EMC Expert Systems for Evaluating Automotive Designs

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Automobiles are Complex Electronic Systems

There are more computers in the typical new automobile than in a typical campus computer learning center.

Automobiles are Complex Electronic Systems

Functions typically controlled electronically include:

- Engine ignition (spark, timing)
- Fuel injection
- Emissions controls
- Collision avoidance systems
- Heating/air conditioning
- Navigation systems
- Suspension systems
- Transmission controls
- Lights, horn, wipers, defrosters …
- Entertainment systems
- Braking (anti-lock brakes)
- Steering (steering assist, 4-wheel steering)
- Seat & pedal positions
- Communication systems
- Safety systems
- Noise cancellation
- Security systems

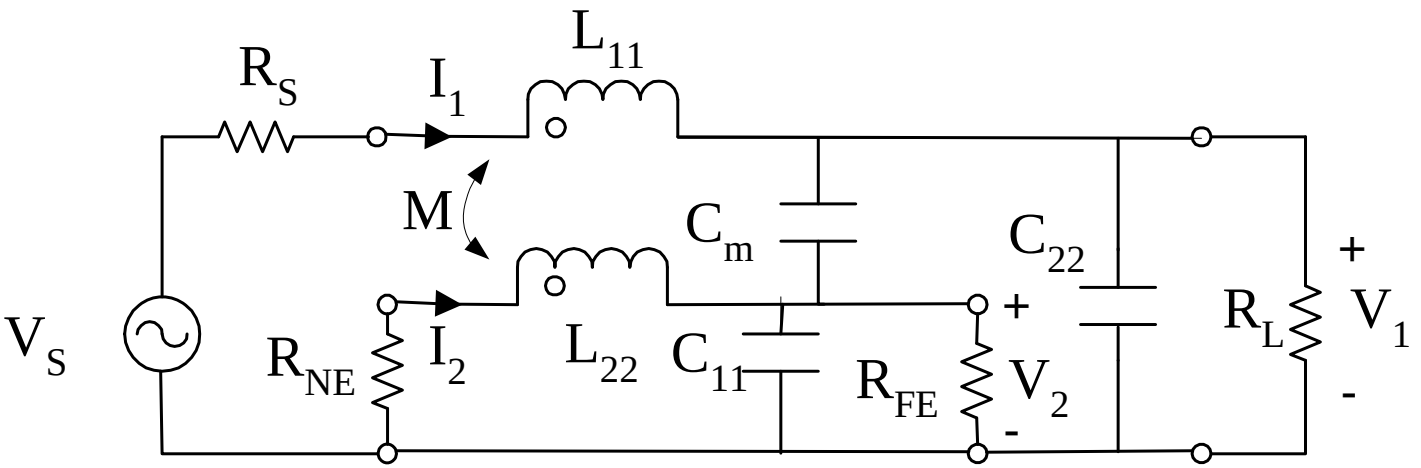
Automobiles are Complex Electronic Systems

- Many current automobile designs have nearly 100 microprocessors
- Number of processors expected to double in 5 years.
- A typical automobile contains about 5 miles of wiring.

Electromagnetic Compatibility is a Growing Concern

- RF susceptibility
- ESD susceptibility
- EMI affecting wireless communications
- Conducted Intra-system interference

SPICE or EM Models Don't Locate EMC Problems



(Although, they can be used to evaluate a suspected problem.)

What is an EMC Expert System?

