Dynamic Testing Of A Dual Line Filter For Common And Differential Mode Attenuation using a Spectrum Analyzer

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Introduction

In today's EMC environment, dual line filtering is needed on diverse items such as motors, entertainment electronics (CD players, video cameras, digital cameras), personal computers (fan motors, disk drives, printers), and other consumer goods. Both common and differential mode noise need to be reduced. There are very few test procedures that measure the effects of a dual line filter in its dynamic state. Typically, a dual line filter is tested in a static state, each side being tested separately, showing the insertion loss of each line. The authors will describe a test methodology in which a spectrum analyzer with a tracking generator and a current probe are used for the dynamic testing of a dual line filter.

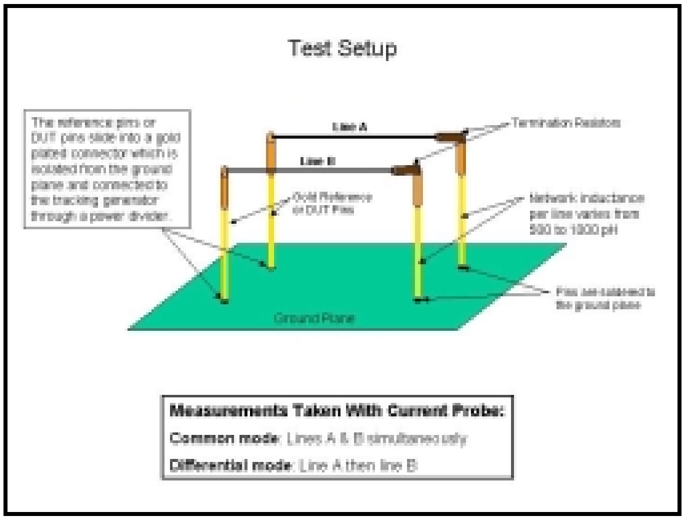

Figure 1. Measurement test setup.

Test Configuration

The test setup is shown in Figure 1. Several different dual line filter configurations are used for the device under test (DUT), as shown in Figure 2. The DUT is characterized using the tracking generator from the spectrum analyzer as the noise source for the measurements. The tracking generator is connected to a power divider so both sides will receive equal amounts of noise. The actual test is conducted on a ground plane with the DUT pins isolated from the ground plane. The other side of the DUT is connected to miniature transmission lines, as shown in Figure 3. The different filter configurations that need reference ground are attached to the top of the ground plane and the transmission lines are terminated to a 50 ohms load per line. The line A & B combination will have the two load resisters in parallel, so the combined load is ½ the single line load. The load termination can be changed to match the real world resistance of the electronic module requiring filtering.

A small current probe is used to measure both lines A & B (common mode) as shown in Figure 4, line A (differential mode) as shown in Figure 5, and then line B (differential mode) as shown in Figure 6. In Figures 4 through 6, the current probe is placed on a plastic spacer to position the probe consistently, for all measurements. A baseline is done using gold plated pins to set the reference level of the tracking generator. Once the baseline is established, the pins are removed and the DUTs are substituted in their place.

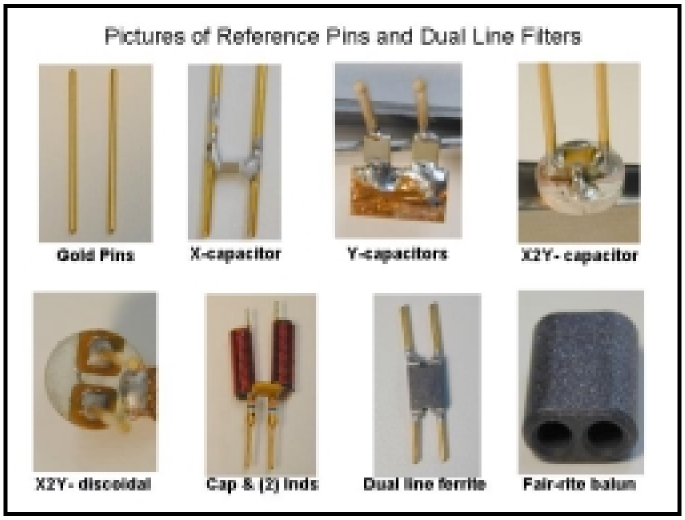

Figure 2. Devices under test (DUT).

