EUROPEAN COOPERATION

ECSS

FOR SPACE STANDARDIZATION

Space engineering

Multipaction design and test

This draft is distributed to the ECSS community for Public Review.

Start of Public Review: 27 February 2019
End of Public Review: 26 April 2019

DISCLAIMER FOR DRAFTS
This document is an ECSS Draft Standard. It is subject to change without any notice and may not be referred to as an ECSS Standard until published as such.

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-20-01C Working Group, reviewed by the ECSS Executive Secretariat and approved by the ECSS Technical Authority.

Disclaimer

Published by: ESA Requirements and Standards Division
ESTEC, P.O. Box 299,
2200 AG Noordwijk
The Netherlands

Change log

Change log for Draft development	
Previous steps	
ECSS-E-ST-20-01C Draft 43 7 December 2018	WG Draft updated by Jérôme and Klaus on 7 Dec 2018 (WebEx)
ECSS-E-ST-20-01C-V51(02Jan2019) 2 January 2019	Draft for Review (DFR) submitted to ES on 8 January 2019
ECSS-E-ST-20-01C DFR1 15 January 2019	Parallel Assessment 16 January – 1 February 2019
Current step	
ECSS-E-ST-20-01C DIR1 26 February 2019	**Public Review** **27 February – 26 April 2019**
Next steps	
	Draft with implemented DRRs
	DRR Feedback
	TA Vote for publication
	Preparation of document for publication (including DOORS transfer for Standards)
	Publication
	Change log for published Standard (to be updated by ES before publication)
	First issue
	First issue revision 1. Changes with respect to version C (date) are identified with revision tracking. Main changes are:
	Second issue The summary of changes between this issue and ECSS…… is as follows: • xxx

Table of contents

Figures

Tables

Introduction

In the context of increased RF power and component miniaturization, more and more attention shall be paid to multipactor which is critical for space missions based on satellite telecommunication or navigation payloads, or active microwave instruments for Earth Observation or Science. The multipactor phenomenon is an electron avalanche discharge occurring in high vacuum initiated by primary electrons inside a RF component in presence of a high local RF voltage or electric field.

In order to verify by analysis that a RF component is multipactor free, accurate EM modelling tools are required. These tools need more and more computation resources to cope with RF components with complex geometries, advanced manufacturing techniques, new materials and processes, and complex RF signals. The verification by test also requires some up-to-date test facilities, that provide high power amplification, electron seeding techniques, multiple and accurate detection methods, ability to generate complex signals, and the ability to reproduce the space representative environment conditions.

This standard is an update of previous version of ECSS-E-20-01A Rev.1, that takes into account the state-of-art of new verification approaches, and associated margins.

1 Scope

This standard defines the requirements and recommendations for the design and test of RF components and equipment to achieve acceptable performance with respect to multipactor-free operation in service in space. The standard includes:

- verification planning requirements,
- definition of a route to conform to the requirements,
- design and test margin requirements,
- design and test requirements, and
- informative annexes that provide guidelines on the design and test processes.

This standard is intended to result in the effective design and verification of the multipactor performance of the equipment and consequently in a high confidence in achieving successful product operation.

This standard covers multipactor events occurring in all classes of RF satellite components and equipment at all frequency bands of interest. Operation in single carrier CW and pulse modulated mode are included, as well as multi-carrier operations. A detailed clause on secondary emission yield is also included.

This standard does not include breakdown processes caused by collisional processes, such as plasma formation.

This standard is applicable to all space missions.

This standard may be tailored for the specific characteristic and constrains 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 – Glossary of terms
ECSS-E-ST-10-02	Space engineering –Verification
ECSS-E-ST-10-03	Space engineering - Testing
ECSS-E-HB-20-01	Space engineering – Multipactor handbook
ECSS-M-ST-10	Space project management – project planning and implementation
ECSS-M-ST-40	Space project management – configuration and information management
ECSS-Q-ST-20	Space product assurance – Quality assurance
ECSS-Q-ST-20-08	Space product assurance – Storage, handling and transportation of spacecraft hardware
ECSS-Q-ST-70-01	Space product assurance – Cleanliness and contamination control
ECSS-Q-ST-70-02	Space product assurance – Thermal vacuum outgassing test for the screening of space materials
ESCC-20600	Preservation, packaging and despatch of ESCC component
ISO 14644–1:2015	Cleanrooms and associated controlled environments – Part 1: Classification of air cleanliness by particle concentration

3
Terms, definitions and abbreviated terms

3.1 Terms and definitions from other standards

a. For the purpose of this standard, the terms and definitions from ECSS-S-ST-00-01 apply, in particular the following terms:
   1. acceptance
   2. bakeout
   3. component
   4. development
   5. equipment
   6. integration
   7. uncertainty
   8. validation
   9. verification

b. For the purpose of this standard, the terms and definitions from ECSS-E-ST-10-02 apply, in particular the following terms:
   1. acceptance stage
   2. analysis
   3. inspection
   4. model philosophy
   5. qualification stage
   6. review of design
   7. test
   8. verification level

c. For the purpose of this standard, the terms and definitions from ECSS-E-ST-10-03 apply, in particular the following terms:
   1. acceptance margin
   2. qualification margin

d. For the purpose of this standard, the terms and definitions from ECSS-Q-ST-70-02 apply, in particular the following terms:
   1. outgassing

3.2 Terms and definitions specific to the present standard

3.2.1 analysis margin

required margin of the nominal operational power with respect to the theoretical threshold power resulting from a Multipactor analysis

3.2.2 assembly

process of mechanical mating of hardware after the manufacturing process

3.2.3 backscattered electron

incident electron that was re-emitted from the material surface with or without energy loss.

3.2.4 batch

group of component produced in a limited amount of time with the same manufacturing tools, that originates from the same manufacturing lot, and followed the same manufacturing processes

NOTE This definition is more specific than the one from the ECSS Glossary ECSS-S-ST-00-01.

3.2.5 batch acceptance margin

allowance of the power level above the nominal operational power over the specified component lifetime, excluding testing, to be applied to component of the same batch

3.2.6 critical gap

region of the circuit at which the discharge occurs at the lowest input power for a given frequency within the operating frequency band.

NOTE Critical gap does not correspond necessarily to the smallest gap.

3.2.7 discharge

<CONTEXT: multipactor testing> simultaneous response on two or more independent detection methods

NOTE The term "multipactor discharge" is synonymous.

3.2.8 event

<CONTEXT: multipactor testing> short time response on one detection method

3.2.9 ferromagnetic material

substances which exhibit a magnetism in the same direction of an external magnetic field

3.2.10 gap voltage

voltage over the critical gap

3.2.11 heritage

Level of similarity relatively to the following elements characterizing a component:

- geometry of the whole component,
- the temperature range,
- the operational frequency,
- the constitutive material and surface coating properties.

3.2.12 nominal operational power

maximum operational power of the component over its in-orbit lifetime

3.2.13 multicarrier average power

sum of the average power of each carrier

$$P_{avg} = \sum_{i=1}^{N} P_i$$

where:

Pi is the average power of each individual carrier

N is the number of carriers

3.2.14 minimum inflexion point

frequency times gap distance product, corresponding to multipactor order one, at which there is a change in the slope of the breakdown voltage curve and the breakdown voltage is minimized

NOTE Figure 3-1 is given as example. See for more information the Multipactor handbook ECSS-E-HB-20-01.

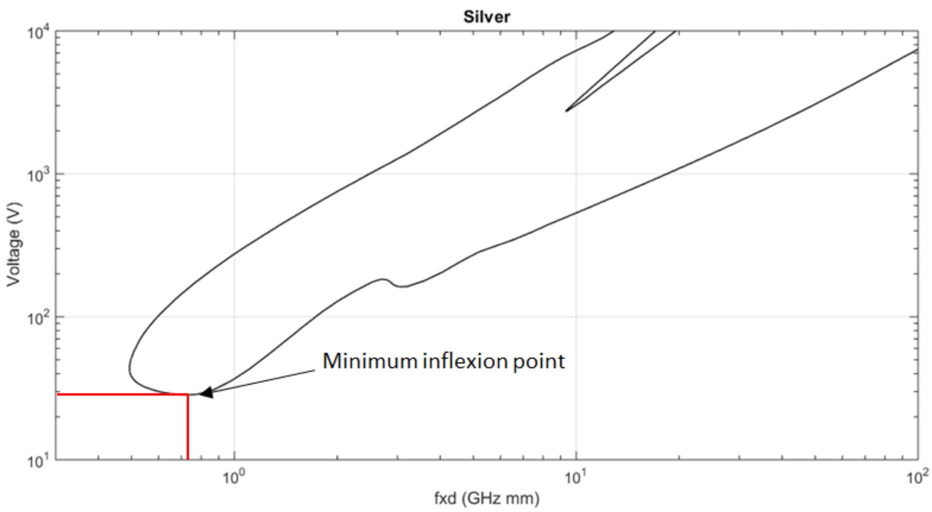

Figure 3-1: Minimum inflexion point for Silver multipactor chart.

3.2.15 multipactor discharge

see "**discharge**"

3.2.16 multipactor threshold

<CONTEXT: multipactor testing> lowest power level for which a multipactor discharge has occurred

3.2.17 multicarrier signal

<CONTEXT: multipactor testing> signal composed of a number of independent CW signals at different frequencies

3.2.18 qualification test

test performed on a single flight standard unit for establishing that a suitable margin exists in the design and built standard

NOTE Such suitable margin is the qualification margin.

3.2.19 secondary electron emission yield (SEY)

see "**total secondary electron emission coefficient**"

3.2.20 total secondary electron emission coefficient

ratio of the number of all emitted electrons to the number of incident electrons of defined incident kinetic energy and angle, specific of a material surface under electron irradiation under high vacuum conditions

NOTE 1 The total secondary electron coefficient is the sum of the true secondary electron coefficient and the backscattered electron coefficient.

NOTE 2 The term "**secondary electron emission yield**" is synonymous.

3.3 Abbreviated terms

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

Abbreviation	Meaning
AC/DC	alternating current/direct current
BAT	batch acceptance test
BSE	back-scattered electron emission
CFRP	carbon-fibre-reinforced plastic
CW	continuous wave
DC	direct current

Abbreviation	Meaning
DML	declared materials list
DPL	declared processes list
DRD	documents requirements definition
DUT	device under test
EQSR	equipment qualification status review
ECSS	European Cooperation for Space Standardization
EM	electromagnetic
EMC	electromagnetic compatibility
ERS	European remote sensing satellite
ESCC	European Space Components Coordination
FM	flight model
HPA	high power amplifier
IF	intermediate frequency
LNA	low noise amplifier
OMUX	output multiplexer
PDR	preliminary design review
PIC	particle in cell
PID	process identification document
PIMP	passive intermodulation product
RF	radio frequency
SEE	secondary electron emission
SRR	system requirements review
REG	regulated electron gun
RS	radioactive source
SEY	secondary emission yield
TEM	transverse electromagnetic mode
TRB	test review board
TRP	temperature reference point
TRR	test readiness review
TVAC	thermal vacuum chamber
TWTA	travelling wave tube amplifier

Abbreviation	Meaning
UAT	unit acceptance test
UV	ultraviolet
VSWR	voltage standing wave ratio
WG	wave guide
WOCA	worst case analysis

3.4 Nomenclature

The following nomenclature applies throughout this document:

a. The word "shall" is used in this Standard to express requirements. All the requirements are expressed with the word "shall".

b. The word "should" is used in this Standard to express recommendations. All the recommendations are expressed with the word "should".

NOTE It is expected that, during tailoring, recommendations in this document are either converted into requirements or tailored out.

c. The words "may" and "need not" are used in this Standard to express positive and negative permissions, respectively. All the positive permissions are expressed with the word "may". All the negative permissions are expressed with the words "need not".

d. The word "can" is used in this Standard to express capabilities or possibilities, and therefore, if not accompanied by one of the previous words, it implies descriptive text.

NOTE In ECSS "may" and "can" have completely different meanings: "may" is normative (permission), and "can" is descriptive.

e. The present and past tenses are used in this Standard to express statements of fact, and therefore they imply descriptive text.

4 Verification

4.1 Verification process

a. The process of verification of the component or the equipment with respect to multipactor performance shall demonstrate conformance to the margin requirements defined in clauses 4.6 and 4.7.

b. Verification of the component or the equipment with respect to multipactor shall be performed as part of the overall verification process specified in ECSS-E-ST-10-02, by applying Table 4-1..

c. Each component or equipment shall have a dedicated multipactor verification plan as specified in 4.2.2a.

NOTE It can involve a combination of design analyses, inspections, development testing, qualification testing, batch acceptance testing and equipment or component acceptance testing.

d. Multipactor performance shall be verified at equipment level.

e. If multipactor performance cannot be verified at equipment level, as specified in 4.1d, then verification may be performed at component level that for multipactor critical components.

