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Close-field probing series
Webinar #2 of 2, March 26, 2014

Cost-effective uses of close-field probing in every project stage: emissions, immunity and much more

Keith Armstrong
CEng, EurIng, FIET, Senior MIEEE, ACGI

Presenter Contact Info
email: keith.armstrong@cherryclough.com
website: www.cherryclough.com

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Measuring radiated and conducted RF emissions

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Using close-field probes to check radiated emissions

¼ Set the spectrum analyser's input attenuator to 0dB, and set the desired frequency range…
- ¿ if trying to correlate with 'proper' EMC tests, set the same resolution and video bandwidths…

– connect the probe, and move it all over the surface of the equipment (while it is operating)…
- ¿ using all three 90° orientations, paying particular attention to all seams, joints, hinges, gaskets, displays and controls…

– also move the probe in a similar way over the surfaces of all connectors and conductors

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Using close-field probes to check radiated emissions
continued…

¼ Watch the spectrum analyser screen during this process for the locations that measure the highest levels at the frequencies we are concerned with

¼ Close-field probes *always* measure very strong fields very close to any digital ICs or PCB traces carrying clocks or data…

– but often these do not contribute to emissions…

– so it is generally best to hold the probe about 25 or 50mm away from devices and PCB traces

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Maintaining a fixed spacing with a probe

¼ Close-field probes are very sensitive to spacing, but it is difficult to maintain a fixed spacing by hand…

– one solution is to encapsulate the probe in a block of epoxy, or acrylic, with the right dimensions…

– press the surface of the encapsulation against the tested object to ensure correct spacing

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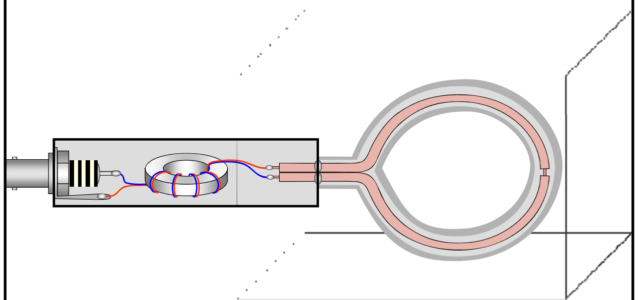
Encapsulating a probe makes it easier to maintain a fixed spacing



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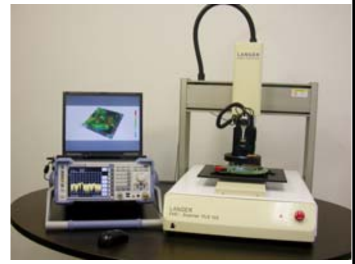
Another solution is to program an industrial robot to move the probe…

– which is most suitable when we are going to compare a lot of items that are all the same size

- This is a robotic near-field probe…
  - being used to plot near-fields over a whole PCB, which can be used for diagnosis or comparisons



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Using close-field probes to check radiated emissions
continued…

- When searching for problems, a quick scan over the joints, conductors, etc., will often reveal the main emitters…
  - which can then be investigated more closely
- But comparing one device, PCB, equipment, etc. with another…
  - requires a fixed routine (procedure) for moving the probe over the joints, displays, controls, connectors, cables, etc. with the various probe orientations

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Obtaining an emissions ‘signature’

- Set the spectrum analyser to ‘peak hold’…
  - and go through the fixed routine of scanning over the joints, displays, controls, conductors, etc…
  - the final display on the spectrum analyser is the emissions ‘signature’ for the item
- Compare ‘signatures’ to see if there are any significant differences…
  - useful for testing the effects of modifications
- Remember to *always* use the same probe, cables, spectrum analyser settings, test bench set-up, and routine

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Obtaining an emissions ‘signature’
continued…

- Greater discrimination…
  - obtain a number of ‘peak hold’ emissions signatures for each product…
  - each signature covering a different part of the product, e.g. keyboard, display, connector panel, case seams, mains cable, Ethernet cable, etc.

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Using close-field probes to check conducted emissions

- Exactly the same as measuring radiated emissions, except that the spectrum analyser is set to a different frequency range…
  - and for lower frequencies, larger-diameter probes may be preferred because they are more sensitive
- This time, holding the probe against the insulating jacket of the cable being checked…
  - close to where the cable enters or exits the equipment (e.g. < 100mm)…
  - and varying its orientation to find the worst-case

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Avoiding overload (inc. out-of-band) and intermodulation

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Spectrum analyser input mixers can be overloaded by strong signals *even outside the frequency range being measured*…

- causing meaningless intermodulation (IM) noise to appear on the screen, ruining the measurement

- **If we suspect this might be happening,** ***we do not use the analyser's attenuator!***
  - put an external 10dB through-line attenuator in series with the probe signal, at the analyser input…
  - if the signals are valid, they will reduce by 10dB…
    - but intermodulation noises will reduce by 20dB or more

