Electromagnetic Compatibility (EMC) Design and Testing of Unmanned Airborne Vehicles (UAV) and Systems

“Mixed Signals May Have Misguided U.S. Weapons”
Pentagon Probing Electronic Interference Also Suspected in F111 Crash During Libya Strike

“Zapping Fly-By-Wire Flight Controls”
Electromagnetic interference poses a hazard for the new electronic airliners
Airline Pilot, Dec., 1988

“Radio waves suspected in copter falls”
The Philadelphia Inquirer, Nov. 12, 1987

Background

Use of Unmanned Airborne Vehicles (UAVs) for Public Safety (such as forest fire detection) and Law Enforcement is ever increasing. Recently added applications are agricultural aerial application, specifically in industrial plantations.

Furthermore, although traditionally a topic for science fiction, use of UAVs for military (warfare) applications, is being seriously studied, while several UAVs have already been developed by various armies. Some believe the future of modern warfare will be fought by automated weapons systems. Many militaries are investing heavily in research and development towards testing and deploying increasingly automated systems.

The most prominent system currently in use is the UAV (e.g., IAI "Pioneer" & RQ-1 "Predator") which can be armed with air-to-ground missiles and remotely operated from a command center in reconnaissance roles.

It is well known and sometimes reported that unmanned airborne vehicles (UAVs) suffer from loss of control and unpredictable performance due to electromagnetic interference, or EMI.

Some unique EMC matters are pertinent to UAVs, including:

Reliance on RF channels as their sole source of command and control, such as:

- GPS
- Uplink controls from operator
- Downlink telemetry transmitter from UAV
- Downlink video transmitter from UAV

In addition, avionic components, such as flight management computers, air data system and sensors, inertial measurement unit and payload systems such as mission management computers, video or infrared cameras, EW wideband radio receivers. Armament and electrically initiated explosive devices may also be incorporated on UAVs.

Due to the nature of their operation, and the criticality of RF channels, for the operation of the UAVs, on the one hand, coupled with the fact that most UAVs are constructed from composite materials, providing minimal to no shielding, makes the EMC performance of UAVs a major challenge, both for "intra-system" (on-board) compatibility and for "inter-system" compatibility (with the external electromagnetic environment).

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Some unique EMC matters are pertinent to UAVs, particularly the reliance on RF channels with high signal capacity between operator and the UAV as their sole source of command and control, such as:

- GPS
- Uplink controls from operator
- Downlink telemetry transmitter from UAV
- Downlink video transmitter from UAV

Reliable wireless communication is therefore a prerequisite for mission success and a key factor in the work of military, police and other UAVs.

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The discipline of Electromagnetic Compatibility (EMC) is concerned with the design of Electronic Systems, while minimizing electromagnetic coupling and interference from within the system and between the system to its environment.

The discipline of electromagnetic compatibility covers and requires involvement in a wide range of other fields of engineering, mechanical and packaging engineering, electronic engineering, etc.
For adequate control of EMI in aerospace systems, and particularly in unmanned airborne vehicles (UAVs) and their associated airborne equipment, strict standards and regulations have been developed. These standards require the suppression of electromagnetic emissions from circuits and systems, and their increased immunity to externally induced interference.

Meeting the strict EMC standards, as well as ensuring the satisfactory performance of the equipment in its intended electromagnetic environment onboard UAVs requires the implementation of technical measures into the system’s design and integration on such platforms.

Proper implementation of the necessary design measures in the early stages of the design of electronic equipment and aerospace system integration, UAVs in particular, is a cost-effective approach for the control of EMI in modern electrical and electronic and systems. Such measures can and should be implemented from circuit to system as well as at the platform integration.

Interference between collocated electromagnetic emitters and sensors is a well-known and common occurrence, particularly on UAVs, densely populated with high-power broadband emitters and many sensitive receiving systems, with their multiple respective antennae collocated in close vicinity. Antenna to antenna coupling might cause interference effects ranging from temporary impairment in system performance to permanent damage in equipment. This problem is amplified and is particularly acute when multiple antennae are operated simultaneously in a relatively small area, such as that of an aircraft. Therefore, due consideration to Radio Frequency (RF) Compatibility must be given in the antenna allocation and deployment design, in frequency assignment and in time sharing of Tx-Rx pairs.

