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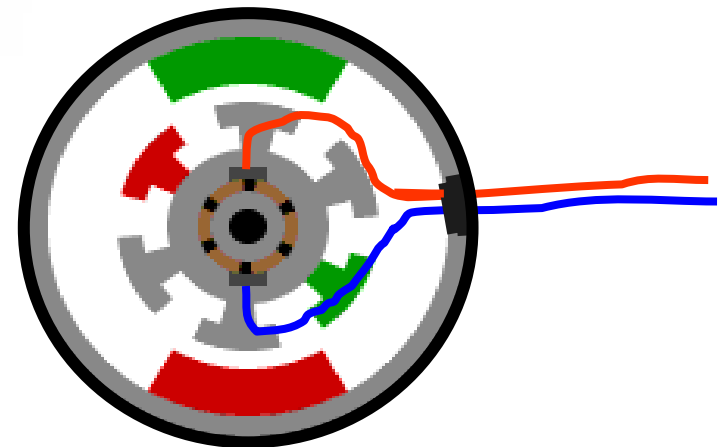
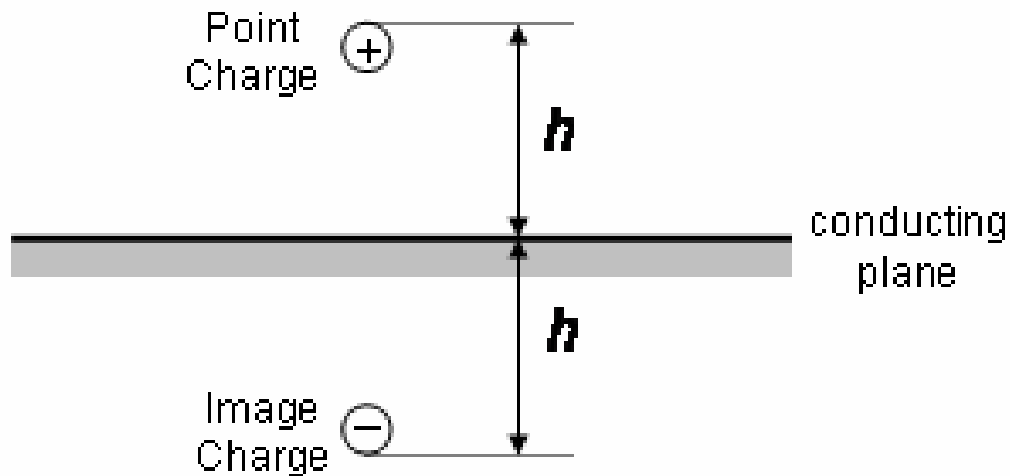


Present by: Jim P. Muccioli

Using Image Planes on DC Motors to Filter High Frequency Noise

Presented at 2004 IEEE International EMC Symposium
in Santa Clara, CA

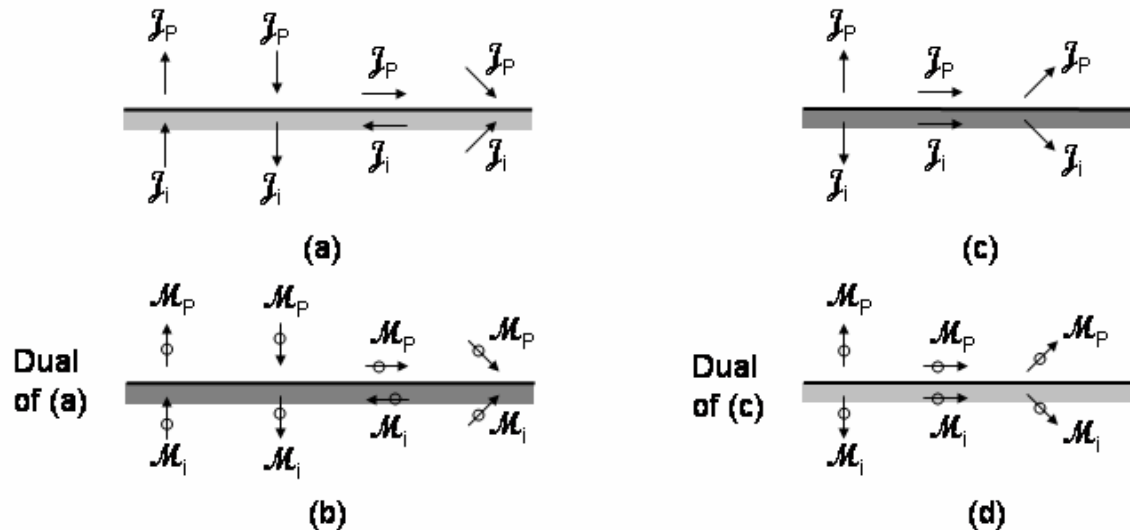
- To investigate Image Theory as a broadband filter approach for DC Motors



