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RF Current Probes versus LISNs for Assessing Conducted Emissions

When it comes to assessing conducted emissions, which do you use; an RF current probe or a line impedance stabilization network (LISN)? As in all things related to EMC, it depends. The 5 μH or 50 μH LISN is specified by the appropriate EMC standards depending on your product type for compliance testing, so that would be the method of choice, normally. The RF current probe is useful for measuring common mode (CM) RF currents in cables or wires, although, it can be configured to measure differential mode (DM) currents.

EMI Troubleshooting versus Pre-Compliance Testing

Before we decide on whether to use a LISN or current probe, let's first look at the difference between general troubleshooting and pre-compliance testing. General troubleshooting is usually performed with a current probe and a spectrum analyzer or oscilloscope. The goal is to identify sources of RF harmonic currents in attached I/O or power cables and to help determine fixes that reduce the resulting harmonic product emissions. For troubleshooting, we're mainly looking for relative changes.

Pre-compliance testing, on the other hand, attempts to duplicate the way the compliance tests are run to the best ability possible and to compare with actual test limits. This requires copying the test setup used by the compliance test labs as best we can, given the facilities available.

Conducted Emissions - Conducted emissions testing for industrial, scientific, commercial, consumer and medical products is performed according to CISPR 11 or 22 and requires a LISN between the source of AC (or DC) line voltage and the product under test. A spectrum analyzer is connected to the 50 Ω port and the conducted RF noise voltage is displayed on the analyzer. Different model LISNs are made for either AC or DC supply voltage. In addition, you may want to add a calibrated transient protector to protect the input of the analyzer in case of power line transients when switching from line to neutral or when powering up the EUT.

A 5 μH LISN, such as the Com-Power Model LI325C, is used for most DC-powered products and the 50 μH LISN, such as the Com-Power LI125C is used for AC line-powered products and for MIL-STD-461 testing. The LISN must be placed over, and bonded to, a conductive ground plane according to the standards. The LISN measures the vector sum of the CM and DM currents. What you measure on the output port is a voltage across a 50 Ω load and is usually expressed as dBμV, which will match the limits according to the standards.

While the LISN and current probe methods are similar, they do not provide the same answer. The LISN outputs a voltage that is the vector sum of both CM and DM, while the RF current probe normally just measures CM when simply clamped around a cable. If the power wiring in the measured cable is inserted into the probe aperture such that the differential currents add, then the DM measurement can be recorded. That is, a current probe can measure either CM or DM, but not both together. See details below.

General troubleshooting with an RF current probe

Clamping a current probe around a wire or cable will measure the CM RF currents flowing in that wire or cable. They typically use a toroidal core of broadband ferrite or similar material and are simply an RF transformer with the measured wire or cable as the primary winding and the measuring port, the secondary (Figure 1). The frequency range and sensitivity of the probe will depend on the type of material used and the number of turns of wire wound around the core on the secondary winding. The Com-Power RF current probes are calibrated form 10 kHz to 400 MHz. The ratio of output voltage at the secondary and measured current on the primary is known as the transfer impedance or transducer factor and is expressed in Ohms or dBΩ.

