Space L-band high power ferrite isolator

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A. Verger[1], E. Laroche[1], J.-L. Roux[2]

[1]*Cobham Microwave*
31 Avenue de la Baltique, 91978 Villebon Sur Yvette Cedex, FRANCE
Email:aurelie.verger@cobham.com
eric.laroche@cobham.com

[2]*CNES*
18 Avenue Edouard Belin, 31401 Toulouse, FRANCE
Email: Jean-Luc.Roux@cnes.fr

INTRODUCTION

In recent years, power capability of amplifiers used in telecommunication or GPS payloads increased continuously. Consequently, ferrite isolators, which protect amplifiers, must be designed to be used at such power levels. It is for this purpose that Cobham Microwave, based on more than 30 years of space experience in high power ferrite isolators, designed L-band coaxial isolators able to handle power levels as high as 200W-CW. This paper will present the results of a CNES funded R&T project which objective is to design, realize and evaluate L-band high power isolator. All aspects: microwave, thermal and mechanical behavior, according to space requirements (ESCC3202 and major payload manufacturers), are taken into account to design isolators that will give the best trade-off to users.

FERRITE ISOLATORS DESCRIPTION

The typical junction isolator is made up of a 3 port stripline circuit sandwiched between 2 ferrites. An isolator transmits a signal in one direction only. The signal applied at port 1 is transmit to port 2, signal entering port2 is directed to port 3 and also port3 to port1. Port 3 is terminated in a 50 Ω load. The signal passes from port1 to port2 with low loss called "Insertion loss". Generally, insertion losses are better than 0.5 dB. In the reverse direction, from port 2 to port1, the signal passes with high loss. As such, it's used to "Isolate" one RF device from another. The typical values of isolation are 20 dB.

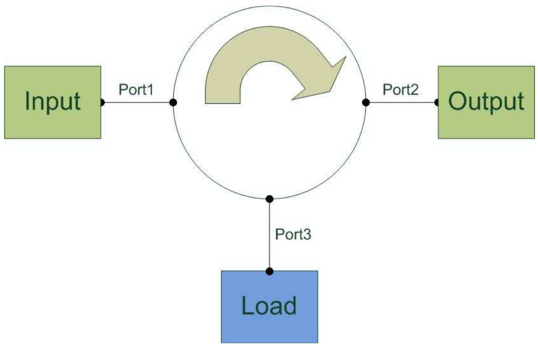

Fig.1. Principle of an isolator

The three port junction function is made by a strip line structure. Moreover, ferrite disks are used in conjunction with permanent magnets to assure the non-reciprocal effect of microwave signal in the junction. The ferrite material used shows non linear effects, a good stability in the temperature range and low insertion losses.
The gyromagnetism effect in ferrite material is a phenomena which does not need any power supply : only a permanent magnet included in the isolator provide the necessary field to create the circulation , only in one way , assuring an isolation between the amplifiers and the other equipments
To make an isolator, we have load on port 3. The chip load is dimensioned to present a good VSWR within the operating frequency and temperature range.
Each equipment type shall be provisioned with high power handling TNC female connectors. The isolator TNC connectors are designed to comply with MIL-STD-348A. These connectors are equipped with venting holes.

Cobham have performed a thermal analysis with SolidWorks [1]. Indeed, the body size is an important parameter. High power such 200 W induced high temperatures inside isolator. So, the body should dissipate temperature, considering all derating limits (glue, connectors, ...). All the computations take into account the Temperature Reference Point (TRP) at +85°C.
This analysis shows the hot spot for all elements of the isolator. Fig.2 shows the temperature in nominal and short-circuit condition, for 200 W power with no heat flux cable. All temperatures are compliant with maximum acceptable temperatures (materials and processes) in both mode.

