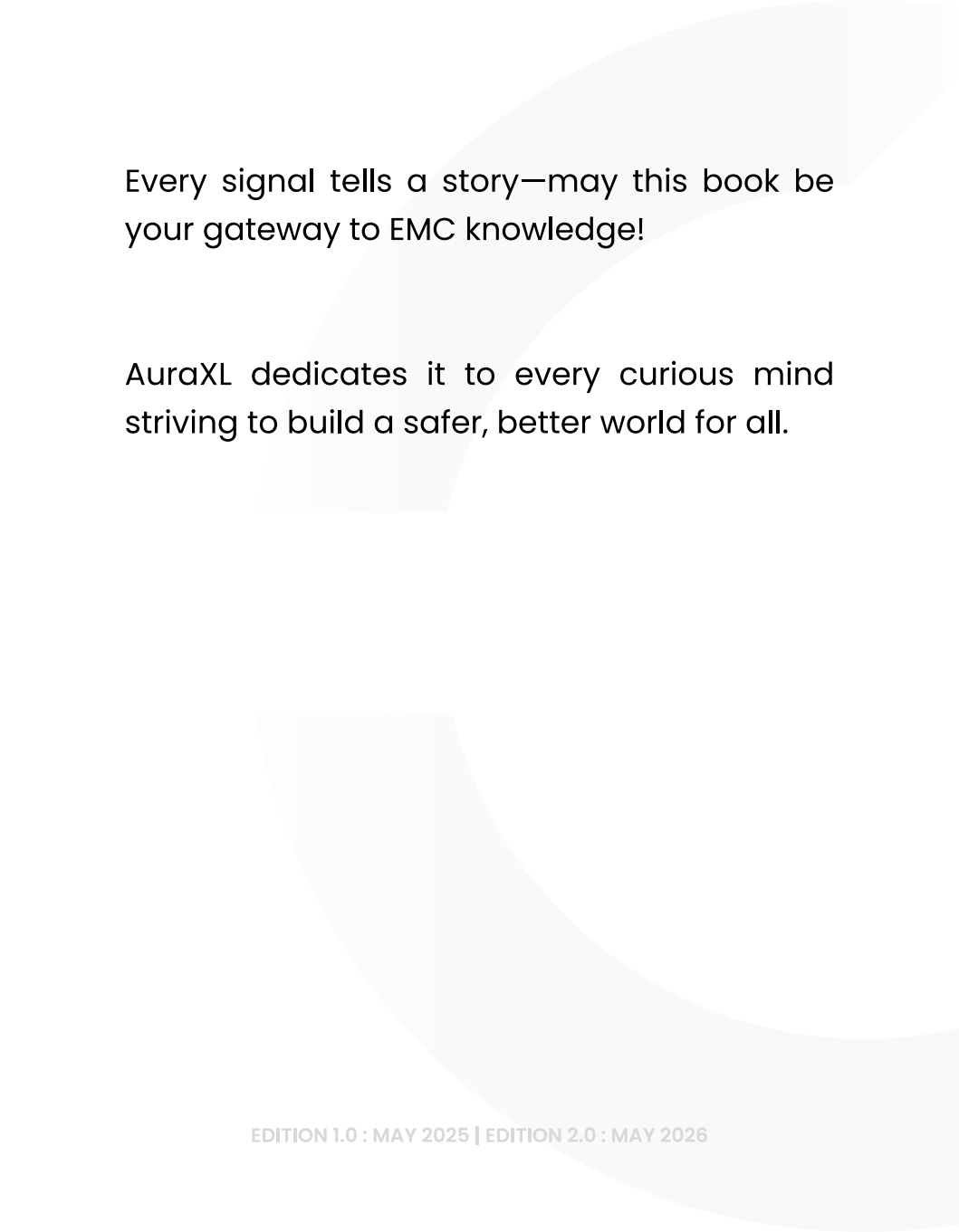




Your Partner in EMC Excellence

Auraexcel Private Limited, Pune, INDIA



Every signal tells a story—may this book be your gateway to EMC knowledge!

AuraXL dedicates it to every curious mind striving to build a safer, better world for all.



Radiating Excellence

Aura symbolizes a positive energy and unique presence, while **'XL'** stands for excellence. Together, **AuraXL** embodies the idea of **Radiating Excellence** through cutting-edge solutions, driven by a smart, innovative, and quality-focused approach.

Our Vision



"Our vision is to be the world's most trusted partner, empowering customers to achieve product success, operational excellence, and seamless global market access—creating a better, safer world for all."

Introduction



Electromagnetic Interference (EMI) refers to the unwanted disturbances in electronic devices caused by internal and / or external electromagnetic fields. Electromagnetic Compatibility (EMC) ensures that electronic systems can operate in their intended environments without interfering with each other.

As vehicles become more reliant on electronics—ranging from safety-critical features like airbags and braking systems to infotainment—EMI/EMC compliance is crucial to prevent malfunctions that could lead to serious accidents or fatalities.

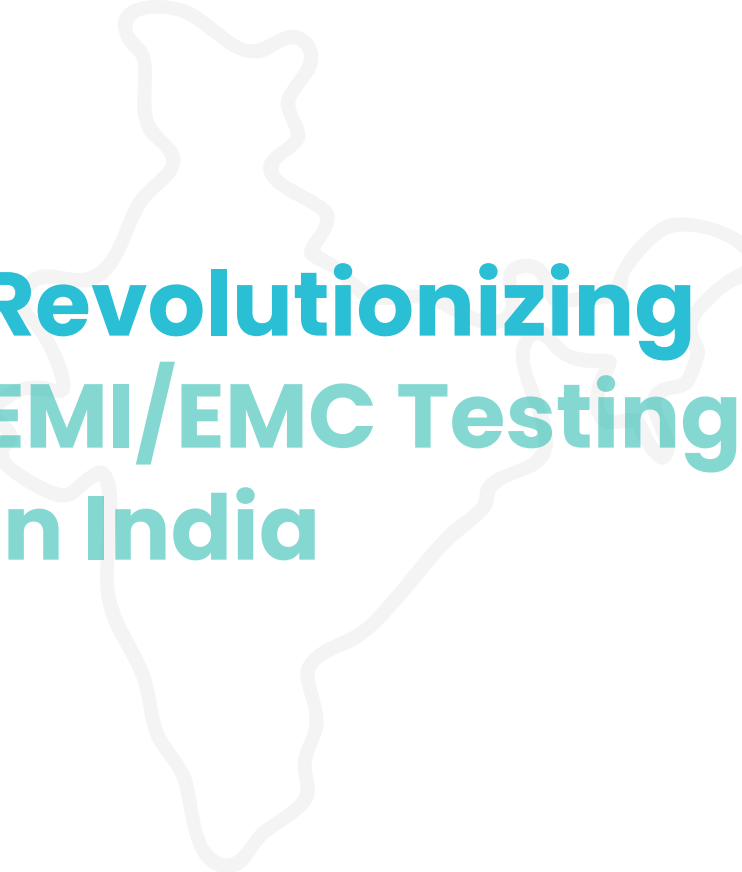
Challenges Faced by Customers



Lack of Awareness: Many customers are unaware of the importance of EMC testing, regulatory standards, and compliance, causing delays in product certification and market access.

Limited Access to Quality Labs: India has very few high-quality EMI/EMC labs, forcing manufacturers to rely on overseas testing, increasing costs and lead times.

Low Assurance: Inconsistent results and lack of lab expertise can reduce confidence in testing, causing delays, loss and rejections.



Revolutionizing EMI/EMC Testing in India

AuraXL is poised to transform EMI/EMC testing in India by establishing a world-class facility that meets the highest global standards. With state-of-the-art technology, deep expertise, and a customer-first approach, we provide reliable, high-quality testing services tailored to the evolving needs of the automotive industry.

Your Trusted Partner for EMC Excellence



Beyond testing, we are committed to holistic management across processes, projects, products, and people, ensuring efficiency, innovation, and excellence at every stage. We also prioritize the development and empowerment of the EMC community, fostering knowledge-sharing, collaboration, and growth to strengthen the overall EMC ecosystem in India.

By bridging critical gaps in EMI/EMC awareness, accessibility, and assurance, AuraXL is set to be the driving force behind safer, more reliable, and globally compliant electronic systems.

Our Team



Our leadership team comprises seasoned professionals with over 50 years of combined experience in EMI/EMC testing, engineering, and business management. Each team member brings specialized knowledge and a strong global network, ensuring operational excellence and strategic growth.



**“EMC is in c
Quality is i**



our Blood
n our DNA"

Aura Research and Technology (ART)



- State of the **ART** EMC labs across India
- EMC test & measurement products design and development



