verify EM-Clamp test equipment, use the same process as for BCI (below) but with the BCI injection clamp replaced by the EM-Clamp.

To verify hand-held or mobile transmitters, check that they can successfully make and maintain a call and that their batteries are fully charged. The electric fields that they emit at 10 cm distance in all three orientations (horizontal, horizontal at right angles, and vertical), where appropriate, should have previously been measured in a test laboratory and the results for each transmitter recorded in the Test Report.

To verify special equipment to simulate broadcast transmitters, base-stations, or ISM equipment (as defined in EN 55011) refer to the EMC Test Plan for the equipment. The possibilities are too numerous and varied to be covered here.

Include details of the on-site verification and a judgement on whether the test equipment is functioning correctly in the EMC Test Report.

6.3.3 Verifying conducted immunity test equipment 0.15 - 400 MHz

The BCI test equipment must be calibrated in a laboratory, as described in the later section, and the results of the calibration made available at the on-site test site.

The injection clamp's calibration jig must be available at the on-site test site, and measurements of the BCI test system made on-site using the laboratory calibration set-up as described in the later section.

To save time in the on-site verification it is not necessary to test all of the frequency steps during this on-site verification. The maximum and minimum frequencies (150 kHz and 400 MHz) must be tested, plus a sufficient number of other frequencies to give confidence in the test equipment – a minimum of one spot frequency test for each decade of the frequency range.

The BCI test equipment's measurements made at the on-site test site must be compared with its laboratory calibration results. The on-site verification is successful if these two sets of results differ by less than ± 3dB.

Include details of the on-site verification and a judgement on whether the test equipment is functioning correctly in the EMC Test Report.

6.3.4 Verifying electro-static discharge test equipment

Prior to visiting the site – ideally when the ESD gun to be used has just been returned from its most recent calibration and has not yet been used for any testing – a simple plastic ESD verification fixture must be constructed that holds the tip of the ESD gun at a fixed distance of 3 mm from an earthed metal plate. No part of the plastic fixture may be closer than 8mm to the tip's metal end, except for the part that holds the earthed metal plate.

The calibrated ESD gun's air-discharge tip is placed correctly in the verification fixture and the gun set to +1kV and operated. No discharge should occur at +1kV. The gun's voltage should be increased gradually until discharges just begin to occur. The voltage at which this happens must be recorded. The process must be repeated with negative test voltages, and then both positive and negative voltages with the contact discharge tip. The result will be a 'calibration test report' for that specific ESD verification fixture, for that specific ESD gun, which will just list the four voltages displayed by the gun (plus the humidity and altitude of the laboratory – or air pressure – at the time of the test) The identification code for the gun's ground lead, and its arrangement during the above tests, must also be documented in the fixture's calibration report.

The ESD verification fixture must be taken to the on-site test site along with the ESD gun, so it is best if the ESD verification fixture and its calibration report are always stored in the ESD gun's case, along with the gun's ground lead.

The same verification procedure as above is gone through at the on-site test location, using the same verification fixture and the same gun ground lead in the same arrangement. The voltages at which the gun has to be set for it just to begin to discharge to the earthed plate are recorded (for positive and negative voltages and with the air and contact discharge tips.

These four on-site voltages are compared with those obtained during the calibration of the verification fixture, and the differences noted. If the altitude and humidity of the on-site test site are known to be close to their values when the ESD fixture was tested in the laboratory, differences of ±300V are considered acceptable. But if they are not known to be the same, differences of ±600V may be considered acceptable depending upon the estimated differences in humidity and altitude.

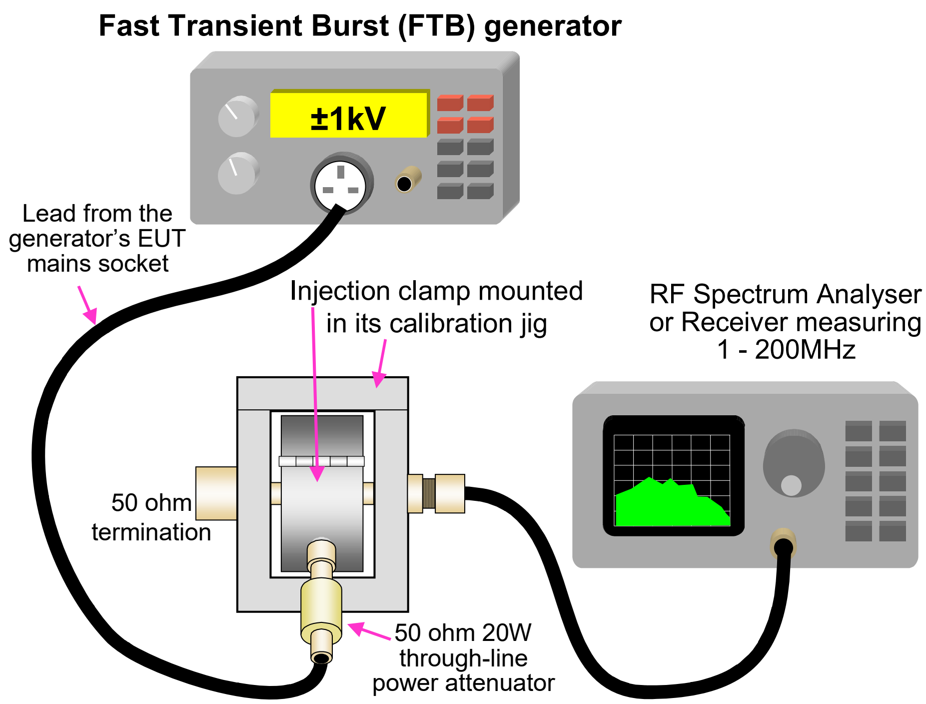
Include details of the on-site verification and a judgement on whether the test equipment is functioning correctly in the EMC Test Report.

6.3.5 Verifying fast transient burst test equipment

Before going to the on-site test site – ideally when the fast transient burst (FTB) generator to be used has just returned from its most recent calibration and has not yet been used for any testing – obtain a laboratory reference measurement for the FTB generator's direct output by injecting fast transient bursts at ±1kV into the FTB on-site verification fixture.

The FTB on-site verification fixture is simply the BCI verification system (see later), with its RF source (signal generator plus power amplifier) replaced by a lead and a 50 ohm RF power attenuator having at least 26dB of attenuation and capable of handling 1kV transient inputs. The lead connects the FTB generator's direct output to the RF attenuator, as shown in Figure C.

Figure C ***The FTB generator verification fixture***



The energy in the FTB generator's transients is low, but the voltage is high so the 50 ohm RF power attenuator will probably need to be rated for 20 Watts power so that it will handle the peak voltages. When selecting an attenuator, always check (using an oscilloscope) that the peak voltage at the output of the attenuator is exactly what you would expect given its attenuation specification with an input voltage of 1.2kV from the FTB generator.

The 50 ohm RF power attenuator and the loss in a typical BCI injection clamp should limit the peak amplitude at the spectrum analyser's input to about 1V and prevent the possibility of damage to the spectrum analyser's RF mixer stage. However, prior to the first test, it is recommended that data is obtained on the conversion factor (amps to volts) of the BCI clamp and the maximum input voltage of the spectrum analyser – and then calculations are done based on the FTB generators ability to source 1kV peak into a 50 ohm load, to check whether more than 26dB of RF attenuation should be used. (Note that a spectrum analyser's internal attenuation setting cannot be used to increase its maximum input voltage rating.

The FTB generator is set to output its transient bursts at its normal repetition rate and the spectrum analyser is set to 'peak hold' free-run mode for the frequency range 2MHz to 200MHz with either a 100kHz or 120kHz resolution bandwidth. The test is allowed to run until no significant further changes are observed in the measured spectrum (this should take much less than one minute). The resulting spectrum display is saved as the laboratory reference result to be used for on-site verifications. Two laboratory reference results will be saved, one for the +1kV and one for the -1kV FTB settings, and they should each record the full set-up details for the spectrum analyser.

The FTB verification fixture's lead, RF power attenuator and laboratory reference results must be taken to the on-site test site along with the FTB generator, so it is best if the lead, attenuator and laboratory reference results are always kept with the FTB generator.

When on-site, and after the BCI test system has been verified to be functioning correctly (see earlier), the same procedure as described above is gone through, using exactly the same FTB generator, lead, RF attenuator, BCI calibration equipment, and spectrum analyser settings, and the set-up of Figure A above.

The two spectrum displays obtained on-site (for +1 kV and -1 kV respectively) are then compared with the laboratory reference results, and the differences noted. If the differences are within ±3dB, the FTB generator is judged to be in full working order.