The collocation of a great number of powerful transmitters produces an intense radiated electromagnetic environment that might cause adverse health effects to personnel and inadvertently initiate Electrically Initiated Explosive Devices (EIEDs), which are abundant on airborne platforms such as UAVs, in weapon and other systems.

Of special concern are the very common cases of modifications to existing platforms, which typically consist of installation of new systems on already existing platforms. In such cases, the host platform is optimized for its initial configuration, and careful measures are required, when integrating new systems into such a platform, in order to preclude degradation of an otherwise “fragile” EM compatible platform.

**Course Objectives**

This four-day comprehensive Course provides the trainees with the necessary tools for identification, analysis and understanding of the electromagnetic phenomena in electrical and electronic equipment and systems as well as platform EMC design, integration and testing, pertaining to aerospace systems, especially focused on UAVs.

In addition, the Course is intended to teach the engineering know-how practices enabling the engineer to design the airborne system and its successful integration on
an airborne platform, in order to achieve the necessary EMC compliance, particularly with composite structures.

The Course will emphasize the basic principles and practical applications, with mathematical derivations and calculations kept to the minimum necessary.

The Course will cover most topics related to the discipline of airborne-platform EMC, which the design engineer may encounter along his daily work. This includes identification of emission and susceptibility modes, cable and shielding design, grounding and bonding, enclosure shield design and maintaining shield integrity, EMI filtering and transient protection, RF compatibility between wireless systems, lightning, static electricity and radiation hazards.

Practical solutions to practical problems, as well as “real life case studies” are used as examples, and are extensively used along the Course. Bring your interference problems and return with practical and useful solutions.

**Target Trainees**

The Course is intended for electrical, electronic, mechanical, QA and system engineers and technicians, who are involved in the design and development, integration and qualification or engineering management of aerospace, particularly UAV, electronic and electrical equipment and systems.

**Benefit to the Participants**

Participants in the Course will:-

- Comprehend the unique concerns of EMI on airborne platforms, and particularly – on UAVs
- obtain a systematic approach to equipment, system and platform EMC design, integration and testing.
- acquire a fundamental knowledge of the problem and interference sources in electrical and electronic systems and platforms
- familiarise themselves with the characteristics of the electromagnetic environment, typical of aerospace platforms

In addition, participants are encouraged to bring forward actual design problems and questions they encountered, which the instructor will attempt to assist in their solution.
About the Trainer

Elya B. Joffe – EMC Engineering Specialist

Elya Joffe is President and EMC/E³ Engineering Specialist of "Elya Joffe – Electromagnetic Solutions, Ltd. – an engineering consulting company in Israel. Elya holds a B.ScEE in Electrical Engineering from the Ben Gurion University in Israel, is a Registered Professional Engineer.

Elya Joffe is also an iNARTE (International Association for Radio, Telecommunications and Electromagnetics Engineers) certified Senior EMC Engineer, EMC MIL-STD Specialist, ESD Control Engineer and EMC Master Design Engineer.

Elya Joffe has 39 years of experience in government and industry, in EMC/E³ (Electromagnetic Compatibility/Electromagnetic Environmental Effects) for air, land and sea electronic systems and platforms. He is actively involved, as an EMC/E³ Specialist, in the EMC design of commercial and defense systems.

Elya Joffe is also well known in Israel and abroad for his activities in EMC training and education, and has authored, developed and presents many courses on Electromagnetic Compatibility and related topics. He has authored and co-authored over 30 papers in EMC and EMC-related topics, both in the IEEE Transactions on EMC and Broadcasting, as well as in the proceedings of International EMC and Product Safety Engineering Symposia.


