EMC for Systems and Installations

Part 6 – CE plus CE ≠ CE!   What to do instead

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This is the final article in a series of six bi-monthly articles on EMC techniques for system integrators and installers, which will also interest designers of electronic units and equipment. The material in this series is based on the new book "EMC for Systems and Installations"[1], which I co-wrote with Tim Williams of Elmac Services. These six articles focus on practical details, ignoring the background information that every engineer needs, and so they contain much less material than [1]. This series addresses the practical issues of controlling interference and improving reliability, which would still be commercially and financially necessary even if the EMC Directive did not exist. EMC management, testing, legal and compliance issues are also not covered in this series (although they are in [1]).

The topics covered in these six articles are:

0) General Introduction – the commercial need for EMC in systems and installations

1) Earth? what earth? (The relevance of what is usually called 'earth' or 'ground' to EMC)

2) EMC techniques for installations

3) EMC techniques for the assembly of control panels and the like

4) Filtering and shielding in installations

5) Lightning and surge protection

6) CE plus CE ≠ CE!   What to do instead

These EMC techniques apply to the majority of land-based systems and installations, and will be relevant for many others. However, some special systems and installations may use different or additional techniques, as mentioned early in the first article in this series. Some of the techniques in this series may contradict established or traditional practices, but they are all well-proven and internationally standardised best practice at the time of writing, and professional engineers have an explicit duty (professional, ethical, and legal) to always apply the best knowledge and practices.

Remember that safety should never be compromised by any EMC technique. Where errors or malfunctions in electronic circuits or software could *possibly* have safety implications, this is known as functional safety. In such instances, meeting the EMC Directive and its harmonised EMC standards will probably <u>not</u> be enough to meet safety laws. For more on this read the IEE's new professional guidance document "EMC and Functional Safety" [2].

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6.1 Introduction: achieving compliance whilst also reducing costs

The CE + CE = CE approach to EMC compliance is often used by control panel builders, systems integrators, and personal computer assemblers. *Unfortunately, it does not work*. (And it does not work for the Low Voltage Directive either.)

The only EMC directive court cases so far held in the UK have shown that the CE + CE approach does not have legal validity. Most EMC test laboratories will also tell you that they have never tested a control panel made using CE + CE approach that passed the tests that need to be applied when self-declaring compliance with the EMC directive.

So why doesn't this tempting approach actually work, and can anything be done to make it work? These questions are the subject of this article. In fact, a CE + CE *type* of approach can be made to work very well indeed, if a little engineering expertise and good plain common sense is added to the basic formula. Compliance with other Directives, such as LVD or Machinery Safety can also benefit from a similar approach to that recommended below.

Leaving aside questions of legal compliance, experience shows that many very expensive problems with systems and installations are caused by interference. The interference may be 'intra-system' – occurring within the cabinet housing the electronic units (e.g. motor drive interference with sensitive transducers) or it may be 'inter-system' – the product or system works fine until installed on the customer's site, when it suffers from instrumentation errors or becomes unreliable.

The costs of dealing with such issues, even if they only occur on one out of ten systems, can be so high as to compromise the financial viability of a company. There are actual examples where a single interference problem has made a company bankrupt, and this is of special concern where a contract includes penalty charges. As advanced electronic technology finds its way into everything, no matter how humble, the possibilities for interference are increasing. They are also increasing because modern technologies (digital, switch-mode, wireless communications) all tend to emit electromagnetic disturbances, whilst at the same time they use integrated circuits with ever-increasing densities and lower operating voltages which makes them more susceptible to electromagnetic disturbances. So even where European EMC compliance is not a goal, the techniques described here should significantly reduce financial risks, which will be music to the ears of the financial directors or vice-presidents.

The EMC compliance and reliability of a final apparatus, whether it is a product, system, or installation, is the legal responsibility of the final manufacturer or assembler – the company who sells it under their own name. In the EU, users of apparatus also have a duty to only "take into service" apparatus which meets the essential requirements of the EMC Directive, although many are not aware of this or of the possibility that their operations could be closed down within a few hours if their installation causes an interference nuisance.

Many final apparatus contain complex electrical and/or electronic items that have been purchased from other suppliers, for example:

- Finished products may contain bought-in sub-assemblies such as computer boards, or complete units such as power supplies, PLCs, computers, motor drives, panel meters, instrumentation and control modules, etc. (some of which may be finished products in their own right).
- Finished systems and installations are usually constructed from bought-in finished products,

and systems, such as computers, telecommunications gear, instrumentation and control equipment, machinery, etc.

The EMC performance of the final apparatus depends upon the electromagnetic (EM) emissions and immunity performance of the bought-in items. But the "CE + CE = CE" approach can not in fact give any confidence in achieving due diligence, and leads to uncontrolled business risks (although in some circumstances it may be capable of achieving a *presumption* of conformity).

The only occasion when the CE + CE = CE approach stands any chance of working is when the individual CE marked items *really are* EMC compliant, and when they are each installed some distance away from each other (usually a few metres). Industrial control panels are often constructed of CE marked power supplies, PLCs ands/or computers, motor drives, displays and control panels, etc., all much closer together than a few metres, and test laboratories all over the UK report that when they do test such equipment to the relevant EMC standards, they almost always fail. It is this experience, over many years, that has given rise to this article.

Liability for non-compliance can not easily be passed on to the supplier of a non-compliant item. Even where this may be possible, contingent losses such as product recall costs, harm to brand-image, etc., may well prove impossible to recover from suppliers or their insurers. Where a final apparatus is found to be non-compliant by reason of the non-compliance of an incorporated item, enforcement agencies are likely to take action against both the final manufacturer and the supplier of the item.

The correct way to ensure that incorporated items do not compromise the compliance of the final apparatus is not to rely on CE marking, but instead to ensure that their EM engineering performance is adequate. The recommendations below are easy for engineers to adopt, being similar to the process they go through to ensure that functional performance is adequate. These recommendations make it quite easy to achieve due diligence for the final apparatus whilst also minimising development and manufacturing costs and timescales and reducing financial risks.

If you feel that you can’t afford the time to implement all these recommendations, at least you will be aware of the corners you are cutting. Engineering is all about compromise, but correct engineering judgement ism impossible unless you know what you are compromising. In general, the time taken by following these recommendations will be more than compensated by the reduction in panic-driven ‘fire-fighting’, and in the warranty and other financial costs of unreliable products, systems, and installations.

There may be a learning curve to climb to use these recommendations. Once climbed, designers will feel a cold shiver whenever they contemplate the financial risks they once exposed their companies to by merely insisting that the items they constructed products, systems, or installations from were CE marked and had Declarations of Conformity.

