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Specifying the EMC performance of a final product

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An example procedure

for specifying the EMC performance of a final product

***Note 30 November 2018:** This document was written in 2003 and has not yet been updated to deal with the changed compliance requirements in the current EMC Directive 2014/30/EU, or to include our improved understanding and experience since 2003.*

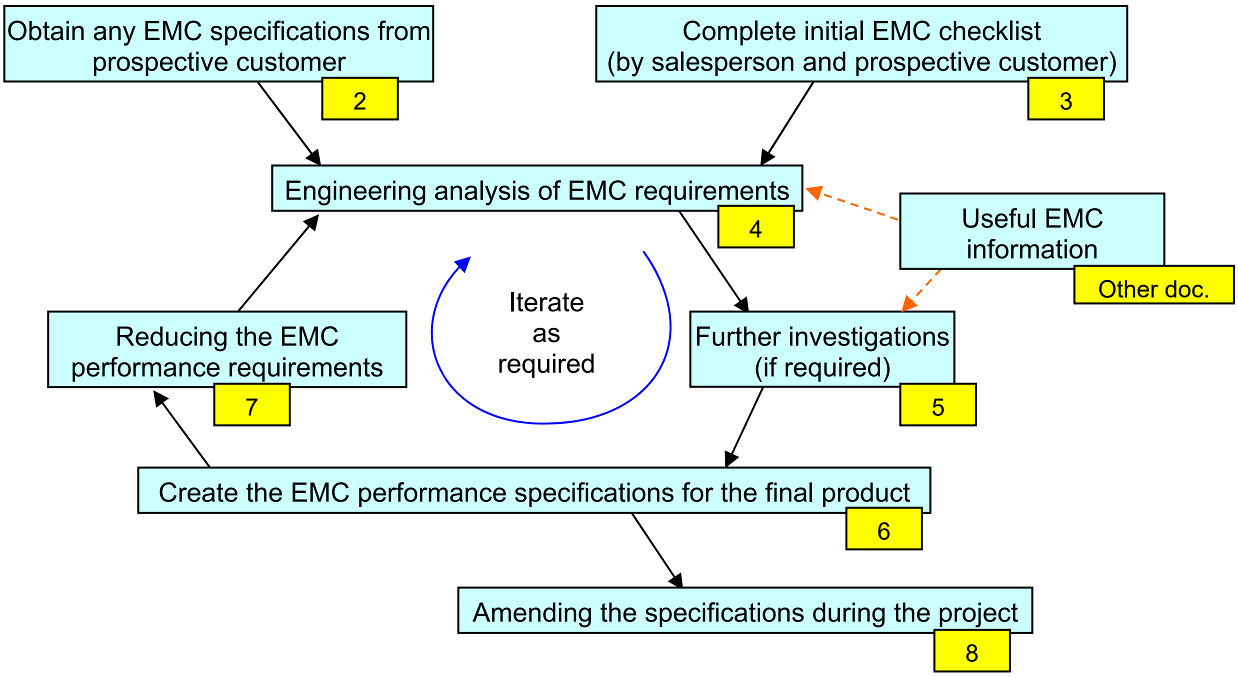
However, we believe its basic principles are still valid and useful and so are making it available on that basis.

Contents

1 Introduction

The aim of this procedure is to write an EMC performance specification for the final equipment. Establishing this specification is *vital* – without it all the EMC work is mere guesswork, compliance with the EMCD's protection requirements would be unknown, and under-engineering would be as much a risk as over-engineering (and either of these undesirables can significantly increase financial and commercial risks).

This EMC performance specification must use existing EMCD notified standards wherever possible, modified and extended where necessary. Where EMCD notified standards aren't appropriate, the next choice is EN, IEC or CISPR standards that do not have equivalents notified under the EMCD. Finally, military and other standards should be used with great care to avoid over-specification (the ruin of more than one company).



To decide what EMC performance is needed for the final product, it is commonplace in some industries for each project to begin with a full EMC site survey in an attempt to fully characterise the electromagnetic environment that it will be expected to operate in. But an EMC site survey can only measure an existing site, and planned developments can mean that the EM environment actually experienced by the final product when it is commissioned might be quite different.

