EMC and New Technologies in Automotive Systems

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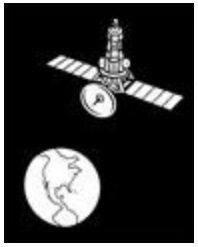
Automotive Systems “Past and Present”

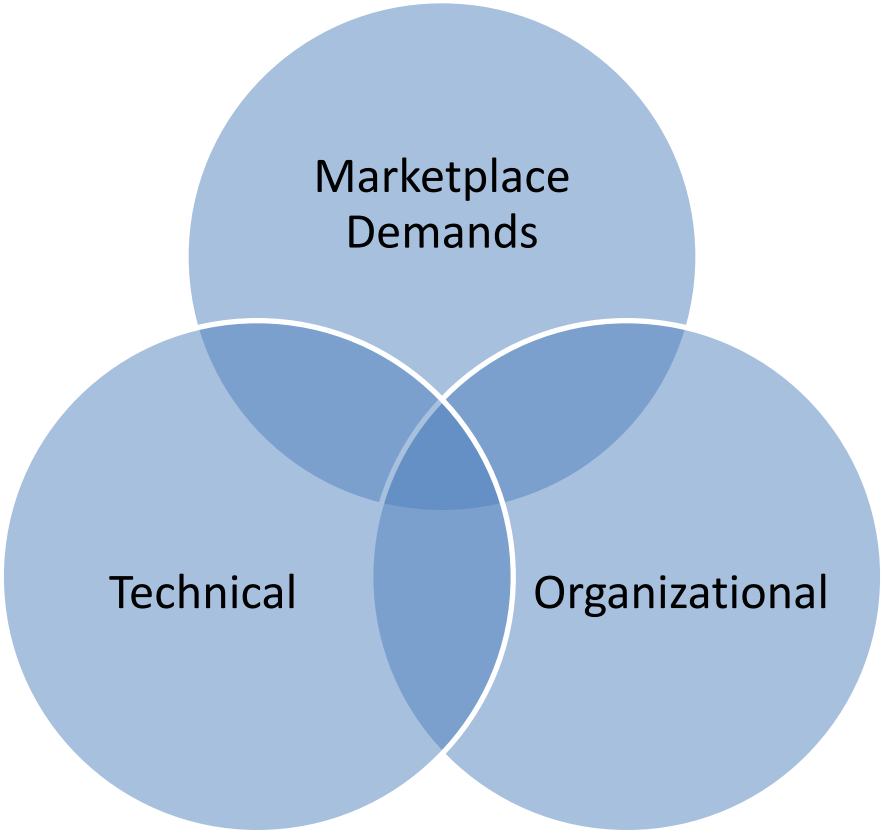
- Today’s vehicles contain *three centuries of technology…19th century internal combustion engines…combined with 20th century electrical systems…and 21st century electronics….*

Automotive EMC...from Spark to Satellite…



Automotive EMC Goals

- Highest priority is to exceed expectations of the customer.
- Meet challenges of technology content in vehicles.
- Develop organization that supports EMC.

