EMC Testing and Amplifier Selection

APPLICATION NOTE / 5A-076

Maury Microwave Inc. — April 2025

Introduction

Electromagnetic Compatibility (EMC) testing ensures that electronic devices operate as intended within their electromagnetic environment without causing or experiencing interference. A critical component of EMC testing is the amplifier, which plays an essential role in generating the required test signals. The selection of an appropriate amplifier is fundamental to achieving accurate, efficient, and repeatable EMC testing results.

Understanding EMC Testing Requirements

EMC testing consists of two primary aspects:

> **Emission Testing**: Evaluates the electromagnetic disturbances emitted by a device

> **Immunity Testing**: Assesses the device's resistance to external electromagnetic influences.

For immunity testing, high-power RF signals must be generated to simulate real-world electromagnetic interference. The performance of the selected amplifier directly impacts the accuracy, reliability, and repeatability of EMC tests.

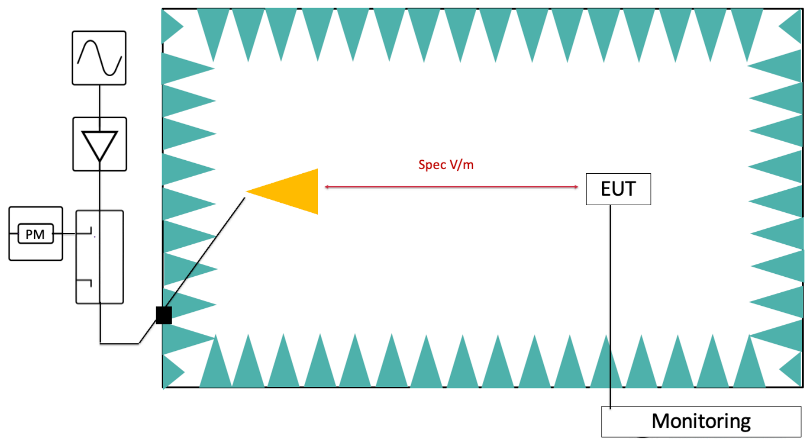

Figure 1. Simplified immunity test block diagram

Key Considerations for Amplifier Selection

When selecting an amplifier for EMC testing, several factors must be considered:

> Frequency range

> Power output

> Linearity

> Gain stability

> Load Matching and VSWR tolerance

> Cooling

> Modulation

> Compliance with EMC standards

Frequency Range and EMC Standards

EMC testing requires amplifiers that cover a broad frequency spectrum, often from kHz to GHz, to support different applications and industry standards. Common EMC standards and their corresponding frequency requirements include:

COMMERCIAL STANDARDS:

IEC 61000-4-3 (Radiated Immunity): 80 MHz – 6 GHz, typically requiring 10V/m at 3m.
IEC 61000-4-6 (Conducted Immunity): 150 kHz – 230 MHz, requiring 3V/m to 10V/m (contact injection).

MILITARY STANDARDS:

MIL-STD-461 RS103 (Radiated Susceptibility): 2 MHz – 40 GHz, requiring 50V/m to 200V/m at 1m.

AEROSPACE STANDARDS:

DO-160 Section 20 (Radiated and Conducted Susceptibility): 100 MHz – 18 GHz, requiring 20V/m to 200V/m at 1m.

MEDICAL STANDARDS:

IEC 60601-1-2 (Electromagnetic Disturbance and Immunity): 150 kHz – 2.7 GHz, requiring 3V/m to 10V/m at 3m.

ISO 14708-3 (Active Implantable Medical Devices Immunity): 9 kHz – 3 GHz, requiring 10V/m at 1m.

AUTOMOTIVE STANDARDS:

ISO 11452-2 (Radiated Immunity in Vehicles): 10 kHz – 18 GHz, requiring 30V/m to 200V/m at 1m.

ISO 11452-4 (Bulk Current Injection for Conducted Immunity): 1 MHz – 400 MHz, requiring injection levels from 10mA to 300mA.

The frequency range coverage of an amplifier is often a limiting factor in achieving a truly broadband test solution. To overcome this constraint, test benches commonly incorporate a switch matrix; however, this approach increases insertion loss between the amplifier and the antenna while also raising the overall system cost. The additional insertion loss necessitates higher output power from the amplifier to maintain the required field strength. Consequently, broadband amplifier solutions are ideal for EMC testing, as they minimize these limitations and enhance test efficiency.