6.2 Why "CE + CE = CE" cannot be relied upon

6.2.1 What can go wrong with CE + CE?

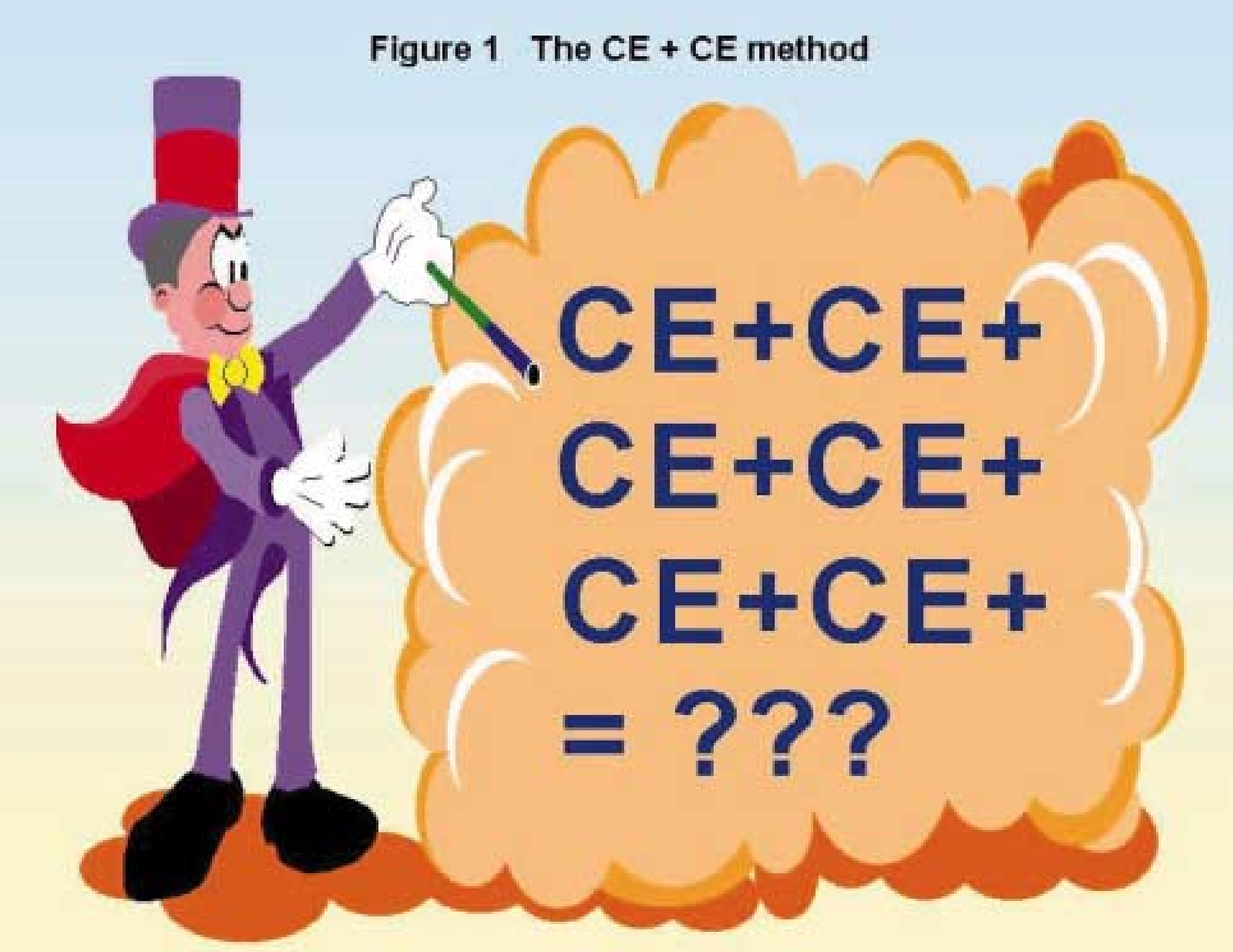


Figure 1 The CE + CE method

- When they sign their Declarations of Conformity and affix the CE mark to their products, some suppliers are known to lie.
- Some suppliers don't use the due diligence that their customers require.
- Some suppliers may have tried hard, but make serious errors.
- Suppliers of items intended for incorporation into final apparatus sometimes apply standards which make it easier for them to affix the CE mark, and not the rather tougher standards that their customers have to apply to their final apparatus.
- Where the installation of an item differs from the way it was set up when tested for EMC, this makes a complete nonsense of the item's EMC test data and any assumptions of compliance.
- Test laboratories, Competent Bodies, and Notified Bodies, can all make mistakes when they assess EMC for an item intended for incorporation.

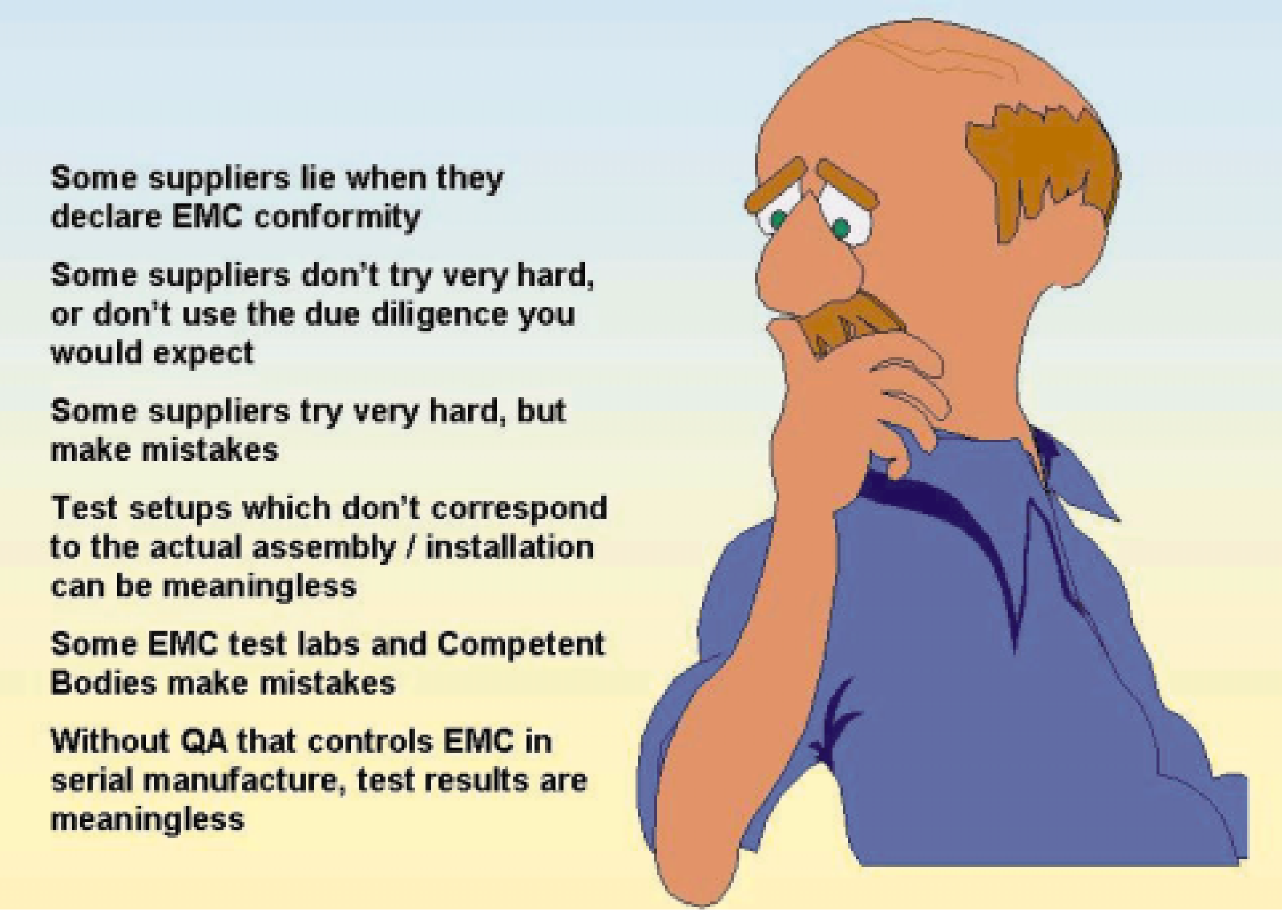


Figure 2 How much confidence can you have in the CE mark?

