Electromagnetic Compatibility of Direct Current Motors in an Automobile Environment

James Muccioli, X2Y Attenuators, LLC
Terry North, DiamlerChrysler
Keith Frazier, Ford Motor Company
Dale Sanders, X2Y Attenuators, LLC

SAE 2005 WORLD CONGRESS

Why is there a need for this paper?

Motor suppression has become a major issue for Big three

- The number of electronic applications in automobiles is increasing
  - Applications have broader and higher operating frequencies
- The number of motor applications in automobiles is increasing
  - A typical automobile has a range of 50 – 80 DC motors
- Cost – typical motor suppression cost $1-3 per motor
- If current electronic and motor applications continue, suppression requirements will increase.

What is the purpose of this paper?

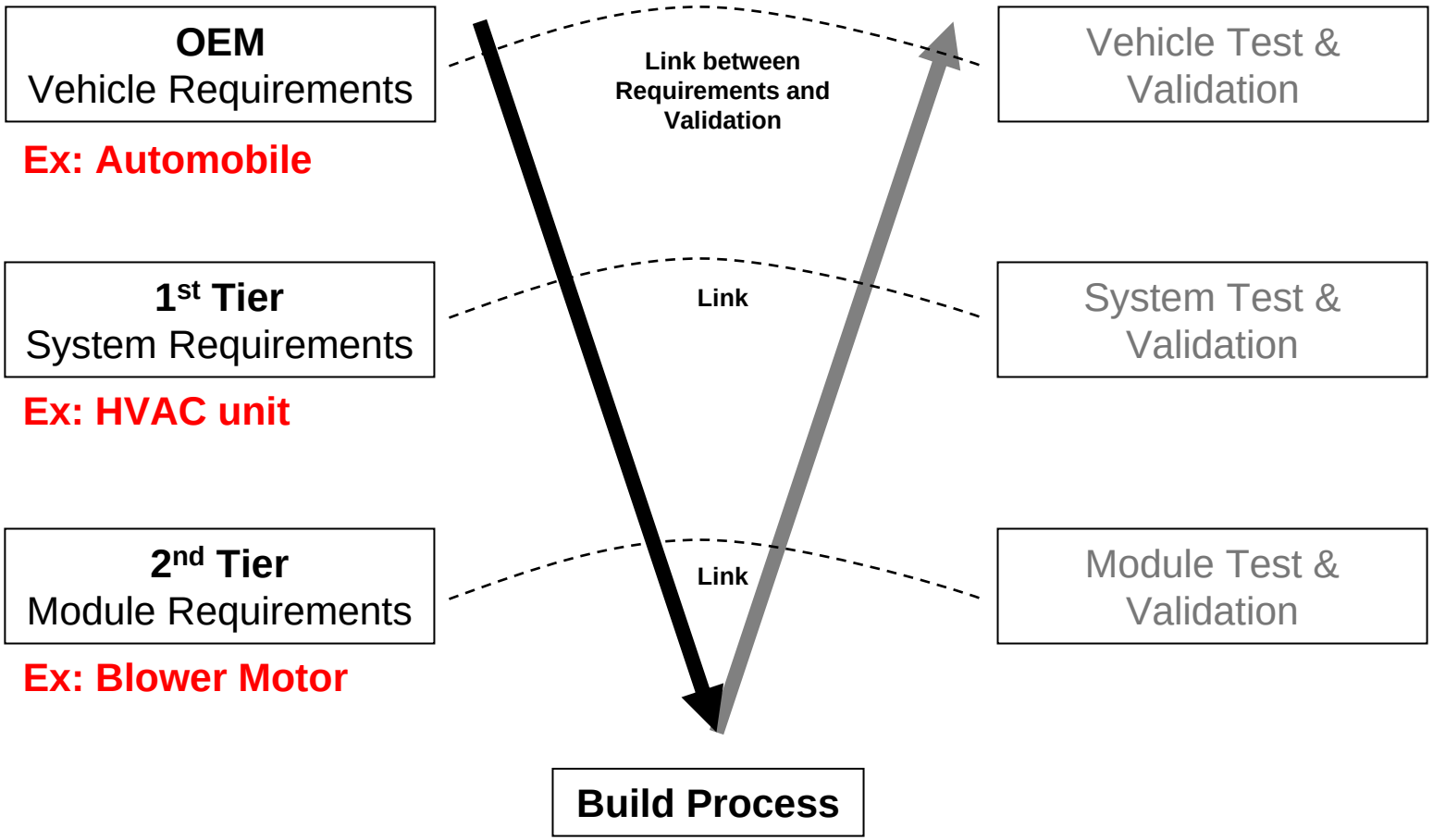
The purpose of this paper is 3-fold

- "Handbook" of Big Three DC motor EMC requirements
- Frame Motor EMC in terms of an industry wide issue
- Address design considerations of DC motors that effect EMC

Myth – EMC isn't cost-effective

- EMC improves performance & reliability, which lowers warranty cost.
- Module level EMC reduces system level integration issues, thus time-to-market and cost.
- JD Power customer satisfaction numbers which effect sales.
- Allows for system engineering which reduces time-to-market

