MEMS redundancy switches for a LTCC Switch Matrix Hybrid Module

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MEMS devices for different applications

Depending on the specific application, different types of devices can be developed.

For example in rx/tx antenna applications where high switching rate and high reconfiguration cycles are required, switches are specifically oriented to dynamic behavior.

RELIABILITY & PERFORMANCES:

- no degradation in mechanical contact (micro welding or similar)
- no fatigue (changing in mechanical properties over many cycles)
- damping effect (effect of the air resistance which increases the actuation time)
- bouncing of mechanical contact
- ….

Design and reliability of micro-machined RF-switches are analyzed in literature mainly in terms of the robustness to cycling stress: **REDUNDANCY APPLICATIONS REQUIRE A DIFFERENT APPROACH**

MEMS devices for redundancy circuits

Because of its attractive performances, attention is currently moving to the possibility of using RF-MEMS to implement redundancy switches in satellite applications. Redundancy is implemented to assure the equipment operation when a failure occurs in the main section, therefore the switch must be able to disconnect the main circuit and connect the redundant one. This operating mode can be defined as “static”: the switch could remain “statically” in the same status (on or off) for long time (months or even years).

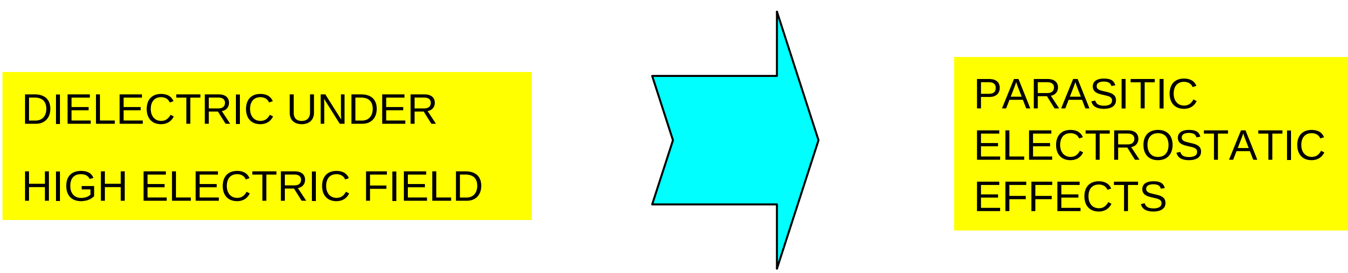
RELIABILITY & PERFORMANCES:

- no degradation in elastic properties after long term actuation stress
- no degradation in mechanical contact (micro welding or similar)
- no sticking due to surface energy effects
- no dielectric charging

MEMS for redundancy application: the charge trapping problem

In the common electrostatically driven MEMS the movable membrane can be put into contact with a fixed metallic electrode by the application of an electrical field: the actuation electrode is usually covered with a thin dielectric layer (typically some 100nm) in order to prevent ohmic contact and so current absorption.

<u>In this case the parasitic charging effect is the main failure mechanism for sticking!!!!</u>



The charging mechanism is a very complex topic, which involves several contributions (depending also on the bonding type):

- ionic polarization (relaxation time 10^{-12} sec)
- dipolar orientation (relaxation time 10^{-12} sec)
- **translation polarization (free charge presence) (relaxation from milliseconds to years)**

DIELECTRICLESS SOLUTION

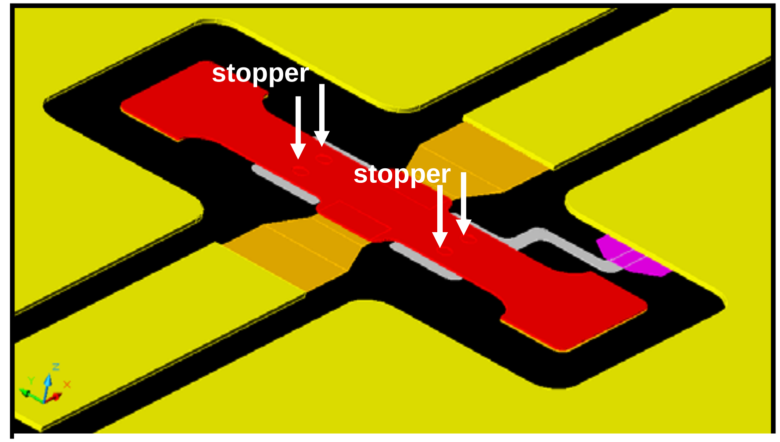
In order to solve the problem we have chosen to REMOVE the whole dielectric layer and to introduce some "stopping pillars" structures to sustain the bridge in actuation state:

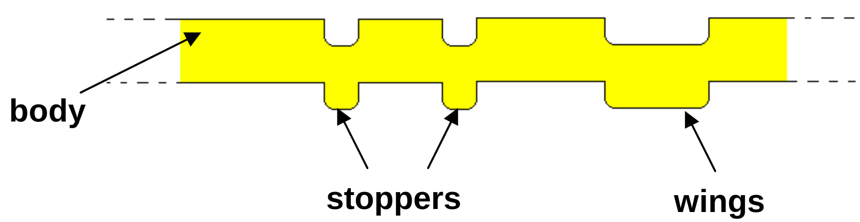
MEMS on LTCC: Structure design

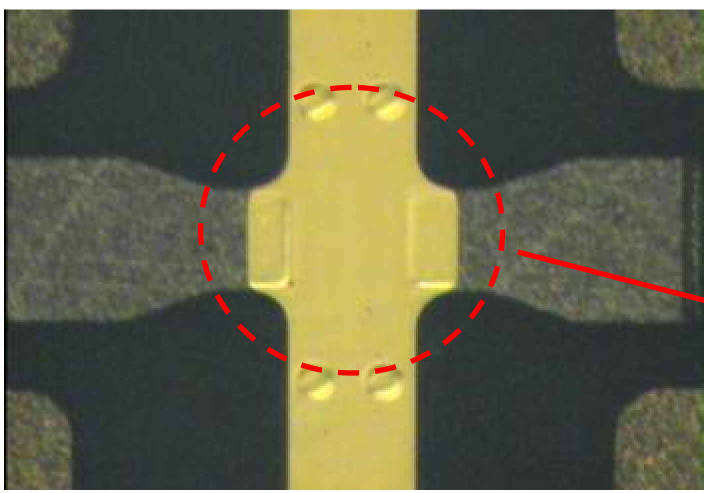
Four stopping pillars have been designed.

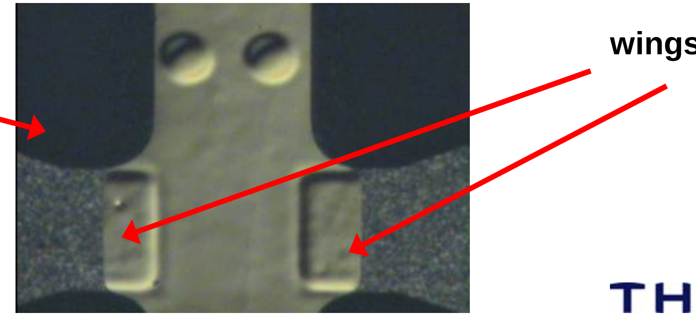
Stopping pillars have been designed in the bridge by means of a non-planar shape of suspended membrane.

In the same way also the wings have been shaped in order to stay at a lower height than the bridge's body.



