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EMI EMC: Background, Standards and Design Aspects

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Abstract

In a multi subsystem environment, in order for the subsystems to interoperate, electromagnetic interference and compatibility aspects have to be addressed. This is a critical aspect of the design and identifying the EMI and EMC aspects at the specifications stage itself lends to a better final design outcome. This paper provides a brief overview of the current standards and elucidates the EMI EMC design aspects with the help of three case studies viz. Antenna Platform for LCA MMR, IDSN32 SRCU and Anuchitra DBS. The methods, measures and design practices used for a successful EMI-EMC performance outcome are elucidated.

Keywords: Anuchitra DBS, APL for LCA MMR, IDSN32, MIL-STD-461C

Acronyms: AC: Alternating Current, APL: Antenna Platform, CAN: Controller Area Network, CE: Conducted Emission, CM: Common Mode, CS: Conducted Susceptibility, DBS: Deep Brain Stimulator, DCDC: DC to DC Converter, EMC: Electromagnetic Compatibility, EMI: Electromagnetic Interference, ESD: Electro-Static Discharge, HF: High Frequency, IDSN32: Indian Deep Space Network 32m, IPG: Implantable Pulse Generator, LCA: Light Combat Aircraft, MMR: Multi-Mode RADAR, MOSFET: Metal Oxide Field Effect Transistor, PCB: Printed Circuit Board, RADAR: Radio Detection and Ranging, RE: Radiated Emission, RS: Radiated Susceptibility, SFD: Smart Feedback Device, SRCU: Sub-Reflector Control Unit

1. Introduction

Electromagnetic emissions can be of the Radiated type called the Radiated Emissions RE or of the Conducted type called the Conducted Emissions CE. Electromagnetic Interference EMI is the maximum amount of RE and CE that any subsystem is allowed to generate. These are typically represented in the form of Emission spectrums with a contour defining the envelope. Electromagnetic susceptibility can be of the Radiated type called the Radiated Susceptibility RS or of the Conducted type called the Conducted Susceptibility CS. Electromagnetic Compatibility EMC is defined as the amount of CS and RS that the system must withstand without causing any deterioration in its performance. These are specified as power levels at various frequencies.

Based upon the operating environment with varying RE, RS, CE and CS levels, corresponding EMI EMC standards for the Military and Industry have evolved. Implanted medical devices have additional requirements in terms of defibrillation and MRI compatibility.

This paper will deal with three case studies namely the APL for LCA MMR, IDSN32 SRCU and the Anuchitra DBS.

2. Antenna Platform APL for LCA Multimode Radar MMR

The APL for LCA MMR is mounted in the nose-cone of the Light Combat Aircraft LCA protected by a Radome. The APL steers the 1m dia slotted array RADAR antenna to the commanded angles with the required positioning accuracy under the specified aircraft roll, pitch and yaw body rates. APL is powered with MIL-STD-704 compliant 115V, 3phase, 400Hz power supply. The 115V is the phase voltage, the line voltage is approximately 200V. The "Safety of Flight" test plan for the APL identifies among other tests, the EMI and EMC tests as per MIL-STD-461C which APL must pass in order to be deemed safe and not detrimental for the rest of the aircraft.

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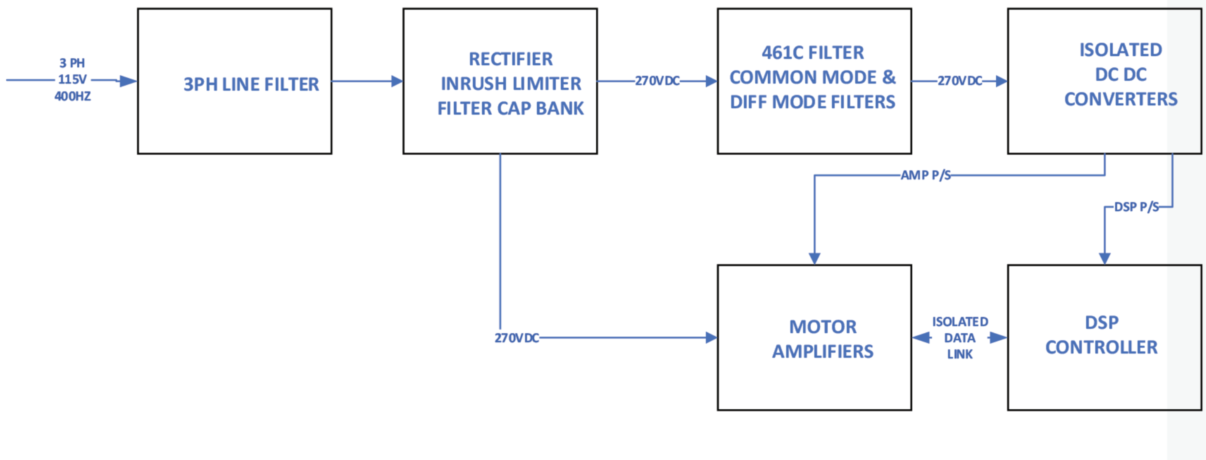


Figure 1. APL electrical line diagram.