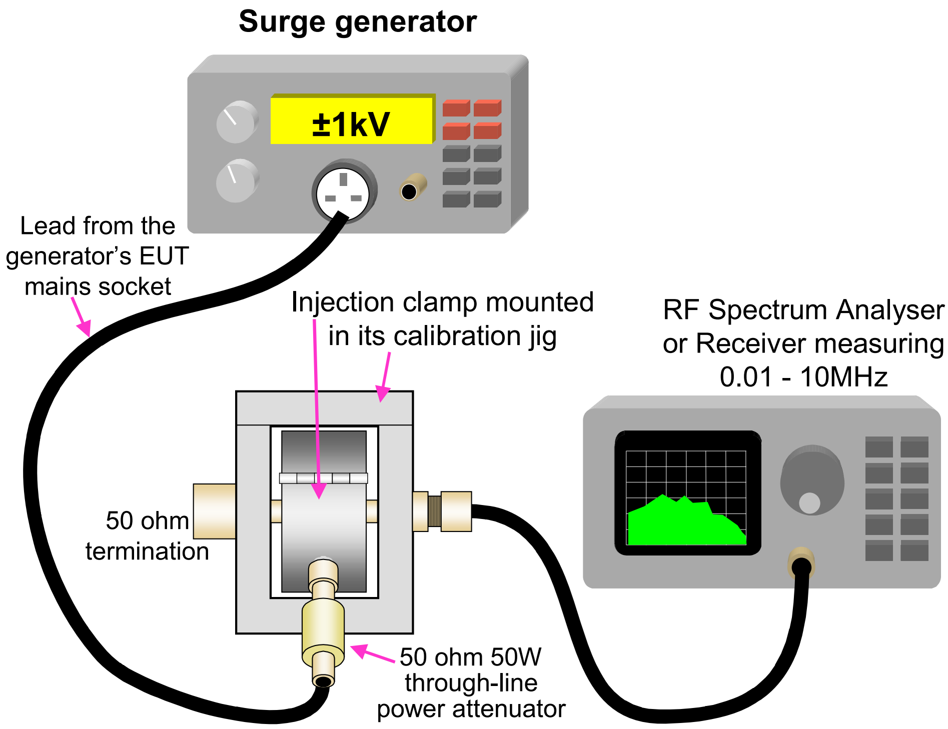
Include details of the on-site verification and a judgement on whether the test equipment is functioning correctly in the EMC Test Report.

6.3.6 Verifying the surge test equipment

A surge verification fixture is constructed and laboratory reference results obtained at ±1kV – and then used on-site for verification – in exactly the same way in every detail as for the verification of the FTB generator described above.

The only difference is that the spectrum analyser is set to measure the frequency range 10kHz to 1MHz with a resolution bandwidth of either 10kHz or 9kHz, plus it may take longer to obtain a reasonable spectrum display because the repetition rate of the surge generator is slower than that of the FTB generator. See Figure D.

Figure D The surge generator verification fixture



Include details of the on-site verification and a judgement on whether the test equipment is functioning correctly in the EMC Test Report.

6.3.7 Verifying mains dips and interruptions test equipment

A calibrated oscilloscope is used at the on-site test site (using test probes rated for safe use on mains voltages and taking all necessary safety precautions), to test the output of the dips and interruptions generator after it has been unpacked following its handling and transport to the site.

The oscilloscope's measured results for a number of the tests required by the test plan (a minimum of two very different generator settings) are compared with the settings on the generator, and the differences noted.

Include details of the on-site verification and a judgement on whether the test equipment is functioning correctly in the EMC Test Report.

6.3.8 Verifying the current measurement clamp

A current measurement clamp is used in BCI testing, and one may also be used in conducted emissions testing (see section 4). Although they will often be the same clamp, they could be different units.

The clamp which is to be used for immunity testing can be verified using exactly the same method as used for the clamp for conducted emissions testing, as described in 14.3.1 and Figure A, except that the measurement range must be from 150kHz to 400MHz.

If BCI testing is to be conducted above 400MHz, the measurement clamp must be verified up to the highest frequency used. If a signal generator rather than a CSS is used to create the reference signal, verification at one frequency point per decade is sufficient as long as the minimum (150kHz) and maximum (400MHz or higher) frequencies are also verified.

6.3.9 Verifying the RF attenuators

All the 'through-line' RF attenuators used for verifying the performance of the immunity test equipment tests should have also been verified at the on-site test site beforehand.

It is easy to test these attenuators by connecting the output of the signal generator or CSS to the input of the spectrum analyser, then adding the through-line attenuator in series and checking that the measured signal falls by the expected amount over the whole measured frequency range.

The spectrum analyser should be set to measure the frequency range from 100kHz to the highest frequency required by the Test Plan for the equipment to be tested.

When the signal generator is used, it can be set to sweep repeatedly over the same frequency range as the spectrum analyser, but spot-frequency measurements at the maximum and minimum frequencies to be tested will be sufficient.

The maximum error permitted is ±1dB from the attenuator's attenuation specification.

Include details of the on-site verification and a judgement on whether each attenuator is functioning correctly in the EMC Test Report.

6.4 Power-frequency magnetic field immunity testing

This test is only applicable to devices susceptible to magnetic fields (as described by EN 61000-6-2).

Consideration should be given to testing such devices separately prior to integration into the final equipment and detailing these actions within the Technical Construction File.

6.4.1 Requirements for the Test Plan and Test Report

The following specific information should be detailed in the test plan:

- List all devices susceptible to magnetic fields and their location within the equipment.
- Detail the test methods and test levels used.

Note that, in general, sufficient information must be provided in the EMC Test Report and its associated documentation and computer data files to:

a) Be able to repeat the test on the equipment exactly, at any date in the future.

b) Show that the equipment's functions remained within their normal functional performance specifications during this test (taking into account the accuracy and repeatability of the instruments used to measure the equipment's functional performance).

6.4.2 Using alternative test transducers

Issue

Testing of power magnetic fields is normally carried out using a Helmoltz Coil or similar transducer. While these tests can be carried out on site they are normally reserved for the testing of small equipment in test laboratories.

Guidance

Where the equipment is identified as being safety critical then it is strongly recommended that consideration is given to using the test methods exactly as detailed in EN 61000-4-8.

All devices and items of equipment which might be susceptible to power-frequency magnetic fields at 30 A/m should be identified from the design drawings for the equipment, and listed in the EMC Test Report.

Ideally, the devices or items concerned will be removed from the equipment, or identical units obtained, and tested in a representative functional circuit on a test bench, using the proper IEC/EN 61000-4-8 test method.

Where the above is not practical, use the alternative methods as described below.

Example Method:

Where a suitable coil with known characteristics is not available, design and make one instead. Calculate the number of turns in a portable single coil which will generate the required field level using the local power supply (or using a stepped-down voltage from a variable transformer or a safety-isolating transformer). Detail the coil's calculation in the Test Report.

Having obtained or constructed the coil and connected it to the local supply, move the coil over the surface of the equipment in the near vicinity of devices susceptible to magnetic fields and record any deviations from the equipment's performance in the test report. The plane of the coil should be parallel to the surface of the equipment during these tests.

The coil generates its designed magnetic field along its axis of rotation (i.e. along the coil's centre line), close to the plane of the coil. As a general rule, the field strength generated by single coil (regardless of how many turns of wire there are on the coil) will only remain within specification for a distance along the centre line of the coil equal to one-quarter of the coil's diameter. So a 1 meter diameter coil is only useable for a distance of up to 250mm.

Safety

Take all necessary safety precautions when constructing the coil, connecting it to the power supply, and using it. IEC 61010-1 is the relevant safety standard and its safety requirements must be followed in full.

Using an isolating step-down transformer with under 25Vac output would require the coil to have fewer turns of thicker wire than would be needed if the coil driven by the full mains voltage, but should eliminate many of the safety design issues associated with the coil itself.

Note:

Appendix A of EN 55103-2, and some military standards provide more information of the design of coils for magnetic immunity testing.

6.4.3 Where the equipment is large

Issue

Testing of power magnetic fields using a portable single coil is usually done at the boundaries of the equipment under test. At distances of more than one-quarter of the coil's diameter from the plane of a single coil, the generated field strength reduces to unacceptably low levels. So where the potentially susceptible device or item of equipment is inside a large equipment, it may be so far from the boundary of the equipment that it will not experience a sufficiently strong field from the test coil.

Guidance

When it is impractical to remove the device or item of equipment concerned, or use an identical part and test it using IEC/EN 61000-4-8, apply the alternative single-portable-coil method described above but place the coil inside the boundary of the equipment in such a way that it exposes the device or item to be tested to the necessary field.

The magnetic field generated by the coil is directional, along the coil axis. So, where possible, testing should be carried out with the coil arranged in three mutually perpendicular directions, one at a time, for each tested device or item.

6.5 Radiated RF electromagnetic field immunity testing

This test is designed to be carried out in an anechoic chamber. Normally national regulations do not allow the test to be carried out on-site, outside a shielded room, as the fields generated could disrupt equipment and communications in the locality.

