Suppression Techniques using X2Y® as a Broadband EMI Filter

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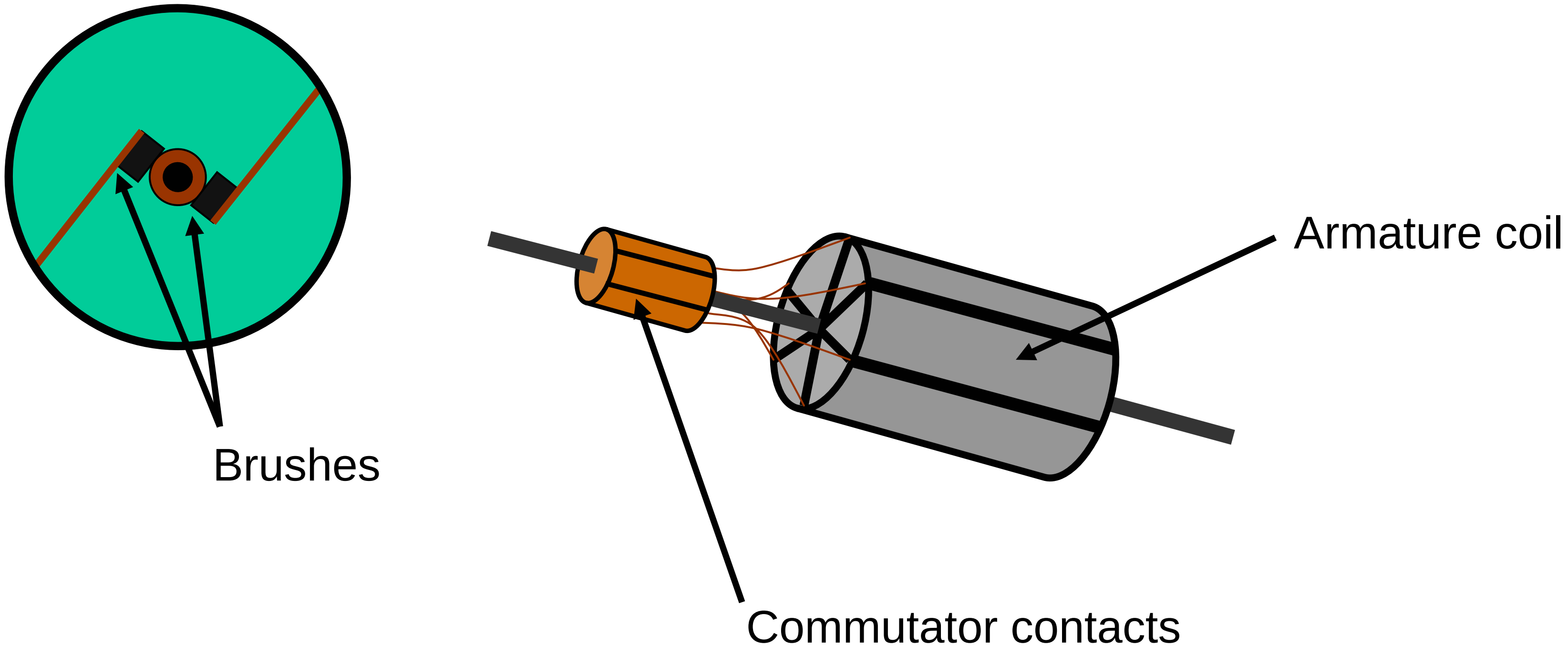
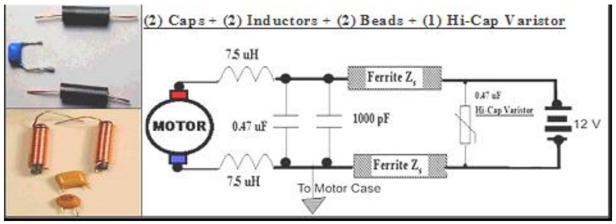
Presentation Outline

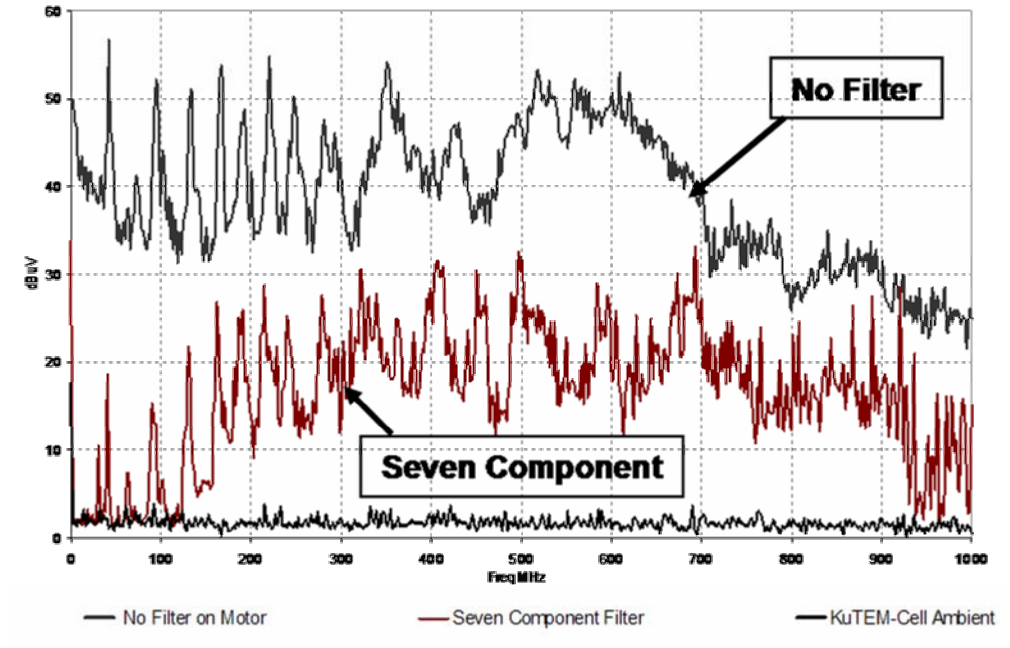
- Broadband Filtering of Motors
- Internal Construction & Model of X2Y
- Other Applications & Testing
- Conclusions

Electromagnetic Noise Sources In Motors



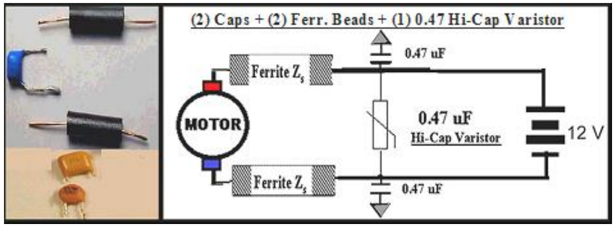
Seven Component Motor Filter

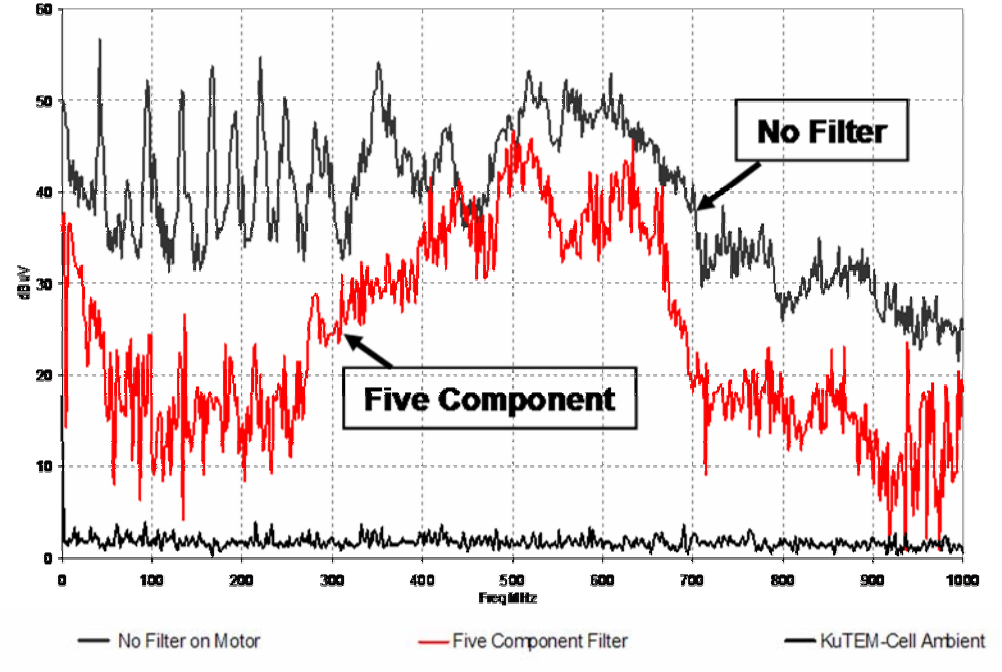




The seven component filter design includes (2) 7.5 uh inductors to limit the amount of noise that passes through and then uses (2) x-capacitors, 0.47 uF and 1000 pF, to bypass the noise to the motor case which is grounded. The filter network also uses (2) ferrite beads that provide high impedance at the frequencies of the unwanted noise. The beads' ferromagnetic material used in the circuit absorbs the noise and dissipates it as heat, due to a time varying magnetic field. The last component in the network is a 0.47 uF cap-varistor placed across the power leads to clamp the noise to 14 volts and bypass any remaining noise to ground.

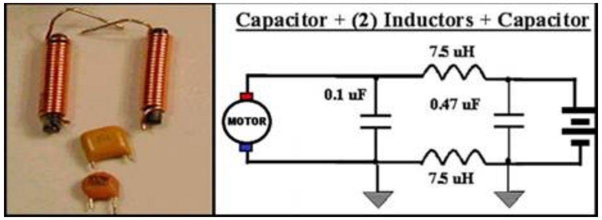
Five Component Motor Filter

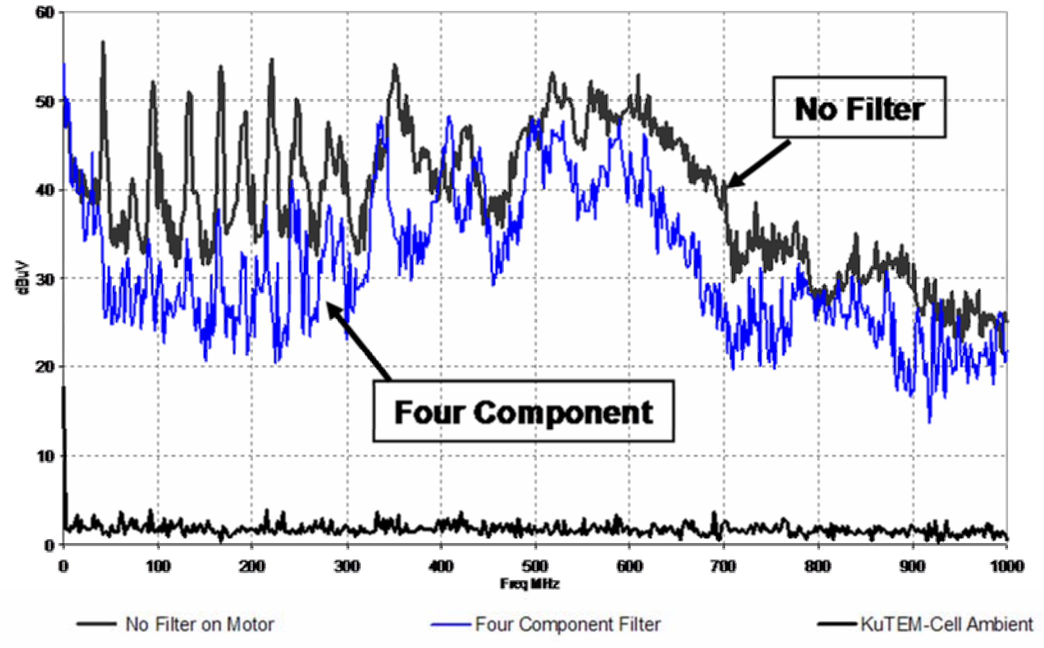




The five component network starts with (2) ferrite beads that provide high impedance at the frequencies of the unwanted noise and uses a 0.47 uF cap-varistor to clamp the noise to 14 volts. (2) 0.47 uF y-capacitors are also connected from the power leads to motor case ground to bypass the remaining noise to ground.

