EMC for Motor Drive Systems

Akinori Shiga

JSOL Corporation

JMAG EMC Studio

EMC for Motor Drive Systems

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Agenda

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1. What are Noise Problems of Motor Drives?
2. Logic of Electromagnetic Noise Simulations
3. Solutions Realized by Combining JMAG and EMC Studio
4. Example Analysis

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1. What are Noise Problems of Motor Drives?

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What are Electromagnetic Noise Problems of Motor Drives?

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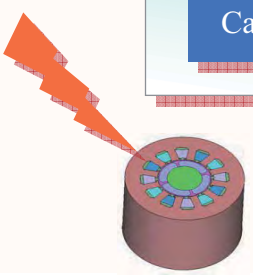
- Electromagnetic noise problems caused by the motor drive system are increasing in present development based on the background indicated below.
- Controlling electromagnetic noise has to be considered in addition to motor performance and control methods.

Demands of motor drives

High-efficiency | High-speed response | Miniaturization | High output | Safety

Reinforcing designs

Carrier frequency Up | High density implementation | More precise testing



Expose electromagnetic noise problems for motor drives

Types of Electromagnetic Noise

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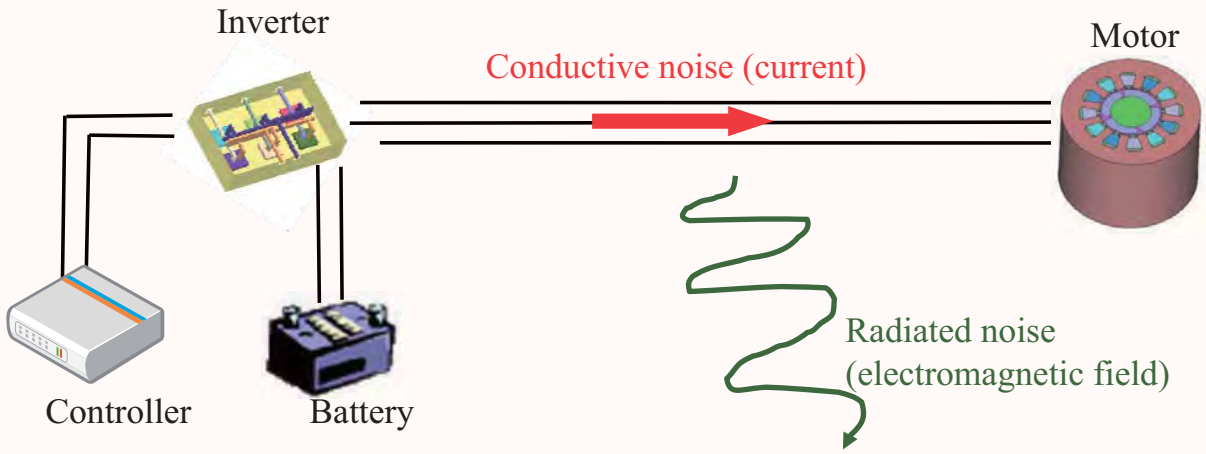
- The transmission of electromagnetic noise is separated into conductive noise and radiated noise.
  - Radiated noise is especially strong from cables.
- Countermeasures to limit both conductive and radiated noise are necessary.
  - Conductive noise countermeasures are vital because the radiation decreases fundamentally by limiting the conduction (current).



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2. Logic of Electromagnetic Noise Simulations

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Circuit Analysis and Electric Field A]nalysis

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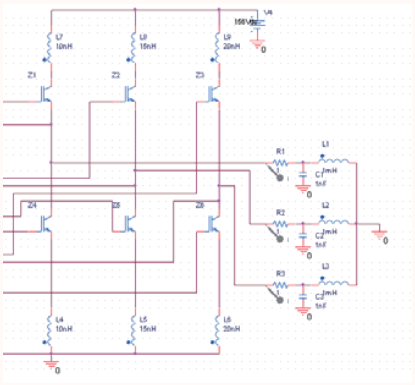
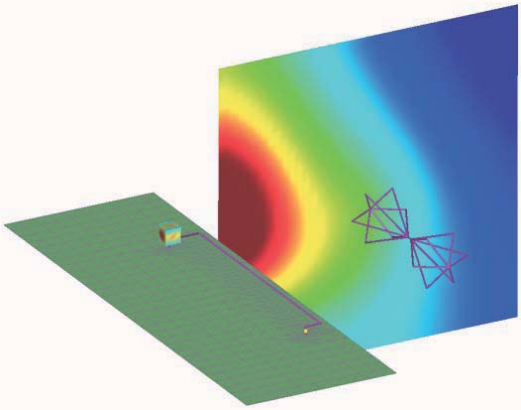
- Simulations effective for electromagnetic noise analysis are largely separated into electric field analysis and circuit analysis.
- Conductive noise (current/voltage) can be calculated using a circuit analysis and radiated noise (electric/magnetic fields) can be calculated using a electric field analysis.





