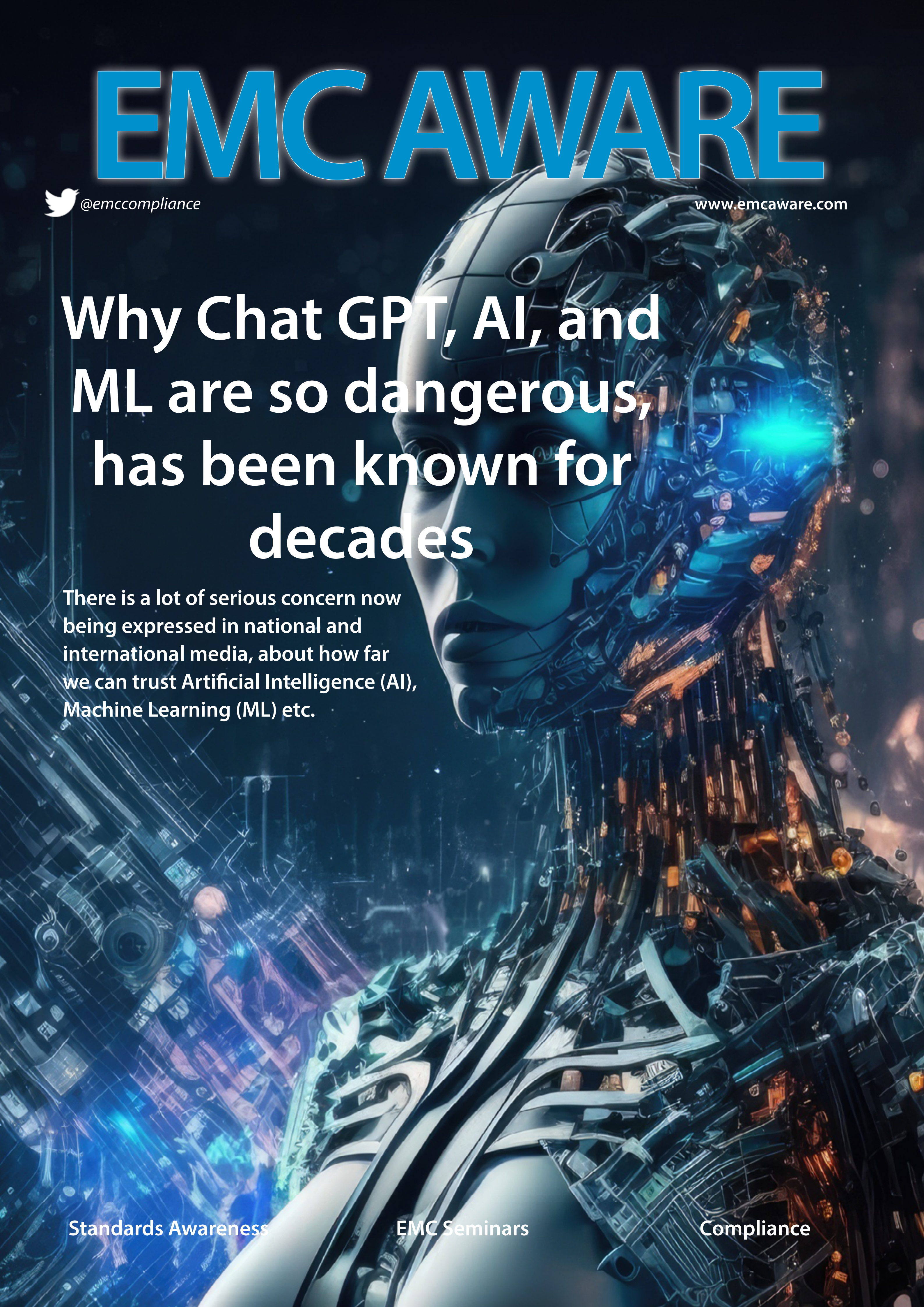
EMC AWARE

@emccompliance

www.emcaware.com

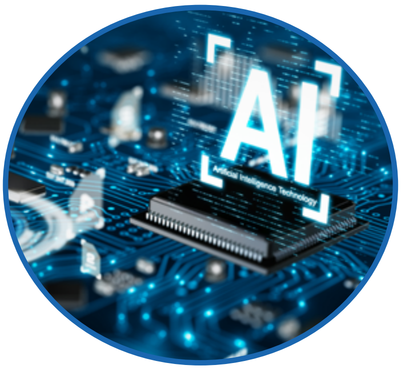


Why Chat GPT, AI, and ML are so dangerous, has been known for decades

There is a lot of serious concern now being expressed in national and international media, about how far we can trust Artificial Intelligence (AI), Machine Learning (ML) etc.

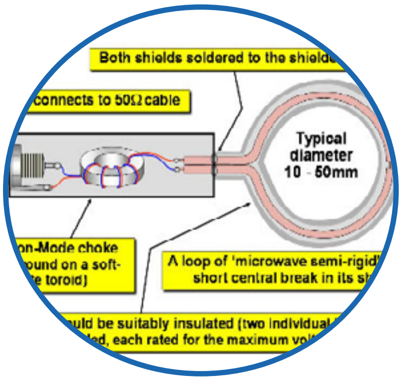
Standards Awareness EMC Seminars Compliance

Contents



4

8



21

50

MESSAGE FROM THE EDITOR

Dear Readers,

It has now been 30 years since we have been following European normalised standards for electromagnetic compatibility - a working lifetime! What happened in that time and where did it all go? Quite a few of us are looking to retiring, some are still present in our more mature years and some of us have started not too long ago in this field of EMC.

How did we learn all the theory and practical bits when there were no formal courses available? Are there any academic courses on EMC available today for the aspiring newcomer?

Now we have reached the point where the personnel have reached maturity and new blood is required. How much have you managed to transfer over to your successors in terms of EMC information for equipment design, test and fault finding? Would they have your confidence to meet the same degree of throughput and capability as you did?

For those of you that have started recently how do you feel in this specialist arena? What made you decide to get into the field of EMC? How have you been supported by your company and your colleagues. Is this an interesting job to do? If you have been doing nothing but EMC Tests, would you like a change to another area? Remember EMC is just not about testing.

For those of you that are deciding on retirement, maybe you could consider giving back some of your knowledge and expertise to students at a local education establishment. Try providing a lecture on EMC and its effects, on an occasional basis, once or twice a year or a little more frequently. The academic staff might be most appreciative of your offer as they may not have the practical experience in EMC. It would also keep your skills honed.

Those of you who are in the midst of your career, have you noticed if you are busy and there is a skills shortage in EMC people; the planners, the designers and testers and now the consultants. Which route have you decided on and do you have the freedom to make that choice?

In the northern hemisphere, we note that EMC experienced staff originally in the design and test fields have moved over to planning and consultancy. Possibly the demand is driven by the renewable energy sector as well as the logistical and strategic needs of the military. It has also been noted that there are some countries in western Europe that do not have EMC Test labs located within their borders.

In the southern hemisphere, due to large projects starting, we have personally seen the high demand for EMC design engineers and also EMC commissioning and installation engineers. As the test phase takes effect, EMC testers from the test labs will move to the production facilities. So there will be a demand for qualified EMC personnel.

Please tell me your experiences and views at ***editor.emcawaremag@gmail.com***

All the very best in your future endeavours.

Chris Nicholas

Chris Nicholas
Editor

Why Chat GPT, AI, and ML are so dangerous, has been known for decades

by Keith Armstrong, www.cherryclough.com

Chat GPT, AI, ML, etc., are now using digital systems in almost every possible application. Not just cars, trucks, trains, planes, surgery – where safety implications are obvious – but in everything else, where the implications for a great deal more than mere safety risks are almost unimaginable. This situation could have been avoided

There is a lot of serious concern now being expressed in national and international media, about how far we can trust Artificial Intelligence (AI), Machine Learning (ML) etc.

Not to destroy civilisation as we know it. For example, see ***https://www.bbc.co.uk/news/world-us-canada-65452940.***

What makes it especially alarming, is that this issue even featured as a serious news item on the BBC Radio 4's regular news roundup at 7am on 1st May 2023 – because scientific, technical or engineering matters are almost never mentioned on this programme. And, when they are mentioned, the interviewers always show how smug they feel at not being able to understand anything about the topic being described by their highly-respected interviewee.

So it seems clear that Chat GPT, AI, ML, etc., could be an existential threat to humans!

With my 'human being' hat on. I am worrying whether there is any way my family and friends can even survive the next decade. Or whether we might as well just give up, now that so many of the dystopian science fiction stories I have read, and films I have seen. e.g., ***https://en.wikipedia.org/wiki/I,_Robot_(film***), are coming true at once.

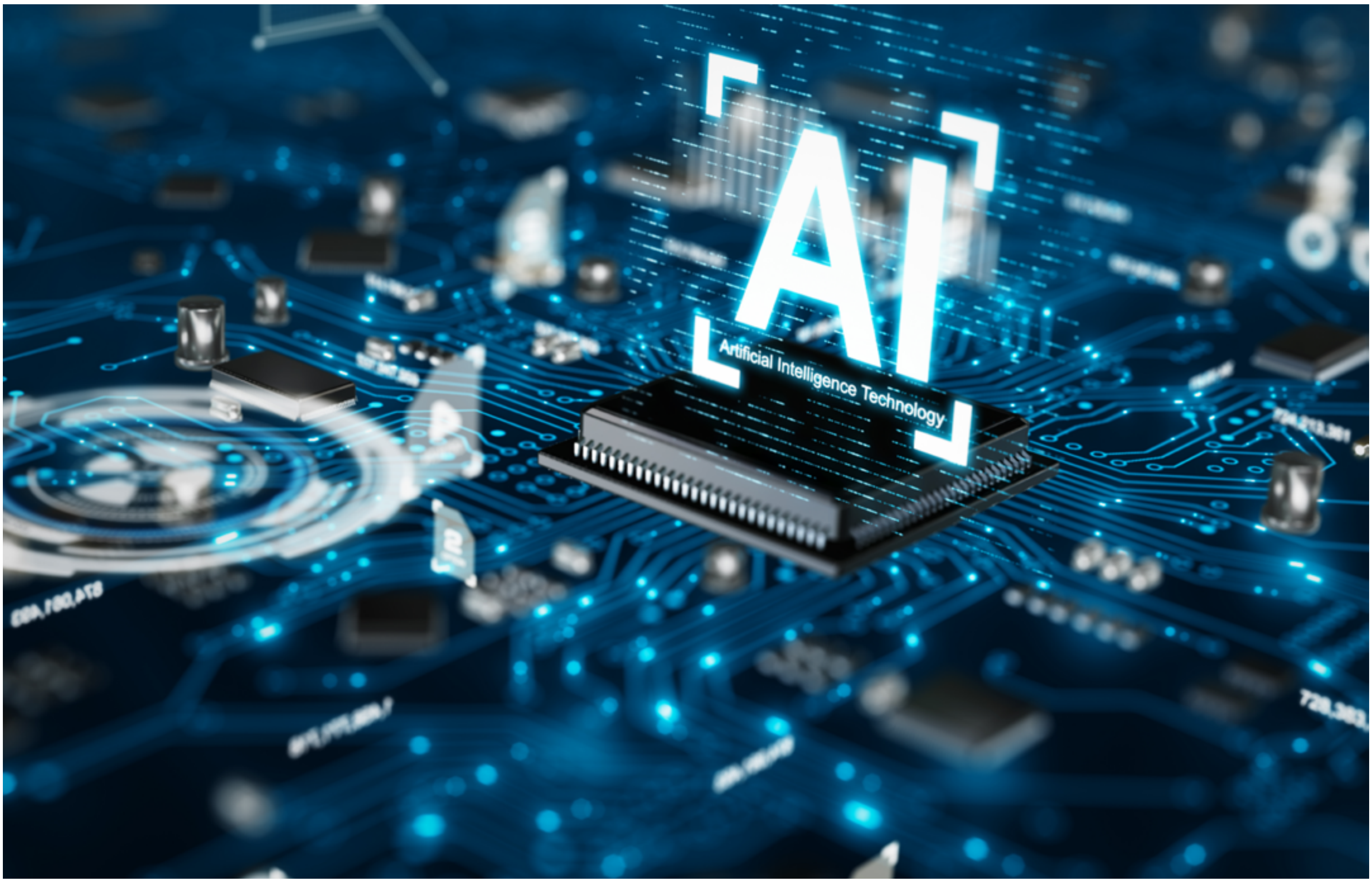
However – with my 'EMI hat' on what I find especially interesting is that the problem now being discussed is an inherent problem with programmable digital systems. I understand that this problem was first identified in the 1970s and was one of the reasons for the creation of IEC 61508, first published in 2000. It has two components:

i))The inherent unpredictability of digital systems[2]
Digital systems are non-linear, so we can't test a percentage of the digital states and assume that the results prove anything about any untested states.

ii) The inherent untestability of modern digital systems[3]
Programmable digital systems (hardware and software) have far too many possible digital states to ever be 100% tested – even once.

Until recently, there were very few safety-critical systems relying on AI or ML, and all were operated by trained personnel. When they malfunctioned, the damage was contained, and rarely excited any interest in national or international media.

But Chat GPT, AI, ML, etc., are now starting to use digital systems in every possible application. From self-driving cars, trucks, trains, ships and planes – where safety implications are obvious – to everything else, used by anyone, including human communications in words and sounds.



This civilisation-spanning use by everyone, could result in almost unimaginably worse consequences, than mere safety risks!
(Even without considering the possible effects of 'bad actors' or deepfakes.)

Interesting, isn't it, how a problem that has been well-known since the 1970s in the digital systems industry, could now present a serious threat to humanity.

Footnotes:

1 Since 1997 – with the help of many others – I have been researching how to deal with the problems outlined in i) and ii) above, as regards the effects of EMI on the functional safety of digitally-controlled safety-critical systems.

See: *https://www.emcstandards.co.uk/we-can-t-fully-test-digital-systems*
and the many papers, articles, presentations posted at: *https://www.emcstandards.co.uk/emiemc-risk-management.*

This research resulted in the publication, in 2017, of the IET's Code of Professional Practice on Electromagnetic Resilience, see:
https://shop.theiet.org/code-of-practice-for-electromagnetic-resilience.

In turn, IET 2017 led to the first published standard on EM Resilience: IEEE-1848-2020, which is (for now) the state of the art on managing the functional safety and other risks that can be caused by EMI. You can purchase it from: *https://standards.ieee.org/ieee/1848/7221/*

2 From [A]: "….in general, a successful series of tests provides little or no information about how a digital system would behave in circumstances that differ, even slightly, from the test conditions."

From [B]: "Unlike linear systems, digital systems lack continuous behaviour. Relationships between inputs and outputs can be complicated, discontinuous and not predictable…"

3 Given 2 above, we would hope to be able to prove that the behaviour of a given digital system was acceptable, by testing it thoroughly.
For a safety-critical system, we would ideally want to test 100% of all its possible digital states. But even if 99% of all possible digital states could be tested as being safe-enough, we should never assume that the untested 1% would not be very dangerous.

It's easy to show that, unfortunately, we never have nearly enough time to even test 1% of all possible digital states, never mind 99%! Even if using very powerful testing resources.

From [B]: "Unfortunately, a digital system, particularly its software, is usually sufficiently complex that it is not practical to test all possible inputs and outputs exhaustively."

References:

[A] See: "Computer Based Safety-Critical Systems", IET, October 2009, no longer published (but I have a copy I'd be happy to share).

[B] See: "Computer Based Safety-Critical Systems", IET, 2013, ***https://www.theiet.org/media/9534/computer-based-safety-critical-systems.pdf***

Note: I can provide many more references from experts other than the IET, if required.

Important note: Please don't get confused between the risks of not achieving compliance with the EMC Directive, and the functional safety risks that can be caused by the occurrence of EMI (even when the EMC Directive is complied with).
See: ***https://www.emcstandards.co.uk/risks-associated-with-emc-and-emi-don-t-g***

I will be providing Training Workshops at the upcoming EMC and CI 2024 event in Newbury, England in May, register at ***www.emcandci.com***

EMC guru Keith Armstrong will hold a 2-3 day ”design electronics with good EMC”seminar in Helsinki, Warsaw and Milano!

We are offering a 2-day seminar on EMC at PCB level with the internationally recognized EMC expert and author, Keith Armstrong with the option to attend a third day for EMC at Equipment, System and installation level with EMC experts Chris Nicholas and Andy Degraeve

Keith Armstrong has more than 30 years of experience in EMC, and is the author of numerous books and publications on EMC and PCB/Equipment design. He is the past chairman of the IEEE's Professional Group, a member of the IEEE's EMC and Product Safety Societies, and chaired the team that published IEEE Std 1848:2020 on Managing the Functional Safety Risks caused by EMI. Keith will share the latest design techniques for PCBs to reduce the risk of failed EMC tests resulting in delayed product launches.

Chris Nicholas is a graduate of Salford Univ, Lancs.,UK, and has over 35 years in the RF design of military, aerospace, automotive, commercial and retail electronics- Most recently, at Lockheed Martin UK, he set up and managed the Military EMC pre-compliance facility.

Andy Degraeve is a graduate of KU Leuven, Belgium and an IEEE member. Andy joined Keith Armstrong consultants in 2020 as an expert in Electromagnetic Compability, Imunity and FS.

Click here for information and registration for **Helsinki** 4-6 October

Click here for information and registration for **Warsaw** 6-8 November

Click here for information and registration for **Milano** 9-10 November

Date & place

4-6/10-2023 - 08:30—16:30, Scandic Aviacongress, Helsinki/Vantaa

6-8/11-2023 - 08:30—16:30, Radisson Blu Sobieski Hotel, Warsaw

9-10/11-2023 - 08:30—16:30, Crowne Plaza City, Milano

Certificate of attendance will be issued on request!

Banana Skins 931-940

Compiled by: Keith Armstrong, www.cherryclough.com

931) Demonstrating EMI from Battery Packs and Mitigation by Field Cancellation

While EMI has been extensively studied for decades, it appears that EMI generation from battery packs is not well known and has not been well investigated. In this demonstration, we will show that a lithium-ion battery pack used for powering a wearable electronic device commonly used in US underground coal mines (i.e., a continuous personal dust monitor (CPDM)) can generate strong EM emissions that interfere with other mining safety equipment, such as proximity detection systems. We will also show that the EM emissions generated by the battery pack can be effectively mitigated by a novel EMI mitigation method that is based on a field cancellation technique. Background: The CPDM is a mandatory device for underground coal miners, according to the Mine

Safety and Health Administration (MSHA) regulation (30 CFR § 75.1732). It protects the health of the miners by monitoring a miner's dust exposure.

Unfortunately, not long after the CPDM was placed in the field, it was discovered that the electromagnetic energy emitted by a CPDM interfered with another critical device, called the proximity detection system (PDS), which monitors the distance between miners and mining equipment and protects miners from being accidentally pinned or crushed by mining equipment.

After the incidents of EM interference, an investigation followed, and it was concluded that the battery was the major culprit of the EM emission of the CPDM. Several electromagnetic interference (EMI) mitigation methods were then proposed by vendors and by researchers at the National Institute for Occupational Safety and Health (NIOSH). These include, but are not limited to, a copper-mesh pouch made by Strata (the PDS vendor), shielding on the battery pack, administrative control on the miners (maintaining six-inch distance between CPDM and PDS device), and others. Each method has its pros and cons; yet none of them has addressed the issue satisfactorily.

*(Taken from the description of a demonstration by for Alan Zhang and Chenming Zhou, of the National Institute for Occupational Safety & Health, Cincinnati, OH, USA; to be held in the Exhibition Hall during the IEEE 2023 EMC+SIPI International Symposium, July 31 - Aug 4, 2023, Grand Rapids, Michigan, USA, **https://emc2023.org/**)*

932) FCC Threatens Fines for Illegal Use of Mobile Frequencies

A Pennsylvania man has been ordered to cease operating surveillance cameras that are interfering with cellular service in his area. According to a Citation and Order issued by the U.S. Federal Communications Commission (FCC), officers of the FCC's Enforcement Bureau launched an investigation in June 2022 into claims by T-Mobile that harmful interference to its cellular services in the York, PA area was emanating from surveillance security cameras installed at a single-family home in York, PA occupied by Luis Martinez.

The Bureau's investigation confirmed T-Mobile's findings, and Enforcement Bureau officers instructed Martinez to either remove the cameras or readjust the camera's settings so that the device operated within the 2.4 GHz band.

Although Martinez reportedly disconnected the cameras, he eventually switched them back, reinitiating the interference.

(*From In Compliance magazine, **https://www.incompliancemag.com**, July 2023 edition)*

933) Distributed Energy Resource microgrids impact grid power quality

The microgrid test bed demonstration with the power quality analyzer paired with high-performance CVD sensors proved that DERs are susceptible to generating power quality phenomena such as supraharmonics, voltage instability, THD, and flicker. The test scenarios performed yielded power quality-related observations in three of the seven experiments. Islanded conditions demonstrated instability with voltage fluctuations, THD, and evidence of supraharmonic frequencies in the 4–16-kHz range.

TABLE 2. Test scenarios and event observations summary.

Test Scenario No./Event	DER Source and Experiment	Test Sequence	Observations
4	Islanding, all DERs	1. Transition into island. 2. Transition out of island.	– Voltage dropped to 6.9 kV (7.2 kV L-G nominal) – Supraharmonic frequencies (conducted emissions) observed up to 12 kHz – Flicker present
6	Solar inverters, islanded and isolated	1. Isolate each of the three solar inverters. 2. Run the three inverters independently. 3. Run all inverters simultaneously.	– Variation/instability observed in voltage magnitude – Voltage dropped to 6.84 kV (7.2 kV L-G nominal) – Supraharmonic frequencies (conducted emissions) observed up to 14 kHz – Two frequency observations up to 60.5 Hz
7	Wind turbine, islanded and isolated	1. Turn the wind turbine on. 2. Turn the wind turbine off. 3. Turn the wind turbine on. 4. Turn the wind turbine off.	– Voltage dropped to 7.01 kV (7.2 kV L-G nominal) – Supraharmonic frequencies (conducted emissions) observed up to 16 kHz – One frequency observation up to 60.6 Hz
Island Event	—	—	– Voltage sags at 5.76 kV and frequency observations up to 60.3 Hz – THD up to 20.8% and flicker P_{st} >1.0 – Supraharmonic frequencies (conducted emissions) observed up to 24 kHz.

In addition to the test scenarios, an unintentional event was measured and recorded with the CVD sensors and power quality analyzer. This event involved an islanded condition with a sequence of switching DERs that resulted in approximately 45 min of power quality issues. During this event, observations were recorded including voltage sags at 5.76 kV, a frequency of 60.3 Hz, flicker Pst >1.0, THD up to 20.8%, and supraharmonic frequencies up to 24 kHz. Table 2 (below) summarizes the power quality issues observed during the three test scenarios and the microgrid islanding event.

These measurement observations demonstrate that DERs do have an impact on grid power quality and that supraharmonic frequencies are present beyond what traditional technologies can measure at the MV level.

Traditional transformer technologies (designed based on magnetic induction) may have frequency cutoff measurement limitations that inhibit their ability to measure supraharmonic frequencies. Traditional IEDs may have frequency measurement limitations if they are designed to measure up to typical industry guidelines at the 50th harmonic (3 kHz). While the impact of supraharmonic activity on MV grid reliability is not thoroughly understood, this study demonstrates that DERs do generate them and that they can be measured with capable sensors and power quality analyzers. The CVD sensor and power quality analyzer system applied in this microgrid test bed have demonstrated supraharmonic frequency measurement of 4–24 kHz that may be limited or undetectable with traditional measurement systems.

