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**Close-field probing series
Webinar #1 of 2, November 20, 2013**

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



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1 of 43

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2 of 43

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Contents

Webinar #1 of 2, November 20, 2013

- 1 Introduction
- 2 Making our own close-field probes
- 3 Buying close-field probes and low-cost spectrum analysers
- 4 Current probes, pin probes, other useful types of probes
- 5 Using close-field probes

Webinar #2 of 2, March 26, 2014

- 6 Measuring radiated and conducted RF emissions
- 7 Avoiding overload (inc. out-of-band) and intermodulation
- 8 Measuring radiated and conducted RF immunity
- 9 Assessing PCB decoupling, RF References, shielding effectiveness, and much more
- 10 Detailed uses for close-field probing at every lifecycle stage
- 11 Some useful references

3 of 43

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Cost-effective uses of close-field probing

1

Introduction

1.1 4 of 43

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Close-field EMC probing (often called near-field probing) is difficult to do accurately

- ¼ But it is an excellent qualitative technique
- ¼ It can quickly identify emissions problems, when used with a spectrum analyser ('receiver')...
- ¼ It can quickly reveal weak points for immunity, when used with transient and/or radio-frequency (RF) generators...
- ¼ And it can help design PCBs, shielding, and much else

1.2 5 of 43

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Close-field EMC probing is low-cost and very useful

- ¼ We can easily make close-field probes...
 - ε even from a paper clip...
 - and they can be used to great effect with spectrum analysers costing as little as £800...
 - or with oscilloscopes that we already have (it helps to be able to do Fourier transforms in our heads!)
- ¼ Once people learn to use close-field probes...
 - they wonder how they ever managed without them!

1.3 6 of 43

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Cost-effective uses of close-field probing

2

Making our own close-field probes

2.1 7 of 43

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Easily make two kinds of close-field probes

- ¼ The *magnetic field probe*...
 - a 'shorted turn' shielded from electric fields, sometimes called a 'loop' probe
- ¼ The *electric field probe*...
 - a very short 'whip' antenna
- ¼ The largest probe dimension should be less than 1/6th of the wavelength at the highest frequency to be measured (e.g. < 1GHz: < 50mm dia.)

2.2 8 of 43

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Construction of a good-quality close-field magnetic probe

Both shields soldered to the shielded metal case

50Ω BNC connects to 50Ω cable

Common-Mode choke (bifilar wound on a soft-ferrite toroid)

A loop of 'microwave semi-rigid' with a short central break in its shield

Typical diameter 10 - 50mm

The loop should be suitably insulated (two individual layers recommended, each rated for the maximum voltage)

2.3 9 of 43

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An easier magnetic field probe design (but lower performance)

Shield and centre conductor both soldered to shield

Epoxy, or other strain relief

50Ω BNC

Suitably insulated

'Microwave semi-rigid' loop with central break in shield

Would benefit from a CM choke, or at least a ferrite toroid on the lead that connects the probe to the measuring instrument

2.4 10 of 43

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An even easier magnetic field probe (with even lower performance)

Only the centre conductor is soldered to the shield

Epoxy, or other strain relief

50Ω BNC

Suitably insulated

No central break in the shield

Would benefit from a CM choke, or at least a ferrite toroid on the lead that connects the probe to the measuring instrument

2.5 11 of 43

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Construction of an electric field probe

Centre conductor of "microwave semi-rigid" exposed by 5 - 10mm, and insulated

50Ω BNC

Epoxy, or other strain relief (preferably a shielding metal case, soldered to the shield of the semi-rigid)

Suitable insulation (two individual layers recommended, each rated for the maximum voltage to be probed)

Would benefit from a CM choke, or at least a ferrite toroid on the lead that connects the probe to the measuring instrument