Estimating conductive noise → circuit analysis

Estimating radiated noise → Electric field analysis

Comparing the Circuit Analysis Results & Measured Results for Conductive Noise

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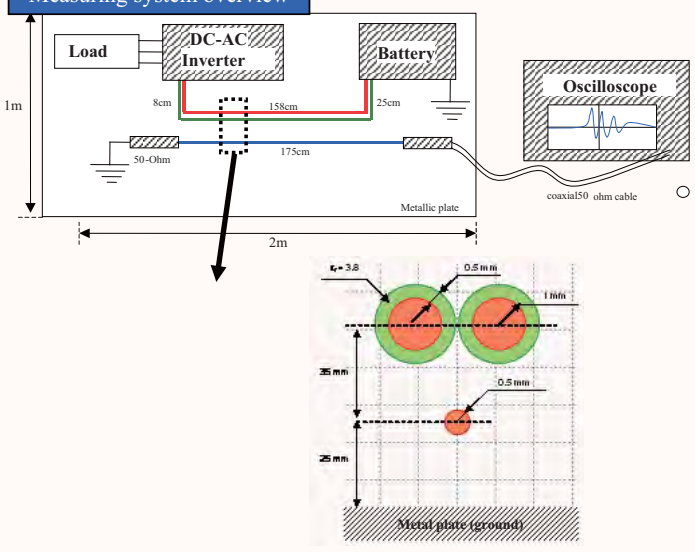
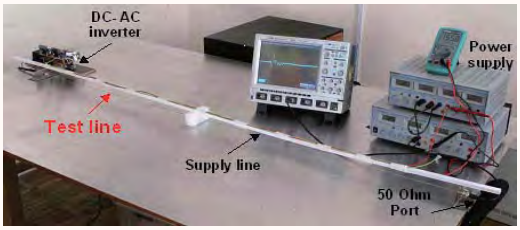
- This example compares circuit simulation to measured results by measuring the voltage induced in a cable running next to an inverter cable.
- Why do the analysis and measured results completely differ?