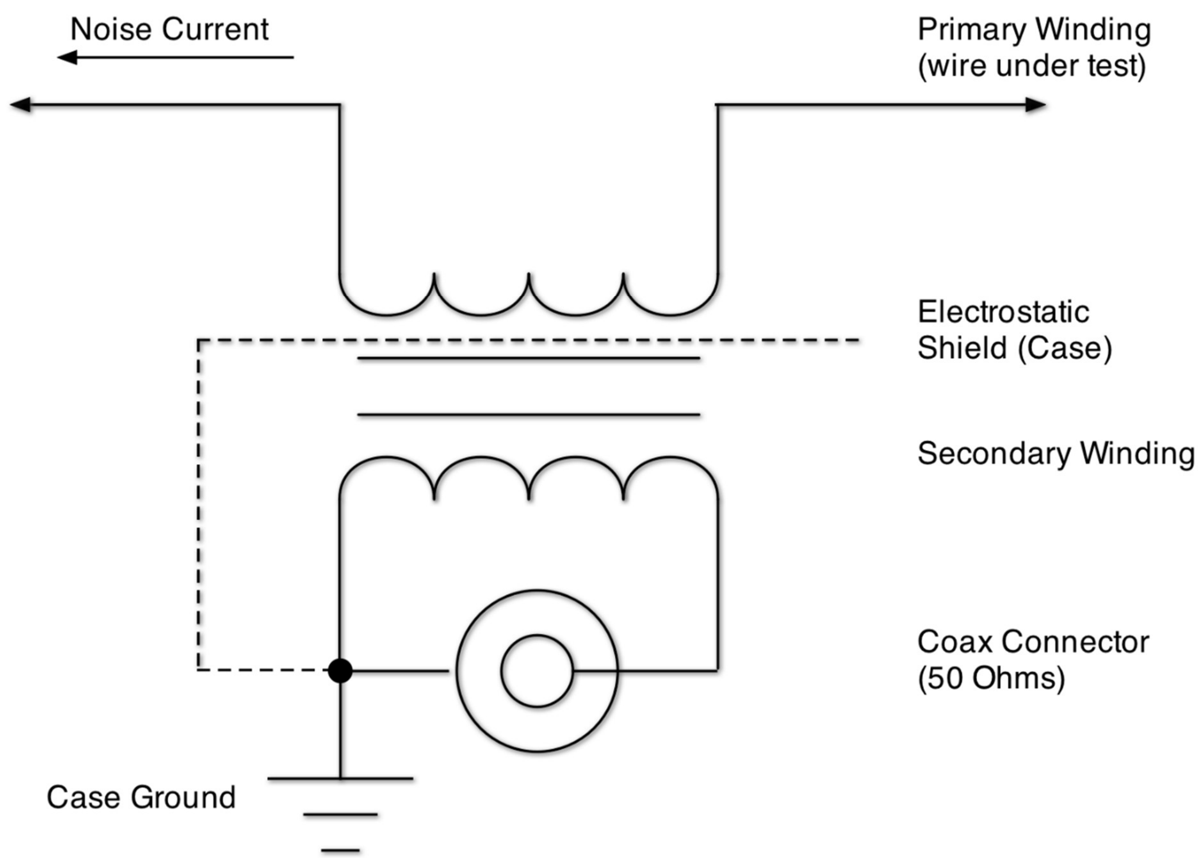

Figure 1 – A current probe is simply a transformer that measures the current is a wire or cable and a voltage is measured at the output port. Calibrated current probes will come with a transfer impedance chart allowing you to convert the measured voltage to the current flowing through the wire or cable.

Current probes, such as the Com-Power Model CLCE-400 or CLCE-452 are very useful as a troubleshooting tool and may be used with either spectrum analyzers or oscilloscopes. Measuring current on I/O or power cables can indicate which cables may be the main cause of radiated emissions. The reduction of RF currents on those cables can often reduce the radiated emissions from the equipment under test. Importantly, by knowing the harmonic common-mode current flowing in the cable at a certain frequency you can calculate the expected E-field emission level and compare to the radiated emission limit. In other words, you can predict pass/fail for a particular cable by simply measuring the RF current through that cable (Reference 1).

Pre-Compliance or Formal Compliance Testing

In the case of pre-compliance or compliance testing, you'll need a calibrated LISN and to duplicate the test setups as best you can. This is easier than most EMC tests, because the test setups are pretty straightforward.

The test setup according to CISPR 11 or 32 for industrial, scientific, commercial, consumer or medical products is shown in Figure 2. This requires a 50 μH line LISN. Frequencies are tested from 150 kHz to 30 MHz using average or quasi-peak detection.