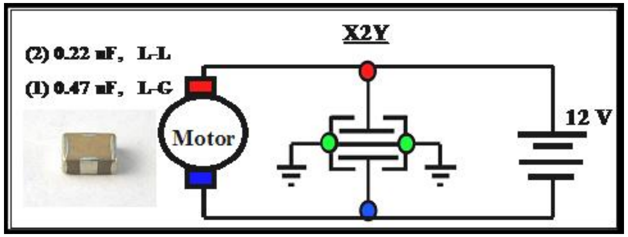
Four Component Motor Filter

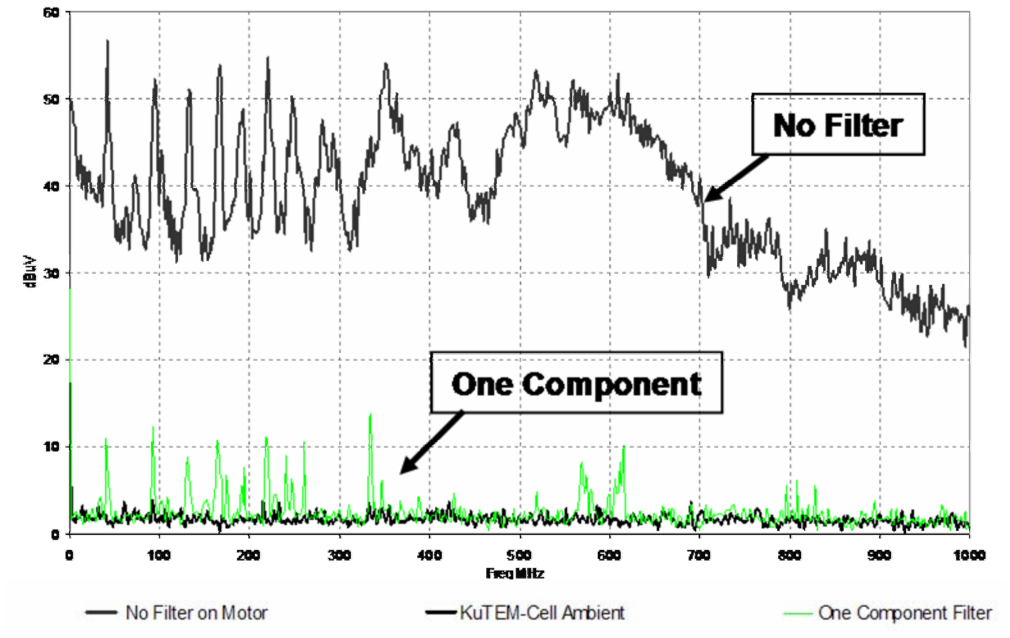




The four component filter, uses (1) 1000 pF x-capacitor to bypass the noise to ground and the motor case. Then (2) 7.5 uh inductors limit the noise and a second x-capacitor at 0.47 uF bypasses the remaining noise to the motor case which is grounded.

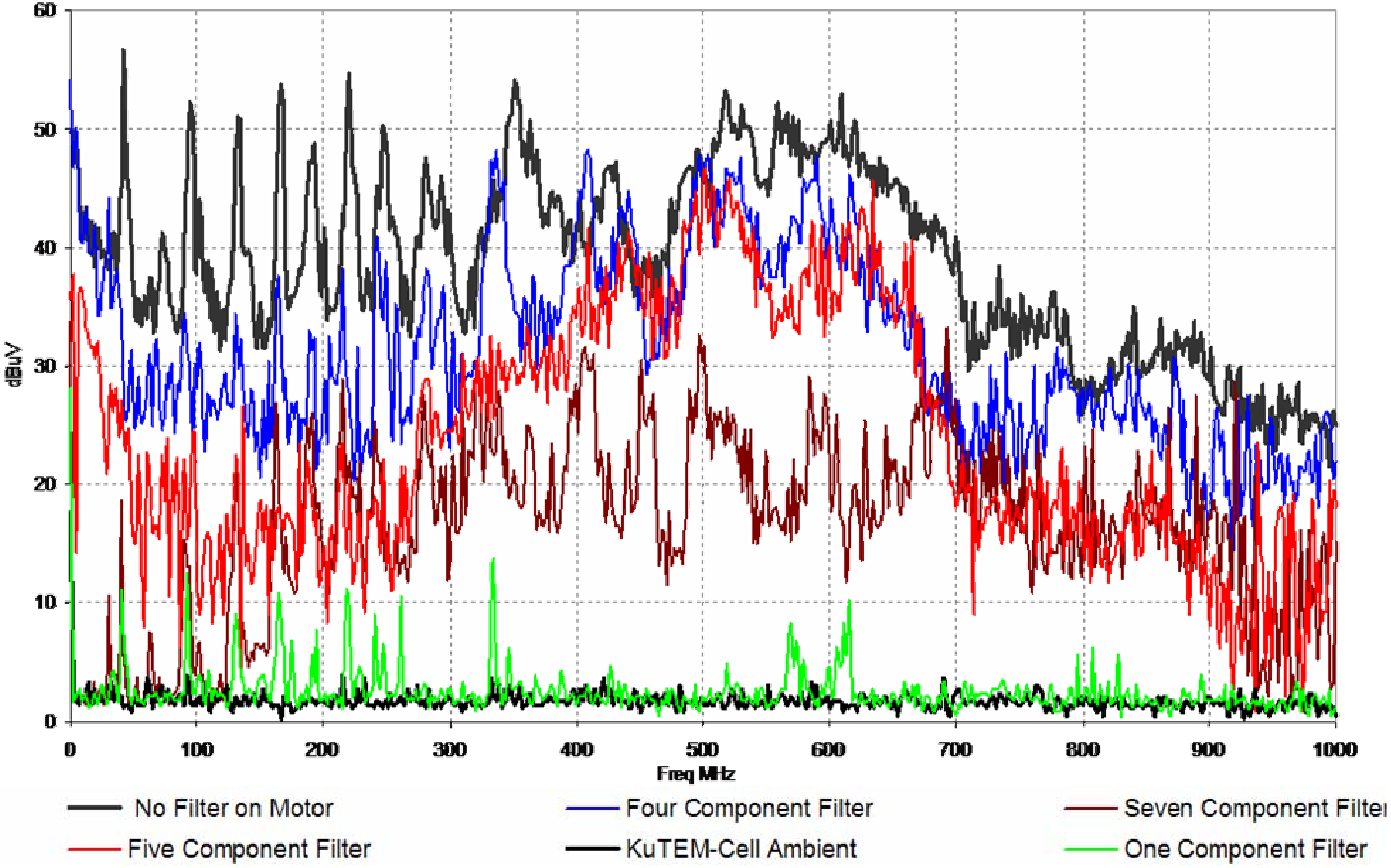
One Component Motor Filter





The one component filter is a 1410 sized package chip. This chip is configured in what is called an X2Y® layered architecture that combines an unique electrode layering method and uses an internal image plane between capacitor plates to minimize internal inductance and resistance. Alternating electrode layering allows opposing internal skin currents that are essentially 180 degrees out of phase to cancel out. This device was also designed to have its internal mutual inductance fields cancel.

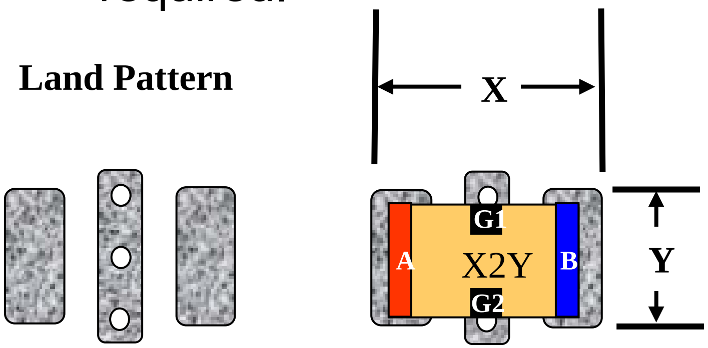
Filter Performance Comparisons



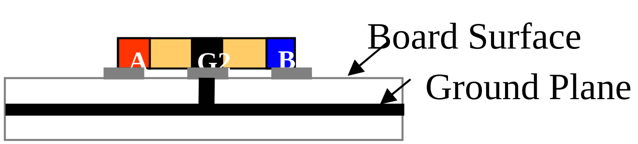
Proper Grounding

The importance of connecting both the G1 and G2 terminations is highlighted in the test data below. The land pad under the G1 and G2 terminations of the X2Y component should be continuous. Two vias minimum are required, three vias will lower inductance and improve performance. Two solder connections, one at G1 and one at G2 are required.