For example, the EM environment of a green field site will be quite different when the plant that is to house it is built and operating. In such a case an EMC site survey only reveals what there is already in the environment (e.g. an electrically noisy water or gas pumping station on the other side of the hill, or a military base with high-power radio communications or radars within a few miles).

Another problem with site surveys is that they don't measure the final product's exposure to transient events such as voltage surges due to lightning, or high-voltage disconnection due to a fault, since it is difficult to get representative examples of such phenomena to occur when the measuring equipment is set up and running.

And, of course, site surveys only measure the EM threats *to* the final equipment, they do not measure the threats to other existing or planned equipment/systems/installations *from* the emissions from the final product.

Many final products will need to do little more than meet the EMC performance as expressed in the generic EMC standards EN 61000-6-1, -2, -3, or -4.

This procedure starts with a checklist to identify whether there are any areas of the final product's predicted EM environment which might need to go beyond the most relevant EMC standards.

2 Obtain any EMC specifications from the customer

Some potential or actual customers may provide an EMC specification for the final product – these *can sometimes* be comprehensive, accurate, useful and save a great deal of time.

But the purchasing departments of many organisations often simply repeat the same EMC specification without thinking about whether it is in fact suitable for the project concerned. Such specifications can be too weak for a given project and might not result in a successful design or in EMCD compliance – or else they can be too strong and might add unnecessary cost and delay, to no-one's benefit in the end.

There are well-known examples of both types of errors in customer's EMC specifications, known to have cost their suppliers a great deal of money and in at least one case driving the supplier out of business.

So it is important to get an EMC specification from the customer, if one is forthcoming, but it is just as important to go through the rest of this procedure to check that following the customer's EMC specification is reasonable or not, and to tender or quote a price and delivery that is more likely to result in low-risk financial benefits.

(There is little point in undertaking projects which have a high risk, or which don't produce financial benefits. Good EMC engineering, as expressed in these procedures, is a way to reduce financial risks and improve financial benefits.)

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3 Complete the initial EMC checklist

This checklist is to be completed by the manufacturer's salespeople in conjunction with potential customers, and assessed by engineering well before each tender submittal or quotation on price or delivery.

a) Will the final product be operated from a low-voltage AC mains supply where the supply from the distribution transformer is shared by more than one organisation? YES ☐ NO ☐

b) Will the final product's low voltage AC mains supply be shared by heavy power equipment, industrial manufacturing or processes and the like? YES ☐ NO ☐

c) Will the final product be physically located <30m from a radio or TV receiver antenna? YES ☐ NO ☐

d) Will the final product be physically located <30m from heavy power equipment, industrial manufacturing or processes and the like? YES ☐ NO ☐

e) Will the final product be located in electricity generation or distribution facilities, or take part in electricity generation or distribution functions? YES ☐ NO ☐

If the answer to any of questions f) onwards is YES, please give as many details as are available (e.g. type of equipment, physical proximity, whether the mains power supply is shared, etc.). Please list all the possible candidates for EMC problems, even though many of them may turn out not to present any difficulties.

f) Will the final product be <10m from a radio or TV receiver antenna? Will it be <100m from, or share the same power supply as, very sensitive equipment that – if its electronics or software malfunctions – could have safety or other serious implications? YES ☐ NO ☐

h) Will the final product be <5m from indoor cellphone base-stations, <30m from outdoor cellphone base-stations or paging system transmitters, <3km from broadcast radio or TV transmitters, <1km from marine vessels, or <50km from fixed radar installations (e.g. airports, harbours, military installations)? YES ☐ NO ☐

i) Might hand-portable radio communication devices be used <3m to the final apparatus (e.g. cellphones, wireless-enabled personal organisers or PCs)? YES ☐ NO ☐

j) Might vehicle mobile radio communications be used <10m to the final product? (e.g. motor cars, fire engines, police cars, ambulances, helicopters, aircraft, trucks, etc.) YES ☐ NO ☐