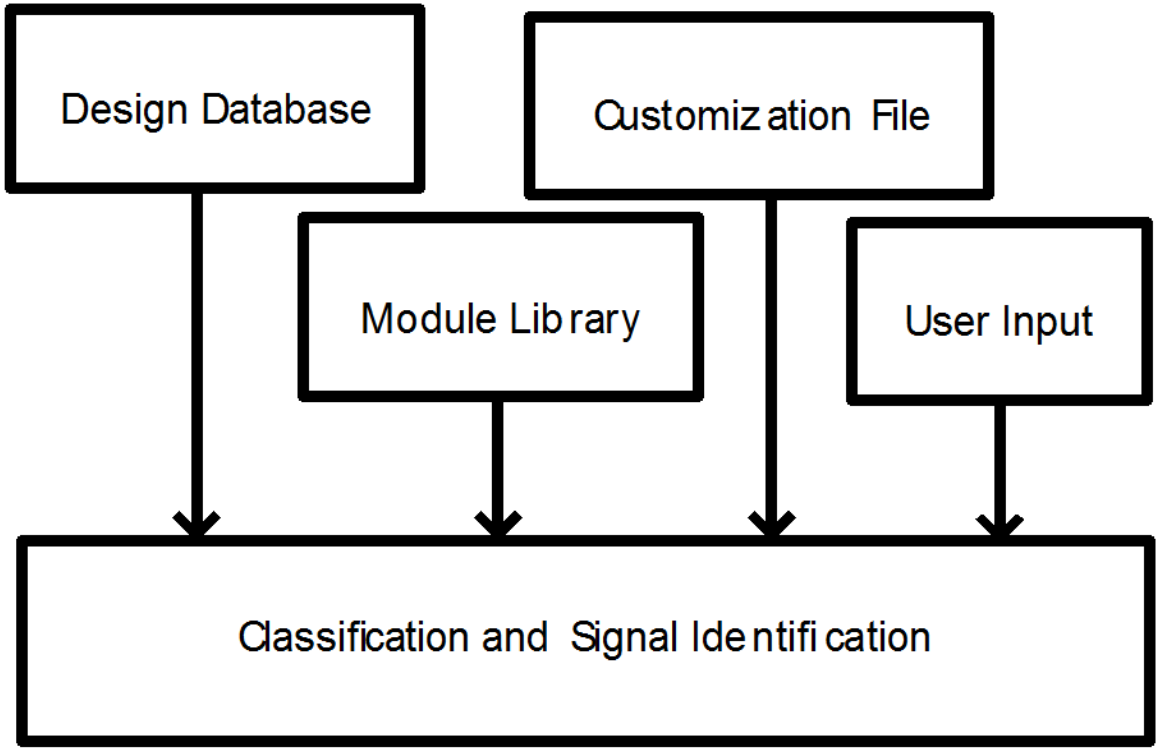
- Reviews existing automobile specifications in a database.
- Looks for possible EMC problems
- Evaluates potential problems (likely worst case)

EMC Expert System Objectives

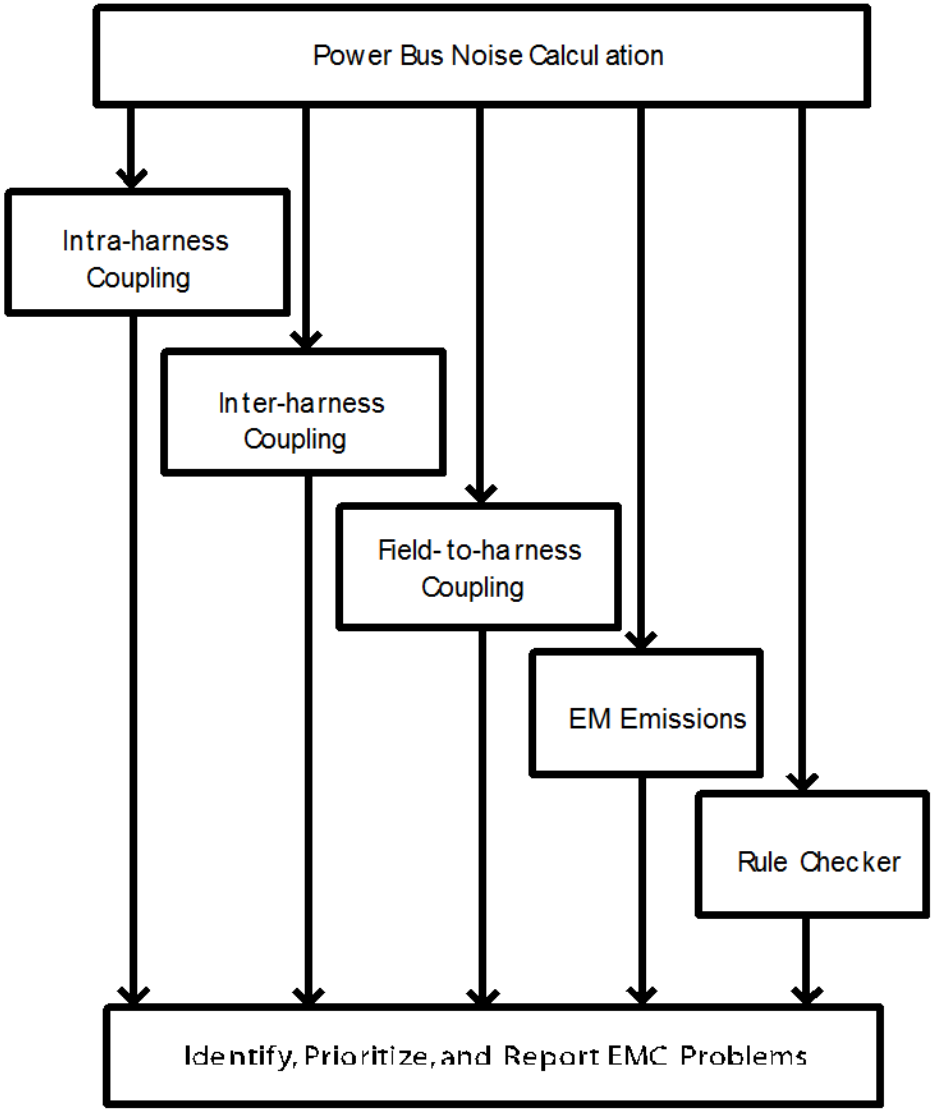
Develop an EMC expert system to detect and eliminate potential EMC problems early in the design process