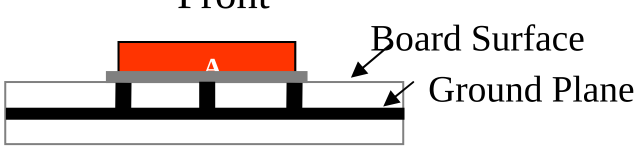
Land Pattern



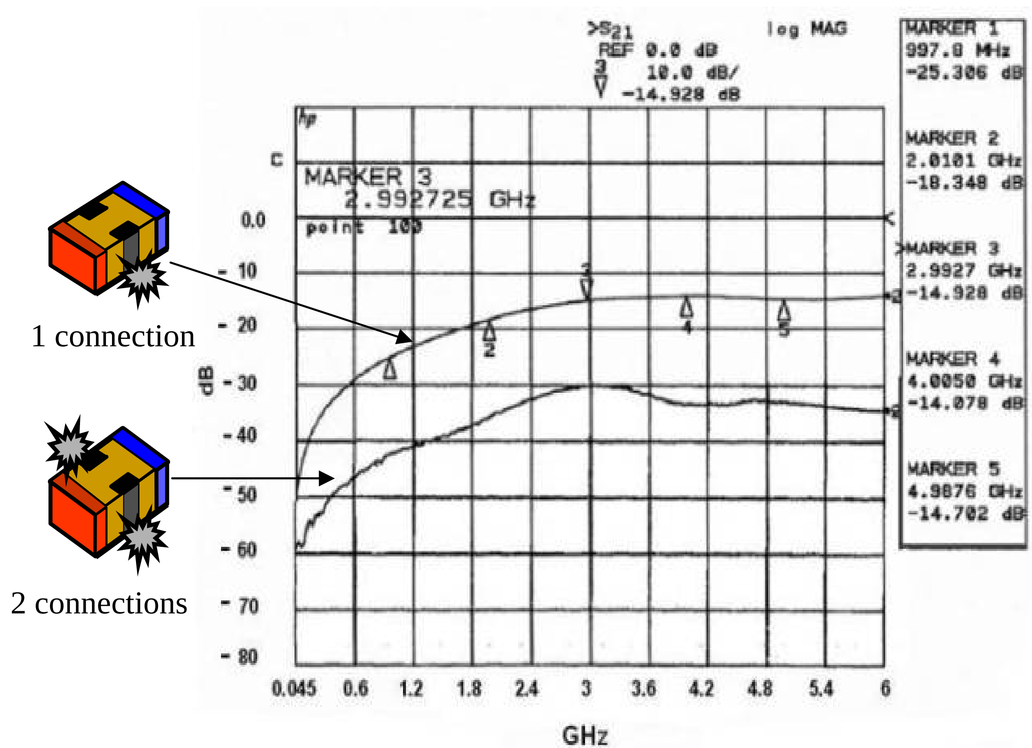
Board View



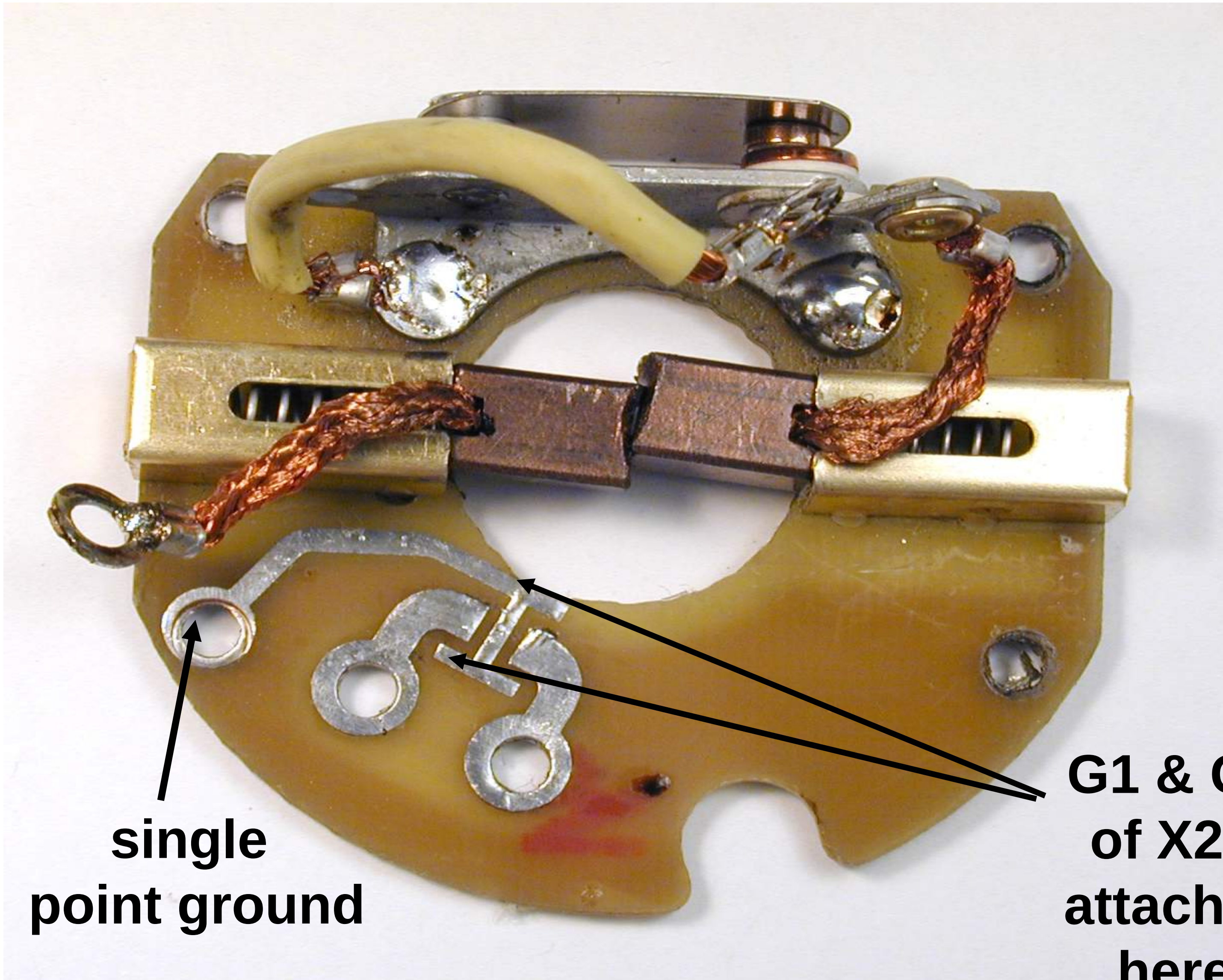
Front



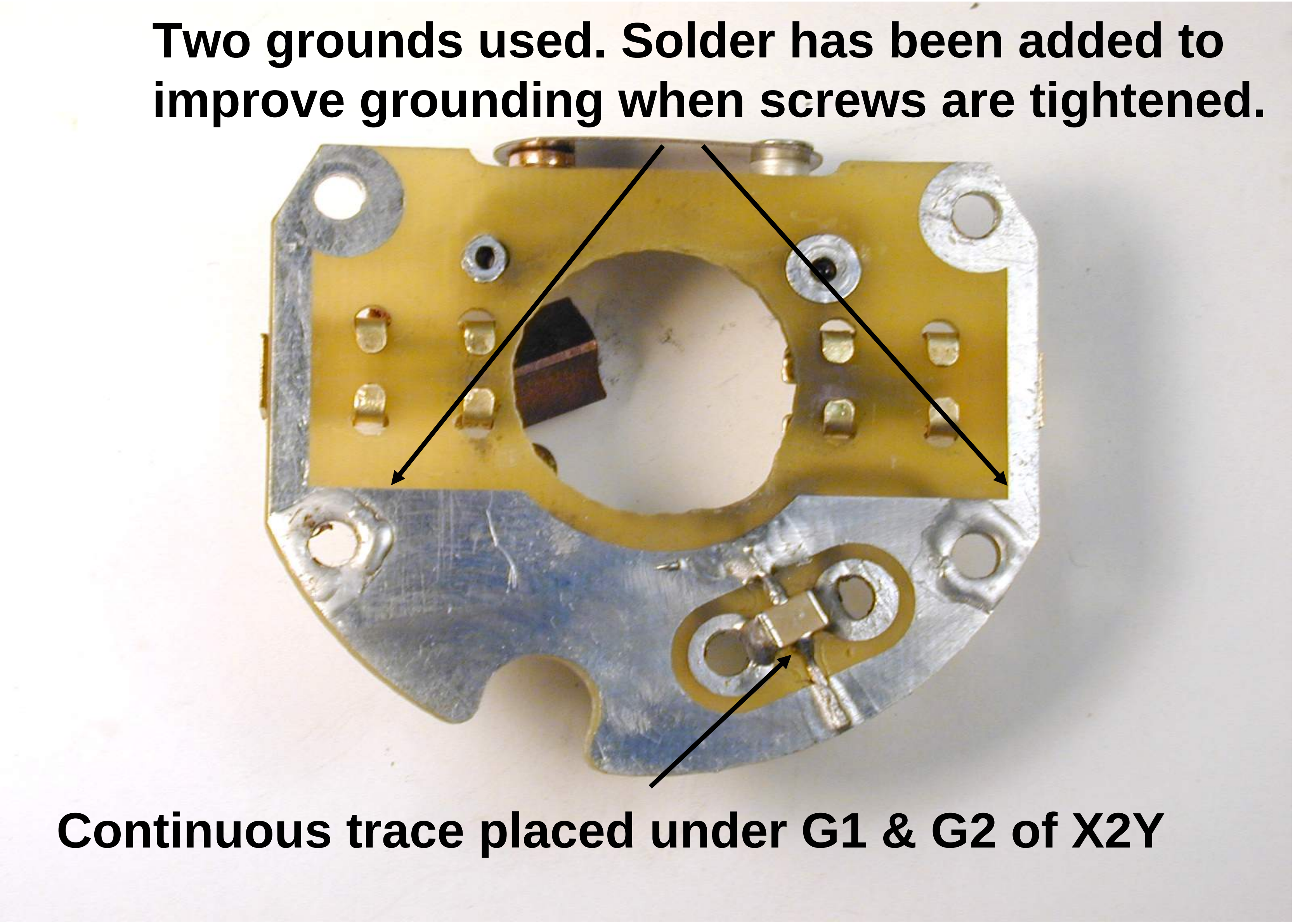
Side



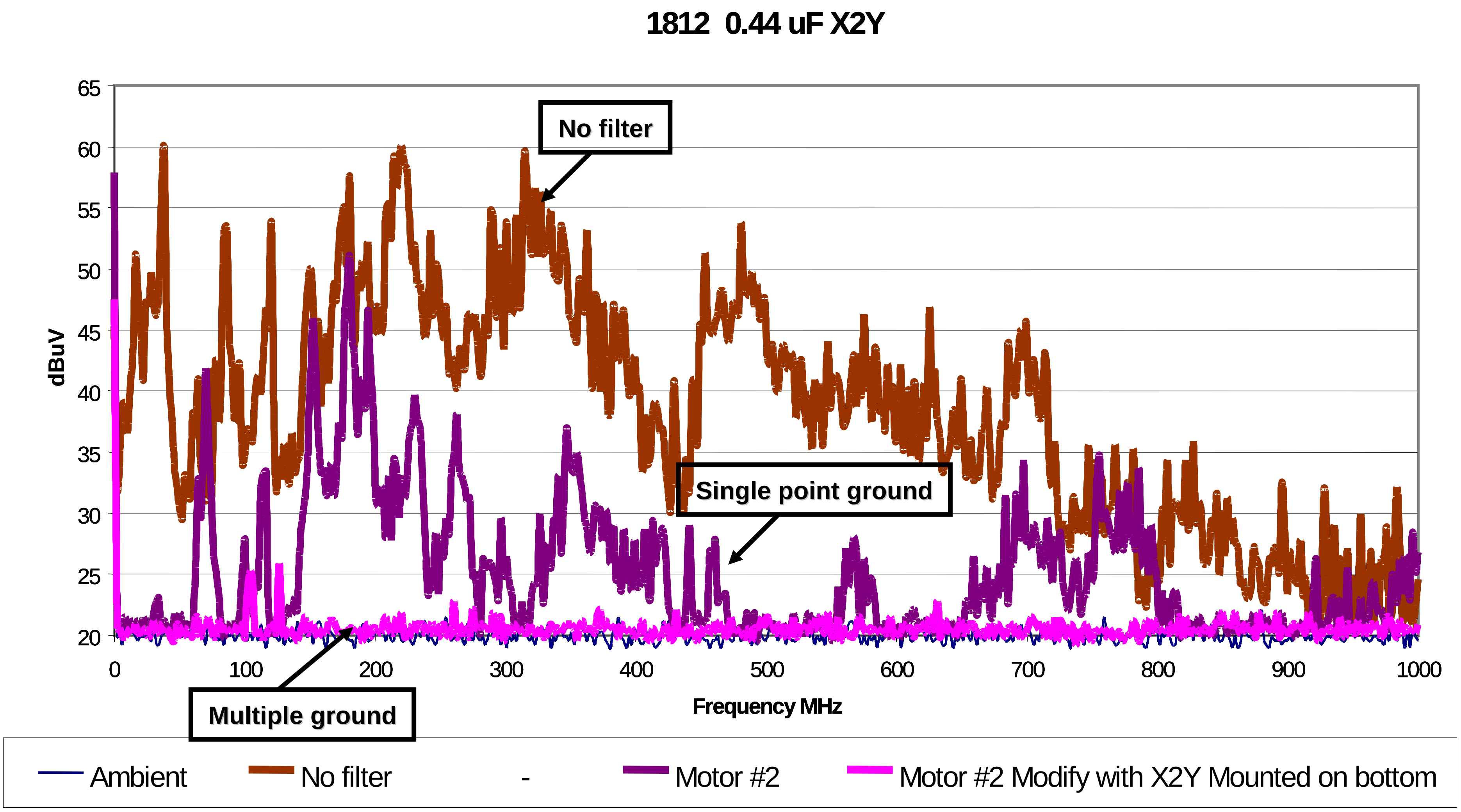
Single Point Ground



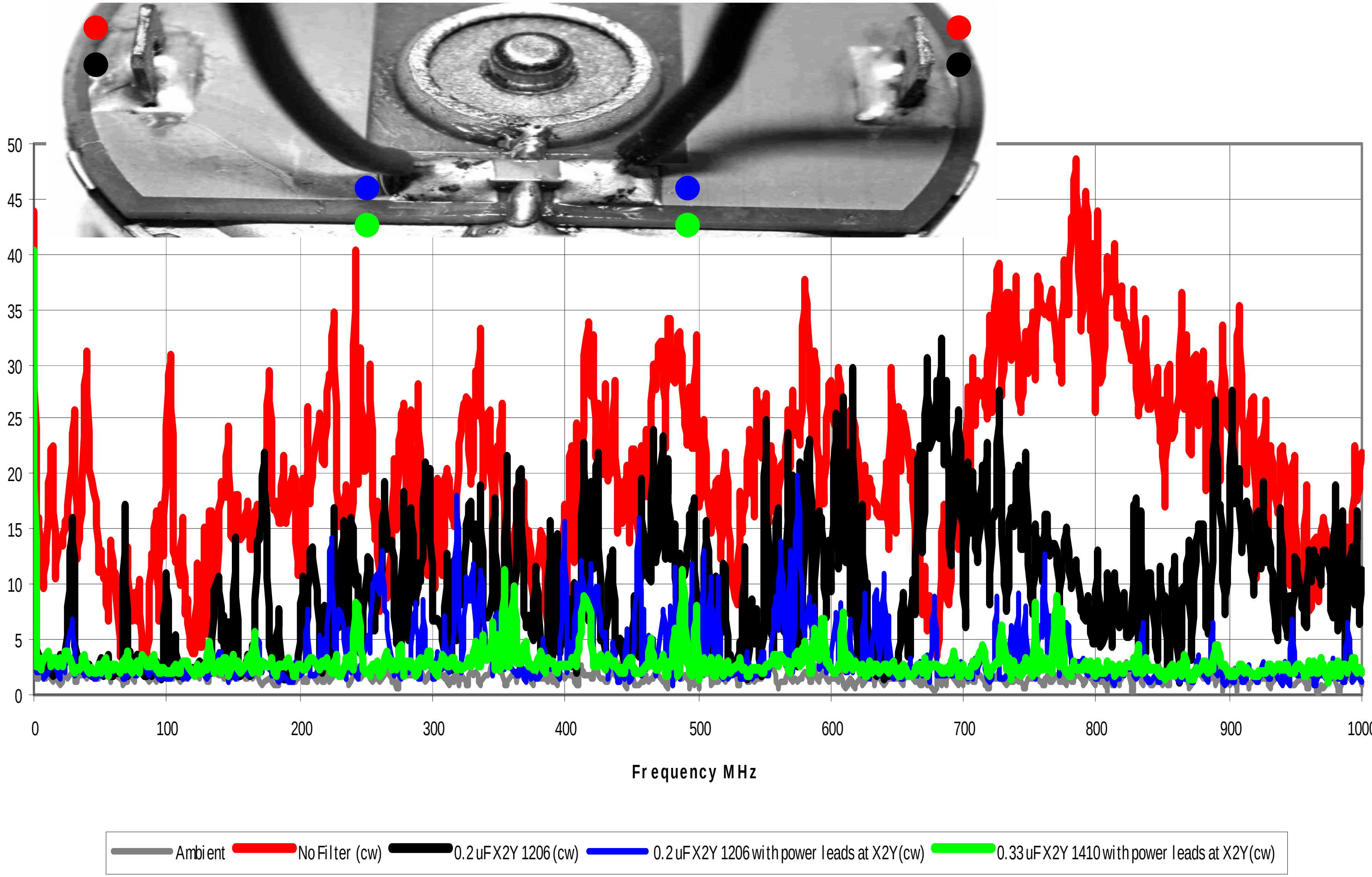
Parallel Ground



Ground Performance Data



Trace Inductance



X2Y Technology in Balance

Internal Construction and Model of X2Y

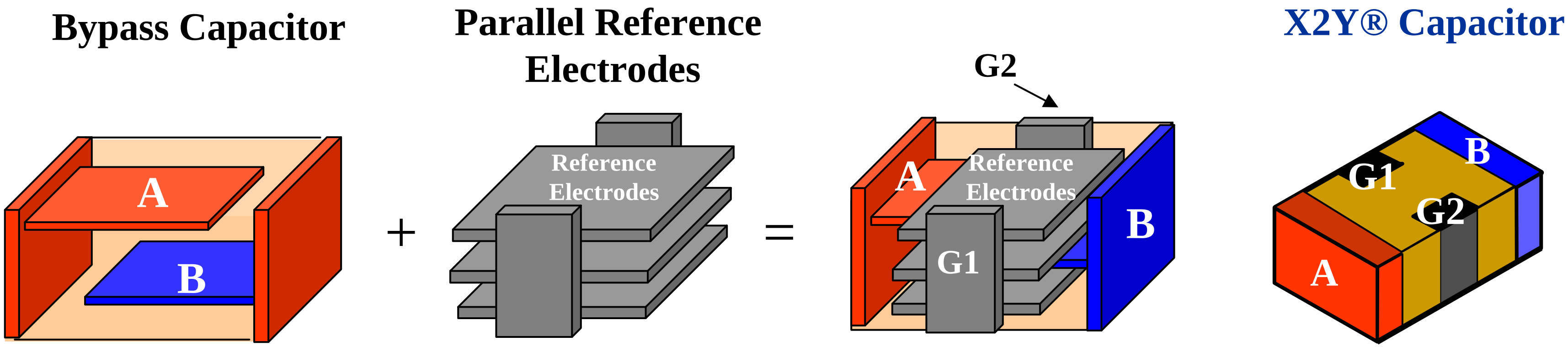
- Internal Construction
- Balanced Performance
- Coaxial Behavior
- Current Loop

Internal Construction

The X2Y structure consists of:

1. A standard bypass capacitor.
2. Parallel reference electrodes.
3. Two additional side terminations called G1 and G2.