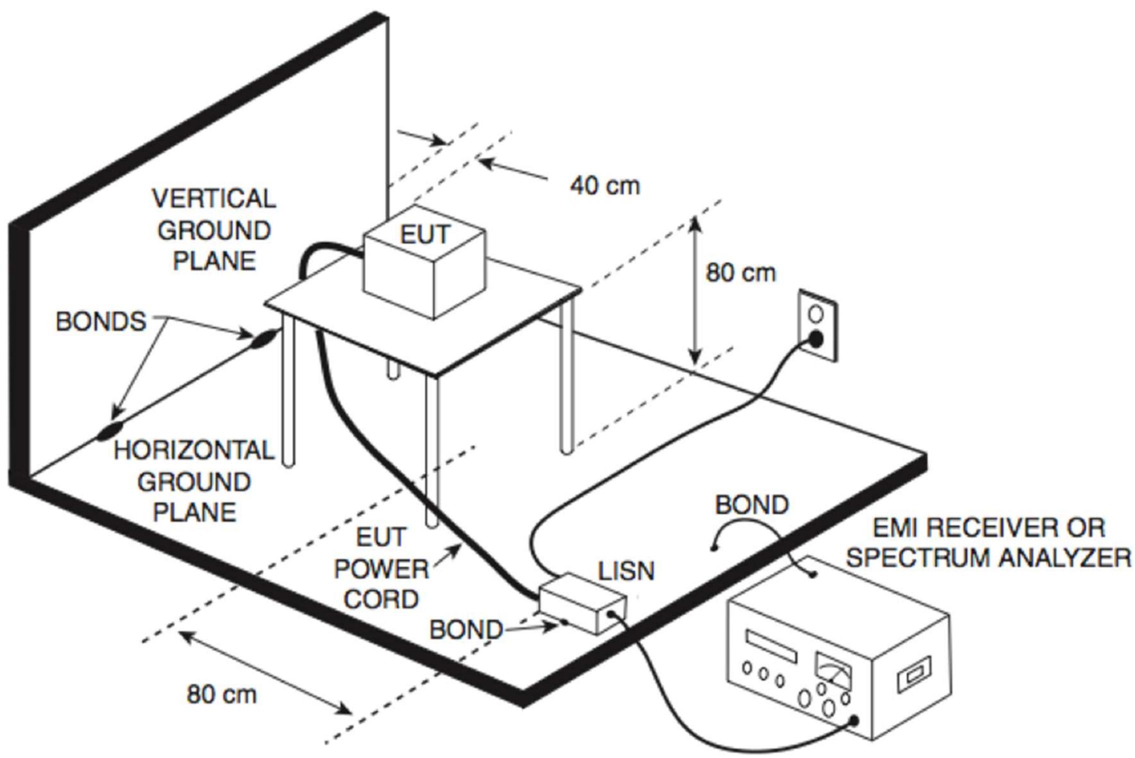

Figure 2 - The basic test setup for CISPR 11/32 conducted emissions. Refer to the latest standards for details.

For automotive testing of components, modules or systems according to CISPR 25, we use the test setup in Figure 3 and a 5 μH LISN. A metal table top and cable arrangement is used similarly to the MIL-STD test setup below. Automotive testing is complex and often manufacturers will have their own specific standards and limits, but based largely on CISPR 25.