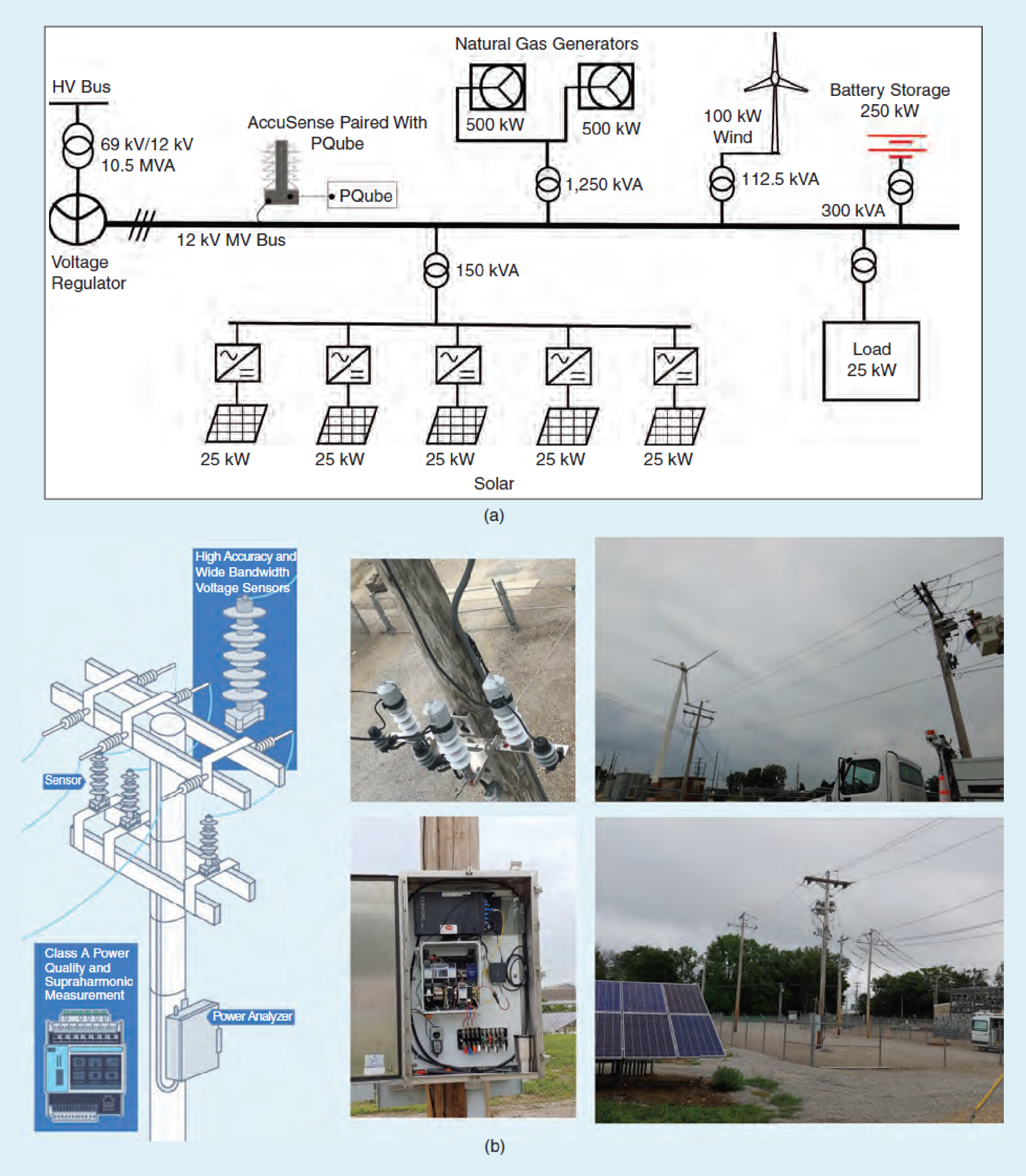


Figure 2. (a) Simplified scheme of the microgrid test bed network and location of measuring devices. (b) Renewable energy sources at the microgrid and field installation of voltage sensors. MVA: mega volt amperes.

(Taken from "Supraharmonic Measurements in Distributed Energy Resources – Power quality observations in a microgrid", by Mattewos Tefferi , Nick Nakamura, Brad Barnes, and Nenad Uzelac, in IEEE Electrification Magazine, Vol. 11 No.2 June 2023, https://ieee-pes.org/publication-item/electrification-magazine)

934) Man Indicted for Selling "Ground" to Electrical Engineering Students

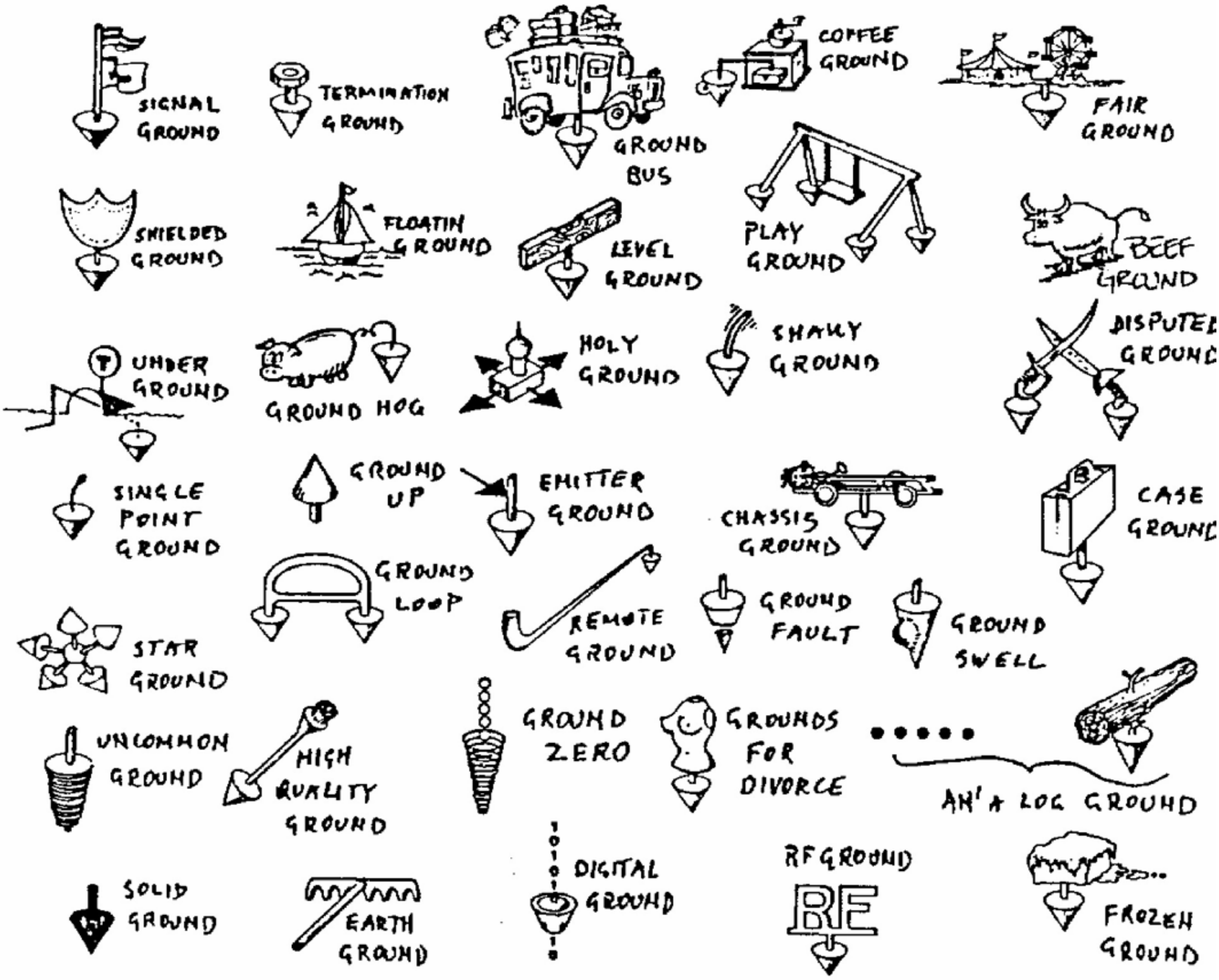
A scammer has been indicted for selling meaningless physical land to neophyte electronics students.

A man with a long record of scams and cons has been indicted for selling entry-level electrical-engineering students small parcels of real land, leveraging the fact that they had been told their circuits and systems needed as much "ground" as possible.

The unidentified man says he got the idea from listening to his niece, a first-year student in an electronics program. She told him that the instructor and textbooks repeatedly cited the need for more and better "ground" to make circuits work, or for system safety—you could never have enough of this so-called "ground."

After listening to her, the alleged con artist developed a long list specific ground types to sell, such as signal ground, ac-line ground, power ground, RF ground, and shield ground. It did seem like you just never have enough of this thing called ground.

Taken from: **"The Ground Myth"**, by Dr. Bruce Archambeault, IEEE Fellow, May 2009, IBM Distinguished Engineer, IBM, Research Triangle Park, NC, USA, https://web.mst.edu/~jfan/slides/Archambeault2.pdf



Unlike some scams where the buyer gets meaningless, fake deeds to non-existent or unbuildable land, this scam worked differently. The indicted man would find odd-shaped pieces of real available land (similar to fabric remnants) and work with the owners to buy those few square feet here and there. He would then resell these small pieces at a much higher price complete with a legitimate deed to the students, saying "you'll be needing more ground for your projects to succeed, and as you know, they're not making more land."

Note that the charges don't claim he sold land that he did not own or misrepresented the land itself. Instead, the charges are focused on selling land under false representation of the application of the land. Ironically, it's not entirely clear if the charges against him (no pun intended) will actually "stick," since the transactions themselves were completely legal and properly done.

Of course, for higher-power transmitter towers and antennas such as those used by commercial broadcasters, especially in the lower-frequency "medium wave" band (several megahertz and lower frequencies/long wavelengths), the land on which the antenna sits actually is critical. In most cases, these antennas need acres of relatively conductive ground to form a ground plane under the antenna, as well as install grounding rods for the lightning rods protecting the antennas. But that's a different "ground" story and a few square feet won't make a difference.

(Taken from an item by Bill Schweber, in Electronic Design magazine, March 31, 2023, ***https://www.electronicdesign.com/technologies/analog/article/21262750/electronic-design-man-indicted-for-selling-ground-to-nave-ee-students***)

935) CAN Bus crashed by intermittent contact, caused car to stop unexpectedly

We had an issue with one of our electric cars last week. There was a broken wire in the rear seatbelt clips that warns you when a passenger unclips their seatbelt. It was shorting out very many times a second. By doing this it crashed the CAN Bus and the car came to a halt.

It could not be turned off even for a few minutes, while its backlog of messages cleared. The driver then turned the car off, then back on again, when it could be driven again.

I had a similar issue in my electric car (but not actually stopping the car). So, I found the connector plug from the seat belt clips and disconnected them. Now no more issues.

This is a safety feature that can become a safety issue!
I am always very keen on unintended consequences being investigated, for everything.

But it appears to me that there have been no discussions or plans for this particular safety issue, which is presumably due to a flaw in the basic CAN Bus system, unless it is an error in the way the CAN Bus has been implemented in these two electric cars.

However, my understanding of safety-related systems is that they should always fail to a safe state, even if implemented incorrectly. A vehicle that simply stops without warning while driving on the public highway is not very safe!

(Taken from a private conversation in May 2023 with an anonymous person.)

936) Arcing stories

I did not make this video but we had a failure that was very similar: ***https://www.youtube.com/watch?v=GicGZcWfkfE***, and the arc wiped out everything from ELF through US CB (27MHz).

The power pole eventually caught fire and the top 10 feet burned. Our volunteer fire department wanted to spray the burning/arching section with water. Fortunately a Kentucky State Police officer arrived and convinced them it might be a suboptimal solution!

A friend worked in TV for 30 years and ran into studio halogen lights where the filament opened and arced. He'd sunburn, and the bulbs would frequently explode.

*(Taken from the Editor's private email correspondence with Jeff L Green in Kentucky, USA, in early 2023. For more on arcing or exploding light bulbs, the Editor suggests visiting 'Ed's Hall of Shame' at: **https://www.on4ww.be/emi-rfi/QST_May_2005_pp70_72.pdf** – it's amazing that a gas mixture in a lamp would support an arc at 12V!)*

937) Twenty stories of Radio Interference from Jeff L Green

The B-Field loop has been a great aid in tracking down our home grown EMI.

To the sane, Dr. Counselman's efforts might appear demented, but, when you are trying to receive signals right at your local ambient RF noise floor, you are forced to take extreme measures.

I'm lucky. I live in a rural area with a fairly low RF noise floor. We were able to reduce our home grown EMI to near ambient with fairly sane steps. Commercial EMI filters, "ground inductors." Our worst EMI source is the washing machine. It uses variable speed drives and I suspect it is impossible to filter enough to meet FCC Part 15 unintentional radiators limits. Not that Part 15 limits are all that RF quiet.

Fortunately, we can work around the EMI and not do laundry when I'm trying to dig out some signal almost buried in the noise.

I thought electric fences would be a major problem but the short bursts are fairly easy for a modern software defined radio's noise blanker to take care of.

This is an interesting web page that shows some EMI mitigation steps: ***https://www.on4ww.be/emi-rfi.html***.

(Taken from the Editor's private email correspondence with the amazing Jeff L Green in Kentucky, USA, in early 2023. The link he very kindly provides above has 20 fascinating examples of EMI covering such everyday items as: shoe stores, ceiling lamps, clothes dryers, Porsche garages; street lamps; snow; restaurants, nightclubs, etc, etc!)

938) Things Not On the Schematic: How the Parasitic Element Affect Results

The engineer had found the use of a capacitor on a specific trace would solve a radiated emissions issue. However, placement on the connector where we put the capacitor during engineering work was not a production solution. So, the capacitor which was moved less than 1 inch away from the connector and turned sideways to fit on the circuit board. However, this degraded the emission results several dB and increased it above the limit. How could that be? They were identical on the schematic.

It has been said that the field of EMC is the design of circuits which consider things that do not appear on a schematic. These are the parasitic elements, the electric and magnetic field created by the circuit and coupled into adjacent circuits, wires, and components, and issues of unknown or uncontrolled current paths. To control these issues, it requires being aware of these fields, how they are generated, and the mechanism by which they couple, as well as how currents are generated and how they return to the source of the energy which created those currents.

*(This is a very brief extract from a very interesting article by Patrick Andre in March 30, 2023, **https://interferencetechnology.com/things-not-on-the-schematic-how-the-parasitic-element-affect-results/.***

*Patrick is a truly excellent EMC Consultant, the owner of Andre Consulting, Incorporated, **https://andreconsulting.com/** of Mill Creek, WA, USA, **help@andreconsulting.com**, 001 (206) 406-8371.*

Patrick is also the joint author (with Kenneth Wyatt, another truly excellent EMC Consultant) of the "EMI Troubleshooting Cookbook for Product Designers" published by SciTech for the IET in 2014, ISBN: 978-1-61353-09-1 in hardback, and 978-1-61353-041-2 in PDF.)

939 Power supply noise is not necessarily fixable with only decoupling capacitors and vias

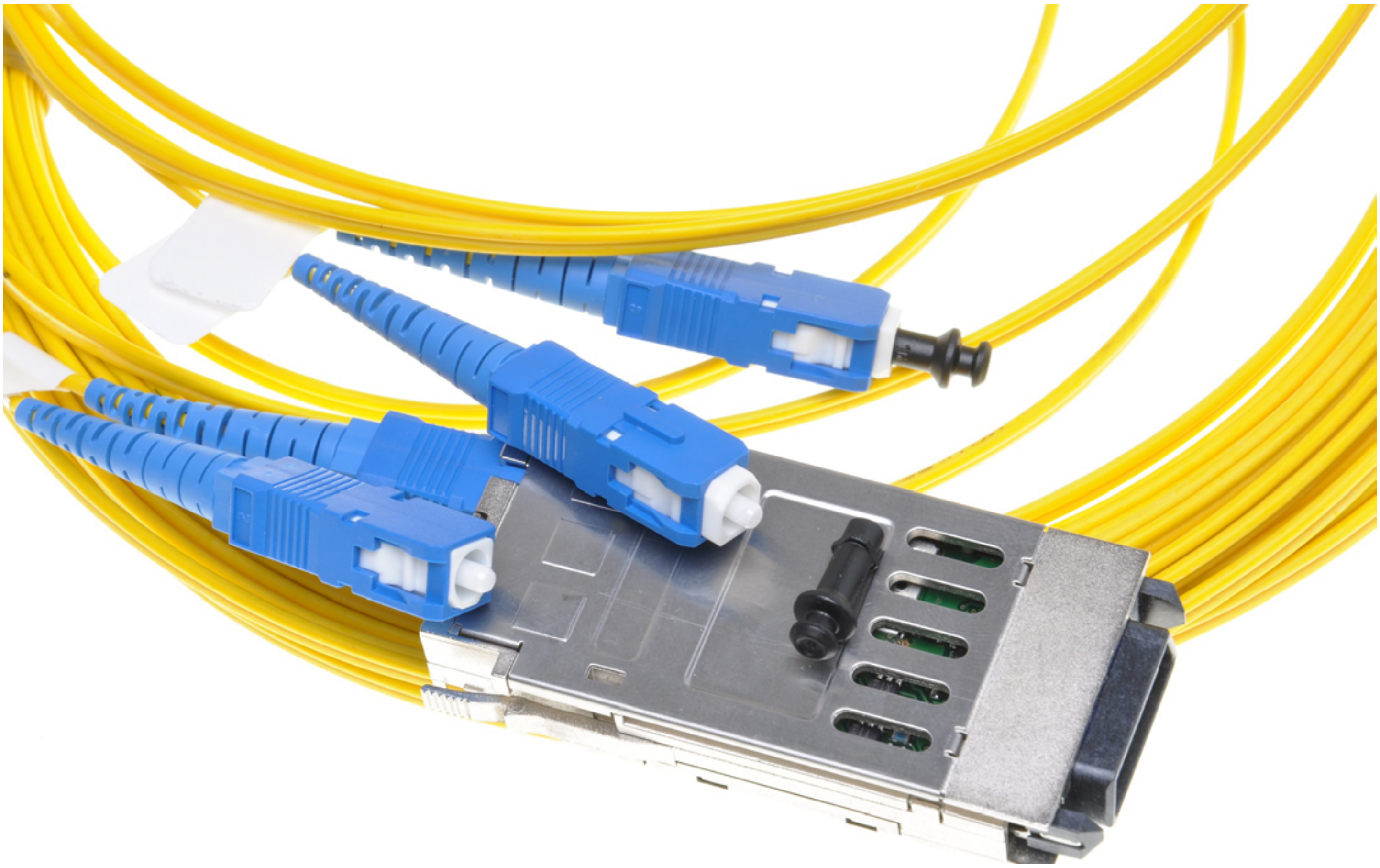
Whilst it *may* appear that designing and making 10 & 25 GBPS quad optical fibre to copper transceivers on a hybrid carrier little more than an inch across would be a basically simple task and not really one where EMC could be much of a problem, you'd be disappointed.

Briefly, at 10GBPS binary NRZ data, fundamental 5GHz, bit length 100ps, if there's a length imbalance of as little as 2-3ps (0.2-0.3mm on alumina), most engineers would say, "yeah, differential imbalance less than 10-20% *nobody* will spot that amount of jitter on a bit!".
How wrong.

Consider the differential input buffer transistors. Normally flipping a *constant* current flow of a few mA between each other. Super common-mode rejection. Yay. Now apply a few pS of imbalance to the input MESFET gates. Where does the *second* transistor of the input switching pair get it's current from now? The other transistor is *still* happily sinking all our bias? Yep, you grab it

STRAIGHT out of the supply or "ground". Result - *ALL* the data you're trying to throw down a fibre now appears *EVERYWHERE* (and it rattles around a bit for added jitter off the impedance mismatches at 5GHz on any power connection, bond-wire or via - "shake, rattle, scroll").

Now, here's an interesting bit, remembering what the good Keith teaches ... consider the energy.



If simulation tells us ~ -20dB of signal power is sufficient to *completely* close the eye-diagram, the minimum spec for differential imbalance is *really* easily obtained (but you do need the back of an envelope!). If all the imbalanced energy appears as rail interference, phase balance must be better than the same ratio. -20dB is 1/100th, 1%. A *MUCH* more stringent spec (but neither difficult or expensive, thankfully!). Very interesting.

Unfortunately everyone is convinced "power supply noise" is something decoupling capacitors and vias fix. Never mind. Still it's a really interesting bit of physics going on.

Feel free to bin all this or use it, but thanks again for your "just remember ***all** the "basics" approach to EMC.
It really works.
Every.
Time.

(Taken from a personal Linked In communication with Simon Clifford (of Gt. Yarmouth, Norfolk), Feb 4th 2022.)

940) Are Christmas fairy lights really ruining your Wi-Fi?

Internet in the home lives and dies by the strength of your Wi-Fi, but lots of things cause interference. Here's why, and what to do about it

The UK's telecoms regulator Ofcom has warned that Christmas lights can slow down your Wi-Fi, but is it really time for those lights to stay in the box?

Are fairy lights causing my Wi-Fi to slow down? Yes, but … and it's a big but …contrary to what the Christmas naysayers among us may say, no more so than everything else.

The Wi-Fi signal can be disrupted by anything that causes interference as it is broadcast around your house. Fairy lights can cause some interference, but they're far from the worst offender.

Why do fairy lights cause interference?

It's all to do with electromagnetic radiation. Everything from light to microwave ovens and deep space radios use electromagnetic waves either to carry information or to impart energy.

Wi-Fi uses electromagnetic waves to send information to and from your broadband router and your mobile device or computer.

But everything that has electricity running through it also generates an electromagnetic field, and this causes interference to the electromagnetic waves attempting to travel through it.

Fairy lights are a mass of wires carrying a current which creates a small electromagnetic field and thus a little interference.

What else causes interference?

Most things, if placed between your device and your router, can cause interference. But some are a lot worse than others. Here's a quick (not exhaustive) list:

Terrible

- Microwave ovens – when it's off it's a metal box (which is bad), but when it is on it uses high-powered microwaves at around 2.4GHz (the same frequency as Wi-Fi) creating a black hole around it for Wi-Fi signals

Really bad

- Radiators, fridges, freezers, toasters, kettles, washing machines, tumble driers, dishwashers, ovens, AGAs (one for the posher readers there), steel baths – and computers themselves – are all metal objects and often have liquid-containing pipes in them
- Water pipes – water loves radio waves, the water absorbs the energy from them
- Cordless telephones – DECT phones use the same frequencies as Wi-Fi and are often unfortunately placed next to the router
- Other people's Wi-Fi networks – depending on your router's placement in relation to other people's routers, this can be a very big problem (more on that later)

Bad

Humans – people are great at absorbing Wi-Fi

- Insulation – the same dense stuff that keeps heat in the walls and ceilings also causes issues for Wi-Fi
- TV – normally not a big issue unless you place your router behind it
- Speakers – basically electromagnets so can cause interference
- Fairy lights – can create weak electromagnetic fields

Good

- Christmas tree – the tree is not dense enough to cause a real issue
- Light upholstery – most sofas, beds and other furniture is not very dense and causes little issue for Wi-Fi
- Pets – unless you own a bear, they're probably not big enough to cause issues unless they sit directly on the router

(Taken from "Are Christmas fairy lights really ruining your Wi-Fi?" by Samuel Gibbs in The Guardian, Tue 1 Dec 2015, ***https://www.theguardian.com/technology/2015/dec/01/christmas-fairy-lights-ruining-wi-fi****. But I don't agree with the inclusion of speakers in the 'Bad' list – Editor.)*

Keith's public training course schedule for September and October:

An introduction to "METAMATERIALS for FILTERING and SHIELDING ABOVE 6 GHz", e.g. using PCB copper patterns (free) when discrete filter components don't work well or are costly. On-line only, afternoon of Friday, 22 September in European/UK timezones.
Details and registration: ***https://www.eventbrite.be/e/metamaterials-for-filtering-and-shielding-above-6-ghz-tickets-597783615887?aff=odcleoeventsincollection***

If you missed our June courses on "GOOD, QUICK, COST-EFFECTIVE SI, PI, and EMC for PCBs", we are running it again at ESSEX UNIVERSITY, COLCHESTER, UK, on 10 and 11 October!
Details: ***https://lnkd.in/eSVCVsVn*** Register: ***https://bit.ly/pcbds-reg***
Other links: ***https://www.pcbdesignschool.com/essential-emc-course, https://www.pcbdesignschool.com/advanced-emc-course https://www.linkedin.com/feed/update/urn:li:activity:7085135770348343296***
On-line streaming is not available, but earlier versions of these courses are available as video webinars from ***https://emcstandards-shop.fedevel.education/index.html***.