The side terminations combine with the parallel reference electrodes to form the basic structure. The parallel reference electrodes have properties similar to a *Faraday Cage* and an *Image Plane**.



***Reference** to "Effect of an Image Plane on Printed Circuit Board Radiation" by Robert F German, Henry W. Ott, and Clayton R. Paul, IEEE International Symposium on Electromagnetic Compatibility, Washington, D.C., August 21-23, 1990.

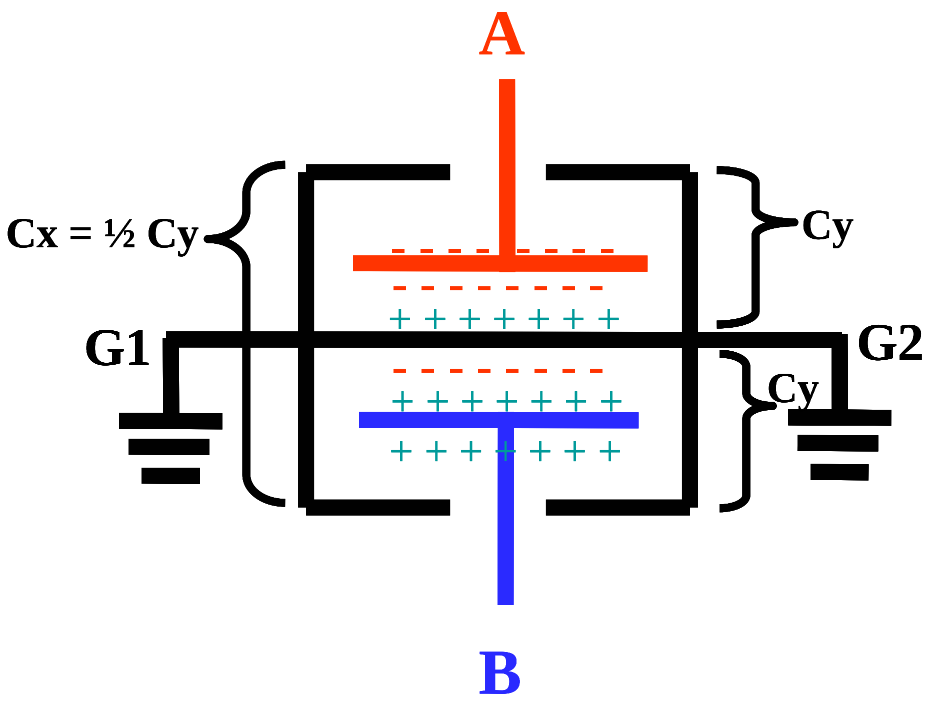
Balanced Component

Inserting a "Faraday cage" structure inside a bypass capacitor changes an unbalanced, single ended device into a balanced device. "*A balanced device is composed of two nominally identical halves.*" *

<u>Balance in a single body:</u>

- Two tight tolerance Cy capacitors, typically 1-3%
- Equal aging effects
- Temperature tracking
- Balanced filtering