- Emissions add up, e.g. a fully-EMC-compliant motor drive will often have emissions just under the limits in the appropriate test standard. When two or more such drives are fitted in a cabinet their combined emissions are often found to exceed the limits for the final apparatus.
- A CE mark may have been affixed quite legally to an item intended for incorporation into other apparatus by a professional supplier, on the basis of its *compliance with the Low Voltage Directive (LVD) or Machinery Safety Directive (MSD) alone.* Its CE mark therefore has no relevance for EMC performance or compliance.
- UK case law indicates that a successful defence of due diligence cannot be assured where the manufacturer, assembler, or user, has merely relied upon statements made by suppliers. (For more on this, read the document “Complying with the Law” produced by Warwickshire Trading Standards at www.warwickshire.gov.uk/business/duedili.htm, especially its Appendix 1 items 6 and 7.)
- Without QA that controls EMC in serial manufacture, test results are meaningless.

6.2.2 Emissions add up

Imagine a single child screaming in a restaurant. That is bad enough. Now imagine ten children all screaming in the same restaurant at the same time. They all scream in different ways, using different parts of the audio spectrum, but the effect is a lot worse. All digital, switch-mode, or wireless circuits (and some analogue ones) scream – but they do it in the electromagnetic spectrum, and ten electromagnetic screamers are still a lot worse than just one.

EMC emissions standards are written around limits for items of equipment, and a final product or system has just the same emissions limits applied as the individual electronic units it is constructed from. So when choosing the units to use the possibility of emissions ‘build-up’ should be considered.

A recent example of such emissions build-up was mentioned in the Banana Skins column in the October issue of the EMC+Compliance Journal. Lighting installers will fit a hotel or supermarket out with 50 or 100 so-called ‘electronic transformers’, each rated around 50 Watts, for powering low-voltage halogen lamps (I was in a hotel recently which had at least 50 halogen downlighters in *each* of its many function rooms).

Each electronic transformer is CE marked, but even if it fully meets all the relevant emissions standards – when a number are used in a single installation their emissions are almost certain to exceed the limits for that system. The example of such a real-life problem given in Banana Skins was of such a system where the combined harmonic emissions from the ‘electronic transformers’ so distorted the waveform of the mains supply they were connected to that traditional transformers connected to the same supply overheated (due to increased core losses).

Overheating of cables and motors is another typical effect of supply waveform harmonic distortion. People often think that harmonic emissions are merely an EMC issue, whereas they can in fact have potentially very dangerous implications for overheating, toxic fumes, and fire, especially in older installations (which may use half-sized neutrals, or even smaller). I have heard of some buildings (especially in South Africa) where the neutrals have one-eighth the cross-sectional area (csa) of the phase conductors, whereas present-day recommendations are that they should always be at least the same csa as the phase conductors, with some experts recommending double the csa to cope with the harmonic currents typical of modern electronic equipment.

According to the correspondent in Banana Skins, most of the companies who make the electronic transformers aren’t concerned about the possibility of emissions build-up, despite the fact that they know their products can be used in large quantities on a single installation, and the installers themselves “couldn’t care less”. Do we really have to wait for a building to be burnt down, with loss of life (it could be yours or mine), before these people take their ethical and legal responsibilities to their customers seriously?

6.2.3 It is best to ignore the CE mark completely

To be able to have confidence in the compliance of the final apparatus it is necessary to approach the EMC of its incorporated items from the point of view of their proven EM engineering performance, and to *ignore everything to do with whether they are CE marked or not*.

The next section discusses how to establish the EM performance specifications for a purchased item. The final section describes how to check suppliers' EM evidence. Even if the recommendations in the next section are not followed, those in the final section will help sort out the suppliers who really are offering compliant items with good engineering specifications, from those who are merely going through the motions of CE marking.