- System (vehicle) level
- Use design maxims and simple formulae
- Work with incomplete information
- Run repeatedly throughout design cycle
- Complement – not replace – human expert and more sophisticated numerical modeling tools
- Guide non-expert

EMC Expert System Structure (TOP)



EMC Expert System Structure (The Rest)



Estimation of Intra-Harness Coupling

Procedure for Developing Algorithm

- Start with multi-conductor transmission line equations
- Simplify equations by assuming:
  - Transmission line geometry is uniform along length
  - Coupling media is air
  - Transmission lines are lossless
  - The definition of the maximum coupling is:

$$X = \frac{V_{2MAX}}{V_{1MAX}}$$

Simplified Formulas

When two circuits are next to each other (in the same harness bundle, strong coupling)

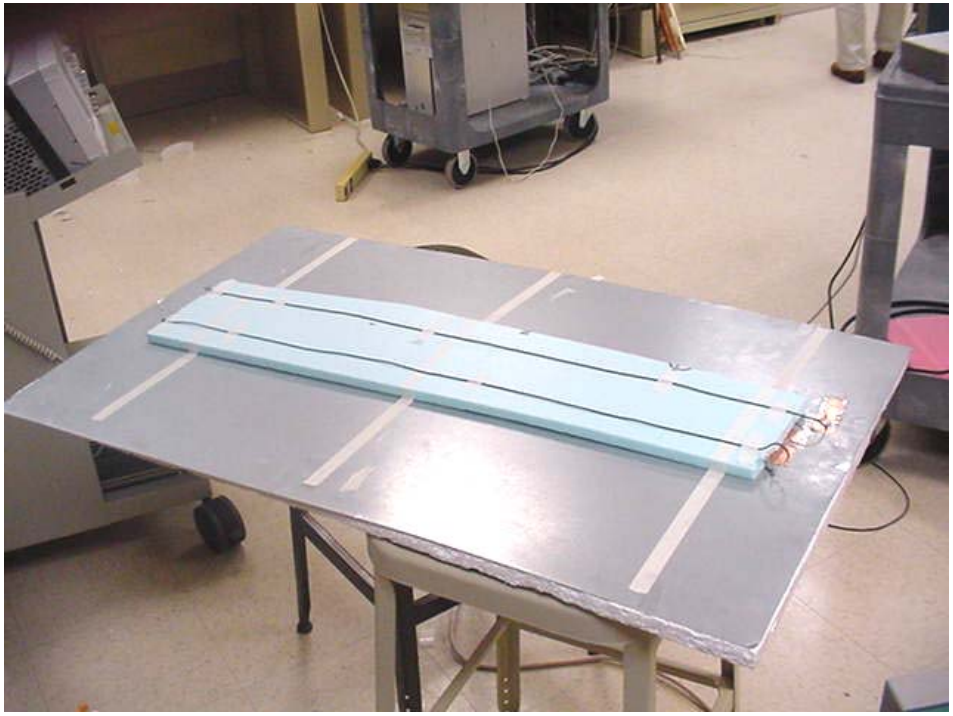
$$X_{MAX} = \frac{C_m}{C_{22} + C_m}$$

When two circuits are in different harness bundles (weak coupling) and the aggressor and victim circuits are both shorted or both open at far end