When radiated immunity testing is not practical or permissible – the conducted immunity testing (which normally extends up to 80MHz) is extended to either 400 or 1000 MHz (see 14.7 below) – preferably to 1000MHz (1GHz).

Where the equipment has only been tested to 400MHz and is to be used in the vicinity of fixed transmitters or radars (e.g. radio or TV broadcast, paging, cellphone base stations, military bases, airfields or airports, harbours, etc.) – or mobile radio or radar transmitters (e.g. cellphones, mobile phones, walkie-talkies, handy-phones, vehicle mobile radio or radar including land, sea and air, etc.) – or ISM equipment as defined in EN 55011 – and where there is significant exposure from these at frequencies above 400 MHz – then the following should be applied….

a. The conducted immunity testing should be extended above 400 MHz at the frequencies identified, for all cable ports regardless of their length, where conducted injection transducers are available that will operate successfully at these frequencies and can be applied at the test site.

b. The equipment's installation requirements should detail that trials shall take place to confirm there is no degradation in the performance of the equipment with the identified transmitters or ISM equipment operating in close proximity to the equipment.

   In the case of mobile transmitters such as walkie-talkies, the actual devices that will be used on the site should be used to verify the lack of performance degradation. They should be operated on all channels and at full transmitter power, using modified handsets where required.

   Cherry Clough have a Test Method for the proximity of hand-held mobile radio transmitters and will be pleased to make it available.

Conducted immunity testing at frequencies above 80MHz is only a poor substitute for radiated immunity testing, and is progressively less useful as frequencies increase. This is because at such high frequencies joints in metalwork, printed-circuit boards and very short wires can become very effective antennas. So where conducted immunity testing has been carried out up to 1GHz, e.g. by using the EM-Clamp method as described in 14.7 below, it is recommended that point b) above is applied as well.

Where the site is exposed to fixed or mobile radio or radar transmitters that are sources of significant radiated fields (say, above 1V/m) and operate at frequencies above 1GHz or below 150kHz, the site testing should be extended to cover those frequencies in order to ensure compliance with the EMC Directive's Protection requirements, even though such frequencies are not covered by EN 61000-6-2 or EN 61000-4-3.

Cherry Clough have a guide to Assessing an Electromagnetic Environment which includes guidance on the levels to be expected from fixed and mobile radio and radar sources, and will be pleased to provide it on request.

6.5.1 Requirements for the Test Plan and Test Report

The following specific information should be included in the test plan:

- Frequency and power of any intentional radio or radar transmitters (fixed or mobile) or ISM equipment that might be used in close proximity to the equipment.
- The test method(s) used to verify that the equipment would continue to operate in the presence of the above transmitters or ISM equipment.

Note that, in general, sufficient information must be provided in the EMC Test Report and its associated documentation and computer data files to:

a) Be able to repeat the test on the equipment exactly, at any date in the future

b) Show that the equipment's functions remained within their normal functional performance specifications during this test (taking into account the accuracy and repeatability of the instruments used to measure the equipment's functional performance).

6.6 Electrostatic Discharge (ESD) immunity testing

The basic Standard EN 61000-4-2 allows the testing of equipment in its final configuration.

Section 7.2 and Fig 7 of EN 61000-4-2 give details of the test set-up.

6.6.1 Requirements for the Test Plan and Test Report

Section 8.3 of EN 61000-4-2 details the specific requirements for the Test Plan.

Section 9 of EN 61000-4-2 details the specific requirements for the Test Report.

Note that, in general, sufficient information must be provided in the EMC Test Report and its associated documentation and computer data files to:

a) Be able to repeat the test on the equipment exactly, at any date in the future.

b) Show that the equipment’s functions remained within their normal functional performance specifications during this test (taking into account the accuracy and repeatability of the instruments used to measure the equipment’s functional performance).

6.6.2 Testing issues

Issue	The standard refers to a post-installation test, not an on-site test.
Guidance	The test standard gives a test set up for ESD testing outside a laboratory (the post-installation test), so follow this test method as closely as possible when performing on-site testing.

Note that the post-installation test described in EN 61000-4-2 (which we will use as an on-site test) requires the use of a ground plane with dimensions at least 0.3 x 2 meters.

6.7 Conducted RF immunity testing

This testing is normally carried out over the frequency range 150 kHz to 80 MHz using the methods detailed in EN 61000-4-6. For the purpose of this test methodology standard the frequency range is extended to 400MHz using Bulk Current Injection (BCI) – or to 1GHz using the EM-Clamp described in EN 61000-4-6 – to replace the radiated immunity testing that would be illegal to perform outside of a shielded room (see above).

It may also be possible to extend the frequency range to at least 230MHz using CDNs, although special constructions of CDN may be needed above 230MHz and they should always be calibrated to prove their efficacy.

Where Dispensations 1 or 2 apply to any cable port (see section 3 of this standard) it is not required to be tested for conducted RF immunity.

6.7.1 BCI versus EM-Clamps and CDNs

CDN testing for mains and d.c. power cables, over the frequency range 150kHz to 80MHz, is a requirement of EN 61000-6-2 (and EN 61000-4-6). However, in some installed sites the use of a CDN might be impractical for a number of reasons…

i) The voltage of the cable might be much higher than the rating of the available CDNs

ii) It may be undesirable to cut a cable on a completed installation, to install a CDN

iii) There may be no access room to fit a CDN

In these situations testing using BCI should be used, as described below.

CDN testing above 80MHz, or EM-Clamp testing to 1GHz, using the method described in EN 61000-4-6, is strongly preferred for a number of reasons…

a) The variability of the test is very much lower, considerably improving test accuracy and repeatability.

b) The rating of the RF power amplifier required is less, reducing its size, cost and weight.

But it may not be possible to find CDNs that operate successfully above 230MHz, and there may be no room to employ a CDN on some installations.

The EM-Clamp is a long transducer and its use requires access to at least 600mm of accessible cable at the point where it enters the equipment to be tested. On some installations this is not possible, and the much shorter BCI transducers should be used instead simply because they are the only ones that can be fitted.

6.7.2 Requirements for the Test Plan and Test Report

Sections 8 and 9 of EN 61000-4-6 detail the documentation requirements for the test plan and test report.

Note that, in general, sufficient information must be provided in the EMC Test Report and its associated documentation and computer data files to:

a) Be able to repeat the test on the equipment exactly, at any date in the future.

b) Show that the equipment's functions remained within their normal functional performance specifications during this test (taking into account the accuracy and repeatability of the instruments used to measure the equipment's functional performance).

6.7.3 Using the CDN or EM-Clamp test methods

These test methods and their calibration procedures are fully described in EN 61000-4-6.

Where EN 61000-4-6 is lacking in some specific guidance for the EM-Clamp method, refer to the BCI test method described in the next section. It is reasonable to follow the BCI method with the BCI current injection transducer replaced by an EM-Clamp.

6.7.4 Using the Bulk Current Injection (BCI) test method

Issue

EN 61000-4-6 describes three methods of testing in order of preference:

1) CDN (Coupling-Decoupling Network)
2) EM-Clamp
3) Bulk Current Injection (BCI)

Guidance

While it is recognised that BCI is considered the least repeatable of the test methods, it is also the most flexible in that the current injection clamp can be clamped to cables in difficult orientations and the use of a second clamp (the measurement clamp) allows real-time control of the current injected into the equipment under test.

The BCI test equipment required:

- Signal generator covering the frequency range required
- Spectrum analyser covering the frequency range required
- 20dB RF 'through-line' attenuator rated 5 watts, suitable for the frequency range required.
- RF power amplifier covering the frequency range required, and rated at 200 watts rms at least
- RF current injection clamp covering the frequency range required
- RF current measurement clamp covering the frequency range required
- A 50 ohm calibration jig for the RF current injection clamp. Constructional details for suitable 50-ohm calibration jigs are given in IEC/EN 61000-4-6 Annex A and Figure A.2 but most people purchase them from the supplier of the current injection clamp.

The BCI test method:

1) Calculate the required current to be injected into the tested cable and detail the results in the Test Plan.

   It is generally assumed that electrical cables have an RF characteristic impedance (for their common-mode signals) of 150 ohms. So to convert a common-mode RF voltage specification to a current specification simply divide the voltage by 150.

