PROJECT REPORT ON

Electromagnetic Compatibility (EMC) and Electromagnetic Interference (EMI) Testing

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Abstract:

This report provides a comprehensive overview of Electromagnetic Compatibility (EMC) and Electromagnetic Interference (EMI) testing within the Defence Research and Development Organization (DRDO) of India. The objectives of EMC/EMI testing include ensuring operational integrity, compliance with standards, safety, and reliability of defence systems. DRDO's approach encompasses state-of-the-art facilities such as anechoic chambers, reverberation chambers, open area test sites, and shielded enclosures. The testing phases range from design review to post-compliance monitoring, adhering to standards like MIL-STD-461. Detailed testing procedures for emissions and susceptibility, as well as specialized tests like ESD and transient immunity, are covered. Case studies of radar systems and communication equipment illustrate practical applications. Challenges such as evolving threats, complex systems, and resource intensity are addressed with innovative solutions. This report underscores DRDO's commitment to ensuring the reliable performance of its systems in complex electromagnetic environments.

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Introduction:

Electromagnetic Compatibility (EMC) and Electromagnetic Interference (EMI) testing are critical aspects of designing and deploying electronic and electrical systems, especially in defence applications. The Defence Research and Development Organization (DRDO) of India is deeply involved in ensuring that its systems meet stringent EMC and EMI standards to ensure reliable operation in complex electromagnetic environments. EMI/EMC test facility at CVRDE is a unique facility which can cater compliance testing of electronic & electrical subsystems of Armoured Fighting Vehicles and platform testing up to 70 tons. The facility includes a Semi-Anechoic Chamber (22 m x 16 m x 10 m), a Subsystem Testing Anechoic Chamber (9 m x 6 m x 6 m) and common control rooms. It consists of vehicle smoke extraction system and a turn-table which can withstand distributed loads up to 1.5 tons/m2. Hybrid absorbers are fully lined on all the sides and ceiling. The chambers consists of remote audio/ video monitoring, movable floor absorbers, RF shielded sliding doors with auto ramp for platform / subsystem entry. Shielding effectiveness of test facility conforms to IEEE 299 requirements. Simultaneous testing of subsystem and platforms can be conducted in the respective chambers with automated EMI/EMC test system as per MIL-STD-461 (Army, Navy and Air-force requirements)

Objectives of EMC/EMI Testing:

1. **Ensure Operational Integrity**: To ensure that electronic and electrical systems function correctly without mutual interference.

2. **Compliance**: To comply with national and international standards for electromagnetic emissions and susceptibility.

3. **Safety**: To ensure the safety of personnel and equipment from electromagnetic hazards.

4. **Reliability**: To guarantee the reliable performance of defence systems in various operational environments.

DRDO's Approach to EMC/EMI Testing

Facilities and Infrastructure

DRDO has established state-of-the-art facilities for EMC/EMI testing, including:

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- **Anechoic Chambers**: Shielded rooms designed to completely absorb reflections of electromagnetic waves.

- **Reverberation Chambers**: Chambers designed to create a statistically uniform electromagnetic field for testing.

- **Open Area Test Sites (OATS)**: Outdoor facilities for measuring emissions without reflections from nearby structures.

- **Shielded Enclosures**: Rooms designed to block external electromagnetic fields for precise testing.

Testing Phases:

1. **Design Review**: Initial phase where potential EMC/EMI issues are identified during the design stage using simulation tools.

2. **Pre-Compliance Testing**: Early-stage testing to identify and mitigate EMC/EMI issues before full compliance testing.

3. **Compliance Testing**: Comprehensive testing to ensure that systems meet all relevant standards and regulations.

4. **Post-Compliance Monitoring**: Continuous monitoring of deployed systems to ensure ongoing compliance and address any issues that arise.

Standards and Regulations:

DRDO adheres to several national and international standards for EMC/EMI, including:

- **MIL-STD-461f**: A military standard for controlling EMI characteristics of subsystems and equipment.