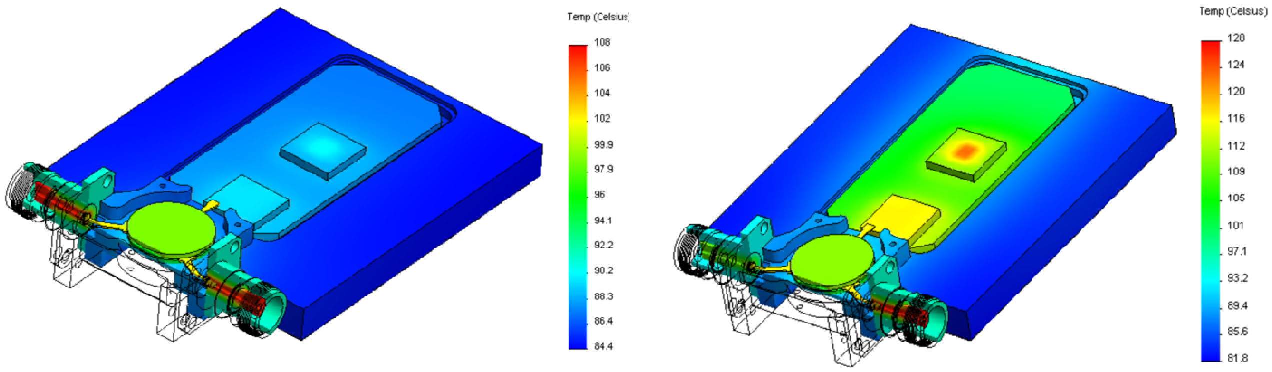

Fig.2. Temperature diagram for 200 W in nominal and short-circuit condition

A mechanical analysis, made by MECANO I&D confirms that the design is compliant with ESCC Generic Specification No. 3202, Issue 1, October 2002.

Moreover the design and process take into account multipactor effect.

Finally, the isolator design used to realize L-band high power ferrite isolator is shown on Fig.3. The external element dimensions are 100x70x25mm.

Fig.3. L-band isolator design

L-BAND ISOLATOR MEASUREMENTS

Through the CNES contract, we have particularly study two bandwidths: 1.15 GHz – 1.25 GHz and 1.55 GHz – 1.65 GHz in order to cover the global L-band frequency. In this paper we present the results for the lower band.
All tests presented below are performed in Cobham except vibration test.

RF Measurements

The RF measurements have been made at three temperatures: ambient, low and high, considering high and low temperatures respectively 85°C and -30°C. As we can see on Fig.4, insertion loss are better than 0.23 dB, isolation better than 21 dB and return loss at input and output port better than 22 dB.

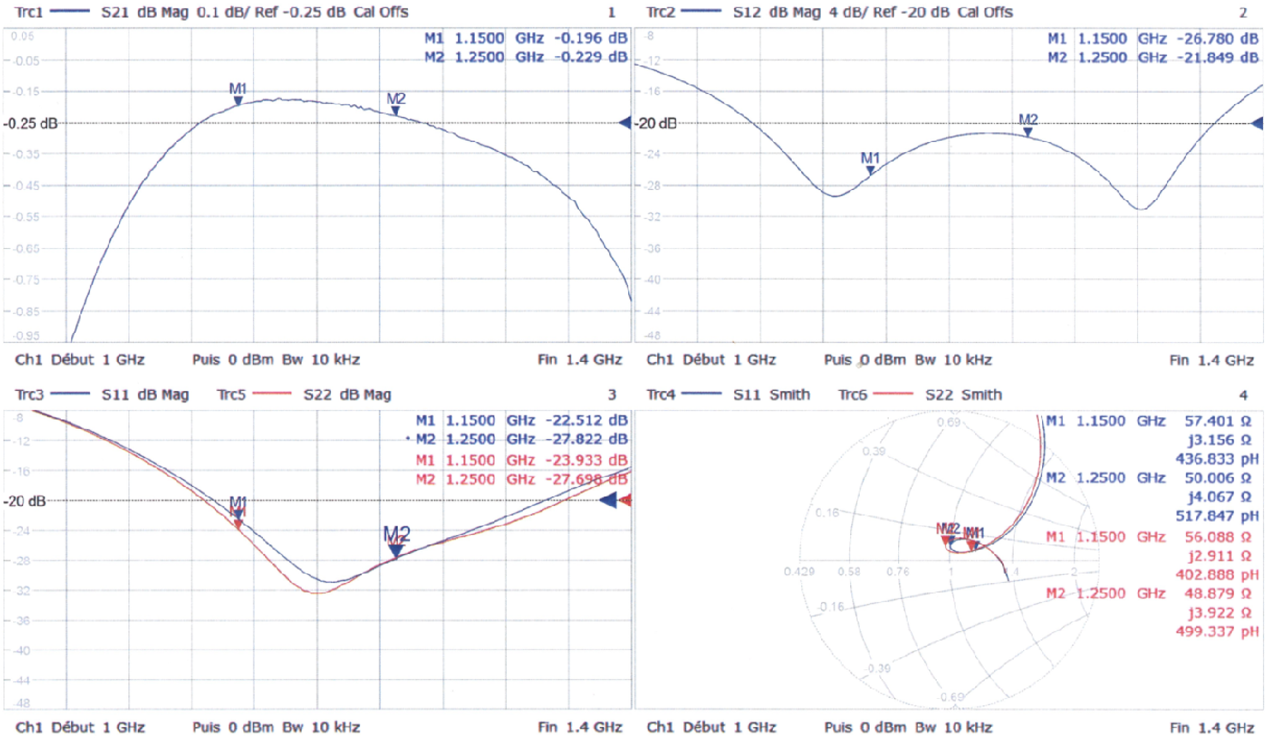

Fig.4. RF measurements at 25°C

Fig.5 presents the measurement at 85°C. As we can see, there is a shift due to ferrite and magnet behavior. So insertion loss decreases to 0.33 dB with isolation better than 21 dB and return loss better than 26 dB.