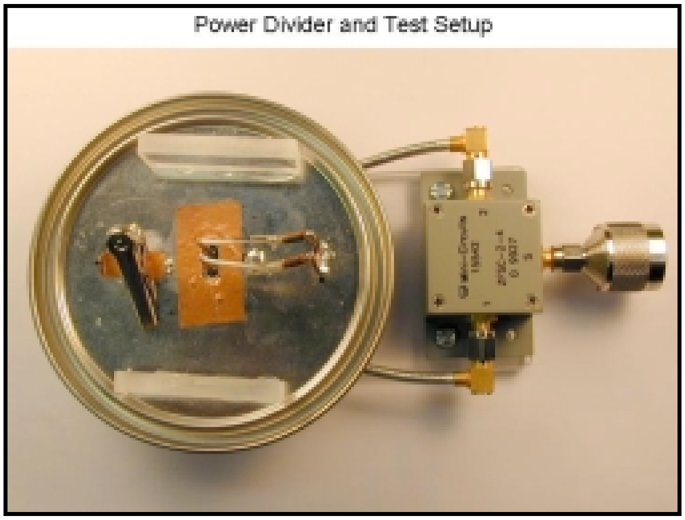

Figure 3. Test setup with miniature transmission lines.

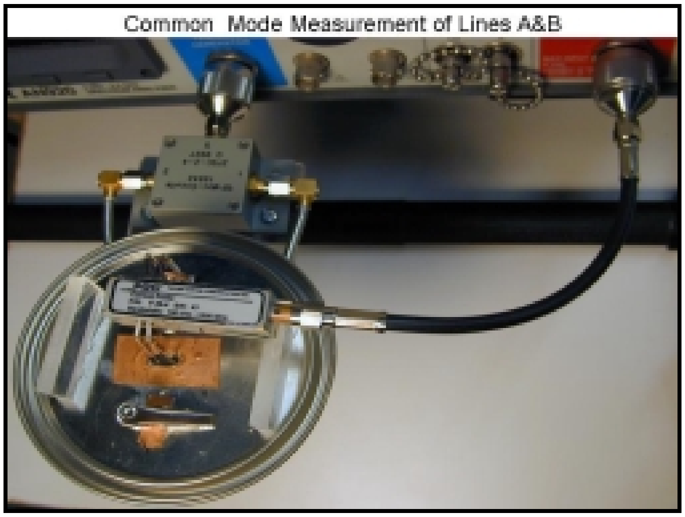

Figure 4. Common mode measurement of lines A & B.

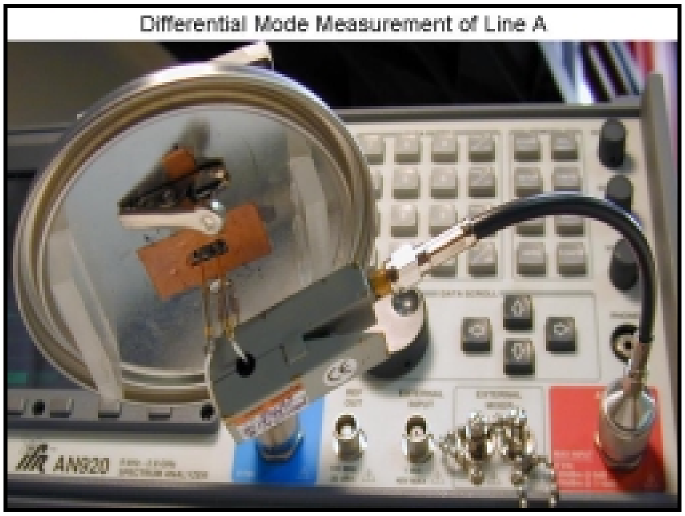

Figure 5. Differential mode measurement of line A.

