

과제제안요구서

[스페이스파이오니어사업 세부과제]

“ 인공위성용 200mN급 고추력 전기추진시스템 개발 ”

인공위성용 200mN급 고추력 전기추진시스템

□ 추진배경

- 제3차 우주개발진흥기본계획에 따라 정지궤도복합위성-2호의 후속으로 차세대 정지궤도위성 개발 ('28, '29), 현재 진행중인 달궤도선 개발 사업의 마무리 이후 달착륙선('30) 및 소행성샘플귀환선('35) 사업이 추진될 계획임
 - 전기추력기는 비추력이 기존의 화학식 추력기와 비교하여 매우 높아 정지궤도 위성 또는 소행성 샘플귀환선과 같은 연료 요구량이 높은 사업에 주요 시스템으로 연구개발이 필요함
 - 차기 사업에서의 활용을 위해서는 높은 수준의 TRL을 갖는 전기추진 시스템 개발이 필요하며, 개발기간은 최소 7-10년 이상으로 예상되므로 사전 기술 확보가 필수적임
- 주요 위성선도국은 이미 전기추진시스템을 저궤도/정지궤도위성과 심우주탐사용 인공위성에서 활용하고 있음
 - 2000년대 이후에 전기추진 활용이 점차 증가하고 있으며 심우주탐사 이외의 다양한 위성에서의 활용이 확대되고 있음
 - 정지궤도위성의 궤도전이 및 궤도조정에 사용되는 화학 추진시스템을 대체함으로써 위성본체의 무게를 절감하고 이를 통해 탑재체 용량 증가 및 발사 비용이 감소됨
 - 심우주탐사 및 귀환 임무의 경우 높은 비추력 특성에 따라 전기추진의 활용 비중이 매우 높으며 이러한 임무에는 고추력/고신뢰도의 전기추진 기술은 반드시 확보가 필요함
- 국내 저궤도 소형위성용 10mN급 전기추력기 개발 및 운용을 통해 전기추진 관련 기술이 일부 확보되어 있음
 - 소형 위성용 10 mN급 홀추력기/추진시스템 개발 및 운용을 통해 전기 추진 관련 기술을 확보함
 - 정지궤도 위성 및 우주탐사에 필요한 대형 전기추력기 개발을 위한 기반 기술로 활용 가능함
 - 주요 위성선도국은 전기추력기를 활용한 저궤도/정지궤도위성과 심우주탐사용 인공 위성에 전기 추력기를 활용하고 있음

과제제안요구서(RFP)

연구과제명	인공위성용 2000mN급 고추력 전기추진시스템	
1. 연구목표		
■ 연구개발 목표		
○ 정지궤도위성용 대용량 전기추진시스템 개발	200mN급, 1,500sec, 5KW급 전기추진시스템의 우주환경시험 성능검증	
주요 요구 항목	해외선도국 성능수준 (평균치)	개발목표
Power	• 2,500 - 5,000W	• 5KW급
Nominal Thruster	• 100 - 300mN	• 200mN
Specific Impulse	• 1,730 - 2,000sec	• 1,500sec
Specific Thrust	• 50-60mN/KW	• 50-60mN/KW
Total Impulse	• 15MNs	• 1.25MNs ¹⁾
Specified Lifetime	• 15,000hrs	• 1,736hrs
Specified Cycles	• 9,415	• 500

주요 요구 항목	해외선도국 성능수준 (평균치)	개발목표
Thrust Efficiency	• 50%	• $\geq 50\%$
Flow Control Efficiency	• $\pm 5\%$	• $\pm 3\%$
Power Supply Voltage	• Input : 100V • output : 300 - 400V	• Input : 100V • Output : 1,500V ²⁾ (TBR)
Power Supply Efficiency	• 90	• $\geq 90\%$
Power Supply Voltage Slew Rate	• 5ms	• $\leq 5\text{ms}$
Propellant	• Xenon	• Xenon
Data Interface	• MIL-STD-1553B	• MIL-STD-1553B

Note:

1) 추력기의 수명시간 조건은 추력기의 종류 및 추력 값의 크기에 따라 달라질 수 있으므로, 수명시간으로 표기하기보다 총 임펄스(Total Impulse)로 표기하였으며, 국내 정지궤도위성에 활용 가능한 요구조건을 만족할 수 있도록 목표 설정.

2) 5KW급 전력공급장치의 개발사양(출력전압)은 전기추력기의 개발타입 선정에 따라 일부 변경될 수 있음. 즉, ION 전기추력기의 전원은 최대 1,500VDC(TBR), HALL 전기추력기의 전원은 최대 500VDC(TBR)로 전기추력기의 개발사양 선정에 따라 사업단과 과제수행기관의 협의하에 변경될 수 있음.

※전기추력기의 개발 타입과 위성체의 운영 규격에 따라 일부 사양은 변경 가능

2. 연구내용 및 연구성과

■ 연차별 연구내용

○ 1차년도

- 200mN급 전기추진시스템 예비 개념설계
- 5KW급, 1,500VDC(TBR) 고전압/고출력 전력공급장치 예비설계
- 해외 전기추력기 개발 전문업체와 기술 교류 및 협력체계 구축

○ 2차년도

- 200mN급 전기추진시스템 상세설계 및 기능모델(EM) 설계
- 5kW급, 1,500VDC(TBR) 고전압/고출력 전력공급장치 상세설계 및 EM 설계

○ 3차년도

- 200mN급 전기추진시스템 기능모델(EM) 조립/시험
- 5kW급, 1,500VDC(TBR) 고전압/고출력 전력공급장치 기능모델(EM) 제작/시험
- 주요 Long Delivery Parts 규격설정 및 구매

○ 4차년도

- 200mN급 전기추진시스템 기능모델(EM) 기능시험
- 5kW급, 1,500VDC(TBR) 고전압/고출력 전력공급장치 기능모델(EM) 기능시험
- 200mN급 전기추진시스템 성능검증모델(QM) 설계/제작
- 5kW급, 1,500VDC(TBR) 고전압/고출력 전력공급장치 성능검증모델(QM) 설계/제작

○ 5차년도

- 200mN급 전기추진시스템 성능검증모델(QM) 조립 및 우주환경 성능시험
- 5kW급, 1,500VDC(TBR) 고전압/고출력 전력공급장치 성능검증모델(QM) 조립 및 우주환경 시험
- 200mN급 추력기 및 추진시스템 수치해석기반의 수명 및 성능 평가
- 200mN급 전기추진시스템의 수명시험

○ 6차년도

- 200mN급 전기추진시스템의 수명시험 및 평가

■ 시험검증 방법

- 전기추력기의 기능시험 및 성능시험을 위한 테스트베드 구축
 - 200mN급 전기추진시스템의 성능 측정을 위한 측정장비 구축
 - 5kW급 전기추진시스템의 기능시험을 위한 5KW급 전원장비와 부하장비 구축
 - 5kW급 전기추진시스템의 운영모사 및 시험 모니터링을 위한 장비 구축
 - 5kW급 고전압/고출력 전력공급장치의 전도성 노이즈 측정과 모니터링을 위한 장비 구축
- 우주환경 시험시설을 활용하여 정지궤도용 고추력 전기추진시스템의 성능 검증
 - 한국항공우주연구원(TBC)의 발사환경시험 시설(진동시험, 음향시험, 등)을 활용한 전력조절기의 기계적 구조물의 내구성 시험
 - 한국항공우주연구원(TBC)의 열진공 챔버를 활용한 우주환경에서의 전력조절기 성능시험
 - 한국항공우주연구원(TBC)의 EMI/EMC 시설과 장비를 이용한 전자파 특성 시험
 - 전기추진시스템의 수명시험은 국내 시험시설/장비의 미확보시 해외시설(TBC) 이용을 고려

■ 최종성과물 및 활용방안

최종성과물	목표 체계	성과활용방안
정지궤도위성과 심우주 탐사를 위한 200mN급 고추력 전기추력기 시스템	▪ 200 mN급 고추력 전기추진시스템의 핵심기술 개발 ▪ 5KW급 고추력 전기추진시스템의 검증모델(200mN 전기추력기/5kW급 전력공급장치) 개발 ▪ 2028년 이후, 차세대 정지궤도위성을 통한 200mN급 전기추진시스템의 우주인증(체계사업) 추진	▪ 2028년 이후, 차세대 정지궤도위성 천리안위성을 활용한 200 mN급 전기추진시스템의 시험운영 및 우주인증(우주 헤리티지) 확보(안) ▪ 2030년대 이후 개발할 차세대 정지궤도위성의 전기추진시스템으로 표준화 및 상용화

3. 특기사항

- (1)전기추력기의 개발 타입(HALL, ION, 등) 선정에 따라 5KW급 전력공급장치의 개발사양(출력전압)은 일부 변경될 수 있음. 즉, ION 전기추력기의 입력전원은 최대 1,500VDC (TBC), HALL 전기추력기의 전원은 최대 500VDC (TBC)로 전기추력기의 개발사양 선정에 따라 사업단과 과제수행기관의 협의하에 전기추력기의 구동을 위해 변경될 수 있음.
- (2)전기추력기의 수명시간 조건은 추력기의 종류 및 추력 값의 크기에 따라 달라질 수 있으므로, 수명시간으로 표기하기보다 총 임펄스(Total Impulse)으로 표기하고, 국내 정지궤도위성에 활용 가능한 요구조건을 만족할 수 있도록 목표 설정.

4. 연구기간 및 연구비

- (연구기간) ' 21.5.~' 26.12 (6년)
- (연구비) 200억원(중소기업 기관부담금 기준 49.9억원 포함)

(단위: 억원)

구분	2021	2022	2023	2024	2025	2026	합계
정부 지원금	5.7	22.1	37.5	37.6	30	17.2	150.1
민간 부담금	1.89	7.35	12.47	12.5	9.97	5.72	49.9
합계	7.59	29.45	49.97	50.1	39.97	22.92	200

※ 연구기간 및 연구비는 정부의 예산사정 및 평가결과 등에 따라 변동될 수 있음

제안 요청서

스페이스파이오니어사업 세부과제
인공위성용 200mN급 고추력 전기추진시스템 개발

2021. 04.

스페이스파이오니어사업단

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제 1 장. 개요

본 제안요청서는 공모를 통하여 ‘인공위성용 200mN급 고추력 전기추진시스템 개발’을 수행할 업체를 선정할 목적으로 작성한다.

제 1 절. 제안요청서의 구조

본 제안요청서는 제 2 장 ‘제안서 제출 요령’ 제 3 장 ‘기술적 요구사항’, 제 4 장 ‘기타 특수조건’ 및 특수조건 등이 요구하는 붙임의 양식 등을 포함하며, 제 2 장에서는 제안서 제출요령 및 사업관리 등 방안 등을, 제 3 장 및 제 4 장에서는 참여업체가 수행해야할 업무 및 조건 등을 정의한다.

제 2 절. 본 사업의 목표

가. 연구의 목표

인공위성용 200mN급 고추력 전기추진시스템 개발

주요 요구 항목	해외선도국 성능수준 (평균치)	개발목표
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Propellant	• Xenon	• Xenon
Data Interface	• MIL-STD-1553B	• MIL-STD-1553B

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- 2) 5KW급 전력공급장치의 개발사양(출력전압)은 전기추력기의 개발타입 선정에 따라 일부 변경될 수 있음. 즉, ION 전기추력기의 전원은 최대 1,500VDC(TBC), HALL 전기추력기의 전원은 최대 500VDC(TBC)로 전기추력기의 개발사양 선정에 따라 사업단과 과제수행기관의 협의하에 변경될 수 있음.

나. 최종 성과물 및 활용 체계

최종성과물	목표 체계	성과활용방안
정지궤도위성과 심우주 탐사를 위한 200mN급 고추력 전기추력기 시스템	200 mN급 고추력 전기추진시스템의 핵심기술 개발 5KW급 고추력 전기추진시스템의 검증모델(200mN 전기추력기/5kW급 전력공급장치) 개발 2028년 이후, 차세대 정지궤도위성을 통한 200mN급 전기추진시스템의 우주인증(체계사업) 추진	2028년 이후, 차세대 정지궤도위성 천리안위성을 활용한 200 mN급 전기추진시스템의 시험운영 및 우주인증(우주 헤리티지) 확보(안) 2030년대 이후 개발할 차세대 정지궤도위성의 전기추진시스템으로 표준화 및 상용화

제 3 절. 주요 용어 및 약자

○ 기술자료 : 메모, 서신, 영상 및 음성 기록물, 사진, 설계, 컴퓨터 S/W, 공정(절차)서 및 계약서 등 일체의 자료 및 정보

- KARI Korea Aerospace Research Institute
- COC Certificate of Conformity
- DR Design Review
- EPS Electric Propulsion System
- ETU Electric Thruster Unit
- FCU Flow Control Unit
- ICD Interface Control Drawing 또는 Document
- LVM Latch Valve Module
- MRR Manufacturing Readiness Review
- NCR Non Conformance Record
- OBC On-Board Computer
- PPU Power Processing Unit
- KIP Key Inspection Point
- MIP Mandatory Inspection Point
- S/C Spacecraft
- SCD Source Control Drawing
- TBD To Be Determined

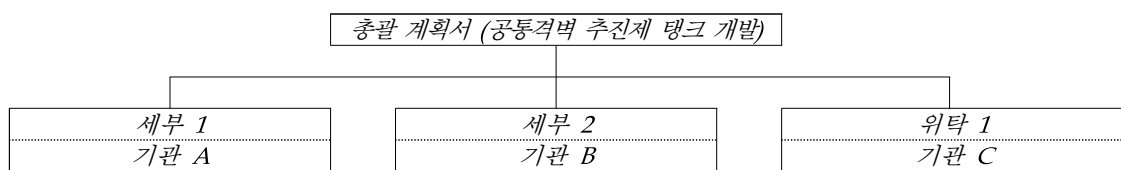
○ TBR	To Be Resolved
○ TBC	To Be Confirmed
○ TRR	Test Readiness Review
○ PTR	Post Test Review
○ S/C Bus	Spacecraft Bus
○ EDC	Effective Date of Contract
○ ECO	Engineering Change Order
○ KO	Kick Off Meeting
○ SRR	System Requirement Review
○ PDR	Preliminary Design Review
○ CDR	Critical Design Review
○ PSR	Pre-Shipment Review
○ MRR	Manufacturing Readiness Review
○ TRR	Test Readiness Review
○ XFU	Xenon Feed Unit

제 2 장. 과제계획서 제출 요령

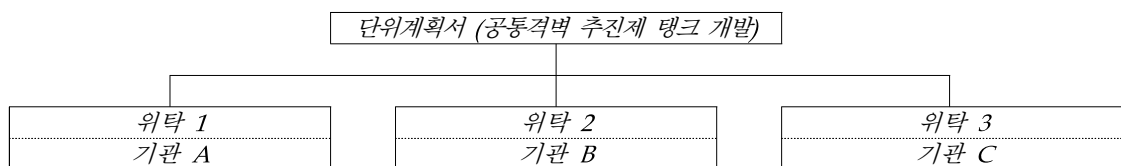
제 1 절. 작성 과제계획서 양식 안내

붙임의 ‘2021년 국책연구본부 신규 계획서 양식’에 작성하되, 참여기업은 사업의 추진 구조에 따라 각각 총괄, 세부, 위탁, 단위 과제계획서를 제출하여야 한다.

<참고> 컨소시엄 구성 시



<참고> 단독 기업/기관 제안 시



제 2 절. 과제계획서 작성 목차

과제계획서는 2021년 국책연구본부 신규 계획서 양식을 기준으로 하여 아래에서 명시한 각각의 세부 항목은 모두 포함하여야 한다.

1. 연구개발과제의 필요성
2. 연구개발과제의 목표 및 평가 기준, 설정 근거
3. 연구개발과제의 내용, 추진체계 및 일정
 - 1) 연구개발과제의 내용
 - 총괄과제 개발 대상 설계 및 세부 개발안
(요구조건에 대한 Compliance Matrix 포함)
 - 검증계획
 - 업무 범위 (RFP 제3장 제3절의 납품목록 포함)

- 제작, 조립 및 시험 계획
- 공정 및 품질관리 방안
- 2) 연구개발과제의 추진체계
 - 사업관리 방안
 - 사업실패 대응계획 (Back-up Plan)
 - 품질인증 체계
 - 우주급 부품 (구성품) 조달계획 (구매관리)
 - 중점관리품목 및 위험요소 관리 방안
 - 자체개발분야 기술의 세부개발안
 - 하청생산 및 위탁 연구 계획 (필요시)
- 3) 추진 일정 (아래 일정 포함)
 - SRR (System Requirement Review)
 - PDR (Preliminary Design Review)
 - CDR (Critical Design Review)
 - MRR (Manufacturing Readiness Review)
 - TRR (Test Readiness Review)
 - PAT (Pre-Acceptance Test)
 - PSR (Pre-Shipment Review)
 - FAT (Final Acceptance Test)
- 4. 연구개발성과의 활용방안 및 기대효과
 - 1) 연구개발성과의 활용방안
 - 2) 연구개발성과의 기대효과
- 5. 연구수행역량 (연구개발기관 현황 및 역량 포함)
- 6. 연구개발비 사용에 관한 계획
- 7. 연구개발 안전 및 보안조치 이행계획
- 8. 연구개발성과의 사업화 전략 및 계획

제 3 절. 과제계획서 평가 지표 (안)

평가항목	평가 주안점	배점
연구계획 (30)	연구주제안내서(RFP)와의 부합성	10
	연구목표의 명확성 및 달성 가능성(타당성)	10
	연구내용 및 추진체계의 합리성 (컨소시엄 구성 적절성 확인 포함)	10
체계연계성 (30)	체계연계를 위한 중점기술개발 방안 및 구체성	15
	체계연계를 위한 계획의 구체성 ◦ 체계연계에 대한 리스크 식별 및 대응방안이 우수한가?	15
연구역량 (20)	참여기관 실적의 우수성, 적합성 및 수행능력 평가	10
	참여기관의 재무 건정성 및 신뢰성	5
	참여연구원 구성의 적절성	5
결과활용 (20)	연구결과 활용가능성 및 파급효과	10
	연구결과와의 실용성 및 적용방안의 구체성	10
합 계		100

제 4 절. 컨소시엄 또는 기술이전

사업제안기관은 “붙임#5. 한국항공우주연구원 전기추진시스템 개발을 위한 보유기술”에 제시한 기술을 고려하여 컨소시엄을 구성하거나 기술이전 형태로 사업추진계획을 제안할 수 있다.

제 3 장. 기술적 요구사항

제 1 절. 요구조건

본 제안 요청서의 붙임#2와 붙임#3의 요구조건에 근거하여 설계, 세부 개발안과 Compliance Matrix와 Verification Matrix를 작성한다.

붙임#2 “인공위성용 200mN급 고추력 전기추진시스템 개발사양서 (SPOO-SP-EPS-001)”

붙임#3 “품질인증요구규격서(General Unit Product Assurance Requirements) (SPOO-D0-800-002)”

제 2 절. 요구사항

가. 성능 요구조건

Model Items	성능 요구조건
Nominal Thruster	200mN
Specific Impulse	1,500sec
Total Impulse	1.25MNs
Efficiency	50%
Power	5KW급

나. 개발요구사항

주요 요구 항목	개발목표
Power	• 5KW급
Nominal Thruster	• 200mN
Specific Impulse	• 1,500sec
Specific Thrust	• 50-60mN/KW
Total Impulse	• 1.25MNs ¹⁾
Specified Lifetime	• 1,736hrs (TBR)
Specified Cycles	• 500
Thrust Efficiency	• ≥50%
Flow Control Efficiency	• ±3%
Power Supply Voltage	• Input : 100V • Output : 1,500V ²⁾ (TBR)

주요 요구 항목	개발목표
Power Supply Efficiency	• $\geq 90\%$
Power Supply Voltage Slew Rate	• $\leq 5\text{ms}$
Propellant	• Xenon
Data Interface	• MIL-STD-1553B

Note:

- 1) 추력기의 수명시간 조건은 추력기의 종류 및 추력 값의 크기에 따라 달라질 수 있으므로, 수명시간으로 표기하기보다 총 임펄스(Total Impulse)로 표기하였으며, 국내 정지궤도위성에 활용 가능한 요구조건을 만족할 수 있도록 목표 설정.
- 2) 5KW급 전력공급장치의 개발사양(출력전압)은 전기추력기의 개발타입 선정에 따라 일부 변경될 수 있음. 즉, ION 전기추력기의 전원은 최대 1,500VDC(TBC), HALL 전기추력기의 전원은 최대 500VDC(TBC)로 전기추력기의 개발사양 선정에 따라 사업단과 과제수행기관의 협의하에 변경될 수 있음.

다. 연차별 목표 및 평가지표 (예시)

평가항목	가중치(%)	연차	연차별 목표 (조건/환경)
(정성) 200mN급 전기추진시스템 개발 추진 현황	20	1차년도 (1단계 1차년도)	전기추진시스템 예비설계 - 전기추력기(헤드부/Cathode/Neutralizer/공급장치)/수치해석 - 고전압 전력공급장치
		2차년도 (1단계 2차년도)	전기추진시스템 상세설계 - 전기추력기(헤드부/Cathode/Neutralizer/공급장치)/수치해석 - 고전압 전력공급장치 상세설계 전기추력기/전력공급장치의 기능모델(EM) 설계
		3차년도(단계) (1단계 3차년도)	전기추력기(헤드부/Cathode/Neutralizer/공급장치) EM 제작 전력공급장치의 EM 제작/시험 수치해석 기반의 수명시험/성능분석 준비
		4차년도 (2단계 1차년도)	전기추진시스템의 EM 기능 및 통합시험 - 전기추력기(헤드부/Cathode/Neutralizer/공급장치) EM 시험 - 전력공급장치의 EM 시험 전기추력기(헤드부/Cathode/Neutralizer/공급장치) QM 설계/제작 전력공급장치의 QM 설계/제작 수치해석 기반의 수명시험/성능분석
		5차년도 (2단계 2차년도)	전기추진시스템의 QM 우주환경 통합시험 - 전기추력기(헤드부/Cathode/Neutralizer/공급장치) QM 시험 - 전력공급장치의 QM 시험

평가항목	가중치(%)	연차	연차별 목표 (조건/환경)
			수치해석 기반의 수명 및 성능 분석
		6차년도(최종) (2단계 3차년도)	수치해석 기반의 수명시험/성능분석 전기추진시스템의 QM 수명시험
(정성) 200mN 급 전기추력기 (헤드부 / Cathode/Neut ralizer/공급장 치) 설계/개발	20	1차년도 (1단계 1차년도)	전기추력기 초기모델 설계/제작/검증 시험 (50 mN 급) 전기추력기 형상 및 자기장 설계(200 mN 급)
		2차년도 (1단계 2차년도)	전기추력기 DM 개발 및 EM 설계
		3차년도(단계) (1단계 3차년도)	전기추력기 EM 제작/조립
		4차년도 (2단계 1차년도)	전기추력기 EM 시험 및 QM 형상/자기장 설계
		5차년도 (2단계 2차년도)	전기추력기 QM 개발 및 성능평가 QM 전력/추력기 통합시험
		6차년도(최종) (2단계 3차년도)	QM 전력/추력기 통합시험(계속) 및 수명시험
(정량) 5KW급 고전압/고출력 전력공급장치 개발	20	1차년도 (1단계 1차년도)	5kW급 고전압 전력공급장치의 예비설계 - Anode, Cathode의 전원 예비설계 회로 - 추력기 사양에 따라 최대 1.5KV(TBR) 출력 - 전원 변환 효율: 90% 이상
		2차년도 (1단계 2차년도)	5kW급 고전압 전력공급장치의 상세설계 - Anode, Cathode의 전원 상세설계 회로 - 추력기 사양에 따라 최대 1.5KV(TBR) 출력 - 전원 변환 효율: 90% 이상 - EM 설계 도면
		3차년도(단계) (1단계 3차년도)	5kW급 고전압 전력공급장치의 EM 제작/시험 - 추력기 사양에 따라 최대 1.5KV(TBR) 출력 - 최대 5kW 출력 - 전원 변환 효율: 90% 이상
		4차년도 (2단계 1차년도)	5kW급 고전압 전력공급장치의 QM 제작 - QM 전력공급장치 설계/제작 도면
		5차년도 (2단계 2차년도)	5kW급 고전압 전력공급장치의 QM 환경시험 - 추력기 사양에 따라 최대 1.5KV(TBR) 출력 - 최대 5kW 출력 - 전원 변환 효율: 90% 이상

평가항목	가중치(%)	연차	연차별 목표 (조건/환경)
		6차년도(최종) (2단계 3차년도)	5kW급 고전압 전력공급장치의 QM 환경시험 - 추력기 사양에 따라 최대 1.5KV(TBR) 출력 - 최대 5kW 출력 - 전원 변환 효율: 90% 이상
(정량) 고전력 전기추력기 성능 시험	20	1차년도 (1단계 1차년도)	초기모델 추력 성능 평가 (추력: 50 mN @ ~1 kW)
		2차년도 (1단계 2차년도)	전기추력기 EM 방전 시험 (Power 5kW 급)
		3차년도 (1단계 3차년도)	전기추력기 EM 방전 시험 (Power 5kW 급)
		4차년도 (2단계 1차년도)	전기추력기 EM 성능 평가 (Power 5kW 급) - 추력: 200 mN (TBC) - 비추력: 1500 s (TBC) 단, EM의 추력/비추력은 사업 단과 과제수행기관의 협의하에 변경될 수 있음
		5차년도 (2단계 2차년도)	전기추력기 QM 성능 평가 (Power 5kW 급) - 추력: 200 mN - 비추력: 1500 s
		6차년도 (최종)	전기추력기 QM 수명 평가 (Power 5kW 급) - 추력: 200 mN - 비추력: 1500 s - 전충격량 : 1.25 MNs
(정량) 200mN 급 전기추진시스템의 성능 평가	20	1차년도 (1단계 1차년도)	
		2차년도 (1단계 2차년도)	
		3차년도(단계) (1단계 3차년도)	
		4차년도 (2단계 1차년도)	전기추진시스템의 EM의 기능시험 연계 평가 - 200mN 추력, 1500sec 이상 비추력 - 5kW 출력, 90% 이상의 효율 - 최대 1.5KV 출력(추력기 사양에 구동 전원 상이함) 단, EM의 추력/비추력은 사업 단과 과제수행기관의 협의하에 변경될 수 있음
		5차년도 (2단계 2차년도)	전기추진시스템의 QM의 우주환경 성능시험 평가 - 200mN 추력, 1500sec 이상 비추력 - 5kW 출력, 90% 이상의 효율

평가항목	가중치(%)	연차	연차별 목표 (조건/환경)
			- 최대 1.5KV 출력(추력기 사양에 구동 전원 상이함)
		6차년도(최종) (2단계 3차년도)	전기추진시스템의 QM의 수명시험(시뮬레이션/열진공 챔버) 평가 결과
합계	100		

○ 평가항목의 설정 근거

평가항목	목표 설정근거
(정성) 200mN급 전기추진시스템 개발 추진 현황	전기추진은 기존 화학추진 방식 대신 1,500~3,500sec 수준의 높은 비추력을 얻을 수 있어, 10배 이상의 추진연료 사용효율, 탑재 추진제 및 발사체의 질량 감소, 위성 운용시간의 증가 및 발사비용 절감 등이 있음. 개발 목표인 대용량 200mN급의 전기추력기는 세계 최고 수준의 기술이며, 차세대 정지궤도위성의 완전 전기추진시스템(Full Electric Propulsion System)의 개발을 목표로 함. 그리고 전기추력기의 개발종류(Hall, ION, 등)에 따라 200mN급의 추력을 발생하기 위한 비추력, 출력 전압/전류, 추력기의 동작에 따른 전원/전력 등은 변경될 수 있음.
(정성) 고전력 전기추력기 설계/개발	전기추력기는 전기에너지를 기반으로 고비추력을 갖는 추진시스템으로, 현재 선진국들에서 우주탐사 및 상업용 위성에 매우 활발하게 활용되고 있음. 국내의 연구개발기술은 약 수십 mN급 추력기 기술로 해외 선도연구 그룹의 수백 mN급 연구 개발 실적은 없는 상황임. 본 사업에서 200 mN급 고전력 전기추력기의 개발을 통해 저궤도에서 정지궤도, 우주탐사 임무에도 가장 폭넓게 활용 할 수 있는 필수기술로 세계적으로 우주추진 연구기술을 주도할 수 있음.
(정량) 5KW급 고전압/고출력 전력공급장치 개발	200mN급의 전기추력기 구동을 위한 전력공급장치의 최대 예상 전력. 1kW급 모듈형 전력변환장치를 기본으로 개발하여 전력공급장치의 필요 요량에 따라 모듈형 전력변환장치를 확장할 수 있는 전력공급장치로 개발할 예정. 따라서 1KW급 이내의 소형 전기추력기부터 대용량 전기추력기의 전력공급장치 개발에 활용할 수 있는 전력공급장치 개발임. 전력공급장치 개발용량: 5kW
(정량) 고전력 전기추력기 성능시험	200 mN급 전기추력기는 clustering을 통해 궤도천이 및 심우주탐사에도 활용될 수 있으며, 추력을 감소시켜 남북자세제어 등의 보다 간단한 임무에도 활용이 가능함. 현재 정지궤도 공공복합통신위성의 임무에서 요구되는 1.25MNs 수준의 전충격량과 더 높은 추력 및 비추력 값을 통해 향후 국내의 우주개발에 세계적 수준의 연구그룹과 대등한 수준의 연구를 수행 할 수 있음. Total Impulse : 1.25MNs
(정량) 200mN급 전기추진시스템의 성능평가	200mN급 전기추력기는 차세대 정지궤도위성의 완전 전기추진시스템(Full Electric Propulsion System) 개발을 목표로 정지궤도위성의 우주환경을 고려하여 성능시험을 수행. 그리고 시뮬레이션과 열진공 챔버를 활용하여 수명시험을 수행/검증할 예정임. 수명시간 : 1,736시간(TBR)

라. 시험검증방안

- “인공위성용 200mN급 고추력 전기추진시스템” 개발을 위해 EM 개발을 통한 기능구현, QM을 통한 성능검증을 수행함
- 우주환경시험은 국내 시설과 시험인력을 이용하여 진행할 예정임. 단, 국내 시험시설의 미확보시 해외 시험을 활용할 예정임
- 수명시험은 국내 시험시설이 확보되면 국내에서 시험/검증 예정임. 단, 국내 시험시설의 미확보시 해외 시험을 활용할 예정임

제 3 절. 납품항목 목록 (TBR)

가. 납품 문서 목록 (TBR)

Program Management		
SPPO-EPS-PN-01	Development Management Plan	P-EDC+1M, R-As required
SPPO-EPS-PN-02	Monthly Schedule Reports	Monthly
SPPO-EPS-PN-03	Monthly Progress Reports	Monthly
Program Assurance		
SPPO-EPS-PA-01	Product Assurance Plan	F-EDC+2M
SPPO-EPS-PA-02	EPS Verification Plan	P-SRR, R-As revised, F-CDR
SPPO-EPS-PA-03	Manufacturing Flow Diagram	P-SRR, R-As revised, F-CDR
SPPO-EPS-PA-04	Reliability Prediction Report	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-05	Part Identification List	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-06	Part Approval Document	As generated
SPPO-EPS-PA-07	Special In-process Controls Report	PSR
SPPO-EPS-PA-08	Photo Identification Report	PSR
SPPO-EPS-PA-09	Screening & Qualification Report	PSR
SPPO-EPS-PA-10	Acceptance Test Report	TRB, PSR
SPPO-EPS-PA-11	Verification Report	PSR
SPPO-EPS-PA-12	End Item Data Package	PSR
SPPO-EPS-PA-13	Assurance Status Report	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-14	Fabrication and Assembly Flow Plan	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-15	Inspection and Test Record	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-16	Limited Life Item List	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-17	Reliability Prediction	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-18	FMECA	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-19	Critical Item List	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-20	Part Stress Analysis	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-21	Worst case Analysis	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-22	Parameter Trend Analysis	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-23	Justification for Derating Rules	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-24	Materials Identification List	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-25	Process List	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-26	MUA with the following documents;	P-SDR, R-As revised, F-CDR

	- Material and/or process specifications - Evaluation plan and/or report	
SPPO-EPS-PA-27	Contamination Control Plan	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-28	Contamination Analysis Plan	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-29	Contamination Budget Report	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-30	EEE Part Plan	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-31	Part Identification List	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-32	PAD	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-33	Part Specification	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-34	DPA Procedure and Report	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-35	Radiation Assessment Report	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-36	Part Evaluation Plan and Report	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-37	User' s Manual	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-38	Safety Assessment Report	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-39	M&P Plan	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-40	M&P Identification List	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-41	RFA	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-42	M&P Specification (TBR)	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-43	M&P Evaluation Plan and Report	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-44	Software Assurance Plan	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-45	Software List	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-46	Budget Analysis of Resource	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-47	Software Test Plan and Report	P-SDR, R-As revised, F-CDR
SPPO-EPS-PA-48	Software Maintenance Plan	P-SDR, R-As revised, F-CDR
System Engineering		
SPPO-EPS-SE-01	EPS Specification	P-SRR, R-As revised, F-CDR
SPPO-EPS-SE-02	Design Review Data Package - Kick-off 1. SRR (System Requirement Review) 2. SDR (System Design Review) 3. PDR (Preliminary Design Review) 4. CDR (Critical Design Review) 5. TRR (Test Readiness Review) 6. TRB (Test Review Board) 7. EM PSR (Pre-shipment Review) 8. QM PSR (Pre-shipment Review)	Design Review
SPPO-EPS-SE-03	Design Review Report	After Design Review
SPPO-EPS-SE-04	Performance Analysis Report	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-05	Structure Analysis Report (TBR)	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-06	Thermal Analysis Report	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-07	Radiation Analysis Report	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-08	EPS Design Description	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-10	Electrical Interface Control Document	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-11	Mechanical Interface Control Document	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-12	Thermal Interface Control Document	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-13	Drawing Tree	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-14	Mechanical Engineering Drawing	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-15	Electrical Engineering Drawing	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-16	Thermal model and report	P-SDR, R-As revised, F-CDR

SPPO-EPS-SE-17	3D CAD model (STEP file format)	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-18	Structure FEM model (Nastran format) and report (TBR)	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-19	EPS Cleaning Procedure	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-20	Geometrical Measurement Report(TBR) Mechanical and optical references . Flatness . Die alignment . Pixel location . Optical distance between image plane and window	P-TRB, F-PSR
SPPO-EPS-SE-21	Electrical Measurement Report	P-TRB, F-PSR
SPPO-EPS-SE-23	Operation Manual	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-24	Part Identification List	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-25	PAD with the following documents; - Part specification - Evaluation plan and/or report	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-26	Mass Property Report	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-27	Power Budget Analysis Report	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-28	EMI/EMC Analysis Report	P-SDR, R-As revised, F-CDR
SPPO-EPS-SE-29	Design Description for EPS software (TBR)	P-SDR, R-As revised, F-CDR
System Handling & Transportation		
SPPO-EPS-SH-01	Transportation, Storage Plan and Requirement	P-CDR, F-PSR
SPPO-EPS-SH-02	Photos taken at the level of board level assembly	F-PSR
System Test		
SPPO-EPS-ST-01	Qualification and Acceptance Test Plan	P-SDR, F-CDR
SPPO-EPS-ST-02	Qualification and Acceptance Test Procedure	4 weeks before ATP
SPPO-EPS-ST-03	Qualification and Acceptance Test Data (including cal. Curve for analog signal)	2 weeks after ATP
SPPO-EPS-ST-04	Qualification and Acceptance Test Report	2 weeks after ATP
SPPO-EPS-ST-05	EMI/EMC test procedure	P-CDR, R-as generated
SPPO-EPS-ST-06	EMI/EMC test data	P-CDR, R-as generated
System Operation		
SPPO-EPS-SO-01	EPS Command and Telemetry Handbook(TBR)	P-SDR, R-As revised, F-CDR
SPPO-EPS-SO-02	Operational Handbook and Manual (including treatment of ignition material)	P-SDR, R-As revised, F-CDR

※ 상기 납품문서는 사업단과 세부과제 주관기관의 협의하에 조정될 수 있음.
또한, 작성 및 관리방법에 대해서는 사업단에서 지원/협력할 수 있음.

나. 하드웨어 개발 목록 (일정은 제안시 변경 제안 가능)

No	Item	Quantity	Delivery Date	Notes
1	EM	1 set	EDC + 40 months (TBC)	상용부품을 사용한 기능모델 개발 및 기능시험
2	QM	1 set	EDC + 67 months (TBC)	MIL 급이상의 부품을 사용한 성능시험

제 4 절. 진도점검회의

아래의 주요 진도점검회의는 본 사업 연구개발성과의 체계연계를 위해 필수적으로 판단되는 사항이며, 아래 진도점검회의 외에도 스페이스파이오니어사업단 및 관련 부처, 연구재단 및 연구개발수행기관의 요구발생시 수시로 설계 및 개발경과 관련 회의가 개최되어야 한다.

동시에 연구개발수행기관은 매달 사업단에 연구개발진도 보고서를 제출한다.

□ 주요일정

- SRR (System Requirement Review)
- PDR (Preliminary Design Review)
- CDR (Critical Design Review)
- MRR (Manufacturing Readiness Review)
- EM PTR (Post-test Readiness Review)
- QM PTR (Post-test Readiness Review)

표 4 사업 주요일정 (제안시 변경 제안 가능)

사업기간	사업일정	예정일 (TBD)	비고
2021.5.1. ~ 2026.12.31	EDC	TBD	
	SRR	EDC + 2 months	
	PDR	EDC + 7 months	
	CDR	EDC + 18 months	
	MRR	EDC + 33 months	
	EM PTR	EDC + 40 months	
	QM PTR	EDC + 65 months	
	PSR	EDC + 67 months	

※ EDC : Effective Date of Contract, 협약일

제 4 장. 기타 특수조건

본 제안요청서의 첨부#2와 본 장에서 언급하는 것에 상충하는 것이 있다면 본 장의 내용이 우선한다.

제 1 절. 연구개발수행기관의 책임 및 의무사항

연구개발수행기관은 주요 제작 공정 및 품목을 사진(연도/월/일 포함) 혹은 동영상으로 기록하여 유지한다.

제 2 절. 개발품목 시험

- 연구개발수행기관은 본 사업의 과제제안요청서에 언급된 “개발” 품목의 검증시험을 도면에 명기하여 수행해야 한다.
- 단, 검증시험 방법에 이견이 있을 시, 개발수행기관이 제시하는 방법이 당초 제안요청서에서 요구하는 방법과 차이가 없음을 입증해야 한다.
- 연구개발수행기관은 수용 가능한 경우 사업단에서 요구하는 검증시험을 추가 비용 없이 수행하고, 수행 후 2주일 내에 시험 결과를 사업단에 제출해야 한다. 요구성능 미달 시, 이에 대한 기술회의를 사업단과 수행한 후 제시된 개선책에 따라 재시험을 수행해야 한다.
- 모든 검증시험 경우, 계획서는 사전에 사업단의 승인을 득해야한다. 연구개발수행기관의 시험 항목 및 방법 변경 시는 사업단과 서면 협의 후 새로운 방법에 대한 검증이 선행되어야 한다.
- 이러한 검증시험은 연구개발수행기관에 의해 수행되거나 “연구개발수행기관과 계약을 맺은 전문 시험기관에 의하여 수행될 수 있으며, 이 경우 사업단이 지정한 검사원이 입회할 수 있다.
- 본 제안요청서에서 요구하는 계획 이외의 환경시험은 협의하여 수행한다.

제 3 절. 제품보증

- 연구개발 수행기관은 사업단의 제품보증 요구조건(Products Assurance Requirements, 이하 “PAR”) 및 사업단의 승인을 받은 연구개발수행기관의 제품보증계획서(Product Assurance Program Plan, 이하 “PAPP”)를 준수하여 “개발” 된 납품품목을 납품해야 한다.
- 연구개발수행기관은 “PAR” 및 “PAPP”에 따라 제품보증 활동을 수행해야

하며, 이에 적합한 조직과 인력을 구성해야 한다.

- 사업단은 연구개발수행기관 혹은 연구개발수행기관의 외주업체에 대한 제품 보증 활동을 주기적으로 확인 및 감독 할 수 있으며, 필요시 시정 조치를 요구할 수 있다.
- 사업단이 연구개발수행기관 혹은 연구개발수행기관의 외주업체에 대한 품질확인(MIP: Mandatory Inspection Point 포함)을 실시하는 경우, 연구개발 수행기관은 사업단이 요구하는 모든 필요한 지원을 제공해야 하며, 품질확인에 대한 승인을 득해야 한다.
- 연구개발수행기관은 “PAPP”에 따른 전 과정 및 납품품목의 품질에 대한 최종 책임을 진다.

제 4 절. 진도관리

- 연구개발수행기관은 계약 완료일까지 개발에 대한 진도보고서(일정계획 포함)를 매월 사업단에게 제출해야 한다.
- 연구개발수행기관은 위 제3장 제4절 진도점검 회의 일정에 따라 진도점검 회의를 개최해야 한다.
- 연구개발수행기관은 사업단의 요구에 따라 주간, 격주 혹은 월간 단위로 “개발” 회의를 진행하고 사업단의 요구에 따라 관련 자료를 제출해야 한다.
- 사업단은 필요하다고 판단되는 시기에 연구개발수행기관에 대한 실사를 실시할 수 있으며, 실사결과에 따라 필요시에는 연차평가 및 차년도 협약에 반영한다.

제 5 절. 도면관리

- “연구개발수행기관은 “개발”에 관련된 모든 도면이 제작 시작 전 사업단의 서면 승인이 완료되도록 지원해야 한다.
- 연구개발수행기관에 의하여 생성되는 도면은 사업단에 의한 “도면작성방법”, “도면 작성 및 배포 절차” 및 “도면번호” 등을 따르며, 사업단의 형상 관리 절차에 따라 사업단의 CDMO(Configuration Data Management Office)에 등록한다.
- 또한, 연구개발수행기관은 “PAPP”에 따른 자체 도면관리 체계를 갖추어야 한다.

제 6 절. 사업단(체계연계지원팀 등)의 기술 관리 수용

- 사업단(체계연계지원팀 등)의 세부 개발 사양 검토 및 요건이 반영되도록 하여야 한다.
- 사업단(체계연계지원팀 등)이 지정한 연구진 출입 및 관련 자료, 연구성과물 등에의 열람을 보장하고, 기술 관리가 수행될 수 있도록 지원하여야 함
 - ※ 연구개발계획서 내 기술관리를 수용할 수 있는 추진 계획을 제시하여야 함
- 최종 연구성과물의 활용도 제고를 위하여, 후속 체계사업과 관련된 제반사항(시험 등) 지원 등을 성실히 수행하여야 함

제 7 절. 해외 수출면허 규정

본 사업의 개발품은 해외 수출면허 규정의 제한을 받지 않도록 개발하여야 함.
개발 특성상 해외수출면허 부품사용이 불가피할 경우 이후 개발을 위한 대안이나 대비계획을 제시하여야 함

제 8 절. 불입

불입은 본 제안요청서의 일부로 본다.