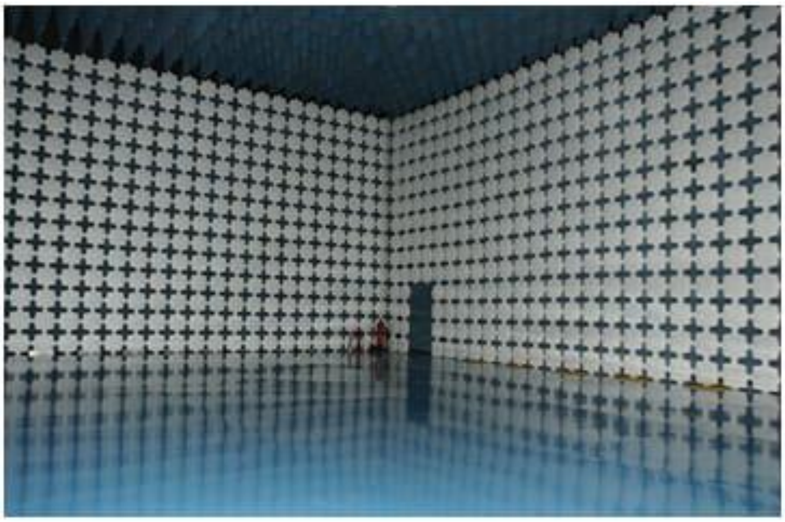
- **RE102**: This standard covers Radiated Emissions, typically in the frequency range of 10 kHz to 18 GHz. It applies to equipment and systems to ensure they do not emit electromagnetic disturbances that could interfere with other equipment.
- **RS103**: This standard pertains to Radiated Susceptibility, testing equipment for its ability to operate as intended when subjected to radio frequency (RF) electromagnetic fields.
- **CE102**: This standard covers Conducted Emissions in the frequency range of 10 kHz to 10 MHz. It ensures that the emissions conducted along the power lines do not exceed specified levels.
- **CS101**: This standard pertains to Conducted Susceptibility, ensuring that equipment can operate properly when subjected to RF signals conducted along power and data lines.

Faradays cage

The Defence Research and Development Organisation's (DRDO) Electronics and Microwave Component Development Establishment (CVRDE) is likely to have the capability to perform EMC testing using a Faraday cage.

Faraday cage is a metal enclosure that blocks electromagnetic waves. They are named after Michael Faraday, the scientist who discovered the principle.

EMC testing is the process of measuring the electromagnetic emissions and susceptibility of an electronic device. It is important to ensure that devices comply with regulatory requirements and do not interfere with other electronic devices.

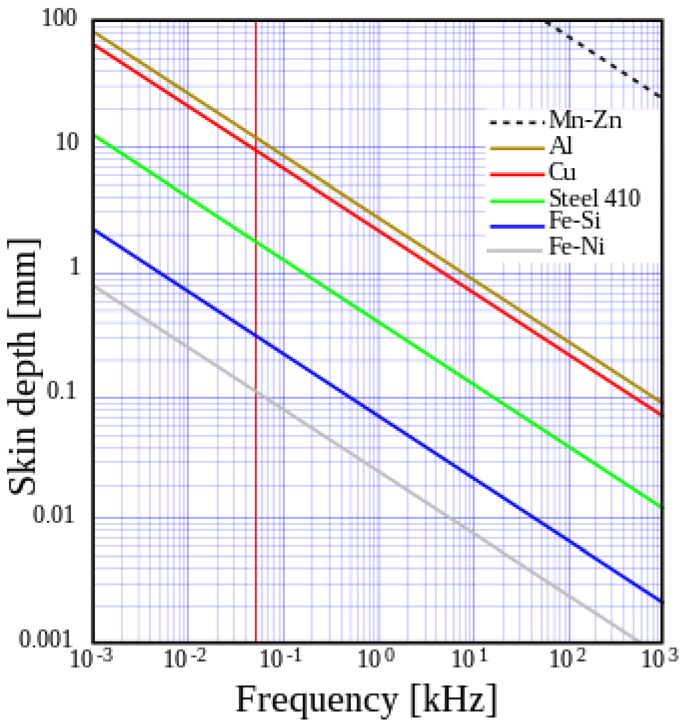


Using a Faraday cage for EMC testing:

- The device under test (DUT) is placed inside the cage.
- Electromagnetic waves are generated outside the cage at various frequencies.
- The amount of electromagnetic energy that leaks into the cage and affects the DUT is measured.
- This measurement helps determine the DUT's susceptibility to electromagnetic interference.