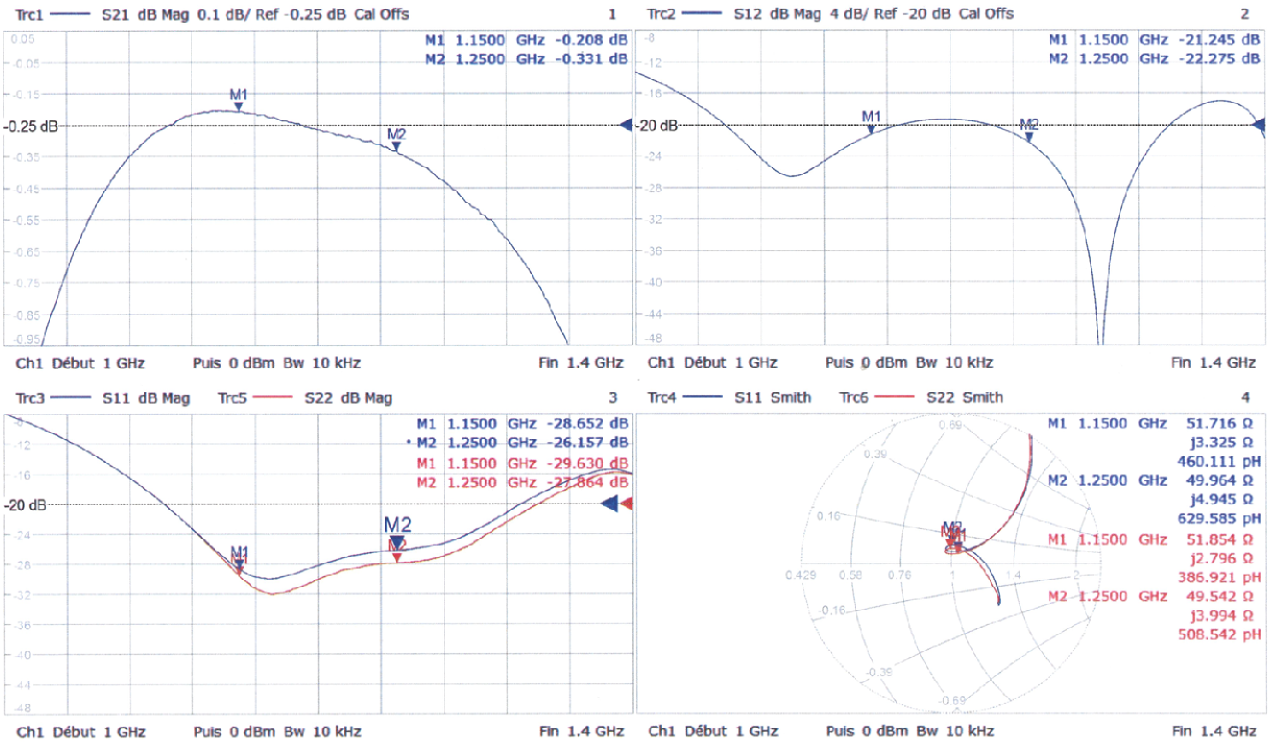

Fig.5. RF measurements at 85°C

The electrical performances at cold temperature (-30°C), shown on Fig.6, are better than 0.27 dB, isolation better than 24 dB and return loss at input and output port better than 22 dB.