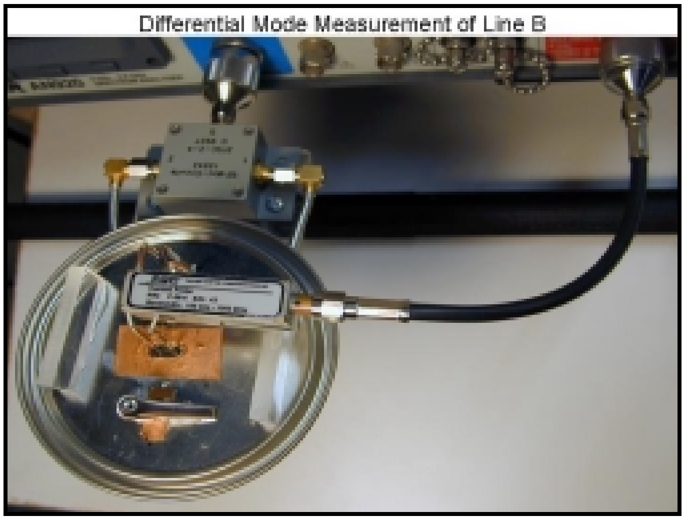

Figure 6. Differential mode measurement of line B.

Test Methodology

The purpose for using a miniature current probe as shown in Figure 7 (Fischer Custom Communications F-36-4) is to make quantitative measurements of the currents (magnetic fields) generated by the electrical noise from the tracking generator on the transmission lines. The current probe can be used in a non-shielded room because only the magnetic fields related to the electromagnetic radiation potential of the tracking generator affect the probe and it is relatively insensitive to stray electric fields. The windings of the probe are in a shield that reduces E-field pickup. Typical values of shielding from external E-fields vary from 60 dB below 100 MHz to greater than 30 dB at 450 MHz. The current probe can be used on an unfiltered electronic module to determine the amount of insertion loss required. The current probe is then used on the miniature transmission line, with the appropriate load, to correlate the insertion loss required. The cable from the current probe to the spectrum analyzer is 6 inches long, to minimize the signal loss and reflections.

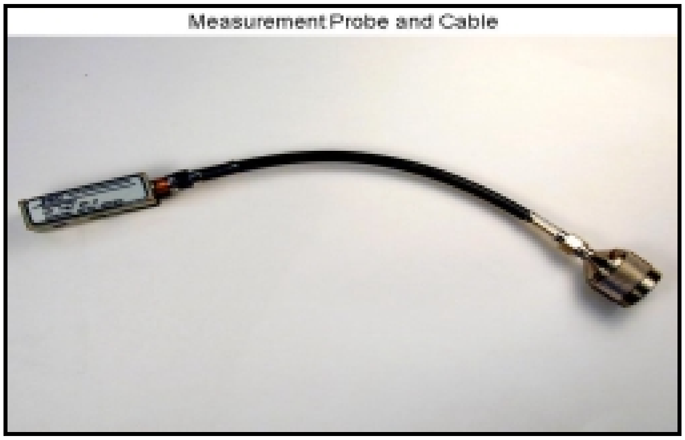

Figure 7. Fischer Custom Communications F-36-4 current probe.

The current probe has transfer impedance from 100 kHz to 1000 MHz, as shown in Figure 8. The transfer impedance Z_t is defined as the ratio of voltage developed across the output of the probe to the conductor under test. The current I_P in the conductor is calculated from the current probe output E_S in volts divided by the probe transfer impedance Z_t:

$I_P = E_S / Z_t$ (Equation 1)

The spectrum analyzer used in this test is an IFR AN920 (9 kHz - 2.9 GHz) and the frequency range is set from 100 kHz to 1.2 GHz. The resolution is set to 120 kHz and the video bandwidth is set to 1 MHz so that the spectrum analyzer does not filter the signals being analyzed.

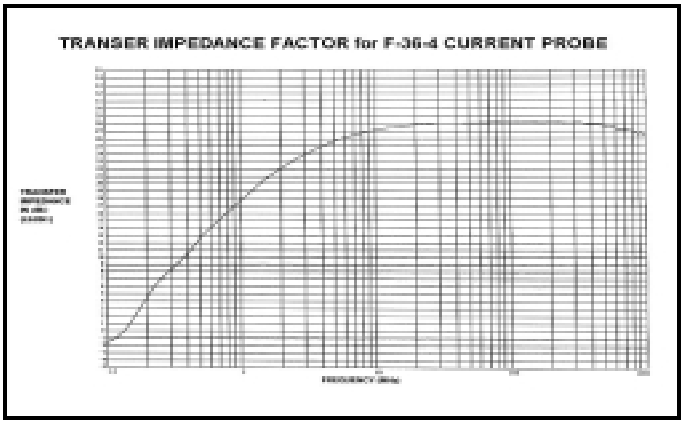

Figure 8. Current probe transfer impedance factor.