Benefits of using a Faraday cage for EMC testing:

- Provides a shielded environment to isolate the DUT from external electromagnetic interference.
- Enables accurate measurement of the DUT's emissions and susceptibility.
- Creates a controlled environment for repeatable testing.



Skin depth vs. frequency for some materials at room temperature, red vertical line denotes 50-Hz frequency: Mn–Zn – magnetically soft ferrite Al – metallic aluminum Cu – metallic copper steel 410 – magnetic stainless steel Fe–Si – grain-oriented electrical steel Fe–Ni – high-permeability permalloy (80%Ni–20%Fe)

BROADBAND ANTENNA

A broadband antenna, also sometimes called a wideband antenna, is designed to operate effectively over a wider range of frequencies compared to standard antennas. There's a trade-off though, as they typically won't be as efficient at any single frequency as a specifically designed antenna for that frequency.

Here's some key information about broadband antennas:

- **Applications:** They're ideal for situations where you need to receive or transmit across a range of frequencies without needing to swap antennas. Examples include:
    - Shortwave radio listening (covers a large portion of the radio spectrum)

      pen_spark

    - Cellular communication base stations (supporting multiple cellular bands)
    - EMI/RFI testing (need to detect emissions across a wide range)
- **Types:** Several antenna designs can achieve broadband operation, some common ones include:
    - **Dipole Antennas:** Can be designed for wider bandwidths by using thicker elements or special shapes.

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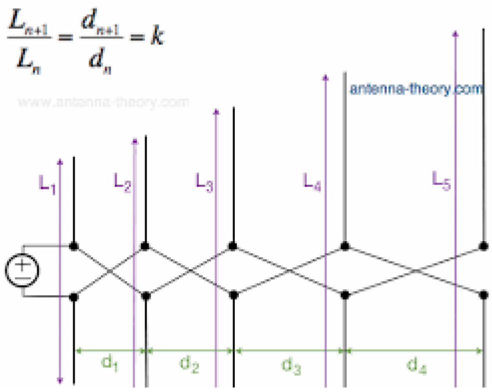
      Broadband Dipole Antenna

- **Log-Periodic Dipole Array (LPDA):** A multi-element antenna with good directivity and wide bandwidth.



LogPeriodic Dipole Array Antenna

- **Biconical Antenna:** Offers omnidirectional coverage with a wide bandwidth.

Biconical Antenna

- **Spiral Antennas:** Can be particularly compact and broadband.

Spiral Antenna

- **Limitations:** While they offer wider bandwidth, they generally have lower gain (signal strength) compared to a specifically designed antenna for a single frequency.

If you're looking for an antenna for a specific application, it's important to consider the frequency range you need and the trade-offs between bandwidth and gain.

BICONICAL ANTENNA

A biconical antenna is a broadband antenna consisting of two roughly conical conductive objects, nearly touching at their points, resembling a butterfly or bowtie shape. These antennas are known for their wide operating bandwidth, typically exceeding three octaves.

Biconical Antenna

Here are some key characteristics of biconical antennas:

- **Broad Bandwidth:** As mentioned earlier, they can operate over a wide range of frequencies, making them suitable for various applications.
- **Omnidirectional Radiation Pattern:** They radiate signals almost equally in all horizontal directions.
- **Linear Polarization:** Their radiated waves are polarized in a single plane.
- **Simple Construction:** They are relatively easy to design and manufacture.

Due to these features, biconical antennas find use in several applications, including:

- **EMC Testing:** They are widely used in Electromagnetic Compatibility (EMC) testing to measure the radiated emissions and susceptibility of electronic devices. Their broad bandwidth allows for efficient testing across a wide range of frequencies.

Biconical Antenna EMC Testing

- **Signal Monitoring:** They can be used for monitoring various radio signals due to their wide operating range.
- **Signal Generation:** In some cases, they can be used for generating electromagnetic waves for specific applications.
- **Calibration Antennas:** They can serve as reference antennas for calibrating other antennas.

Biconical antennas, while offering several advantages, also have some limitations to consider:

- **Lower Gain:** Compared to directional antennas, they have a lower gain, meaning they transmit or receive signals with less strength in a specific direction.
- **Physical Size:** Biconical antennas can be physically large, especially for lower frequencies.