Power

As outlined in the previous section, immunity testing requires sufficient power to generate the specified electric field strength (V/m) at the designated distance, as defined by various standards. The relationship between the required field strength (E) and power (P) at a given distance (d) is expressed by the following formula:

$$P = \frac{E^2 d^2}{30G}$$

where G represents the antenna gain.

Once P is determined, the insertion loss (IL) between the amplifier and the antenna must be factored in to accurately define the required amplifier power. Additionally, considerations such as the modulation peak-to-average ratio (PAR) should be accounted for to ensure the amplifier operates within its linear region.

Example:

- Application: Automotive ISO 11452-2
- Frequency: 6-18 GHz
- Antenna Gain (G): 15dBi
- Electric field (E): 200 V/m
- Distance: 1 m
- Insertion Loss (IL): 4dB

Based on these parameters, the minimum required amplifier power is 85 W. For a robust and reliable system, selecting an amplifier in the 150–250 W range is recommended.

Linearity and Harmonic Distortion (Class A and AB):

A linear amplifier ensures that the output signal accurately represents the input while minimizing harmonic distortion and unwanted spectral emissions, which could interfere with test measurements.

Class A amplifiers offer exceptional linearity; however, they are less efficient, leading to increased power consumption, higher operational costs, and greater cooling requirements. In contrast, modern Class AB amplifiers strike a balance between efficiency, linearity, and reliability. They achieve significantly higher efficiency than Class A amplifiers while maintaining relatively low distortion, making them well-suited for applications where moderate linearity is required without excessive heat dissipation.

ADVANTAGES OF CLASS AB AMPLIFIERS FOR EMC TESTING:

- **Higher Efficiency**: Class AB amplifiers operate more efficiently than Class A amplifiers, reducing overall power consumption and thermal output.
- **Balanced Linearity**: While not as linear as Class A amplifiers, modern Class AB amplifiers provide sufficient linearity for many EMC tests while significantly reducing power wastage.
- **Cost-Effectiveness**: Enhanced efficiency reduces operational and cooling costs, making Class AB amplifiers a more economical choice.
- **Reduced Cooling Requirements**: Reduced heat dissipation enhances long-term reliability and lowers the need for extensive cooling infrastructure.
- **Adequate Performance for Many EMC Tests**: For many conducted and radiated immunity tests, the harmonic distortion levels of Class AB amplifiers are within acceptable limits, making them a practical choice where extreme linearity is not mandatory.

Gain and Stability: The Perfect Solution for TWT Replacement

An EMC amplifier must deliver consistent gain while maintaining low noise and stability to ensure repeatable test results. Solid-State Power Amplifier (SSPA) technology provides exceptional gain stability with minimal noise addition, making it the preferred choice over older Traveling Wave Tube (TWT) technology for EMC applications.

Minimizing gain compression is critical to maintaining a stable output power level throughout testing. Modern GaN-based SSPAs offer soft gain compression, allowing the amplifier to sustain high compression points and operate efficiently over a broader dynamic range compared to previous technologies.

Other Considerations

- **Load Matching and VSWR Tolerance**: Amplifiers should be selected to handle the proper load conditions and high Voltage Standing Wave Ratio (VSWR) presented from the components in front of the amplifier (cable, antenna, chamber).
- **Cooling and Thermal Management**: High-power amplifiers generate significant heat, necessitating proper cooling mechanisms. Over-temperature protection ensures long term reliability.
- **Modulation Capabilities**: Some EMC tests require modulated signals (e.g., pulse modulation for radar susceptibility testing). The amplifier should support amplitude, frequency, and pulse modulation as required by the test standard. Select the amplifier based on the performance of intermodulation and distortion at the relative PAR value.
- **Compliance with EMC Standards** ensure the amplifier meets regulatory requirements such as FCC, CE, and MIL-STD specifications. Pre-certified amplifiers simplify test setup and ensure compliance.

Maury Amplifiers (MPA):

Maury Microwave amplifier line uses modern SSPA GaN technology to deliver outstanding power levels with large broadband frequency coverage. The class AB models offer the linearity performance required by the standard with the advantage of a more compact and reliable design.