Filter Configurations

The filter configurations shown in Figure 9 are divided into four different types.

The first type of filter uses capacitors to bypass the noise to a lower potential reference. The X-capacitor filter and the Y-capacitors filter bypass the noise when the capacitor goes into self-resonant frequency. The self-resonance of the filter is dependent upon its capacitive and inductive values and those of the system in which it placed.

The second type of filter is the X2Y® architecture that uses an internal image plane between capacitor plates to minimize internal inductance and resistance. This image plane is also the zero reference plane for the capacitors. It allows the internal skin currents that are 180 degrees out of phase to cancel out. The mutual inductance can be positive, negative, or even zero.[1] This device was designed to have the mutual internal inductance cancel.

The third type of filter is a capacitor and inductor combination in which the capacitor bypasses the noise and then the inductors limit the amount of noise that passes through.

The fourth type of filter uses ferrite material that provides high impedance at the frequencies of the unwanted noise. The ferromagnetic material absorbs the noise and dissipates it as heat, due to a time varying magnetic field.

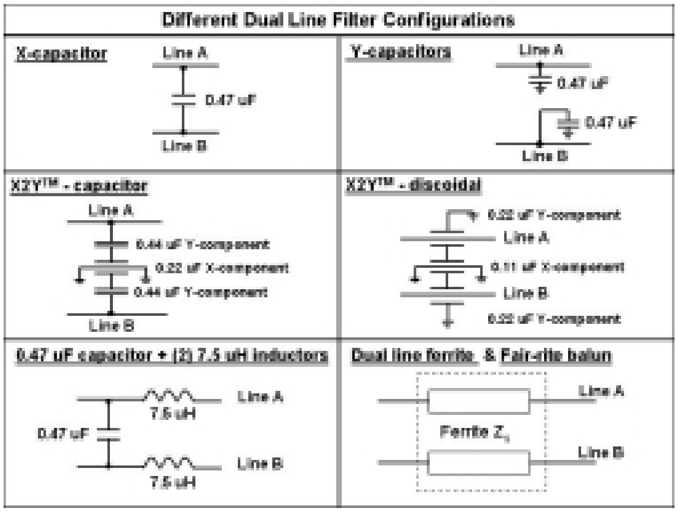

Figure 9. Different dual line filter configurations.

Test Results

In Figures 10 through 12, measurements using lines with gold pins only are the baseline. The delta between the

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[1] ***Walker, C. S., Capacitance, Inductance and Crosstalk Analysis,©1990 Artech House, Inc., Norwood, MA, p.102***

baseline and the filter measurements in these figures is the insertion loss in dBuV.

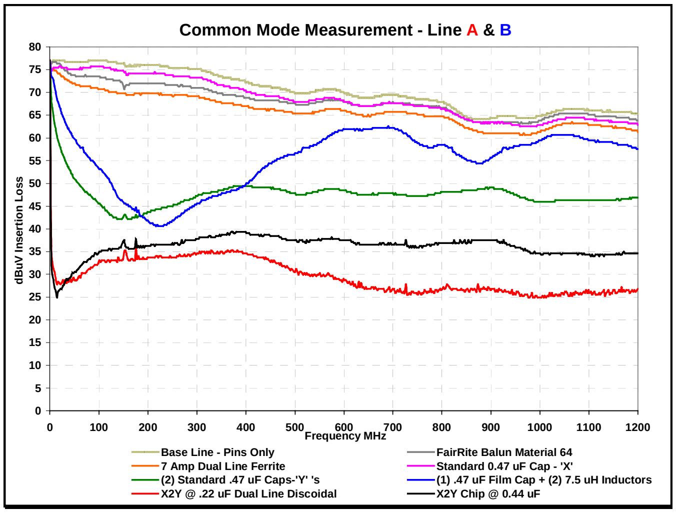

Figure 10. Common mode measurements of lines A & B

The baseline in Figure 10 is 77 dBuV at 100 kHz and drops to 65.99 dBuV at 1.2 GHz, which is a difference of 11.01 dBuV over the frequency range.