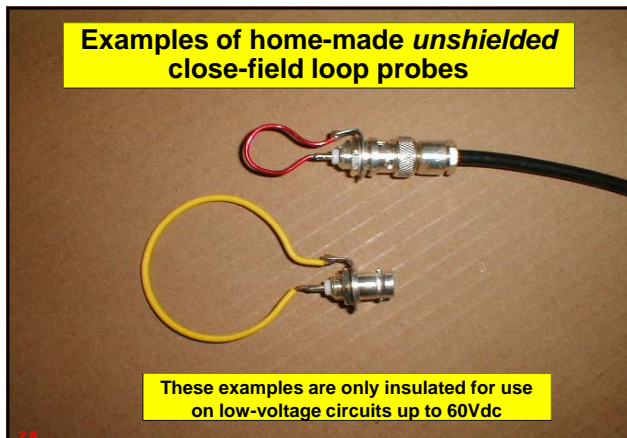
2.6 12 of 43

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Unshielded loop probes

- ¼ Close-field probing using magnetic-field probes will not detect *electric* fields...
 - and an electric-field probe will not detect *magnetic* fields
- ¼ So, sometimes a simple loop of unshielded wire can be helpful...
 - this will detect both *magnetic* and *electric* fields...
 - can save time in locating problem areas when the nature of the source is unknown

2.7 13 of 43

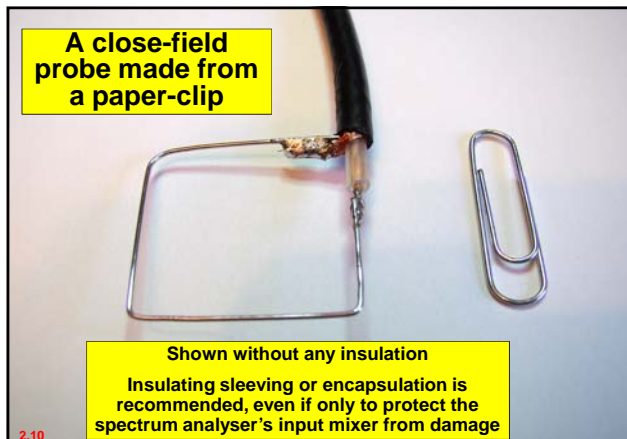


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Many close-field probes are circular

- ¼ But rectangular probe shapes can be more convenient...
 - for testing flat items such as printed-circuit boards (PCBs)

2.9 15 of 43



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A variety of other probe designs are possible

- ¼ Multi-turn coils have more sensitivity...
 - but resonate at lower frequencies than a single-turn coil of the same diameter...
 - due to the capacitive coupling between the turns
- ¼ Some people wind tiny coils on the sharpened points of pencils, for measuring up to 30GHz...
 - the resulting tiny cone-shaped multi-turn winding helps reduce resonances whilst increasing sensitivity

2.11 17 of 43

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A variety of other probe designs are possible continued...

- ¼ Some people use half of an RF ferrite cylinder or toroid and put a turn or two around it...
 - the ferrite acts as an antenna for magnetic fields...
 - commercial products based on this principle are often called 'surface current probes'

2.12 18 of 43

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POLL QUESTIONS

19 of 43

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Cost-effective uses of close-field probing

3

Buying close-field probes and low-cost spectrum analysers

20 of 43

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Commercially-available close-field probes

There are a number of suppliers of close-field probes...

- most of them have built-in amplifiers, or are too weak for other reasons, so *must not be used for immunity testing...*
 - ↳ because they *won't* work, and they *will* be damaged...
- and some are calibrated in dBµA/m (H-field) or dBµV/m (E-field)

21 of 43

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Aronia AG, E & H near-field probe set DC - 9GHz, PBS2 preamplifier



Laplace Instruments RF-100



ETS-Lindgren 7405 with optional preamplifier

22 of 43

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Some of the many close-field probe kits from Langer EMV-Technik 100kHz to 6GHz, E & H field

23 of 43

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Agilent 11945A kit, H-field 9kHz-30MHz, H-field 30MHz-1GHz plus preamp
 Low price for 2nd-user (ebay, etc.)