** *Needed for high speed circuits*

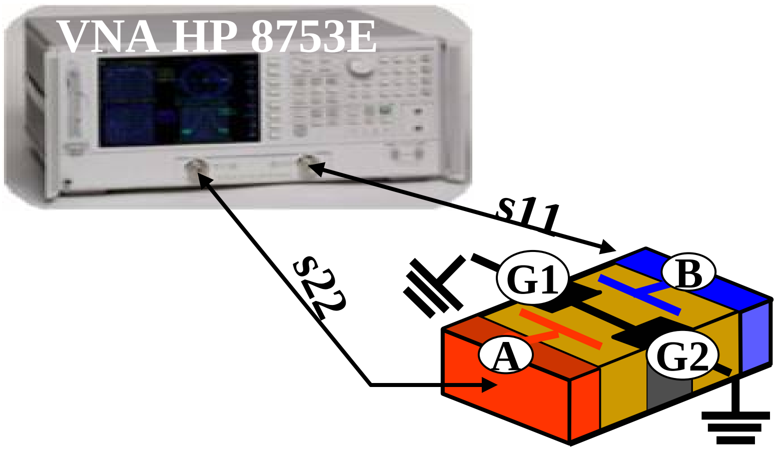


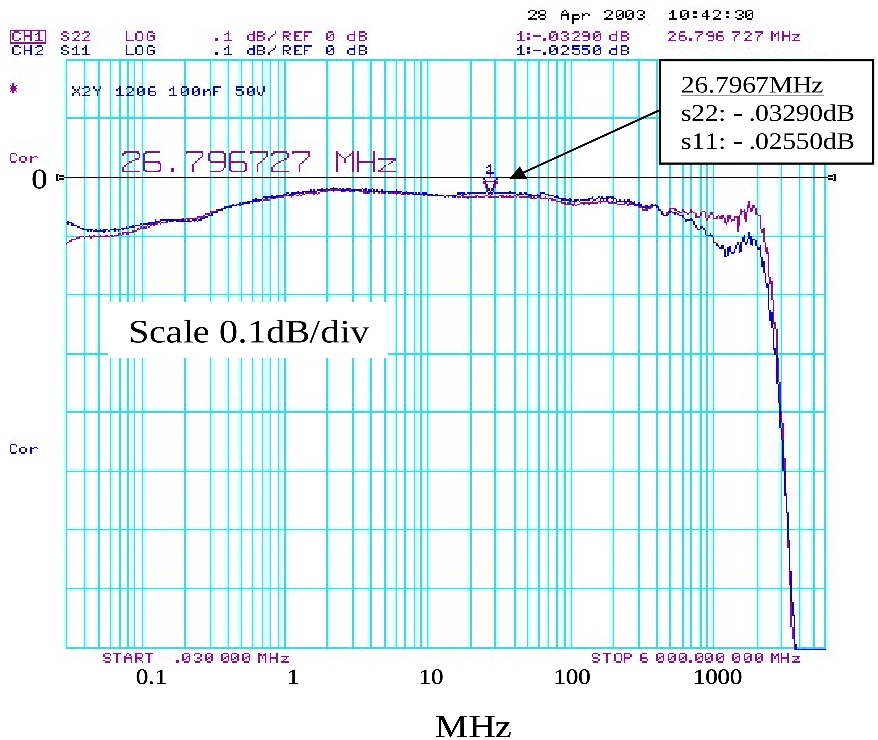
* Balanced Device Characterization, Agilent Technologies, http://cp.home.agilent.com/upload/cmc_upload/tmo/downloads/EPSG084733.pdf (slide#3)

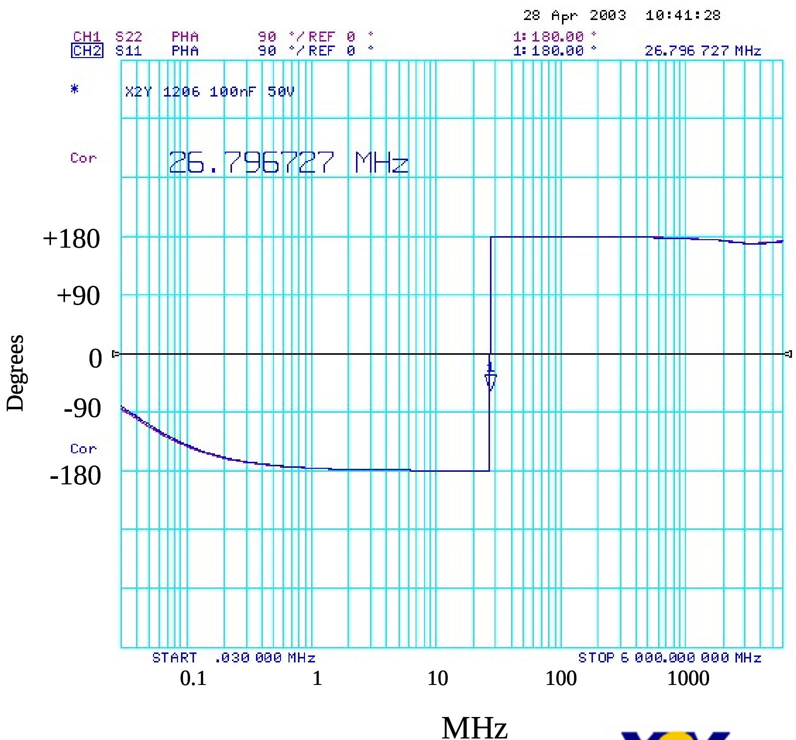
** Differential-to-common-mode conversion, By Howard Johnson, PhD -- EDN, 10/17/2002, http://www.e-insite.net/ednmag/index.asp?layout=article&articleid=CA250820

Balanced Component Performance

The X2Y capacitor is measured with a VNA and microwave test fixture from 30kHz-6GHz. By making an s11 and s22 (reflection) measurement we can see the balanced performance of the component from 30kHz-6GHz.

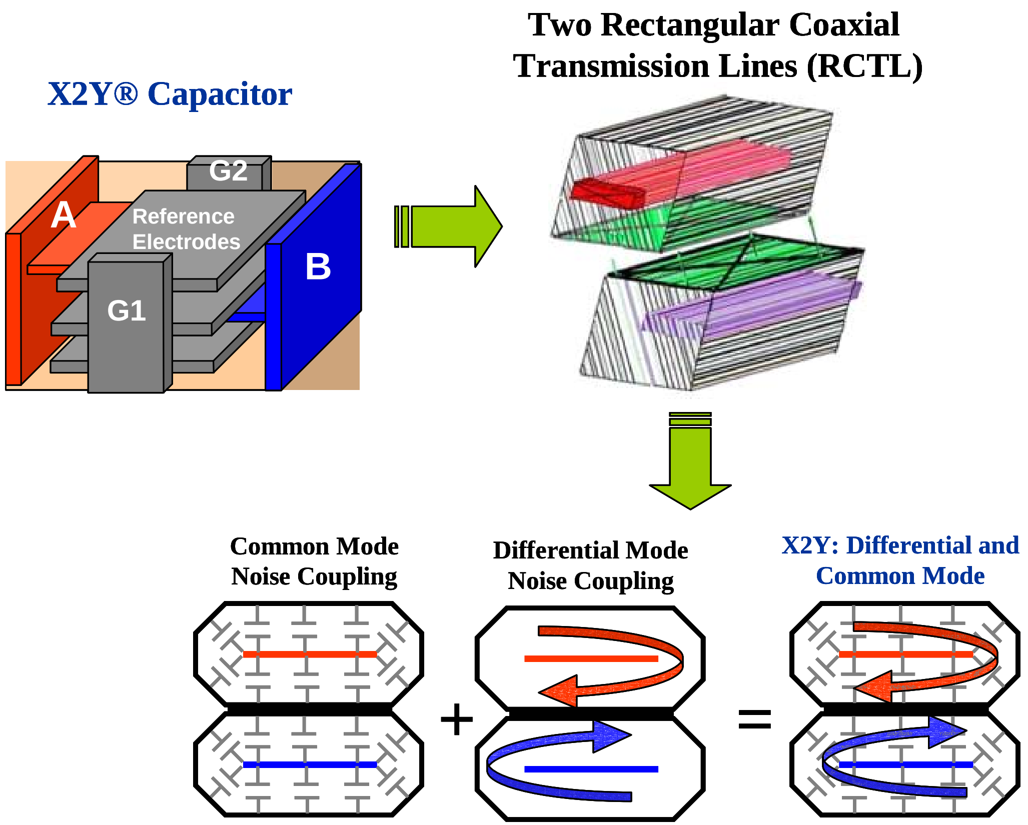






Coaxial Behavior

The X2Y design is similar to a dual rectangular coaxial structure that was studied and modeled by the National Bureau of Standards*. The reference electrodes form a non-ideal shielded container for each conductor inside the capacitor.



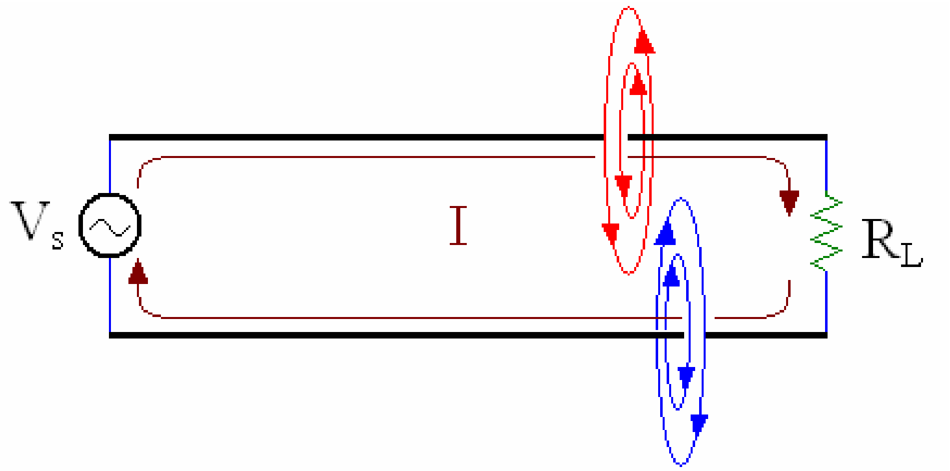
At high frequency, the circuit noise in each capacitor will choose the low impedance path of the reference electrodes and opposing noise currents will cancel, similar to an "Image Plane".

***Reference** to "Theoretical and Experimental Analysis of Coupling Characteristics of Dual TEM Cells" by P.F. Wilson, D.C. Chang, Department of Electrical Engineering, University of Colorado & M.T.Ma, M.L. Crawford, Electromagnetic Fields Division, National Bureau of Standards, Boulder, CO 80303 © 1983 IEEE

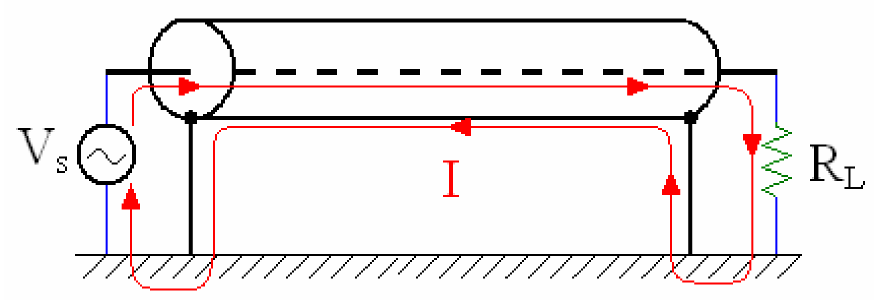
X2Y® Technology in Balance

Coaxial Theory

Current flowing in a loop creates magnetic fields 180° out of phase on the signal and signal return conductors. As frequency increases, so do the fields (di/dt). As the fields couple onto opposing conductors they cancel due to mutual inductance.