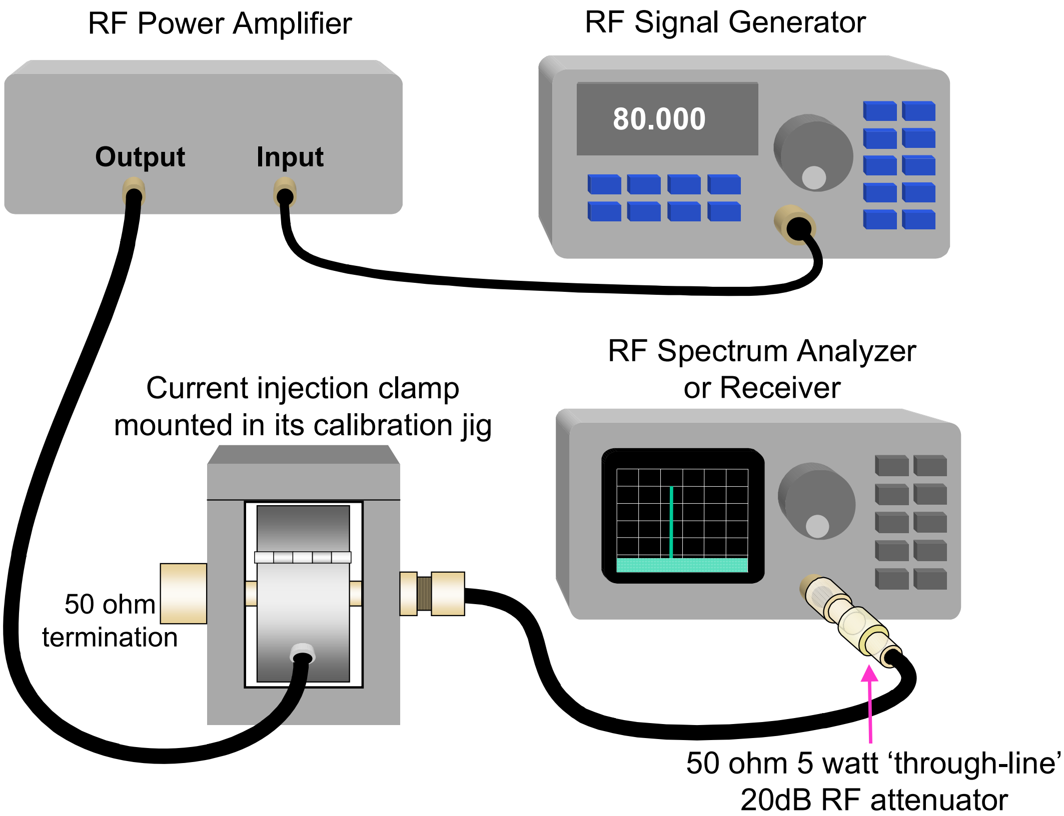
   So for the 10V rms radiated immunity test level required by EN 61000-6-2 the current to be injected into the tested cable would be 66.7mA rms (94.3mA peak) before the modulation is applied, and 170mA peak (340mA peak-to-peak) after the modulation has been applied .

   Where a radiated immunity test is being simulated by BCI, it is generally assumed that the test current should equal the Volts/meter specification divided by 150 ohms.

   So for the 10V/m radiated immunity test level required by EN 61000-6-2 the current to be injected into the tested cable would be 67mA (94.3mA peak) before the modulation is applied, and 170mA peak (340mA peak-to-peak) after the modulation has been applied .

2) Set-up the BCI test system in a laboratory according to Figure E (below) and calibrate it. This is best done when the test equipment has recently returned from its external calibration and has not yet been used for any testing.

Figure E ***The test set-up for the BCI system's calibration***



The BCI test system's laboratory calibration procedure is described in the three steps a) to c) below.

a. Record the models and serial number of the equipment used for the BCI calibration so that exactly the same equipment will be used for the on-site BCI testing.

Record the setting of the RF power amplifier's gain or level control (if it has one), and do not change it during the BCI calibration procedure.

Set the signal generator's output to be 80% amplitude modulated (AM) with 1kHz sinewave modulation.

Set the spectrum analyser to measure the level of the signal in milliVolts using the peak detector only.

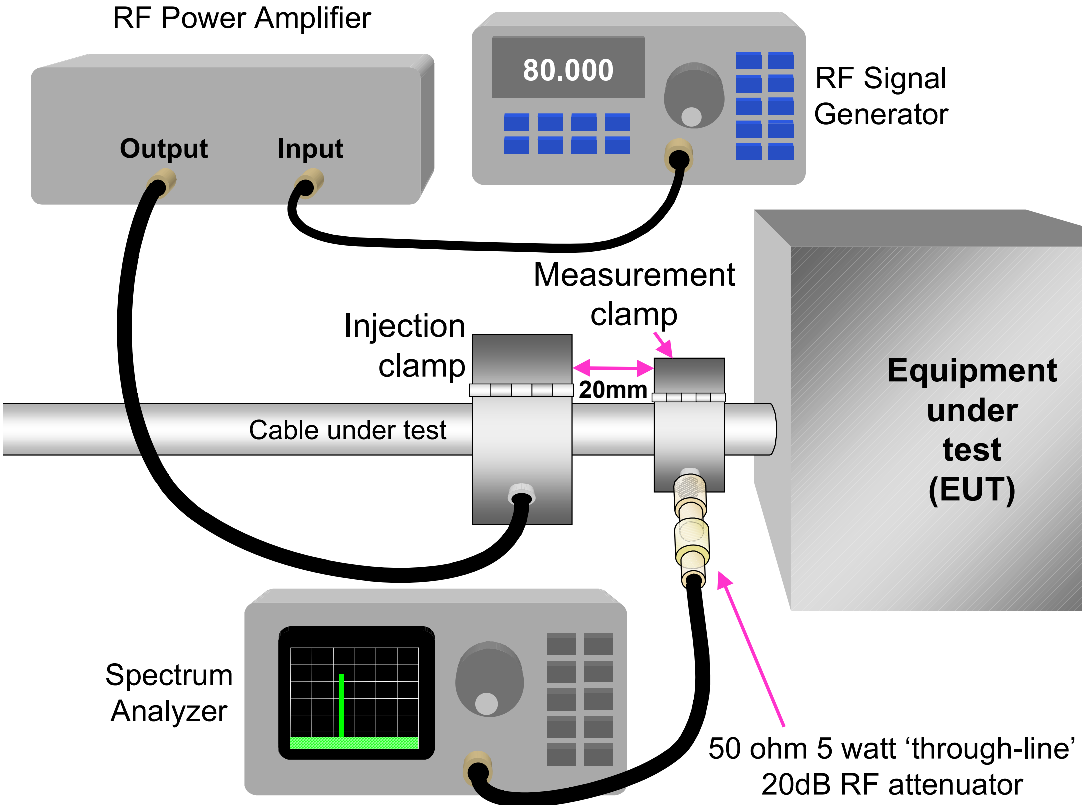
b. At each of the frequencies to be tested, adjust the output of the signal generator until the peak level of the injected current measured by the spectrum analyser is at the required level (e.g. 170mA, in the earlier examples), then record the frequency and the signal generator's output level.

Note: The spectrum analyzer measures one-tenth of the voltage that the injected current from the injection clamp gives rise to in the 50 ohm input impedance of the 20dB RF power attenuator. So the measured peak injected current is equal to the measured voltage on the spectrum analyzer divided by 5. For example: a 170mA peak injected current would measure 850mV on the spectrum analyzer.

c. Create a table that lists the signal generator's output setting, for each of the frequencies to be tested, for the desired level of injected current. Record on this table, the setting of the volume or gain control of the RF power amplifier, and all the model numbers and serial numbers for the equipment used.

3) The test set-up for BCI testing a cable port is shown by Figure F.

Figure F ***The set-up for BCI testing a cable port***



Fit the current measurement clamp onto the cable to be tested, as close as possible to the point at which the cable enters the equipment under test. Ensure that the cable to be tested is located centrally inside the clamp, using pieces of non-conductive plastic foam or rubber if necessary.

Next, fit the current injection clamp to the cable to be tested, approximately 20 mm from the current measurement clamp. As before, ensure that the cable is centrally located within the clamp.

Using exactly the same items of equipment as were used for the BCI's calibration, connect the output of the signal generator to the input of the RF power amplifier, and connect the output of the RF power amplifier to the input of the current injection clamp.