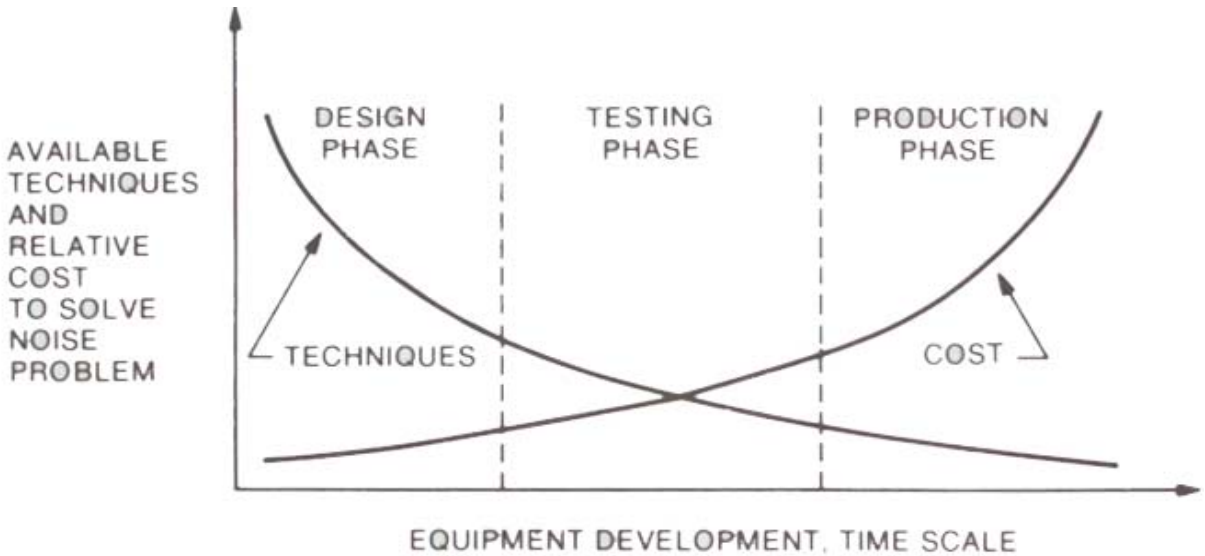
System Engineering for DC Motors



When should EMC suppression be addressed?

EMC suppression should be addressed at the beginning of a design

- More cost-effective design options available
- Cost can be driving consideration for design



Ott, Henry. "Noise Reduction Techniques in Electronic Systems," 2nd edition, John Wiley & Sons, Inc., New York, 1998, page 6.

What are the OEM requirements?

DaimlerChrysler (DCX) – https://adxi.autoweb.net

- DC-10614 *"EMC Performance Requirements --- Components"*
- DS-100 *"Vehicle Design Requirements for EMC Compliance"*
- DC-10615 "*Electrical System Performance Requirements for Electrical and Electronic Components*"

Ford Motor Company – www.fordemc.com

- ES-XW7T-1A278-AC *"Component and Subsystem Electromagnetic Compatibility Worldwide Requirements and Test Procedures"* 10 October 2003.

General Motors (GM) – http://global.ihs.com/

- GMW3103 *"General Specification for Electrical/Electronic Components and Subsystems; Electromagnetic Compatibility; Global EMC Component/Subsystem Validation Acceptance Process"*
- GMW3097 "General Specification for Electrical/Electronic Components and Subsystems, Electromagnetic Compatibility (EMC)"

Types of Motor Classification

DC Motors are defined by type of commutation and duration it is used.

- Commutation
  - Brush commutated (BC) or sparked generated
  - Electronically commutated (EC) or non-sparked generated.
- Duration
  - Long-duration
  - Short-duration (operator controlled)

What are the Required EMC Tests?

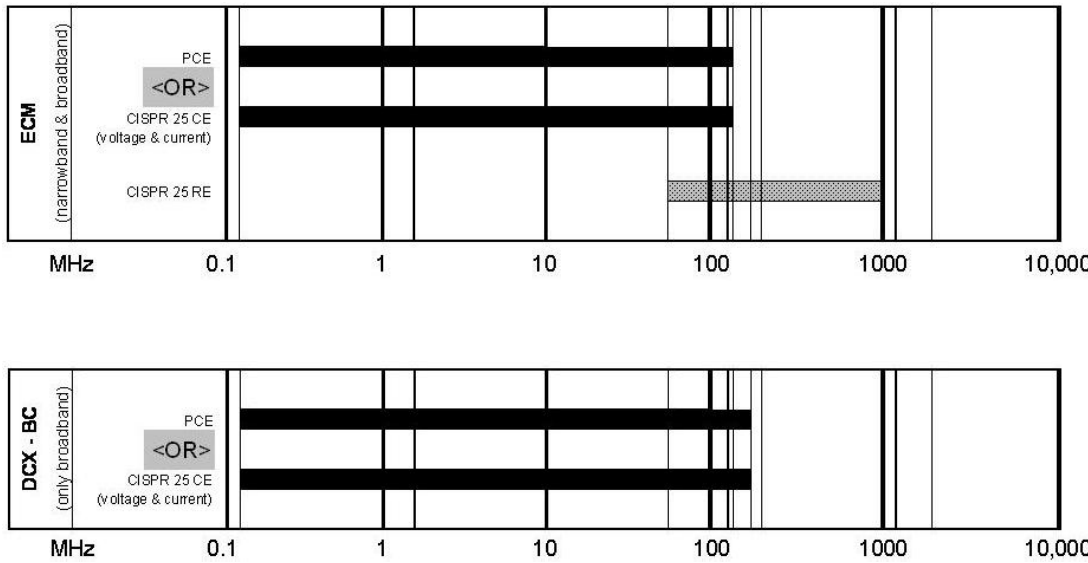
There are 3 main test performed on DC motors. Specific limit levels and required tests depend on motor classification.