Elya Joffe is Senior Member of IEEE, and has served as a member of the IEEE EMC Society of the Board of Directors since the year 2000 and is the Past President of the IEEE EMC Society and of the IEEE Product Safety Engineering Society.

Elya Joffe also served as a “Distinguished Lecturer” of the IEEE EMC Society, for the years 1999 through 2000.

Elya Joffe received several awards from the IEEE and EMC Society for his activities. Most notably – he is a recipient of the IEEE EMC Society “Laurence G. Cumming Award for Outstanding Service” for “outstanding Service and leadership as the Israeli IEEE EMC Chapter Chairman, contributing to the EMC standardization of commercial products in Israel, promotion of the IEEE International EMC Symposium as Chairman and Contributing to the overall success of the IEEE EMC Society” (Ca. 2002), the "Honorary Life Member Award" of the IEEE EMC Society for "outstanding service to the EMC Society in globalization, regional and international standardization, and for on-going EMC chapters and membership initiatives" (Ca. 2004), the IEEE EMC Society "Technical Achievement Award" for "over two decades of significant professional achievements in airborne and avionics EMC and printed circuit design/analysis for fast digital/analog signals and for significant contributions to the understanding of interference coupling to avionics, and RFI emissions from avionics and cost effective EMC measures for increasing systems' immunity to EMI" (Ca. 2004), the IEEE EMC Society "Symposium Chair Award" "in appreciation for
contribution as Chair of the 2003 IEEE Symposium on Electromagnetic Compatibility in Istanbul" (Ca. 2004) and the IEEE “Third Millennium Medal” “...in recognition and appreciation of valued services and outstanding contributions”.

Elya Joffe is also the recipient of the very prestigious "2006 IEEE RAB Larry K. Wilson Transnational Award" "For outstanding contribution to enhancement of the transnational character of IEEE through promotion of conferences, membership and chapter development on a regional and global basis".

Elya Joffe is a member of the very prestigious honor societies: IEEE Eta-Kappa-Nu (IEEE-HKN) and the "dB Society".

**Course Outline**

**Day 1**

**Module 1: Introduction – Why Design for EMC?**

In this Module, fundamental concepts of electromagnetics and EMC are presented. Those include:
- Nature of an EMI Problem in Aerospace Platforms System Integration
- “EMI - The Silent Threat”: A Video Presentation
- Why EMC Awareness?
- The Aerospace Platform Electromagnetic Environment
- The uniqueness of EMC concerns regarding UAVs

**Module 2: UAV-and Aerospace Applicable EMC Standards – Equipment and System**

In this Module, the basic EMC standards, especially those applicable to aerospace, and particularly UAV platforms are presented. Topics discussed include:
- Philosophy of EMC Standardization
- Overview of MIL-STD-461G – An Equipment Level Interface Standard
- Overview of MIL-STD-464C – A System Level Interface Standard
- Overview of MIL-STD-704 – A Platform Power Quality Standard
- Use of NDI and COTS Equipment in Aerospace Systems and Platforms
- Specifying and Tailoring EMC requirements
- Class Exercise: Specifying EMC Requirements for UAVs

**Day 2**

**Module 3: Aerospace Platforms and UAV EMI**

In this Module, the typical EMI sources and interference characteristics and nature are discussed. This section will also serve as the introduction to the system-level EMI control measures. Topics discussed include:
- Sources of Aerospace-system intra-system and inter-system EMI
Module 4: Integrating COTS in Aerospace and UAV Platforms

In this Module, the challenges associated with the integration of commercial/off the shelf equipment in aerospace platforms, with emphasis on UAVs, will be addressed. Topics discussed include:
- The challenge of system integration on small (and dense) platforms
- Compatibility assessment
- Verification of compliance
- Class Exercise: Evaluating compatibility of COTS in a UAV

Module 5: EMC Risk Assessment and Risk Management

In this Module, the methodology for assessing the risk associated with aerospace (and particularly UAVs) EMC, especially where platform modifications are concerned. The discussion will cover:
- Philosophy of risk management and assessment
- Assessment of risk level
- Acceptable risk?
- Risk reduction techniques