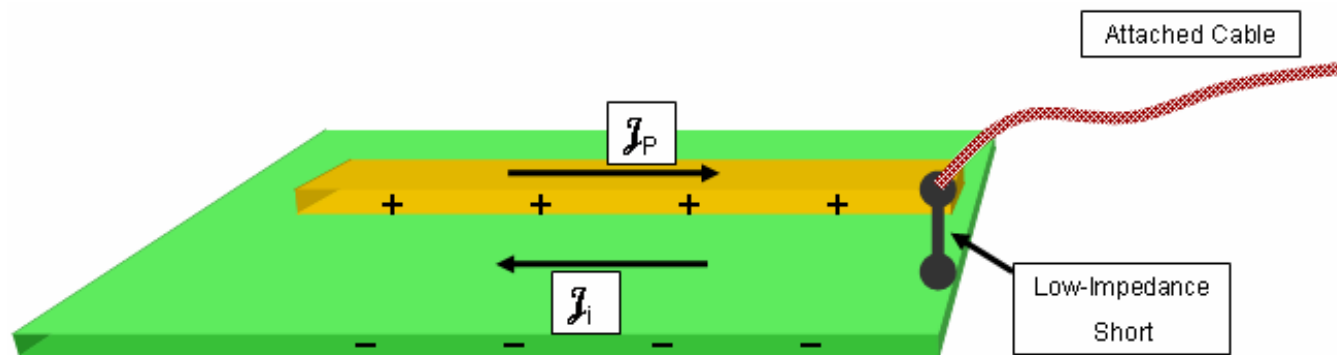
- The fundamental conservation of charge incurs time varying electric currents above an electric conductor images.

$$\nabla \cdot \mathbf{J} + j\omega\rho = 0$$

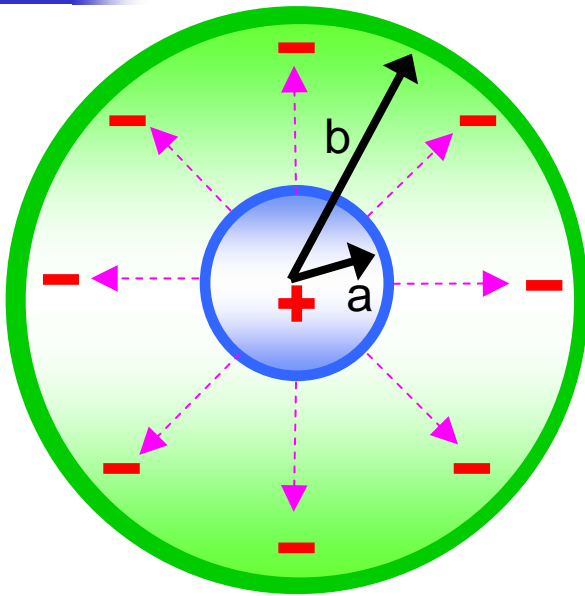
- Maxwell's Equation immediately concludes Magnetic currents above a magnetic conductor has images.



- German, Ott, & Paul, “*Effect of an Image Plane on Printed Circuit Board Radiation*,” IEEE EMC Symposia Records 1955 to 1995, vol. IEEE04, 1996.

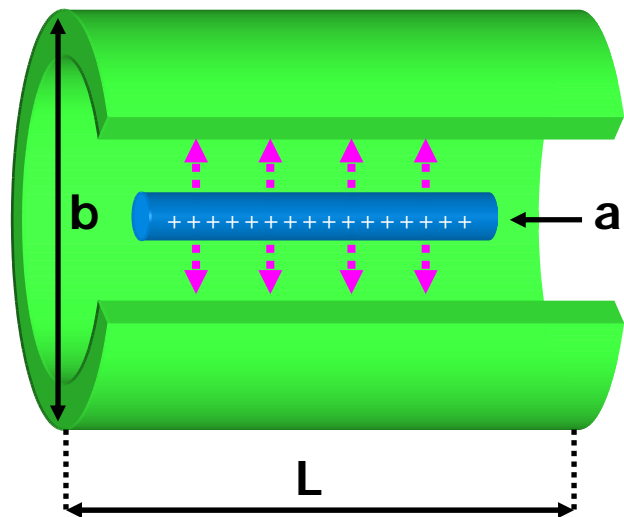


- Hsu. “*The Validity of Using Image Plane Theory to Predict Printed Circuit Board Radiation*,” IEEE EMC Symposia Records 1955 to 1995, vol. IEEE04, 1996.
- Fessler, Whites, & Paul, “*Effect of Image Plane Dimension on Radiated Emissions*,” IEEE EMC Symposia Records 1955 to 1995, vol. IEEE04, 1996.



- 2 spheres with radii a & b .
- Uniform distribution of E- & H-fields in all directions.
- Perspective of center sphere, outer sphere is infinitely large (completely encompassed)
- 3-dimensional.

