Segment 2 – EMC Testing

• Overview of testing methods.
• Types (“Precompliance” versus “Final”).
• Testing methods for the non-EMC engineer.
• Test equipment EVERYONE should have.
Why Do EMC Testing?

- EMC requirements exist for almost ALL electronic systems.
- Governments have legal requirements.
- Most companies have EMC as a part of product performance requirements.
- Typical method to assure compliance is by standard test methods and subsequent data review.
Legal Requirements for EMC

• Defines maximum levels for emissions – and minimum levels for susceptibility (immunity).
• In the U.S., the Federal Communications Commission (FCC) has authority for EMC requirements – as defined in FCC “Part 15”.
• Other countries have requirements based upon typically upon “CISPR” standards.
• Violation of EMC requirements CAN include fines AND / OR jail!
**EMC Testing Approach**

- In previous years – EMC testing focused on “system level” evaluations - the emphasis is now moving to component level requirements and performance.
- No matter what approach is used – devices are required to be identified as meeting requirements.
Representative Test Set-Ups For Emissions Measurements

- The figures shown are the equipment under test (EUT) and it’s wiring connections.
  - Radiated Emissions (RE) are measured with an antenna.
  - Conducted Emissions (CE) are measured using a receiver.
Immunity To External Fields

- The goal: to understand the compatibility of the electronic system with the environment.

![Diagram illustrating immunity to external fields with labeled signals and frequencies.]
Characteristics of Today’s RF Environment

- Consists of both high power “remote” sources and lower power “local” sources.
- Most high power “remote” sources result in an equipment exposure of low to medium E/M fields.
- Some low power “local” sources can actually produce E/M fields much larger than the higher power remote sources!
Electric field strength is measured in terms of “Volts/meter” and is function of transmitter power, antenna gain, and distance from source.
**Immunity: Test Practices**

- How can a product be tested to ensure appropriate immunity levels?
  - Measures should be implemented to “design in” appropriate immunity characteristics based on the expected RF environment the equipment will be subjected to.
  - System and component testing can be conducted by simulating “external” sources to ensure immunity characteristics.
Electric Field Strength Example

• A circuit board is located 10 meters from a rooftop antenna transmitting 1000 watts. The electric field strength would be (per the previous equation):

\[ P_t = 1000 \text{ w}, \ r = 10 \text{ m} \rightarrow E = 17 \text{ V/m}! \]
Immunity Testing

- Test set-up similar to emissions testing.
- EUT is configured in operational condition, then RF energy is radiated to the test set-up.
- Direct connection to EUT may also be implemented.
The Bulk Current Injection (BCI) Test Method

- 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.
Terminology Used in EMC Testing – Decibel “dB”

- Expresses the relationship between two quantities.
  - For power it’s defined as: \( dB = 10 \log \left( \frac{P_1}{P_2} \right) \)
    - If \( P_1 = 10 \) watts, and \( P_2 = 5 \) watts \( \Rightarrow \) 3 \( dB = 10 \times 0.301 \)
    - If \( P_1 = 5 \) watts, and \( P_1 = 10 \) watts \( \Rightarrow \) -3 \( dB = 10 \times (-0.301) \)
  - For voltage and current:
    - Since \( P = (I^2) R \) or \( (V^2)/R \) \( \Rightarrow \) \( dB \) \( (V \) or \( I) = 20 \log \left( \frac{X}{Y} \right) \)
      - If \( X/Y = 2 \), \( \log \left( \frac{X}{Y} \right) = 0.301 \) \( \Rightarrow \) 6 \( dB = 20 \times (0.301) \)
      - This is true only when the resistance (impedance) is the same for both measurements!
**Typical EMC Test Measurement Units**

- For EMC measurements, many values are expressed as a “dB” value.
- Convention is to add a letter to the “dB” to indicate the reference (denominator).
  - A value of 2 dBV ➔ Means “2 dB greater than 1 volt”
  - A value of 62 dBuA ➔ Means “62 dB greater than 1 uA”.
- Notation of “dBm” ➔ Means compared to 1 milliwatt (with a 50 ohm impedance).
Testing Methods –
Precompliance and Final Tests

• Pre-compliance testing can have a significant benefit towards prevent program delays due to late identification of EMC issues.