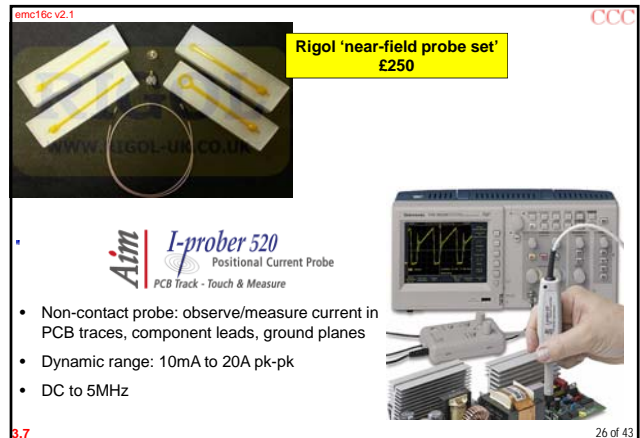
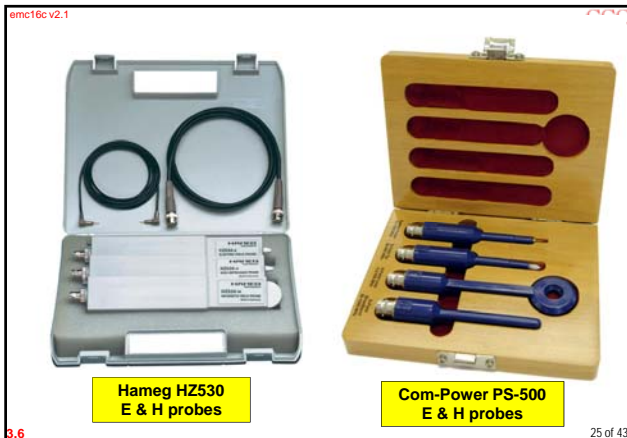


Teseq NFPS1 set, H-field 9kHz-30MHz, H-field 30MHz-1GHz, E-field 9kHz-1GHz built-in preamps



Agilent N9311X-100 set, H-field 30M-3GHz (looks like Langer RF2 !)

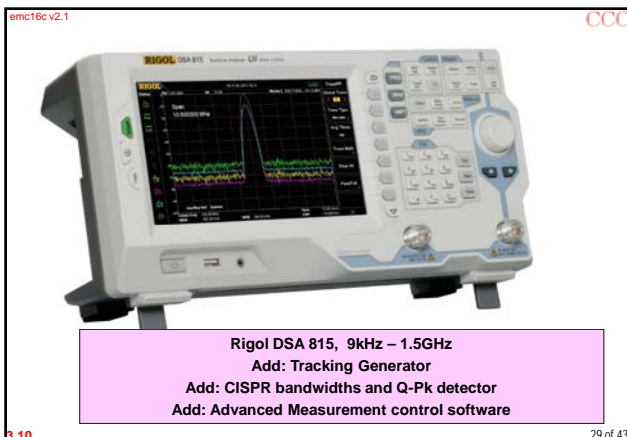
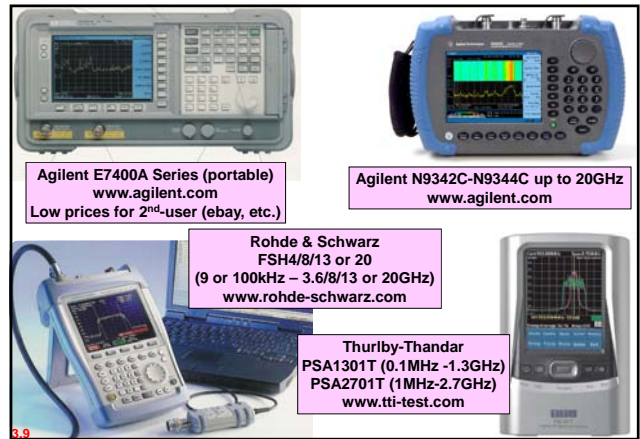
24 of 43



A wide variety of low-cost spectrum analysers are available

Used with close-field probes (or current probes, see later) to check conducted or radiated emissions... and for design diagnoses/assessments

There are expensive models with a variety of sophisticated functions... including CISPR Quasi-Peak and Average detectors... and there are medium and low-cost models... available to over 6GHz



Cost-effective uses of close-field probing

4

Current probes and pin probes

These are not close-field probes, but are also very useful for cost-effectiveness in all lifecycle stages

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Current probes can also be very useful

• 20 Hz to 1 GHz
 tip-on, fixed window and ace types
 jaw sizes 1/2" to 5"
 direct connection to conductor
 s-fer impedances from 1 to 10 ohms
 pulse handling capabilities > 6,000 amps

Provide accurate measure of RF current within an electrical conductor for ...