Our 2-day course on "GOOD, QUICK, COST-EFFECTIVE SI, PI, and EMC for PCBs",
and our 1-day course on "GOOD EMC for EQUIPMENT, SYSTEMS and INSTALLATIONS"
In HELSINKI, FINLAND, on 4-6 October 2023.
Details and registration: ***https://userdata.paloma.se/Pictures/17249/Archive/(default)/InvitationEMCseminarinHelsinkiKeithArmstrongandChrisNicholas.pdf***
On-line streaming is not available, but earlier versions of these courses are available as video webinars from ***https://emcstandards-shop.fedevel.education/index.html***.

See you there!
Keith


REO
FULL SPEED AHEAD INTO THE FUTURE OF MOBILITY
Tel: +44 1588 673411
main@reo.co.uk
www.reo.co.uk


mvg
Microwave Vision Group
ON-DEMAND EMC TESTING CHAMBERS
TO MEET YOUR MOST SPECIFIC NEEDS
• EMC Test Chambers
• Shielded Doors
• RF Shielded Rooms
• EMC Antennas
• EMC Accessories
Learn more at: www.mvg-world.com/emc
Contact: www.mvg-world.com/en/contact

Using close-field probes to reduce design risks early in a project -Part 1-

First published in the EMC Journal, Issue 112, June 2014
Keith Armstrong, www.cherryclough.com

Contents

1 Introduction to Part 1

This article, and the ones that will follow it, are about dealing with EMC issues during design and other project stages, to save time and money; reduce project/ financial risks, and to help ensure that if we take products to a 'proper' EMC test lab for compliance testing, they will pass on the first test.

(It is important to note that for CE marking for legal sales in the European Union, there is no legal requirement under the EMC Directive to have ever done any EMC testing, which is a big help to start-up companies. Many established companies use EMC laboratory testing to help demonstrate that their products comply, but it is important to note that a product can pass all of the relevant EMC test standards and yet cause or suffer EMI in real-life and so fail to comply with the Essential Requirements of the EMC Directive. Discussing these issues goes beyond the remit of this article, but I have often written about them in the past.)

Close-field EMC probing (often called near-field probing) is difficult to do accurately, but it is an excellent qualitative technique that can be used to compare the EM characteristics of one thing, with those of another.

For this reason, although - like computer simulation - close-field probing cannot (generally, yet) be used to prove that a particular EMC laboratory test would be passed, it is of huge benefit in helping us discover and fix EMC problems.

These EMC problems can arise in all stages in the life of a module, product, equipment, system or installation (which I'll call an 'item' in the rest of this article) - from its initial proof-of-concept, through design, development, regulatory approval, Quality Assurance in serial manufacture, installation, etc. all the way to upgrades, repairs and refurbishments.

I think we all realise that the best time to deal with a risky design issue is as close to the start of a project as possible, when design changes cost little and there is plenty of design freedom. But many companies still guess at EMC design issues, leaving the discovery of

EMC problems until near the end of a project when any changes are very costly and there is little design freedom.

It is a common joke that if you ask two EMC consultants the same question you will get three different answers - but one thing that all of the EMC consultants I have ever met agree on, is that time and cost will be saved overall by dealing with EMC design issues earlier in a project, compared with leaving them until the end.

The choice of materials for the construction of an item, and its mechanical design, is often done a long time before the electronic hardware is ready to be fitted into it, and this is often some time before its software is ready and all of its functions can be tested.

When EMC problems are discovered at this late stage in a project, it is often the case that a different choice of mechanical materials and/ or a different mechanical design would easily solve the problem - unfortunately these are issues that are pretty much 'set in stone' and difficult, costly and time-consuming to change.

2 Making and/ or buying close-field probes

Close-field EMC probing is low-cost and very useful, and for decades I (and many others) have been using them to detect the 'leakages' from electronic items to discover and fix the 'weak spots' that are probably causing the EMC test failures. For examples of this, see [1] [2] and [3].

These techniques can help to reduce the delays in time-to-market caused by the shortcomings in the EMC design, sometimes dramatically so. For example, it is not very unusual to find a problem and its solution in a few minutes, by using a close-field probe, when engineers working without the benefit of close-field probing have already spent several weeks and got nowhere. Once people learn to use close-field probes as described in these references, they wonder how they ever managed without them!

However, there are ways of using close-field probes to de-risk a range of EMC design issues very early in a project - long before the hardware or software are designed - when the mechanical design is being started and the constructional materials chosen.

I have read about these techniques from time to time, and promised myself I would investigate them, but you know how time flies....

Anyway, I was recently asked to present a full-day seminar on close-field probing techniques that save time and cost, and so I thought it was time that I finally got to grips with the kinds of techniques described by Scott Roleson [4] [5] [6], Doug Smith [7], Dr. Arturo Mediano [8], Ken Wyatt [9], by Tim Williams in the EMC Training Programmes held at EMC-UK events over recent years [10], and anecdotally by many others.

The material that I have gathered as a result will take more than one article in the EMC Journal to describe, so this article is mostly an introduction.

We can easily make close-field probes, even from a paper clip, see Figures 1, 2, 3 and 4. The largest probe dimension (i.e. the diagonal or major diameter of a loop) should be less than 1/ 6th of the wavelength at the highest frequency to be measured (e.g. for < 1GHz: < 50mm diameter) so that - even when placed close to a large lump of dielectric such as a PCB - they are still 'electrically small' and well below their frequency of first resonance.

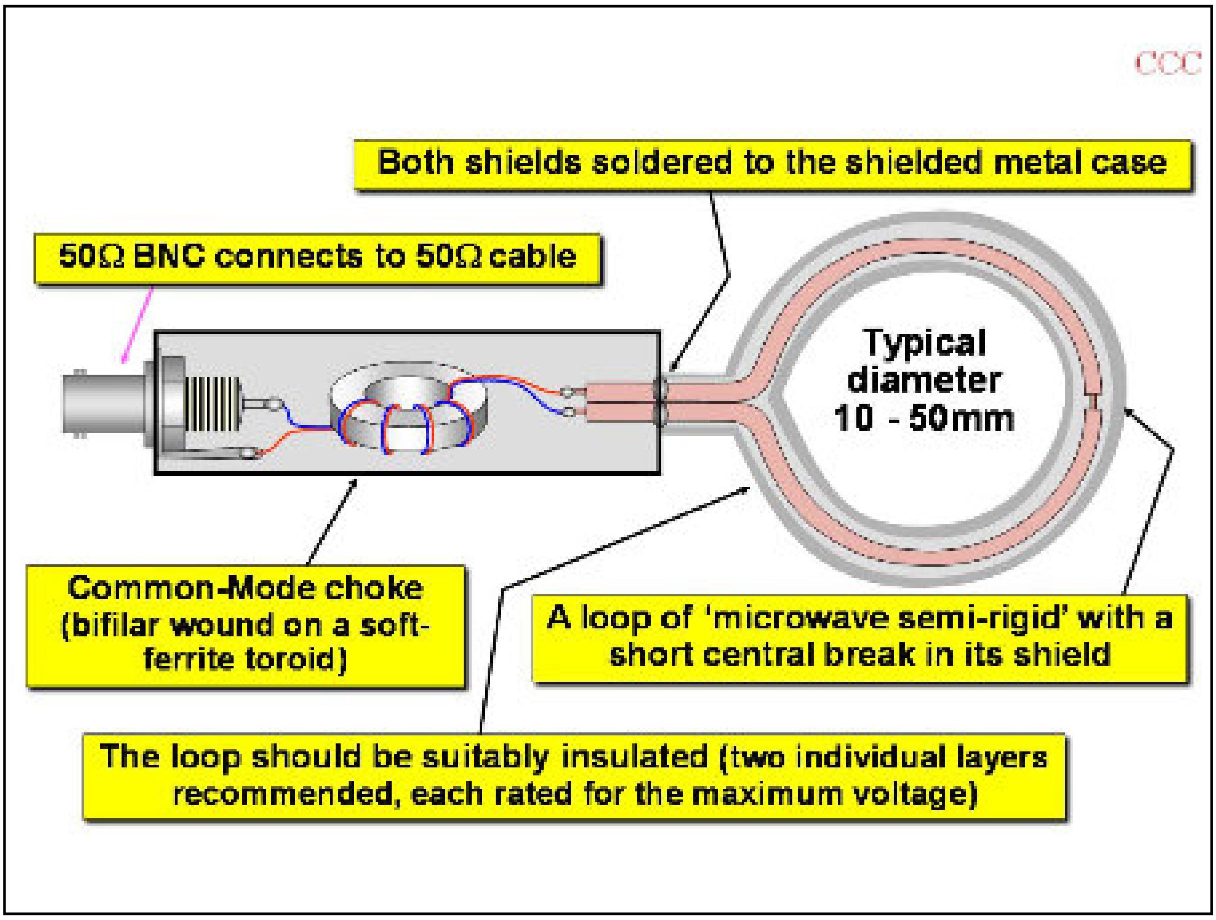


Figure 1 The construction of a good-quality close-field magnetic probe

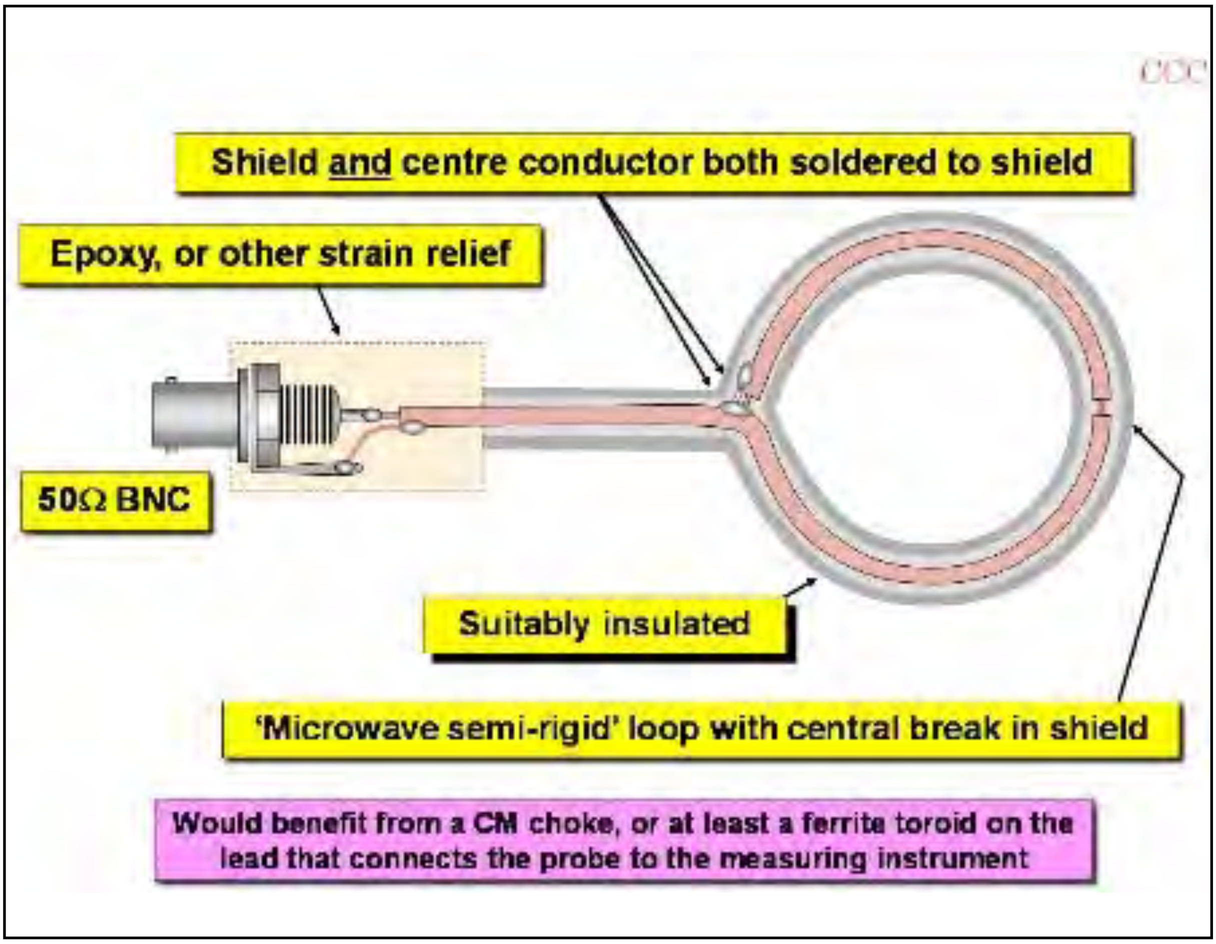


Figure 2 An easier magnetic field close-field probe design (but not so good)

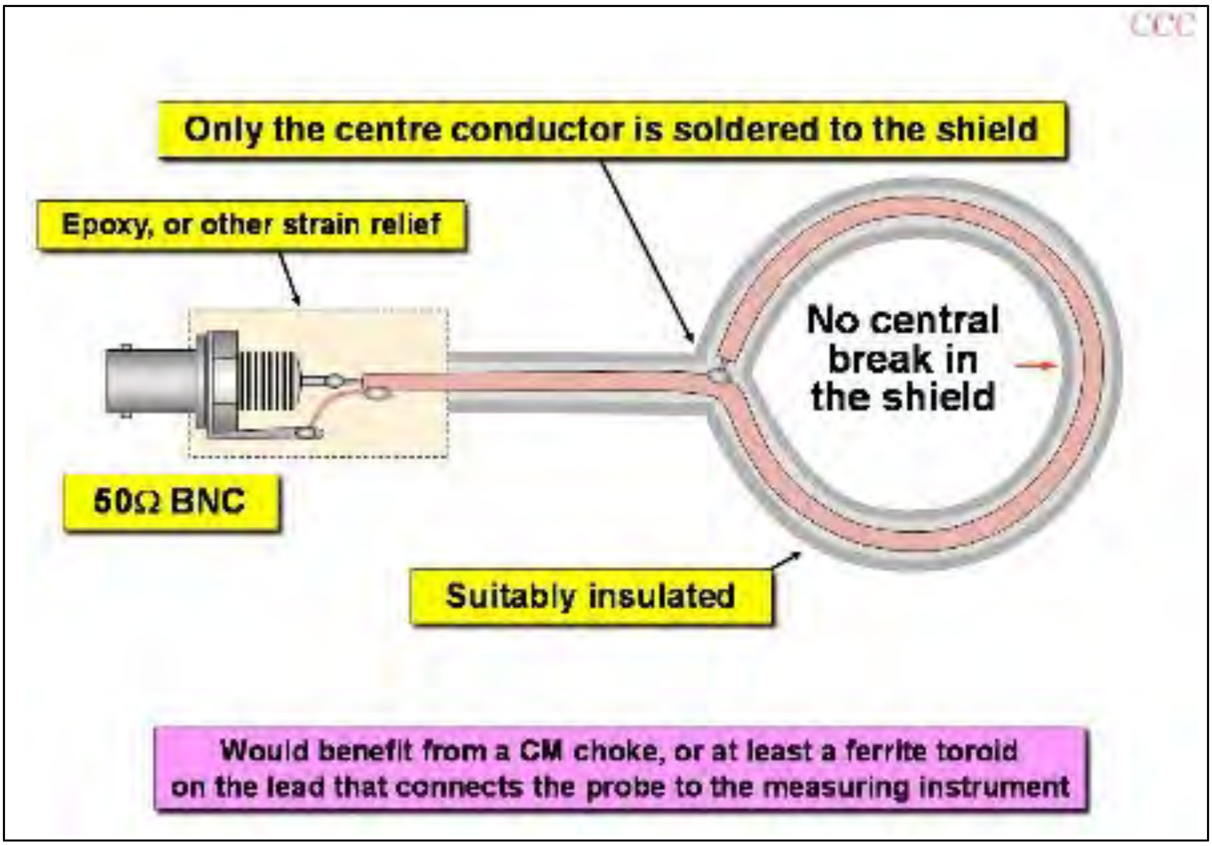


Figure 3 The simplest magnetic close-field probe design (but even less good)

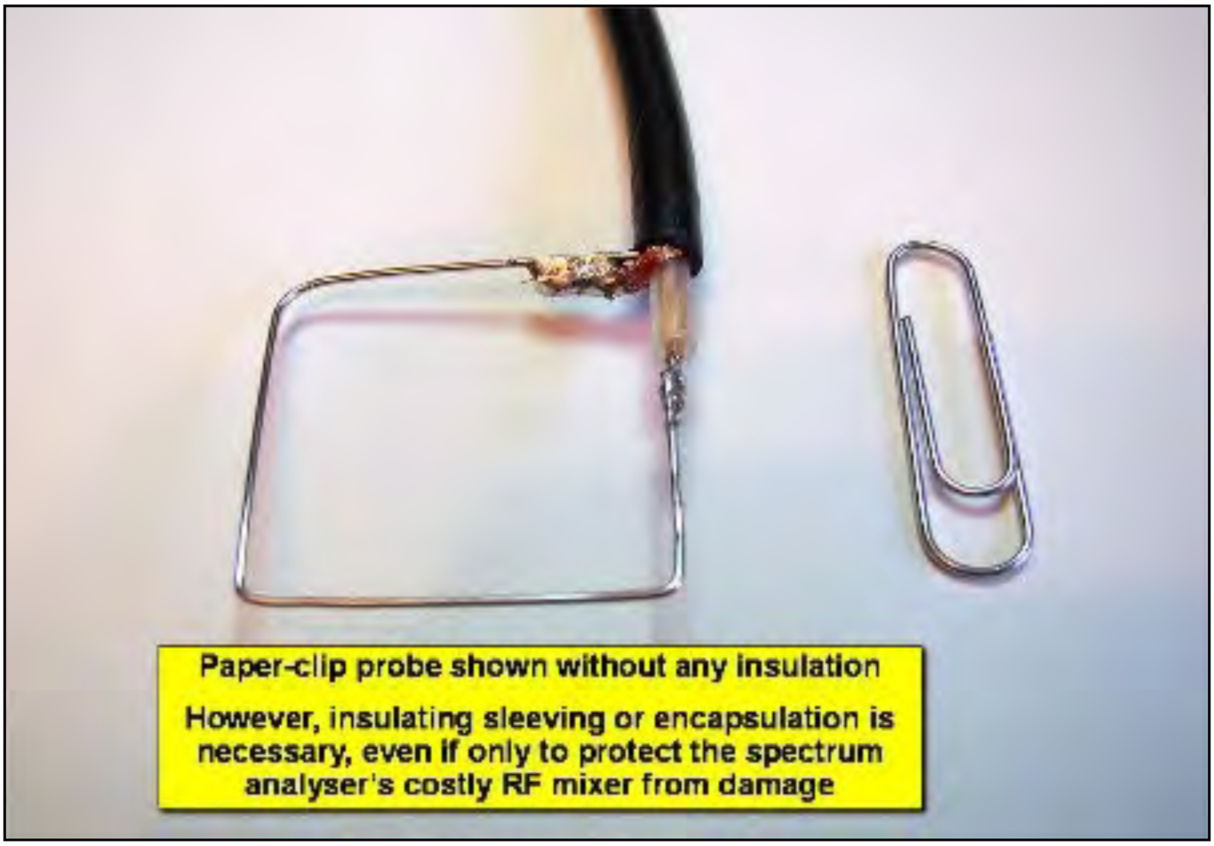


Figure 4 Using a paper clip to make an unshielded close-field probe

Close-field probes are often hand-made from 'microwave semi-rigid' cable, e.g. RG402 (approx. 3mm outside diameter) or RG405 (approx. 2mm outside diameter) because the stiffness of this type of cable helps the probes to retain their shape and so give more repeatable results, and also because their solid copper shields are very effective indeed.

An additional benefit is that the dielectric material in these semi-rigid cable types is solid Teflon, and so is unaffected by soldering at any normal temperatures. SMA connectors (male and female types) are readily available for soldering directly to these same cable types, helping to make robust and reliable probe assemblies.

Magnetic-field close-field probes are often called 'loop' probes, but there is no good reason for making them in a circular shape. In fact, rectangular probes have some advantages when used on flat surfaces, as is often the case in practice. And, I have recently discovered that making them rectangular is much easier and quicker than trying to bend semi-rigid cable into a neat circle!

I don't plan to discuss electric-field close-field probes in this article, because as yet I have no real experience with them. But I often use unshielded loop probes (like the paper clip probe in Figure 4) when searching for 'leakages' and 'weak spots', because they pick up electric (E) fields as well as magnetic (H) fields. When we don't know the nature of a possible leakage (i.e. whether it leaks E or H fields) using an unshielded loop probe can help save time in locating it.

Figure 5 shows four probes that are simply made of enamelled copper wire soldered to SMA PCB-mount connectors: unshielded loop probes that I really ought to insulate better (so I never let anyone else use them).

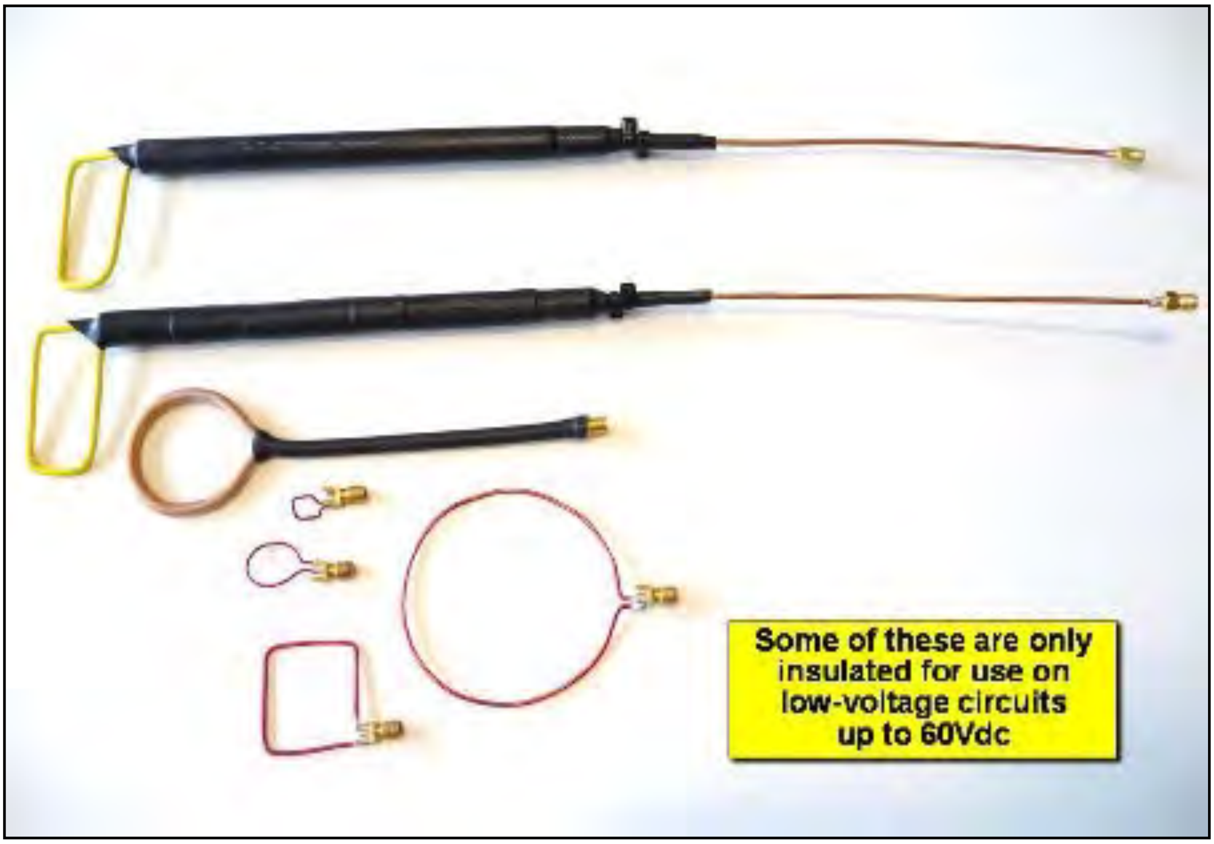


Figure 5 The range of close-field probes that I use (at the time of writing)

When we don't feel like spending the time making our own close-field probes, or when a professional appearance matters, we can purchase close-field probes from numerous suppliers of EMC test equipment, for example those in Figures 6, 7, 8 and 9.