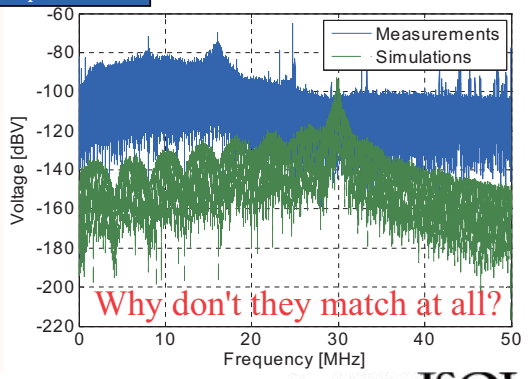
Measuring system overview



Picture of measuring system



Compared results



Comparing the Circuit Analysis Results & Measured Results for Conductive Noise

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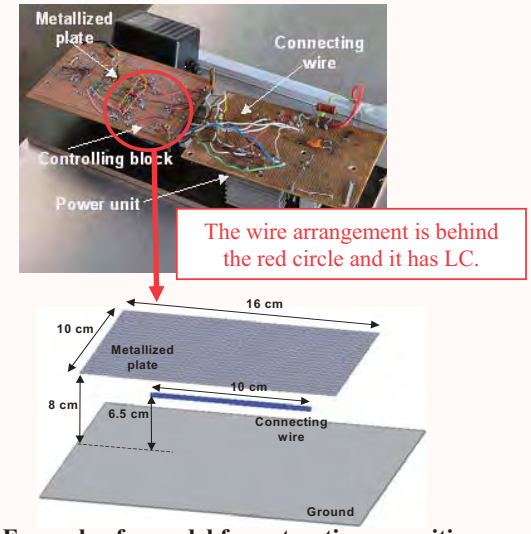
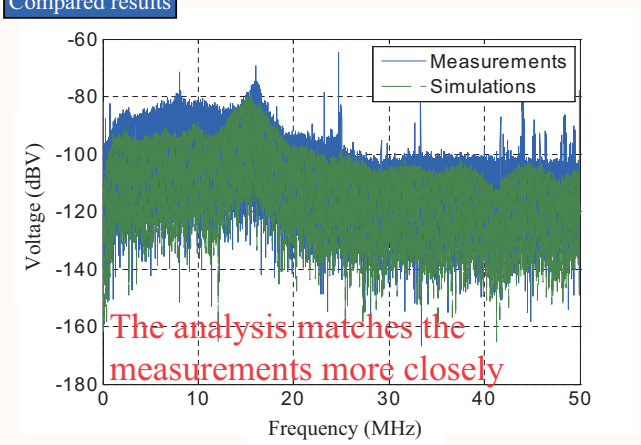
- The difference results from a circuit model that does not include the parasitics of the metal wire (L, C)
- A conductive noise analysis closer to the actual measurements can be run by accounting for the parasitics of the cable, inverter, and motor.

Enlarge diagram around inverter



Example of a model for extracting parasitics

Compared results



Necessity of Parasitics for Conductive Noise

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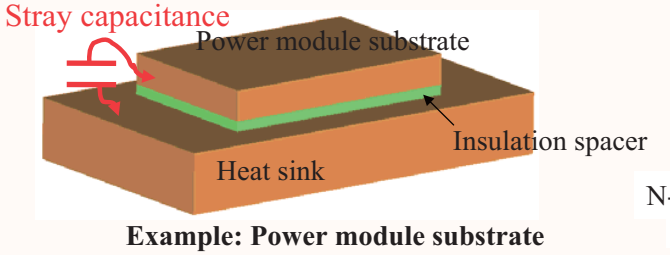
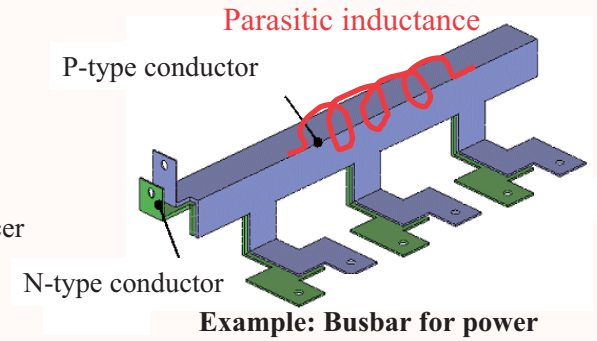
- Metal, such as the inverters, motors, and cables, have the same behavior as a capacitor (C) and coil (L) at high-frequencies. = Parasitics
- These parasitics largely affect the flow of current.
  - C is produced if there is a gap → causes leakage current and resonance
  - L is produced in long pieces of metal → causes resonance
- A conductive noise analysis needs to be run by measuring the parasitics.



Example: Power module substrate and heat sink



Example: Busbar for power transmission used in an inverter

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3. Solutions Realized by Combining JMAG and EMC Studio

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Solutions Available by combining JMAG and EMC Studio

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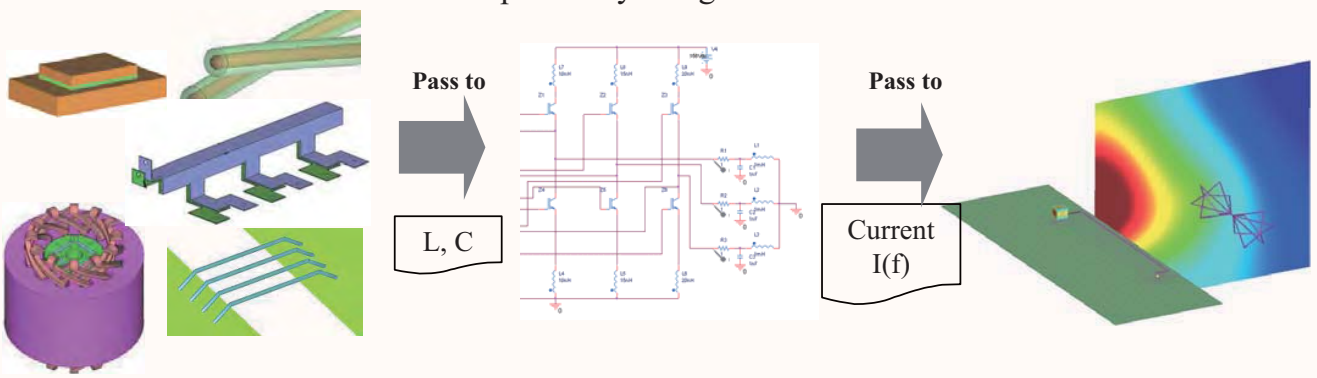
- Comprehensive noise simulations can be performed from the conductive noise to the radiated noise of motor drives by sequentially linking JMAG, EMC Studio, and a circuit analysis tool.
  - STEP 3 can also be run independently using measured or estimated values.