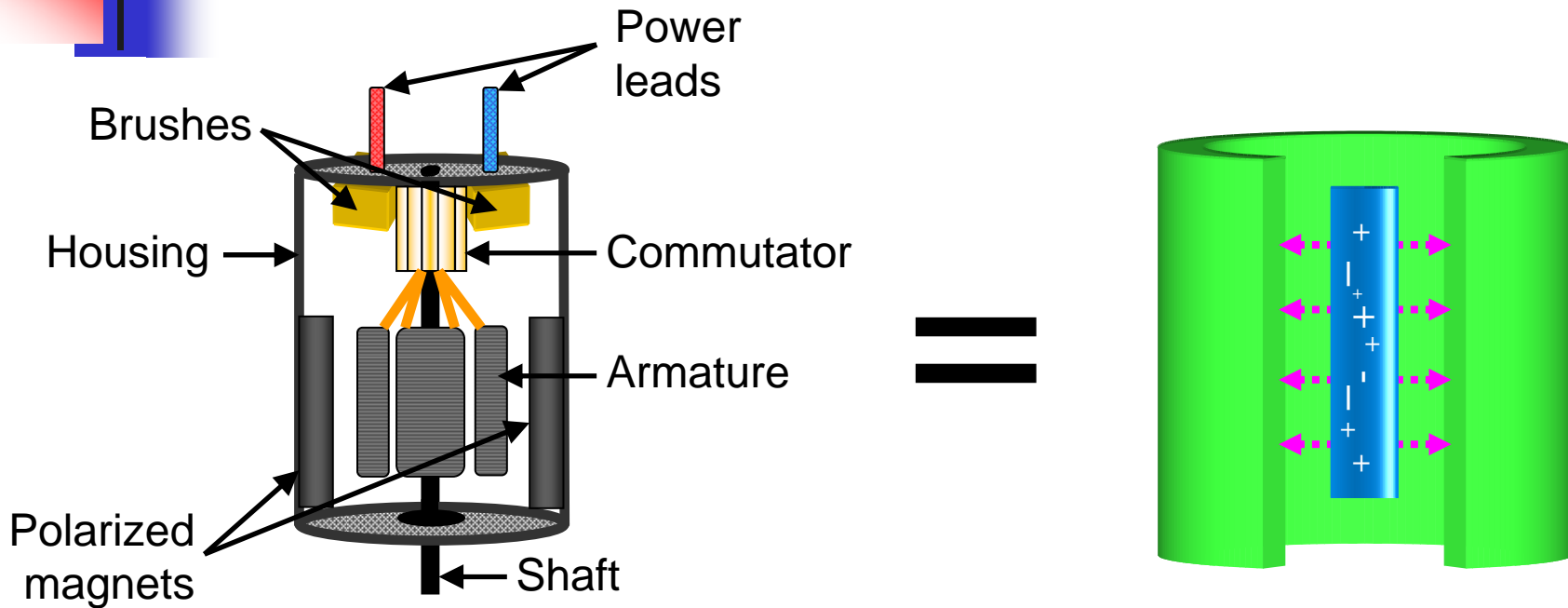
$$C = 2\pi\epsilon_0 \frac{ab}{b-a}$$



- $L \gg b$, edge fringing is negligible.
- Uniform distribution of E- & H-fields in all directions.
- 3-dimensional.

$$C = 2\pi\epsilon_0 \frac{L}{\ln\left(\frac{b}{a}\right)}$$

DC Motor Viewed as Cylindrical Image Sphere



- The internal current loop inherent to DC motors couples noise to the housing in 3-D.
- If a low impedance short that blocks DC is applied between the housing and +/- Power leads to the housing, noise cancels.

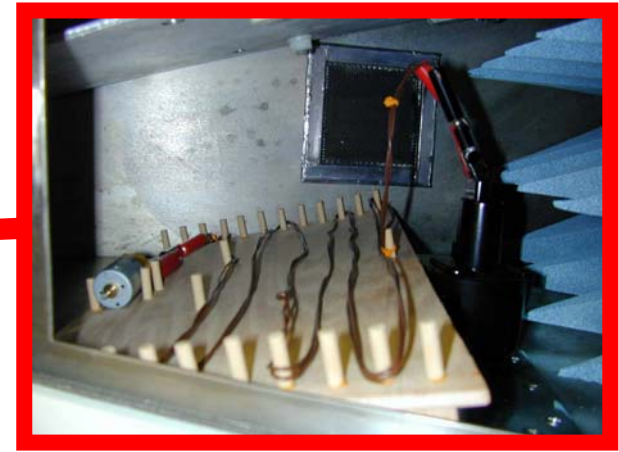
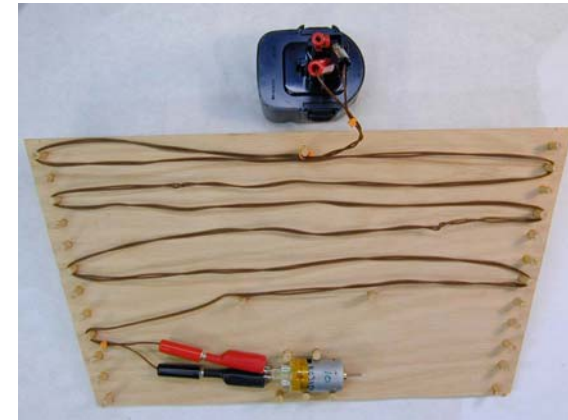
■ Location, Location, Location

- Lead/Trace length from power leads to filter.
- Connection geometry to the housing (G1/G2).
- Placement at the exit point of the housing.

