SAE Aerospace
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AEROSPACE INFORMATION REPORT

SAE AIR1221

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Electromagnetic Compatibility (EMC) System Design Checklist

RATIONALE

AIR1221 has been reaffirmed to comply with the SAE five-year review policy.

1. SCOPE:

1.1 This checklist is to be used by project personnel to assure that factors required for adequate system electromagnetic compatibility are considered and incorporated into a program. It provides a ready reference of EMC management and documentation requirements for a particular program from preproposal thru acquisition. When considered with individual equipments comprising the system and the electromagnetic operational environment in which the system will operate, the checklist will aid in the preparation of an EMC analysis. The analysis will facilitate the development of system-dependent EMC criteria and detailed system, subsystem, and equipment design requirements ensuring electromagnetic compatibility.

1.2 It should be noted that all subjects are not covered and that all items listed may not be required on a given program.

2. MANAGEMENT CONTROL REQUIREMENTS FOR THE PROGRAM:

Examples of specific requirements to be considered include:

a. Work Statement, System Specification, and other procurement documentation
b. EMC Board (charter, members, etc.)
c. Vendor Monitoring
d. Periodic Design Review
e. Milestones/Schedules

3. DOCUMENTATION AND INFORMATION REQUIREMENTS FOR THE PROGRAM:

Examples of such a list are:

a. EMC Plan, Including System-Dependent EMC Requirements
b. System Test Plan
c. EMI Threat Estimates Analysis (e.g., Vulnerability to Jamming)
d. Frequency Assignment/Allocation
e. Test Methods and Procedures

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3. (Continued):

   f. Subcontractor Requirements
   g. Subcontractor EMC Plan, Test Plan, Test Reports
   h. System Test Report
   i. Operational Environmental Criteria

      1. Electromagnetic (friendly and hostile)
      2. Physical/Dynamic

   j. Electrical Power Requirements
   k. Methods for Maintaining Configuration Control on System
   l. Packaging and Installation Criteria
   m. Cable EMC design Requirements (routing, bundling, shielding, etc.)
   n. Antenna Isolation Requirements
   o. Signal Flow Diagrams
   p. Grounding Diagrams

4. EMC VERIFICATION/CERTIFICATION REQUIREMENTS:

   List the requirements for system, subsystem, and equipment EMC verification and certification. Examples are:

   a. System Compatibility - (Inter and Intra)

      1. EMC margin
      2. Degradation criteria
      3. Operational environment susceptibility
      4. Operational demonstration

   b. Subsystem/Equipment Criteria

      1. Emission
      2. Susceptibility

   c. System Safety

      1. Personnel
      2. Ordnance
      3. Fuel/propellants

5. TYPES OF EQUIPMENT AND CHARACTERISTICS:

Tabulate the various equipment/subsystems within the system, together with the appropriate parameters thereto. Examples are:

a. Equipment Types

1. Power
2. Command/Control
3. Tracking, Telemetry, and Command (TT & C)
   (a) Radar/Tracking
   (b) Voice communications
   (c) Telemetry/Data communications
4. Guidance/Navigation
5. Attitude control/Automatic flight control systems
6. Electromechanical components and subsystems
7. Instrumentation/Sensors
8. Special purpose
   (a) ECM/ECCM
   (b) Nuclear Detection
   (c) Cryptographic
   (d) Infrared/Laser
9. Ordnance, EED's, S & A's
10. AGE/checkout

b. Characteristics

1. Duty cycle
2. Waveform
3. Power
4. Modulation
5. Frequency and required spectrum
6. Voltage/Current
7. Harmonic characteristics - Power supply
8. Sensitivity/Resolution
9. Minimum threshold responses - amplitude and duration
10. Accuracy
11. Special Provisions

6. SYSTEM APPLICATIONS, OPERATIONAL ENVIRONMENTS, AND SPECIAL CONSIDERATIONS:

Tabulate the operational environment and special considerations (such as EMS, electromagnetic security - and EMP, electromagnetic pulse, as well as intersystem restrictions) for the various subsystems/equipments of the system under consideration (see Table 1). The customer should be consulted on the extent to which the operational environment should be considered, and the resources to be applied to such studies.

TABLE 1 - Sample Tabulation

Applications	Type of Equipment	Operational Environment*	Special Considerations
Spacecraft			
Space Boosters			
Ground Support Equipment			
Ground Installations			
Ship			
Submarine			
Aircraft			

*Includes EMP, lightning, P-static, RF Ambient (friendly and otherwise), EMS, etc.

