Chapter 1

INTRODUCTION

1.1 Introduction to Ruggedised Electronics:

Ruggedised Electronics is very distinct from perspective of its quality standards as compared to industrial/commercial electronics. Ruggedised Electronics should have qualities like land-worthiness, sea-worthiness & air-worthiness and it should function properly in dense Electromagnetic Interference (EMI) environment without polluting the environment further by emitting radiation into it. Essentially it requires the R & D and manufacturing set up to meet the specialised needs of ruggedisation. The state-of-the-art electronics is designed to comply with stringent quality standards required for the robust design [1, 2]. For any product to reach at this stage, it is essential that reasonable amount of resources are dedicated for undertaking R & D, ruggedisation and concurrent engineering of the same. Design of Electronic Product is a very long drawn-out process, starting with identification of needs for ruggedisation, formulation of specifications for equipment, validation / evaluation and testing of the equipment as per the standards, modification and up-gradation, if any and thereafter freezing of the design for the product and finally installation & commissioning of the equipment at end user sight. The redundancy of critical state-of-the-art electronics could be also an important aspect in electronics in which the rate of failure of electronic system is minimized to attain more adequate safety margin. The failure rate, MTBF and Reliability prediction of ruggedised electronic products is absolutely necessary. The product designed is required to be subjected to various climatic test conditions such as temperature extremities, humidity conditions, high altitude conditions, corrosion, mould growth conditions, dynamic test conditions, viz bump, shock and vibration, which equipment may face during tenure of its storage or operational life. The test reports by national laboratories, on previously conducted environmental and dynamic tests on various communication systems present probable faults/ damages as an outcome of tests and conceptual technical approach to overcome these faults. This may lead to development of new innovative ruggedisation methodologies to be implemented on electronic products.
Most of the electronics used should be compatible with very stringent specifications for Electromagnetic Interference /Electromagnetic Compatibility (EMI/EMC) standards [18]. Radiation from RF/ Mobile phone, cell towers and electronic equipment produces hazardous effect on human organism and contributes to health problems [37-39]. The electromagnetic interference is defined as any electromagnetic energy, be it radiated, induced, or conducted, which degrades the performance of any electronic equipment in the vicinity and also causes several harmful effects on environment, human body etc. Electromagnetic changes in the environment can adversely affect the energy balance of the human organism and contribute to diseases. We are surrounded by stress-producing electromagnetic fields generated by the electrical wiring in homes and offices, wireless equipments, televisions, mobile telephones, computers and video terminals, microwave ovens, overhead lights, high voltage power lines, and the hundreds of motors that can generate higher than normal electromagnetic field [39]. EMI can also affect electronic and communication systems badly [19]. Hence efforts should be taken to minimize these radiation levels within safer limits and the product is required to comply with EMI/EMC test conditions as well. The awareness regarding RF Audit and these emission standards on the part of the policy makers at the governmental level will help to a great extent to formulate the EMI/EMC requirements, which can be made mandatory for the manufacturers of electronic equipments. Compliance with these Radiation Standard requirements regarding EMI/EMC will go a long way in alleviating the problems associated with the medical hazards faced by the society which is one of the aspects of ruggedisation.

1.2 Ruggedisation Aspects:

In the implementation, right from the beginning the process of ruggedisation starts. Ruggedisation means making the product sturdy, robust and suitable to meet the various stringent requirements. Ruggedisation starts with selection of MIL Grade components like resistance, capacitors, ICs, and transistors etc. In case these categories are not available, the Environmental Stress Screening [ESS] / Burn-In procedures may be undertaken on the components/ PCBs and various Screening procedures are adopted to improve the MTBF and reliability of Electronic Product [3, 4].

Specialized PCB design techniques, soldering and wiring techniques are required to be adopted to fabricate the electronics on card level. For ruggedised enclosures/cabinet designs,
special techniques such as using Gaskets for EMI protection and ingress protection need to be
undertaken to house the electronics in the cabinet [22-25]. The environmental testing is also
undertaken on finished electronic product to meet various requirements. Sophisticated design and
engineering techniques are undertaken in order to make the strategic electronics completely
ruggedised to suit the required environment [43, 44].