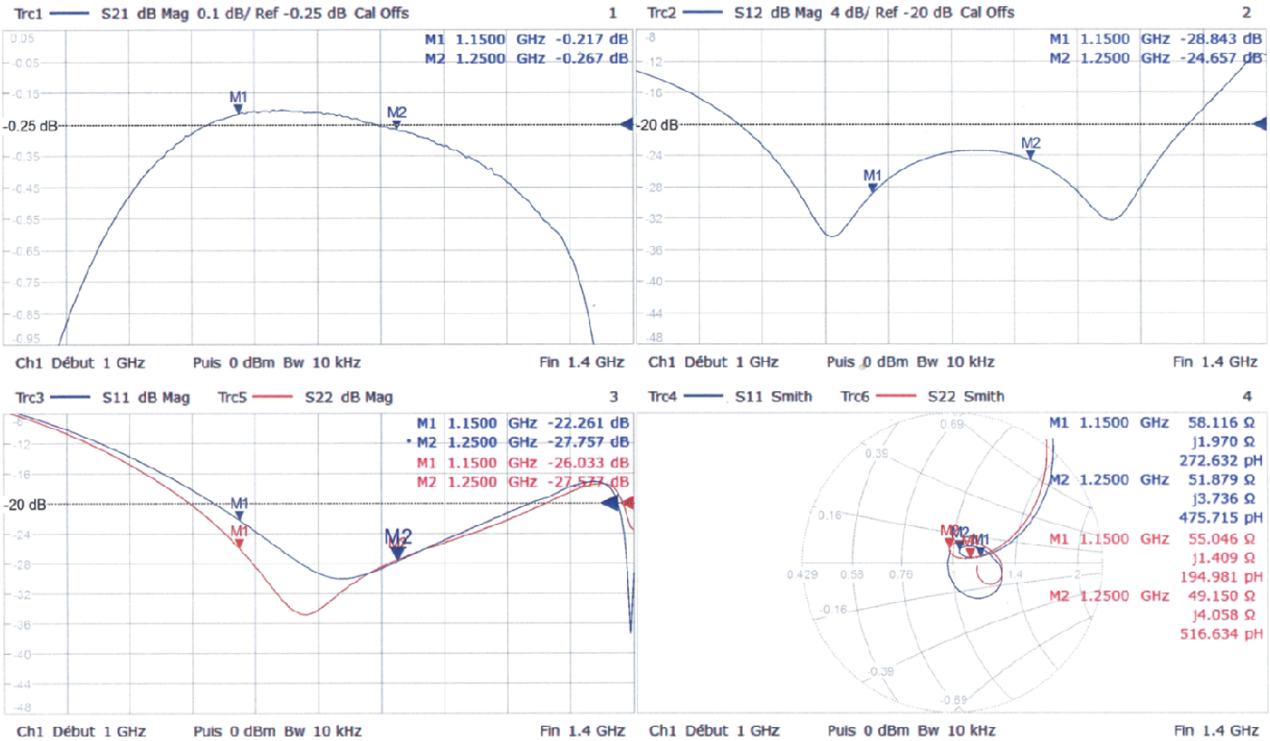

Fig.6. RF measurements at -30°C

Glitch test

The isolator was subjected to temperature cycling between -30°C and +85°C. During these two cycles, the insertion loss, measured at the center frequency of the isolator, is continuously monitored and recorded once 100 ms. The success criteria of this test is no discontinuity, step or spike shall exceed 0.1 dB. Fig.7 shows the glitch measurement for an isolator at 1.20 GHz. This isolator is free of glitch.

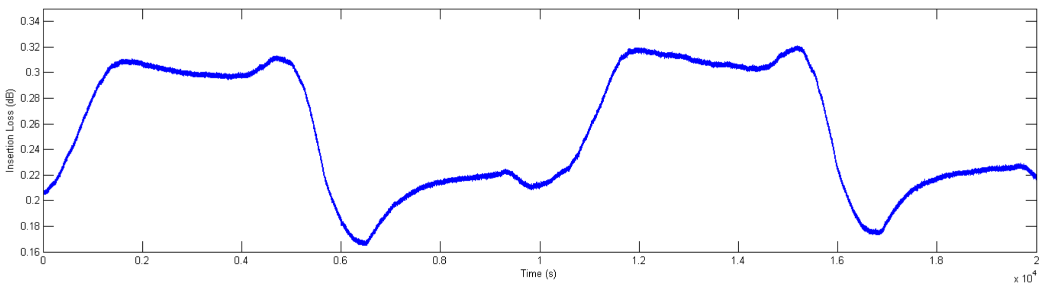

Fig.7. Glitch test measurement

EMC test

This test is made in a Faraday cage with absorbing materials in order to avoid multiple reflections on metallic walls in the cage. The test consists in research of the maximum value radiated by the isolator. Fig.8 shows the measurement for an isolator at 1.2 GHz. For a measurement of -82 dBm, the corresponding shielding effectiveness is 77 dBi.

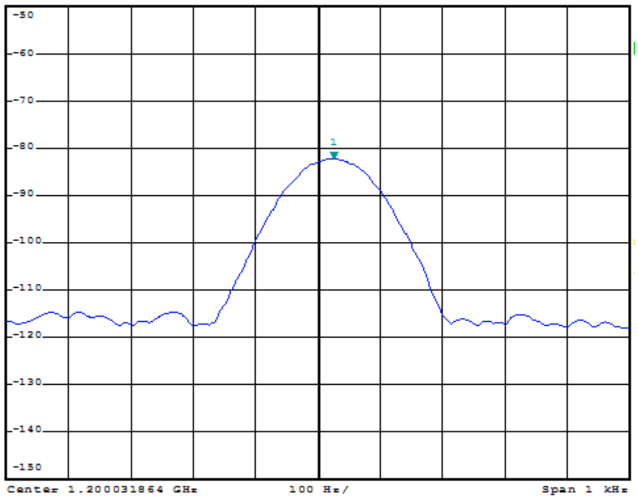

Fig.8. EMC measurement

Temperature cycling

An endurance temperature cycling was made with an other part with bandwidth requirements of 50 MHz. Indeed, 200 cycles between -40°C and +90°C were applied. The RF measurements at ambient temperature before and after this test are similar as we can see on Fig.9 and Fig.10.