Set the RF power amplifier gain or level control to the same setting as was used for the BCI's calibration. Connect the spectrum analyser or receiver to the output of the current measurement clamp

4) To test a cable port – at each of the frequency steps to be tested,

a. Set the signal generator's output to the level previously determined by the BCI's calibration for that frequency.

b. Monitor the actual RF current in the cable using the spectrum analyser and current measurement clamp. This requires using the measurement clamp's conversion factor (from the cable current into a measured voltage in a 50 ohm load, sometimes called 'transducer factor'), which will be found from the current measurement clamp's calibration chart, graph or table and will vary with frequency. Don't forget to allow for the effect of the 20dB attenuator.

c. Adjust the signal output from the signal generator so as to meet the following two criteria…

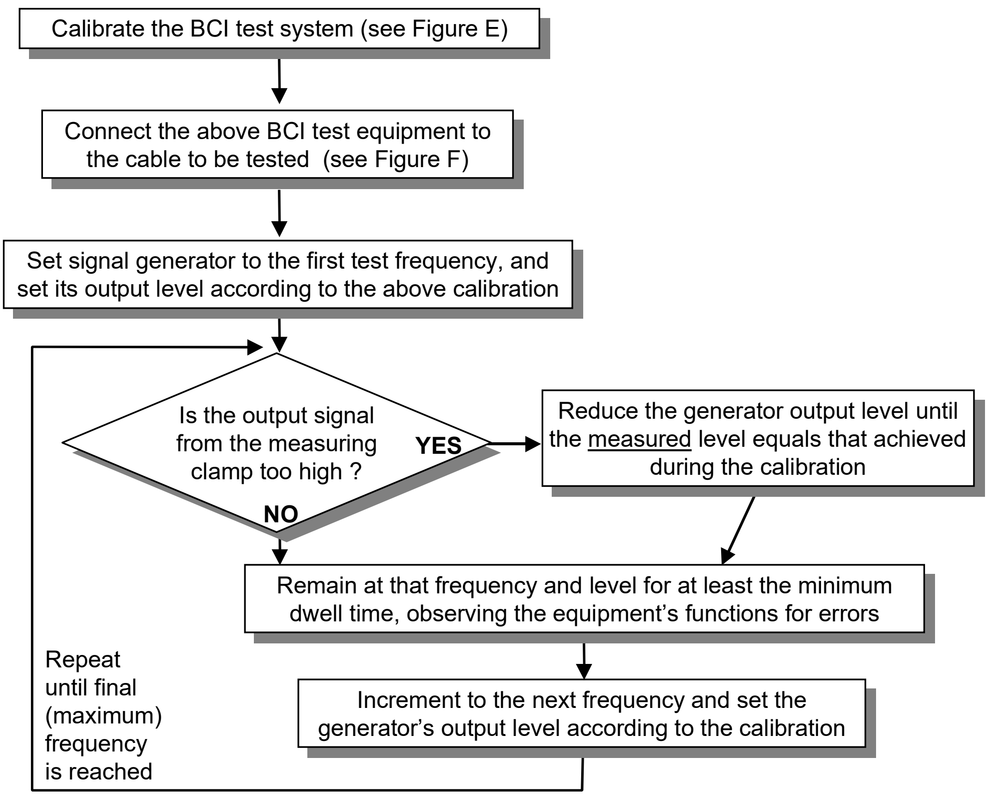
   i. If the measuring clamp's output shows that the RF current injected into the cable is below the level set by the BCI's calibration, this is acceptable.

   ii. If the measuring clamp's output shows that the RF current actually injected into the tested cable is above the level set by the BCI's calibration, reduce the output of the signal generator until the measuring clamp indicates that the injected current is equal to the level set in the BCI's calibration.

d. Inject the current (set according to c above) into the cable for at least the 'dwell time' required by EN 61000-4-6 to detect a change in the equipment functions being tested. At the end of the dwell time change the frequency to the next step and go through steps a-c again.

Figure G shows the above procedure in a graphical fashion.

Figure G ***The procedure for BCI testing a cable port***



5) This is an explanation of the level setting procedure in step 4 above and in Figure G.

   For a given drive into the RF injection clamp the common-mode impedance of the cable or cables being tested will determine the level of the RF current actually injected into the tested cable.

   A cable's common-mode impedance may be higher than was assumed by the BCI calibration at some frequency steps, and lower at other frequency steps. A high common-mode impedance will result in injected currents in the tested cable which are below the previously calibrated levels. This is acceptable provided the drive signal into the injection clamp remains at the previously calibrated level.

   However, a low common-mode impedance will result in increased level of injected current into the tested cable, and this could lead to over-testing and possibly even damage to the equipment under test. For each frequency step at which an excessive output is seen from the measurement clamp, the injection current should be reduced to what was set during the BCI's calibration – by reducing the signal generator's output so as to reduce the drive signal into the injection clamp.

6.7.5 Choosing the size of the frequency steps and dwell time

Issue — How to choose the frequency steps and dwell time to be used for conducted immunity testing.

Guidance — Use the guidance in EN 61000-4-6, extended to 400MHz or 1GHz (when using the EM-Clamp) as required.

Note that some of the equipment functions which are slow to respond may require a long dwell time, at each frequency step, so as to be sure that any error in the function can be reliably observed.

6.7.6 Preventing interference with other equipment

Issue — Unlike the CDN and EM-Clamp test methods, the BCI method does not have any directionality when injecting currents into cables. This means that as well as the injected current going into the equipment under test, it can radiate from the rest of the cable and cause interference with other equipment (especially radio-communications) and it is also conducted into the equipment connected to the cable's other end and can cause interference with that.

Guidance — Be aware that the performance degradation caused by the BCI tests could be the result of interference with the equipment at the other end of the cable from the equipment under test.

Fit a number of ferrite clamps, sleeves, etc. over the cable on the other side of the BCI set-up to the equipment under test. These should be made of a soft ferrite, intended for use as RF suppressers, and they are available in a range of sizes from a number of suppliers (Fair-Rite, Steward, Ferrishield, etc.).

Where large cable diameters are concerned clamp-on split ferrites may not be available, so ferrite-loaded sheet or shielded "Zippertubing" or knitted wire mesh can be wrapped around the cable.

Zippertubing or knitted mesh can only reduce radiated interference (and only then if it is terminated correctly), but equipment may be able to be protected from conducted interference from the cable by fitting a mains filter to it (providing it is grounded properly).

6.8 Fast Transient Burst testing

The basic Standard EN 61000-4-4 allows the testing of equipment in its final configuration.

Section 7.3 of EN 61000-4-4 gives details of the test set up.

Where Dispensations 1 or 2 apply to any cable (see section 3 of this standard) it is not required to be tested for fast transient bursts.

6.8.1 Requirements for the Test Plan and Test Report

Sections 8 and 9 of EN 61000-4-6 detail the requirements for the Test Plan and Test Report.

Note that, in general, sufficient information must be provided in the EMC Test Report and its associated documentation and computer data files to:

a) Be able to repeat the test on the equipment exactly, at any date in the future

b) Show that the equipment's functions remained within their normal functional performance specifications during this test (taking into account the accuracy and repeatability of the instruments used to measure the equipment's functional performance).

6.8.2 Use of EN 61000-4-4's post-installation test method

Issue The standard refers to a post-installation test, not an on-site test.

Guidance The standard gives a test set up for fast transient burst testing outside a laboratory (the post-installation test), so this set-up should be followed as closely as possible.

Note that a ground reference plane of at least 1 meter square must be used when on-site testing, and various minimum and maximum distances achieved (all described in IEC/EN 61000-4-4).

6.8.3 Capacitive injection on to power conductors

Section 7.2 of EN 61000-4-4 indicates that a 33nF capacitor can be used to connect the pulse directly to a power conductor.

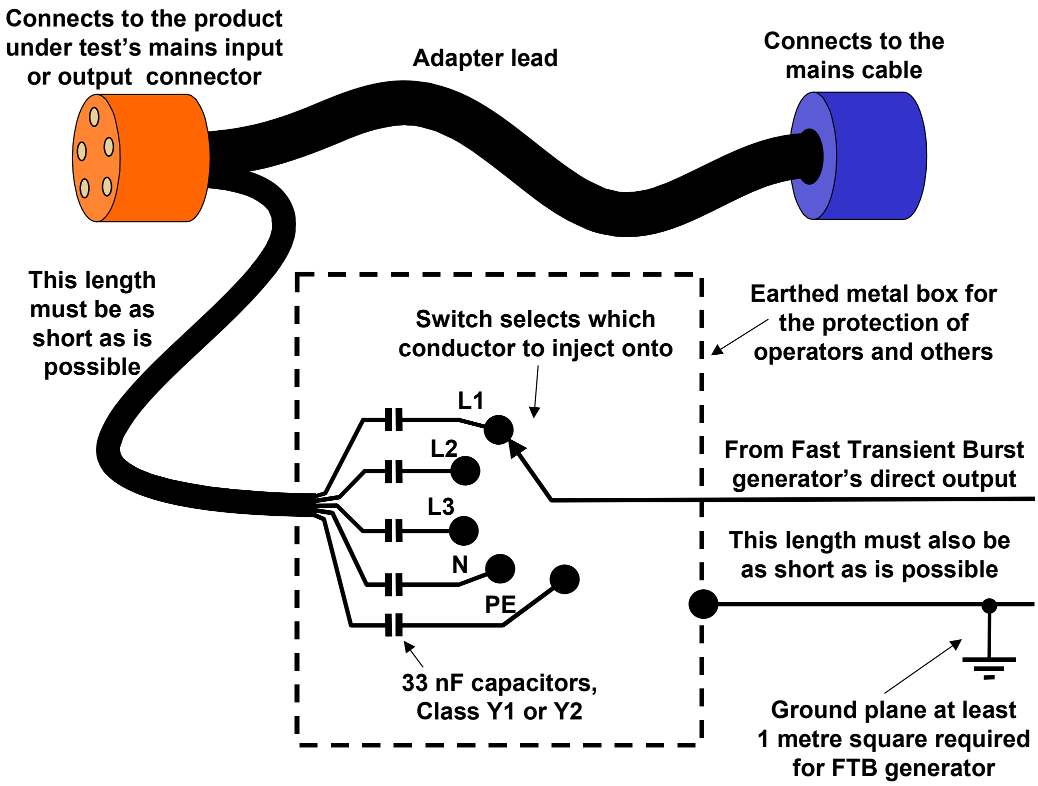
Issue The standard indicates that the 33nF capacitor should be used only on power supplies greater than 100A.