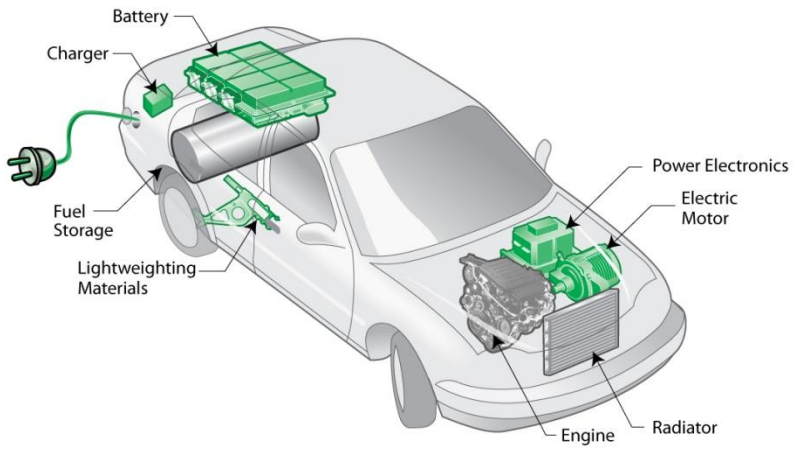


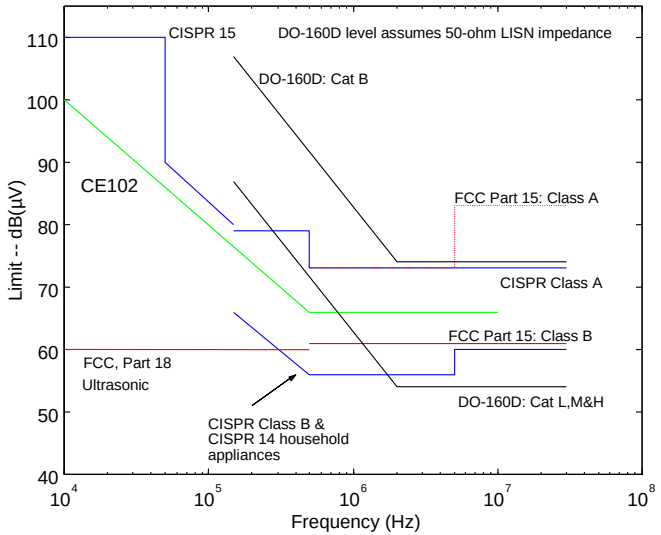
Automotive EMC Is Changing

- Global shift towards new propulsion systems is changing the content of vehicles.
- These new systems will need appropriate EMC methods, standards, and utilization of EMC approaches from other specialties.
- Many of these systems will utilize high voltage components and have safety aspects that may make automotive EMC more difficult *and safety takes priority!*

New Requirements May Apply?

- Continuing vehicle evolution may result in new requirements / regulations.
- “Plug In” Vehicle – classified as a household appliance for EMC? (Vehicle Figure Is Courtesy of Argonne National Laboratory)





Automotive Systems of the Future

	Low Voltage Systems	Low Power PWM Signals	High Voltage Drive Systems	High Power PWM Signals
Conventional	X	X		
Hybrid	X	X	X	X
Electric	X	X	X	X
Fuel Cell	X	X	X	X

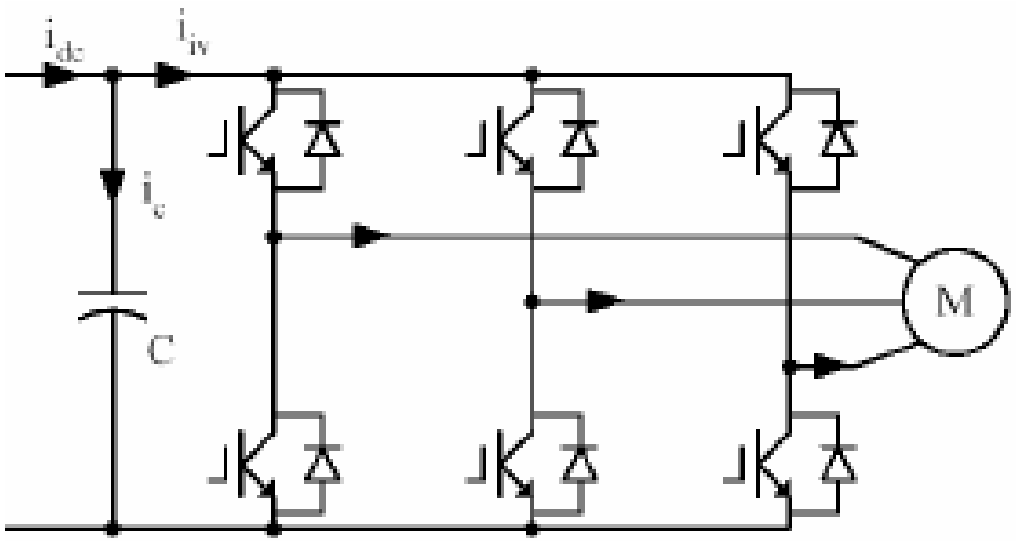
- Incorporation of high power electric drive systems *as well as today's conventional ones.*
- EMC techniques from other industries will become important in automotive EMC.