Ruggedised electronics, if used in defence sector may play a vital role in defence communication
systems in fighting the war effectively and efficiently with fewer sacrifices of intelligent
manpower resources. But to meet the stringent and challenging requirements, equipment has to
be ruggedised and highly strategic as well. The communication systems that are to be used in
harsh environment and also exposed to electromagnetic interference are generally called as
strategic communication systems.

The study of this research work primarily focuses on ruggedisation methodologies for
electronic products that find end user applications in defence area or similar stringent
environment like automotive industries.

1.3 Background and Motivation:

From the summary of the introduction in section 1.1, following areas for research are
identified after reviewing the reference papers, reports and discussion with defence electronics
industry:
1) Environmental Stress Screening (ESS) / Burn-In, Screening environment and typical failure
   mechanisms, 2) Equipment design methodology and compatibility for EMI/EMC, 3) Equipment
design methodology and compatibility for Environmental & Dynamic conditions, 4) Equipment
design methodology and compatibility for Ingress Protection, 5) Equipment compatibility for
Corrosion and Mould Growth conditions, and 6) EMI/EMC considerations for PCB design.

Discussions have been carried out regarding compatibility requirements of ruggedised
equipments with different manufacturers such as Defence Electronics Manufacturers Association
(DEMA), Powertek, Defence Institute of Armament Technology (DIAT), Maharashtra
Electronics Corporation Ltd. (MELTRON), DRDO/DRDL, BEPL, Pune etc. Integrated approach
of using concurrent engineering practices for developing the methods of ruggedisation for typical
strategic Communication System (GPS VTS) is required. This process of ruggedisation involves
the use of recent technologies, materials and innovations. Piecemeal experimentations and
observations have been conducted for the compliance of various standards by equipment designers, however comprehensive and integrated study of new methods that can be evolved to meet stringent requirements of ruggedised equipment is needed. The research is undertaken after adopting integrated approach in the various research areas. The GPS based Vehicle Tracking System Models (GPRS and SMS based) are proposed as strategic Communication System models after discussion with defence equipment manufacturers and literature review for validation and testing of ruggedisation methodologies. The publication details on GPS based vehicle tracking systems are available [45, 46] however, the more integrated research work is needed on ruggedisation of GPS based Vehicle Tracking Systems. There is a high potential at national level for research work on development and implementation of ruggedisation of GPS VTS systems and its probable end user applications in stringent environment such as defence sector and automotive sectors. With these issues in background and motivation from various references & different discussions, the problem statement for multidisciplinary research work is framed with primary focus on ruggedisation. With relevant theoretical background, practical implementations and tests specifications, the validation results for ruggedisation methodologies on GPS VTS Models are presented in the chapters to follow.

1.4 Aims and Objectives:

1.4.1 Global Objectives:

Main objective of this research work is to develop ruggedisation methodologies for strategic Communication System. It involves the following:

- Study of the present standards, methods and their comparison with the present systems,
- To explore, expand and devise new strategic methodologies of ruggedisation,
- To arrive at decisions on scope, area wise for different methods that can help to devise new methods by using recent technology, materials & innovations, and
- To carry out simulations and practical experimentation to validate the ruggedisation methodologies proposed.

The research work is undertaken after adopting integrated approach to meet the stringent requirements of equipment design methodologies and compatibility for standards such as Electromagnetic Interference / Electromagnetic Compatibility (EMI/EMC), environmental
stress screening (ESS), Environmental test conditions, Ingress protection, Corrosion and Mould growth protection. The developed ruggedised system need to be compatible to all these standards. The tests include Environmental, Dynamic, Corrosion, Mould growth, Radiated / Conducted Emission and Susceptibility, ESS and Burn-in, etc. [1-5], [18]. The objective of the research is also to analyze the effect of all these tests on the equipment leading to probable damages/failures in the system for which cognizance must be taken in the design for improvement of reliability of the equipment to make the equipment compatible with stringent requirements. The outcome of these tests may be probable damages like failure of semiconductor devices & components, destruction of electronic circuits, breakage of PCB, damages in the enclosures, drift in the specifications / parameters, functional impairments, malfunctioning of the equipment, etc.