- AI enabled EMC software for designers

aquair

The Future of Live EMC Data



📱 Scan to watch the demo

The AuraXL Advantage



Up to 3× faster
turnaround time

Shorter development
timelines



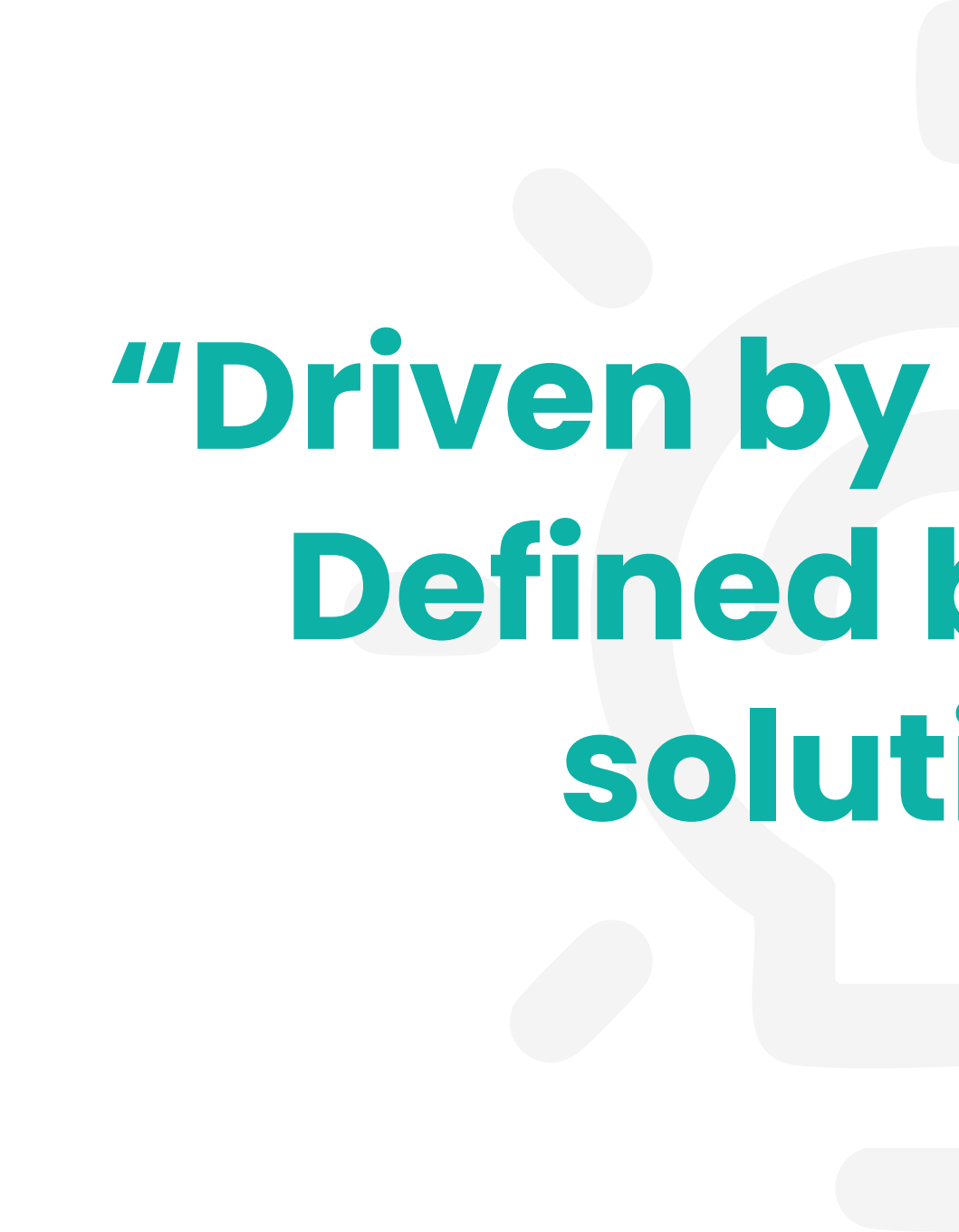
Up to 2× more
economical

Lower Validation
Cost

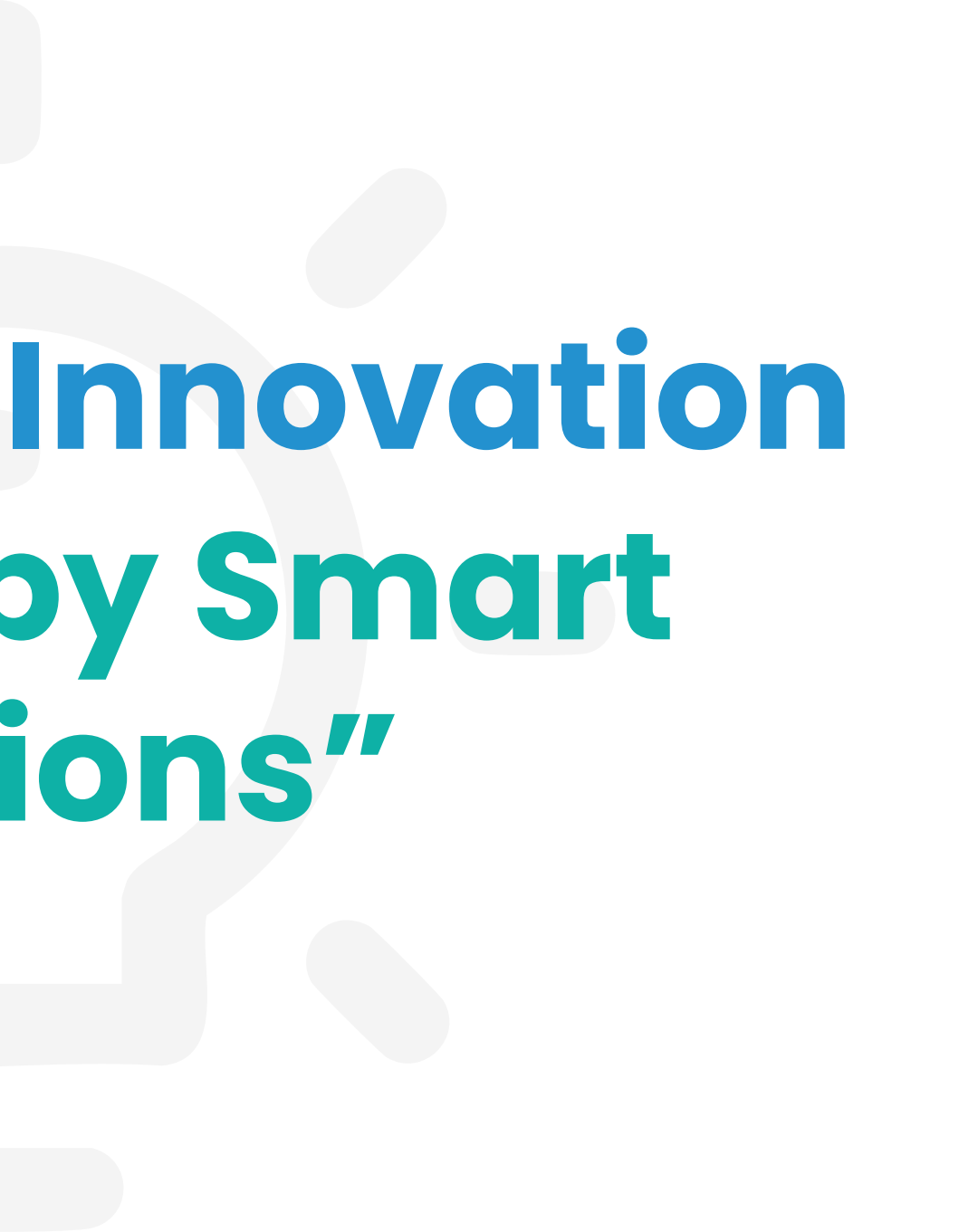


Quality in
our DNA

Faster market entry



**“Driven by
Defined k
solution**



**Innovation
by Smart
ions"**

Aura Innovation and Management (AIM)



- Project Management
 - Turnkey solutions for EMC lab
- Product Management
 - Authorised partner for



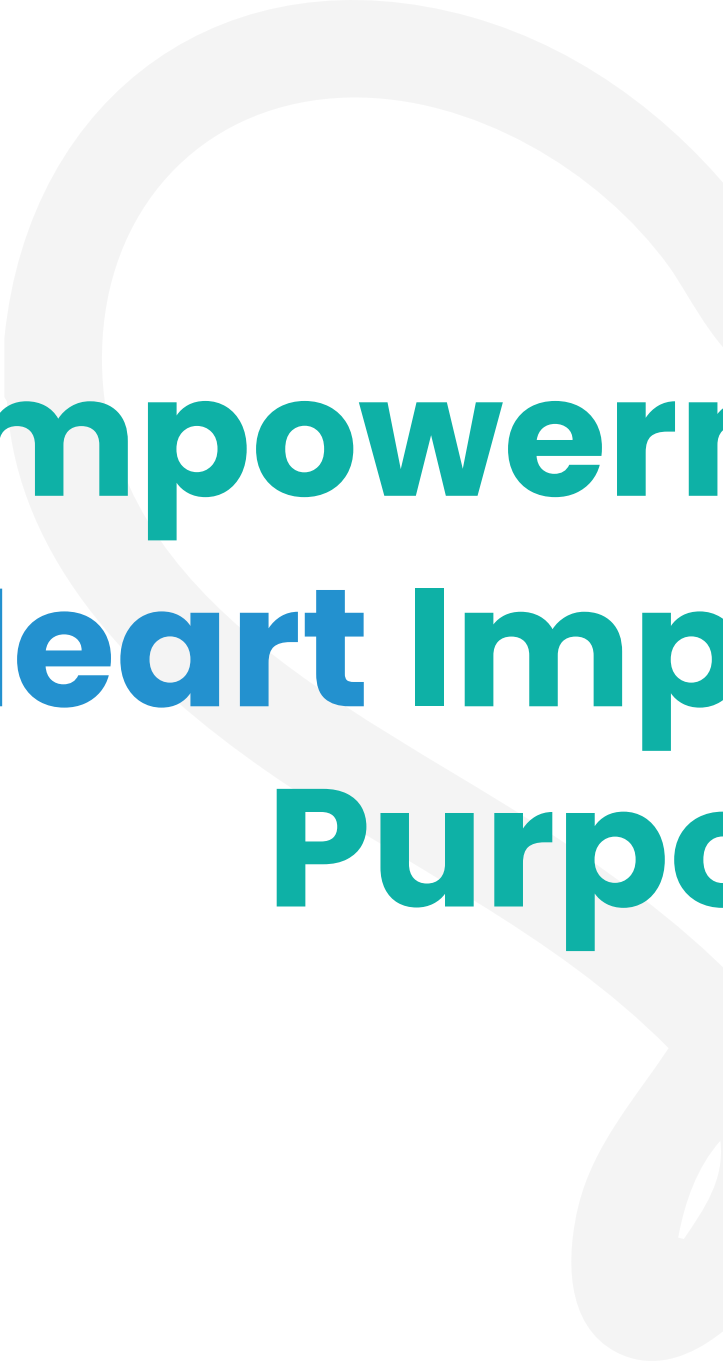
• messtechnik
EMC Test and Measuring Systems

BOLAB shieldex

- Process Management
 - Electronic Laboratory Information Management System



- People Management
 - Empowering skills, Elevating Careers
 - Train, Mentor & Grow with Industry Excellence!



**“Empower
Heart Imp
Purpo**



**ment with
act with
se"**

Aura Initiative for Development and Empowerment (AIDE)

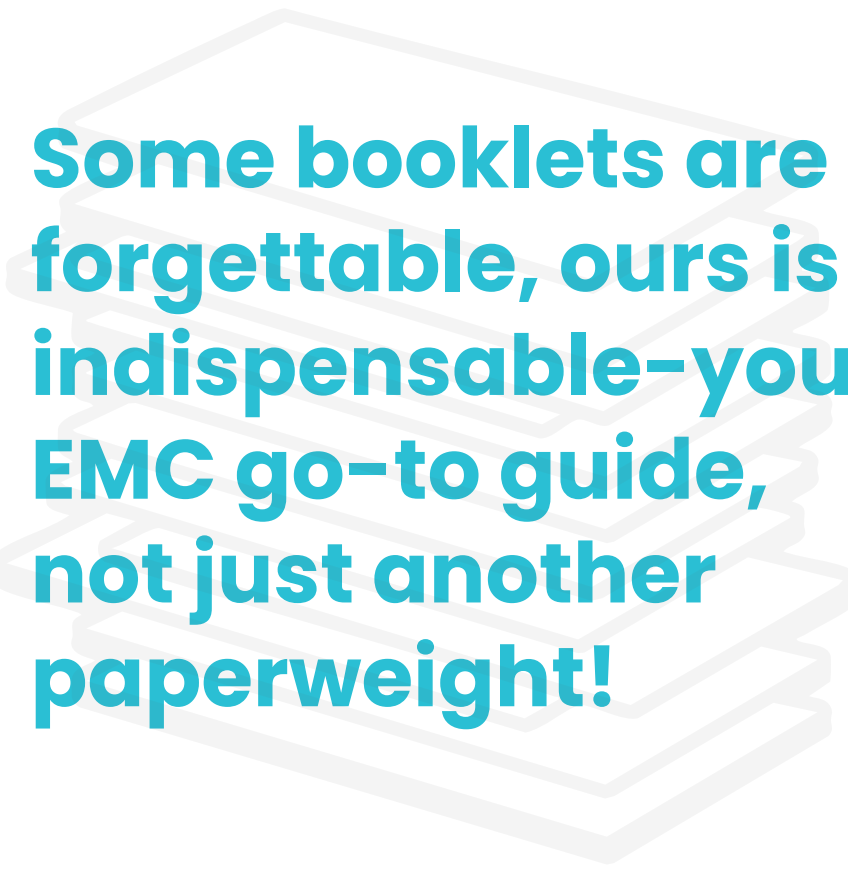


EMCircle: Building the EMC Community A collaborative platform uniting EMC professionals, fostering knowledge exchange, mentorship, and industry growth.



Advancing EMC Innovation Premier conferences bringing experts, researchers, and businesses together to discuss trends, challenges, and solutions.

Giving Back to Society: A CSR-driven initiative empowering social entrepreneurs and fostering sustainable societal development through impactful support.



Some booklets are forgettable, ours is indispensable—your EMC go-to guide, not just another paperweight!

Waves of Wisdom

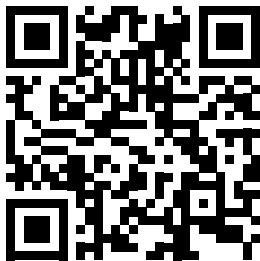


Unlocking the Secrets of EMC



The Invisible Force – Electromagnetism

Electromagnetism is one of the four basic forces in nature. It's like a superpower that makes light, energy, and everything around us work. It's a basic part of how the world is made.



*Watch me: YouTube Video
(3min)*

What are Electric Charges?