- Conducted Emissions (CE)
- Radiated Emissions (RE)
- Conducted Transients (CT)

DaimlerChrysler (DCX)

Frequency Spectrum

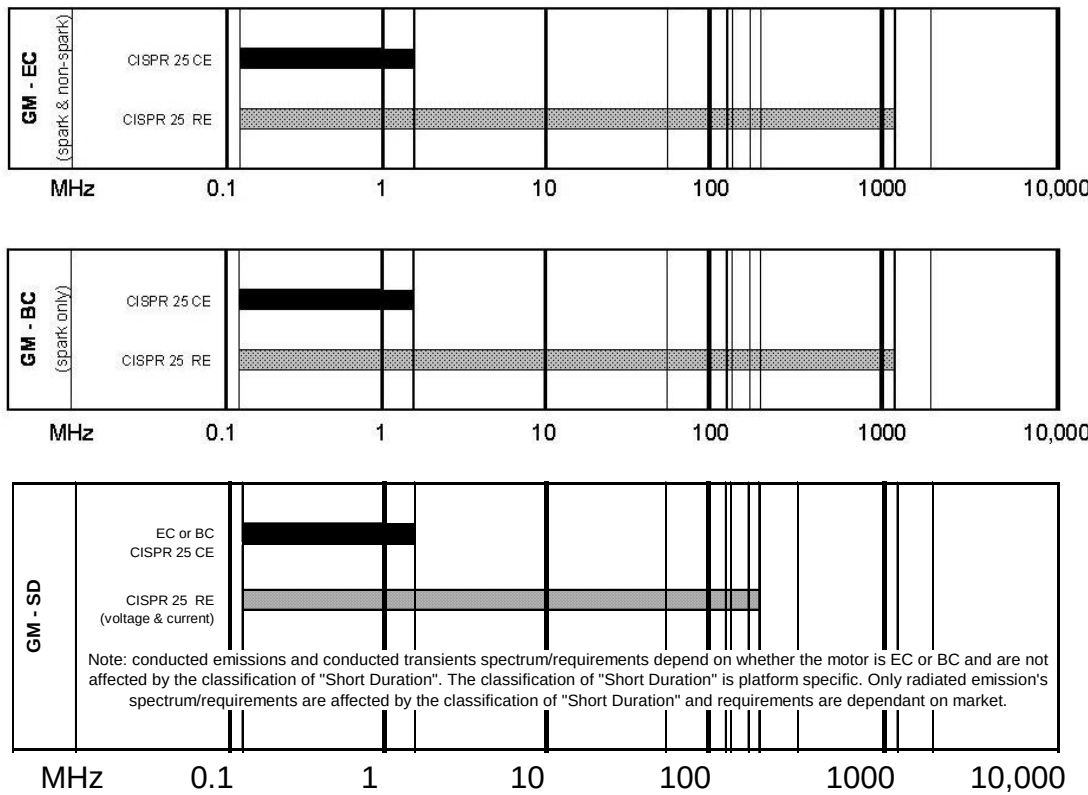
- Conducted Emissions (CE)
  - EC = 150 kHz – 110 MHz
  - BC = 150 kHz – 200 MHz
- Radiated Emissions (RE)
  - EC = 76 MHz – 1 GHz
  - BC = none
- Conducted Transients (CT)
  - 12V & 42V motors = ±80V
  - 24V = +80/-150V



General Motors (GM)

Frequency Spectrum

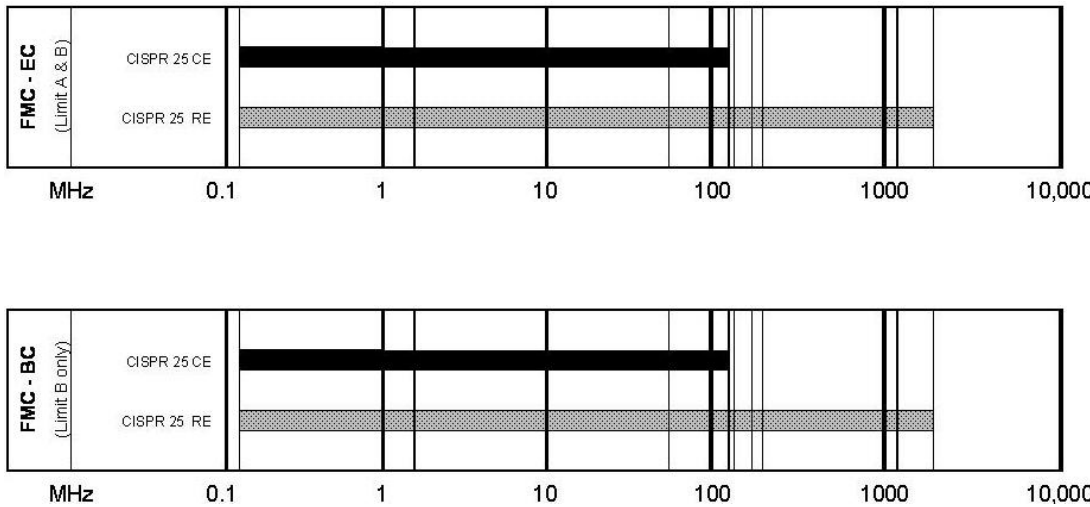
- Conducted Emissions (CE)
  - EC = 150 kHz – 1.71 MHz
  - BC = 150 kHz – 1.71 MHz
  - SD = same as EC & BC
- Radiated Emissions (RE)
  - EC = 150 kHz – 1.583 GHz
  - BC = 150 kHz – 439 MHz
  - SD = 150 kHz – 242.4 MHz
- Conducted Transients (CT)
  - EC & BC = +100/-150V
  - SD = same as EC & BC



