Investigation of fatigue and failure mechanisms of low power isolators and circulators
Abstract

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This Abstract summarizies all the work performed during the ESA TRP activity “Investigation of fatigue and failure mechanisms of low power circulators and isolators” according to ESA invitation to tender AO/1-6664/10/NL/NA. A presentation of this work has been made during the 2013 ESA Space Passive Component Days Symposium at ESTEC (https://escies.org/download/webDocumentFile?id=60875)

Ferrite devices are key hardware in satellite payloads but their reliability aspects are not well documented and especially, there is no evaluation or qualification data available in the ESCC system.

The objective of this ESA funded TRP project is to identify and validate the failure and fatigue mechanisms of low power ferrite devices such as circulators and isolators and to assess experimentally the maximum allowable stress levels and so the data necessary for the ESCC specifications (e.g. for derating, screening and qualification).

In task 1, a technical survey has been performed to identify the different technologies, their markets and the competition analysis. An analysis of the constitutive materials, assembly parameters, RF performances and applicable requirements of these passive RF devices has been made.

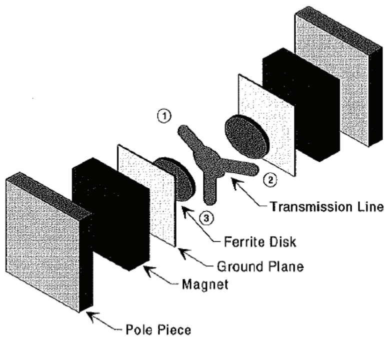

Fig. 1. Stripline circulator construction

Fig. 2. Coaxial isolator

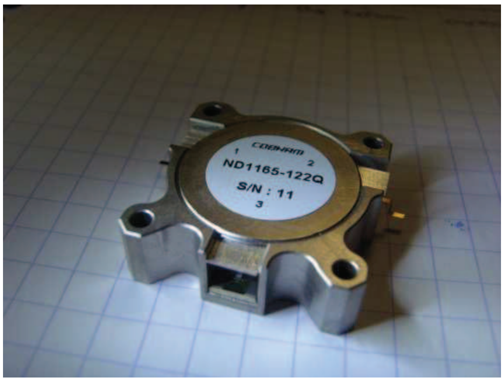

Fig. 3. Drop-In isolator

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In task 2, the failure mechanisms of ferrite devices are reviewed, with description of the relevant laws, physics of failure, and acceleration models. Finite Element Analysis as well as acceleration and fatigue life prediction models are used to predict the maximum stress testing levels (temperature, vibration, shock and RF power) and the maximum number of cycles for fatigue.

In task 3, the relevant documentation of the selected devices has been established (PID, detail specification, FMECA).

In task 4, the fatigue and failure laws are applied and validated for a drop-in isolator structure selected for the evaluation activity. This is done by means of a mechanical analysis using Finite Element Modeling.

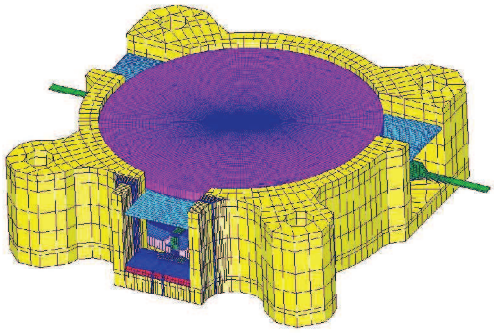

Fig. 4. Finite Element Model of the Isolator structure under investigation

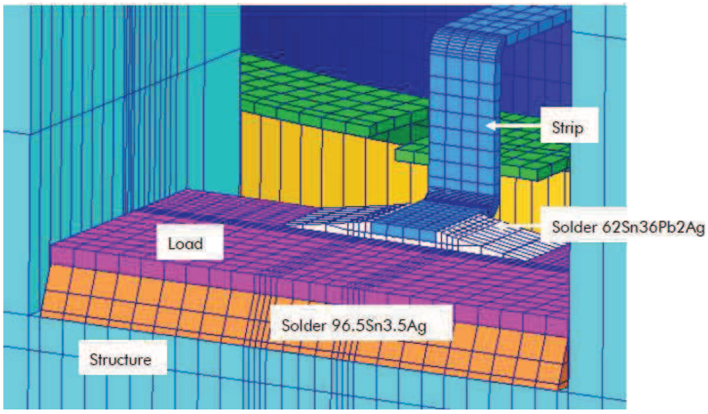

Fig. 5. Zoom on the solder area (chip load to housing and strip to load assembly)

In Task 5, an Evaluation Test Plan based on ESCC requirements is defined and implemented on test units in order to verify these failure predictions.

In task 6, the evaluation devices are manufactured and the evaluation testing is performed and analysed in the final task 7.

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The conclusions of this activity are the following:

- The ESCC 3202 Qualification levels have been confirmed and margins have been assessed.
- Several failures, never seen through all qualifications, have been detected at higher stress levels giving a better knowledge of potential issues and indicating some potential improvements on design and procurement specifications.
- An actual assessment of the accuracy of the mechanical simulations (FEM, thermoelastic and creep/fatigue) shows their limited reliability of the results due to large uncertainty in the models, in the pre-load estimations and in the mechanical properties of some materials.
- Some arguments are provided for the improvement of the relevant ESCC and ECSS specifications