4.2 31 of 43

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Current probes measure the RF current in a cable

¼ If placed around the whole cable, they measure its common-mode (CM) current...
 – which is usually the current that causes most of the radiated emissions

¼ If placed around an individual conductor...
 – they measure the differential-mode current, which is usually the wanted signal or power current plus some RF noise

CCC 32 of 43

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Example of a 'home-made' current probe

50Ω through-line termination (for oscilloscopes with high-impedance inputs)

Cable under test passed through hole in ferrite cylinder along with the loop of co-axial cable

Split RF suppression ferrite cylinder in a plastic clip-on housing

Loop of co-axial cable, with centre conductor bonded to shield

4.4 33 of 43

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Current probes continued...

¼ If the measured CM currents on a cable exceed 2.5µA between 30 and 230MHz...
 – the product could fail Class B radiated limits due to that cable alone, when tested on a 10m OATS...
 • 5.6µA maximum for Class B between 230MHz and 1GHz
 • 7.9µA and 17.7µA respectively for Class A

¼ Measuring CM currents requires "transducer correction factors" for each individual probe...
 – obtained by measuring output currents from a signal generator (calibrated output voltage) into 50Ω resistor

CCC 34 of 43

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'Pin probes' can also be useful...

• ...although they are not really close-field probes...

– for measuring the voltage noise on the wanted signal...
 – or injecting RF currents and/or voltages...
 – directly into IC and semiconductor pins

4.6 35 of 43

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Construction of a 'pin probe'

Epoxy, or other type of strain relief

Suitable insulation (two individual layers recommended, each rated for the maximum voltage to be probed)

50Ω BNC

Low-value capacitor (e.g. 10pF) with suitable voltage rating, soldered in series with centre conductor.

Pin exposed for direct contact

Both would benefit from a CM choke bifilar wound on a soft-ferrite toroid as shown earlier, or at least a ferrite clipped onto their lead

4.7 36 of 43

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5

Using close-field probes

5.1 37 of 43

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The most important issues

- ¼ **Don't damage the spectrum analyser, or the equipment being probed !!!**
 - z e.g. by touching a conductor with a part of a probe
- ¼ **Don't electrocute yourself, or others !!!**
- ¼ **Only use probes that are insulated to withstand the maximum possible voltage of the circuits to be probed...**
 - i.e. which comply with all relevant parts of both IEC 61010-1 and IEC 61010-031...
 - and don't have any damage to their insulation

5.2 38 of 43

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Using close-field probes continued...

- ¼ **The probes are sensitive to near-field signals...**
 - so tend to ignore ambient RF noise...
 - making it easier to identify EMC problems
- ¼ **They must be held very close to an item to operate, and are usually used to probe...**
 - seams and apertures in shielding enclosures...
 - cables and connectors...
 - PCB traces, ICs, transistors and heatsinks

5.3 39 of 43

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Using close-field probes continued...

- ¼ **Some regions of some types of probes are more sensitive than others...**
 - so for repeatability it is important to use the probe the same way each time
- ¼ **Loop probes (magnetic-field) are polarised...**
 - they pick-up or emit magnetic fields more strongly when the fields are perpendicular to the plane of the loop...
 - so orienting the loop can help identify where a problem is located

5.4 40 of 43

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Close-field probes are all different

- ¼ **It is difficult to make comparisons between the results of different designs of close-field probes...**
 - and there is no direct comparison between close-field probe test results and the results of 'proper' EMC tests

5.5 41 of 43

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Close-field probes are all different continued...

- ¼ **But if we keep using just a few particular probes with specific items of test equipment (spectrum analyser, signal generator, etc.)...**
 - and use them to test equipment that has passed (or failed) full-compliance EMC tests...
 - we soon become familiar with how our probes' results compare with 'proper' EMC testing

5.6 42 of 43


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43 of 43