Figure 7 Some of the many close-field probe kits from Langer EMV-Technik

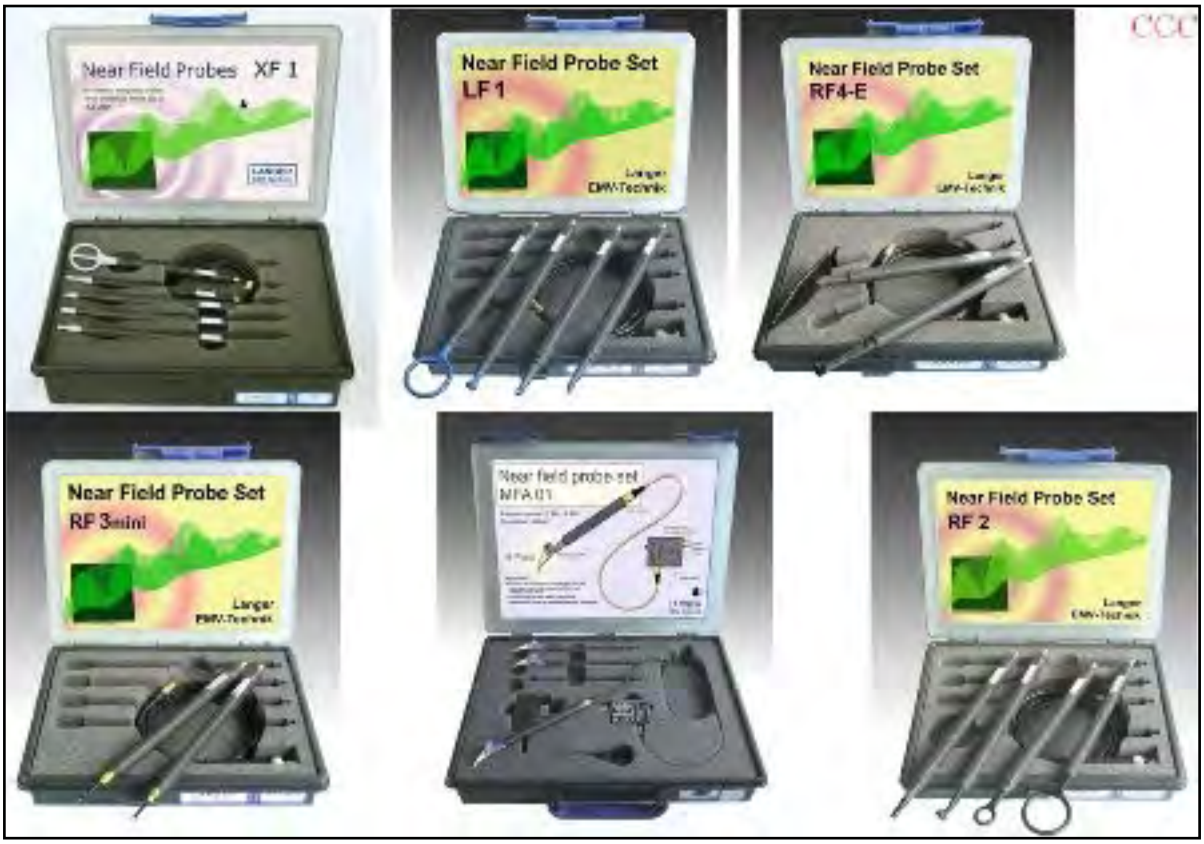


Figure 7 Some of the many close-field probe kits from Langer EMV-Technik

Figure 8 Hewlett-Packard's venerable close-field probes, and currently available ones from Agilent (soon to be renamed Keysight Technologies) and Teseq (which used to be Chase EMC)

Figure 9 Examples of close-field probes from Hameg and Com-Power

Close-field probes can be used to great effect with spectrum analysers costing as little as £800, such as those in Figures 10 and 11. These are all portable instruments, but some require mains power whilst others can run on their built-in batteries - very handy for discovering problems in the field.

Figure 10 Examples of portable spectrum analysers, including some very low-cost ones

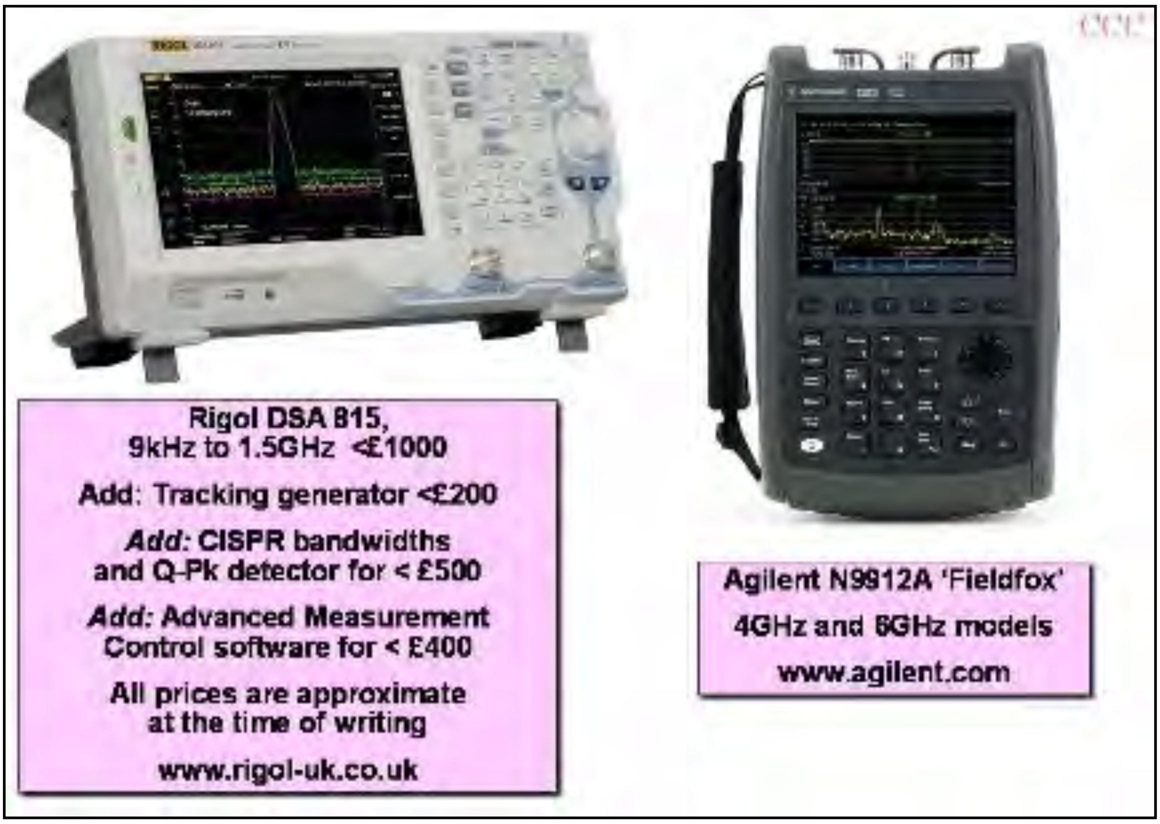


Figure 11 Some more examples of portable and low-cost spectrum analysers

It is also possible to use close-field probes with oscilloscopes that we probably already have, although we would have to learn to view and understand the resulting waveforms instead of spectra. Some oscilloscopes have FFT capabilities, but I have rarely found the spectra they produce to compare with the same probe measuring the same thing using a spectrum analyser. However, I recently learned that Tektronix are now offering oscilloscopes with built-in ‘time domain’ spectrum analysers that are compliant (or nearly so) with CISPR 16 requirements and of course are much faster than the traditional swept-narrowband filter type of spectrum analyser.

To repeat the excellent work of Roleson, Smith, Mediano, Wyatt and Williams and use close-field probing to discover and solve EMC design issues before there is any hardware that can be operated to check for leakages, requires either a broad-band noise source or a spectrum analyser with a tracking generator.

A wide-range of broad-band noise sources are available from various suppliers, with useable upper frequencies from 1GHz to 40GHz. They may be called Comparison Noise Emitters (CNEs); Reference Noise Generators (RNGs); Emissions Reference Sources (ERSs); Comb Generators, etc., and there is even a rather lovely Universal Spherical Dipole Source (USDS).

Having searched on and off for an affordable spectrum analyser with a tracking generator for over a decade (my preference running to second-hand Agilent E7400s from eBay) I finally purchased a Rigol DSA 815 for a little over £1000. This is a Chinese brand, with a very high quality presentation and a user interface that - up to a point - is almost identical to the E7400 series (and even its predecessor, the HP8591E series - the ‘green screen’ portable workhorse of the EMC industry for many years).

Ken Wyatt had reviewed the very same model in 2012, [11], and been very impressed with its price/ performance ratio. He also used it in [9].

Trying to repeat the work described in references [4] through [9], I found that my usual quick-to-make low- cost H-field probe construction method (Figure 3) gave very variable results in some sensitive types of measurements. I think it must be that because they were not very well balanced, they were very susceptible to hand-capacitance and even just the proximity of metal and dielectric objects (or bodies).

By trial and error I found that adding about 200mm of ferrite tubes gave much better, more repeatable performance, allowing me to use my quick and easy-to-make close-field probes. Figure 12 shows two such probes under construction, with their strings of ferrite tubes exposed.

Because EMI-suppressing ferrite materials are conductive to some degree,I wanted to prevent variations in contact resistance from occurring between the tubes and the copper shield. I also wanted to reduce hand- capacitance effects as much as I could. So before feeding the tubes onto the probes, I first covered the copper semi-rigid cables’ shields with heat-shrink insulating sleeve (just visible (yellow) at either end of the strings of ferrites in Figure 12).

I don’t know if this precaution was worthwhile, but it seemed like a good thing to do.

Then I ransacked the various ferrite sample kits I had been given over the last 24 years to find ferrite tubes that had inner diameters just large enough to slip over the heat-shrink sleeving. As Figure 12 shows, they were mainly from Wurth, Kitagawa and Steward (which is now owned by Laird Technologies). I don’t think the type of ferrites used matters a great deal, as long as they have their highest impedances generally around the middle of the frequency range of interest for close-field probing - in my case between 50 and 1000MHz.

To get a good fit to the heat-shrunk semi-rigid cable, the SMA connector should only be soldered to the semi- rigid after the ferrites have been assembled onto the probe.

With at least a 200mm length of ferrite tubes slid onto the 'handle' of the probe, I then heat-shrunk over the top of them all, to stop them from moving around and possibly affecting performance. Also, the shrink sleeving might help to reduce hand-capacitance effects, and will certainly help to protect the ferrites from damage - they are very brittle and can easily become cracked by rough handling or accidents.

Figure 12 A view of my new probes during a assembly

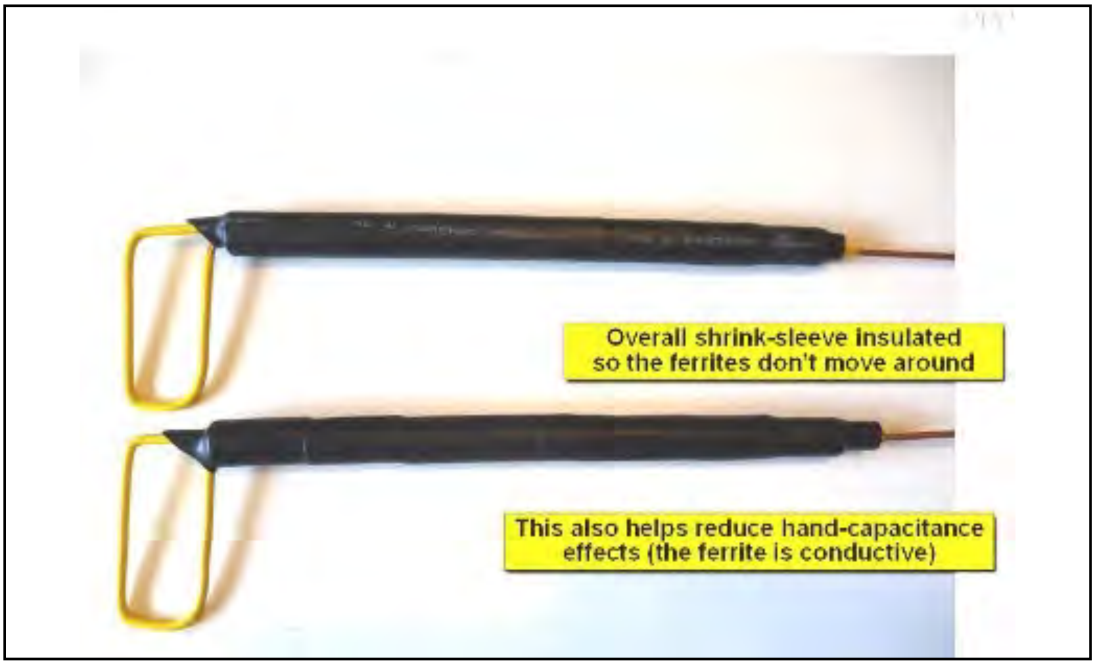


Figure 13 My new RG405 probes when finally assembled

I made two sets of two probes with long ferrite 'handles' - four in all. One pair used RG402 ('3mm') semi- rigid, and the other pair used RG405 ('2mm'). (The RG402-based probes I bent into a special shape to use with a clamping arrangement for measuring sheet materials - about which I plan to write in a future article.)

3 The 2-probe method of finding flaws in shielding

The first close-field probing technique I want to describe uses two probes, one energised by the spectrum analyser's RF output from its tracking generator, the other connected to its RF input, as shown in Figure 14.

The metal box being used is my 'famous demo box' - created over a weekend using hand tools (and it shows) for a bit of entertainment during a break in an EMC conference in 1992. It - and much prettier, professionally-made versions of it - have since been used to give hundreds of EMC demonstrations worldwide.

(My demo box is intentionally unpainted and free from other surface treatments, because its aluminium- zinc casting alloy maintains a low contact resistance (unlike plain aluminium) which is important for making good connections to conductive gaskets and also for various things that I use it to demonstrate. It looks rather ugly, but my professionally-made versions had nice shiny mirror surfaces, achieved by a technique similar to French-polishing.)

My demo box is based on having a noisy circuit inside, plus connectors for power and data cables, to be close-field probed in the traditional way of looking for leakages, as a means of demonstrating good practices in enclosure shielding, cable shielding, and filtering.

But here I am using it without any power to its internal circuits, to see how much of what I know about its EMC design issues can be discovered by using a spectrum analyser (SA) with a tracking generator (TG) and two close-field (CF) probes. To see if such EMC design flaws could be reliably detected during the early stages of an item's mechanical design, when design freedom is high and design changes cost little.

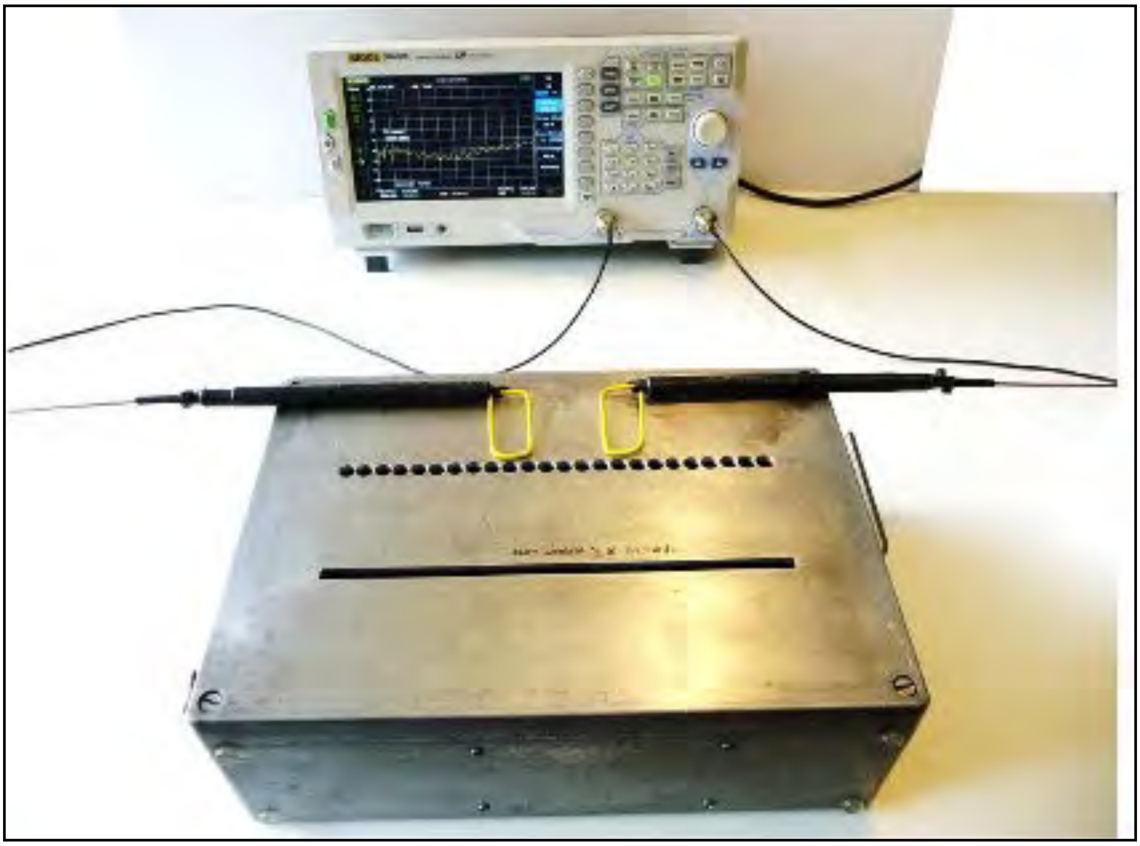


Figure 14 Looking for shield imperfections with two CF probes - the set-up (1)

In Figure 14 I am holding the two CF probes - one connected to the TG's RF Output, the other to the SA's RF input - close against the solid metal of the demo box's lid. Figure 15 shows the result on the SA's screen: the measure of the RF energy that couples between the two probes.

Figure 15's amplitude is scaled at 10dB/ decade, the internal pre-amplifier is switched on to reduce the noise floor, the RF attenuator is set (manually) to 0dB and the top of the amplitude scale is -20dBm (although the units don't matter, only the dBs, because we are making comparisons: relative measurements, not absolute ones).

The horizontal axis displays the frequency range from 10MHz to 1GHz, on a linear scale. The resolution bandwidth (RBW) is 120kHz, the video bandwidth (VBW) is 300kHz, and the TG's output level is set to - 10dBm so as not to overload the RF input when we get to Figures 20 and 21.

(I suppose I could have set the RF attenuator to -10dB and the TG to 0dBm, but I am used to setting the RF attenuator to 0dB to maximise sensitivity when using CF probes to measure leakages with low-cost SAs, so it has become a habit.)

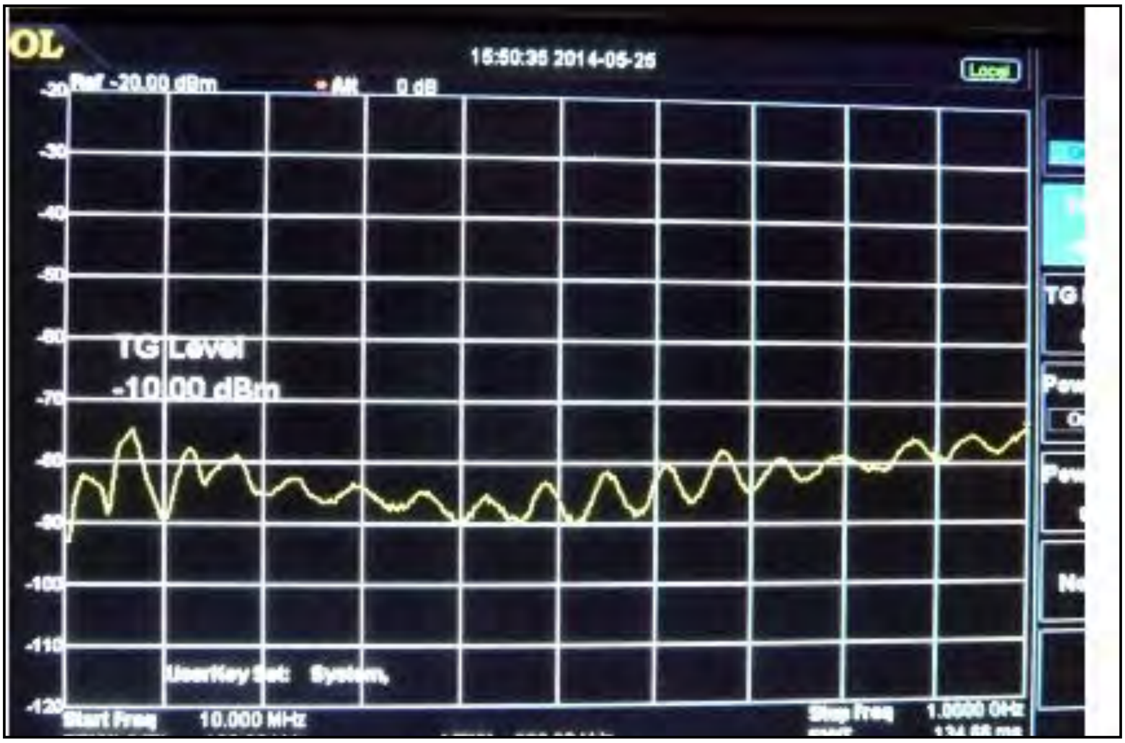


Figure 15 Looking for shield imperfections with two CF probes - the display (1)

Figure 15 shows that the coupling between the two probes is about -80 to -90dBm between 10MHz and 700MHz (i.e. an attenuation of -60 to -70 dB, given that the Reference Level is -20dBm), with a slight rise to

-75dBm to -80dBm (i.e. -55 to -60dB) around 1GHz.

The ripples that can be seen on the display are most probably due to the reflections caused by the impedance mismatches inherent in my probe design - which puts a short-circuit at the end of a coaxial 50 transmission line. The ripples are not important for this kind of measurement, so I don't mind them.

Figure 16 shows the two probes in the same physical relationship to each other and the lid of the metal box, but now slid forward to lie over the row of small holes, which has the same open area for ventilation as the larger slot we will come to in Figures 20 and 21.