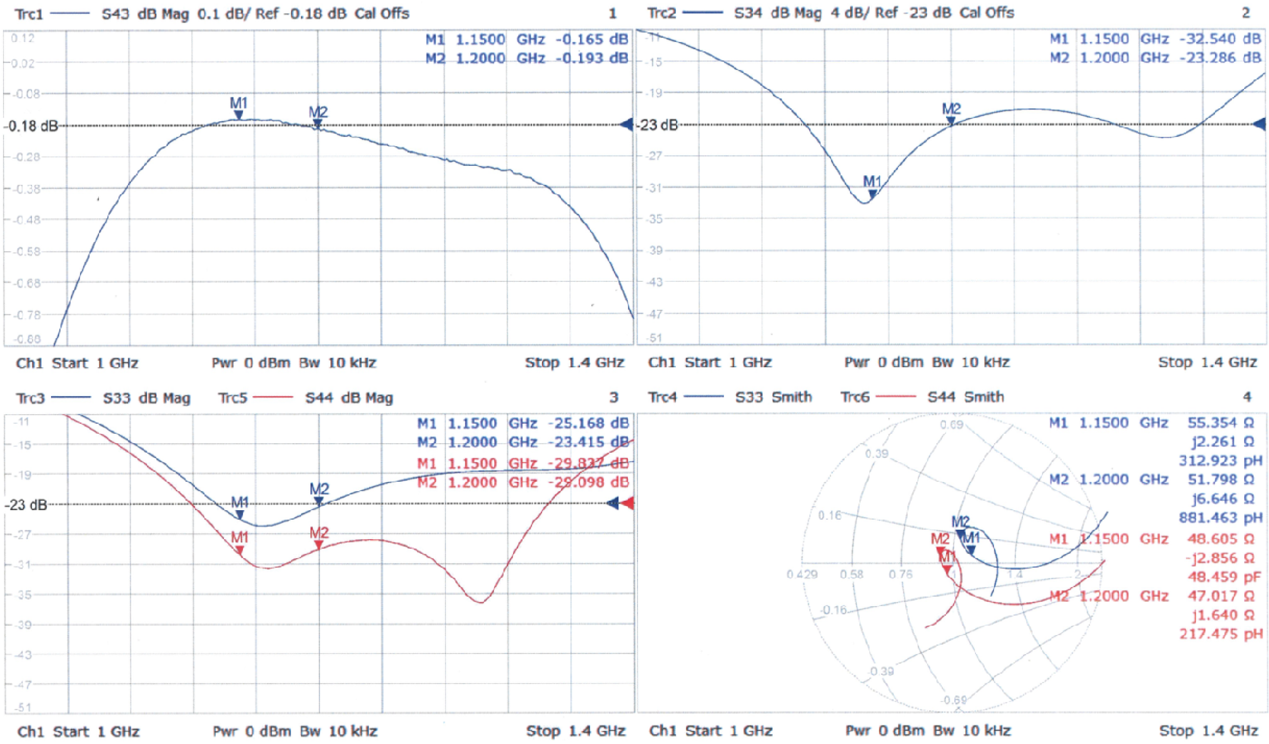

Fig.9. RF measurement before temperature cycling at 25°C

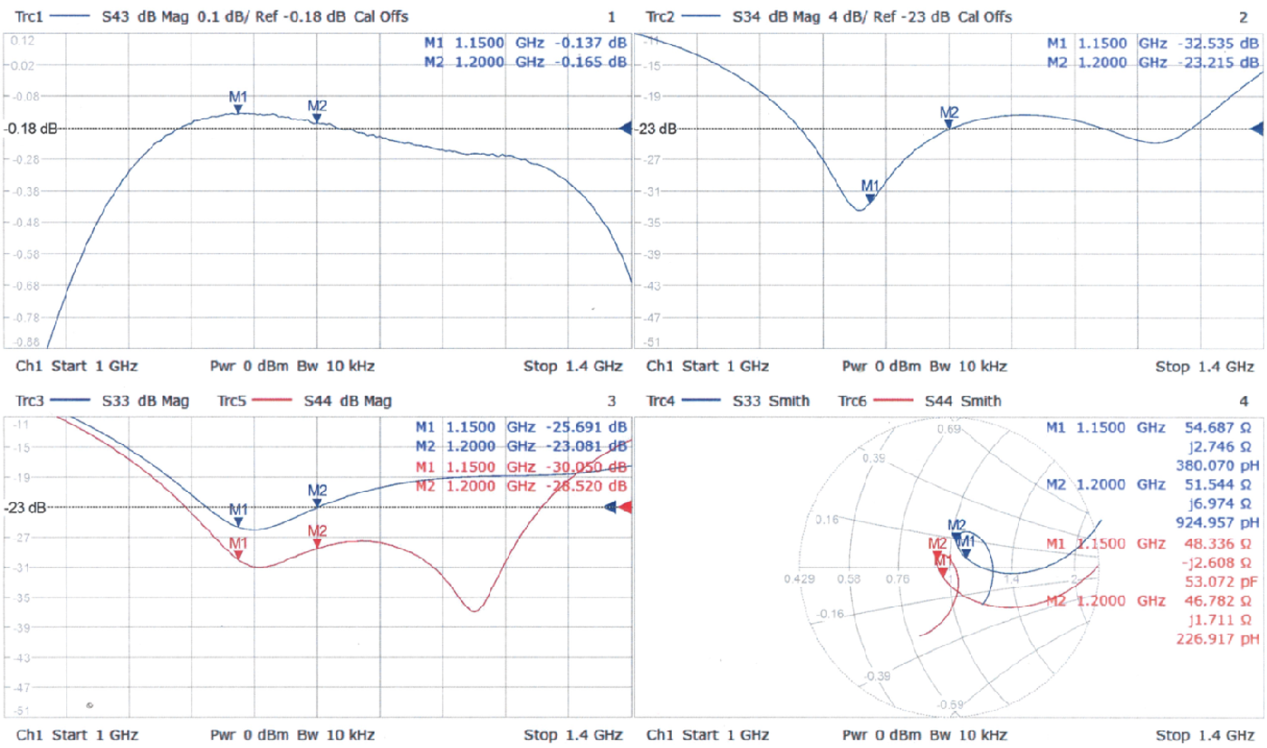

Fig.10 RF measurement after temperature cycling at 25°C

Power test

All power tests are made in Cobham facilities. For that, Cobham hands two vacuum chambers and automatic test bench.

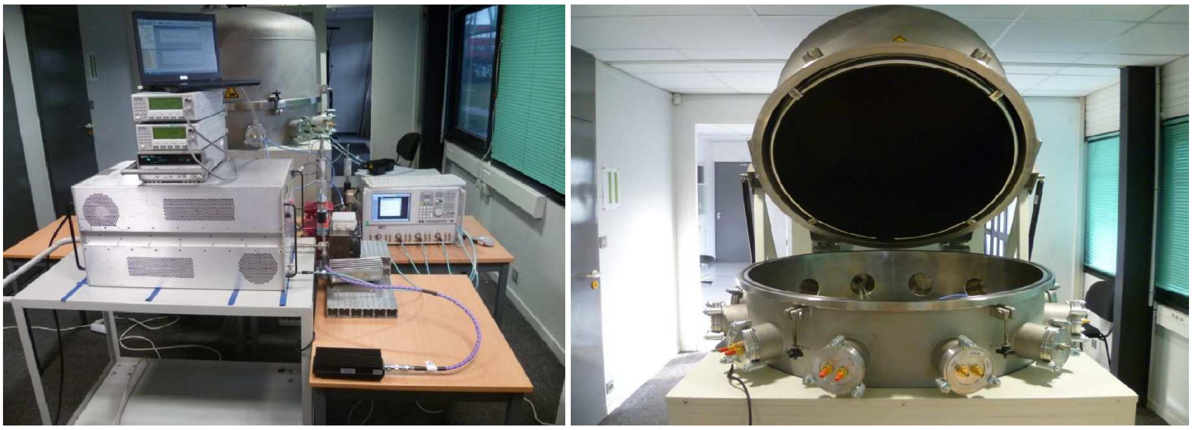

Fig.11 Pictures of thermal vacuum chamber

The test success criteria are:

- no large increase of return loss;
- no large decrease or increase of any temperature, except those due to power modification and thermal stabilization;
- no large increase or decrease of output power of the isolator.

During the test, the following parameters are monitored and recorded:

- input power level;
- output mismatch power level;
- input reflected power level;
- temperature in several locations on the isolator;
- chamber pressure and temperature.

Fig.12 presents the power handling test sequence for 200 W in forward mode.