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IM noise can be eliminated with filters…

- designed to attenuate the very strong out-of-band signal(s)…
  - and installed between probe and spectrum analyser
- 'Preselectors' are bandpass filters that automatically follow the spectrum analyser's measuring frequency…
  - but are not portable instruments and require a spectrum analyser that has a GPIB control bus
- Or else use an EMC 'Receiver' instead of a Spectrum Analyser

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Measuring radiated and conducted RF immunity

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Using close-field probing to check radiated immunity

- A wide variety of signal generators can be used with close-field probes to create very localised magnetic or electric fields, e.g.…
  - transient generators, as used for testing fast transient bursts or electrostatic discharge (ESD),
    e.g. as used for testing to IEC 61000-4-4 or -2..
  - or RF signal generators, with modulation and frequency sweeping capabilities,
    e.g. as used for testing to IEC 61000-4-3 or -6…
    - some people recommend fitting 50Ω resistors in series with loop probes, but most signal generators work happily into a short-circuit

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Using close-field probing to check radiated immunity
continued…

- Choose a signal source that corresponds with the type of EM phenomenon concerned…
  - e.g. RF; Fast Transients; ESD, etc…
  - and set-up the source accordingly…
    - e.g. for an RF signal: sweeping over the frequency range, with 1kHz sinewave amplitude modulation at 80% depth
- Set the test signal to a low level, then connect the probe to the output of the signal source

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The outputs of RF signal generators are not very powerful…

- …usually only enough to test individual devices with close-field or 'pin' probes…

- For other immunity tests they will usually need boosting by an RF power amplifier…
  - e.g. to test at the levels used by immunity standards, a current injection probe can need a 200W RF amplifier…
  - always connect a suitably powerful 50Ω RF resistor in series with close-field loop probes (or in parallel with E-field probes) to load the RF amplifier correctly

- ***Always*** **take *all* safety precautions when using EMC immunity test equipment, or RF power !!!**

Using close-field probing to check radiated immunity
continued…

- For radiated immunity (whether transient or RF), move the probe over the equipment just as we would for radiated emissions…
  - and observe the functions of the equipment being tested for errors or malfunctions…

- If no problems observed, increase test level and do it all again…
  - repeat until immunity problems are observed…
    - or the signal source is at maximum output

Using close-field probing to check radiated immunity
continued…

- If using swept (or stepped) RF, the sweep (step) rate should be slow enough for the equipment to respond…
  - which can mean moving the probe very slowly so that each area is exposed to the full frequency range…
  - or else test several times with a smaller sweep frequency range

Obtaining an immunity 'signature'

- Go through the fixed routine of scanning over the joints, displays, controls, connectors, conductors, etc. in exactly the same way…
  - the highest signal level that can be set before the functional performance becomes unacceptable is the immunity 'signature' for the item

- Compare signatures for significant differences…
    - useful for testing the effects of modifications

- Remember to always use the same probe, cables, signal generator and settings, test bench set-up, and the same routine

Using close-field probing to check conducted immunity
continued…

- For conducted immunity (whether transient or RF), follow the same procedure as for radiated immunity…
  - but this time holding the probe against the insulating jacket of the cable being tested…
  - close to where the cable enters or exits the equipment (e.g. < 100mm, as we do for conducted emissions)…
  - using the same probe orientation that we found gave the maximum emissions measurement for that probe…
    - larger-diameter probes may be preferred, because they are more sensitive to lower frequencies

Using close-field probing to check radiated or conducted immunity
continued…

- Individual devices can be tested by holding the probe very close to them…
    - don't forget to find the worst-case probe orientation

- Alternative techniques include using current probes to inject transient or RF currents directly into cables…
  - always check that the probe rating is sufficient…
    - manufacturers design current injection probes differently from current monitoring probes

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Using close-field probing to check radiated or conducted immunity continued…

¼ **'Pin probes' can be used to inject test signals directly into the pins of devices…**

– always start off with a *very* low test level

¼ **To find the maximum sensitivity of a device, modulate the RF signal with the same frequencies used by the device, e.g.…**

¿ 1MHz square wave clock for a chip connected to a digital bus clocked at 1MHz…

¿ 0.5Hz (or less) pulse modulation for analogue circuits with a long time constant (e.g. temperature sensors)

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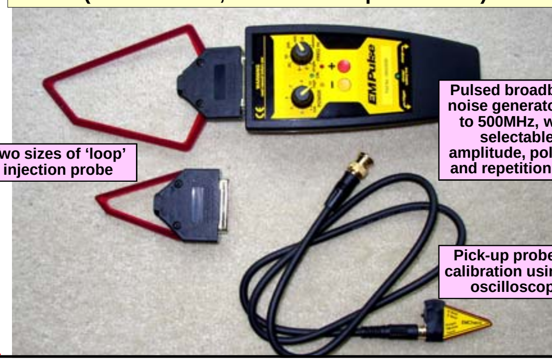
Example of a 'noise injector' product