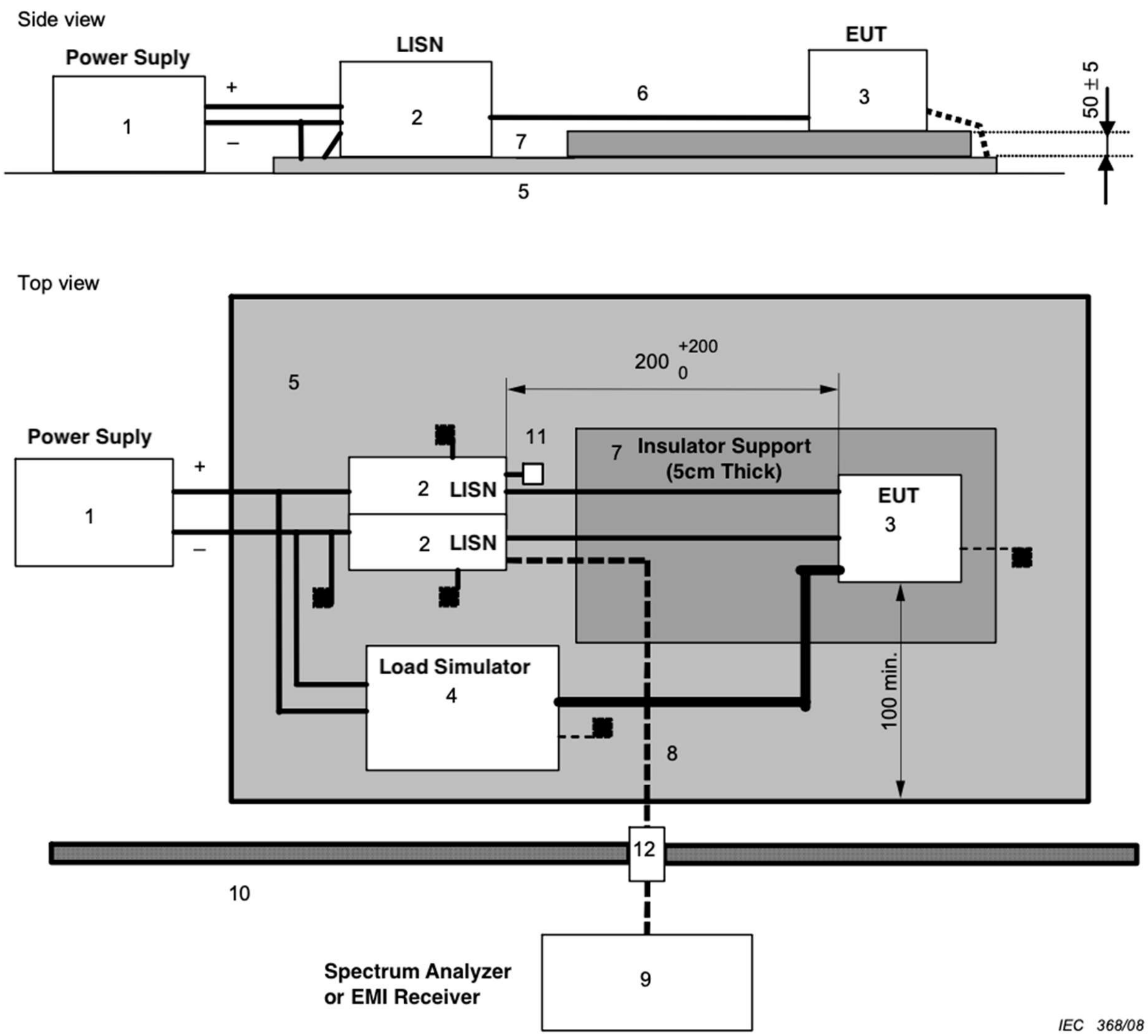

Figure 3 - An example of a general test setup for CISPR 25 testing. Testing components or modules uses a similar setup Refer to the latest standard for details.

The test setup according to CE102 MIL-STD-461 uses a 50 µH LISN (according to the latest MIL-STD-461G). Most military EMC tests are tested in a similar environment to where the product is to be installed. Therefore, the test is generally performed on a metal tabletop with the power cable running 5 cm above the metal plane and stretched out to 2 m length (Figure 4). Frequencies are tested from 10 kHz to 10 MHz.

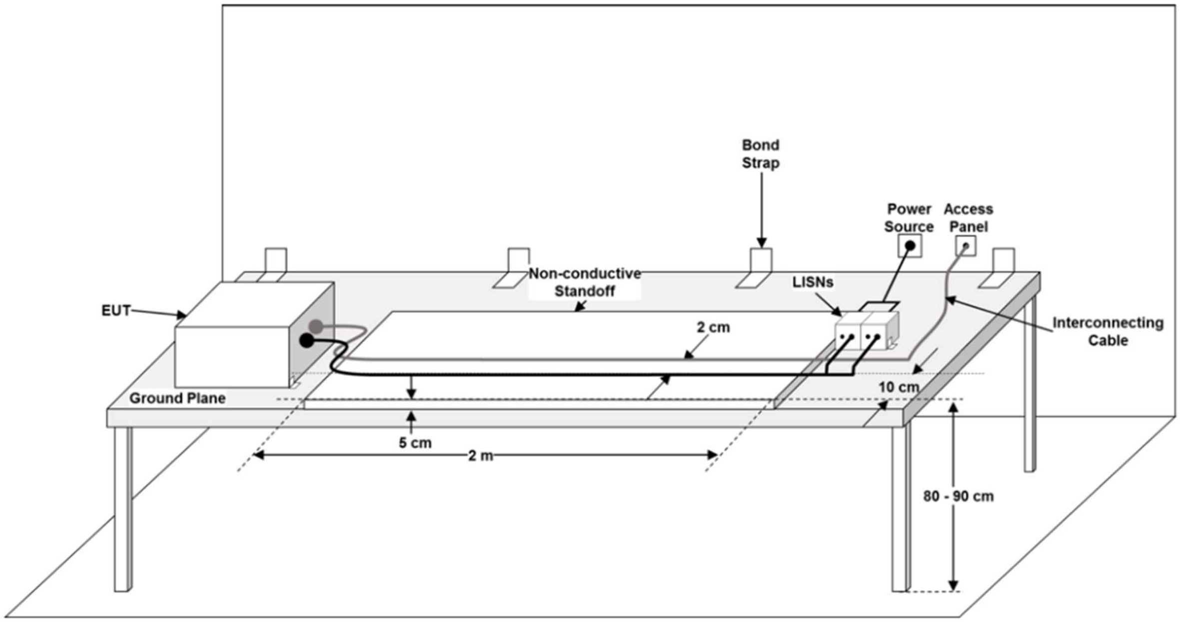

Figure 4 – An example of the test setup for CE102 conducted emissions per MIL-STD-461.