Table 4-1: Classification of equipment or component type according to the qualification status from a multipactor point of view (adapted from Table 5-1 of ECSS-E-ST-10-02)

Category	Description	Comments	Verification type
Am	Off the shelf equipment or component without modifications and: • subjected to a multipactor verification process (only analysis or also test) with a power level and qualification environment at least as severe as that imposed by the actual mission requirements, and • produced by the same manufacturer and using the same manufacturing processes and procedures		Review of design
Bm	Off the shelf equipment or component without modifications. However: • It has been subjected to a multipactor verification process (only analysis or also test) with a power level less severe as that imposed by the actual mission requirements, and qualification environment at least as severe as that imposed by the actual mission requirements, and • produced by the same manufacturer and using the same manufacturing processes and procedures	For this document, modification of project specifications apply to power only	Review of design, analysis margin evaluation and if necessary test
Cm	Existing equipment or component with modifications. Modification includes: • minor changes to design • change of parts • change of materials, processes, manufacturer • change to a more severe environment imposed by the actual mission requirements • change of frequency • change of signal characteristics	In case the equipment or component with modification includes a change of materials and processes, the materials and processes subject to change see requirement 9.2a.	Review of design, analysis and if necessary test
Dm	Newly designed and developed equipment or component or use of	No analysis and test heritage for the	Review of design, analysis

Category	Description	Comments	Verification type
	non-already qualified material or process.	new design or material and process	and if necessary test

4.2 Multipactor verification plan

4.2.1 Generation and updating

a. A multipactor verification plan shall be produced at the CDR at the latest.

b. The multipactor verification plan specified in 4.2.2a shall be kept up-to-date and under configuration control.

NOTE The detailed verification plan adopted for any particular project can depend on the qualification status of the equipment and on the model philosophy or production philosophy adopted.

c. The inputs for the multipactor verification plan shall include as a minimum:

1. equipment or component requirements specification,
2. proposed design,
3. equipment or the component qualification status as per Table 4-1,
4. equipment or component type as per Table 4-2.

4.2.2 Description

a. The multipactor verification plan shall be in conformance with the Verification Plan DRD specified in Annex A of ECSS-E-ST-10-02 plus the following items:

1. the verification route as per Figure 4-1: ,
2. list of the multipactor deliverable documents per review,
3. description of tests or analysis to be performed.

NOTE The list of Multipactor deliverable documents is given in Table A-1.

b. The multipactor verification plan shall present a coherent sequence of activities that are proposed in order to provide adequate evidence that the requirement specifications for the product are achieved for each delivered item.

c. The multipactor verification plan shall state the criteria for successful completion of each of the verification activities.

4.3 Power requirements

4.3.1 General power requirements

4.3.1.1 Nominal power

a. The nominal power shall be the specified input power for which the equipment is designed and verified to be multipactor free.

b. The nominal power shall be the RF power level to which the analysis margin and test margin refers.

c. The nominal power specified at equipment level shall not take into account RF boundary conditions, neither from payload assembly nor from test bed.

NOTE The nominal power for multicarrier signal can be given as power per carrier, or a list of power per carrier.

4.3.1.2 Increased power ΔP due to payload mismatch

a. The increased power ΔP of the Table 4-3, Table 4-4, Table 4-6 and Table 4-7 shall be calculated by taking into account the mismatch at the RF boundaries of the equipment or the component.

4.3.1.3 Failure

a. At payload level, the design and the verification of the equipment identified as critical shall take into account failure modes.

b. As a minimum, the failure modes shall include the following:

1. failed equipment
2. hot switching
3. overdrive scenario
4. unexpected thermal variations
5. unexpected full or partial RF power reflection
6. unexpected increase of input power

c. For multipactor design and verification, the failures modes shall be taken into account only if the equipment recovery is possible.

d. For multipactor design and verification, failure modes that are not recoverable should not be taken into account.

e. At equipment level, the multipactor design and verification shall take into account the impact of the applicable failure modes identified at payload level.

f. The increased power ΔP shall be determined by taking into account the change of RF boundary conditions due to applicable failure modes.

4.4 Classification of equipment or component type

4.4.1 General classification of equipment or component type

a. The classification of equipment or component types given in Table 4-1 and in Table 4-2 shall be used to determine the applicable multipactor margin.

NOTE This requirement defines a classification of equipment or component types according to the materials employed in the construction and the geometry and according to the qualification status from a multipactor point of view.

b. In case of doubt when determining the classification of any particular equipment or component, the type with a higher number and a lower level of qualification status shall be used.

c. An equipment consisting of several components shall have the type of the component with the highest number and the lowest level of qualification status.

d. An RF equipment assembly consisting of equipment shall have the type of the equipment with the highest number and the lowest level of qualification status.

e. In case the equipment or component has multiple potential critical gaps of different nature, each one shall be classified as P1 or P2 and follow the verification approach as defined in 4.2.

NOTE Examples of potential critical gaps of different nature are metal/metal, metal/dielectric or dielectric/dielectric.

f. In case SEY characterization of materials present in an equipment or component including dielectrics materials is not performed, it shall be considered as P3 equipment or component.

Table 4-2: Classification of equipment or component type according to the material and the geometry

Type	Characteristics	Parameters for equipment or component knowledge
P1	Equipment or component with metal only in the critical gap area. Metal(s) and geometry of equipment or component are known.	Minimum parameters: • RF path dimensions of the equipment or component • Tuning range of the equipment or component (if applicable) • SEY of the metal(s) • CTE of the material(s) (if applicable) • DC EM field (if applicable)
P2[(1)]	Equipment or component with dielectric and possibly metal in the critical gap area. Dielectric material(s), metal(s) and geometry of the equipment or component are known.	Minimum parameters: • RF path dimensions of the equipment or component • Tuning range of the equipment or component (if applicable) • SEY of the dielectrics and possibly metal(s) • CTE of the material(s) (if applicable) • DC EM field (if applicable) • Charging (if applicable)
P3[(1)]	Any equipment or components not classified as Type P1 or Type P2.	If any of the parameters needed for P1 or P2 is unknown, the component or equipment is classified as P3.
[(1)] Any P2/P3 component/equipment with a geometry involving 3 media (dielectric, metal and vacuum) and with a sharp edge in the metallic part exhibiting high RF field are prone to generate breakdown phenomena such as "triple-point" discharge which are difficult to analyse and predict. (For more information, see the corresponding clause of the Multipactor handbook ECSS-E-HB-20-01).		

4.5 Verification routes

a. Verification shall be accomplished by one of the verification routes shown in Figure 4-1.

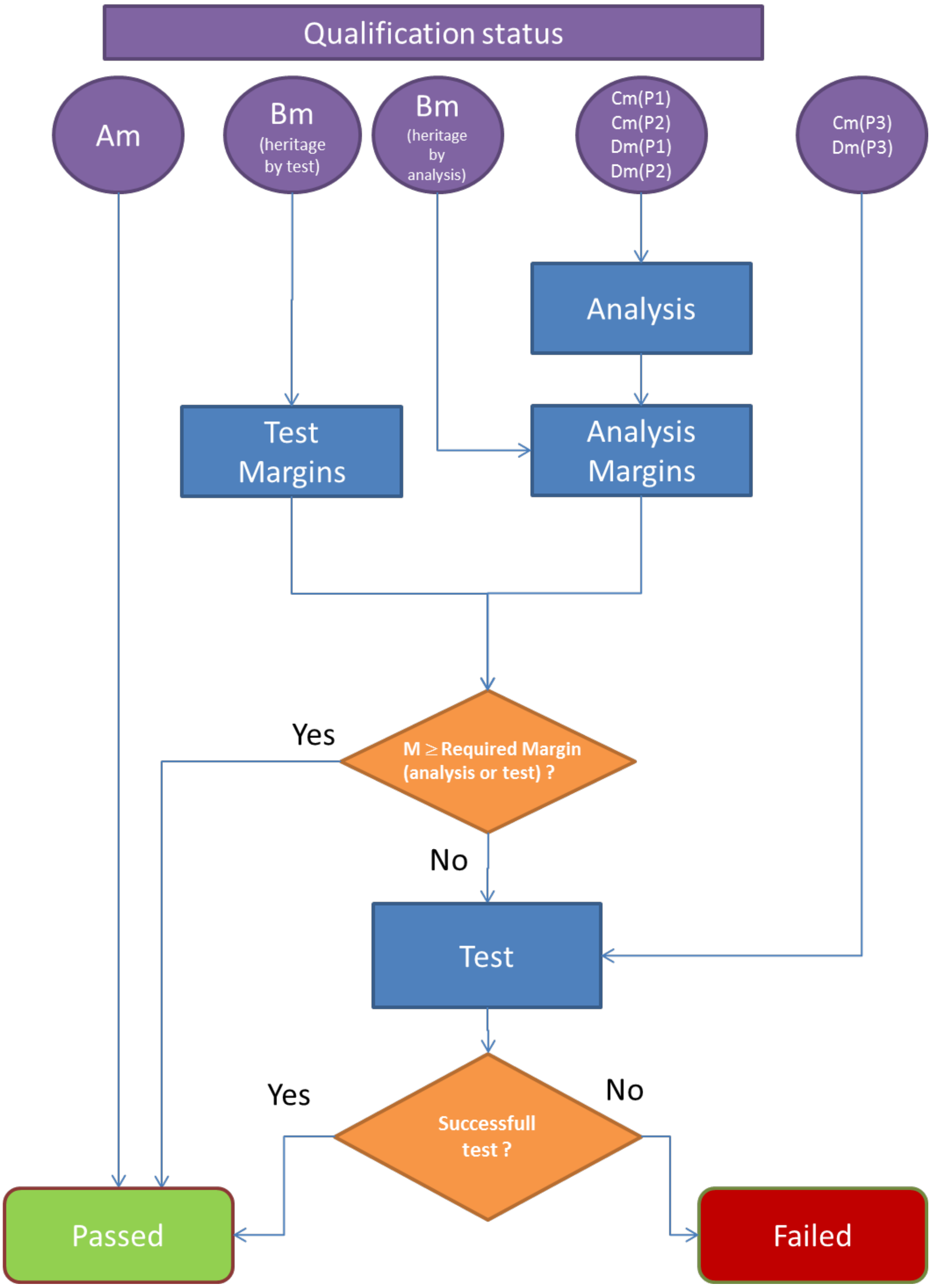

Figure 4-1: Verification routes per component/equipment type and qualification status for multipactor conformance

4.6 Single carrier

4.6.1 General

Clause 4.6 states the numerical values of the margins to be used for CW and pulsed systems.

4.6.2 Verification by analysis

4.6.2.1 Analysis types

a. The Multipactor analysis shall be performed following one of the two possible design analysis levels, L1 and L2, as per clause 5.3.2.

4.6.2.2 Analysis margins

a. The nominal margins shown in Table 4-3 and Table 4-4 for the different contributions and equipment or component types according to the heritage status shall be applied.

b. The reduced margins, as indicated in Table 4-3 and Table 4-4, may be used if justification is given by the supplier.

NOTE The nominal and reduced margins as indicated in Table 4-3 and Table 4-4 include modelling error.

Table 4-3: Margins w.r.t. nominal power applicable to P1 and P2 equipment or components with Bm or Cm category verified by analysis

Margins and associated justification	Margin type	L1 analysis **P1 equipment or component** Margin [dB]	L2 analysis **P1 equipment or component** (no presence of dielectrics or ferromagnetic material in the whole equipment) Margin [dB]	L2 analysis **P1 equipment or component** (other cases) Margin [dB]	L2 analysis **P2 equipment or component**(1) Margin [dB]
Nominal dimension & ECSS SEY	Nominal margin	6+ΔP	7+ΔP	8+ΔP	N/A
Manufacturing tolerance/thermal stability dimension & ECSS SEY	Reduced margin	5+ΔP	6+ΔP	7+ΔP	N/A
Nominal dimension & WOCA SEY (ageing, temperature) justified by measurement (2)	Reduced margin	4+ΔP	5+ΔP	6+ΔP	8+ΔP(3)
Manufacturing tolerance/thermal stability dimension & WOCA SEY (ageing, temperature) justified by measurement (1) (2)	Reduced margin	3+ΔP	4+ΔP	5+ΔP	7+ΔP(3)

(1) Worst case analysis combining both as-built/thermal stability dimension and real SEY characterized by measurement.

(2) The SEY is characterized by measurement by the supplier as described in the clause 9.2.

(3) Charging impact is taken into account as per 5.3.2.3.1c.

Table 4-4: Margins w.r.t. nominal power applicable to P1 and P2 equipment or components with Dm category verified by analysis

Margins and associated justification	**Margin type**	**L1 analysis**	**L2 analysis**		
		P1 equipment or component	**P1 equipment or component** (no presence of dielectrics or ferromagnetic material in the whole equipment)	**P1 equipment or component** (other cases)	**P2 equipment or component**[1]
		Margin [dB]	**Margin** [dB]	**Margin** [dB]	**Margin** [dB]
Manufacturing tolerance/thermal stability dimension & WOCA SEY (ageing, temperature) justified by measurement [1] [2]	Reduced margin	6+ΔP	8+ΔP	10+ΔP	12 +ΔP[3]

[1] Worst case analysis combining both as-built/thermal stability dimension and real SEY characterized by measurement.

[2] The SEY is characterized by measurement by the supplier as described in the clause 9.2.

[3] Charging impact is taken into account as per 5.3.2.3.1c.

4.6.3 Verification by test

4.6.3.1 Test margins

a. The test margin shall be defined according to the equipment or component type and the heritage status.

b. The test margins as shown in Table 4-5 shall be applied.

NOTE Margins shown in Table 4-5 are those for a payload mismatch of -12 dB.

c. Any deviation from requirement 4.6.3.1b shall be proposed by the supplier and agreed with the customer.

d. Multipactor tests shall be conducted at the temperature range defined in clause 6.3.

e. For P1 equipment or component of type Bm and Cm, the test at ambient temperature may be performed if justifications are provided of the non-impact of temperature over any parameter affecting the breakdown threshold.

NOTE Discussions regarding test at ambient can be found in the Multipactor handbook ECSS-E-HB-20-01.