Ford Motor Company

Frequency Spectrum

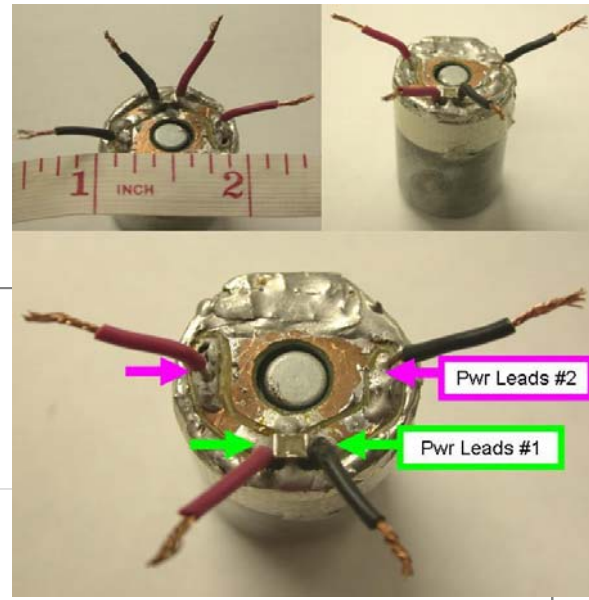
- Conducted Emissions (CE)
  - EC = 150 kHz – 108 MHz
  - BC = 150 kHz – 200 MHz
- Radiated Emissions (RE)
  - EC = 150 kHz – 2.5 GHz
  - BC = 150kHz – 2.5 GHz
- Conducted Transients (CT)
  - EC & BC = +100/-150V



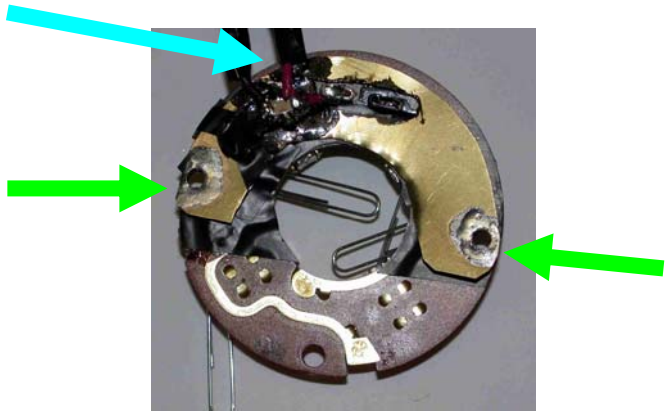
Design Considerations for Motor EMC

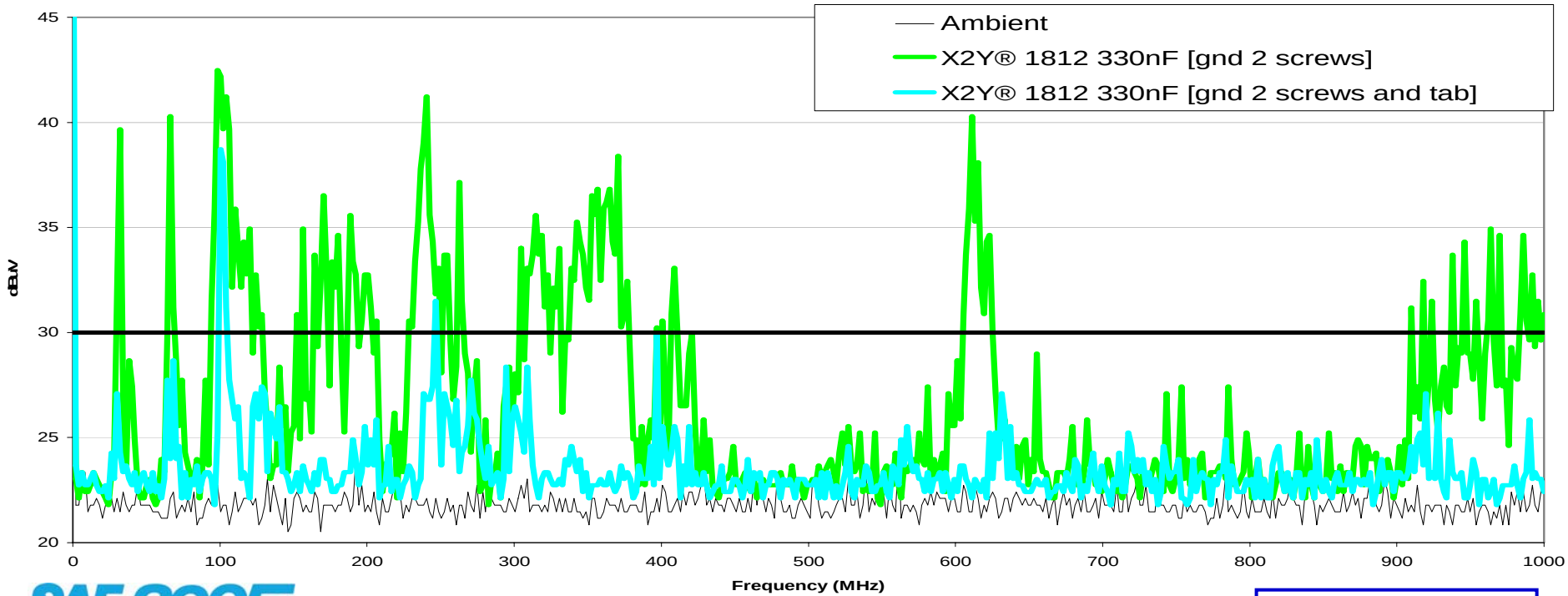
- Lead length between power leads and filter
- Ground connection to filter
- Housing/end-cap material and holes
- Location of filter
- Joints