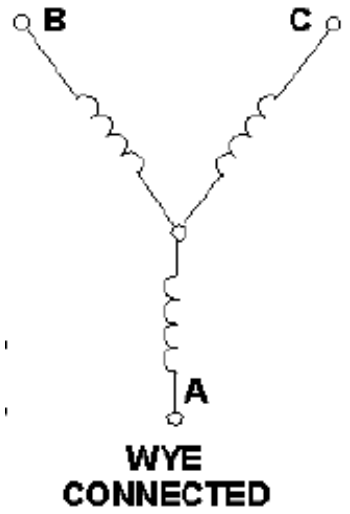
EMC Aspects of Variable Speed Electric Drives

Why Use Electric Drives?

- Advances in power electronics as well as motor design and manufacturing have made electric drives very attractive.
- The benefits of electric drives include high efficiency with lower mass as a result of implementation of adjustable/variable speed or frequency drives (ASD/VSD/VFD).
- Provide energy efficiency and flexibility over existing “conventional” drive systems.

Schematic of Three Phase Controller and Motor Circuit



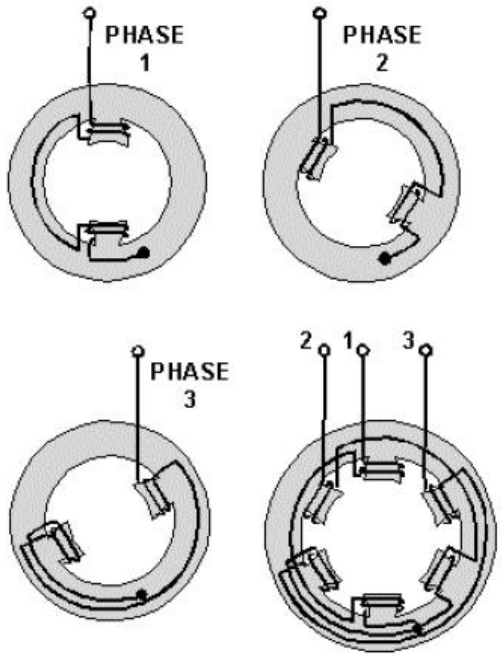


- IGBT's generate three-phase motor drive current which is supplied to "Wye" stator windings.

Electric Drive Control Systems

- Control systems for electric drives typically consist of active switching of the primary current for the motor (similar to basic switching power supply).
- Output voltage is determined by switching speed and “on” duration of the drive transistor's).
- Multiple phases can be obtained by utilizing multiple driver transistors with appropriate timing.

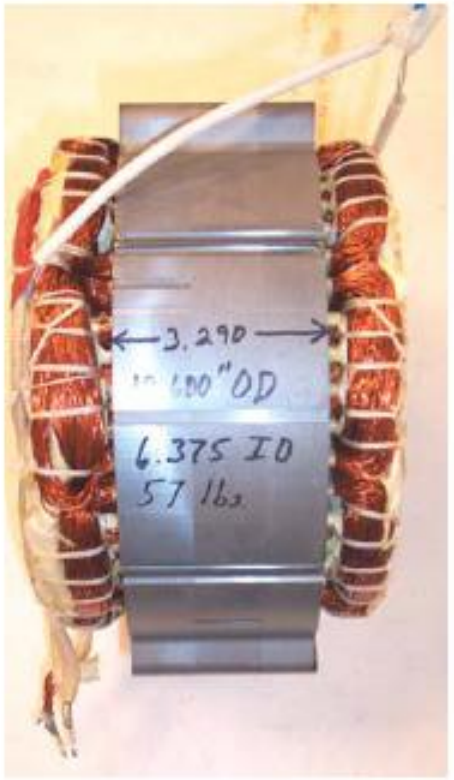
Steps in the Construction of A Drive Motor



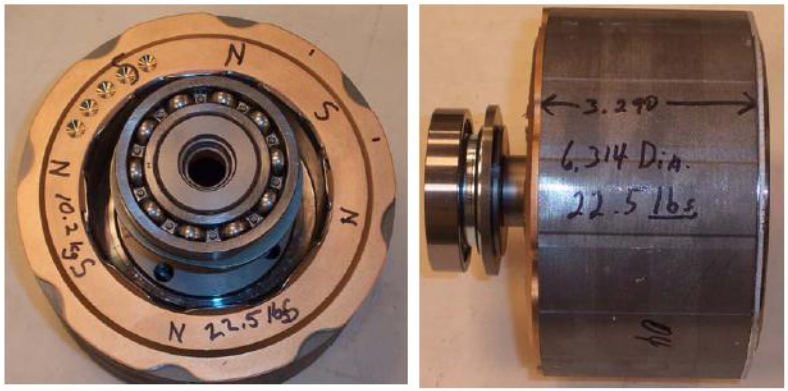
- A stator is produced that contains a number of “poles” that are used to hold the windings.
- Application of drive current for each phase generates magnetic field.