Table 4-5: Margins w.r.t. nominal power applicable to P1, P2 and P3 equipment or components verified by test

Equipment or component type	**P1** (dB)	**P2 or P3** (dB)	
Heritage status	**All**	**Bm(1)**	**Bm(2), Cm, Dm**
Qualification Test	6	6	6
Batch Acceptance Test	4	4	5
Unit Acceptance Test	3	3	4
(1) Heritage by test (2) Heritage by analysis			

4.7 Multicarrier

4.7.1 General

Clause 4.7 states the numerical values of the margins to be used for multicarrier systems.

The margins by analysis and test are defined with respect to either the power per carrier of the multicarrier signal, or the multicarrier average power, or the equivalent CW power as specified in 6.4.3.2a.

4.7.2 Verification by analysis

4.7.2.1 Analysis types

a. The Multipactor analysis shall be performed following one of the two possible levels L1 and L2 as per clause 5.3.2.

4.7.2.2 Analysis margins

a. The nominal margins shown in Table 4-6 and Table 4-7 for the different contributions and equipment or component types according to the heritage status shall be applied in addition to the nominal power.

b. The reduced margins as indicated in Table 4-6 and Table 4-7 may be used if justification is given by the supplier.

NOTE The nominal and reduced margins as indicated in Table 4-6 and Table 4-7 include modelling error.

Table 4-6: Margins applicable to P1 and P2 equipment or components with Bm or Cm category verified by analysis

Margins and associated justification	Margin type	L1 analysis	L2 analysis		
		P1 equipment or component	P1 equipment or component (No presence of dielectrics or ferromagnetic material in the whole equipment)	P1 equipment or component (other cases)	P2 equipment or component(1)
		Margin (dB)	Margin (dB)	Margin (dB)	Margin (dB)
Nominal dimension & ECSS SEY (3)	Nominal Margin	6+ΔP	7+ΔP	8+ΔP	N/A
Manufacturing tolerance/thermal stability dimension & ECSS SEY (3)	Reduced Margin	5+ΔP	6+ΔP	7+ΔP	N/A
Nominal dimension & WOCA SEY (ageing, temperature) justified by measurement (2)	Reduced Margin	4+ΔP	5+ΔP	6+ΔP	8+ΔP(3)
Manufacturing tolerance/thermal stability dimension & WOCA SEY (ageing, temperature) justified by measurement(1) (2)	Reduced Margin	3+ΔP	4+ΔP	5+ΔP	7+ΔP(3)

(1) Worst case analysis combining both as-built/thermal stability dimension and real SEY characterized by measurement.

(2) The SEY are characterized by measurement by the supplier as described in the clause 9.2.

(3) Charging impact is taken into account as per 5.3.2.3.1c..

Table 4-7: Margins applicable to P1 and P2 equipment or components with Dm category verified by analysis

Margins and associated justification	Margin type	L1 analysis	L2 analysis		
		P1 equipment or component	**P1 equipment or component** (No presence of dielectrics or ferromagnetic material in the whole equipment)	**P1 equipment or component** (other cases)	**P2 equipment or component**(1)
		Margin [dB]	**Margin** [dB]	**Margin** [dB]	**Margin** [dB]
Manufacturing tolerance/thermal stability dimension & WOCA SEY (ageing, temperature) justified by measurement(1) (2)	Reduced Margin	6+ΔP	8+ΔP	10+ΔP	12+ΔP(3)

(1) Worst case analysis combining both as-built/thermal stability dimension and real SEY characterized by measurement.

(2) The SEY are characterized by measurement by the supplier as described in the clause 9.2.

(3) Charging impact is taken into account as per 5.3.2.3.1c.

.

4.7.3 Verification by test

4.7.3.1 Test margins

a. The test margin shall be defined according to the equipment or component type and the heritage status.

b. The test margins as shown in Table 4-8 shall be applied for test performed in single carrier with an equivalent single carrier CW power determined in 6.4.3.2.

NOTE 1 Margins shown in Table 4-8 are those for a payload mismatch of -12 dB.

NOTE 2 If a single carrier test is not possible, see requirement 6.4.3.1b.

c. Any deviation from Table 4-8 shall be proposed by the supplier and agreed with the customer.

d. Multipactor tests shall be conducted at the temperature range defined in the clause 6.3.

e. For P1 equipment or component of type B and C, the test at ambient temperature may be performed if justifications are provided of the non-impact of temperature over any parameter affecting the breakdown threshold.

NOTE Discussions regarding test at ambient can be found in the Multipactor handbook ECSS-E-HB-20-01.

Table 4-8: Margins w.r.t. nominal power applicable to P1, P2 and P3 equipment or components verified by test

Equipment or component type	P1 (dB)	P2 or P3 (dB)	
Heritage status	**All**	**Bm(1)**	**Bm(2), Cm, Dm**
Qualification Test	6	6	6
Batch Acceptance Test	4	4	5
Unit Acceptance Test	3	3	4

(1) Heritage by test

(2) Heritage by analysis

5
Design analysis

5.1 Overview

Clause 5 defines the minimum requirements for performing a satisfactory design analysis with respect to multipactor. These requirements are applicable for all cases where the chosen route to conformance includes analysis. Implementation of such an analysis can vary from sophisticated three-dimensional multipactor simulations to a much simpler estimation process. The analysis represents the application under the specified conditions.

5.2 Field analysis

a. An analysis of the electromagnetic fields within the complete equipment or component shall be performed in order to establish the worst case multipactor threshold under the specified conditions.

NOTE 1 Multipactor analysis is performed with a proper understanding of the electric fields within the whole equipment or component.

NOTE 2 Specified conditions include parameters such as operational frequency bandwidth, temperature extremes, mismatch conditions, which are applicable to the equipment or component.

b. The analysis shall be accomplished by using one of the following methods:

1. RF EM software,
2. estimations from the appropriate use of equivalent circuit models,
3. analytical solution of canonical geometries.

c. All regions shall be analyzed to identify the multipactor critical gap.

d. If ferrite materials are present in the equipment or component the following two analyses shall be performed:

1. an EM field analysis based on the knowledge of the magnetic properties of such ferrite materials, and
2. a multipactor analysis by taking into account the DC magnetic field applied to the ferrite.

NOTE DC magnetic fields applied to ferrite equipment or components include permanent magnets and coils.

5.3 Multipactor design analysis

5.3.1 Frequency selection

a. The Multipactor design analysis shall be performed at the frequency within the full bandwidth, at which the EM fields yield the lowest breakdown power.

b. For multicarrier analysis, the carrier frequencies of each of the specified channels shall be used.

NOTE Carrier frequency is chosen for multicarrier analysis in order to obtain representative signal envelope characteristics.

5.3.2 Design analysis levels

5.3.2.1 General design analysis requirements

a. Design analysis shall be applied to equipment or components P1 and P2, according to clause 4.6.2 for single carrier and clause 4.7.2 for multicarrier.

b. The level of analysis to be performed shall be agreed between customer and supplier, depending on the complexity of the geometry of the equipment.

c. Depending on the design analysis level, margin shall be adequately applied according to clause 4.6.2.2 or 4.7.2.2.

5.3.2.2 Analysis level 1 (L1)

5.3.2.2.1 General requirements for analysist level 1 (L1)

a. Analysis level 1 shall be applied on equipment or components of type P1.

5.3.2.2.2 Criteria for geometry and material

a. The critical gap shall be similar to a parallel surface or coaxial geometry, and the electron trajectory is only possible between two-surfaces.

b. The material, in terms of SEY, shall be selected according to criteria specified in clause 5.3.3.3

c. In case the analysis includes fringing field effect for iris-like geometries, then analyses may be modified based on relevant heritage or studies on such effect if agreed between the supplier and customer on the degree of similarity of the proposed studies.

NOTE Fringing field effect can increase the multipactor threshold power level (see respective clause in the Multipactor handbook ECSS-E-HB-20-01).

5.3.2.2.3 Analysis methodology for single-carrier case

a. The analysis level 1 with single-carrier signals shall consist of the following steps:

1. Computation of the voltage inside the critical region, Vgap, through analytical formula or an electromagnetic software, for a given input power P_{in}, using the definition of the voltage to power ratio as $k = Pin/Vgap^2$
2. Computation of the multipactor threshold at the corresponding frequency gap distance product, by either:
   (a) using one of the dedicated charts for the list of ECSS materials of clause 5.3.3.4, or
   (b) using a multipactor theory or numerical method for parallel surfaces or coaxial geometry.
3. Computation of input power corresponding to the Multipactor threshold voltage computed in point b as $Pth = k * Vth^2$.

   NOTE The voltage to power ratio of item 1 is equivalent to the voltage magnification factor defined in the handbook.

b. The customer and supplier shall agree on the method to follow regarding requirement 5.3.2.2.3a.2.

c. Different analysis methodologies may be used in agreement with the customer.

d. The resulting threshold shall be compared with the nominal power increased with the dedicated margin of Table 4-3 and Table 4-4.

5.3.2.2.4 Analysis methodology for multi-carrier case

a. The analysis level 1with multi-carrier signals shall consist of the following steps:

1. Computation of the voltage inside the critical region, Vgap, through analytical formula or an electromagnetic software, for a given input power P_{in}, giving the EM fields solved for a frequency equal to the mean frequency of all carriers and using the definition of the voltage to power ratio as $k = Pin/Vgap^2$.

   NOTE This ratio is equivalent to the voltage magnification factor defined in the Multipactor handbook ECSS-E-HB-20-01.
2. Compute the breakdown voltage threshold per carrier by either:
   (a) Using the pulsed model approximation in combination with single-carrier analysis.
   (b) Using the envelope sweep approach in combination with a full multicarrier multipactor theory or numerical method for L1, to find the worst-case pulse width that leads to the minimum breakdown power.

b. The pulsed model approximation, specified in 5.3.2.2.4a.2(a), shall consist of the following steps:

1. Approximate the multicarrier signal by a pulsed signal, consisting of an on-off rectangular signal, with a frequency of the signal equal to the mean frequency of all carriers, and a period equal to that of the envelope of the multicarrier signal.
2. Select the single carrier multipactor theory employed in item 3 in agreement with the customer that allows for analytically computing the electron growth during the "on" interval, and electron absorption during the "off" interval.
3. Compute the electron growth during a period by employing the theory selected in item 2.
4. Select the worst-case as the combination of the duration and amplitude of the pulse, that produces a discharge with the lowest voltage per carrier, by:
   (a) Using the long-term discharge criterion, where the number of produced electrons is higher than the number of absorbed electrons during a period of the multicarrier signal.
   (b) Determining the computation of the voltage per carrier, given the amplitude of the pulse, by the use of a multicarrier envelope fitting function.

NOTE Specific analytical formulas, methodology and different envelope fitting functions are given in the Multipactor handbook ECSS-E-HB-20-01.

c. The envelope sweep, specified in 5.3.2.2.4a.2(b), shall consist of the computation of the Multipactor threshold voltage per carrier given by a full-multicarrier multipactor theory or numerical method for parallel plates, as follows:.

1. Selection of the different time intervals of duration *t* from 0 to T, where T is the multi-carrier period by ensuring that the number of time intervals is large enough for the convergence.
2. Optimization of the carrier phases for each value of *t* in order to maximize the minimum value of the envelope voltage amplitude during the respective time interval of duration *t*.
3. Computation of the Multipactor voltage threshold for each phase scenario resulting from step 2, considering a long-term discharge, where the number of produced electrons is higher than the number of absorbed electrons during a period of the multicarrier signal.
4. Selection of the minimum Multipactor voltage threshold.

NOTE A full-multicarrier theory is able to compute the multipactor dynamics (electron growth in time) for an arbitrary combination of frequencies, amplitudes and phases with no simplification of the signal.

d. The customer and supplier shall agree on the method for the computation of the multipactor threshold voltage, specified in 5.3.2.2.4c.

e. The input power corresponding to the Multipactor threshold voltage computed in 5.3.2.2.4a.2 shall be computed as $P_{th} = k * Vth^2$.

f. Different analysis methodologies may be used in agreement with the customer.

g. The resulting threshold shall be compared with the nominal power increased with the dedicated margin of Table 4-6 and Table 4-7.

5.3.2.3 Analysis level 2 (L2)

5.3.2.3.1 Criteria for geometry and material

a. The secondary emission properties used shall be selected according to criteria specified in clause 5.3.3.3.

b. According to the geometry of the critical gap, any equipment or component type 1 (P1) which cannot be analysed through L1, shall be analysed through L2.

NOTE This includes for instance multiple electron trajectories, complex 3D structures where the critical cannot be locally approximated by a parallel plate or coaxial cases.

c. Type 2 equipment or components (P2) shall be analysed through L2, considering the DC electric field created by the dielectric charging in order to determine the worst case of Multipactor threshold.

5.3.2.3.2 Analysis methodology for single-carrier case

a. The analysis level 2 shall be characterized by the computation of the Multipactor threshold with a 3D coupled RF EM and electron tracking and surface modelling software.

b. A convergence study of the mesh density and of the initial number of electrons shall be performed until the Multipactor threshold is stabilized.

c. The resulting threshold shall be compared with the nominal power increased with the dedicated margin of Table 4-3 and Table 4-4

5.3.2.3.3 Analysis methodology for multi-carrier case

a. The analysis L2 with multi-carrier signals shall be done by using the envelope sweep approach to find the worst-case pulse width that leads to the minimum breakdown power in the following sequence:

   1. Computation of the Multipactor threshold power per carrier given by a 3D coupled RF EM and electron tracking and surface modelling software.