$$X_{MAX} = \frac{C_m}{C_{22} + C_m}$$

Other cases have similar equations

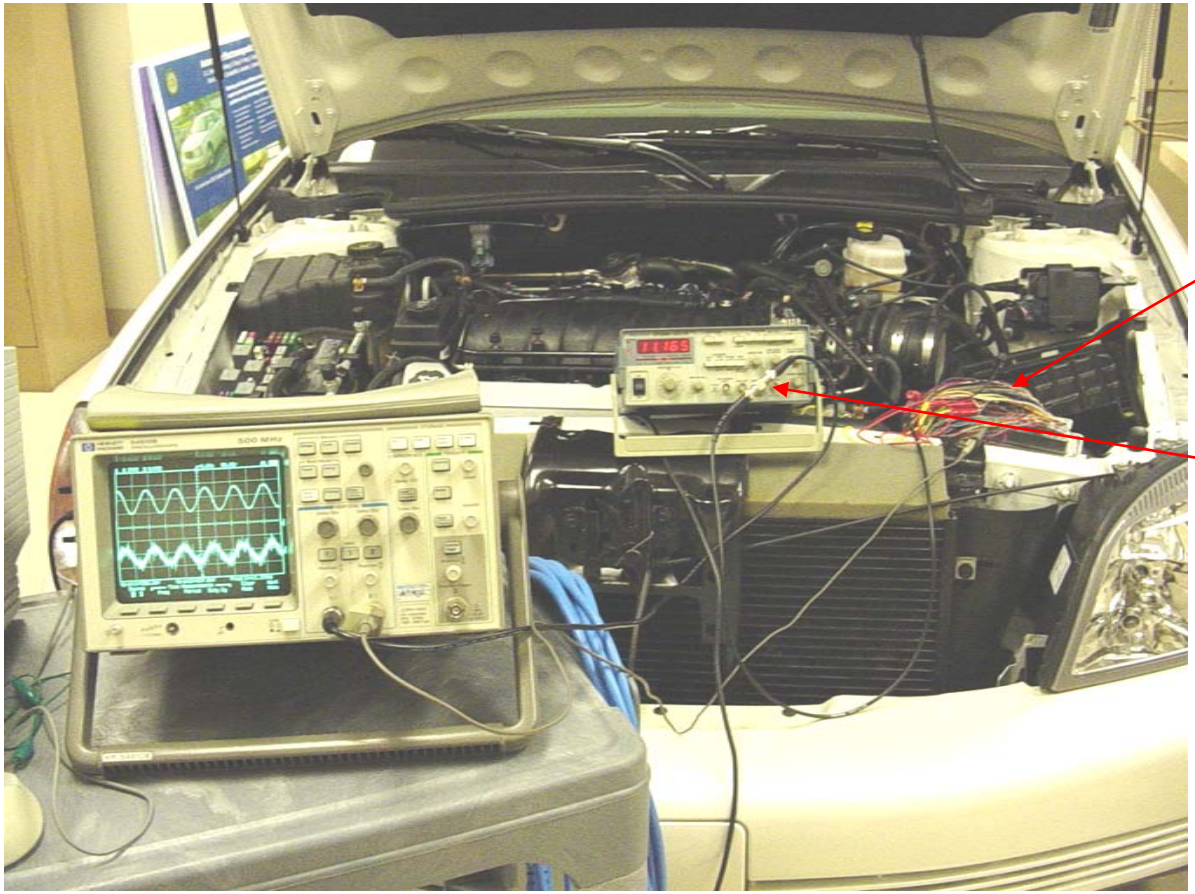
Experimental Setup



Wire length: 87 cm
Height : 1.5 to 4.5 cm
Ground plane: 40” × 24”