7. SYSTEMS ANALYSIS:

Utilize the following factors (as applicable) to assess the ability of the system, subsystems, and equipment (Section 5) to meet the applicable EMC criteria (Section 4) in the expected operational environment (Section 6). This will entail a comprehensive review of system design concepts, mission objectives, characteristics of supporting subsystems and their specifications, signal flow and power distribution diagrams, and equipment characteristics. Use of computer techniques and programs are strongly urged to facilitate this analysis. A sample list would be:

a. System Operational Requirements, Including Required Emissions/Receptions
b. Criticality Categories
c. Antenna Coupling
d. Far Field Coupling
e. Near Field Coupling
f. “H” Field-Power Supplies
g. Common Impedances

7. (Continued):

   h. Transients - Spikes
   i. Load Power Profile
   j. Spurious Signal Sources
   k. Multiple Point and Common Grounds
   l. Characteristics of Intra and Inter-System Signals
   m. Shielding Effectiveness of Materials for Black Boxes, Enclosures, Cabinets, etc.
   n. Predicted Susceptibility and Emission Profiles At Antennas, Ordnance Stations, and Equipment Locations
   o. Antenna Locations and Isolation Parameters
   p. Time-sharing Operational Sequences for All Equipment Modes and Required Blanking Signals and Parameters
   q. Physical Location of Other Operating Equipment or Subsystems With Estimated Shielding Effectiveness
   r. Fail-safe, Reliability, and System Safety Requirements

8. SYSTEM SPECIFICATIONS:

   Prepare individual system EMC specification requirements based on the analysis in Section 7 to ensure protection with reasonable EMC margin over the required frequency ranges. Limits must include radiated (E&H) and conductive emissions and susceptibility criteria, which must be reflected in the EMC Plan.

   Examples of analyzed characteristics and resultant limits for a system (including AVE and AGE) are:

   a. Radiated Emissions (frequency range and permissible levels)

      1. Receiver operating frequencies
      2. Sensitivities
      3. Bandwidths
      4. Operating modes

         (a) Worst-case analysis
         (b) Mission phase operational modes

      5. Spurious rejection capabilities
      6. Transient recovery time
      7. Antenna locations relative to equipment platform or compartment
      8. Antenna gains - back and sidelobe rejection
      9. Structure shielding
      10. Other RF units and circuitry - signal levels and frequency range functions
      11. Steady-state limits - broadband and cw
      12. Transient limits - establish by mission phases, possibly two or more limit curves

8. (Continued):

   b. Conductive Emissions (frequency range and permissible limits)

      1. Signal types, levels, and receptor characteristics established per 8.a.1
      2. Cable coupling
      3. Power distribution

         (a) Sharing conditioned power
         (b) Separate converters
         (c) Primary power utilization

      4. Type of regulation

         (a) Primary power
         (b) Secondary power

      5. Unit power consumption

         (a) Primary power
         (b) Secondary power

      6. Total available bus power
      7. Power circuit interfaces - susceptibility trade-off study
      8. Establish preliminary limits vs frequence

         (a) Primary power lines
         (b) Secondary power lines

   c. Conducted Susceptibility

      1. Primary power lines

         (a) Using equipments
         (b) Interfaces
         (c) Converters - inverters
         (d) Isolation - primary-to secondary power

      2. Secondary power lines (applicable only if separate power converter is used, not if all units use their own converter-regulators)

         (a) Establish desired EMC margins
         (b) Establish power converter isolation

            (1) Primary to secondary
            (2) Secondary to secondary

         (c) Direct secondary power interfaces

      3. Repeat emissions vs susceptibility trade-off study

8. (Continued):

   d. Radiated Susceptibility

      1. On-board transmitters

         (a) Frequencies - fundamental and potential spurious emissions
         (b) Power outputs, peak and average
         (c) Antenna locations and characteristics
         (d) Mission phase(s) employed

      2. Mating vehicle transmitters

         (a) Power output
         (b) Frequencies
         (c) Distance from active subsystems
         (d) Antenna characteristics

      3. Launch environment (relative to active systems)

         (a) Frequencies
         (b) Power levels

      Establish frequencies and power levels to which units are subjected. Establish radiated susceptibility limits accordingly, based on mission operational sequence.

9. EMC BASIC DESIGN PARAMETERS:

   Prepare design requirements for the system covering the following appropriate areas (include in EMC plan):

   a. Frequency Management, Allocation, and Assignment
   b. Grounding - earthing, including ground plane, ground grid, or counterpoise criteria
   c. Electrical Bonding

      1. Equipment to structure
      2. Structure to structure
      3. Special considerations for non-metallics

   d. Structural Shielding
   e. Mechanical Isolation (e.g., sliprings, flexible waveguide, etc.)
   f. Lightning Protection Requirements
   g. Static Electricity (airborne and surface)
   h. EMP Protection Requirements
   i. Equipment Location Criteria
   j. Antenna Location Criteria