Everything is made of tiny things with electric charges. These charges can be positive, negative, or nothing. Like charges push each other away. Opposite charges pull each other together. This is how electricity starts.

Electric and Magnetic Fields

When charges move, they make electric currents and magnetic fields. Think of it like ripples in water. These fields work together to make electromagnetic fields. These fields carry energy.

The Electromagnetic Spectrum

This energy travels in waves. The frequency of the waves tells us how strong they are. We call this the electromagnetic spectrum. It includes:

- Light we can see
- Radio waves for music
- Microwaves for cooking
- X-rays for doctors
- And more!

Earth's Electromagnetism

Deep inside the Earth, hot metal moves. This makes electric currents and magnetic fields. It turns the Earth into a giant magnet. This magnet protects us from harmful radiations from space.

Electromagnetism is not just a science idea. It's how things work. It powers our phones and keeps us safe. Understanding it helps us understand the world.

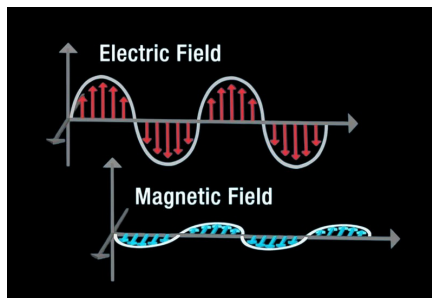
Anatomy of an Electromagnetic Wave

Energy, a measure of the ability to do work, comes in many forms and can transform from one type to another. Examples of stored or potential energy include batteries and water behind a dam. Objects in motion are

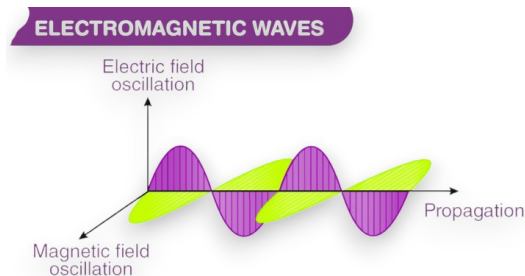
examples of kinetic energy. Charged particles—such as electrons and protons—create electromagnetic fields when they move, and these fields transport the type of energy we call electromagnetic radiation, or light.

Electromagnetic Waves

Electricity can be static, like the energy that can make your hair stand on end. Magnetism can also be static, as it is in a refrigerator magnet.



A changing magnetic field will induce a changing electric field and vice-versa—the two are linked. These changing fields form electromagnetic waves. Electromagnetic waves differ from mechanical waves in that they do not require a medium to propagate. This means that electromagnetic waves can travel not only through air and solid materials, but also through the vacuum of space.



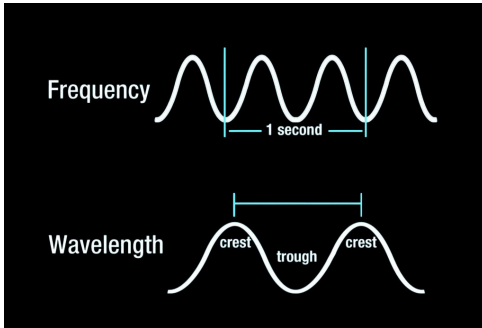
In the 1860's and 1870's, a Scottish scientist named James Clerk Maxwell developed a

scientific theory to explain electromagnetic waves. He noticed that electrical fields and magnetic fields can couple together to form electromagnetic waves. He summarized this relationship between electricity and magnetism into what are now referred to as **"Maxwell's Equations."**

Electromagnetic wave is described by its frequency (Hertz), wavelength (meters), and energy (electron volts).

Frequency: The number of wave cycles that pass a fixed point in one second.

Wavelength: The distance between two successive crests or troughs of a wave.



$$f = c / \lambda$$

Where:

f is the frequency (in Hertz)

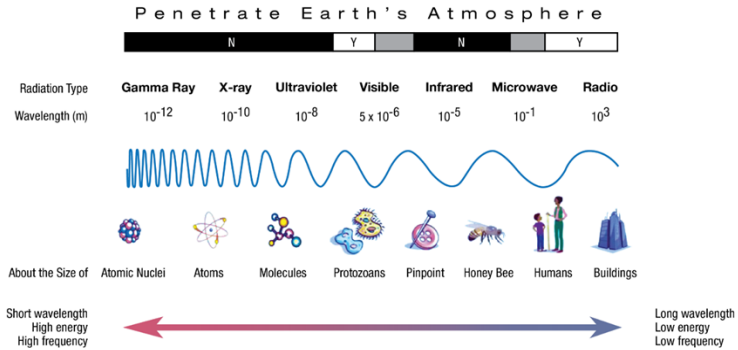
c is the speed of light (approximately 3×10^8 meters per second in a vacuum)

λ (lambda) is the wavelength (in meters)

EM Spectrum (Electromagnetic Spectrum):

This is the entire range of electromagnetic radiation, from the lowest frequencies (radio

THE ELECTROMAGNETIC SPECTRUM



waves) to the highest (gamma rays). It encompasses everything.

RF Spectrum (Radio Frequency Spectrum):

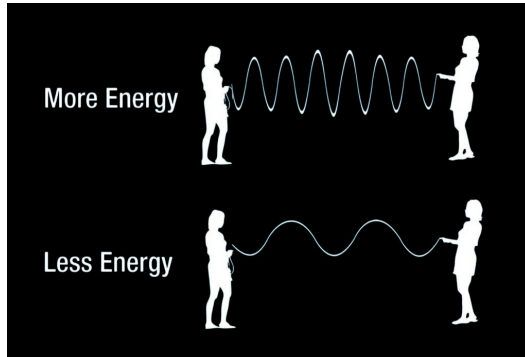
This is a subset of the EM spectrum, specifically the range of frequencies used for radio communications. It includes radio waves and microwaves.

Energy and Frequency: A Simple Rule

Here's the key: the shorter the wavelength (and thus, the higher the frequency), the more energy the wave carries.

Low Frequency, Low Energy:

Imagine gently waving a jump rope. It takes little effort. Low-frequency EM waves, like radio waves, have long wavelengths and carry less energy. They're great for sending signals over long distances, but they don't have enough energy to do things like cook food.



High Frequency, High Energy:

Now, imagine shaking the jump rope really fast, making lots of tight waves. It takes much more energy. High-frequency EM waves, like microwaves, have short wavelengths and carry a lot of energy. This is why microwaves, which operate in the gigahertz (GHz) range, can heat food. The high-frequency waves cause water molecules in the food to vibrate rapidly, generating heat.

Example: Microwave Cooking

Think of a microwave oven. It uses microwaves, which are high-frequency EM waves. These waves penetrate food and cause the water molecules inside to vibrate. This vibration creates heat, which cooks the food. Because microwaves have a much higher frequency than radio waves, they carry much more energy, enough to heat your food quickly.



Example: Listening to FM Radio in Your Car

When you tune your car radio to an FM station, you're using radio waves to listen to music or talk shows. The radio station broadcasts audio signals by encoding them onto radio waves at a specific frequency (e.g., 102.7 MHz). Your car's antenna picks up these radio waves, which are then processed by the radio receiver. The receiver decodes the encoded audio signal and converts it back into sound that you hear through the speakers.



Example: Wi-Fi and Cellular network

As a person navigates their day, they seamlessly switch between Wi-Fi and cellular networks for connectivity. At home, Wi-Fi enables internet access via radio waves from a router, while on the go, cellular networks transmit RF signals to towers for calls and data. Apps rely on both, streaming over Wi-Fi and switching to cellular as needed. While Wi-Fi offers localized connectivity, cellular networks provide broader coverage, ensuring

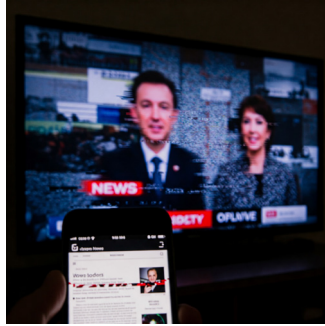


constant access to communication and information. These RF technologies have revolutionized digital connectivity, making seamless communication an integral part of modern life.

What is EMI/EMC?

Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC) play a crucial role in the functioning of electronic devices.

Imagine using your smartphone near a speaker and hearing an unexpected buzzing sound—this interference is caused by unwanted electromagnetic signals disrupting the speaker's normal operation.



In simple terms, **EMI** refers to the unwanted disturbance from electrical or electronic devices, while **EMC** ensures that all devices can operate together without interfering with each other.

This "noise" we call EMI can come from many sources: power lines, motors, radio transmitters, even other electronic devices. When this noise gets into an electronic system, it can cause malfunctions. In automotive electronics, this can be extremely

dangerous.



For example, imagine a car's Anti-lock Braking System (ABS) is controlled by an Electronic Control Unit (ECU). If EMI from the engine's ignition system, car radio, or external sources (ex.: RADAR signal) disrupts the ABS ECU, it might cause the brakes to malfunction. In a critical situation, this could lead to a serious accident. Modern vehicles are packed with electronics: engine control units,

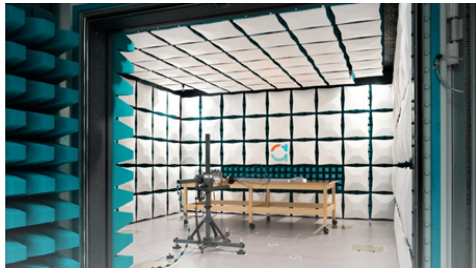
infotainment systems, safety sensors, and more. If these systems aren't designed to be electromagnetically compatible, the potential for dangerous failures is very real.

Why EMC?

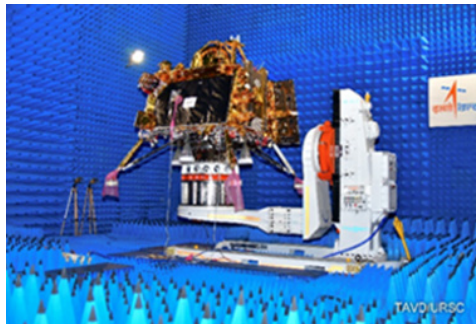
With the increasing use of electronic components in modern vehicles and devices, ensuring EMC compliance is essential. EMC testing guarantees that electronic systems can function reliably in their intended environments without causing or suffering from interference.

EMC compliance is critical not only for safety but also for regulatory compliance, product reliability, and overall user confidence. Across industries—from consumer electronics to

aerospace technology—robust EMC design ensures seamless performance and prevents catastrophic failures.



(Automotive Component Testing inside Absorber Lined Shielded Enclosure)

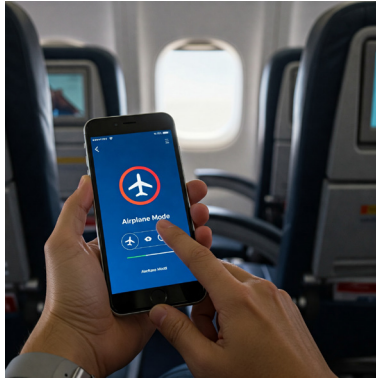


(Chandrayaan-3 Lander EMI/EMC testing)
Courtesy of ISRO

Whether it's ensuring a child's toy doesn't emit disruptive interference, maintaining signal integrity in televisions, safeguarding critical automotive control systems, or preserving reliable communication in spacecraft, EMC adherence is not just a requirement but a necessity to prevent catastrophic failures, ensure seamless performance in real-world conditions and to guarantee operational reliability, safety, & regulatory adherence in an increasingly interconnected world.

Why Airplane Mode Matters: The Science of EMI & Flight Safety

Airplane mode is required during takeoff and landing to minimize potential electromagnetic interference (EMI) with the



aircraft's critical communication and navigation systems. Electronic devices, such as smartphones, tablets, and laptops, emit radio frequency (RF) signals, which, in high concentrations, could disrupt cockpit instruments, radar, or avionics systems responsible for safe flight operations.