   2. Comparison of the obtained power threshold per carrier with the nominal power per carrier increased with the dedicated margin of Table 4-6 and Table 4-7.

b. The computation of the multipactor threshold power per carrier, as specified in 5.3.2.3.3a.1, shall consist of:

1. Selection of the different time intervals of values of pulse duration t from 0 to T, where T is the multi-carrier period by ensuring that the number of time intervals is large enough for the convergence.
2. Optimization of the carrier phases for each value of *t* in order to maximize the minimum value of the envelope voltage amplitude during the respective time interval of duration *t*.
3. Computation of the Multipactor power threshold for each phase scenario resulting from step 2, considering a long-term discharge, where the number of produced electrons is higher than the number of absorbed electrons during a period of the multicarrier signal.
4. Selection of the minimum Multipactor power threshold.

c. Different analysis methods may be used in agreement with the customer.

NOTE Alternative methods are described in the handbook.

d. A convergence study of the mesh density and of the initial number of electrons shall be performed until the Multipactor threshold is stabilized.

5.3.2.4 Validation of theory and software

a. For parallel-plate theory and both 3D EM and electron trajectory computation, any technique shall be validated by either:

1. demonstrable heritage, or
2. multipactor breakdown computation of representative sample and comparison with experimental results or results coming from a validated theory or software.

NOTE Examples of representative samples are given in the Multipactor handbook ECSS-E-HB-20-01.

5.3.3 Available data for Multipactor analysis

5.3.3.1 General

a. The analysis margin strategy to be applied shall depend on the available data for two parameters, dimensions and SEY:

1. Dimensional accuracy and stability:
   (a) Nominal values
   (b) Worst case, including manufacturing tolerances and thermal effect.
2. SEY available data
   (a) ECSS SEY data
   (b) Measured SEY, including ageing and temperature effect and charging (if applicable)

b. For each case specified in 5.3.3.1a, the dedicated margin of Table 4-3, Table 4-4, Table 4-6 or Table 4-7 shall be applied depending on the level analysis and the type of equipment or component.

5.3.3.2 Dimensional accuracy and stability

a. The worst case dimension shall be determined using following steps:

1. take into account accuracy and stability of the dimensions of the equipment or component, including manufacturing tolerances and the thermal effect.
2. study the effect of the thermo-elastic distortion on the qualification temperature range.
3. use the smallest dimension of the critical gap, provided that the RF equipment or component remains compliant with the electrical performance specifications.
4. evaluate the lowest breakdown power within the whole gap dimensional variation range, if the fxd product is lower than the minimum inflexion point of the curve, and select the gap yielding the lowest breakdown power.
5. compute the dimensional variation over the iris length in the presence of short irises, and select the longest iris length as the worst-case for all cases.

b. For the nominal dimension, the analysis shall be performed without taking into account the manufacturing tolerances and the thermal effect.

c. In case tuning elements are present in P1 or P2 equipment or component, the predicted worst and best case threshold power shall be derived by taking into account the range of the tuning elements.

5.3.3.3 SEY available data

a. SEY data used in the analysis shall be representative of the material in the critical part of the equipment and come from either measured SEY or ECSS SEY.

b. For measured SEY, the SEY curve shall be the worst case taking into account the ageing, contamination and temperature and charging properties as specified in requirement9.3a.

c. If no ad-hoc SEY measurement data are available, and the material is listed in Table 9-1, the corresponding material of the database shall be taken.

d. If no ad-hoc SEY measurement data are available, and the material is not listed in Table 9-1, no analysis is possible and the equipment or component shall be classified as P3.

e. P1 equipment or components shall be analysed with either measured SEY or ECSS SEY data.

f. P2 equipment or components shall be analysed with measured SEY data.

g. If different materials are present at the critical gap, the material with the worse SEY envelope curve shall be taken for analysis level 1.

5.3.3.4 ECSS Multipactor charts

a. To compute the threshold level for L1 analysis according to clause 5.3.2.2 the values of Table 5-1 shall be taken.

NOTE The multipactor charts in Figure 5-1 to Figure 5-5 are a visual representation of breakdown voltage for each of the metals listed in Table 9-1.

Table 5-1: Tabulated values of the lowest breakdown voltage threshold boundary of the multipactor charts, computed with the SEY data of Table 9-1

fxd (GHz mm)	Breakdown Voltage (V)			
	Aluminium	**Copper**	**Silver**	**Gold**
0,43	33,8			
0,47	28,5	36,6		
0,49	27,4	33,4		41,0
0,50	27,0	32,5	38,3	38,1
0,53	26,1	30,8	33,7	34,5
0,56	25,4	29,7	31,7	32,8
0,59	24,7	28,8	30,4	31,6
0,62	24,2	28,1	29,5	30,8
0,66	24,0	27,7	28,9	30,2
0,70	23,8	27,4	28,5	29,8
0,74	24,1	27,5	28,5	29,7
0,78	24,7	27,7	28,7	29,8
0,82	25,9	28,7	29,7	30,6
0,87	27,2	29,9	30,9	31,6
0,92	29,3	31,9	32,9	33,5
0,97	31,5	34,0	35,2	35,7
1,02	34,4	37,0	38,3	38,6
1,08	37,7	40,3	41,7	42,0
1,14	41,6	44,4	45,9	46,0
1,21	46,2	49,0	50,8	50,8
1,28	51,3	54,2	56,2	56,2
1,35	56,9	60,3	62,5	62,4
1,43	63,4	67,0	69,5	69,3
1,51	70,5	74,8	77,2	77,0
1,59	78,4	83,3	86,0	85,8

fxd (GHz mm)	Breakdown Voltage (V)			
	Aluminium	**Copper**	**Silver**	**Gold**
1,68	86,1	91,9	95,4	95,3
1,78	94,3	101,4	105,6	105,6
1,88	102,0	110,8	116,0	116,0
1,99	110,1	120,9	126,9	127,0
2,10	117,4	130,1	137,5	137,6
2,22	124,8	139,7	148,5	148,7
2,34	130,5	148,2	159,4	159,4
2,48	133,7	156,7	170,6	170,3
2,62	131,8	160,2	179,7	179,2
2,77	128,4	154,3	182,2	181,3
2,92	129,6	149,2	167,6	168,7
3,09	134,0	150,6	162,4	163,6
3,27	139,7	155,2	165,4	166,3
3,45	147,8	163,0	172,8	173,6
3,65	156,6	171,7	181,4	181,8
3,85	167,8	183,4	193,5	193,9
4,07	179,6	195,8	206,3	206,6
4,30	193,1	211,2	222,9	223,2
4,55	207,5	227,6	240,4	240,7
4,81	221,7	244,6	258,2	258,5
5,08	236,5	262,5	276,9	277,2
5,37	249,5	277,3	292,2	292,7
5,67	261,8	290,7	306,4	307,1
5,99	273,1	302,9	321,1	321,8
6,33	284,0	314,4	336,2	336,9
6,69	298,3	329,6	353,4	354,0
7,07	317,5	350,3	373,3	373,9
7,47	337,5	372,1	394,8	395,4
7,90	357,3	394,5	419,2	419,7
8,34	378,3	418,0	444,8	445,3
8,82	399,9	441,6	469,9	470,5
9,32	422,4	466,6	496,5	497,1

fxd (GHz mm)	Breakdown Voltage (V)			
	Aluminium	**Copper**	**Silver**	**Gold**
9,85	446,2	493,1	525	525
10,41	471,4	521	554	555
11,00	498,9	551	586	587
11,62	528	583	621	621
12,28	559	617	657	657
12,98	592	653	695	695
13,71	626	691	736	736
14,49	662	731	779	779
15,31	700	773	825	825
16,18	742	819	874	873
17,10	786	867	925	924
18,07	832	919	981	980
19,10	881	974	1039	1038
20,18	934	1032	1102	1100
21,32	990	1093	1168	1166
22,53	1050	1160	1240	1236
23,81	1113	1229	1315	1311
25,16	1181	1305	1397	1392
26,59	1254	1385	1483	1478
28,10	1370	1512	1577	1570
29,69	1532	1704	1677	1668
31,38	1682	1870	1783	1773
33,16	1797	2000	1897	1885
35,04	1875	2089	2019	2006
37,03	1885	2087	2152	2136
39,13	1926	2129	2293	2274
41,35	2052	2269	2448	2425
43,70	2186	2418	2611	2585
46,18	2332	2581	2791	2761
48,80	2486	2753	2981	2946
51,57	2654	2941	3191	3150
54,49	2833	3141	3414	3367

fxd (GHz mm)	Breakdown Voltage (V)			
	Aluminium	**Copper**	**Silver**	**Gold**
57,59	3026	3359	3659	3604
60,85	3232	3593	3921	3858
64,31	3453	3845	4206	4132
67,95	3690	4115	4514	4430
71,81	3894	4383	4846	4752
75,88	4050	4642	5208	5101
80,19	4283	4952	5595	5474
84,74	4698	5368	6014	5878
89,55	5117	5798	6458	6306
94,63	5440	6200	6936	6767
100,00	5782	6624	7440	7254

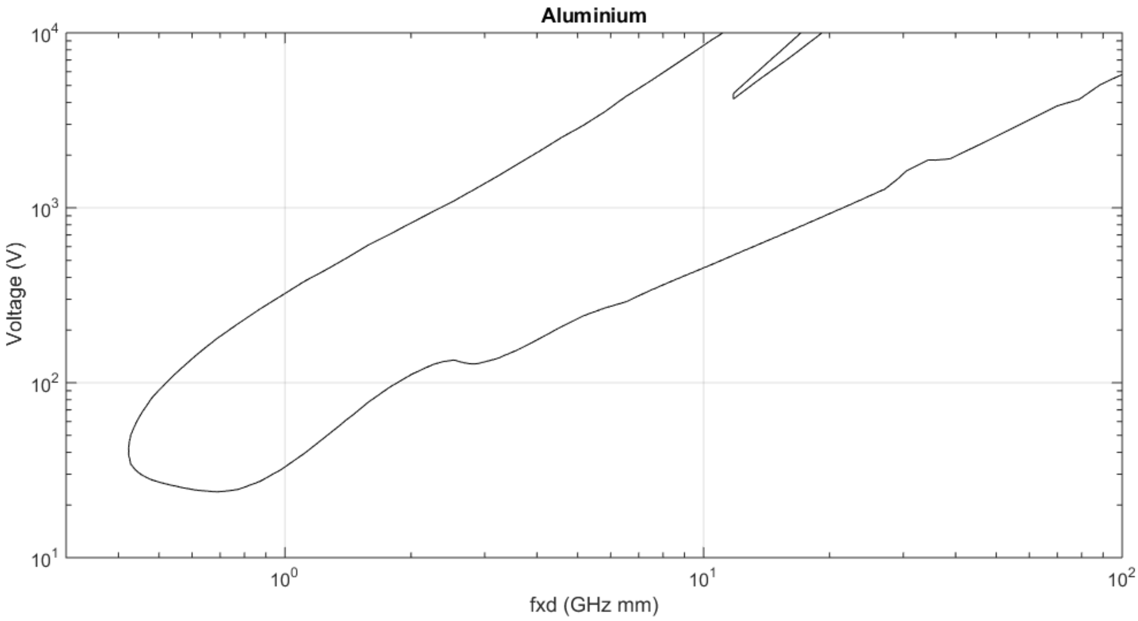

Figure 5-1: Multipactor chart for standard Aluminium obtained with parameters from Table 9-1

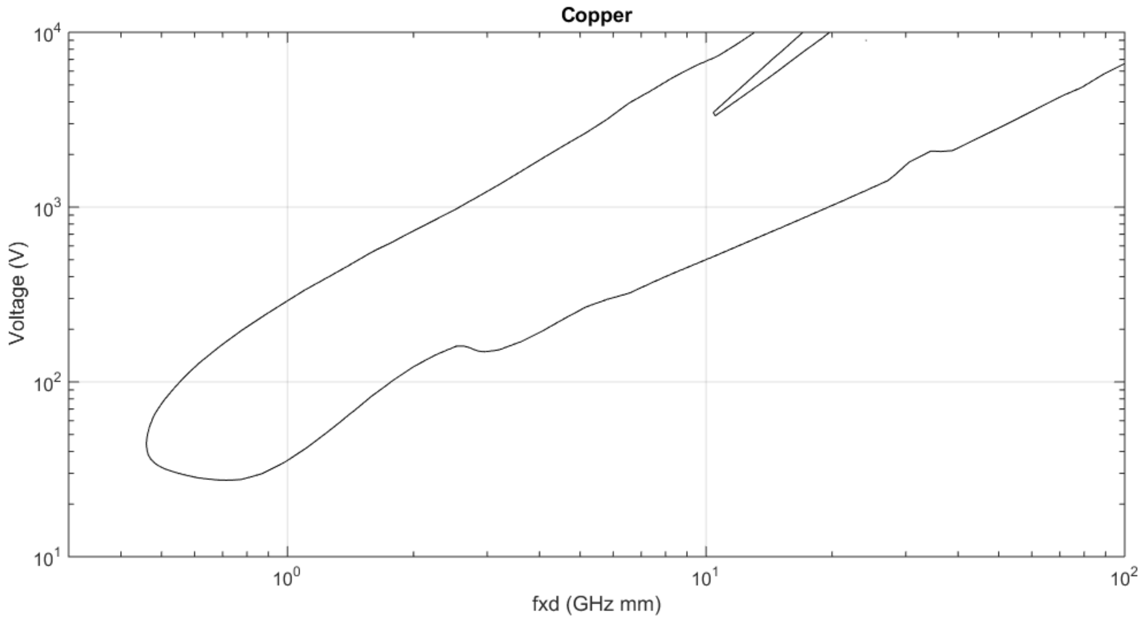

Figure 5-2: Multipactor chart for standard Copper obtained with parameters from Table 9-1