Overall, biconical antennas are a valuable tool for various applications requiring a broadband antenna with an omnidirectional radiation pattern.

Horn antenna

A horn antenna is a microwave antenna that utilizes a flaring metal waveguide shaped like a horn to direct radio waves in a beam. Due to their design, horn antennas are widely used in applications requiring moderate gains at UHF and microwave frequencies (above 300 MHz). Here are some of its applications:

pen_spark

- **Feed horns** for larger antenna structures such as parabolic antennas.

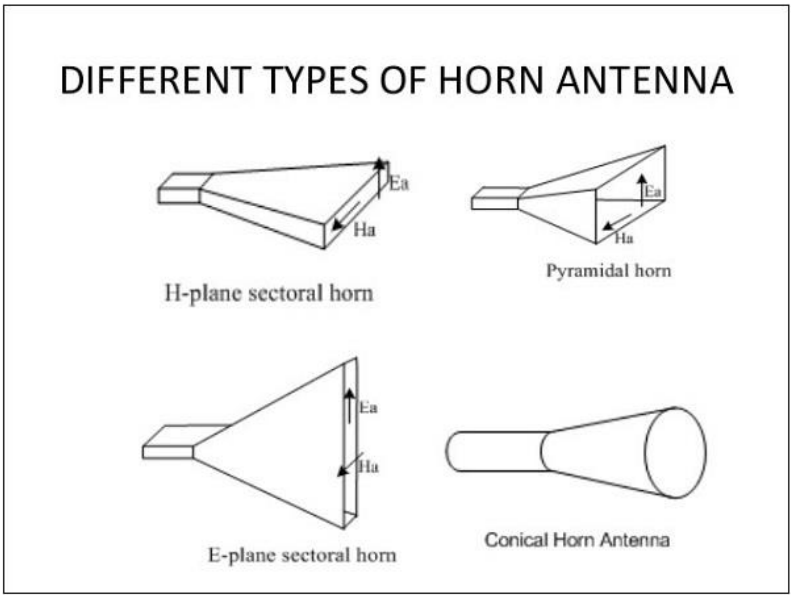
  Horn antenna feed horn

- **Standard calibration antennas** to measure the gain of other antennas.
- **Directive antennas** for radar systems, automatic door openers, and microwave radiometers.

  Horn antenna radar

They are favored for several reasons including:

- **Moderate directivity:** They can focus radio waves into a tight beam.
- **Broad bandwidth:** They can operate over a wide range of frequencies.
- **Low losses:** Signal strength is preserved.
- **Simple construction and adjustment:** They are relatively easy to manufacture and use.



VECTOR NETWORK ANALYSER:

Vector Network Analyzers (VNAs) are not used for direct calculations in EMC compliance testing. EMC testing focuses on measuring the actual radiated and conducted emissions of a device and comparing them to regulations. VNAs, however, provide valuable information for **designing and troubleshooting circuits** to minimize these emissions before formal testing.

Vector Network Analyzer (VNA) used in EMC testing by DRDO (Defence Research and Development Organization) might look like:

1. **Equipment Setup**: Typically, a VNA used in EMC testing at DRDO would be housed in a controlled laboratory environment designed to minimize electromagnetic interference (EMI). The setup includes the VNA itself, usually a sophisticated instrument with multiple ports for connecting cables to the Device Under Test (DUT).
2. **Display and Controls**: The VNA has a digital display screen that shows various parameters such as S-parameters (like S11 and S21), frequency settings, and measurement results. It also includes controls for setting measurement parameters, adjusting frequency ranges, and calibrating the instrument.
3. **Connection to DUT**: Cables connected to the VNA ports are used to interface with the DUT. These cables are carefully chosen to minimize signal loss and maintain accurate measurement integrity. The DUT is placed in an anechoic chamber or on a test bench designed to isolate it from external electromagnetic interference.
4. **Testing Process**: During EMC testing, the VNA sends signals through the cables to the DUT and measures how the DUT responds in terms of reflection (S11) and transmission (S21) of electromagnetic waves across a range of frequencies. This helps in assessing the DUT's performance in terms of signal integrity, impedance matching, and susceptibility to interference.
5. **Data Analysis**: The VNA records and analyzes data to generate reports that detail the performance characteristics of the DUT under various EMC conditions. These reports are crucial for ensuring that the DUT meets the required electromagnetic compatibility standards for military applications.