One issue is that when testing outside of a shielded room or semi-anechoic chamber, there may be a number of ambient signals from sources like FM and TV broadcast transmitters, cellular telephone, and two-way radio. This would also include interference from noisy power lines, other equipment, LED lighting or power sources in the immediate vicinity. This is usually less of an issue for conducted emissions than for radiated emissions, but these ambient emissions may exist along with those of the EUT.

This is especially an issue when using current probes described below. It's a good practice to run a baseline plot on the analyzer using "Max Hold" mode to build up a composite ambient noise floor plot (EUT off). Then, activate additional traces for the actual measurements. For example, it's common to display three plots or traces on the screen; the ambient baseline, the "before" plot, and the "after" plot with some fix applied.

Bench top testing

It’s important to bond the LISN to a ground plane, but for most bench top products, you may rig up a quick troubleshooting test by placing aluminum foil on the workbench, bonding the LISN to that with copper tape or taped down braid and placing the EUT on top of the foiled area. This ground plane (foil) allows a path for common mode currents to return back to the LISN.

For DC-powered automotive (and sometimes for 115 VAC 400 Hz applications for military) products, we use a 5 μH LISN using the same basic test setup. A temporary test setup may be set up on the workbench, similar to the AC mains test. While this is not exactly the setup used in CISPR 25, it should at least reveal any “red flags”.

Troubleshooting conducted emissions with an RF current probe

While the measured results differ between LISNs and current probes, the current probe can still give an approximate indication of peaks in conducted (CM) EMI. In particular, if your product is failing at the compliance test lab, clamp your current probe around the power supply (DC or AC mains) and take a measurement. You can compare this to their formal LISN measurement and get some idea where failing frequencies occur. From that reference point, you may try various filtering mitigations in-house, where there are usually better resources on hand.

Figure 5 - A Com-Power CLCE-400 RF current probe measuring the line cord common mode harmonic emissions on a product under test.

Figure 6 shows a common mains filter topology, where the "X" capacitor, in conjunction with the DM inductance of the CM choke, forms the DM portion of the filter and the "Y" capacitors and CM choke form the CM portion of the filter.

Depending on the situation, either the DM or CM (or both) currents will dominate from a product power supply. Depending on which dominates will determine which type of filtering needs to be improved.

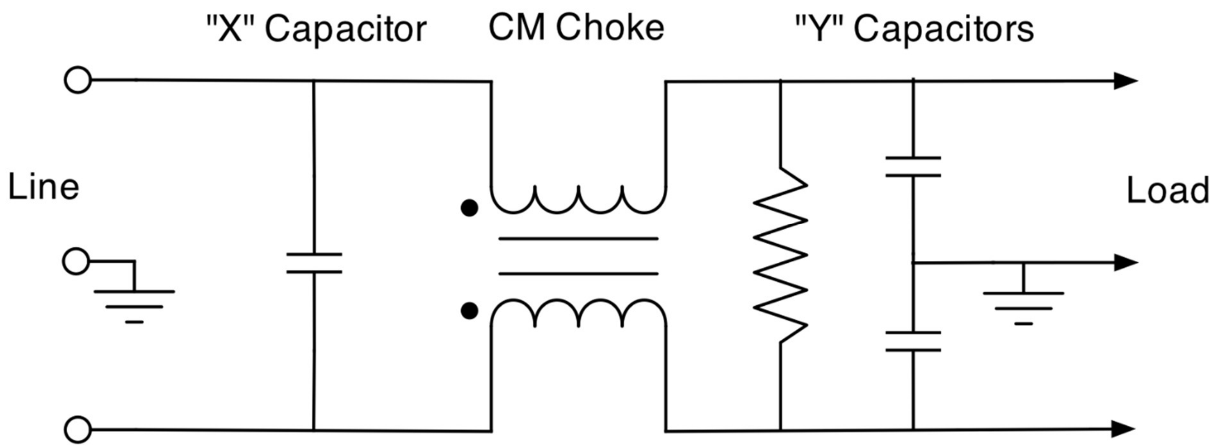

Figure 6 - A common topology for a mains EMI filter.