(an 'EMPulse', visit www.empulse.co.uk)



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Cost-effective uses of close-field probing

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Assessing PCB decoupling, RF References, shielding effectiveness, and much more

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PCB uses of emissions probing

¼ **Using small probes with oscilloscopes and/or spectrum analysers, to (for e.g.)…**

– check/improve decoupling by monitoring Vcc noise…

– see if plane splits in planes are causing problems…

– monitor waveforms without making a connection, e.g…

¿ to check they are not suffering too much noise

¿ to see if transmission-line termination is good / needed

¿ to see which pins are associated with emission problems

– check switch-mode power converter designs for unwanted overshoots and ringing

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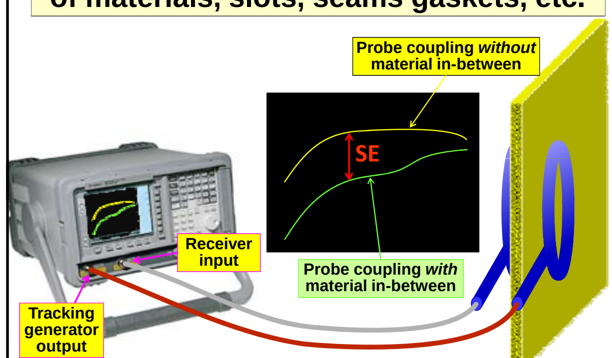
Assessing shielding effectiveness (SE) of materials, slots, seams gaskets, etc.



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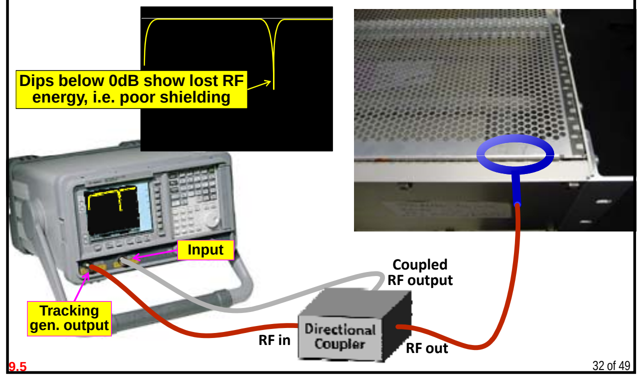
Assessing the SE of shielded *boxes*

– one probe inside the box (e.g. on one side of a seam) *connected to spectrum analyser via a bulkhead-mounted shielded connector…*
  - the second probe on the outside to look for 'leakages'

– if no tracking generator, place a battery-powered broadband noise emitter inside the shielded box…
  - and probe around the outside for 'leakages'

A range of York EMC Ltd noise emitters up to 40GHz

Using a directional coupler



Many more applications for probing with directional couplers, e.g…

– identifying circuit resonances, by the peaks and/or dips they cause in the response…

– detecting the frequencies of passive RFID antenna tags (and helping to tune them, if required)

- If used with current clamp instead of probe…

  – can measure resonances in cables and metalwork, e.g. to check…
    - transmission line terminations (DM and CM), cable shield terminations (at both ends), building installations' structural resonances, etc.

Cost-effective uses of close-field probing

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Detailed uses for close-field probing at every stage in a product's lifecycle

The 'proof of design principle' stage

- To check whether a new design idea might suffer costly EMC problems later in a project…

  – with either hardware or software

- 'What-if' EMC experiments are easy and quick when using close-field probes

Finding the 'highest frequency of concern'

- A great deal of EMC design depends upon the 'highest frequency of concern'…
  - e.g. the frequencies associated with the rise and fall-times of digital, switch-mode or PWM signals…

  – but data sheets don't include such information…
    - they might include maximum rise/falltimes, but we need to know their *minimum* values (highest frequency spectra)…

  – but close-field probing very quickly reveals the highest frequencies of concern…
    - for both emissions and immunity

Product Design

- It is very worthwhile making experimental test boards or assemblies…
  - to check alternative EMC design approaches *before committing a lot of design effort*
- This is especially important when adopting a new technology…
  - e.g. new types of microprocessors, power switchers, etc..

Component selection

- Some apparently similar ICs have *much* worse emissions or immunity than others…
  - I have seen >>40dB difference between equivalent types of microprocessors that cost the same!
- Close-field probing can very quickly identify which ICs should be avoided…
  - e.g. by comparing results when directly probing ICs…
    - either on their manufacturers' evaluation boards…
    - or operating on experimental boards (which don't have to be designed like the final boards)

Product Development

- Quickly reveals errors in…
  - printed-circuit board layout (traces and planes)…
  - IC power supply noise and decoupling…
  - shielding realisation…
  - filter realisation…
  - wiring harness construction and cable types…
  - cable shield and filter bonding methods…
  - connectors and glands…
  - etc.