붙임#1. 보안유지 서약서

보안유지 서약서

관 련 : 2021년도 스페이스파이오니어사업 세부과제 선정 관련
기술문서 습득

과 제 명 :

수령자 및 수령기관(이하 수령인)은 2021 스페이스파이오니어사업의 세부과제 선정과 관련된 제안요청서에 부속한 기술문서를 수령함에 있어, 본 기술문서들이 보안 및 재산적 정보로 간주됨을 인정하고 동의합니다. 본 기술문서의 수령 목적은 오로지 2021 스페이스파이오니어사업의 세부과제에 선정되기 위함이며, 수령인은 본 기술문서 상의 정보 및 검토과정에서 습득한 모든 정보와 지식을 자신의 재산적 정보를 보호하는 관리수준과 동일한 정도로 타인에게 누설되지 않도록 보호하여야 함을 인정하고 동의합니다. 수령인은 스페이스파이오니어사업단(이하 사업단)의 사전 서면 승인 없이 기술문서를 상기 관련에서 규정한 목적이외에는 사용할 수 없음을 인정하고 동의합니다. 본 기술문서 뿐 아니라 이에 기반하여 복사 또는 복제로 창출된 모든 기술적 정보는 사업단의 소유이며 세부과제 선정 과정 이후, 사업단의 서면 요청 시점으로부터 30일 이내에 수령인의 선택에 의하여 즉각 사업단에 반환되거나 파기되어야 하며, 파기의 경우 수령인은 상기 서면 요청일로부터 30일 이내에 동 요청을 이행하였다는 서면 확인서를 사업단에 제공하여야 함에 동의합니다.

2021년 4월 일

수령기관 : _____ (인)

수령자 : _____ (인)

붙임#2. 인공위성용 200mN급 고추력 전기추진시스템 개발사양서 (SPPO-SP-EPS-001)

- 별도문서

* 상세기술자료는 스페이스파이오니어사업단(한국항공우주연구원 내)에 방문, 보안서약서(붙임#1 참조) 오프라인 제출 이후 직접 수령 가능

붙임#3. 품질인증 요구규격 (General Unit Product Assurance Requirements)

- SPPO-D0-800-002 D.00, General Unit PAR_.doc



Space Pioneer Program
**Product Assurance Requirements
for General Unit**

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1. INTRODUCTION

1.1. GENERAL

1.1.1. 과제에서 합의된 요구사항에 대한 적합성 입증(Compliance Demonstration to Consensus Requirements)

- 스페이스파이오니아사업에 참여하는 장비/유닛의 개발시 요구사항(Requirements)은 RFP문서에서 정하는 기본 요구사항(General Requirements)이다.
- 세부과제 주관기관은 기본 요구사항에 추가하여 목표로 하는 실용위성 또는 목표시장에서 포지셔닝 하고자 하는 기대목표를 충족하기 위하여 추가적으로 필요한 요구사항(Voluntary Consensus Standards/Specifications)을 제안하여야 한다.
- 세부과제 주관기관은 과제에서 정한 기본요구사항과 합의된 추가하고자 입증하고자 하는 요구사항(Consensus Standards/Specifications)에 적합함을 입증(Demonstration of Compliance to Requirements)하여야 한다.

1.1.2. 사업단 참여 보장(Access Right)

- 스페이스파이오니아 사업의 목적을 위해 필요한 활동을 이행할 수 있도록 사업단 또는 사업단이 지정한 대리인이 세부과제 주관기관의 시설(협력업체 및 참여기관을 포함한다.) 및 문서에 접근(제공을 포함한다.)할 수 있도록 협조하여야 한다. 지적재산과 관련한 내용을 포함하는 경우, 비밀유지합의서(Non-disclosure agreement)와 같은 제도적 장치를 통해 문서 및 시설에 대한 접근을 보장할 수 있는 적극적인 방안을 고려하여야 한다.

1.1.3. 사실 기반 확인(Evidence based Verification)

- 세부과제 주관기관은 적합성에 대한 입증이 사실(설계, 해석, 시험, 검사, 도면, 절차서/표준서, 운용 매뉴얼/절차 등의 객관적인 증거)에 기반한 적합성 확인이 되도록 하여야 한다.

1.1.4. 적합성점검표(Compliance Summary Table)

- 세부과제 주관기관은 본 문서에 대한 적합성 입증계획 및 입증결과를 요약한 적합성점검표 (Compliance Summary Table)를 과제 착수시점에 작성하여 과제기간 동안 입증결과를 요약한 내용을 업데이트하여 재개정 관리를 이행하여야 하며, 과제종료시점에 최종본을 제출하여야 한다.

1.1.5. 프로그램 기술관리 검토회의 (Program Review)

- 세부과제 주관기관은 다음의 개발품에 대한 검토회의(Design Reviews and/or EQSR, MRR, TRR/PTR, PSR) 수행체계를 갖추어야 한다. 수행체계는 INPUT(작성문건, 발표자료 템플릿)과 OUTPUT(회의록, Action Item, Data Package)의 관리를 포함하여야 한다.
- 세부과제 주관기관은 검토회의와 관련하여 APPENDIX D를 참조한다.
- 기술관리 검토회의의 Go/No-Go Decision 권한은 사업단에게 있다.

1.2. 약어 및 정의 (ACRONYMS AND DEFINITIONS)

ABCL	As Built Configuration List
ACA	At Contract Award
AIT	Assembly, Integration, and Test
ASIC	Application Specific Integrated Circuit
ASTM	American Society for Testing and Materials
CADM	Configuration And Data Management
CCB	Configuration Control Board
CDR	Critical Design Review
CDRL	Contractual Document Requirements List
CFE	Customer Furnished Equipment
CI	Configuration Item
CIDL	Configuration Item Document List
CIL	Critical Items List
COC	Certificate of Conformance
CPPA	Centralized Part Procurement Agency
CVCM	Collected Volatile Condensable Mass
DDEF	Displacement Damage Equivalent Fluence
DDSF	Displacement Damage Sensitive Fluence
DPA	Destructive Physical Analysis
ESCC	European Space Component Coordination
EEE	Electrical Electronic, and Electromechanical
EGSE	Electrical Ground Support Equipment
EIDP	End Item Data Package
EM	Engineering Model
EMC	Electromagnetic Compatibility

EOL	End of Life
EPPL	European Preferred Part List
ESA	European Space Agency
ESD	Electrostatic Discharge
ESR	Equipment Suitability Review
FDIR	Fault Detection, Isolation, and Recovery
FM	Flight Model
FMECA	Failure Modes, Effects, and Criticality Analysis
FTA	Fault Tree Analysis
GIDEP	Government Industry Data Exchange Program
GSFC	Goddard Space Flight Center
IC	Integrated Circuit
ICD	Interface Control Document
IOC	Interoffice Correspondence
KIP	Key Inspection Point
LAT	Lot Acceptance Test
LET	Linear Energy Transfer
M&P	Materials and Processes
MGSE	Mechanical Ground Support Equipment
MIL-STD	Military Standard
MIP	Mandatory Inspection Point
MMIC	Microwave Monolithic Integrated Circuits
MPCB	Material and Process Control Board
MRB	Material Review Board
MRR	Manufacturing Readiness Review
MUA	Material Usage Agreement
NASA	National Aeronautics and Space Administration
NCR	Non-Conformance Report
NDT	Non-Destructive Testing
NPSL	NASA Parts Selection List
NSPL	MIL-STD-975, NASA Standard Electrical, Electronics, and Electromechanical Parts List
NVR	Nonvolatile Residue
PA	Product Assurance
PAD	Part Approval Document

PAPP	Product Assurance Program Plan
PAR	Product Assurance Requirements
PCB	Part Control Board
PDR	Preliminary Design Review
PEM	Plastic Encapsulated Microcircuit
PIL	Part Identification List
PIND	Particle Impact Noise Detection
PM&P	Parts, Materials and Processes
PMPCB	Parts, Materials, and Processes Control Board
PPL	Preferred Part List
PPM	Part Per Million
PSA	Part Stress Analysis
PSR	Pre-Ship Review
QA	Quality Assurance
QCI	Quality Conformance Inspection
QPL	Qualified Part List
RF	Radio Frequency
RFA	Request for Approval
RFD	Request for Deviation
RFW	Request for Waiver
SEB	Single Event Burn Out
SEFI	Single Event Functional Interrupt
SEGR	Single Event Gate Rupture
SEL	Single Event Latch Up
SEP	Single Event Phenomenon
SES	Single Event Snap Back
SET	Single Event Transient
SEU	Single Event Upset
SOW	Statement of Work
TCI	Technology Conformance Inspection
TID	Total Ionizing Dose
TML	Total Mass Loss
TRR	Test Readiness Review
TQCM	Thermal Electrically Controlled Quartz Crystal Microbalance
UV	Ultraviolet Ray

WCA Worst Case Analysis

2. APPLICABLE DOCUMENTS

Applicable documents and revision levels listed herein form a part of this document.

If any conflict arises between this PAR and those referenced, the requirements of this PAR shall take precedence and govern until resolved by KARI.

2.1. US MILITARY AND NASA DOCUMENTS

MIL-STD-750	Test Methods for Semiconductor Devices
MIL-STD-883	Test Methods and Procedures for Microelectronics
MIL-STD-889 A	Dissimilar Metals
MIL-STD-975 M	NASA Standard Electrical, Electronics, and Electromechanical Parts List
MIL-STD-981C	Design, Manufacturing and Quality Standards for Custom Electromagnetic Devices for Space Applications
MIL-STD-1547 B	Electronic Parts, Materials, and Processes for Space and Launch Vehicles
MIL-HDBK-217 F Notice 2	Reliability Prediction of Electronic Equipment
MIL-PRF-38534G	Hybrid Microcircuits, General Specification for
GSFC EEE-INST-002	Instructions for EEE Part Selection, Screening, Qualification, and Derating
NASA-STD-(I)-6001A	Flammability, Off-gassing, and Compatibility Requirements and Test Procedures

2.2. ESA DOCUMENTS

ECSS-E-30 Part 6A	Mechanical - Part 6: Pyrotechnics
ECSS-Q-ST-30-11C	Derating - EEE Components
ECSS-Q-60-11A	Derating and End-of-life Parameter Drifts - EEE Components
ECSS-Q-ST-60-02C	ASIC and FPGA Development
ECSS-Q-ST-60-12C	Design, Selection, Procurement and Use of Die-form Monolithic Microwave Integrated Circuits
ECSS-Q-ST-60-14C	Reliefing Procedure - EEE Components
ECSS-Q-70B	Materials, Mechanical Parts and Processes
PSS-01-608	Generic Specification for Hybrid Microcircuits
ECSS-Q-70-36A	Material Selection for Controlling Stress-corrosion Cracking

3. 제품보증 관리(PRODUCT ASSURANCE MANAGEMENT)

3.1. 제품보증 계획(PA PROGRAM PLANNING)

3.1.1. 제품보증 조직/책임(PA Organization and Responsibilities)

- 스페이스파이오니아사업에 참여하는 위성용 장비 개발기관(이하 "세부과제 주관기관"이라 한다.)은 책임과 권한을 갖는 제품보증 책임자(이하 "PA책임자"라 한다.)와 PA 엔지니어링(신뢰성, 안전성, 신뢰성, 재부품공정, 소프트웨어 보증) 담당자 및 PA 품질/관리(품질관리, 오염관리, 구매관리, 안전관리) 관련 담당자를 지정하여야 한다.

[주기] 우주제품은 우주사용중 수리가 어려운 1회 개발/제작/사용의 특징을 갖는 제품군이므로 개발/검증 단계에서부터 PA 책임자 및 전문 PA 인력의 참여가 필수적으로 요구된다.

[주기] 별도의 PA책임자를 지정하지 않는 경우, 세부과제 주관기관 과제책임자(PM)가 PA 책임자의 기능을 겸하는 것으로 간주하여야 한다.

[주기] "전기전자부품 관리", "소프트웨어 보증"에 한해, 제품 개발 범위에 포함되지 않는 경우 해당 담당자를 두지 않아도 된다. 이 외의 모든 PA 분야에 대해서는 담당자를 지정하여야 한다.

- PA책임자는 PA 업무를 이행함에 있어서 PA 엔지니어링 담당자와 품질/관리 관련 담당자의 업무를 관리하여야 한다.

3.1.2. PA책임자의 협업(PA Management Interfaces)

- 세부과제 주관기관은 PA책임자가 다음의 업무를 이행하도록 하여야 한다.

- 1) PA책임자는 PA 관련 이슈와 관련하여 세부과제 주관기관 과제책임자와 협력하여야 한다.
- 2) PA책임자는 세부과제 주관기관내 형상관리, 위험관리, 체계종합, 엔지니어링 개발 부서와 PA 관련 이슈와 관련하여 협력하여야 한다.
- 3) PA책임자는 참여업체 및 Lower-Tier업체와의 PA 관련 이슈를 관리하여야 한다.
- 4) PA책임자는 과제의 기술검토회의(Design Review/EQSR, MRR, TRR, PTR, PSR)에 참여하여 PA 관련 이슈, PA 문서, PA 활동현황 등 PA 관련 내용을 제시하여야 한다.

3.1.3. 제품보증 이행계획서(PA Plan)

- 세부과제 주관기관은 스페이스파이오니아 사업에서 정한 본 문서에 따른 장비 제품보증요구사항(PA Requirements for General Unit)을 만족하는 제품보증 계획서를 스페이스파이오니아 사업단에 작성하여 제출하고 이행하여야 한다. 제품보증 이행계획서(PAP, PA Plan)의 문서 구성은 **APPENDIX A**를 참조한다.

[주기] 세부과제 주관기관은 향후 실용위성개발에 참여시에 고객이 발행하는 제품보증요구사항(Subcontractor PA Requirements)을 만족하는 제품보증계획서를 작성하여 제출하여야 하며, PA책임자는 고객의 Subcontractor PAR 요구사항에 따라 PA 관련 이슈에 대응하여야 한다. 세부과제 주관기관은 Subcontractor PAR과 본 PAR for General Unit의 목적과 다루는 범위가 차이가 있을 수 있음을 명확하게 인지하고 적절한 대책을 수립하여 시행하여야 한다.

3.2. 제품보증계획 이행(PA PLAN IMPLEMENTATION)

3.2.1. PA 관리(PA management)

- 세부과제 주관기관은 설계 초기 단계부터 제품보증 요건에 대한 적합성을 고려한 설계를 수행하여 PA 관련 이슈를 식별하고 관리하여야 한다.
- 세부과제 주관기관은 PA 이행계획을 구현하는 데 필요한 PA 자원을 식별하고 PA 작업을 이행할 수 있는 자원을 제시하여야 한다.
- 세부과제 주관기관은 참여업체 및 Lower-Tier 협력업체가 본 문서 및 PA 이행계획에 따라 관리됨을 보증하여야 한다.

3.2.2. PA 진행현황보고(PA Status Reporting)

- 세부과제 주관기관은 PA책임자가 개발일정별로 요구되는 제품보증문서 현황 및 개발중 발생하는 모든 PA 관련 이슈를 관리하여야 한다.
- PA책임자는 최소한 다음 사항을 포함한 PA 현황보고서(PA Status Report)를 작성하여 진행현황을 사업관리의 일부로 보고하여야 한다. PA 현황보고서는 정기적으로 보고되는 과제현황보고서의 일부로 통합하여 관리할 수 있다. PA Status Report에 포함되어야 할 내용은 **APPENDIX B**를 참조한다.

3.2.3. 중요관리대상 관리(Critical Items control)

- 세부과제 주관기관은 중요관리대상(Critical Item)을 식별하고 식별된 중요관리대상의 리스크를 제거(removal)하거나 완화(mitigation) 또는 원하지 않는 결과를 예방하기 위하여 취해야 하는 방안을 포함하는 조치계획(action plan)을 수립하고 관리하여야 한다.
- 중요관리대상 관리와 관련하여 **APPENDIX H**를 참조한다.

3.2.4. 문서 작성 및 자료 관리(Documentation and Data control)

- PA 책임자는 PA 이행계획 실행에 필요한 활동이 진행되는 모든 장소에서 유효한 문서 및 데이터가 사용될 수 있도록 하여야 한다. 유효하지 않은 문서 및 데이터는 사용시점에 사용장소에서 제거되도록 하여 의도하지 않은 사용을 방지하여야 한다.
- PA 책임자는 PA 승인이 필요한 문서를 포함하여 승인이 필요한 과제문서를 식별하여야 한다.

3.2.5. 품질기록(Quality Records)

- 세부과제 주관기관은 모든 PA 작업의 완전하고 성공적인 이행을 위한 객관적인 증거를 제공하고 요구 사항 준수를 입증하기 위해 품질 기록 관리체계를 수립하고 유지해야 합니다.

3.2.6. 형상관리 관련 PA 역할(PA contribution to configuration management)

- PA 책임자는 형상관리활동의 일부로 참여하여 도면, 시험 계획/절차서, 규격서/절차서 (해당문서의 변경사항을 포함한다.)의 사용을 위한 배포(Release)가 적합한 지를 확인해야 한다.
- PA 책임자는 설계형상(As-designed configuration status)이 문서로 모두 식별되었는지와 제작 착수전에 배포되는 지를 확인하여야 하며, 제작형상(As-built configuration status)이 문서로 모두 문서로 식별 및 기록되어 제품과 함께 최종산출물(EIDP)의 일부로서 제공되도록 하여야 한다.

3.2.7. 부적합관리(Nonconformance control)

- 세부과제 주관기관은 고객(향후 실용위성 개발기관 또는 차상위 서브시스템/장비유닛 개발기관)에게 주의 및 판단이 필요한 정보를 제공할 수 있도록, 개발중 발생한 모든 제작/시험/시험운용 중 발생하는 부적합과 이에 대한 처리내용 및 예방조치를 포함하는 정보를 제공할 수 있는 체계를 수립하여 운용하여야 한다.
- 부적합기록(Nonconformance Record) 체계, 부적합검토위원회(MRB) 구성, 부적합검토위원회(MRB) 회의록 체계 등을 포함하여야 한다.
- 세부과제 주관기관은 부적합관리 계획 수립시 **APPENDIX E**을 참조한다.
- 개발단계에서 부적합은 인정되지 않는 것이 일반적이다. 따라서 세부과제 주관기관은 **Major** 부적합은 설계 변경을 통해 제품의 특성으로 반영하는 것을 원칙으로 하여야 한다.

[주기] 세부과제 주관기관은 개발단계에서 고객(Satellite System Integrator) MRB에 의한 피드백을 받을 수 없음을 인지하여야 하며, 향후 이러한 MRB에 대응하는 체계를 갖추어야 한다. 세부과제 주관기관에서 수용한 NCR은 향후 고객(Satellite System Integrator)에게 보고되어야 하며, 최종 판단권한은 고객에게 있음을 인지하여야 한다.

3.3. CONFIGURATION CONTROL (형상관리)

- 세부과제 주관기관은 형상관리계획 수립시 **APPENDIX F**를 참조한다.
- 개발단계에서 규격에 대한 RFD/RFW를 통한 면제 처리는 인정되지 않는 것이 일반적이다. 따라서 세부과제 주관기관은 RFD/RFW로 예상되는 규격 불일치는 설계 변경을 통해 제품의 특성으로 반영하거나, 재제작/재시험 등을 통해 규격을 만족함을 보여야 한다.

[주기] 세부과제 주관기관은 개발단계에서 고객(Satellite System Integrator) CCB에 의한 피드백을 받을 수 없음을 인지하여야 하며, 향후 이러한 CCB에 대응하는 체계를 갖추어야 한다.

4. PA 기능별 요건(PA REQUIREMENTS PER DISCIPLINES)

4.1. QUALITY ASSURANCE (품질보증)

- 세부과제 주관기관은 **APPENDIX G**를 만족하는 제품보증 관리 계획을 수립하여 이행하여야 한다.
- 세부과제 주관기관은 세부과제 주관기관 내에 제품개발에 적합한 품질보증 체계를 수립하여 이행할 책임이 있다.

[주기] ISO9001, AS9100, TS16949와 같은 품질경영시스템 인증이 별도로 개발하고자 하는 우주개발품의 업무범위를 포함하고 있지 않는 한, 우주개발에 적합한 품질경영시

시스템을 갖추고 있음으로 해석되지 않아야 한다. AS9100 항공우주 품질경영시스템의 목적에서 선언하고 있는 바와 같이, 고객 및 제도적 요건을 반영한 품질경영시스템을 구축하여 운용하기 위해 노력해야 한다.

- 세부과제 주관기관은 구매품(하드웨어, 소프트웨어 및 서비스)의 구매관리 체계 수립 시, 추적성 확보를 위해 사용 자재의 원재작자 보증서(Original Manufacturer's COC)가 확보될 수 있도록 구매요구사항의 일부로 기술하고 인수검사시 이를 확인하여야 한다.
- 세부과제 주관기관은 개발단계에서 고객(Satellite System Integrator)에 의한 고객검사(MIP, Mandatory Inspection Point)의 지정 및 실행에 의한 피드백을 받을 수 없음을 인지하여야 하며, 고객검사 수준의 기능적으로 독립적인 인력에 의한 전문적인 자주검사(KIP, Key Inspection Points)가 수행될 수 있도록 검사체계를 구축하여야 한다.
- KIP/MIP 검사를 상정하는 경우 다음을 고려하여야 한다.
 - 1) 중요공정(critical process)이 수행된 후 실시
 - 2) 후속공정에서 검사를 위한 접근이 불가능한 경우 후속공정전 실시
 - 3) 메카니즘의 조립 기간동안 실시
 - 4) Safety Critical Item의 장착 과정동안 실시
 - 5) Qualification Test 및 Acceptance Test 전/후 실시

4.2. RELIABILITY (신뢰성)

- 세부과제 주관기관은 **APPENDIX H**를 만족하는 신뢰성 관리 계획을 수립하여 이행하여야 한다.
- 세부과제 주관기관은 목표로 하는 실용위성 또는 목표시장에서 포지셔닝 하고자 하는 기대목표를 충족할 수 있는 신뢰도를 제안하고, 이를 만족하도록 신뢰도예측보고서(Reliability Prediction Report)를 통해 이를 입증하여야 한다.
- 세부과제 주관기관은 고장모드, 영향 및 치명성분석(FMECA)을 수행하고 Single Point Failure, Critical Item, Limited Life Item 등을 식별하여야 한다. 세부과제 주관기관은 FMECA의 세부과제 주관기관 설계부서에서 주관하도록 업무 분장하여야 하고, Critical Item으로 식별된 항목이 적합하게 검증되는 지를 PA에서 확인하도록 업무 분장하여야 한다.
- 세부과제 주관기관은 전기전자 유닛의 경우 PSA를 수행하여야 한다.
- 세부과제 주관기관은 전기전자 유닛의 경우 WCA를 수행하여야 한다.
- 세부과제 주관기관은 실용위성 사용을 목표로 하는 장비/유닛이 Limited Life Item에 해당하는 경우, Life cycle test 프로그램 계획을 수립하고 이행하여야 한다.

4.3. SAFETY (안전성)

- 세부과제 주관기관은 **APPENDIX I**를 만족하는 안전관리 계획을 수립하여 이행하여야

한다.

4.4. MATERIAL, PART AND PROCESS CONTROL (자재/부품/공정 관리)

- 세부과제 주관기관은 **APPENDIX J**를 만족하는 자재/부품/공정관리 계획을 수립하여 이행하여야 한다.
- 세부과제 주관기관은 **Prohibited/Restricted Material**이 사용되지 않도록 설계에 반영하여야 한다. **Prohibited/Restricted Material**로 식별되는 경우 **Critical Item**으로 식별하고, **Hermitically sealing**과 같은 **Mitigation** 방안 또는 유사한 기능을 수행하는 대체 물질의 활용을 통한 **Removal** 방안 등을 조치계획을 수립하여야 한다.
- 세부과제 주관기관은 기존 실용위성 개발에서 공정역량이 확인된 기관의 공정(**KARI-approved Process or NASA/ESA Space Heritage Process**)을 최대한 활용하여야 한다. 그렇지 않은 경우, 별도의 공정검증계획서를 구체적으로 수립/제시하고 이를 공식적으로 승인받아야 한다.
- 세부과제 주관기관은 **Non-standard/Non-qualified Parts/Process**가 포함된 경우, 공정검증 및 사용가 판정을 위해 추가적인 비용/일정/시간이 소요되는 것이 검증된 우주제품의 특징임을 인지하고 이에 대한 고려를 하여야 한다.
- 세부과제 주관기관은 **DML(재료목록)**, **DMPL(기계부품목록)**, **DPL(공정목록)**을 설계완료 시점에서 공식적으로 제시하고 승인받아야 하며, 해당 내용의 정보와 도면, 작업지시서(**Shop Order, Traveler**), 작업기록, 검사기록 등의 정보가 일치하는 지를 교차 검증하여야 한다.

4.5. EEE PARTS CONTROL (전기전자부품 관리)

- 세부과제의 주관기관은 **APPENDIX K**를 만족하는 전기전자부품관리 계획을 수립하여 이행하여야 한다.
- 표준부품의 사용 : 세부과제 주관기관은 목표로 하는 **APPENDIX K** 적용시, 개발품이 저궤도위성에만 사용되는 경우 **Table K-1. EEE Part Quality For LEO**을 참조하며, 그 이외의 중궤도위성, 정지궤도위성, 달탐사 등에서 사용을 목표로 하는 경우에는 **Table K-2. EEE Part Quality For GEO**를 참조하여 표준부품을 사용하여야 한다.
- 비표준부품의 사용 : **QM**을 개발하는 경우, 표준부품과 **form, fit, function**이 동일한 비표준부품을 사용할 수 있다. 이 경우에 **part identification list**에 향후 **FM** 개발 시 사용될 부품의 부품번호와 본 과제에서 사용하는 **QM** 부품의 부품번호를 모두 기록해야 한다. 표준부품과 **form, fit, function**이 동일한 비표준부품이 없는 경우, **QM**제품에도 표준품을 사용해야 한다. 표준부품과 **form, fit, function**이 동일한 비표준부품을 사용하는 경우, 부품제조사의 시험/검사를 생략하고 수입검사만을 진행할 수 있다.
- 상용부품의 사용 : **Form, fit, function**이 동일한 표준부품이 존재하지 않는 비표준부

품은 상용부품으로 정의하며, 상용부품의 사용은 최소화해야 한다. 비용이나 개발기간 단축의 목적으로 상용부품을 사용할 수 없으며, 유사한 성능이나 기능을 갖는 표준부품이 없으며 기능을 구현하는데 불가피한 경우에만 사용이 가능하다.

- 상용부품 사용 시에는 해당 부품이 설계변경 없이 FM에도 사용될 수 있다는 것을 보증을 위하여, QM 하드웨어 제작 착수 전 해당 상용부품에 대하여 EEE-INST-002 요구사항에 따라서 screening 및 qualification이 완료되어야 한다. 만약 해당 부품에 대하여 EEE-INST-002의 screening 및 qualification 내용을 포함하는 시험성적서 또는 이와 동등한 수준의 시험성적서를 확보할 수 있는 경우 시험의 면제가 가능하다. 또한 부품 종류별로 3개씩 DPA를 수행하여야 한다.
- APPENDIX K 9.4에 명시된 특수한 부품은 EEE-INST-002가 아닌 APPENDIX K 9.4에 명시된 문서를 따라서 시험을 수행한다.
- 우주용 규격에 따른 시험 데이터가 없는 상용부품을 선정하는 경우, EEE-INST-002에 따른 시험 결과 또는 방사선 시험결과가 요구사항을 만족하지 못하면 새로운 부품을 선정해야 한다. 세부과제의 주관기관은 상용부품의 사용 시, 시험 결과가 우주부품 요구사항을 만족하지 못하면 새로운 부품의 납기 소요 및 방사선 시험 기간 소요, 설계 변경 기간 소요 등으로 프로젝트 기간 내 QM의 개발 및 검증을 완료할 수 없는 리스크가 있음을 인지하여야 한다. 원칙적으로 상용부품은 불가피한 경우를 제외하고는 사용하지 않아야 하며, 상용부품을 사용하더라도 screening, qualification 및 방사선 시험 데이터가 존재하여 우주용으로 사용가능함이 알려진 부품을 선정해야 한다.
- 표준품을 포함한 모든 능동소자 부품에 대해서는 ECSS-Q-ST-60-15C 및 APPENDIX K를 따라서 radiation analysis report를 작성해야 하며, 이 때 사용하는 radiation data는 제조사에서 제공하는 데이터, 또는 최근 4년 이내에 시험결과를 인용해야 한다. 데이터 확보가 불가능한 경우 APPENDIX K의 radiation hardness 요구사항에 따라서 방사선 시험을 수행하여 데이터를 확보해야 한다.
- QM 제작 착수 전 부품의 스크리닝, Lot 수락시험 결과보고서 작성 및 radiation analysis report, part identification list 작성이 완료되어야 한다.
- Single event effect 중 부품에 영구적인 손상을 주는 효과의 LETth가 60 MeV·cm²/mg 보다 작은 경우 사용을 금지한다. Single event effect 중 부품의 오동작을 발생시키는 효과는 LETth가 60 MeV·cm²/mg 보다 작은 경우 다른 부품으로 교체를 검토하거나, 이를 억제할 수 있는 설계(필터, TMR, EDAC 등)를 구현해야 한다. Radiation analysis report에는 구현한 설계를 반영하여 연간 오동작 발생횟수를 예측하여 기술하여야 한다. 궤도환경은 개발된 과제를 통하여 제품이 사용될 것으로 예상되는 궤도를 개발기관의 책임 하에 모사하여 적용한다.
- 세부과제의 주관기관은 자체적인 PMPCB 또는 이에 준하는 회의체를 구성하여 QM에 사용되는 모든 전기전자부품에 대한 적합성 여부를 검토하여야 하며, 필요 시 스

페이스파이오니아 사업단의 요구에 의하여 회의내용 및 관련 문서를 확인할 수 있도록 관리하여야 한다.

- Part Identification List에 들어가는 내용은 ECSS-Q-ST-60C rev.2의 Annex B를 따른다.
- 세부과제의 주관기관은 **APPENDIX K**의 subcontractor와 customer 역할을 동시에 수행한다. 만약 협동연구기관(공동연구기관, 위탁연구기관 등)에서 납품받는 전기전자 부품이 있다면 이 부품에 대하여 주관기관은 customer 역할을 하며, 협동연구기관은 subcontractor 역할을 갖는다.
- 세부과제 주관기관의 전기전자부품 담당자는 상기 역할을 수행하기 위하여 ECSS-Q-ST-60C, ECSS-Q-ST-60-15, EEE-INST-002 문서 및 연관 문서의 내용을 충분히 이해하여야 한다.

4.6. CLEANLINESS & CONTAMINATION CONTROL (청정도 및 오염 관리)

- 세부과제 주관기관은 장비/유닛의 개발시 청정도를 고려한 설계하여야 한다.
- 설계 베이스라인이 청정도 요구사항과 불일치하는 경우, 설계변경 대상으로 식별하고 시정조치를 이행하여야 한다.
- 세부과제 주관기관은 사용을 목표로 하는 실용위성, 위성개발 프로세스상의 단계, 상위 서브시스템/유닛에 요구되는 적합한 청정도 및 오염관리 기준을 설정하여야 한다.
- Cleanliness Level guidelines
 - 1) Unit including Mirror, Lens, Focal Plan and Contamination critical items, handling/testing: Cleanroom class 1,000 or better
 - 2) Other unit handling/testing: Cleanroom class 100,000 or better
 - 3) General integration/assembly/testing: Cleanroom class 100,000 or better
- Outgassing (RML and CVCM) guidelines
 - 1) 최소 Outgassing 기준은 RML <1%, CVCM<0.1%으로 한다. 기준을 초과하는 경우, RFA를 작성하고 사용에 대한 정당성(Justification)을 제시하여야 한다.
 - 2) 오염민감품목 주변 자재의 Outgassing 기준은 다음을 참조한다.

Mass of material concerned(gram) around Room Temp.	CVCM (%)	RML (%)
>100	<0.01	<1
10 ~ 100	<0.05	<1
<10	<0.1	<1

Mass of material concerned(gram) below Room Temp.	CVCM (%)	RML (%)
>100	<0.01	<0.1
10 ~ 100	<0.05	<1
<10	<0.1	<1

- 세부과제 주관기관은 제작/조립/시험/보관/운송/궤도임무 기간 동안 세부과제 주관기관이 설정한 청정도 및 오염관리 기준을 만족하기 위한 관리계획을 수립하여 시행하여야 한다. 장비/유닛의 클린룸 시설 수준 및 노출시간 등이 청정도 요구사항을 만족하는 지를 확인할 책임은 세부과제 주관기관에 있다.
- 세부과제 주관기관은 조립/운송/위성체 발사장 작업에서 고려하여 할 주의사항(Precautions)과 조치방안(Provisions)을 제시하여야 한다.
- 세부과제 주관기관은 분자오염(Molecular contamination)을 저감하기 위한 조치로 수행되는 Bake-out 요건(수행시점/온도/시간) 설정하여야 한다. 오염민감품목의 경우 비행 궤도(In-orbit)에서의 교차오염(Cross-contamination)을 예방하기 위한 궤도상 Bake-out 요건을 포함하여야 한다.
- 청정도 및 오염관리 계획 수립시 **APPENDIX L**를 참조한다.

4.7. 소프트웨어 보증(SOFTWARE ASSURANCE)

- 소프트웨어 개발을 포함하는 경우, 세부과제 주관기관은 소프트웨어 보증 계획을 수립하여 시행하여야 한다. 소프트웨어 보증 계획은 PA 계획서의 일부로 작성하거나 별도 문서로 작성할 수 있다.
- 소프트웨어 보증 계획 수립시 **APPENDIX M**를 참조한다.

APPENDIX A. 제품보증 이행계획서 (PAP)의 구성

A.1 일반사항

- PAP 구성요구사항 중 "소프트웨어 보증"과 같이 개발하는 장비/유닛에 포함되지 않는 경우, 해당 절(Section)은 유지하고 비적용(Not Applicable)으로 본문에 기술한다.
- 표지를 포함하여야 한다.
- 문서관리 번호(제/개정 번호 포함)를 포함하여야 한다.
- 작성자, 세부과제 주관기관책임자(Project Manager), 제품보증책임자(PA Manager)의 서명을 포함하여야 한다.
- 목차를 포함하여야 한다.
- 제/개정 이력을 포함하여야 한다.
- 개정 이력(Rev., 제개정일자, 제/개정 내용 및 관련 문서위치(Section) 정보)를 포함하여야 한다.

A.2 구성

A.2.1. 일반사항(GENERAL)

- 작성의 목적, 목표 및 이유를 제시한다.

[주기] PAP의 목적은 세부과제 주관기관이 정한 임무목표와 관련하여 우주제품의 품질을 보장하고 해당 PA 요구사항에 적합함을 입증하기 위해 세부과제 주관기관이 이행하는 활동을 기술하기 위한 것이다. 사용을 목표로 하는 실용위성 구분, 위성개발 프로세스상의 단계, 상위 서브시스템/유닛 등에 대한 정보를 포함한다.

A.2.2. 관련 문서 및 참조문서(APPLICABLE AND REFERENCE DOCUMENTS)

2.1 관련 문서(Applicable Documents)

2.2 참조 문서(Reference Documents)

A.2.3. 제품보증 관리(PA MANAGEMENT)

A.2.3.1 제품보증 조직/인력 및 업무분장(PA Organization/Personnel and Activities)

- 본 문서의 본문 "제품보증 계획(PA program planning)" 요구 사항을 충족하기 위해 적용할 활동, 프로세스 및 절차를 제시한다. 조직/인력(책임과 권한 포함)을 포함하여야

한다.

[주기] 해당 제품보증 요구 사항을 충족하기 위해 개발기과에서 적용할 활동, 프로세스 및 절차를 제시한다.

A.2.3.2 제품보증 이행(PA Implementation)

본 문서의 본문 "제품보증계획 이행(PA Plan Implementation)" 요구 사항을 충족하기 위해 세부과제 주관기관에서 적용할 활동, 프로세스 및 절차를 제시한다.

A.2.3.3 품질보증(Quality Assurance)

품질보증을 이행하기 위해 세부과제 주관기관에서 적용할 활동, 프로세스 및 절차를 제시한다.

A.2.3.4 신뢰성(Reliability)

신뢰성 요구사항을 충족하기 위해 적용할 활동, 프로세스 및 절차를 제시한다.

A.2.3.5 안전성(Safety)

안전 요구사항을 충족하기 위해 세부과제 주관기관에서 적용할 활동, 프로세스 및 절차를 제시한다.

A.2.3.6 전기전자부품(EEE Parts)

EEE 부품 요구사항을 충족하기 위해 세부과제 주관기관에서 적용할 활동, 프로세스 및 절차를 제시한다.

A.2.3.7 소재 및 공정(Materials and Process, M&P)

재료 및 공정 요구사항을 충족하기 위해 세부과제 주관기관에서 적용할 활동, 프로세스 및 절차를 제시한다.

A.2.3.8 소프트웨어 품질보증(Software Assurance)

소프트웨어 보증 요구사항을 충족하기 위해 세부과제 주관기관에서 적용할 활동, 프로세스 및 절차를 제시한다.

A.2.3.9 청정도 및 오염관리(Cleanliness and Contamination Control)

청정도 및 오염관리 요구사항을 충족하기 위해 세부과제 주관기관에서 적용할 활동, 프로세스 및 절차, 시설을 제시한다.

APPENDIX B. PA 현황보고서 (PA STATUS REPORT) 포함내용

B.1 구성

B.1.1 PA Status Report 문서번호, 개정이력(Rev.000), 보고일자

B.1.2 Milestone status (이행일자, 회의록 관리번호)

- Kick off Meeting, Design Review, MRR, TRR, PTR, PSR

B.1.3 EEE Part status

- 미승인 부품 status(mitigation plan 포함)
- DCL 문서 발행 현황(작성 및 개정 Rev.)
- Part Approval Document of EEE Part (PAD)

B.1.4 Material, Mechanical Part, Process status

- 미승인 자재/부품/공정 status(mitigation plan 포함)
- Request for Approval of M&P(RFA)
- DML 문서 발행 현황(작성 및 개정 Rev.)
- DMPL 문서 발행 현황(작성 및 개정 Rev.)
- DPL 문서 발행 현황(작성 및 개정 Rev.)

B.1.5 Nonconformance status

- 사내 별도관리 되는 경우, 관리문서번호로 표시

B.1.6 KIP/MIP status

B.1.7 Critical Items (including mitigation plan status)

B.1.8 PA Documentation Status

- FMECA 문서 발행 현황(작성 및 개정 Rev.)
- PSA 문서 발행 현황(작성 및 개정 Rev.)
- WCA 문서 발행 현황(작성 및 개정 Rev.)

B.2 참조

B.2.1 EEE Part status

B.2.2 Material, Mechanical Part, Process status

- 공정검증 대상 식별 및 진행현황
- 공정검증 식별 현황, 추가적인 공정검증이 필요한 공정 진행현황을 관리하여야 한다. 실용위성에서 검증된 이력이 없는 시설/기관에서 이행되는 공정은 비승인 공정으로 판단되어야 하며, 적절한 공정검증 표준에 따라 공정검증 계획 수립, 계획에 따른 검증 진행, 결과보고서의 작성을 통해 공정의 적합성을 확보하여야 한다.
 - a. 공정검증 기준으로 사용되는 표준서의 식별
 - b. 공정검증 기준에 따른 적절한 시설, 장비의 식별
 - c. 공정검증 기준에 따른 시편, 시험종류 및 절차, 검사 종류 및 절차 식별
 - d. 공정검증 기준에서 정한 기준을 만족하는 결과에 대한 판단

B.2.3 Nonconformance status

세부과제 주관기관의 NCR 관리체계에 따라 발생 이력/조치현황 관리

B.2.4 KIP/MIP status

작성문서현황: 계획된 자주검사(KIP, Key Inspection Points)에 따라 이행한 검사결과 현황 및 생성된 검사보고서 목록(일자, 관리번호, 검사결과 등)

APPENDIX C. 제품보증 양식 (FORMS)

This section describes the minimum information should be included in the PA forms. The Subcontractor can use his own report form if his form includes all the contents of the template provided in this Section.

C.1. 변경제안서 (Change Proposal)

Change Proposal shall include at least following information:

- 1 : Document number for change proposal
- 2 : Title of change proposal
- 3 : Applicable CI number
- 4 : Applicable model type (FM, PFM, EM, etc.)
- 5 : Applicable serial number
- 6 : Class of change (class 1, class 2)
- 7 : Affected documents due to this change
- 8 : Price influence due to this change
- 9 : Schedule influence due to this change
- 10 : Description of changes
- 11 : Reasons for changes
- 12 : Subcontractor's CCB approval
- 13 : KARI's CCB approval

C.2. 면제요청서 (Request for Waiver)

- 1 : Document number for RFW
- 2 : Title of RFW
- 3 : Applicable part number
- 4 : Applicable model type (FM, PFM, EM, etc.)
- 5 : Applicable serial number
- 6 : Document number of drawing or specification for applicable product
- 7 : Description of RFW
- 8 : Reasons for RFW
- 9 : Any adverse effect expected due to this waiver
- 10 : Document number for applicable nonconformance report
- 11 : Subcontractor's MRB approval

12 : KARI's MRB approval

C.3. 완화요청서 (Request for Deviation)

- 1 : Document number for RFD
- 2 : Title of RFD
- 3 : Applicable part number
- 4 : Applicable model type (FM, PFM, EM, etc.)
- 5 : Applicable serial number
- 6 : Part number of next assembly
- 7 : Document number of drawing or specification for applicable product
- 8 : Description of RFD
- 9 : Reasons for RFD
- 10 : Any adverse effect expected due to this deviation
- 11 : Document number for applicable nonconformance report
- 12 : Subcontractor's CCB approval
- 13 : KARI's CCB approval

C.4. 부적합보고서 (Nonconformance Report)

- 1 : Document number for nonconformance report
- 2 : Title of nonconformance report
- 3 : Applicable part number
- 4 : Applicable model type (FM, PFM, EM, etc.)
- 5 : Applicable serial number
- 6 : Description of nonconformance
- 7 : Classification of nonconformance (major, minor)
- 8 : Cause of nonconformance
- 9 : Subcontractor's MRB disposition proposal
- 10 : Any corrective actions proposed by Subcontractor's MRB
- 11 : Subcontractor's MRB approval
- 12 : KARI's MRB approval

C.5. 전기전자부품 식별목록 (PID ; EEE Part Identification List)

- 1 : Part number (commercial equivalent designation)
- 2 : Family
- 3 : Part type or Electrical function

- 4 : Package
- 5 : Value or range of values with tolerance for non-qualified parts (optional)
- 6 : Description of the part
- 7 : Component manufacturer / Country
- 8 : Generic procurement specification
- 9 : Detail procurement specification (with issue and revision for non-qualified parts/commercial parts)
- 10 : Specification amendment (including issue and revision),
- 11 : Name of the procurement agent (CPPA, supplier, distributor),
- 12 : Quality level and lot test (ESCC LAT or LVT, MIL TCI or QCI or CI),
- 13 : Space qualified status (yes or no),
- 14 : RVT (yes or no),
- 15 : Reference of the PAD or Justification Document, where required,
- 16 : Approval status of the part,
- 17 : Change identification between each PIL issue,
- 18 : Date-code (only for as-built PIL).