l) Will the final product be <30m from heavy power equipment or equipment that uses radio-frequency energy, or share their mains supplies or cable routes? (e.g. gas-insulated/other HV switchgear; HV transformers; electromagnetic stirrers; arc furnaces; aluminium smelters; electroplaters; electrolytic processes; electric welding; arcs >10milliseconds; plastic welders or sealers; induction heaters; industrial microwave heaters or dryers; diathermic processes; RF-assisted welders; RF-assisted wood or card gluers; electromagnetic pulse devices; variable speed drives for AC or DC motors >100kW or their motors; etc.) YES ☐ NO ☐

m) Will the final product be <100m from overhead HV cables, <10m from overhead MV cables, or <30m from LV cables where the phases and neutrals are run separately (including electric underfloor heating and the like)? YES ☐ NO ☐

n) Will any of the final product's control, signal, or data cables exit the building? YES ☐ NO ☐

o) Will the final product be exposed to direct lightning strike, or to uncontrolled voltage surges from equipment with very large energy storage? YES ☐ NO ☐

p) Is the final product protected by a structure that provides lightning protection for electronic equipment to BS 6651 Annex C (or equivalent)? YES ☐ NO ☐

q) If any of the electrical or electronic devices, systems, or software in the final product suffered from errors or malfunctions, could the consequences possibly include safety incidents, serious financial losses, or significant environmental damage? YES ☐ NO ☐

4 Engineering analysis of EMC requirements

The initial EM checklist is completed before a project is undertaken, to help identify problem areas which might require special EMC engineering techniques to be used.

It is then analysed by engineers with appropriate EMC competency, feeding appropriate cost and timescale estimates into the tender submittal and quotation process.

The engineers performing this task will need a reasonable degree of familiarity with the EMCD's EMC standards and how actual testing using them is done.

Convenient access to all relevant EMC standards (e.g. held in a standards library) is a necessity. The latest versions of any standards should be used at the start of each project. There is usually no need to change versions of a standard during a project that last less than two years, unless the new version corrects a mistake in the previous one.

BSI have a scheme that allows for the automatic updating of a list of standards, and is strongly recommended as it will save a great deal of time in trying to keep track of developments in standards.

4.1 Selecting the EMC standards to base the final product's specification upon

Questions a) to e) in the above checklist help to identify which generic standards are the most appropriate to form the basis for the EMC specification for the final product.

YES answers to questions a) to e) imply the following standards….

a) or c) EN 61000-6-3 (commercial and light industrial emissions)

b) or d) EN 61000-6-2 (industrial immunity)

e) IEC 61000-6-5 (power generation immunity)

NO answers to questions a) to e) imply the use of EN 61000-6-4 (industrial emissions) or EN 61000-6-1 (commercial and light industrial immunity). These are easier standards to meet than EN 61000-6-3 and -2, so represent the minimum EMC requirements for a final product.

The following are acceptable combinations of generic standards for the final product:

Emissions:	+	*Immunity:*
EN 61000-6-3 (commercial/light industrial)	+	EN 61000-6-1 (commercial/light industrial)
EN 61000-6-4 (industrial)	+	EN 61000-6-2 (industrial)
EN 61000-6-3 (commercial/light industrial)	+	EN 61000-6-2 (industrial)
EN 61000-6-4 (industrial)	+	EN 61000-6-5 (power generation)
EN 61000-6-3 ((commercial/light industrial)	+	EN 61000-6-5 (power generation)

Note that the combination EN 61000-6-4 + EN 61000-6-1 (the easiest of all the generics) should not be used without the agreement of the EMC Competent Body for that specific project. This agreement should be in writing and form part of that project's EMC documentation.

Although it is likely that the above generic standards will be the most suitable for many types of final products, certain types may have their own "product standards" for emissions or immunity (or both) and in general these should be used as the basis of the final product's EMC performance specification instead of the generics. Examples include…

EN 55022and EN 55024 for the emissions and immunity of Information Technology Equipment (e.g. computers, telecommunications, and computer/telco systems and rooms).

EN 61326 for emissions and immunity of control and measuring equipment.