Module 6: Signals and Coupling Modes

In this Module, fundamental characteristics of signals as they pertain to EMC will be addressed. In particular, the discussion will cover:
- Common- and Differential Mode Signal Propagation
- Spectral contents of signals
- "Real-World" Components and Interconnects
- Return Current Propagation
- Transmission Line Principles and Effects

Module 7: Field and Cable Interactions

In this Module, which is one of the most important in the Course, electromagnetic interactions between cables and fields are addressed. The discussion will cover:
- Electromagnetic emissions from cables and Coupling of fields to cables
- Coupling between cables (crosstalk) and its mitigation
- Cable classification and design
- Cable Shield Design and Implementation
Day 3

Module 8: Shielding

In this Module, the need and nature of electromagnetic shielding will be addressed. The discussion will cover:

▪ Shielding Enclosures, Materials and their Nature
▪ Shielding Compromises and Aperture Control

Module 9: Grounding and Bonding

In this Module, Grounding and Bonding – two of the most important concepts in system design will be addressed. The discussion will cover:

▪ The Grounding Problem or – "What is 'Ground'?"
▪ Grounding Design Fundamentals
▪ "Ground Loops" and their Mitigation
▪ Grounding and its implication on Power Distribution Schemes
▪ Electrical Bonding

Module 10: Terminal Protection: Filtering and Transient Suppression

In this Module, terminal protection, including filtering and transient suppression are discussed. Intended to suppress conducted EMI, in particular, the techniques and their implementation will be explained. The discussion will cover:

▪ Conducted EMI and Transients on aerospace platforms
▪ of Filters and their Basic Topologies
▪ Nature of Transients
▪ Transient Protection Devices and Circuits
▪ Installation of Filters and Transient Protection Devices

Day 4

Module 11: Electromagnetic RF Compatibility in Aerospace and UAVs

In this Module, the special case of interaction between collocated transmitters and receivers will be discussed. The discussion will cover:

▪ The Electromagnetic Spectrum
▪ Spectrum Management: Frequency Allocation vs. Frequency Assignment
▪ Characteristics of Components associated with RF Compatibility Problems
▪ Mutual interference Modes in Airborne RF Systems
▪ Antenna to Antenna Coupling Analysis
▪ Antenna Placement Considerations
▪ Solutions for RF Compatibility Problems
Module 12: Electromagnetic Radiation Hazards (EMRadHaz)

In this Module, the interaction of electromagnetic fields with personnel, fuel and ordnance will be addressed, with special emphasis on hazards analysis and safety considerations. The discussion will cover:

▪ HERP (Hazards of EM Radiation to Personnel)
▪ HERF (Hazards of EM Radiation to Fuel)
▪ HERO (Hazards of EM Radiation to Ordnance)
▪ EMRadHaz Analysis & Calculation

Module 13: Lightning and Static Electricity in Aerospace Platforms

In this Module, the interaction of lightning and static electricity with aerospace platforms, particularly UAVs, and their associated equipment will be discussed, including:

▪ Lightning Interaction with Aircraft
▪ P-static Interaction with Aircraft
▪ Lightning and P-Static Protection Principles in Aerospace Systems
▪ Special issues with UAVs...

Module 14: Aerospace System EMC Checkup Methodology

In this Module, the methodology for verification of compliance of aerospace platforms, including UAVs, platform with EMC air-worthiness requirements will be addressed. The discussion will cover:

▪ Objectives and Philosophy of Equipment and System-Level EMC Tests
▪ Principles of System-Level EMC Verification
  o HERP, HERF and HERO Testing Principles
  o RF Compatibility Verification
  o Interoperability Tests
  o Engine Run Tests
▪ System-Level EMC Verification Documentation
▪ EMC Test Schedule
▪ Interpretation of Test results
▪ When could and should waivers be granted?

Module 15: Summary/Questions and Answers/Open Discussion Session

Nearing the conclusion of the course a time slot for questions and answers, and feedback from the attendees is allocated.