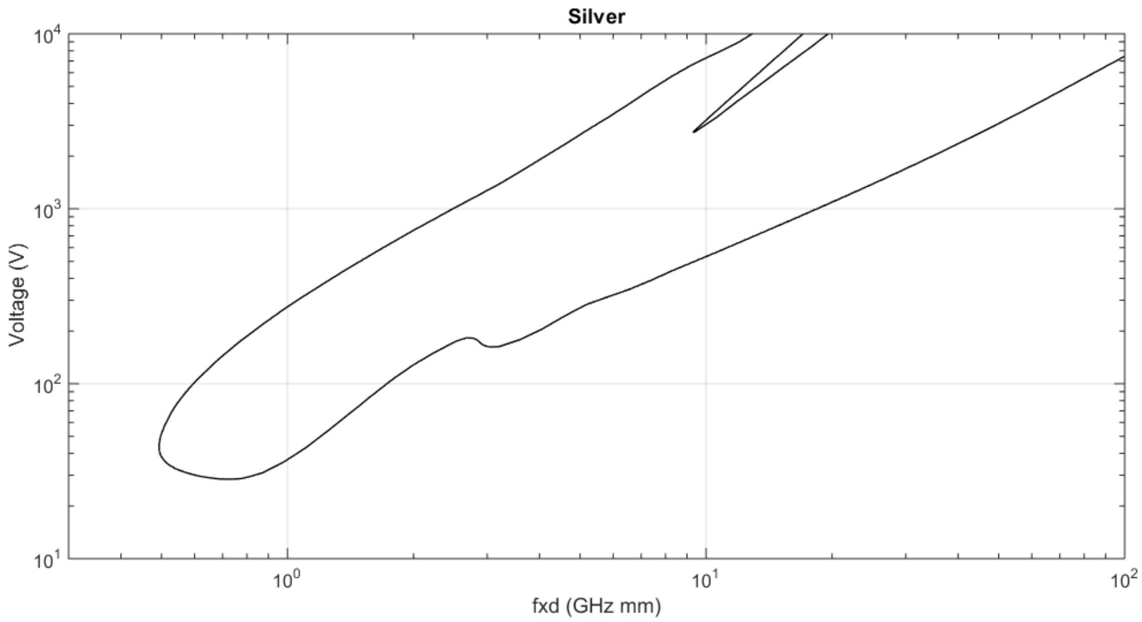

Figure 5-3: Multipactor chart for standard Silver obtained with parameters from Table 9-1

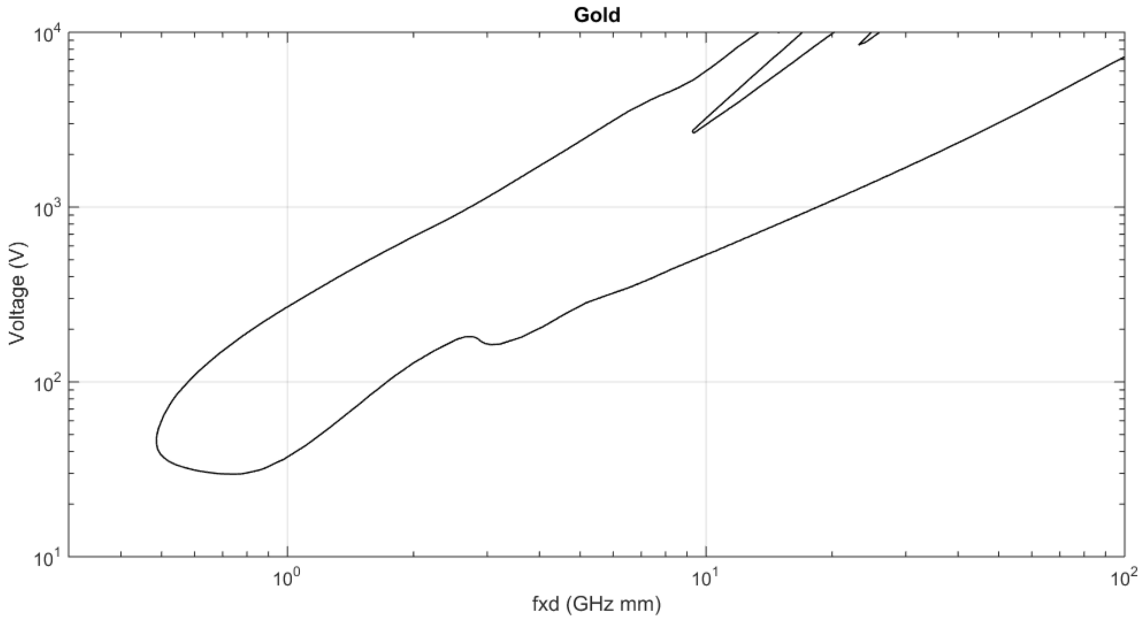

Figure 5-4: Multipactor chart for standard Gold obtained with parameters from Table 9-1

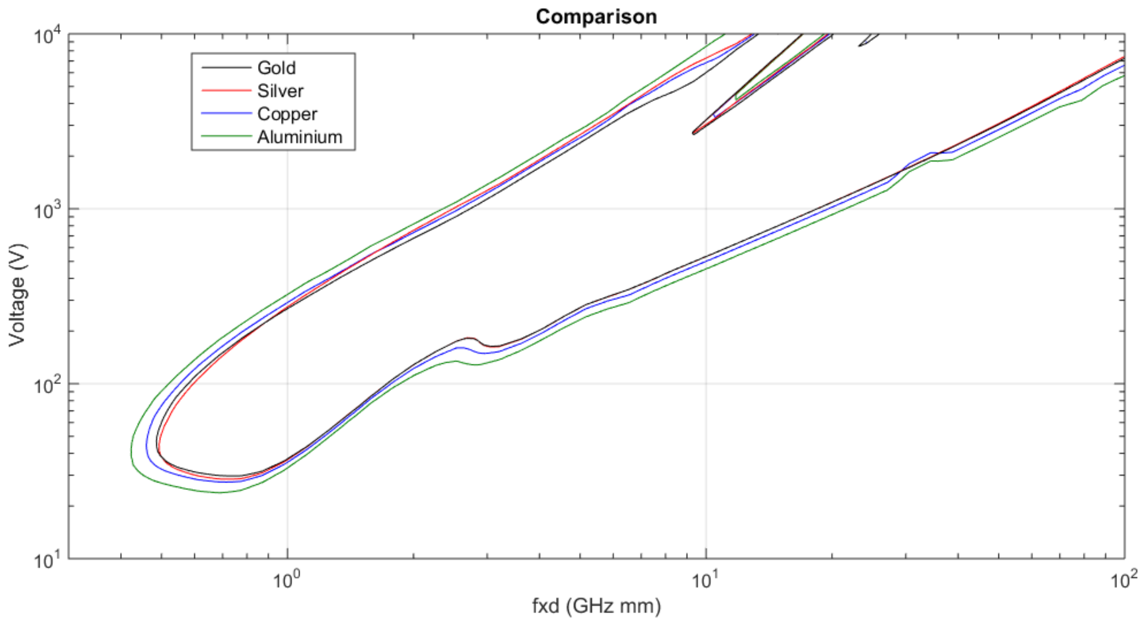

Figure 5-5: Comparison of Multipactor charts for all standard materials obtained with parameters from Table 9-1

6
Multipactor - Test conditions

6.1 Cleanliness

a. Airborne particulate cleanliness class 8 as per ISO 14644-1 or better conditions, shall be maintained throughout the equipment or component assembly, test, delivery and post-delivery phases.

b. In addition, standard clean room practices for handling flight equipment and for general prevention of contamination, agreed with the customer, shall be strictly applied.

c. Protective covers to prevent the ingress of contaminants shall be used.

d. If surfaces are vulnerable to contamination the surface molecular and particle contamination shall be monitored in accordance with clause 5.4.2 of ECSS-Q-ST-70-01.

e. If the contamination monitoring, specified in 6.1d, shows that the specified levels are exceeded, the surface shall be cleaned according to the requirement of clause 5.4.1 of ECSS-Q-ST-70-01.

NOTE Contamination is any unwanted molecular or particulate matter, including microbiological matter, on the surface or in the environment of interest that can affect or degrade the relevant performance or life time.

6.2 Pressure

a. A vacuum bake-out shall be performed on all equipment or components before multipactor testing.

b. The combination of maximum temperature and time duration used for the bake-out shall be equivalent to that which is present in the relevant environment of the satellite payload in orbit.

NOTE The above requirement allows for accelerated bake-out at higher temperatures over relatively short time periods, where the maximum allowable temperature has been approved by the customer. Refer to the ECSS Multipactor handbook ECSS-E-HB-20-01, for further details on determining equivalence of outgassing conditions.

c. Multipactor testing shall be performed at pressures below $1{,}0 \times 10^{-3}$ Pa in the thermal vacuum chamber.

NOTE A lower pressure inside the critical regions of the equipment or component can be achieved by providing an adequate combination of:

- pressure in the vacuum chamber,
- venting design for the equipment or component, and
- time for moisture to outgas from the equipment or component.

d. The pressure in the thermal vacuum chamber shall be monitored continuously during the test.

e. If, as a consequence of the monitoring specified in 6.2d, any unexpected pressure increases are detected, these events shall be noted in the test report and correlated against the readings of the multipactor detection methods.

6.3 Temperature

a. Multipactor tests shall be performed at the temperature extremes defined for the DUT.

b. For P1 equipment or component of type Bm and Cm, test at ambient temperature may be performed if justifications are provided and agreed with the customer, of the non-impact of temperature over any parameter affecting the breakdown threshold.

NOTE Discussions regarding test at ambient can be found in the corresponding clause ECSS Multipactor handbook ECSS-E-HB-20-01.

c. A equipment or component tested at extreme temperatures as described in 6.3a shall be tested at the hot and cold extremes with reference to the relevant temperature range:

1. For qualification tests, the qualification temperature range for EQM and QM.
2. For batch- and unit tests, the acceptance temperature range for PFM and FM.

d. In the case that a reduced temperature range is agreed with the customer, the new temperature limits may be used for the tests specified in 6.3a.

e. As a minimum the Temperature Reference Point (TRP) of the DUT shall be monitored during the complete test duration, for ambient tests as well as for tests performed at extreme temperatures.

f. A maximum acceptable temperature of the TRP shall be specified by the customer.

g. The thermal dissipation in the DUT caused by the selected multipactor test signal profile, CW, pulsed or multi-carrier, shall be analysed.

h. The maximum average power applied during multipactor testing shall be no greater than the value used in the thermal analysis.

6.4 Signal characteristics

6.4.1 Applicable bandwidth

a. The applicable bandwidth for a multipactor test shall be defined as follows:

1. For a qualification test, the applicable bandwidth is the full bandwidth for which the equipment or component is designed.
2. For a batch- or unit test, the applicable bandwidth is the bandwidth, which is applicable for the current project or application.

6.4.2 Single-frequency test case

a. The test frequency shall be determined in accordance with 5.3.1.

6.4.3 Multi-frequency test case

6.4.3.1 General

a. A test with a single carrier, applying an equivalent power as specified in clause 6.4.3.2. shall be performed.

b. If a single carrier test is not possible, a test with a multi-carrier signal, subjected to a frequency multiplex with CW carriers located in accordance with the operational frequency plan and with free-running phase per carrier may be performed under the condition that the test margins and test conditions, including the duration, are agreed between supplier and customer.

c. If the two tests specified in 6.4.3.1a and 6.4.3.1b are not possible a test with a reduced number of carriers applying an equivalent power as specified in clause 6.4.3.3 may be performed with free-running phase per carrier under the condition that the test margins and test conditions, including the duration are agreed between supplier and customer.

6.4.3.2 Multi-frequency test with a single carrier applying an equivalent power

a. For the multi-carrier tests performed with an equivalent CW single carrier, test margins of Table 4-5 shall be applied.

b. A single carrier equivalent power for a test as described under 6.4.3.2a above shall be defined as follows:

1. perform a single carrier analysis at the average frequency of the multicarrier signal in accordance with clause 5.3.2.1 and 5.3.2.2.3

for L1 or 5.3.2.3.2 for L2 where the threshold power in Watts is denoted $P_{th,sc}$,

2. perform a multicarrier analysis on the same analysis level, L1 or L2,as the single carrier analysis specified in 1 above,
3. calculate the average threshold power in Watts, sum of all carrier power values, found in the multicarrier analysis, denoted $P_{th,mc}$ with *m* the number of carriers, using for both, the single carrier and the multi carrier analysis, identical design charts, identical electromagnetic computational model as well as identical material parameters and geometry definitions,
4. calculate the equivalent power for a single carrier test of a multicarrier device using following formula: $P_{eq,sc} = P_0 \cdot P_{th,sc}/P_{th,mc}$, where P0 is the nominal multicarrier average power in Watts, sum of all carrier power values, of the input signal,
5. verify that the computed equivalent power from step 4 for a single carrier test of a multicarrier device is always bounded by $P_0 \leq P_{eq,sc} \leq NP_0$, where N is the number or of carriers,
6. The single carrier test frequency is the average frequency of the multi-carrier signal as for the single carrier analysis in step 1.

NOTE 1 If the single carrier analysis was an L1 analysis performed according to clause 5.3.2.1 and 5.3.2.2.3, the multicarrier analysis is performed according to clauses 5.3.2.1 and 5.3.2.2.4.

NOTE 2 If the single carrier analysis was an L2 analysis performed according to clauses 5.3.2.1 and 5.3.2.3.2, the multicarrier analysis is performed according to clauses 5.3.2.1 and 5.3.2.3.3.

