Adding Up Emissions

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Wouldn't it be nice if we could use CE marked components and sub-assemblies to construct products and be confident that they would meet the EMC Directive! This is something of a holy grail for manufacturers of one-off and limited production products such as some computers and most industrial controls. This article briefly describes how to achieve this most desirable objective.

It also describes how in the future it should be possible to achieve EMC due diligence merely by selecting the components and subassemblies to be used from a floppy disc or CD-ROM, along with making sure that assembly and service staff follow EMC instructions.

Why CE + CE does not equal CE

As I'm sure everyone knows by know, having absorbed the details of the Cardiff Trading Standards prosecutions of two computer companies who used CE marked "components" to build PCs, there are a few significant problems with the CE + CE = CE approach.

1.

The first problem is that the components and sub-assemblies may not have been EMC tested at all (just having a CE mark is no guarantee of EMC compliance, it could have been applied just for the Low Voltage Directive).

2.

Even if a component or sub-assembly is claimed to have adequate EMC performance, and/or is CE marked to the EMC directive, it may not have been tested properly. It is impossible to have any confidence in EMC performance solely on a manufacturer's declaration, as court cases in the UK under other directives have sown. Confidence can only really be achieved if the manufacturer provides actual evidence of EMC performance - from a test lab in whom we can also have confidence (such as a NAMAS/UKAS accredited lab).

3.

Even if the component or subassembly has been tested properly according to the test standard, it may not have been set-up in the way described by the instructions provided with the product. The instructions provided with a product should always describe in full the enclosure, cable, and connector types and all the installation techniques required to achieve the intended EMC performance. They should also include a clear statement about the environments the product is intended for use in, and any limitations to use.

4.

Even if a component or sub-assembly has been tested in accordance with its manufacturers' installation instructions, it is often the case that its purchaser does not actually follow these instructions or use it in the environments for which it was intended. Most wiremen and other assembly personnel use the materials and techniques they are familiar with from their early days, and often ignore instructions provided with the components and sub-assemblies.

5.

If all the above is achieved correctly, there is a good chance that the immunity performance of the overall assembly will be as good as that of the weakest component or sub-assembly, but the problem with emissions is that they add up. Ten identical motor drives in a cabinet will produce ten times the emission noise power of one drive, so merely using components and sub-assemblies that individually meet the emissions standards required for the finished product usually just ensures that the final product is over the emissions limit.

The RSS method

However, there is an electronics industry standard technique for finding the resultant noise from a multiplicity of uncorrelated noise sources - the RSS method (for Root Sum Square), and we can use it for calculating EMC emissions compliance.

Where noise sources are correlated (such as a number of items all running from a master clock, such as digital signal processing boards) the line spectra produced by the harmonics of the digital signals are likely to be all in phase at exactly the same frequencies, so these emissions can be expected to add up linearly (e.g.: a 6 dB increase for every doubling of the number of identical units).

PC boards will share one or more data buses which are clocked in sync., but usually rely on their own clocks for their internal processing, so some of their emissions will be correlated with each other, and some will be uncorrelated.

In most industrial control panel assemblies, the individual electronic units and motors emit uncorrelated emissions, for which the RSS method is suitable. RSS-ing the emissions from a number of identical noise sources (such as a number of drives) gives a 3 dB increase for every doubling of the number of identical units.

One crude result from this is that, for uncorrelated emissions, if all the individual items could be relied upon to never be higher than 9 dB below the emissions limit line for the final product, then the final product would probably meet the limit line as long as no more than 8 items were used and their manufacturers' detailed instructions had been obtained and followed faithfully. (Any number of EMC-passive items, such as filament lamps, can also be included.). So if each of the items used met the emissions limits of EN 50081-1, an assembly of 8 of them would be likely to meet EN50081-2, all else remaining the same.

For items which are never worse than 20 dB below a limit line, up to 64 could be used without their uncorrelated emissions adding up and exceeding the limit.

Where items are different, such crude calculations can lead to over-engineering. Where emission frequencies are not similar, adding items merely makes for a busier spectrum and does not increase the measured levels. This is where the RSS technique can be used to advantage.

Ideally, an RSS summation would be applied to every single frequency covered during an emissions measurement - but this would result in a large amount of data. Processing such large data arrays is easy on modern computer spreadsheets, but the problem arises in getting the data into the computer in the first place - since test labs output their results as printed graphs the only way to get the data at present is to read the graph and key the data into a spreadsheet, and it is difficult to read the frequencies with the accuracy required. Test labs usually store measurement data to disc, but their data formats are incompatible with each other and probably with standard spreadsheets as well.