Electromagnetic Interference (EMI):

Unchecked RF emissions from multiple passenger devices could contribute to

unwanted interference, potentially affecting the aircraft's ability to communicate with air traffic control or navigate accurately.

Electromagnetic Compatibility (EMC):

Aviation systems are rigorously tested to ensure they can operate reliably in environments with multiple electronic devices. However, enforcing airplane mode is a precautionary measure to reduce EMI risk, ensuring all systems function without disruption during critical flight phases like takeoff and landing.

While modern aircraft are designed with robust EMC considerations, regulators impose these restrictions as a safeguard against any unforeseen interference that could impact flight safety.

EMC: A Critical Factor in Modern Electronics

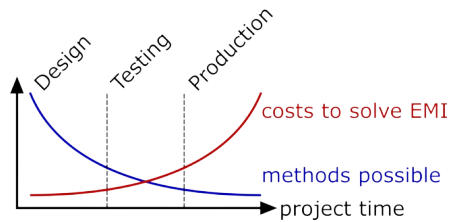
In the past, electromagnetic compatibility (EMC) was often an afterthought in electronic design. However, with the increasing complexity of electronic circuits, it has become a fundamental aspect of engineering. As electronic systems become more compact and switching frequencies rise, the challenges of EMC grow significantly.

Modern processors, operating with billions of transistors below 10 nm and clock speeds exceeding 4 GHz, generate higher electromagnetic emissions. While these advancements pose greater EMC challenges, emerging technologies—such as shorter transmission lines, more GND layers in PCBs, automatic error correction—are also enhancing EMC performance.

In any real-world electronic system, signals inherently carry noise, making complete elimination impossible without ideal filters—components that do not exist in reality. When unwanted noise triggers unintended circuit functions, it results in electromagnetic interference (EMI), which can lead to system malfunctions. The primary goal of EMC engineering is to mitigate noise levels so that interference no longer disrupts device functionality. As circuits become more intricate, proactive EMC strategies are essential to ensure reliability and compliance with industry standards.

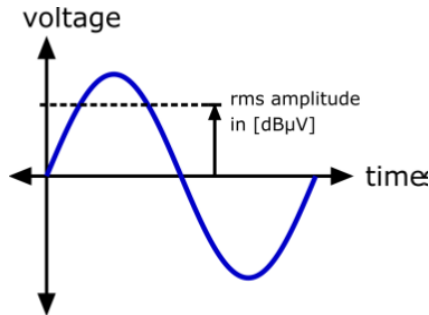
EMC as an Integral Design Consideration

Despite common misconceptions, **EMC should not be viewed as a mere regulatory**



checkbox or an afterthought but as an essential design parameter from the outset. Integrating EMC principles early in the product development process reduces costly redesigns and enhances overall system efficiency. Addressing EMC concerns during the initial stages allows for flexible, cost-effective modifications, whereas late-stage fixes often require additional components and expensive testing. By embedding EMC into the design philosophy, engineers can develop more robust, interference-free products while minimizing delays and compliance risks.

Decibel (dB) in EMC and RF Measurements³



The **decibel (dB)** is a logarithmic unit used to express ratios, making it ideal for handling the vast range of signal strengths encountered in EMC and RF engineering. It is derived from the unit **Bel**, which represents a power ratio on a **10-logarithmic scale**, while the prefix "**deci**" (**dB**) signifies a **0.1 Bel** factor. Unlike standard units, dB is always **relative**, meaning it represents the difference between two values rather than an absolute measurement.

Understanding dBμV and dBm in EMC

dBμV (decibels relative to 1 microvolt) is commonly used in EMC to measure voltage levels:

$$20 \cdot \log_{10} \frac{V_{[V]}}{1\mu V} = V_{[dB\mu V]}$$

For example, if an EMI receiver detects **1V**, it corresponds to **120 dBμV**, indicating strong interference that could affect electronic systems.

$$20 \cdot \log_{10} \frac{1V}{1\mu V} = 120 \text{ dB}\mu V$$

$$1\mu V \cdot 10^{\frac{120 \text{ dB}\mu V}{20}} = 1V$$

dBm (decibels relative to 1 milliwatt) is primarily used in **RF and spectrum analysis** to measure power:

$$10 \cdot \log_{10} \frac{P_{[W]}}{1mW} = P_{[dBm]}$$

A **0 dBm** signal equals **1 mW**, positive dB values indicate amplification, and negative dB values represent attenuation.

Key dB Concepts in EMC & RF Engineering

- **dB always represents a ratio:** A positive dB value means gain, while a negative value indicates attenuation.
- **At -3 dB, power is halved**, and voltage is reduced by $\sqrt{2}$.

- **Differences between signals are expressed in dB**, e.g., if $A = 100 \text{ dB}\mu\text{V/m}$ and $B = 80 \text{ dB}\mu\text{V/m}$, the difference is **20 dB**.

Sources, Victims, and Coupling Paths

For an EMC problem to occur, three key elements must be present: a **source** of electromagnetic interference (EMI), a **coupling path** that transmits the interference, and a **victim** that is affected by the disturbance.

Imagine you're listening to your favorite radio station or watching league match on TV, but suddenly, an unfamiliar buzzing noise disrupts the signal. This interference might be caused by a nearby power tool, a faulty electrical circuit, or even a mobile phone.

In this scenario:



The power tool (or mobile phone) is the **source** of electromagnetic interference (EMI).

The airwaves or electrical wiring act as the **coupling path**, allowing the interference to travel from the source to the victim.

The radio/TV is the **victim**, experiencing the unwanted disturbance.

In the world of Electromagnetic Compatibility (EMC), these three elements—source, coupling path, and victim—play a crucial role in understanding and mitigating EMI.

Electromagnetic interference can propagate in two primary ways:

Conducted Interference: When unwanted noise travels through power lines, circuit traces, or cables (typically below 30 MHz).

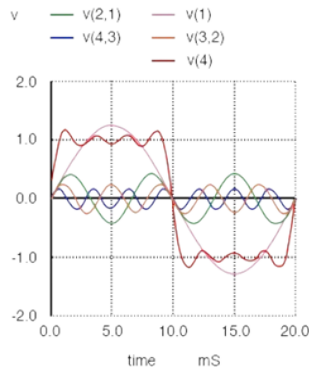
Radiated Interference: When high-frequency electromagnetic waves (typically above 30 MHz) propagate through the air, affecting nearby electronic systems.

Modern electronic devices, especially those with high-frequency switching circuits, are

both potential EMI sources and victims.

Digital circuits, with their rapid signal transitions, generate noise that can disrupt sensitive analog components like operational amplifiers. Recognizing these interference mechanisms and their coupling paths is essential for designing robust, interference-free electronic systems

Periodic Functions and EMC



Periodic functions are important in science, especially in Electromagnetic Compatibility (EMC) since electromagnetic waves are periodic.

If we add two sine waves of the same frequency, the result is another sine wave. But if they have different frequencies, they form a more complex periodic function. **Jean Baptiste Joseph Fourier (1768–1830)** discovered that any periodic function can be broken down into a sum of sine and cosine waves, called harmonics. This helps in EMC by analyzing and controlling unwanted electromagnetic interference (EMI).

What Are Harmonics?

A harmonic is a frequency that is a multiple of

the fundamental frequency.

- A 10 Hz wave is the first harmonic (Fundamental Frequency).
- A 20 Hz wave (2×10 Hz) is the second harmonic.
- A 50 Hz wave (5×10 Hz) is the fifth harmonic.
- A 100 Hz wave (10×10 Hz) is the tenth harmonic.

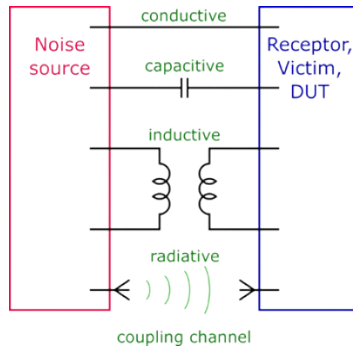
Harmonics can cause unwanted emissions and signal distortions, leading to EMI issues.

Square Waves and Fourier Analysis

A square wave is made up of an infinite series of sine waves, specifically odd harmonics (1st, 3rd, 5th, etc.). The more harmonics present, the closer it looks like a perfect square wave. However, these harmonics can cause unwanted high-frequency noise.

Coupling Mechanisms in EMC

Electromagnetic interference (EMI) does not affect a system randomly—it follows specific paths to couple into circuits. Understanding these coupling mechanisms is crucial for identifying and mitigating EMC issues. The four primary coupling mechanisms are:



1. Galvanic (Conductive) Coupling

Galvanic coupling occurs when two circuits share a common conductive path, such as a ground or power line. If one circuit generates noise, it directly affects the other circuit due to shared impedance.

Example:

A motor driver and a microcontroller share the same ground plane. When the motor

operates, it generates sudden current changes, causing voltage fluctuations in the ground. These fluctuations interfere with the microcontroller, leading to erratic behavior.

Mitigation Tips:

- Use star grounding to provide separate return paths for different circuit sections.
- Implement low-impedance grounding with thick traces or ground planes.
- Use isolated power supplies or optocouplers to break direct conductive paths between sensitive circuits.

2. Capacitive Coupling

Capacitive coupling occurs when two conductors separated by a dielectric (such as air or PCB material) act like a capacitor. A voltage change in one conductor induces a displacement current in the adjacent conductor, leading to unwanted noise.

Example:

A high-speed digital signal line on a PCB runs parallel to an analog sensor trace. Due to capacitive coupling, the digital signal induces noise in the analog trace, distorting the sensor readings.

Mitigation Tips:

- Increase spacing between high-speed and low-speed signal traces.
- Use grounded shielding between signal lines to block capacitive effects.
- Minimize loop areas in circuit design to reduce parasitic capacitance.

3. Inductive Coupling

Inductive coupling occurs when a changing current in one circuit generates a magnetic field that induces a voltage in a nearby conductor. This follows Faraday's Law of Induction and is particularly problematic in

in circuits with large current loops.

Example:

Power cables running parallel to an Ethernet communication cable induce unwanted voltages, leading to data corruption and transmission errors.

Mitigation Tips:

- Twist signal and return conductors to cancel out mutual inductance.
- Change loop orientations by 90 degrees to reduce coupling.
- Use magnetic shielding or ferrite beads to block magnetic field interference.

4. Radiated Coupling

Radiated coupling happens when electromagnetic waves from a source travel through **free space** and induce voltages in another circuit. This is a far-field effect that commonly occurs when components act as unintended antennas

Example:

A high-frequency switching power supply emits electromagnetic waves that interfere with a nearby Wi-Fi module, reducing wireless signal strength and increasing transmission errors.

Mitigation Tips:

- Shorten signal traces to minimize antenna effects.
- Use a solid ground plane to provide a return path for high-frequency currents.
- Employ shielding enclosures or EMI gaskets to contain emissions.

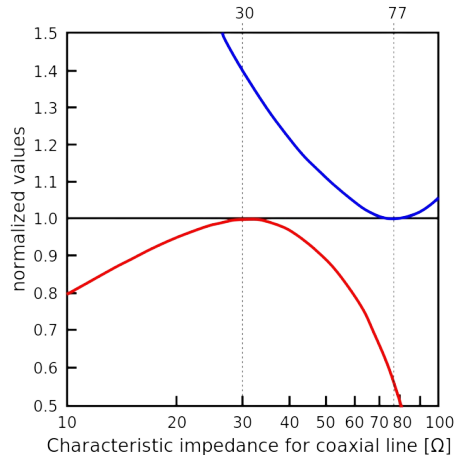
By understanding and addressing these coupling mechanisms, engineers can enhance EMC compliance, prevent signal integrity issues, and design robust electronic systems. Proactive PCB layout, grounding techniques, shielding, and proper component placement are key to mitigating EMI risks.

What is 50-Ohm Impedance and Characteristic Impedance?