Actual Stator Construction

- Figure at right shows a typical stator from a variable speed drive motor.
- Significant portion of the stator (and it's mass) is due to the large number of windings required.



Permanent Magnet Rotor Construction

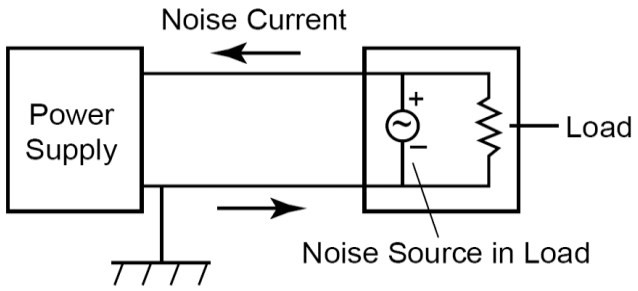


- Rotor contains high-strength permanent magnets arranged around the perimeter.
- “Movement” of field in stator causes magnets to try to track the field – resulting in rotation.

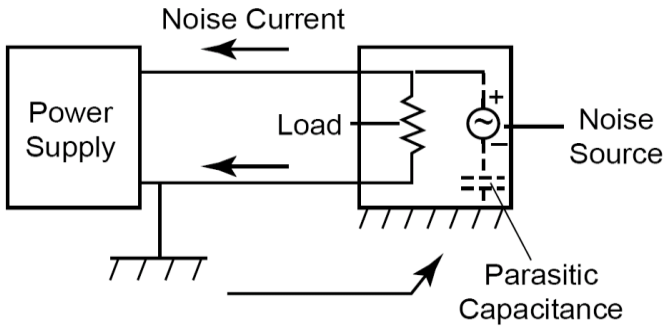
Typical Electric Drive Motor Specifications

- The motor shown at left has an output capability at 1500 RPM of:
  - 50 kW (approximately 67 hp)
  - 400 NM (approximately 300 ft-pounds).

Electric Drive EMC Issue: Conducted Emissions



Differential Mode



Common Mode

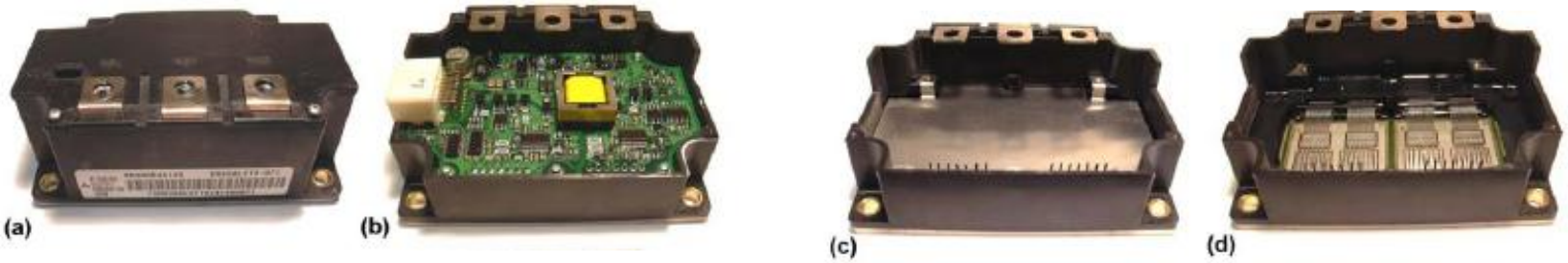
- Differential Mode Current – Emissions can be due to the high voltage / current of the “intended” circuit.
- Common Mode Current – Current can flow in an “untended” path due to capacitive coupling.

Operation of Electro-Mechanical Devices and EMC

Balancing EMC and Performance Requirements

- Important to understand the speed of operation of electro-mechanical devices compared to fast “slew rate” power signals from power drive devices such as Insulated Gate Bipolar Transistors (IGBT).
- The switching operation results in low power dissipation (in the drive devices) along with:
  - Semiconductor operation at an order of magnitude faster than the response time of electromechanical devices.
  - Causing radiated/conducted emission issues.

