EMC DESIGN OF A MODERN FIGHTER AIRCRAFT - A CASE STUDY

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BSTRACT

A modern fighter aircraft is highly "electronic-intensive" with large number of equipments and systems. All these systems have to work safely and efficiently in a hostile electromagnetic environment. To achieve this objective it is essential to adopt systematic EMC measures throughout the life cycle of the design and development of a combat aircraft. This paper addresses an integrated approach using a mix of analysis and testing adopted by the EMC design team of Indian Light Combat Aircraft (LCA) Programme in order to achieve an operational aircraft with minimal EMI problems.

1. INTRODUCTION

1.1 A modern fighter aircraft is highly "electronic intensive" with safety critical systems like fly-by-wire flight control system and Full Authority Engine Control System along with Avionics and sensors suite consisting of Navigation, Communication, Electronic Warfare and Radar Systems. With such a large number of systems which have to safely and efficiently work in a hostile electromagnetic environment it is essential to adopt systematic and analytical EMC measures throughout the life cycle of the design and development of a combat aircraft. This paper addresses various aspects of EMC design and analytical tools as adopted by the EMC design team of the Indian Light Combat Aircraft Programme in order to achieve the overall objective of operational aircraft with minimal EMI problems.

1.2 The EMC design team has evolved an EMI control plan and an EMI Test Plan at the early Preliminary Design Phase (PDP). The location of all electronic and electrical subsystems has been finalised after an EMC analysis to minimise the inter system EMI problems. Similarly an analysis of the mutual coupling between onboard antennas has been carried out using In-house software to arrive at optimum locations of antennas on the aircraft to avoid EMI problem. Using analytical tools the effect of aircraft structure in distorting the antenna pattern has been studied for the IFF Antenna. A 1:10 scale model of the LCA has been used to measure the radiation pattern of V/UHF Fin Cap antenna when mounted on LCA.

1.3 On the intra system front, a grounding plan has been formulated using Hybrid grounding scheme. In order to avoid ground loop problems low frequency signals and power lines have been floated with respect to the aircraft structure. Intensive interaction with subsystem designer has ensured that the EMI problems are minimised. The EMC Test Plan for subsystems has been tailored from MIL-STD-461C taking into consideration the use of carbon composites in many areas of the aircraft structure. An analysis of the emission from onboard transmitters and the shielding provided by the aircraft fuselage has revealed the necessity to use RS03 levels of 40V/M in certain areas and at certain frequencies. An overall aircraft level test plan based on MIL-STD-1818 has been prepared for both emission and susceptibility testing especially for flight critical systems like Digital Flight Control System. A fibre optic cable data link has been configured to monitor the aircraft parameters during susceptibility testing. A plan for using Bulk Current Injection techniques has been prepared.

2. SEVERITY OF EMI PROBLEMS IN A FIGHTER AIRCRAFT

2.1 A modern fighter aircraft extensively uses electronic and electrical equipmentsand systems to meet the objection of an efficient and effective weapon system platform. Compared to older aircraft, there are a large number of flight critical and safety critical electronic systems like Fly-By-Wire Flight systems which may get affected by EMI and have catastrophic effects. Various general systems on aircraft like Environmental Control System, Brake Management System and Fuel Gauging System are all operated with microprocessor based digital electronic units. Added to these are the Avionics, Sensor and Weapon Systems including navigation, communication, displays and stores management and radar system. With such a large number of RF, digital and analog systems the frequency coverage is from very low frequencies (400 Hz) to 40 GHz. There are sensitive receivers co-located with high power transmitters. Mutual interference between subsystem is exacerbated by the dense packaging of the equipments in the limited space available inside the aircraft.

2.2 In addition to the mutual interference between systems on the aircraft and the radiation from onboard transmitters, the electromagnetic environment created by outside emitters such as Airport radar, communication and navigation systems, TV and Radio transmitters, Walkie Talkies and other Telecommunication systems such as cellular radios can create interference to onboard system which could affect safety of aircraft due to problem in flight critical systems such as Flight Control System. For this purpose it is essential to analyse the likely Electromagnetic emitters which may be encountered by the aircraft during various missions. The aircraft systems have to be hardened against the external EM Environment so defined.

2.3 Increased use of composite material in theaircraft structure including the wing and fuselage has resulted in a decrease in the shielding effectiveness provided by the aircraft structure. The shielding is further compromised by various apertures and canopy. Special treatment of canopy by conductive coating by optically transparent conductive material can alleviate the problem to some extent.

2.4 Due to increased use of electronics for all systems of aircraft, the length of cables used has increased tremendously. These cables act like antennas when exposed to external radiation. Extensive shielding leads to increase in the weight of the aircraft.

2.5 New techniques like SpreadSpectrum Communication System (Frequency Hopping, Direct Sequence etc) increase the EMI problem on aircraft and the EM situation has to be analysed taking into consideration large bandwidth required by these systems.

3. EMC DURING THE LIFE CYCLE OF DEVELOPMENT OF AN AIRCRAFT

3.1 The EMC aspects have to be addressed during the entire life cycle of development of a fighter aircraft for the conceptual and Project Definition Phase (PDP) to the final integration and flight testing. flow chart indicating the EMC activities is given in figure 1. During PDP, a EMC control plan has to be formulated indicating the various EMC activities. Various documents like Design guidelines, Grounding Plan, EMC Test Plan at subsystem level have to be formulated, reviewed and sent to various work centres.As a large number of work centres are simultaneously developing few hundreds of subsystems, EMC coordination is a massive task and has to be carried out systematically. Intra system and Intersystem EMC Analysis and Prediction is also carried out. This is especially useful for optimally locating various antennas on aircraft to minimise EMI.

3.2 The EMC engineer has to participate in all design reviews of different subsystems. All Design Review documents contain a chapter on EMC design. The purpose is to ensure that EMC design is built into the subsystem so that utilisation of EMC fixes after EMC tests are minimised. All subsystems have to meet MIL-STD-461C as tailored to LCA. Any waiver is considered by a Central Waiver Board after the impact of the waiver on aircraft integration and performance is evaluated.