In electrical engineering, characteristic impedance refers to the inherent opposition a transmission line presents to alternating current (AC) signals, affecting how signals propagate along the line. A commonly used standard is 50-ohm impedance, particularly prevalent in radio frequency (RF) applications.

Why 50 Ohms?

The selection of 50 ohms as a standard stems from a balance between power handling and signal attenuation in coaxial cables. Historically, engineers determined



Attenuation (blue) is lowest at 77 Ω (for $\epsilon_r = 1$)

Maximum power capacity (red) peaks at 30 Ω

that a 50-ohm impedance offers an optimal compromise:

Power Handling: Cables with characteristic impedances around 30 ohms can handle maximum power. However, they exhibit higher attenuation, leading to signal loss.

Signal Attenuation:

Cables with impedances around 77 ohms minimize attenuation but have reduced power handling capabilities.

Therefore, 50 ohms was chosen as a middle ground, providing efficient power transmission with acceptable attenuation levels.

While 50 ohms is standard for many RF applications, other impedances like 75 Ohms are commonly used in broadcast and cable television due to its lower attenuation properties, making it suitable for transmitting video signals over long distances.

Reflection Coefficient and VSWR: Understanding Their Impact on Instruments

Reflection Coefficient (Γ)

The reflection coefficient (Γ , Gamma) is a measure of how much of an electromagnetic wave is reflected when it encounters an impedance mismatch in a transmission line. It is defined as:

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

where:

- Z_L is the load impedance
- Z_0 is the characteristic impedance of the transmission line

A Γ value of 0 means there is no reflection (perfect match), while a Γ value of 1 means full reflection (complete mismatch).

Example:

If a 50-ohm cable is connected to a 100-ohm antenna, part of the signal will be reflected back instead of being transmitted efficiently.

$$\Gamma = \frac{50 - 50}{50 + 50} = \frac{0}{100} = 0$$

Since $\Gamma=0$, no signal is reflected, meaning perfect impedance matching. This ensures maximum power transfer and minimal signal loss.

$$\Gamma = \frac{100 - 50}{100 + 50} = \frac{50}{150} = 0.333$$

This means 33.3% of the signal will be reflected due to impedance mismatch, reducing efficiency and potentially causing standing wave issues.

Achieving perfect **50Ω impedance** matching is crucial in RF and high-frequency circuits to ensure maximum power transfer and minimal signal reflection. When impedance is mismatched, part of the signal reflects back, causing Voltage Standing Wave Ratio (VSWR) issues.

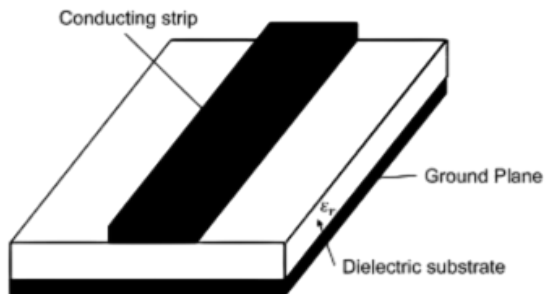
What is a Transmission Line?

A transmission line is a specialized conductor designed to efficiently carry electrical signals from one point to another, especially in high-frequency applications. It ensures minimal signal loss and impedance matching to prevent reflections.

Examples:

Coaxial Cable (Coax) – Used in RF communication, TV signals, and antennas due to its shielding, which reduces interference.

Microstrip Line – Found in PCBs for high-frequency circuits, where a signal trace runs over a ground plane to control impedance.



Voltage Standing Wave Ratio (VSWR)

VSWR (Voltage Standing Wave Ratio) quantifies the level of impedance mismatch by measuring the ratio of the maximum and minimum voltage in a standing wave pattern created by reflections in a transmission line. It is given by:

$$VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

A VSWR of 1:1 indicates perfect matching (no reflections).

A higher VSWR means more reflected power, leading to potential signal loss and equipment damage.

Examples:

A VSWR of 2:1 means that only about 10% of the power is reflected, whereas a 10:1 VSWR results in about 67% power reflection, which can be harmful.

When $\Gamma = 0 \rightarrow \text{VSWR} = 1.0$

This represents a perfect match between the transmission line and the load, meaning zero reflections and maximum power transfer.

When $\Gamma = 0.33 \rightarrow \text{VSWR} \approx 1.99$

This indicates a moderate mismatch, causing some signal reflection, which can lead to power loss and reduced efficiency in RF systems.

Impact of High VSWR on Instruments:

Reduced Power Transfer – A significant amount of the transmitted signal is reflected, reducing efficiency.

Heat Generation – Reflected power causes excessive heating in the transmitter or amplifier, leading to failure.

Damage to Components – High VSWR can overheat and damage RF power amplifiers, causing permanent failure.

Distorted Signals – Standing waves create signal integrity issues, leading to degraded performance in communication systems.

Causes of High VSWR:

Impedance Mismatch – The load impedance differs from the characteristic impedance of the transmission line.

Faulty Connectors or Cables – Damaged or loose connections create discontinuities leading to reflections.

Incorrect Termination – Improperly terminated cables can cause standing waves.

Water or Moisture in Cables – Can alter the impedance and lead to increased reflections.

Physical Damage to Cables – Bends, cuts, or breaks can create impedance mismatches.

Antenna Mismatch – If an antenna is not tuned to the operating frequency, reflections increase.

Mitigation Tips:

Ensure impedance-matched components (e.g., 50-ohm cables with 50-ohm antennas) and use quality RF connectors. Properly terminate transmission lines and inspect cables for damage. Managing VSWR prevents signal loss, protects equipment, and ensures optimal performance.

Common-Mode vs. Differential-Mode Noise in EMI/EMC

Introduction

Electromagnetic Interference (EMI) is a critical concern in electronic systems, especially in high-frequency applications. To effectively mitigate EMI, engineers must differentiate between two primary types of noise: **Differential-Mode (DM) Noise** and **Common-Mode (CM) Noise**. Both types of noise impact system performance and electromagnetic compatibility (EMC) but have distinct sources and mitigation strategies.

1. Differential-Mode Noise

Differential-mode noise occurs when current flows in a loop from the power source to the load and returns via a designated path. This is the normal operational mode for circuits, but unintended disturbances can still arise.

Example: In a PCB, a clock signal carrying periodic pulses generates high-frequency noise along the intended signal path.

Causes:

- High-frequency switching in circuits
- Poor PCB layout with large loop areas.
- Harmonics generated by non-linear amplifiers.

Effects:

- Signal distortion and data corruption
- Increased electromagnetic radiation

Mitigation Strategies:

- **Minimize Loop Area: Keep** high-frequency traces short and close together.
- **Optimize PCB Layout:** Route signal and return paths effectively to reduce interference.
- **Filtering:** Use LC filters to suppress unwanted high-frequency components.
- **Reduce Signal Slew Rate:** Adjust rise and fall times of switching signals.

2. Common-Mode Noise

Common-mode noise occurs when unintended currents travel along conductors in the same direction, exploiting unintended paths such as chassis, cables, or even air. This often results in radiated emissions.

Example: Power cables acting as unintended antennas due to parasitic capacitance, leading to radiated EMI.

Causes:

- Poor grounding and shielding.
- Parasitic capacitances in PCB traces.
- External radiated interference coupling into cables.

Effects:

- Increased radiated emissions leading to EMC compliance failures.
- Interference with nearby sensitive electronics.

Mitigation Strategies:

- **Use Common-Mode Chokes:** These suppress unwanted noise while allowing differential signals to pass.
- **Implement Proper Grounding:** Reduce ground loops and provide a low-impedance return path.
- **Shielding:** Use shielded cables and enclosures to minimize radiation.

- **Filtering:** Utilize Y-capacitors to divert common-mode currents to the ground.

Filtering and Shielding in EMI/EMC

Filtering

Filtering is used to reduce unwanted electromagnetic noise while allowing the desired signals to pass through. In EMI/EMC, filters help remove noise from power lines, signal lines, and interfaces to ensure proper operation of electronic devices.

Filters can be passive (using resistors, inductors, and capacitors) or active (using operational amplifiers for more precise control). Common types include:

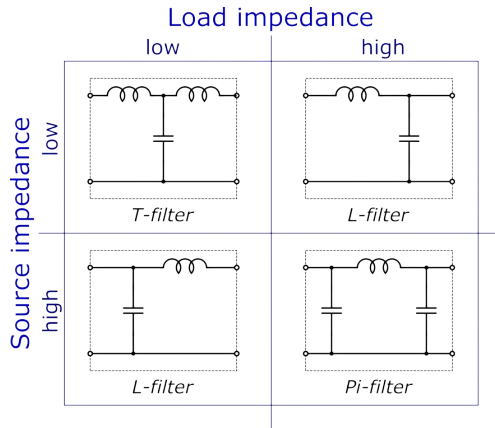
Low-pass filters – Allow low frequencies and block high frequencies.

High-pass filters – Allow high frequencies and block low frequencies.

Band-pass filters – Allow only a specific range of frequencies.

Band-stop filters – Block a specific range of frequencies

Key components of EMI filters include capacitors (to block high-frequency noise), inductors (to block low-frequency noise), and ferrite beads (to suppress high-frequency noise on cables). Proper placement of filters in circuits is essential to intercept noise before it reaches sensitive components.

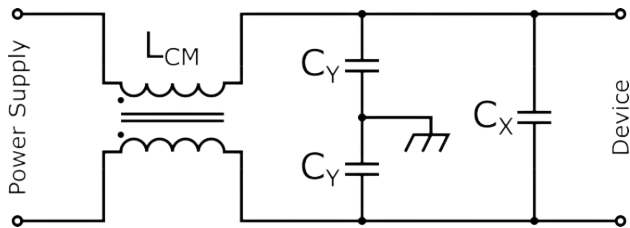


When designing filters, engineers must consider factors such as frequency response, attenuation level, impedance characteristics, and insertion loss to maintain signal integrity while effectively reducing interference.

EMI Filters: Controlling Electromagnetic Interference

EMI filters are essential for reducing unwanted

electromagnetic noise in power supply lines, ensuring compliance with EMC regulations. A typical EMI filter consists of components that target both **common-mode** and **differential-mode** noise.



- **Common-mode filtering** uses a common-mode choke (L_{CM}) and Y-capacitors (C_Y) to divert noise traveling in the same direction on both power lines to the ground.
- **Differential-mode filtering** relies on the

stray inductance of the choke and an **X-capacitor (CX)** to suppress noise between the live and neutral lines.

The placement of these components varies depending on circuit design, with common-mode chokes typically positioned where less current flows to optimize size and cost. **Class-X and Class-Y capacitors**, rated for safety per IEC 60384-14, are crucial in EMI suppression, with Y-capacitors being the only type allowed to connect to the protective earth (PE).

Additionally, capacitors serve multiple roles in circuits:

- **Bulk capacitors** stabilize DC voltage and

prevent power dropouts.

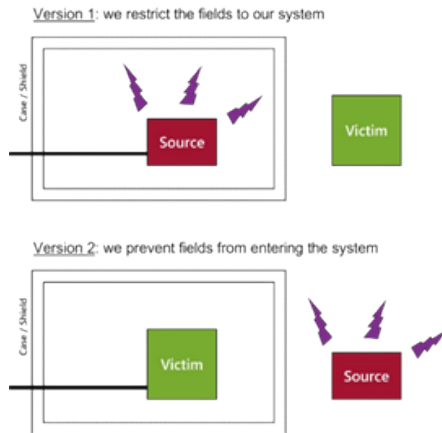
- **Filter capacitors** create an AC short to remove high-frequency noise.
- **Decoupling capacitors** act as local charge reservoirs to minimize voltage fluctuations near sensitive components.

By strategically designing EMI filters, engineers can effectively mitigate interference, ensuring reliable and noise-free operation of electronic systems.