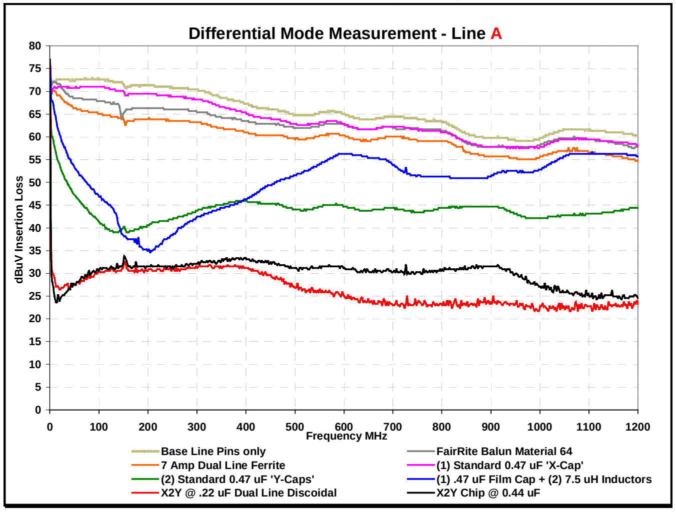

Figure 11. Differential mode measurement of line A.

The baseline in Figure 11 is 77 dBuV at 100 kHz and drops to 60.37 dBuV at 1.2 GHz, which is a difference of 16.63 dBuV over the frequency range.

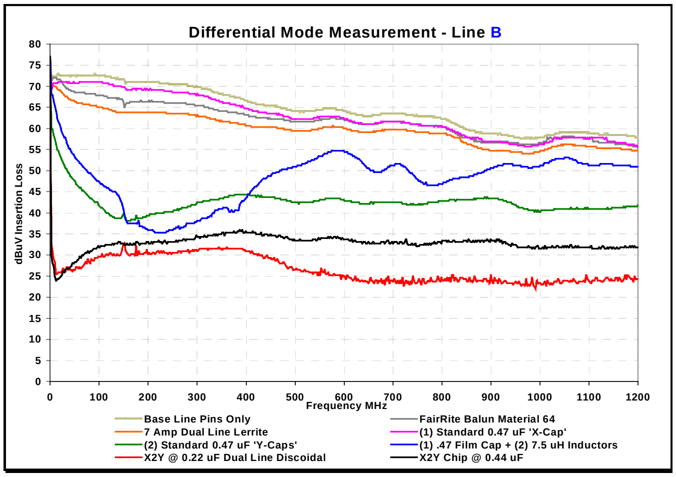

Figure 12. Differential mode measurement of line B.

The baseline in Figure 12 is 77 dBuV at 100 kHz and drops to 57.86 dBuV at 1.2 GHz, which is a difference of 19.14 dBuV over the frequency range. When the baseline of A is compared to B, the difference is only 2.51 dBuV for this test setup. Therefore, the baseline will be normalized in Figures 13 through 15 to show insertion loss.

Comparisons of Test Results

Figure 13 shows the common mode insertion loss of the different types of filters for lines A & B. The X-capacitor filter, the dual line ferrite filter, and the Fair-rite balun filter provide less than -10 dBuV of insertion loss. The Y-capacitors filter and capacitor & (2) inductor filter provide -34 dBuV insertion loss at approximately 150 MHz to less than –20 dBuV at 1.2 GHz. The best filter is the X2Y architecture that provides -49 dBuV at 100 kHz to -39 dBuV at 1.2 GHz.

