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Using close - field probes to reduce design risks early in a project (part 2)

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Using close-field probes to reduce design risks early in a project

— *Part 2* —

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Contents

7 Introduction to Part 2

This is the second part of a short series of articles about using close-field probing techniques to deal with EMC issues during design and other project stages, in order to:

- save time and money
- reduce project/financial risks
- help ensure that *if* we take products to a 'proper' EMC test lab for compliance testing (which is not a legal requirement for CE marking) they will pass on the first test.

It is often the case that, by the time the prototype electronic PCBs and software is ready for its first functional tests, the mechanical design (and the materials it uses) and the cable harness design are considered to be finished, and it is not unusual for production tooling and jigs to have already been made.

Some of us may have also worked for manufacturers who would commence volume-manufacture of enclosures and/or cable harnesses before it had been possible to operate and test any electronics!

Inevitably, Murphy's Law applies, so that even if the functional testing does not reveal any problems with the mechanical and cable harness design, the EMC testing does – with the result that long delays and large costs are incurred while they are redesigned to be able to comply with EMC standards, regulations and/or Directive.

[13] and [14] show us that time to market has, since 2000 (if not before), been the most important issue for the financial success of new electronic products, at least in the consumer markets, with their BOM (Bill Of Materials) cost considered to be of less importance (but see [15]).

But many manufacturers still leave any/all EMC testing to (very expensive) test laboratories, testing in accordance with published EMC standards, when their new product is otherwise ready for market and its glossy brochures have been printed, marketing/sales programmes are under way, and booths booked for up-coming exhibitions!

These articles describe a number of close-field probing techniques that can be used to assess the electromagnetic (EM) characteristics of materials, mechanical enclosures and cabling, long before any prototype electronic printed circuit boards (PCBs) have been designed or constructed, never mind any prototype software/firmware written to run on them.

Part 1 of this series [12] briefly described close-field EMC probing (often called near-field probing); its limitations and benefits, and showed how to make some simple but very effective probes from commonly-available low-cost materials and components.

[12] also described, with photographs, the following three close-field probing techniques:

- The 2-probe method of finding flaws in shielding
- The 1-probe 'reflectometer' method of finding flaws in shielding
- The 2-probe 'internal illumination' method

This article describes:

- the 2-probe method for discovering the EM characteristics of materials, and of holes, gaps, and joints in them

The next article(s) will cover the following close-field probing techniques:

- The 2-loop-probe method of finding resonances in cables
- The 2-clamp-probe method of finding resonances in cables
- The 1-clamp-probe 'reflectometer' method of finding resonances in cables
- The 1-clamp-probe 'reflectometer' for finding flaws in cable screen terminations and connectors

All of these close-field probe techniques can be used very early in a project:

- before any electronics or software/firmware are available
- using test equipment that costs just a little over £1,000
- by mechanical design engineers who have no special EMC knowledge or training
- without requiring a special location (such as a shielded room or anechoic chamber), i.e. in a normal office, design laboratory, workshop or (even in a manufacturing plant, so can be used for QA in serial manufacture)

8 The 2-probe method for discovering the EM characteristics of materials, and of holes, gaps, and joints in them

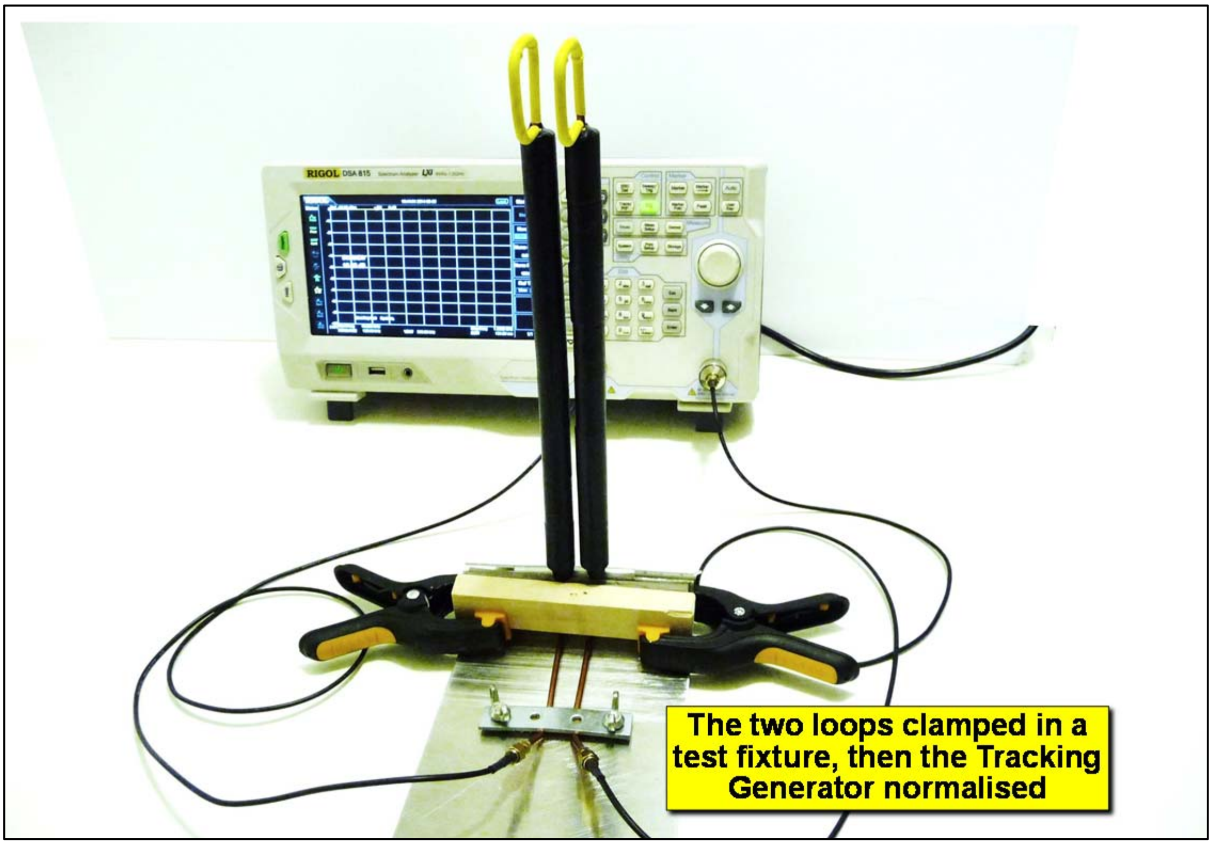

Figure 41 The two ferrite-handled loops clamped in a test fixture

Figure 41 shows a bent piece of aluminium that I call my 'Test Fixture' – which was originally a piece of scrap I had been saving for years in case I found a use for it – supporting two identical close-field probes with ferrite 'handles'.

The purpose of the test fixture is to reliably hold the two probes spaced just a little apart, so that sheets of materials to be tested can be placed between them without disturbing the positions of the probes.

These two probes are identical to those I described making in Figures 12 and 13 of [12] – except that their microwave semi-rigid conductors are extended by about 150mm beyond their ferrite 'handles' and bent to help provide mechanical stability when clamped in the test fixture.

Material samples tend to come in a wide variety of shapes and sizes, and I found that having long ferrite tubes on the 'handles', on these otherwise very simple close-field probes, was very important indeed. Without the ferrite handles, the shape and size of the test sample affected the measurements, making it very difficult to compare one sample with another. But with the ferrite handles – as long as there was sufficient material outside the area enclosed by the (yellow insulated) loops – sample shapes and sizes had no effect.

In addition, I found that it was necessary to make reliable low-resistance metal-to-metal connections between the surfaces of the probes' microwave semi-rigid conductors and the metal structure of the test fixture. Because the aluminium piece I was using was rather old, its surface had become very oxidised and difficult to make electrical contact with – so I abraded it down to shiny metal using emery cloth over the areas that would come into contact with the probes.

I suspect that differential-mode to common-mode conversion in the SMA coaxial cables I was using to connect the probes to the spectrum analyser was responsible for the need to electrically bond the screens of the two probes to test fixture. I wonder if this electrical bonding would not be so important if I used high-spec low-loss double-screened coaxial cables.

A proper test fixture would have the aluminium cleaned back to shiny metal and then its surface treated with a reliably-conductive non-oxidising process such as alochrome (using trivalent chromium, please!), aludine, or Iridite. Aluminium can also be tin-plated, which would have better galvanic compatibility with the copper semi-rigid cable screens, or of course the test fixture could be made of mild steel with zinc or tin plating, or stainless steel.

As it is, whenever I come to use the plain aluminium test fixture shown in Figure 41, I must remember to first of all 'clean' the areas in contact with the copper of the probes, using an abrasive of some sort to remove the oxidised film that will have built up since I last used it.

Figure 41 shows that one of the clamped loops is connected to the RF tracking generator output of the Rigol DSA815 spectrum analyser I was using (9kHz to 1.5GHz, with Tracking Generator option costs a little over £1000, see [12]). The other loop is connected to the spectrum analyser's RF input.

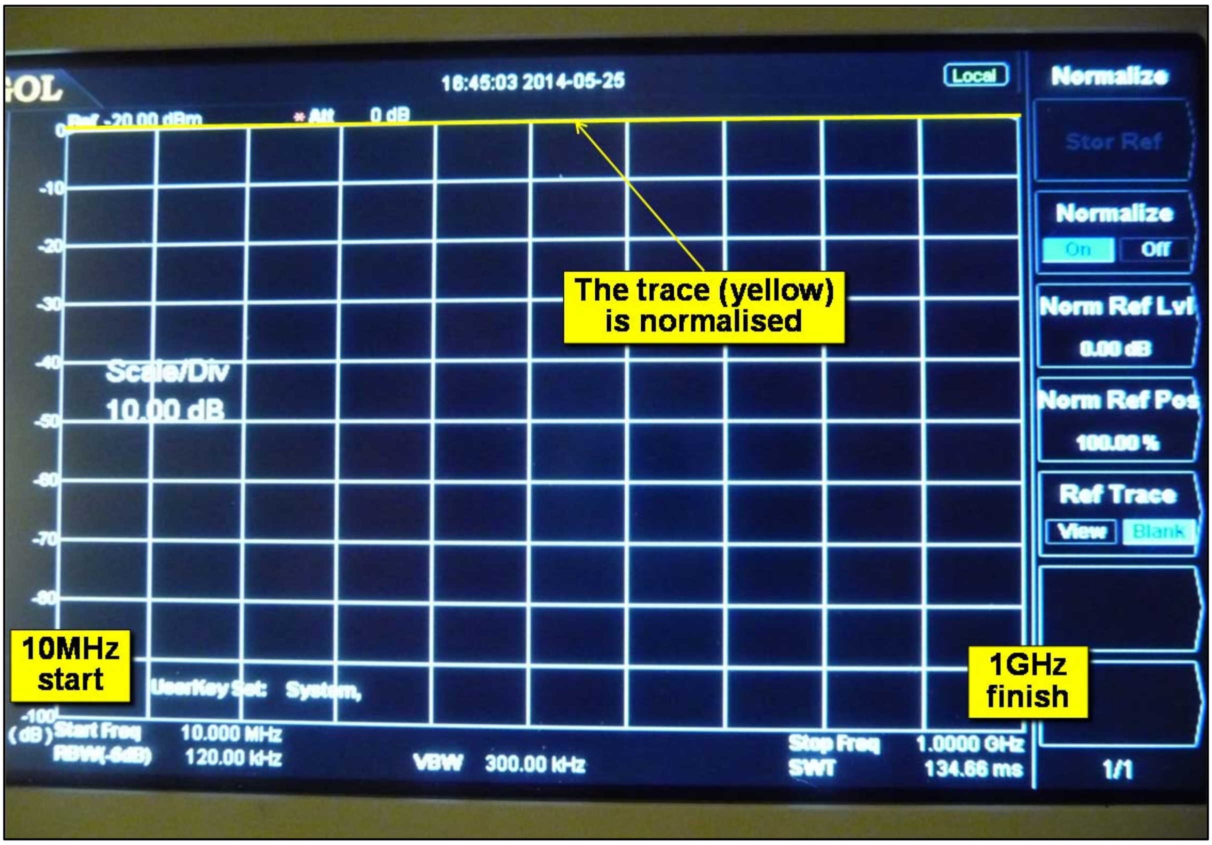

Figure 42 The two ferrite-handled loops are normalised

The tracking generator is 'normalised' – compensating for the frequency-dependant attenuation of the coupling between the two probes and resets the amplitude scale so that the result is a straight line at the 0dB line at the top of the display, as shown in Figure 42.

Without the digital processing functions in modern spectrum analysers, normalisation of a test set-up like this would be a very tedious process of recording the attenuation values for a number of frequencies and using them as correction factors for subsequent measurements of materials at the same frequencies.

These days, is we were using a spectrum analyser that lacked the necessary digital processing functions, we would use a spreadsheet to apply these correction factors. But long, long ago, deep in the mists of time, we used pen and paper, and the measurements I am about to describe in the remainder of this article would have taken very many hours to do, probably more than two full days, instead of the 30 minutes they actually took me.

(This alone creates an excellent business case for replacing an old analyser with a tracking generator but without an automatic normalising function, with a new analyser that has normalisation. The time saved by using the new analyser when doing the sort of close-field probe tests described in these articles, many of which require normalisation, will pay back the cost of the new analyser within a few days. Or within a couple of weeks, if we purchase a costly Agilent (now Keysight Technologies) or Rohde & Schwarz model.)

When normalised, the amplitude display is scaled in dB, simply a ratio, and not dBm, dBV, dBμV, dBμA, dBpT, dBμA/m, dBμV/m or any of the other amplitude scales we use in our EMC work. We use this to display the attenuation-versus-frequency – otherwise known as the Shielding Effectiveness (SE) – achieved by the materials and constructions we place between the two probes.

The Rigol display also tell us that the Reference Level (the 0dB line) is at -20dBm. Because I had set the tracking generator's output level to +10dBm, this tells us that the dynamic range of the spectrum analyser has been reduced by 30dB in order to draw a nice straight line along the top of the screen when it normalises the coupling between the two probes in Figure 41.

As we will soon see, this reduced dynamic range limits the maximum SE that can be measured by this low-cost spectrum analyser.

Figure 43 A 0.35mm thick copper sheet, the first material tested

The first material whose shielding effectiveness we test should be something with very good SE over the frequency range we are scanning (10MHz to 1GHz for the tests shown here) to check that our 2-probe test set-up is working as well as it can, and has no problems.

Figure 43 shows the shiny, clean, new copper sheet that I use for this, which is 0.35mm thick and 300mm square.

(Copper is not as good at shielding when its surface is dull and oxidised, or not smooth for any reason. This is why, when we use copper or brass for shielding, we always plate it with tin.)