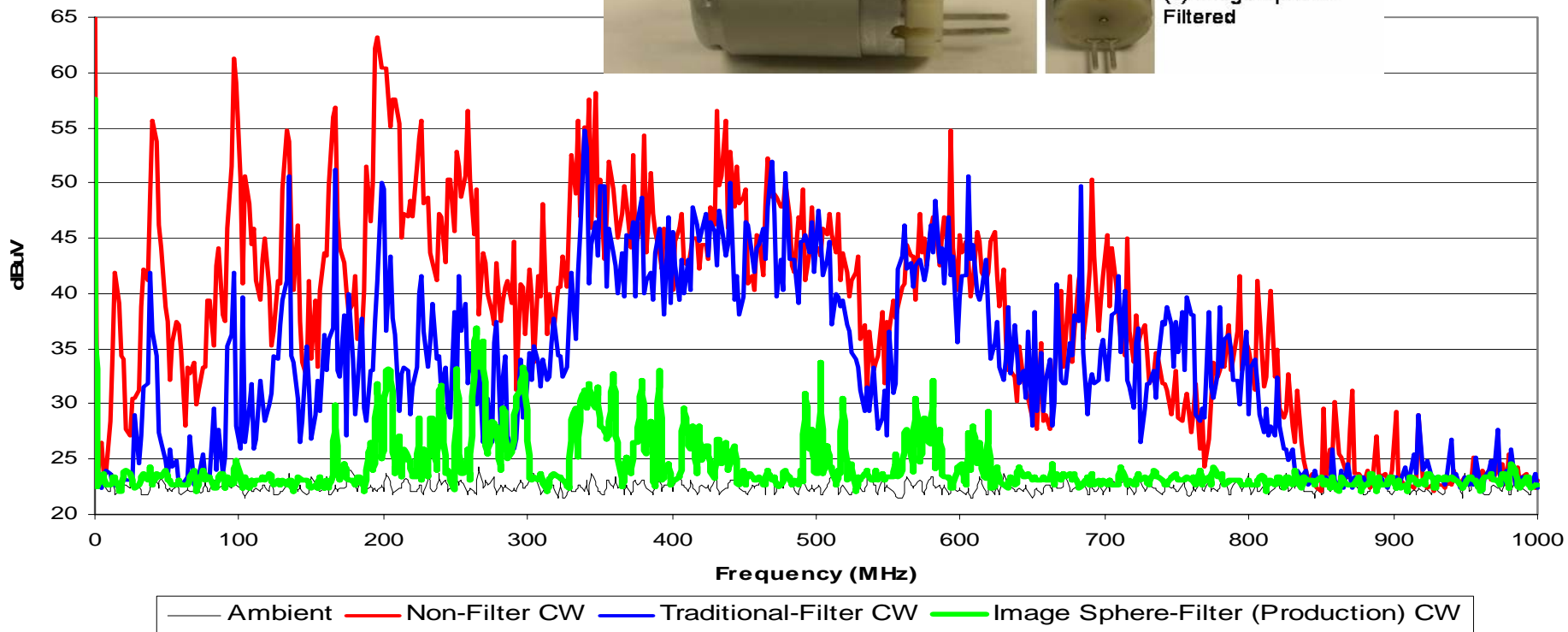
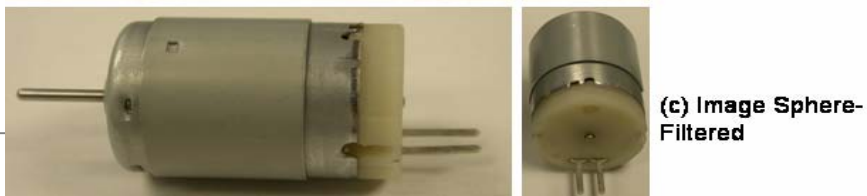
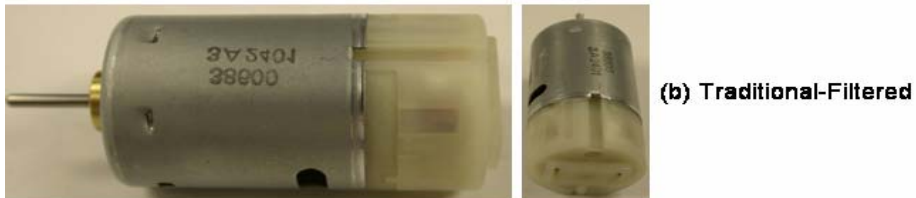
■ Other considerations

- Prevent phase shift – balance between filter elements and power leads.
- To filter from kHz to GHz – broadband low-impedance filter.