Examples of Electric Drive Controller



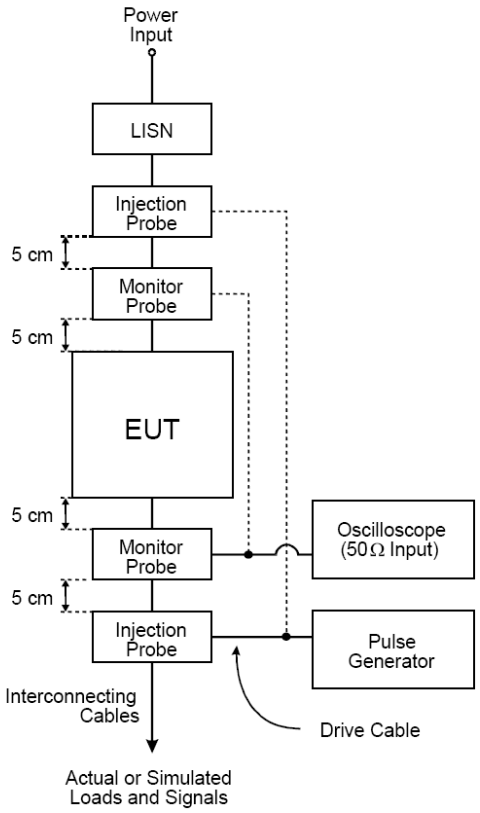
- Figures (a) and (b) show the control electronics.
- Figure (c) shows an EMC shield over the IGBT's to prevent noise from affecting low-level signals.
- Figure (d) shows the driver IGBT's.

Adaptation of “Common Approaches” From Other Industries

Why Wiring is Important to Automotive EMC

- Early systems (and vehicles) had few components to be connected - recent systems have increased wiring complexity, similar to many non-automotive systems.
- Many automotive engineers consider wiring "just a piece of wire" *and the chassis is "GROUND" (this is not true – impedance exists).*
- Wiring will still be used for many systems in the future and we need to understand relevant physical parameters.

Bulk Current Injection (BCI) Test Method



- Consists of injection of RF or pulse energy on wiring harness.
- Typical BCI testing is to 400 MHz.
- General rule: 1.5 mA of RF current induced on a cable is equivalent to ½ wavelength cable in a field strength of 1 V/M.

Shielding Methods For Radiated or Conducted Noise

- May be used to decrease radiated noise or to increase immunity to external E/M fields.
- Can be used as a diagnostic step to determine a specific sensitive component or wire.
- Sometimes incorporated into a design as an integral method to meet EMC requirements.

Electric and Magnetic Shielding – The Quick Way!

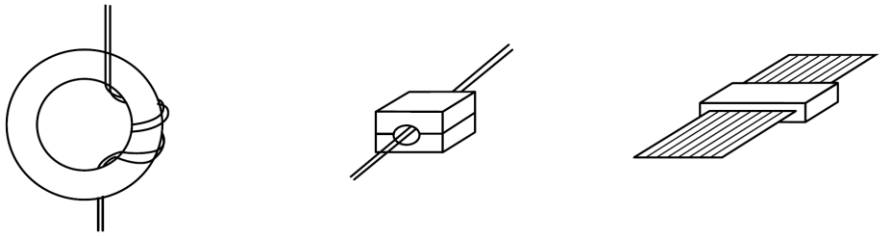
- Common household aluminum foil can be a very effective shield for electric fields in a diagnostic process.
- Use of clamp-on ferrites can reduce conducted noise due to magnetic fields.

CE Diagnostic Process

- Important to understand that RF current on wiring can cause CE (which may then result in RE) issues.

- If testing shows that CE needs to be reduced, it may be possible to add an inductance (sometimes called a “choke”) to the wiring to reduce the magnitude of this current.