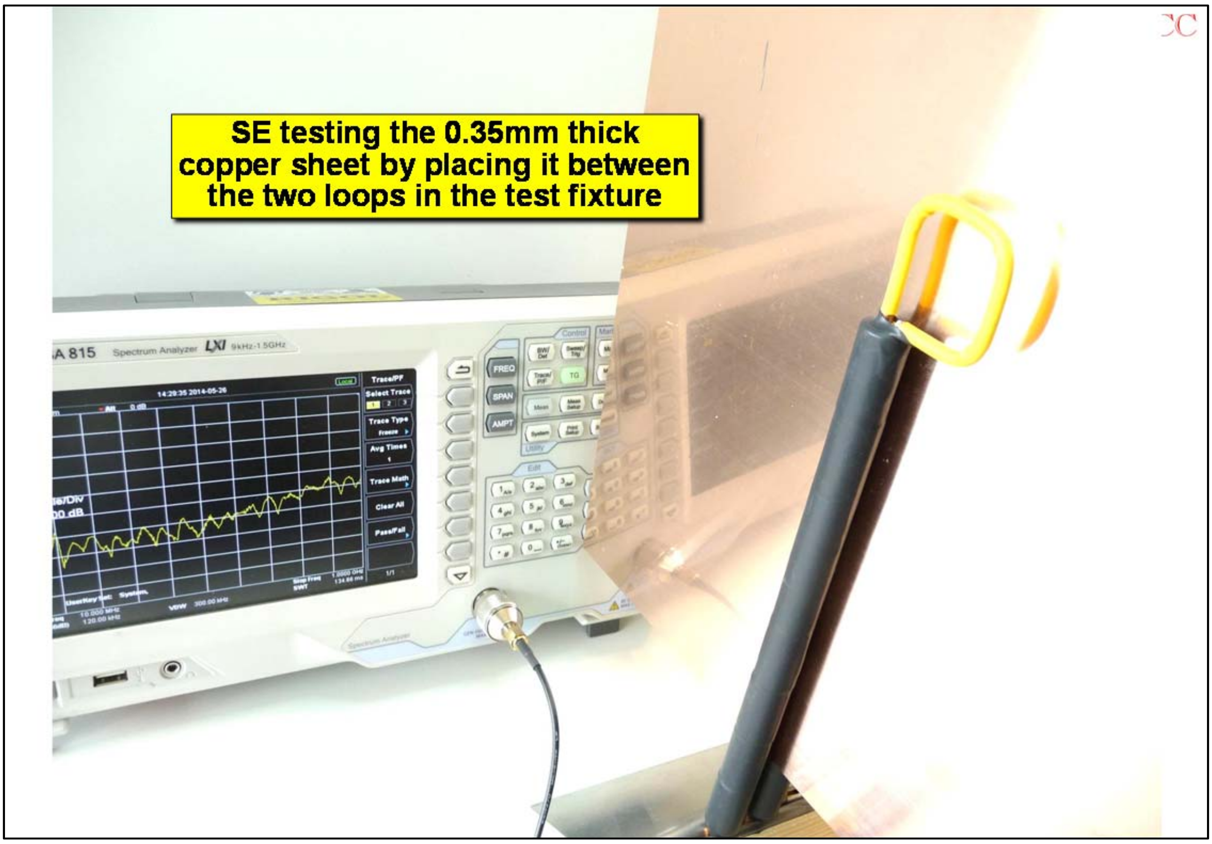

Figure 44 The copper sheet inserted in the 2-probe test set-up

Figure 44 shows the copper sheet carefully slid between the two probes without disturbing them, and the resulting spectrum analyser display – which is repeated in Figure 45 below.

For a stable and repeatable test of a material, the parallel pair of probe loops seems to need to be at least two loop dimensions away from the sides of the sample. This is easy to check by watching the analyser display and seeing when it stops recording lower values.

This is, admittedly, a rather crude test fixture that needs a steady hand to position the copper sheet between the probes without altering their positions. There are many other ways of constructing the test fixture that would hold the probes more firmly and so be easier to use, and really I wish I had thought this issue through before I made the fixture shown in Figure 41!

If we suspect that we have knocked a probe out of position, we withdraw the sheet and check to see if the measurement is once again aligned with the 0dB line at the top of the display, exactly as it was when normalised – as shown in Figure 42.

If the display is not exactly correct, we press the button on the spectrum analyser and renormalize it – which takes about 3 seconds. If the display is a long way from being correct, we reposition the probes to get it as close as we can and then press the ‘normalise’ button. (If we were doing this by hand, we would have to record a new set of correction factors and enter them in our spreadsheet.)

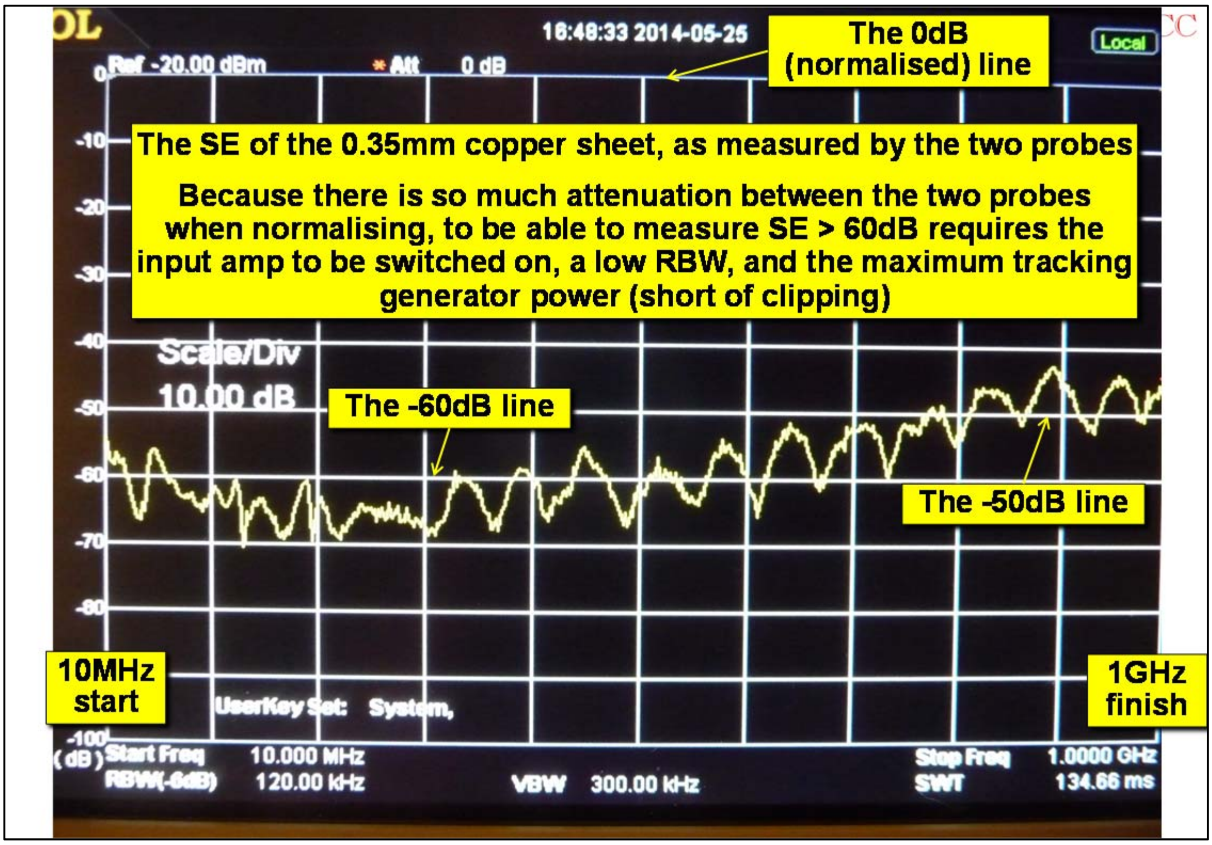

Figure 45 The analyser's display with the copper sheet in the 2-probe test set-up

Figure 45 shows that the copper sheet achieved about -60dB of attenuation at 10MHz, falling to around -65dB over the range 100MHz to 300MHz, then rising to around -47dB at 1GHz.

Another way to report this, would be to say that the copper sheet achieved about 60dB of SE at 10MHz, rising to around 65dB over the range 100MHz to 300MHz, then falling to around 47dB of SE at 1GHz.

It would have been interesting to actually switch off the tracking generator (TG) and see how close the measurement was to the noise floor of the instrument, compared with the attenuation achieved by the copper sheet. If nothing else, it might point to cable and connector coupling between the TG output and receive input, or even crosstalk between them inside the instrument.These SE figures are much less than would be achieved by 0.35mm thick copper when tested to an official SE test standard, and they tell us the limitations of our test method. If we want to use this type of test to determine whether a material will give us better SE results than these, we need to make some improvements!

One way of improving the maximum SE that can be measured is to reduce the resolution bandwidth (RBW) of the spectrum analyser and hence reduce its noise floor. The results shown here are with 120kHz RBW, and we would expect the noise floor to reduce by 10dB for every ten-fold reduction in RBW. For example, to measure SE to 85dB from 100MHz – 300MHz, we would set the RBW to 1kHz – about one hundredth of the current setting of 120kHz.

(120kHz is a RBW setting used by CISPR EMC test standards which are meaningless for this sort of measurement. I now wish that I had set the RBW to 100kHz instead, to make this point.)

Unfortunately, the analyser's sweep time is automatically related to its RBW, and reducing the RBW from 120kHz to 1kHz would multiply the sweep time by 100. Instead of taking a couple of seconds, it would take nearly three minutes to cover the range 10MHz to 1GHz – not very appropriate when we are holding a sample in place by hand!

The short answer, is that if we want to measure substantially better SE than is shown in Figure 45, to be able to quickly compare hand-held samples of materials, we will need to use a spectrum analyser with a substantially lower noise floor, which will also cost substantially more than this very low-cost DSA415.

The ripple in the measurement is almost certainly caused by the mismatch between the impedance of the probe (a shorted turn) and the 50Ω impedance of the analyser's input and output, the flexible connecting cables, the connectors, and the semi-rigid conductors used to make them with. We should be able to reduce the height of these ripples by fitting 6dB (or more) through-line attenuators at the connections to one or both probes. Each would reduce the maximum SE that could be measured by 6dB (or more), but this may not matter if the dynamic range was still sufficient for our purposes.

However, many consumer/commercial/industrial applications do not need SEs better than those shown in Figure 45 – which will become evident below.

8.1 Assessing the effects on SE of holes, gaps and jointing methods

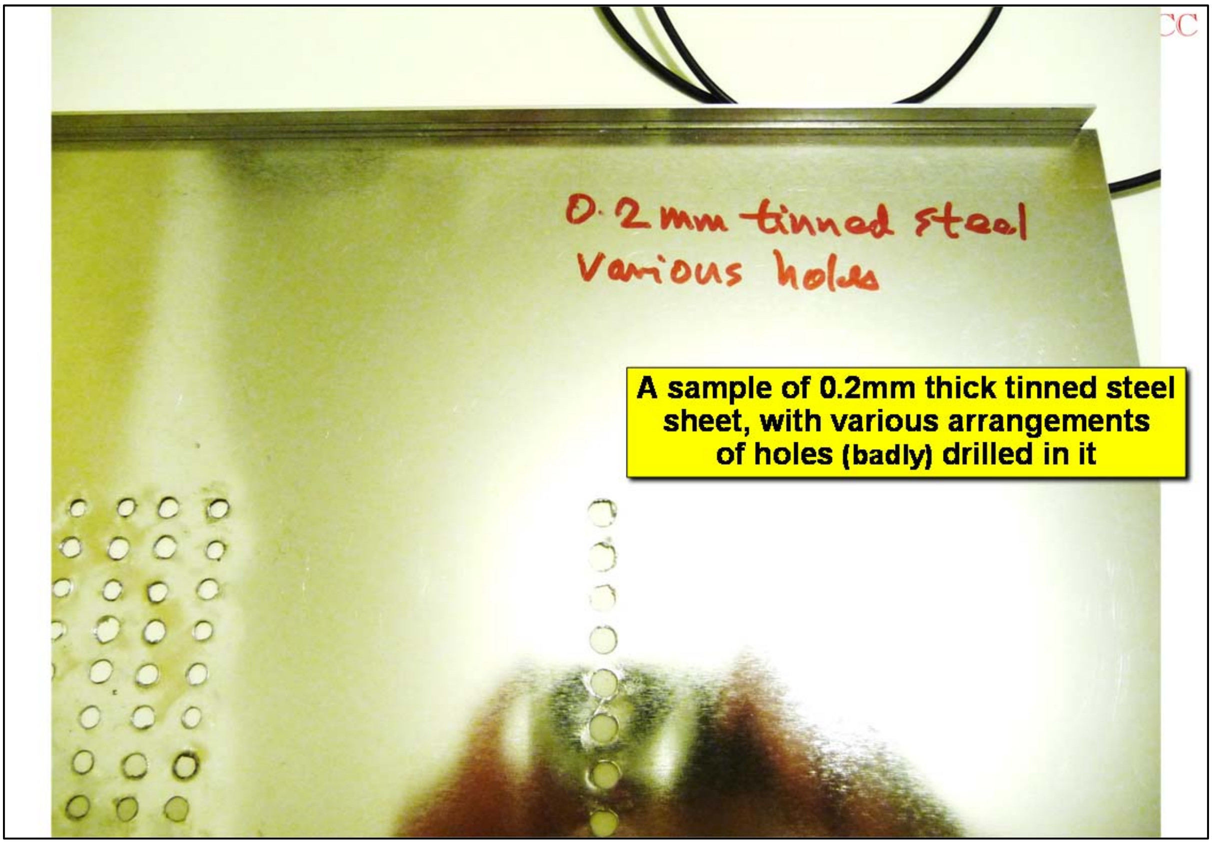

Figure 46 A sample of tin-plated steel with various arrangements of holes in it

Figure 46 is of one of a number of examples I created for demonstrating the effectiveness of this 2-probe technique for assessing the SE of holes, gaps and jointing methods. All are made from 0.2mm thick tinned sheet steel, and this one has various arrangements of drilled (rather crudely, it must be said) holes in it.

Figure 47 shows the 2-probe set-up of Figure 41 being used to test the SE of a hole-free area of the tinned steel sheet shown in Figure 46. The method used for this test (and for all the others in this article) is exactly the same as was used for the 0.35mm thick copper sheet in Figures 44 and 45 and their associated text, above.

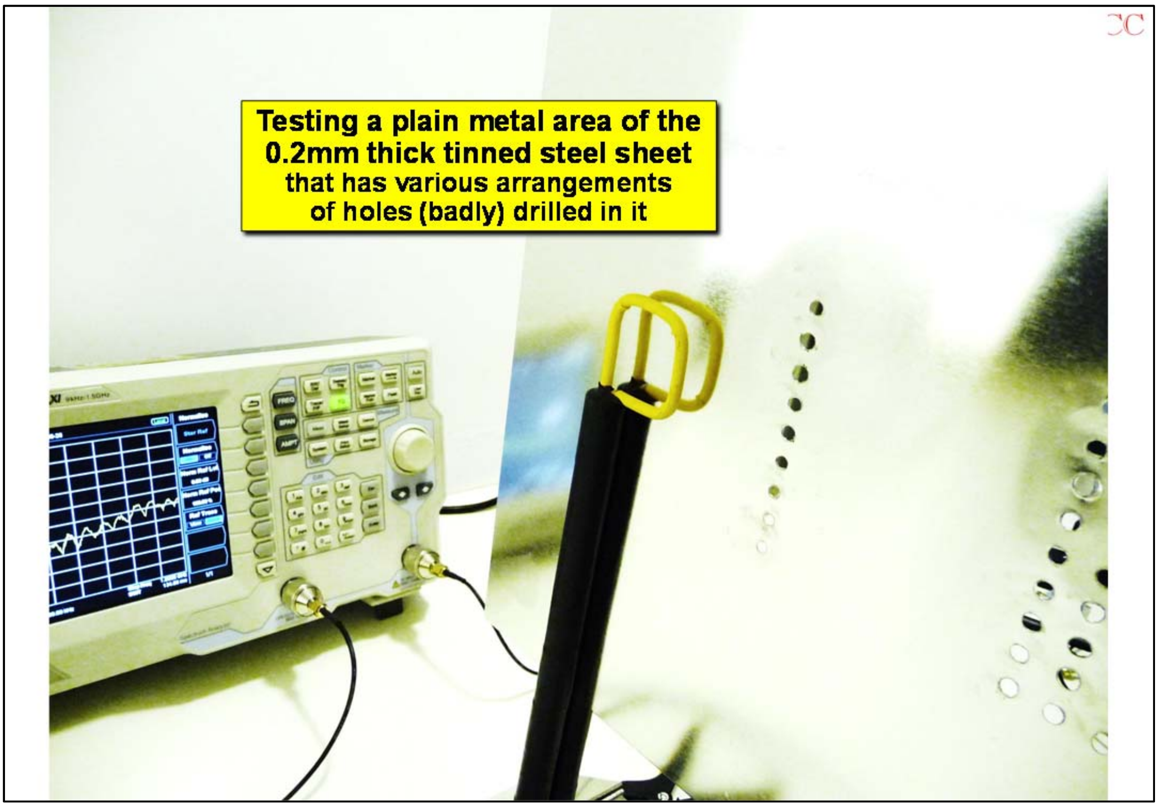

Figure 47 The tin-plated steel sheet inserted in the 2-probe test set-up

Before every test the 2-probe setup is normalised, and the sample is inserted between the probes without disturbing their positions. The sample is positioned so that the edges of the sample are further from the probes than twice the probes' dimensions, and the SE is read directly off the spectrum analyser's display, which can be seen in Figure 47 and is shown in full in Figure 48.