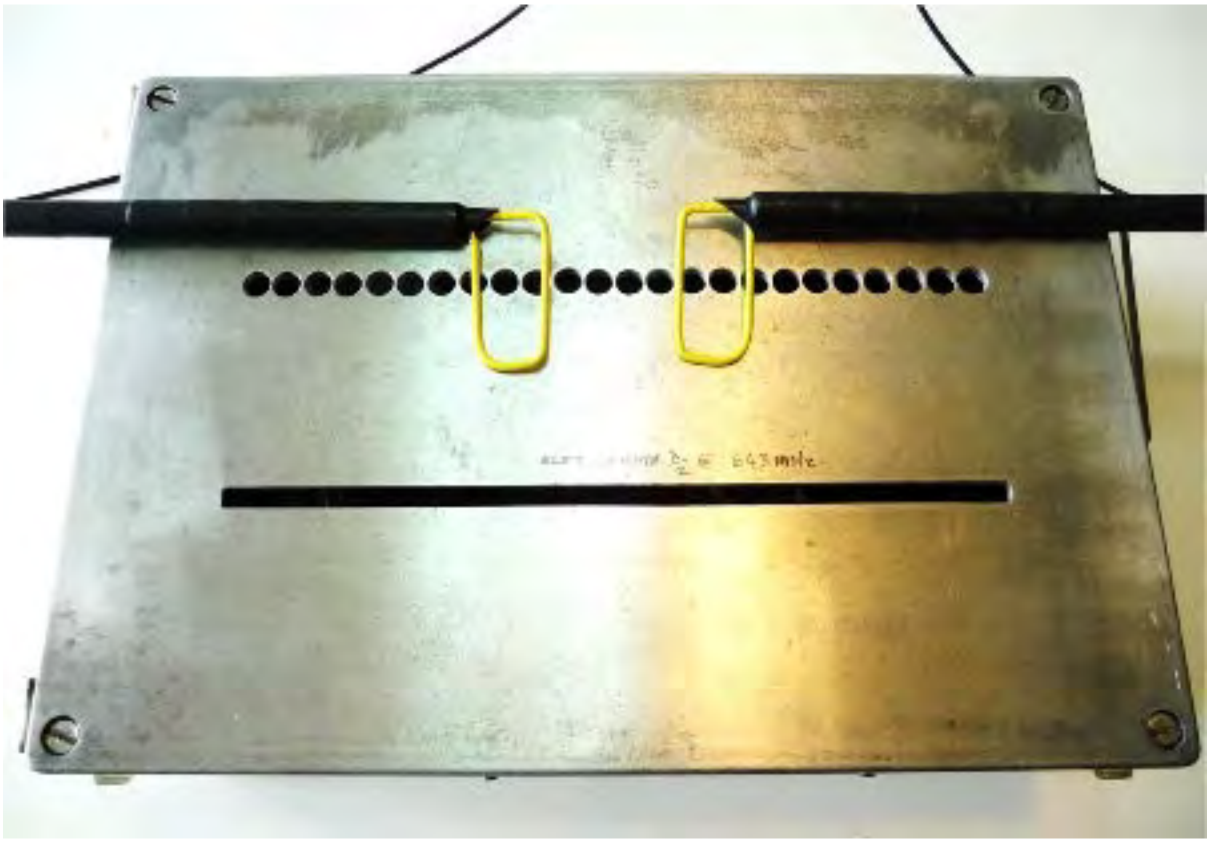


Figure 16 Looking for shield imperfections with two CF probes - the set-up (2)

Figure 17 shows almost exactly the same poor coupling between the probes as for set-up (1) in Figure 15.

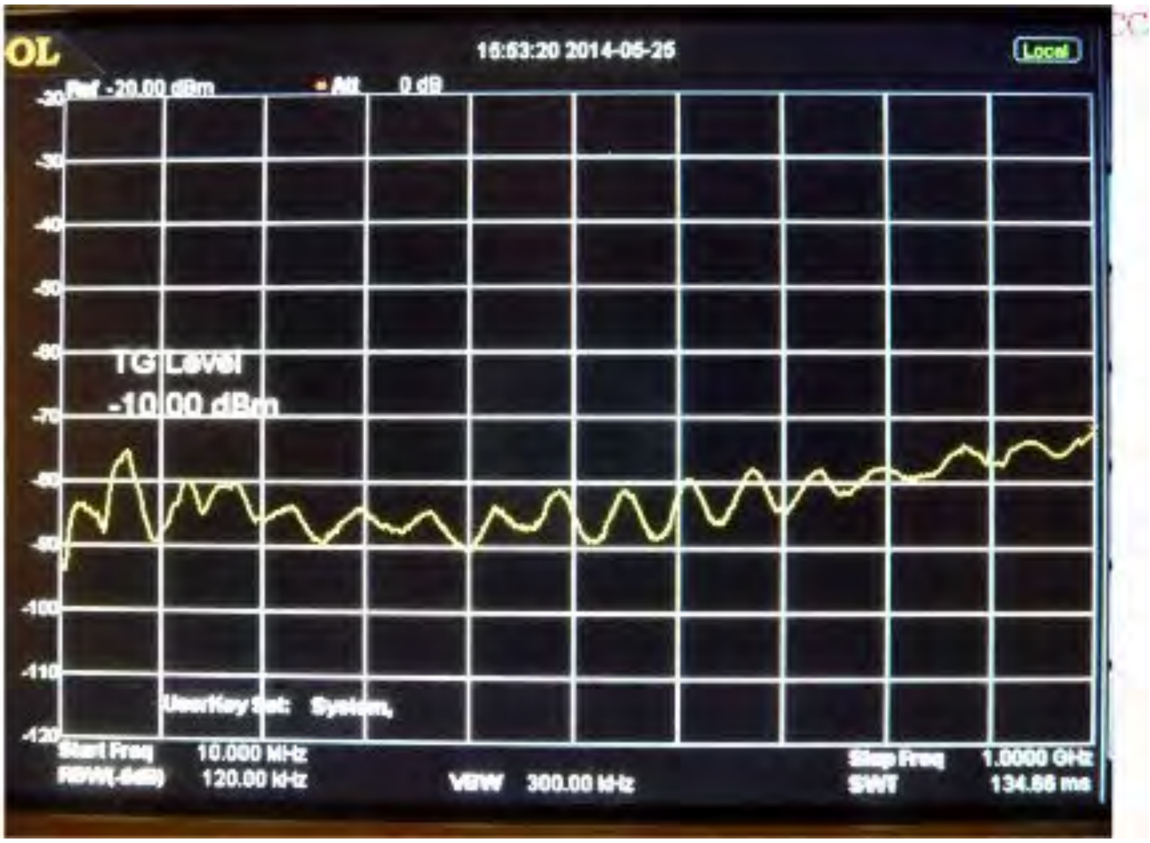


Figure 17 Looking for shield imperfections with two CF probes - the display (2)

Figure 18 shows the probes, still held in the physical relationship to each other and the lid of the metal box, but now slid even further forward to lie over the solid metal in between the row of small holes and the larger slot. Figure 19 shows almost exactly the same poor coupling between the probes as for set-up (1) in Figure 15 and set-up (2) in Figure 17.

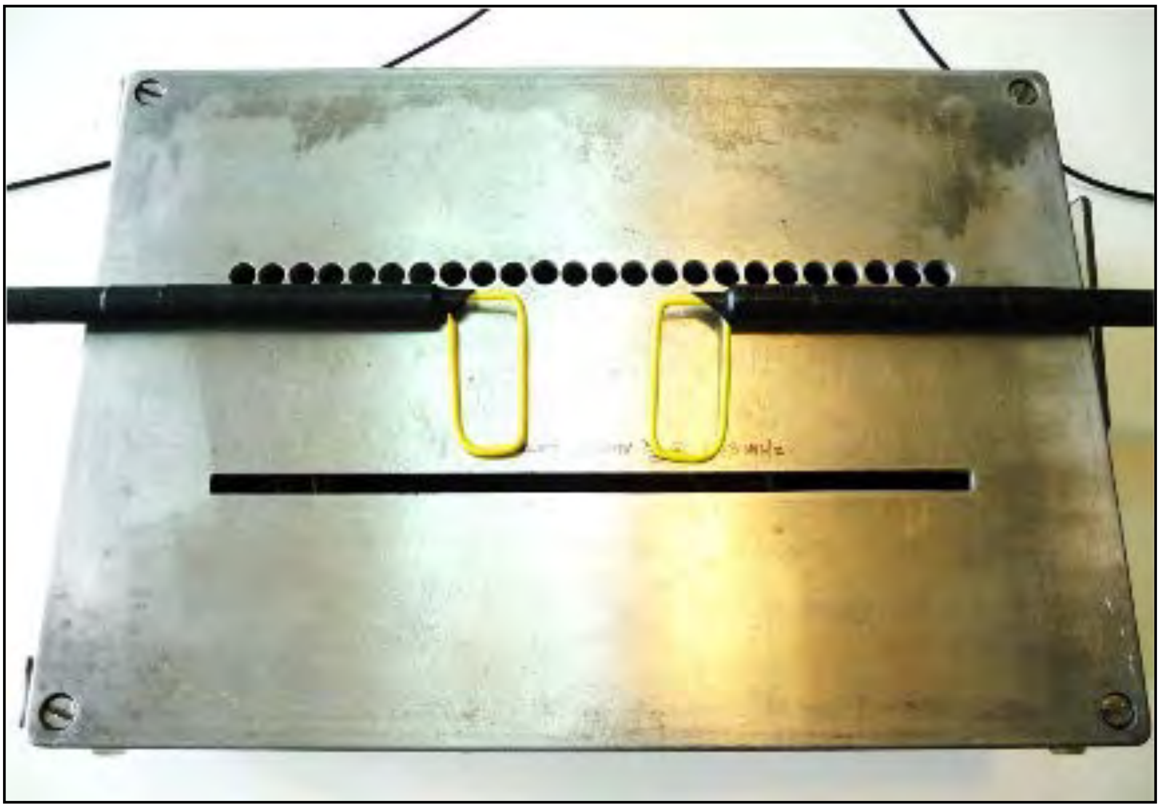


Figure 18 Looking for shield imperfections with two CF probes - the set-up (3)

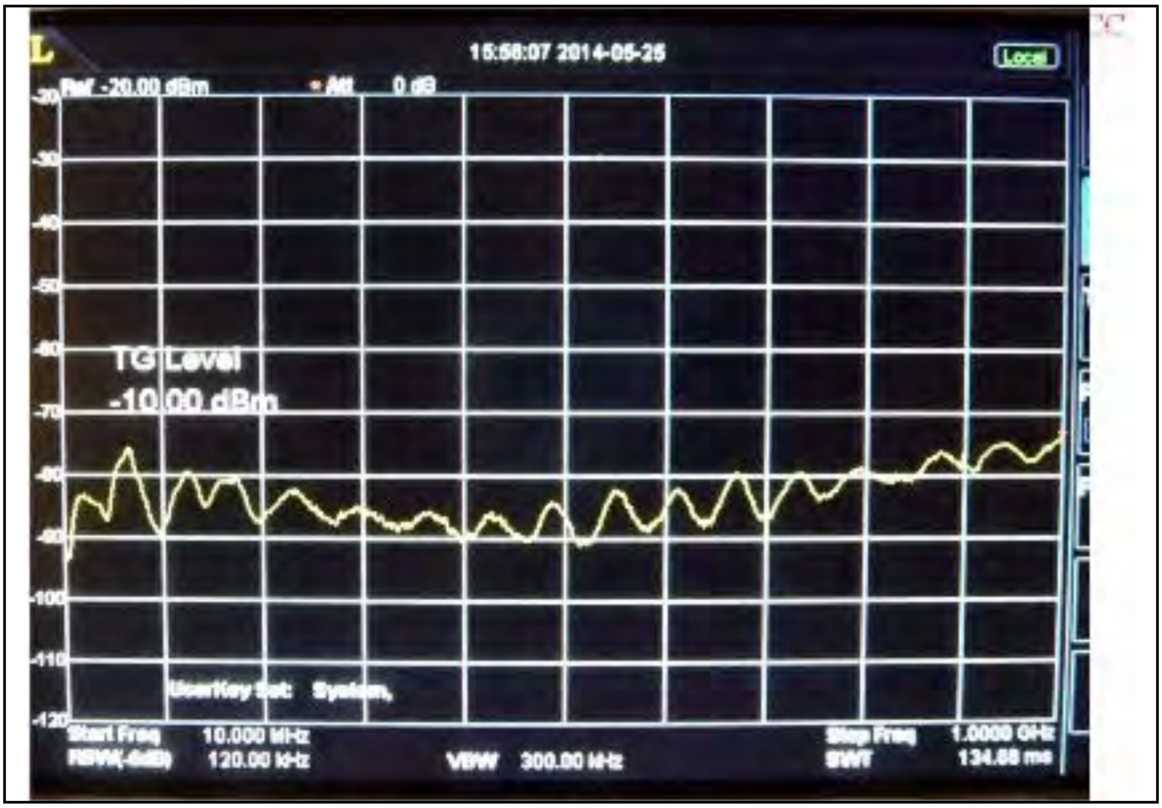


Figure 19 Looking for shield imperfections with two CF probes - the display (3)

Figure 20 shows the probes, as previously in the same physical relationship to each other and the lid of the metal box, but now slid further forward to lie over the large slot. Figure 21 shows markedly higher coupling between the probes than we saw with set-ups (1), (2) or (3) (Figures 15, 17 or 19 respectively).

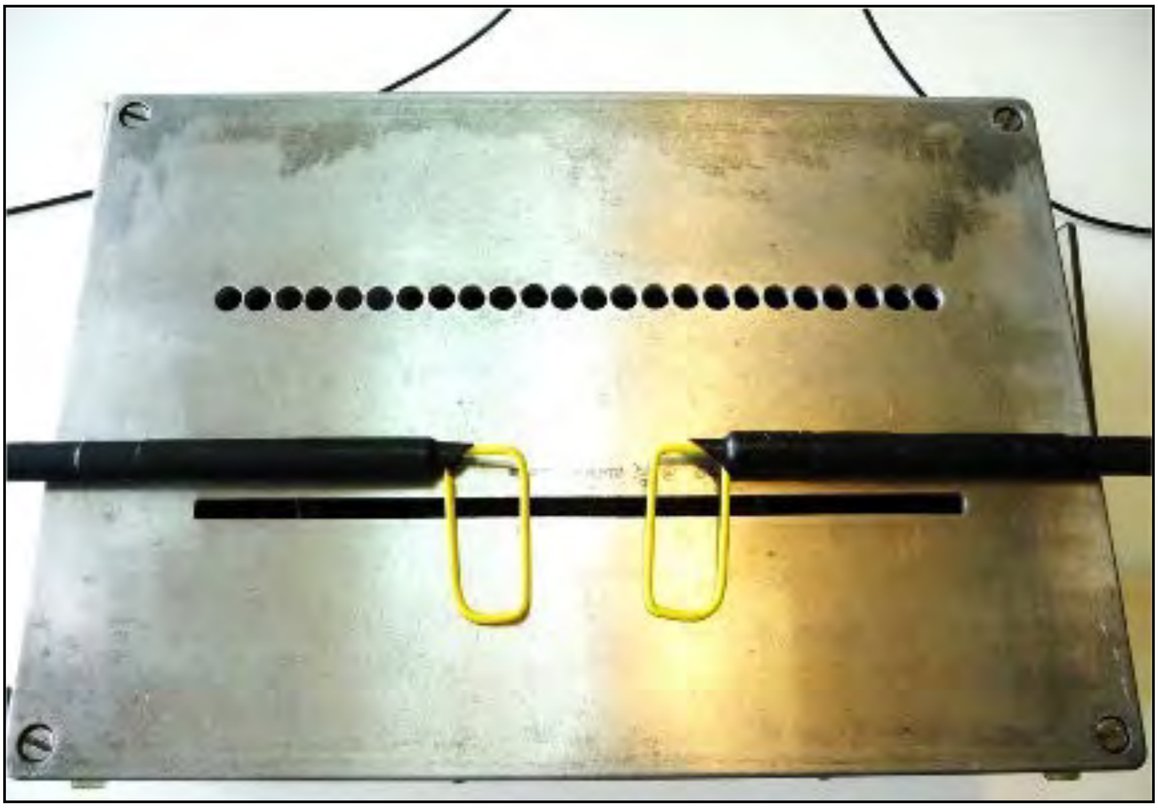


Figure 20 Looking for shield imperfections with two CF probes - the set-up (4)

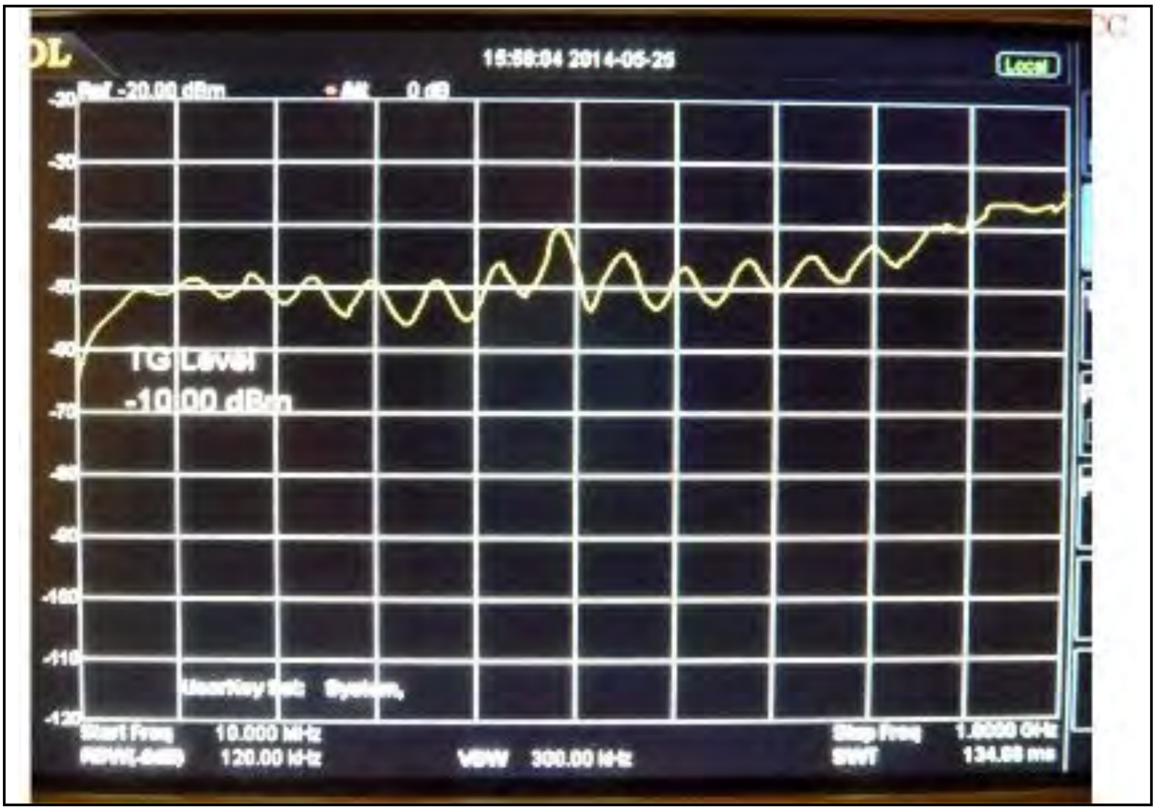


Figure 21 Looking for shield imperfections with two CF probes - the display (4)

Figure 21 shows that over most of the frequency range, the receive probe is now picking up around -45 to - 55 dBm (i.e. an attenuation of -25 to -35dB), rising above about 700MHz to around -35dBm (i.e. -15dB attenuation) at 1GHz. To see if this roughly 35dB increase in coupling (decrease in attenuation) between the two CF probes is caused by the slot rather than the close proximity of the edge of the box lid, set-up (5) is shown in Figure 22 and its results in Figure 23.

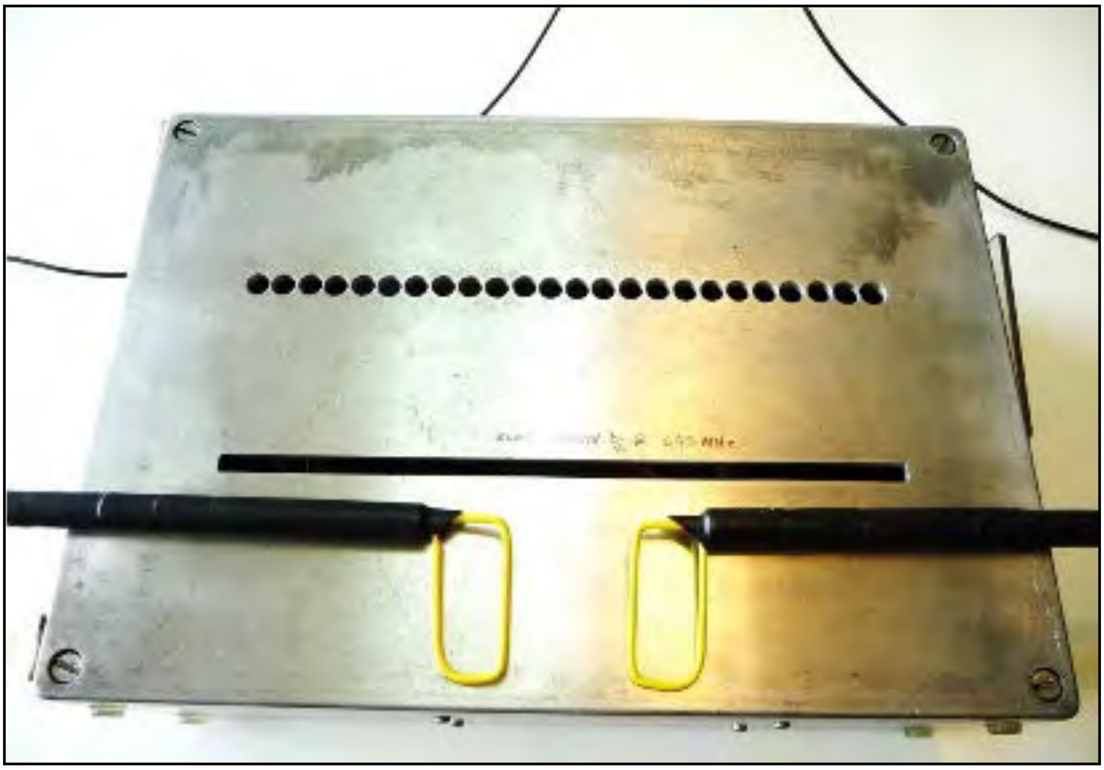


Figure 22 Looking for shield imperfections with two CF probes - the set-up (5)

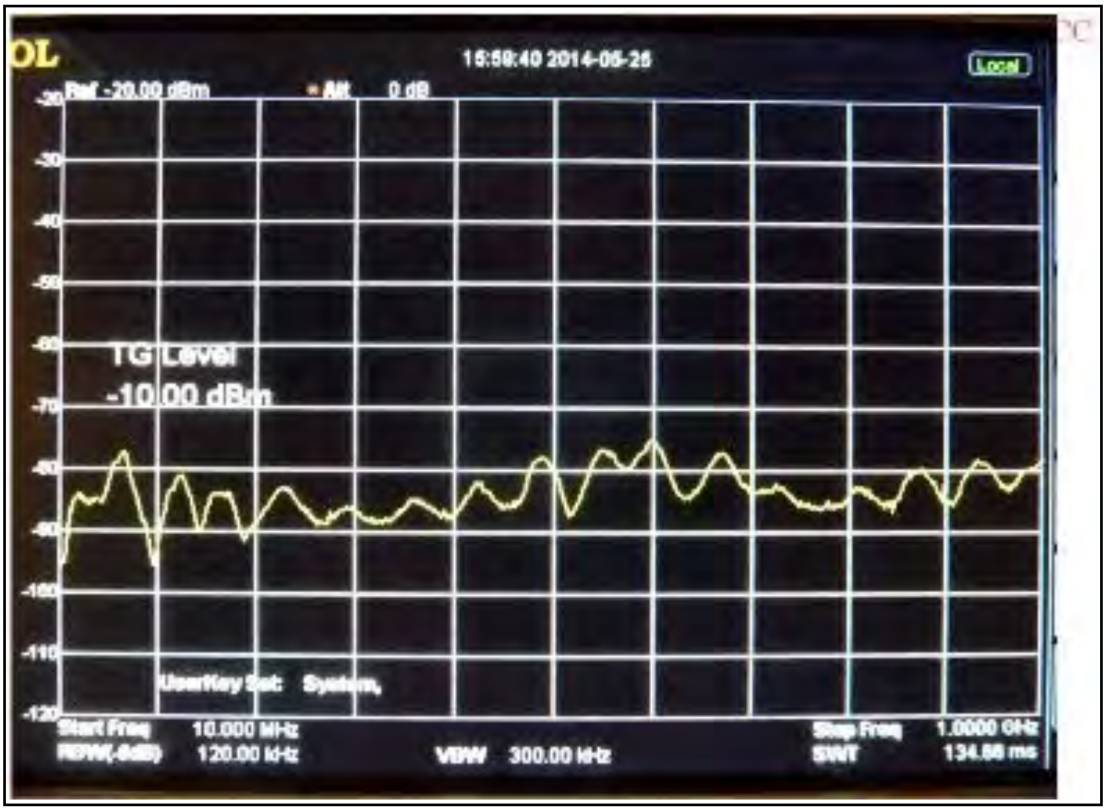


Figure 23 Looking for shield imperfections with two CF probes - the display (5)

Figure 23 shows that the coupling between the CF probes is once again as low as it was for set-ups (1), (2) and (3).

Clearly, the large slot allows RF energy in the range 50MHz to over 1GHz to couple much more strongly between the two CF probes, than the other structures on the lid of the box. We might expect this to indicate that we should expect much less shielding effectiveness from the slot, than from the row of holes having the same ventilation aperture, and indeed this is what we see when probing the powered-up box for its RF leakages in its traditional 'demo' role.