Shielding

Shielding protects electronic devices from external electromagnetic interference and

prevents them from emitting unwanted signals. It works by enclosing the device or specific components in conductive materials that block electromagnetic fields.



Types of Shielding:

Electric field shielding – Uses conductive enclosures (Faraday cages) to redirect

external electric fields away from sensitive components.

Magnetic field shielding – Uses high-permeability materials (like ferrite) to divert low-frequency magnetic fields or conductive enclosures to counteract high-frequency fields.

Common Shielding Materials:

Metals such as aluminum, copper, and steel for general EMI shielding.

Ferrite materials for low-frequency magnetic field shielding.

Shielding must be carefully designed to avoid gaps, apertures, and improper grounding,

which can weaken its effectiveness. Cables also require shielding to prevent noise pickup or radiation.

Faraday Cage: Shielding Against Electric Fields



A **Faraday cage** is a protective enclosure made of conductive material that prevents external electric fields (E-fields) from affecting the electronics inside. This shielding effect occurs because conductive materials allow free electrons to move in response to external E-fields.

When an external E-field is applied to the cage, the free electrons within the conductor redistribute—shifting to one side, while leaving positive charges on the opposite side. This movement generates an opposing electric field inside the cage that cancels out the external field. As a result, the total E-field within the cage becomes zero, ensuring that any sensitive electronics or $\vec{E}_{total} = \vec{E}_{ext} + \vec{E}_{int} = 0$ components inside remain unaffected by external electromagnetic disturbances.

Classification of EMI/EMC Testing

EMI/EMC testing ensures that electronic devices do not emit excessive electromagnetic interference (EMI) and can function correctly in their intended electromagnetic environment. Testing is

classified into two main categories:

1. Emission Testing (Measuring Unwanted Interference)

Emission tests evaluate whether a device emits electromagnetic noise within acceptable limits. Excessive emissions can disrupt other electronic devices.

- **Conducted Emissions** – Measures unwanted signals conducted through power or data lines (e.g., noise on AC mains, Battery lines in Automotive).
- **Radiated Emissions** – Measures electromagnetic waves radiated from the device into the environment (e.g., emissions from circuit boards or cables).

2. Immunity (Susceptibility) Testing (Ensuring Device Resilience)

Immunity tests assess a device's ability to function correctly when exposed to external electromagnetic interference.

- **Conducted Immunity** – Evaluates a device's resistance to EMI introduced through power or data cables (e.g., power line surges).
- **Radiated Immunity** – Tests the device's ability to withstand electromagnetic fields from external sources (e.g., radio transmissions, mobile networks).

3. Specialized EMC Tests

Beyond basic emissions and immunity tests, additional evaluations ensure safety and compliance:

- **Electrostatic Discharge (ESD) Testing** – Simulates static electricity discharges to check if a device can handle human touch.
- **Electrical Fast Transient (EFT) Testing** – Assesses a device's response to fast electrical noise pulses, such as switching transients.
- **Surge Testing** – Simulates high-energy voltage spikes, such as those caused by lightning or power grid fluctuations.

- **Magnetic Field Immunity** – Evaluates a device's tolerance to strong magnetic fields, crucial for medical, automotive and industrial applications.

These tests follow international standards like **CISPR, IEC, ISO, and MIL-STD**, ensuring compliance for commercial, automotive, aerospace, and military applications.



In the **automotive domain**, these standards serve as baseline references for test methods. However, each automotive OEM across the globe develops its own EMC specifications, which are often more stringent than ISO, CISPR, or UNECE standards. Automotive equipment manufacturers must comply not only with these international standards but also with specific OEM requirements.

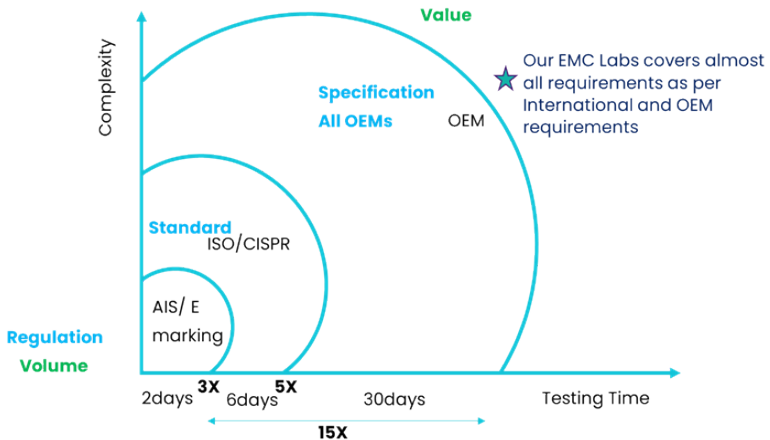
These OEM specifications evolve frequently to accommodate new technologies and enhance vehicle safety. As a result, **automotive EMC testing is one of the most complex** domains in EMC. Each OEM has multiple specification versions that change regularly, making compliance a continuous challenge.

Moreover, automotive EMC testing is no longer limited to low-voltage (LV) electronic components. The increasing demand for testing high-voltage (HV) components, connected devices, and electric vehicle (EV) technologies has further complicated the landscape. Since these components integrate diverse technologies, **EMC labs must continuously develop and upgrade** their methodologies for:

- **Measurement techniques** to meet OEM specifications in measuring emissions or generating test levels of immunity.
- **Monitoring methods** to ensure reliable test results.
- **Sample operating modes** that replicate

real-world situations in a controlled lab environment.

This evolving complexity demands cutting-edge EMC testing facilities that stay ahead of technological advancements to meet both regulatory and OEM-specific standards.



At **AuraXL**, we continuously monitor OEM specification updates and technological advancements. By collaborating with our **global network of experts and suppliers**, we swiftly adopt new testing methodologies and cutting-edge technology. This enables us to deliver **high-quality EMC services** that meet the **stringent requirements of OEMs**.

Our commitment to excellence ensures that we **benchmark our lab against leading global facilities**, maintaining world-class standards and positioning AuraXL as a trusted partner for automotive EMC compliance.

Our Edge: What Sets AuraXL Apart



Fastest Report Delivery

Because speed to market matters as much as compliance. Reports delivered in hours and in critical cases, minutes-not days or weeks



Handholding from Requirement to SOP

We don't just test. We guide you from specification interpretation to SOP alignment-until your product is market-ready



Largest Test Coverage

Comprehensive automotive EMC coverage across LV, HV, EV, ADAS, including systems with CAN FD, Ethernet, and next-generation vehicle networks



Advanced Monitoring Systems

Automated monitoring with reduced human intervention for higher precision and consistent quality. Examples: Light intensity monitoring, DUT current monitoring, mk-motion based DUT monitoring

Our Edge: What Sets AuraXL Apart



Debug-Friendly Lab Setup

Identify, rework, and fine-tune samples inside the lab itself, accelerating root-cause analysis and design closure



Future-Ready Infrastructure

Expandable chambers, scalable systems, and compliance frameworks aligned with evolving global OEM standards



Customer-Centric DNA

Every engagement is more than a transaction, it is a long-term partnership built on trust, precision, and shared success

aquair

The Future of Live EMC Data

Making EMC Test Data Live – for Faster Design Decisions

The Problem

EMC test results are still shared as:



Printed
Reports



Static
PDFs



Compressed
Plots



Screenshots over
emails & calls

Result



Slow
Analysis



Misinterpretation



Repeated
Discussions



Delayed design
decisions

The Aquair Breakthrough

Aquair transforms static EMC reports into live, interactive intelligence.

Possibly the **first platform in the world** to make **EMC test data truly live** – enabling engineers to explore, compare, and decide faster in today's rapid automotive design cycles.

What Makes aquair Different



Zero-Tolerance Security

OTP-based login for authorized users only.



Delta Difference Tables

Exact numerical comparison across runs.



True Zoom. No Compression.

Explore real EMC data at any frequency.



Multi-Run Comparison

Compare multiple tests to see real progress.



Flexible Visualization

Change plot colors, toggle plots and limits.



Freedom to Experiment

Change limits and see impact instantly.



Clean Screenshots

Instant capture with no cursor disturbance.



Full-Screen Analysis

Focus on details when it matters most.

Why aquair Matters

- Faster EMC debugging
- Better stakeholder collaboration
- Confident, data-driven decisions
- Shorter development cycles

Stop reading EMC reports. Start using EMC data.



 **Scan to watch the demo**



Where the Spectrum Comes Alive

The world runs on invisible connections.

Signals. Frequencies. Wireless systems. Intelligent electronics.

As technologies evolve rapidly, the need for a common platform to connect industries, experts, and innovation has never been greater.

That is where **Spectrang** begins.

Spectrang is a global platform bringing together the electromagnetic ecosystem across:

- EMC
- RF & Wireless
- Electronics
- Emerging Spectrum Technologies

Designed for engineers, researchers, industry leaders, innovators, and technology providers, Spectrang creates experiences that inspire collaboration, knowledge exchange, and future-ready innovation.

Our Platforms



Spectrang Expo

A showcase of technologies, products, solutions, and breakthrough innovations shaping the future of connectivity.



Spectrang Conference

Technical talks, research insights, keynote sessions, and industry discussions driving engineering advancement.



Spectrang Conclave

A leadership forum bringing together decision-makers, policymakers, and visionaries shaping the future of the spectrum ecosystem.



Spectrang Training

Hands-on workshops and practical learning experiences designed to build real-world engineering expertise.

Why Spectrang?

- Innovation & Technology Showcase
- Global Knowledge Exchange
- Practical Learning Experiences
- Future-Focused Ecosystem
- Industry + Academia Collaboration



The Future is Connected

From communication systems to intelligent electronics, the electromagnetic world is evolving faster than ever.

Spectrang is built to bring this world together.

Innovation. Knowledge. Collaboration.

All Across the Spectrum.



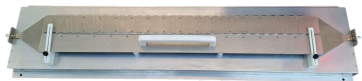
emcGear is driven by the vision of making India self-reliant in **Electromagnetic Compatibility (EMC) testing and solutions**. As a proud torchbearer of the **Make in India** initiative, we are committed to building a world-class **EMC ecosystem**—designed, developed, and delivered on Indian soil for Indian and global industries.

Beyond cutting-edge EMC solutions, **emcGear** empowers Indian **EMC labs** with **advanced instruments, precision accessories, and global methodologies** to enhance **capabilities, accuracy, and efficiency**. From **new setups to upgrades**, we ensure labs meet **world-class compliance standards**.



Automotive Radiating Source (Long Wire Harness)

The Radiation Source meets CISPR 25 Edition 4 standards for ALSE performance validation (150 kHz – 1 GHz).



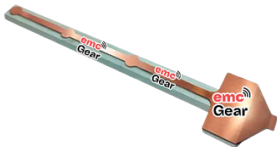
Capacitive Coupling Clamp (as per ISO 7637-3)

Capacitive Coupling Clamp (CCC) Engineered for fast transient injection on automotive electronics sub assembly components signal lines as per ISO 7637-3.



ESD Target Plate as per ISO 10605 and IEC 61000-4-2

ESD target plate, featuring a CTR2 target and a 20dB attenuator. The entire setup is designed to be easily movable on wheels for convenient storage.



Field Coupling Plane

Field coupling plane, designed in accordance with ISO 10605 for indirect testing of automotive wiring harnesses, features a Plane/DUT area measuring 200x400mm (Customizable based on DUT size). It includes three islands, each separated by 500mm, and is supported by isolation material with a thickness of 50mm.



Battery Box

According to CISPR 25 standards, automotive EMC testing requires battery buffering. Our customizable automotive battery box supports 12V, 24V, and various Ah capacities. It features a proper metal ground plane for optimal grounding, along with protections against leakage and overcurrent via fuses. Additionally, it offers input and output voltage.



**Much More
Stay Tuned**

AuraXL is the authorized sales and service partner of
MK-Messtechnik GmbH in India and Singapore.