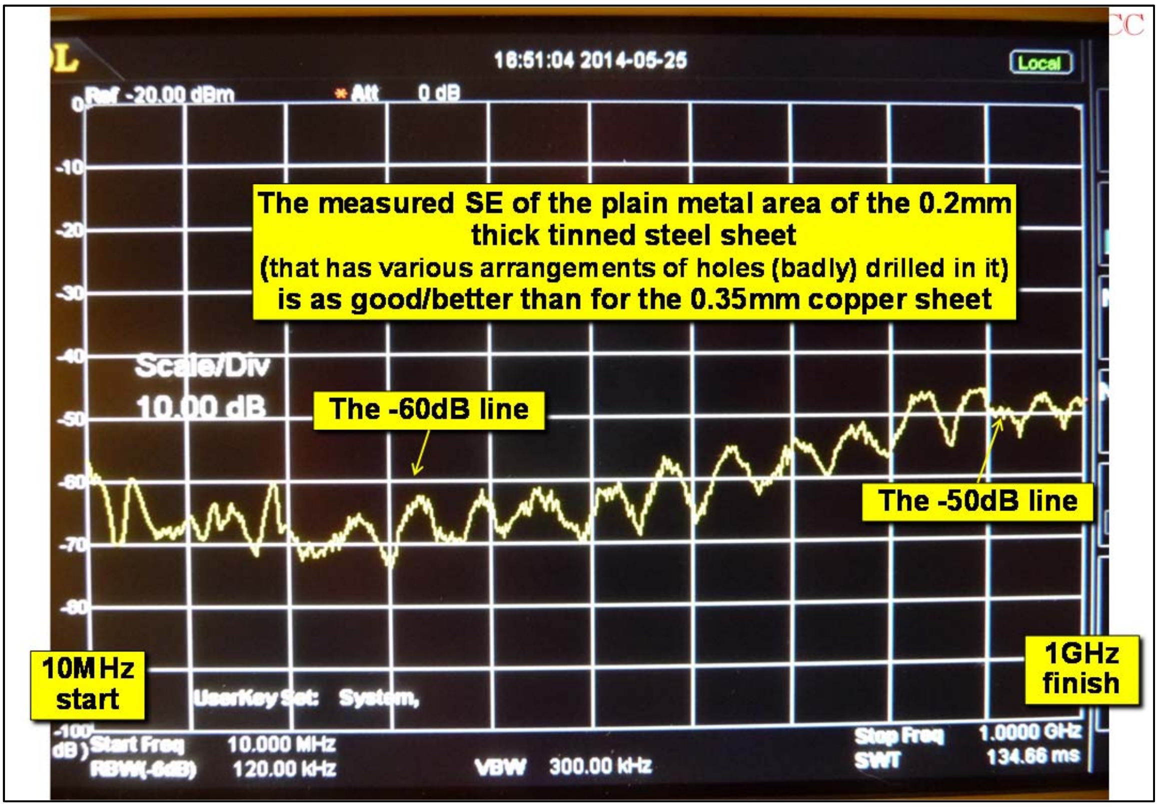

Figure 48 The analyser's display with the tinned steel sheet in the 2-probe test set-up

Figure 48 shows that, if anything, the plain area of the 0.2mm tinned steel sheet has slightly better SE from 10MHz-1GHz than the 0.35mm thick copper sheet.

Figure 49 shows the sample shown in Figure 46 moved to place the probes at the centre of a row of 4mm diameter holes on 10mm spacing, and Figure 50 shows the resulting analyser display.

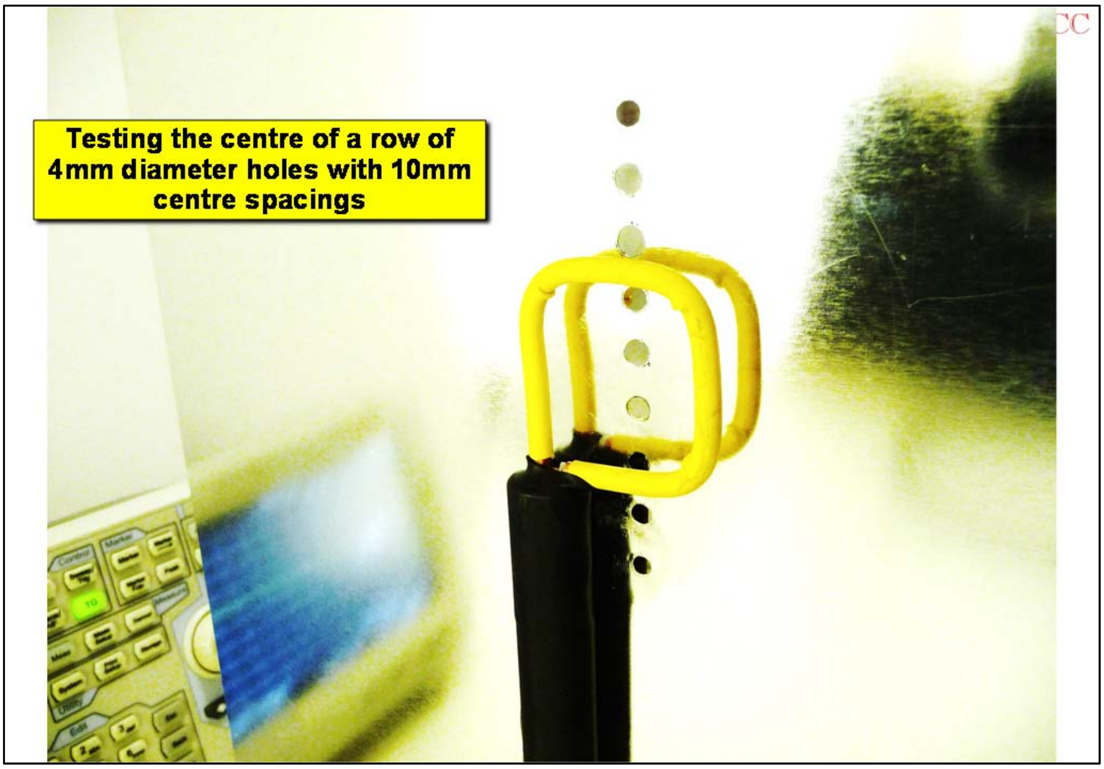

Figure 49 Measuring a line of 4mm holes on 10mm spacing in the 0.2mm tin-plated steel

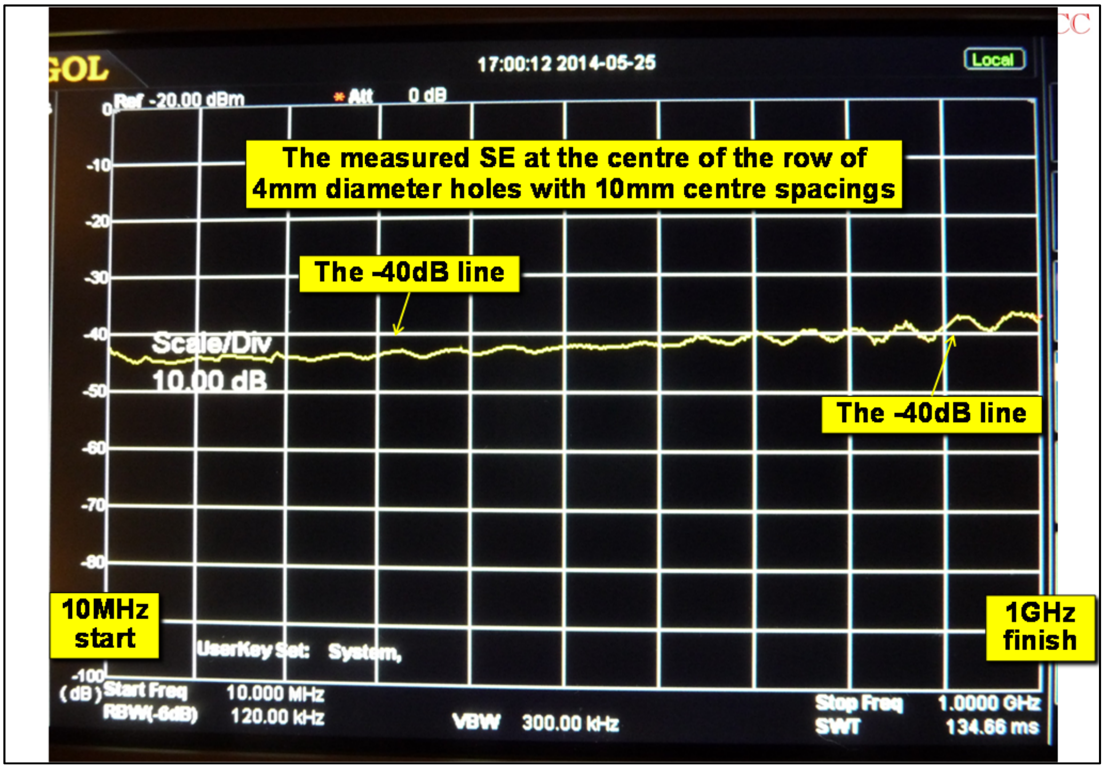

Figure 50 The analyser's display when measuring the line of 4mm holes on 10mm spacing

Figure 50 shows that the row of 4mm diameter holes on 10mm spacing has reduced the SE measured in Figure 48 by about 20dB below 300MHz and by about 10dB at 1GHz.

So, although this test set-up is not capable of measuring very high values of SE, it is more than adequate for detecting the degradation in SE caused by a few small ventilation (for e.g.) holes.

Figures 51 and 52 show that an array of 5mm diameter ventilation holes on 10mm spacings reduces the SE by a further 10dB below 300MHz and by about 5dB at 1GHz when compared with the line of 4mm holes in Figures 49 and 50. Compared with the results for the plain tinned-steel sheet shown by Figures 47 and 48, these figures show that the array of 5mm holes on 10mm spacings reduces the SE by about 30dB between 100MHz and 300MHz and by about 15dB at 1GHz.

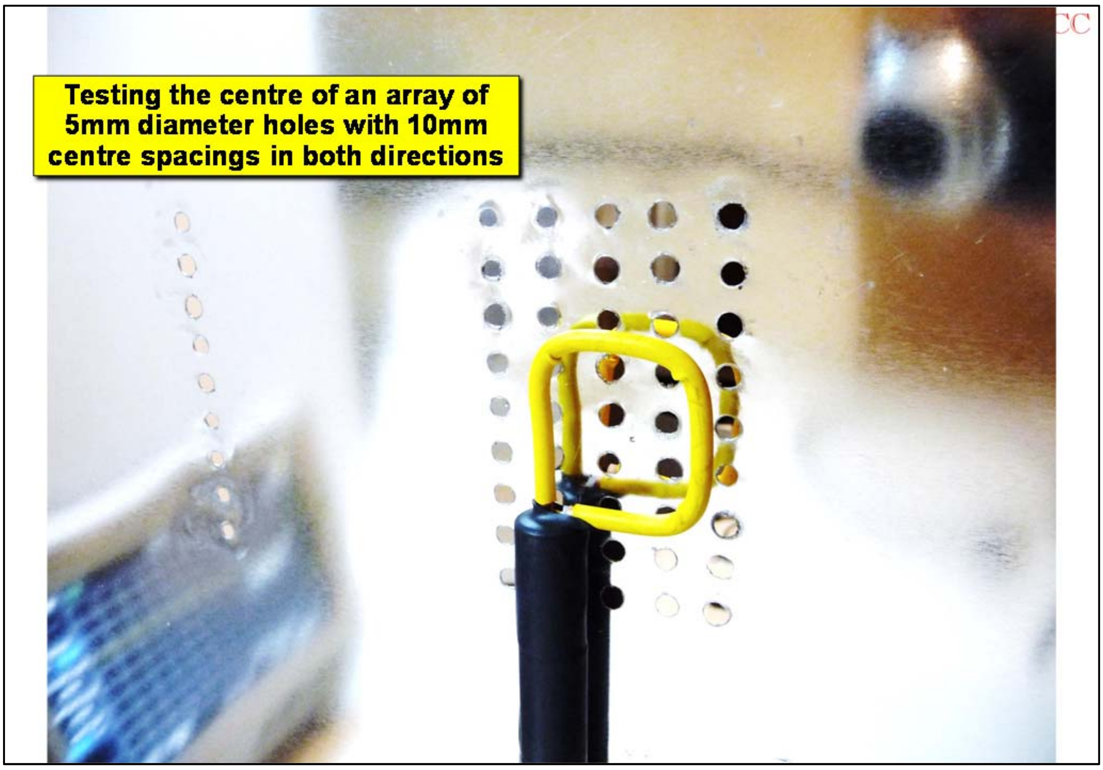

Figure 51 Measuring an array of 5mm holes on 10mm spacing in the 0.2mm tin-plated steel

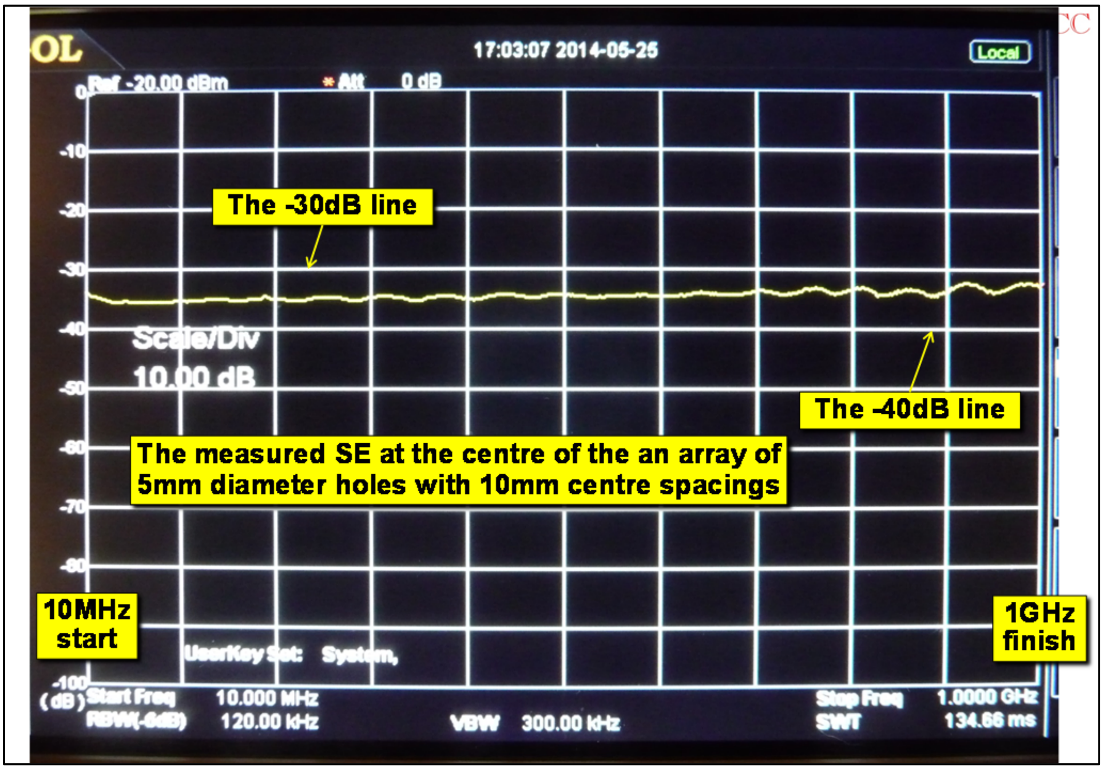

Figure 52 The analyser's display when measuring the array of 5mm holes on 10mm spacing

Figures 53 and 54 show that a line of 6mm diameter ventilation holes with 10mm spacing reduces the SE by more than the line of 4mm holes in Figure 50, but not by quite as much as the array of 5mm holes in Figure 52.