So there we have it - a mechanical EMC design flaw revealed very early in a project well before there was any hardware or software that could make it possible to test the item in a laboratory to any of the relevant published standards for EMC compliance, such as CISPR 22 or 24 (EN 55022 or EN 55024).

And I haven't mentioned it so far, but a very important and useful feature of most CF probing techniques is that they can be done almost anywhere, anytime, on our desks or assembly/ test benches, and certainly don't need a shielded room!

If our neighbour happens to be operating a very noisy prototype in close proximity, we may need to wait until he or she stops, or move a metre or two to quieter location, and it may also prove necessary in some situations to load all the mains or other cables to our desk or test bench (not just the power cable to the SA, but all of them) with clip-on ferrite tubes. But in many cases such measures are not needed.

Those who need high-performance shielding, and/ or to shield frequencies much higher than 1GHz, will of course find that the row of holes in set-up (2) (Figure 16) has too little shielding effectiveness (although not anything like as bad as the large slot).

If high-performance shielding is required, there are a number of improvements to this two-probe method that should help (although I haven't tried them myself yet):

Increase the TG's output level.

Use an external RF power amplifier if necessary, but in this case feed its RF output to the energised probe through a 50 6dB attenuator of the same or higher power rating as the amplifier, so as not to provide the amplifier with so much of an impedance mismatch that it could be damaged.

Vary the physical relationships between the two probes, and between the probes and the metal surface, to see if greater sensitivity can be achieved.

Try using probes with larger loop areas.

Use a more expensive SA with a larger dynamic range (i.e. a lower noise floor). Use a narrower RBW to improve the dynamic range.

Use trace averaging to help improve the dynamic range (only useful when the noise floor, when the two probes are both over solid metal, looks like random noise).

Use high-performance double-screened RF coaxial cables from the SA to the probes, load the cables with clip-on ferrites, keep the RF Output cable far away from the RF Input cable.

Alternatively, the 'internal RF excitation' method shown in Figures 35 through 40 in this article might prove to be more suitable.

Continuing with the 2-probe method of detecting flaws in shielding, the lid of my 'famous' demo box is fitted to its base with a conductive gasket clamped between them - except where part of the gasket is mi sing along one long edge.

Figure 24 shows the 2-probe method applied to a lid-to-base joint where we know the conductive gasket is present (it is written on the box!). Let's call this set-up (6). Figure 25 once again shows poor coupling between the two probes (just as we had for set-ups (1), (2), (3) and (5) above).

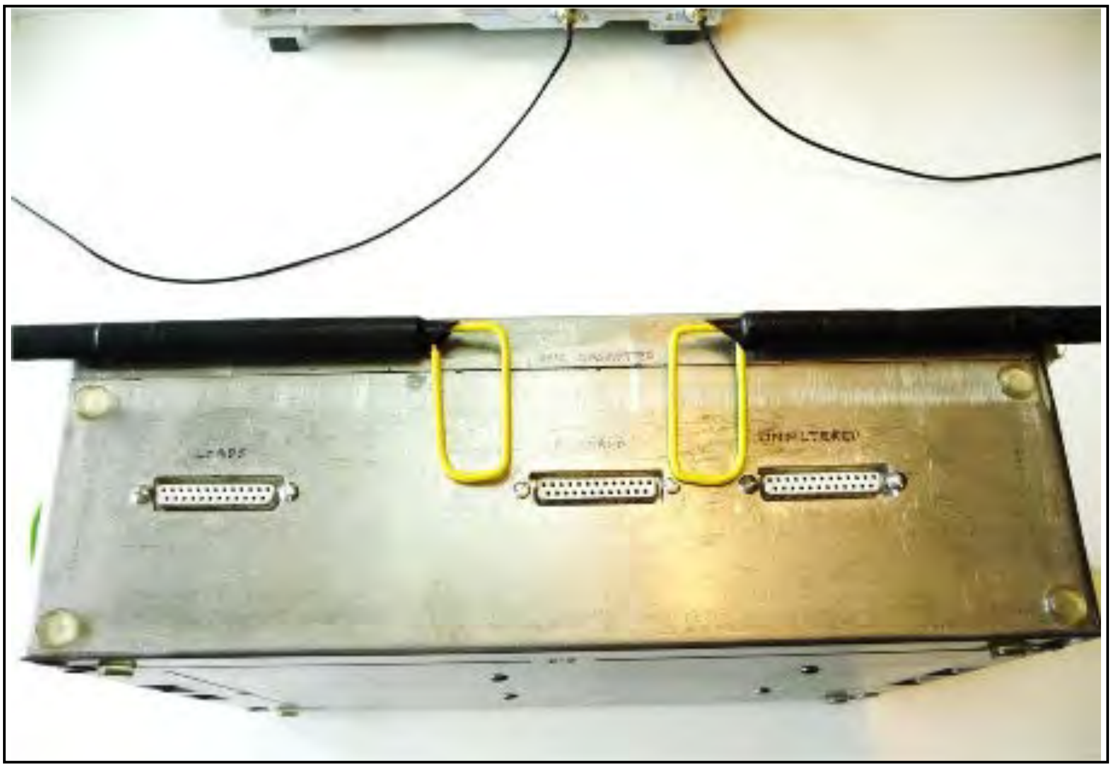


Figure 24 Looking for gasketting imperfections with two CF probes - the set-up (6)

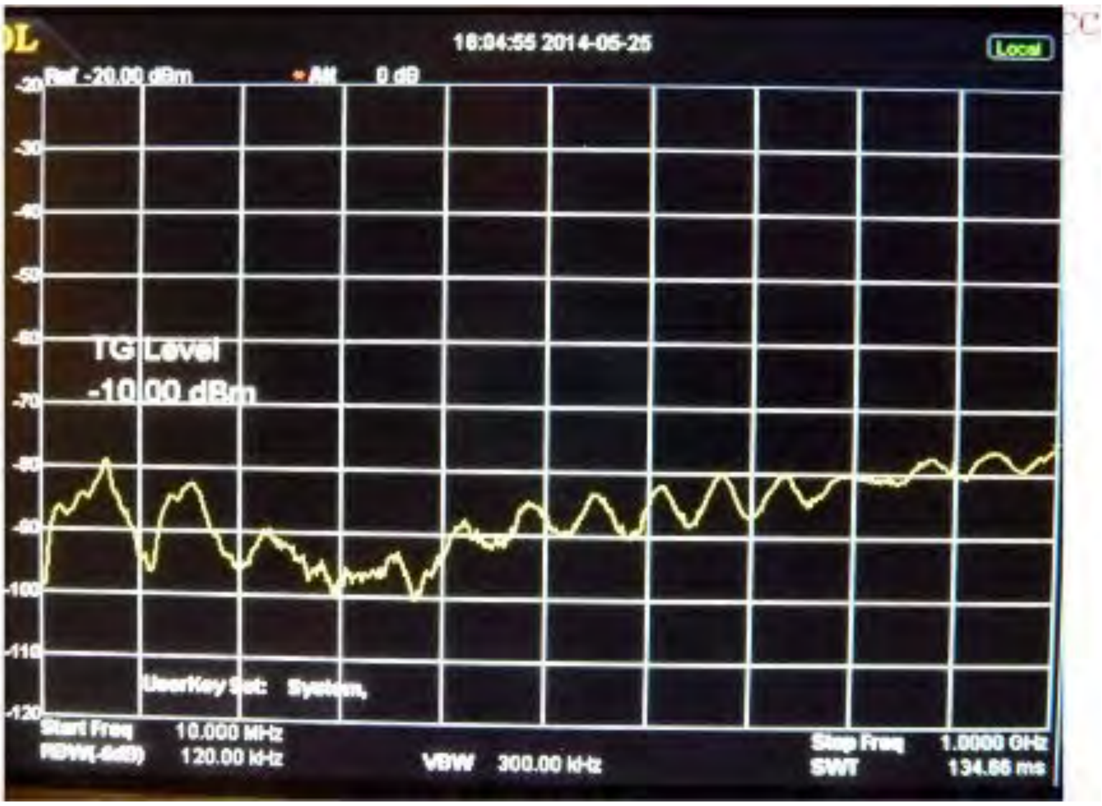


Figure 25 Looking for gasketting imperfections with two CF probes - the display (6)

But when the probes are applied to the side with the missing gasket, as shown in Figures 26 and 27, we quickly see that the coupling between them has increased by 20 to 30dB.

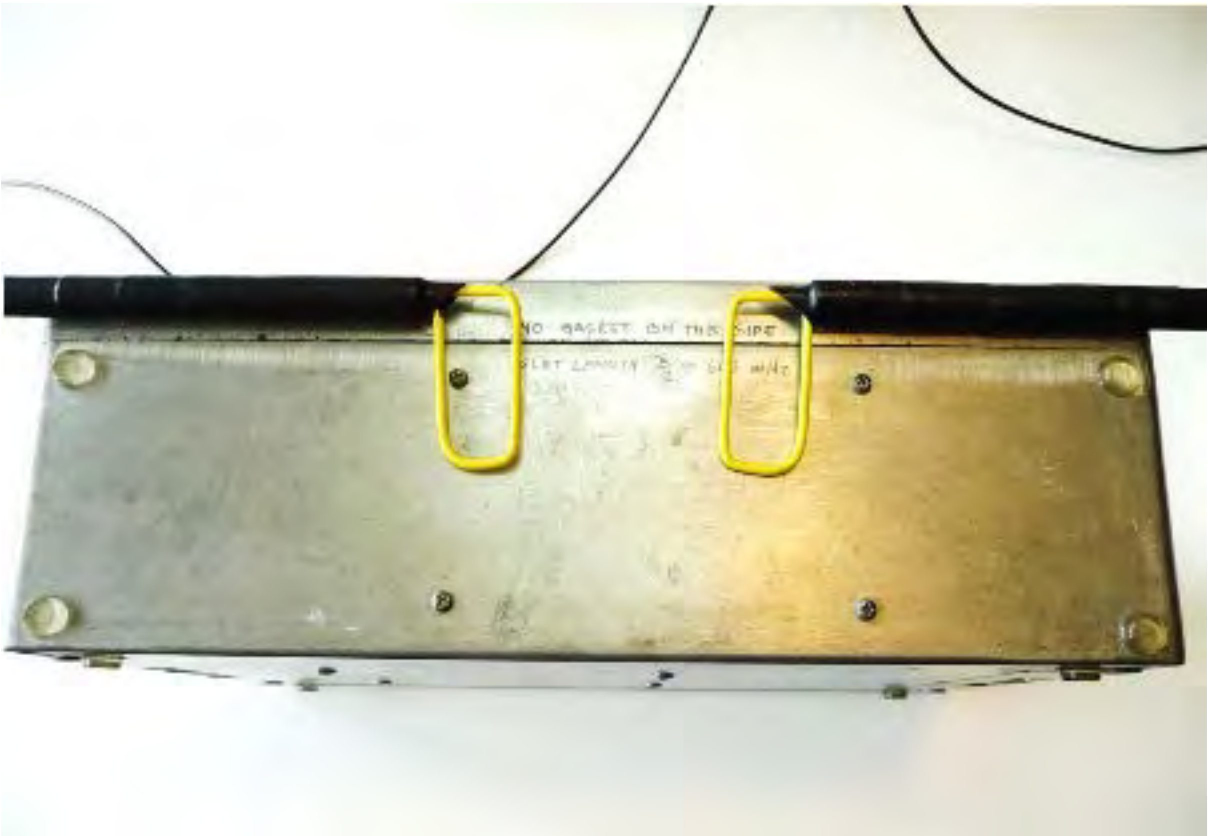


Figure 26 Looking for gasketting imperfections with two CF probes - the set-up (7)

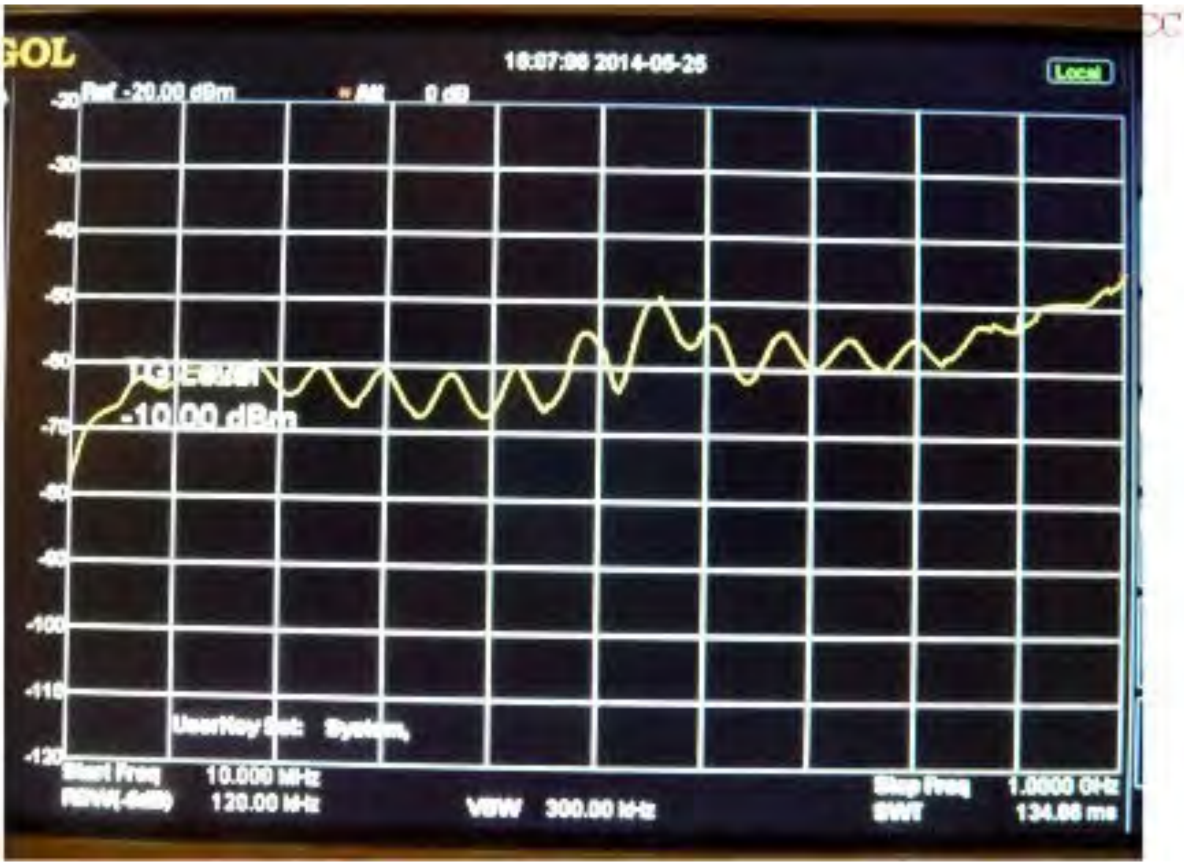


Figure 27 Looking for gasketting imperfections with two CF probes - the display (7)

As well as being able to be used for checking adequate gasket design at an early stage in a project, this technique could be used in serial manufacture to discover whether a gasket had been mis-assembled; and used when fault-finding in the field to discover if a gasket had become ineffective due to corrosion, in both cases being a quick diagnostic tool that does not require dismantling the item concerned to be able to look at the gasket (or where it should be).

4 The 1-probe 'reflectometer' method of finding flaws in shielding

Figures 28 and 29 show one of my new ferrite-handled probes being used with a directional coupler, in this case a Mini-Circuits' ZFDC-20-5+ with SMA connectors that match my CF probes and cables.

This little module cost me about £80, and is specified to have nominally -19.5dB of directional coupling from 100kHz to 2GHz. I am using it backwards as a reflectometer - as Figure 29 shows.

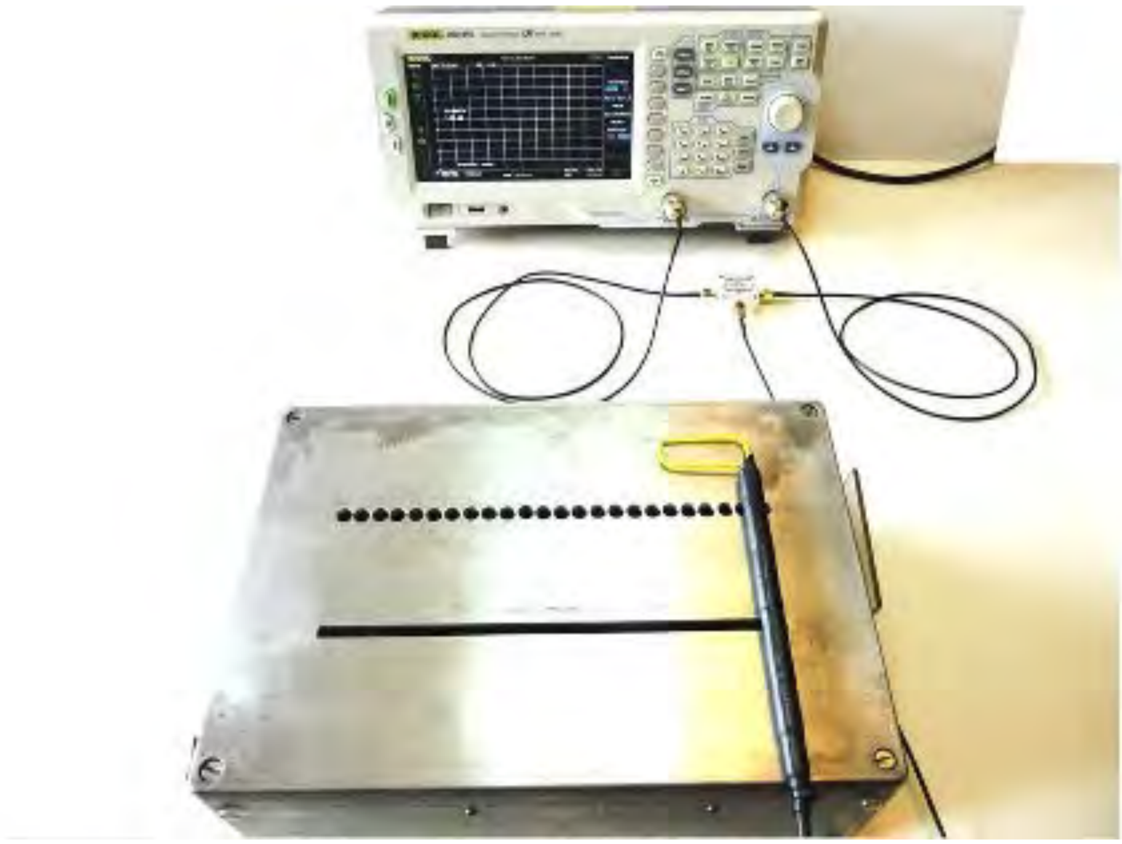


Figure 28 Looking for shielding imperfections with a reflectometer - normalising

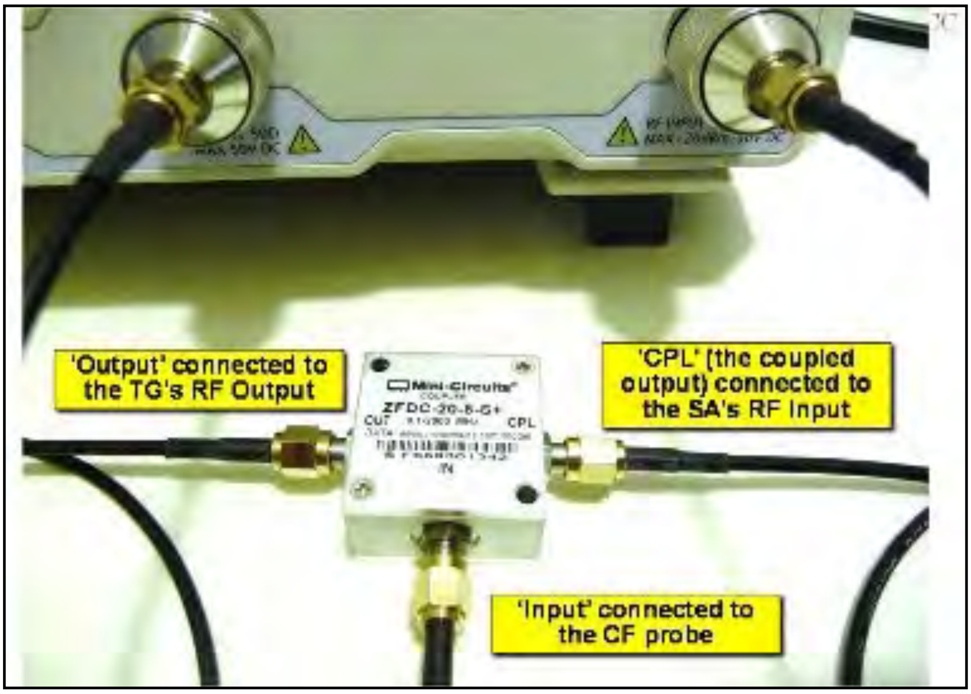


Figure 29 A closer view of the direct ional coupler in Figure 28

Used in this way, any RF that is not reflected at the impedance mismatch caused by the 'shorted-turn' CF probe will be revealed as a dip in the response, but - as Tim Williams of Elmac Services warned me- the 20dB or so loss in the directional coupler makes this a relatively insensitive method. So as can be seen in Figures 30 and 32, I have set the vertical axis to 1dB per division. All the other SA and TG settings are the same as for the two-probe method described earlier.

With this method, the first step is to 'normalise' the measurement with the probe held against a solid piece of metal, as shown in Figure 28. Figure 30 shows the resulting display - a straight line along the 0dB line at the top of the display.

Figure 30 Looking for shielding imperfections with a reflectometer - the normalised display

Figure 31 shows set-up (8), with the normalised probe moved to the large slot on the top of the box, without changing its proximity to the box's metal surface (it is always held against it, touching the metal surface).