STEP 1	STEP 2	STEP.3
Extract parasitics	Conductive noise analysis	Radiate noise analysis
<Electric field analysis> JMAG/EMC Studio	<Circuit analysis> A circuit analysis tool such as Spice	<Electric field analysis> EMC Studio

Extract Circuit Parameters using JMAG/EMC Studio (STEP.1)

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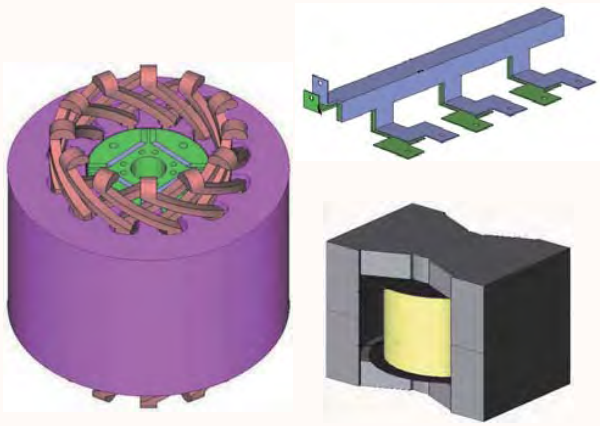
- JMAG/EMC Studio have specialized electromagnetic field analysis functions to extract parasitics that can effectively estimate the parasitics of metal geometry indispensable in conductive noise analyses.

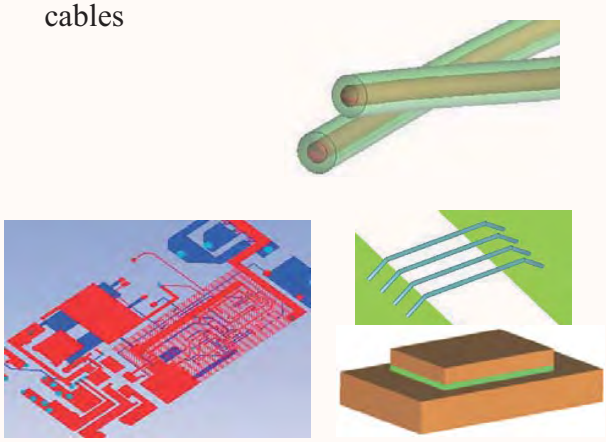
Features of JMAG

- High calculation accuracy
- Effectively calculates winding and antisurface stray capacitance of busbars, motors, and transformers



Features of EMC Studio

- High-speed calculations
- Features to obtain the Land C in one analysis (*coming soon)
- Effective for printed circuit boards and various cables