EN 55011 for emissions from industrial, scientific, and medical equipment that uses RF energy.

EN 50091-2 for uninterruptible power supply equipment.

The official list of harmonised EMC standards (product and generic) which have been notified under the EMC Directive is at: http://europa.eu.int/comm/enterprise/newapproach/standardization/harmstds/reflist/emc.html.

Where a relevant product-specific standard exists, a generic standard may only be used as the basis of the final product's EMC performance specification with the agreement of the EMC Competent Body for that specific project. This agreement should be in writing and form part of that project's EMC documentation.

4.2 Basic EMC performance for emissions of harmonics and flicker

EN/IEC 61000-3-2 covers the emissions of harmonic currents into the 400/230V mains supply for equipment which consumes up to 16A/phase, whilst IEC 61000-3-12 covers harmonic emissions for equipment up to 75A/phase. Medium voltage equipment is covered by IEC 61000-3-6.

EN/IEC 61000-3-3 covers the emissions of voltage fluctuations, flicker and switch-on inrush currents into the 400/230V mains supply for equipment which consumes up to 16A/phase, whilst EN/IEC 61000-3-11 covers harmonic emissions for equipment up to 75A/phase. MV equipment is covered by IEC 61000-3-7.

A YES answer to question a) means that the EMCD requires both EN/IEC 61000-3-2 and EN/IEC 61000-3-3 to be applied to equipment which consumes up to 16A/phase – but both these standards contain loopholes which "professional" or "special" equipment may be able to employ to avoid having to meet any actual emissions limits.

At the time of writing the other four standards are not mandatory under the EMCD.

However, it is generally best from a good engineering and risk-reduction point of view to apply all of the above six standards where they are appropriate, to avoid creating interference problems for other equipment and for the power distribution networks themselves.

The EMC Control Plan should record the decisions taken on whether to apply harmonics and flicker standards, and why.

4.3 Use of special standards, plus extending the basic standards

After the basic standards have been determined, questions g) -q) in the initial questionnaire help to determine whether there is any need to amend or extend the EMC performance specifications are expressed by the basic standards (chosen as described above).

They may also show that there are additional EMC standards which should be applied, to cover types of EM disturbances that are not covered at all by the basic standards.

If the answers to questions g) to q) are YES, further investigations by engineering personnel will generally be required, as described by C.5.

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5 Further EMC investigations (if required)

Analysis of this completed checklist might identify areas where more detailed information is required. This could involve engineers in:

- Telephone calls or emails
- Requests for documentation (e.g. EMC test reports on specific equipment)
- Visits to look around and ask questions
- Simple tests using low-cost portable EMC instrumentation
- Calculations or computer-based simulations
- Full-scale EMC tests on-site carried out by EMC experts

This additional work will often be associated with the proposed location of the final product.

But where a third party's equipment, system or installation could have an impact on the EMC performance specification of the final product, this additional work might need to involve the third party. Where this equipment was supplied during the last five years its manufacturer may actually have some documents indicating its EMC emissions and immunity. Older equipment will often not have such information. In both cases EMC checks, calculations, or full site tests may be required.

Where the equipment doesn't yet exist, estimates of its EMC emissions and immunity based on the technology it will use, its method of construction, the relevant EMC standards and how well the manufacturer intends to apply them will need to be made.

It can be difficult to determine what levels of emissions or immunity performance are required for a final product in a given situation, and we can provide guides and references to help with this.

Remember that the EMCD's standards are supposed to represent the *minimum acceptable* levels of EMC performance for typical items of equipment when used on their own. These standards were never intended to cope with unusual situations or low-probability EM disturbances, or with situations where different items of apparatus are in close proximity to each other.

6 Create the EMC performance specifications for the final product

The purpose of this procedure is to determine whether the final product's EMC performance can be totally described by the EMC standards listed in C.4, or whether these standards need to be extended in some areas, by decreasing emissions limits or increasing immunity levels, or extending their frequency range.