C.6. 부품승인문서 (PAD ; Part Approval Documents)

- 1 : Doc No - Unique sequential number
- 2 : Issue of document
- 3 : Date of issue
- 4 : Name of project using the part
- 5 : Name of the person submitting the PAD
- 6 : Name of the company submitting the PAD
- 7 : Family - Capacitor, resistor, etc.
- 8 : Group - Ceramic, tantalum, etc.
- 9 : Part Number in accordance with the procurement specification. It may be generic to cover different range of parts. (e.g. range of resistors or capacitors or variants for connectors & accessories)
- 10 : Commercial Equivalent Designation
- 11 : Technology/Characteristics - Additional details of the components covered by the PAD
- 12 : Pure tin free (Y/N) When tin $\geq$ 97% (inside the component and terminations)
- 13 : Generic specification
- 14 : Detail specification with issue and revisions only required for non-qualified parts
- 15 : Specification Amendment Relevant specification with issue and revisions

- 16: Quality level as defined in Section K.
- 17: Procurement by - Identify the name of the company procuring the part. This can be Subcontractor himself, CPPA, distributor, or a combination thereof.
- 18: Manufacturer/Country
- 19: Approval status - Information about known approvals (EPPL, ESCC, ESCC/QML, MIL, MIL/QML, or other approvals / previous usage.)
- 20: Evaluation program required - Y/N as applicable
- 21: Procurement inspections and test - Y/N as applicable
- 22: DPA sample size
- 23: Complementary tests Testing/Inspection in addition to that defined in the procurement specification shall be identified, e.g. PIND, up screening,
- 24: Lot Acceptance - Identify level and subgroups
- 25: Radiation Hardness Data for Total Dose.
- 26: Radiation Hardness Data for SEL / SEU / SET / SEFI / SEB / SEGR, others – LET_{th} and Cross-section, etc.
- 27: Evaluation Test Data reference - Reference of the test report for Total Dose, Single Event Latch up / Single Event Upset / Single Event Transient / Single Event Functional Interrupt / Single Event Burn out / Single Event Gate Rupture. Radiation test report shall include data source information.
- 28: RVT Radiation Verification Test - Y/N as applicable
- 29: Remarks - Any additional information
- 30: Approval customer - Signature signifies acceptance
- 31: Approval first-level supplier

C.7. 구매규격 (Procurement Specification)

- 1 : A description of the purpose, content and the reason prompting its preparation,
- 2 : A list of the applicable and reference documents,
- 3 : Any additional terms, definitions or abbreviations,
- 4 : Absolute maximum ratings,
- 5 : Electrical and mechanical parameters and limits,
- 6 : Screening, burn-in, and acceptance requirements,
- 7 : Package material and lead finish,
- 8 : Documentation/data requirements,
- 9 : Delta limits when applicable,
- 10 : Criteria for percent defective allowable,

- 11 : LAT or LVT, QCI or TCI,
- 12 : Marking,
- 13 : Storage requirements,
- 14 : Requirements for lot homogeneity,
- 15 : Serialization (when applicable),
- 16 : Protective packaging and handling requirements,
- 17 : Radiation Verification Testing requirements, when applicable.

C.8. 승인요청서 (Request for Approval)

- 1 : Document number for materials approval document
- 2 : Category of the material (adhesive, screw, etc.)
- 3 : Chemical nature of the material
- 4 : Material name
- 5 : Manufacturer
- 6 : Document number of generic specifications
- 7 : Document number of detail specification
- 8 : Specification amendment information
- 9 : Quality level of the material
- 10 : Compliance status to the program requirements
- 11 : Reference of applicable qualified part list
- 12 : Heritage program information
- 13 : Environmental condition of application
- 14 : Document number of applicable process specification
- 15 : Description of application
- 16 : Rational for application of the material (In case of noncompliant material)
- 17 : Plan for supplementary verification
- 18 : Deliverable documents list
- 19 : Subcontractor's MPCB approval
- 20 : KARI's PMPCB approval

C.9. 재료 식별목록 (Materials Identification List)

- 1 : Document number for materials identification list
- 2 : Part number of EI
- 3 : Revision status
- 4 : Part number of the material

- 5 : Materials name
- 6 : Description of the material
- 7 : Document number of specifications
- 8 : Chemical nature of the material
- 9 : Application purpose
- 10 : The location where the material is used
- 11 : TML characteristics
- 12 : CVCM characteristics
- 13 : Reference of outgassing information
- 14 : Document number of applicable process specification

C.10. 공정 목록 (Process List)

- 1 : Document number for process list
- 2 : Part number of EI
- 3 : Revision status
- 4 : Name of the process
- 5 : Description of the process
- 6 : Document number of process specification
- 7 : Main parameter of the specification
- 8 : Application Purpose
- 9 : The location where the material is used
- 10 : Flight materials used in the process
- 11 : Process heritage or qualification information

APPENDIX D. 프로그램 검토회의 (PROGRAM REVIEW) 수행

The Subcontractor shall maintain a review process for the End Product. This review process will consist of Design Reviews, MRR, TRR, and PSR.

The Subcontractor shall notify Customer (Satellite System Integrator) of the agenda 15 working days before scheduled meeting.

In case Customer (Satellite System Integrator) participates in the reviews, Customer (Satellite System Integrator) shall have the right to make a “Go” or “No Go” decision.

Meeting minutes and action items from the reviews shall be documented and provided to Customer (Satellite System Integrator).

D.1. DESIGN REVIEWS

The PDR and CDR shall evaluate the ability of the End Product to meet the program requirements such as PAR, equipment specification, and interface control documents.

For the End Product which is already developed and qualified in the previous program, ESR may substitute for Design Reviews.

During the review process, at least the following information shall be provided:

- a. Compliance status to the design requirements including qualification status
- b. Schematics or major characteristics of the design
- c. Analysis results

D.2. MANUFACTURING READINESS REVIEW

The MRR shall evaluate the preparedness of the Subcontractor's manufacturing processes for fabricating the End Product to the standards described by this PAR. During the review process, at least the following information shall be provided:

- a. Configuration status
- b. Manufacturing flow and instruction for critical process
- c. Any design changes from the CDR baseline

D.3. TEST READINESS REVIEW

The TRR shall evaluate the preparedness of End Products and the Subcontractor's processes for the testing of End Product to the applicable specifications. During the review process, at least the following information shall be provided:

- a. Configuration status

- b. Nonconformance status
- c. Compliance Matrix which shows test criteria and specification requirements
- d. Test procedures

D.4. PRE-SHIP REVIEW

The PSR shall evaluate compliance to the applicable requirements and the completeness of the activities required by the contract. During the review process, at least the following information shall be provided:

- a. Summary of open actions during contract period
- b. Requirement compliance status
- c. EIDP documents
- d. Configuration status
- e. Nonconformance status
- f. Acceptance test and analysis results
- g. Contractual deliverable status
- h. Visual inspection of the End Product

D.5. ASSURANCE STATUS REPORTS

The Subcontractor shall report periodically on the status of the PA Program as part of the progress report. The following subjects shall be addressed in the progress report as appropriate:

- a. Significant or unsolved PA issues
- b. Summary of waiver and deviation requests
- c. Summary of nonconformance and failures
- d. Summary of configuration changes
- e. Summary of key inspection and test activities
- f. Status summary of PAD, RFA, and nonconventional processes
- g. Change summary of EEE part, materials, and processes list
- h. Results of trend analyses and alerts surveys
- i. Status of procurement and Supplier's PA Program

APPENDIX E. 부적합관리 (NONCONFORMANCE CONTROL)

E.1. GENERAL

The Subcontractor shall establish and maintain a nonconformance control system in order to track nonconformances systematically and to prevent reoccurrence. The system shall provide a disciplined approach to the identification and segregation of nonconforming items, recording, reporting, review, and disposition of nonconformances, and the implementation of corrective actions.

Overstress analyses are required for nonconformances which occur during the unit test or during operation susceptible to overstress of other components.

All nonconformances shall be closed prior to product shipment.

E.2. NONCONFORMANCE

E.2.1. Nonconformance Classification

Nonconformances shall be classified into minor or major on the basis of the severity of their consequences.

Major nonconformances are those with possible impact on:

- A. Unit performance including life duration, environmental compatibility, etc.
- B. Unit interfaces or environmental characteristics such as thermal, vibration, RF, EMC, etc.
- C. Unit reliability, especially due to the part problem.
- D. Unit operation such as impacts on the operation manual, additional operational constraints, etc.

Disposition of the major nonconformances shall be submitted to Customer (Satellite System Integrator)'s MRB for review and approval before implementation.

Minor nonconformances are all other nonconformances which are not classified as major.

Minor nonconformances may be disposed and implemented at Subcontractor level, but it's disposition status shall be provided for Customer (Satellite System Integrator) with the Nonconformance Status List.

E.2.2. Nonconformance Report

Nonconformance shall be recorded directly on formal report forms at the time of observation. Interim records such as scratch pads and notebooks are prohibited. Voiding of a recorded discrepancy shall be accomplished without destruction of the record or its legibility.

A nonconformance report shall contain sufficient data for the complete identification of non-conforming item, the description of nonconformances, the status of related actions, and analysis of nonconformances.

In case of minor nonconformances, the Subcontractor may use his own document form and control system. But in case of major nonconformances, the Subcontractor's report shall include all the contents provided in APPENDIX C.

The inspection status and identification of nonconforming items shall be documented at the point and time of discovery in the item's document folder and shall be immediately subject to review.

List of all nonconformances and the major nonconformance report shall be submitted to Customer (Satellite System Integrator) and all nonconformance report shall be kept available by Customer (Satellite System Integrator) at the Subcontractor's facilities.

E.3. MATERIAL REVIEW BOARD

Major nonconformances shall be reviewed and disposition taken by a formal MRB, established at all contractual levels.

A member of the Subcontractor's PA organization shall act as chairman. And an approved member of the Subcontractor's engineering organization shall be responsible for reviewing the nonconformances and making decisions on the engineering aspects of such nonconformances.

The Subcontractor's MRB shall submit the review results of major nonconformances to Customer (Satellite System Integrator)'s MRB with the proposed disposition for approval by Customer (Satellite System Integrator)'s MRB.

E.4. NONCONFORMANCE STATUS LIST

The Subcontractor shall maintain the list of nonconformances for the contracted item. This list shall identify the status of each nonconformance.

The status of all nonconformances shall be reported to Customer (Satellite System Integrator) through assurance status reports.

E.5. ALERT INFORMATION

The Subcontractor shall provide Customer (Satellite System Integrator) with selected alerts that document problems related with deliverable flight item as reported by the GIDEP, ESA alert, or the equivalent from the Subcontractor's country, if applicable.

APPENDIX F. 형상관리 (CONFIGURATION MANAGEMENT)

다음은 국내 실용위성에서 요구하고 있는 형상관리 요구사항의 예시이다. 위성 시스템 레벨의 피드백은 개별 위성개발 과제와 연동되어야 하므로 본 과제의 범위를 넘어서나. 세부과제 주관기관은 본 과제에서 이행되지 않는 부분에 대해서는 모사 검증 등 적절한 대안을 수립하여 시행한다.

[주기] Subcontractor는 세부과제 주관기관으로 해석한다.

[주기] 납품은 개발종료로 해석한다.

국내 실용위성급 형상관리 요구사항의 예시는 다음과 같다.

F.1. GENERAL

The Subcontractor shall maintain a Configuration Management program to identify CIs, to control any changes, and to account for the configuration status of each CI.

The Subcontractor shall appoint a person to be responsible for the implementation, operation and monitoring of the program configuration and data management.

F.2. CONFIGURATION IDENTIFICATION

Configuration identification shall incrementally establish and release controlled documentation for the purpose of identifying configuration characteristics of the End Item until it is fully defined with respect to its intended functional, performance and physical characteristics, thereby ensuring the continuous integrity of the product configuration.

Documents necessary for Configuration Identification shall be presented at the Subcontractor's key review described in Section 3.5. If the documents are approved, this will form the configuration baselines.

The CIs shall be developed and maintained through distinct sequential levels of detail:

- a. The functional baseline is identified by the overall performances, interfaces, and design requirements. The contract, equipment specification by Customer (Satellite System Integrator), and SOW shall consist of a functional baseline. This baseline will be established at the contract.
- b. The development baseline is identified by the technical specifications written by the Subcontractor for his top level and lower level CIs to satisfy the functional baseline requirements. The Subcontractor's development specifications and engineering documents at Design Reviews shall consist of a development baseline. This baseline will be

established at Design Reviews.

- c. The production baseline is identified by the released detailed solution for FM production, testing, and operation. Drawings, associated lists, and work instructions together with test procedures shall consist of a production baseline. This baseline will be established at MRR. Baselines and approved changes from those baselines constitute the current configuration identification.

F.3. CONFIGURATION CONTROL

The Subcontractor shall maintain a configuration control system by which, any change or relaxation to the configuration identification of a CI after formal establishment of its baselines, will be identified, evaluated, classified, justified, approved and implemented or rejected.

F.3.1. Change Classification

Any change between Customer (Satellite System Integrator) and the Subcontractors shall be classified into Class 1 or Class 2. The criteria for change classification are described herein.

Class 1 changes impact the contractual or technical agreement reached between Customer (Satellite System Integrator) and the Subcontractor. In particular, any of the following changes will have a definite impact on the agreement:

- a. Functions, performances, and weight as defined in the contract, specifications, and SOW requirements
 - b. Safety, reliability, and maintainability
 - c. Interface control requirements
 - d. Interchangeability of any item if the item has already been delivered
 - e. Any delivered technical manuals
 - f. Costs and schedule
- Class 1 changes shall be submitted to Customer (Satellite System Integrator)'s CCB for review and approval before implementation.
 - Class 2 changes are those which are not classified as Class 1, but those are necessary to meet technical and contractual requirements and provisions.
 - Class 2 changes may be implemented after Subcontractor's CCB approval, but shall be forwarded to Customer (Satellite System Integrator) for information.

F.3.2. Configuration Control Board

The Subcontractor's CCB, chaired by the program manager or his designee, shall be responsible for the following activities:

- a. Review, evaluate, classify, and process all changes proposed.
- b. Direct activities to accommodate Customer (Satellite System Integrator)'s change requests.
- c. Direct activities necessary to implement approved changes.

The Subcontractor's CCB authority, membership, and procedures shall be defined in the PA Program Plan.

F.3.3. Change Documentation

The Subcontractor may initiate the change procedure with the following change documents:

- a. Change Proposal : The document used by the Subcontractor, either in response to a Change Request or on its own initiative, to propose a change in the current approved configuration identification.

In case of a Class 2 change proposal, the Subcontractor may use his own document form and control system. But in case of a Class 1 Change Proposal, the Subcontractor's form shall include all the contents provided in APPENDIX C, and shall contain all information, drawings, and justifications.

The Class 1 Change Proposal shall be submitted to Customer (Satellite System Integrator)'s CCB for approval.

- b. Request for Waiver (RFW) : This aims to cover a nonconformance discovered during manufacturing or test of an item, which has been proposed suitable for use by the Subcontractor's MRB. This shall be submitted with a nonconformance report and MRB dispositions.
- c. Request for Deviation (RFD) : This will be submitted to depart from a requirement, prior to manufacture and test of an item. When approved, deviations will be part of the configuration baseline of the CIs.

Incorporation of changes into any document shall be carried out by the Subcontractor responsible for the issuing of the document.

The document change log sheet shall clearly identify references to Change Proposals.

F.4. INTERFACE CONTROL DOCUMENTS

For each End Product, the Subcontractor shall provide Customer (Satellite System Integrator) with ICDs including as a minimum the following:

- a. Electrical ICD : Power, primary secondary switching diagrams, protection characteristics of each function, connectors list and electrical characteristics of the signals on each pin of each connector, etc.
- b. Command and Telemetry ICD : Command and telemetry characteristics, points, type,

mnemonics, transfer function, bits and status meaning, etc.

c. Mechanical ICD : Geometry, dimensions, fixings, weight, inertia, and position of center of gravity, etc.

d. Thermal ICD : Thermal characteristics.

When approved by Customer (Satellite System Integrator), ICD become a requirement for the Subcontractor. Then, any change to approved ICDs shall be processed as a Class 1 change.

At lower levels, any Lower Tier Subcontractor having design authority over an interface between CIs is responsible for the control of those interfaces and required to establish ICDs to control them.

F.5. CONFIGURATION STATUS ACCOUNTING

The Subcontractor shall implement a status accounting system capable of maintaining and verifying the configuration and change status of all deliverable equipment for which he has design responsibility.

The major elements to be provided are the following documents:

- a. CIDL : The CIDL shall describe current issue and revision of documents and approved changes. CIDL shall include :
 - Basic CI information
 - Requirements data list : Documents concerning the functional baseline.
 - Specifications data list : Documents concerning the development baseline
 - Design data list : Documents concerning the production baseline.
 - Operations support data list such as transportation, handling, storage, installation, operation, calibration, maintenance, users manuals, etc.
- b. ABCL : The ABCL will list the relevant applicable production baseline and the approved waivers for this baseline, and will establish the actual composition of the CI by hardware identification number.

F.6. CONFIGURATION VERIFICATION

The Subcontractor is responsible for the configuration verification of each deliverable CI:

- a. Comparison between the as designed configuration and the as-built and tested configuration
- b. Justification of any differences

Customer (Satellite System Integrator) will verify configuration of a CI during program reviews and MIP.

F.7. DOCUMENTATION MANAGEMENT

The Subcontractor shall establish a data center and maintain applicable data during the mission life of the End Product.

Each Subcontractor shall maintain a documentation management system to:

- a. Maintain a database for all documents produced under the contract,
- b. Verify that all documents required in the SOW are produced and delivered,
- c. Introduce approved changes in the baseline documents,
- d. Set up a receipt, recording, and dispatch system for all the program documents.

For each document, a change log sheet shall be provided to list the different issues with dates, information about the reason for modification or the incorporated Change Proposal.

APPENDIX G. 품질보증 (QUALITY ASSURANCE)

G.1. GENERAL

The Subcontractor shall maintain a QA system consistent with ISO 9001 or equivalent standards.

Customer (Satellite System Integrator) shall have the right to verify conformity of the Subcontractor's Quality System or to verify the product in accordance with the specified requirements at the Subcontractor's facilities and/or his Supplier's facilities.

G.2. QUALITY ASSURANCE SYSTEM

G.2.1. Quality Assurance Program

The Subcontractor shall implement and maintain a QA program to ensure that appropriate quality requirements are established and implemented to verify progress and to ensure prompt detection and correction of deficiencies. This program shall include the items manufactured or processed by the Subcontractor, as well as items procured from Suppliers or Lower Tier Subcontractors.

Design rules and methods shall be consistent with this PAR. Fabrication, integration, testing, and maintenance are conducted in a controlled manner such that the End Item conforms to the applicable requirements.

The Subcontractor shall prepare a Quality Manual covering the requirements of this document. The Quality Manual shall include or reference the Quality System procedures.

The Supplier and Lower Tier Subcontractor shall ensure that the Quality System procedures are readily available to Subcontractor's personnel, who are responsible for ensuring compliance with requirement, and to Customer (Satellite System Integrator).

G.2.2. Organization

A QA manager shall be assigned and shall manage the program to ensure compliance with quality requirements outlined in this PAR.

The Subcontractor shall define and document the responsibility and authority of personnel who perform work affecting quality for ensuring that the Quality System is established, effectively implemented, and maintained.

G.2.3. Personnel Training

The Subcontractor shall maintain a training program to ensure adequate skill level conforms to End Product requirements. Training shall be emphasized for the tasks which affect the quality and reliability of the End Product being procured.

Training records for personnel affecting quality shall be maintained.

G.2.4. Personnel Certification

The Subcontractor shall maintain a system of personnel certification covering activities such as welding, soldering, connector assembly, assembly, bonding, potting, plating, cleaning, NDT, and other activities requiring special skills. Only certified personnel shall perform the above activities. The certification shall be issued in accordance with applicable MIL, ESA, or equivalent specifications.

G.3. PURCHASING AND PROCUREMENT

The Subcontractor shall establish adequate controls for the procurement of hardware, software, and services. The control of procurement activity includes selection of procurement sources, control of purchase documents, surveillance of Suppliers and control of incoming items.

G.3.1. Supplier and Lower Tier Subcontractor Control

The Subcontractor shall impose the requirements in this PAR on his Suppliers and Lower Tier Subcontractors as appropriate.

The Subcontractor shall be responsible for implementing and maintaining an effective system of control over his procurement sources to ensure that hardware, software, and services purchased for the program meet the requirements outlined in this PAR.

The Subcontractor shall ensure that all purchased special processes and personnel are properly certified in accordance with the requirements of this PAR.

G.3.2. Source Inspection

The Subcontractor shall exercise surveillance over all the activities carried out by his Suppliers and Lower Tier Subcontractors during the contract period.

The Subcontractor shall ensure that each of his Suppliers implements adequate surveillance over their lower level Suppliers, in accordance with this PAR.

Purchased products shall be verified upon receipt or at his Supplier's facility before shipment.

G.3.3. Procurement documents

The Subcontractor shall ensure that supplies are precisely identified and that all applicable requirements are properly defined in the procurement documents.

The Subcontractor shall ensure that requirements contained in lower tier procurement documents are traceable and can be demonstrated.

G.4. PRODUCT TRACEABILITY

G.4.1. Product Identification and Traceability

The Subcontractor shall establish and maintain documented procedures for identifying a product or lot by suitable means from receipt and during all phases of production, delivery, and installation. All similar assemblies and subassemblies shall be serialized.

The Subcontractor's system shall be capable of retrieving the identification and serialization record at the subassembly level. It shall also be capable of retrieving fabrication and test records of identifiable articles, materials, and parts in the event verification of the articles, materials, or parts becomes necessary.

G.4.2. Photographic Identification

Prior to final closure of subassemblies and assemblies, a color photograph shall be taken to identify the location and presence of parts therein.

The photograph shall be of sufficient clarity to enable the viewer to readily identify part identification and location. The photograph shall be identified with the applicable part number, revision, serial number, and date.

If the assembly is reopened for rework or adjustments and the validity of the photograph affected, an additional photograph shall be taken.

A copy of these photographs shall be included in the EIDP.

G.5. INSPECTION AND TEST

The Subcontractor shall plan inspections and tests during manufacturing, assembly and integration process where maximum assurance for correct processing and prevention of unrecoverable or costly nonconformance can be obtained.

The Subcontractor shall perform formal inspection at critical process, called KIP inspections. These shall verify that all the actions have been completed and the product satisfies applicable requirements.

Among the inspections and tests, some selected inspections which is critical to performance

and schedule, shall be performed by Customer (Satellite System Integrator) . This is called MIP inspection. MIP inspection plan shall be agreed with Customer (Satellite System Integrator) and described in the manufacturing flow diagram.

G.5.1. Receiving Inspection and Test

The Subcontractor shall perform receiving inspections and tests to verify that parts and materials conform to the requirements of this PAR. The Subcontractor shall inspect the product to ensure that it conforms to applicable procurement document.

Receiving inspection shall be performed in accordance with a pre-planned checklist. The checklist shall describe item characteristics and its expected criteria.

G.5.2. In-Process Inspection and Test

The Subcontractor shall perform in-process inspection and test surveillance operations to verify compliance with engineering and manufacturing requirements.

Inspection shall be planned at points in the fabrication and test cycle where subsequent manufacturing operations would make any previous operations difficult to inspect.

Each inspection points shall be defined as a specific step in the assembly traveler documents. Among these inspections, KIP/MIP shall be described in the manufacturing flow diagram. And the Subcontractor shall notify Customer (Satellite System Integrator) of KIP/MIP event.

Prior to shipment, the Subcontractor shall perform formal inspections and tests of End Products to ensure that they conform to applicable drawings and specifications with respect to configuration, performance, construction, workmanship, and identification.

Test equipment and setups shall be verified to be of proper configuration as required by the test procedure and to have valid calibration and certification status.

The Subcontractor shall establish controls which shall identify and physically segregate rejected items from conforming items. Also, he shall establish controls for conditionally accepted items which will allow tracking through assembly and, if required, retrieval of such items to prevent shipment in the End Product.

G.5.3. Acceptance Test

The Subcontractor shall perform acceptance test to verify compliance with contractual performance requirements.

Acceptance test shall verify environmental compatibility of the End Product as required by contract documents.

Acceptance test result shall be certified by the Subcontractor Quality Manager and approved by

Customer (Satellite System Integrator) before unit shipment.

G.5.4. Equipment Calibration

The Subcontractor shall maintain a calibration system in accordance with the applicable MIL or ESA requirements.

Records of calibration shall be maintained and made available for review by Customer (Satellite System Integrator) upon request.

G.6. CONTROL OF FABRICATION

G.6.1. Work Instruction

The Subcontractor's production operations shall be accomplished through controlled and documented work instructions. This instruction shall be clear, complete, and current and shall indicate the proper methods, tooling, location, and equipment required to accomplish the work. In case specific process specification is applicable, the instruction shall follow applicable specification.

Work instruction for the hardware assembly will be a traveler document.

Applicable instructions and aids shall be located in the work areas and personnel shall be familiar with the pertinent contents.

The Subcontractor Quality System shall provide for effective review and update of work instructions and specifications to assure compliance with contract requirements.

G.6.2. Manufacturing Flow Diagram

For each type of deliverable End Product, the Subcontractor shall prepare and maintain a manufacturing flow diagram identifying manufacturing and inspection operations.

The Subcontractor shall establish the KIP and MIP on the manufacturing flow diagram and provide this to Customer (Satellite System Integrator) for concurrence. These shall include visual as well as mechanical inspections and tests as appropriate.

G.6.3. Manufacturing Flow Control

In order to ensure quality uniformity, the following practices shall be implemented by the Subcontractor and his Suppliers:

- a. In general, once installed and inspected, a piece part, other than mechanical fasteners, shall not be reinstalled in deliverable hardware.
- b. An inspection per process specification and drawing requirements shall be performed and a

surveillance of equipment and personnel certification and compliance with process specifications instructions will be checked on a periodic basis.

- c. Store surveillance shall be performed to verify that handling, packaging, and environmental requirements is complied, and to verify that part type segregation is being implemented.
- d. Completed work shall be inspected prior to cover-up the assembly and prior to assembly traveler closeout as a minimum. Major inspection points shall be delineated in flow diagrams for electronic hardware.
- e. Special verification of polarized capacitors is required prior to power on. In addition, polarity shall be verified by voltage measurement at first power on. All capacitors require discharging before installation.
- f. All feed through filters shall be tested for insulation resistance after installation and the actual reading recorded on the assembly traveler.
- g. Threaded fasteners shall be torqued to the values specified on assembly drawings or travelers.
- h. All socket contacts shall have the separation force measured and all removable type contacts shall have a contact retention test performed to be assured of locked in contacts. Separation forces for all connector types shall be measured after conditioning.
- i. ESD protective dust caps shall be installed and delivered on external connectors. For high sensitivity ESD units, grounded shorting plugs are suggested.
- j. Flight hardware connectors which interface to GSE shall be protected by connector savers.
- k. The Subcontractor shall maintain accountability and configuration control of all parts during all phases of production.

G.6.4. Handling

The contractor shall prevent handling damage during all phases of manufacturing, assembly, integration, testing, storage, transportation and operation, through the use of followings:

- a. Protective measure during handling,
- b. Handling devices, and
- c. Procedures and instructions.

G.6.5. Storage

The contractor shall have secure storage areas available for:

- a. Incoming materials,
- b. Intermediate items needing temporary storage, and
- c. End Items before shipping.

Limited-life materials, suspended limited-life materials, nonconforming items awaiting MRB disposition, scrap items and all other items which are designated to be stored separately for health or safety reasons, shall be placed in segregated areas within the storage area. Each segregated area within the stores shall be clearly identified and labeled.

Controls shall be maintained over acceptance into and withdrawal from the storage area. Records shall be maintained to ensure that all stored items are within the usable life limits and adequately controlled and retested, and to provide traceability within the storage area.

G.6.6. Preservation

The Subcontractor shall ensure that items subject to deterioration, corrosion or contamination through exposure to air, moisture or other environmental elements are preserved by methods that ensure maximum protection consistent with life and usage.

G.6.7. Packaging

The container and packaging condition shall protect delivered hardware from the external environmental variation or events. The packaging condition for transportation shall consider the following items:

- a. ESD protective measure for the electronic End Product
- b. Environmental monitoring provisions such as humidity, shock, etc.
- c. Use of double bag to maintaining cleanliness
- d. Subcontractor's QA seal after final inspection before shipment
- e. Use of reusable container box is recommended.

G.6.8. Electrostatic Discharge Control

The Subcontractor shall implement an ESD control program based on the requirements of MIL-STD-1686 and MIL-HDBK-263 as a guide. All ESD sensitive parts shall be shipped in protective packages with clear indication of the part's ESD sensitivity.

Handling and protective procedures are to be documented in the Subcontractor's fabrication, inspection and process procedures. Procedures shall have instructions for the use of equipment, tools and materials, operating guidelines, approved packaging materials, and ESD controlled workstation requirements for the handling and protection of ESD sensitive electronic parts.

G.7. END ITEM DATA PACKAGE

The Subcontractor shall prepare legible and reproducible EIDP for each deliverable End Item under the contract as described by this PAR. Each EIDP shall be reviewed by Subcontractor

personnel for accuracy, content, and legibility prior to submittal to Customer (Satellite System Integrator).

The major contents of the EIDP shall be submitted to Customer (Satellite System Integrator) for review at least 10 working days prior to the PSR.

During the PSR, the EIDP shall be presented to a Customer (Satellite System Integrator) representative for review along with the deliverable item and shall be approved by review members. The PSR shall be held after final acceptance of the item by the Subcontractor QA and prior to shipment.

Final acceptance of the item shall be contingent upon the acceptability of the EIDP at Customer (Satellite System Integrator).

Each data package shall be bound, divided into these sections and completed in this order:

- a. Title page containing End Item description, Customer (Satellite System Integrator) part number, revision number, serial number, specification number, and purchase order number.
- b. Review and approval page of Subcontractor acceptability with signatures of an engineering representative, a configuration representative, a program manager, and a QA manager. This will be COC.
- c. ABCL, showing the as built revision of the Subcontractor's lowest detail drawing level of the End Item including the applicable serial number.
- d. User's manuals which contains operation constraints and handling precautions
- e. Nonconformances and changes section:
 - Nonconformance Status List. This list shall contain all of the minor and major nonconformance status.
 - Copies of all the Subcontractor's change proposals which classified as Class 1
 - Copies of all the Subcontractor's major nonconformance reports. These will include retest instructions.
 - Waivers and deviations requests
 - All applicable letters
- f. Inspection report according to the mechanical ICD. This report shall include measurement results.
- g. Contamination budget report. This report shall be prepared for contamination critical hardware.
- h. Acceptance test report which contains analysis and test results, including special engineering test, as applicable.
- i. Trend analysis report for the critical parameter
- j. Listing of test equipment used, including manufacturer, model number, serial number, and

date of last calibration

k. The level of contamination at the delivery for the contamination critical hardware

l. Cumulative logs for operating time or operating cycles, vibration time per axis, number of temperature and pressure cycles, number of switch actuations, and connector mate and demate cycles. This log summary shall be annotated with part number, serial number, and date

m. Photographic identification logs

G.8. CONFIGURATION CONTROL

Engineering, manufacturing, and tooling drawings and specifications are subject to a system of configuration control in accordance with Section 5 of this PAR.

The system shall ensure that only drawings, test procedures, and specifications of the latest applicable revision are available to operational personnel at the appropriate points during manufacturing, inspection, and testing. The system shall ensure the removal of obsolete documents from manufacturing, inspection, and test areas.

G.9. CONTAMINATION CONTROL

The Subcontractor shall have contamination control procedures for measuring and maintaining the required levels of cleanliness during the various phases of hardware assembly and testing.

Contamination control requirements are further detailed in Section 11 of this PAR.

G.10. CUSTOMER FURNISHED EQUIPMENT

The Subcontractor shall establish and maintain documented procedure for the control, verification, storage, and maintenance of CFE.

When CFE is furnished by Customer (Satellite System Integrator) , the Subcontractor shall inspect to detect damage in transit and provide for the protection, periodic inspection, and controls necessary to preclude damage or deterioration during handling, storage, or use.

The Subcontractor shall report to Customer (Satellite System Integrator) any parts which are damaged, malfunctioning, or otherwise unsuitable for use and shall determine and report the probable cause and necessity for withholding such CFE from use.

Unsuitable CFE shall be handled in such a manner as to prevent further damage and additional repair costs.

G.11. GROUND SUPPORT EQUIPMENT

The status of the MGSE, EGSE, and test aids used for manufacturing or testing the hardware

being procured shall be controlled by the Subcontractor's QA system.

Validation of equipment shall be carried out before use with the FM. This validation shall include a calibration status check, a maintenance status check, and a functional demonstration. Evidence of validation shall be available to Customer (Satellite System Integrator) upon request.

APPENDIX H. 신뢰성 (RELIABILITY)

H.1. GENERAL

The Subcontractor shall establish, implement, and maintain a reliability program plan as a part of Product Assurance Plan.

The product shall comply with the reliability requirements listed here:

- a. The product failure rate shall respect the reliability objective specified in the product technical requirement.
- b. The product shall respect the derating rules for EEE parts.
- c. All parts shall demonstrate compliance with space environment specification.
- d. The product shall provide provision for failure detection and switching off.
- e. The product shall avoid failure propagation in case of redundancy.
- f. The product shall respect the design safety factors.
- g. The product shall be designed to meet the lifetime specified in the technical specification.

In case hardware configuration is modified, related analysis and reports shall be updated and resubmitted to Customer (Satellite System Integrator).

H.2. RELIABILITY PREDICTION

A reliability prediction shall be performed under the actual environmental and stress condition.

For the high reliability parts which have appropriate quality level, MIL-HDBK-217F Notice 2 shall be used preferably as the failure rate database. If the parts are not covered by MIL-HDBK-217F Notice 2, failure rate investigation methods or its data source shall be agreed with Customer (Satellite System Integrator).

The reliability prediction report shall include functional schematics, parts reliability data, equipment reliability model, and any assumption used for the analysis.

H.3. FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS

FMECA analysis procedures and documentation shall be performed in accordance with ECSS-Q-ST-30-02 or equivalent standards with the severity categories described in Table H.1 and H.2. The FMECA shall identify how each failure mode is detected and shall recommend counter-measures to render such consequences. FMECA shall be accompanied by FDIR process.

For the failure modes of redundancy interface circuit or the failure modes resulting in a severity of category 1, the failure mode shall be analyzed to the depth of parts level.

In case of a unit including software, the effects of software errors shall be assessed at the functional level.

Common-mode analyses shall be performed on reliability and safety critical items to identify the root cause of failures that have a potential to negate failure tolerance levels. This analysis shall be included in the FMECA.

An FTA shall be performed at system and subsystem level for specified top events when specifically requested.

Table H.1 Severity category definitions at equipment level

Severity Category	Definition
1	Failure mode causes damage by propagation to interfacing units
2	Failure mode causes the loss of required function
2R	Failure mode causes the loss of redundant function
3	Failure mode causes the degradation of the required function
4	Failure mode causes minor degradation
5	No effect

Table H.2 Severity category definitions at subsystem level

Severity	Category	Definitions
Catastrophic	1	Failure modes that could result in serious injury or loss of life or loss of launch vehicle
	1R	Failure modes of redundant hardware item that, if all failed, could result in Category 1 effects.
	1S	Failure in a safety or hazard monitoring system that could cause the system to fail to detect a hazardous condition or fail to operate during such condition and leads to Severity Category 1 consequences.
Critical	2	Failure modes that could result in loss of one or more mission objectives.
	2R	Failure modes of redundant hardware items that could result in Category 2 effects if all failed.
Significant	3	Failure modes that could cause degradation to mission objectives.
Minor	4	Failure modes that could result in insignificant effect to mission objectives.

H.4. PART STRESS ANALYSIS

The derating rules applied to EEE parts will limit the application conditions of voltage, current, power, temperature, mechanical environment, and duty cycle to achieve part failure rates consistent with reliability requirements.

ECSS-Q-ST-30-11, GSFC EEE-INST-002, or MIL-STD-975 shall be applied to the application of all EEE parts. In case other derating rules are used, justification for the rules shall be submitted to Customer (Satellite System Integrator) for approval.

All of the EEE parts shall be derated to establish derating levels, and analyses shall be performed to demonstrate that each part meets the stress derating criteria in each phase of the mission of the equipment in normal, transient and contingency operating modes.

The list of the parts exceeding the stress criteria with its respective parameters is presented in the Part Stress Analysis document. Areas of noncompliance shall be identified with proposed solutions or justifications for use.

Deviation from derating criteria shall be subjected as a RFD.

H.5. WORST CASE ANALYSIS

The Subcontractor shall provide an analysis of the effects on design performances as it is influenced by part parametric variations, environmental effects, radiation effects, input and output variations, part tolerance, aging, etc.

This analysis shall verify that within reasonable combinations of specification characteristics and parts tolerance, the design meets specified performance in worst mission period.

A final assessment report shall include the functions on which analysis has been performed, the supporting circuits, and compliance status.

H.6. TREND ANALYSIS

The critical parameters of the End Product that can be monitored during testing shall be identified at Design Reviews and trends shall be tracked during testing.

The analysis results shall be included in the EIDP. Items with unusual or abnormal trends shall be noticed to Customer (Satellite System Integrator).

H.7. CRITICAL ITEM LIST

Critical items shall be identified and maintained in a critical items list throughout the product's life cycle. An item shall be considered critical when:

- a. It is not a space qualified design or technology.
- b. It has safety hazards for hardware or personnel.
- c. Failure mode severity is assigned to category 1.
- d. The relevant failure rate is not justified.
- e. It is hardware which is sensitive to age or wear or requires special ground handling conditions. This will be a Limited Life Item.
- f. Parts are out of accepted derating conditions.
- g. Parts or materials are not qualified.

The critical item list document shall include the following information as a minimum:

- a. Item description
- b. Reason for criticality
- c. Risk mitigation plan

All reliability critical items shall be incorporated in the risk management system for the criticality mitigation process.

H.8. LIMITED LIFE ITEM

The End Product shall be designed considering operational life, storage life, and assembly, integration and test life.

All parts of the End Product being procured shall be reviewed for wear or degradation during its designed lifetime. Analytic or test data justification shall be developed showing that an adequate life margin exists.

Limited life items are hardware subject to degradation due to age, operating time, or cycles and thus require periodic replacement, refurbishment, retest, or operation to assure that its mission performance will not be degraded beyond acceptable limits. These items shall be identified in the Limited Life Item List with the accumulated time or cycle tracking and maintenance records.

If deliverable hardware requires maintenance activities during storage, assembly, and testing period, the Subcontractor shall describe appropriate maintenance activities in the user's manual and agree with Customer (Satellite System Integrator) before unit shipment.

APPENDIX I. 안전관리 (SAFETY)

I.1. GENERAL

The Subcontractor shall observe applicable safety laws or ordinances.

The Subcontractor shall implement a safety program that will ensure the identification and control of hazards during fabrication, testing, transportation, ground activities, and launch operations.

Hardware and software nonconformance that occur during the course of the verification program shall be reviewed for their safety implications.

I.2. HAZARDOUS OPERATIONS

The Subcontractor safety engineer shall identify all potentially hazardous operations in the Subcontractor's facilities.

When the operation could result in hazardous effect on the personnel, an investigation shall be performed to identify and adequately control the hazards.

A report of each investigation shall be available for review at the Subcontractor's facility.

I.3. COMPLIANCE TO SAFETY REQUIREMENTS

The Subcontractor shall demonstrate that the End Product is compliant with safety requirements of the applicable launch site range. The demonstration of safety compliance shall be accomplished by the appropriate analysis or test.

The Subcontractor shall submit a safety assessment report applicable to the phase of the program at the time of design review. The contents of the safety assessment report shall be consistent with the requirements of the applicable launch vehicle and launch site requirements.

The safety reports shall include, as a minimum, a description of the product design, safety requirement compliance status, hazard analysis or test results, and other applicable safety related information.

I.4. SUPPORT FOR SAFETY REVIEW

The Subcontractor shall provide technical support to Customer (Satellite System Integrator) for applicable safety reviews.

APPENDIX J. 자재/기계부품 및 공정 (MATERIAL, MECHANICAL PART AND PROCESS)

J.1. GENERAL

The Subcontractor is required to observe the requirements of this PAR. The Subcontractor is also fully responsible for selection, procurement, and application of the materials and processes. The Subcontractor shall provide a materials and processes plan as a section of PAPP or as a separate document. The document shall describe all activities implemented for conformance to program requirements.

J.2. MATERIALS SELECTION

Materials shall be selected with full consideration of the effects of the space environment and shall satisfy applicable requirements based on the criteria described herein.

Use of materials with a history of successful spacecraft applications and existing specifications and databases will minimize verification efforts.

Materials used in a conventional process with successful flight heritage and which meet the selection criteria within this PAR will be classified as compliant materials.

Noncompliant materials are any materials not defined as compliant. These will include the materials which meet the requirements but are not used in conventional applications.

Off-the-shelf hardware for which a detailed materials list is not available and where the included materials cannot be easily identified and/or changed shall be considered to be noncompliant.

Compliant materials shall be used in the fabrication of flight hardware to the maximum practical extent.

Noncompliant materials shall be deemed critical, as defined in Section J.8.1 of this PAR, and the Subcontractor shall prepare a RFA package, with adequate justification for its use, and submit it for review and approval to Customer (Satellite System Integrator)'s PMPCB.

J.2.1. Restricted Materials

Due to limited life, safety concerns, or known instability, the following materials are not recommended:

- a. Beryllium or selenium except internal to hermetically sealed devices.
- b. Unalloyed electrodeposited tin unless subsequently fused or reflowed.
- c. Corrosive solder fluxes unless detailed cleaning procedures are specified that include verification methods to ensure removal of residual contaminants.

- d. Teflon, vinyl, polyvinyl chloride used as an insulator for electrical harness wire. Fluorocarbon polyimide wire 'Kapton®' is to be controlled as a critical item.
- e. Materials which exhibit or are known to exhibit natural radioactivity such as uranium, potassium, radium, thorium or any alloys thereof.
- f. Indium and indium solder
- g. Magnesium
- h. Lithium

Where the use of any of these materials is unavoidable, the application shall be evaluated on a case-by-case basis and the Subcontractor shall prepare a RFA package, with adequate justification for its use, and submit it for review and approval to Customer (Satellite System Integrator)'s PMPCB.

J.2.2. Prohibited Materials

The use of pure mercury, cadmium, pure electrodeposited or hot dipped tin-plated surface coatings, zinc and PVC is prohibited.

These materials can be used in the way that unit design mitigates material instability. The Subcontractor shall prepare a RFA package, with adequate justification for its use, and submit it for review and approval to Customer (Satellite System Integrator)'s PMPCB.

J.3. MATERIALS REQUIREMENTS

J.3.1. Corrosion

Metallic materials selected for use in flight hardware shall be corrosion resistant or protected from corrosive environments by finishing and prevention of moisture condensation on corrosion susceptible hardware by environmental control or using seals and metallurgical joints.

Non-metallic parts shall not have a corrosion stimulating effect on other materials when exposed for their specific useful life.

Incompatible couples defined by MIL-STD-889 shall be avoided. Such dissimilar metals may be used in intimate contact, but only if the assembly is protected in a manner as to preclude moisture.

J.3.2. Stress Corrosion

Metals and alloys shall not have a propensity towards stress corrosion cracking, as defined in Table I of ECSS-Q-70-36A. Metals and alloys in Table II or III of ECSS-Q-70-36A may be used with Customer (Satellite System Integrator)'s PMPCB approval.

Metals and alloys that are susceptible to stress corrosion cracking shall be avoided in sustained tensile applications.

J.3.3. Hydrogen Embrittlement

Metals, particularly high strength steels and titanium alloy, which will be exposed to a hydrogen rich environment or subjected to processes that can introduce hydrogen in the metal, shall be evaluated for susceptibility to hydrogen embrittlement. Any resulting reduction in performance will be highlighted and appropriate measures will be taken to eliminate the effect.

J.3.4. Magnetism

The use of magnetic materials is not permitted, if it can be avoided, and shall be avoided as far as practicable to allow for a high degree of magnetic cleanliness for the spacecraft. All magnetic materials are to be identified in the materials list and a justification for their use shall be submitted for review and approval to Customer (Satellite System Integrator)'s PMPCB.