MK Messtechnik GmbH is a global leader in high-precision EMC testing solutions. For over 20 years, MK Messtechnik has designed, developed, and produced cutting-edge EMC monitoring devices, adhering to the latest standards. Its solutions are **trusted by top automotive OEMs and EMC laboratories in Germany, Europe, and worldwide.**

Its advanced camera & audio systems, optical signal transmission, and automated testing/DUT monitoring tools like MK Motion ensure **error-free, reduced human intervention, and seamless, reliable, and repeatable** EMC compliance tests, setting new industry benchmarks.

As the authorized partner of MK Messtechnik in India and Singapore, **AuraXL ensures seamless access to world-class EMC testing technology.** By integrating advanced automation, real-time DUT monitoring, and optical transmission, **we help Indian automotive OEMs and labs** to achieve higher efficiency, accuracy, and compliance with global standards, reducing human intervention and errors.

automotive links:

- optoA2B
- optoCAN-FD/ -SW / -LS / -HS
- optoLIN / -K
- optoFlex
- optoSENT
- optoPSI5
- optoDSI3
- opto5x (CAN-FD/ LIN / others)



analogue/digital links:

optoTTL (1-16 channels)
transmission of analogue signals
from 1 to 16 channels from DC to 100
kHz 30 MHz

LVDS Links:

- optoLVDS
- optoCML (GMSL 2 / GMSL 3)
- optoAPIX2 / 3
- optoLVDS (FPD III / FPD IV)

optical links for LVDS or GMSL signals
with different chipsets (Maxim, TI, ADI,
SONY, Inova,...), optional integration of
POC, wake or other signals



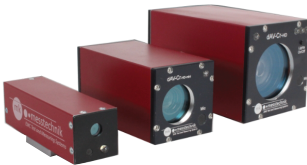
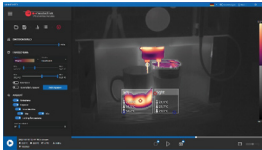
automotive Ethernet links:

- optoLAN 10GBase-T1
- optoLAN 10GBase-TX
- optoLAN 1000Base-T1
- optoLAN 100Base-T1
- optoLAN 3x100Base-T1
- Media Converter

10GBase-T1 <-> TX

100/1000Base-T1

100Base-T1



camera systems

Full HD Camera

(10x, 20x, 30x zoom and μ)

4k quad multi viewer

4k camera, IR camera

mk-motion

motion detection software

recording software

full compatible Surveillance Line

Basic line and Low Price Line for cost saving

Various mountings for cameras

Industry / Consumer Links:

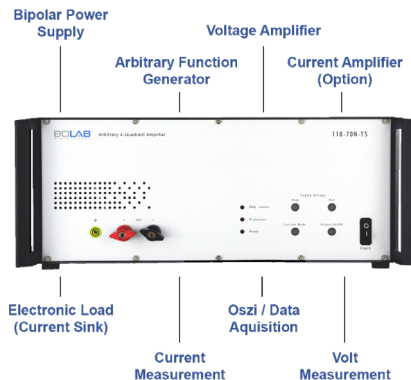
- optoHDMI
- optoUSB 2.0 / 3.X
- optoRS232
- optoRS485
- optoLAN 100/ 1000Base-TX





BOLAB Systems GmbH is a German engineering company specializing in advanced automotive electrical and power electronics testing solutions. With deep expertise in vehicle electrical system simulation, BOLAB develops high-performance low-voltage and high-voltage test systems, including precision 4-quadrant voltage and current amplifiers. These systems enable accurate validation of automotive components according to global standards such as ISO, LV123, LV124, and OEM-specific requirements. Trusted by leading automotive OEMs and Tier-1 suppliers across Europe, BOLAB solutions support the development and validation of next-generation conventional, hybrid, and electric vehicles.

As the **authorized partner of BOLAB Systems in India**, AuraXL enables Indian automotive OEMs, suppliers, and EMC laboratories to access world-class vehicle electrical testing technology. By integrating advanced power simulation and electrical network testing solutions, AuraXL helps the Indian automotive ecosystem achieve higher accuracy, efficiency, and compliance with global automotive validation standards.



Comprehensive Test System for VW 80000, LV124, ISO 16750, ISO 7637, and More.

High-Voltage Testing According to VW 80300 and LV 123
Including waveform libraries for:
LV123 | VW 80300 | VW 80303 | PSA | ISO 21498 | MBN LV 123 | ISO 7637-4 etc.



BOLAB systems offer a unique and unparalleled solution for high-end mobile testing of Electric Vehicles. Specifically, there is no other product on the market that provides a complete test solution for VW80000 with 15 kW (1,000 V / 15 A) in such a compact form factor—a small 19" rack with a height of only 10 U.

Moreover, BOLAB systems excel in their capability to cover a wide range of voltage profiles, including LV 124, LV 148, VW80000, VDA 320, and OEM standards. These systems can effectively handle voltage profiles up to 2000 A, providing comprehensive testing solutions that meet the industry's most stringent standards.

With BOLAB systems, you can confidently conduct your high-voltage testing for Electric Vehicles, knowing that you have access to a cutting-edge solution that offers exceptional performance and compliance with various industry standards.

shieldex

Shieldex – Advanced EMC Shielding Solutions AuraXL partners with Shieldex to deliver advanced electromagnetic shielding solutions for high-performance EMC applications. Shieldex is globally recognized for its innovative metallized textiles and conductive materials designed for reliable EMI shielding, grounding, and absorber integration.

With proven expertise in material engineering and precision manufacturing, Shieldex products provide lightweight, durable, and high-efficiency shielding performance suitable for automotive, aerospace, electronics, and advanced EMC laboratory environments.

What if your EMC lab dream no longer needed massive infrastructure or investment to begin?

Together, Shieldex and AuraXL bring a smarter approach with lightweight, movable, and reliable EMC tents designed for fast setup and flexible testing. These economical solutions help engineering teams start EMC validation early, debug faster, and accelerate product development with confidence. A practical way to begin your EMC journey- simple, scalable, and built for innovation.

Shieldex® EMC Enclosure

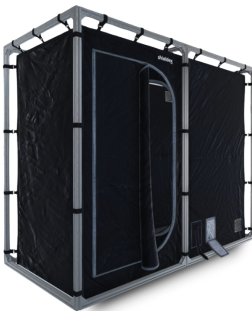
Our Shieldex® EMC enclosures are the ideal choice for laboratory tests and measurements in the frequency range from 0.03 to 40 GHz and shield up to 95 dB. Due to their flexible and lightweight components, our shielded tents are portable and can be erected and dismantled in a very short time.



Design your own EMC enclosure!

At Shieldex, we offer our customers the best possible solution for their needs. For this reason, we decided to develop a configurator that allows our customers to design their individual Shieldex® shielding enclosure. The configurator is easy to use and guides the user step by step through the tent design process. You can choose from various options such as frame, floor, entrance system and size as well as additional components. The configurator allows you to customize your shielding enclosure and tailor it to your specific needs.

<https://www.shieldex.de/en/configurator/>



Contact Us



Ashish Tyagi

Business Head

+91 90962 75565

Ashish.Tyagi@auraxl.com



Ranga Madala

Technical Director

+91 90962 65565

Ranga.Madala@auraxl.com



Jeevan Hebbalu

Managing Director

+91 90967 65565

Jeevan.Hebbalu@auraxl.com

Grab This EMC Cheat Sheet "A quick reference worth keeping on your desk."

Log↔Linear Voltage

dBμV to Volts	$V = 10^{((dB\mu V - 120)/20)}$
Volts to dBμV	$dB\mu V = 20 \log(V) + 120$
dBV to Volts	$V = 10^{(dBV/20)}$
Volts to dBV	$dBV = 20 \log(V)$
dBV to dBμV	$dB\mu V = dBV + 120$
dBμV to dBV	$dBV = dB\mu V - 120$

Log↔Linear Power

dBm to Watts	$W = 10^{((dBm - 30)/10)}$
Watts to dBm	$dBm = 10 \log(W) + 30$
dBW to Watts	$W = 10^{(dBW/10)}$
Watts to dBW	$dBW = 10 \log(W)$
dBW to dBm	$dBm = dBW + 30$
dBm to dBW	$dBW = dBm - 30$

Log↔Linear Current

dBuA to uA	$\mu A = 10^{(dB\mu A/20)}$
uA to dBuA	$dB\mu A = 20 \log(\mu A)$
dB A to A	$A = 10^{(dB A/20)}$
A to dB A	$dB A = 20 \log(A)$
dBuA to dBA	$dB A = dB\mu A - 120$
dB A to dBuA	$dB\mu A = dB A + 120$

Log↔Linear Impedance

dB(ohms) to ohms	$Z = 10^{(dB(ohms)/20)}$
ohms to dB(ohms)	$dB(ohms) = 20 \log(Z)$

Term Conversion

dBm to dBuV	$dB\mu V = 90 + 10 \log(Z) + dBm$
dBuV to dBm	$dBm = dB\mu V - 90 - 10 \log(Z)$
dBuA to dBm	$dBm = dB\mu A + 10 \log(Z) - 90$
dBm to dBuA	$dB\mu A = dBm - 10 \log(Z) + 90$
dBuA to dBuV	$dB\mu V = dB\mu A + 20 \log(Z)$
dBuV to dBuA	$dB\mu A = dB\mu V - 20 \log(Z)$
Volts to Amps & Watts	$A = \frac{V}{Z} \quad W = \frac{V^2}{Z}$
Amps to Volts & Watts	$V = A * Z \quad W = A^2 * Z$
Watts to Volts & Amps	$V = \sqrt{W * Z} \quad A = \sqrt{\frac{W}{Z}}$

RF related, Field Strength & Power Density

dBuV/m to V/m	$V / m = 10^{(((dB\mu V / m) - 120)/20)}$
V/m to dBuV/m	$dB\mu V / m = 20 \log(V / m) + 120$
dBuV/m to dBmW/m2	$dBm / m^2 = dB\mu V / m - 115.8$
dBmW/m2 to dBuV/m	$dB\mu V / m = dBm / m^2 + 115.8$
dBuV/m to dBuA/m	$dB\mu A / m = dB\mu V / m - 51.5$
dBuA/m to dBuV/m	$dB\mu V / m = dB\mu A / m + 51.5$
dBuA/m to dBpT	$dBpT = dB\mu A / m + 2$
dBpT to dBuA/m	$dB\mu A / m = dBpT - 2$
W/m2 to V/m	$V / m = \sqrt{(W / m^2) * 377}$
V/m to W/m2	$W / m^2 = \frac{(V / m)^2}{377}$
wound coil Flux Density	$\mu T = \frac{4\pi(turns)(amps)}{20(radius, m)}$
uT to A/m	$A / m = \frac{\mu T}{1.25}$
A/m to uT	$\mu T = 1.25 * (A / m)$

Antenna (Far Field)

Gain, dBi to numeric

$$Gain_{numeric} = 10^{(dBi/10)}$$

Gain, numeric to dBi

$$dBi = 10 \log(Gain_{numeric})$$

Gain, dBi to Antenna Factor

$$AF = 20 \log(MHz) - dBi - 29.79$$

Antenna Factor to gain in dBi

$$dBi = 20 \log(MHz) - AF - 29.79$$

Field Strength given Watts, Numeric Gain, Distance in meters

$$V/m = \frac{\sqrt{30 * \text{watts} * Gain_{numeric}}}{Meters}$$

Field Strength given Watts, dBi gain, Distance in meters

$$V/m = \frac{\sqrt{30 * \text{watts} * 10^{(dBi/10)}}}{Meters}$$

Transmit Power needed, given desired V/m, Antenna numeric gain, Distance in meters.