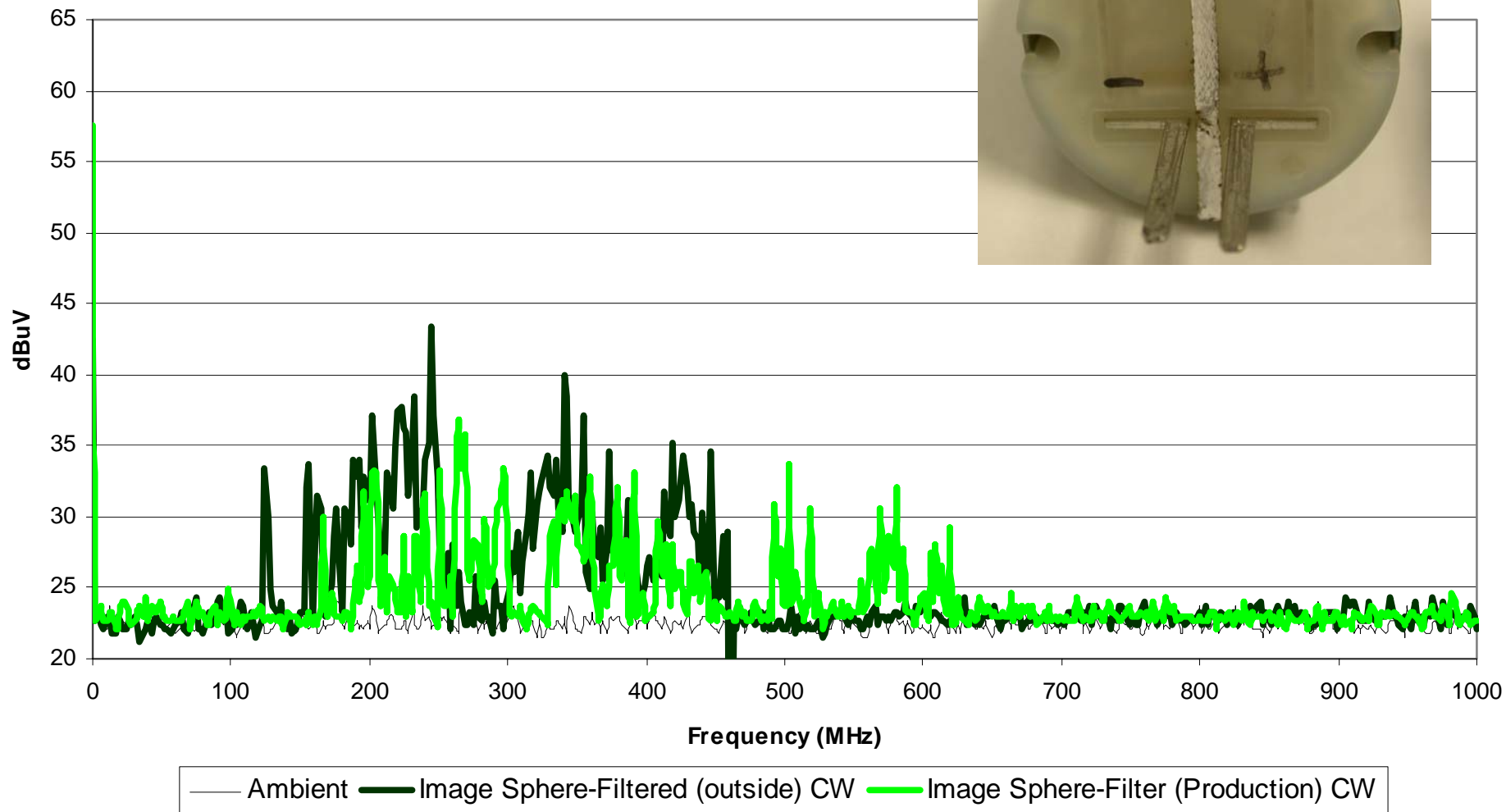
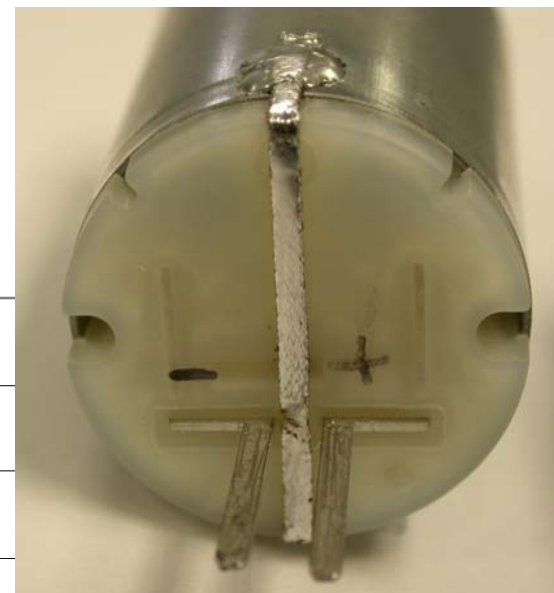
- Motor is attached to DC power supply by 3 meter cable.
- Radiated emissions are measured in a GTEM (ETS-Lindgren IC-GTEM 250) with a spectrum analyzer (IFR AN920).