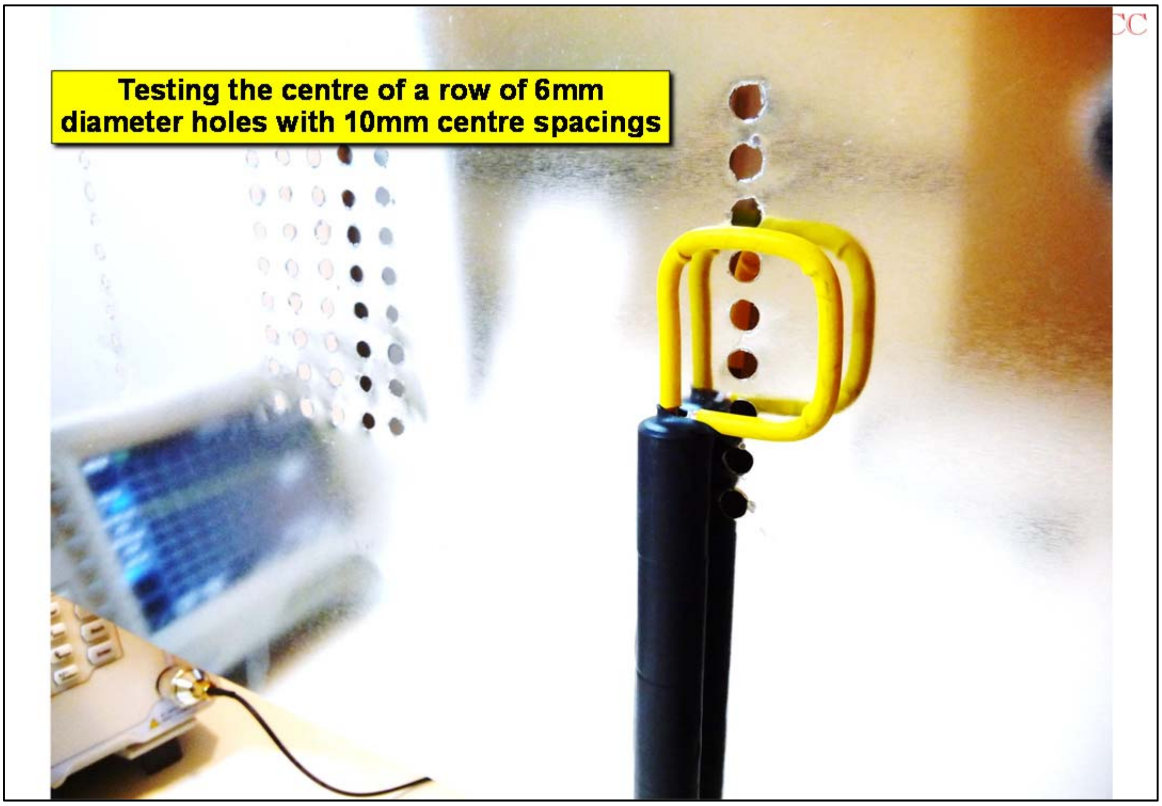

Figure 53 Measuring a line of 6mm holes on 10mm spacing in the 0.2mm tin-plated steel

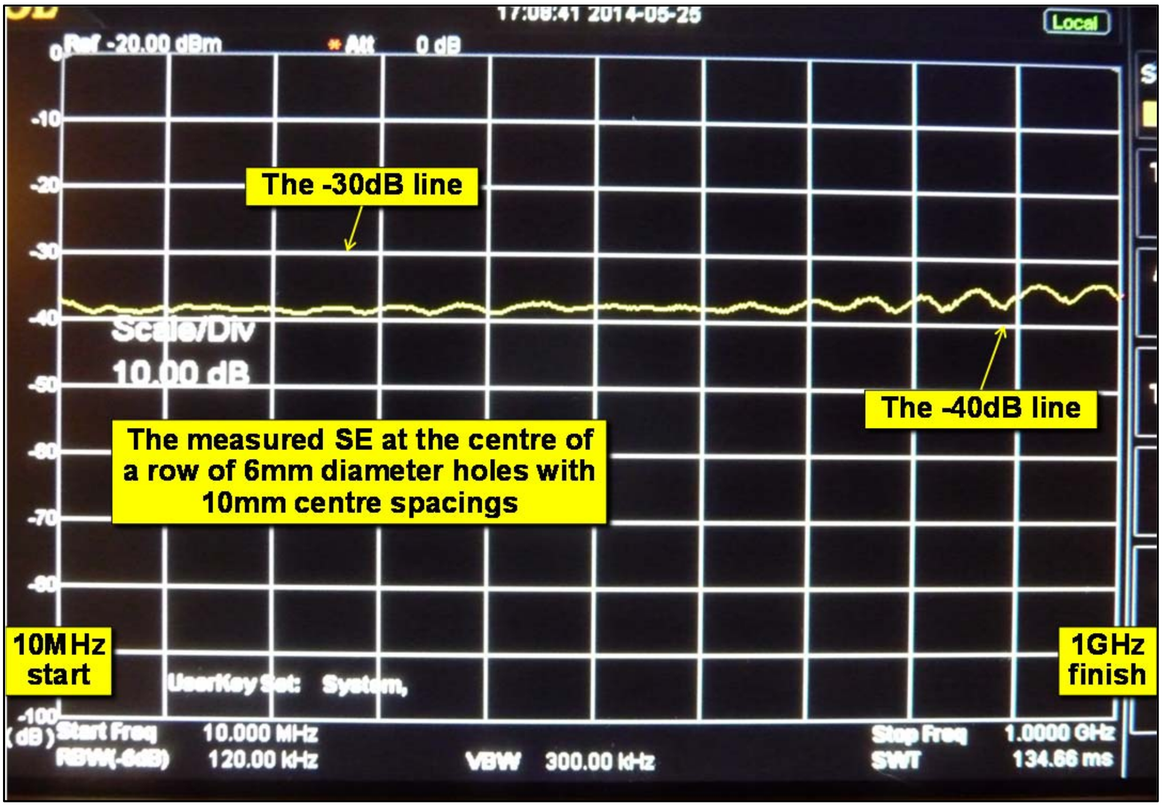

Figure 54 The analyser's display when measuring the line of 6mm holes on 10mm spacing

Figure 55 introduces the next test in my demonstration: two sheets of the same 0.2mm tin-plated steel that has been used in Figures 47-54 above have been placed with their edges abutting each other, and electrically bonded together with solder blobs on a 68mm spacing all along their common seam.

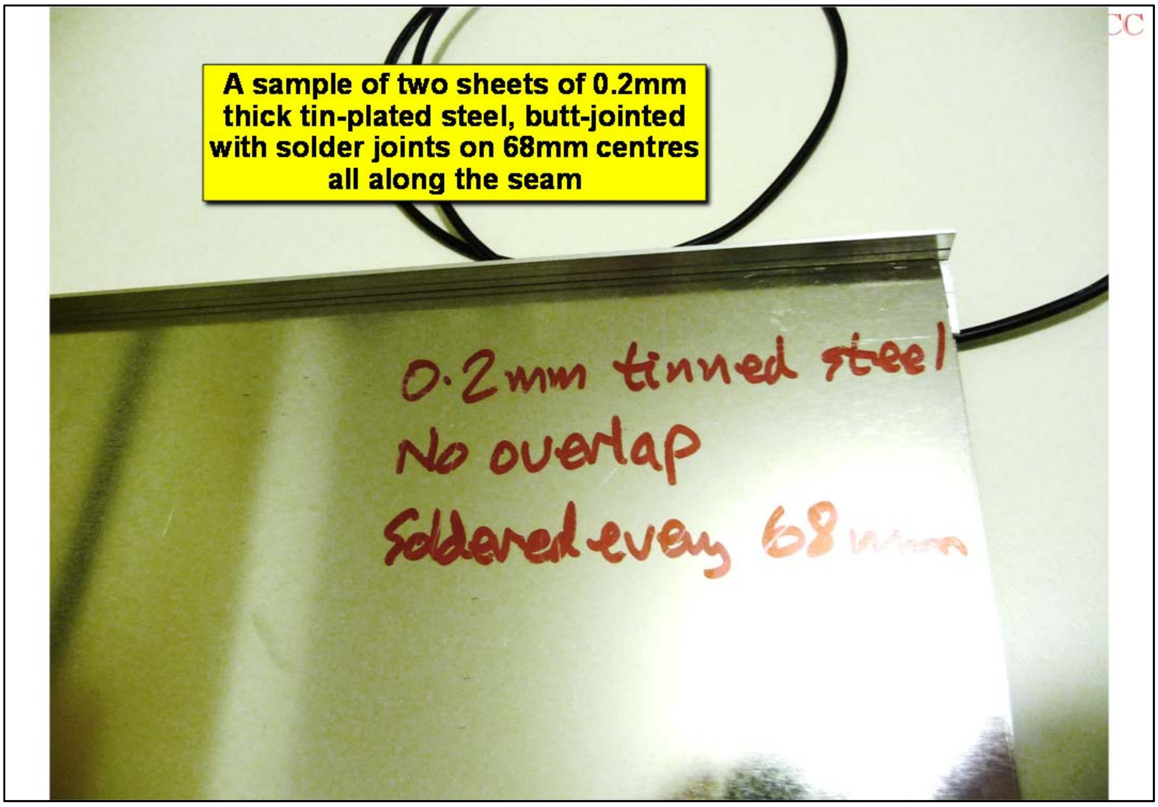

Figure 55 The butt-jointed tin-plated steel sheet to be tested

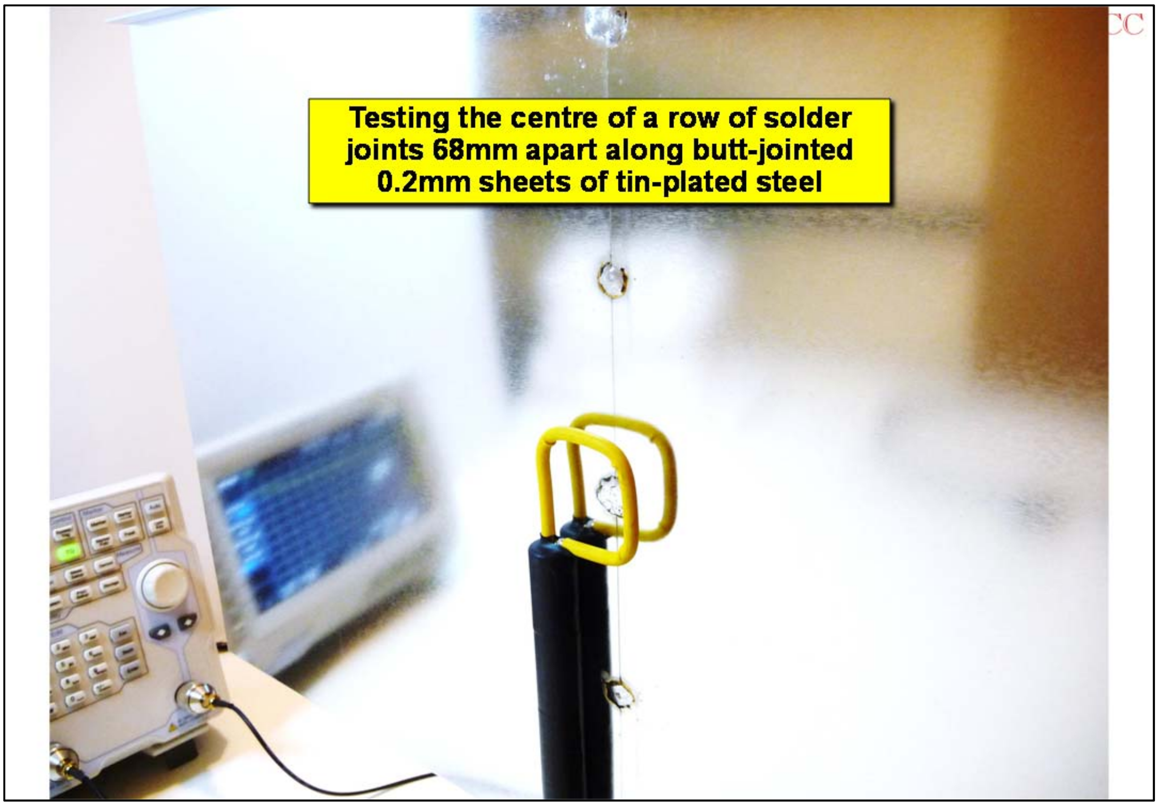

Figure 56 Measuring the butt-jointed 0.2mm tin-plated steel

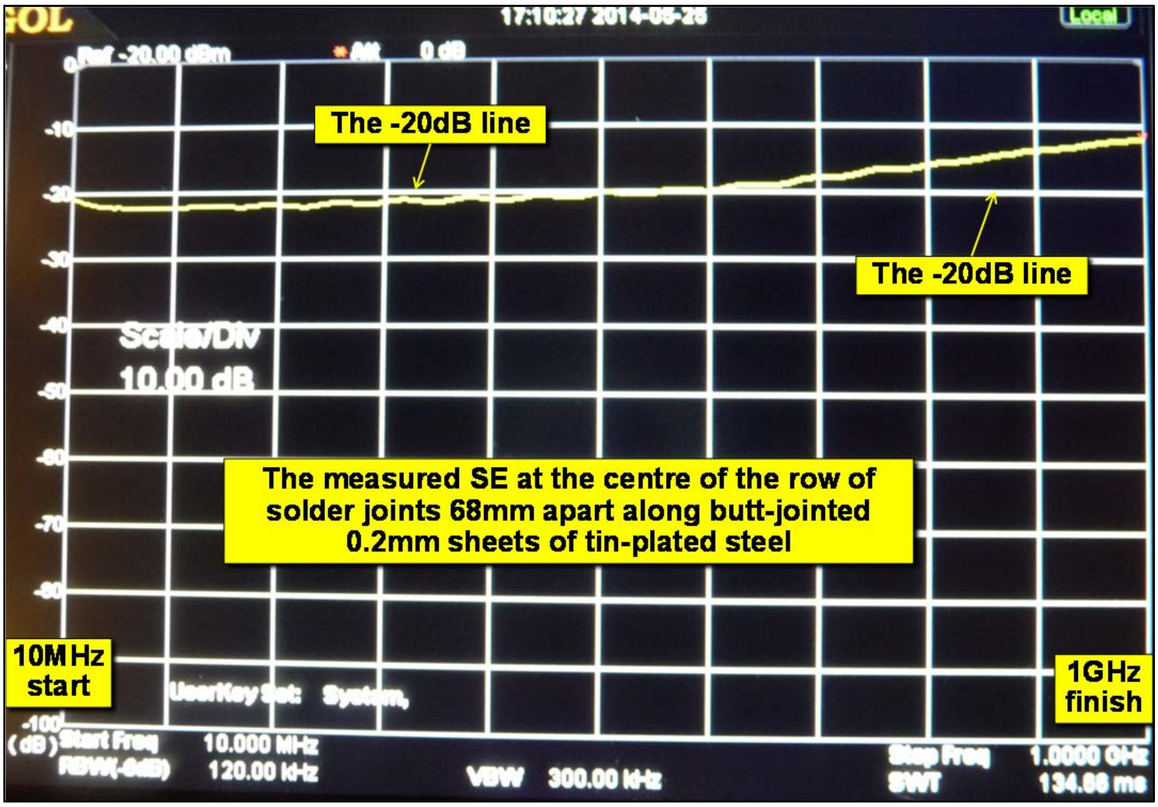

Figure 57 The analyser's display when measuring the butt-jointed 0.2mm tin-plated steel

Figure 56 shows the actual test – with a central solder joint along the seam positioned in the centre of the loop probe pair – whilst Figure 57 shows the analyser's screen in full. The SE has reduced considerably from the values achieved by the plain metal sheet (see Figure 48) in this test set-up, and is now only 20dB at 10MHz (down from 60dB), 22dB from 100MHz to 300MHz (down from 70dB) and 12dB at 1GHz (down from 50dB).

But never mind the degradation in SE values, the absolute value of the SE that is achieved is simply not very good at all, with this metal jointing method.

It is true that this jointing method is not sturdy, and is so impractical that it would never be used, but it <u>is</u> quite common to see people connecting metal parts of enclosure shields together with short wires or braid straps, and assuming that because they are all 'earthed' or 'grounded' together they must provide good RF shielding.

This simple test method, which is easy to set up using low-cost equipment, and is very quick to do, shows that even if the lengths of the connecting wires or straps was under 1mm, the SE would be poor. And of course it is fairly obvious that using longer wires or straps would not improve the SE.

So here is an example of how the risks of making bad mechanical design decisions for EMC can easily and quickly be identified very early in a project by people with little/no EMC expertise, at their normal workbenches.

Clearly, butt-jointing metal shielding is not very effective. If the soldered joints were spaced only half as far apart (34mm), I would expect the SE to improve by about 6dB across the measured frequency range – still not very good.

Another common metal jointing technique is to overlap two pieces of sheet metal by enough to fix them together mechanically, for example by using self-tapping screws, pop-rivets, nuts and bolts, or spot-welding, and this is tested by the next sample, shown in Figure 58.