Guidance Wiring the power supplies to industrial equipment through the transient generator at an on-site location would be difficult and possibly dangerous.

Connecting 33nF Y1 or Y2 safety-approved capacitors to each phase of the supply, and its neutral and protective earth (PE), allows the direct output of the fast transient burst generator to be connected to each phase of the equipment under test's power connection in turn, without interrupting the mains power.

Figure H below sketches an outline design for a switch box containing the five off 33nF capacitors required, plus an adapter cable. It should be designed and constructed to comply with all the relevant requirements of the latest edition of IEC/EN 61010-1.

Figure H ***A fast transient burst on-site injection adapter***



Safety Note: When working on hazardous voltages such as the mains supply, always take all safety precautions. If you aren't an expert in such safety issues, arrange for the hazardous work to be done (or closely supervised) by someone who is.

6.8.4 Use of capacitive clamp on I/O and communication cables

When testing a large equipment it is unlikely that the majority of cables can be made to configure to the laboratory test set-ups set out in EN 61000-4-4, due to mechanical problems such as cable size and routing.

Section 7.3.2 of EN 61000-4-4 gives guidance on the methods that can be used to carry out the test.

Issue Section 7.3.2 of EN 61000-4-4 gives two methods:

1. Direct injection via 100pF capacitor
2. The use of a flexible clamp or tape with the same capacitance (from the clamp to the cable's conductors) as the capacitive coupling clamp.

Guidance The use of the flexible clamp is preferred due to ease of use and non-intrusive nature.

Details of the flexible clamp's calibration should be included in the test report.

6.9 Surge

Surge testing is recognised as being the most destructive of the industrial immunity tests and testing at system level could result in degradation of components leading to possible failure over time.

Where Dispensation 4 applies (see section 3 of this standard) the equipment under test is excluded from the requirement to be tested for surges

The basic standard EN 61000-4-5 refers to the testing of equipment under final installation conditions. These methods would therefore be the most reasonable ones to apply during on-site testing.

Section B.3.1 of EN 61000-4-5 gives guidance on the test levels and possible test configurations.

6.9.1 Requirements for the Test Plan and Test Report

Sections 8 and 9 of EN 61000-4-5 detail the requirements for the Test Plan and Test Report.

Note that, in general, sufficient information must be provided in the EMC Test Report and its associated documentation and computer data files to:

a) Be able to repeat the test on the equipment exactly, at any date in the future

b) Show that the equipment's functions remained within their normal functional performance specifications during this test (taking into account the accuracy and repeatability of the instruments used to measure the equipment's functional performance).

6.9.2 Use of capacitive injection

Issue	Figure 6 and 8 in EN 61000-4-5 show the use of a decoupling network when using direct injection.
Guidance	The use of a decoupling network on the supply of large equipments that are tested on-site is unrealistic due to constraints on the size of the required coupling network. The test should be carried out using direct injection via an 18μF capacitor. Care should be taken to make sure that the combination wave generator is connected to a different mains supply from that of the equipment under test. Also take care that equipment in the immediate locality of the equipment under test is not powered from the same mains supply as the equipment under test, so that it is not exposed to the surge testing too.
Safety Note:	When working on hazardous voltages such as the mains supply or the outputs of surge generators, always take all safety precautions. If you aren't an expert in such safety issues, arrange for the hazardous work to be done (or closely supervised) by someone who is.

6.10 Voltage dips, dropouts and interruptions.

One of the major reasons for having to test equipment on-site is that its power supply requirements exceed 50 amps.

But the test equipment that can generate and switch currents of this magnitude is not very portable, so is difficult to use on-site.

Where Dispensation 3 (see section 3 of this standard) is applicable, the equipment under test does not need to be tested for voltage dips dropouts and interruptions.

6.10.1 Requirements for the Test Plan and Test Report

Sections 8 and 9 of EN 61000-4-11 detail the requirements for the Test Plan and Test Report.

Note that, in general, sufficient information must be provided in the EMC Test Report and its associated documentation and computer data files to:

a) Be able to repeat the test on the equipment exactly, at any date in the future

b) Show that the equipment's functions remained within their normal functional performance specifications during this test (taking into account the accuracy and repeatability of the instruments used to measure the equipment's functional performance).

6.10.2 Agreeing the test levels and methods

Where voltage dips dropouts and interruption testing is to be carried out, either on the entire equipment or on its subsystems or components – the test levels and test methods must be detailed in the Test Plan and agreed with Cherry Clough Consultants prior to the test.

Safety Note: These tests should only be carried out by people trained in the use of hazardous voltages.

7. Testing immunity to close proximity of mobile radiocommunication devices

Note: Since this document was first published, a laboratory test method has been established by the automotive industry for the very close proximity of hand-held radio transmitters (cellphones, walkie-talkies, Kindles and other e-book readers, etc.). This is ISO 11452-9, which is based on the Ford Motor Company's original test method RI 115 (available from www.fordemc.com/docs/download/FMC1278.pdf in November 2017).

ISO 11452-9 uses fewer antenna positions than Ford RI 115; and if applying ISO 11452-9 this document recommends that all of the original RI 115 antenna positions are used.

7.1 The purpose of this test

An increasingly wide variety of mobile radiocommunication devices are being used, sometimes without the people using them being aware that they are actually employing a mobile radio transmitter.

Vehicle-mobile radiocommunication transmitters can be much more powerful than handheld or portable types. But handheld or portable devices can be in very close proximity to electronic equipment or their cables, exposing them to RF fields which are higher than those from vehicles at likely vehicle distances – and much higher than the fields used in EMC Directive immunity testing standards.

In fact, the immunity test standards used by the EMC Directive (including those for the industrial environment) all specifically state that their tests *do not cover the close proximity of mobile radio transmitters*.

However, close proximity of radio transmitters is now a normal part of the electromagnetic environment. So we need to apply additional tests to those in the EMC Directive immunity standards, to ensure that equipment will continue to work as required, or at least fail in an acceptable manner without damage or loss of data (depending on its application).

Where safety-related electronic systems are concerned, foreseeable misuse must be taken into account. People have been known to wonder what would happen if they stick the antenna of their walkie-talkie into a disc drive slot (or press the antenna against a touch screen) and key the 'talk' button.

People have also been known to hold the antenna of their walkie-talkie against cable routes to improve reception. In one case this caused an oil rig to move out of position by interfering with its thruster system, in another it interfered with the safe load warning system and caused a crane to collapse.

Such behaviour is at least silly (at worst malicious) but it is foreseeable and must not be capable of causing safety hazards. This test method should be extended as required where safety-related electronic equipment or systems are concerned.

Here are a few of the more common transmitter types that can be found on mobile or portable devices…

- CT1 (1.6 and 77.5MHz)
- Citizen's Band (CB: 27MHz)
- Walkie-talkies e.g. private mobile radio systems or private business radio (VHF: 55-85MHz and 163-210MHz; UHF: 425 - 462MHz)
- Tetra (400 - 430MHz)
- License-free walkie-talkies and short-range devices (433 and 866 MHz)
- Cellphones, e.g. GSM and GPRS (900MHz and 1.8GHz), with UMTS coming soon (1.9 - 2.1GHz)
- DECT (1.8GHz)
- Bluetooth (2.45GHz)
- Zigbee (IEEE 802.15.4: 2.45GHz)
- Wi-Fi (IEEE 802.11: 2.45 and/or 5GHz)
- HiperLAN/2 (5GHz)

Increasingly, radiocommunications are being 'embedded' in a wide variety of portable, mobile or fixed electronic products (such as laptop computers and PDAs, vending machines, etc.), adding functionality to the product without the user being aware that a radio transmitter is in use. This makes control of the radio transmitters on a site very difficult.

These tests are an attempt to gain confidence that the functional performance, reliability and safety of equipment will not be compromised by mobile or portable wireless radiocommunications devices. Their success will depend on the thoroughness, skill and care with which they are carried out.

7.2 When to apply this test

This test should be carried out on every individual item of equipment when it has been installed and commissioned. This applies to equipment that is made in-house and legacy equipment, as well as new equipment.

When an item of equipment is modified in any way (cables, cable routes, hardware or software modifications or upgrades, etc.) it should be completely retested.