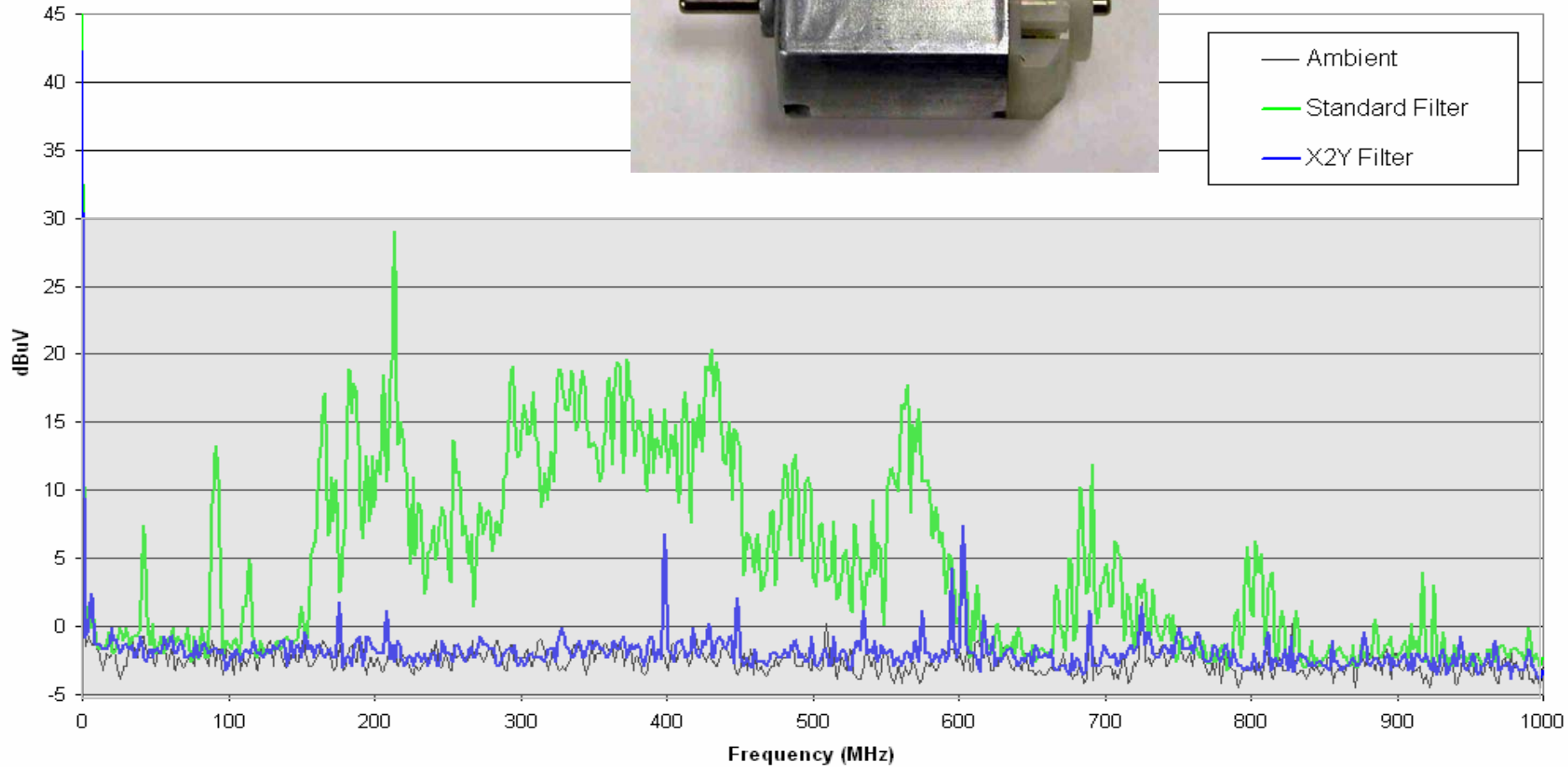
Radiated Emissions - Washer Pump Motor



Radiated Emissions - Washer Pump Motor (continued)