Figure 58 introduces this sample as having two sheets of the same 0.2mm tin-plated steel that was used above, placed with their common edges overlapping by 5mm, and (as before) electrically bonded together with solder blobs on a 68mm spacing all along this seam.

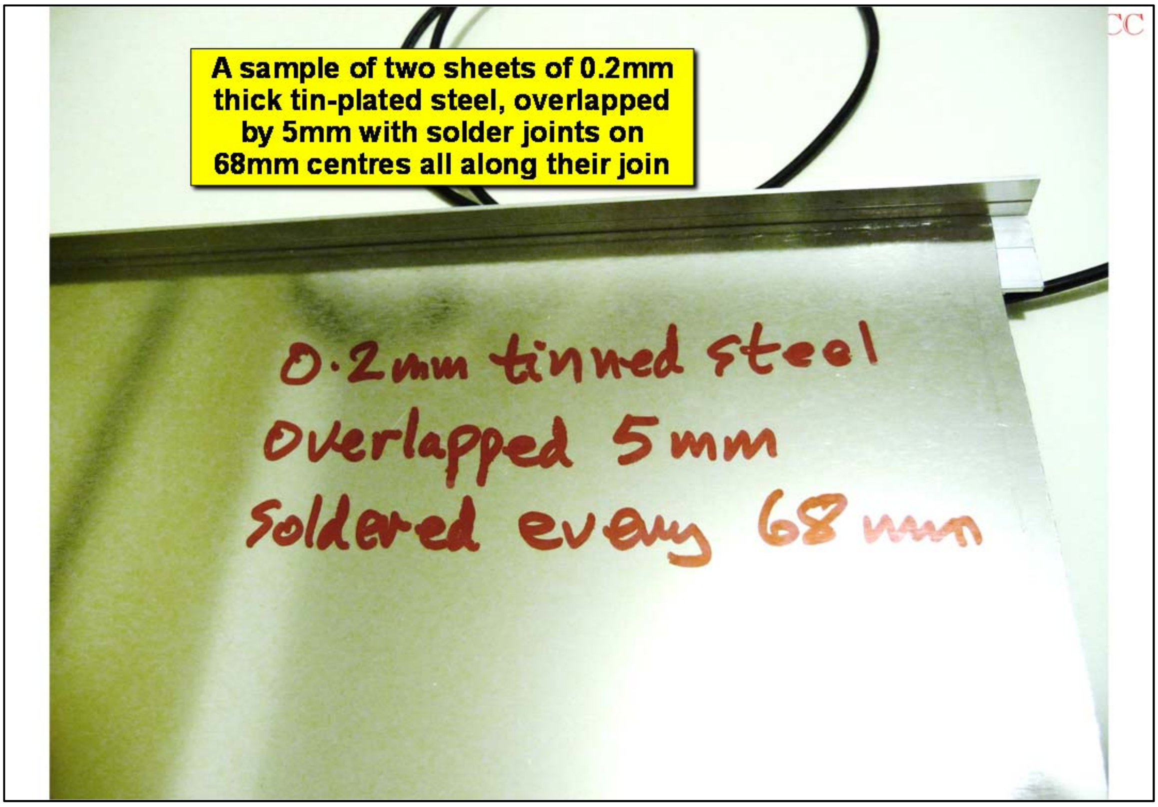

Figure 58 The 5mm overlapped tin-plated steel sheet to be tested

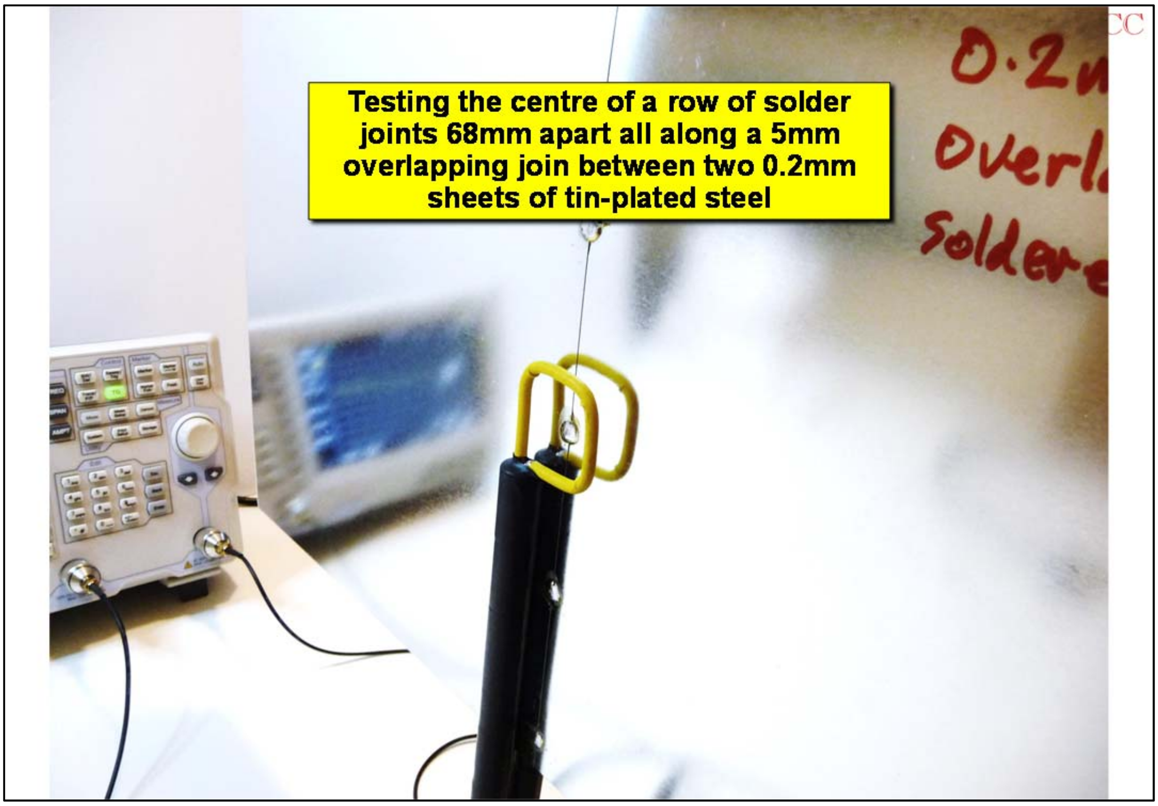

Figure 59 Measuring the 5mm-overlapped 0.2mm tin-plated steel

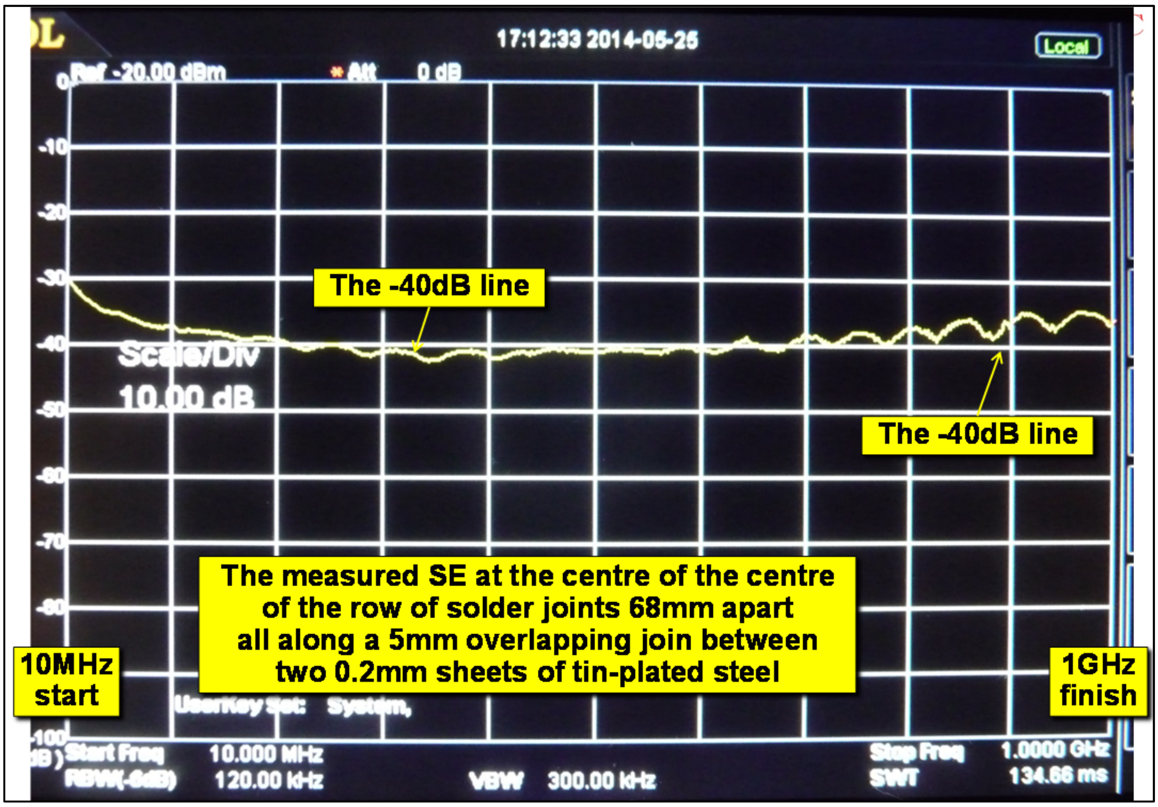

Figure 60 The analyser's display when measuring the 5mm-overlapped 0.2mm tin-plated steel

Figure 59 shows the actual test – with a central solder joint along the seam positioned in the centre of the loop probe pair – and Figure 60 shows the analyser's screen in full.

Compared with the butt-jointed sheets shown above, the SE has improved by a useful amount, up by 10dB to 30dB at 10MHz, and up by 20dB between about 200MHz and 1GHz, with about 35dB at 1GHz.

Once again, I would expect that halving the spacings between the electrical bonds (solder blobs in this case) would improve the SE by 6dB across the measured range.

Figure 61 shows another sample in this series, which is the same as the last one but has increased the overlapping from 5mm to 55mm. As for the previous two samples, the sheets are electrically bonded together with solder blobs on a 68mm spacing all along this seam.

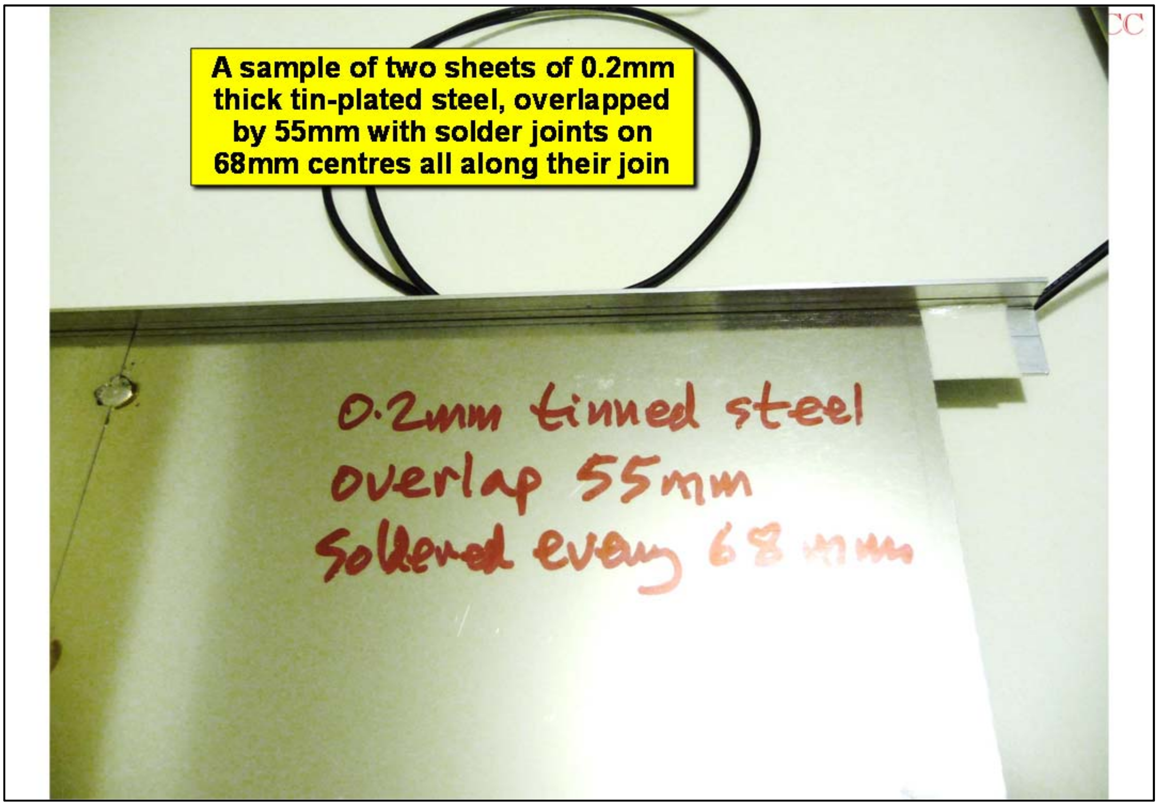

Figure 61 The 55mm overlapped tin-plated steel sheet to be tested

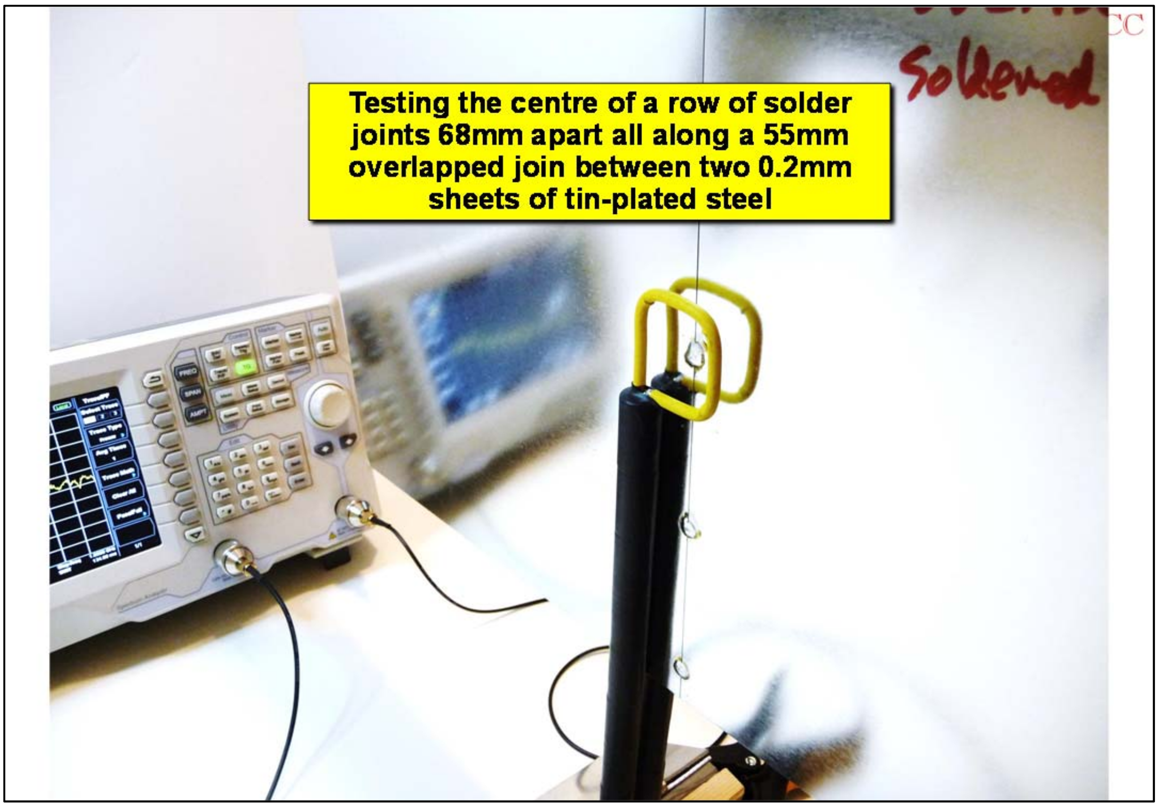

Figure 62 Measuring the 55mm overlapped 0.2mm tin-plated steel

Figure 62 shows the actual test – with a central solder joint along the seam positioned in the centre of the loop probe pair – and Figure 63 shows the analyser’s screen in full.