A standard RF current probe, can also be used to assess either CM or DM currents, depending on how the power wiring is passed through the probe aperture. Figure 7 shows the conventional method for measuring common mode currents and Figure 8 shows a method where the common mode currents are canceled and twice the DM current is measured (a 6-dB increase).

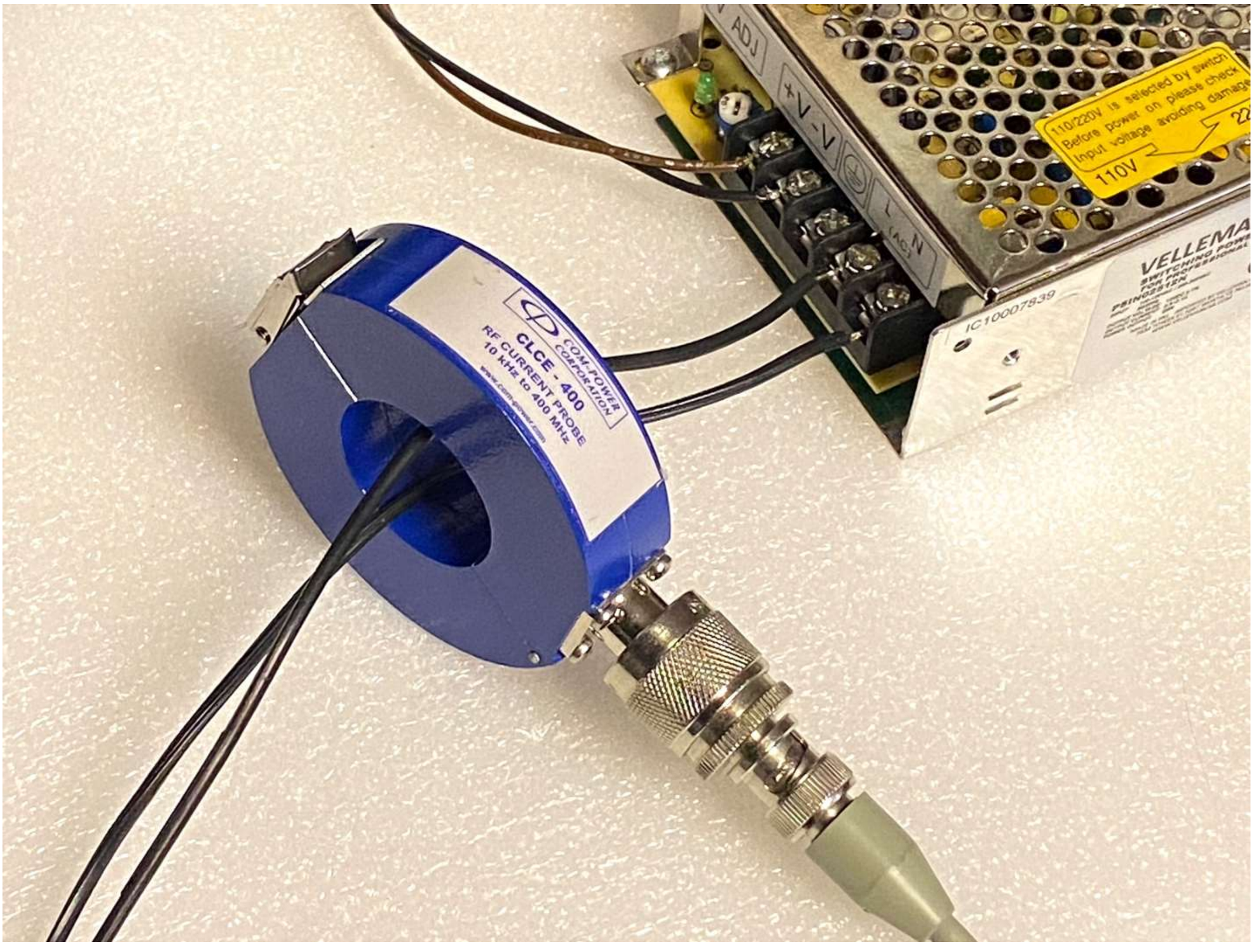

Figure 7 - When both mains wires pass through the probe aperture together, you'll measure common mode harmonic emissions.