3.3 A detailed aircraft level EMC Test Plan is formulated. This includes both Intrasystem and Intersystem Tests. Both emission and susceptibility Tests are carried out. Better current Injection Tests are planned at various points of aircraft harness.

4.0 EMC CONTROL PLAN AND GUIDELINES FOR EMC DESIGN.

4.1 The EMC design being adapted to Light Combat Aircraft programme emphasises the top down approach in EMC control for the aircraft, addressing both Intrasystem EMC and Inter system EMC.

4.2 The EMC-control is effected in two phases namely during project definition phase, where aircraft configuration, layout studies, system specifications were addressed and in detailed design phase where detailed analysis, implementation issues and testing aspects were addressed.

4.3 INTRASYSTEM EMC Control plan addresses the data collection of intentional transmitters, and receivers, their spectrum pollution and susceptance over the entire band width. An EMC analysis of the LCA system was carried out taking into consideration the emission spectrum and susceptibility of transmitter and receiver, degradation due to effect of Intermodulation and crossmodulation and antenna to antenna coupling. E and H field mapping was also done due to on-board and external transmitter.

4.4 The above analysis lead to layout changes to ensure the electromagnetic shielding of transmitting units from victims by physical isolation or by introduction of metal barriers, formation of functional colonies etc.

4.5 The frequency assignments and antenna locations were studied from EMC and functional point of view and locations were reassigned to ensure optimal isolation without affecting the functional requirement.

4.6 The grounding concept hitherto being adopted in the aircraft design underwent a metamorphical change, necessitated due to the system configuration of aircraft and also due to extensive use of composite material in the aircraft structure Along with grounding design, the power distribution system also underwent a radical deviation from the conventional powering scheme.

4.7 Based on the analysis and E&H field mapping, test specifications test plan at unit level was generated. The specifications are essentially tailored from MIL-STD-461C tailored to LCA requirements. The test procedures are derived from MIL-STD-462 (Notice-3). The lightning tests specifications are derived from SAE-AE4L-87-3. The shielding integrity and bonding requirements are derived from MIL-B-5087B.

4.8 The aircraft level EMI test specifications, plans and procedures are derived from MIL-STD-1818 and reported literature on testing with F-18A programme. The EMC guidelines were generated both at aircraft level and at unit level.

4.9 The power distribution scheme, which hitherto followed concept of using the aircraft structure as return path for both AC, DC, RF & signal currents was changed to dedicated return paths for AC & DC power lines. A distributed primary power and the use of SMPS/DC-DC converters in Line Replaceable Unit (LRU) ensured adequate isolation between primary and secondary currents.

4.10 The concept of floating ground or equipment sub star within the unit and connected to aircraft structure at only one point for low frequency and RF currents flowing through the aircraft structure redefined the overall concept of grounding design. Clear guidelines in grounding design of analog, digital, high current grounds, RF grounds and hybrid grounds with ability to control individual ground potentials was the additional advantages gained due to the new concept of grounding design being implemented in LCA.

4.11 The extensive usage of HighSpeed microprocessor and I/O controller, PLAS, ASICS etc., called for extensive and careful study of the grounding scheme at LRU level. Extensive usage of multi layer board PCB introduced additional advantage in controlling EMI at unit level. The guidelines for achieving EMC at unit level were discussed for implementation and compliance. The deviations if any were studied in detail including the penalties at aircraft level prior to waiver.

5. GROUNDING DESIGN

The grounding design of A/c systems also had to adapt itself to the changes in technology with time. Increased use of complex electronic system and the use of computers in aircraft structure are some of the factors influencing grounding design. In the conventional aircraft,the power ground, system ground and safety grounds were terminated to the aircraft structure at the nearest ground plane. This design was adequate as the system used were simple and there were no electronic flight critical systems.

With increase in complexity of aircraft systems and dependence on systems for executing flight critical and safety critical functions there is a need to have a critical look at the conventional grounding design.

The hitherto adapted grounding concept could not support the required signal references and also lead to a phenomenon of common mode coupling or ground impedance coupling. Also due to usage of heterogenous materials for aircraft structure the ground plane impedance could not be controlled to extremely low values. The effect of mixing various load, and source currents and the effect of the same is given in figure 2.

In LCA we have adapted a deviation to hitherto followed concept of structure being used as return path for signal and power and RF ground currents.A hybrid grounding scheme of single point grounding for low frequencies and multi point grounding for high frequencies has been adopted as given in figure 3.

The guidelines followed for selecting the scheme is

- Single point grounding scheme is

employed for all systems with operating frequencies below 1 MHz.

- Systems operating with frequency between 1 & 10 MHz employ either single point grounding scheme or multi point grounding scheme depending on the length of the ground plane ie., lg

  Where lg is length of ground plane and is the wave-length corresponding to the frequency of operation.

- All the systems operating above 10 MHz employ multipoint grounding scheme.

However in large platform like aircraft though the design requirements demand the grounding design to the one specified above, often it happens many off-the-shelf or vendor developed units will not comply with requirement.

To ensure that aircraft level grounding design to meet the overall requirement of ensuring equipotential ref. grounds for all signals, a concept of "System in a System" is being implemented.

The system in a system concept allows the unit/system designer to implement the grounding scheme (like commoning of power returns and or signal returns to chassis within the unit with care being taken to ensure primary aircraft power to isolate w.r.t. unit secondary power returns, signal returns and chassis.

The input/output interfaces need to be isolated using either transformer coupling or opto coupling. The I/O interfaces need to be differential in nature to ensure minimisation of ground loops currents.

The unit or system will be installed on isolated ground plane or on A/c ground plane with bonding resistance requirements as per MIL-B-5087B (ie., bonding resistance to be < 2.5 mohms) w.r.to a/c master ground ensure the signal reference of other A/c systems of a/c with the system implementing a deviation in overall grounding scheme. A typical scheme is being given in figure 4.