In essence, the VNA used in EMC testing by DRDO plays a vital role in evaluating the electromagnetic behavior of defense equipment, ensuring reliability and performance in challenging operational environments.

Here's a breakdown of how VNAs are used to support EMC activities:

1. **S-Parameter Analysis:** VNAs measure the S-parameters of a device, which describe how it scatters incoming electromagnetic waves at various frequencies. By analyzing these parameters, engineers can identify potential problems like:
   - **Impedance Mismatch:** When a circuit's impedance (resistance to current flow) doesn't match the connected components, it can cause reflections of the signal. These reflections can manifest as unwanted emissions during EMC testing.
   - **Resonances:** Certain frequencies can cause a circuit to resonate, leading to amplified signals and potential emissions.
2. **Filter Design and Verification:** VNAs play a crucial role in designing and verifying filters used to suppress unwanted emissions in electronic devices. By measuring the filter's response at different frequencies, engineers can ensure it effectively attenuates (reduces) the problematic signals before they become emissions.

Calculations performed by VNAs:

VNAs don't perform calculations directly related to EMC compliance limits. However, they measure various parameters that can be used for calculations relevant to EMC design:

- **Return Loss (S11):** A measure of how much power is reflected back from a port on a device. A high return loss indicates good impedance matching and reduces the chance of emissions.
- **Insertion Loss (S21):** A measure of how much power is transmitted through a device. Filters are designed to have high insertion loss for unwanted frequencies (attenuating them) and low insertion loss for desired frequencies.

<u>Overall:</u>

VNAs are a valuable tool for EMC prevention, not direct compliance testing. By analyzing S-parameters and using them for filter design and verification, VNAs help minimize unwanted emissions before a device undergoes formal EMC testing with dedicated equipment.

EXAMPLE READINGS:

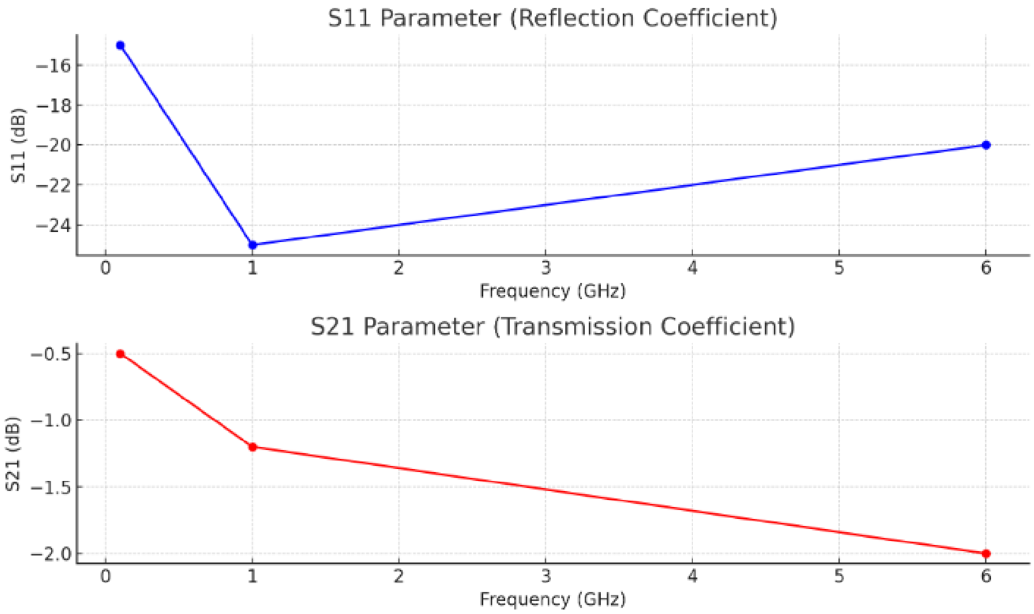
Here's an example reading from a Vector Network Analyzer (VNA) used in an Electromagnetic Compatibility (EMC) test for CVRDE (Combat Vehicles Research and Development Establishment):

Test Scenario:

- **Device Under Test (DUT):** Electronic control module for a combat vehicle.
- **Frequency Range:** 100 MHz to 6 GHz.