1.4.2 Detailed Objectives:

The strategic GPS based Vehicle Tracking Systems (SMS based and GPRS based) used for positioning and localization are proposed as the Models for the research work. The detailed objectives of this research proposal are as follows:

- To Implement & test GPS VTS Models (GPRS & SMS based).
- To develop and implement different ruggedisation methodologies for GPS VTS Models.
- To predict Failure Rate, MTBF and Reliability for GPS VTS Models.
- To use simulation tools, viz Matlab, ANSYS for investigating ruggedisation methodologies proposed.
- To validate its ruggedisation aspects by conducting the various tests as per Environmental, Dynamic standards.
- To validate the ruggedisation methodologies implemented for GPS VTS Models for EMI/EMC Standards.
- To conduct EMI/ EMC tests to investigate Radiated and Conducted Emission levels from GPS VTS models and reduce them to safety level for human being to minimise health hazards [37].

The GPS VTS Models with various ruggedisation methodologies proposed need to be compatible with following standards:

- Environmental Stress Screening (ESS)/ Burn-In, (MIL-LBD 8214),
- Environmental, Corrosion and Mould Growth standards (MIL-810 / JSS-55555),
EMI/EMC standard (MIL-461E).

The reference test specifications are proposed for the category in which equipment installed in ground based wheeled vehicles with partially-protected conditions for Army based applications [1]. The test results would be analysed further to decide the compatibility of the model with these standards. Finally objective of this research work is also to freeze a specific approach for ruggedisation of strategic GPS Based Vehicle Tracking system, end user application of which could be in Army based wheeled vehicles or stringent automotive applications.

1.5 Scope of Work:

The scope of work includes the implementations of GPS VTS Models, development of different ruggedisation methodologies for GPS VTS Models and its validation / testing as per specifications of different standards.

1.5.1 Methodologies and Techniques proposed:

In the process of research work different ruggedisation methodologies shall be implemented on the GPS VTS Models (GPRS and SMS based) and performance would be validated by using any of the following techniques:

i) Simulation by software like ANSYS, Solidadge, Pads and Matlab, etc.

ii) Validation of Ruggedisation methodologies are to be undertaken by laboratory testing at some of the national laboratories such as ETDC, Pune, ARAI, Pune, SAMEER, Mumbai, ERTL, Mumbai, BEPL, Pune or at some of the local laboratories where sufficient testing facilities are available.

iii) Field Trials at different places.

iv) Results of previously conducted tests/trials for particular methodology would be considered as a reference. As there are constraints on conducting all the tests in the laboratories to prove the methods and concepts, testing would be undertaken partly by simulation and partly by laboratory testing / field trials.

1.5.2 Proposed List of ESS/ Burn-In, Environmental, Dynamic and EMI/EMC Tests:

The validation of GPS VTS Models is proposed in research work by conducting following tests on components / PCB and GPS VTS models:

(a) ESS/ Burn-In tests on Components/ assembled PCB [3-4]:
   • Temperature Cycling and Burn-In
(b) Environmental, Dynamic tests (Operational / Storage) [1-2]:

- Low Temperature
- High Temperature
- High Altitude
- Solar Radiation
- Tropical Exposure
- Mould Growth
- Corrosion (Salt spray)
- Vibration
- Drop
- Toppling
- Bump
- Shock

(c) EMI/EMC Tests [18]:

- Radiated Emission
- Conducted Emission
- Radiated Susceptibility
- Conducted Susceptibility

(d) Ingress protection Tests [5]:

- Ingress of Dust
- Ingress of Water (Drip proof)

1.6 Organization of Thesis:

Chapter 1 – Introduction

This chapter introduces various aspects related to ruggedised electronics and also highlights on the environmental standards and EMI /EMC standards for compatibility requirements. The chapter explains, need to minimize radiated emissions for minimizing the medical hazards faced by the society. It also outlines the necessity of ruggedisation methodologies to be implemented on a typical strategic communication system for ensuring compatibility requirements. At the end,
the motivation and global / detailed objective are laid down to convey scope of research work. It concludes with organizational aspects of thesis report.