During the implementation, care need to be exercised to ensure primary power returns and safety grounds and signal grounds are not mixed at unit level. As seen in Fig. 4 at aircraft level they are commoned ensuring no large circulating currents are flowing through them (with exceptions signal currents of the order of microamps to milliamps being coupled). The single point grounding scheme at aircraft level offers following advantages:

- Common signal references for digital serial/discrete I/Os.

- A dedicated non-current carrying line ensures all systems are operating with common signal reference. This scheme ensures the proper functioning of system even in an external EMI scenario or induced currents flowing through the aircraft structure. This design also ensures hardening against lightning currents.

- Ensures isolation of primary currents, analog grounds, digital grounds, RF grounds, high current grounds. Also facilitates the bypassing high frequency currents by usage of bypass capacitors.

- Grounding design does not depend on the materials of A/c structure.

6.0 AIRCRAFT ELECTRICAL HARNESS EMC CONSIDERATIONS

The aircraft electrical harness or aircraft loom establishes the physical means to provide functional interface of aircraft subsystems. The electrical harness design calls for selection of cable type, cable grouping/bundling and physical routing along the aircraft structure to provide the functional interfaces of the complex system. It may be noted that basic geometry of the loom sharing individual signals is also a major path of interference coupling to the system. It is mandatory to employ EMC guidelines to minimise/control the system level EMI.

The basic design consideration of aircraft loom envisages optimum choice/type of wires, cables connector catering the functional/ environmental/EMI-EMC requirements. Besides, it is essential to realise system with minimum weight. This can be in conflict with the EMC requirements. For example shielded all cables can add to the weight of loom. Hence shielding should be done selectively.

The major design guidelines for EMC are -

1. All the power lines should have dedicated return line and aircraft structure should not be used as power return.

2. The DC/AC power lines should be twisted pair, preferably shielded to minimise generation/pickup of magnetic fields and controlled radiation.

3. All the digital signal should utilise shielded wires to minimise HF radiation and should have appropriate shield termination depending on the operating frequency.

4. All the signals above 10MHz should preferably use coaxial cables.

5. Low level analog signal should utilise shielded twisted pair to provide protection against electric and magnetic fields.

6. The electrical interface for Pyros/EEDs and hazardous elements should employ double shielded twisted pair with shields independently connected to source and other shield of load.

7. The signal grouping in bundles should ensure that dynamic signal range should not exceed 30 dB dynamic range.

8. System grounding scheme to be evolved and implemented to minimise EMI.

Presently connectors are available with built-in custom filter, the filtering of unwanted emission can be effected at connector itself. However, this adds to weight and requires extra space which is at a premium in the aircraft. Hence the use of filter connector is done selectively after analysing the criticality and susceptibility.

The 'shielding' techniques calls for a shielded wire, the shield providing at least 90% optical coverage to control the emission of electric fields. The shield terminatioin depends on the signal type and also EMI environment. In a situation where shielding against low frequency magnetic fields is required, it is essential to ground shield termination at one end only. In case of protection against high frequency electric field is required, it is essential to provide shield termination both at source and load end of the harness. For optimal protection, the shields used should provide a 360 deg coverage. It is a conventional practice to form a shield ring to which all the individual shields are connected and shield ring is connected to connector through a short pigtail. It is essential to ensure shortest length of pigtail.

In a situation where shielding in excess of 60dB is to be provided, EMI backshells are used which provide full 360 deg coverage for the internal wires of the harness. In case where adequate space for backshell is available, heat shrinkable conductive boots may be used. Backshells are especially recommended for safety critical system like Flight Control System.

7.0 EMC ANALYSIS

7.1 As discussed in the EMI/EMC control plan, the EMI/EMC analysis is carried out for emitters and susceptors.

7.2 The EMI analysis is carried out in two phases:

(a) Project Definition Phase and (b) Detailed Design Phase

7.3 Analysis in Project Definition Phase.

7.3.1 In the project definition phase analysis is carried out to study location management, frequency assignments etc., The EMI analysis is carried out for intentional transmitters and receivers.

7.3.2 The various analysis being carried out are listed below:

- Antenna to antenna coupling taking into account the shading factor offered by the geometry of A/c structure by approximating the aircraft structure into various canonical models like ellipsoids, plates, cones, etc.

  Modelling of Transmitters for harmonic and spurious emissions based on the type of modulation.

  Modelling of receivers for co-channel susceptibility thresholds, selectivity models and spurious responses. Intermodulation products, and desensitisation criteria due to the presence of other transmitters/ emitters.

  Once the layout is finalised, frequency spectrum is modelled. E&H field mapping was done also taking into consideration the resonant frequencies of windows, apertures and cavities leading to tailoring of EMI/EMC test specifications regarding radiated susceptibility.

7.3.3 However an update of these analysis is carried out based on the actual inputs replacing the default characteristics. Since the non linear characteristics are modelled as piece-wise, linear characteristics, it is easy to modify the characteristic inputs in the analysis package. Also while specifying on the susceptibility levels, the interference margins of the order of 10 dB is taken into consideration.

7.4 Analysis in Detailed Design Phase

During the detailed design phase, the actual characteristics of the equipments are used in the analysis. The cable to cable coupling analysis are carried out after the completion of system interconnect design.

7.5 EMC Models

Some of the models used in analysis of emitters and susceptors are discussed below:

7.5.1 Antenna to Antenna coupling

$$e_1(f)_{(\theta,\phi)} = e_1(f_0)_{(\theta,\phi)} + A\log_{10} f/f_0 + B + \text{SHADEFACTOR}.$$

A and B are slope and intercepts of antenna gains characteristics with respect to frequency f. fo is the desired frequency.

The radiation of each antenna is superposed with the aircraft geometry and location. The gain patterns are studied for applicable and nonapplicable regions, initially carried out in free space mode for interference studies w.r.t. coupling studies. The shading factors estimated by analysis of aircraft structures as canonical models are applied to the free-space antenna to antenna coupling.