6.4.3.3 Multi-frequency test with reduced number of carriers applying an equivalent power

a. A reduced number of carrier equivalent power for a test as described under 6.4.3.2 shall be defined as follows:

1. Select the reduced frequency plan in order to have the same average frequency and the same voltage envelope period as the original multi-carrier signal.
2. If item 1 is not possible due to test facility constraints, a different frequency plan with a reduced number of carriers can be used in agreement with the customer.
3. Perform a multicarrier analysis for both frequency plans, with reduced number of carrier or not, with the same analysis level in accordance with clause 5.3.2.2.4 for L1 and clause 5.3.2.3.3 for L2,
4. calculate the threshold power found in the multicarrier analysis, denoted $P_{th,mc,n}$, with *n* being the reduced number of carriers compared to $P_{th,mc,m,}$ with m being the original number of carriers, using for both cases identical simulation models.,

5. calculate the equivalent power for a multicarrier test with a reduced number of carriers using following formula:

$$P_{0,mc,n} = P_{0,mc,m} \times P_{th,mc,n}/P_{th,mc,m}$$

Where:

$P_{0,mc,n}$ is the nominal power of the input signal for n carriers

$P_{0,mc,m}$ is the nominal power of the input signal for m carriers

$P_{0,mc,n}$ is the nominal power of the input signal for n carriers

6.4.4 Pulsed testing

a. Pulsed testing may be applied in the cases of equipment or components operating in CW mode.

NOTE For equipment or components operating in CW mode, pulsed testing is an alternative commonly used to avoid thermal effects, which could generate temperature levels in the unit beyond the maximum allowed limits. For this reason, the duty cycle is proportionally and gradually reduced to keep the average CW level constant as the peak power is increased towards the required test margin. This is achieved by varying the PRF between each power step to allow the mean power to be maintained, such that it does not exceed the maximum permitted level.

b. The pulse width shall be equal or greater than 20 microseconds with a duty cycle of at least 2%.

c. The pulse duration used to test equipment or component that experience pulsed excitation in service shall be between 20 microseconds and the longest pulse duration that the equipment or component experiences in service.

d. The suitability of the proposed pulse width and duty cycle as well as compliance with the definition of sensitivity and rise time for the detection methods as described in 7.3.2 and 7.3.3 shall be demonstrated through the reference sample multipactor test according to 8.3b.2.

6.5 Electron seeding

6.5.1 General

a. If seeding is proven to be inefficient on the real DUT at the critical area, the verification by test may be performed on a dedicated BB or EM unit where the design of outer parts and structures is modified in such a way that the critical gaps can be properly seeded.

6.5.2 Multipactor test in CW operation

a. An electron seed source shall be used for CW Multipactor test.

b. Electron seeding may not be used, if the test site demonstrates, with a known reference sample representative of the DUT with respect to the material, the surface properties, the wall thickness and the gap dimensions according to 8.3b.2 that the expected multipactor threshold is achieved.

6.5.3 Multipactor test in pulsed operation

a. An electron seed source shall be used in pulsed testing.

b. In those test cases where electron seeding is ineffective due to restricted access to the critical areas, the test signal shall be in CW mode and validated in accordance with 6.5.2b.

c. If, in a test case as described in 6.5.3b, it is not possible to perform CW test, the pulsed test may be performed using a longer pulse width and higher duty cycle than what is defined in 6.4.4, pending customer approval on a case by case basis.

6.5.4 Multipactor test in multi-carrier operation

a. An electron seed source shall be used in the multi-carrier environment.

b. If the test site demonstrates with a reference sample according to 8.3b.2 that the expected multipactor threshold is achieved, electron seeding may not be used.

6.5.5 Seeding sources

a. Any applied method or technique of electron seeding shall be implemented aiming at the critical gap where multipactor breakdown can occur during the test.

b. If the DUT has more than one critical gap, where a seeding source is required according to 6.5.5a, at least one seeding source shall be used at each critical gap, simultaneously or consecutively.

c. The seeding electrons shall have a direct path to the critical gap where seeding is required.

NOTE For a radioactive β source according to 6.5.5d.4, the direct path requirement is applicable to the secondary low energy electrons.

d. At least one of the following seeding sources shall be used:

1. UV light source, which produces electrons by the photoemission mechanism.
2. An electron gun, which produces a known beam of electrons where both the energy and flux can be characterised.

3. A charged wire probe, which produces electrons by the point discharge mechanism.

4. Radioactive β source, which produces high-energy electrons that, after impacting with metal surfaces or propagation though metallic or dielectric walls, yield a supply of secondary low energy seed electrons.

   NOTE If a metallic or dielectric wall is too thick, the high-energy electrons will not be able to propagate and the supply of secondary low energy electrons will not be sufficient. Recommendations for wall thickness are provided in the Multipactor handbook ECSS-E-HB-20-01.

6.5.6 Seeding verification

a. It shall be verified during the test facility validation, according to clause 8.3, using the chosen detection methods and a reference sample with a known multipactor threshold, that the seeding method is able to produce a sufficient number of seed electrons in the critical gaps of the DUT.

b. The reference sample shall have a geometry, which allows for a representative path of the seeding electrons compared to the seeding electron path of the DUT.

   NOTE Further guidelines can be found in the Multipactor handbook ECSS-E-HB-20-01.

7 Multipactor - Methods of detection

7.1 General

This clause defines the minimum requirements for the detection methods used for multipactor testing. Details of such test methods are included in the Multipactor handbook ECSS-E-HB-20-01.

7.2 Detection methods

a. The detection methods shall be selected from the following list:

1. Global methods:
   (a) Close to carrier noise
   (b) Phase noise
   (c) Harmonic noise
   (d) Phase nulling.
   (e) Pulse envelope detection
   (f) Low-level amplitude modulation of test signal
2. Local methods:
   (a) Optical
   (b) Electron probe
3. Novel detection methods, providing demonstration of its effectiveness and validation as per clause 7.3.

b. At least two detection methods shall be present in the test configuration and at least one of them be a global method.

NOTE It is good practise to use both local and global detection methods simultaneously.

7.3 Detection method parameters

7.3.1 Verification

a. The testing entity shall verify that the detection methods selected are able to detect multipactor events.

b. The verification specified in 7.3.1a shall be done during the test facility validation, according to 8.3b.2, using the chosen detection methods and a reference sample with a known multipactor threshold.

NOTE Further guidelines can be found in the Multipactor Handbook ECSS-E-HB-20-01.

7.3.2 Sensitivity

a. When phase nulling is used as a detection technique, it shall be tuned regularly throughout the test campaign by minimising the null level, in order to maximise detection sensitivity.

NOTE It is good practice that the lowest residual level of the nulling system is kept at least 45 dB below the level obtained with only one of the two nulling paths connected to the detection system.

b. When harmonic detection is used, the residual harmonic level in the test system shall be minimised, in order to improve detection sensitivity.

NOTE It is good practice to keep the residual harmonics system level at least 100 dBc with respect to the carrier power level.

c. The testing entity shall ensure that neither the DUT nor any of the equipment or components of the test bed itself is rejecting the selected harmonic frequency.

d. For pulsed signal tests, the signal from the phase nulling and the residual harmonics detection systems shall be sampled with a frequency that is sufficient to detect multipactor events on single pulses.

NOTE For pulsed signals, it is good practice that the sampling rate is sufficient to provide at least 10 points during each single pulse.

e. For CW tests, the sampling density shall be such that short events are not missed.

NOTE For CW signals, a sampling rate of at least 1 kHz is best practice.

f. The bandwidth of each detection system shall be sufficient to detect signal variations with at least the same resolution in the time domain as the interval between sampling points.

NOTE The sampling rate of the monitoring equipment is determined by the combination of the sweep time and the number of points in a sweep.

g. A global detection system shall be considered triggered when the residual level, nominal response without discharge, experiences a significant increment with respect to the peak residual level.

NOTE An increment can be considered significant if it has a magnitude larger than 5 dB – 6 dB. The triggering of the global detection method complies with the nature of a Multipactor breakdown discharge (sudden, self-extinguished after its ignition), in order to avoid misleading diagnostics (e.g. thermal issues on the device under test confused for multipactor discharge).

h. In local detection methods, electron probe and photodetection, the following conditions should be met:

1. electron probe current noise floor be lower than 10^{-11} A with a sampling rate of at least 1 reading/second.
2. photo electron probe noise floor not exceeding |0,5| V with a sampling rate of at least 1 reading/second.

i. A local detection system shall be considered triggered when the measured value experiences an abrupt variation, significantly higher than the typical deviation measured in the last minute of the measurement.

NOTE An increment can be considered significant if it has a magnitude larger than 4 times the typical deviation measured in the last minute of the measurement.

7.3.3 Rise time

a. Each global detection method selected shall have a rise time of less than one tenth of the RF pulse width applied to the DUT in single carrier.

NOTE This does not apply to local detection methods, which are technologically limited to longer rise times.

b. For multicarrier operations the rise times shall be short enough to detect breakdown within the period of the multicarrier signal envelope.

NOTE For multi-carrier tests, the use of sensitive, short rise time detection methods enables recording of occasional isolated transient events, particularly if a fast seeding environment is provided.

8 Multipactor - Test procedure

8.1 General

a. The execution of a multipactor test shall be controlled by a detailed test procedure aligned with the requirements provided in this clause.

NOTE Further requirements applicable to the test procedure are provided in clause 8.6.

b. Unless otherwise stated, the requirements in clauses 8.2 to 8.7 shall be applicable to single carrier as well as multicarrier tests.

8.2 Test bed configuration

a. The multipactor test bed configuration shall conform to the following conditions, as a minimum:

1. Use calibrated equipment where it is required in a measurement role.
2. Use continuous monitoring of the RF power applied to the test item.
3. Provide continuous thermal monitoring and control for the test item.
4. Use continuous pressure monitoring within the vacuum chamber.
5. Use detection methods in accordance with 7.2.
6. Use seeding source in accordance with 6.5.5
7. Provide RF signal generation and amplification.

b. All reference planes used for RF power monitoring shall be calibrated at the test frequency or frequencies.

c. As a minimum, the following two reference planes shall be identified for the calibration specified in 8.2b:

1. The reference plane corresponding to the input port of the test item where input and reverse power are monitored.
2. The reference plane corresponding to the output port of the test item where the transmit power is monitored.
3. Multiport test items, like circulators typically need multiple reference planes.

NOTE 1 Multiport test items, like circulators typically need multiple reference planes.

NOTE 2 It is good practise to use a sliding short at the output port to ensure in-phase condition at the critical gap.

NOTE 3 RF items with only one port, such as antennas and loads can be treated on a case by case basis as agreed with the customer.

d. If any element of the RF chain was modified, replaced, added or removed, the calibration shall be repeated.

e. The return loss seen from the DUT output port into the test setup at the reference plane described in 8.2c.2 shall be equal or better than -18 dB.

f. In case of deviation from requirement 8.2e, the supplier shall propose a correction action to be agreed with the customer.

NOTE This correction action can be an increment on the input RF power proportional to the mismatch.

8.3 Test bed validation

a. Validation of the test bed shall consist of two distinct steps defined in requirement 8.3b and 8.3c.

b. The first step shall be performed immediately before the multipactor test of the equipment, according to the following sequence:

1. Demonstration of the multipactor-free operation of the test bed, using a transmission line thru replacing the DUT, conducted up to at least the maximum input power foreseen during the test.
2. Demonstration of the correct functioning of all detection systems and seeding sources used conducted by using a reference sample with a known multipactor threshold.

NOTE 1 See also 6.5.6 Seeding verification and 7.3.1 Verification.

NOTE 2 The maximum input power includes the sum of nominal power, the mismatch correction (if applicable) and the test margin.

NOTE 3 The seeding configuration during the verification of multipactor-free test bed operation is representative of the configuration during the test of the DUT. If, for example, a coaxial connector at the DUT input port is irradiated by a radioactive β source during the test of the DUT, the same connector is irradiated in a similar way also during the verification. Parts of the test bed that are not affected by the seeding during the test of the

DUT are not necessarily not seeded during the verification.

NOTE 4 Recommendations concerning the reference sample can be found in the Handbook.

c. The second step shall be performed immediately after the multipactor test of the equipment, depending on its outcome.

d. If a multipactor discharge was detected during the test, the demonstration of the multipactor-free operation of the test bed as per requirement 8.3b.1 shall be repeated and the verification be performed at the maximum power level the DUT was subject to and, if possible, at higher power levels to include margin for potential surface conditioning of the test setup.

NOTE The purpose of this test is to exclude the test setup as a potential root cause of the observed discharge. Surface conditioning caused by the first discharge (if in the setup) can increase the multipactor threshold of the setup, therefore additional power can be applied if possible.

e. If no multipactor discharge was observed during the test, the demonstration of the correct functioning of all detection systems and seeding sources as per requirement 8.3b.2 shall be repeated.

f. The test bed validation as per requirement b.1 shall be performed at the same pressure and temperature conditions as for the equipment test.

g. For extended or multiple tests with an identical configuration, the validation should be periodically repeated at a rate proposed by the supplier and agreed with the customer.

h. If any element of the RF chain was modified, replaced, added or removed, the validation shall be repeated.

8.4 Test sequence

a. The S-parameters of the equipment or component to be tested shall be measured at the test site prior to multipactor testing within a frequency range including all frequencies relevant to the detection systems of the test setup.

NOTE 1 The purpose of the S-parameter measurement prior to multipactor testing is:

- to document the status of the equipment or component at the test start, after transportation to the test site (if applicable),
- to provide the possibility to compare the performance of the equipment or component before and after the multipactor test.