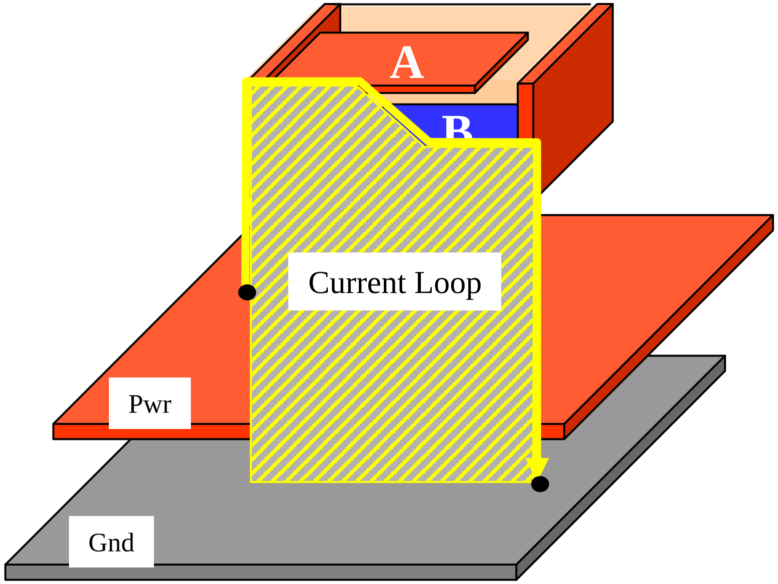
At high frequency, the shield of coax cable provides a lower impedance signal return than the ground plane. The reduction in loop area results in a maximum of mutual inductance cancellation of high frequency noise.



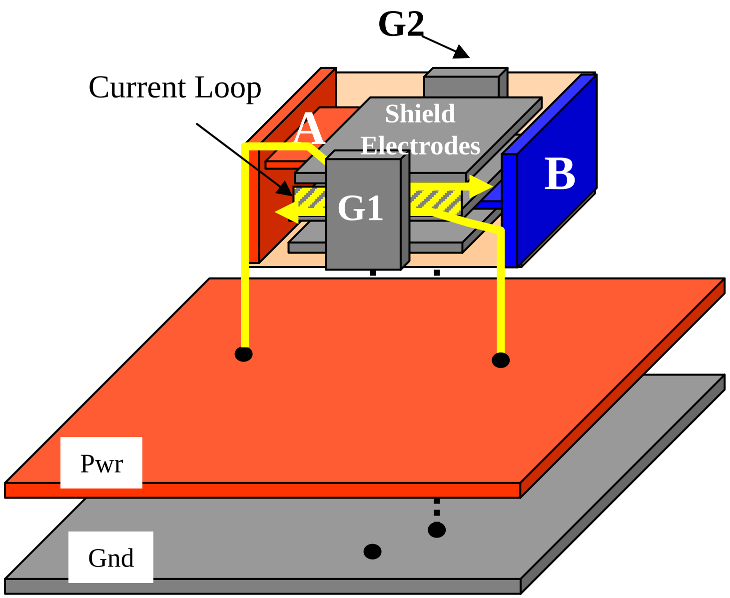
Current Loop X2Y vs. Standard Cap

Standard capacitors have their inductance in "series" with the board layers and form an inductive loop when mounted on a PCB. The inductive loop degrades the circuit performance. In X2Y *every other layer* within the single component body is in opposition to cancel the magnetic fields.

Bypass Capacitor



X2Y Capacitor



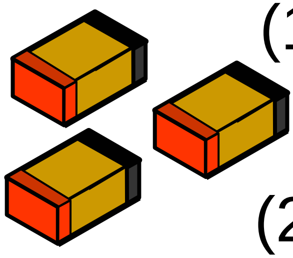
Other Applications & Testing

- X & (2)Y's vs. X2Y Comparison
- Computer Power Filtering
- Insertion Loss for Connectors

X & (2)Y's vs. X2Y Comparison

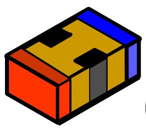
X2Y is compared to an equivalent discrete circuit using a PCB and HP8753E Vector Network Analyzer (VNA).

<u>(3) Standard Caps</u> vs. <u>(1) X2Y Cap</u>



(1) 1206 1nF 50V

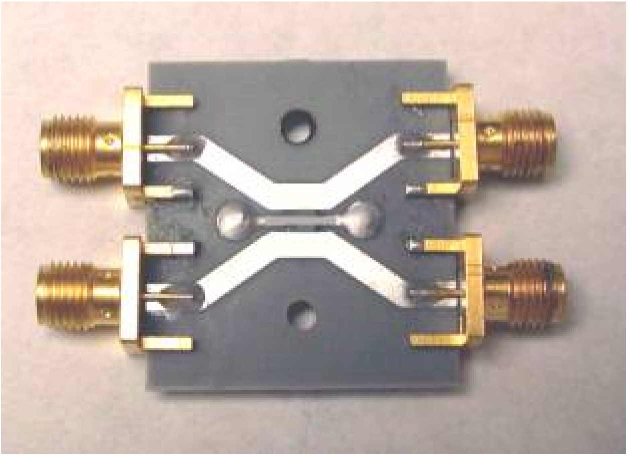
(2) 1206 2.2nF 50V



(1) 1206 2.2nF 50V
(X value = ½ of 2.2nF)

HP 8753E Network Analyzer

Test Board

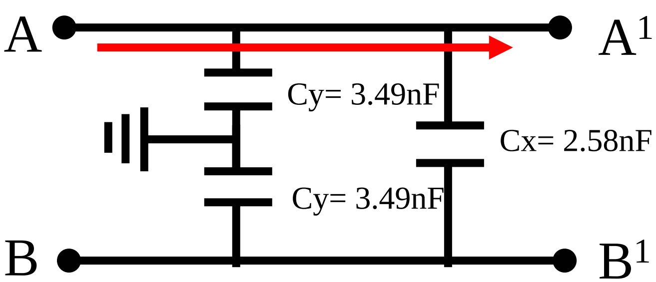


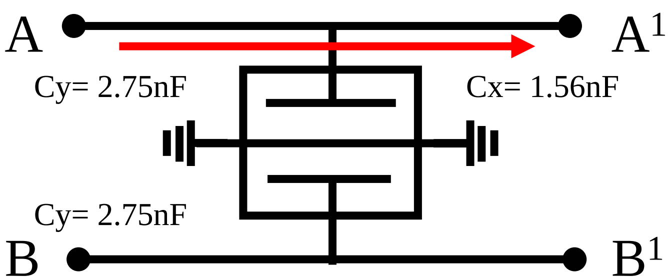
X & (2)Y’s vs. X2Y Comparison

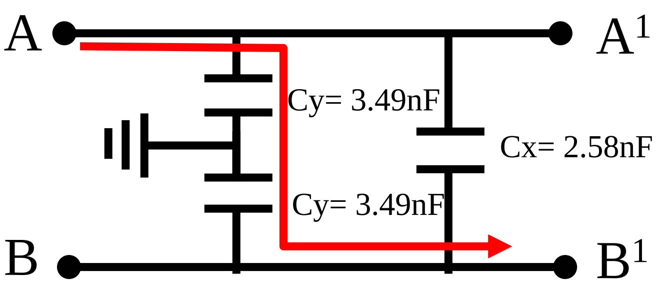
Two measurements are made for each DUT. All Ports are terminated with 50 Ohms, either through port connection to the VNA or by SMA termination caps.