To overcome this, the emissions profile for each item is broken down into an arbitrary number of frequency ranges (150 - 200 kHz, 200 - 300 kHz, 300 - 500 kHz, etc.) and the worst case emissions in each range entered into the RSS spreadsheet. When all the items used in the final product have been entered, the spreadsheet calculates the root of the total sum of the squares of each individual reading, for each band, compares them with the limit line, and gives a pass/fail result for each band. It can also draw a graph of the total emissions. The narrower the number of frequency ranges used, the greater will be the time taken but there will be a lower possibility of significant over-engineering.

If the total emissions are over the limit, a different choice of components and sub-assemblies may give a better result, or else filtering and shielding may be applied. Where suitable quieter components are available, using these is likely to be the least expensive way to reduce emissions, since the lowest-cost EMC techniques are only available to the electronic circuit designer and the writer of the embedded software.

Adding filters and shielding to an RSS-ed result

Alternatively, to reduce conducted emissions, data on the attenuation of a suitable mains filter may be subtracted from the total. There is no need to RSS the effect of a filter, but it is important to use only the worst-case filter data - not the usual 50 Ohms/50 Ohms common-mode measurement. Many reputable filter manufacturers publish both common-mode and differential-mode attenuation data, for 50 Ohms/50 Ohms, 0.1 Ohms/100, and 100 Ohms/0.1 Ohms terminations. The worst-case attenuation data from all of these should be used, for each frequency band in the spreadsheet. Note that most simple filters actually provide gain below 1 MHz, when both ends are not terminated in 50 Ohms (as they almost never are).

To reduce radiated emissions, a shielded enclosure may be added. In this case the attenuation data used should be the worst-case found from magnetic, electric, and plane-wave tests. There is no really standardised test method for enclosures, and the test methods used will not accurately simulate the particular components used, so it is a good idea to aim for a final safety margin of 10 dB or more. As for mains filters, the attenuation figures are not RSS-ed.

Note that when using shielded enclosures all the cables entering or leaving the enclosure should be screened and/or filtered, with their screens and/or filter grounds terminated metal-metal at the point of entry and with each of the screens, connectors, glands, and filters having at least the same attenuation performance (with worst-case terminations) as is required for the enclosure as a whole. The enclosure should also not be modified in any way, except for the fitting of cable connectors/glands and bulkhead filters. If a screened window is required to view a VDU, the enclosure should be a type already fitted with a shielded window. Where apertures are required to be cut for door-mounted controls or non-bulkhead-mounting filters, care is needed (such as the use of the clean box/dirty box method) not to compromise the enclosure shielding.

It is important to realise that although normal metal enclosures generally provide some shielding at most frequencies, they are also prone to "beaming" which can actually increase emitted field strengths in some directions, at some frequencies, giving emissions measurements on the beam which are higher than when no enclosure was used at all. Consequently the enclosures to be used should be those which have been properly tested for their shielding effects by a test lab we can have confidence in.

So, providing all the components and sub-assembly items have been tested the way we intend to install and use them, and providing we install and use them in the way they were tested, we can have confidence in the immunity of the final product, and also have confidence in the emissions that have been added up using the RSS technique.

RSS mathematics

I have not given the details of the RSS mathematics, as they are available free of charge in one of the common spreadsheet formats from SGS (phone 0191 377 2000, fax 0192 377 2020 and ask for their RSS disc).

If you are doing it yourself, however, note that the dBµV figures from the measurements must be converted into normal microvolts before RSS-ing, and the result converted back into dBµV for comparison with the limits. Filter and enclosure attenuation may be subtracted in dB.

Presumption of conformity and CE marking

For a presumption of conformity: if you are expert enough to cope easily with all the issues outlined above, the RSS method may be a good way to self-certify to a standard. My experience is that most companies do not have the necessary EMC skills just yet, and because of this most Competent Bodies I am sure would recommend that it is used as part of a Technical Construction File route. Testing an example to show that the RSS technique gave an adequate prediction is also a good idea, at least in these early days.

Remember that there is no issue of meeting a test standard when a TCF route is followed, so the inevitable differences between the RSS-ed result and the results of any actual EMC testing are not important if the Competent Body is satisfied that the Protection Requirements of the directive will be met.

Protection Requirements

It is worth re-iterating at this point that products which meet harmonised standards, or have approved TCFs, can still be taken off the market by Trading Standards Officers without court action if they actually cause an EMC problem.

For more information on this, please refer to my article "The Electromagnetic Environment and its impact on EMC and Safety" in the June 1997 issue of the EMC Journal (pages 20 to 25), and/or read my paper on "The Electromagnetic Environment" at the IEE's 10th International conference on EMC September 1-3 1997 (copies of which are available from the IEE's Publication Sales on 01438 313 311.