In case of omni directional antennas, the radiation cones in Azimuth-elevation are considered assuming the aircraft structure offers the ground plane for antenna excilation.

The analysis is carried out for optimal location of antennas for coverage and direction also to ensure physical, line of sight isolation and frequency separation.

7.5.2 Transmitters/Emitters models

Transmitters are modelled for harmonic emissions by

$$P_T(f_{NT}) = P_T(f_{0T}) + C\log_{10}\frac{n \cdot f_{0T}}{f_{0T}} + K + K_s + D$$

Where C&D are slope and intercepts of the frequency characteristics of the transmitter M (f) is the modulation envelope given by

$$M(\Delta f) = M_i(\Delta f_0) + K\log_{10}\frac{\Delta f}{f_0}$$

K is attenuation constant depending on the type of modulation and m_i is the modulation index at fo.

Ks is the shielding effectiveness of the unit or the insertion loss at the antenna terminals.

P_T(fnt) is analysed over the entire frequency range and resulting frequency spectrum is utilised for further analysis.

7.5.3 Receiver/Susceptor analysis

The receiver response spectrum is given in figure 5. The inband response sensitivity threshold where SNR=0 dB is called co-channel susceptibility thresholds. Normally receivers or susceptors are modelled/analysed for front end saturation. In case of super heterodyne or coherent receiver each stage of mixer and IF is treated as independent stages cascaded, with individual system characteristics.

Co-channel susceptibility threshold is estimated by equation PR(for) = $FKTB_R$

where PR (for) = Co-channel susceptibility/ threshold
R = noise figure of rx front and
K=Boltzman's constant
T=Noise temperature of the system
BR = Bandwidth of the receiver

Normally PR (fo_R) is estimated for 3dB, 20dB, 60dB bandwidths. The spurious response frequency of receiver is determined by equation

$$f_{SR} = \left| \frac{Pf_{LO} \pm f_{IF}}{q} \right|$$

P&q are integers
FSR = Spurious response freq
f_{LO} = Local oscillator freq
f_{IF} = I. F frequency

After determining the FSR spurious response susceptibility thresholds are estimated by eqn

$$P_R(f_{SR}) = P_R(f_{OR}) + I \log_{10} \frac{f_{SR}}{f_{OR}} + J + K_S$$

where PR (FSR) = spurious response susceptibioity threshold.
PR(FOR) = Co-channel susceptibility threshold.

$f_{OR} \hat{=} \left| \frac{Pf_{LO} \pm f_{IF}}{q} \right|$ Rx inband response frequency.

where I & J are slope and intercepts and PR (fSR) is the spurious response susceptibility threshold. A coupled spurious response analysis of receivers is carried out to determine the potential EMI by searching

$$\left| \left| \frac{Pf_{LO} \pm f_{IF}}{q} \right| \pm f_{NT} \right| \leq B_R$$

where FNT is the frequency of transmitters. Nas integers 1, 2, 3 ... to cover frequency range upto 40GHz. BR is the bandwidth of receiver at 3dB, 20dB, 60 dB. After search and determination of frequency fNT and fSR the amplitude margin is determined by

$$P_R(f_{SR}) - P_T(f_{NT}) = IM.$$

If Interference Margin (IM) is positive.and greater than 10dB. The system has adequate EMI Margin. If IM is negative, the situation is a cause of concern, due consideration has to be taken in reallocation of frequency or physical/shielding of transmitters and receivers or both are not possible, time management. Intermodulation products are determined by

$$\left| mf_N \pm nf_F \right| \leq \left| f_{OR} \pm \frac{B_R}{2} \right|$$

where m & n are integers m+n) is called the intermodulation order.

f_N is the transmitter frequency or nf_N is the harmonic frequency of transmitter.

f_F or nf_F is searched in the data base for nfT the fundamental of on board transmitter or harmonics likely to cause intermodu-lation interference.

If a frequency exists of or equal to or within band width of transmission ie.,

$$\left| nf_T \pm n'f_F \right| \leq B_T$$

Where BT is bandwidth of transmission frequency envelope, then a potential inter modulation exists. If so further amplitude analysis is carried for power available at receiver terminal which can cause intermodulation interference.

Similarly desensitization and cross modulation analysis are carried out for degradation in signal to noise ratio and desired sensitivity of receivers due to the presence of other transmissions.

The cable to cable coupling analysis is carried out by basically modelling the cable as transmission line model with

$$Z_0 = \frac{R + j\omega L}{G + j\omega L}$$

and characterising for the line parameters of R,L,G & C for each type and gauge of the cable per unit length taking into account the height above the ground plane from multi conductor transmission method of modelling. The coupled voltage at frequency $w=2\pi f$ is determined by Matrix

$$[V_0] = [I + ZY][V_{IN}]$$

Where VO = O/P voltage on the line and coupled voltage

I = Identity Matrix

$Z = Z_S + jwl + Z_L$

$Y = G + jwc + Y_L$

Vin = input voltage at frequency w = 2 f for digital signals f = 1/To, 1/T raise, 1/Tfall, all are considered for anlysis.

The resultant Vo is determined by

$$V_0 = \sqrt{(V_{of})^2 + (V_{of_{raise}})^2 + (V_{of_{fall}})^2}$$

ie., RMS value of Vo at fT, f fraise, f fall frequencies. The cable to cable coupling analysis calls for formating of cable path, segment length, cables in the group/bundle, type of wire, gauge of wire, type of signal, frequency of signal, raise and fall time of signals (if applicable) and amplutide levels. Also it is necessary to model in source and load impedances as

$$Z_S = R_S + j\omega L_S + 1/j\omega C_S$$

$$Z_L = R_L + j\omega L_L + 1/j\omega C_L$$

The (Vo) resultant is compared with upper and lower threshold of the desired signals voltage levels to evaluate the interference margins.