6.3 Determining the EMC specifications for an incorporated item

6.3.1 Assessing the EM threats to the final apparatus

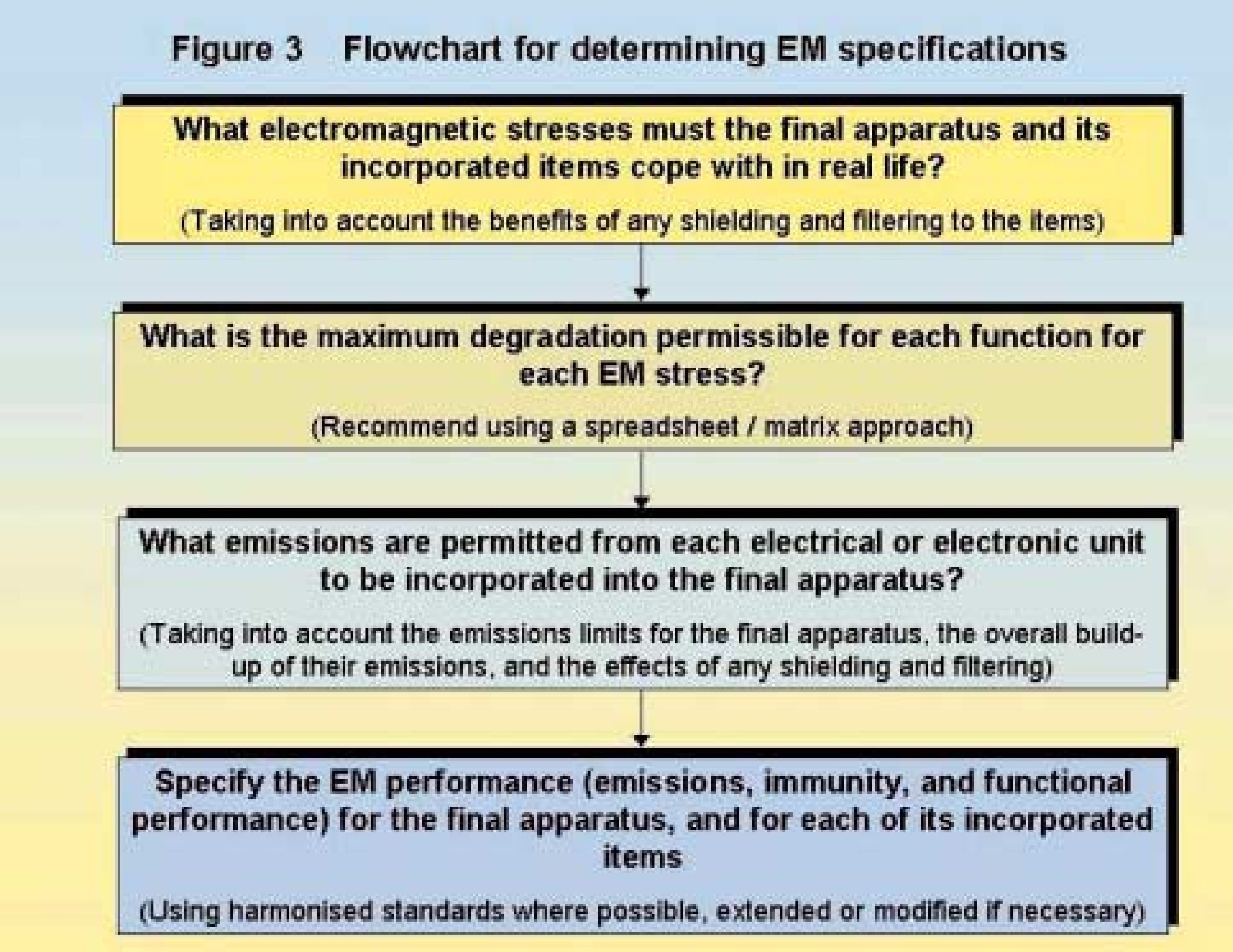


Figure 3 Flowchart for determining EM specifications

To begin with it is necessary to decide which EMC standards and levels the final apparatus needs to comply with, considering its likely or possible operational electromagnetic (EM) environments.

This may not be as simple as choosing harmonised standards from a list, because harmonised EMC standards may not adequately cover the actual electromagnetic environment. Other standards may have to be employed, and/or unique specifications written, to ensure that the final apparatus meets the essential Protection Requirements of the EMC Directive.

Assessing the EM environment usually involves (at least) a paper assessment of the EM threats the apparatus will normally be exposed to. This is often based on a visual survey, or knowledge of the user’s situation, and the very readable IEC 61000-2-5 will be found a very useful guide for this purpose.

Site surveys may turn out to be needed in cases where the EM threats are unknown or unquantifiable, but even these are no good for infrequent events such as lightning surges, for which standards such as BS6651 Appendix C provide a detailed analytical technique instead for apparatus installed in the UK (other countries may have different standards reflecting their more extreme exposure to lightning).

As an example of the possible inadequacy of immunity standards, consider an operator who is expected to use a walkie-talkie radio handset whilst controlling a machine. Even the generic heavy industrial EMC immunity standard (EN 50082-2) will not be tough enough to cover the level of exposure of the control surface to the EM fields from his hand-held.

Another example: the generic immunity standards (EN 50082-1 and EN 50082-2) will only make the application of tests for surges, dips and dropouts in the AC supply mandatory from 1st July 2001 and 1st March 2002 respectively. This is despite the fact that these disturbances are as old as supply networks themselves, and are responsible (according to some accounts) for the vast majority of interference events and warranty returns. Even so, the tests required by the new versions of these standards are known to often fall short of real-life disturbances.

A third example: a user might expect to install a plastic welder or similar high-power radio-frequency apparatus close to the final apparatus (e.g. a blister-packaging machine used close to a checkweigher) (e.g. an anaesthetic machine close to a surgical diathermic knife). This is a similar situation to the walkie-talkie exposure example above, and is not covered by (in fact is usually specifically excluded by) harmonised immunity standards.

6.3.2 Foreseeable extremes and misuse

For the EM performance of non-critical functions it is enough to consider the normal operating environment of the apparatus. But for all critical functions (whether safety-critical or mission-critical) it is necessary to consider all reasonably foreseeable situations, even if they have a low probability.

This includes considering foreseeable misuse: such as the probability that an operator or visitor will use a mobile radio device (e.g. cellphone or walkie-talkie) in areas where their use is banned.

Where electromagnetic interference can cause a safety hazard or increase risk, such possibilities are covered by safety directives and *not* by the EMC directive, so they should figure in all risk analyses under the Low Voltage and Machinery Directives. An example here is the possibility of interference with a PLC controlling an industrial robot, causing it to "go wild" and operate outside of its programmed range. It is known that some robot manufacturers do not consider this safety risk when creating the technical documentation required by the MSD, despite only guarding for the robot's programmed range, and despite deaths known to have occurred in Japan due to this very problem. Refer to [2] for more on this.

6.3.3 The electromagnetic stresses on an incorporated item

Having determined the likely EM stresses on the final apparatus, the immunity specifications for the items to be purchased may be derived.

Sometimes incorporated items are protected from the external environments to a degree (e.g. a shielded metal enclosure can reduce field strengths), but sometimes they are exposed to higher stresses – for example, an item mounted near to a variable-speed motor drive may suffer intense local exposure to electromagnetic fields, and enclosing them both in a metal cabinet can increase the threat.

Where shielding and filtering is used to reduce the external threats on an incorporated item to manageable levels, great care must be taken to follow the guidance in [1] or at least in the previous 5 articles in this series, if their intended benefits are to be achieved.

The resulting engineering specification for the purchased item will ideally be a list of harmonised EMC standards, but may have to include modifications to them, e.g. field strength increased to 30V/m at 417 - 419MHz to cope with 4 watt VHF walkie-talkies no closer than 0.5 metres. Other standards may also need to be added, e.g. surge testing to EN 61000-4-5 (surges), EN 61000-4-8 (magnetic fields), EN 61000-4-11 (dips and dropouts), EN 61000-4-12 (ring wave transients), or others at defined levels. Sometimes it may be necessary to use unharmonised EN, IEC, ISO, IEEE, VDE, or BS (for example) EMC standards, or even proprietary standards to completely specify the required immunity performance.

6.3.4 Functional performance requirements

To complete the engineering specification for the immunity performance of a purchased item, the functions that the item performs (or that depend upon its correct operation) are analysed for their criticality. Safety-critical or safety-related functions (such as emergency-stop shutdown systems) are allowed no significant degradation of performance over the whole range of electromagnetic threats, including those caused by reasonably foreseeable error, misuse, overload, failure of another item, supply failure, fuse-blowing, etc.

Where the degradation of a non-safety-related function could cause significant financial loss (such as loss of production), or embarrassment to a project (such as a satellite launch being delayed) it may be decided to treat it as if it were safety-critical. These functions are often referred to as 'mission-critical'. Less critical functions may be allowed temporary degradations of performance during transient stresses. Monitoring, reporting, and alarm functions often fall into this category, as long as they automatically recover after the event.

This exercise should result in a spreadsheet matrix of functions versus EM threats, with the maximum permitted functional degradation for each function when exposed to each threat written into the resulting cells.

The use of a product is important when deciding criticality of functions. Some DC power supplies actually switch their output off whilst they are experiencing transient overvoltages, whereas others will ride through such transients without significant deviation of their output voltage. Both of them may legally claim that they meet the relevant generic EMC immunity standard, since these allow any amount of temporary degradation of performance during transient tests (performance criterion B).