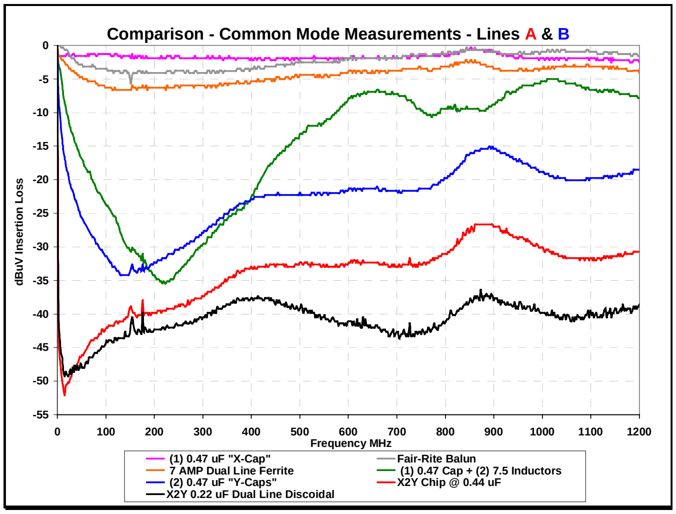

Figure 13. Insertion loss of lines A & B.

Figures 14 & 15 show the differential mode noise insertion loss of line A and line B respectively. Again, the filter configurations have similar results to the common mode noise insertion loss. The X2Y architecture provides the greatest amount of insertion loss over the frequency range of 100 kHz to 1.2 GHz.

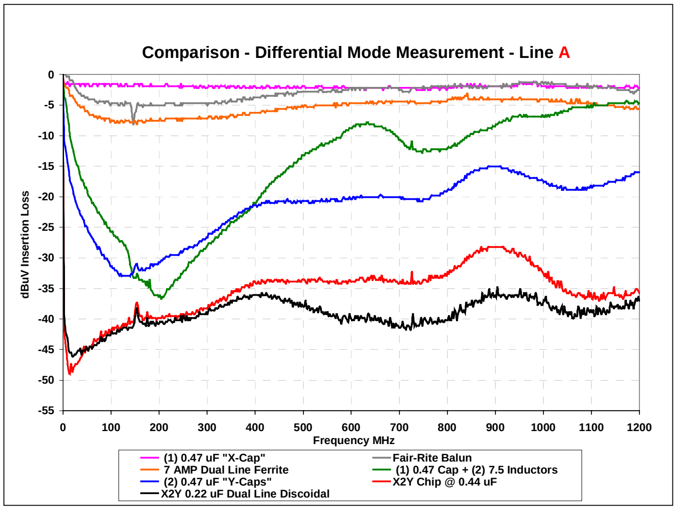

Figure 14. Insertion loss of line A.

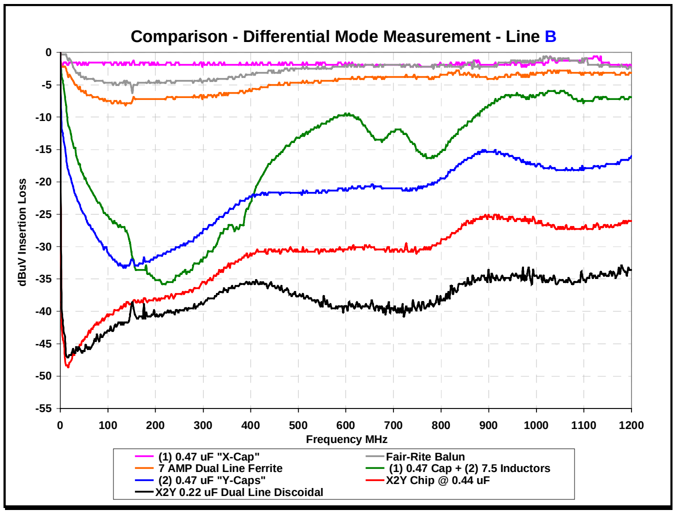

Figure 15. Insertion loss of line B.

Since the X2Y architecture had the best performance in both common mode and differential mode insertion loss, a separate test was conducted to analyze cross-talk. The noise was applied on line A and measured on line A. Then the noise was measured on line B to see how much noise from line A coupled through to line B. This shows how much cross-talk cancellation the X2Y architecture can provide. Figure 16 shows that the X2Y architecture will provide between –38 dBuV to –50 dBuV of insertion loss.