Chapter 2 – Review of Literature Survey

The chapter contains theoretical propositions, methodology and implementation details from various articles in international and national journals, conferences, seminars, workshops, and standard textbooks. Various technical papers related to methodologies, testing and compatibility requirements with environmental standards, ESS, burn-in procedures, EMI EMC standards are referred. Also military standards related to environmental conditions, EMI EMC conditions are studied. The chapter also outlines the survey of various applications notes & datasheets related to the entities and devices used in the GPS VTS Models. The summary of literature review is presented in this chapter. In the concluding remarks, the area of research is identified and need of investigation is outlined.

Chapter 3 - Practical Models, Strategic Communication System, GPS Based Vehicle Tracking System (SMS & GPRS based)

The chapter outlines the functional block schematic, the working and the implementation of GPS VTS Models. The section also discusses the technical specifications and features related to the devices and entities used for GPS VTS Models. It specifically explains the working and implementation of GPS VTS Model I (SMS based), GPS VTS Model II (GPRS based) and GPS VTS Model III (Mobile SMS based). The chapter outlines functional modifications suggested in present GPS VTS (GPRS based) model with the incorporation of DGPS and Mobile Wi-Max technology. At the end, the applications and the future scope for GPS VTS Models are discussed.

Chapter 4 – Ruggedisation Methodologies Proposed for GPS VTS Models

The chapter outlines ruggedisation methodologies proposed for GPS VTS Models to meet compatibility requirements with environmental, dynamic and EMI EMC test standards. Initially, the theory and mathematical equations related to EMI/EMC are outlined, and the shielding parameters for HE 30 and HE 9 enclosures are simulated using MATLAB. The sources of EMI and its hazardous effect on human beings are also discussed. The chapter also discusses selection of material for enclosures, conductive gaskets, honeycomb mesh and other methodologies. The design and implementation of HE 30 and HE 9 Enclosures is presented. The simulation of HE 30 enclosure for finite element analysis (FEM) using ANYSYS is elaborated. The chapter also discusses about methodologies such as conformal coating, heating mats, shock mounts, etc.
The section ends with summary of ruggedisation methodologies proposed and implemented on GPS VTS models.

**Chapter 5 – Reliability Improvement using ESS and Burn-In on GPS VTS Models**
The chapter outlines need of ESS / burn-in on electronic products. Various failure rates, MTBF and reliability models for different electronic components are discussed. The reliability prediction for GPS VTS Models is also presented. The chapter presents mathematical models for screening parameters. At the end, the parameters proposed for ESS and Burn-In for GPS VTS Models are outlined. The test results for ESS / burn-in on GPS VTS Model PCBs are presented.

**Chapter 6 – Validation, Testing and Compatibility of GPS VTS Model for Environmental and Dynamic Standards.**
The chapter gives the summary of environmental tests conducted on GPS VTS Models for validation of various ruggedisation methodologies. The chapter elaborates on the specifications and the requirements of different environmental and dynamic tests conducted on GPS VTS Models. It outlines the test results and the proposed ruggedisation methodologies for GPS VTS Models. It also outlines probable failures / damages as an outcome of the test. The environmental tests include extreme temperature conditions, dynamic conditions like vibration & bump, high altitude conditions and ingress protection conditions, etc.

**Chapter 7 – Validation, Testing and Compatibility of GPS VTS Model with EMI/EMC Standard.**
The chapter outlines summary of EMI/EMC tests conducted for GPS VTS models. It indicates the test results for Radiated & Conducted Emission tests conducted on GPS VTS Models with HE30 and HE9 Enclosures at local and national EMI laboratories. The test results in the form of spectra and tables are presented. The chapter also elaborates on validation of the GPS VTS Models for Conducted & Radiated susceptibility tests and Field trials conducted at national EMI test laboratory and TV Tower location. The chapter also presents the near field radiations for GPS VTS PCBs measured with EMI PCB scanner.

**Chapter – 8 Contributions and Future Scope**
The section highlights the contribution made to the field of ruggedisation methodologies proposed for GPS VTS Models during the research work & the future scope and openings available in the area of the research.

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