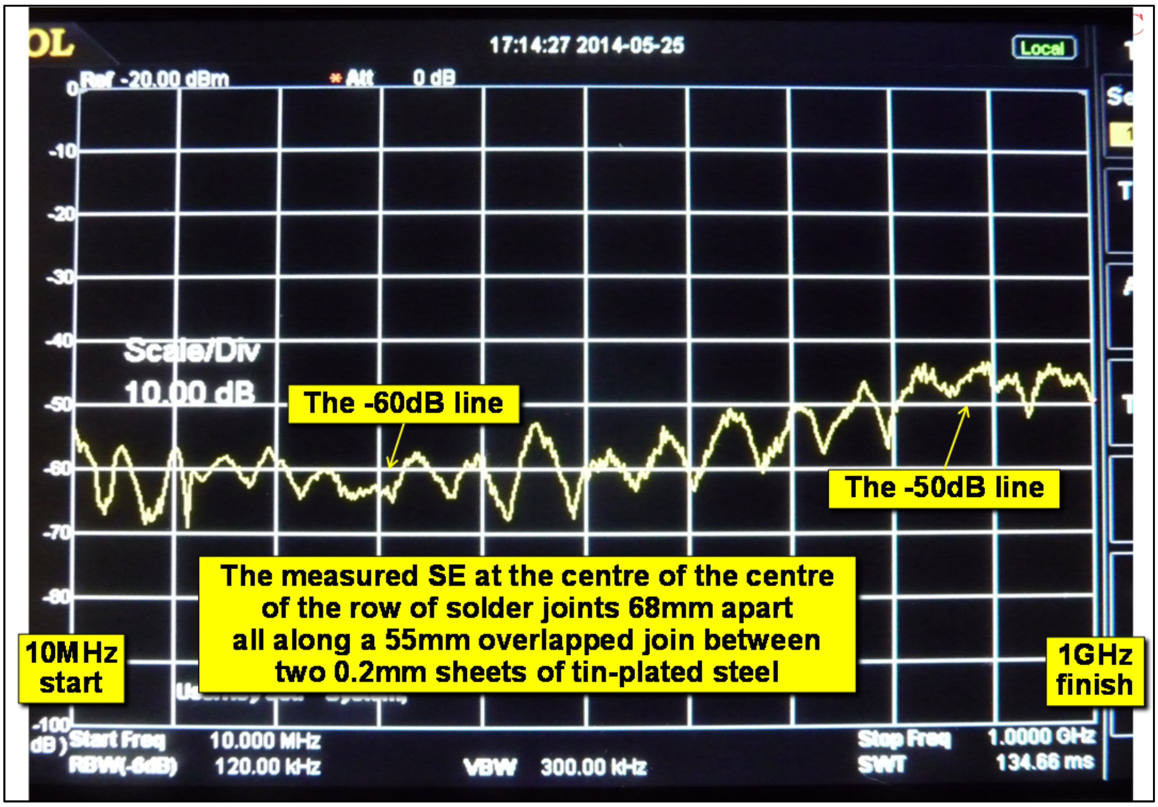

Figure 63 The analyser's display when measuring the 55mm overlapped 0.2mm tin-plated steel

The increase in SE by increasing the overlap from 5m to 55mm varies from 30 dB to 20dB.

Sheet steel is essentially free, whereas metal fixings are not. The costs of metal fixings are much more than the cost of the parts, and includes the labour-costs of assembling them, the QA costs of inspecting their correct assembly, and the warranty costs associated with their omission or failure (for example because they were not tightened to the correct torque when assembled, and so over time have worked loose and become ineffective electrical bonds, reducing SE and allowing interference to occur when it should not have).

A common method for improving the SE at metal sheet joints with small overlaps is to fit their overlapped seams with costly conductive gaskets. Compressing these gaskets requires careful attention to the strength of the metal structures to be jointed and the number of fixings, for the gaskets to work effectively and not be a waste of money.

However, this simple test has demonstrated that simply by overlapping sheet metal by enough (essentially, by at least the same distance as the spacing between the electrical bonds) can make very significant improvements in SE for essentially no cost.

I often want to use the technique of increasing metal overlap when I am trying to fix a product that is failing its EMC tests due to inadequate SE of its enclosure, but it is not at all easy to do in general, so I end up adding more fixings, conductive gaskets, etc., – all of which add to the overall cost of manufacture and increase the costs of QA and the likelihood of warranty claims (because there are more things to go wrong!).

In my training courses I am always encouraging designers to use techniques such as increased metal overlapping at the joints and seams in shielded enclosures, because it is a powerful shielding technique that is essentially free – providing it is designed-in from the start.

Now, with this simple, quick, low-cost test technique, mechanical designers can evaluate the EM characteristics of various designs of assemblies and construction methods before they ever even open their CAD software and start to create the design.

8.2 Assessing shielding materials

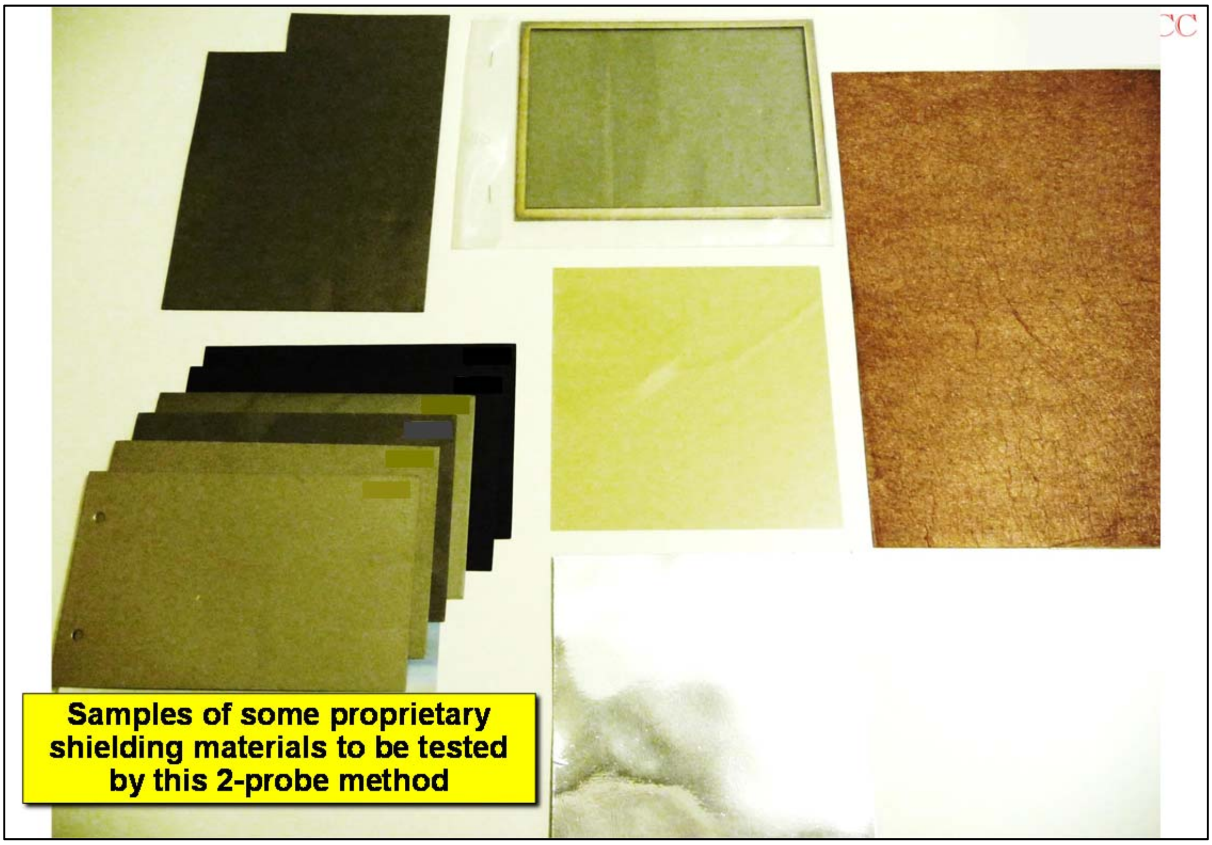

Figure 64 A range of proprietary shielding materials to be evaluated

Figures 44 and 47 show that 0.35mm copper and 0.2mm tin-plated steel are, when free from holes, gaps and joints, at the limit of the SE that can be measured by this low-cost and quick 2-probe method.

However, we can’t always use such metals (e.g. when we want to shield visual display screens), and also are often exhorted by advertisers to purchase more costly shielding materials, often claimed to have wonderful performance.

Usually, we do not discover whether these materials live up to the promises of their sales brochures until we are in an EMC test lab doing testing, whether pre-compliance (costly and time-consuming) or full-compliance (very costly and very time-consuming).

However, using the 2-probe set-up which is the subject of this article, we can very quickly determine whether these materials are any good for our purposes, or not.

I must point out that this 2-probe test set-up measures the SE of materials by exposing them to ‘near-field’ magnetic fields, which may not always be appropriate where shielding is required.

(For an explanation of near- and far-fields, see Chapter 2.4 of [16]. And for a discussion of shielding techniques, see its Chapter 6.)

In general (but not always!) the close-field magnetic-field measurements described here give worse SE results than the same material would achieve when exposed to far-field electromagnetic fields (sometimes called plane waves), or when exposed to ‘near-field’ electric fields.

It should be possible to make a low-cost close-field electric field probe version of this 2-probe test, probably using a pair of coaxial probes so as to only excite the tested material over a small area so as not to suffer from the ‘edge effects’ of different shapes and sizes of samples.

However, to measure the SE of materials to 60dB or above at frequencies up to 1GHz or above when exposed to far-field plane waves, requires a whole different level of effort and cost. This requires a shielded chamber – either anechoic or stirred-mode – with the material to be tested clamped over a hole in one of its walls with a good electrical bond to the metal wall of the chamber all around the perimeter of the sample of material. This is not an easy or quick test to set up, and it is not low-cost either (unless you already own the shielded chamber).

Ideally, it uses two shielded rooms – each one either anechoic or stirred-mode – with a common metal wall with the material sample clamped and electrically bonded all around a hole in their common wall.

In the following, the figures show both the test of the material and the spectrum analyser's display of SE over the same frequency range as before: 10MHz to 1GHz, with the test set-up having been normalised before each test.

I have not included figures showing the SE display alone, in order not to overburden the printers of the EMC Journal, and so I hope that the yellow SE plots on the display are visible when printed.

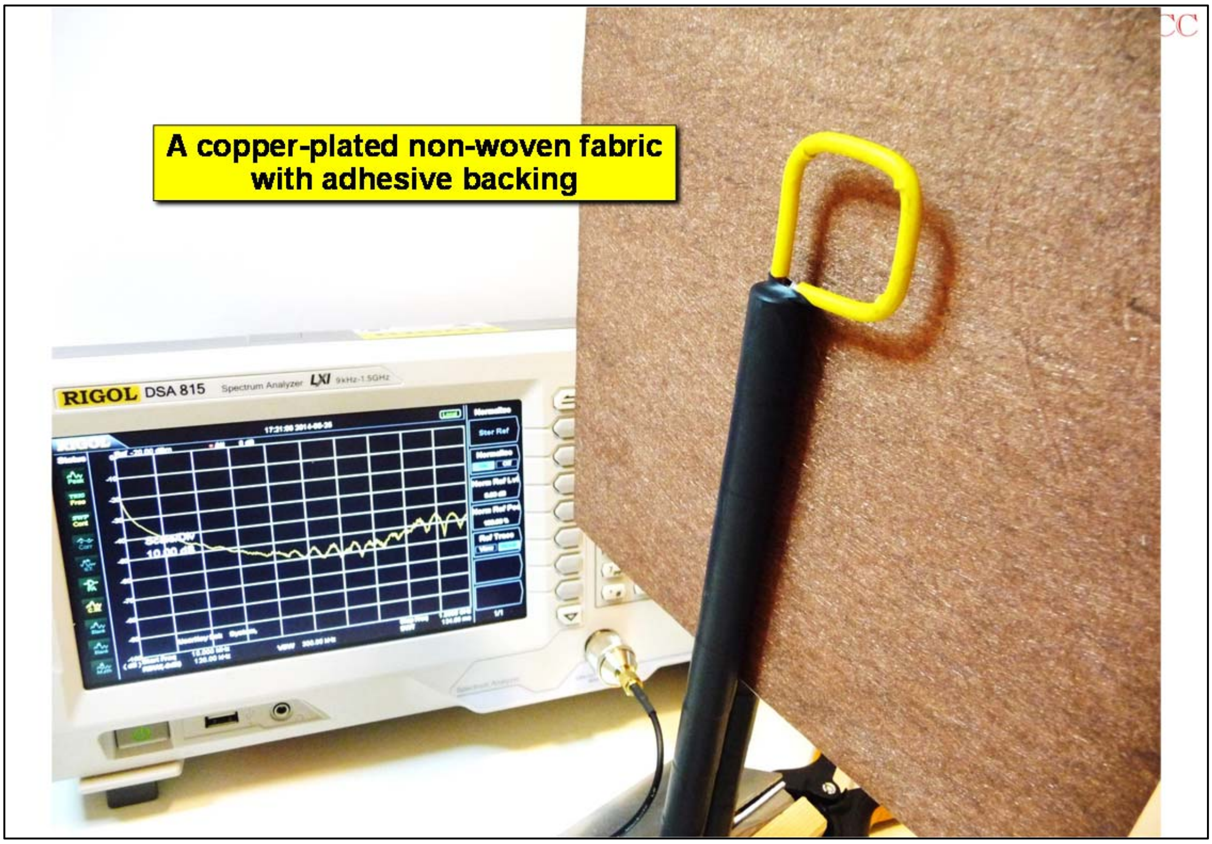

Figure 65 A copper-plated non-woven fabric with adhesive backing

Figure 65 shows a copper-plated non-woven fabric, which only achieves an SE of 20dB at 10MHz, increasing to about 55dB over the range 400MHz to 800MHz, and falling off slightly to 50dB at 1GHz. Not bad at all, above 300MHz on this test.

Figure 66 shows a thin aluminium-coated PVC sheet, which was surprisingly good on this test: 60dB of SE at 10MHz reducing to about 50dB at 100MHz then staying at this level all the way to 1GHz. Not bad at all, and much better SE than I had expected below 200MHz!