• Intention is to identify very early whether there are any “major contributor's” that would prevent EMC compliance from being achieved.

• Final tests would then confirm the product meets the EMC requirements.
Goals of EMC Pre-Compliance Testing

• Helps facilitate and identify a “Design for EMC” approach.
• Testing conducted by simulating component operation as it would function in the complete system, without requiring complete system functionality.
• If component passes test no action is required. If it does not pass - use the test data to determine corrective action plans.
“Cost of EMC” and Solutions Available

• Goal should be to identify options to address EMC early in the design stage. Early attention minimizes cost – and maximizes available options.

• Use “Pre-Compliance” methods whenever possible.

<table>
<thead>
<tr>
<th>Cost of EMC</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMC Solutions</td>
<td>Many</td>
<td>Some</td>
<td>Few</td>
<td>None</td>
</tr>
<tr>
<td>Program Phase</td>
<td>Design</td>
<td>Development</td>
<td>Validation</td>
<td>Production</td>
</tr>
</tbody>
</table>
Key Benefits of Pre-Compliance Testing

• Helps in the early development of a component that meets-component level EMC without requiring subsequent system-level corrective actions.
• Depends on utilizing the results of the pre-compliance testing for guidance to improve the design.
• Important to always keep in mind the final program requirements and that final compliance will be required.
Pre-Compliance EMC Testing Program Plan

• This would be used to ensure proper component test set-up, operation, and instrumentation requirements are met.

• The process includes:
  – Definition of test modes, and input signals similar to application usage.
  – Construction and connection of representative wiring aspects and routing.
  – “Load” definition.
  – Determination of methods used for test monitoring.
Metrics for Pre-Compliance

- By its nature – Pre-compliance provides an overall evaluation of the EMC performance of a component or system.
- In order to maximize the likelihood that the final EMC testing will be successful, there is evidence that a 9 dB “margin” at the design phase will:
  - Provide sufficient tolerance to provide a high degree of confidence of passing the final EMC tests.
  - The test margin covers both manufacturing tolerance and measurement tolerance.
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 1: Effects Due to Wiring

- Put component/system into it’s operational modes and move power wires, signal lines, and observe if any unanticipated conditions occur.
  - System I/O sensitivities can be identified.
  - Changes the effect of “parasitic” inductive or capacitive coupling characteristics from the wiring.
**Test 2 – Radiated Emissions and Radiated Immunity “Quick Test”**

- 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 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 detect both NB and BB 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.
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

- Consists of toroids, cylinders, or rectangles made from ferrite material.

- Typically installed without cutting into wiring.
Use of Chokes for CE

- Sometimes are used to enable component to pass CE requirements without circuit modifications.
- There are many examples of chokes on power supply cabling and computer video cables used to pass legislated EMC requirements.
Effectiveness of CE Chokes

- Common mode chokes can be effective due to the reduction of the “unintended” current that typically is the cause of CE problems.

- It is important to conduct a careful review of data before and after application of common mode chokes can help to identify if CE is being affected by the chokes.
Test 3: Localized Shielding

- May be used to increase immunity to E/M fields.
- Typically consists of a shield for the electric field vector and can be done with a ferrite for magnetic field induced currents on the wiring.
- 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.
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.
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 $\lambda$!
Voltage, Current, and Continuity Measurements

- The advent of very inexpensive electrical test meters means that several can be kept very conveniently to be used for measurements of wire resistance and conductive assemblies.
My Personal Favorite – The “MFJ-269”

- Designed for antenna engineering, this device generates a NB RF signal from 1.7-174 MHz.
- Measures (at user selected frequencies) complex Z, C, L, and cable loss factors.
EMC Testing for “Final Compliance”

• Initial EMC testing (both for development and Precompliance) should be used *only* as an indicator of component/system performance (*not as a substitute*)!

• Initial work can actually shorten program timing and enhance the ability to pass final testing with the complete test set-up and required test instrumentation – *which is the ultimate goal*. 
Summary of EMC Testing

- EMC testing is an essential part of producing an “EMC compliant” product.
- Test methods are defined to identify emissions, immunity sensitivities, and effects of system interactions.
- Pre-compliance testing can be used as a first indicator of EMC performance.
- Final EMC testing is accomplished according to test specifications using high quality instruments.