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4. Example Analysis

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Example Analysis

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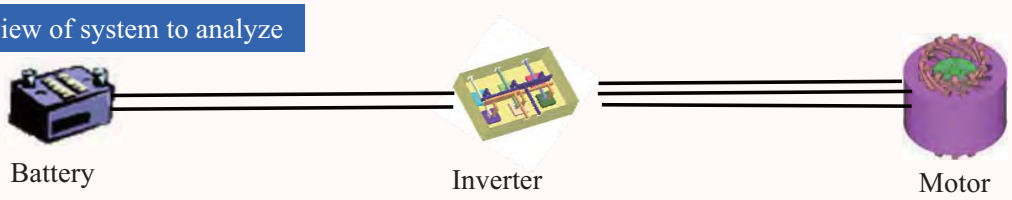
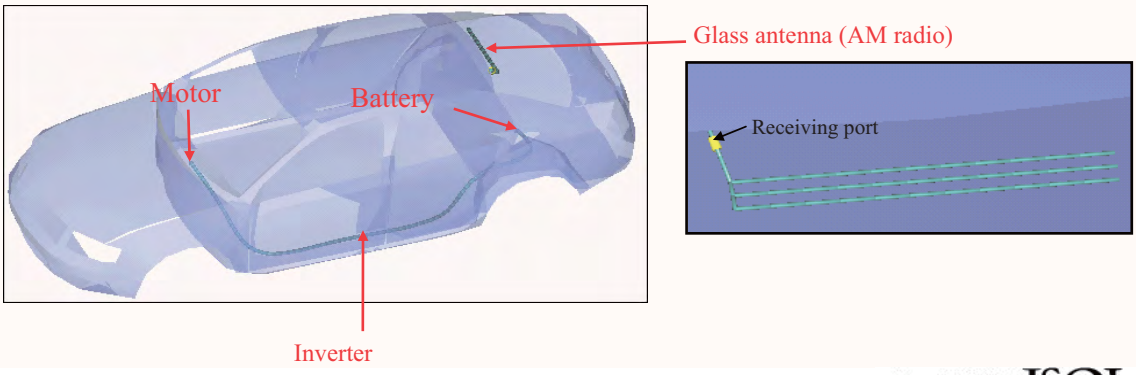
- The following is an example analysis using JMAG and EMC Studio to obtain the conductive noise of the motor drive and the radiated noise of the drive system built into the vehicle.

Overview of system to analyze



System built into vehicle



STEP 1. Extrude Circuit Parameters (Electric Field Analysis)

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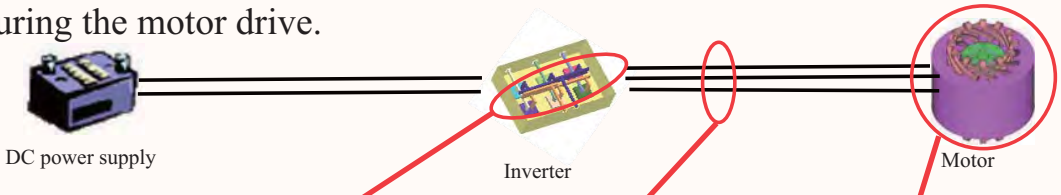
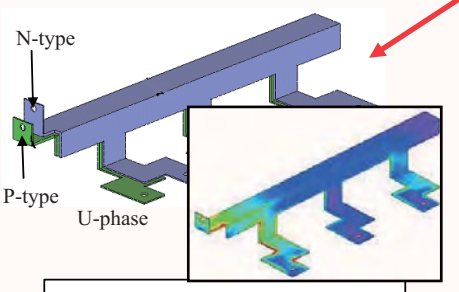
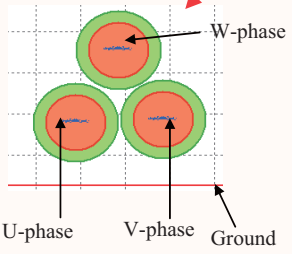
- The parasitic inductance and stray capacitance which plays a vital role in conducting noise can be calculated by specifying the geometry of each part configuring the motor drive.

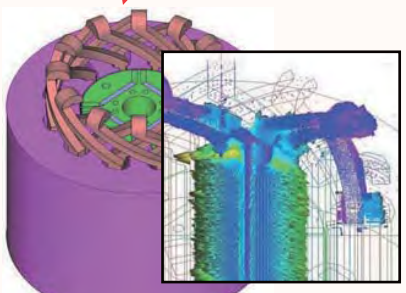




Self-inductance of busbar in inverter (1MHz)
U-phase13 nH
V-phase 21 nH
W-phase 31 nH



Self-inductance of cable
U-phase 690 nH
V-phase 600 nH
W-phase 860 nH



Stray capacitance between winding and frame for each phase
33 pF

STEP 2. Run a Conductive Noise Analysis (Circuit Analysis)