Figure 1 shows the power line diagram for the APLCE. The incoming 4 wire power line is passed through a line filter to help reduce the harmonics injected into the line. This helps meet the CE requirement envelope. The HF capacitors and surge suppressors help meet the CS06 requirements. The filtered AC is fed to a 3 phase bridge rectifier followed by an active MOSFET based inrush current limiter, limiting the surge currents drawn by the filter capacitor bank. This also helps reduce the harmonic content in the input current. The 270VDC thus produced forms the back bone power supply for the APL control electronics. Motor amplifiers use this DC bus to power the four three phase inverter bridges with local snubbers to reduce conducted emissions. The logic power supplies are generated from this 270VDC bus using isolated DCDC converters with a carefully designed input common mode and differential mode filter to meet the CS and CE requirements of MIL-STD-461C. The logic power supplies for the DSP controller and Motor Amplifiers are mutually isolated to prevent common mode noise injection and fault propagation. The data link is further galvanically isolated using passive giant magnetostriction based isolators. The DCDC outputs are passed through HF feedthrough capacitors to reduce the switching noise artifacts. Individual card cassettes of the APLCE are enclosed in an aluminium enclosure which has a dual role of providing conductive heat transfer as well as RE and RS protection. To reduce RE, special care is taken in PCB layout. Power trace inductance is kept to a minimum by use of wide traces and copper fills, critical nets are routed with surrounding shielding layers. Discrete wire interconnects are avoided by using flex-rigid-flex type PCB design. Resolver and Motor wiring is fully shielded to minimise RE and RS.

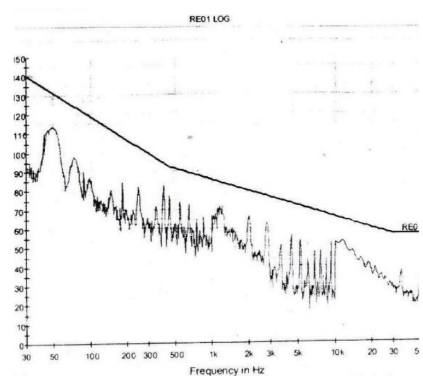


Figure 2. RE01 test on APL, Y axis is dBpT.

Figure 2 shows a representative result of one of the EMI EMC tests on APL. The limit line contour and emission spectra are clearly seen.

As a result of the good engineering practices and careful EMI EMC design, APL was able to clear the EMI EMC tests in the first go. The units are in series production and flying on LCAs.

3. IDSN32 SRCU

The Indian Deep Space Network IDSN 32m tracking antenna set up at Bylalu, near Bangalore to track spacecraft starting with the Chandrayaan 1, uses a repositionable 3.2m Subreflector at the focal point to compensate for gravity induced droop deformations of the reflector from its ideal parabolic shape. The deformations cause the focal point to shift, the subreflector is repositioned to the resultant new focal point using a 5 axis positioner servo system.

The Subreflector Control Unit SRCU consists of 5 drives controlled by a single control computer. The electronics is housed in a half height cabinet in the control room. The 5 Motors, 5 Motor Smart Feedback Devices SFDs and 5 contactless, time of flight type magnetostriction position sensors are located 60mts away at the subreflector. This posed several challenges in signal integrity and EMC which were tackled in the design.

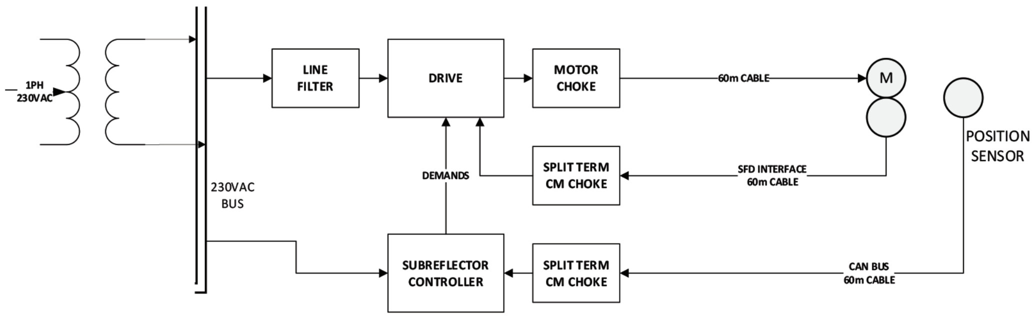


Figure 3. SRCU: One axis.