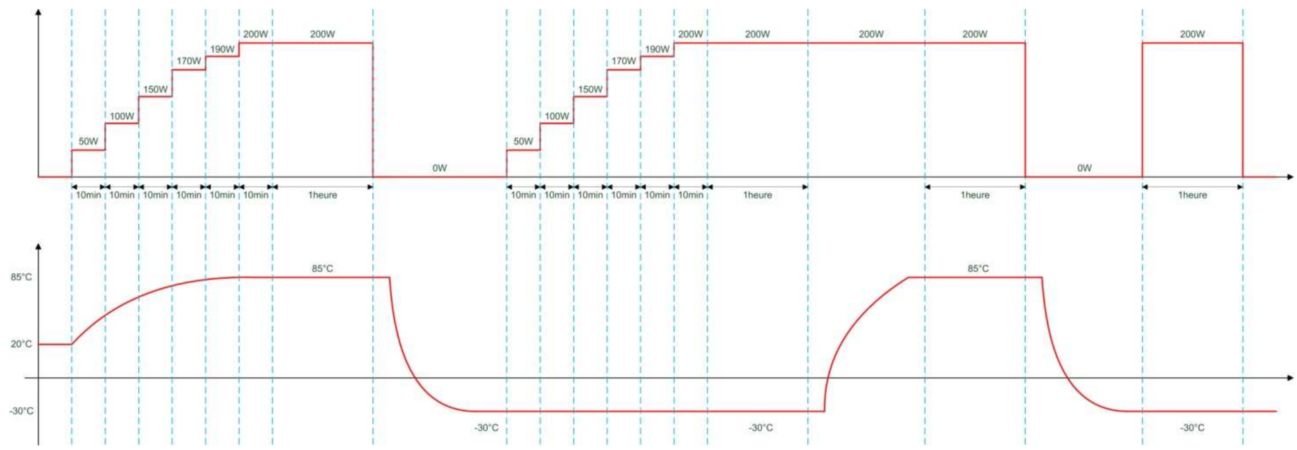

Fig.12 Power handling test sequence

We can see on Fig.13 the temperature in several locations on the isolator during the first hot temperature cycle. There is no unexpected large increase of temperature.

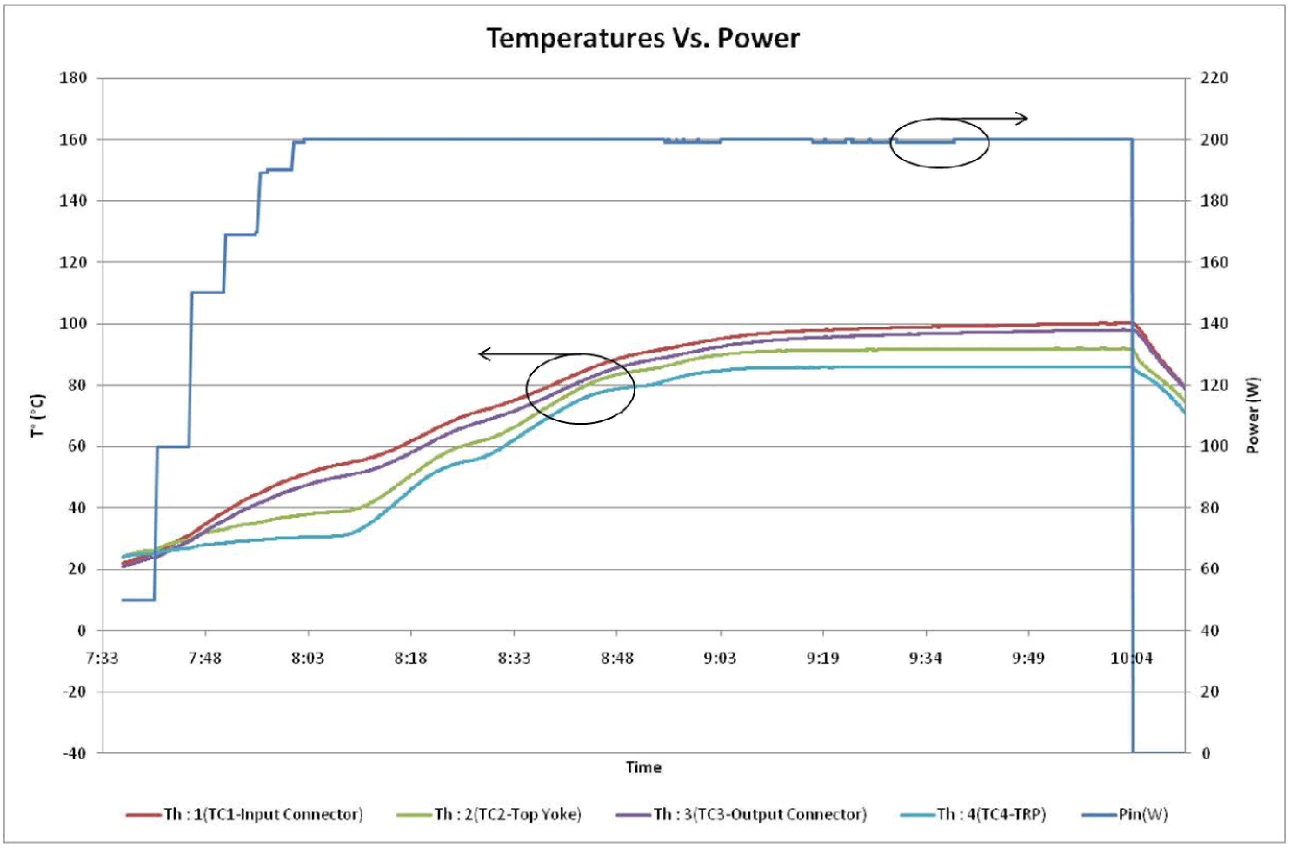

Fig.13 Temperature vs Power

Fig.14 shows no large increase of return loss. So, the power test with 200W-CW is successful.