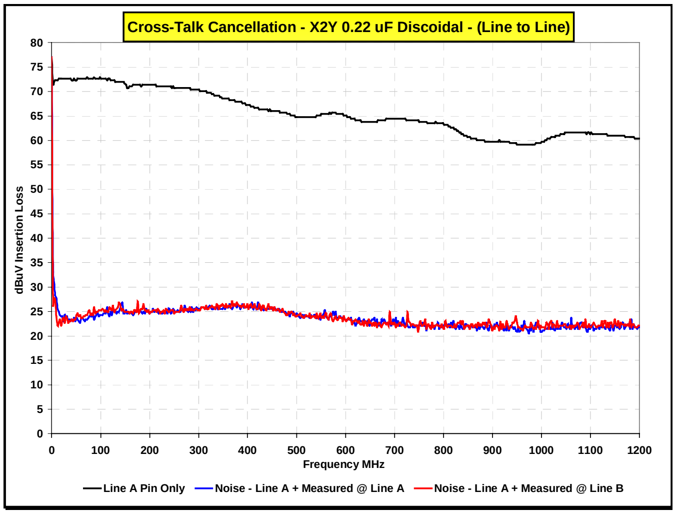

Figure 16. X2Y discoidal cross-talk cancellation - line to line.

Figure 17 shows the common mode insertion loss of lines A & B from 100 kHz to 140 MHz. The X2Y architecture responds very quickly to common mode noise compared to a normal capacitor. This can happen only if the internal mutual inductance is cancelled.

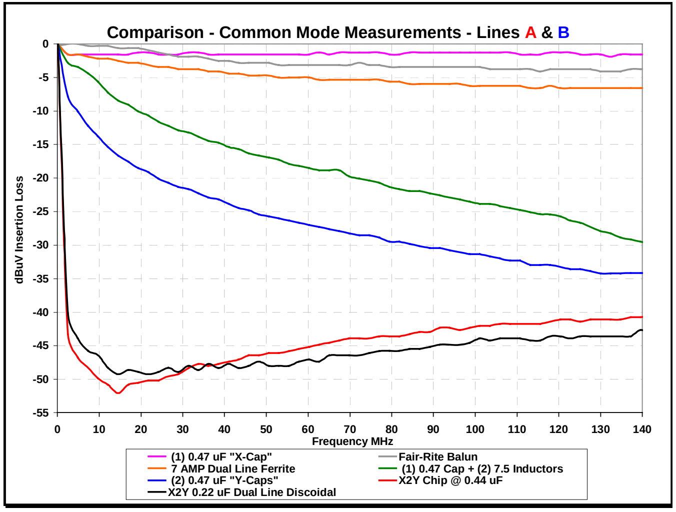

Figure 17. Common mode insertion loss to 140 MHz.

Conclusion

The test methodology used to measure the dual line filters is repeatable and easy to run. The combination of test setup with miniature transmission lines and small current probe proved to be very effective when measuring the common mode and differential mode insertion loss to 1.2 GHz.

When analyzing the different types of filtering configurations, the X2Y architecture provided the largest amount of insertion loss over the frequency range of 100 kHz to 1.2 GHz. The load network in this test was built to 50-Ω impedance, but can be changed to meet any specific load requirements.

Acknowledgements

We would like to thank Joe Fischer from Fischer Custom Communications, Inc. for supplying the calibrated current probe used in the test setup.

Sources

Fischer Custom Communications, Inc.; 2917 W. Lormita Boulevard, Torrance, CA 90505, 310-891-0635, http://www.fischercc.com/

X2Y Attenuators, LLC; 2700 West 21st Street, Suite 11, Erie, PA 16506-2972, 814-835-8180, http://www.x2y.com/

Syfer Technology Limited; Old Stoke Road, Arminghall, Norwich, Norfolk NR14 8SQ, England, +44 (0) 1603 723300, http://www.syfer.com/

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Anthony A. Anthony *is the inventor of the X2Y Circuit and Layered Technology, which is contained in (2) issued U.S. Patents. Additionally, Tony is sole inventor or co-inventor of 23 international patents pending, all of which are related to X2Y Technology. He is the founder and managing partner of X2Y Attenuators, LLC. He has enjoyed a 35-year career in the electronic components industry and was formerly with Erie Technological Products, Murata/Erie and Spectrum Control, Inc. as a National Sales/Applications Engineer. Mr. Anthony has extensive experience in EMC design applications and holds a B.S.E.E. from the United States Naval Academy. Tony can be reached by e-mail at: x2y@x2y.com*