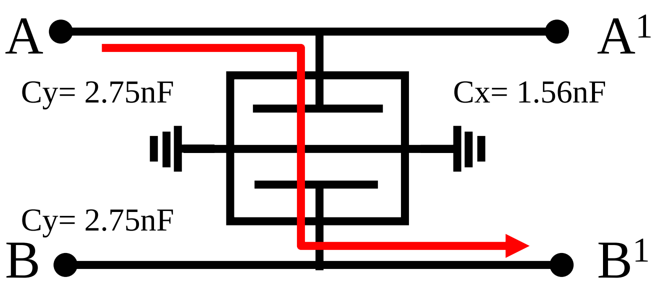
(3) Standard Caps

(1) X2Y Cap



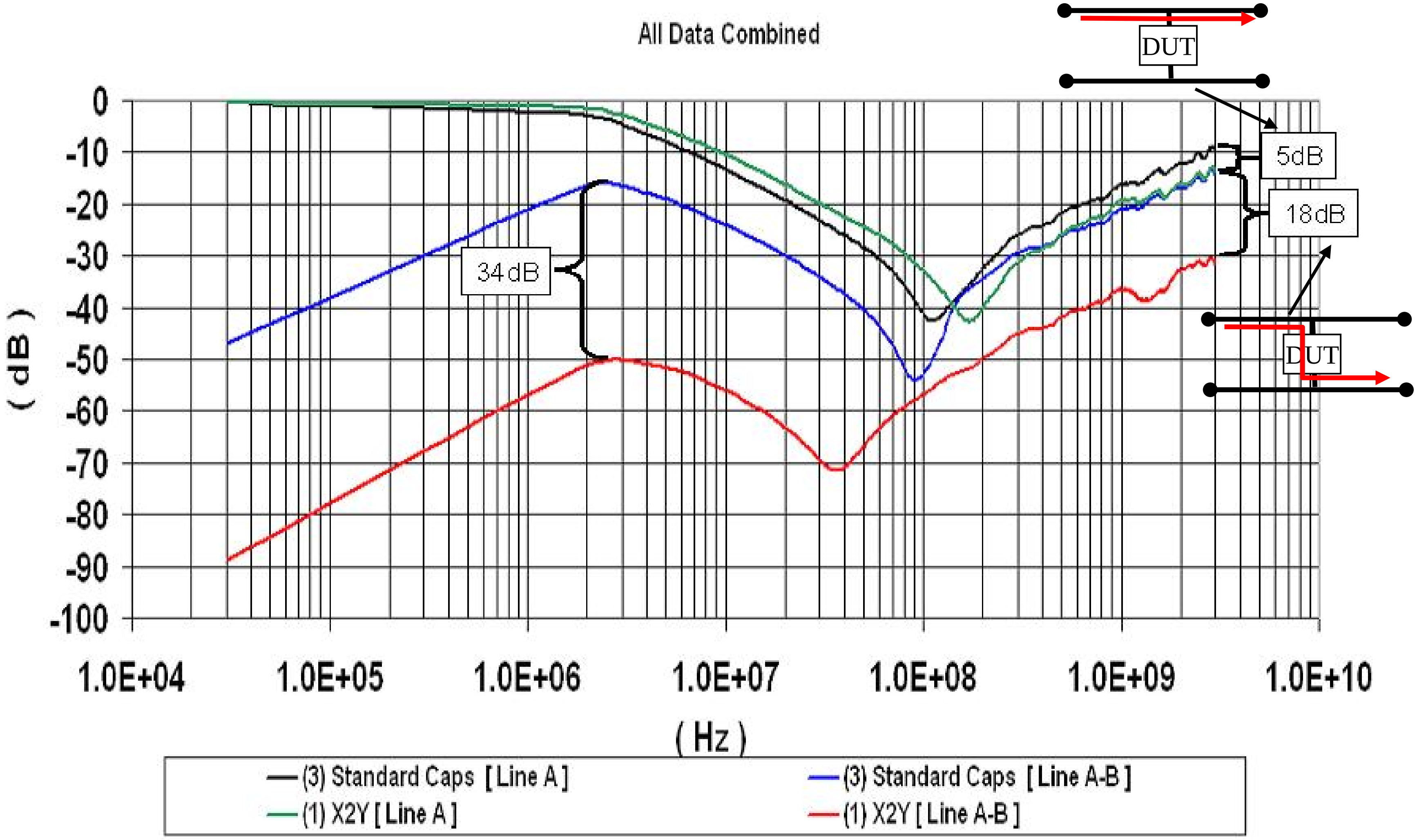






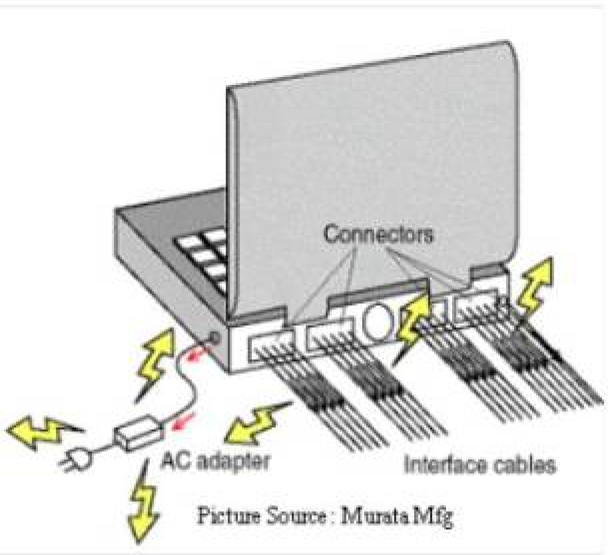
X & (2)Y's vs. X2Y Data

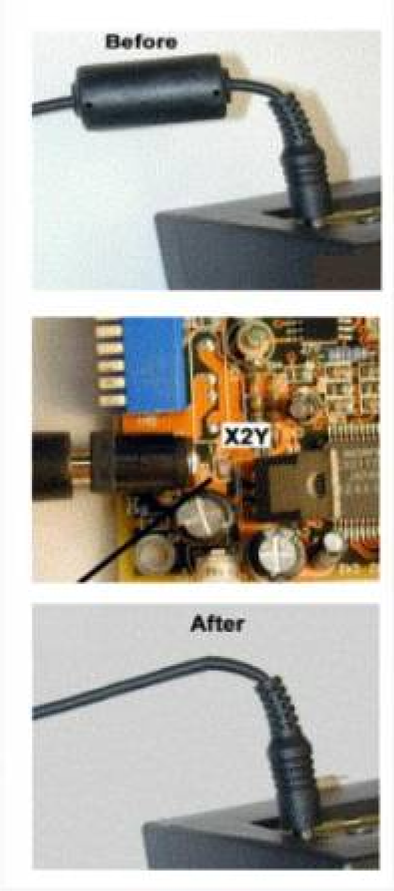
The X2Y significantly outperforms standard components in differential mode.



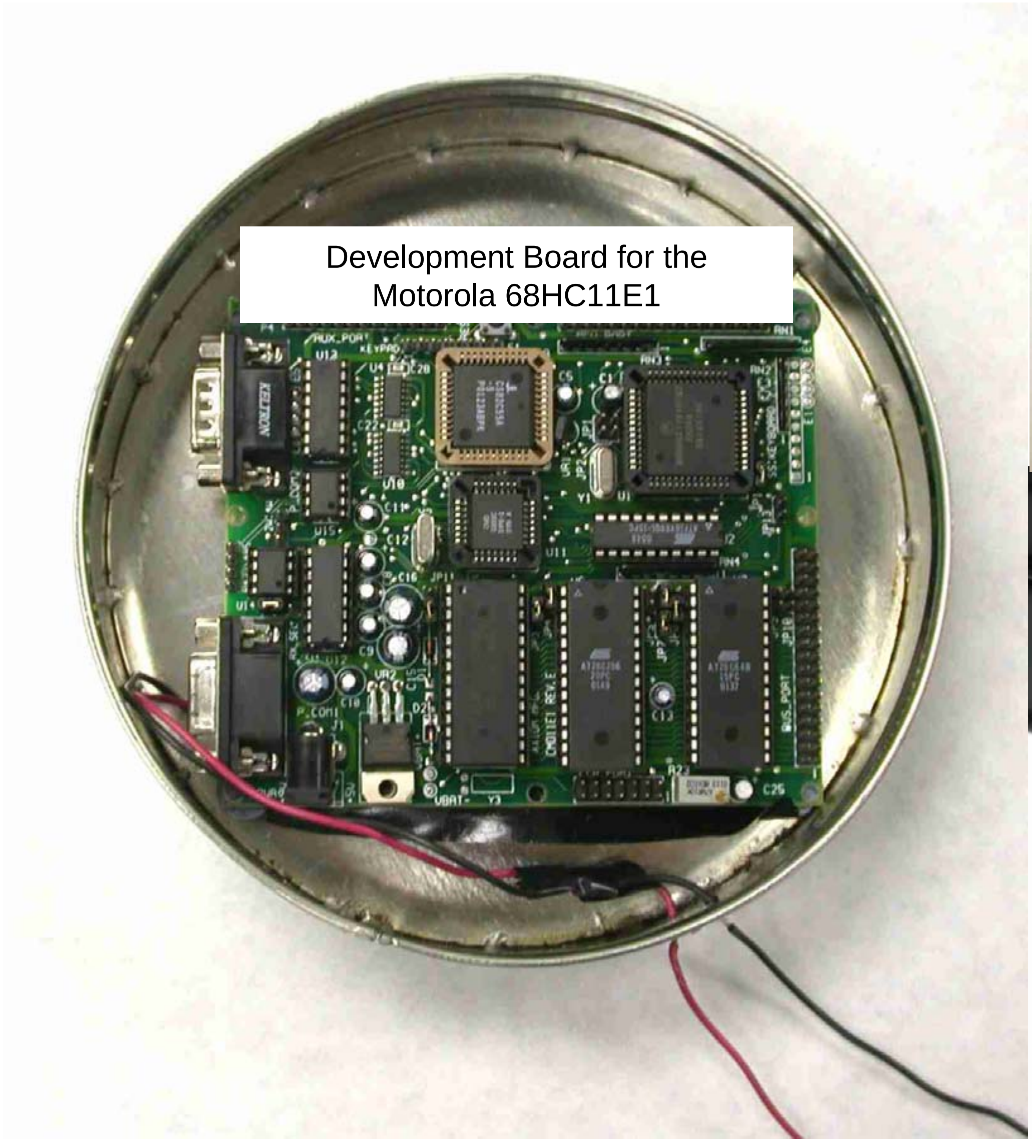
Computer Power Filtering

I/O cables require filtering. X2Y is working to remove the ferrite from the power cord in this application.

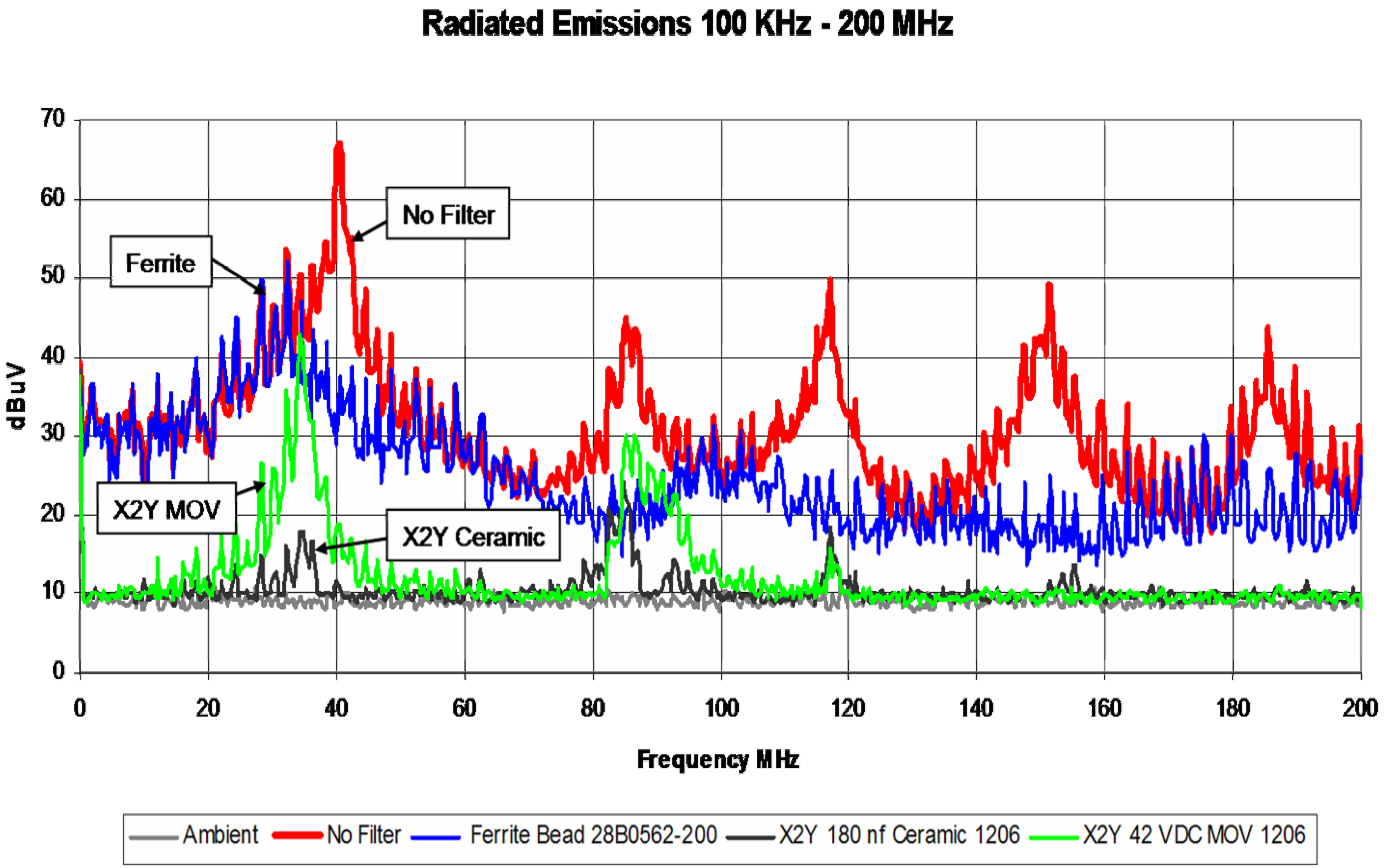




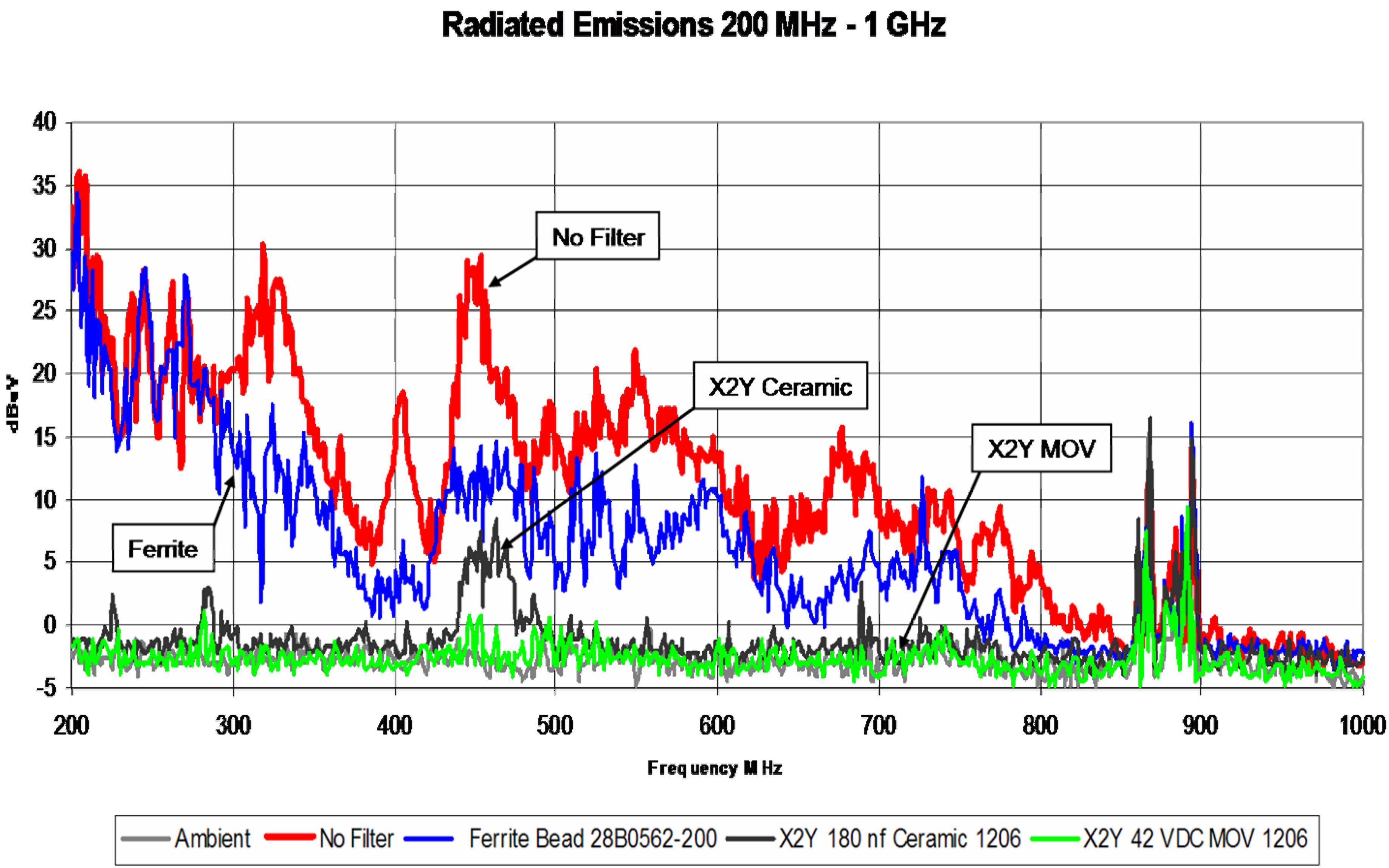
Development Board Test Set-Up



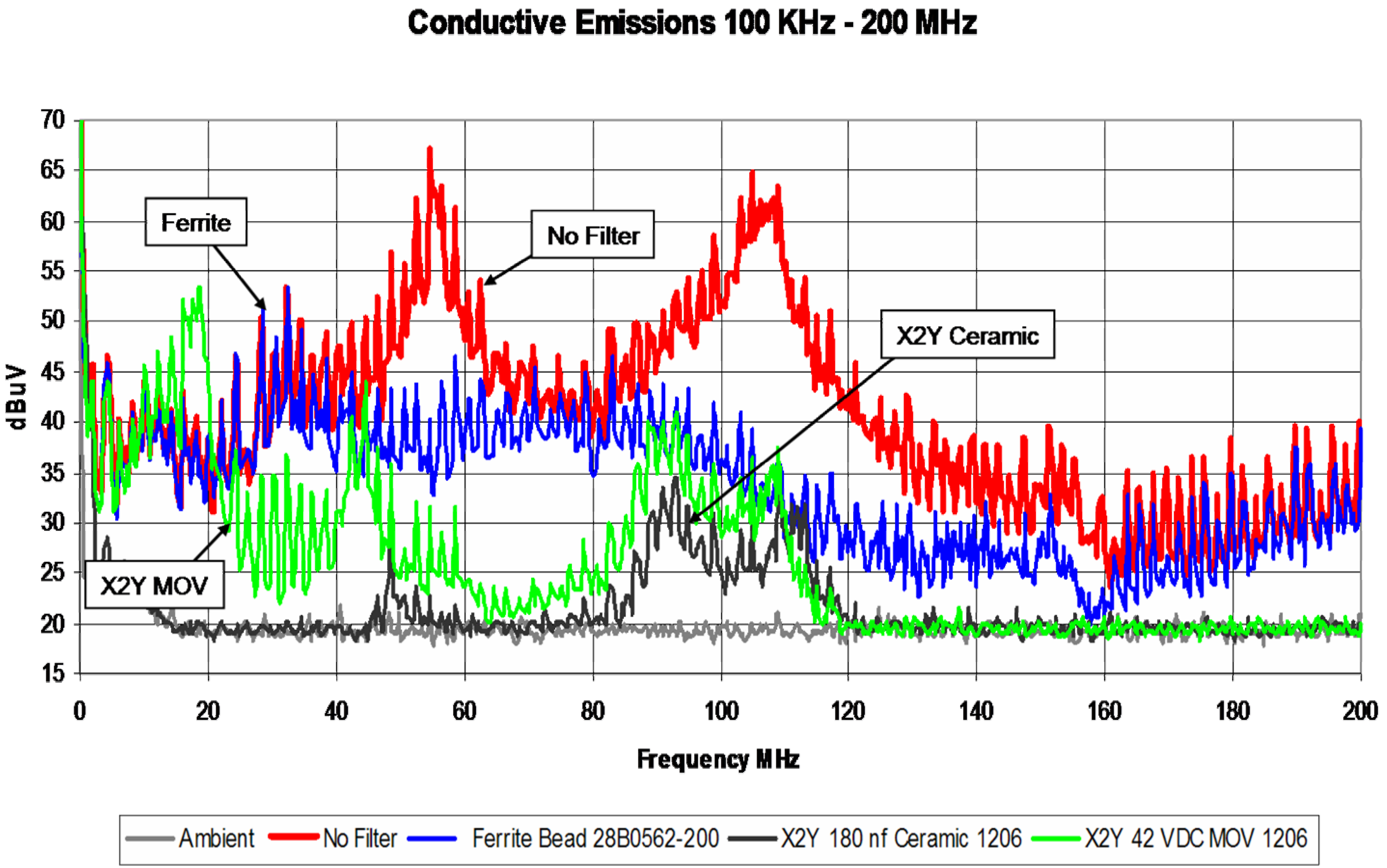
Development Board Test Data



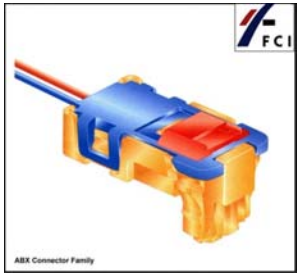
Development Board Test Data

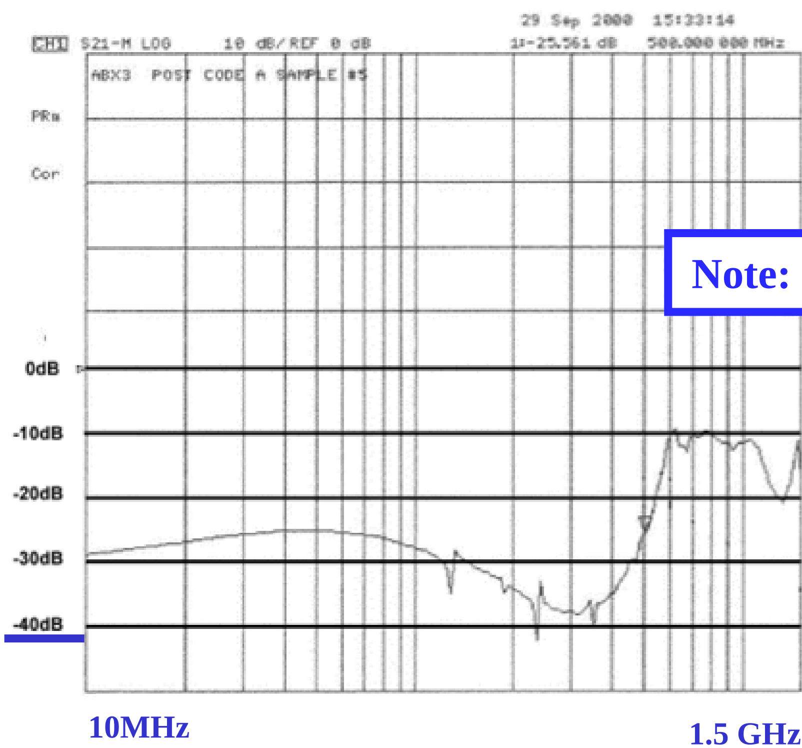


Development Board Test Data

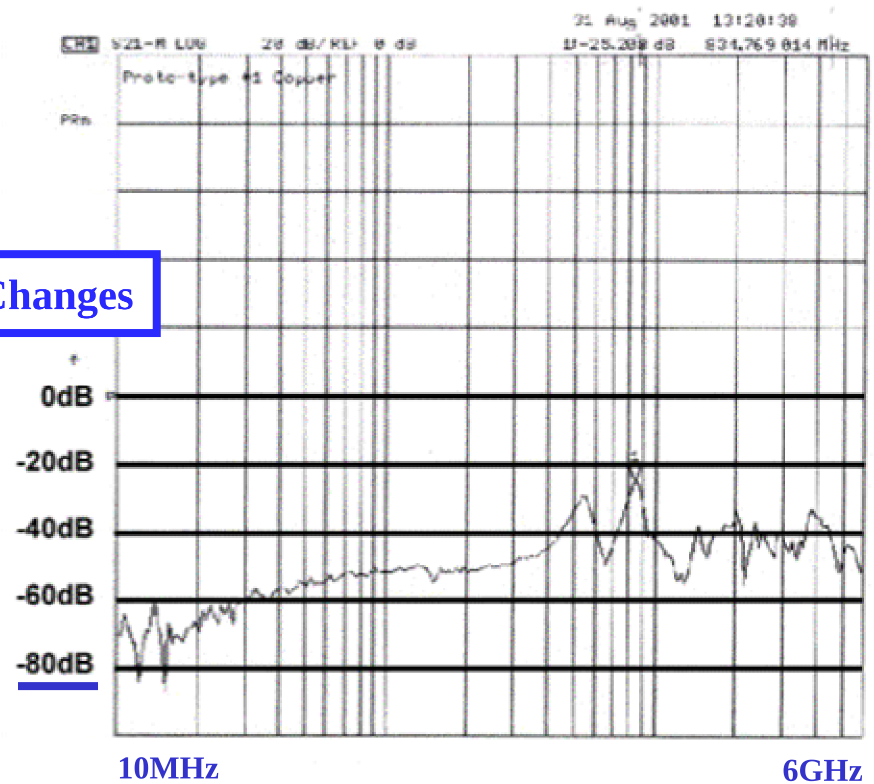


Insertion Loss for Connectors





Note: Scale Changes



ABX-3 with Ferrites

ABX-3 with X2Y® (no ferrites)

Conclusion

- Discrete Components are Affected at High Frequency by Parasitics
- X2Y is a Single Component for Broadband Filtering Applications
  - Balanced
  - Low Inductance
  - Perform at High Frequencies
- Several Applications of X2Y filters are possible for EMI reduction