J.3.5. Fluid Compatibility

Metallic and nonmetallic materials that will be in contact with an identified fluid shall be compatible with that fluid. If compatibility data are not available, testing shall be performed according to NASA-STD-(I)-6001A test number 15.

Metallic materials directly exposed to propellants shall not exhibit surface corrosion.

J.3.6. Vacuum Stability

Only materials that have TML and CVCM less than the requirements in Section 11 shall be used in a vacuum environment.

J.3.7. Flammability

Major use organic materials for flight shall be nonflammable or self-extinguishing in air in the application configuration.

J.3.8. Radiation Sensitivity

Exterior and exposed materials shall be capable of functioning as intended in an orbital charged particle and UV radiation environment.

J.3.9. Electrostatic Discharge Protection

Materials used in areas sensitive to electrostatic discharge shall be selected to ensure that the

maximum potential difference between any two points on the spacecraft is within the limits of applicable ESD/EMC requirements.

J.4. MECHANICAL PARTS SELECTION

Mechanical parts shall be selected with full consideration of the effects of the space environment and shall be selected on the basis of previous space heritage in an identical application.

Mechanical parts which has successful flight heritage and will be procured to the ESA or MIL specification will be classified as standard part.

Nonstandard parts are any mechanical parts not defined as standard. These will include the standard parts used in alternative application.

Standard part shall be used in the flight hardware design to the maximum practical extent.

Where a mechanical part is not controlled by an ESA or MIL specification, current and fully configured specifications applicable to the relevant Subcontractor should be used to ensure full control over the procurement and performance of the mechanical part.

All materials that comprise a mechanical part must be individually assessed in accordance with the requirements of this document and listed on the Materials Identification List.

Nonstandard parts shall be deemed critical, as defined in Section J.8.1 of this PAR, and the Subcontractor shall prepare a RFA package, with adequate justification for its use, and submit it for review and approval to Customer (Satellite System Integrator)'s PMPCB.

J.5. PROCESS SELECTION

All manufacturing and assembly processes used shall be carefully selected so that material integrity is maintained and physical property changes are well understood and controlled.

Processes which has successful flight heritage with the use of compliant materials will be classified as conventional process.

Nonconventional processes are any processes not defined as conventional. For the nonconventional processes, process verification is required.

Conventional processes shall be used in the fabrication of flight hardware to the maximum practical extent.

If a nonconventional process is applied, the Subcontractor shall verify for the desired process application on the basis of tests, similarity, analyses, inspection, existing data, or a combination of those methods.

Nonconventional process shall be deemed critical, as defined in Section J.8.1 of this PAR, and the Subcontractor shall prepare a RFA package, with adequate justification for its use, and

submit it for review and approval to Customer (Satellite System Integrator)'s PMPCB.

J.6. SPECIFIC REQUIREMENTS

J.6.1. Pyrotechnic Parts

The selection, procurement and application of pyrotechnic devices shall conform to the requirements of ECSS-E-30 Part 6A. All devices selected for use must be subject to the qualification, acceptance and verification testing of this specification.

Primary and redundant devices must not be taken and installed from the same lot.

The pyrotechnic device subsystem must be subject to an end-to-end test prior to launch.

J.6.2. Shelf Life Materials

Materials with limited lifetime characteristics shall be subject to lot/batch acceptance tests, and shall have the date of manufacture and shelf-life expiration date marked on each lot/batch.

Storage conditions must be controlled to avoid degradation of the material. Storage conditions and shelf life should be stated in the procurement specification.

The material whose shelf life has expired shall be segregated from other conforming materials and shall not be used on the FM fabrication unless the material is validated by means of appropriate tests.

J.7. PROCUREMENT

The Subcontractor shall describe the procurement methods.

The procurement of materials shall be done by formal procurement document. These procurement documents shall be approved by the Subcontractor's MPCB.

J.8. MATERIALS AND PROCESS APPROVAL

J.8.1. Critical Materials and Processes

For the materials, mechanical parts, and processes identified as critical, the Subcontractor shall prepare a RFA package, with adequate justification for its use, and submit it for review and approval to Customer (Satellite System Integrator)'s PMPCB.

The definition of a critical material, mechanical part or process is as followings:

a. Materials

- It is new, has no previous space use or is non-validated, in the application in question.
- Previous use has highlighted technical issues.

b. Mechanical parts

- It is new, has no previous space use or is non-qualified, in the application in question.
- Previous use has highlighted technical issues.
- Failure of the mechanical part can adversely affect the performance or destroy a major part or function of the spacecraft.
- The quality of the mechanical part cannot be assessed by simple tests.

c. Processes

- It is new, has no previous space use or is non-validated, in the application in question.
- Previous use has highlighted technical issues.
- Failure of the process can adversely affect the performance or destroy a major part or function of the spacecraft.
- The Subcontractor has no prior application experience.
- The quality of the process cannot be assessed by examining the End Product.

All critical materials, mechanical parts, and processes shall be evaluated and qualified. The qualification reports are to be approved by Customer (Satellite System Integrator). The qualification of all critical materials, mechanical parts or processes shall be completed and accepted by Customer (Satellite System Integrator) before the materials, mechanical parts or processes are used on FM hardware.

RFA shall include all the contents defined in APPENDIX C.

J.8.2. Material and Process Control Board

The selection, application, and approval of materials and process shall be implemented through the Subcontractor's MPCB.

The major activities of the Subcontractor's MPCB are listed below:

- a. Review and approve process specification, materials specification, and procurement document.
- b. Prepare verification plans for nonconventional processes.
- c. Investigate materials and process related issues during the entire program life cycle.
- d. Prepare material identification lists and process lists and submit them to Customer (Satellite System Integrator).
- e. Prepare RFA documents and submit them to Customer (Satellite System Integrator)'s PMPCB for approval.

J.9. MATERIALS, MECHANICAL PARTS AND PROCESSES LIST

The Subcontractor shall prepare a list of materials, mechanical parts, and processes identified

in this program.

The lists shall cover all materials and processes used in the equipment, including those used at lower tier Subcontractors level and all materials, mechanical parts and processes used during the AIT phase.

The lists shall include all the contents defined in APPENDIX C.

J.10. SPECIFICATION

All of the materials and mechanical parts shall be procured in accordance with the standard specification or customized specification designated for the material.

All of the Subcontractor's processes shall be recorded and maintained in the form of process specifications.

The specification shall contain all necessary physical, environmental, performance, and qualification requirements.

Specification for the noncompliant materials and/or nonstandard parts shall be submitted with the RFA document.

The process specifications shall be available to Customer (Satellite System Integrator) at the Subcontractor's facilities.

J.11. RECEIVING INSPECTION

Each material shall be submitted to a receiving inspection. The objective of the inspection is to verify the compliance with the procurement specifications and the purchase order requirements. Receiving inspections shall at least include data review and visual inspection. Characterization tests shall be performed if required.

J.12. TRACEABILITY

The Subcontractor shall ensure that it is possible to reconstitute the material or part's history, either individually or by the manufacturing lot.

The Subcontractor shall ensure that the full traceability of materials and parts is maintained and recorded throughout the mission life of the End Product.

J.13. PROPRIETARY INFORMATION

Where materials, mechanical parts, or processes are considered proprietary by the Subcontractor and/or Supplier, Customer (Satellite System Integrator) will respect the right of the third party to withhold certain details. However sufficient information must be made available to Customer (Satellite System Integrator) to allow a full evaluation of the material, mechanical

part, or process with respect to the mission environment and lifetime requirements and to allow a full risk assessment to be carried out. The level of information exchange will be defined on a case-by-case basis dependent on the sensitivity of the requested information.

APPENDIX K. 전기전자부품 (EEE PARTS)

K.1. GENERAL

EEE parts for qualification models shall be from the same design type (Form, Fit, Function) and manufacturer as the ones intended to be used on FMs.

The Subcontractor shall ensure that all parts requirements are flowed-down to all his Subcontractors and ensure that all his Subcontractors are compliant to these parts requirements.

K.2. PARTS SELECTION

The Subcontractor shall ensure that the selected parts meet the operating, environmental, radiation, material, safety, quality and reliability conditions defined for the program.

[QUALITY REQUIREMENT FOR EEE PARTS FOR GEO]

EEE parts listed in the EPPL part I, ESCC QPL parts, NPSL level 1 parts (with disposition of the associated application note), GSFC EEE-INST-002 level 1 parts (with disposition of the associated application note), and MIL QPL/QML parts (a quality level is based on the NPSL level 1) shall be used as the primary basis for parts selection.

[QUALITY REQUIREMENT FOR EEE PARTS FOR LEO]

EEE parts listed in the EPPL part I and II, ESCC QPL parts, NPSL level 1 and 2 parts (the associated application note shall apply), GSFC EEE-INST-002 level 1 and 2 parts (the associated application note shall apply), and MIL QPL/QML parts (a quality level is based on the NPSL level 1 or 2) shall be used as the primary basis for standard parts selection.

EEE parts which satisfy the screening requirement of Section K.3 and APPENDIX K will be classified as program standard parts. Nonstandard parts are any parts not defined as standard parts.

Standard parts shall be used in the flight hardware design to the maximum practical extent. When equipment development and qualification conditions or technical issues do not allow use of the above standard level, the next available level in the above ESCC or US MIL systems shall be considered.

In the case that a valid and acceptable status cannot be demonstrated, an adequate evaluation program shall be implemented to comply with the requirements specified for the program.

If nonstandard parts are used in the flight hardware, the Subcontractor shall prepare a PAD

package, with adequate justification for its use and supplementary test, and submit it for review and approval to Customer (Satellite System Integrator)'s PMPCB.

K.2.1. Radiation Hardness

All the parts used in the end product shall be selected to meet their mission application for the specified, predicted radiation environment. These requirements are established for all kinds of radiation including cosmic, trapped and solar flares.

The Subcontractor shall implement radiation hardness assurance programs which assess actual radiation tolerance of the selected components for compliance with the KOMPSAT or GEOKOMPSAT radiation requirements in term of Total Dose, displacement damages, and single events effects.

The Subcontractor shall issue a radiation assessment report identifying all sensitive components with respect to the relevant radiation effects, their impact and giving an adequate design solution for the equipment. The radiation assessment report shall be submitted to Customer (Satellite System Integrator).

- a. Total Ionizing Dose (TID) : In order to reduce the Total Dose risk, parts can be shielded or replaced. Any other solutions may be used as appropriate.
 - $2 \times \text{Received Dose Level} < \text{TID Sensitivity of the parts}$: FM lot is accepted as is.
 - $1.3 \times \text{Received Dose Level} < \text{TID Sensitivity of the parts} < 2 \times \text{Received Dose Level}$: Radiation lot acceptance test is required. If FM lot parametric and functional hardness is larger than 1.3 times the dose level, the FM lot is accepted.
 - $\text{TID Sensitivity of the parts} < 1.3 \times \text{Received Dose Level}$: The part is not acceptable as is. Shielding of parts, replacement, or any other solutions shall be found.
- b. Displacement Damage: In order to reduce the displacement damage risk, parts can be shielded or replaced. Any other solutions may be used as appropriate.
 - $2 \times \text{Received DDEF Level} < \text{DDSF of the parts}$: FM lot is accepted as is.
 - $1.3 \times \text{Received DDEF Level} < \text{DDSF of the parts} < 2 \times \text{Received DDEF Level}$: Radiation lot acceptance test are required. If FM lot parametric and functional hardness is larger than 1.3 times the DDSF level, the FM lot is accepted.
 - $\text{DDSF of the parts} < 1.3 \times \text{Received DDEF Level}$: The part is not acceptable as is. Shielding of parts, replacement, or any other solutions shall be found.
- c. Single Event Phenomenon (SEP) : Evaluation of SEP shall be performed according to the following criteria. LETth(SEP) means threshold LET for a specific kind of SEP. The source of part radiation data will be considered when evaluation of SEP.

- $60 \text{ MeV}\cdot\text{cm}^2/\text{mg} < \text{LET}_{\text{th}}(\text{SEP})$: Part is considered as not sensitive to the specific SEP. FM lot is accepted as is.
- $15 \text{ MeV}\cdot\text{cm}^2/\text{mg} < \text{LET}_{\text{th}}(\text{SEP}) < 60 \text{ MeV}\cdot\text{cm}^2/\text{mg}$: Part is sensitive to heavy ion induced SEP but not sensitive to proton induced SEP. Heavy ion induced SEP rate and their effects shall be analyzed to identify the effects and criticality. Risk reduction actions required if the mitigation is necessary from the analysis. Final decision will be taken at Customer PMPCB.
- $\text{LET}_{\text{th}}(\text{SEP}) < 15 \text{ MeV}\cdot\text{cm}^2/\text{mg}$: Part is sensitive to heavy ion and proton induced SEP. Heavy ion and proton induced SEP rate and their effects shall be analyzed to identify the effects and criticality. Risk reduction actions required if the mitigation is necessary from the analysis.

The use of part, which is not acceptable as is, shall be reviewed and approved by Customer PMPCB.

K.2.2. Restricted Parts

The Subcontractor shall ensure that materials which are not hermetically sealed within components meet the requirements of Section 10 regarding outgassing, flammability, toxicity, and criteria required for the intended use.

The Subcontractor shall insure that EEE part does not contain health and safety hazard materials such as beryllium oxide, cadmium, lithium, magnesium, mercury, or radioactive material.

The Subcontractor shall also evaluate the robustness of selected EEE components to the stresses induced during assembly process.

For limited life, known instability, safety hazard or reliability risk reasons, the use of EEE parts listed below shall be prohibited:

- a. Component using pure tin material plating
- b. Hollow core resistors
- c. Potentiometers (except for mechanism position monitoring)
- d. Non-metallurgically bonded diodes
- e. Semiconductor dice without passivation or glassivation over exposed active area
- f. Wet slug tantalum capacitors other than capacitor construction using double seals and a tantalum case
- g. TO5 relays without double welding of the mechanism to the header or with any type of integrated diodes inside
- h. Wire-link fuses $< 5\text{A}$
- i. RNC90 resistors above $100 \text{ k}\Omega$ (for new design)

- j. TO3 and DO4/DO5 packages (for new design)

K.3. PROCUREMENT

The Subcontractor shall describe the procurement scheme in the parts control plan.

The procurement of materials shall be done by formal procurement document. These procurement documents shall be controlled by Subcontractor's responsibility.

To reduce the risk of procuring counterfeit parts, when parts are not directly procured from the manufacturer, the supplier shall procure parts only from distributors duly franchised by the parts manufacturer.

K.3.1. Quality Level

All EEE parts to be incorporated into flight hardware shall be subjected to screening tests. These screening tests shall be designed so that accumulated stress will not jeopardize the part reliability.

The baseline of quality level used to procure or to up-screen EEE parts is described in APPENDIX K.10

K.3.2. Procurement Specification

Any EEE part intended for use in flight hardware shall be procured to controlled specifications. International specifications systems such as ESCC or MIL, recognized as suitable for space applications, shall be used by the Subcontractor.

This document shall be configuration controlled by the Subcontractor, and submitted to Customer (Satellite System Integrator) PMPCB for approval through the PAD process.

The EEE parts procurement responsible is requested to ask the manufacturer to give notification of any product change affecting qualification, performance, quality, reliability and interchangeability and to communicate this information to the Subcontractor (if applicable).

The issue and revision of the detail procurement specifications shall be specified in the Part Identification List.

K.3.3. Lot Acceptance Test and Quality Conformance Inspection

Any lot of EEE parts shall be submitted to a LAT (ESCC system) or QCI/TCI (MIL system) procedure according to the following rules:

- a. ESA qualified parts : For ESA qualified parts, LAT is implemented in accordance with the ESA specifications.
- b. MIL qualified parts : For MIL qualified parts, QCI/TCI is implemented in accordance with the

quality level of the MIL specification.

- c. Non-qualified parts : For non-qualified parts purchased to source control drawing, LAT or QCI shall be performed in accordance with the closest applicable ESA or MIL specification. The content of the lot acceptance is ESCC level LAT1 or level LAT2 or LVT(subgroups 1, 2, and 3) or comparable QCI. Customer (Satellite System Integrator) will approve the proposed level during PMPCB, through the PAD provided by the Subcontractor.

When a lot built with different sub lots is submitted to LAT/QCI, the distribution of these sub lots shall be identified and the LAT/QCI sampling shall be representative of this distribution.

A failure analysis shall be performed on any part which failed during the LAT/QCI/TCI. Analysis result shall be available for review by Customer (Satellite System Integrator), on request.

EEE parts used during life test of LAT/QCI /TCI are prohibited to be used as flight parts.

K.3.4. Destructive Physical Analysis

The DPA shall be performed on 3 samples per lot for nonstandard parts belonging to the following categories:

- a. Hybrid circuits,
- b. Microcircuits,
- c. Discrete semiconductors,
- d. Relays and switches,
- e. Crystals and Oscillators,
- f. Passive microwave devices,
- g. Capacitors (ceramic, tantalum, and variable),
- h. Filters

Either standard or not, the DPA shall be performed on 3 samples per lot on relays, oscillators, and hybrids. The DPA sample size may be reduced in some cases which shall be submitted to Customer (Satellite System Integrator) for approval through the PAD process.

The Subcontractor shall verify that the outcome of the DPA is satisfactory prior to the installation of the components into flight hardware.

The DPA procedure and reports, which includes photos, shall be provided to Customer (Satellite System Integrator) for review on request.

K.3.5. Radiation Hardness Verification

Radiation sensitive parts, as defined in K.2.1, and for which applicable existing test data is insufficient shall be subjected to RVT.

RVT shall be performed in accordance with internationally recognized standards, such as ESCC

Basic Specifications No. 22900 and No 25100, MIL-STD-750 Test Method 1080, MIL-STD-883 Test Method 1019, or JEDEC JESD57.

The results of RVT shall be documented by a report and shall be provided to Customer (Satellite System Integrator) for review on request.

K.4. SPECIFIC PARTS REQUIREMENTS

K.4.1. Application Specific Integrated Circuits (ASIC)

ECSS-Q-ST-60-02 or equivalent MIL specification shall apply for the design development of ASICs.

K.4.2. One Time Programmable Devices

For FPGA, ECSS-Q-ST-60-02 or equivalent MIL specification, shall apply for the design development. The Subcontractor shall submit a post-programming procedure, depending on part types (including, when necessary, electrical tests, programming conditions and equipment, burn-in conditions, additional screening tests and specific marking after programming) to Customer (Satellite System Integrator) for approval.

K.4.3. Hybrids Devices

The Subcontractor shall manufacture Hybrids in accordance with the requirements of MIL-PRF-38534 Class K or ECSS-Q-ST-60-05 shall apply.

K.4.4. Electromagnetic Devices

The in-house magnetic parts shall be designed and screened using MIL-STD-981 as a guide line.

K.4.5. Microwave Monolithic Integrated Circuits

ECSS-Q-ST-60-12 or equivalent MIL specification shall be applied.

K.5. PARTS EVALUATION PROGRAM

The Subcontractor shall implement a part evaluation and approval testing program in absence of an approved demonstration that a part has the ability to conform to the requirements for performance, quality, reliability, and environmental resistance as required for the program.

The evaluation program, documented by an evaluation plan, shall identify the manufacturing baseline in order to ensure that the flight parts shall be built according to the same technology

and manufacturing processes as the evaluated components.

In the case that a change affects the qualification status, a new qualification or a delta qualification shall be undertaken.

For commercial parts, the Subcontractor is encouraged to perform a single procurement for evaluation and flight parts in order to ensure that the evaluation results are representative of the flight parts.

The evaluation plan is based on the following elements:

- a. Constructional analysis
- b. Manufacturer assessment
- c. Evaluation testing (according to the Qualification or LAT/QCI of the ESCC/MIL standard parts depending on the part consideration)
- d. Radiation testing (if applicable, depending on the component sensitivity and the program requirements)

Reduction or omission of any element of the evaluation requirements shall be justified on the basis of documentary evidence provided by the responsible of the evaluation program.

The evaluation plan shall be submitted to Customer (Satellite System Integrator) for approval, in the frame of PAD process. The evaluation results, documented by an evaluation report, shall be submitted to Customer (Satellite System Integrator) for approval.

The preliminary PAD approval does not prejudice its final acceptance. The final approval shall be definitely pronounced when the evaluation is successfully completed.

Failure analysis shall be conducted on any part which failed during this evaluation program, in order to determine the reason for failure and to react at procurement level or at part selection level.

K.6. PART IDENTIFICATION LIST

The Subcontractor shall issue a Part Identification List, identifying all EEE parts used for each unit. The Subcontractor Part Identification List shall include Lower Tier Subcontractor's or Supplier's Part Identification List. The subcontractor shall issue the Part Identification List and the As-built Part Identification List in editable and sortable electronic format.

K.7. RECEIVING INSPECTION

Each part shall be submitted to an incoming inspection. The objective of the inspection is to verify the compliance with the procurement specification and the purchase order requirements.

The receiving inspection shall at least include following verifications:

- a. Compliance with the purchase order requirements

- b. Manufacturer Certificate of Conformance (COC)
- c. Integrity of the parts by visual inspection
- d. Packaging of the components
- e. Review of delivered documentations
- f. Quantity

K.8. HANDLING AND STORAGE

The Subcontractor shall establish and implement procedures for handling and storage of EEE parts in order to prevent any degradation, taking into account the possible use of plastic packages.

As a minimum the following areas shall be covered:

- a. Control of storage environment such as temperature ($22\pm 5^{\circ}\text{C}$), humidity ($45\% < \text{RH} < 65\%$ max), cleanliness
- b. Appropriate measures and facilities for segregating and protecting parts during incoming inspection, storage and delivery to manufacturing
- c. Control measures to ensure that parts susceptible to ESD are identified and handled only by properly trained personnel using antistatic packaging, tools and other means, including procedures

For PEM Devices, specific requirements for handling, storage, and bake-out before mounting shall be applied.

K.9. NONCONFORMANCE

Any observed deviation of EEE parts from requirements of applicable specifications, procedures and drawings shall be controlled by the nonconformance control system.

The nonconformance control system shall handle all nonconformances occurring on EEE parts during:

- a. Manufacturing (if available), screening and acceptance tests,
- b. Incoming inspection,
- c. Integration and test of equipment,
- d. Storage and handling.

K.10. QUALITY REQUIREMENT

TABLE K-1. QUALITY REQUIREMENT FOR EEE PARTS FOR LEO

Category	Quality Requirement		
Cables & wires, low frequency	ESCC	ESCC 3901 level B	
	MIL	MIL-W-22759 MIL-DTL-16878	
	Other	NEMA-WC27500	
Cables, coaxial, radio frequency	ESCC	ESCC 3902 level B	
	MIL	MIL-C-17	
	Other	-	
Capacitors, chip, ceramic	ESCC	ESCC 3009 level C	(Note 1)
	MIL	MIL-PRF-55681 EFRL R min MIL-PRF-123	
	Other	-	
Capacitors, molded, ceramic	ESCC	ESCC 3001 level C	(Note 1)
	MIL	MIL-PRF-20 EFRL R min MIL-PRF-39014 EFRL R min MIL-PRF-123 MIL-PRF-49470 EFRL T	
	Other	-	
Capacitors, glass (CYR type)	ESCC	ESCC 3004 level C	Not recommended for new design
	MIL	MIL-PRF-23269 EFRL R min	
	Other	-	
Capacitors, mica	ESCC	ESCC 3007 level C	
	MIL	MIL-PRF-39001 EFRL R min	
	Other	-	
Capacitors, chip, solid tantalum (TAJ, T495, CWR11, ...)	ESCC	ESCC 3011 level C ESCC 3012 level C	All capacitors shall be surge current tested.
	MIL	MIL-PRF-55365 WFRL C min	
	Other	-	
Capacitors, non-solid tantalum, electrolytic (CLR 79)	ESCC	ESCC 3003 level C	39006 / 22, 25, 30, 31 and "H" designated devices are recommended
	MIL	MIL-PRF-39006 EFRL R min	
	Other	-	
Capacitors, solid tantalum, electrolytic (CSR type)	ESCC	ESCC 3002 level C	Surge current test mandatory on low ESR capacitors (CSR21 and CSR33)
	MIL	MIL-PRF-39003 WFRL C min	
	Other	-	
Capacitors, super metallized plastic film, (CRH type)	ESCC	ESCC 3006 level C	
	MIL	MIL-PRF-83421 EFRL R min	
	Other	-	

Category	Quality Requirement		
Capacitors, super metallized plastic film, (CHS type)	ESCC	ESCC 3006 level C	
	MIL	MIL-PRF-87217	
	Other	-	
Capacitors, variable	ESCC	ESCC 3010 level C	Not recommended for new design
	MIL	-	
	Other	-	
Connectors, circular and rectangular, non-filter contacts	ESCC	ESCC 3401 level B	Outgassing control such as vacuum bake out is required for military circular connectors for contamination critical application.
	MIL	MIL-DTL-24308 (rect.) class M or K MIL-DTL-38999 (circ.) class G or H	
	Other	GSFC S-311-P-4, P-10(rect,)	
Connectors, circular and rectangular, filter contacts	ESCC	ESCC 3405 level B	Life test 1000H/125°C /1.5 V _r is mandatory on each tubular ceramic lot.
	MIL	-	
	Other	-	
Connectors, Printed Circuit Board	ESCC	ESCC 3401 level B	
	MIL	-	
	Other	-	
Connectors, Microminiature rectangular	ESCC	ESCC 3401 level B	
	MIL	MIL-DTL-83513	
	Other	-	
Connectors, RF coaxial	ESCC	ESCC 3402 level B	Outgassing control such as vacuum bake out is required for military parts for contamination critical application.
	MIL	MIL-PRF-39012	
	Other	-	
Crystals resonators	ESCC	ESCC 3501 level B	Crystal shall be built using a cultured premium Q swept material.
	MIL	MIL-PRF-3098	
	Other	-	
Diodes, low frequency	ESCC	ESCC 5000 level B	PIND test (Note 2,3)
	MIL	MIL-PRF-19500, JANTXV	
	Other	-	
Diodes, high frequency	ESCC	ESCC 5010 level B	PIND test (Note 2,3)
	MIL	MIL-PRF-19500, JANTXV	
	Other	-	
Filters, EMI	ESCC	ESCC 3008 level C	
	MIL	MIL-PRF-28861, class S	
	Other	-	
Fuses CERMET	ESCC	-	
	MIL	MIL-PRF-23419	
	Other	-	

Category	Quality Requirement		
Fuses (wire link $\geq$ 5A)	ESCC	-	Burn-in(168H / 85°C / 50% rated current) is mandatory on each lot. Specific derating shall be applied.
	MIL	MIL-PRF-23419	
	Other	-	
Heaters	ESCC	ESCC 4009 level C	
	MIL	-	
	Other	GSFC S-311-P-079	
Procured inductors, molded & chip	ESCC	ESCC 3201 level C	
	MIL	MIL-PRF-39010 EFRL R min MIL-STD-981 class S	
	Other	-	
Inductors & Coils, non-molded	ESCC	ESCC 3201 level C	
	MIL	MIL-STD-981 class S	
	Other	-	
Procured transformers	ESCC	ESCC 3201 level C	
	MIL	MIL-PRF-39010 EFRL R min MIL-STD-981 class S	
	Other	-	
Integrated circuits	ESCC	ESCC 9000 level B	PIND test (Note 2,3) FPGA (Note 4)
	MIL	MIL-PRF-38535, class Q	
	Other	-	
Integrated circuits Microwave (MMIC)	ESCC	ESCC 9010 level B	PIND test (Note 2,3)
	MIL	MIL-PRF-38535, class Q	
	Other	-	
Microwave passive parts (circulators, isolators)	ESCC	ESCC 3202 level B	
	MIL	-	
	Other	-	
Microwave passive parts (coupler, power dividers)	ESCC	ESCC 3404 level B	
	MIL	MIL-DTL-23971, "space flight"	
	Other	-	
Microwave passive parts (attenuators, loads)	ESCC	ESCC 3403 level C	
	MIL	MIL-PRF-39030 (loads) S letter (screened parts) MIL-DTL-3933 (attenuators) S letter (screened parts)	
	Other	-	
Oscillators (hybrids)	ESCC	ECSS Q-ST-60-05 Level 1	Lot sample DPA required (Note 3)
	MIL	MIL-PRF-55310 (class 2) level S	
	Other	-	

Category	Quality Requirement		
Resistors, fixed, film (RNC, RLR or MBx xxxx type, except RNC90)	ESCC	ESCC 4001 level C	
	MIL	MIL-PRF-55182 EFRL R min MIL-PRF-39017 EFRL R min	
	Other	-	
Resistors, high precision, fixed, metal foil (RNC90)	ESCC	ESCC 4001 level C-	100 KΩ max allowed. (Values above 100 KΩ are restricted for space flight use)
	MIL	MIL-PRF-55182/9 EFRL R min	
	Other	-	
Resistors, network, thick film	ESCC	ESCC 4005 level C	Lot sample DPA is required prior to use. Particulate attention should be paid to the integrity of the termination attachment to the resistive element (i.e., cracked solder joints, misaligned connections, etc.)
	MIL	MIL-PRF-83401 M part number level	
	Other	-	
Resistors, current sensing (RLV type)	ESCC	-	
	MIL	MIL-PRF-49465	
	Other	-	
Resistors, power, fixed, wirewound (RWR type)	ESCC	ESCC 4002 level C	
	MIL	MIL-PRF-39007 EFRL R min	
	Other	-	
Resistors, power, fixed, wirewound, chassis mounted (RER type)	ESCC	ESCC 4003 level C	
	MIL	MIL-PRF-39009 EFRL R min	
	Other	-	
Resistors, precision, fixed, wirewound (RBR type)	ESCC	-	Diameter of wires shall be greater than 0.03mm.
	MIL	MIL-PRF-39005 EFRL R min	
	Other	-	
Resistors, fixed, film, high voltage (RHV type)	ESCC	ESCC 4001 level C	
	MIL	-	
	Other	-	
Resistors, fixed, thick and thin film chip	ESCC	ESCC 4001 level C	
	MIL	MIL-PRF-55342 EFRL R min	
	Other	-	
Relays, electromagnetic, latching and non-latching	ESCC	ESCC 3601, level B ESCC 3602, level B	Products based on MIL-PRF-39016 are allowed with ESCC screening. Lot sample DPA required (Note 3)
	MIL	MIL-PRF-39016 EFRL R min + ESCC screening according to chart 3	
	Other	-	

Category	Quality Requirement		
Solar cells	ESCC	PSS-01-604	
	MIL	-	
	Other	-	
Switches, thermostatic	ESCC	ESCC 3702 level B	
	MIL		
	Other	GSFC S-311-641	
Switches, non RF	ESCC	ESCC 3701 level B	
	MIL	MIL-PRF-8805	
	Other	-	
Thermistors	ESCC	ESCC 4006 level B	
	MIL	MIL-PRF-23648	
	Other	GSFC S-311-P-018	
Transistors, low frequency	ESCC	ESCC 5000 level B	PIND test (Note 2,3)
	MIL	MIL-PRF-19500, JANTXV	
	Other	-	
Transistors, High frequency, (bipolar and GaAs)	ESCC	ESCC 5010 level B	PIND test (Note 2,3)
	MIL	MIL-PRF-19500, JANTXV	
	Other	-	
Opto-couplers, Opto-discrete devices	ESCC	ESCC 5000 level B	PIND test (Note 2,3)
	MIL	MIL-PRF-19500, JANTXV	
	Other	-	
Hybrids	ESCC	ECSS-Q-ST-60-05 level 2	Lot sample DPA required (Note 3)
	MIL	MIL-PRF-38534 class K	
	Other	-	
Surface Acoustic Waves (SAW)	ESCC	ESCC 3502 level C	
	MIL	MIL-PRF-38534 class K	
	Other	-	
Charge Coupled Devices (CCD)	ESCC	ESCC 9020 level B	
	MIL	-	
	Other	-	

Note 1 : For ceramic capacitors procured through ESA or MIL specifications but in an extended, non-qualified, range of value or not belonging to ESA QPL or MIL QML/QPL, the humidity, steady state, low voltage test (c.f. ESCC 3009, § 5.2.2) is mandatory if $U \leq 50V$ and $C \geq 1\mu F$.

Note 2 : Particle Induced Noise Detection (PIND) test is applicable to all cavity packages of active components, except non-metal packaged diodes.

- For semiconductor devices the JANS criteria is applicable per MIL-PRF-19500 : The lot shall be submitted to 100% PIND testing according to test condition A (per method 2052 of MIL-STD-750).

- For integrated circuits the Class level V criteria is applicable per MIL-PRF-38535 :
The lot shall be submitted to 100% PIND testing according to test condition A (per method 2020 of MIL-STD-883).

Note 3 : Additional DPA and PIND test need not be performed for Level 1 devices (ESCC (level B), JANS, and Class V, S, K)

Note 4 : Antifuse-based FPGA shall be used for design. If flash memory or SRAM-based FPGA will be used for design, PAD shall be submitted to KARI PMPCB for approval including radiation risk reduction actions such as EDAC and TMR.

TABLE K-2. QUALITY REQUIREMENT FOR EEE PARTS FOR GEO

Category	Quality Requirement		
Capacitors, super metallized plastic film, (CHS type)	ESCC	ESCC 3006 level C	
	MIL	MIL-PRF-87217	
	Other	-	
Capacitors, variable	ESCC	ESCC 3010 level C	Not recommended for new design
	MIL	-	
	Other	-	
Connectors, circular and rectangular, non-filter contacts	ESCC	ESCC 3401 level B	Outgassing control such as vacuum bake out is required for military circular connectors for contamination critical application.
	MIL	MIL-DTL-24308 (rect.) class M or K MIL-DTL-38999 (circ.) class G or H	
	Other	GSFC S-311-P-4, P-10(rect.)	
Connectors, circular and rectangular, filter contacts	ESCC	ESCC 3405 level B	Life test 1000H/125°C /1.5 V _r is mandatory on each tubular ceramic lot.
	MIL	-	
	Other	-	
Connectors, Printed Circuit Board	ESCC	ESCC 3401 level B	
	MIL	-	
	Other	-	
Connectors, Microminiature rectangular	ESCC	ESCC 3401 level B	
	MIL	-	
	Other	-	
Connectors, RF coaxial	ESCC	ESCC 3402 level B	Outgassing control such as vacuum bake out is required for military parts for contamination critical application.
	MIL	MIL-PRF-39012	
	Other	-	
Crystals resonators	ESCC	ESCC 3501 level B	Crystal shall be built using a cultured premium Q swept material.
	MIL	MIL-PRF-3098	
	Other	-	
Diodes, low frequency	ESCC	ESCC 5000 level B	PIND test (Note 2)
	MIL	MIL-PRF-19500, JANS	
	Other	-	
Diodes, high frequency	ESCC	ESCC 5010 level B	PIND test (Note 2)
	MIL	MIL-PRF-19500, JANS	
	Other	-	
Filters, EMI	ESCC	ESCC 3008 level B	
	MIL	MIL-PRF-28861, class S	
	Other	-	
Fuses CERMET	ESCC	-	
	MIL	MIL-PRF-23419	
	Other	-	

Category	Quality Requirement		
Cables & wires, low frequency	ESCC	ESCC 3901 level B	
	MIL	MIL-W-22759	
	Other	NEMA-WC27500	
Cables, coaxial, radio frequency	ESCC	ESCC 3902 level B	
	MIL	MIL-C-17	
	Other	-	
Capacitors, chip, ceramic	ESCC	ESCC 3009 level C	(Note 1)
	MIL	MIL-PRF-55681 EFRL R min MIL-PRF-123	
	Other	-	
Capacitors, molded, ceramic	ESCC	ESCC 3001 level C	(Note 1)
	MIL	MIL-PRF-20 EFRL R min MIL-PRF-39014 EFRL R min MIL-PRF-123 MIL-PRF-49470 EFRL T	
	Other	-	
Capacitors, glass (CYR type)	ESCC	ESCC 3004 level C	Life test 1000H/125°C /1.5V _r is mandatory on each lot. (Not recommended for new design)
	MIL	MIL-PRF-23269 EFRL R min	
	Other	-	
Capacitors, mica	ESCC	ESCC 3007 level C	
	MIL	MIL-PRF-39001 EFRL R min	
	Other	-	
Capacitors, chip, tantalum (TAJ, T495, CWR11, ...)	ESCC	ESCC 3011 level C ESCC 3012 level C	All capacitors shall be surge current tested.
	MIL	MIL-PRF-55365 WFRL C min	
	Other	-	
Capacitors, non-solid tantalum, electrolytic (CLR 79)	ESCC	ESCC 3003 level C	
	MIL	MIL-PRF-39006 EFRL R min	
	Other	-	
Capacitors, solid tantalum, electrolytic (CSR type)	ESCC	ESCC 3002 level C	Surge current test mandatory on low ESR capacitors (CSR21 and CSR33)
	MIL	MIL-PRF-39003 WFRL C min	
	Other	-	
Capacitors, super metallized plastic film, (CRH type)	ESCC	ESCC 3006 level C	
	MIL	MIL-PRF-83421 EFRL R min	
	Other	-	

Category	Quality Requirement		
Fuses (wire link $\geq 5A$)	ESCC	-	Burn-in(168H / 85°C / 50% rated current) is mandatory on each lot. Specific derating shall be applied.
	MIL	MIL-PRF-23419	
	Other	-	
Heaters	ESCC	ESCC 4009 level C	
	MIL	-	
	Other	GSFC S-311-P-079	
Procured inductors, molded & chip	ESCC	ESCC 3201 level C	
	MIL	MIL-PRF-39010 EFRL R min MIL-STD-981 class S	
	Other	-	
Inductors & Coils, non-molded	ESCC	ESCC 3201 level C	
	MIL	MIL-STD-981 class S	
	Other	-	
Procured transformers	ESCC	ESCC 3201 level C	
	MIL	MIL-PRF-39010 EFRL R min MIL-STD-981 class S	
	Other	-	
Integrated circuits	ESCC	ESCC 9000 level B	PIND test (Note 2)
	MIL	MIL-PRF-38535, class V or S	
	Other	-	
Integrated circuits Microwave (MMIC)	ESCC	ESCC 9010 level B	PIND test (Note 2)
	MIL	MIL-PRF-38535, class V	
	Other	-	
Microwave passive parts (circulators, isolators)	ESCC	ESCC 3202 level B	
	MIL	-	
	Other	-	
Microwave passive parts (coupler, power dividers)	ESCC	ESCC 3404 level B	
	MIL	MIL-DTL-23971, "space flight"	
	Other	-	
Microwave passive parts (attenuators, loads)	ESCC	ESCC 3403 level C	
	MIL	MIL-PRF-39030 (loads) S letter (screened parts) MIL-DTL-3933 (attenuators) S letter (screened parts)	
	Other	-	
Oscillators (hybrids)	ESCC	ECSS Q-ST-60-05 Level 1	
	MIL	MIL-PRF-55310 (class 2) level S	
	Other	-	

Category	Quality Requirement		
Resistors, fixed, film (RNC, RLR or MBx xxxx type, except RNC90)	ESCC	ESCC 4001 level C	
	MIL	MIL-PRF-55182 EFRL R min MIL-PRF-39017 EFRL R min	
	Other	-	
Resistors, high precision, fixed, metal foil (RNC90)	ESCC	ESCC 4001 level C-	100 K Ω max allowed. (Values above 100 K Ω are not suggested for space flight use)
	MIL	MIL-PRF-55182/9 EFRL R min	
	Other	-	
Resistors, network, thick film	ESCC	ESCC 4005 level C	Lot sample DPA is required prior to use. Particular attention should be paid to the integrity of the termination attachment to the resistive element (i.e., cracked solder joints, misaligned connections, etc.)
	MIL	MIL-PRF-83401 M part number level	
	Other	-	
Resistors, current sensing (RLV type)	ESCC	-	
	MIL	MIL-PRF-49465	
	Other	-	
Resistors, power, fixed, wirewound (RWR type)	ESCC	ESCC 4002 level C	
	MIL	MIL-PRF-39007 EFRL R min	
	Other	-	
Resistors, power, fixed, wirewound, chassis mounted (RER type)	ESCC	ESCC 4003 level C	
	MIL	MIL-PRF-39009 EFRL R min	
	Other	-	
Resistors, precision, fixed, wirewound (RBR type)	ESCC	-	Diameter of wires shall be greater than 0.03mm.
	MIL	MIL-PRF-39005 EFRL R min	
	Other	-	
Resistors, fixed, film, high voltage (RHV type)	ESCC	ESCC 4001 level C	
	MIL	-	
	Other	-	
Resistors, fixed, thick and thin film chip	ESCC	ESCC 4001 level C	
	MIL	MIL-PRF-55342 EFRL R min	
	Other	-	
Relays, electromagnetic, latching and non-latching	ESCC	ESCC 3601, level B ESCC 3602, level B	Products based on MIL-PRF-39016 are allowed with ESCC screening.
	MIL	MIL-PRF-39016 EFRL R min + ESCC screening according to chart 3	
	Other	-	

Category	Quality Requirement		
Solar cells	ESCC	PSS-01-604	
	MIL	-	
	Other	-	
Switches, thermostatic	ESCC	ESCC 3702 level B	
	MIL		
	Other	GSFC S-311-641	
Switches, non RF	ESCC	ESCC 3701 level B	
	MIL	MIL-PRF-8805	
	Other	-	
Thermistors	ESCC	ESCC 4006 level B	
	MIL	MIL-PRF-23648	
	Other	GSFC S-311-P-018	
Transistors, low frequency	ESCC	ESCC 5000 level B	PIND test (Note 2)
	MIL	MIL-PRF-19500, JANS	
	Other	-	
Transistors, High frequency, (bipolar and GaAs)	ESCC	ESCC 5010 level B	PIND test (Note 2)
	MIL	MIL-PRF-19500, JANS	
	Other	-	
Opto-couplers, Opto-discrete devices	ESCC	ESCC 5000 level B	PIND test (Note 2)
	MIL	MIL-PRF-19500, JANS	
	Other	-	
Hybrids	ESCC	ECSS-Q-ST-60-05 level 1	
	MIL	MIL-PRF-38534 class K	
	Other	-	
Surface Acoustic Waves (SAW)	ESCC	ESCC 3502 level B	
	MIL	MIL-PRF-38534 class K	
	Other	-	
Charge Coupled Devices (CCD)	ESCC	ESCC 9020 level B	
	MIL	-	
	Other	-	

Note 1 : For ceramic capacitors procured through ESA or MIL specifications but in an extended, non-qualified, range of value or not belonging to ESA QPL or MIL QML/QPL, the humidity, steady state, low voltage test (c.f. ESCC 3009, § 5.2.2) is mandatory if $U \leq 50V$ and $C \geq 1\mu F$.

Note 2 : Particle Inducted Noise Detection (PIND) test is applicable to all cavity packages of active components, except non-metal packaged diodes.

- For semiconductor devices the JANS criteria is applicable per MIL-PRF-19500 : The lot shall be submitted to 100% PIND testing according to test condition A (per method 2052 of MIL-STD-750).

- For integrated circuits the Class level S criteria is applicable per MIL-PRF-38535 :
The lot shall be submitted to 100% PIND testing according to test condition A (per method 2020 of MIL-STD-883).

APPENDIX L. 청정도 및 오염관리 (CLEANLINESS & CONTAMINATION CONTROL)

L.1. GENERAL

The Subcontractor shall maintain a contamination control program applicable to the End Product. The program shall consist in defining the specific cleanliness requirements and setting forth the approaches to meeting them, and then in implementing the control and monitoring activities.