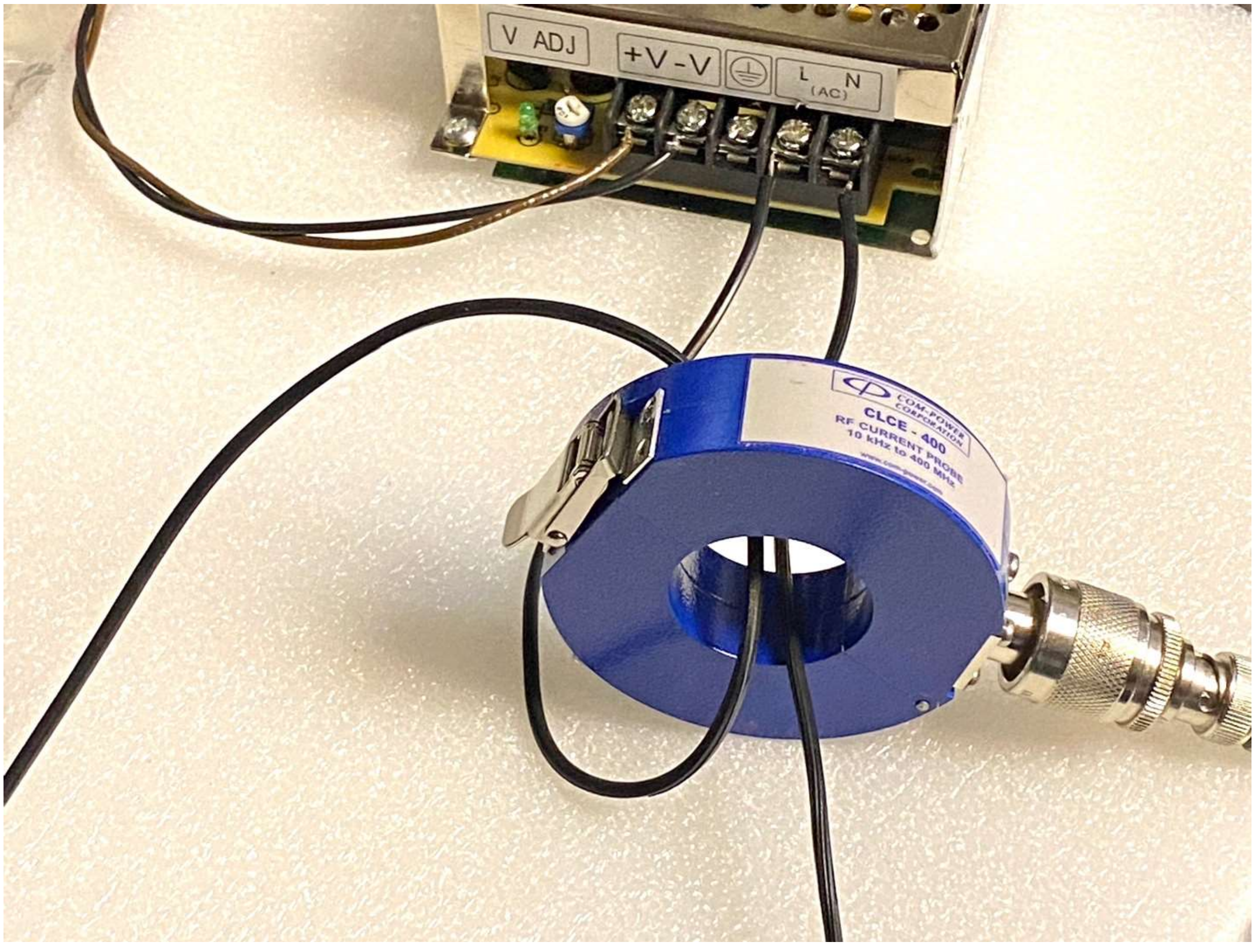

Figure 8 - By looping one side of the mains in the opposite direction through the probe aperture, the common mode currents are canceled and you'll measure twice the differential mode harmonic emissions.

Summary

Comparing the measurement results between a LISN and RF current probe will be different, but the common RF current probe can be used to generally gauge the level of conducted emissions from the EUT and so is useful for troubleshooting. However, if you wish to perform accurate pre-compliance testing in order to compare exactly to the measurements used by a compliance test lab, then a LISN must be used, along with a compliant test setup.

References

1. *The HF Current Probe: Theory and Application*: