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Manager's Role in Electromagnetic Interference (EMI) Control

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Manager's role in EMI Control*

- What is the worst that can happen?
- When is EMI engineering most effective?
- What does EMI engineering encompass?
- Think: Source – Coupling -- Victim
- What is the cost structure of the EMI control effort?
- How is EMI activity related to project schedule?
- What EMI effort is required during the definition phase?
- What is the concept of EMI control?
- How is the EMI control effort organized?
- How will the EMI requirements be verified?
- Why is there such mystique surrounding EMI?
- Manager's Summary of EMI engineering

* Items in the presentation highlighted in **RED** are particularly important management attention items

What is the worst that can happen?

- NASA Reference Publication 1374

  "Electronic System Failures Attributable to EMI"

Catastrophic	Non-operable	Nuisance
AC-67 lightning	Wake shield expr	Space experiments
U.S.S. Forrestal	NOAA 11 & 12	Loss of data
H.M.S. Sheffield	Spacelab RAU	MRO workarounds
Blackhawk helicopter	Spacelab vacuum	COTS equipment

- Problems can be traced to lack of EMI awareness

Improper specification – lack of tailoring

Lack of equipment-level testing – increases risk

Power switching -- stability

Spacecraft charging – materials issue

Poor maintenance – bonding, gaskets

When is EMI engineering most effective?

- EMI control is most effective when applied early
  - The earliest possible consultation with EMI engineering will yield risk management and cost control benefits by tailoring EMI requirements (as required by applicable standards) to ensure that mission unique operational features are adequately addressed in proposals and bidder responses.
  - Virtually all textbooks on EMI system design stress that the longer EMI engineering gets pushed out on the schedule, the greater the impact in recovering from poor design choices. Cost is exponential with time (slide 6).
  - Evaluation of the prime contractor (NARTE certification) is perhaps the single most important early indicator of EMI control expertise– this cannot be overlooked leading into preliminary design.
  - All NASA flight project reviews must address EMI control at system and box-level.
  - Early consultation with EMI engineering will help pin-point potential sources and victims, allowing efficient embedded EMI control design.

What does the EMI engineering encompass?

- Definitions – Interference versus compliance
  - EMI: performance degradation of an equipment/subsystem due to unintentional electromagnetic coupling to/from another part of the system or environment
  - EMC: the ability of a system to perform its mission without degradation of performance, both to or from electromagnetic environments internal or external to the system
- Sub-specialties of EMI engineering
  - Circuit design layout/packaging, filter design, power-quality effects, parasitic effects of electronic components, shielding/gaskets, RF communications, EMI test methods, EMI specifications relative to limit-tailoring, grounding, bonding, P-Static, ESD, lightning, RF personnel safety, RF hazards to ordnance/fuel, multipaction, high resistive materials relative to spacecraft charging, arcing effects, anything and everything that can lead to avionic upset or damage
- What causes EMI? It's quite simple really. (Waves are waves)
  - It's all about di/dt. In the most basic sense, electric and magnetic fields (and voltage drops) are caused by accelerating charge. As the AC current frequency increases, the rate of change of the current increases, thereby increasing the radiated field intensity. There are very few universal truths in applying the EMC discipline.
  - Think: Source/Coupling/Victim

Source → Coupling → Victim

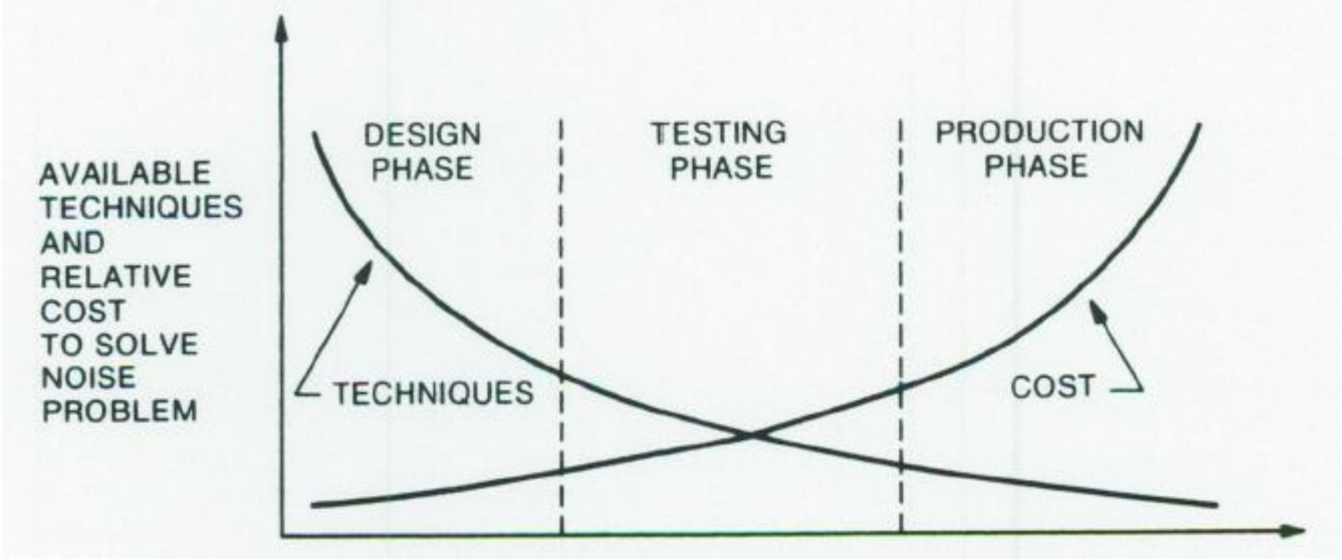
frequency control | separation | filtering/shield

EMI control options become very limited as design progresses

Early EMC Good Design Options	By PDR/CDR	Late in Program
PC board design	not likely	not possible
Logic family	not likely	not possible
Grounding	very unlikely	not possible
Filtering	possible	limited to ferrites
Shielding	possible	cable over-shields
Physical separation	difficult	no real estate
Transient suppression	possible	very limited
Wiring/cabling	possible	not likely
Connector choices	not optimal	not possible
Packaging	difficult	not possible
Thermo-mechanical	not optimal	very limited

What is the cost structure of the EMI control effort

EMI Control as Cost Avoidance*



EQUIPMENT DEVELOPMENT, TIME SCALE

As equipment development proceeds, the number of available noise-reduction techniques decreases dramatically. At the same time the cost of EMI control may grow significantly.

* FROM “Noise Reduction Techniques in Electronics Systems” by Henry W. Ott, AT&T Bell Labs, 1988.

What is the cost structure of the EMI control effort?

- Except for very large programs, full-time EMI engineers are not required, but every project needs one for 80 hours prior to RDR. What is required is the critical application of skills at appropriate times.
- Project cost (and schedule) estimates for the EMI control effort range from 2% to over 10% of the avionic budget, based on project avionic complexity, but more often by how far its application is pushed out on the schedule.
- Lack of attention in preparation for, and participation in design reviews, not only results in missed application of requirements, but equally important, misses opportunity to evaluate the expertise and authority of the contractor EMI control team that will ensure EMI requirements are adequately applied.
- Verification test results should not be a surprise, but should confirm analysis predictions that the design meets requirements. After the test verification activity begins, EMI control options are extremely limited, and cost and schedule are at risk.

EMI activity related to project schedule

• Request for proposal	• Tailoring of applicable documents
• Proposal evaluation	• Response to key EMI challenges
• Requirement Design Review	• Draft EMI Control Plan
	• Contractor personnel evaluation
	• Need for multipaction assessment
• Preliminary Design Review	• Details of design, pre-compliance
	• Baseline EMI Control plan
	• Specify wiring, filtering, shielding
	• Choose digital logic family
• Box-level EMI testing	• Catches 95% of EMI design issues
	• Iterate EMI Control Plan as needed
	• Box-level data review / analysis
• Critical Design Review	• Readiness for fab, final system test
• System testing	• Flight EMI system verification
	• Process any non-compliances
• Pre-ship Review	• Present any non-compliance that results in operational workarounds

EMI Requirements During Definition Phase

- **Define – RF environment**
  - Intentional
    - *Receivers*
    - *Transmitters*
  - Unintentional
    - *Local – on-board effect on receivers/instruments*
  - External to system
    - *Probability of occurrence*
- **Define – Power Quality**
  - Nominal
    - *Time domain, steady state and transients*
    - *Frequency domain, Audio, RF*
  - Off-nominal
    - *Special conditions, interrupt*

- **Define – Signal integrity**
  - Limit rise time
  - Limit overshoot
  - Limit timing jitter

- **Define – Tailoring**
  - Notch emissions limits
  - Notch susceptibility limits
  - Operational exclusions

- **Define – EMI Safety Margins**
  - Critical functions
  - Ordnance
  - Other

What is the concept of EMI control?

- The EMI control process is often misunderstood
  - EMI control is often thought to be only a verification process
    - It is specification, analysis, design, more analysis, then (equipment-level) test and retest (system level verification)
  - EMI engineering enables design – but does not constrain it
    - EMI engineering requires a multi-discipline approach
    - Avionics – Power system grounding, RF system, cabling, packaging,
    - Structure – bonding, fault current, lightning
    - Thermal – application/control of high resistivity materials
  - Failure to properly apply the EMI control process will result in a less robust operating system, affecting simultaneous operations, signal integrity, data rates, useful life, and the knowledge of interference vulnerabilities

How is the EMI control effort organized?

- EMI engineers most often are a subset of an electrical/avionics design organization, even though their function can be 50% quasi-quality management in nature because of multi-discipline responsibilities
- The EMI control process must have visibility at the highest levels of engineering management – this is a requirement in some EMI standards
- Most often the lead organization for EMI control is at the prime contractor, with ‘value-added’ expertise from the procuring entity, meaning this function must be in place at the very beginning of the project to be technically effective and efficient

How will the EMI requirements be verified?