9. EMC TEST PLAN AT AIRCRAFT LEVELS

The aircraft level EMC test plan encompasses the EMC compliance at aircraft levels. Though all the systems are expected to comply EMC test requirements as MIL-STD-461C (tailored to the program), the a/c level EMI/EMC tests are envisaged based on the tailored specifications of MIL-STD-1818.

The EMI/EMC tests need to be conducted in the anechoic shielded chamber. However, if anachoic shielded chamber is not available, open air test site (OATS) is resorted to.

The EMI/EMC tests at aircraft level are normally divided into 5 types.

* Conducted emission tests
* Conducted susceptibility tests
* Radiated emission tests
* Radiated susceptibility tests
* Ground plane interference tests

Conducted and radiated susceptibility tests are carried out to demonstrate 6dB margin and 20dB margin on conducted and radiated emissions over the entire frequency range of A/c functioning for electronic systems and hazardous/ critical systems.

While carrying out the EMC tests, the systems and functional types are classified into various criticalities like - flight/safety critical/hazardous

- mission critical.

The susceptibility margins need to be 20dB for flight critical/safety critical and hazardous systems. For non-critical items demonstration 6dB margin is found adequate as per MIL-STD-1818 for intrasystem EMC.

However, to evaluate the EMC perforfmance inter system EMI, radiated susceptibility test is carried out for 200V/mtr. over the entire frequency range of interest and also at spot frequency with the estimated levels for EMI due to Airport tower, radar, TV tower etc.

The ground plane interference (GPI)

test is to evaluate the performance of aircraft due to ground plane interference due to A/c power supply systems on aircraft and improper ground plane potentials.

The test specifications for GPI tests are:

* 3V RMS at freq.320Hz to 500Hz
* 8V spike of microsec and 100PPB
* One volt RMS from 500Hz to 100MHz
* 1V DC

on ground plane of the aircraft.

The GPI test configuration of GPI test is given in figure 6.

The GPI test is needed as many of the off-the-shelf and vendor supplied items does not conform to the grounding design of aircraft.

Hitherto radiated susceptibility test set up called for elaborate and expensive set up of high power amplifiers, directional antennas. Also the field distribution could not be uniform plane wave during the tests. In LCA we have planned to carry out the susceptibility tests by use of bulk current injection probes (BCI) upto 1GHz.

The procedure involved are essentially calibrating the radiation to bulk injection current transformation at various locations on a/c. Applying extrapolation method, the current through BCI probe is injected for susceptibility test. The test methods and procedures are given in the latest issue of MIL-STD-462.

The EMC compliance tests at aircraft level are carried out for various system functioning, by energising applicable functional loops and stimulating or simulating I/Ps and evaluate the outputs for susceptibility thresholds.

For conducted susceptibility, radiated susceptibility and ground plane interference tests will enable the designer to evaluate the EMC margins for conducted and radiated EMI Both Intra System and Inter System.

A fibreoptics link has been configured to link the aircraft to the ground checkout system of LCA for monitoring various parameters of different system.

CONCLUSIONS

A systematic and analytical approach covering all EMC aspects for subsystem design to aircraft integration has been implemented for the Indian LCA programme. EMC Engineers were involved in all aspects of Project Definition Phase, Detailed Design Phase and the Integration activities. This has yielded good results in minimising EMC problem on aircraft. A critical hybrid grounding scheme has minimised ground loop problems which normally can create serious problems in a modern aircraft. A detailed aircraft level test plan is being implemented to verify the performance of flight critical systems like Fly By Wire Flight Control System.