Typical CE Chokes



Multi Turn Common Mode Choke

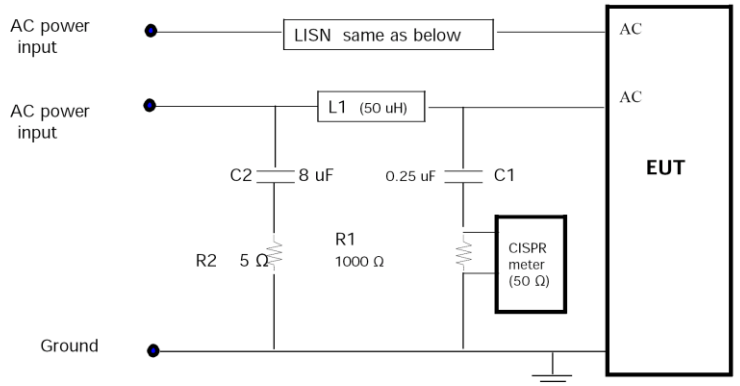
Single Turn Common Mode Choke

Single Turn Common Mode Choke Over Ribbon Cable

- Consists of toroids, cylinders, or rectangles made from ferrite material. installed without cutting into wiring
- There are many examples of chokes on power supply cabling and computer video cables used to pass EMC requirements.

CE Testing With LISN

- At right is a LISN and it's connection to an equipment under test (EUT).
- The purposes of a LISN are only to have a constant impedance and connection for CE measurements.



(neglecting the effects of C1, C2 and R1)

Frequency	Equivalent Impedance (ohms)
10 kHz	5.36
20 kHz	7.25
40 kHz	11.99
50 kHz	14.41
100 kHz	25.11
200 kHz	37.74
500 kHz	47.21
1.0 MHz	49.26
2.0 MHz	49.80
5.0 MHz	49.98
8.0 MHz	50.00
30.0 MHz	50.00

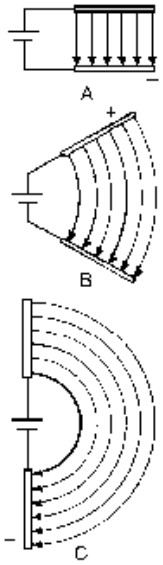
LISN Confusion!

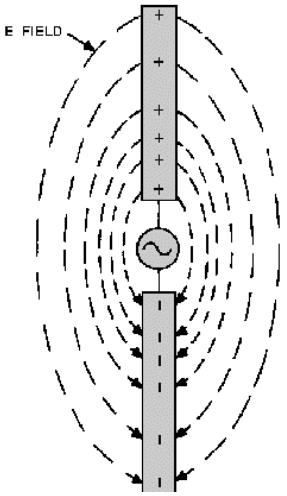
- Sometimes it is stated that the intent of the LISN is to duplicate the wiring harness for the EUT. *This is not true!*
- There is empirical evidence that systems have wire harness inductance of:
  - Large systems = 50 uH (such as aircraft)
  - Small systems = 5 uH (such as automotive)
- LISN's should be selected based on the frequencies of the measurements required.

Wireless System Operational Parameters and Effect of Automotive Systems

Antenna Basics

- Most wireless system antennas are designed to utilize the *electric field component* of E/M wave for communication.
- This type of antenna can be represented as an “open” capacitor.





Electrical Model of Antenna Parameters

- An antenna can be represented just like any other type of electrical component.
- Can be expressed as a complex impedance load:

$Z_{ant} = R_r + jX$ (ohms)

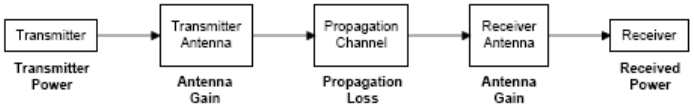
Where:

R_r is the "Radiation Resistance" (a derived value describing how effective the antenna is in transferring power to/from the medium)

jX is the value of the sum of the reactance (due to series inductance and capacitance). *When "jX = 0" the antenna is "resonant".*

Communication “Link Budget”

- The “link budget” determines the received-signal power for a line-of-sight communication link:



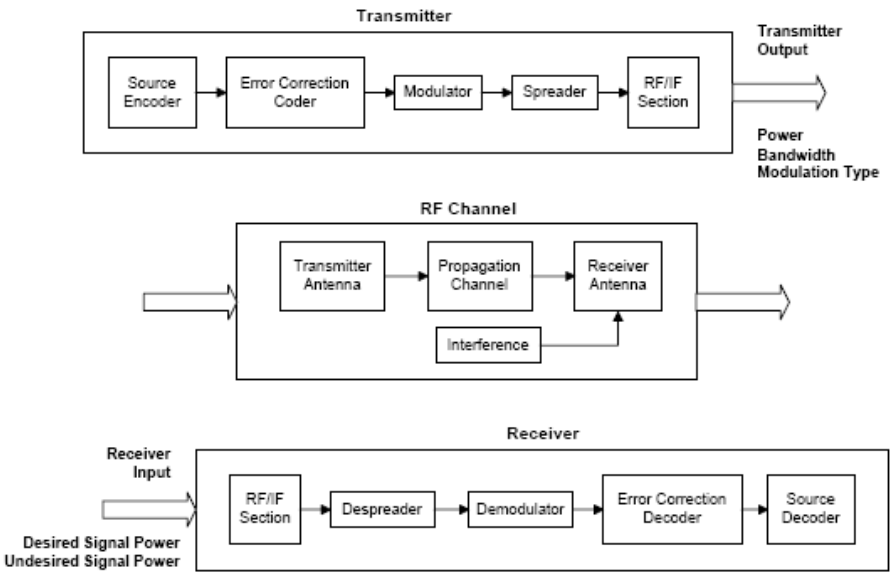
Where:

Pt	= Signal power at transmitter output, in dBm
Gt	= Transmitter antenna gain, in dBi
L	= Propagation loss, dB
Gr	= Receiver antenna gain, in dBi
Pr	= Signal power at the receiver input, in dBm

Benefit of Digital Modulation Methods

- Digital systems can provide robustness to EMC issues in the communication link by error detection and correction methods as well a through bit-error-rate (BER) parameters.
- If a higher BER can be accommodated, this may allow minimal link budget values.
- Goal is an acceptable balance of transmitter / receiver specifications (such as sensitivity, signal to noise ratio), path loss, and BER.

Automotive System Impact Upon “Link Budget”



- Link budget calculations can be significantly affected by interference sources from vehicle systems.
- Can affect both the “channel” and the receiver performance.

Wireless System EMC - Summary

- The proliferation of wireless systems in a vehicle environment can result (ironically) in the demand for more immune/robust systems.
- System compatibility can be evaluated by understanding the basics of EMC as applied to other technologies.
- By understanding how antennas can be represented and wireless systems function, the performance of wireless systems in the presence of automotive systems can be determined.

Development of “Simple” EMC Test Methods / Approaches That ANY Engineer Can Use

Test Methods for the Non-EMC Engineer

- EMC analysis work CAN be conducted by the “non-EMC” engineer.
- Approaches involve simple test methods that are designed to address common EMC issues.
- Allows engineers insight into their design’s overall EMC capability – *before formal EMC testing takes place.*

Test Equipment for EMC Work (for everyone!)

- EMC initial diagnosis and analysis can be accomplished by using common items found in an electronics lab.

- Goal is to perform basic tests to identify the “Source-Path-Receiver” present in *every* EMC problem.

RE and RI ”Quick Tests”

- Configure component/system into operational mode and use a portable radio to identify emissions.
  - AM/FM radio receivers - AM setting useful to trace BB noise - FM useful to trace NB noise.
  - Clamp ferrites on harnesses to eliminate effect of conducted energy.
- For immunity – Handheld transmitters can provide local high magnitude fields to identify potential issues.

An RE and CE Detector!

- Acts as a “receiver” in the “Source-Path-Receiver” model.
- Best ones for EMC work are the lowest selectivity analog receivers.
- Can be used to detect both radiated and conducted noise.

Radiated Immunity – The "Handy Way"

- Use "license free" handheld receiver/transmitters at close distances to produce field strengths that duplicate significantly higher fields from other sources.

Pocket Sized Tools

- An electrical oriented "multi-tool" can be used to cut wire and remove paint/corrosion.
- Use of a tape measure can help identify wires that act as "undesired antennas" due to their length > 10 % of λ.

My Personal Favorite – The "MFJ-269"

- Designed for antenna engineering, this device generates a RF signal from 1.7- 174 MHz.
- Measures (at user selected frequencies) complex impedance (Z), capacitance (C), and inductance (L) of wires/components.

Summary

- Automotive EMC has been continually evolving to meet the challenges that new technology brings.
- The automotive industry in undergoing a complete “re-invention” of itself to meet demands of today’s world.
- Understanding of the basics of these new technologies and will enable Automotive EMC to meet these challenges!