Lead Length between Power Leads and Filter



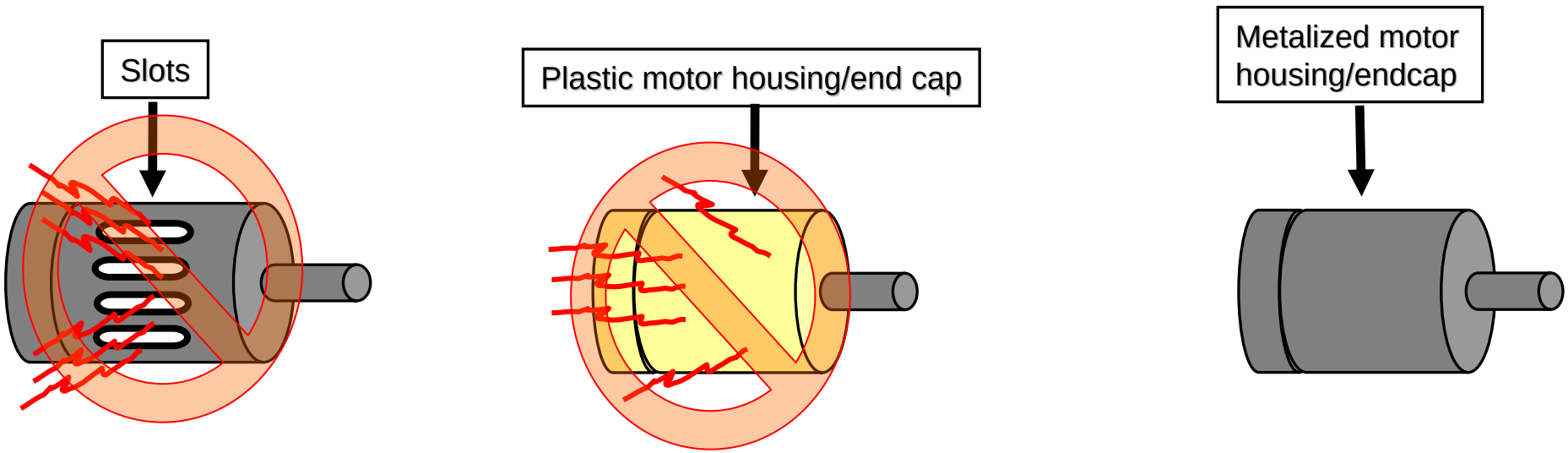
Ground Connection to Filter



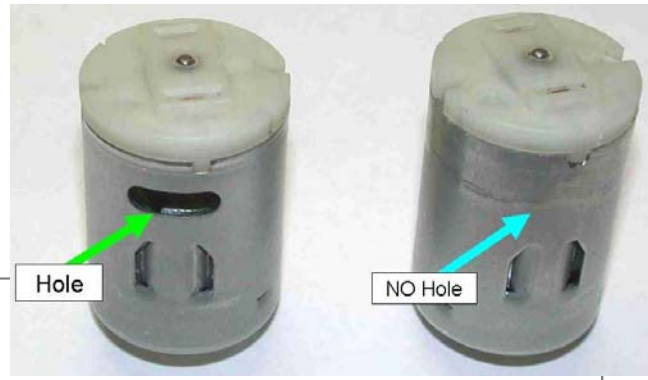


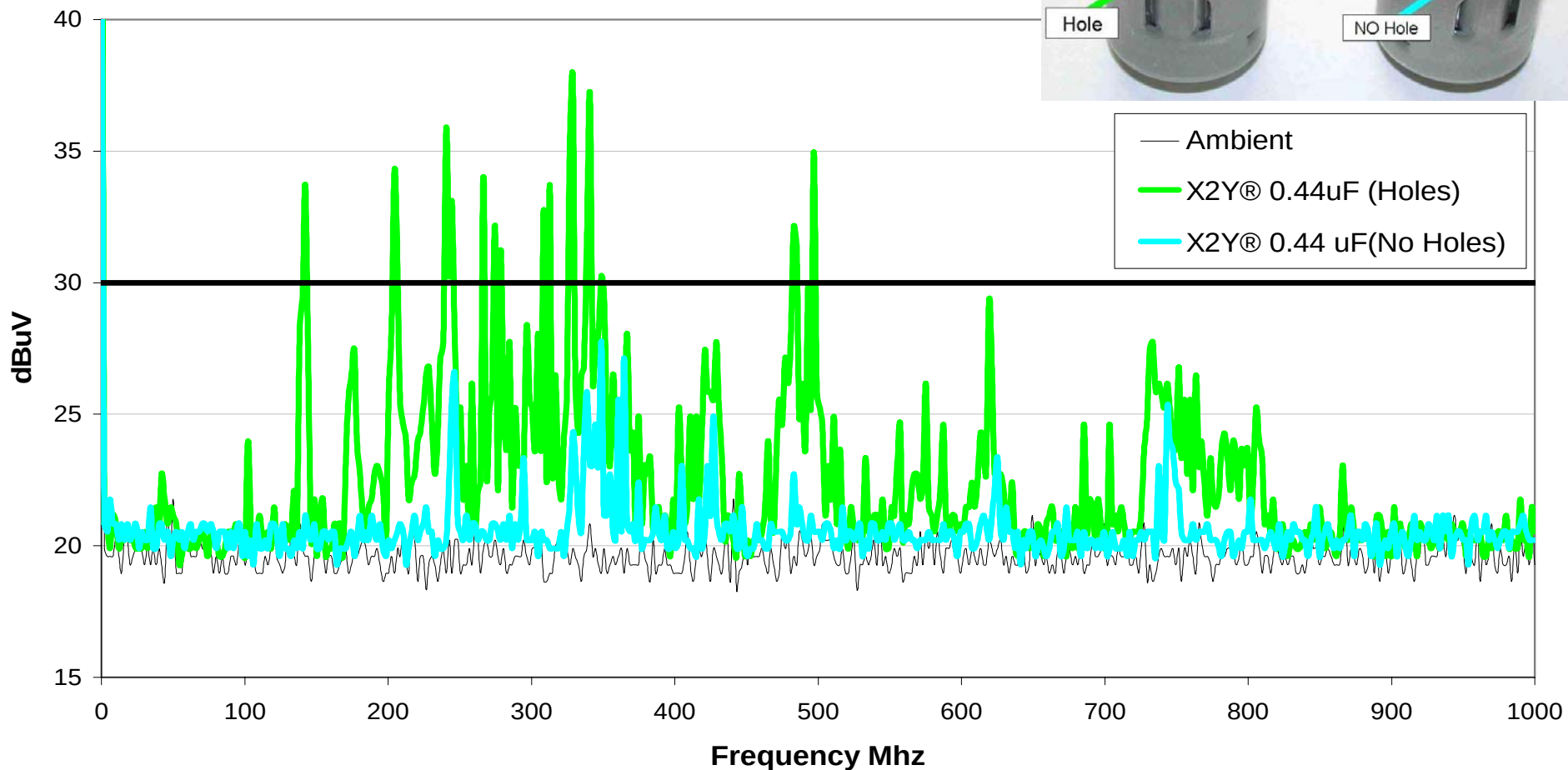
Housing/end-cap material and holes

- Housing/end cap should be metal or metalized to provide shielding.
- Slots should be eliminated or minimized to keep from making them “slot antenna”.