The contamination sensitive components shall be identified and shall be controlled specially. Contaminants include all materials of molecular or of particulate nature whose presence degrades hardware performance. The source of the contaminant materials may be the hardware itself, the test facilities, and the environments to which the hardware is exposed. All hardware and support equipment shall be received by Customer (Satellite System Integrator) in visibly clean condition.

L.2. CONTAMINATION CONTROL

The Subcontractor shall define a contamination allowance for performance degradation of contamination sensitive hardware such that, even in the degraded state, the hardware will meet its mission objectives. The contamination allowable shall be assessed in a timely manner such that results can be used to assess the adequacy of and, if necessary, to modify the design of the hardware.

In case the Subcontractor develops contamination sensitive equipment, he shall provide contamination control plan. This plan shall describe methods for controlling contamination and for ensuring that the contamination allowance is not exceeded. It shall identify the controls, inspections, tests, analyses, and documentation necessary for measuring and maintaining the levels of cleanliness required during the various phases of the hardware lifetime including the spacecraft system AIT and Launch preparation period.

In case the Subcontractor develops contamination sensitive equipment, contamination analysis shall be performed and its result shall be submitted to Customer (Satellite System Integrator) for review. This analysis will show Procedures, standards, and specifications referenced in the contamination control plan shall be available for review at the Subcontractor's facilities.

L.3. EQUIPMENT CLEANLINESS REQUIREMENTS

The Subcontractor shall define specific cleanliness criteria suitable for his process and the End

Product. General rules are listed below:

- a. Selection of materials will be based on TML and CVCM parameters. The outgassing criteria shall be $TML < 1\%$ or $CVCM < 0.1\%$.
- b. Elements with organic material shall be baked out during 48 hours at 65 °C or equivalent conditions according to the material characteristics.
- c. Airborne cleanliness class for Integration or assembly operation shall be better than 100,000 class and shall be defined to ensure that the contamination allowance is not exceeded and it shall be specified in the contamination control plan.
- d. The Subcontractor shall monitor molecular contamination and particulate contamination. The contamination budget at delivery shall satisfy the criteria defined by Contamination Analysis results.
- e. For the cleanliness critical hardware, particulate cleaning shall be done by vacuum cleaning only. Molecular cleaning may be done with an approved procedure.

L.4. CLEANLINESS REQUIREMENTS FOR TRANSPORTATION

The End Product shall be double packed within sealed plastic bags for the transportation or storage phases:

- a. The inner bag shall be sealed with cleaned equipment inside and with no loose parts which could damage the equipment.
- c. The outer bag shall be sealed with the inner bag inside and desiccant bags. Even if the desiccant bag is damaged, the hardware shall not come in contact with loose desiccants.
- c. The materials used for equipment packaging, such as plastic bags and foam, shall be designed with materials presenting no free particles and no organic materials outgassing.
- d. If special packing requirements are required by the nature of hardware, those are described in the contamination control plan.

L.5. VACUUM BAKE OUT

Materials which are considered as contamination critical shall be submitted to vacuum bake out. The bake out parameters shall be agreed with Customer (Satellite System Integrator) on a case-by-case basis. These parameters must be identified in the Material List.

An outgassing test must be performed on the materials after vacuum bake out to demonstrate compliance with the requirements of Section L.3. In all instances, a test reference from an ESA or NASA approved source must be provided to assure the accuracy of the data.

All of the deliverable flight items shall undergo vacuum environment before delivery.

APPENDIX M. 소프트웨어 품질보증 (SOFTWARE QUALITY ASSURANCE)

M.1. GENERAL

The Subcontractor shall establish a Software Assurance Program which includes the entire software development processes and the methods used to ensure software quality.

The Software Assurance Program shall include the processes such as requirements definition, software design, coding, code review, software configuration management, testing, release management, and product integration.

The Software Assurance Plan shall include the followings:

- a. The software development cycles (milestones, input, output, etc.) the types of activities (verification, validation, tests, etc.) on each development phase
- b. The methods, tools, and rules to be applied
- c. Development environment implemented
- d. Dedicated actions to inspect Lower Tier Subcontractor
- e. Quality arrangements for the warranty phase

M.2. LIST OF SOFTWARE

The Subcontractor shall prepare list and keep up to date a list of all software components which are part of the End Product under his responsibility. The list shall include:

- a. Name and identification in the product tree structure
- b. Reference of the associated requirement specification
- c. Name of the provider
- d. Criticality of the software component
- e. Programming language and the volumes of associated code specifying the method or tool for calculation of these volumes
- f. For re-use software, the overall rate of re-use
- g. Development machine and its operating system
- h. Target machine and its operating system

A set of milestones shall be defined for each software component to be consistent with the product development cycle and criticality.

M.3. MANAGEMENT OF RESOURCES

The Subcontractor shall perform performance budget evaluations during design for memory

occupation and CPU load during execution.

Budget analysis results of resources for on-board software shall be provided to Customer (Satellite System Integrator) during Design Review.

M.4. SOFTWARE CONFIGURATION

Software configuration document is a living document. It remains available at project milestone and is delivered with any software for validation or acceptance. The configuration document shall explicitly identify the differences between the version delivered and the previous delivered version. It shall be supported by an information technology tool.

The component of a deliverable software product shall be identified and marked when configured for delivery with a non-removable label on each physical medium. It shall include at least the name of the software, its version number, and its configuration document reference.

M.5. DOCUMENT MANAGEMENT

The following documents shall be managed in parallel with related software components:

- a. Documents describing development or quality procedures to be implemented during the software life cycle
- b. Documents derived from software product development, including the documentation intended for operators and users of the software system.

M.6. SOFTWARE SPECIFICATION

The software specifications shall define all topics necessary to satisfy applicable requirements. Each requirement in the specification shall be identified by a unique reference.

M.7. DESIGN

The design description shall cover the hierarchy, dependency, interfaces of the software components, dynamic sequencing of components, and data flow checks.

Software design shall minimize dependencies with respect to the operating system and the hardware in order to contribute to software maintainability and portability.

M.8. CODING

Programming language adapted to the software product and to the design method shall be used. Coding rules and conventions for consistent naming shall be defined for each programming language. Dedicated coding rules shall be defined to avoid using risky instructions and use the real time executive retained to best effect. In particular, the following shall be prohibited:

- a. Dynamic memory allocation
- b. Use of generic characteristics.

The source code shall subject to configuration management.

M.9. TESTS

The test strategy shall define test level, types of test, and test coverage. For on-board software, the test strategy shall define:

- a. The target processor environment which shall be simulated or shall be executed really on the development chain
- b. The tests that will be performed on the development processor and those performed on the real target processor (validation shall include central flight software coupling with the target processor)
- c. How are handling tests of software integrated in an equipment
- d. How are handling re-used software

When requirements are not covered by test, verification activities such as simulations, inspection, or analysis shall be performed.

After validation, the areas affected by changes or corrections shall be identified and subject to re-testing. In the event of re-testing, any documentation related to tests (test case specification, procedures, report, etc.) shall be updated.

M.10. DELIVERY, INSTALLATION, AND ACCEPTANCE

Before the software is presented to Customer (Satellite System Integrator) for acceptance, the Subcontractor shall ensure that:

- a. The source and object codes supplied
- b. All agreed changes have been implemented
- c. All nonconformances have been declared and resolved
- d. All necessary facilities are available

Once acceptance tests have been performed, the Subcontractor shall prepare a report which ensure conformance with software requirements and establish the conclusion concerning the test result for the software product subjected to such tests accepted, accepted on condition, or rejected.

M.11. MAINTENANCE PREPARATION

Maintenance plans and procedures shall deal with maintenance in terms of correction and adaptation. Any adaptation or correction to the software product shall be covered by non-

regression tests. Any adaptation or correction to the software shall be documented in compliance with the documentation management and product configuration management procedures.

M.12. PROCURED SOFTWARE

The term 'Procured Software' covers both software bought off-the-shelf and software used after having been developed outside the contract to which the present requirements apply.

The choice of Procured Software shall be described and proposed to Customer (Satellite System Integrator) in the form of a list of software components. The list of software components shall include as a minimum:

- a. Order criteria (version, options, extensions, etc.)
- b. Intellectual ownership constraints
- c. Acceptance inspection criteria (qualification, documentation, etc.),
- d. Maintenance organization
- e. Standby solutions if the product were unavailable

Any software procured to be used in a software product shall be identified and registered by configuration management for that product, as for developed software.

붙임#4. EMC 시험규격

- “ECSS-E-ST-20-07C Rev.1 EMC Spec.pdf”



Space engineering

Electromagnetic compatibility

ECSS Secretariat
ESA-ESTEC
Requirements & Standards Division
Noordwijk, The Netherlands

Foreword

This Standard is one of the series of ECSS Standards intended to be applied together for the management, engineering and product assurance in space projects and applications. ECSS is a cooperative effort of the European Space Agency, national space agencies and European industry associations for the purpose of developing and maintaining common standards. Requirements in this Standard are defined in terms of what shall be accomplished, rather than in terms of how to organize and perform the necessary work. This allows existing organizational structures and methods to be applied where they are effective, and for the structures and methods to evolve as necessary without rewriting the standards.

This Standard has been prepared by the ECSS-E-ST-20-07 Working Group, reviewed by the ECSS Executive Secretariat and approved by the ECSS Technical Authority.

Disclaimer

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Change log

ECSS-E-ST-20-07A	Never issued
ECSS-E-ST-20-07B	Never issued
ECSS-E-ST-20-07C 31 July 2008	First issue
ECSS-E-ST-20-07C Rev. 1 7 February 2012	First issue Revision 1 Changes with respect to ECSS-E-ST-020-07C (31 July 2008) are identified with revision tracking. Requirements modified: • 4.2.5.1a.: corrected cross-reference in Note to 5.4.5. • 4.2.11.2e.: Note with example deleted • 4.2.11.2g: modified • 5.2.1a.1. and 5. modified • 5.3.3a. to d. modified • 5.3.4a.: Note 2 deleted and quote sign in text corrected • 5.4.3.3a.3.(a):added to requirement " for differential mode testing and Figure 5-9 for common mode testing" • 5.4.4.4a.3.(b): corrected in requirement reference to EUT switch to read "Figure 5-11.b" • 5.4.9.2a.2.: changed bandwidth from "10 MHz" to "50 MHz" • 5.4.11.3e.2.: corrected reference to Figure to read "Figure 5-27" Editorial corrections in requirements: • The possessive case-like notation " 's " used to mean plural after acronyms have been corrected, e.g. "EED's" and "LISN's" has been changed into "EEDs" respectively "LISNs"when it means plural in 4.2.2.2c, 5.2.4a, 5.2.4b, 5.2.4c, 5.2.6.3a, 5.2.6.5a, 5.2.6.6.3.c, 5.2.6.6.3.d, 5.2.6.6.3.f, 5.3.2b, 5.4.3.2.a.9 • Corrected in 5.3.4a the incorrect "unquote" sign. • 5.4.4.5b NOTE: Corrected typo in word "Typical" Modifications in informative parts: • 4.2.11.1: added reference to clause 4.2.11.2 and Figure 4-1 (Figure was moved from 4.2.11.3), corrected style of paragraph from "requirement" to "informative text". Text of Note modified.

	• Figure 4-1 modified and moved to clause 4.2.11.1. • 5.4.1: corrected reference from "5.4.11.4" to read "5.4.12" • Table 5-3: cross- references in last column corrected. • Annex A.2: corrected in 3rd bullet "ICE" to read "Ice", "measurement" to read "measurements"" and reference to read "Figure A-1" • Figure A-1: Caption of Figure modified • Figure A-2 moved from A.2 to A.4 • A.4: corrected in 2nd bullet reference to read "Figure A-2" • Figure A-3 moved to A.9 • A.6.2: Formula corrected • A.9: corrected in 2nd and 4th bullet reference to read "Figure A-3" • Figure A-4 moved to A.10 • A.10: corrected in first paragraph reference to read "5.4.7" • A.10: corrected in 1st bullet reference to read "Figure A-4" • A.11: corrected in first paragraph reference to read "5.4.8" • A.13: corrected in first paragraph reference to read "5.4.10" • A.14: corrected in first paragraph reference to read "5.4.11" • A.15: corrected in first paragraph reference to read "5.4.12"
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Introduction

Electromagnetic compatibility (EMC) of a space system or equipment is the ability to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

The space system is designed to be compatible with its external natural, induced, or man-made electromagnetic environment. Natural components are lightning for launchers, the terrestrial magnetic field for space vehicles. Spacecraft charging is defined as voltage building-up of a space vehicle or spacecraft units when immersed in plasma. Electrostatic discharges result from spacecraft charging with possible detrimental effects. External man-made interference, intentional or not, are caused by radar or telecommunication beams during ground operations and the launching sequence. Intersystem EMC also applies between the launcher and its payload or between space vehicles.

Intrasystem EMC is defined between all electrical, electronic, electromagnetic, and electromechanical equipment within the space vehicle and by the presence of its self-induced electromagnetic environment. It comprises the intentional radiated electromagnetic fields and parasitic emission from on-board equipment. Both conducted and radiated emissions are concerned. An electromagnetic interference safety margin is defined at system critical points by comparison of noise level and susceptibility at these points.

1

Scope

EMC policy and general system requirements are specified in ECSS-E-ST-20.

This ECSS-E-ST-20-07 Standard addresses detailed system requirements (Clause 4), general test conditions, verification requirements at system level, and test methods at subsystem and equipment level (Clause 5) as well as informative limits (Annex A).

Associated to this standard is ECSS-E-ST-20-06 “Spacecraft charging”, which addresses charging control and risks arising from environmental and vehicle-induced spacecraft charging when ECSS-E-ST-20-07 addresses electromagnetic effects of electrostatic discharges.

Annexes A to C of ECSS-E-ST-20 document EMC activities related to ECSS-E-ST-20-07: the EMC Control Plan (Annex A) defines the approach, methods, procedures, resources, and organization, the Electromagnetic Effects Verification Plan (Annex B) defines and specifies the verification processes, analyses and tests, and the Electromagnetic Effects Verification Report (Annex C) document verification results. The EMEVP and the EMEVR are the vehicles for tailoring this standard.

This standard may be tailored for the specific characteristic and constraints of a space project in conformance with ECSS-S-ST-00.

2

Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revision of any of these publications do not apply. However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

ECSS-S-ST-00-01	ECSS system - Glossary of terms
ECSS-E-ST-20	Space engineering - Electrical and electronic
ECSS-E-ST-20-06	Space engineering - Spacecraft charging
ECSS-E-ST-33-11	Space engineering - Explosive systems and devices
ECSS-E-ST-50-14	Space engineering – Spacecraft discrete interfaces
IEC 61000-4-2 (Edition 1.2)	Electromagnetic compatibility (EMC) - Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test

3

Terms, definitions and abbreviated terms

3.1 Terms from other standards

For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01 apply, in particular for the following terms:

- critical item**
- customer**
- equipment**
- item**
- launcher, launch vehicle**
- mission**
- requirement**
- safety critical function**
- supplier**
- spacecraft, space vehicle**
- subsystem**
- system**
- test**
- verification**

For the purposes of this Standard, the following terms have a specific definition contained in ECSS-E-ST-20:

- conducted emission**
- electromagnetic compatibility**
- electromagnetic compatibility control**
- electromagnetic interference**
- electromagnetic interference safety margin**
- emission**
- high-voltage**
- lightning indirect effects**

radiated emission
radiofrequency
susceptibility
susceptibility threshold

For the purposes of this document, the following terms have a specific definition contained in ECSS-E-ST-20-06:

electrostatic discharge (ESD)
secondary arc

For the purposes of this document, the following term has a specific definition contained in ECSS-E-ST-33-11:

electro-explosive device (EED)

3.2 Terms specific to the present standard

3.2.1 ambient level

level of radiated and conducted signal, and noise that exist at the specified test location and time when the equipment under test is not operating

NOTE E.g. atmospherics, interference from other sources, and circuit noise or other interference generated within the measuring set compose the “ambient level”.

3.2.2 antenna factor

factor that, when properly applied to the voltage at the input terminals of the measuring instrument, yields the electric or magnetic field strength

NOTE 1 This factor includes the effects of antenna effective length, mismatch, and transmission losses.

NOTE 2 The electric field strength is normally expressed in V/m and the magnetic field strength in A/m or T.

3.2.3 common mode voltage

voltage difference between source and receiver ground references

3.2.4 contact discharge method

method of testing in which the electrode of the high-voltage test generator is held in contact with the discharge circuit, and the discharge actuated by a discharge switch

3.2.5 electromagnetic environmental effects

impact of the electromagnetic environment upon equipment, systems, and platforms

NOTE It encompasses all electromagnetic disciplines, including electromagnetic compatibility; electromagnetic interference, electromagnetic vulnerability, hazards of electromagnetic radiation to personnel, electro-explosive devices, volatile materials, and natural phenomena effects.

3.2.6 field strength

resultant of the radiation, induction and quasi-static components of the electric or magnetic field

NOTE The term “electric field strength” or “magnetic field strength” is used, according to whether the resultant, electric or magnetic field, respectively, is measured.

3.2.7 ground plane

metal sheet or plate used as a common reference point for circuit returns and electrical or signal potentials

3.2.8 improper response

subsystem or equipment response which can be either inadvertent or unacceptable

3.2.9 inadvertent response

proper subsystem functional response (within normal range of limits) actuated by electromagnetic interference, but occurring at other than the normal operational cycle, which in turn causes improper response to the total space system

3.2.10 line impedance stabilization network (LISN)

network inserted in the supply leads of an apparatus to be tested which provides, in a given frequency range, a specified source impedance for the measurement of disturbance currents and voltages and which can isolate the apparatus from the supply mains in that frequency range

3.2.11 not operating

condition wherein no power is applied to the equipment

3.2.12 overshield

shield surrounding a bundle or a shielded cable

3.2.13 passive intermodulation product

generation of a signal at frequency $f = n \cdot f_1 + m \cdot f_2$ from two signals at frequencies f_1 and f_2 where n and m are positive or negative integers, by a passive device, usually an electrical contact

3.2.14 port

place of access to a device or network where energy can be supplied or withdrawn, or where the device or network variables can be observed or measured

3.2.15 power quality requirements

requirements which define the conducted voltage noise or impedance the power user can expect

NOTE Noise e.g. from load regulation, spikes, and sags.

3.2.16 soft magnetic material

ferromagnetic material with a coercivity smaller than 100 A/m

3.2.17 spurious emission

electromagnetic emission from the intended output terminal of an electronic device, but outside of the designed emission bandwidth

3.2.18 test antenna

antenna of specified characteristics designated for use under specified conditions in conducting tests

3.2.19 unit

equipment that is viewed as an entity for purposes of analysis, manufacturing, maintenance, or record keeping

NOTE E.g. hydraulic actuators, valves, batteries, and individual electronic boxes such as on-board computer, inertial measurement unit, reaction wheel, star tracker, power conditioning unit, transmitters, receivers, or multiplexers.

3.3 Abbreviated terms

For the purpose of this standard, the abbreviated terms of ECSS-S-ST-00-01 and the following apply:

Abbreviation	Meaning
AC	alternating current
ACS	attitude control system
AM	amplitude modulation
AWG	American wire gauge
BCI	bulk cable injection
CE	conducted emission
CS	conducted susceptibility
CW	continuous wave
DC	direct current

EED	electro-explosive device
EGSE	electrical ground support equipment
EHF	extremely high frequency (30 GHz-300 GHz)
EMC	electromagnetic compatibility
EMCAB	electromagnetic compatibility advisory board
EMCCP	electromagnetic compatibility control plan
EMEVP	electromagnetic effects verification plan
EMEVR	electromagnetic effects verification report
EMI	electromagnetic interference
EMISM	electromagnetic interference safety margin
ESD	electrostatic discharge
EUT	equipment under test
HV	high voltage
ICD	interface control document
LEO	low Earth orbit
LF	low frequency
LISN	line impedance stabilization network
MGSE	mechanical ground support equipment
PAM	pulse amplitude modulation
PCM	pulse coded modulation
RE	radiated emission
RF	radio frequency
r.m.s.	root-mean-square
RS	radiated susceptibility
SHF	super-high frequency (3 GHz-30 GHz)

4

Requirements

4.1 General system requirements

EMC policy and general system requirements, and the spacecraft charging protection program are specified in ECSS-E-ST-20 Electromagnetic Compatibility clause and EMC Plan DRD.

4.2 Detailed system requirements

4.2.1 Overview

This clause 4.2 defines the requirements for design and realization at system level. They are the basis for definition of activities of the EMC programme to ensure space-system-level compatibility with minimum impact to programme, cost, schedule, and operational capabilities.

4.2.2 EMC with the launch system

4.2.2.1 Overview

General system requirements for “EMC with the launch system” are defined in ECSS-E-ST-20.

4.2.2.2 Detailed system requirements

- a. Overload capability of the spacecraft RF receivers during the pre-launch and launch phases with or without fairing, shall be demonstrated by the spacecraft supplier.

NOTE 1 It is expected the electromagnetic environment generated by companion payloads is assessed by the launching company and addressed in the User's Manual.

NOTE 2 A conductive fairing is likely to cause resonances and cavity effects.

- b. Spacecraft equipment shall not exhibit any malfunction, degradation of performance or deviation beyond the tolerance indicated in its individual

specification after being exposed, even not operating, to the electromagnetic environment from the launcher and launch site.

NOTE Most of spacecraft equipment is not operating during launch. During the launching sequence spacecraft transmitters and receivers (platform and payload) can be either in OFF- or ON-state depending on the launch vehicle.

- c. The electromagnetic interference safety margin (EMISM) of safety critical equipment shall be applied to equipment in ON-state during prelaunch and launch phase and to [EEDs](#).

4.2.3 Lightning environment

4.2.3.1 Overview

Protection of the space system against both direct and indirect effects of lightning can be a combination of operational avoidance of the lightning environment and electrical overstress design techniques.

4.2.3.2 Requirements to the space system

- a. Assessment of risk, on the launch pad inside the protected area, for the space system and its equipment against direct and indirect effects of lightning before lift-off, shall be performed.
- b. The spacecraft supplier shall obtain from the launching company the electromagnetic environment imposed on the launcher payloads in case of lightning.

4.2.4 Spacecraft charging and effects

4.2.4.1 Overview

Mitigation of risks related to spacecraft charging results of a combination of rules and methods preventing voltage build-up and so minimizing the occurrence of ESD, and techniques for controlling EMI from residual ESD.

ECSS-E-ST-20 addresses management of spacecraft charging protection and system-level performance under effects of spacecraft charging and related ESD or secondary arcs.

ECSS-E-ST-20-06 addresses charging control and risks arising from spacecraft charging and other environmental effects on the spacecraft's electrical behaviour.

4.2.4.2 EMI control requirements to system and equipment in relation with ESD

- a. Analysis or tests at system level shall be performed for assessing the threat at subsystem or equipment level.

NOTE Analysis or tests can be defined in the time or frequency domain. They are expected to evaluate the coupling level from the ESD source to critical points.

- b. EMI control from residual ESD shall be performed by a combination of shielding and passive or active filtering techniques, implemented on the main structure, at subsystem level or inside equipment.
- c. EMI control efficiency shall be verified by test at subsystem or equipment level.

4.2.5 Spacecraft DC magnetic emission

4.2.5.1 Spacecraft with susceptible payload

- a. As part of the EMCCP, a magnetic cleanliness control plan shall document:

- 1. magnetic control guidelines
- 2. emission limits to magnetic sources
- 3. a magnetic budget
- 4. specific test methods applied to equipments for emission measurement and characterization

NOTE The test method described in [5.4.5](#) providing a dipole model can be inadequate and replaced by a multiple dipole model or a spherical harmonics model.

4.2.5.2 Attitude control system (ACS)

- a. As part of the EMCCP, a magnetic budget shall be maintained providing:
 - 1. Three-axes components of the space vehicle magnetic dipole (component decreasing with the inverse cube law with distance).

NOTE Typical values lie in the range 1 Am² or less for small spacecraft to much more than 10 Am² for large spacecraft.

- 2. If the solar array is rotating in the space vehicle axes, separate evaluation for the main body and the solar array.
- 3. When the space vehicle is using a magnetic sensor as part of the ACS, evaluation of the magnetic induction at its location.

NOTE The angular deviation is the basic requirement; however, the requirement is generally expressed in

terms of modification of the natural field strength at the sensor location. For LEO spacecraft if the error on each axis is less than $1\ \mu\text{T}$, the modification of the direction is kept less than 20 milliradians.

- b. The specified maximum magnetic field value shall comprise the remanent magnetization (magnets, electro-magnets in off-state, or residual perm-up due to hysteresis of soft materials), the induced magnetization of soft materials by the geomagnetic field, and the momentum of current loops.

4.2.6 Radiofrequency compatibility

- a. Spurious emissions requirements at antenna ports shall be specified for RF compatibility purpose by the spacecraft supplier.
- b. When specifying limits and frequency ranges, the following issues shall be included:
 - 1. sensitivity of possible victim receiver subsystems including out-of-band response,
 - 2. no limits apply to transmit frequencies and information carrying modulation bandwidths,
 - 3. highest and lowest intentional frequency used by space system receivers,
 - 4. antenna port attachments, gain/loss characteristics.

4.2.7 Hazards of electromagnetic radiation

Assessment of hazards to electromagnetic radiation is a part of the process specified in ECSS-Q-ST-40-02 "Hazard analysis", clause "Hazard analysis requirements".

4.2.8 Intrasystem EMC

- a. Intrasystem EMC shall be achieved by:
 - 1. allocation of equipment-level EMI requirements documented in the EMCCP, including:
 - (a) limits on conducted and radiated emission,
 - (b) susceptibility thresholds.

NOTE Recommended data is defined in Annex A for equipment and subsystems.

- b. control of conducted and radiated propagation paths methods defined by clauses 4.2.10 to 4.2.13.

4.2.9 EMC with ground equipment

- a. The EGSE and MGSE used for spacecraft integration and ground testing shall:
 - 1. Not degrade the EMC performance of the spacecraft;
 - 2. Have no impact on grounding or isolation.
- b. The EGSE shall be immune to signals used for spacecraft susceptibility tests.

4.2.10 Grounding

4.2.10.1 Overview

As specified in ECSS-E-ST-20, a controlled ground reference concept is defined for the space system. Structural elements, antenna and RF reference grounds, power and signal returns, shields and cable shields, safety grounds, EGSE grounds are considered.

4.2.10.2 Requirements

- a. A system-level grounding diagram shall be established including the EGSE.
- b. A ground reference shall be identified for each power, signal, or RF source or receiver.
- c. An upper value of common mode voltage shall be specified considering:
 - 1. power quality requirements defined in ECSS-E-ST-20 for “Spacecraft bus”,
 - 2. type of detectors and sensitivity,
 - 3. characteristics of analogue signal monitor receiver circuit, in accordance with ECSS-E-ST-50-14, Table 5-2 d,
 - 4. characteristics of bi-level signal monitor receiver circuit, in accordance with ECSS-E-ST-50-14, clause Table 6-2 e,
 - 5. hazards due to fault currents internal to the space vehicle or between the space vehicle and its EGSE.
- d. When power and signal share common paths (wire or structure), the magnitude of ground impedance shall be limited over the affected signal spectrum.

NOTE Non-exclusive techniques for reducing the impedance are decrease of common path length, decrease of wire and ground impedance, filters on common paths.

4.2.11 Electrical bonding requirements

4.2.11.1 Overview

Bonding requirements are a mean for fulfilling grounding requirements.

Normative provisions are specified in clause 4.2.11.2 and illustrated in Figure 4-1.

NOTE Bonding requirements for charging control are specified in ECSS-E-ST-20-06 “Electrical continuity”, including surfaces and structural and mechanical parts.

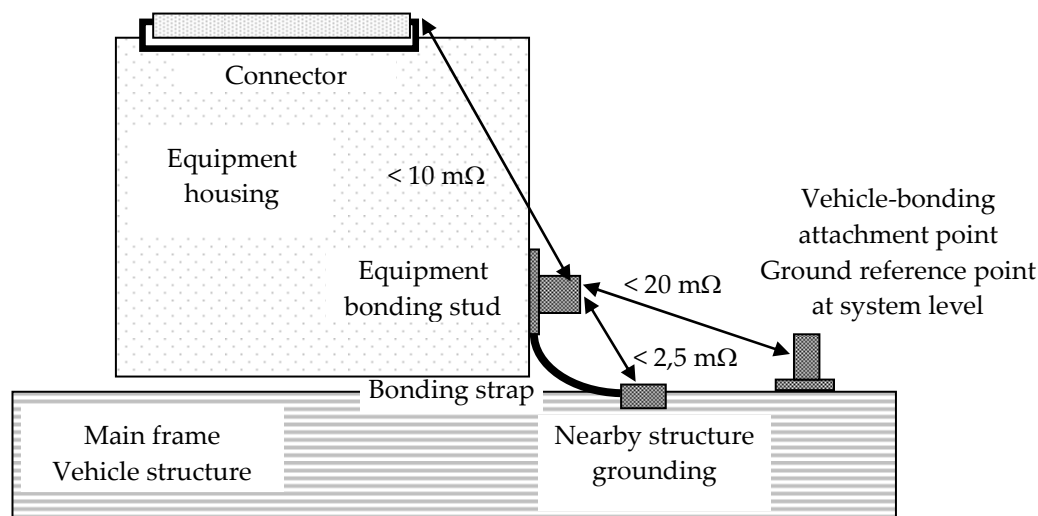


Figure 4-1: Bonding requirements

4.2.11.2 Normative provisions

- A vehicle bonding attachment point connected to the vehicle structure shall be provided as a ground reference point at system level.
- An equipment bonding stud connected to the unit housing shall be provided as a ground reference at equipment level.
- Each unit housing shall be bonded to the nearby spacecraft structure from the equipment bonding stud.
- The DC resistance between the equipment bonding stud and the nearby spacecraft structure shall be less than 2,5 mΩ.
- The inductance between the equipment bonding stud and the nearby spacecraft structure shall be less than 30 nH.
- The DC resistance between the unit housing and the vehicle bonding attachment point shall be less than 20 mΩ.
- The DC resistance between the equipment bonding stud and each connector housing shall be less than 10 mΩ.
- Bonds shall be capable to carry the fault currents determined by analysis at system level, without fusing, burning, or arcing.

- i. If the structure is used as the return current path, bonding provisions shall be such that DC and AC voltage drops along power paths comply with clause 4.2.10.2c.

4.2.11.3 External grounds

- a. The functionality of connecting grounding cables for charge equalization shall be provided on space systems.

NOTE Charge equalization is needed prior to implementing other procedures or the application of power across the interface.

4.2.12 Shielding (excepted wires and cables)

4.2.12.1 Overview

When shielding is used to control EMC with the environment, it can be provided by the basic space vehicle structure designed as a “Faraday cage”, by enclosures of electronics boxes, or by cable or bundle overshields.

4.2.12.2 Requirement

- a. Electronics units and cables external to the basic space vehicle structure shall have individual shields providing attenuation to EMI.

NOTE It is important to consider apertures used for pressure drop during ascent and for outgassing.

4.2.13 Wiring (including wires and cables shielding)

4.2.13.1 Classification of cables

- a. Categorisation of harness and separate routings for wires of different categories shall be defined as follows:
 - 1. applicable to critical lines as defined in ECSS-E-ST-20, Clause “Electromagnetic interference safety margin”.
 - 2. made on the basis of the characteristics of the signals on the wire (and hence the interference generated), and on the susceptibility of the circuit to EMI.
- b. Wires falling into one category shall be assembled into a same bundle.
- c. Bundles of different categories shall be separated either by a separation distance of 5 cm from the outer circumference or by a metallic screen when they are routed on parallel paths.

NOTE Overshields or spacecraft walls can be used to fulfil the requirement.

- d. Wires and cables shall be marked in such a manner that personnel can visually identify the EMC category for each wire or cable.

4.2.13.2 Cable shields

- a. Cable shields shall not be used as an intentional current carrying conductor, except coaxial cables in radiofrequency circuits and high-speed data links using coaxial cables.
- b. Cable shields, other than overshields, shall have an insulated sheath to prevent uncontrolled grounding.
- c. Connectors used to carry shielded wires shall
 - 1. not use a nonconductive finish,
 - 2. provide contact to the equipment housing with a resistance less than 10 m Ω through the equipment connector body as shown.

- d. Bonding of cable shields shall be as following:

- 1. Bonding to chassis ground is performed at both ends:
 - (a) through the equipment connector body,
 - (b) using a backshell that provides for circumferential bonding of shields, or using a halo-ring.

NOTE No grounding inside the equipment through a connector ground pin in order to prevent any perturbation inside the equipment.

- 2. Connection to electrical reference is performed through dedicated pins.

NOTE This case typically appears in the design of detection chains.

- e. Overshields shall be bonded to chassis ground:

- 1. at both ends,
- 2. using a 360° direct contact or a bond strap of less than 30 nH

NOTE See NOTE of clause 4.2.11.2e.

- f. Overshields should be bonded to chassis ground at intermediary points with a separation distance less than 1m between two grounding points.

5

Verification

5.1 Overview

5.1.1 Introduction

This Clause specifies general conditions for EMC testing, requirements for verification at system level and detailed procedures for unit and subsystem level testing.

5.1.2 Electromagnetic effects verification plan

The electromagnetic effects verification plan (EMEVP) provides the instruction for conducting all activities needed to verify electromagnetic effects requirements. This document defines the approach, methods, procedures, and specific test conditions. The content is specified in the EMEVP DRD of ECSS-E-ST-20. The EMEVP is the vehicle for tailoring procedures and test conditions.

5.1.3 Electromagnetic effects verification report

The electromagnetic effects verification report (EMEVR) documents activities and report analysis or test results in relation with the verification of the electromagnetic effects. It is established based on the electromagnetic effects verification plan (EMEVP). The content of the EMEVR is defined in the EMEVR DRD of ECSS-E-ST-20 supplemented by specific requirements defined hereafter in 5.3 and 5.4.

5.2 Test conditions

5.2.1 Measurement tolerances

- a. The tolerance for EMC testing shall be as follows:
 - 1. Distance: ± 5 %
 - 2. Frequency: ± 2 %
 - 3. Amplitude, measurement receiver: ± 2 dB

4. Amplitude, measurement system (includes measurement receivers, transducers, cables, connectors): ± 3 dB
5. Time (waveforms): ± 5 %
6. Resistors: ± 5 %
7. Capacitors: ± 20 %

5.2.2 Test site

5.2.2.1 Overview

Shielded enclosures or unshielded sites are used for testing.

Shielded enclosures prevent external environment signals from contaminating emission measurements and susceptibility test signals from interfering with electrical and electronic items near the test facility.

In unshielded sites, the tests are performed during times and conditions when the electromagnetic ambient is at its lowest level.

5.2.2.2 Shielded enclosures

- a. The enclosures shall be large such that the EUT arrangement requirements of 5.2.6 and antenna positioning requirements described in the individual test procedures are satisfied.
- b. RF absorber material shall be used when performing electric field radiated emissions or radiated susceptibility testing to reduce reflections of electromagnetic energy and to improve accuracy and repeatability.

NOTE Example of RF absorber material are carbon impregnated foam pyramids, and ferrite tiles.

- c. The RF absorber shall be placed above, behind, and on both sides of the EUT, and behind the radiating or receiving antenna as shown in Figure 5-1.
- d. Minimum performance of the material shall be as specified in Table 5-1.

NOTE The manufacturer's specification of their RF absorber material (basic material only, not installed) can be used.

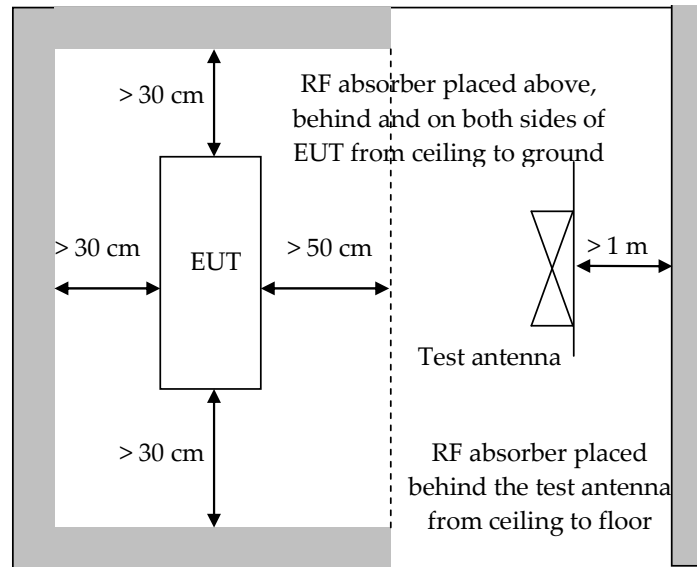


Figure 5-1: RF absorber loading diagram

Table 5-1: Absorption at normal incidence

Frequency	Minimum absorption
80 MHz – 250 MHz	6 dB
above 250 MHz	10 dB

5.2.2.3 Ambient electromagnetic level

- a. The ambient electromagnetic level shall be measured with the EUT not operating and all auxiliary equipment turned on.
- b. During testing, at least one of the following conditions shall be met:
 1. the ambient is at least 6 dB below the individual test limits,
 2. the EUT complies with the individual test limits,
 3. it is shown that recorded data exceeding the limits cannot be generated by the EUT (emission tests) or cannot sensitize the EUT (susceptibility tests).
- c. Background plots shall be reported for each test configuration unless all recorded data is at least 6 dB below the individual test limits.

5.2.2.4 Ambient conducted level

- a. Ambient conducted levels on power leads shall be measured with the leads disconnected from the EUT and connected to a resistive load that draws the same rated current as the EUT.

5.2.3 Ground plane

5.2.3.1 General

- a. If the actual installation is known, the EUT shall be installed on a ground plane that simulates the actual installation.
- b. If the actual installation is unknown or multiple installations are expected, then the EUT shall be installed on a metallic ground plane.
- c. Ground planes shall be 2 m² or larger in area with the smaller side no less than 75 cm.
- d. When a ground plane is not present in the actual EUT installation, the EUT shall be placed on a non-conductive table.

NOTE In such a case, test methods are specific and are likely to differ from the ones in the present standard.

5.2.3.2 Metallic ground plane

- a. When the EUT is installed on a metallic ground plane, the ground plane shall have a DC surface resistance not larger than 0,1 mΩ per square.
- b. The DC resistance between metallic ground planes and the shielded enclosure shall be 2,5 mΩ or less.
- c. The metallic ground planes shall be electrically bonded to the floor or wall of the basic shielded room structure at least once every 1 m.
- d. The metallic bond straps shall be solid and maintain a five-to-one ratio or less in length to width.
- e. Metallic ground planes used outside a shielded enclosure shall extend at least 1,5 m beyond the test setup boundary in each direction.

5.2.3.3 Composite ground plane

- a. When the EUT is installed on a conductive composite ground plane, the surface resistivity of the actual installation shall be used.
- b. Composite ground planes shall be electrically bonded to the enclosure with means suitable to the material.

5.2.4 Power source impedance

- a. The impedance of power sources providing input power to the EUT shall be controlled by Line Impedance Stabilization Networks ([LISNs](#)) for all measurement.
- b. [LISNs](#) shall not be used on output power leads.
- c. The [LISNs](#) shall be located at the power source end of the exposed length of power leads specified in 5.2.6.6.
- d. The LISN circuit shown in Figure 5-2 shall be used.

NOTE 1 The LISN can be split in several cases, one per power lead.

NOTE 2 The series inductances represent the inductances of the wiring; the series resistances represent the resistances of the wiring and of the central protections.

NOTE 3 The $50\ \Omega$ resistors result in $100\ \Omega$ at high frequency, similar to the characteristic impedance of the line.

NOTE 4 The feed-through capacitors provide a short-circuit at high frequency and make the LISN symmetrical

NOTE 5 Connecting the regulation wires of the laboratory supply at the LISN input in order to provide sufficiently low impedance at low frequency is an appropriate method. The source impedance is then dominated by the series resistances in the LISN. Alternatively, a large capacitor (between 1 mF and 10 mF) will be used.

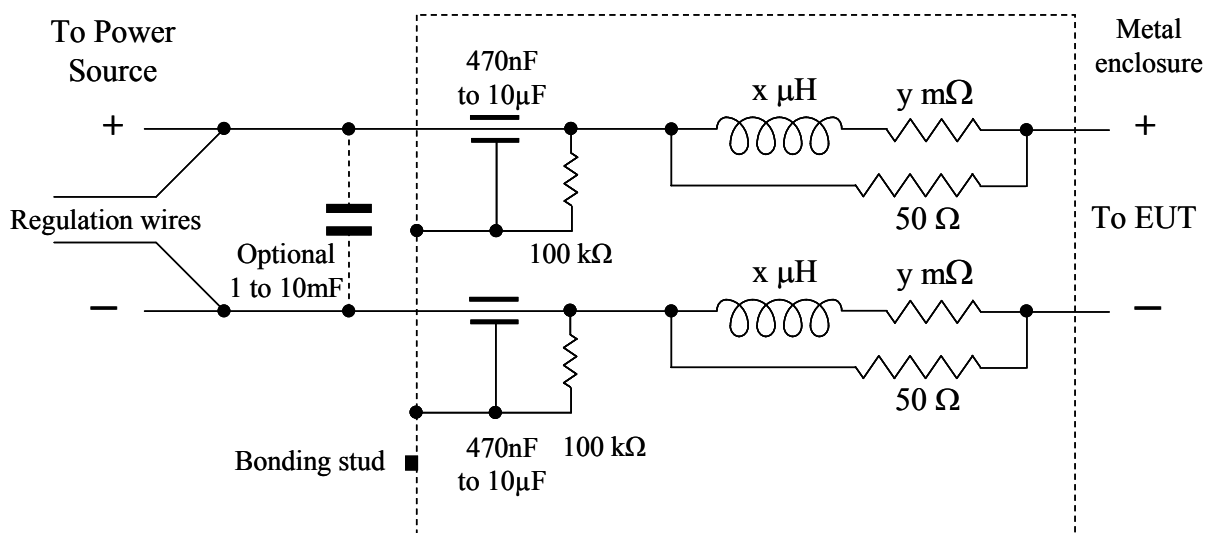


Figure 5-2: Line impedance stabilization network schematic

- e. If no value is specified $x = 2\ \mu\text{H}$ and $y = 0,1\ \Omega$ shall be used.

NOTE The x and y values, respectively the inductance and the resistance inserted in each lead are expected in the EMEVP.

- f. Magnetic coupling between inductors shall be avoided.
- g. If the return line is grounded at the power source in the actual installation (star distribution), the return line of the LISN shall be grounded on the power source side.
- h. If the return line(s) of the actual installation is locally grounded (chassis return), the return line of the LISN need not be provided, and the tests shall be performed with the return(s) tied to case.

- i. The LISN impedance shall be measured at least annually under the following conditions:
 - 1. the impedance, measured between the power output lead on the EUT side of the LISN and the metal enclosure of the LISN,
 - 2. an unterminated power input terminal on the power source side of the LISN.

5.2.5 General test precautions

5.2.5.1 Safety

- a. Clause 4.2.7 shall apply for tests involving high electromagnetic power or high voltage test equipment.

5.2.5.2 Excess personnel and equipment

- a. Only the equipment and the personnel used to perform the test shall be present in the test area or enclosure.

5.2.5.3 Overload precautions

- a. Checks shall be performed to assure that an overload condition does not exist.

NOTE Measurement receivers and transducers are subject to overload, especially receivers without preselectors and active transducers.

- b. Overload condition shall be corrected.

NOTE This can be done by instrumentation changes.

5.2.6 EUT test configurations

5.2.6.1 General

- a. The EUT shall be configured as shown in the general test setup of Figure 5-3 and maintained during all testing.

NOTE For radiated tests, it may be desirable to have the LISN outside of the shielded room.