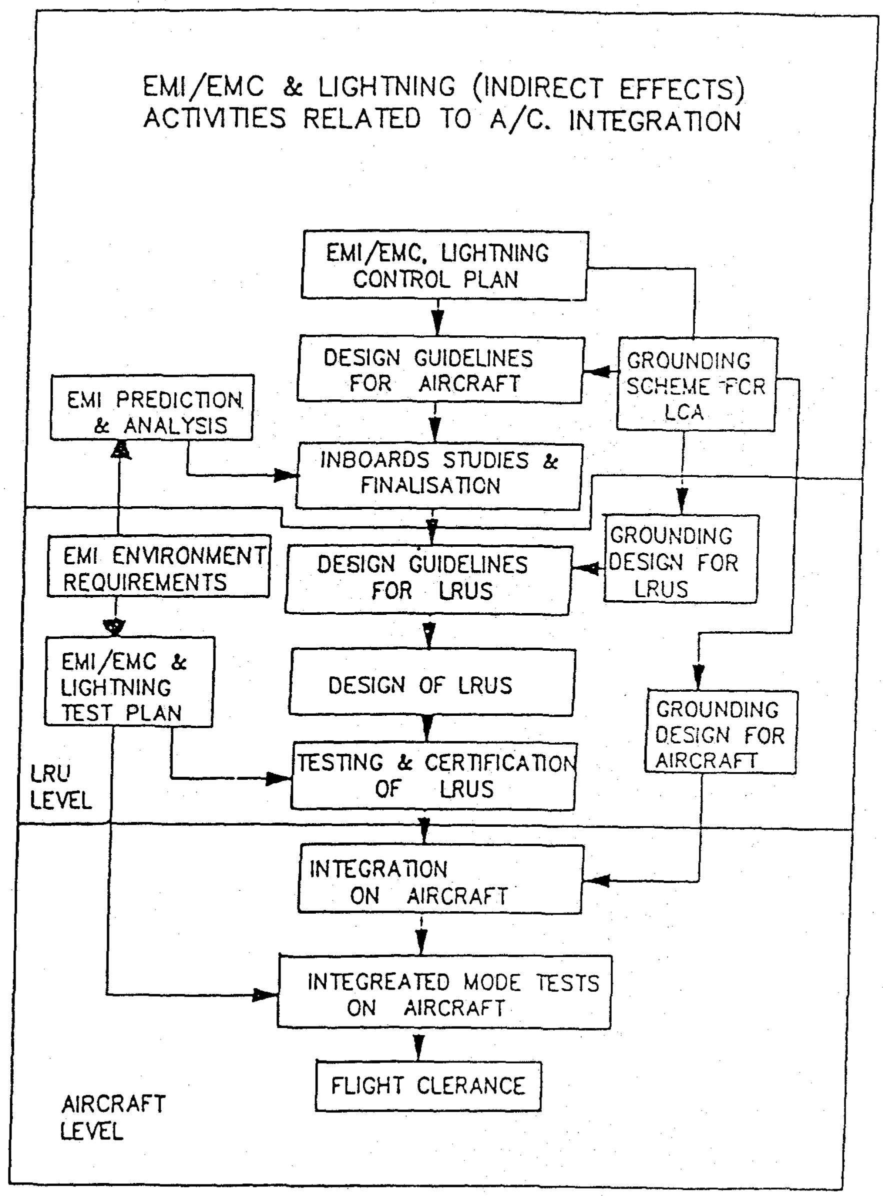
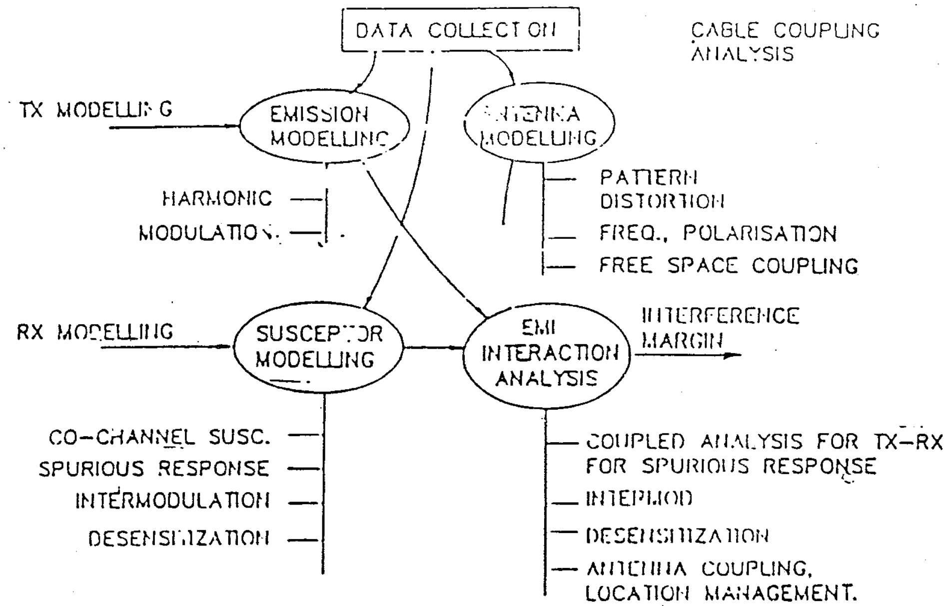
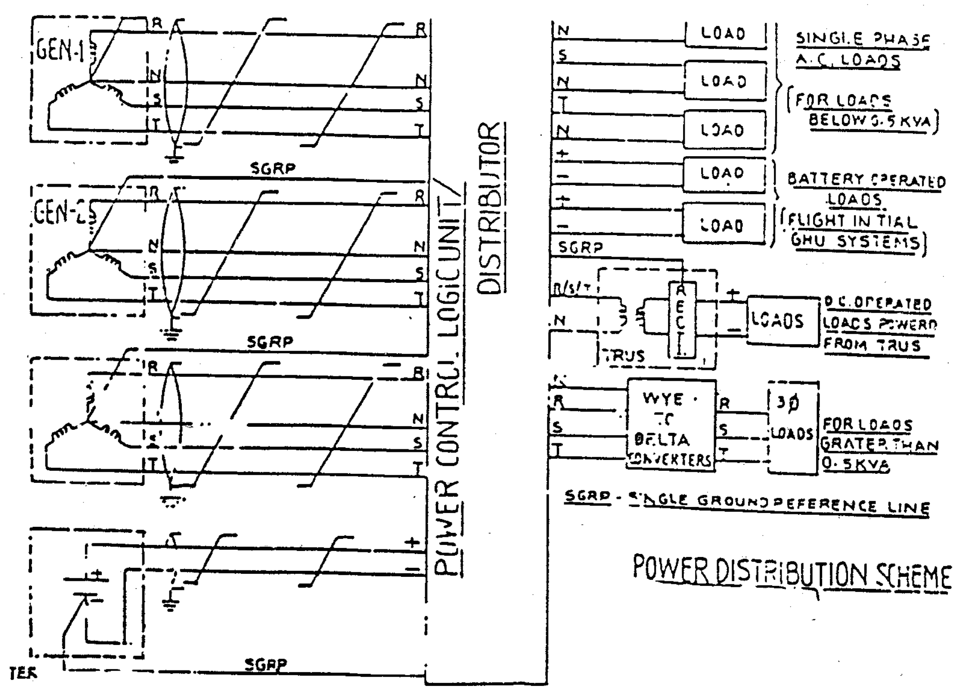


FIG 1 : FLOW CHART OF EMI/EMC ACTIVITIES DURING LIFE CYCLE OF AIRCRAFT DEVELOPMENT PROGRAMME

EMI PREDICTION AND ANALYSIS



EMI PREDICTION AND ANALYSIS CARRIED OUT FOR LCA.



POWER DISTRIBUTION SCHEME

LCA GROUNDING PHILOSOPHY

ALL POWER LINES SHOULD BE ASSOCIATED WITH DEDICATED RETURN LINES.

PRIMARY POWER SHOULD BE ISOLATED WITH INTERNAL POWER SOURCES.

ANALOG GND, HIGH FREQUENCY GND, DIGITAL GND, HIGH CURRENTGND, HAVE TO BE TERMINATED TO INTERNAL POWER SOURCE RETURNS NEAR THE POWER UNIT, CALLED SYSTEM GND OR EQPT SUBSTAR. THIS SUBSTAR SHOULD BE ISOLATED FROM CHASSIS OF THE EQPT.