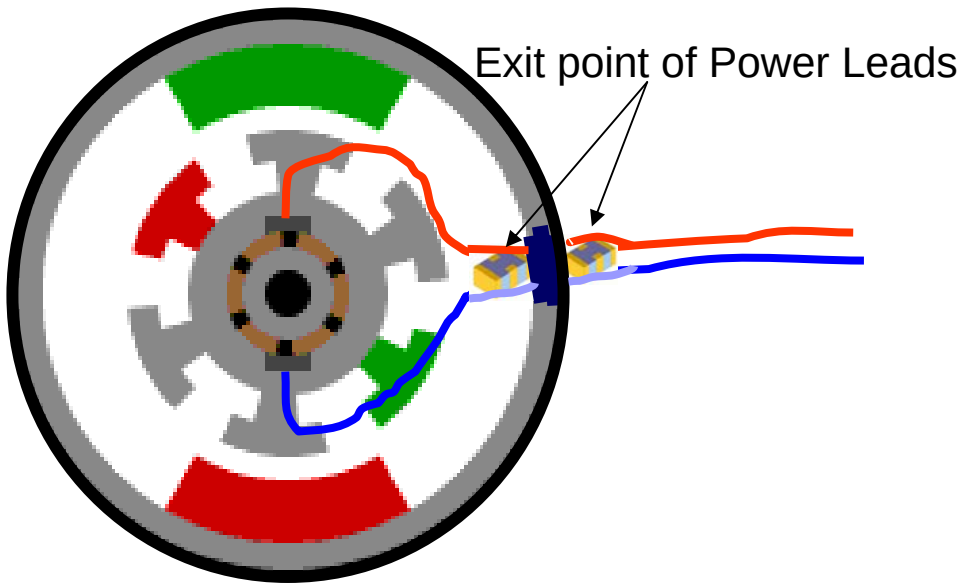
Housing/end-cap material and holes





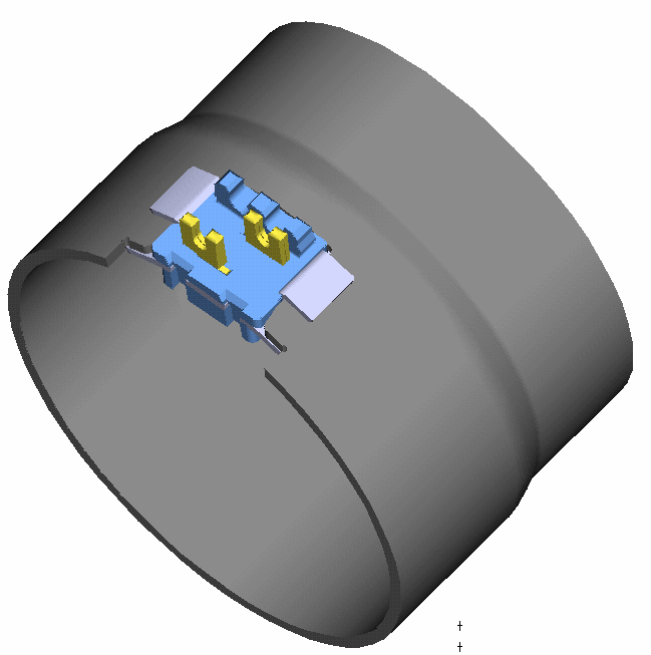
Location of Filter

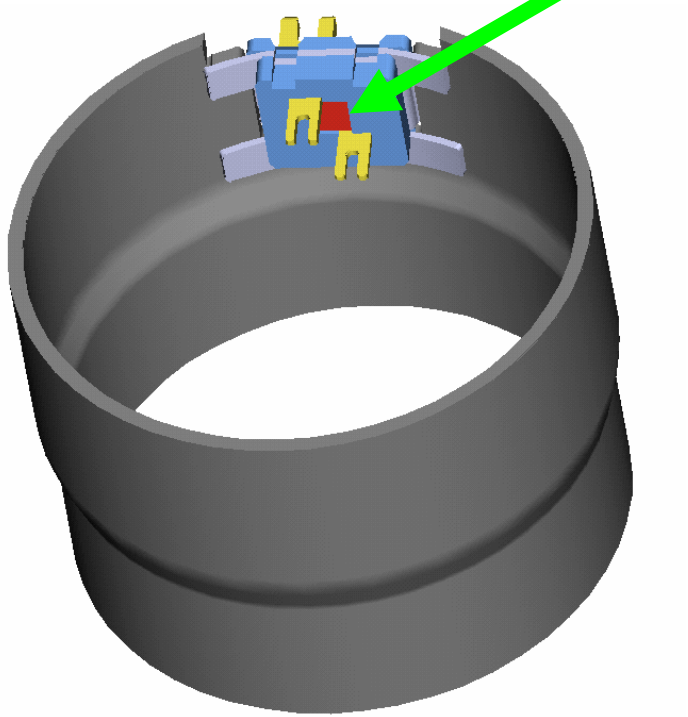
Filter should be located at the exit point of the power leads to prevent noise from coupling around the filter.



Filtered Connectors

- Easy to implement
- Reduce design time
- Doesn't require internal modifications
- Cost-effective



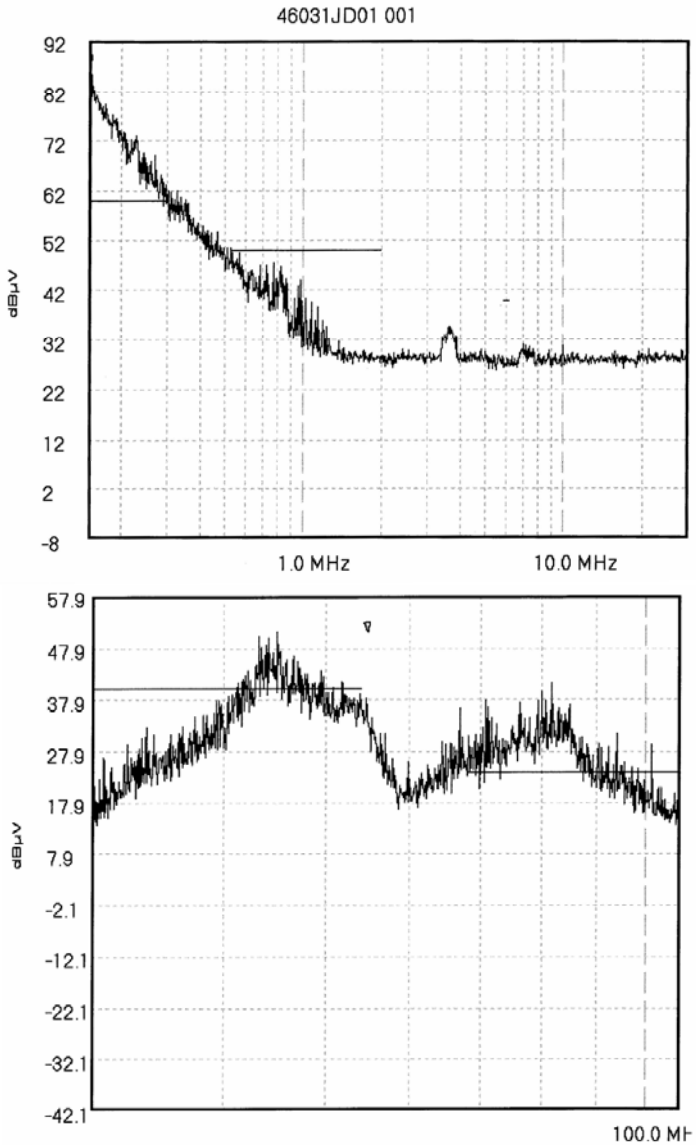


*Pictures courtesy of ITT Industries (Cannon)

Filtered Connectors (continued)

CISPR 25 Conducted

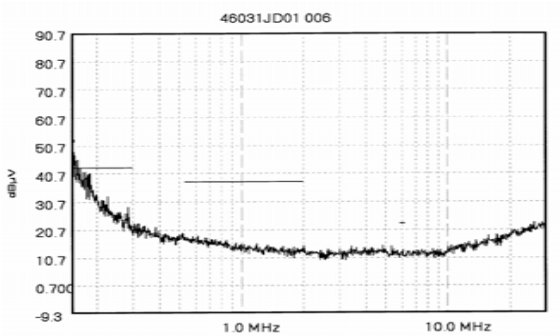
Class	Levels in dB(µV)				
	0.15MHz to 0.3MHz	0.53MHz to 2.0MHz	5.9MHz to 6.2MHz	30MHz to 54MHz	68MHz to 108MHz
1	100	82	64	64	48
2	90	74	58	58	42
3	80	66	52	52	36
4	70	58	46	46	30
5	60	50	40	40	24
Broadband Conducted emissions as per table 6 of CISPR 25					
This part passes at level 5 from 0.53MHz up to 108MHz					