When a new radio service is added to the site – for example if the site's private mobile radio system is changed to a different type, or if a wireless LAN system is installed and can be used by portable and mobile devices – then these tests should be carried out using examples of the new radio transmitting devices as new test devices.

7.3 What test devices should be used?

Identify all the portable devices that could employ radiocommunications that could be used in and around the site where the equipment is installed, paying particular attention to walkie-talkies and mobile phones of any type.

The devices used should always include the site's own private mobile radio system and portable wireless LAN devices, plus any mobile radio communications used by regular contractors. Both 900MHz (e.g. Vodaphone) and 1.8GHz (e.g. Orange) cellphones should also always be used, both GSM and GPRS types.

Mobile or portable devices which can include radio transmitters include…

- Handheld mobile phones, such as walkie-talkies, cellphones, DECT cordless telephones.
- Desktop computers (portable), laptops, palm computers, PDAs or other devices with wireless LAN, Ethernet or Internet connectivity.
- Any devices with wireless connections to a keyboard, mouse, microphone headset, instrumentation, etc.

Where one device includes a particular type of radio transmitter – there is no point in testing a different type of device that uses the same type of transmitter with the same frequency and RF power. For instance, testing with a cellphone which uses the GSM 900MHz system (e.g. as provided in the UK by Vodaphone) also covers a GSM 900MHz PCMCIA card in a laptop computer, even if it is used for internet connection instead of voice.

Analogue walkie-talkies will need some sound in their microphones so that their RF fields are modulated. Strapping a little battery-powered buzzer to their mouthpiece is a simple solution to this problem (the irritating noise this makes can be damped by placing large amounts of 'Blu-Tack' over the buzzer and onto the handset).

Where LAN or other data connections are involved (e.g. Bluetooth) it may be necessary to arrange for data to be sent continually, as these types of transmitters might shut down to conserve power (whilst maintaining the connection) if they detect an idle period. An RF spectrum analyser can be used to discover whether a device's transmitter shuts down when idle or not, if it is not known or easily discoverable.

It will require some preparatory work to determine whether the above issues arise and how best to deal with them without hindering the on-site testing.

Each item of equipment must be tested using the all the different types of mobile radio transmitter that could reasonably foreseeably be used in close proximity (i.e. closer than 2 metres).

The test devices used, and any steps taken to ensure they transmit modulated RF fields continuously, must be recorded in the final Test Report.

Alternately….

It might be practical to simulate a handset with a signal generator, power amplifier, and home-made antenna, as described for simulating GSM handsets by Gary Thomason and Vsevolod Ivanov of Dell Inc., in their paper "*Method for Evaluating System Immunity to Wireless GSM Devices*" presented at the IEEE International EMC Symposium, Chicago, USA, August 8-12 2005, ISBN: 0-7803-9380-5, pp 726 – 729.

Basically they used a length of coaxial cable, stripped the shield back by 8.4cm to make an antenna that was efficient for GSM850, GSM900, GSM1800 and GSM1900 signals, and drove it from an RF power amplifier at 2W for GSM850 and GSM900, and at 1W for GSM1800 and GSM1900. The signal generator that provided the power amplifier's input was set to produce bursts of RF at the appropriate handset transmitter frequencies, each lasting for 50µs at the rate of 217Hz.

7.4 Verifying the test devices prior to testing

Before the tests are started, calls or other wireless connections are made with the mobile radiocommunications 'test devices' to be used for these tests, to check that they operate correctly.

During the test the integrity of the call or connection should be regularly checked, either by speaking to someone at the 'other end' or by sending or receiving control or data signals.

The battery charge indicators on each device should also be regularly checked during the tests – replacing the device (or its battery) with the same type before its battery gets too low to maintain functionality.

If at any time a call or connection is found to have been lost, it must be remade and the testing with that device redone from the last point at which it was known to have been maintaining a connection.

It is a good idea to have spare (fully charged) battery packs and battery chargers available during these tests.

Tests must not be carried out using devices which are powered from the mains supply, unless this is how they would normally be used in practice.

The final Test Report must record the judgement of the test engineer on whether he/she believes the test devices to have been functioning correctly throughout the test.

7.5 The locations on the equipment to be tested

Ideally, every location on the equipment or its cables where people could foreseeably place their portable electronic devices nearby is to be tested. But some areas of equipment are more vulnerable than others.

As a guide, and to help save testing time, at least the following areas should be tested….

a) Mouse, trackerball, joystick, graphics tablet, etc.: testing at its cable entry is sufficient. If it is a wireless or infra-red mouse (or trackerball) a single test at the centre of its body is sufficient.

b) Keyboards: test at least at their cable entry plus the middle of their front edge. If it is a wireless or infra-red keyboard test at least at its antenna or infra-red receiver, plus the middle of its front edge.

c) All accessible cables should be tested at two places: the point where they enter or exit an item (such as a keyboard or mouse) and the point where they enter or exit an equipment or connector panel.

d) Same as above for all fibre-optic cables and connectors.

e) For each item of equipment test once in the middle of each accessible connector panel, and in the middle of each ventilation grille.

f) Control panels should be tested at each control. Where there are a large number of controls, only test at controls which are approximately 100mm apart from each other. Always test the most commonly used controls – and the controls which, if they malfunctioned, would give the greatest cause for concern.

g) Displays or touch-screens are tested at each of their four corners, in the middle of each side, and in the centre of the display area.
Where a display dimension is smaller than 300mm – test the extremes of that dimension only.

Where a display dimension is smaller than 150mm – test in the centre of that dimension only. Where a display is smaller than a 75mm square – test in the centre of the display only.

h) Antennas where a portable or mobile device could reasonably foreseeably be held in close proximity: test at their base and also at a point halfway along their length.

i) Infra-red ports, microphones and loudspeakers: test at their location.

j) Along any seams or joints in a metal enclosure, or along the edges of any doors, panels or covers, but only where it is reasonably foreseeable that a portable or mobile device might be held in close proximity. To save time, test at 150mm spacings along the length of the seam or edge.

k) At 150mm spacings over any plastic surface (unless it is known to be simply a cover for the metal enclosure underneath, in which case don't test it).

- Electromechanical controls such as switches that are connected to electromechanical devices such as relays – and which do not employ and are not connected to any electronic devices – *do not need to be tested* and neither do their cables.

Where the tested equipment is safety-related, test more thoroughly than the minimum described above. The greater the possible safety consequences, the more important it is to be very thorough with this test and take longer over it.

To help save time during the test, any number of test devices may be used by a number of testers at one time – as long as the devices are more than 500mm apart from each other. They must each have a wireless connection made, of course.

Cellphones are small and can be held in the same hand that is operating a control or touching a touch-screen, so all of the locations listed above (at least) should be tested with a cellphone.

But some devices containing radio transmitters are less likely to be in close proximity to some vulnerable areas. For instance, desktop or laptop computers are portable, but will generally be placed on top of equipment, cabinets, chairs or tables, maybe even on the floor, but they are unlikely to be placed with their radio transmitting antennas very close to a touchscreen. Assess what exposure could reasonably possibly occur from the various test devices, and test accordingly, being more thorough and cautious where equipment is safety-related.

The places where the tests are carried out, for each type of test device, must be described in the final Test Report. Sketches and photographs (preferably annotated) showing the test locations are the easiest way to document the test locations.

7.6 Setting-up and monitoring the equipment to be tested

When finally installed at its operational site, each item of equipment that could be exposed to mobile radiocommunication devices must be tested when set-up for normal operation.

If the tested equipment has a number of modes of operation, the mode which is most typical of normal use should be fully tested as described here, but if this is not readily identifiable fully test the mode which would have the greatest consequences if it were to suffer errors or failures.

To save time with second and subsequent operational modes it is only necessary to retest controls that have changed functions, or that have become 'active'. This would include touch-screens, but not displays on their own even if their display functions have changed.

However, where operational modes have safety-related functions, each mode should be fully tested.

It is necessary to monitor the functional performance to determine whether interference is occurring. In the case of a magnet power supply the output voltage can be measured with a voltmeter, in the case of a display a visual assessment is sufficient. Other functions will require other means of monitoring, and the monitoring means must have sufficient resolution and stability to reliably detect errors.

RF interference can cause controls or displays connected to (or employing) digital processors to 'freeze' – giving the impression that everything remains OK when in fact control has been lost. So it is always necessary to check that normal operation of the tested controls and display has not been affected. It helps to test displays using an image that has a continually changing field, such as a blinking icon or some other animation.

Electronic test equipment used for monitoring must kept far away from the test devices, because many of them are very susceptible to RF fields or RF voltages/currents and can easily give erroneous results. When an electronic instrument records an unacceptable change in a measured parameter, always check whether it was the instrument that was being interfered with or the equipment under test. Electronics-free moving-coil or moving-iron meters are recommended, if only as a check on whether electronic test gear is interference-free.

Many people have wasted large amounts of time and money trying to solve immunity problems, only to eventually discover that it was their test gear that was at fault. So don't fall into this trap.