There are two aspects to a final product's EMC performance specification:

- The maximum emissions and the minimum immunity specifications (basically, what EMC test equipment might measure from the product or impose upon it) derived from the assessment of the final products EM environment (see C.2 to C.5 above) – see C.6.1, C.6.2 below.
- Specifications for the functional performance to be achieved when the final product is subjected to the worst-case EM threats in its environment (e.g. during immunity testing) – see C.6.3 below.

6.1 Important note on narrowband interferers and receivers

An important point to note when dealing with immunity requirements (EM threats to the final product) associated with radio transmitters (especially hand-helds and vehicle mobile) is that the transmitters only operate over narrow frequency ranges, but the frequency response of the product can vary significantly depending on its age, movement of internal and external cables, replacement of faulty units, small modifications, etc.

So, for example, a final product that passes an immunity test that simulates a 30V/m field from an RF plastic welding machine operating at, say, 40.68MHz on one day might fail the exact same test a few weeks later.

Where significant cable movement is possible (e.g. flexible cables not tied down along their lengths) the frequency response of the final product can vary very widely indeed.

Where the final product is not subject to variations in its cabling (and no other cables can be run in its trays or conduits) or other aspects of its construction, it may be sufficient to test a frequency band of ±10% either side of the transmitted frequency range (e.g. at 30V/m over the range 36 to 45MHz in the above example).

But where the final product could suffer from various cable routes, addition of nearby cables, etc., a ±25% band should be the minimum used (e.g. at 30V/m over the range 30 to 50MHz, in the above example).

Similar broadening of the frequency range should be assumed for the emissions from the final product, where a narrowband radio receiver is to be protected.

6.2 Examples of EMC performance specifications

The aim is to specify the EMC of the final product using EMCD test standards as far as possible, only deviating from them or adding to them where necessary. This is to make the validation (testing) work simple and low-cost.

For example, if the only issue resulting from the checklist and its subsequent analysis (see C.2 to C.5) was that GSM 900 cellphones could be used as close as 100mm to a keyboard, mouse, microphone, touch shield or other human interface the immunity specification in such a case might be written as:

> "Immunity: as EN 61000-6-2:2001 but with the minimum radiated immunity specification increased to 80V/m over the frequency range 750 to 1000MHz for the human-machine interfaces only".

However, if the only issue was that GSM 1800 cellphones could be operated as close as 100mm to a human-machine interface, the radiated immunity performance would need to be *extended* beyond the present 1000MHz range. In this case the immunity specification might be written as:

> "Immunity: as EN 61000-6-2:2001 but with an additional radiated immunity specification of a minimum of 80V/m over the frequency range 1500 to 2100MHz for the human-machine interfaces only".

Sometimes additional EMC standards may need to be employed to help write the EMC performance specification for the final product, most often because the above standards simply don't cover a particular EM disturbance.

For example, if 'ring wave' surges can appear on the power supply, or if the power supply also supplies a contactor which can arc for longer than 10milliseconds (generating what are known as 'damped oscillatory waves'), then specifications taken from IEC 61000-4-12 may need to be employed (*as well as* the more usual EN 61000-4-5 surge specifications called up by the generic immunity standards). For example an immunity specification might say:

> "Immunity: as EN 61000-6-2:2001 with a minimum radiated immunity specification of 30V/m from 30MHz to 50MHz, plus an additional radiated immunity specification of at least 80V/m from 1500MHz to 2100MHz for the human-machine interfaces only, plus damped oscillatory waves at 2kV common mode and 2kV differential mode according to IEC 61000-4-12 ".

The above example uses the generic immunity standard for the industrial environment and adjusts it to cope with a nearby 40.68MHz plastic welding machine, a GSM 1800 cellphone at 100mm, and an arcing contactor connected to the same mains supply.

Where walkie-talkies or cellphones are required to be used by operators, emissions from the final product might make reception difficult nearby. The comments of C.6.1 apply to emissions as well as to immunity. An example for a 410MHz private mobile radio system might be:

> "Emissions: as EN 61000-6-3:2001 with a reduced specification for radiated emissions with a maximum of 20dBμV/m at 3m antenna distance from 310 to 510MHz."

NOTE: These examples and figures above are for example only and must not be thought typical of such situations. Each final product needs its own EMC assessment.