Where a power supply is feeding lamp and indicator circuits it may be acceptable for it to hiccup during a transient (although annoying). But where a power supply is feeding a circuit involved in critical functions (e.g. a PLC, relays, contactors, pneumatic solenoids, etc., controlling machine operations) it is obviously important to choose a power supply which rides-through the transient, especially as some premises have been logged as experiencing several hundred transients on their mains supplies every day.

Marketing people often claim that there is no commercial advantage to be had in EMC, which only goes to show that they are missing a significant means of creating a difference between their products and their competitors.

6.3.5 Emissions may be too high

Harmonised emissions standards allow emissions to occur, and these may be too high in situations where sensitive apparatus is nearby. This is especially important in some scientific and medical situations, usually where sensitive measurements are involved.

How many machinery manufacturers who, when asked to install a waste crushing and packaging machine at a hospital, would automatically ask what there was on the other side of the wall that their contactors and motor drives might interfere with?

6.3.6 Emissions can add up

The total electromagnetic emissions from a number of incorporated items will exceed their individual emissions. In some cases this will result in a busier emitted spectrum without any increase in emitted levels, but in other cases the emissions from the various units will be so close together in the spectrum that they will measure as higher emissions levels. But the emissions standard that will apply to a final product which incorporates a number of units in one enclosure with a single power cord often differs very little from the emissions standards that apply to the incorporated units.

A crude but effective way to determine whether emissions from units are likely to just create a busier spectrum, or will add up, is to obtain their emissions graphs and divide them into frequency segments, noting the maximum level achieved within each segment. It is usual in such exercises to use the ten frequency divisions in each frequency decade (1-2, 2-3, 3-4, 4-5, etc.) as the segments.

Convert each segment's maximum measurement from dB microvolts (or, for radiated emissions, dB microvolts/metre) into microvolts (or microvolts/metre). Then 'add together' all the maximum levels in each segment from all of the units to give the total maximum emissions for that segment.

Where the units operate from a synchronous master clock, the emissions should be added arithmetically. Where the units operate from independent clocks, even if the clocks are nominally at the same frequency, they should be added as the “square root of the sum of the squares”. Once added together, the total for each segment is then converted back into dB microvolts (or dB microvolts per metre) and compared with the relevant limit lines.

Filters and shielding can be added to reduce the dB totals, but in these cases it is very important to use all the selection and assembly techniques described in the earlier parts of this series – if their actual performance is not to be a huge disappointment.

Increases in overall emitted levels are most likely to occur when a number of identical units are incorporated into a final apparatus. For identical units whose clocks aren’t synchronised – ten of them may be crudely assumed to increase the total emissions by 10dB. When identical units are synchronised to a "master clock", ten of them may be crudely expected give an overall emissions level 20dB higher than a single unit.

For harmonic emissions the mains frequency acts as a synchronous clock, so these should always be added arithmetically. 50 ‘electronic transformers’ would have harmonic emissions 50 times (34 dB) higher than those from one unit of the same type.

Of course, this is a rather crude technique, but it does seem to work quite well in practical cases. Narrower frequency ranges should give greater accuracy, but lead to more work.

6.3.7 Specifying the item

Once all the above is done, it is possible to write a complete engineering specification for the EM performance of an incorporated item. This should include all the EM stresses it is to withstand, the amount of performance degradation allowed for each function during the application of each EM threat, and the amount of electromagnetic emissions it must not exceed.

In many cases this specification will be able merely to list harmonised EMC standards to describe the stresses and electromagnetic emissions. As long as critical functions are not involved the specifications for functional performance degradation may not be onerous for the item supplier.

The specification should be sent to the favoured item suppliers for their replies, pointing out that actual *independent evidence* of conformity with the specification will be required from the successful tenderer. Sales people will readily supply an EU Declaration of Conformity, but this is not *evidence*, so some education of suppliers' sales people is to be expected (judging suppliers' evidence is discussed below.)

6.3.8 Negotiating and compromising with suppliers

Suppliers may not be able to meet the specification, or may not be able to provide all the evidence that is required. Negotiations may ensue, leading to the acceptance of a reduced specification or reduced amount of evidence. It may also prove possible to alter the design of the apparatus to accommodate the specifications of standard items.

All engineering is compromise, and the great advantage of following these recommendations is that the designer of the final apparatus will be working with *known* compromises rather than invisible and unexpected ones.

Murphy's Law (which it often appears all other physical laws and engineering project timescales are subservient to) guarantees that an unknown engineering compromise will cause the worst possible problems at the worst possible moment. So following these recommendations may be thought of as an anti-Murphy procedure.

It is almost always commercially best to use items with adequate EM performance, rather than to purchase items which are (or may be) inadequate and deal with the resulting issues later on. Material costs may increase, but since it costs less to deal with problems at earlier stages of integration the final apparatus should benefit from least overall cost, and improved margins. The usual rule of thumb is that it costs 10 times as much to deal with a problem at the next higher level of integration, until the apparatus leaves the company for the user (in which case multiplying factors of 100 to 1000 are not unusual).

A final requirement is to make sure that the agreed EMC specifications (and the agreed requirements for evidence that they have been achieved, as discussed below) are written into the purchasing contracts agreed by the item suppliers. Some legal experts also recommend agreeing indemnity clauses too, where the supplier agrees to indemnify the purchaser against his costs should the goods turn out to be below specification.

Suppliers who claim to offer high specifications, low cost, and CE marking, but prove unable to provide acceptable *evidence* of actual EM performance, know that in the final analysis the law is "buyer beware". So one effect of following these recommendations is that the number of suppliers tends to reduce to those who have shown that they can actually satisfy their customers' real engineering needs.

6.4 Checking suppliers' evidence of EM performance

The real engineering EM performance of an item is unknown until *evidence* of engineering performance and quality control has been seen, and checked to be satisfactory (ideally by comparison with its purchasing specification determined as described above).

Not many suppliers yet provide the functional performance specifications achieved by their items during EMC immunity tests, so it may be necessary to pursue this vital data.