- determine the suitability of the detection methods to be used (for example harmonic detection).

NOTE 2 An illustration of the test sequence is given in Figure 8-1.

b. The RF interfaces shall be calibrated according to 8.2b.

c. The test bed shall be validated according to clause 8.3.

d. The vacuum chamber containing the test equipment shall be evacuated and baked-out for a sufficiently long period to enable adequate venting and outgassing according to 6.2a, 6.2b and 6.2c.

e. The test on the equipment shall be performed by applying first the lowest test power, and then increasing in steps to the maximum test power.

f. The power profile versus time shall be determined considering the following test parameters:

1. Signal characteristics; CW, pulsed, pulse duration, duty cycle, multicarrier, modulation,
2. Power compensation for return loss seen by the DUT output port, if applicable,
3. Seeding,
4. Maximum test power,
5. Thermal stabilisation time when applicable.

NOTE 1 It is good practice that the power profile includes several intermediate power steps including the nominal power level.

NOTE 2 Recommended methods to define levels and time duration for the power steps can be found in the Multipactor handbook ECSS-E-HB-20-01.

g. During the test as a minimum the following parameters shall continuously be monitored and recorded:

1. Responses from the detection systems,
2. Return loss and insertion loss of the equipment or component,
3. Input power,
4. Temperature,
5. Pressure.

NOTE It is good practice to use a common time base for all recordings.

h. Any detected pressure rise above the value specified in clause 6.2 or temperature above the maximum allowed value at the TRP according to requirement 6.3f shall cause an interruption of the test until satisfactory conditions are restored.

i. During the stepping up of test power, the definitions, and acceptance criteria defined in clause 8.5 shall be applied.

NOTE An illustration of the test sequence is given in Figure 8-1.

j. After reviewing all the test results, the vacuum chamber shall be returned to ambient pressure.

k. On completion of the test, validation according to 8.3c shall be performed.

l. The S-parameters of the tested equipment or component shall be measured at the test site after multipactor testing.

NOTE The purpose of the S-parameter test after multipactor testing is to document the status of the equipment or component after the test, before shipping the equipment or component from the test site (if applicable). Comparisons of S-parameter measurements before and after the multipactor tests are not primarily intended to be used to detect signs of multipactor discharges but can of course be part of an investigation as defined in 8.5.4.

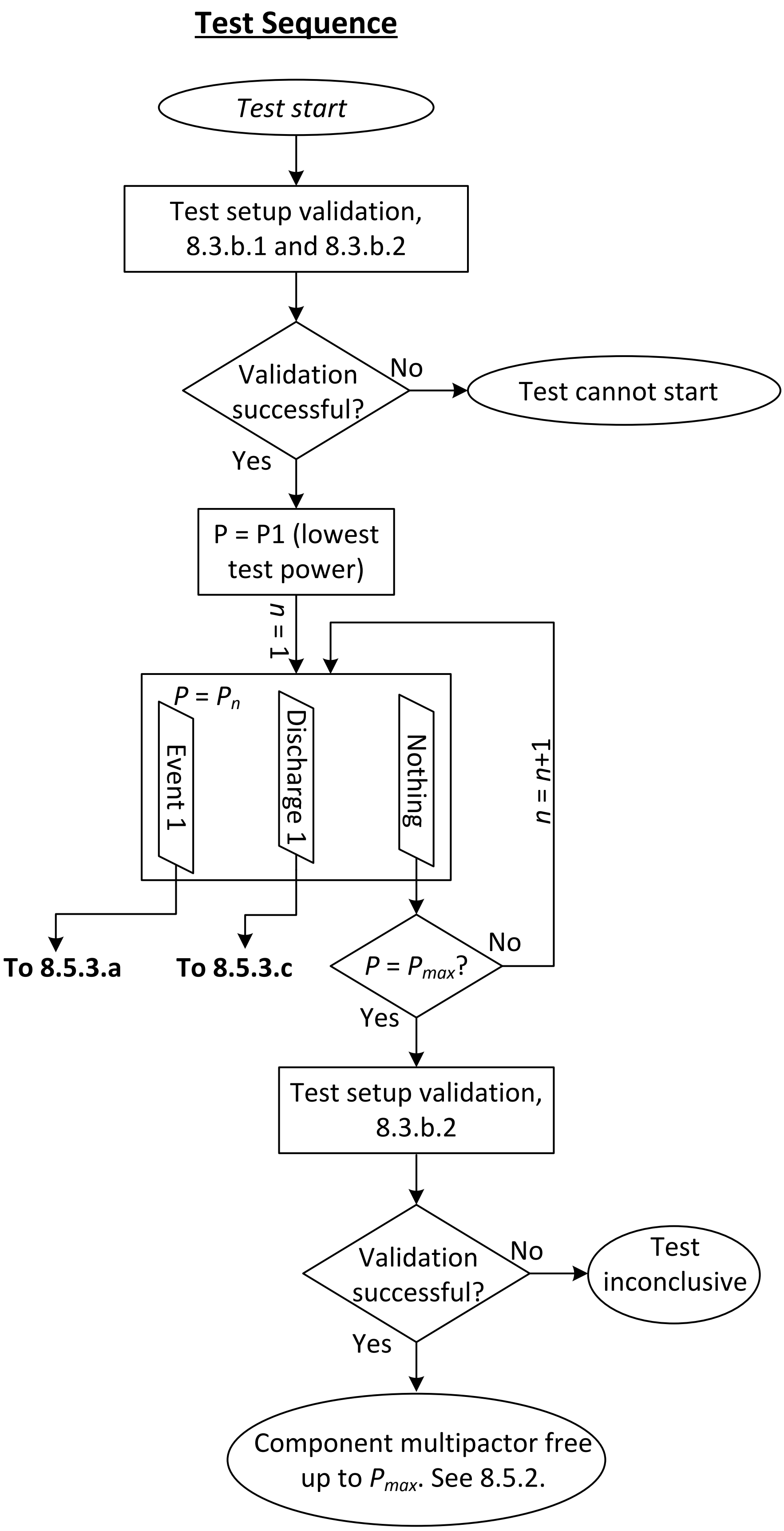

Figure 8-1: Illustration of test sequence

8.5 Acceptance criteria

8.5.1 Definitions

For all evaluations related to the requirements in clause 8.5, it is reminded that the definitions of the terms "**Event**" 3.2.8 "Discharge" 3.2.15 and "Multipactor Discharge Threshold" 3.2.16 are strictly applied.

8.5.2 Multipactor Free Equipment or component

a. The tested equipment or component may be declared multipactor free up to the maximum test power if:

   1. No multipactor discharge or event was detected during the test in any of the detection systems at any input power up to the maximum test power, and

   2. the test setup was successfully validated before and after the test according to 8.3b and 8.3b respectively.

b. On a case by case basis, pending customer approval, the equipment or component may be declared multipactor free up to the maximum test power if:

   1. Investigations related to events or to a single non-repeatable discharge as described in clause 8.5.4 lead to the conclusion that the observed phenomena are not related to multipactor, and

   2. the test setup was been successfully validated before and after the test according to 8.3b and 8.3b respectively.

8.5.3 Steps in case of Discharges or Events during test

a. If one or several events are detected at power level *n* during the measurement, the following steps shall be taken:

   1. Keep the power constant at power level *n* for the remaining dwell time after the last event.

   2. If the power level *n* is equal to the maximum test power, perform an investigation according to 8.5.4 in order to establish the cause of the event.

   3. After completing the power step where event or events were detected, continue the test with the next power level, *n*+1.

   4. If further events are detected at power level *n*+1, repeat the procedure from steps 1, 2 or 3.

   5. If a discharge is detected during steps 1, 2 or 3 stop the test and take the multipactor discharge threshold as the level where the first event was observed.

   6. If no event or discharge is detected during step 3, continue the test with power level *n*+2.

7. If further events are detected at power level *n*+2 or higher, repeat the procedure from steps 1, 2 and 3.

8. If a discharge is detected at power level *n*+2 or higher, continue the test in accordance with the procedure for discharges in 8.5.3c and once the test is completed select, pending on the test result either:

   (a) to take the multipactor threshold as the level where the first event was observed during the test, or.

   (b) if an investigation in accordance with clause 8.5.4 concludes that the first event or events seen during the test were not related to multipactor, perform, pending customer approval, the determination of the multipactor threshold according to the procedure for discharges in 8.5.3c.

9. If no further events or discharges are detected during the subsequent power steps up to the maximum test power, perform an investigation in accordance with clause 8.5.4 in order to explain the detected event or events.

   NOTE An illustration of the various steps is given in Figure 8-2.

b. The results of the investigation of 8.5.3a.9 shall be reported to the customer to conclude on the nature of the discharge or event.

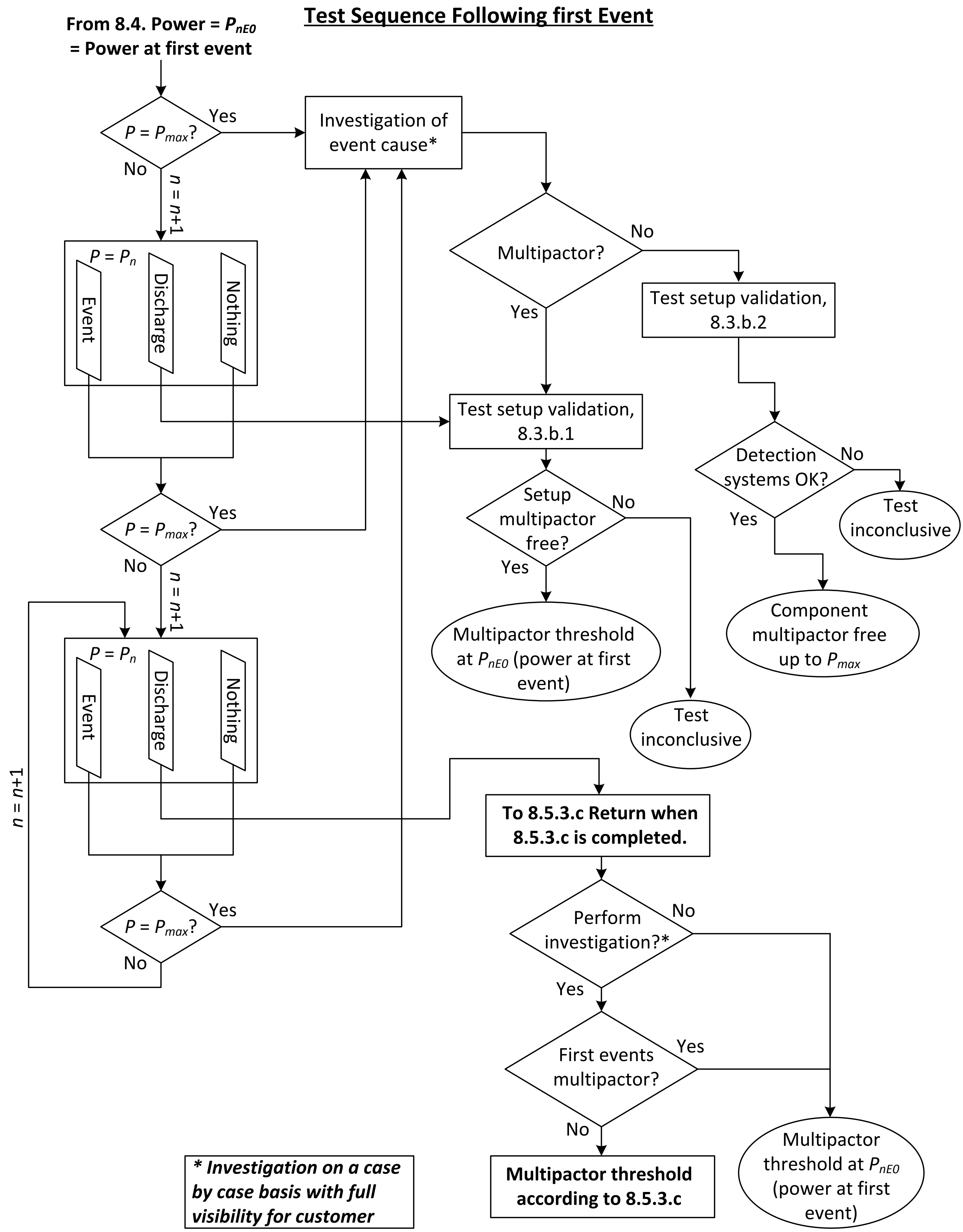

Figure 8-2: Illustration of test sequence following first Event

c. If a-discharge is detected at power level *n* during the measurement, the following steps shall be taken:

1. Reduce the power until no discharges or events are detected.
2. Keep the power at the level at which no discharges or events were detected for the nominal duration of a power step.
3. Bring back the power to level *n*, where the first discharge was detected and keep it for the nominal duration of a power step.
4. If no further discharge or event was detected during step 3, continue the test with the subsequent power steps until either a second event or discharge is detected or the maximum specified test power is reached.
5. If, during steps 3 and 4, events or discharges occur, record the lowest power level where a discharge was detected as the multipactor discharge threshold.
6. If, during steps 3 and 4, no events or discharges occur, select, pending on the test result either:
   (a) take the multipactor threshold as the level where the single discharge was observed during the test, or
   (b) perform an investigation in accordance with clause 8.5.4 in order to explain the detected potential discharge.

   NOTE An illustration of the various steps is given in Figure 8-3.

d. The results of the investigation of 8.5.3c.6(b) shall be reported to the customer to conclude on the nature of the discharge or event.