The line diagram for one axis is shown in Figure 3. There are 4 more such axes in the system.

The main EMI aggressor was a 20kW HPA which was injecting large CM noise in CE mode into the mains line. To arrest and attenuate this disturbance a 110dB common mode attenuation mains isolation transformer is used. To reduce line harmonics a line filter is used at the input of the drive. Motor chokes are used to counteract the long cable capacitance and to reduce the dV/dt of the PWM output, thus increasing insulation life and reducing RE. The motor cables are shielded to additionally prevent RE leakage.

The SFD interface is proprietary and differential requiring termination. A novel split termination scheme was evolved to additionally attenuate differential mode noise, increasing the robustness of this link. Common mode filter chokes for data lines was also carefully selected and installed.

A single Controller Area Network CAN bus interfaces the 5 position sensors to the controller. A scheme of weak and strong split terminations was evolved. The farthest nodes were strongly terminated, the intermediate nodes were provided with weak split terminations. This increases the noise immunity. Additionally, CAN common mode chokes were also used.

As a result of these measures the SRCU unit could be successfully operated in a highly noisy environment coupled with extra-long cable lengths.

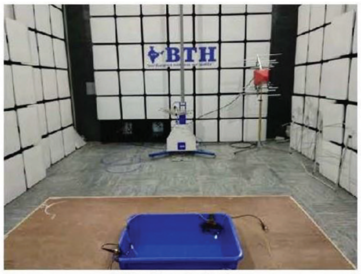
4. Anuchitra DBS

The Anuchitra Deep Brain Stimulator DBS is an Implantable Pulse Generator IPG developed by a team comprising of engineers from ED, CnID, RCnD, CDM and SCTIMST. Anuchitra is surgically implanted under the clavicle. A set of electrodes are separately surgically implanted leading from this IPG to the brain. Impulses generated by this device help relieve symptoms of Parkinsons and essential tremor.

The IPG is powered from a rechargeable captive battery and communicates with its programmer device over a LF wireless link. The battery is wirelessly recharged. The IPG enclosure is made of a bio compatible Titanium alloy.

EMI EMC compliance is of paramount importance to the IPG and is governed by clauses of ISO 14708-3 and IEC IEC60601-1-2 which among other aspects cover protection of the active implantable medical device from damage caused by external defibrillators and electrical fields applied directly to the patient. Another very critical test is the force experienced by the IPG under fast varying magnetic fields of the sort during a MRI scan. The force can cause the implant to move and cause injury to the patient. Such a consideration precludes the use of ferrite materials in the electronics circuitry. Special care for isolation from the enclosure and ESD protection to all inputs and outputs have to be provided. For this purpose the outputs are capacitively coupled and each output is ESD protected with suitable transient suppressors.

ISO 14708 certified testing labs were not available in India, however IEC61000 test facilities were available. In order to test the robustness of design it was decided to study, identify and explore the possibility of suitably tailoring the IEC 61000 test levels, in order to meet the intent of ISO14708 tests. This effort was painstaking and a test plan was evolved using tailored levels of IEC61000. Anuchitra DBS successfully passed these tailored EMI EMC tests confirming the importance of careful design, good engineering practices and diligent implementation by all the subsystem designers and integration team.



Radiated Immunity Test Setup

Figure 4. Anuchitra test setup.

5. Conclusion

The case studies presented are all distinct and challenging in their own way. APL was a flight worthy system thus military EMI standards were applicable with very tough operating envelope. IDSB32 was a mission critical system with Signal integrity challenges, The AnuChitra DBS was an implanted medical system with human life and safety implications.

The three case studies presented conclusively show that consideration of EMI EMC and Signal Integrity aspects, applicable standards and testing requirements at the specifications stage itself is a sure recipe for a successful design outcome. Good engineering practices like adequate decoupling, transient and ESD suppression, common mode and differential mode filtering, isolation transformers and careful PCB and cable layout are imperative for successful EMI-EMC compliance.

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