- EMI requirements are first verified by analysis
  - Prior to procurement, EMI requirements must be ‘tailored’ to account for mission unique operability
  - This requires definition of the mission external environment, and the environment local to the operating platform
  - Based on power quality and RF system definitions, the EMI analysis verifies adequacy of filtering, shielding, and circuit design parameters to maintain defined safety margins and signal integrity for all required interoperability scenarios.
- EMI requirements that are defined by test
  - Qualification testing is required at the box and system level
  - If the analysis task has been adequate, test is a formality
  - Problems here are a reflection on management of the program, and cost and schedule are at considerable risk

How will the EMI requirements be verified?

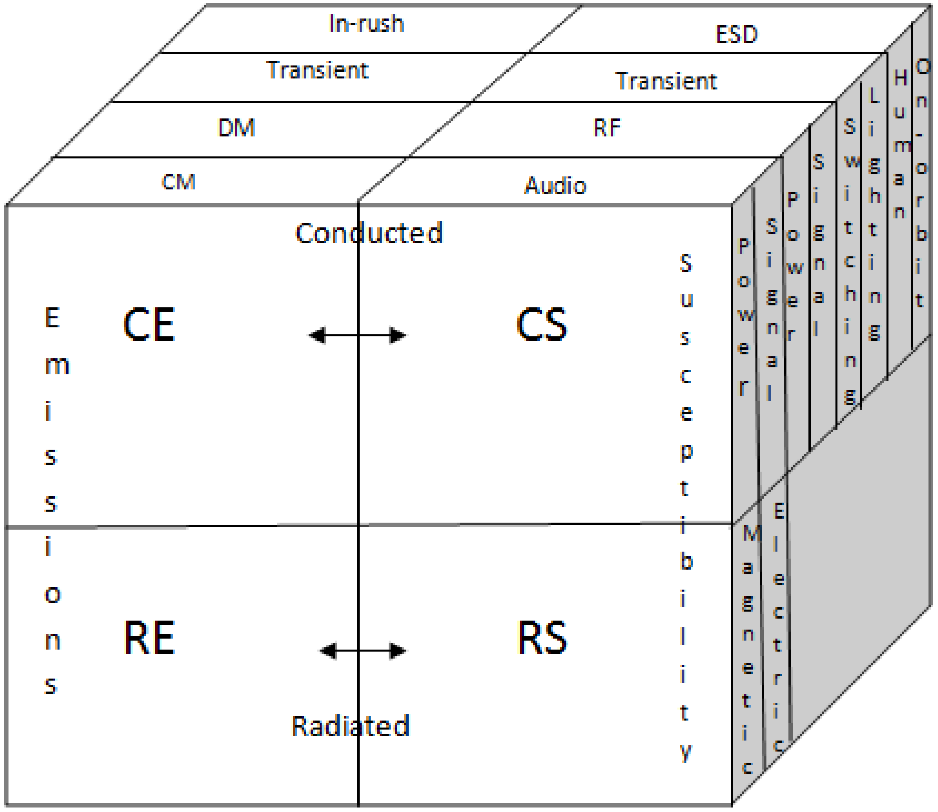
Each individual piece of equipment is required to be qualified to these test categories.

Normally this suite of tests takes one week at the box-level.

System level tests generally do not require ‘conducted’ tests unless connected to an external power source.

For space systems, radiated susceptibility is the most critical and time consuming of these required tests.

EMI Box-level test categories



Why is there such mystique surrounding EMI?

There are a multitude of variables to consider

The answer to most EMI questions is: "Well, that depends."

The reason for this is that how one designs for minimizing an EMI coupling situation on a circuit board, or in a box, is completely different than for external inter-system coupling situations.

This is because radiated near-field / far field effects may vary as 1/r3 to 1/r, and because the circuit load impedance (hi-Z or lo-Z) determines whether the coupling is magnetic field or electric field dominant (wave impedance).

If the interference coupling is conducted in nature, then determining the current path is paramount, and since current always takes the 'path of least impedance', the current paths are probably different as signal/noise frequency increases. Basic EMI control options are spectrum control, separation, filtering, & shielding.

Most electronic designers are not taught to think about circuit response beyond the schematic diagram components -- parasitic capacitance and inductance.

The latter is the 'bread and butter' of the EMI control engineer.

Management summary of EMI Engineering

- EMI control is not black magic
- It is a methodical, well documented process
- To be effective, it must be applied/funded early
- It necessarily exercises pervasive design judgment
- It augments as a quasi-quality assurance function
- It must be accountable to higher levels of authority
- It ensures highly functional designs are greatly robust
- It does not usually require huge amounts of funding
- It can have severe negative implications if ignored
- Ask your EMI engineer out to lunch