Wire radii: 0.8 mm, 20#
Distance: 2 mm to 9 cm
Termination: short, open, 300 ohm

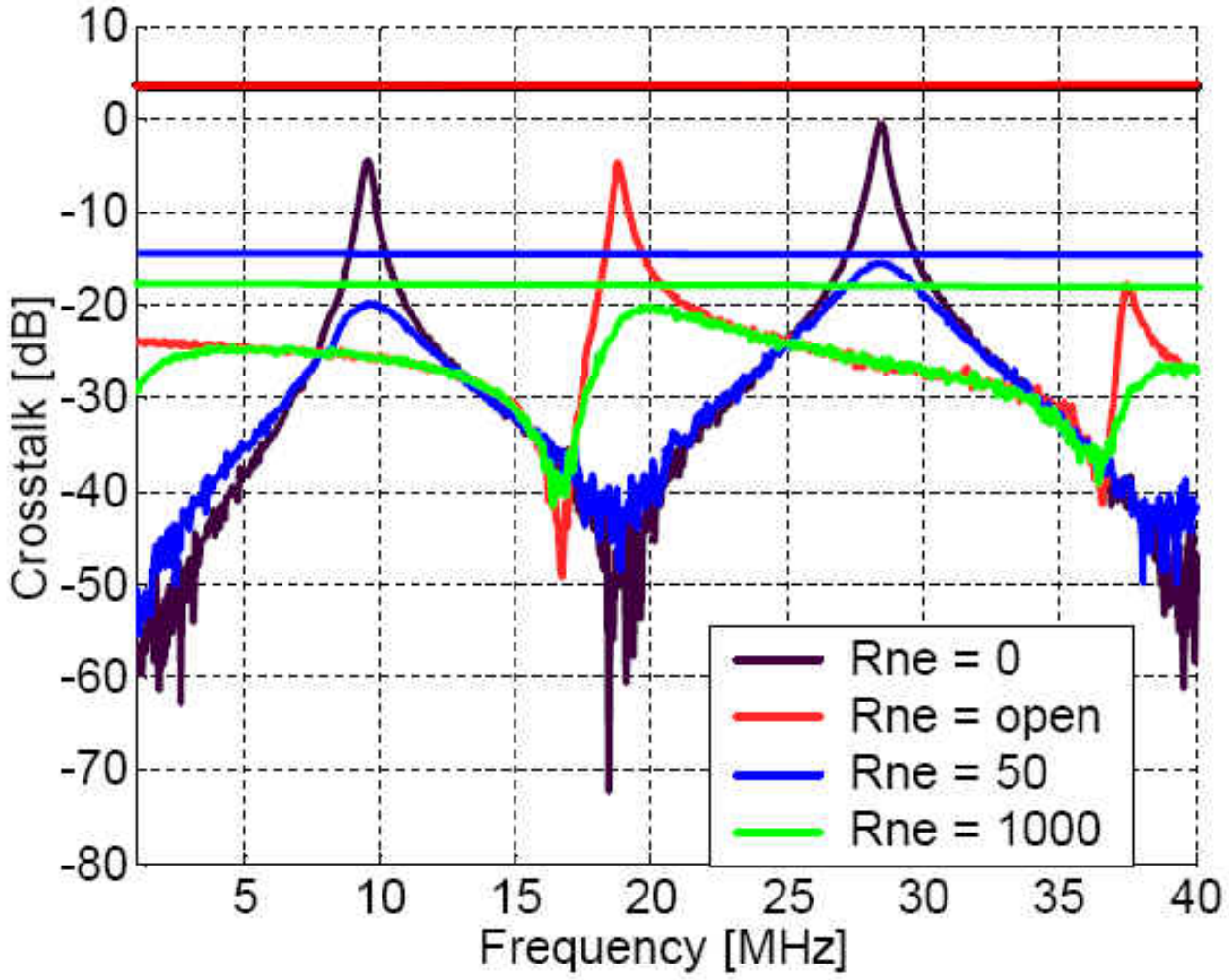
Measurement Setup



Culprit and
Victim circuits

Signal Generator

Example Result



Estimation of Field-to-Harness Coupling

Expert System Estimate

IF $Z_S < 300$ ohms

IF $Z_{Load} < 300$ ohms

$$Gain = \frac{4Z_{Load}H}{Z_S + Z_{Load}}$$

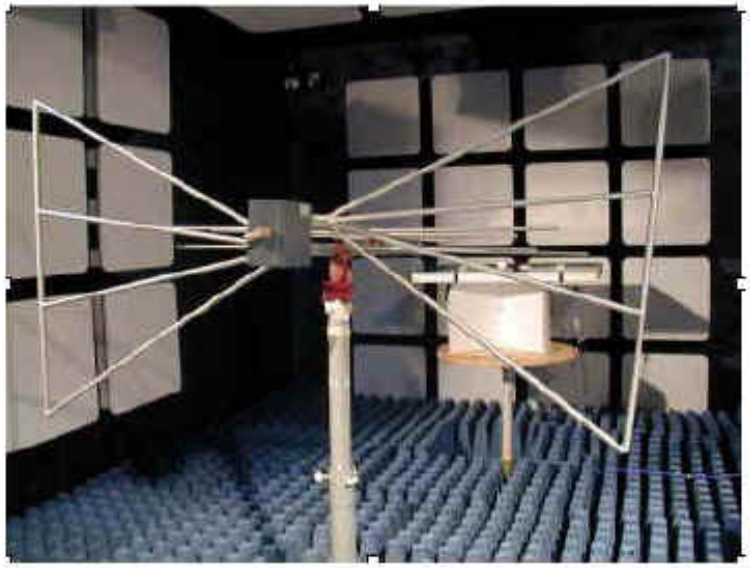
ELSE

$$Gain = \frac{2Z_{Load}Z_0H}{Z_0^2 + Z_SZ_{Load}}$$

ELSE