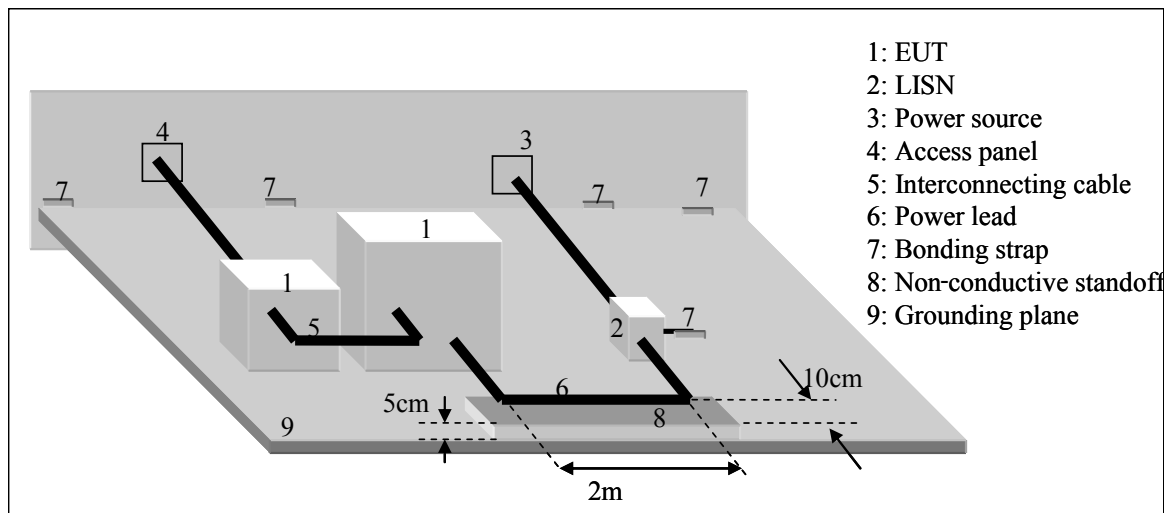


Figure 5-3: General test setup

5.2.6.2 Bonding of EUT

- a. Only the provisions included in the design of the EUT shall be used to bond units.

5.2.6.3 Shock and vibration isolators

- a. [EUTs](#) shall be secured to mounting bases having shock or vibration isolators if such mounting bases are used in the actual installation
- b. The bonding straps furnished with the mounting base shall be connected to the ground plane.
- c. When mounting bases do not have bonding straps, bonding straps shall not be used in the test setup.

5.2.6.4 Safety grounds

- a. When external terminals, connector pins, or equipment grounding conductors are available for safety ground connections and are used in the actual installation, they shall be connected to the ground plane.

NOTE Arrangement and length are specified in 5.2.6.6.

5.2.6.5 Orientation of [EUTs](#)

- a. [EUTs](#) shall be oriented such that surfaces that produce maximum radiated emissions and respond most readily to radiated signals face the measurement antennas.
- b. Bench mounted EUTs comprising interconnecting cables shall be located (10 ± 2) cm from the front edge of the ground plane.

5.2.6.6 Construction and arrangement of EUT cables

5.2.6.6.1 General

- a. Electrical cable assemblies shall simulate actual installation and usage.

NOTE 1 Proper construction techniques such as use of twisted pairs, shielding, and shield terminations are determinant features.

NOTE 2 Details on the cable construction used for testing are defined in the EMEVP DRD of ECSS-E-ST-20, and maintained in the EMEVR DRD of ECSS-E-ST-20.

- b. Shielded cables or shielded leads (including power leads and wire grounds) within cables shall be used only if they have been specified in installation requirements.

5.2.6.6.2 Interconnecting leads and cables

- a. Individual leads shall be grouped into cables in the same manner as in the actual installation.
- b. Up to 10 m, interconnecting cable lengths in the setup shall be the same as in the actual installation.
- c. If a cable is longer than 10 m in the actual installation, the cable length in the set up shall be between 10 m and the actual length.
- d. The cable arrangement shall be such that it satisfies the following conditions:
1. At least the first 2 m (except for cables that are shorter in the actual installation) of each interconnecting cable associated with each enclosure of the EUT are run parallel to the front boundary of the setup.
 2. Remaining cable lengths are routed to the back of the setup and placed in a zigzagged arrangement.
- e. When the setup includes more than one cable, individual cables shall be separated by 2 cm measured from their outer circumference.
- f. For bench top setups using ground planes, the cable closest to the front boundary shall be placed 10 cm from the front edge of the ground plane.
- g. All cables shall be supported 5 cm above the ground plane (except for interconnecting cables between enclosures of the EUT that are higher in the actual installation).

5.2.6.6.3 Input power leads

- a. Two metres of input power leads (including neutrals and returns) shall be routed parallel to the front edge of the setup in the same manner as the interconnecting leads.
- b. Each input power lead, including neutrals and returns, shall be connected to a LISN.

- c. Power leads that are bundled, as part of an interconnecting cable in the actual installation, shall be configured in the same fashion for the 2 m exposed length and then shall be separated from the bundle and routed to the [LISNs](#).
- d. After the 2 m exposed length, the power leads shall be terminated at the [LISNs](#) in such a manner that the total length of power lead from the EUT electrical connector to the [LISNs](#) shall not exceed 2,5 m.
- e. All power leads shall be supported 5 cm above the ground plane.
- f. If the power leads are twisted in the actual installation, they shall be twisted up to the [LISNs](#).

5.2.6.7 Electrical and mechanical interfaces

- a. Either the actual equipment from the platform installation or loads that simulate the electrical properties present in the actual installation shall terminate electrical input or output interfaces.

NOTE Example of these electrical properties are impedance, grounding and balance.

- b. Signal inputs shall be applied to the electrical interfaces to exercise EUT circuitry.
- c. EUT with mechanical outputs shall be loaded under expected conditions.
- d. When variable electrical or mechanical loading is present in the actual installation, testing shall be performed under expected worst-case conditions.
- e. When active electrical loading is used, it shall be ensured that the active load meets the ambient requirements of 5.2.2 when connected to the setup, and that the active load does not respond to susceptibility signals.

NOTE Example of active electrical loading is the test set.

- f. Antenna ports on the EUT shall be terminated with shielded, matched loads if the RF link is not used during the test.

5.2.7 Operation of EUT

5.2.7.1 General

- a. During emission measurements, the EUT shall be placed in the operating mode, which produces maximum emissions.
- b. During susceptibility testing, the EUT shall be placed in its most susceptible operating mode.
- c. When the EUT has several available modes (including software controlled operational modes), the number of modes to be tested for emission and susceptibility shall be such that all circuitry is evaluated.

NOTE It is expected that the customer defines or agrees operating modes.

5.2.7.2 Operating frequencies for tuneable RF equipment

- a. Measurements shall be performed with the EUT tuned to not less than three frequencies within each tuning band, tuning unit, or range of fixed channels, consisting of one mid-band frequency and a frequency within $\pm 5\%$ from each end of each band or range of channels.

5.2.7.3 Operating frequencies for spread spectrum equipment

- a. Operating frequency requirements for two major types of spread spectrum equipment shall be as follows:
 - 1. frequency hopping: measurements are performed with the EUT utilizing a hop set which contains a minimum of 30 % of the total possible frequencies, and the hop set is divided equally into three segments at the low, mid, and high end of the EUT operational frequency range,
 - 2. direct sequence: measurements are performed with the EUT processing data at the highest possible data transfer rate.

5.2.7.4 Susceptibility monitoring

- a. The EUT shall be monitored during susceptibility testing for indications of degradation or malfunction.

NOTE This monitoring is normally accomplished using built-in-test, visual displays, aural outputs, and other measurements of signal outputs and interfaces.

- b. If EUT performance is monitored through installation of special circuitry in the EUT, the modifications shall not influence test results.

5.2.8 Use of measurement equipment

5.2.8.1 Overview

Any frequency selective measurement receiver can be used for performing the testing described in this standard if the receiver characteristics (that is sensitivity, selection of bandwidths, detector functions, dynamic range, and frequency of operation) meet the constraints specified in this standard and are sufficient to demonstrate compliance with the applicable limits.

5.2.8.2 Detector

- a. A peak detector shall be used for all frequency domain emission and susceptibility measurements.

NOTE This device detects the peak value of the modulation envelope in the receiver pass band. Measurement receivers are calibrated in terms of

an equivalent root mean square value of a sine wave that produces the same peak value.

- b. When measurement devices other than peak detector are used for susceptibility testing, correction factors shall be determined and applied for test signals to adjust the reading to equivalent r.m.s. values under the peak of the modulation envelope.

NOTE Example of such measurement devices are oscilloscopes, non-selective voltmeters, and field strength sensors.

5.2.8.3 Calibration fixture (jig)

- a. When current measurements are performed on the central line of a coaxial transmission line a transmission line with $50\ \Omega$ characteristic impedance, coaxial connections on both ends, and space for an injection probe around the centre conductor shall be used for calibration.

NOTE Figure 5-4 represents an arrangement described in MIL-STD-461E.

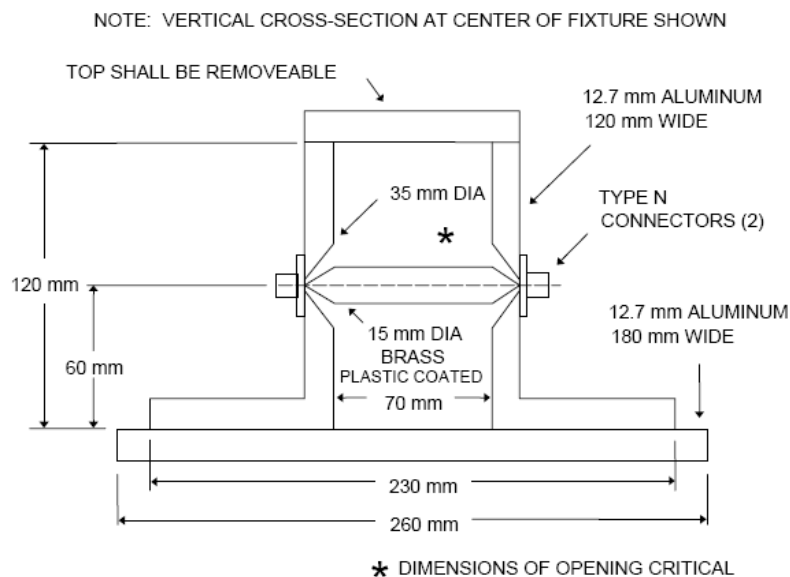


Figure 5-4: Typical calibration fixture

5.2.9 Emission testing

5.2.9.1 Bandwidths

- a. The measurement receiver bandwidths listed in Table 5-2 shall be used for emission testing.

NOTE These bandwidths are specified at the 6 dB down points for the overall selectivity curve of the receivers.

- b. Video filtering shall not be used to bandwidth limit the receiver response.

- c. If a controlled video bandwidth is available on the measurement receiver, it shall be set to its greatest value.
- d. If receiver bandwidths larger than those in Table 5-2 are used, no bandwidth correction factors shall be applied to test data due to the use of larger bandwidths.

NOTE Larger bandwidths can result in higher measured emission levels.

Table 5-2: Bandwidth and measurement time

Frequency Range	6 dB bandwidth	Dwell time	Minimum measurement time (analogue measurement receiver)
30 Hz - 1 kHz	10 Hz	0,15 s	0,015 s/Hz
1 kHz - 10 kHz	100 Hz	0,015 s	0,15 s/kHz
10 kHz - 150 kHz	1 kHz	0,015 s	0,015 s/kHz
150 kHz - 30 MHz	10 kHz	0,015 s	1,5 s/MHz
30 MHz - 1 GHz	100 kHz	0,015 s	0,15 s/MHz
Above 1 GHz	1 MHz	0,015 s	15 s/GHz

5.2.9.2 Emission identification

- a. All emissions regardless of characteristics shall be measured with the measurement receiver bandwidths specified in Table 5-2.

5.2.9.3 Frequency scanning

- a. For emission measurements, the entire frequency range for each test shall be scanned.
- b. Minimum measurement time for analogue measurement receivers during emission testing shall be as specified in Table 5-2.
- c. Synthesized measurement receivers shall step in one-half bandwidth increments or less, and the measurement dwell time shall be as specified in Table 5-2.
- d. For equipment that operates, such that potential emissions are produced at only infrequent intervals, times for frequency scanning shall be increased such that any emission is captured.

5.2.9.4 Emission data presentation

- a. Amplitude versus frequency profiles of emission data shall be automatically generated and displayed at the time of the test.
- b. Except for verification of the validity of the output, data shall not be gathered manually.
- c. The information shall be displayed after application of correction factors, including transducers, attenuators, and cable loss.

- d. Data output of the EUT test result shall be in the form of amplitude over time (for the time domain plots) and amplitude over frequency (for frequency domain plots), superimposed with the EMI test limit.
- e. Units of measurement for frequency domain emissions measurements shall be reported in units of dB referenced to 1 μ V, 1 μ A, 1 μ V/m, 1 pT depending on the unit defined in the test limit.
- f. For time domain measurements, oscilloscope plots shall include the amplitude physical unit (V or A) conversion factors V into A if not done automatically by the oscilloscope, and the oscilloscope sensitivity, time base settings and measurement bandwidth.
- g. For frequency domain plots, emission data shall be reported in graphic form with frequency resolution of 1 %, or twice the measurement receiver bandwidth, whichever is less stringent.
- h. In the event of any emissions test result over the emission test limit above 100 MHz, greater accuracy of its frequency shall be reported with resolution better than or equal to twice the measurement bandwidth.
- i. Each plot of emission data shall be reported with a minimum amplitude resolution of 1 dB.

5.2.10 Susceptibility testing

5.2.10.1 Frequency stepping

- a. For susceptibility measurements, the entire frequency range for each applicable test shall be scanned.

NOTE Stepped scans refer to signal sources that are sequentially tuned to discrete frequencies.

- b. Stepped scans shall dwell at each tuned frequency for the greatest of three seconds or the EUT response time.

NOTE Ten frequency steps per decade can be used as a basis.

- c. Step sizes shall be decreased such to permit observation of a response.

NOTE For receivers, it can make use of the frequency plan to adjust the number of points.

5.2.10.2 Modulation of susceptibility signals

- a. Susceptibility test signals shall be pulse modulated (on/off ratio of 40 dB minimum) at a 1 kHz rate with a 50 % duty cycle for susceptibility signals at a frequency larger than 100 kHz.
- b. CW test signals shall be used for susceptibility signals at a frequency smaller than 100 kHz.

5.2.10.3 Thresholds of susceptibility

- a. When susceptibility indications are noted in EUT operation, a threshold level shall be determined as follows where the susceptible condition is no longer present:
 1. When a susceptibility condition is detected, reduce the interference signal until the EUT recovers.
 2. Reduce the interference signal by an additional 6 dB.
 3. Gradually increase the interference signal until the susceptibility condition reoccurs; the resulting level is the threshold of susceptibility.
 4. Record this level, frequency range of occurrence, frequency and level of greatest susceptibility, and the other test parameters.

5.2.10.4 Susceptibility data presentation

- a. The susceptibility criteria defined in the EMI test procedure shall be repeated in the test report, or the “as run” EMI test procedure shall be an annex to the EMI test report.
- b. Data showing the frequencies and amplitudes at which the test was conducted shall be provided in graphical or tabular form.
- c. Indications of compliance with the requirements shall be provided.

NOTE Such indications can be provision of oscilloscope plots of injected waveforms with test data.
- d. Information shall be displayed after application of correction factors, including transducers, attenuators, and cable loss.
- e. Data shall be reported with frequency resolution of 1 %.
- f. Data shall be provided with a minimum amplitude resolution of 1 dB for each plot.
- g. If susceptibility is observed, determined levels of susceptibility shall be recorded in the test report.

5.2.11 Calibration of measuring equipment

5.2.11.1 General

- a. Measurement antennas, current probes, field sensors, and other devices used in the measurement loop shall be calibrated at least every two years or when damaged.

5.2.11.2 Measurement system test

- a. At the start of each emission test, the complete test system (including measurement receivers, cables, attenuators, couplers, and so forth) shall be verified by injecting a known signal (as stated in the individual test procedure), while monitoring system output for the proper indication.

- b. When the emission test involves an uninterrupted set of repeated measurements using the same measurement equipment, the measurement system test may be accomplished only one time.

NOTE Example of such repeated measurements is the evaluation of different operating modes of the EUT.

5.3 System level

5.3.1 General

- a. Each item of equipment and subsystem shall have successfully passed functional acceptance test procedures as installed on the platform, prior to system level EMC test.

5.3.2 Safety margin demonstration for critical or EED circuits

- a. A test performed to demonstrate compliance with the safety margin requirement shall use one or more of the following test approaches:
 - 1. Inject interference at critical system points at x dB higher level than exists, while monitoring other system points for improper responses, where x = EMISM.
 - 2. Measure the susceptibility of critical system circuits for comparison to existing interference levels, to determine the margin.
 - 3. Sensitize the system to render it x dB more susceptible to interference, while monitoring for improper response, where x = EMISM.
- b. Safety margin demonstration for something that is susceptible to a time domain circuit (including [EEDs](#)) shall use time domain methods.

5.3.3 EMC with the launch system

- a. If the spacecraft is not powered during launch, EMC testing with the launch system need not be performed.
- b. If the spacecraft is powered during launch, the electric field [radiated emission requirements specified in the Launcher User's manual](#), including intentional transmission, [shall be verified](#).
- c. In case a spacecraft [RF transmitter is operating](#) under fairing, the [following](#) EMISM_s shall be verified:
 - 1. [EMISM with respect to the susceptibility threshold of the EEDs](#).
 - 2. [EMISM with respect to the spacecraft RF receivers' susceptibility threshold \(if operational\) or damage threshold \(otherwise\)](#).

NOTE [This requirement c. applies also to transmitters which are switched off during launch and ascent but can, for example, be switched on temporarily on the launch pad, for a final health check.](#)

- d. [The EMISM between the launch system RF emissions and the spacecraft RF receivers' damage threshold shall be verified.](#)

5.3.4 Lightning

- a. Lightning protection specified in ECSS-E-ST-20 (in clause "Inter-system EMC and EMC with environment"), shall be verified by analysis from equipment demonstration.

NOTE 1 Test at system level need not be performed.

NOTE 2 [deleted.](#)

5.3.5 Spacecraft and static charging

- a. Material use, bonding of discharge elements, thermal blankets, or metallic items using a bond for static potential equalization shall be verified by inspection or measurement at assembly into structure.
- b. If the bond is only used for charging control, the bonding resistance shall be measured with a dc-current in the range 10 to 100 μ A, under only one polarity, with a 2-wires ohmmeter.

NOTE If the bond is only used for charging control the clauses 5.3.10a and 5.3.10b do not apply.

5.3.6 Spacecraft DC magnetic field emission

- a. Spacecraft DC magnetic field emission requirements shall be verified by a combination of analysis and tests.

5.3.7 Intra-system electromagnetic compatibility

- a. For intra-system EMC tests, the support equipment shall provide the functionality of exercising culprits and victims, and include the support equipment instructions.
- b. Wherever 0 dB EMISM is a requirement, functional tests at spacecraft level may be accepted as a verification of EMC.

5.3.8 Radiofrequency compatibility

- a. Except for passive intermodulation products, radiofrequency compatibility shall be verified by a test at system level.
- b. Absence of passive intermodulation products shall be verified in accordance with the requirements for "Passive intermodulation" specified in ECSS-E-ST-20.

5.3.9 Grounding

- a. The system-level electrical grounding and isolation shall be verified by isolation and continuity tests at system assembly.

NOTE The grounding and isolation design is documented by the system-level grounding diagram including EGSE.

5.3.10 Electrical bonding

- a. Except for bonding used only for charging control, the bonding resistances shall be measured using a 4-wires method, under a pulsed DC current of 1 A.
- b. Except for bonding used only for charging control, the probes shall be reversed and re-measured to detect possible non linearities across the bonded junction.

NOTE See clause 5.3.5b.

5.3.11 Wiring and shielding

- a. Wiring category and cable shields shall be verified by review of design and inspection.

5.4 Equipment and subsystem level test procedures

5.4.1 Overview

Test procedures are specified in clauses 5.4.2 through [5.4.12](#) for verifying emission and susceptibility requirements at subsystem or equipment level. Table 5-3 gives the correspondence between procedures and recommended limits defined in Annex A.

Table 5-3: Correspondence between test procedures and limits

Informative limit Annex A	Title of test procedure	Verification Clause 5
A.2	CE on power leads, differential mode, 30 Hz to 100 kHz (1st part)	5.4.2
A.2	CE on power leads, differential mode, 100 kHz to 100 MHz (2nd part)	5.4.3
A.3	CE on power leads, in-rush currents	<u>5.4.4</u>
A.4	CE on power and signal leads, common mode, 100 kHz to 100 MHz	5.4.3
A.5	CE on antenna ports	Specific
A.6	DC magnetic field emission	<u>5.4.5</u>
A.7	RE, low-frequency magnetic field	Specific
A.8	RE, low-frequency electric field	Specific
A.9	RE, electric field, 30 MHz to 18 GHz	5.4.6
A.10	CS, power leads, differential mode, 30 Hz to 100 kHz	<u>5.4.7</u>
A.11	CS, power and signal leads, common mode, 50 kHz to 100 MHz	<u>5.4.8</u>
A.12	CS, power leads, short spike transients	5.4.9
A.13	RS, magnetic field, 30 Hz to 100 kHz	<u>5.4.10</u>
A.14	RS, electric field, 30 MHz to 18 GHz	<u>5.4.11</u>
A.15	Susceptibility to electrostatic discharge	<u>5.4.12</u>

5.4.2 CE, power leads, differential mode, 30 Hz to 100 kHz

5.4.2.1 Purpose

This method is used for measuring conducted emissions in the frequency range 30 Hz to 100 kHz on all input power leads including returns.

5.4.2.2 Test equipment

a. The test equipment shall be as follows:

1. Measurement receiver,
2. Current probe,
3. Signal generator with amplifier,
4. DC-current supply,
5. Data recording device,
6. Oscilloscope,
7. Coaxial "T" connector and coaxial to bifilar transition,
8. 1 Ω and 10 Ω power metal film resistors with inductance lower than 100 nH,
9. LISN defined in 5.2.4.

5.4.2.3 Setup

- a. The test setup shall be as follows:
 1. Maintain a basic test setup for the EUT as specified in 5.2.6 and Figure 5-3.
 2. For measurement system check, configure the test setup as shown in Figure 5-5.
 3. For equipment testing, configure the test setup as shown Figure 5-6.

5.4.2.4 Procedure

- a. The test procedures shall be as follows:
 1. Turn on the measurement equipment and wait until it is stabilized.
 2. If the EMEVP specifies to check the measurement system, check it by evaluating the overall measurement system from the current probe to the data output device, as follows:
 - (a) Apply a calibrated signal level, at 1 kHz and 100 kHz, which is at least 6 dB below the emission limit to the current probe.

NOTE A power amplifier can be necessary at 1 kHz.
 - (b) Apply through the current probe a DC-current equivalent to the EUT supply current.

NOTE 1 A DC current is applied for verifying that the current probe will not be saturated by the EUT DC supply current.

NOTE 2 This DC current is applied through the LISN for applying the same impedance through the probe as with the EUT.
 - (c) Verify the AC current level as measured with the probe by comparison with voltage across the 1 Ω resistor at 1 kHz and the 10 Ω resistor at 100 kHz; also, verify that the current waveform is sinusoidal.
 - (d) Scan the measurement receiver for each frequency in the same manner as a normal data scan. Verify that the data-recording device indicates a level within ± 3 dB of the injected level.
 - (e) If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.
 3. Test the EUT by determining the conducted emissions from the EUT input power leads, hot line and return, and measure the conducted emission separately on each power lead, as follows:
 - (a) Turn on the EUT and wait for its stabilization.
 - (b) Select a lead for testing and clamp the current probe into position.

- (c) Scan the measurement receiver over the frequency range, using the bandwidths and minimum measurement times specified in Table 5-2, clause 5.2.9.1.
- (d) Repeat 5.4.2.4a.3(b) and 5.4.2.4a.3(c) for each power lead.

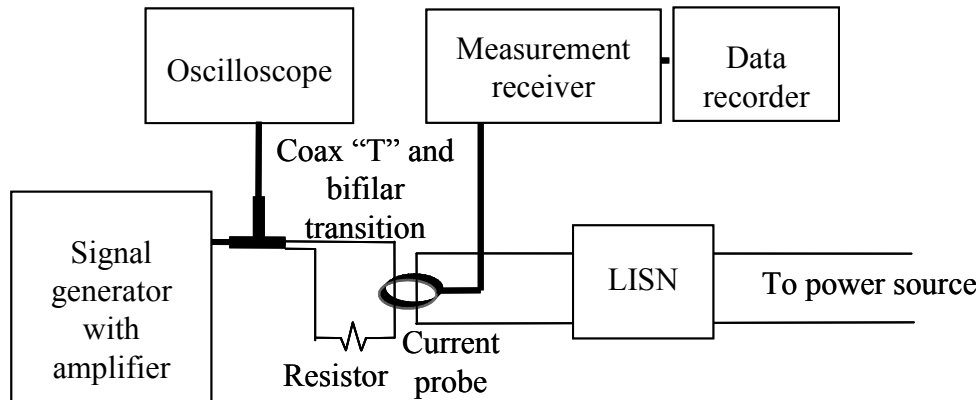


Figure 5-5: Conducted emission, 30 Hz to 100 kHz, measurement system check

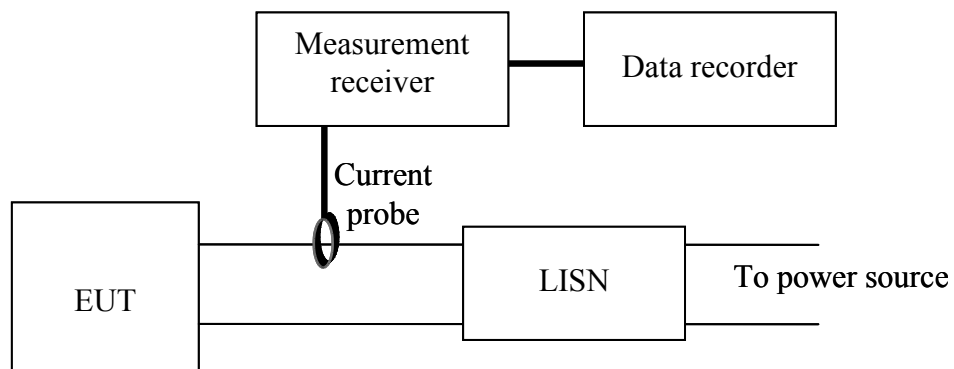


Figure 5-6: Conducted emission, 30 Hz to 100 kHz, measurement setup

5.4.3 CE, power and signal leads, 100 kHz to 100 MHz

5.4.3.1 Purpose

This test procedure is used to verify that electromagnetic emissions from the EUT do not exceed the specified requirements for power input leads including returns, and for common mode emission.

5.4.3.2 Test equipment

- a. The test equipment shall be as follows:
 - 1. Measurement receiver,
 - 2. Current probe,
 - 3. Signal generator,

4. Data recording device,
5. Oscilloscope with 50 Ω input,
6. 50 Ω power divider (6dB "T" connector),
7. 50 Ω coaxial load,
8. Calibration fixture defined in 5.2.8.3,
9. [LISNs](#) defined in 5.2.4.

5.4.3.3 Setup

- a. The test setup shall be as follows:
 1. Maintain a basic test setup for the EUT as specified in 5.2.6 and Figure 5-3.
 2. Configure the test setup for the measurement system check as shown in Figure 5-7.
 3. For compliance testing of the EUT:
 - (a) Configure the test setup as shown in Figure 5-8 [for differential mode testing](#) and Figure 5-9 [for common mode testing](#).
 - (b) Position the current probe 10 cm from the LISN.

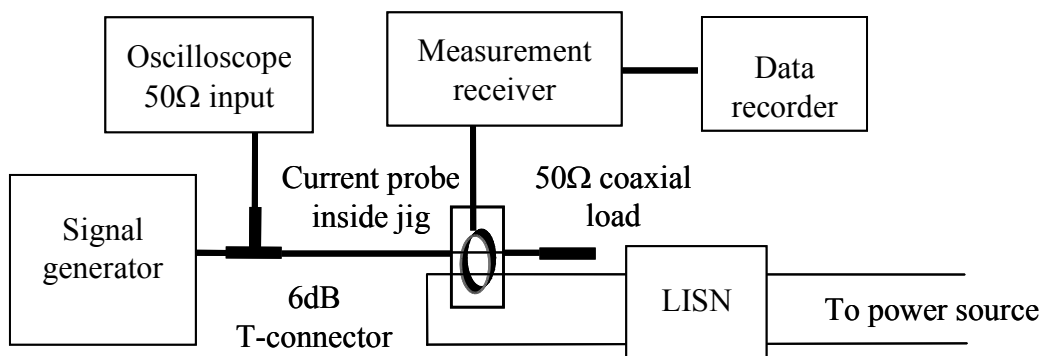


Figure 5-7: Conducted emission, measurement system check

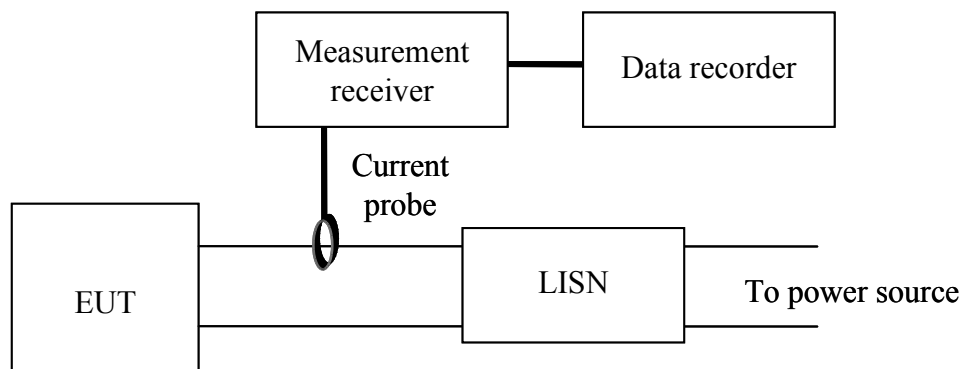


Figure 5-8: Conducted emission, measurement setup in differential mode

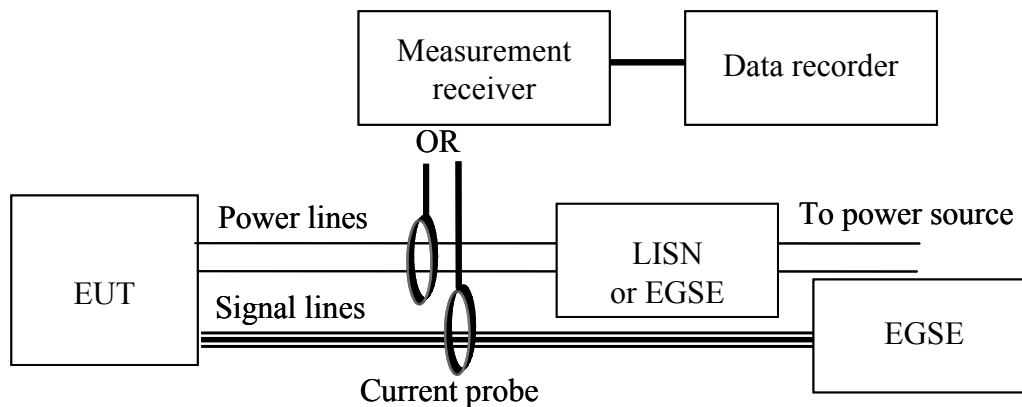


Figure 5-9: Conducted emission, measurement setup in common mode

5.4.3.4 Procedures

a. The test procedures shall be as follows:

1. Turn on the measurement equipment and wait until it is stabilized.
2. If the EMEVP specifies to check the measurement system, check it by evaluating the overall measurement system from the current probe to the data output device, as follows:

- (a) Apply a calibrated signal level that is at least 6 dB below the applicable limit at 1 MHz and 10 MHz or at a level allowing out of the noise reading on the oscilloscope, whatever is greater, to the current probe in the jig.
- (b) Apply through the current probe using a second wire, a DC current equivalent to the EUT nominal supply current.

NOTE 1 A DC current is applied for verifying that the current probe will not be saturated by the EUT DC supply current.

NOTE 2 This DC current is applied through the LISN for applying the same impedance through the probe as with the EUT.

- (c) Verify the AC current level, as measured with the probe by comparison with the voltage on the T derivation.
- (d) Scan the measurement receiver for each frequency in the same manner as a normal data scan, and verify that the data-recording device indicates a level within ± 3 dB of the injected level.
- (e) If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.
3. Test the EUT by determining the conducted emission from the input power leads, hot lines and returns separately, and from each interconnecting bundle (common mode), including the ones with power leads, as follows:

- (a) Turn on the EUT and wait until it is stabilized.
- (b) Select a lead or a bundle for testing and clamp the current probe into position.
- (c) Scan the measurement receiver over the frequency range, using the bandwidths and minimum measurement times specified in Table 5-2, clause 5.2.9.1.
- (d) Repeat 5.4.3.4a.3(b) and 5.4.3.4a.3(c) for each power lead or for each bundle.

5.4.4 CE, power leads, inrush current

5.4.4.1 Purpose

This test procedure is used to verify that the inrush current of the EUT does not exceed the specified requirements for power input leads.

5.4.4.2 Test equipment

- a. The test equipment shall be as follows:
 - 1. Two-channels oscilloscope,
 - 2. Current probe,
 - 3. Spike generator,
 - 4. Data recording device,
 - 5. Coaxial "T" connector,
 - 6. Coaxial to bifilar transition,
 - 7. 1 Ω power metal film resistor with inductance lower 30 nH and peak power capability,
 - 8. LISN defined in 5.2.4,
 - 9. Switching device, fast bounce-free power switch, or an actual power-controller except if the ON/OFF command is implemented in the EUT.

5.4.4.3 Setup

- a. The test setup shall be as follows:
 - 1. Maintain a basic test setup for the EUT as specified in 5.2.6 and Figure 5-3.
 - 2. Configure the test setup for the measurement system check as shown in Figure 5-10.
 - 3. Configure the test setup for compliance testing of the EUT as shown in Figure 5-11.

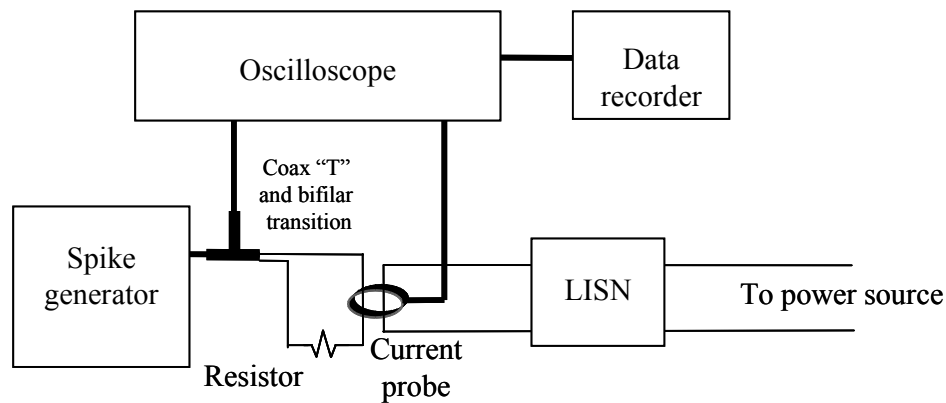


Figure 5-10: Inrush current: measurement system check setup

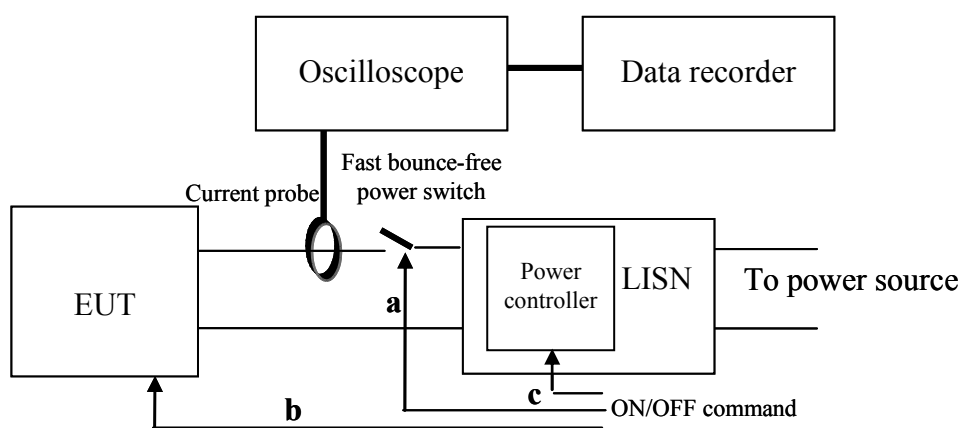


Figure 5-11: Inrush current: measurement setup

5.4.4.4 Procedures

a. The test procedures shall be as follows:

1. Turn on the measurement equipment and allow a sufficient time for stabilization.
2. If specified by the EMEVP, check the measurement system by evaluating the overall measurement system from the current probe to the data output device:
 - (a) Apply a calibrated spike that is at least 6 dB below the applicable limit to the current probe.
 - (b) Apply through the current probe a DC current equivalent to the EUT supply current.

NOTE 1 A DC current is applied for verifying that the current probe will not be saturated by the EUT DC supply current.

NOTE 2 This DC current is applied through the LISN for applying the same impedance through the probe as with the EUT.

- (c) Check the spike current as measured with the probe by comparison with the voltage across the resistor.
 - (d) Perform the measurement with the current probe on an oscilloscope in the same manner as for EUT testing and verify that the data-recording device indicates a level within ± 3 dB of the injected level.
 - (e) If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.
3. Test the EUT by determining the conducted emission from the EUT input power leads, as follows:
- (a) Select the positive lead for testing and clamp the current probe into position.
 - (b) Perform measurement by application of power on the EUT using a mercury relay (Figure 5-11.a), the internal EUT switch (Figure 5-11.b), or the power controller (Figure 5-11.c).

NOTE The method for application of power is defined in the EMEVR

5.4.4.5 Data presentation

- a. In addition to 5.2.9.4, data presentation shall be a graphic output of current versus time displaying the transient characteristics with following conditions:
- 1. amplitude resolution within 3 % of the applicable limit,
 - 2. time base resolution within 10 % of rise time for measurement of rise and fall slopes.

NOTE Rise time is the duration between 10 % and 90 % of peak-to-peak amplitude

- b. Two separate displays shall be provided showing respectively the initial rise time and the full inrush response.

NOTE Typical time bases are 10 μ s full scale for the initial rise time and 1 ms full scale for the full inrush response.

5.4.5 DC Magnetic field emission, magnetic moment

5.4.5.1 Overview

The described test method allows obtaining a rough estimate of the magnetic moment of the EUT (centred dipole approximation). It involves the constraint of measuring the magnetic field at distances typically more than three times the size of the EUT.

If a better model is needed, making it possible to predict the field at closer distances or more precisely than the centred dipole approximation allows, then either multiple dipole modelling techniques or spherical harmonics techniques can be used.

NOTE It is the role of the EMCAB to assess the need for using such techniques, based on mission requirements.

5.4.5.2 Set-Up

- a. The EUT should be set in an earth field compensated area providing zero-field conditions for the intrinsic moment determination.

NOTE 1 This is necessary in case the EUT contains a significant amount of soft magnetic material, as without earth field compensation an induced magnetic moment would appear.

NOTE 2 Earth field compensation is usually ensured by 2 or 3 sets of Helmholtz coils.

- b. A right-handed orthogonal coordinate system XYZ shall be assigned to the EUT geometric centre.
- c. The magnetic sensor (single-axis magnetometer) shall be installed successively on the 6 semi-axes at two different reference distances r_1 and r_2 from the geometric centre of the EUT and shall measure the field projection along these lines.

NOTE The reference distances are typically more than three times the size of the EUT

- d. Alternatively the EUT may be installed on a turntable and rotated in front of a fixed magnetometer, presenting each XYZ axis (positive and negative) successively aligned with the sensor axis.
- e. The magnetic field shall be positive when orientated from the centre of the EUT towards the magnetometer.

5.4.5.3 Test sequence

- a. The test sequence shall be as follows:
1. EUT not operating, initial measurements on the six semi-axes at the reference distances.
 2. Deperm:
 - (a) EUT not operating, application of a deperming field in accordance with Figure 5-12 frequency 3 Hz, maximum amplitude between 4 000 μ T and 5 000 μ T, successively on each XYZ axis of the EUT.

NOTE 1 This is usually done using Helmholtz coils.

NOTE 2 A sequence of symmetrical sine periods of increasing and decreasing amplitude gives better results than a sine wave modulated by exponentials or ramp functions.

- (b) Measurement after deperm on the six semi-axes at the reference distances.
- 3. Perm:
 - (a) EUT not operating, application of a perm field of 300 μT on each XYZ axis.
 - (b) Measurement after perm on the six semi-axes at the reference distances.
- 4. Stray field: EUT operating, measurement on the six semi-axes at the reference distances.
- 5. Final deperm: repeat 5.4.5.3a.2.

5.4.5.4 Data presentation

- a. For DC magnetic field emission, data shall be presented as follows, superseding clauses 5.2.9.4a through 5.2.9.4i:

- 1. For each measurement distance, for each of the 6 semi-axes, the following induction measurements in μT are plotted in tabular form:

$$B_{(+X)}, B_{(-X)}, B_{(+Y)}, B_{(-Y)}, B_{(+Z)}, B_{(-Z)}$$

- 2. For each measurement distance, mean inductions, for each axis, are computed in units of μT and plotted in tabular form, using following equations:

$$B_x = \frac{B_{(+X)} - B_{(-X)}}{2}, B_y = \frac{B_{(+Y)} - B_{(-Y)}}{2}, B_z = \frac{B_{(+Z)} - B_{(-Z)}}{2}$$

- 3. For each measurement distance r , 3-axes magnetic moment components in units of Am^2 are calculated using the following equations and reported:

$$M_x = 5 r^3 B_x \quad M \text{ in units of } \text{Am}^2, r \text{ in meters, } B \text{ in } \mu\text{T}$$

$$M_y = 5 r^3 B_y$$

$$M_z = 5 r^3 B_z$$

- 4. Using values of M_x , M_y and M_z at both distances r_1 and r_2 , values M_1 and M_2 of the magnetic moment are calculated using the following equations and reported:

$$M_1 = \sqrt{M_x(r_1)^2 + M_y(r_1)^2 + M_z(r_1)^2}$$

$$M_2 = \sqrt{M_x(r_2)^2 + M_y(r_2)^2 + M_z(r_2)^2}$$

NOTE If the EUT is a centred dipolar source, then $M_1 = M_2$.