Diagnosing compliance test failures

- When trying to solve a problem at a particular frequency, it is tempting to only scan at that frequency…
  - but fixing a problem at one frequency often causes another problem to pop up at a different frequency!
- So, before starting work, we obtain a signature over the whole tested range (see earlier)…
  - and after an (apparently) successful modification, we always check the whole frequency range again, to make sure no problems have been introduced

QA in volume manufacture

- Different IC batches can have different EMC performance, which can be quickly identified at goods-in by close-field probing
- Non-compliance can result from device tolerances, variations in assembly methods, assembly errors, design changes, etc…
  - can be easily and quickly checked by using emissions 'signatures' as described earlier…
    - if emissions exceed the original by some margin (say >10dB) it tells us that something is wrong, and an in-depth investigation is required

QA in volume manufacture continued…

- For goods-in and volume manufacture…
  - it is important to design EMC test fixtures that can easily be used by unskilled people…
  - and to program the test instruments so they do their job automatically…
  - so all the operator has to do is install the item to be tested in the test fixture, and press 'start'…
  - and look for a green light for 'pass', and a red one for 'fail' (or whatever we prefer)

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QA in volume manufacture continued…

- Why not connect the production EMC test equipment to the main computer system…
  - to help identify *trends* in EMC performance before they become serious issues…
  - because it is much less costly to take action *before* manufacturing a batch of non-compliant products…
    - it's important for *much more* than legal compliance – because products that fail EMC tests are generally unreliable in real life: increasing warranty costs and losing future sales

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Checking the EMC consequences of proposed: design changes, component substitutions, software upgrades, etc.

- The proposed design change is applied (or simulated) on a unit whose close-field probe emissions 'signature' (see earlier) is known…
  - then the new 'signature' acquired and compared with the original…
  - to see if the proposed design change needs more EMC work (e.g. changes to filtering, shielding)….
  - and/or whether the modified product will need to be put through its compliance tests again

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Systems integration and installations

- Close-field probing makes it easy to quickly check whether EMC performance has been compromised by poor assembly, e.g…
  - incorrect filter grounding..
  - incorrect cable shield termination…
  - incorrect type of shielded cable used…
  - incorrect cable routing…
  - missing EMC gaskets…
  - paint over RF bonding areas…
  - fixings not tight enough…
  - etc.

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Maintenance, repair, modifications and upgrades

- Obtain a close-field probe '*signature*' for the product, system or installation when new…
  - or at least, before the maintenance, modification or upgrade occurs…
  - then repeat the exact same procedure afterwards
- Compare the two signatures…
  - to see if the emissions have significantly worsened

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Poll questions

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Cost-effective uses of close-field probing in every project stage: emissions, immunity and much more

the end

Presenter Contact Info
email: keith.armstrong@cherryclough.com
website: www.cherryclough.com

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Cost-effective uses of close-field probing

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Some useful references

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Some useful references...

- ***EMC Testing,*** **by Tim Williams and Keith Armstrong, EMC Compliance Journal, 2001-2002, available from www.cherryclough.com and www.theemcjournal.com**
  - **this is a series with 7 parts, Parts 1 and 2 are especially relevant to close-field probing**
- ***Susceptibility Scanning as a Failure Analysis Tool for System-Level Electrostatic Discharge (ESD) Problems*****, G. Muchaidze *et al,* IEEE Transactions on EMC, Vol. 50 No. 2 May 2008, pages 268-276**
- ***Measuring Structural Resonances*****, Doug Smith, Technical Tidbit, June 2006, www.emcesd.com/tt2006/tt060306.htm**
  - **lots more on close-field probing at Doug's website: www.emcesd.com**

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Some useful references... continued...

- ***Benchtop EMC Testing Techniques for Medical Equipment*** **(using close-field probes), Scott Roleson, Medical Device & Diagnostic Industry Magazine, January 1998, www.devicelink.com/mddi/archive/98/01/025.html**
- ***Evaluate EMI Reduction Schemes with Shielded-Loop Antennas*****, Roleson S, *EDN, 29(10):203—207, 1984.***
- ***Finding EMI Resonances in Structures*****, Roleson S, EMC Test Design, 3(1):25—28, 1992**
- ***Measuring resonance in cables,*** **Ken Wyatt, EDN, October 29, 2013, www.edn.com/electronics-blogs/the-emc-blog/4423597/Measuring-resonance-in-cables**
- ***Near field probes: Useful tools for Electronic Engineers,*** **Dr. Arturo Mediano, EMC-Europe 2013, Bruges, 2-6 Sept, Short Course 1**

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