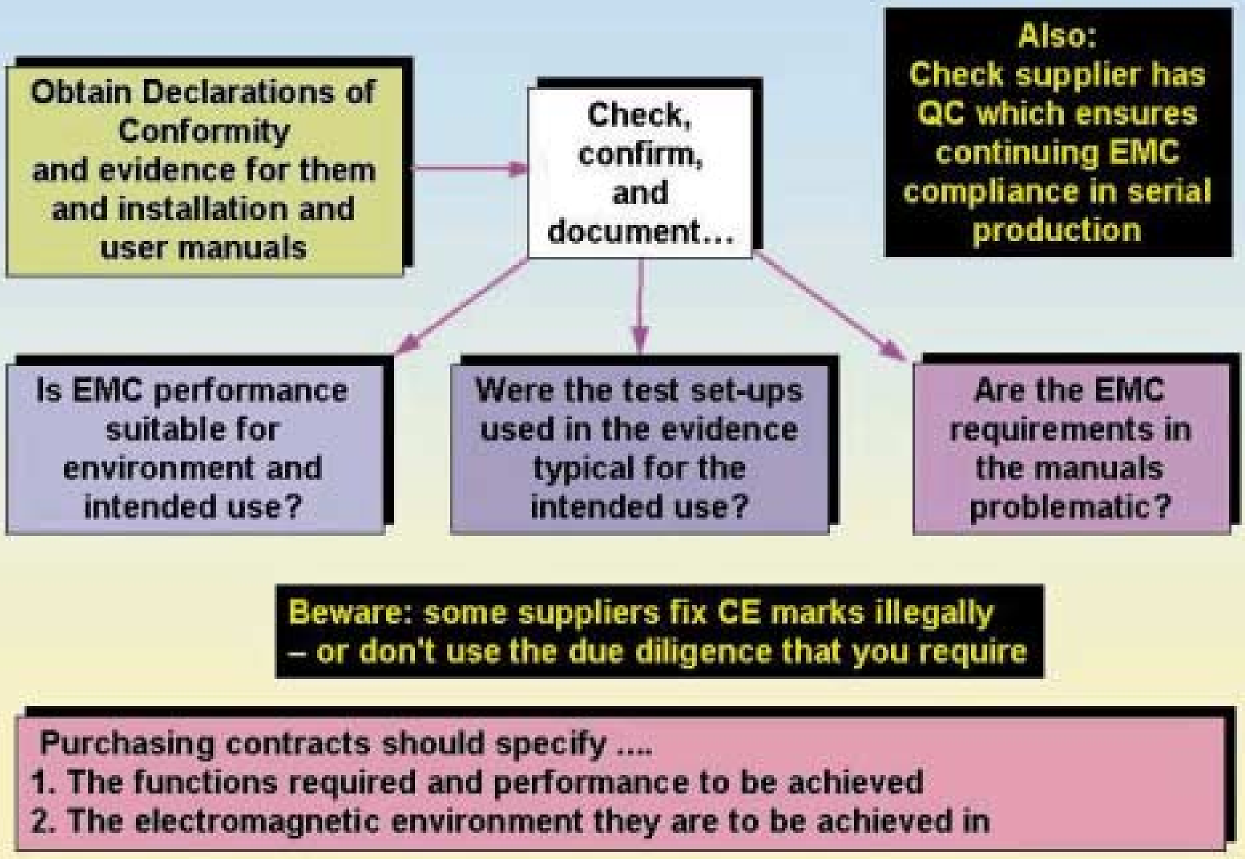
Items for which the necessary evidence is *not* available (for whatever reason) should *not* be purchased, unless it is intended to put the final product through EMC compliance tests, and unless contingency costs and timescales have been allowed for the remedial work and re-testing that is usually required in such situations.

If potential suppliers claim design secrecy issues as a reason for not providing evidence, insist on a trusted third party report which confirms that the item meets all the EM engineering specifications without revealing any of the suppliers supposed secrets. Such reports are not at all expensive or difficult for a supplier to obtain, usually from his test laboratory, *if* he actually has the evidence he claims and *if* the laboratory is accredited (or at least independent and competent).

6.4.1 Checking Declarations of Conformity

A supplier’s Declaration of Conformity (D of C) is not *evidence*, although it may be possible for small companies making low volume apparatus to rely on them where there are no significant implications for safety or financial loss implications (check with the local enforcement officers).

Figure 4 Check, confirm, and document...



Even so, Declarations of Conformity are useful as a guide to the intended use of the item and the competence of its supplier. Things to look for in a D of C include whether they list the EMC standards required by the engineering specification for the item. It may prove difficult to judge whether items are suitable if they list different standards.

Some standards, such as EN 61800-3 for the EMC of motor drives and EN 61131-2 for the EMC of PLCs, cannot be applied to the final apparatus and so may be of little help. These two standards appear to have been written by the manufacturers of drives and PLCs to make their life easier, but without any regard for the needs, costs, and business risks of their customers. Drive and PLC suppliers who have their customers best interests at heart will meet the EMC standards their customers have to meet (usually the relevant generics), with a large margin for emissions (say, 10dB at least) to account for the inevitable variations in their own serial manufacture and the build-up of emissions that often occurs in their customers' products.

It is also worth checking whether the D of C actually covers the item concerned (and not something else), and is clearly signed and dated by the supplier's Technical Director or equivalent. Dates which are only a few days old, for items which have been on the market for many months, must be suspect.

Also check for any inappropriate or unreasonable warnings, limitations to use, or attempts at disclaimers, such as "*Do not use this product if it causes interference*" or "*May stop working when interfered with*" both of which are not unknown. Products not intended for safety-critical application (such as ordinary PLCs) should state that they are not intended for such use at every possible opportunity, as well as on their D of C, although few do.

6.4.2 Problems to watch for concerning standards

It is impossible to discuss the full range of EMC standards here. There is often a lot of confusion over the generic EMC standards – with suppliers choosing those that make it easier for their CE marking, rather than providing the engineering performance that their customers actually need.

Remember that it is the function and user environment of the final apparatus that governs which standards apply to it, rather than the technology it incorporates. This can lead to a number of problems with the standards applied to incorporated items, some of which are described below. For example, commercial and light industrial control panels which use microprocessors have to apply EN 50081-1, and should not use EN 55022 (the EMC emissions standard for information technology) which it is often thought may be applied to anything that uses digital technology.

6.4.3 Problems to watch for concerning the generic EMC standards

There are two sets of two generic EMC standards, each covering emissions and immunity, making four generic EMC standards in all:

- EN 50081-1: this is the tightest generic emissions standard. It applies to residential, commercial and light industrial environments. This is equivalent to EN 55022 Class B, VDE0891 Class B, CISPR22 Class B, and broadly similar to EN 55014-1, EN 55011 Class B, and FCC Part 15 Class B.
- EN 50081-2: this is a more relaxed emissions standard for (heavy) industrial environments. This is broadly similar to EN 55011 Group 1 Class A, and EN 55022 Class A.
- EN 50082-1: this is a fairly relaxed immunity standard for residential, commercial, and light industrial environments (Issue 2: 1997 is much better than the original 1992 issue, and will have to be applied from 1/7/2001 in any case).
- EN 50082-2: this is the toughest generic immunity standard. It applies to (heavy) industry environments.

The best items for general uncontrolled use, or where the user's environment may not be very well defined, are those that meet the toughest standards for emissions and immunity: EN 50081-1 and EN 50082-2. The best items will meet EN 61000-6-2 (which will take over from EN 50082-2 from March 2002) because it includes tests for surges (EN 61000-4-5) and dips and dropouts (EN 61000-4-11) which we know to occur in real life. Standardising on such items makes the selection of items and their use in custom engineering projects much easier.

Items declared using EN 50081-2 are often sold for incorporation in apparatus intended to be used in light industrial and commercial environments – but their emissions are too high for these environments and their use would necessitate additional EMC work and probably EMC testing of the final apparatus, for due diligence to be achieved.

Similarly, items declared using EN 50082-1 are often sold for incorporation in (heavy) industrial environments, where their immunity will be too low without additional EMC work and probably some testing of the final apparatus, for due diligence.

Some items are declared using EN 50081-2 and EN 50082-1, the easiest of all the four generics – but this means they are too noisy for residential, commercial, and light industrial environments and not immune enough for heavy industrial environments, so they cannot be used anywhere without significant additional EMC work, plus (probably) some testing of the final apparatus, for due diligence.