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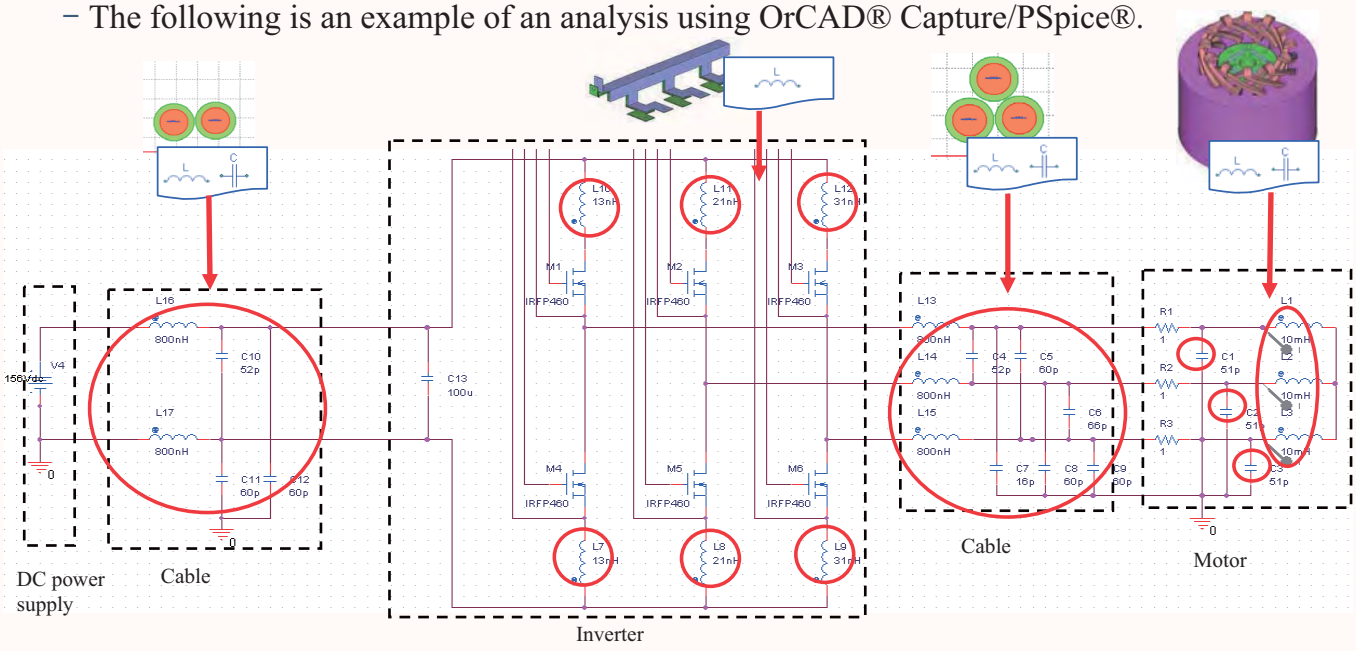
- The conductive noise can be estimated highly accurately and countermeasures can be examined by running a circuit simulation using a motor drive circuit model that includes parasitics.
  - The following is an example of an analysis using OrCAD® Capture/PSpice®.



STEP 2. Run a Conductive Noise Analysis (Circuit Analysis)

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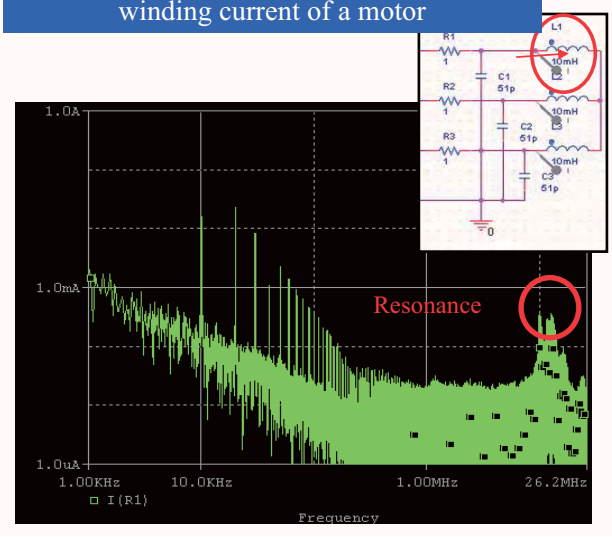
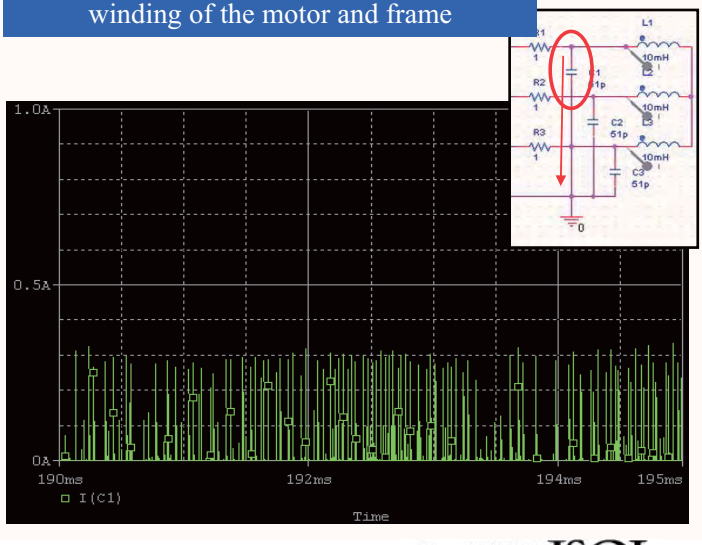
- The intensity, transmission pathways, and countermeasures can be examined using the current waveform and spectrum of each part.
  - Example: Innovations to the filter/busbar geometry...