One TCF for all future products There is no reason why a properly-constituted and quality-controlled RSS-based compliance procedure should not be the basis for a TCF that covers all future products yet to be designed.

Such a TCF can apply to products which are quite unknown at the time its writing and approval, and is a very cost-effective alternative to self-certification.

Selecting components from a floppy disc or CD-ROM

Some manufacturers of industrial components and sub-assemblies are already planning to have their products tested by SGS in the way that they will be used, making the data available as graphs and even as floppy discs or CD-ROMs which can be read straight into the RSS spreadsheet.

There seem to be no reason why other test labs should not follow suit, but to achieve the greatest benefits for all concerned there needs to be a consensus on the way in which the test set-ups are configured for the different kinds of components. Maybe the UKTLA or the ACB can see to it that this is achieved.

In the not-so-distant future, it seems that it may be possible for a PC assembler, industrial control panel designer, or machine manufacturer, to achieve EMC "due diligence" by merely slotting the discs from his favourite suppliers, choosing the models and their quantities, choosing the limits appropriate to his intended user environment, and pressing the calculate button to see whether the total emissions are OK. Of course the spreadsheet could also check that immunity of each component is adequate, but this does not need any summation.

If emissions are too high, he can just substitute noisier components with quiet ones, or slot the discs from his favourite filter and enclosure manufacturers and choose the models that give an adequate safety margin.

The printout from the spreadsheet could be a top-level parts list for the final product, and when combined with the overall emissions graphs and immunity check could be all that is required for showing EMC due diligence, saved in the project file along with the technical files for the Low Voltage or Machinery Safety directives.

Assembly/service staff skills

It is important to realise that this method relies upon components being tested as they are to be used, and used as they were tested. Due diligence will not be achieved if this control is not maintained, and good EMC practices in assembly and installation will also be necessary.

These issues are not trivial - in many ways the whole RSS method will stand or fall by how well wirepersons, assembly, installation, and service staff behave as far as EMC is concerned. They will generally require EMC training and careful control - not to make them EMC experts, but to make sure that they always follow the design drawings and manufacturers instructions, plus the good EMC practices described by their company's own internal documents (which should employ the knowledge expressed in the draft IEC 1000-5-n series, especially -2 and -5).

Why hasn't this method been available for years?

When the EMC directive was first published and we had until 1/1/96 to comply, the component and sub-assembly manufacturers should really have instituted an RSS spreadsheet-based scheme such as described here. Since the directive does not apply to component manufacturers selling to OEMs, most of them decided that EMC was an SEP (Someone Else's Problem) and did nothing, and thereby added higher than necessary costs of compliance onto their customers.

As a rough rule of thumb, solving an EMC problem that would have added £1 to the materials cost of a PCB will cost £100-£1000 at the level of the final assembly, and £10,000 plus if it has to be fixed in the field. It clearly makes excellent economic sense to pay more for components with known good EMC (and the evidence for it) than to put together any old bits and pieces and then wonder how to make the overall assembly EMC compliant.

Unfortunately it seems that many companies' purchasing departments and design departments have been brainwashed with the idea that the lowest possible materials cost will automatically result in the lowest manufacturing price and thus the highest gross margin and greatest competitiveness. Whilst lowest material cost is a good thing, it should not be pursued to the point where the gross margin on the product is decreased, or the company trades illegally, due to the resulting EMC compliance difficulties. So maybe component suppliers are not wholly to blame, as they appear to have merely been responding to the perceived market demands for lowest materials cost.

Even now, when some computer board, motor drive, and power supply manufacturers are testing their products for EMC and affixing the CE mark, it is rare to find components which really do have the full installation instructions and EMC limitations to use that they should have, and even rarer to find ones with published test data.

Most of the few component manufacturers that are CE marking are hoping that everyone will employ CE + CE = CE, and that customers don't use EMC performance as a basis for purchasing decision, but that hope is now dead in the water since the recent Cardiff prosecutions, as any EMC expert could have predicted.

The RSS method, along with everything else necessary to make it work properly, has the potential to make EMC an easy matter for most one-off and small-volume manufacturers, and the first TCF's using this scheme to cover future products as yet undesigned are currently being written.

The important issues of commissioning time have not been covered, and it is worth mentioning, in passing, that when components are designed and tested in accordance with RSS schemes such as described above fewer problems with unwanted electrical interactions are likely during the commissioning stages, leading to speedier delivery, greater reliability, and lower costs overall.

It is even possible that the adoption of a proper RSS scheme could be self-financing, saving costs overall despite the additional component costs and design effort - even if EMC compliance was not legally required.

Archive Index

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