LCA EMPLOYS HYBRID GROUNDING SCHEME.

SINGLE POINT GROUNDING FOR LOW FREQ SYSTEMS.
SINGLE OR MULTI POINT GROUNDING FOR SYSTEMS WITH FREQ BETWEEN 1&10 MHZ DEPENDING ON LENGTH OF GROUND PLANE
MULTI POINT GROUNDING FOR SYSTEMS ABOVE 10 MHZ. INCLUDING HIGH SPEED DIGITAL CIRCUITS.

FIG 2 : HYBRID GROUNDING PHILOSOPHY

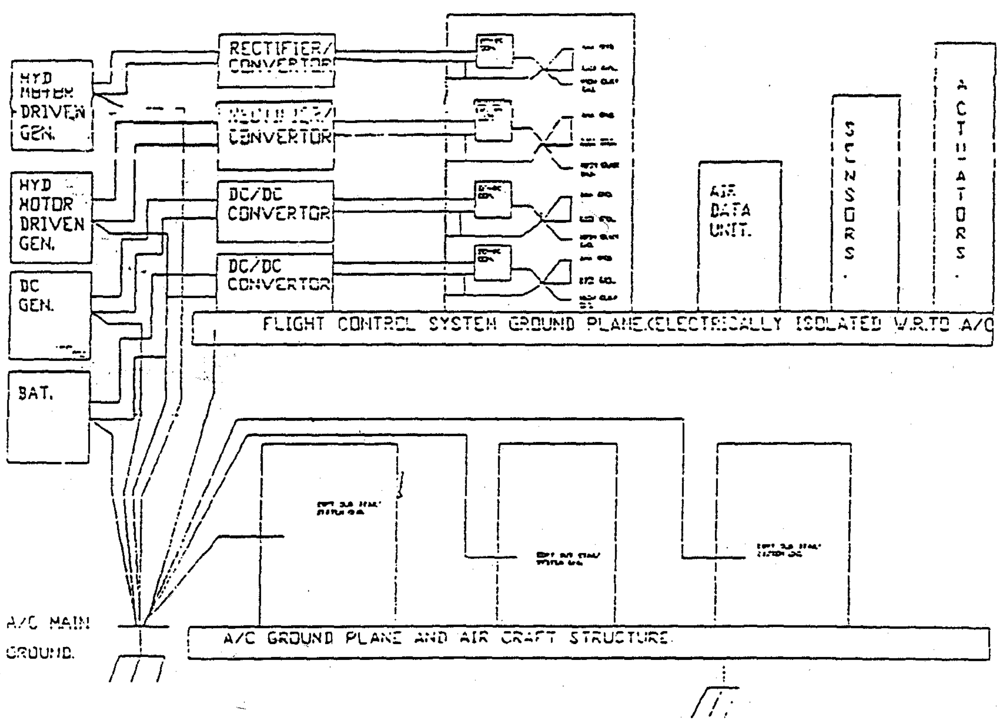


FIG 4 : GROUNDING SCHEME WITH "SYSTEM IN SYSTEM CONCEPT"