Frequency spectrum for the U-phase winding current of a motor



Current waveform between the U-phase winding of the motor and frame



STEP 3. Run a Radiated Noise Analysis When Built Into the Vehicle (Magnetic Field Analysis)

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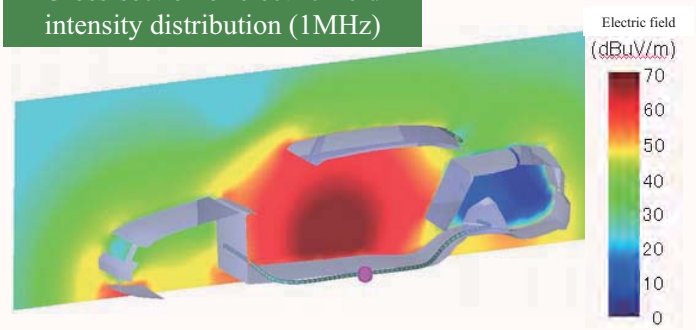
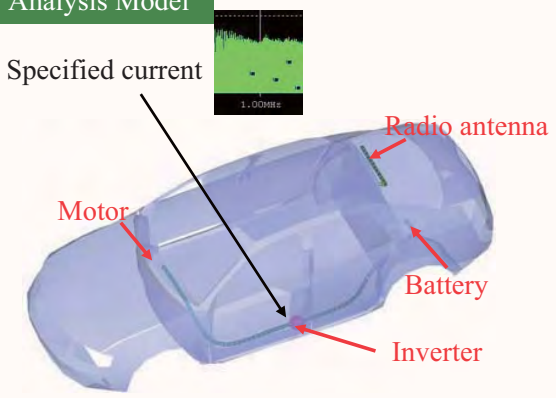
- Interference from surrounding devices such as the radiated electric/magnetic fields and the antenna of the power cables can be predicted.

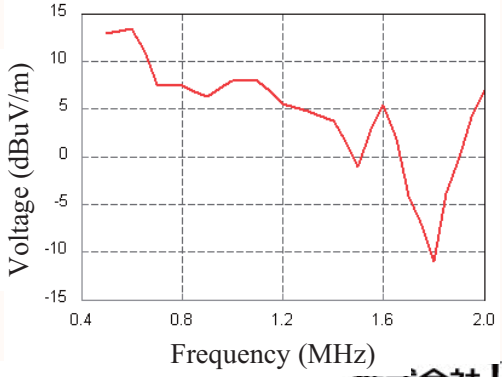
Cross-section of electric field intensity distribution (1MHz)