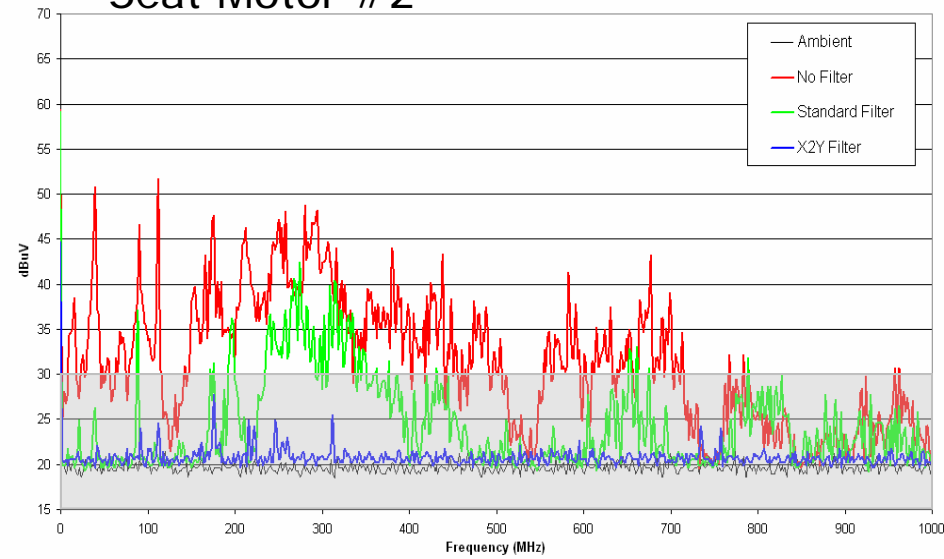
- 30dB pre-amp was used.