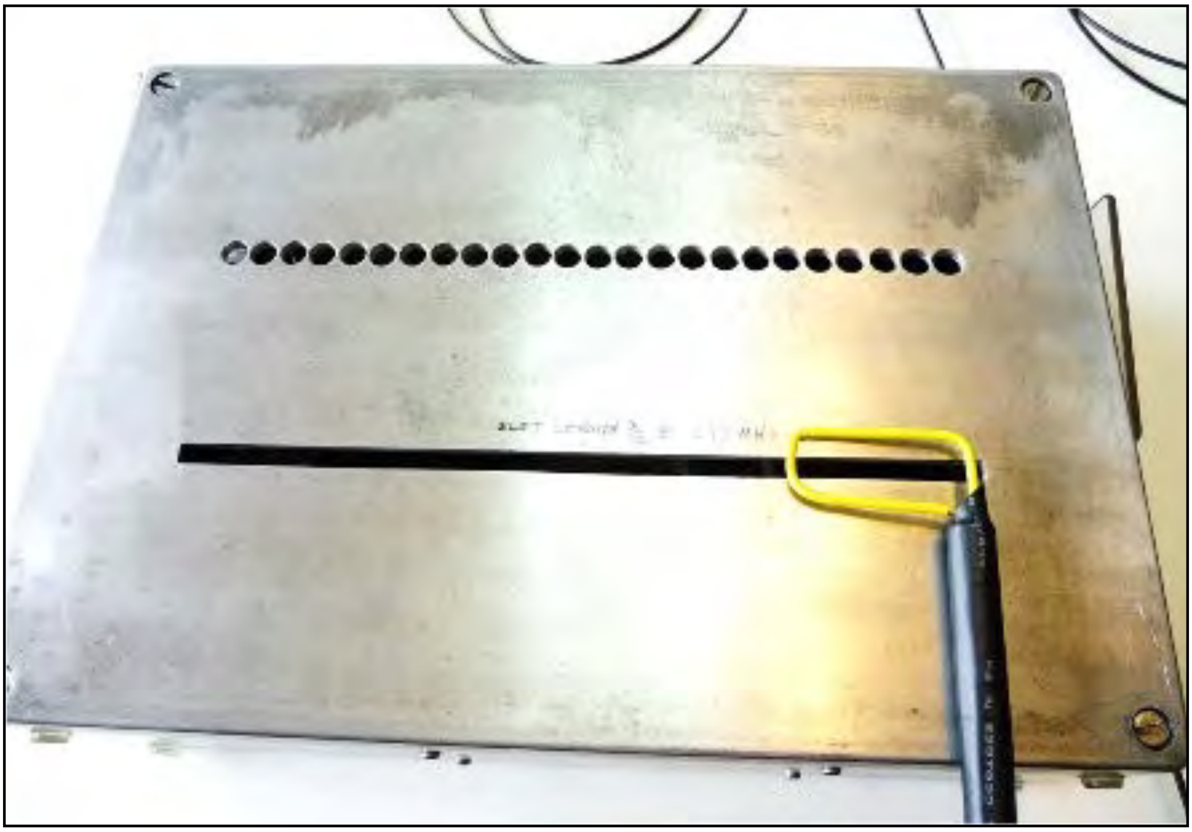


Figure 31 Looking for shielding imperfections with a reflectometer - set-up (8)

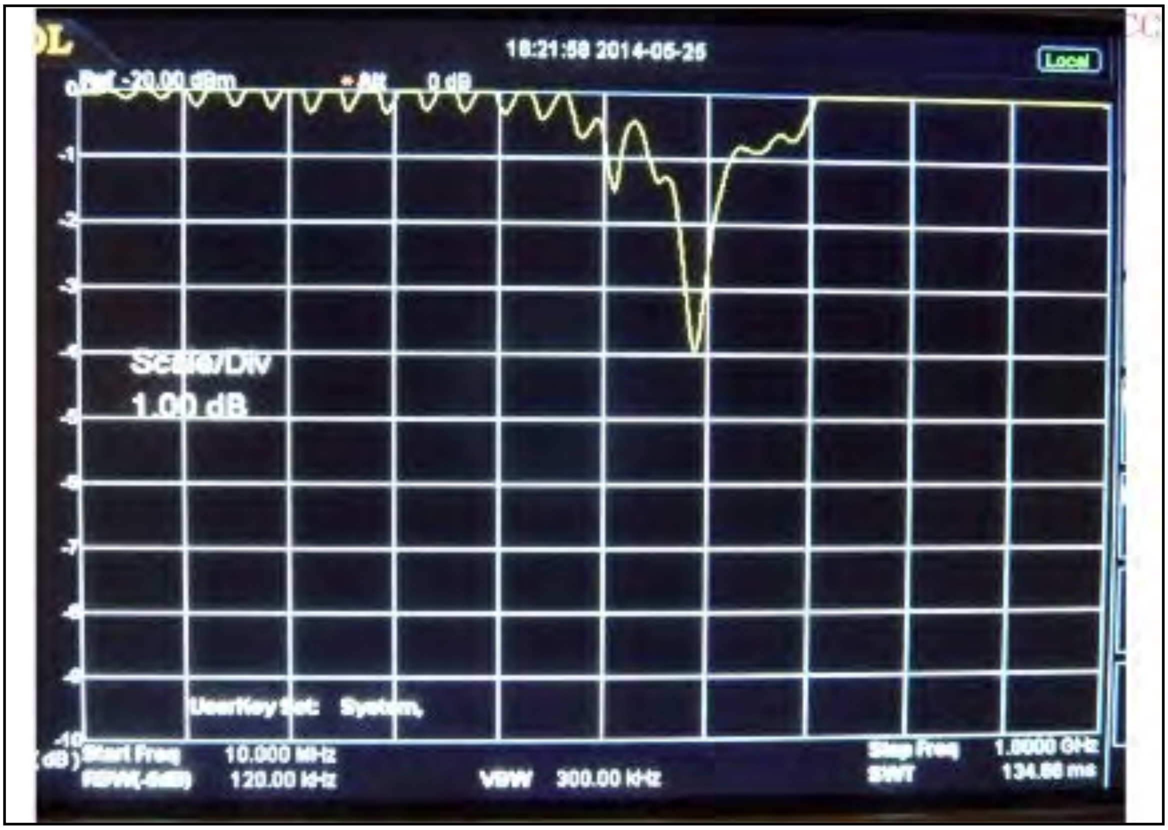


Figure 32 Looking for shielding imperfections with a reflectometer - the display (8)

Figure 32 shows the resulting display, when the CF probe has been moved around so as to maximise the depth of the dip, which is caused by energy being lost into the shield imperfection (instead of being 100% reflected back into the probe as perfect shielding would do).

The maximum dip depth is reached with the probe at one end of the slot, which is not unexpected because it is the location of the maximum magnetic field emissions from an ‘accidental slot antenna’ at resonance.

The dip frequency correlates well with the first resonance frequency at 643MHz (i.e. when the slot’s length equals half a cycle of the wavelength).

This is different from the two-probe method described earlier, which did not reveal anything about the slot’s resonant frequencies. I think this is because the two-probe method simply measures the coupling between the fairly localised eddy current patterns for the probes, which do not extend far enough to excite the whole length of the slot and cause it to resonate.

Quite probably, if when using the two-probe method, we located one probe at each end of the slot, the slot’s first resonance frequency would then show up.

Figure 33 shows the reflectometer method being used to identify the missing gasket on my demo box, with Figure 34 its displayed output.

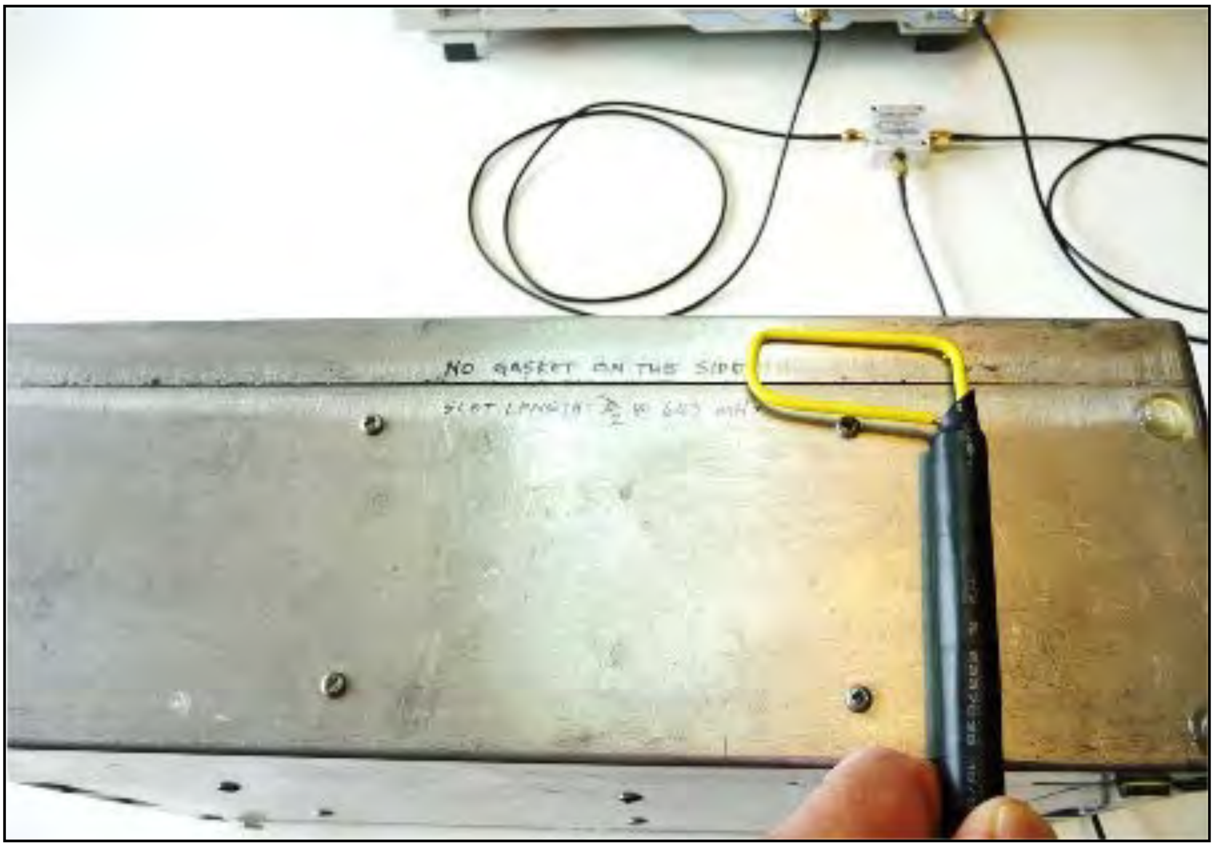


Figure 33 Looking for shielding imperfections with a reflectometer - set-up (9)

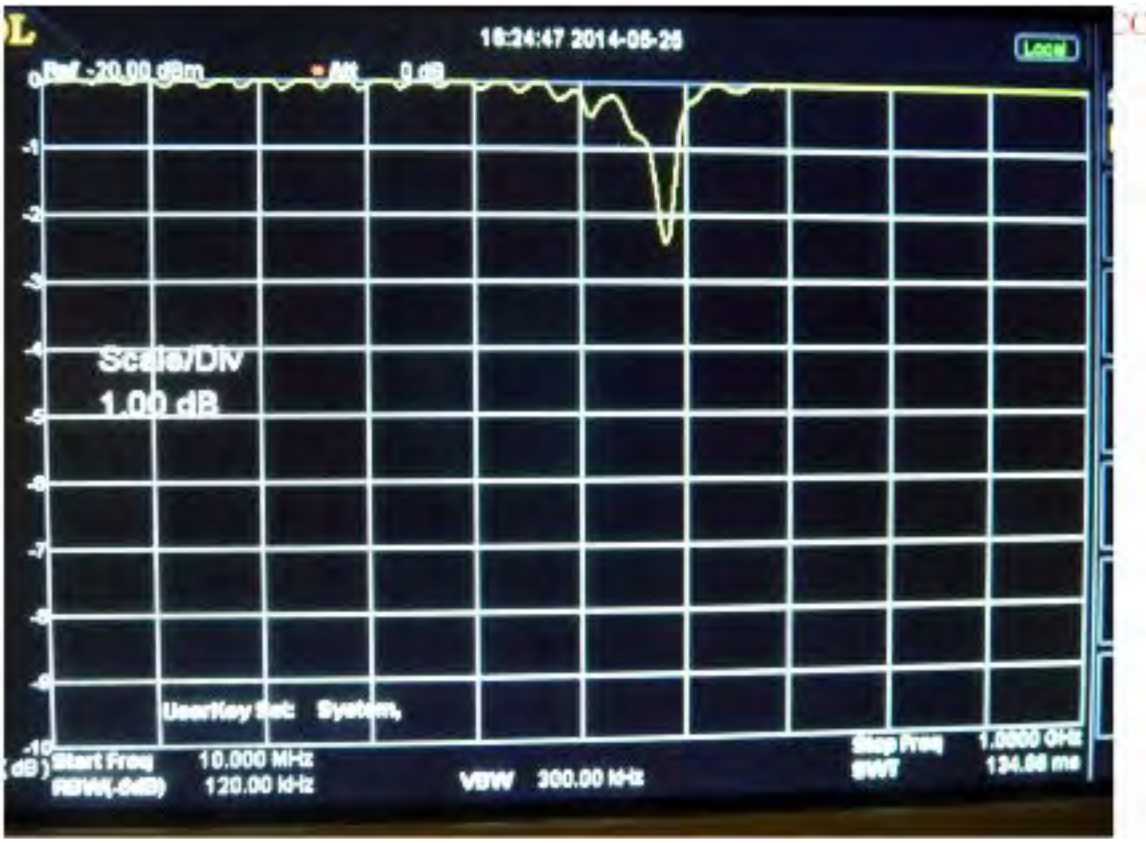


Figure 34 Looking for shielding imperfections with a reflectometer - the display (9)

The dip in Figure 34 is only about 2.5dB, but it is at exactly the same frequency as the dip measured for the large slot in set-up (8) - Figure 31. This was not unexpected, because the demo box's missing length of gasket is exactly the same as the length of the slot in its lid - so they will have the same first resonance frequency.

So not only does this method identify the fact that there is a missing (or badly degraded) gasket, it finds its ends and makes it possible to determine how much length is missing (again, without dismantling the item).

5 The 2-probe 'internal illumination' method

Figure 35 shows one of my more basic CF probes (no ferrites on its handle) probing the row of small holes on the lid of my demo box, while the TG's RF Output is fed directly to a CF probe that is inside the demo box.

Figure 36 shows the location of the CF probe, which is nothing more than a 95mm-long piece of (insulated) wire sticking into the box via a 'through-bulkhead-mounting' SMA connector. This is an E-field CF probe, being used here to 'illuminate' the inside of the box with RF energy from the TG.

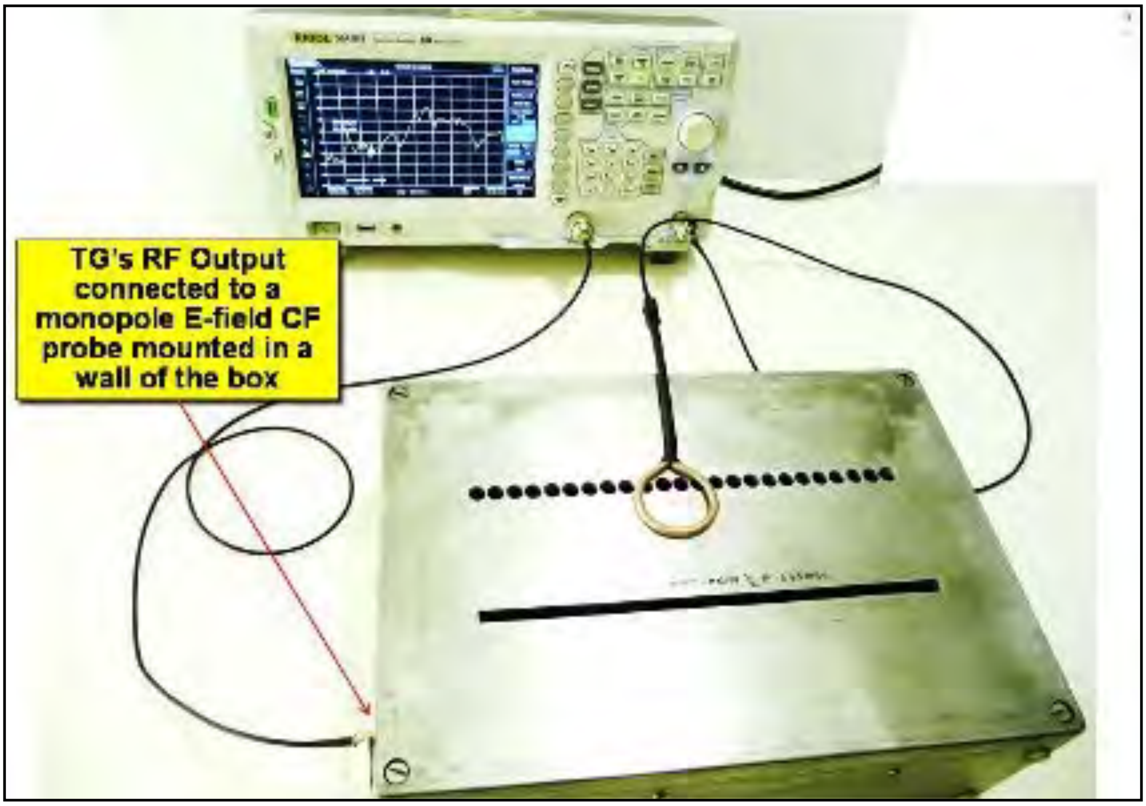


Figure 35 Looking for shielding imperfections with internal illumination- set-up (10)

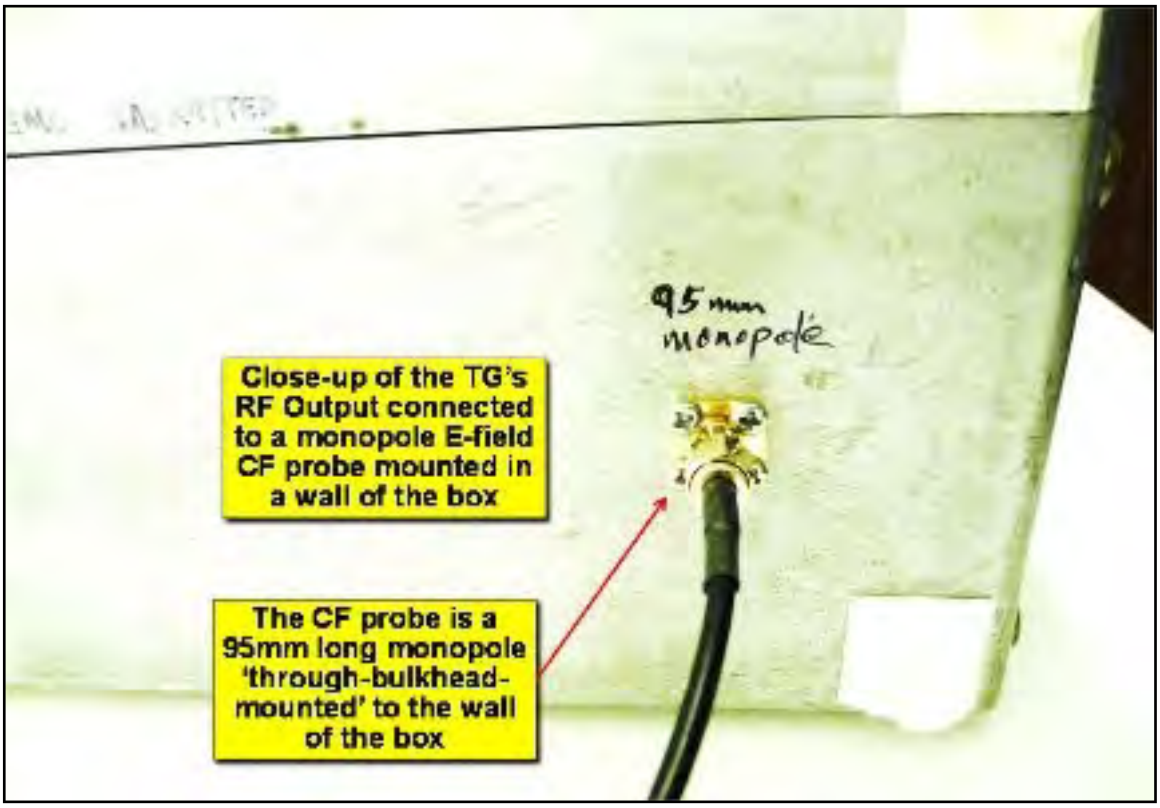


Figure 36 Looking for shielding imperfections with internal illumination - the internal CF probe

Figure 35 shows the capture of the yellow trace whilst the probe is held over the row of small holes, and Figure 37 the capture of the pink trace whilst the probe is held over the large slot (with the yellow trace 'frozen').

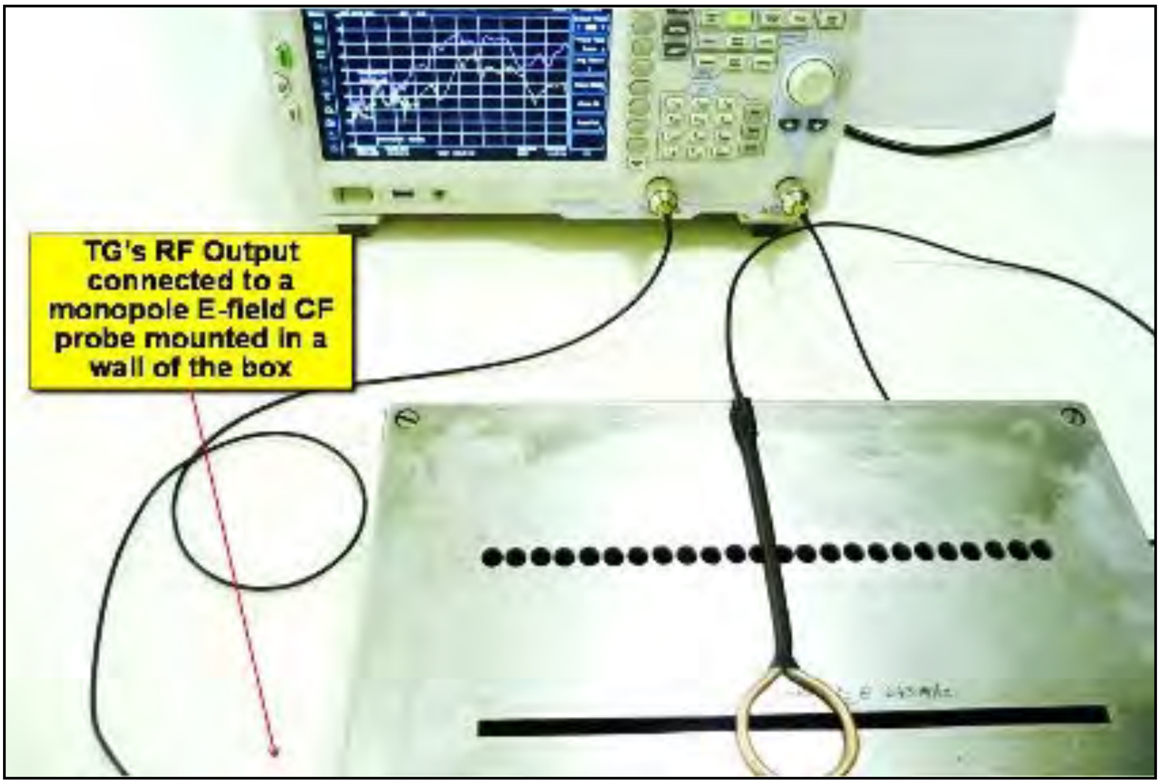


Figure 37 Looking for shielding imperfections with internal illumination- set-up (11)

Figure 38 shows the resulting display. The yellow trace is for the CF probe on the box lid away from the large slot, while the pink trace shows the probe held the same way moved to the middle of the large slot.

Figure 38 Looking for shielding imperfections with internal illumination - displaying both (10) and (11)

Clearly, the moveable CF probe was picking some emissions from the fixed E-field probe inside the box when it was not over the large slot, set-up (10), but also clearly it was picking up significantly more emissions when it was over the slot, set-up (11).

Figures 39 and 40 show exactly the same procedure using one of my newer ‘ferrite handled’ probes (although set-up (12) for the yellow trace was not photographed). These show that - for this kind of CF probe test at least - the ordinary probes do just as well as those with 200mm ferrite tubes.