6.3 Functional performance criteria

As was mentioned at the start of C.6, the functional performance criteria is as essential an element of a final product's EMC specification as the immunity (threat) levels themselves.

Below is a table showing how the performances of the various functions of a final product might be allocated. This table may be used as a guide, but it may not be comprehensive in its list of functions and it may also suggest incorrect performance levels for some projects. The performance specification for each final product should be assessed individually.

Table showing an example of EM disturbances versus functional performance criteria

<table>
<tr><th rowspan="2">Functions</th><th colspan="3">Functional requirements versus the nature of the electromagnetic disturbance
(EM threats to the final product)</th></tr>
<tr><th>Continuous disturbances</th><th>Transient disturbances with high probability</th><th>Transient disturbances with low probability</th></tr>
<tr><td>Protection, teleprotection, safety</td><td rowspan="12">Normal functional performance of the final product</td><td rowspan="6"></td><td rowspan="3"></td></tr>
<tr><td>On-line control of processes</td></tr>
<tr><td>Counting</td></tr>
<tr><td>Command and control</td><td>Short delay (1)</td></tr>
<tr><td>Supervision</td><td>Temporary loss, self-recovered (2)</td></tr>
<tr><td>Man-machine interface</td><td>Stop and reset (3)</td></tr>
<tr><td>Alarm</td><td>Short delay (4), temporary wrong indication</td><td></td></tr>
<tr><td>Data transmission and telecommunication</td><td>No loss, possible bit error rate degradation (5)</td><td>Temporary loss (5)</td></tr>
<tr><td>Data acquisition and storage</td><td colspan="2">Temporary degradation (2) (6)</td></tr>
<tr><td>Metering</td><td colspan="2">Temporary degradation, self-recovered (7)</td></tr>
<tr><td>Off-line processing</td><td>Temporary degradation (6)</td><td>Temporary loss and reset (6)</td></tr>
<tr><td>Monitoring</td><td>Temporary degradation</td><td>Temporary loss</td></tr>
<tr><td>Self-diagnosis</td><td colspan="2">Temporary loss, self-recovered (8)</td></tr>
</table>

Key to the table:

(1) An insignificant delay (compared to the time constant of the controlled process) is acceptable.

(2) Temporary loss of data acquisition, and deviation in event scheduling time is acceptable, but the correct sequence of events shall be maintained.

(3) Manual restoration by operators is allowed.

(4) With respect to the degree of urgency (not to the process).

(5) Temporary bit error rate degradation can affect the communication efficiency; automatic restoration of any stoppage of the communication is mandatory.

(6) No effect on stored data or processing accuracy.

(7) Without affecting the metering accuracy of analogue or digital indication.

(8) Within the system diagnostic cycle.

Note: although safety is mentioned in the above table, these procedures do not necessarily ensure that all EMC issues relating to safety are addressed. EMC-related safety is outside the scope of this document.

7 Reduce the EM performance requirements

The above work can sometimes find that significant additional EMC performance is required, compared with what is described by the EMC standards mentioned above. These are often a cause of great increases in cost and timescale.

But it is wonderful to discover such important EMC problems, because if they had not been discovered at this early stage they could have seriously compromised the customer's satisfaction with the final product, as well as seriously compromising the manufacturer's income from the undertaking.

Whenever such EMC problems are identified before a project is committed to, discussions with the potential customer can often find a way to easily reduce them, if not eliminate them altogether, permitting more-or-less commonplace EMC performance specifications to be used after all. The following sub-sections describe some of the possibilities.

7.1 Segregation of equipment and their cables

Proximity of the final product (or its cables) to a particular equipment, system or installation (or its cables) causes problems which could be alleviated if the distance between them could be increased.

This technique is often called *segregation* and is the most very powerful and low-cost technique available when used in the early stages of a project.

7.2 Training operators in the use of walkie-talkies

Where a private mobile radio system is absolutely required to be used by operators, they can be trained not to hold the transmitters too close to equipment or cables.