Unique broadband designs such as 2-18 GHz, 6-18 GHz, 18-40 GHz allow EMC test bench to reduce test timing with larger frequency sweeps. The wideband options also reduce the components used in front of the amplifier minimizing insertion loss and total cost of the solution.

Figure 2. Examples of Maury Amplifiers Solutions

Below are examples of 2 conventional EM over the air and connectorized testing using Maury Microwave amplifiers and other Maury components designed for accurate power testing such as:

- High video BW power sensors
- Low loss broadband couplers
- Amplitude and phase stable cables

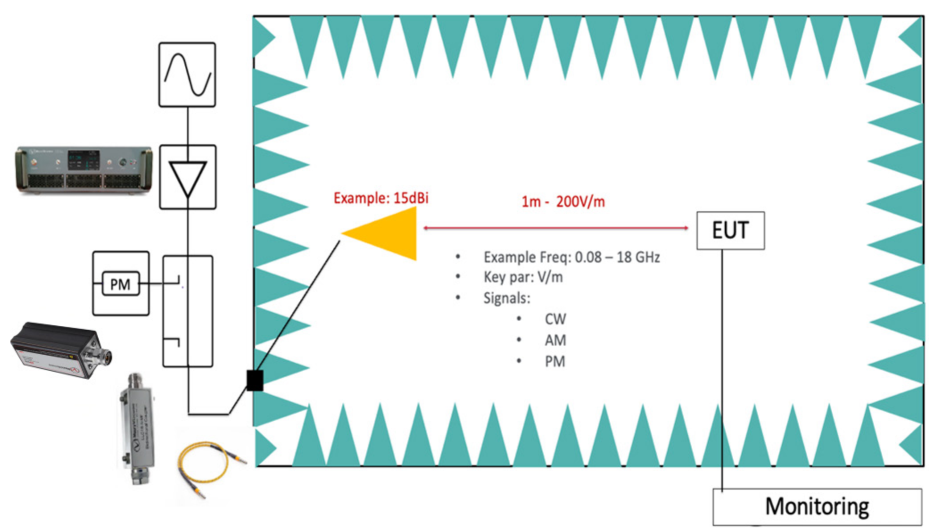

Figure 3. Simplified block diagram for immunity testing

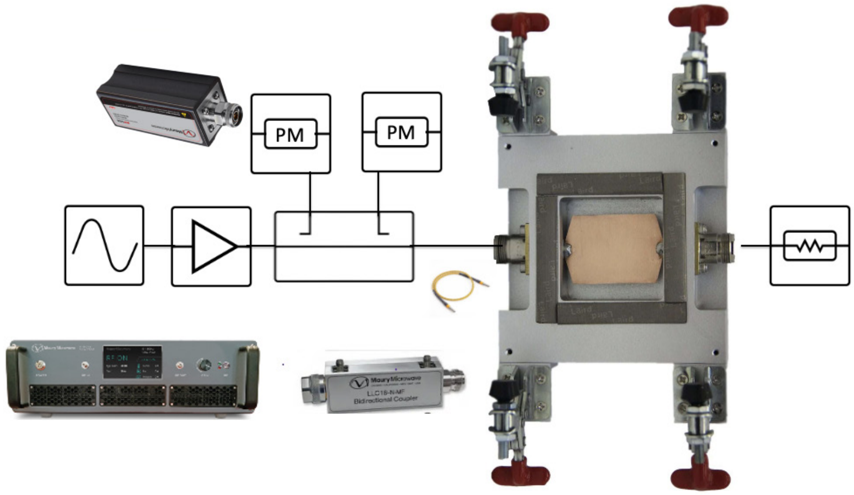

Figure 4. Simplified block diagram for stripline testing

Conclusion

Selecting the right amplifier for EMC testing is critical to achieving accurate and compliant test results. By considering factors such as frequency range, power output, linearity, stability, and thermal management, engineers can ensure reliable and repeatable EMC measurements. Proper amplifier selection enhances the efficiency of the testing process and helps meet regulatory compliance with confidence

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CONTACT US:
W / maurymw.com
E / maury@maurymw.com
P / +1-909-987-4715
F / +1-909-987-1112
2900 Inland Empire Blvd
Ontario, CA 91764