Analysis Model



Induced voltage of radio



STEP 3. Annex: Setting the wave source of measured magnetic fields

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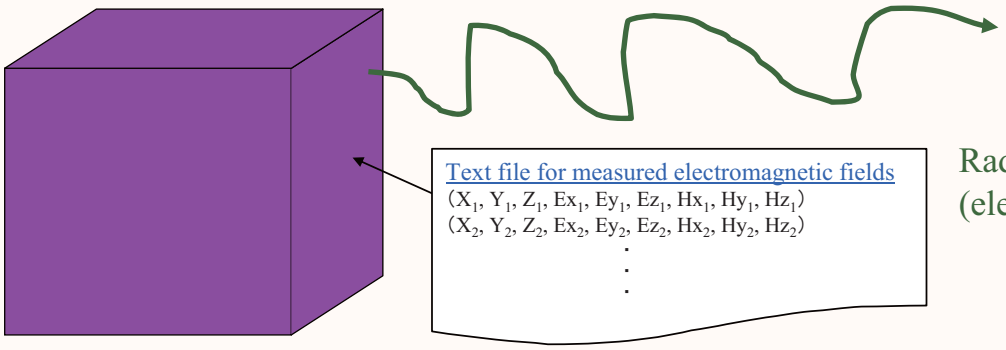
- Electromagnetic fields may be strongly radiated by individual equipment (motor, inverter, etc.) in addition to cables.
  - However, modeling the radiation for individual power electronics equipment is usually difficult
- An analysis in EMC Studio can be run obtaining the saturation of electromagnetic fields by specifying the electromagnetic field distribution for a specific face as an input condition.

Illustration



STEP 3. Annex:: Analysis Example of Radiation Between Equipment/Cables

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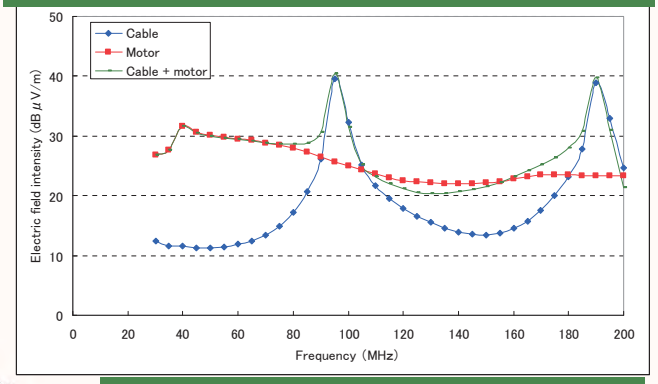
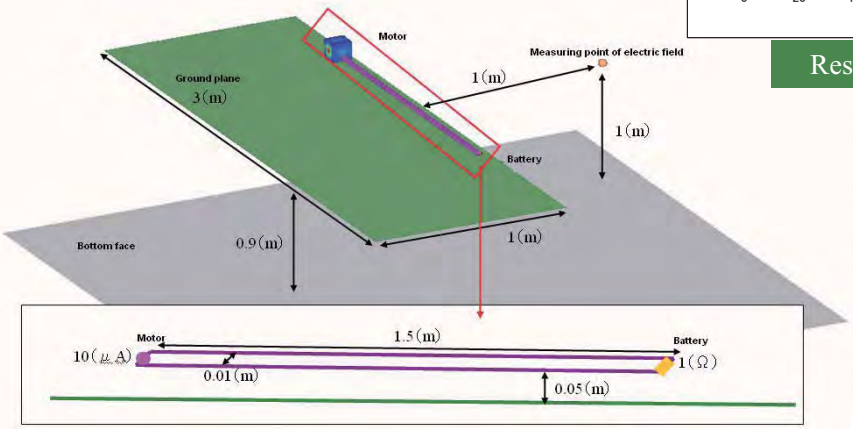
- Example using a DC brushless motor which differs from the previous example
  - The motor is assumed to be the direct radiation and noise current source.
- Effective countermeasures can be examined by comparing how much the equipment and cables contribution to the noise.

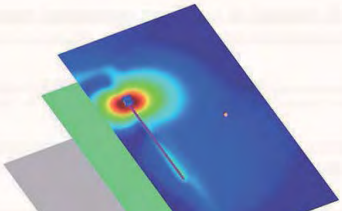
Results: Electric field intensity at measuring points



Analysis model specifications



Results: Electric field analysis (80 MHz)



The radiation of the motor itself is predominate at 80 MHz as indicated by the graph for the electric field intensity.

Conclusion

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- A comprehensive simulation of conductive and radiated noise can be achieved by combining JMAG, EMC Studio, and circuit simulators.
- Functions and examples to fully support users will continue to be enhanced in the future.
- We would like to support every user in the specific challenges they face. Please don't hesitate to contact us regarding any questions, requests, or challenges that you might be facing.

Thank you for coming today.

Contact

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