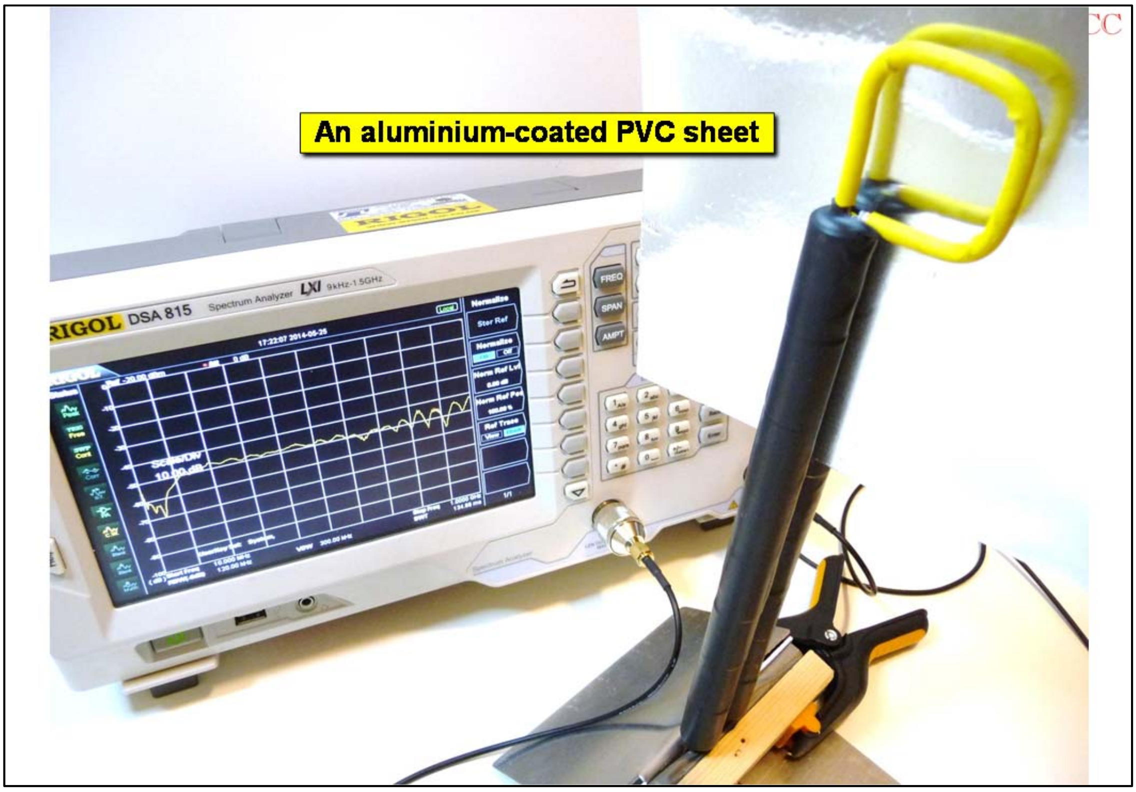

Figure 66 An aluminium-coated PVC sheet

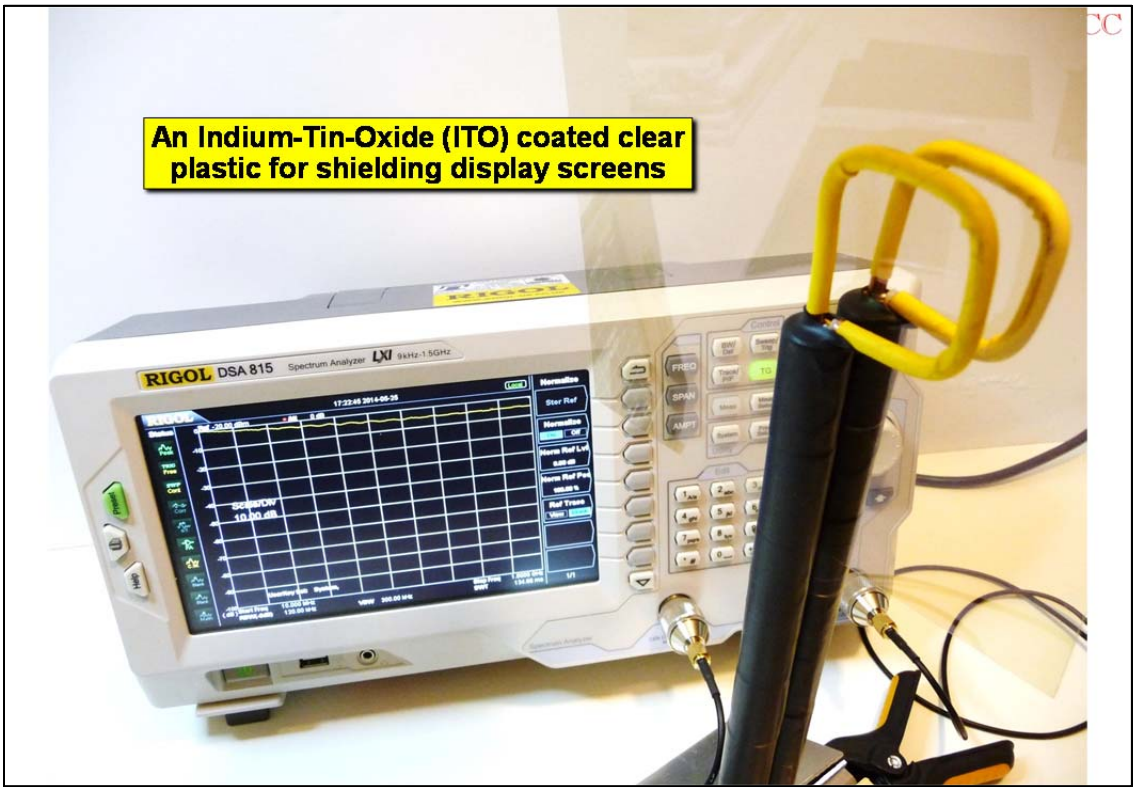

Figure 67 An Indium-Tin-Oxide (ITO) coated clear plastic for shielding visual displays

Figure 67 shows an ITO coated clear plastic sheet, intended for shielding visual display screens. It is hard to see any SE at all from this material, which gradually increases from 0dB at 10MHz to 5dB at 1GHz.

This shows us that it will provide virtually no shielding at all for near-field magnetic fields, but it will probably be a lot better for close-field electric fields over this frequency range, and for plane waves above, perhaps, about 200MHz (this is a guess based on some experience of these types of materials).

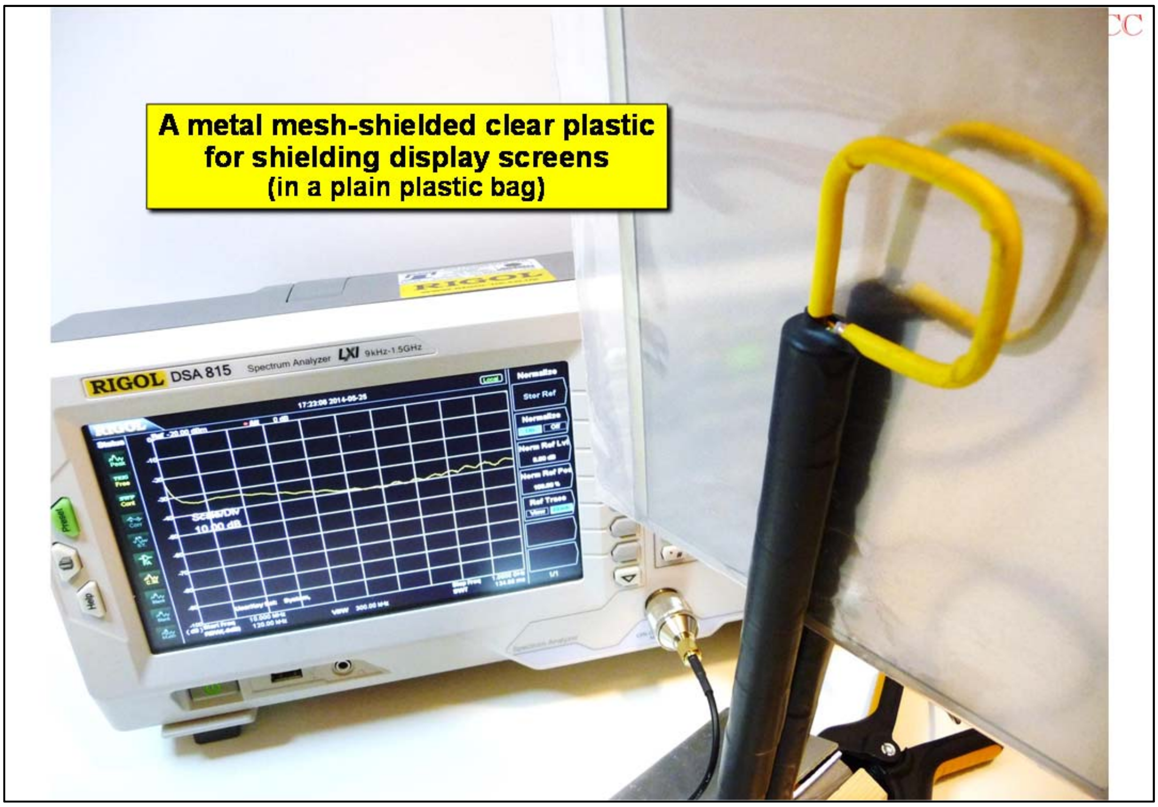

Figure 68 A metal mesh-shielded clear plastic for shielding visual displays (in a plain plastic bag)

Figure 68 shows a metal mesh-shielded clear plastic sheet, also intended for shielding visual displays. This sample has 20dB of SE at 10MHz, increasing quickly to about 33dB at about 50MHz, then increasing more slowly to 40dB at 500MHz. Its SE then remains around 40dB up to about 700MHz after which it degrades slowly to around 36dB at 1GHz.

This is clearly a much better material for shielding displays than the ITO-plated plastic sheet in Figure 67, at least as far as close-field magnetic fields are concerned. I would expect it to be at least as much better than the ITO sheet for close-field electric fields and plane waves as well.

Figure 69 shows a ferrite-loaded synthetic rubber ‘EMI Suppressor’ material, which provided me with another surprise result – unfortunately, it was an unpleasant one.

This was a fairly expensive sample (£20 for a piece 100mm by 150m) of ferrite-loaded synthetic rubber about 1.5mm thick, and on this close-field magnetic field test I expected it to have a lot better SE than 8dB at 10MHz falling slowly as frequency increased to about 1dB at 1GHz.

No wonder I never had any luck with using it as a suppressor when trying to fix products that were failing their EMC tests in test laboratories. I want my £20 back!

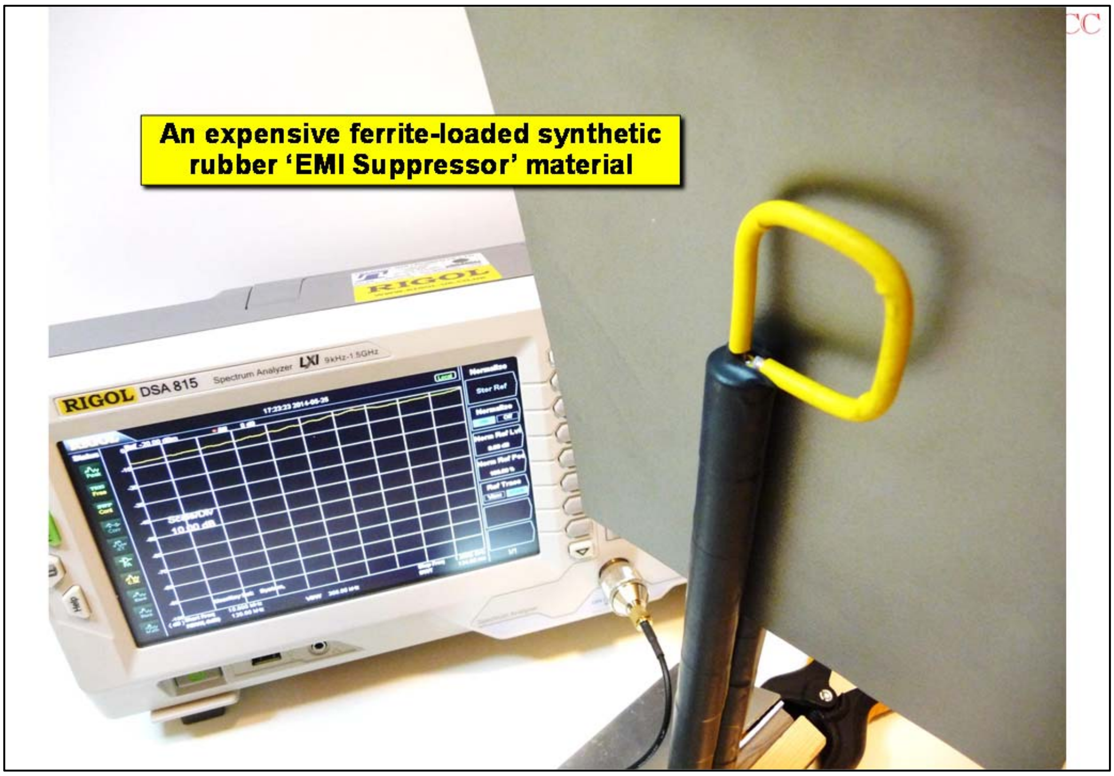

Figure 69 An expensive ferrite-loaded synthetic rubber 'EMI Suppressor' material

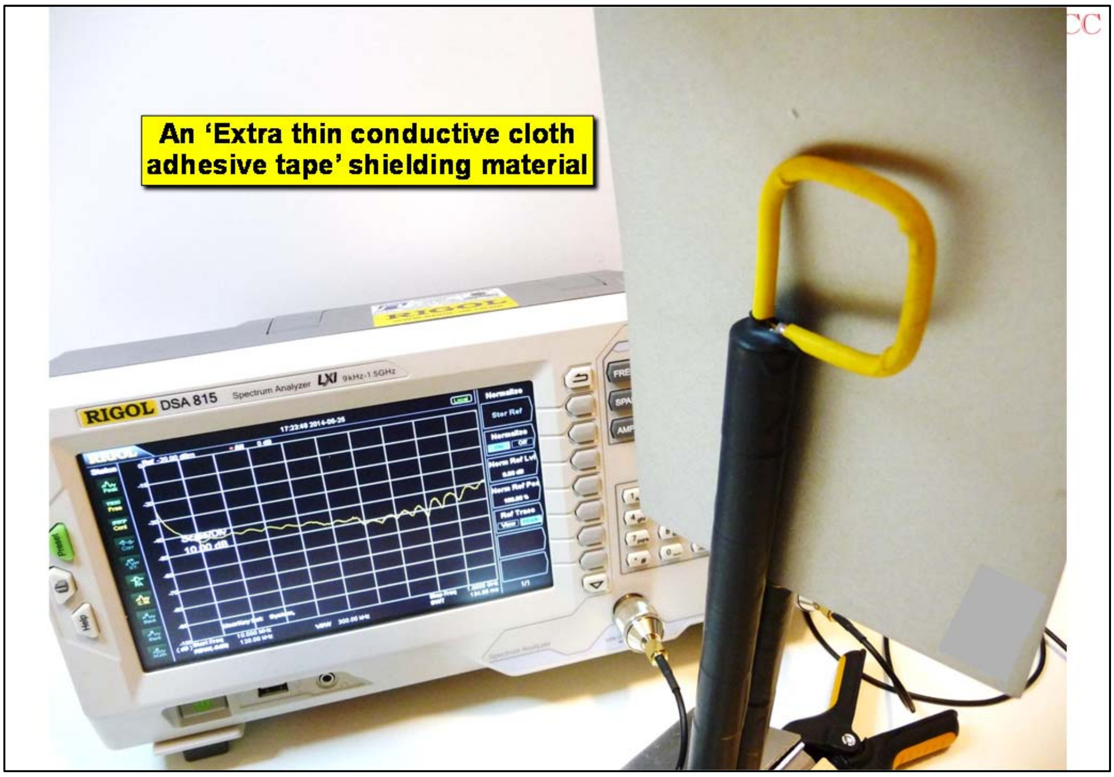

Figure 70 An 'Extra thin conductive cloth adhesive tape' shielding material

Figure 70 shows a sample of an 'Extra thin conductive cloth adhesive tape' shielding material, which gave me yet another surprise!

This small sample of material feels so light and insubstantial that it was hard for me to imagine it would show hardly any SE on this close-field magnetic field test, but in fact it achieved about 25dB at 10MHz, improving rapidly to 45dB at 100MHz.

Its SE remained around 45dB up to about 400MHz after which it improved to 50dB from 600MHz to 800MHz and then fell back a little to 40dB at 1GHz. Surprisingly good.

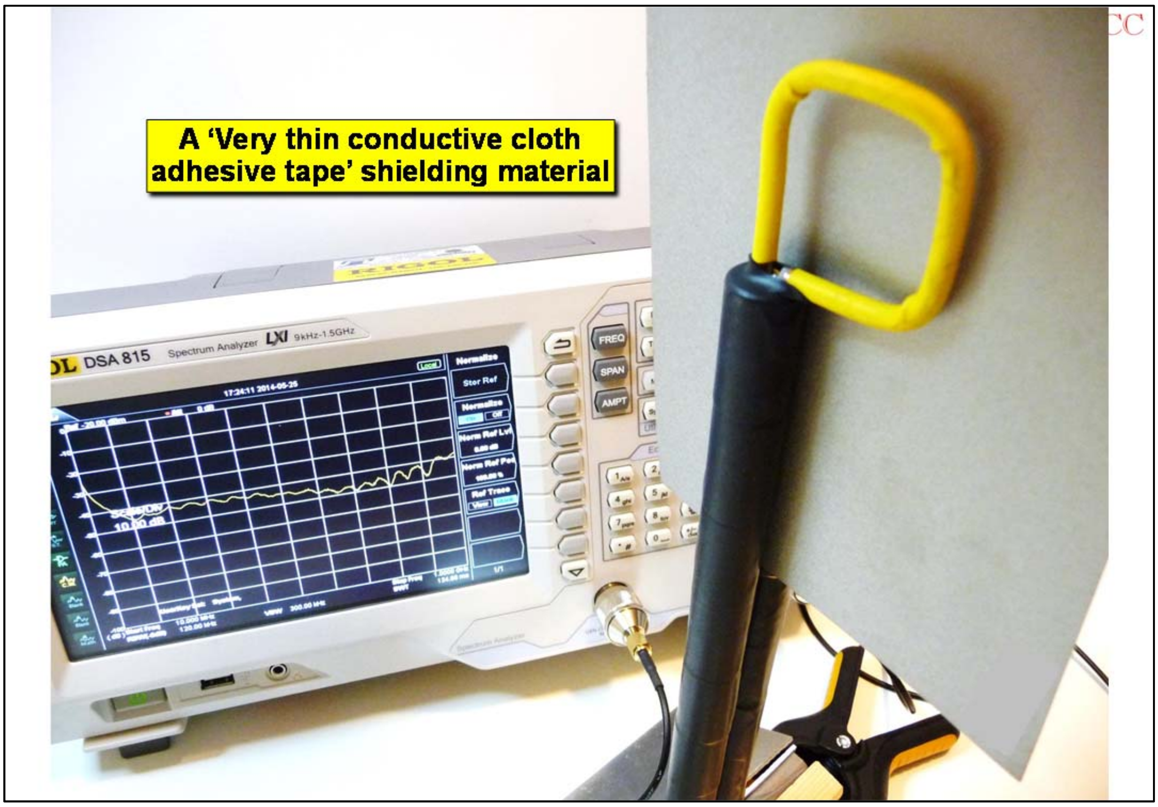

Figure 71 A 'Very thin conductive cloth adhesive tape' shielding material

Figure 71 shows a 'Very thin conductive cloth adhesive tape' shielding material, which is only a little more substantial than the sample shown in Figure 70, and which gives a similar SE result on this test.