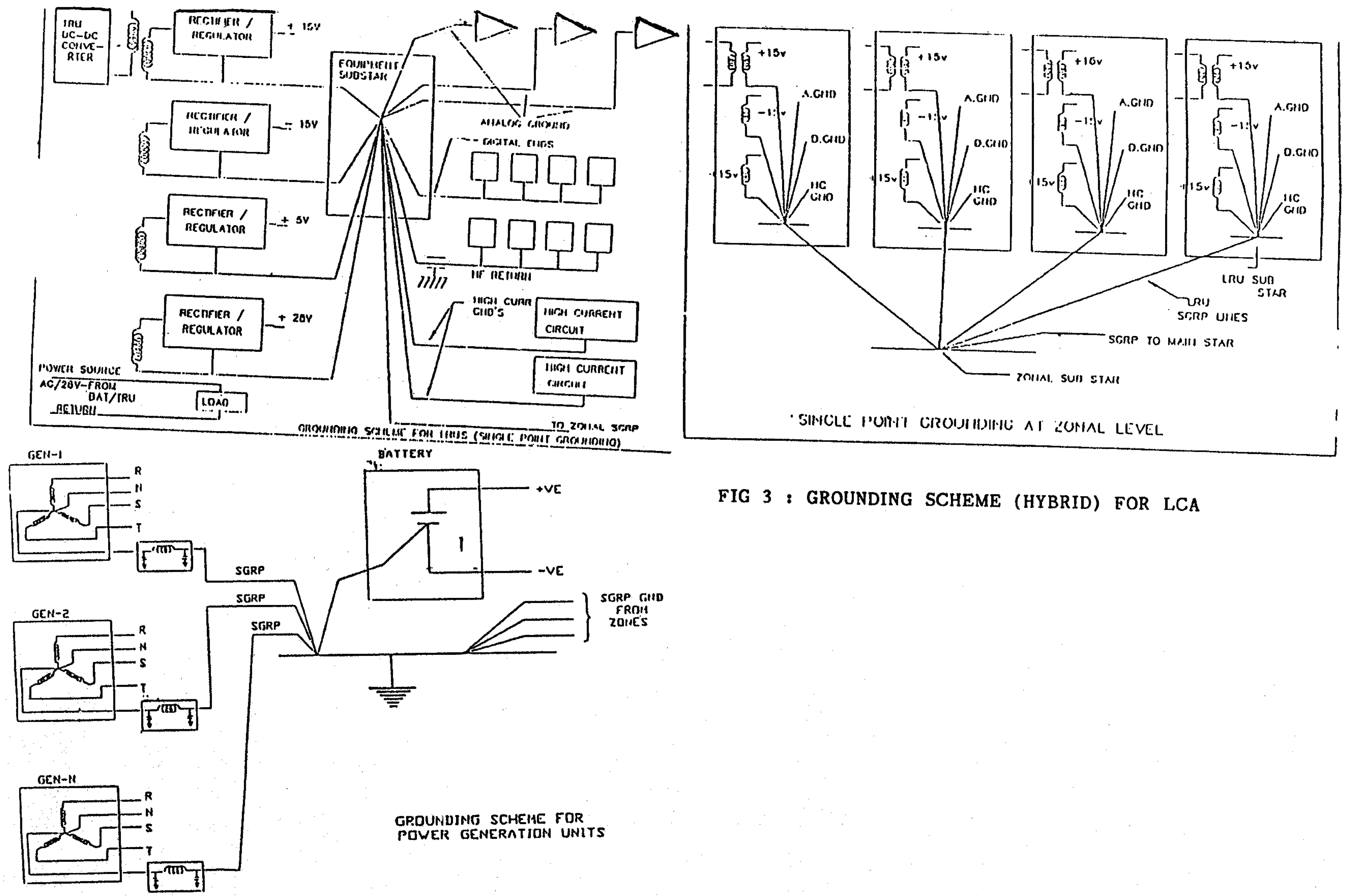
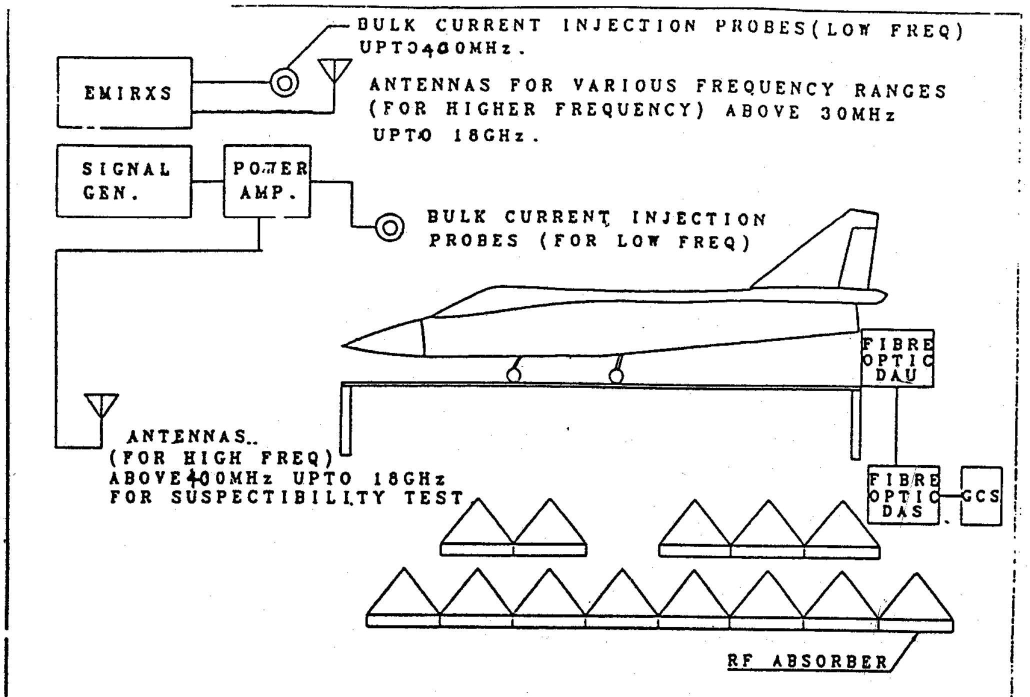


FIG 3 : GROUNDING SCHEME (HYBRID) FOR LCA



A/C ON THE PLATFORM FOR RADIATED EMI/EMC TESTING.

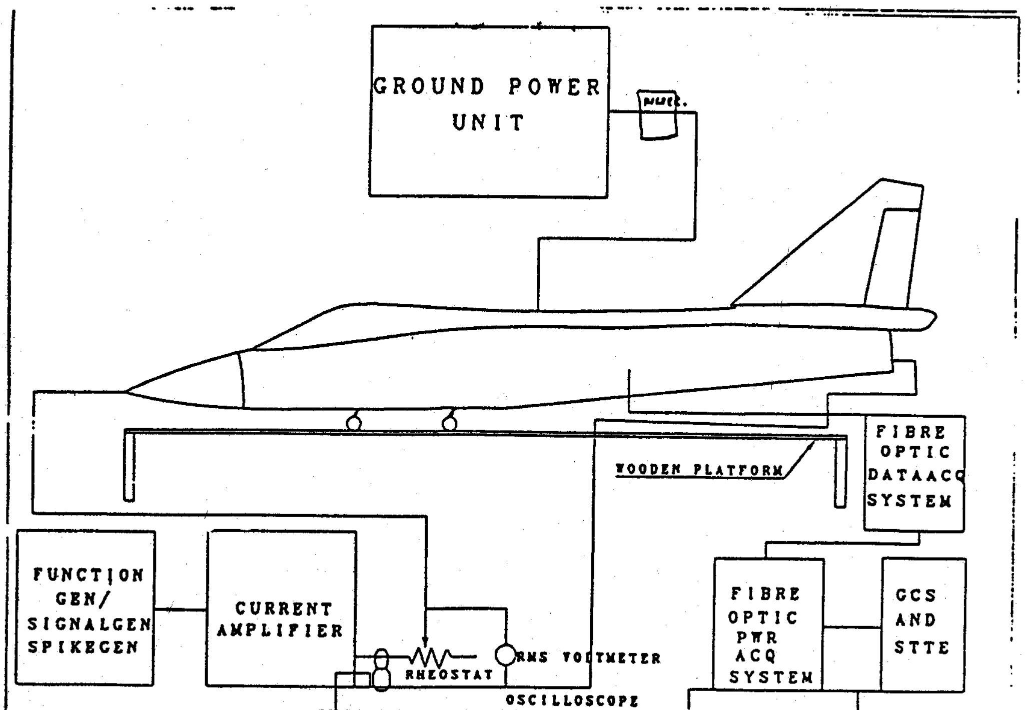


FIG GROUND PLANE INTERFERANCE/SUSCEPTIBILITY TEST SETUP