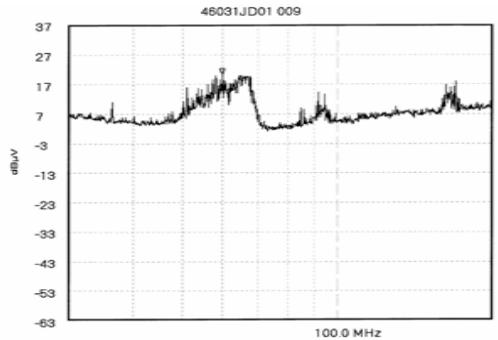


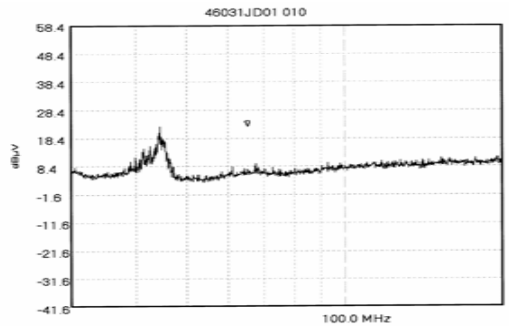
*Data courtesy of ITT Industries (Cannon)

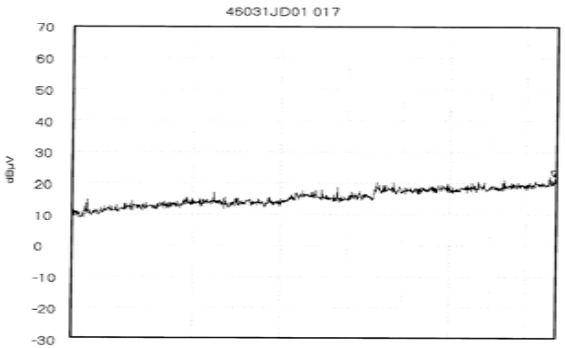
Filtered Connectors (continued)

CISPR 25 Radiated

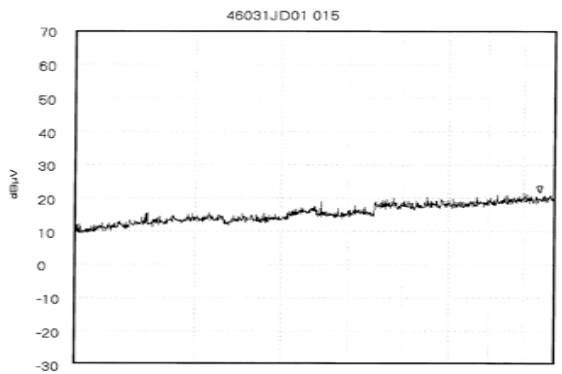








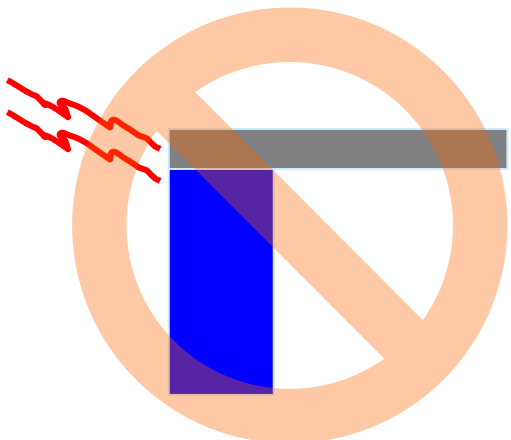
Class	Levels in dB(µV) 0.15MHz to 0.3MHz	0.53MHz to 2.0MHz	5.9MHz to 6.2MHz	30MHz to 54MHz	68MHz to 108MHz	142MHz to 175MHz	380MHz to 512MHz	820MHz to 960MHz
1	83	70	47	47	36	36	43	49
2	73	62	41	41	30	30	37	43
3	63	54	35	35	24	24	31	37
4	53	46	29	29	18	18	25	31
5	43	38	23	23	12	12	19	25
Broadband Radiated emmisions as per Table 10 of CISPR 25								
Worst case values taken from both horizontal and vertical measurements								

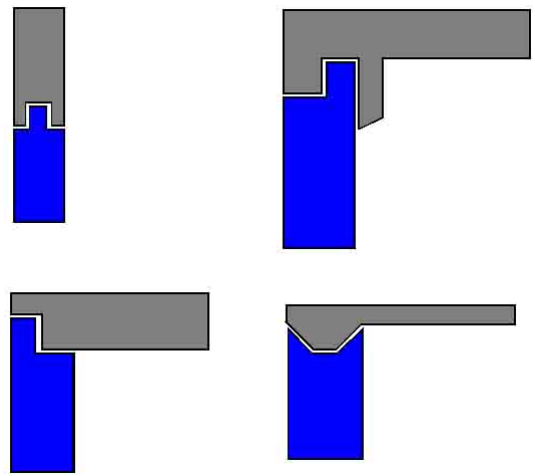


*Data courtesy of ITT Industries (Cannon)

Joints

- Metal joints are typically only design with mechanical strength.
- Electrical conductivity and shielding should also be considered.
  - Joints should overlap and be interlocking.
  - Oils and paint should be removed.
  - Oxidization and galvanic action should be prevented at the joints.





Summary / Questions

Cost-Effective Motor suppression

- Requires knowledge of specs for all tier suppliers
- Must be address early in design cycle at all levels to meet cost targets
- System Engineering approach

- Thank you
  - Terry North, DCX
  - Keith Frazier, Ford Motor Company
  - Don Seyerle & Mark Steffka, GM
  - Dale Sanders, X2Y Attenuators, LLC
  - Doug Walz, Johnson Electric
  - Ian Grey, ITT Industries (Cannon)