6.4.4 Problems to watch for concerning EN 55022

Items which may be classed as information technology or telecommunications equipment, e.g. computers, modems, printers, VDUs, keyboards, etc., are allowed to use the Class A EMC emissions limits in their product-specific EMC standard EN 55022 for use in the commercial and light industrial environments.

But almost all other EMC emissions standards require tighter limits for commercial and light industrial environments (usually equivalent to EN 55022 Class B).

So when an item which meets EN 55022 Class A is incorporated into final apparatus that is not allowed to declare compliance using EN 55022, such items can cause excessive emissions and lead to non-compliance with the relevant EMC emissions standard.

This is a common problem when integrating computers and computing devices into industrial control systems; or printers, keyboards, and displays in almost anything.

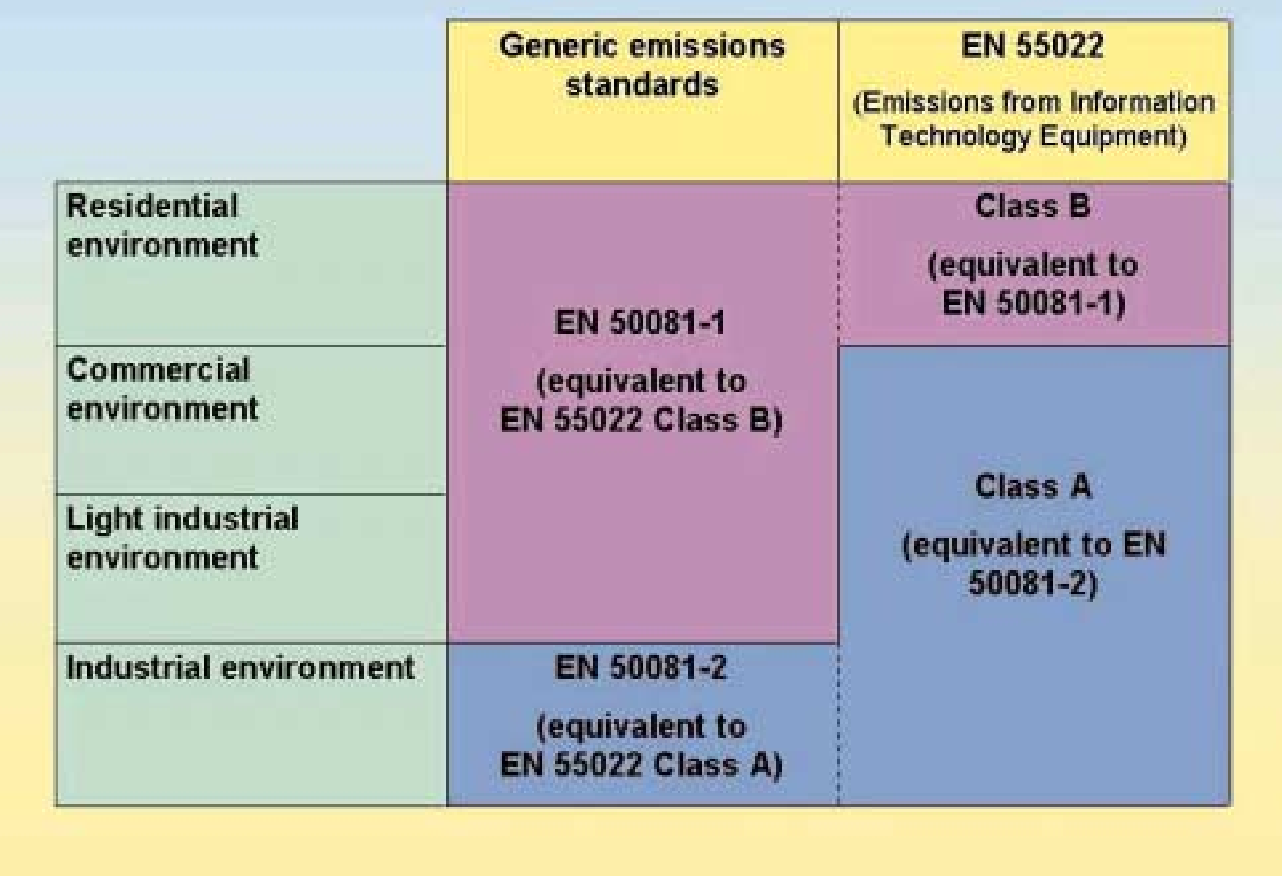


Figure 5 Comparing generic and EN 55022 emissions

6.4.5 Problems to watch for concerning EN 55011

Items declared using EN 55011 are "ISM" equipment: which means they may use electromagnetic energy to achieve their main function. Examples include dielectric heaters such as wood dryers and gluers, plastic welders and bag sealers; induction heaters; electric welders; spark erosion machines; magnetic stirrers; and diathermy equipment, whether medical, physiotherapeutic, or cosmetic (such as some depilatory machines used in beauty salons).

EN 55011 allows some categories of equipment to emit *very high, and even unlimited levels of EMC emissions* at specified frequencies, and so can cause considerable immunity problems for other equipment and even serious health hazards for their operators.

When incorporated in final apparatus that cannot apply the EN 55011 standard, ISM items can cause excessive emissions which lead to non-compliance. Significant additional EMC work and probably some testing, remedial work, and re-testing, of the final apparatus may be required.

6.4.6 Checking assembly and installation instructions

For an item to actually achieve the EM performance that its test and other evidence implies, it is necessary to assemble or install it fully in accordance with its supplier's detailed instructions. This is very important for EMC, which can easily be compromised merely by the use of the wrong type of cable, or the incorrect use of a "pigtail" on the screen of a cable. Suppliers of complex electronic products who cannot (or do not) provide detailed assembly and installation instructions, should be avoided.

A big problem for many one-off and custom engineering projects is that assembly and installation staff do not usually follow suppliers' detailed instructions, preferring to use what they have considered to be "best practices". Many of these practices have survived unchanged for twenty or more years and are more properly called “what I learned when I was an apprentice”. Refer to [1], or at least to the previous five articles in this series (all archived at www.emc-journal.co.uk) for more information on present-day best practices for EMC.

Suppliers' instructions should be checked for inappropriate or vague limitations or instructions, such as the following, all of which have been seen in real life (even on products from supposedly reputable companies):

- "Do not use this product if it causes interference"
- “Do not use this product where it might be interfered with”
- "If interference occurs, fit filter and/or fit product in shielded box"
- "This product may require manual reset after transient interference"
- “This product may fail when exposed to transients or surges”

Assembly and installation instructions should also be checked to see if they specify expensive or exotic cables or connectors, additional filters, shielding, or unusual environmental conditions. These can significantly affect the overall project cost and timescales, a good reason for carefully reading an item's assembly and installation manuals *before* making the decision to purchase it, rather than after as is usually the case.