$$Gain = \frac{2Z_{Load}Z_SH}{Z_0^2 + Z_SZ_{Load}}$$

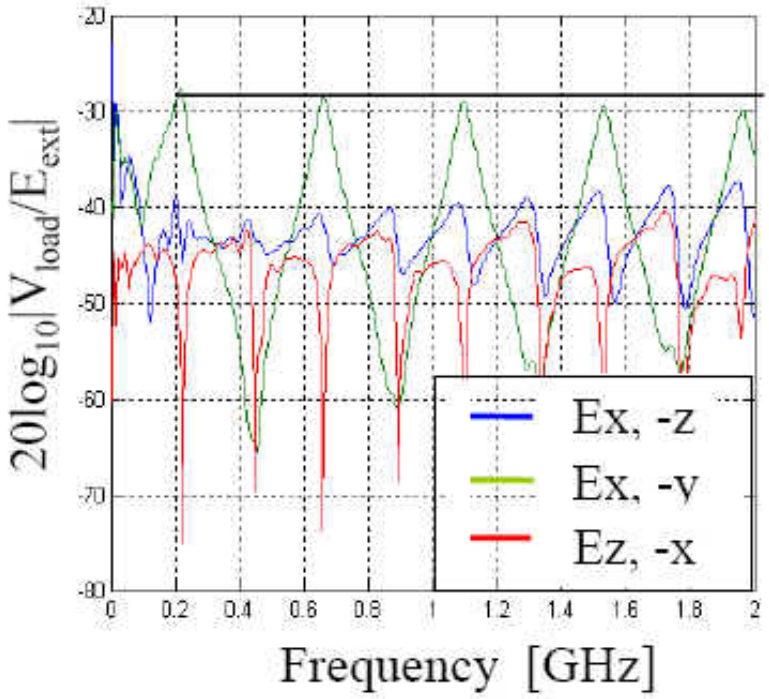
Measurement Set-Up

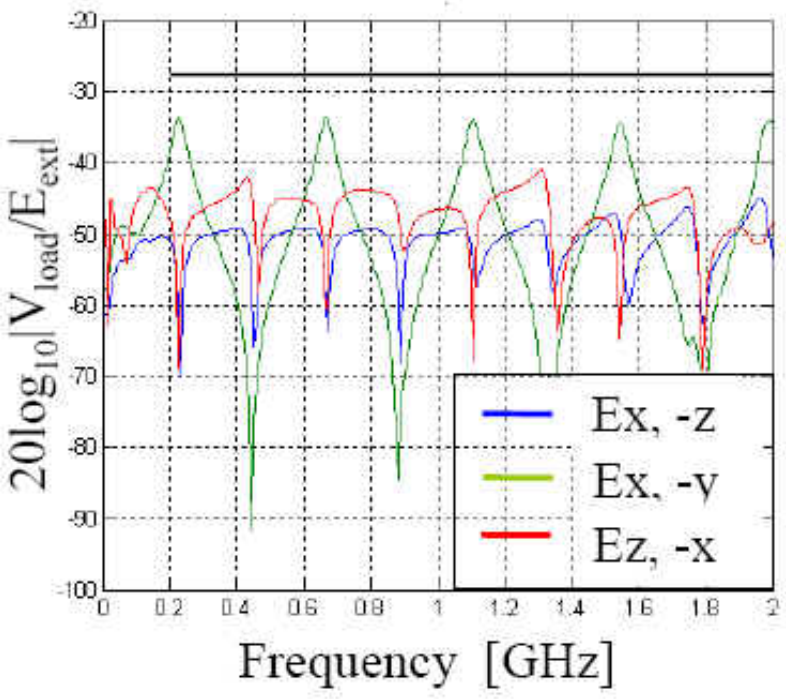


a) Setup layout

b) Top view of circuit

Comparison to Simulation Results





Conclusions

- Number and complexity of automotive electronic systems is rising rapidly
- Many design decisions are made before first prototype is built
- Expert system software will enable designers to detect possible EMC problems early in the design process.