$$\text{watts} = \frac{(V/m * \text{meters})^2}{30 * Gain_{numeric}}$$

Transmit Power needed, given V/m, Antenna dBi gain, Distance in meters

$$\text{watts} = \frac{(V/m * \text{meters})^2}{30 * 10^{(dBi/10)}}$$

Amplitude Modulation

Peak power, given CW power and modulation %.(sine wave AM)

$$W_{peak} = W_{CW} * (1 + (Mod\% * 0.01))^2$$

Average power, given CW power level and modulation % (sine wave AM)

$$W_{avg} = \frac{W_{CW} * (2 + (Mod\% * 0.01)^2)}{2}$$

Average power, given peak power and modulation %

$$W_{avg} = \frac{W_{peak} * (2 + (Mod\% * 0.01)^2)}{2 * (1 + (Mod\% * 0.01))^2}$$

Current Probe

dB(ohm) to Zt (transfer impedance)

$$Z_t = 10^{(dB(ohm)/20)}$$

Zt to dB(ohm)

$$dB(ohm) = 20 \log(Z_t)$$

Conductance (Gt) in dB(s) to transfer impedance, (Zt) in dB(ohms)

$$Z_t = -G_t$$

Transfer Impedance in Zt (dB(ohms)), to Conductance in Gt (dB(s))

$$G_t = -Z_t$$

Power needed for BCI Probe (50Ω), given voltage level into 50Ω load (V) and Probe Insertion Loss I_L .

$$\text{watts} = 10^{((I_L + 10 \log(V^2/50))/10)}$$

Watts needed for 150 Ohm EM Clamp

$$\text{watts} = 10^{((I_L + 10 \log(V^2/150))/10)}$$

Conducted current level using current measuring probe given probe factor in dB(ohm) and probe terminal voltage in dBuv

$$dB\mu A = dB\mu V - dB(ohm)$$

Conducted current level, given probe factor in Zt (ohms) and terminal voltage in dBuv

$$dB\mu A = dB\mu V - 20 \log(Z_t)$$

dB calculations

Compute db delta (volts) $dB = 20 \log\left(\frac{V_1}{V_2}\right)$

Compute dB delta (amps) $dB = 20 \log\left(\frac{A_1}{A_2}\right)$

Compute dB delta (watts) $dB = 10 \log\left(\frac{W_1}{W_2}\right)$

compute new voltage w/ db delta

$$V_{new} = 10^{\left(\frac{(dB\Delta + 20 \log(V_{given}))}{20}\right)}$$

compute new wattage w/ db delta

$$W_{new} = 10^{\left(\frac{(dB\Delta + 10 \log(W_{given}))}{10}\right)}$$

VSWR/reflection coefficient/return loss

VSWR given Fwd/Rev Power

$$VSWR = \frac{1 + \sqrt{\frac{P_{rev}}{P_{fwd}}}}{1 - \sqrt{\frac{P_{rev}}{P_{fwd}}}}$$

VSWR given reflection coefficient

$$VSWR = \frac{1 + \rho}{1 - \rho}$$

Reflection coefficient, ρ , given Z_1/Z_2 ohms

$$\rho = \frac{Z_1 - Z_2}{Z_1 + Z_2}$$

Reflection coefficient, ρ , given fwd/rev power

$$\rho = \sqrt{\frac{P_{rev}}{P_{fwd}}}$$

Return Loss, given fwd/rev power

$$RL(dB) = 10 \log \left(\frac{P_{fwd}}{P_{rev}} \right)$$

Return Loss, given VSWR

$$RL(dB) = -20 \log \left(\frac{VSWR - 1}{VSWR + 1} \right)$$

Return Loss, given reflection coefficient

$$RL(dB) = -20 \log(\rho)$$

Mismatch loss, given fwd/rev power

$$ML(dB) = 10 \log \left(\frac{P_{fwd}}{P_{fwd} - P_{rev}} \right)$$

Mismatch loss, given reflection coefficient

$$ML(dB) = -10 \log(1 - \rho^2)$$

Misc

Linear interpolation with log of freq

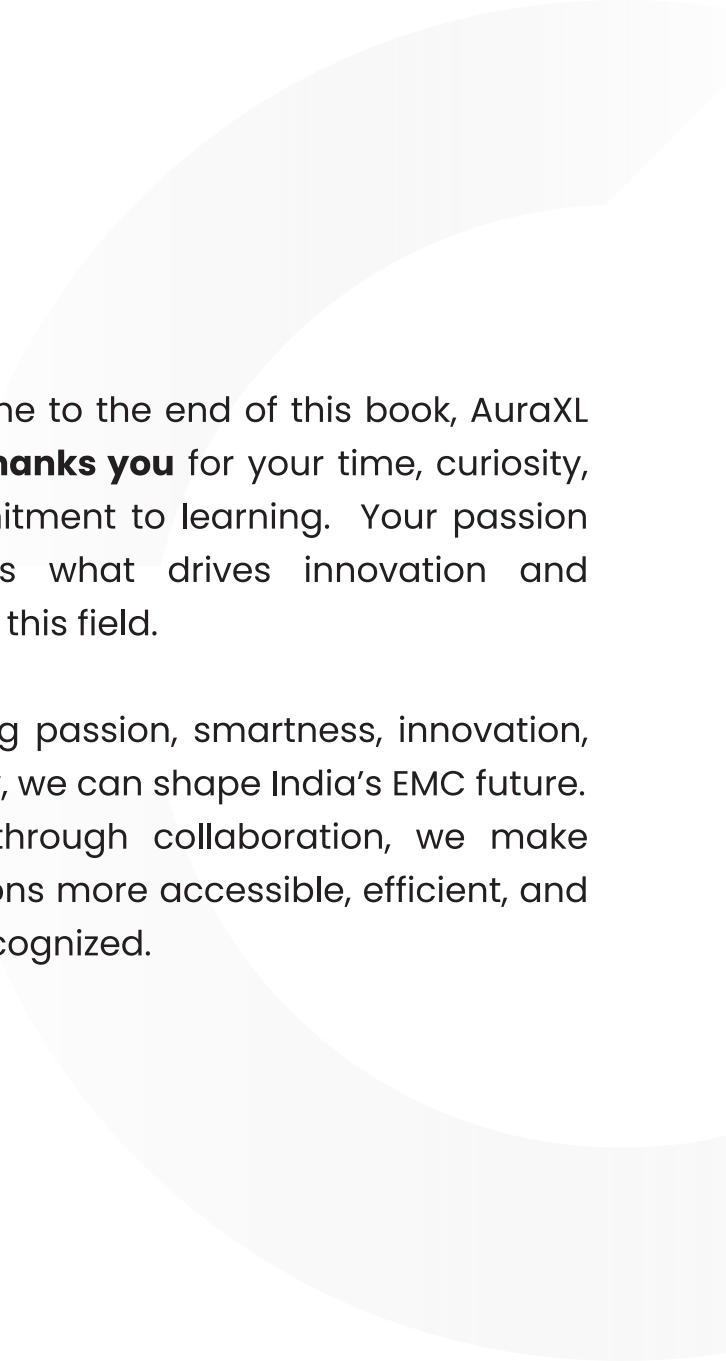
$$Value = \frac{\log(F_X / F_L)}{\log(F_U / F_L)} * (X_U - X_L) + X_L$$

where F_L = lower frequency
 F_U = Upper frequency
 X_L = Value at lower frequency
 X_U = Value at upper frequency
 F_X = Frequency of desired value

TEM Cell Power Needed

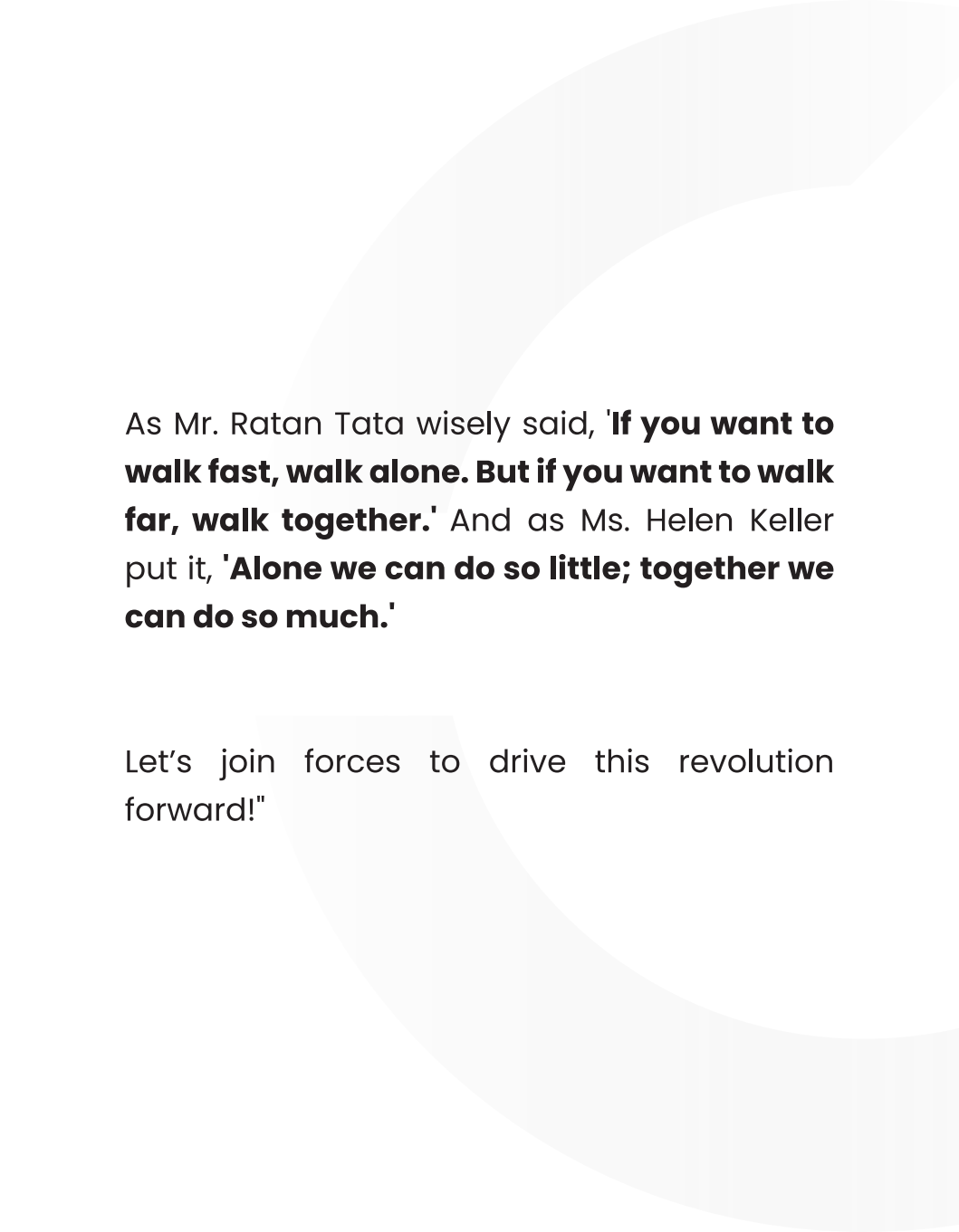
$$Watts = \frac{(V * Height * 0.5)^2}{Z}$$

where V = field strength in V/m
 Z = TEM cell impedance in ohms



As you come to the end of this book, AuraXL sincerely **thanks you** for your time, curiosity, and commitment to learning. Your passion for EMC is what drives innovation and progress in this field.

By nurturing passion, smartness, innovation, and quality, we can shape India's EMC future. Together, through collaboration, we make EMC solutions more accessible, efficient, and globally recognized.



As Mr. Ratan Tata wisely said, '**If you want to walk fast, walk alone. But if you want to walk far, walk together.**' And as Ms. Helen Keller put it, '**Alone we can do so little; together we can do so much.**'

Let's join forces to drive this revolution forward!"

Let's build a world-class EMC ecosystem, step by step!

MORE DETAILS ON

www.auraxl.com

FOLLOW US ON