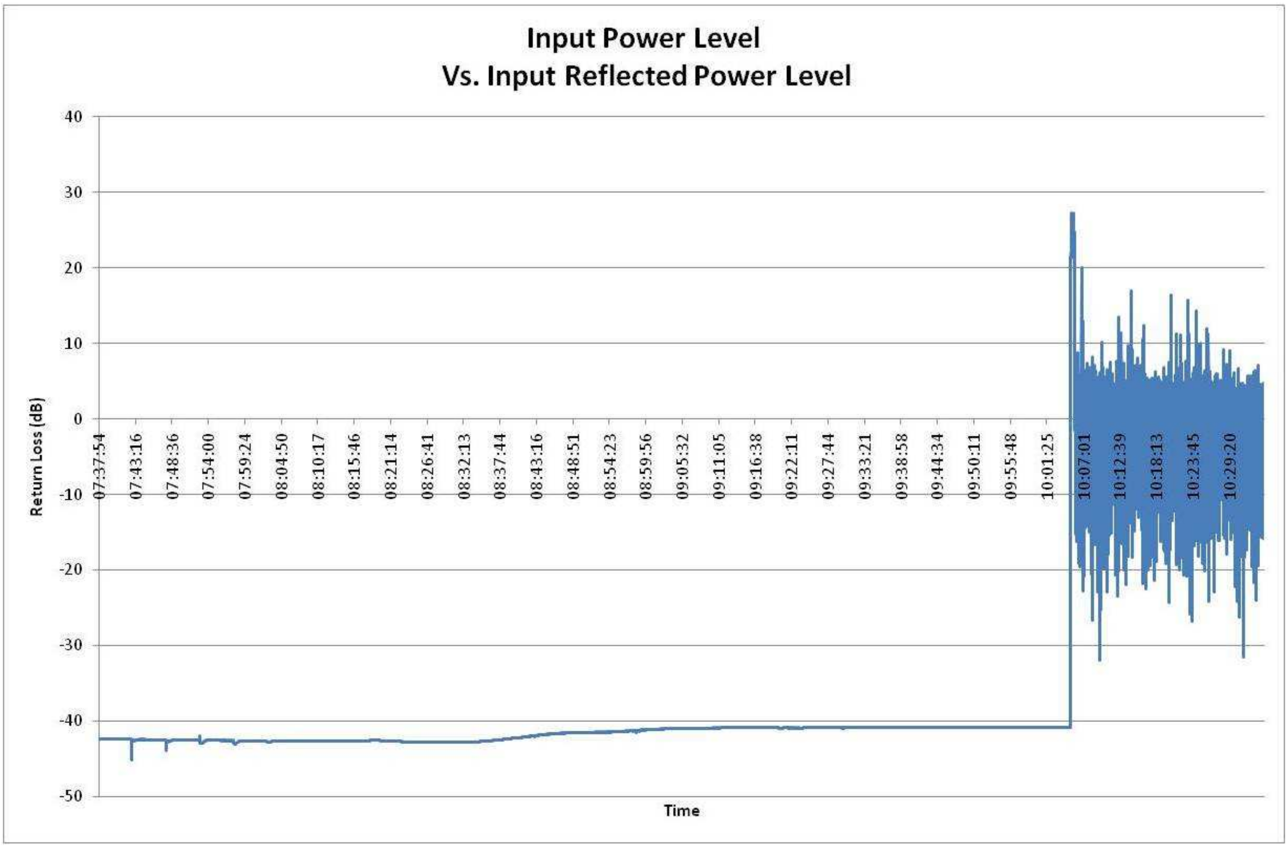

Fig.14 Input power level vs input reflected power level

CONCLUSION

We are designing isolators that can cover a bandwidth of 100MHz in the L-band from 1.14 to 1.65 GHz. Dimensions are 100x70x25 mm, with a mass lower than 210 grams. Typical electrical performances are 0.33 dB insertion loss, 21 dB isolation and 22 dB return loss at input and output ports, considering a 100 MHz bandwidth. These performances are valid for operating temperatures between -30°C and +85°C. High power test benches, including vacuum facilities, have been built and allow Cobham Microwave to perform in-house all necessary tests. It has been already demonstrated that these isolators are able to handle up to 200 W-CW in forward mode under vacuum environment. These high power isolators are glitch-free.
In the context of an ESA project, we will develop this concept for S and C frequency bands and qualify a full range of coaxial high power isolators to be used in telecommunication payloads.

REFERENCES

[1] CAO 3D SolidWorks, Dassault Systèmes SolidWorks Corp, www.solidworks.com, 2013.