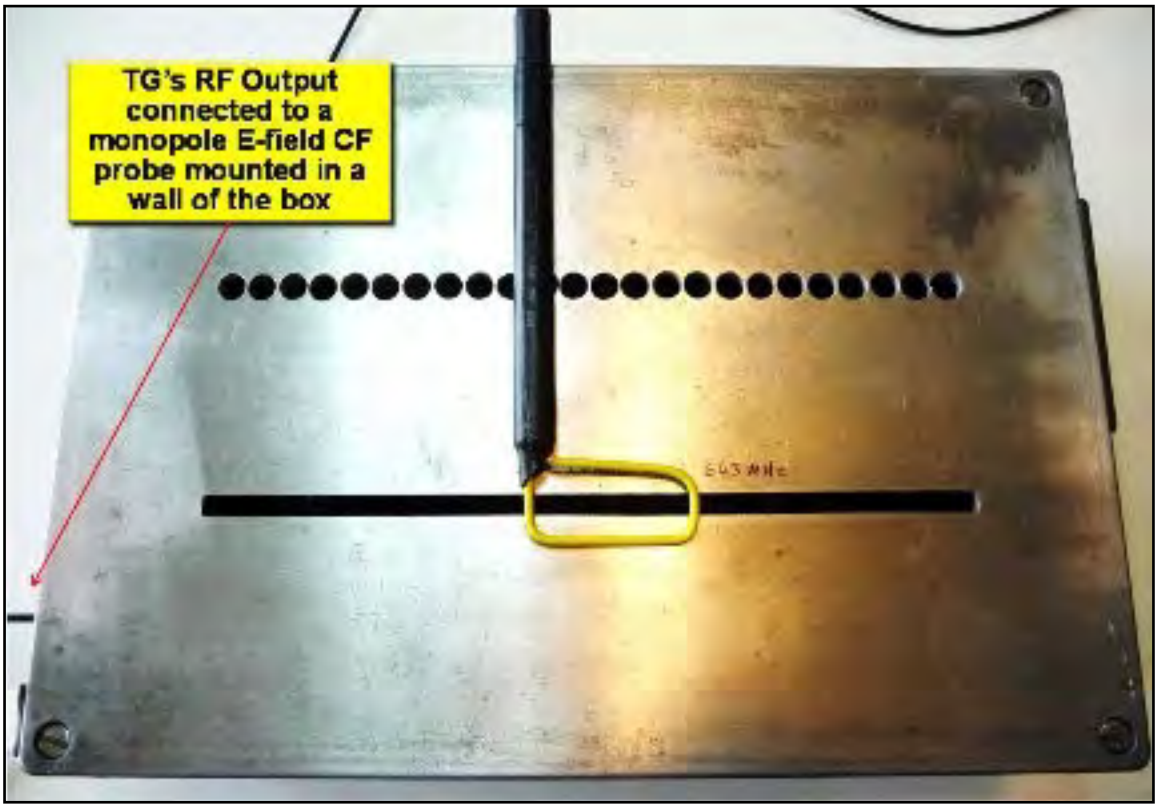


Figure 39 Looking for shielding imperfections with internal illumination- set-up (13)

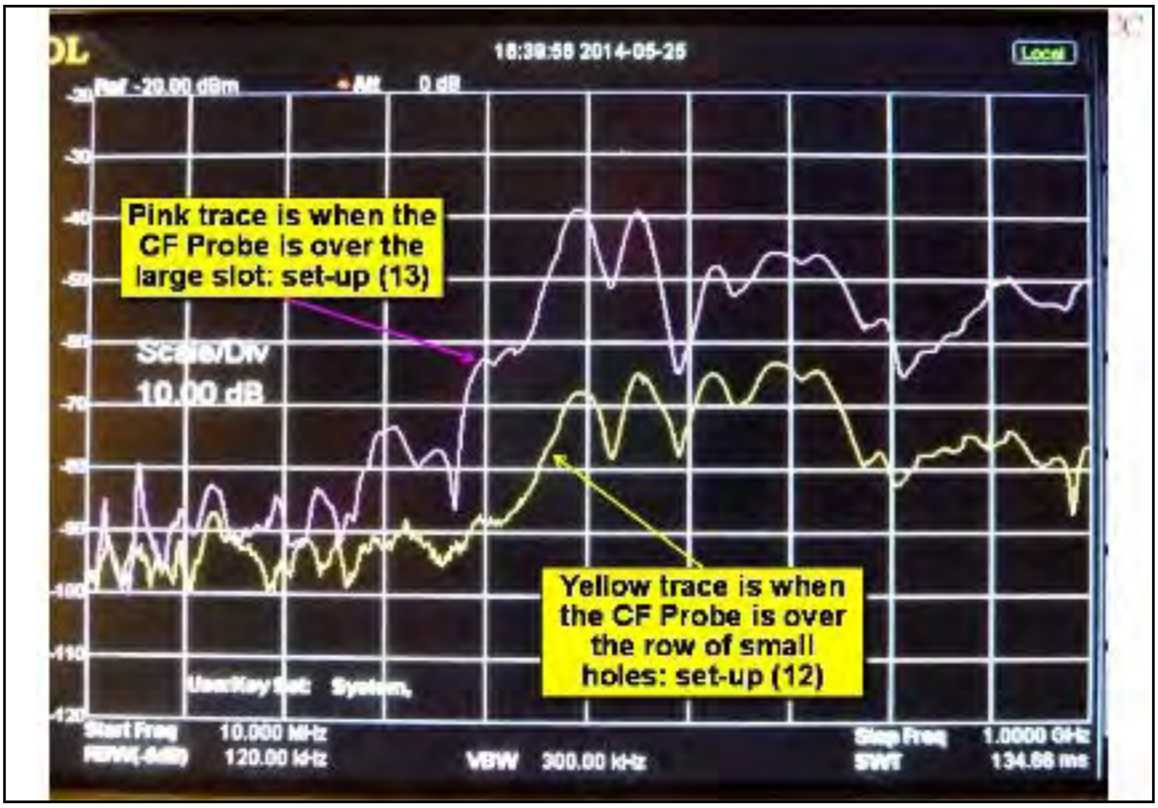


Figure 40 Looking for shielding imperfections with internal illumination -- displaying both (12) and (13)

I have a lot more material on these sorts of CF tests, which can be done by (or for) mechanical designers early in a project to de-risk the choice of materials, assembly methods and overall design - but I have run out of room, so they will have to wait for future editions of the EMC Journal.

6 References for Part 1

[1] "EMCTesting", by Tim Williams and Keith Armstrong, EMCCompliance Journal, 2001-2002, available from *www.cherryclough.com* and *www.theemcjournal.com*. This is a series with 7 parts and only Parts 1 and 2 are especially relevant to close-field probing.

[2] "Signal and Noise Measurement Techniques Using Magnetic Field Probes", by Doug Smith, IEEE 1999 International EMC Symposium, reprinted at *http://emcesd.com/pdf/ emc99-w.pdf.*

[3] "Cost-effective use of close-field probing" webinars parts I and II, by Keith Armstrong, may be viewed at *www.interferencetechnology.com/webinar-series* (scroll down the webpage).

[4] "Evaluate EMI Reduction Schemes with Shielded-Loop Antennas", Roleson S, EDN, 29(10):203-207, 1984, which does not seem to be available via Google.

[5] "Benchtop EMC Testing Techniques for Medical Equipment (using close-field probes)", Scott Roleson, Medical Device & Diagnostic Industry Magazine, January 1998, available from *www.mddionline.com/article/benchtop-emc-testing-techniques-medical-equipment*.

[6] "Finding EMI Resonances in Struct ures", Roleson S, EMCTest Design, 3(1):25-28, 1992, which also does not seem to be available via Google.

[7] "Measuring Structural Resonances" , by Doug Smith, 'Technical Tidbit, June 2006', available from *www.emcesd.com/tt2006/tt060306.htm*. There is a great deal more on close-field probing, other useful diagnostic techniques and much else on EMC and especially ESD at Doug's website: *www.emcesd.com*. A quote from a visitor to this site: "Every time I browse your site, I never get any work done. I spend hours on it and get in trouble." - so don't complain that you were not warned!

[8] "Near field probes: Useful tools for Electronic Engineers", Dr. Arturo Mediano, EMC-Europe 2013, Bruges, 2-6 Sept, Short Course 1.

[9] "Measuring Resonance in Cables", Ken Wyatt, EDN, October 29, 2013, *www.edn.com/electronics-blogs/the-emc-blog/4423597/Measuring-resonance-in-cables*.

[10] For example, EMC-UK 2014: *www.emcuk.co.uk/conference*, but please note that this year's EMC-UK training programme might not cover close-field probing techniques as it often has in previous years.

[11] " First impressions - Rigol DSA815TG spectrum analyser" by Kenneth Wyatt, in EDN, July 06, 2012, *www.edn.com/electronics-blogs/the-emc-blog/4389791/First-Impressions-Rigol-DSA815TG-Spectrum-Analyzer*.

STANDARDS AWARENESS 1

by J. M. Woodgate B.Sc.(Eng.) C.Eng. MIET SMIEEE FAES FInstSCE
Date: 230616

It happens every three to five years

What does? Well, two things. First, a new cohort of budding engineers and technicians join the world of EMC technology. Second, most standards that specify what we have to do to achieve electromagnetic compatibility are updated, which may mean anything from a small amendment to a complete re-write.

Newcomers

The present state is that most of the new people haven't even heard of electromagnetic compatibility, and those that have, even those with higher degrees, have very limited experience. This is because it is a very big subject, with strong practical rather than academic content, and a vast array of technologies that change for every two or three decades of frequency. It would be quite possible to base a graduate course of EMC alone, which would be a very bad idea, because such graduates could not communicate effectively with designers, and it is a fundamental principle that EMC (like safety) must be designed in, not imposed after a design is allegedly 'finished'. Post-imposition always costs a fortune in re-work and time delays.

Standards

In EMC, we have to 'live and breathe' standards, so what is a standard? There is an official wordy definition, but a standard is an agreement by some people to do something in a specific way and report results in a specific way. Both bits of that are essential: it's deceptive to use a standard method of measurement but report the result incompletely or confusingly, or report in standard form the results of a non-standard measurement. This abuse is widespread: everyday one can find in 'specifications' such things as 'Sensitivity 90 dB', which is quite meaningless by itself.

EMC standards come in two genera, emission and immunity, and four species, basic, generic, product-family and product. Internationally, these are produced by the International Electrotechnical Commission (IEC) or its subsidiary body CISPR (whose abbreviation is based on its French title). These standards are adopted either unchanged or only somewhat amended in many countries, and that used to be the case in Europe, where the standards were adopted unchanged by the European standard body CENELEC. Unfortunately, due to a legal ruling on a subject far removed from EMC, CENELEC standards that serve to establish compliance with the EMC Directive have to meet legal requirements, which is resulting progressively in European EMC (and safety) standard differing considerably from their IEC counterparts. The devil is often in the detail: some products may be strongly affected by this, while others are not affected at all. That means that it is necessary to understand the standards in great depth.

Genera and species

Genera

The two genera names are self-explanatory, and are associated with the concept of 'compatibility'. It is not possible to eliminate all unwanted emissions from anything except an incandescent lamp, and we have abolished them. Equally, it is impossible to make anything totally insensitive to electromagnetic radiation, even an incandescent lamp if the radiation is strong enough. There has to be a balance, based on what is practicable and economic to limit emissions and improve immunity.

Note the two terms: it's not practicable to put a display unit in a sealed metal box with no cables attached, and it's not economic to add 20 % to the manufacturing cost of a TV to make it immune to an electric field strength of 20 V/m at all frequencies from 9 kHz to 400 GHz and beyond.

Species

Basic standards specify methods of measurement and the forms for reporting the test equipment and the results. Some still suggest, but not impose, performance requirements, but this is now considered inappropriate and is being eliminated.

Generic standards were originally intended to apply to products that had no product-family or product standard, but now their requirements are regarded as benchmarks. Writers of product-family and product standards have to justify any relaxation in their documents of the requirements of the applicable Generic standard. For some requirements, reference is made to other standards.

Product-family standards specify requirements for all products that share a certain attribute. Some families are very large: IEC 610003-2 and 61000-3-3 apply to all products connected to public electricity supplies that draw 16 A or less.

A Product standard applies to a well-defined product. Most products fall into one or more families.

Emission standards

The Basic emission standard for frequencies above 9 kHz is CISPR 16, produced by CISPR subcommittee CISPR A: it has four parts and several sub-parts. The CENELEC version is EN 55016. There is no Basic emission standard for frequencies below 9 kHz.

The Generic emission standards are IEC 61000-6-3 (for residential environments), 61000-6-4 (for industrial environments) and 61000-6-8 (for professional equipment in commercial and light-industrial locations). That last one is a welcome development, because the audio industry realised the need for such a standard (EN 55103-1 for emissions and EN 55103-2 for immunity) in 1993, before the Generics were written, and they lasted into the 21st century, being replaced by product-family EN 55032 and EN 55035, which has clearly proved unsatisfactory.

The product-family emission standards for frequencies below 9 kHz are prepared by IEC Committee SC77A. There are four at present: for harmonics and interharmonics of the supply frequency IEC 610003-2 (below 16 A per phase) and 61000-3-12 (below 75 A per phase: above that connection has to be negotiated with the supplier), and IEC 61000-3-3 and 61000-3-11 for voltage changes and flicker. Other such standards are under development and will be published in the fairly near future.

For frequencies above 9 kHz, emission standards are produced by CISPR subcommittees. These are product-family standards, with very big families.

CIS/B: Interference relating to industrial, scientific and medical radio-frequency apparatus, to other (heavy) industrial equipment, to overhead power lines, to high voltage equipment and to electric traction

CIS/D: Electromagnetic disturbances related to electric/electronic equipment on vehicles and internal combustion engine powered devices

CIS/F: Interference relating to household appliances tools, lighting equipment and similar apparatus

CIS/H: Limits for the protection of radio services.

CIS/I: Electromagnetic compatibility of information technology equipment, multimedia equipment and receivers.

Immunity standards

Basic immunity standards are in the IEC 61000-4 series. At the moment, there are 39 of these, and one ‘overview’ document.

The Generic immunity standards are IEC 61000-6-1 (for residential environments), 61000-6-2 (for industrial environments), 61000-6-5 (for the power station environment) and 61000-6-7 (for equipment in safety-related systems).

CISPR B and CISPR D do not produce product-family immunity standards, but CISPR F and CISPR I do. There are many product-family and product immunity standards produced by IEC product committees.

Go exploring

There is an immense amount of accessible information on the IEC web site ***http://www.iec.ch***. Explore freely: IEC doesn't bite!

Editor's Interview

In this edition we have been talking to Howard, an electronics design engineer with a keen eye for problem solving and the tenacity to complete the job. For a good few years before his retirement, he was a Technical Fellow with a U.S. Automotive OEM. He spent a lot of time working in the design labs and also in overseas factories ensuring that new product launches happened seamlessly.

Below, he shares his experiences of EMC and the design process.

How did you get into EMC and design of electronic products ?

Having achieved a BSc in Electrical and Electronic Engineering, I started working at Marconi Avionics in 1976. It was really interesting work, designing electronic systems for the MoD.

My first experience of EMC testing taught us a basic lesson about proper screening :

The main units were often manufactured by milling billets of aluminium. The machined interface between the main box and the lid provided an effective RF seal and an 'O' ring gave protection against water ingress. We were confident that the units would not radiate nor be susceptible to external radiation.

We sent a production system to an MoD EMC testing facility. To our surprise, the first round of testing did not pass, although the units were 'quiet' there was far too much leakage from the cables and nearly all the cables had to be re-worked to incorporate better screening.

Prime lesson – radio waves will sneak in or out of any, and every, tiny gap. If you are relying on screening to protect against radiation and/or susceptibility, the screening needs to be 100% complete, (actually any 'hole' in the screening needs to be much smaller than the wavelength of the highest frequency that you need to protect against).

Although we were designing systems for the MoD, EMC wasn't always considered at the initial stages. Only after building and testing the first prototype did we add, or change, components or add mechanical features i.e. more screening and/or grounding, to address any EMC issues.

In hind sight, this design philosophy was somewhat unprofessional; it caused delays and expensive re-work.

The cost of these systems was often secondary to the function and performance. We were fortunate that we could incorporate expensive solutions to resolve any EMC shortcomings.

I don't recall the subject of EMC ever being taught during my studies at university. It wasn't until I started working at Marconi that I had to learn the basics of grounding (separate grounds or star-points), screening, control of clock edges, harmonics, good PCB layout . . . and so forth.

What did you get out of this experience?

There were many experienced engineers in the design labs. We never had training sessions but engineers were always happy to help and advise whenever we had a problem.

In the 1970's we didn't have the luxury of computer aided design, no (or very little) computer circuit simulation. The design of PCB's was done manually by applying sticky black tape onto transparent film, so to make, even a small change, to a PCB design often meant pulling up a lot of the layout and re-laying it.

The layout guys were not happy if they had to re-lay a lot of their design !! Therefore it was very important to consider and design the layout of any PCB with EMC in mind.

Addressing EMC issues in the later stage causes delay and is often expensive. The next big lesson to learn is that EMC must be considered at the initial design stage to avoid a lot of post re-design. Engineers need to understand the EMC requirements and design the product with that in mind. Discuss the design with experts before making the first prototype; that includes both the electronic and mechanical construction.

The operating speed of modern electronics needs careful attention to layout, grounding, and de-coupling. Consult the IC manufacturers to fully understand the best way to use their devices. The manufacturers will normally incorporate layout guidelines in the IC specifications.

How did you see yourself progressing in EMC?

In my later years I moved into the automotive arena (working at Ford Motor Co.), essentially designing in-car entertainment systems and vehicle instrumentation.

In the automotive world, cost is a major consideration and the designs need to be 'very smart' in order to meet the cost and the function, and the stringent vehicle EMC requirements.

The EMC test facilities at Ford were (and probably still are) impressive, with extensive testing capability.

Unlike military equipment, the chassis of a car radio is constructed by bending relatively thin mild steel to form a box, the corners are sometimes riveted to aid strength but usually there are many holes and slots in the chassis, so it does not provide a good RF shield. For vehicle instrumentation (speedometer, tacho etc.) the housings are often plastic so good circuit design and layout are essential.

The EMC requirements can be broken down into various areas; for example: radiation, susceptibility, interference on supply lines, interruption of supply.

A design engineer (or team of engineers) needs to understand how to address each requirement.

Many (probably all) systems now have some degree of embedded software and this can be used to address some EMC requirements (i.e. re-boot strategy, storing data to recover from a power drop-out) but the supporting circuity must be designed to enable the software to function correctly.

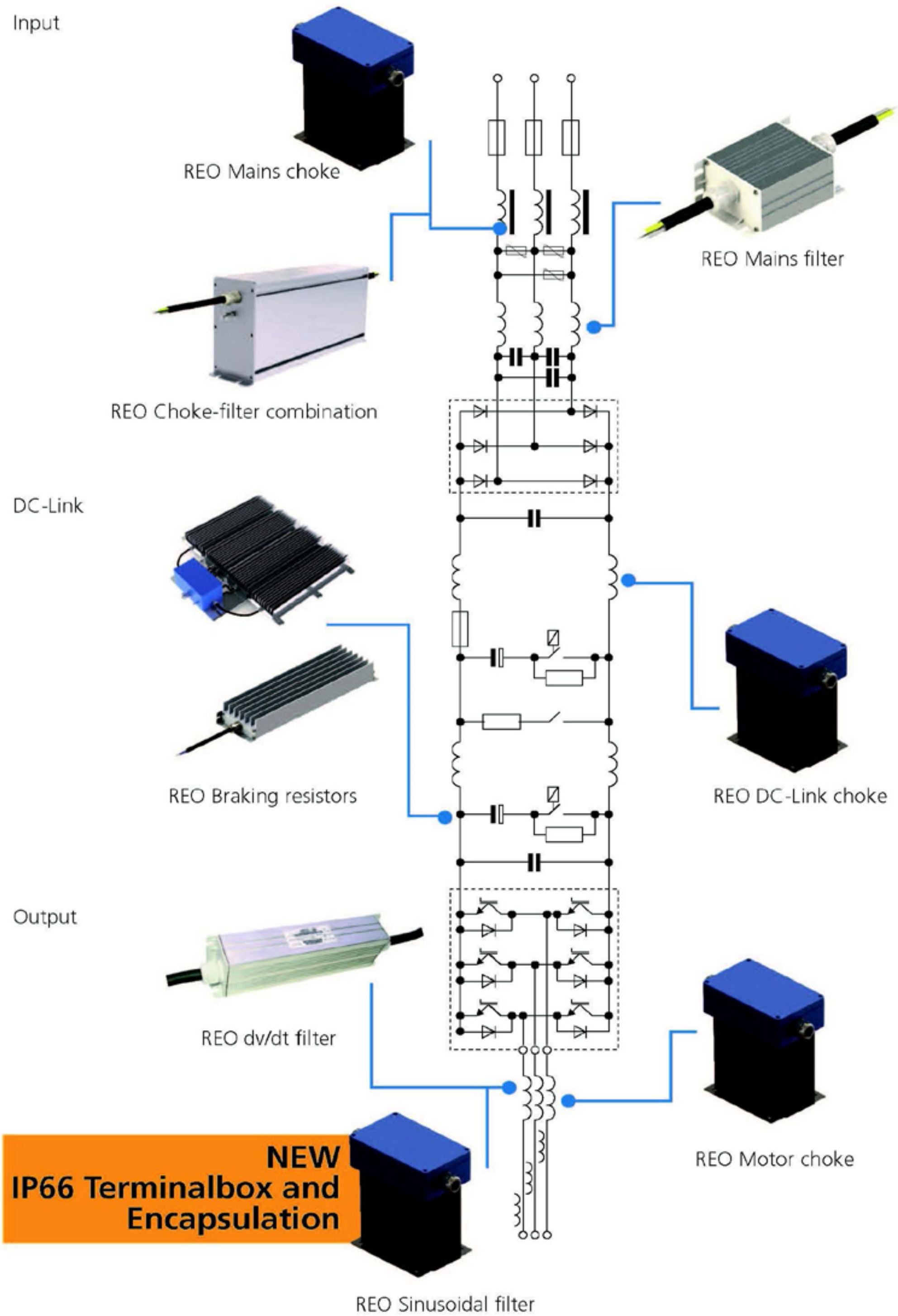
Over the many years of working in systems design we learnt how to design to meet EMC requirements, but I doubt if any one person knows, or has, all the answers. It is essential to discuss and review each of the aspects of the system (electrical and mechanical) with experienced engineers in order to achieve the best result.

Thank you very much for your contribution Howard. These points are most valid! I am sure that our readers will enjoy your experiences.

REO SYSTEM COMPONENTS

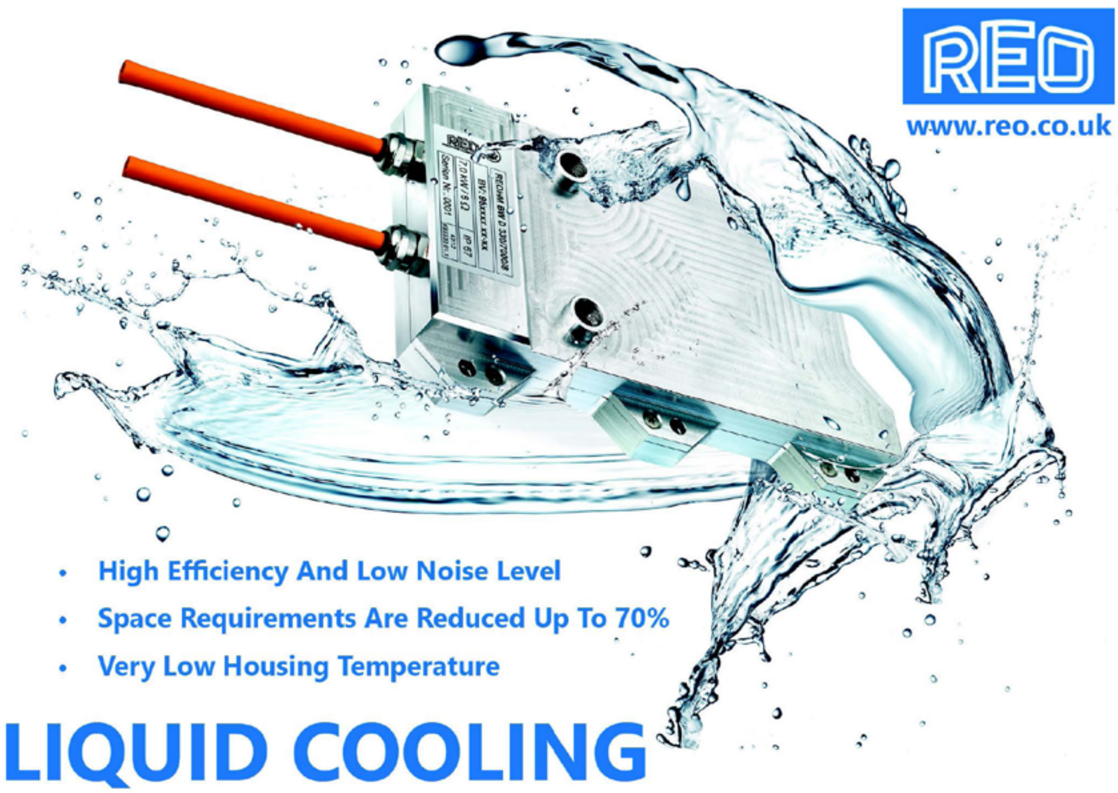
REO
www.reo.co.uk

With high protection IP ratings for inverters



REO achieve highest IP protection class (International Protection)


EMC &Compliance International
Training, Exhibition, and Conference.
22nd and 23rd May 2024,
Newbury UK


REO
www.reo.co.uk
• High Efficiency And Low Noise Level
• Space Requirements Are Reduced Up To 70%
• Very Low Housing Temperature
LIQUID COOLING