The tested equipment's set-up, mode of operation, and means of monitoring its functions, controls and displays, must be recorded in the final Test Report.

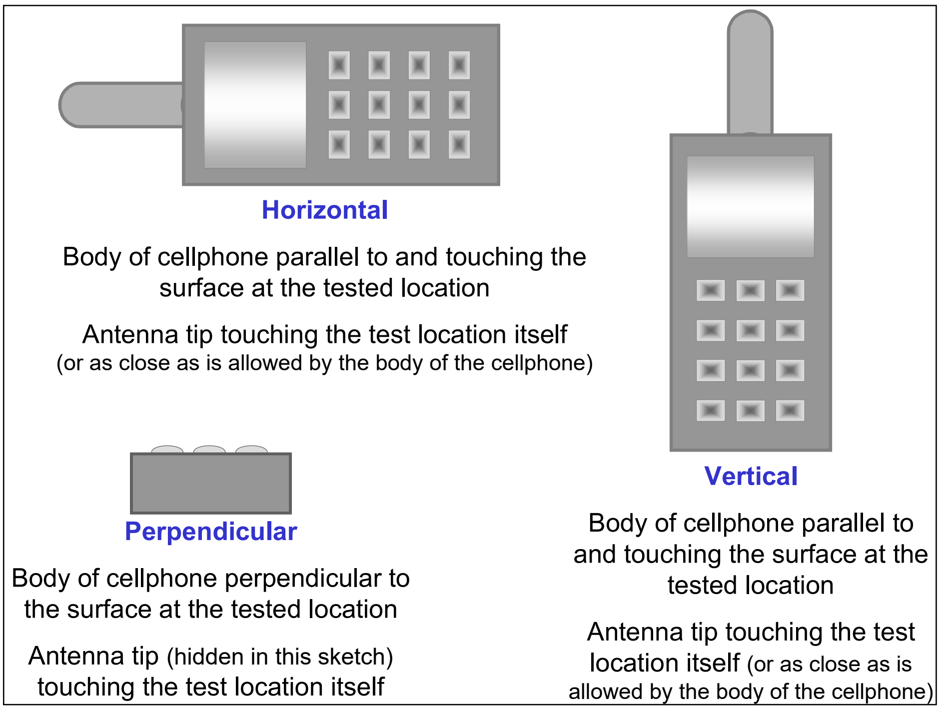
7.7 Performing the tests

Calls or connections must first be initiated with each test device. The connection must be maintained for the duration of the test (refer to the section on verifying the test devices).

The following description refers to the use of a cellphone as a test device. For other types of devices use an appropriately similar method judged by the test engineer to give a similar test coverage.

Where there is no external antenna, treat the edge of the test device where the end of the *internal* antenna is located as the 'tip of the antenna'. Where the location of the internal antenna is unknown and cannot be found out (e.g. by asking the device's manufacturer), use a close-field probe and spectrum analyser to identify the location of its strongest RF transmissions, then use this as the equivalent 'tip of the antenna'.

Test orientations of cellphones (used as an example for all mobile devices)



Where a communication device has a number of channels (typical of walkie-talkies), test each location with it twice: firstly using the lowest channel number and secondly using the highest channel number.

In all the above cases the test duration for any one location and orientation of a cellphone must be no less than 10 seconds. Where an equipment function has a slow response time and it would take longer than 10 seconds to see any change, hold the cellphone in location for long enough to reliably detect a change.

To avoid non-repeatability caused by hand capacitance, the cellphones must not be held during these tests. However, to save testing time it is desirable to be able to rapidly move the cellphones from one orientation to another, and from one location to another, and this can be done if the cellphone is held in some sort of non-conducting holder (e.g. made of wood or plastic) that holds the cellphone at least 200mm away from the test engineer who is operating it.

It is best to develop a code that indicates the test location, test device, and orientation of the test device, to save time and space when writing the final Test Report. (For example: C3H could be the code for tested location C, test device number 3, and horizontal orientation.)

7.8 Making PASS/FAIL or remedial decisions

During these tests continually monitor all the functions of an equipment – this may require a number of people each looking at different monitoring instruments or displays so as not to miss something untoward.

In an ideal world nothing at all would be effected by these tests – but in practice this is often hard to achieve and is not always necessary.

So, when operational or functional errors or display deterioration occur, a judgement is needed on whether they are acceptable or not. It may be necessary to involve experts to decide on their acceptability.

This test method holds the mobile transmitting device as close as possible to the part of the equipment being tested. If an unacceptable deviation in performance occurs and it is felt that such close proximity is not very likely to occur, the test that was failed should be repeated using an increased distance from the tested location, for example 100mm or 200mm.

It might be that the interference with the functional performance at these increased distances are considered acceptable, and no remedial work is required. (Note that for keyboards, mice and other computer I/O devices used on a table, shelf, or worktop, minimal (zero) spacing must always be used.)

Some unacceptable errors might only occur during what are considered to be highly unlikely situations, and it may be felt that a warning notice may be an acceptable way of dealing with this possibility, rather than redesigning the whole equipment. (But warnings might not be suitable for some safety-related functions.)

Alternatively, it might be practical to make it more difficult for a vulnerable location to be exposed to very strong RF fields from mobile or portable devices. For example, at a cable entry to an equipment, a plastic cover could be added which would prevent a cellphone from coming close enough to cause a problem. Such a cover should have a label stating what it is for, to prevent people in future throwing it away and to warn maintenance people who might have to remove it for access.

Where safety is an issue, judgements about what performance is acceptable and what remedial measures or increased test spacings are sufficient must be carefully thought-through. Health and safety officers should be involved, and they may need to discuss these issues with legal staff.

At the end of all the tests the test engineer responsible must make an judgement as to whether the required performance has been achieved, and his/her decision recorded in the final Test Report.

A suitable reporting format is given below…

On-site portable radio transmitter test **For equipment type: ……….. manufactured by: ………… serial number: ………… located at: ………**				
Test ref. no.	**Tested location(s) and type of test device employed** (Refer to sketches or photographs where they would help to repeat the test in future) (Give the RF power and frequency for each radio transmitter used, where known, or describe its type, e.g. Bluetooth)	**Describe the effects on the functional performance of the equipment** **Note any *possible* safety consequences**	**Any remedial measures applied** (and their results)	**PASS/FAIL decision** and recommendations for further actions and any other comments
The decision on the equipment's overall performance on this test:				

7.9 Testing during development

7.9.1 Why test during development?

These tests are on-site tests, and if they discover any problems it will probably be costly to fix them.

It is much better (quicker and less costly) to discover any problems before they occur, during the equipment's development phase.

The same tests as described here can be applied, using similar devices, to an equipment during its development.

Cellphones vary their transmitted RF power depending on how close they are to a base station. In many installations reception is likely to be poor due to the shielding provided by the metal in the structure, so cellphones will be more likely to operate at full power. To ensure that this is the case during development testing it may be possible to obtain cellphones that have been modified so that they only transmit on full power. The author does not know where to get these from, although test labs that specialise in radiocommunications may be able to help.

7.9.2 Testing in an EMC test lab

Alternatively, tests over appropriate frequency bands can be carried out using standard EMC test equipment, using the EN 61000-4-3 or other test methods at field strengths of at least 100V/m over the frequency ranges of concern.

Many test laboratories that test for EMC Directive compliance cannot generate 100V/m using their standard test methods, although labs that test to military EMC standards almost always can.

In an 'EMC Directive' test lab variations and modifications to their usual test methods can help achieve higher field strengths. Being able to 'illuminate' the whole equipment with a field of 100V/m or more saves testing time by testing all the vulnerable areas at once, but field uniformity is not a strict requirement for these tests. These tests can be carried out in ordinary shielded rooms (like the older IEC 801-3 test method, or military test methods) or in reverberant or stirred-mode chambers.

Highly directional antennas, such as horns, can be used and the proximity of the antenna to the part of the equipment being tested can be as small as required (no need to worry about being in the antenna's far field, or the antenna's calibration factors).

A triaxial field probe is generally required to measure the field strength being achieved at the 'tested location' on the equipment.

7.9.3 Equipment set-up

If testing during development, rather than when installed on-site, it is important to set the equipment up as it will be when it is installed at its operational site. All peripheral devices should be connected, the correct types of cable must be used, and cable screens must be terminated as will be done in the final installation.

In general, the full length of each cable should be used. But where cables can be inconveniently long testing, when testing at frequencies above 30MHz such cables need be no longer than 10 metres, and when testing at above 300MHz such cables need be no longer than 3 metres.

The cable environment that will be achieved in the operational site should be recreated or simulated as closely as possible (e.g. parallel earth conductors, trays, ducts, trunking, conduit, etc.; cable shield termination at both ends (or just one); etc.). Simulation should recreate the stray capacitances and inductances that will exist in the final installation.