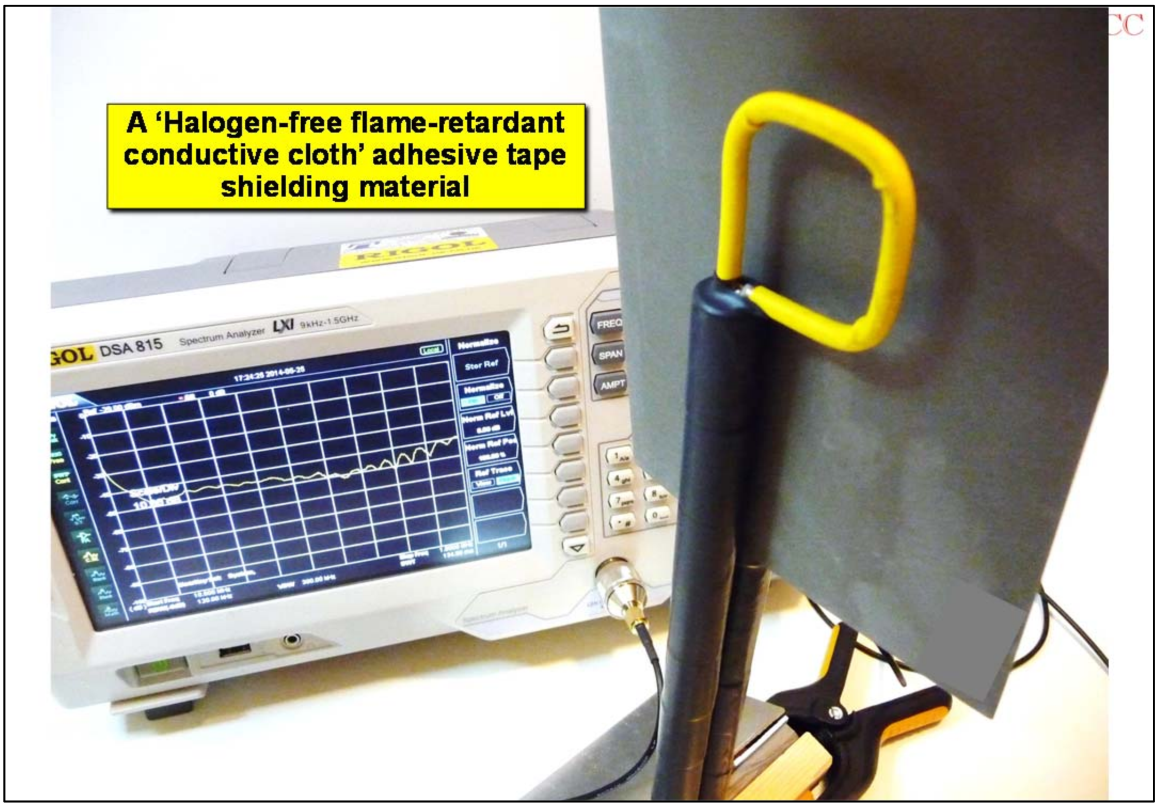

Figure 72 A 'Halogen-free flame-retardant conductive cloth' adhesive tape shielding material

Figure 72 shows a 'Halogen-free flame-retardant conductive cloth' adhesive tape shielding material, which was in turn only a little more substantial than the samples shown in Figures 70 and 71, and which gave an SE result similar to theirs on this test.

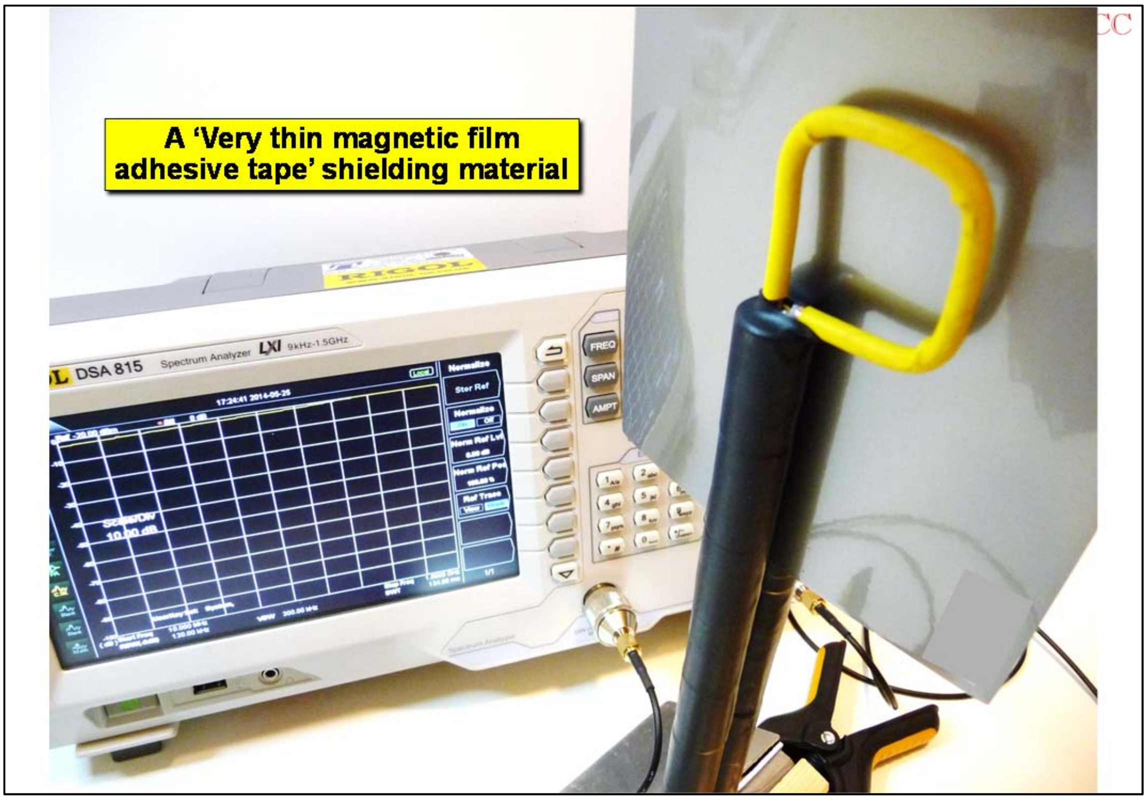

Figure 73 A 'Very thin magnetic film adhesive tape' shielding material

Figure 73 shows a sample of 'Very thin magnetic film adhesive tape' shielding material. As for the sample in Figure 69, I expected it to have good SE on this close-field magnetic field SE test, but – also as for the sample in Figure 69 – I was disappointed: it measured about 3dB at 10MHz falling to 0dB above 800MHz.

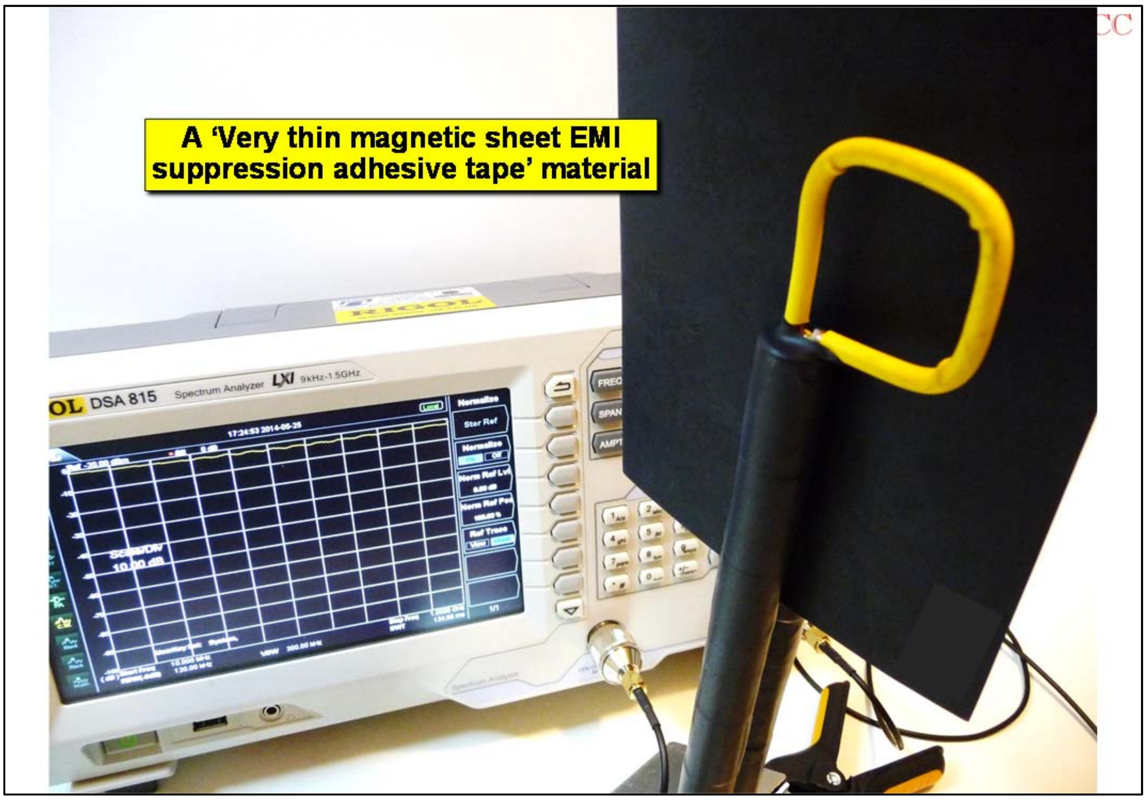

Figure 74 A 'Very thin magnetic sheet EMI suppression adhesive tape' material

Figure 74 shows a sample of a 'Very thin magnetic sheet EMI suppression adhesive tape' similar to that tested in Figure 73. Just as for the samples in Figures 69 and 73, this measured very poorly: 1dB at 10MHz improving (if that is the word) to about 3dB at 400MHz and then falling back to about 2dB by 1GHz.

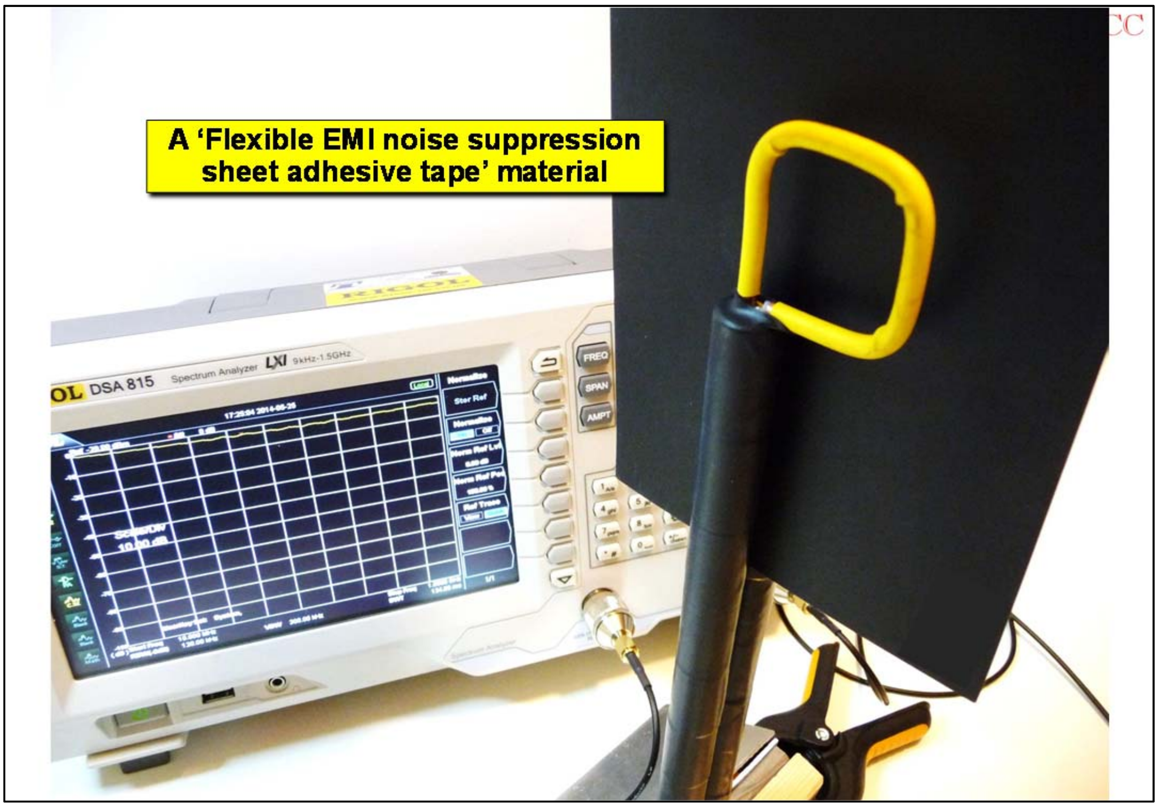

Figure 75 A 'Flexible EMI noise suppression sheet adhesive tape' material

Figure 75 shows a sample of a 'Flexible EMI noise suppression sheet adhesive tape' material, which gave SE performance on this test that was much the same as for the materials in Figures 69, 73 and 74.

The results of the tests shown in Figures 69, 73 and 74 were rather disappointing. It is difficult to see what these materials are intended to do – given that they claim to be magnetic absorbers and this is a magnetic field test.

Perhaps these materials are intended for shielding at much higher frequencies than 1GHz? I have seen data on special materials that 'tune' their characteristics to provide good absorption over certain bands of radar and other microwave frequencies, and are effectively useless outside those bands. But the websites for the manufacturers of the samples in Figures 69, 73 and 74 make no mention of such exotic shielding properties.

Well, that's it for this quick, easy, low-cost 2-probe shielding effectiveness test technique for reducing project and financial risks. The next article(s) in this series will cover the following close-field probing techniques:

- The 2-loop-probe method of finding resonances in cables
- The 2-clamp-probe method of finding resonances in cables
- The 1-clamp-probe 'reflectometer' method of finding resonances in cables
- The 1-clamp-probe 'reflectometer' for finding flaws in cable screen terminations and connectors

I hope that by the time I come to write the next article(s) I have managed to figure out how to get the 1-clamp-probe 'reflectometer' method for finding flaws in cable screen terminations and connectors working properly. I had it working in my own workshop, but when I tried to demonstrate it to 50 engineers in Belgium earlier this year, I couldn't get it to work. Most embarrassing!

Shielded cables with over-moulded connectors often cause problems because their shields are not correctly terminated inside their moulded connectors. The only way of checking them is to X-Ray them, usually from two different angles, or else cut the plastic over-moulding away with a sharp knife – taking care not to remove parts of fingers, or even whole fingers, in the process.

So I hope I can get this method to work well, because it would be a lot less costly and much more flexible and convenient than X-Raying connectors; and a lot less destructive (and dangerous) than cutting the over-moulding off with a knife.

9 References for Part 2

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