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Standard

Standard/Handbook for Multipactor Breakdown Prevention in Spacecraft Components

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Standard/Handbook for Multipactor Breakdown Prevention in Spacecraft Components

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Abstract

This document is intended to provide a standardized process for mitigation of multipactor breakdown within spacecraft components. It is directed toward component designers, satellite system engineers, as well as the customer community to provide worst-case conditions, margin requirements, and verification of these requirements using state-of-the-art methodologies. In addition, recommended methods are provided, with examples, to ensure proper requirement verification for all satellite RF components susceptible to RF breakdown.

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Foreword

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Introduction

This document is intended to provide a standardized process for mitigation of multipactor breakdown within spacecraft components. It is directed toward component designers, satellite system engineers, as well as the customer community to provide worst-case conditions, margin requirements, and verification of those requirements using state-of-the-art methodologies. In addition, recommended methods are provided, with examples, to ensure proper requirement verification for all satellite RF components susceptible to RF breakdown.

The importance of applying the processes and risk mitigation strategies of this document continue to grow with the increase in component power levels. Multipactor and ionization breakdown can lead to device damage and/or significant mission impact; as such, this document provides methodologies to minimize potential risks in applicable RF systems and components. Many of the recent RF breakdown-related issues can be traced back to a lack of standard processes for analysis and test. The processes described in this document are focused on predicting bounding, worst-case conditions for known system parameters and applying these conditions to a broad range of components and RF systems. This new and alternative approach removes excessive, hidden, or stacked margins by using bounding case calculations and measurable/available data for the particular system and component under investigation. Worst-case conditions are combined with standard analysis and test processes to minimize device susceptibility to multipactor.

The document is organized to follow this process in a typical component development flow, starting with high-level component definitions and determination of worst-case system parameters. Subsequent sections continue the process by providing margin requirements and then minimum requirement verifications. These minimum verification requirements utilize state-of-the-art tools for both analysis and test, and they are necessary to avoid many of the failures observed in recent history. Lastly, recommended analysis and test guidelines are provided to illustrate industry best practices and considerations for different component types. A reference geometry for analysis and test validation is also provided as a standard to the industry for comparison purposes.

This document provides new benefits to customer, contractor, and supplier groups by providing clear margin definitions and requirements, while removing excessive margin through the application of this bounding case process. Proper implementation of the latest analysis techniques can, in some cases, eliminate the need for expensive qualification/acceptance testing with more accurate and representative numerical analysis. Adherence to test requirements will provide risk reduction and early issue identification and prevent expensive failures late into the integration cycle. By following the requirements and process outlined in this document, multipactor risk within spacecraft components should be minimized throughout the component life cycle.

In summary, multipactor risk mitigation is made possible via this document through proper and careful analysis processes, test methods, and application of the process detailed in this document.

1 Scope

1.1 Purpose

This document is intended to serve as a standard and handbook for the prevention of multipactor breakdown in spacecraft components and systems. The document provides minimum requirements for risk definition, system analysis, and component analysis and test. Supporting documentation describes proper design, analysis, and test guidelines while also providing the requirements for defining the proper system engineering to identify RF breakdown risks within susceptible components. The document framework is based on defining worst-case parameters as general inputs to analysis or test criteria for all components within the RF system. Using hardware-specific values, these worst-case parameters are defined separately from margin requirements.

With properly defined worst-case conditions, the document addresses required margins for analysis and test for multiple devices categories. Subsequent sections provide minimum verification requirements to demonstrate the margin recommendations for both analysis and test. Applicability of different analysis and test methods to the device class categories is provided, with special cases and considerations.

Multiple appendices based on state-of-the-art industry best practices are also provided as guidelines to aid manufacturers and contractors. Typical approaches including examples for both design and test are provided. A reference geometry is described along with corresponding analysis and test data. This information can be used as a benchmark standard, such that component vendors and manufacturers can have a standard example for RF breakdown.

Incorporating this document and its improved process into the development and test cycles of an RF component will reduce the risks associated with multipactor breakdown failure. The document goal is to concurrently reduce program risk as well as elevated cost of excessive margin requirements. This document shall serve as a baseline and minimum set of criteria for low-risk development and verification of RF spacecraft components.

1.2 Document Applicability and Features

This document is intended for RF and microwave satellite systems and component manufacturers. AIAA ABC provides an overall process approach for multipactor breakdown mitigation using new tools, data, and current industry best practices. Some of the highlighted features of AIAA ABC are:

A device classification structure is given, allowing more specific margin requirements to be levied on the different groupings. The classifications are separated such that verification plans can be tailored to the analysis level of the device and certainty of the electric fields and multipactor regions.

A system analysis process to determine the bounding input power for each device under consideration is provided. Parameters such as voltage enhancement due to voltage standing wave ratio (VSWR) can be accurately predicted, or evaluated, from the actual system hardware.

Margin requirements for component analysis and test are given. Using a complete system and component process, over-conservatism is minimized using improved system knowledge, application of new simulation tools, and refined test methods.

New and expanded minimum verification requirements for analysis and test are provided. Recommended methodologies using the latest technologies and tools are given for reference. Analysis verification requirements utilize classification by device analysis level to allow tailored application of different analysis methods and techniques