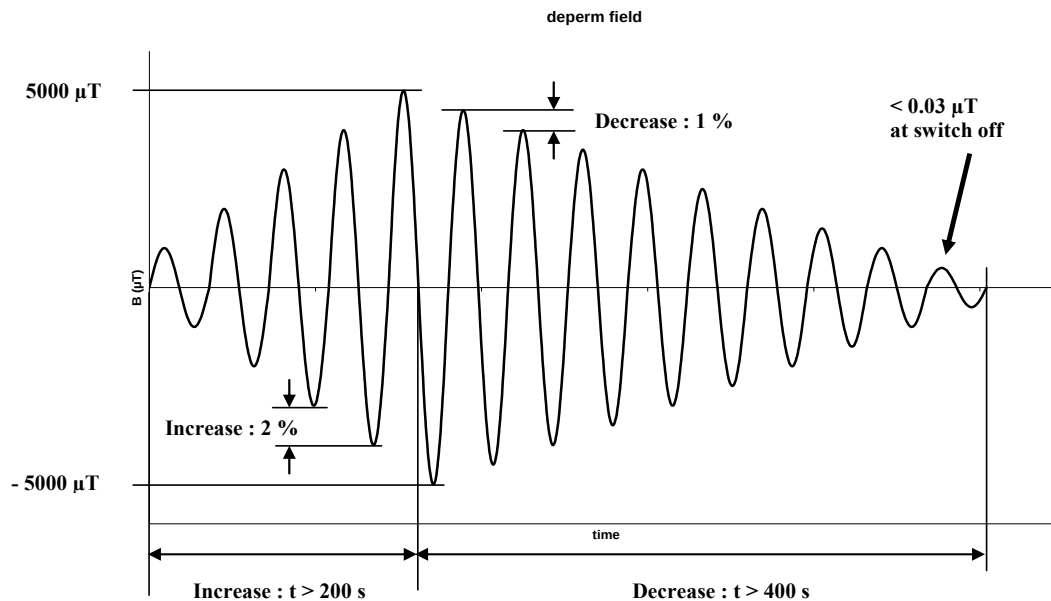


Figure 5-12: Smooth deperm procedure

5.4.6 RE, electric field, 30 MHz to 18 GHz

5.4.6.1 Purpose

This test procedure is used to verify that electric field emissions from the EUT and its associated cabling do not exceed specified requirements.

5.4.6.2 Test equipment

a. The test equipment shall be as follows:

1. Measurement receiver,
2. Data recording device,
3. Linearly polarized antennas,

NOTE The following antennas are commonly used:

- 30 MHz to 200 MHz, biconical, 137 cm tip to tip,
- 200 MHz to 1 GHz, double ridge horn, 69,0 cm by 94,5 cm opening, or log-periodic,
- 1 GHz to 18 GHz, double ridge horn, 24,2 cm by 13,6 cm opening.

4. Signal generators,
5. Stub radiator,
6. LISN defined in 5.2.4, optional.

5.4.6.3 Test setup

- a. A basic test setup for the EUT as shown and described in Figure 5-3 and 5.2.6 shall be maintained to ensure that the EUT is oriented such that the surface that produces the maximum radiated emissions is toward the front edge of the test setup boundary.

NOTE The LISN should be used.

- b. The measurement system shall be checked by configuring the test equipment as shown in Figure 5-13.
- c. To test the EUT antenna positioning, the test setup boundary of the EUT and associated cabling for use in positioning of antennas shall be determined.
- d. To test the EUT antenna positioning, the physical reference points on the antennas shown in Figure 5-14 for measuring heights of the antennas and distances of the antennas from the test setup boundary shall be used as follows:
 - 1. Position antennas 1 m from the front edge of the test setup boundary for all setups.
 - 2. Position antennas above the floor ground plane.
 - 3. Ensure that no part of any antenna is closer than 1 m from the walls and 0,5 m from the ceiling of the shielded enclosure.
- e. The antenna positions shall be determined as follows:
 - 1. For testing below 200 MHz:
 - (a) For setups with the side edges of the boundary 3 m or less, one position, with the antenna centred with respect to the side edges of the boundary.
 - (b) For setups with the side edges of the boundary greater than 3 m, N antenna positions at spacing as shown in Figure 5-15, where N is the edge-to-edge boundary distance (in metres) divided by 3 and rounding up to an integer.
 - 2. For testing from 200 MHz up to 1 GHz, place the antenna in such a number of positions that the entire width of each EUT enclosure and the first 35 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.
 - 3. For testing at 1 GHz and above, place the antenna in such a number of positions that the entire width of each EUT enclosure and the first 7 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB-beamwidth of the antenna.

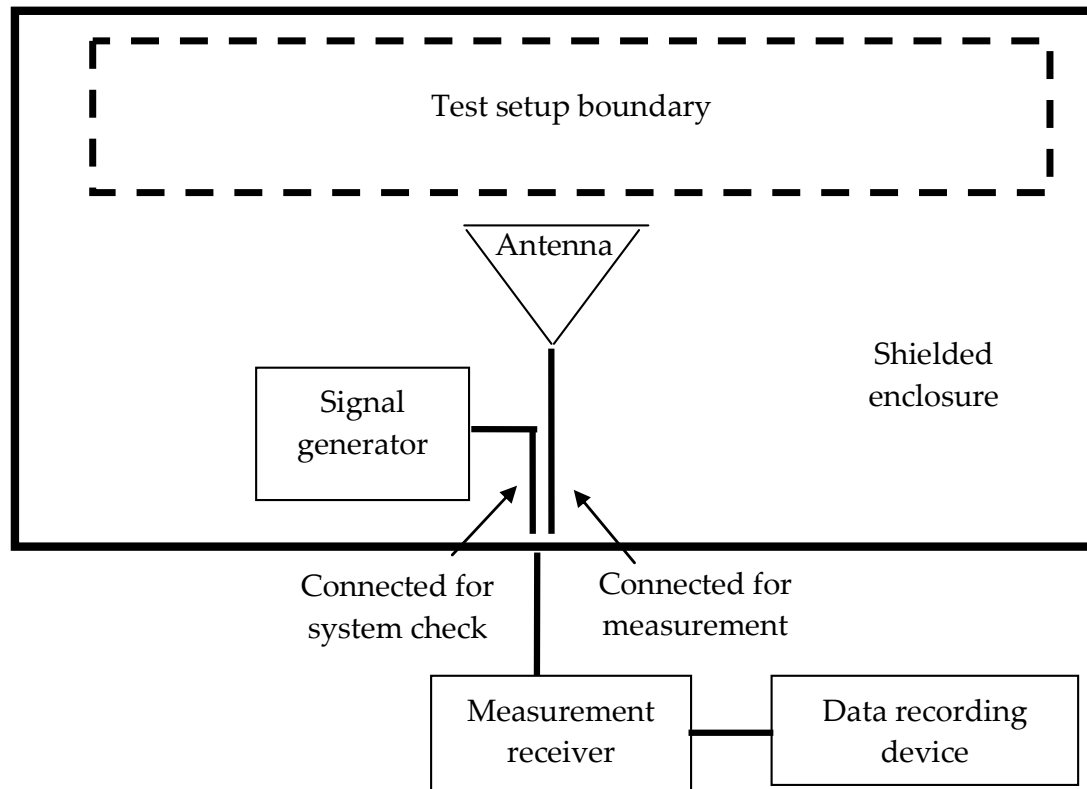


Figure 5-13: Electric field radiated emission. Basic test setup

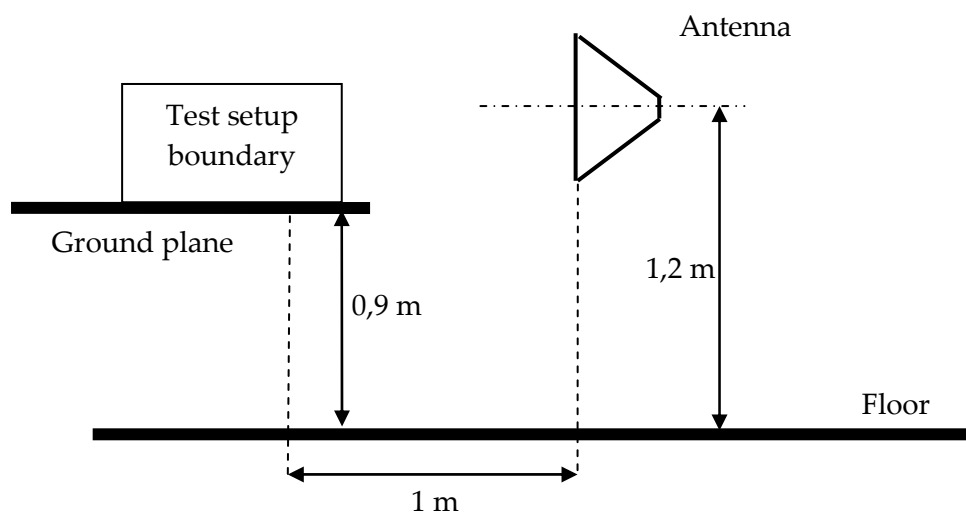


Figure 5-14: Electric field radiated emission. Antenna positioning

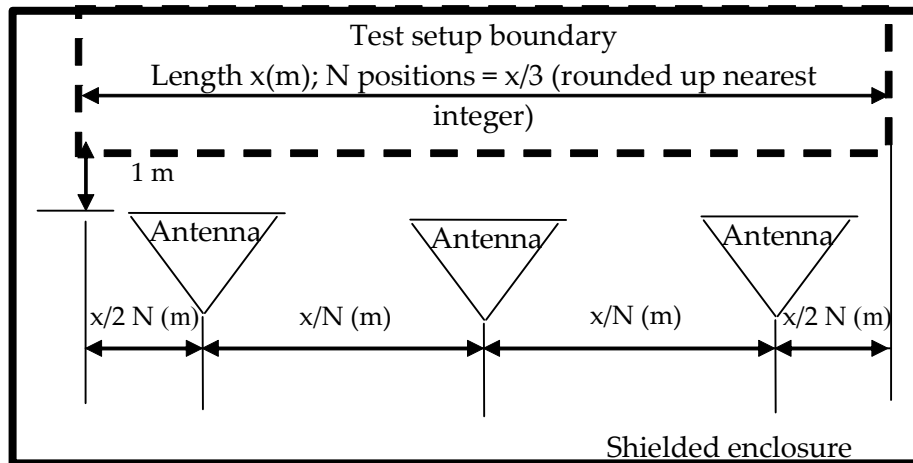


Figure 5-15: Electric field radiated emission. Multiple antenna positions

5.4.6.4 Test procedures

- a. The measurement equipment shall be turned on and waited until it is stabilized.
- b. It shall be verify that the ambient requirements specified in 5.2.2.3 are met and plots of the ambient taken.
- c. The measurement system shall be checked as follows:
 1. Using the system check path of Figure 5-13, perform the following evaluation of the overall measurement system from each antenna to the data output device at the highest measurement frequency of the antenna:
 - (a) Apply a calibrated signal level that is at least 6 dB below the limit (limit minus antenna factor) to the coaxial cable at the antenna connection point.
 - (b) Scan the measurement receiver in the same manner as a normal data scan, and verify that the data-recording device indicates a level within ± 3 dB of the injected signal level.
 - (c) If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.
 2. Using the measurement path of Figure 5-13, perform the following evaluation for each antenna to demonstrate that there is electrical continuity through the antenna:
 - (a) Radiate a signal using an antenna or stub radiator at the highest measurement frequency of each antenna.
 - (b) Tune the measurement receiver to the frequency of the applied signal and verify that a received signal of appropriate amplitude is present.

NOTE This evaluation is intended to provide a coarse indication that the antenna is functioning properly.

There is no requirement to measure accurately the signal level.

- d. The EUT shall be tested by using the measurement path of Figure 5-13 and by determining the radiated emissions from the EUT and its associated cabling as follows:
 - 1. Turn on the EUT and wait until it is stabilized.
 - 2. Scan the measurement receiver for each applicable frequency range, using the bandwidths and minimum measurement times in 5.2.9.1
 - 3. Orient the antennas for both horizontally and vertically polarized fields.
 - 4. Repeat steps 5.4.6.4d.2 and 5.4.6.4d.3 for each antenna position determined under 5.4.6.3c, 5.4.6.3d, and 5.4.6.3e.

5.4.6.5 Data Presentation

- a. In addition to 5.2.9.4, data presentation shall provide a statement verifying the electrical continuity of the measurement antennas as determined in 5.4.6.4c.1(c).

5.4.7 CS, power leads, 30 Hz to 100 kHz

5.4.7.1 Purpose

This test procedure is used to verify the ability of the EUT to withstand signals coupled on input power leads.

5.4.7.2 Test equipment

- a. The test equipment shall be as follows:
 - 1. Signal generator,
 - 2. Power amplifier,
 - 3. 1,5 Ω to 2,7 Ω power metal film resistor with inductance lower 1 000 nH and peak power capability,
 - 4. Oscilloscopes,
 - 5. Current probe,
 - 6. Differential high voltage-probe,
 - 7. injection transformer,
 - 8. LISN defined in 5.2.4 optional.

5.4.7.3 Setup

- a. The test setup shall be as follows:
 - 1. Maintain a basic test setup for the EUT as specified in 5.2.6 and Figure 5-3.

2. Check measurement system by configuring the test equipment in accordance with Figure 5-16, and setting up the oscilloscope to monitor the voltage across the resistor.
3. Test the EUT by configuring the test equipment as shown in Figure 5-17.

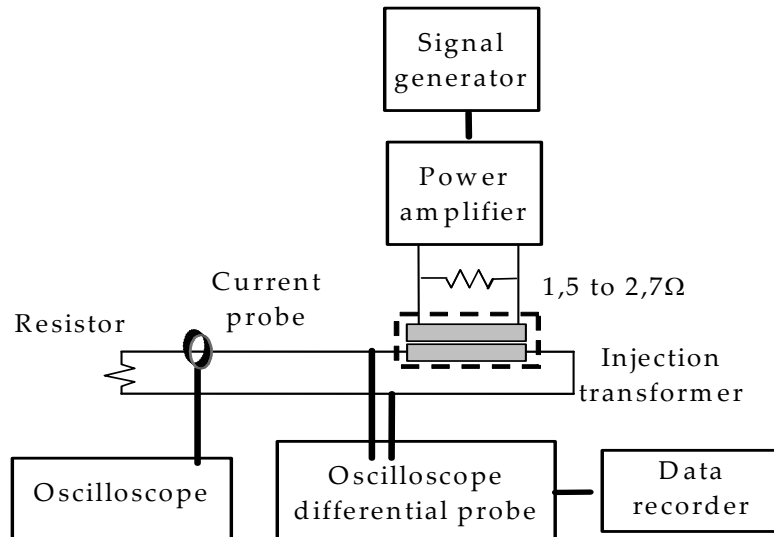


Figure 5-16: CS, power leads, measurement system check set-up

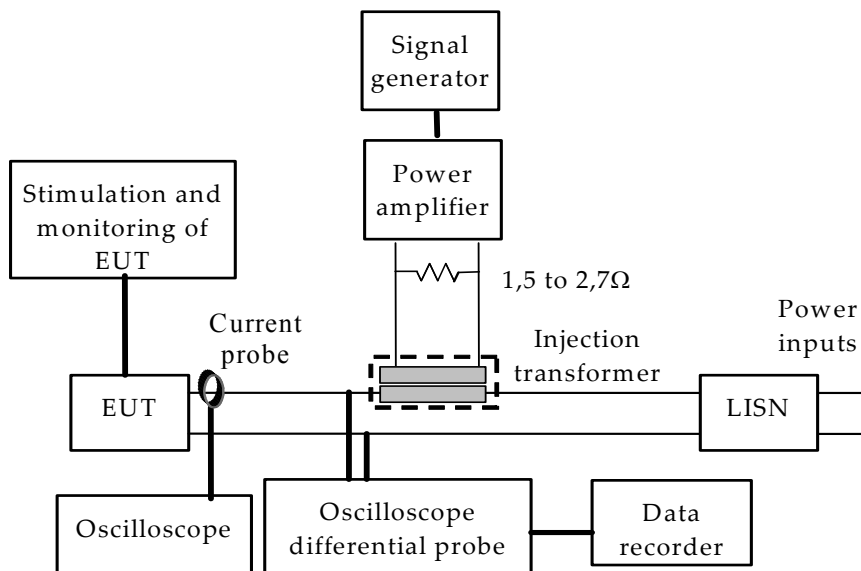


Figure 5-17: CS, power leads, signal injection

5.4.7.4 Procedures

- a. The measurement equipment shall be turned on and waited until it is stabilized.
- b. The measurement system shall be checked using the measurement system check setup for waveform verification as follows:
 1. Set the signal generator to the lowest test frequency.
 2. Increase the applied signal until the oscilloscope indicates the voltage level specified by application of clause 4.2.8, verify that the output waveform is sinusoidal, and verify that the indication given by the current probe is within 3 dB of the expected level derived from the 1 Ω resistor voltage.
 3. Repeat 5.4.7.4b.2 by setting the signal generator to the highest test frequency.
- c. The EUT shall be tested as follows:
 1. Turn on the EUT and wait until it is stabilized.
 2. Set the signal generator to the lowest test frequency, and increase the signal level until the testing voltage or current limit specified by application of clause 4.2.8, is reached on the power lead.
 3. Repeat 5.4.7.4c.2 at all frequency steps through the testing frequency range.
 4. Evaluate the susceptibility as follows.
 - (a) Monitor the EUT for degradation of performance.
 - (b) If susceptibility is noted, determine the threshold level in accordance with 5.2.10.3.
 5. Repeat 5.4.7.4c.2 to 5.4.7.4c.4 for each power lead.

5.4.8 CS, bulk cable injection, 50 kHz to 100 MHz

5.4.8.1 Purpose

This test procedure is used to verify the ability of the EUT to withstand sinusoidal waves coupled on the EUT associated cables and power leads.

5.4.8.2 Test equipment

- a. The test equipment shall be as follows:
 1. Signal generator with amplitude or pulse modulation capability,
 2. pulse generator, 1 kHz – 100 kHz, adjustable duty cycle,
 3. power amplifier, 50 kHz – 100 MHz,
 4. current injection probe, 50 kHz – 100 MHz,
 5. current measurement probe, 50 kHz – 100 MHz,
 6. one or two calibration fixture(s) (jigs) defined in 5.2.8.3,

7. one two-channels oscilloscope, 50 Ω input impedance,
8. waveform recording device,
9. 50 Ω coaxial load,
10. LISN defined in 5.2.4,
11. spectrum analyzer (optional).

5.4.8.3 Setup

- a. The test setup shall be as follows:
 1. Maintain a basic test setup for the EUT as shown and described in 5.2.6 and Figure 5-3.
 2. For calibration:
 - (a) Configure the test equipment in accordance with Figure 5-18.
 - (b) Place the injection probe and the monitor probe around the central conductor of their respective jigs.

NOTE The monitor probe and associated jig are optional.
 - (c) Terminate one end of the jig with a 50 Ω -coaxial load and connect the other end to a 50 Ω -input oscilloscope.
 - (d) If a current monitor probe is used, connect it to another 50 Ω oscilloscope input.
 3. For testing the EUT:
 - (a) Configure the test equipment as shown Figure 5-20.
 - (b) Place the injection and monitor probes around a cable bundle interfacing an EUT connector.
 - (c) Position the monitor probe:
 - 5 cm from the connector if the overall length of the connector and backshell does not exceed 5 cm,
 - at the overall length of the connector and backshell, otherwise.
 - (d) Position the injection probe 5 cm from the monitor probe.

5.4.8.4 Test procedures

- a. The measurement equipment shall be turned on and waited until it is stabilized.
- b. The measurement system shall be calibrated by performing the following procedures using the calibration setup:
 1. Set the frequency of the generator to 50 kHz and apply the pulse modulation, Figure 5-19.

2. Increase the applied signal until the oscilloscope indicates the voltage specified by application of clause 4.2.8.
 3. Verify that both inputs of the oscilloscope, voltage monitored on $50\ \Omega$ and current monitored by the current probe, are consistent within 3 dB. This is applicable only if a current probe is used during calibration
 4. Record the generator settings.
 5. Repeat 5.4.8.4b.2 through 5.4.8.4b.4 for each measurement frequency.
- c. The EUT shall be tested by performing the following procedures and using the EUT test setup:
1. Turn on the EUT and wait until it is stabilized.
 2. Select a bundle for testing and clamp the current probes into position.
 - (a) Set the modulated sine generator to a test frequency, at low output level.
 - (b) Adjust the modulation in duty cycle and frequency.
 - (c) Increase the generator output to the level determined during calibration, without exceeding the current limit specified by application of clause 4.2.8 and record the peak current obtained.
 - (d) Monitor the EUT for degradation of performance.
 - (e) If susceptibility is noted, determine the threshold level as measured by the current monitor probe in accordance with 5.2.10.3.
 - (f) Repeat 5.4.8.4c.2(a) through 5.4.8.4c.2(e) for each test frequency.
 3. Repeat 5.4.8.4c.2. applying the test signals to each bundle interfacing with each connector or all bundles taken together.
- d. The calibration need not be re-performed before testing each EUT bundle.

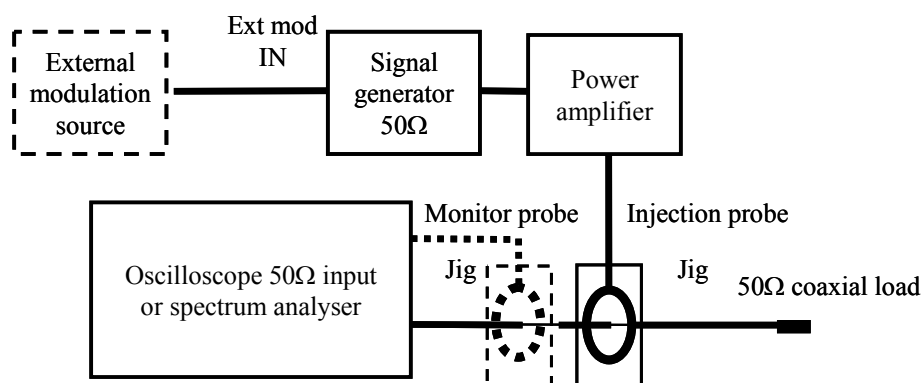


Figure 5-18: Bulk cable injection, measurement system check set-up

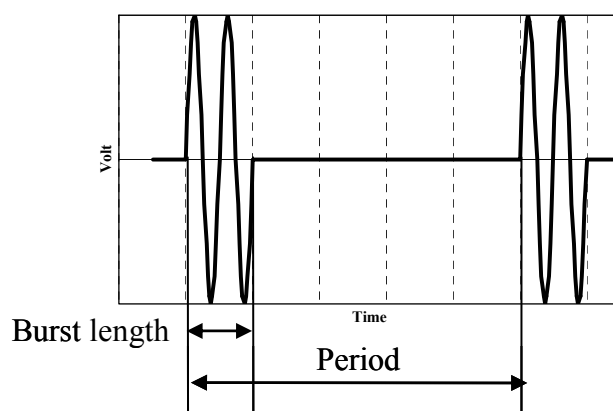


Figure 5-19: Signal test waveform

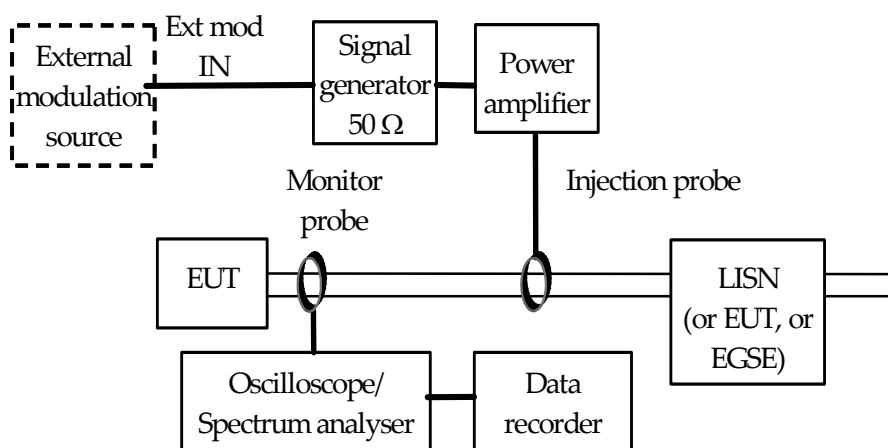


Figure 5-20: CS of power and signal leads, bulk cable injection

5.4.9 CS, power leads, transients

5.4.9.1 Purpose

This test procedure is used to verify the ability of the EUT to withstand short spikes coupled on EUT power leads, including grounds and returns that are not grounded internally to the equipment or subsystem.

5.4.9.2 Test equipment

- a. The test equipment shall be as follows:
 1. Spike generator with following characteristics:
 - (a) Pulse width of 10 μ s and 0,15 μ s,
 - (b) Pulse repetition rate capability up to 10 pulses per second,
 - (c) Voltage output as required, positive then negative,
 - (d) Output control,
 - (e) Adequate transformer current capacity commensurate with line being tested,
 - (f) Output impedance 5 Ω or less for 0,15 μ s and 1 Ω or less for 10 μ s transient,
 - (g) External synchronization and triggering capability.
 2. Oscilloscope with 50 MHz bandwidth or greater.
 3. Differential high-voltage probe.
 4. Isolation transformer.
 5. 5 Ω resistor power metal film resistor with inductance lower 100 nH and peak power capability.
 6. LISN defined in 5.2.4, with added inductor for a total inductance not less than 20 μ H for parallel injection.

5.4.9.3 Setup

- a. The test setup shall be as follows:
 1. Maintain a basic test setup for the EUT as specified in 5.2.6 and Figure 5-3.
 2. For calibration:
 - (a) Configure the test equipment in accordance with Figure 5-21 for verification of the waveform.
 - (b) Set up the oscilloscope to monitor the voltage across the 5 Ω resistor.
 - (c) For EUT testing configure the test equipment as shown in Figure 5-22 (series test method) or Figure 5-23 (parallel test method).

- NOTE 1 With series injection, the internal LISN capacitor at the input power side is protecting the source.
- NOTE 2 With parallel injection, the internal inductance is protecting the source, so a minimum value is needed as specified in 5.4.9.2a.6.

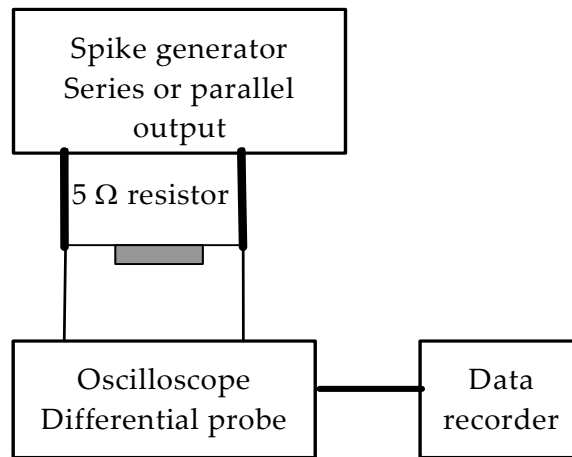


Figure 5-21: CS of power leads, transients, calibration set-up

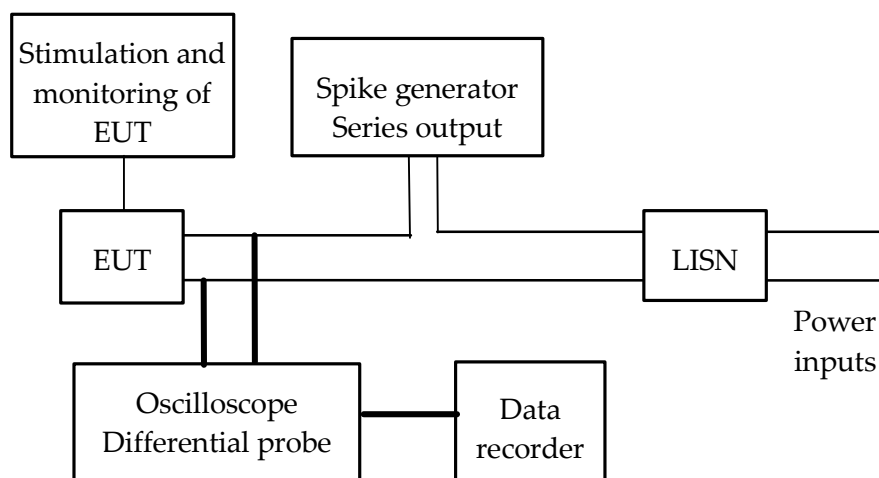


Figure 5-22: CS of power leads, spike series injection test setup

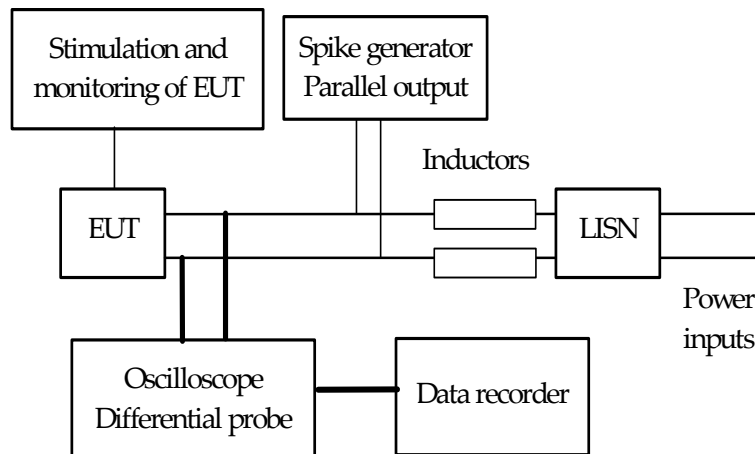


Figure 5-23: CS of power leads, spike parallel injection test setup

5.4.9.4 Procedures

- a. The test procedures shall be as follows:
 1. Turn on the measurement equipment and wait until it is stabilized.
 2. Perform the following procedure using the calibration setup:
 - (a) Adjust the pulse generator for the pulse width, and pulse repetition rate.
 - (b) Adjust the amplitude of the signal to the level specified in associated limit.
 - (c) Verify that the waveform complies with the requirements, if not, correct accordingly.
 - (d) Record the pulse generator amplitude setting.
 3. Test the EUT by performing the following procedure using the test setup:
 - (a) Turn on the EUT and wait until it is stabilized.
 - (b) Adjust the spike generator to a pulse duration.
 - (c) Apply the test signal to each power lead and increase the generator output level to provide the specified voltage without exceeding the pulsed amplitude setting recorded during calibration.
 - (d) Apply repetitive (6 to 10 pulses per second) positive spikes to the EUT ungrounded input lines for a period not less than 2 minutes in duration, and if the equipment employ gated circuitry, trigger the spike to occur within the time frame of the gate.
 - (e) Repeat 5.4.9.4a.3(d) with negative spikes.
 - (f) Monitor the EUT for degradation of performance.

- (g) If susceptibility is noted, determine the threshold level in accordance with 5.2.10.3 and verify that it is above the specified requirements.
- (h) Record the peak current as indicated on the oscilloscope.
- (i) Repeat 5.4.9.4a.3(b) through 5.4.9.4a.3(h) on each power lead.

5.4.10 RS, magnetic field, 30 Hz to 100 kHz

5.4.10.1 Purpose

This test procedure is used to verify the ability of the EUT to withstand radiated magnetic fields.

5.4.10.2 Test equipment

- a. The test equipment shall be as follows:
 - 1. Signal source,
 - 2. Power amplifier,
 - 3. Radiating loop having the following specifications:
 - (a) Diameter: 12 cm
 - (b) Number of turns: 20
 - (c) Wire: N°12 AWG, insulated copper
 - (d) Magnetic flux density: $9,5 \times 10^7$ pT/A of applied current at a distance of 5 cm from the plane of the loop.
 - 4. Loop sensor having the following specifications:
 - (a) Diameter: 4 cm
 - (b) Number of turns: 51
 - (c) Wire: 7-41 Litz wire (7 strands, N°41 AWG)
 - (d) Shielding: electrostatic
 - (e) Correction Factor: manufacturer's data for factors to convert measurement receiver readings to decibels above one picotesla (dBpT)
 - 5. Measurement receiver,
 - 6. Calibration fixture: coaxial transmission line with 50 Ω characteristic impedance, coaxial connections on both ends, and space for a current probe around the centre,
 - 7. Current probe,
 - 8. LISN.

5.4.10.3 Setup

- a. The test setup shall be as follows:
 1. Maintain a basic test setup for the EUT as specified in Figure 5-3 and 5.2.6.
 2. Check the measurement system by configuring the measurement equipment, the radiating loop, and the loop sensor as shown in Figure 5-24.
 3. Test the EUT by configuring the test setup as shown in Figure 5-25.

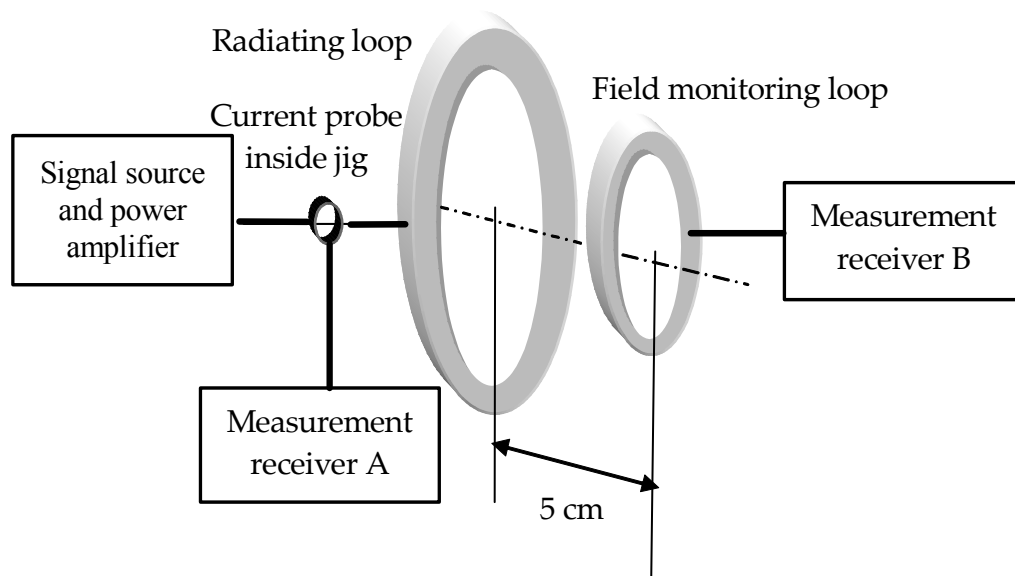


Figure 5-24: Measurement system check configuration of the radiating system

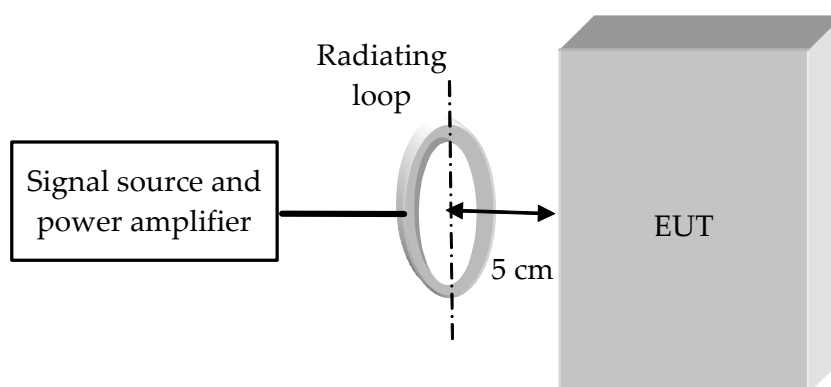


Figure 5-25: Basic test set-up

5.4.10.4 Test procedures

- a. The measurement equipment shall be turned on and waited until it is stabilized.
- b. The following procedure shall be performed using the calibration setup for verification of levels.
 1. Set the signal source to a frequency of 1 kHz and adjust the output to provide a magnetic flux density of 110 dBpT as determined by the reading obtained on measurement receiver A and the relationship given in 5.4.10.2a.3(d).
 2. Measure the voltage output from the loop sensor using measurement receiver B.
 3. Verify that the output on measurement receiver B is within ± 3 dB of the expected value based on the antenna factor and record this value.
- c. The EUT shall be tested by performing the following procedures for determination of location and level of susceptibility.
 1. Turn on the EUT and wait until it is stabilized.
 2. Select test frequencies as follows:
 - (a) Locate the loop sensor 5 cm from the EUT face or electrical interface connector being probed and orient the plane of the loop sensor parallel to the EUT faces and parallel to the axis of connectors.
 - (b) Supply the loop with such a current to produce magnetic field strengths at least 10 dB greater than the limit specified by application of clause 4.2.8 but not to exceed 15 A (183 dBpT).
 - (c) Scan the frequency range.
 - (d) If susceptibility is noted, select no less than three test frequencies per octave at those frequencies where the maximum indications of susceptibility are present.
 - (e) Reposition the loop successively to a location in each 30 by 30 cm area on each face of the EUT and at each electrical interface connector, and repeat 5.4.10.4c.2(c) and 5.4.10.4c.2(d) to determine locations and frequencies of susceptibility.
 - (f) From the total frequency data where susceptibility was noted in 5.4.10.4c.2(c) through 5.4.10.4c.2(e), select three frequencies per octave over the frequency range.
 3. At each frequency determined in 5.4.10.4c.2(f) apply a current to the radiating loop that corresponds to the specified limit, move the loop to search for possible locations of susceptibility without omitting the locations determined in 5.4.10.4c.2(e) while maintaining the loop 5 cm from the EUT surface or connector, and verify that susceptibility is not present.

5.4.10.5 Data Presentation

- a. In addition to 5.2.10.4, data presentation shall provide:
 1. Tabular data showing verification of the radiating loop in 5.4.10.4b.
 2. Tabular data, diagrams, or photographs showing the locations and test frequencies determined in 5.4.10.4c.2(e) and 5.4.10.4c.2(f).

5.4.11 RS, electric field, 30 MHz to 18 GHz

5.4.11.1 Purpose

This test procedure is used to verify the ability of the EUT and associated cabling to withstand electric fields.

NOTE Additional requirements can apply beyond 18 GHz if SHF or EHF payloads are present. These are beyond the scope of the present standard.

5.4.11.2 Test equipment

- a. The test equipment shall be as follows:
 1. Signal generators,
 2. Power amplifiers,
 3. Receive antennas,
 - (a) under 1 GHz, not applicable.
 - (b) 1 GHz to 18 GHz, double ridge horn, 24,2 by 13,6 cm opening.

NOTE Above 1 GHz receive antennas may be not used, see 5.4.11.3b.2.

4. Linearly polarized transmit antennas

NOTE The following antennas are commonly used:

- 30 MHz to 200 MHz, biconical, 137 cm tip to tip,
 - 200 MHz to 1 GHz, double ridge horn, 69,0 cm by 94,5 cm opening, or log-periodic,
 - 1 GHz to 18 GHz, double ridge horn, 24,2 cm by 13,6 cm opening.
5. Electric field sensors (physically small - electrically short),
 6. Measurement receiver,
 7. Power meter,
 8. Directional coupler,
 9. Attenuator,
 10. Data recording device,
 11. LISN defined in 5.2.4, optional.

5.4.11.3 Test setup

- a. A basic test setup shall be maintained for the EUT as shown and specified in 5.2.6. and Figure 5-3.

NOTE The LISN can be used.

- b. For measurement system check, following sensors shall be used:

1. electric field sensors from 30 MHz to 1 GHz.
2. either receive antennas or electric field sensors above 1 GHz.

NOTE For the electric sensors and receiving antennas to be used, see 5.4.11.2a.3 and 5.4.11.2a.5.

- c. Test equipment shall be configured as specified in Figure 5-26.

- d. The measurement system shall be checked as follows:

1. Place the electric field sensors 1 m from, and directly opposite, the transmit antenna as shown Figure 5-27 and a minimum of 30 cm above the ground plane, not directly at corners or edges of EUT.
2. Place the receive antennas prior to placement of the EUT, as shown Figure 5-28, on a dielectric stand at the position and height above the ground plane where the centre of the EUT will be located.

- e. For testing EUT, the transmit antennas shall be placed 1 m from the test setup boundary as follows:

1. 30 MHz to 200 MHz
 - (a) For test setup boundaries ≤ 3 m (including all enclosures of the EUT and the 2 m of exposed interconnecting and power leads specified in 5.2.6.6.), centre the antenna between the edges of the test setup boundary, ensuring that the interconnecting leads represent the actual platform installation and are shorter than 2 m.
 - (b) For test setup boundaries > 3 m, use multiple antenna positions (N) at spacings as specified in Figure 5-27, where the number of antenna positions (N) is determined by dividing the edge-to-edge boundary distance (in metres) by 3 and rounding up to an integer.
2. 200 MHz and above, use multiple antenna positions (N) as shown [Figure 5-27](#), where the number of antenna positions (N) is determined as follows:
 - (a) For testing from 200 MHz up to 1 GHz, place the antenna in a number of positions such that the entire width of each EUT enclosure and the first 35 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna
 - (b) For testing at 1 GHz and above, place the antenna in a number of positions such that the entire width of each EUT enclosure and the first 7 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.

- f. For testing EUT, the placement of electric field sensors shall be maintained as specified in 5.4.11.3d.1.