Measurement Results:

- **S11 Parameter (Reflection Coefficient):**
  - At 100 MHz: -15 dB
  - At 1 GHz: -25 dB
  - At 6 GHz: -20 dB
- **S21 Parameter (Transmission Coefficient):**
  - At 100 MHz: -0.5 dB
  - At 1 GHz: -1.2 dB
  - At 6 GHz: -2.0 dB



Here are the graphs for the S11 and S21 parameters based on the VNA readings:

The first graph shows the S11 parameter, indicating how much power is reflected back at each frequency. Lower values (more negative dB) indicate better matching and less reflection.

The second graph shows the S21 parameter, indicating the transmission efficiency. Lower values (more negative dB) indicate higher losses in transmission.

Interpretation:

- **S11 Parameter:** Indicates the amount of signal reflected back from the DUT. Lower values (closer to 0 dB) indicate better impedance matching and reduced reflection.
- **S21 Parameter:** Shows the signal transmission loss through the DUT. Lower values (closer to 0 dB) indicate lower insertion loss and better signal transmission efficiency.

Result:

Based on the readings obtained from the VNA, the electronic control module demonstrates good impedance matching and acceptable signal transmission characteristics across the specified frequency range of 100 MHz to 6 GHz, meeting EMC requirements for CVRDE applications.

This kind of report helps engineers assess how well the electronic components perform under electromagnetic interference conditions, ensuring they meet the necessary standards for reliability and functionality in combat vehicle applications.

EMC/EMI Testing Procedures:

Emission Testing:

- **Conducted Emissions**: Measuring the electromagnetic energy that emanates from equipment via power cables.
- **Radiated Emissions**: Measuring the electromagnetic energy emitted through the air from equipment.

Susceptibility Testing:

- **Conducted Susceptibility**: Testing the equipment's response to electromagnetic energy introduced through cables.
- **Radiated Susceptibility**: Testing the equipment's response to electromagnetic energy introduced through the air.

Specialized Tests:

- **Electrostatic Discharge (ESD) Testing**: Assessing equipment's ability to withstand electrostatic discharges.
- **Transient Immunity Testing**: Evaluating the equipment's resilience to transient electromagnetic disturbances.
- **Harmonics and Flicker Testing**: Ensuring that equipment does not introduce unacceptable levels of harmonic distortion or voltage fluctuations into the power supply.

Case Studies:

Example 1: Radar Systems

- **Objective**: Ensure radar systems operate without interference from other on board or nearby electronic systems.
- **Testing**: Conducted extensive radiated and conducted emissions tests, followed by susceptibility tests in an anechoic chamber.
- **Outcome**: Identified and mitigated several potential interference sources, leading to enhanced operational reliability.

Example 2: Communication Equipment:

- **Objective**: Guarantee that communication devices operate reliably in diverse electromagnetic environments.
- **Testing**: Included ESD, transient immunity, and harmonics testing.
- **Outcome**: Achieved compliance with MIL-STD-461, ensuring robust performance in field conditions.

Challenges and Solutions:

Challenge 1: Evolving Threats:

- **Description**: The electromagnetic environment is continuously evolving with new sources of interference.
- **Solution**: Continuous updating of testing protocols and standards, leveraging advanced simulation tools.

Challenge 2: Complex Systems:

- **Description**: Modern defence systems are highly complex, with numerous interconnected components.
- **Solution**: Modular testing approaches, combined with comprehensive system-level testing to identify and address issues.

Challenge 3: Resource Intensity:

- **Description**: EMC/EMI testing is resource-intensive in terms of time, expertise, and equipment.
- **Solution**: Investment in automated testing setups and training programs to build a skilled workforce.

Conclusion:

EMC and EMI testing are vital components of DRDO's efforts to develop and deploy reliable defense systems. Through sophisticated facilities, adherence to international standards, and continuous innovation, DRDO-CVRDE ensures that its systems perform optimally in challenging electromagnetic environments. Ongoing research and development, coupled with rigorous testing protocols, underscore DRDO's commitment to operational excellence and technological superiority.

References:

1. MIL-STD-461 Standard Document.
2. IEC 61000 Series Standards.
3. DEF STAN 59-411.
4. DRDO Annual Reports.
5. Technical papers and case studies from DRDO publications.