The right time to discover that the 100 metres of cable you need to meet the supplier’s EMC instructions is only available to special order, has 32 weeks delivery (if you are lucky), has a minimum order quantity of 5 kilometres, and costs £1 per metre plus shipping costs of £2,000 – is *before you place the order for the item*. Then you can instead choose a different supplier, whose product may cost more, but who will allow you to make more of a profit on the project.

The wrong time to discover the above unpalatable facts is when you have just installed the final product and discovered that it will not function correctly, and the contract’s penalty clauses have already come into effect.

6.4.7 Checking test results and certificates

With a little experience, suppliers' test reports can be most revealing. Comments in test reports such as "*this part of the standard was not met …..*" are most revealing.

Full test results from an accredited test laboratory make the most convincing evidence. "Accredited" means that their measurement accuracy, understanding of the standard, quality systems, competency, and independence have all been checked and approved by a government-appointed accreditation body, giving a useful degree of confidence in their test reports.

EMC tests are notoriously inaccurate, with even world-class accredited laboratories experiencing ±6dB differences when measuring the same unit item. It is not unknown for measurements from non-accredited laboratories to be in error by 20dB, or for the wrong performance criterion to be applied (e.g. B ‘any amount of degradation during the test’ to be used instead of A ‘full performance to be maintained during the test’).

Test laboratories can only be accredited for specified test standards – so although we tend to say "Accredited laboratory" what we really mean *is "Laboratory that is accredited for the test standards they have been favourably assessed to*". So don't be fooled by the logo of the accrediting body on the test laboratory letterhead: check whether the laboratory actually is accredited for all the tests covered by its report.

Full test results should include: the exact identification of the model (and version) tested; detailed sketches or photographs of the test set-ups; lists of the test equipment used and their calibration dates; whether the item passed or failed the test; and should be signed by the test engineer. Accredited laboratories may have QA regimes that take care of the equipment calibrations so that they don't need to appear on the test reports.

EMC reports should include emissions graphs showing they are comfortably under the limit lines, and the functional performance criteria for the immunity tests.

Sometimes suppliers provide a test certificate from their test laboratory – one page that summarises the performance of the item. Test agency logos such as VDE, SEMKO, DEMKO, NEMKO, UL, CSA, SEV, BSI, etc., may also appear on the product or its documentation. However, there are plenty of examples of suppliers fraudulently marking their products with agency logos or approval marks without actually having any such approval from the agency concerned, and some suppliers have been found modifying an existing laboratory test certificate (even ones from their competitors) so that it appears to cover a different product.

So it is always best to confirm all certificates with the issuing test laboratory, especially where the item concerned seems to have a bargain price, regardless of the protestations of the salesman. With profound apologies to those few ethical salespersons left: nobody with any sense or experience takes a salesperson's claims seriously. What counts is actual photocopy-able and verifiable engineering evidence. The easiest thing to do is to fax (or scan and email) the purported test report to the test lab concerned and ask them to confirm that it is 100% genuine and unaltered, or else ask them to fax (or email) their copy of the same document back to you, so you can check it is unaltered from the original.

The actual performance as shown by the test reports or certificates should then be compared with the agreed engineering specifications for the item concerned. It is not unknown to find that EM emissions exceed the limit line, or that some of the claimed immunity tests have not in fact been done.

If the test lab that generated the test report is unknown to you, check with the body that is supposed to be accrediting it, or else check with test labs that you know to be trustworthy, to see if you can find out how much confidence to attach to their reports. If this proves difficult, have a trusted test lab check over the report – you may be surprised at the glaring errors that sometimes turn up, such as testing a power supply for RF immunity without connecting it to any output leads or load.

6.4.8 Checking test set-ups

Proper EMC test reports will include sketches or even photographs of the test set-ups employed, and descriptions of how the tests were conducted. These should be checked for the following:

- Do they agree with the supplier's detailed EMC installation instructions? Watch out especially for the use of special types of cables or connectors, and for ferrite clamps and additional bonds to their local RF reference (see section 3.6).
- Do the test set-ups relate to how you intend to use the item? Check especially for a lack of some of the external cables (cables usually create the biggest EMC problems, so leaving them off usually gives better EMC results).
- Were the emissions consciously maximised, and immunity consciously minimised, by the test procedures, methods, and set-ups?

In all EMC test reports, make sure that there are no damning comments along the lines of "*the product only met the standards when .....*". It is not uncommon for the supplier's engineers to apply remedial measures to products during testing, which an aware test engineer will fully record in the test report. What can then happen is that these remedial measures get "forgotten" when the items are manufactured.

6.4.9 Checking EMC Technical Construction Files (TCFs)

Where a product has been declared compliant with EMC Directive by using a TCF rather than harmonised standards, it will be valuable to check the Competent Body's assessment or report on the TCF. It is not uncommon to find a number of warnings where the assessor has not been able to declare the product non-compliant, but nevertheless has serious concerns.

Such warnings are often along the lines of: *"The supplier should make clear to the customer certain specific installation requirements and limitations to use...."*

6.4.10 Suppliers' quality control

The fact that a supplier has had an example of an item tested for EM performance using acceptable standards, and it has passed, ***proves nothing whatsoever about the EM performance of any of the other units of the same type and/or model.***

Even where a supplier has a BS EN ISO 9000 quality system in place, by itself this is no guarantee that the standard items supplied to the manufacturer of the final apparatus have any EM performance at all. All it means is that the company is audited against its quality manual. So it is important to discover what their quality manual says about maintaining the specified EM performance in production.

To control the EM performance of serial-manufactured products a supplier must have controls over design changes and production concessions, unit build standard, repairs, refurbishment, and upgrades, at least as far as all EMC issues are concerned.

Even with all these controls in place a number of elements are still uncontrolled – especially the performance of the components that they buy in – and this makes it necessary for suppliers to have a sample-based testing policy for EMC. The better the suppliers' controls over its design, purchasing, production, and repair, the lower need be its rate of sample testing.

Companies with a "supplier approval" procedure will find it quite easy to add the necessary additional requirements to ensure that the EM performance evidence provided by the supplier stands some chance of being representative of the items actually purchased.

6.5 Conclusions on costs and benefits

The recommendations in this article will generally require more work from designers than they may be used to, but they should be seen as part of a right-first-time approach to improve overall business efficiency and profitability, and reduce financial risks (not to mention reducing the physical and psychological stresses on engineers and reducing their possible exposure to personal liability claims and criminal penalties).

Adopting these recommendations will generally result in:

- cost and time savings for the overall project
- higher reliability for the user
- a lower level of warranty claims
- an improved market image and level of repeat sales

From the financial risk point of view, following these recommendations will result in:

- very significantly reduced exposure to penalty clauses in contracts
- lower risks of banning from the EU market for non-compliance
- significantly reduced exposure to product liability claims

The overall cost to the business of adopting these recommendations should be neutral, or even negative.

6.6 References and further reading

[1] "*EMC for systems and installations*", Tim Williams and Keith Armstrong, Newnes, 2000, ISBN 0 7506 4167 3.

[2] "*IEE Guide on EMC and Functional Safety*", IEE Publications September 2000, free download (a 'Core' document plus nine 'Industry Annexes') in either Word or PDF format from http://www.iee.org.uk/PAB/EMC/core.htm (note: the URL may be case sensitive).