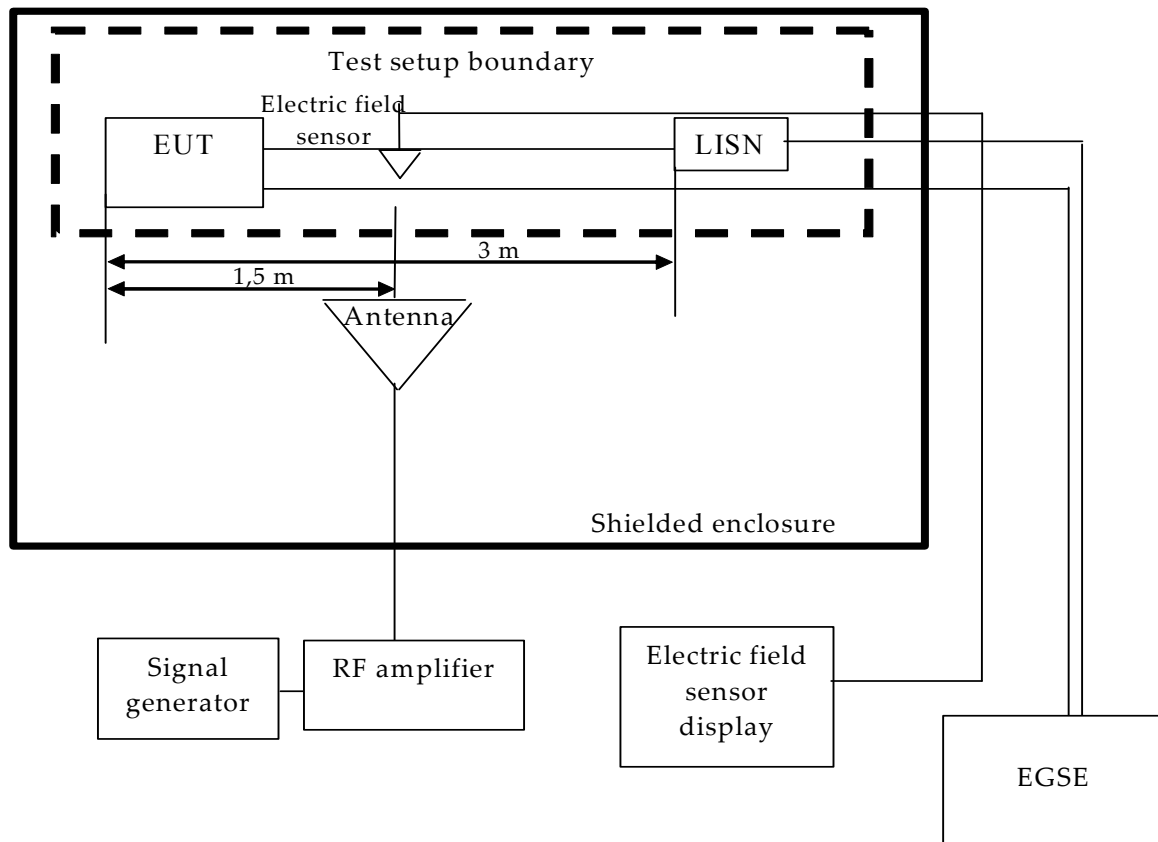


Figure 5-26: Test equipment configuration

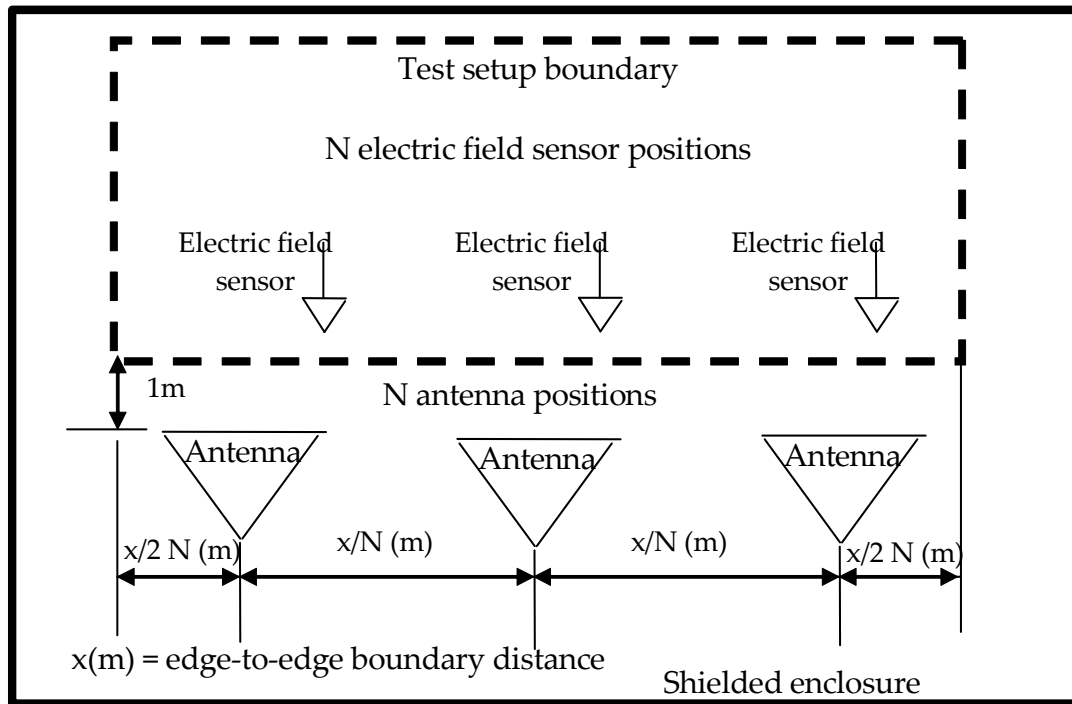


Figure 5-27: RS Electric field. Multiple test antenna positions

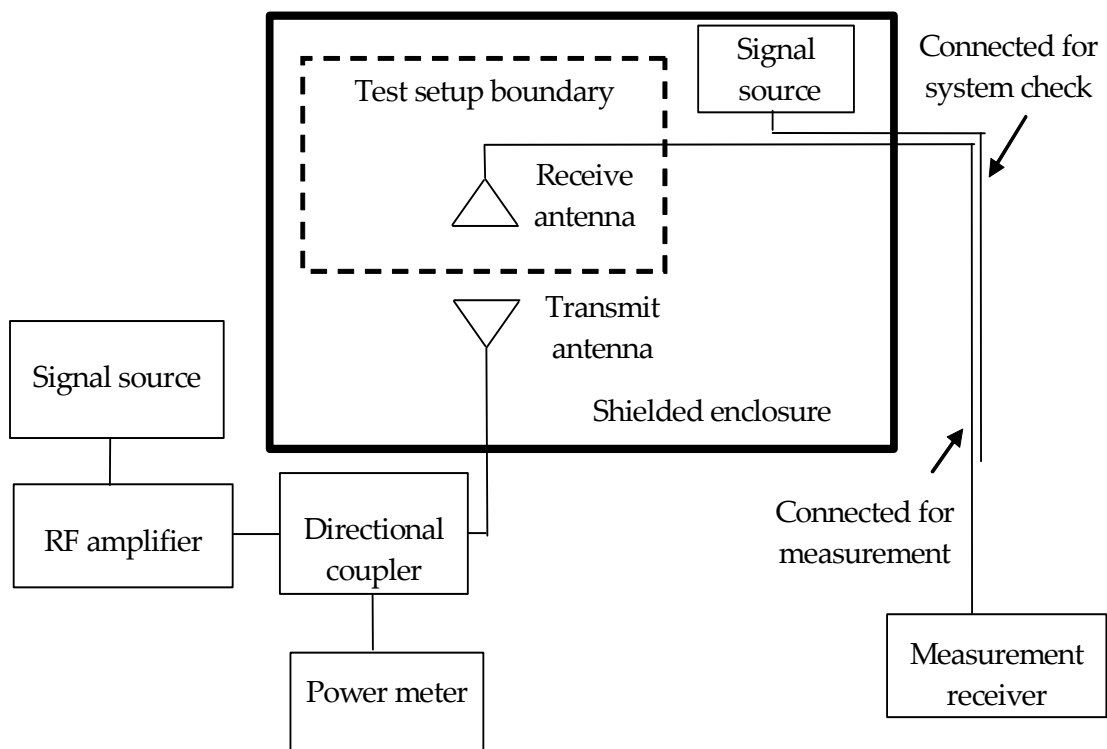


Figure 5-28: Receive antenna procedure

5.4.11.4 Test procedures

- a. The measurement equipment and EUT shall be turned on and waited until they are stabilized.

NOTE It is important at this point to assess the test area for potential RF hazards and take precautionary steps to assure safety of test personnel and fire avoidance.

- b. The measurement system shall be checked and calibrated as follows:
 1. Procedure when using electric field sensors:
 - (a) Record the amplitude shown on the electric field sensor display unit due to EUT ambient.
 - (b) Reposition the sensor until the level measured in (a) above is < 10 % of the field strength to be used for testing.
 2. Procedure when calibrating with the receive antenna:
 - (a) Connect a signal generator to the coaxial cable at the receive antenna connection point (antenna removed), set the signal source to an output level of 0 dBm at the highest frequency to be used in the present test setup and tune the measurement receiver to the frequency of the signal source.
 - (b) Verify that the output indication is within ± 3 dB of the applied signal, considering all losses from the generator to the measurement receiver and, if deviations larger than 3 dB are found, locate the source of the error and correct the deficiency before proceeding.
 - (c) Connect the receive antenna to the coaxial cable as specified in Figure 5-28, set the signal source to 1 kHz pulse modulation, 50 % duty cycle, establish an electric field at the test frequency by using a transmitting antenna and amplifier, and gradually increase the electric field level until it reaches the limit specified by application of clause 4.2.8.
 - (d) Scan the test frequency range and record the input power levels to the transmit antenna to maintain the required field.
 - (e) Repeat procedures 5.4.11.4b.2(a) through 5.4.11.4b.2(d) whenever the test setup is modified or an antenna is changed.

NOTE The ground plane tends to short-circuit horizontally polarized fields, so that more power is needed to achieve the same field value in horizontal polarization as in vertical polarization.

- c. The EUT shall be tested as follows:
 1. Procedure when using electric field sensors:
 - (a) Establish an unmodulated electric field at the test start frequency by using an amplifier and transmit antenna, and

- gradually increase the electric field level until it reaches the limit specified by application of clause 4.2.8.
- (b) Set the signal source to 1 kHz pulse modulation, 50 % duty cycle and apply the modulation.
 - (c) Repeat the test at all frequency tests while maintaining field strength levels in accordance with the associated limit, and monitor EUT performance for susceptibility effects.
2. Procedure when calibrating with the receive antenna:
- (a) Remove the receive antenna and reposition the EUT in conformance with 5.4.11.3e.
 - (b) Set the signal source to 1 kHz pulse modulation, 50 % duty cycle, establish an electric field at the test start frequency by using an amplifier and transmit antenna, and gradually increase the input power level until it corresponds to the level recorded during the calibration routine.
 - (c) Repeat the test at all test frequencies while assuring the transmitter input power is adjusted in accordance with the calibration data collected, and constantly monitor the EUT for susceptibility conditions.
3. If susceptibility is noted, determine the threshold level in accordance with 5.2.10.3.
4. Perform testing over the frequency range with the transmit antenna vertically polarized, and repeat the testing with the transmit antenna horizontally polarized.
- NOTE The settings needed to achieve the specified field level in vertical polarization are reused as is for the test in horizontal polarization.
5. Repeat 5.4.11.4c.4 for each transmit antenna position determined in 5.4.11.3e.

5.4.11.5 Data presentation

- a. In addition to 5.2.10.4, data presentation shall provide:
- 1. graphical or tabular data listing (receive antenna procedure only) all calibration data collected to include input power requirements used versus frequency, and results of system check in 5.4.11.4b.2(c) and 5.4.11.4b.2(d).
 - 2. the correction factors used to adjust sensor output readings for equivalent peak detection of modulated waveforms.
 - 3. diagrams or photographs showing actual equipment setup and the associated dimensions.

5.4.12 Susceptibility to electrostatic discharges

5.4.12.1 Overview

The purpose of this test is to determine the existence of susceptibility to electromagnetic effects of electrostatic discharges.

5.4.12.2 Test equipment

a. The test equipment shall be as follows:

1. DC high voltage supply or an ESD generator as specified in IEC 61000-4-2 (Edition 1.2).

NOTE Use of the ESD generator is less hazardous than use of the DC high voltage supply for test operators.

2. The discharge primary circuit is constituted of:

- (a) 6 kV spark gap,

NOTE 1 An air spark gap or an overvoltage suppressor in a sealed pressurized envelop can be used.

NOTE 2 An air spark gap is less stable and has longer rise time.

- (b) 50 pF capacitance, high-voltage capacitor with inductance less than 20 nH,

- (c) 47 Ω damping resistor (high voltage specification),

NOTE The value can be adjusted at critical damping depending on value of capacitance C and self-inductance of the discharge circuit;

- (d) 10 k Ω resistors (high voltage specification).

NOTE Choke resistors prevent high-frequency components of discharge from flowing in uncontrolled paths so the discharge parameters are not dependent on length and position of high-voltage source wires.

3. Monitoring devices:

- (a) Two current probes, 100 A peak capability and more than 100 MHz bandwidth,

- (b) One high-voltage probe, 10 kV range, 1 MHz bandwidth,

NOTE If the probe input impedance is not high enough, it can prevent gap arcing by lowering the available voltage.

- (c) One two-channels digital oscilloscope with pretriggering capability.

NOTE Typical values are 100 ns pretrigger time, display window in the range 1 μ s to 10 μ s and resolution better than 4 ns.

5.4.12.3 Setup

a. The test setup shall be as follows:

1. Maintain a basic test setup for the EUT as specified in 5.2.6. and Figure 5-3.

NOTE It is important at this point to assess the test area for potential high-voltage hazards and take necessary precautionary steps to assure safety of test personnel.

2. When using an ESD generator as a high-voltage power supply as shown Figure 5-30 or Figure 5-31, it is set in the contact discharge mode.
3. Connect the high-voltage electrode to the discharge circuit at the node between the spark gap and the capacitor.
4. The discharge circuit length is not larger than what is necessary to place in series the 20 cm long coupling wire, the damping resistor, the discharge capacitor, the spark gap and the current probe.

NOTE It is important to ensure that the discharge loop is as small as possible for achieving the transient pulse duration objective defined in 5.4.12.4a.2(d).

5. For calibration the test equipment is configured as shown Figure 5-30, and meeting following provisions:
 - (a) the discharge circuit is not coupled to the EUT,
 - (b) choke resistors are near the capacitor,
 - (c) the current probe monitoring the primary current from the ESD source is near the damping resistor, at the capacitor side,
 - (d) the high voltage probe is measuring the voltage across the capacitor, grounded at the damping resistor side.

NOTE The high-voltage probe is not meant to measure the voltage during the discharge but the voltage reached before discharge

6. Test the EUT by configuring the test equipment as specified in Figure 5-31 and meeting the following provisions:
 - (a) the high voltage probe used for calibration is removed,
 - (b) the EUT is mounted on a conductive ground plane using the space vehicle mount and attach points, and operated using the actual electrical harness, or an EMC test harness of identical construction to the actual harness.

NOTE It is preferable to use the actual electrical harness.

- (c) the discharge circuit is supported 5 cm above the ground plane by a non-conductive standoff with high-voltage insulation capability,
- (d) from calibration, the discharge circuit is kept unchanged in size and shape, and tightly electromagnetically coupled 20 cm along an EUT bundle, held by dielectric bonds

NOTE A maximum separation distance of 1 cm between the injection wire and the outer circumference of the bundle under test is a condition for achieving a tight electromagnetic coupling.

- (e) a current probe is monitoring the primary current from the ESD source near the damping resistor,
- (f) a current probe is monitoring the current in the EUT harness, 5 cm from the EUT connector.

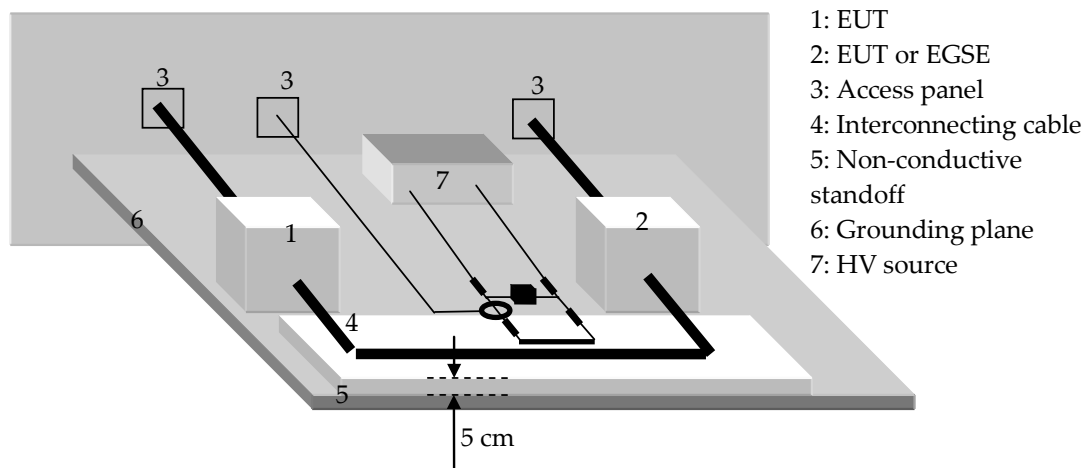


Figure 5-29: Spacecraft charging ESD susceptibility test

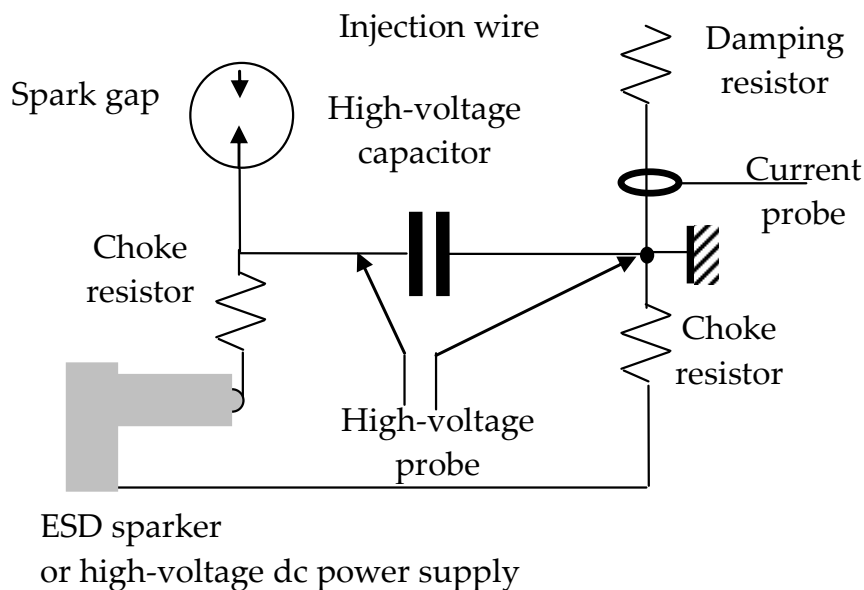


Figure 5-30: Susceptibility to ESD: calibration configuration

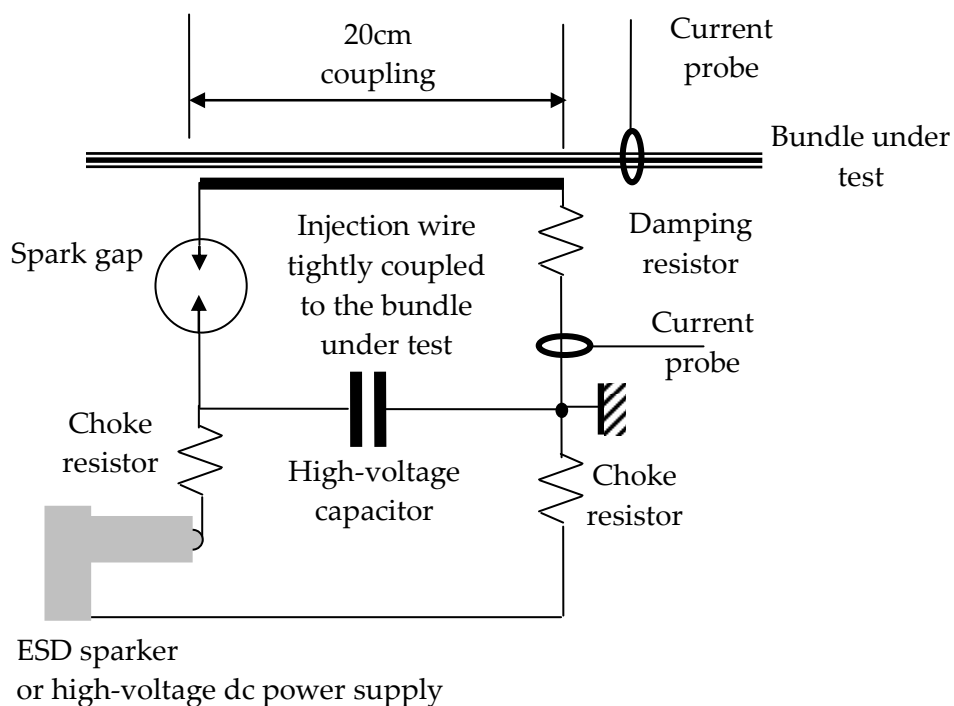


Figure 5-31: Susceptibility to ESD: test equipment configuration

5.4.12.4 Procedure

- a. The test procedures shall be as follows:
1. Turn on the measurement equipment and wait until it is stabilized.
 2. Perform a calibration using the calibration setup:
 - (a) Select the spark gap device or adjust the spark length at the voltage breakdown to be used for the test,
 - (b) Turn on the high voltage generator,
 - (c) Using the high voltage probe, check the breakdown voltage value is stable and within $\pm 30\%$ from the value to be used for the test.
 - (d) Monitor the transient current pulse.

NOTE A goal is 30 A, 30 ns duration at mid-height, rise time as short as possible. Means for minimizing the rise time are adjusting the damping resistor, reducing the size loop, checking that both choke resistors are as close as possible to the capacitor, and technology of the spark gap (nature of gas and shape of electrodes).

 - (e) Record the last current and voltage couple, displayed with a common time reference,
 - (f) Repeat 5.4.12.4a.2(d) and 5.4.12.4a.2(e) with opposite polarity.
 3. Test the EUT as follows:
 - (a) Fully power the unit during the complete ESD test,
 - (b) Turn on the high voltage generator,
 - (c) Establish a pulse discharge at a pulse rate of 1 Hz, with a pulse direction of at least 15 positive and 15 negative,
 - (d) Record the last primary and secondary current couple, displayed with a common time reference,
 - (e) Repeat 5.4.12.4a.3(c) and 5.4.12.4a.3(d) on each bundle interfacing with each electrical connector.

5.4.12.5 Data presentation

- a. Superseding clause 5.2.10.4, data presentation shall be as follows:
1. Provide tables showing statements of compliance with the requirement and the induced current level for each interface connector.
 2. Provide oscilloscope records taken during calibration and EUT testing procedures.
 3. The requirement of 5.2.10.3 does not apply.

Annex A (informative)

Subsystem and equipment limits

A.1 Overview

There is no single method for achieving EMC.

- Low susceptible equipment is for telecommunication spacecraft flying in a severe EMI environment due to on board large power and possible residual ESD.
- Low emission equipment is for scientific spacecraft for preserving high sensitivity of detectors.

Therefore, it is not possible to define a same set of limits for all equipments of all spacecraft and launchers. The EMCCP is the vehicle for tailoring limits and test methods.

However, it is a legitimate demand of equipment supplier to ask for EMI limits outside the frame of a specific project. Conducted and radiated emission limits and susceptibility limits defined hereafter are recommended for space projects.

A.2 CE on power leads, differential mode, 30 Hz to 100 MHz

In differential mode, on each independent power bus, conducted emissions on power leads, induced by loads, can be limited in the frequency domain under following conditions:

- limits are in the range extending from 30 Hz to 100 MHz,
- a maximum I_{NB} in units of dB referenced to 1 μA is a function of frequency defined in Figure A-1,
- in the low frequency range the limit I_{CE} in units of dB referenced to 1 μA (dB μA) is function of the consumption I_{dc} (in amperes) of the equipment on the line, see [Figure A-1](#):

$I_{dc} < 1 \text{ A}$	$I_{CE} = 80$
$1 \text{ A} < I_{dc} < 100 \text{ A}$	$I = 80 + 20 \log_{10}(I_{dc})$
$I_{dc} > 100 \text{ A}$	$I = 120$

The mode is called “differential” because measurements are done separately on hot and return wires, however it comprises common mode components.

“Independent” means connected to separate power sources.

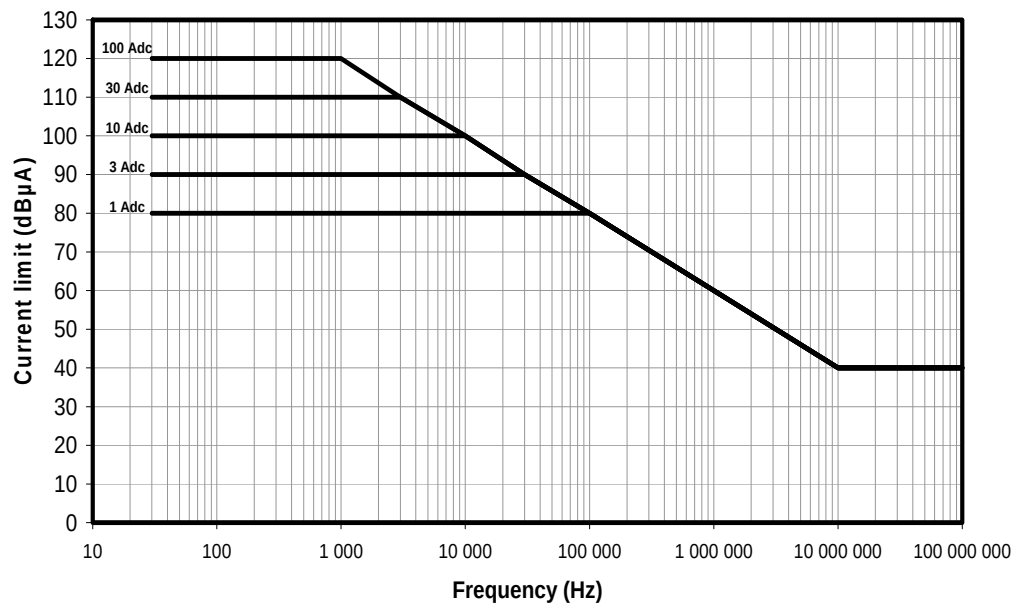


Figure A-1: Power leads, differential mode conducted emission limit

A.3 CE on power leads, in-rush currents

The inrush current of an equipment on the power lines can be limited in the time domain with following characteristics in order to limit the voltage transients on the power bus:

- During any nominal change of configuration, the rate of change of current is limited to 5×10^4 A/s.
- At switching ON the rate of change of current is lower than 2×10^6 A/s, absolute value of rise and fall slopes.
Specific requirements are usually defined for pulsed radars, plasma thrusters power units.

Limits can also be specified for the following characteristics in order to achieve compatibility with the upstream protections of the spacecraft power subsystem.

- inrush current duration (in ms);
- total charge (in mC);
- inrush current slope (in A/ μ s).

A.4 CE on power and signal leads, common mode, 100 kHz to 100 MHz

The conducted emissions on bundles in common mode can be limited with following characteristics:

- limits are in the range extending from 100 kHz to 100 MHz,
- I_{CE} in units of dB referenced to 1 μ A (dB μ A) is lower than the curve of [Figure A-2](#).
- the same limit is defined for all cables taken together or bundle per bundle.

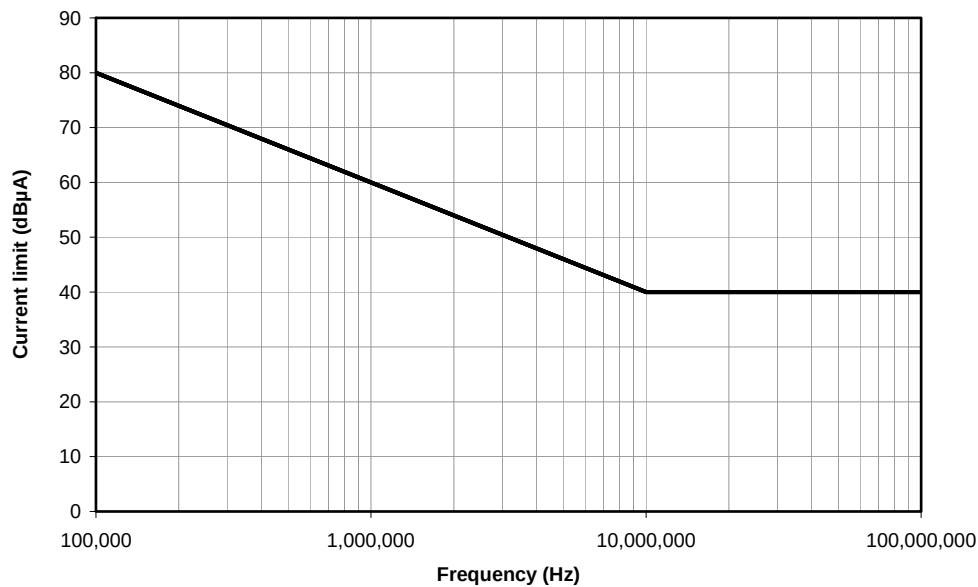


Figure A-2: [Common mode conducted emission limit](#)

A.5 CE on antenna ports

Spurious conducted emissions on antenna ports can be limited to following values:

- receivers 34 dBμV,
- transmitters (stand-by mode): 34 dBμV,
- transmitters (transmit mode):
 - harmonics, except the second and third, and all spurious emissions: 80dB down the level at the fundamental,
 - the second and third harmonics $50 + 10 \log P$ (where P is the peak power output) or 80 dB whichever is less.

Equipment with antennas permanently mounted are not in the scope of this clause.

A.6 DC magnetic field emission

A.6.1 General

The DC magnetic field emission generated by subsystems, equipment and elementary components is limited or characterized for following purposes:

- for establishing the magnetic momentum of the whole space vehicle,
- for establishing the composite DC magnetic field at critical locations.

The components of the magnetic emission are DC current loops, solenoids, the permanent field of hard magnetic materials (magnets) and

the induced magnetic moment by the Earth-field on soft magnetic materials, including hysteresis.

A.6.2 Characterization

Following parameters of magnetic properties can be determined or characterized:

- permanent induction parameters of operating EUT by determination of magnetic induction B in units of μT under magnetic zero-field condition,
- induced parameters of not operating EUT by determination of magnetic induction B in units of μT when immersed in a uniform controlled field of $30\ \mu\text{T}$ (calibrated in absence of EUT) in each of 3 rectangular semi-axes, in both directions,
- determination of the DC magnetic field emission is performed by either measurement or similarity,
- determination by similarity is applied to equipment or subsystems coming from other programs, where re-use as it is or re-use with only little modification.
- assessment of the dipole model by measurement of magnetic induction B at least at two different distances r and comparing respective products $r^3(\text{m})\ B(\mu\text{T})$,

NOTE Distances in the range 0,5 m to 1,5 m can be used.

- magnitude of the magnetic dipole, (when the equipment is assimilated to a dipole) either:
 - by its magnetic moment, or
 - by the magnetic induction at some distance of reference.

When the unit is assimilated to a dipole, the inverse cube law dependence with distance applies, the following relation (worst case) is used for the equivalence between the magnetic moment and the induction at the distance d:

$$B(\text{T}) = 2 \times 10^{-7} \times M(\text{Am}^2) / (d(\text{m}))^3$$

- characterization of the magnetic source when the dipole approximation is inadequate, either by:
 - a multiple moment model, or
 - a spherical harmonics model, or
 - the magnetic induction at the distance of measurement.

The distance of reference is specified by the EMCAB in function of the size of the space vehicle or of the actual distance between magnetic sources and susceptible equipment.

The magnetic induction is a rough indication that can be sufficient for some applications.

The multiple-moment model or the spherical harmonics model is a precise determination sometimes needed for sensitive payloads.

Specific characterization methods are implemented for the multiple-moment model or the spherical harmonics identification.

A.6.3 Limit

The DC magnetic emission of subsystems or equipments can be limited at a level of $0,2 \mu\text{T}$ at a distance of 1m from any face of the equipment.

This limit corresponds to dipole-like equipment with a magnetic moment of 1 Am^2 .

The limitation is achieved through a combination of techniques: current loop area minimization and coaxial or twisted cables use, non-magnetic material use, magnetic shields use, compensation techniques with magnets.

A.7 RE, low-frequency magnetic field

From a few hertz to 50 kHz, the magnetic-field radiated emissions can be measured.

Measurement can be performed at several distances for characterizing the accuracy of a dipole model.

If the EUT can be assimilated to a magnetic dipole, emission limits are expressed by its magnetic dipole momentum.

No limit is defined at equipment level.

The measurement is only for characterization and useful to verify compliance at system level through analysis.

Techniques for fulfilling EMC requirement at system level are an appropriate grounding network, magnetic shields, an optimized location of equipments on the space vehicle.

A.8 RE, low-frequency electric field

From a few hertz to 30 MHz frequency range the electric-field radiated emissions of units can be measured.

The frequency limits are determined by the EMCAB from payload specifications.

The electric field emission from the equipment is expressed in units of dB above $1 \mu\text{V/m}$ at a distance of 1 m.

Measurements at several distances are performed for characterizing the decay law.

No limit is defined at equipment level.

The measurement is only for characterization and useful to verify compliance with system level requirements through analysis.

Techniques for fulfilling EMC requirement at system level are reduction of common mode conducted emission from bundles, and electric shields or appropriate location of equipments on the space vehicle.

A.9 RE, electric field, 30 MHz to 18 GHz

In the 30 MHz to 18 GHz frequency range, electric-field radiated-emissions from equipment and subsystem including interconnecting cables can be limited under following conditions:

- the limit applies to:
 - non-RF equipment,
 - RF equipment connected to passive loads or EGSE, in nominal mode, at nominal power,
- the limit is defined by the curve in [Figure A-3](#).
- the limit is for both horizontally and vertically polarized fields,
- the limit comprises notching lines for launchers or spacecraft receiving bands not represented in [Figure A-3](#).

Additional requirements can apply beyond 18 GHz if SHF or EHF payloads are present. These are beyond the scope of the present standard.

For equipment having all internal rise times longer than 35 ns, the specified upper frequency limit can be reduced to 1 GHz.

For non-RF equipment if the emission is lower than 20 dB below the requirement between 500 MHz and 1 GHz the specified upper limit can be reduced to 1 GHz, with the exception of notches above 1 GHz, still to be tested.

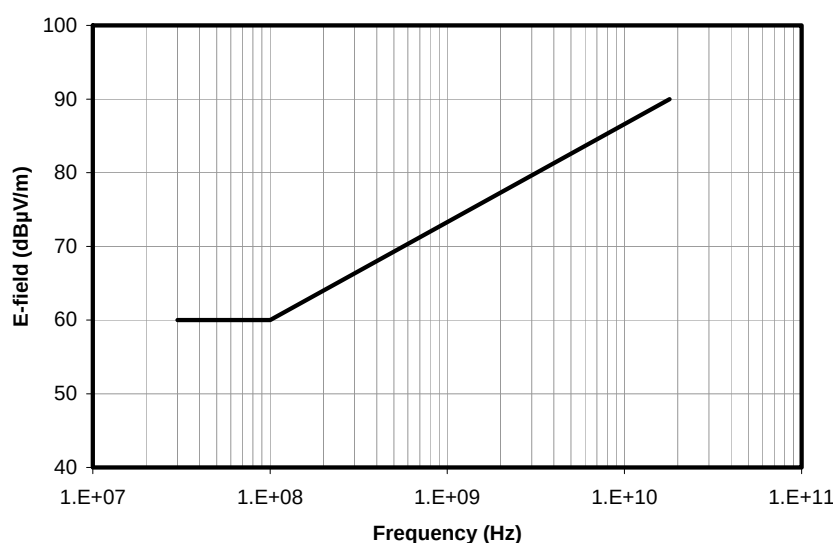


Figure A-3: [Radiated electric field limit](#)

A.10 CS, power leads, differential mode, 30 Hz to 100 kHz

The following levels, known to be achievable and already specified in other standards or project specifications, are proposed for the susceptibility test on the power leads specified in clause 5.4.7.

- the injected voltage level is equal or larger than the level shown in [Figure A-4](#).
- a limitation of the injected current before the specified voltage is reached is applied:
 - the limit of current is 1 A_{rms}
 - the voltage level when the current limit is reached is measured and reported.

The current applied is reported.

Independent power lines are tested separately.

NOTE Independent means “connected to separate power sources”.

Except in the case of structure return, for each power line, hot and return wires are tested separately.

NOTE In case of structure return, the test is only applied to hot wires.

The test signal covers the [30 Hz-100 kHz] frequency range.

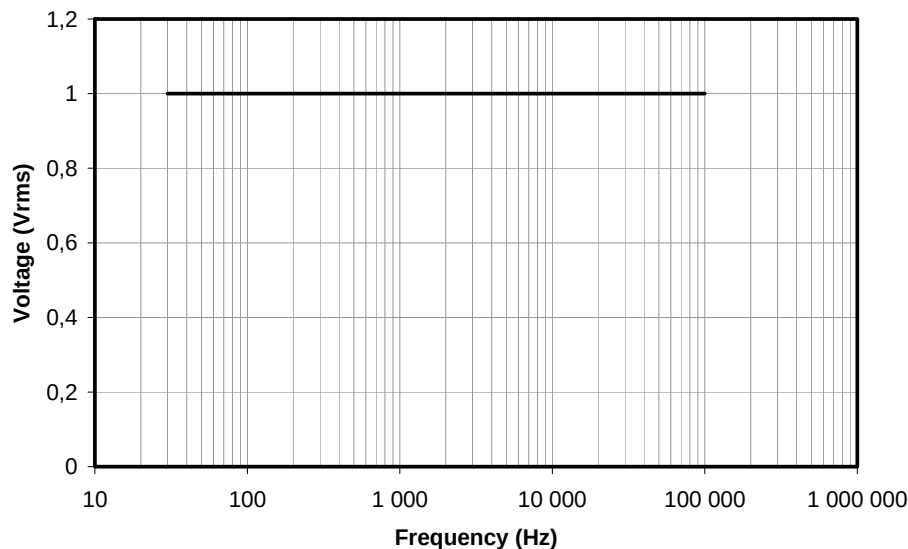


Figure A-4: [Conducted susceptibility limit, frequency domain](#)

A.11 CS, power and signal leads, common mode, 50 kHz to 100 MHz

The following levels, known to be achievable and already specified in other standards or project specifications, are proposed for the susceptibility test on the power and signal leads specified in clause 5.4.8:

- the common mode level of 3 volts peak to peak or larger is applied,
- the limit of the current induced on the bundle is 3 A peak-to-peak,
- the test signal is pulse modulated,

NOTE Square wave modulation is a particular case of pulse modulation.

- the duty cycle is depending on the carrier frequency, according to Table A-1.

The same level is applied to all cables together or to bundles taken separately.

The common mode induced current on the bundle is reported.

The test signal covers the [50 kHz-100 MHz] frequency range.

Table A-1: Equipment: susceptibility to conducted interference, test signal

Frequency range	Pulse repetition frequency	Duty cycle
50 kHz-1 MHz	1 kHz	50 % (squarewave)
1 MHz-10 MHz	100 kHz	20 %
10 MHz-100 MHz	100 kHz	5 %

A.12 CS, power leads, short spike transients

The following levels, known to be achievable and already specified in other standards or project specifications, are proposed for the transient susceptibility test on the power lines specified in clause 5.4.9:

- a series of positive spikes, then a series of opposite spikes superposed on the power voltage shall be applied,
- at any time step, the voltage spike amplitude is:
 - +100 % or -100 % of the actual line voltage if the nominal bus voltage is lower than 100 V, Figure A-5.
 - +50 % or -100 % of the actual line voltage if the nominal bus voltage is equal or larger than 100 V

Level 0 in Figure A-5 represents the DC bus voltage.

Only the positive spike is represented in Figure A-5.

When a negative spike is applied, the absolute instantaneous transient voltage goes down to 0, never negative.

- tests are performed with two spike durations, the first zero-crossing is at $T=150\text{ ns}$ and at $T=10\text{ }\mu\text{s}$.

Independent power lines are tested separately.

Independent means “connected to separate power sources”.

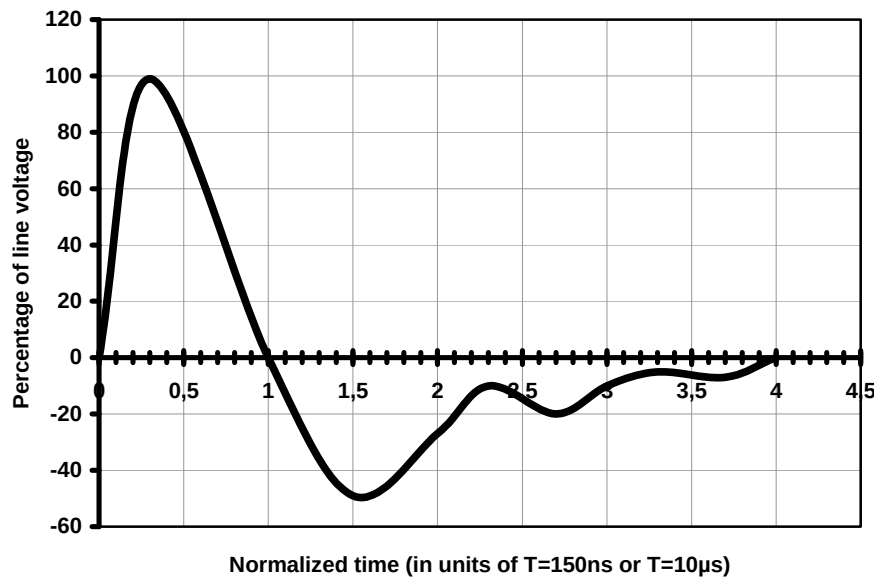


Figure A-5: CS, voltage spike in percentage of test bus voltage

A.13 RS, magnetic field, 30 Hz to 100 kHz

The following levels, known to be achievable and already specified in other standards or project specifications, are proposed for the radiated susceptibility test, magnetic field, specified in clause [5.4.10](#):

- the amplitude of the test signal is equal to or larger than the level in Figure A-6,
- the source is located at 5 cm of any face of the EUT.

The signal test covers the [30 Hz-100 kHz] frequency range.

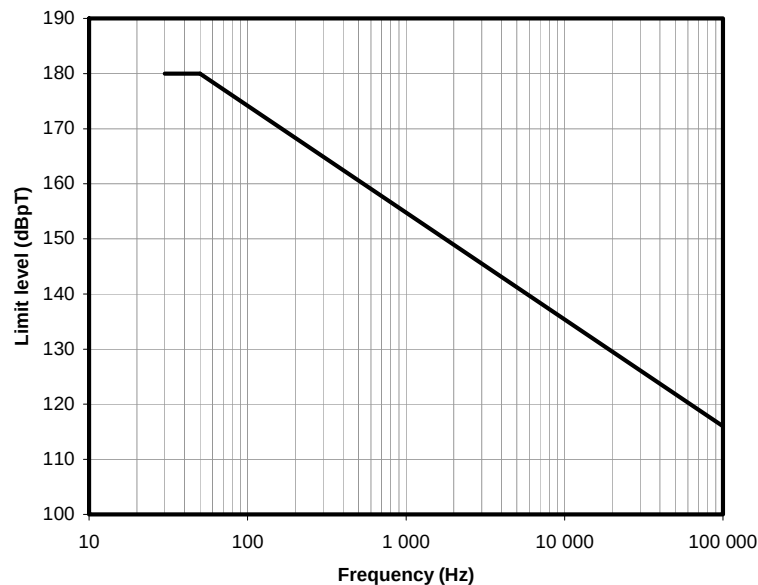


Figure A-6: Radiated susceptibility limit

A.14 RS, electric field, 30 MHz to 18 GHz

The following levels, known to be achievable and already specified in other standards or project specifications, are proposed for radiated susceptibility test, electric field, specified in clause [5.4.11](#):

- the amplitude of the test signal is:
 - equipment in the vicinity of beams, outside of the main frame considered as a Faraday cage: 10 V/m,
 - An electric field of more than 10 V/m is applied if RF analysis demonstrates that the expected electric field seen in flight by the equipment is larger,
 - equipment far from main lobes and secondary lobes, outside of the main frame: 1 V/m,
 - equipment inside the main frame: 1 V/m.

At RF transmit frequencies, the RS level should be tailored up; at RF receive frequencies, the RS level should be tailored down for receivers.

- an AM or PAM test signal is used,
- both horizontally and vertically polarized fields are used,
- circular-polarized fields are not used.

The signal test covers the [30 MHz-18 GHz] frequency range.

Additional requirements can apply beyond 18 GHz if SHF or EHF payloads are present. These are beyond the scope of the present standard.

A.15 Susceptibility to electrostatic discharge

The following dispositions, known to be achievable and already specified in other standards or project specifications, are proposed for the ESD test specified in clause [5.4.12](#).

The test is performed on following equipment, including or not digital circuits:

- units comprising high-voltage power sources,
- units man-handled during normal operation,

This condition applies to manned-flight,

For man-handled equipment, an ESD test by the contact discharge method as defined in IEC-61000-4-2, is more appropriated,

- units outside the main frame of the space vehicle designed as a Faraday cage,
- units connected to sensors, actuators, or other units located outside the main frame designed as a Faraday cage with the exception of the solar array power bus.

Specific tests defined in ECSS-E-ST-33-11 are applied to EEDs.

Test of models expected to be or to become flight models is not performed.

ESD testing can cause latent failures of test article.

Bibliography

- | | |
|--------------|--|
| ECSS-S-ST-00 | ECSS system – Description, implementation and general requirements |
| MIL-STD-461E | Requirements for the control of electromagnetic interference, characteristics of subsystems and equipment, 20 August 1999; Department of Defence, USA. |

붙임#5. 한국항공우주연구원 전기추진시스템 개발을 위한 보유기술

1. 전기추력기 개발
 - HALL 전기추력기 설계
 - HALL 전기추력기 시험/진단
2. 전력공급장치
 - 고전압 전력공급장치 설계
 - 모듈형 전력공급장치의 병렬운전 설계