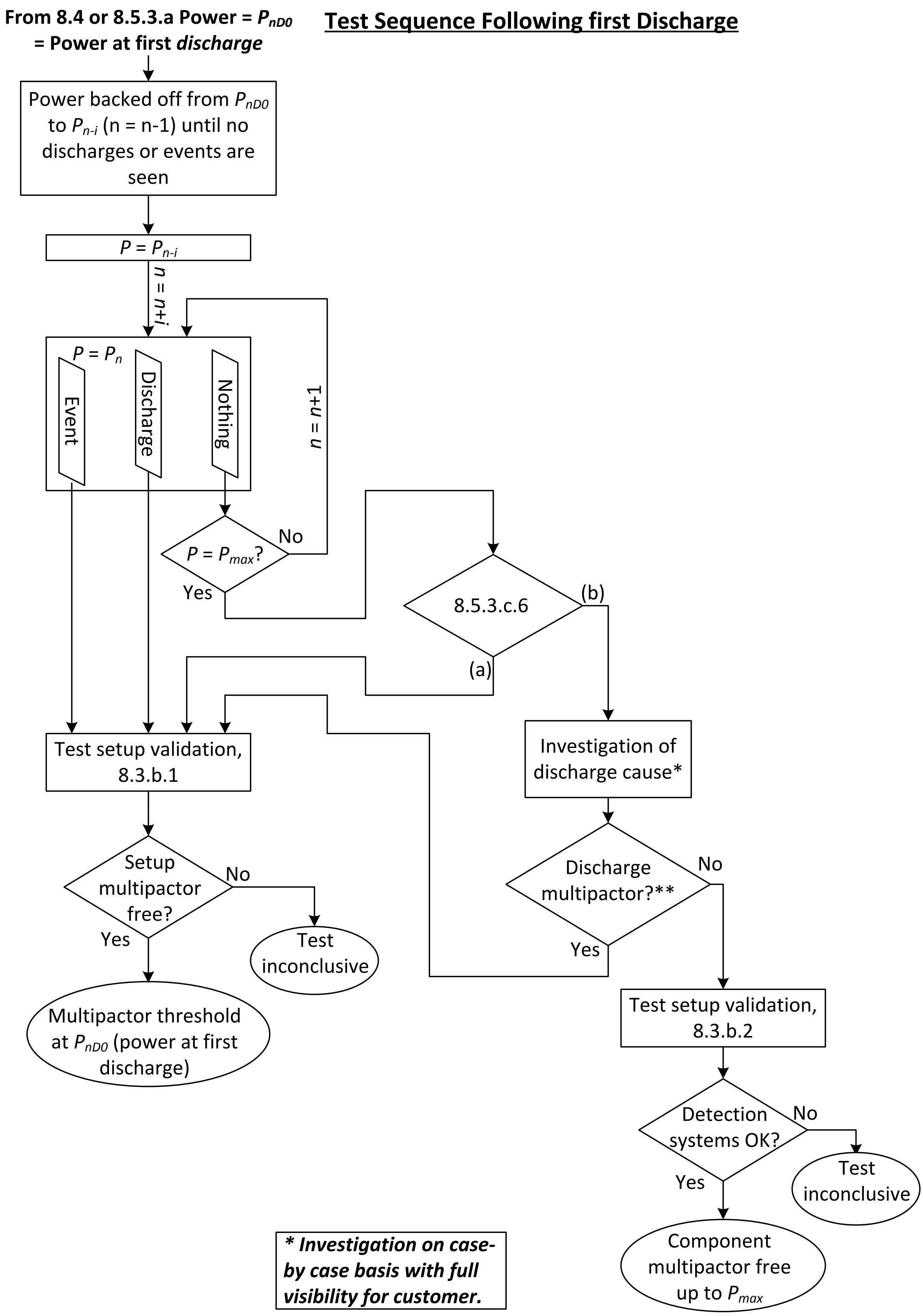

Figure 8-3: Illustration of test sequence following first potential discharge

8.5.4 Investigation of Test Anomalies

a. If non-repeatable or ambiguous events or discharges have occurred, an investigation shall be performed in order to determine the root cause of the event, events or isolated discharge that was observed.

NOTE This investigation can include:

- Continued testing at higher power levels or lower duty cycle, pending approval of the customer.
- Venting of the chamber, followed by a repeated test.
- Validation of the test bed, repeating one or more of the steps described in clause 8.3.
- Evaluation of the conditions under which the event or discharge occurred. For example; Test witness getting close to the test bed, unexpected test bed shock, abrupt increment in temperature leading to a return loss change, fluctuations in the high power amplifier.
- Other aspects that are motivated by the experience and knowledge of the equipment or component supplier, the test supplier or the customer.

b. The investigation of test anomalies shall be performed on a case by case basis, with full visibility for the customer.

c. The investigation and the associated conclusions shall be documented in the test report, see clause 8.7.

8.6 Test procedure

a. The test procedure, in accordance with the DRD of Annex C in ECSS-E-ST-10-03, shall be provided to the customer for approval and include, as a minimum, the following items:

1. List of reference and applicable documents
2. Detailed description of the equipment or component
3. Detailed description of the test bed, as per clause 8.2.
4. Test bed validation process according, as per clause 8.3.
5. Test parameters and detection methods to be used
6. Definition of maximum test power
7. Test sequence including power profile, as per clause 8.4.
8. Success criteria
9. Aborting criteria, when applicable.

NOTE Testing procedures for high power RF loads that are meant to be used in TVAC testing campaigns are described in the Multipactor handbook.

8.7 Test reporting

a. The test report, in accordance with the DRD of Annex C in ECSS-E-ST-10-02, shall be provided to the customer for approval and include, as a minimum, the following items:

1. A detailed test configuration describing the test set-up for each equipment or component, including:
   (a) The test setup block diagram,
   (b) Measurement accuracy (pressure, temperature and RF power),
   (c) Locations and description of the seeding sources.
2. S-parameter Measurements of the sample before and after the multipactor test campaign.
3. Records over time of the environmental conditions of the DUT including temperature, pressure.
4. Evidence of the test setup validation without DUT including the frequency and the maximum power applied.
5. Evidence of the test setup validation with the reference sample including:
   (a) Test frequency,
   (b) Duty cycle,
   (c) Input power profile versus time,
   (d) Expected Multipactor threshold power,
   (e) Detection System responses at the detected discharges and/or events.
6. Report of the Test with the DUT including:
   (a) Thermal bake-out parameters,
   (b) Test frequencies,
   (c) Duty cycle,
   (d) Input power profile versus time,
   (e) List of events,
   (f) Detection System responses,
   (g) Achieved Power w/o Multipactor.
7. A list of all equipment used during the test campaign including calibration dates where relevant.
8. If applicable, investigation and the associated conclusions performed according to clause 8.5.4.
9. Conformances and deviations.

9 Secondary electron emission yield requirements

9.1 General

In this standard, the SEY is the total secondary electron emission yield.

9.2 SEY measurements justification

a. If the manufacturing process or the material of any potential critical gap is changed, a representative SEY sample of the new equipment or component shall be used for SEY measurements.

NOTE Any change of manufacturing process and any change of materials can be traced by means of DPL and DML according to ECSS-Q-ST-70.

b. The stability of the SEY parameters due to ageing shall be verified by SEY or Multipactor measurements.

c. SEY measurements results shall be documented in a SEY Test Report to be agreed with the customer.

NOTE The SEY measurement results can be included in the qualification report of the associated material or process.

9.3 Worst case SEY measurement

a. The worst case SEY measurements, for a set of SEY curves for a given material, shall correspond to the highest SEY value for each primary energy of the full primary energy range versus representative environmental conditions during life time.

NOTE Representative environmental condition during life time include at least temperature and ageing.

b. In case of unexpected SEY measurement results, an investigation shall be performed and documented.

9.4 SEY measurements conditions

9.4.1 Environmental conditions

9.4.1.1 Handling, storage and transportation

a. For all SEY samples, handling, storage and transportation shall be performed according to ECSS-Q-ST-20-08 or ESCC 20600.

b. Each SEY sample shall have a dedicated logbook according to the DRD of ECSS-Q-ST-20 Annex C.

9.4.1.2 Cleanliness

a. The cleanliness and contamination control policy shall be in accordance with the ECSS-Q-ST-70-01.

b. Preliminary visual inspection shall be performed on the item to be measured, in order to detect any presence of visible defects, artefacts and contaminations.

c. SEY measurement shall be performed on samples without preliminary treatment "as received" unless stated differently by the customer.

9.4.1.3 Pressure

a. The SEY measurement shall be conducted using a high vacuum facility $\leq 10^{-6}$ hPa.

9.4.1.4 Temperature

a. The temperature range of the SEY measurement shall be specified by the supplier and approved by the customer.

9.4.2 SEY test bed conditions

9.4.2.1 Incident electron energy

a. SEY measurements of conductive and dielectric materials shall be performed from the lowest primary electron energy to an incident energy level corresponding to 1 keV including the first cross-over energy (E1) for SEY=1.

b. The minimum primary electron energy achievable at the sample surface shall be as low as possible with a minimum value of at least 5 eV.

9.4.2.2 Incident angle

a. The incident angle of the e-beam with respect to the normal to the surface of the sample at the incident point shall be 0° ±2°, unless other angles are specified by the customer.

9.4.2.3 Electron dose

a. The incident electron dose shall not produce surface conditioning effects, modifications or charging effects of the dielectrics.

9.4.2.4 Charging requirements for dielectric samples

a. Before SEY measurements, the SEY dielectric sample shall be discharged to minimize the magnitude and the space dispersion of the surface voltage and considered as the reference condition.

b. For each incident energy, this reference condition shall be recovered.

c. The reproducibility of the SEY curve shall be verified by measurement.

9.4.3 SEY sample characteristics

a. SEY samples for characterization shall be manufactured with surface treatments representative of the manufacturing process and materials corresponding to the RF equipment according to DPL and DML documents.

NOTE SEY measurements can be performed on the SEY samples or on the actual equipment or component.

b. The spot size of the electron beam shall be smaller than the size of the SEY sample and a SEY average value over the whole sample area be guaranteed.

9.5 SEY measurements procedure

9.5.1 SEY Measurements procedure documents

a. The SEY measurements procedure shall include as a minimum the following items:

1. List of reference and applicable documents,
2. Description of the sample,
3. Description of the SEY measurements facility,
4. SEY measurements facility calibration process,
5. Measurements parameters,
6. Measurements sequence.

NOTE 1 The sample is labelled and traced by the customer.

NOTE 2 An example of the SEY measurement procedure can be found in the Multipactor handbook ECSS-E-HB-20-01.

b. The SEY measurements report shall include the following information as a minimum:

1. A detailed measurements configuration describing the SEY measurements facility,
2. A list of all equipment used during the SEY measurements campaign including calibration dates where relevant,
3. Measurements data, including SEY as a function of the primary electron energy with uncertainties, if any, and the values of the following SEY parameters:
   (a) first cross-over energy (E1) for SEY=1,
   (b) maximum of the SEY (SEY_max), and
   (c) primary energy corresponding to the maximum (Emax).

9.5.2 SEY measurement calibration

a. Calibration of the SEY measurements facility shall be performed and the results made available to the customer.

9.6 ECSS SEY data selection

a. In the case companies do not have representative SEY data to perform the analysis, the experimental SEY data of the Table 9-1 for Al, Au, Cu and Ag materials shall be used.

NOTE SEY data from Table 9-1 are taken from average values of experimental measurements of more than 20 samples for each different material. Measurements were performed at normal incidence of the primary electrons and at room temperature. The SEY samples of this table were exposed to the air. See the Multipactor handbook ECSS-E-HB-20-01 for more information.

Table 9-1: SEY parameters for Al, Cu, Au and Ag materials

Material	E1	SEY_max	Emax	SEY_0
Al	17	2,92	276	0,8
Cu	19	2,48	232	0,8
Au	21	2,23	212	0,8
Ag	20	2,34	315	0,8
NOTE: The values of SEY_0 are extrapolated values for zero energy				

Annex A (informative) Multipactor document delivery per review

Scope of the Table A-1 is to present relation of documents associated to activities to support project review objectives as specified in ECSS-M-ST-10.

NOTE Table A-1 constitutes a first indication for the data package content at various reviews. The full content of such data package is established as part of the contractual agreement, which also defines the delivery of the document between reviews.

The table lists the documents necessary for the project reviews.

The various document versions in a row indicate the increased levels of maturity progressively expected versus reviews. The last document versions in a row indicates that at that review the document is expected to be completed and finalized.

NOTE All documents, even when not marked as deliverables in Table A-1, are expected to be available and maintained under configuration management as per ECSS-M-ST-40 (e.g. to allow for backtracking in case of changes).

For better understanding of the Phase Review during which the relevant document is provided, the following assumptions are given:

- All document deliveries are given for equipment or components under development, while for other types of equipment or components the table content can be different and tailored consequently.

Table A-1: Multipactor deliverable document per review

Document or DRD title	EQSR	SRR	PDR	CDR	TRR	TRB
Equipment or component Statement of Compliance to Equipment or component Specifications	Final					
Design Justification File(*)		Preliminary	Preliminary	Final		
Multipactor Analysis			Preliminary	Final (including definition of the analysis margin)		
Multipactor Test Spec & Proc				Preliminary	Final (including definition of the test margin)	
Multipactor Test Result						Final (Multipactor acceptance of the equipment)
(*): Operational Power is justified in the Design Justification File.						

Bibliography

ECSS-S-ST-00	ECSS system – Description, implementation and general requirements
ECSS-Q-ST-70	ECSS product assurance – Materials, mechanical parts and processes