A distance of greater than 1.5 metres generally reduces their RF fields levels down to under the 10V/m specified in the industrial generic immunity standards EN 61000-6-2 (see Table 2 in C.8). Closer proximity than this will require increased immunity performance specifications around the frequency of operation (±10% or ±25%, see C.6.1) of the hand-held.

Also, a distance of >1.5m may be required so that intelligible reception is achieved given the radio emissions of the final product. The emissions standards only suggest a 'protection distance' of 10m or 30m for broadcast radio receivers, but most private radiocommunication systems are *usually* more robust and closer distances *should* be achievable without special measures.

It may prove possible to persuade the potential customer to change his radio-based walkie-talkie system with one based on infra-red, which has no EMC problems relating to proximity at all.

7.3 Banning hand-held radiocommunications

The proximity of hand-held radio transmitters can be a big problem in these modern times. Cellphones, CB radio, amateur radio, TETRA, are all examples of hand-held radio transmitters.

Another problem is Personal Digital Assistants (PDAs), portable computers, portable inventory control equipment which may be fitted with GSM or similar radiocommunications. The users of these will often be unaware that they involve radio transmitters.

Banning the use of such devices near to certain items of equipment is a technique that is often used, but needs constant vigilance by the owner/user because most people don't seem to think before using their mobile phones, or else don't realise that they are radio transmitters.

Bluetooth and IEEE 802.11 are about to become commonplace, but at the moment their transmitted power is so low that they can be ignored unless placed within 200mm of a man-machine interface, transducer or other sensitive part. (Note that EMCD immunity standards state that they do not cover the proximity of mobile radio transmitters, or of equipment that uses RF energy and is covered by EN 55011 or CISPR 11).

7.4 Keeping vehicles away

The final product could be located, or else road vehicle movements guided, so that vehicles which are potentially fitted with various types of radio transmitters (can be as much as 100W RF power) are kept far enough away so that the radiated field levels in the relevant immunity standard are not exceeded. For a typical road vehicle the distance should be >10m to keep exposure below the 10V/m levels in EN 61000-6-2 (see Table 2 in C.8).

Aircraft and helicopters are also fitted with 100W radio, but are also fitted with distance measuring equipment which emits 1kW RF power. Marine vessels are fitted with radars which typically emit 25kW RF power using highly-directional antennae that give much higher fields strengths along their beams. These vehicles need large distances (or shielding and filtering, see below), but are only likely to be a problem near airports, marine routes, harbours or docks).

7.5 Grounding, shielding, filtering, suppression, etc.

A number of remedial EMC measures are available, such as earthing/grounding, shielding, filtering, surge suppression, etc. to help make equipment EM compatible with its operational EM environment. These can generally be applied to the final product's location or to the equipment, system or installation that is causing the problem for the final product.

A potential customer might agree to treat his site (or part of it) using any or all of these remedial measures so as to ease the EMC burden on the final product.

8 Update the EMC performance specification during a project

The EMC performance specification must be generated before a project is undertaken. At this stage there may be a number of uncertainties, requiring estimates to be made in the EMC specification.

During the lifetime of a project these uncertainties should diminish, possibly permitting refinement of the original specification to avoid under- or over-engineering, with their attendant financial risks and risks of failing to meet the EMCD's protection requirements.

It may also happen that unforeseen issues or opportunities may arise during a project. For example, the customer might decide to equip all staff with walkie-talkies, or to replace an existing walkie-talkie system with one based on infra-red.

So the EMC specification is often required to be a 'living document' during a project.

An important aspect of this activity is the need to keep current with possible changes in the final product's operational EM environment, where these changes were not addressed by the original checklist. One way of doing this might be to run through the checklist at regular intervals with the customer during the course of a project, to see what, if anything, has changed. Other methods of keeping aware of possible changes exist, and the method chosen should be described and controlled by the EMC Control Plan.

Take care if amending a final product's EMC performance specification when the performance spec. has been made part of the contract with the customer. On the one hand it is a good idea to make the specification a part of the contract with the customer, on the other it can limit your ability to adapt the specification in the light of new knowledge to save time and cost. Contracts and other agreements with the customer are outside the scope if this document.