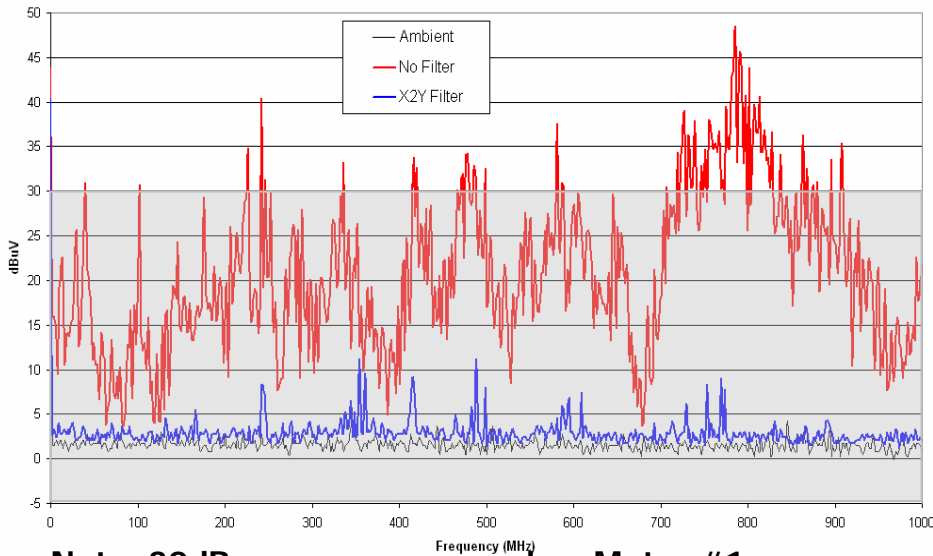
Radiated Emissions - Seat Motors



Seat Motor #2

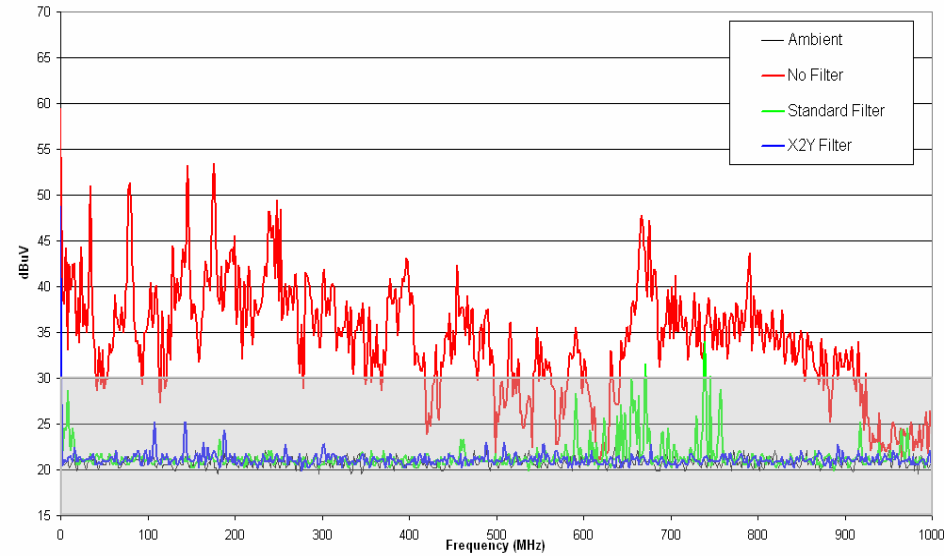


Seat Motor #1

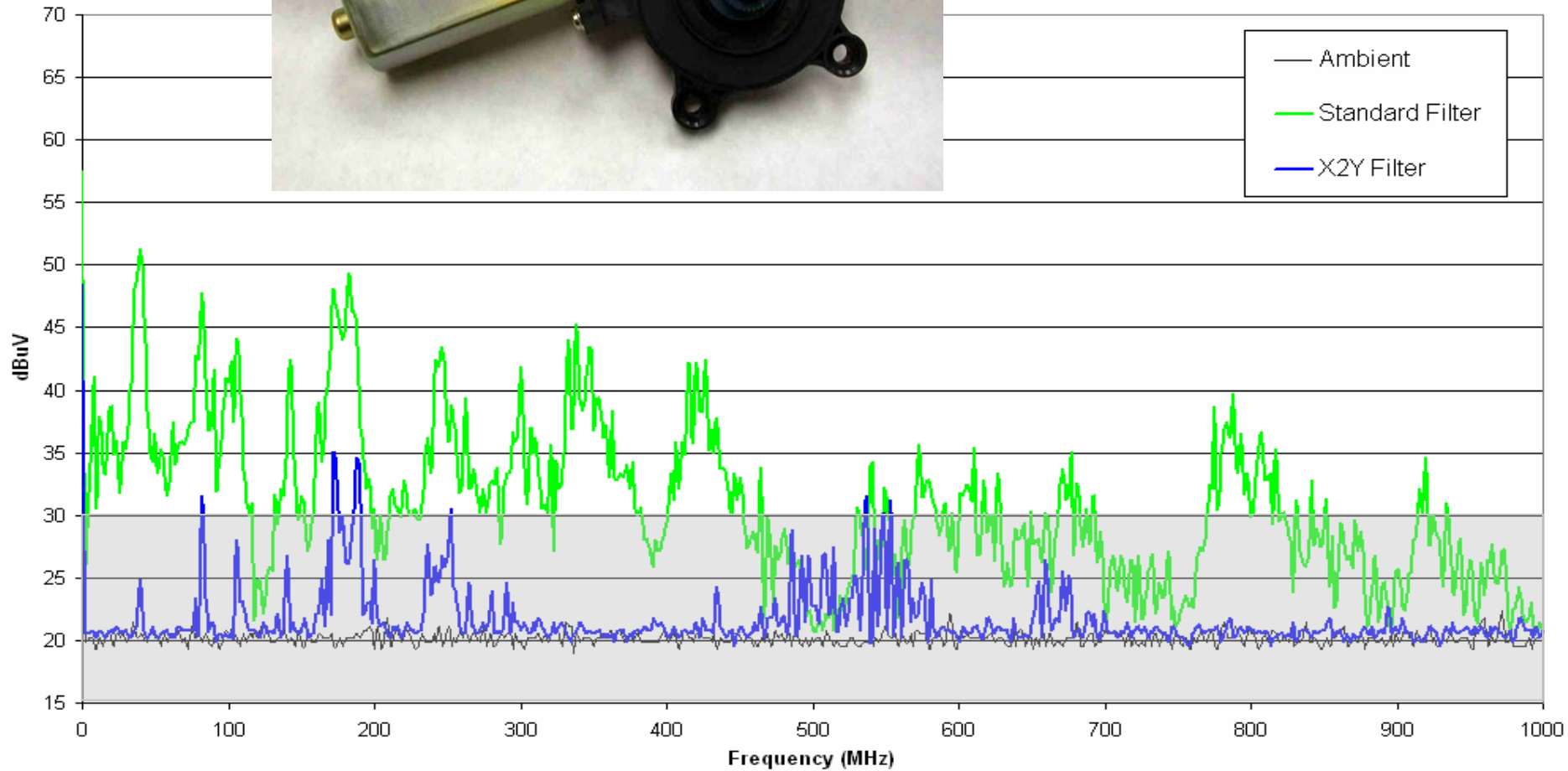


Note: 30dB pre-amp was used on Motor #1

Seat Motor #3



Radiated Emissions - Window Lift Motor



- Typically DC motor design is limited to a mechanical perspective with little thought given to electromagnetic filtering.

- Viewing DC motors as a complex electromagnetic module and applying Image Theory as a means of energy propagation can simplify design focus to include electromagnetic filtering and mechanical aspects.

- Implementing Image Theory at the beginning of the design process results in the following production and manufacturing benefits:
 - Smaller package Motor
 - Cost savings
 - Same type of filter across multiple motor product lines

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Questions?

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