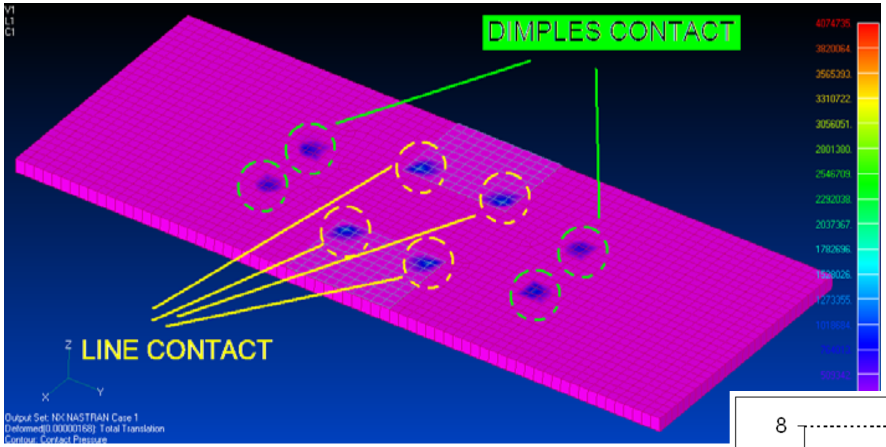






MEMS on LTCC: Study of Contacts

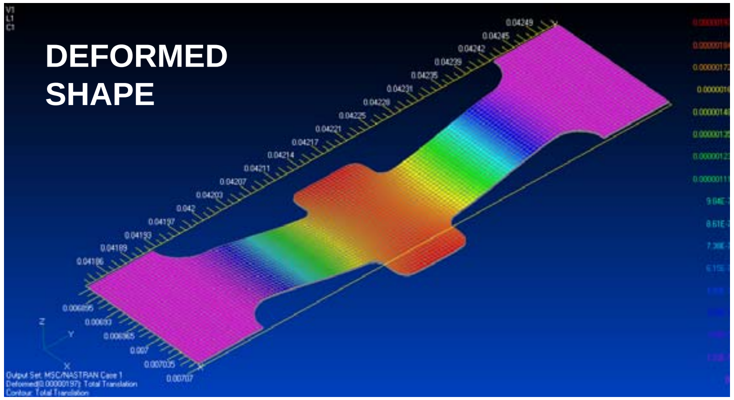
FEM simulation showing contact behavior of devices under electrostatic actuation:

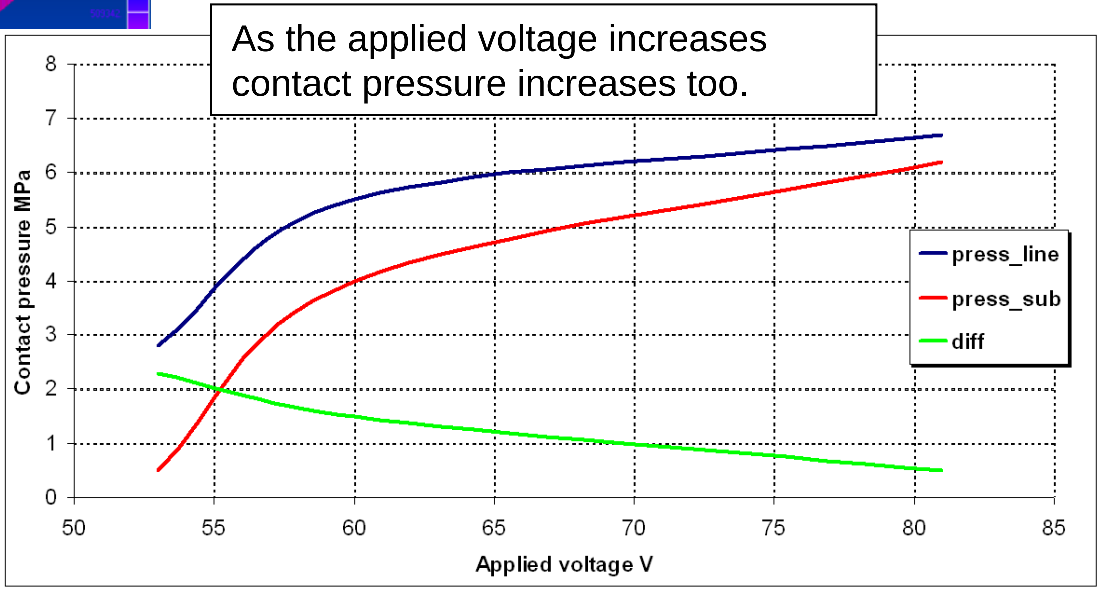


Contact zones have been well defined:

- **LINE CONTACT** (contact of wings on RF line)

- **DIMPLES CONTACT** (contact of stopping pillars on substrate)

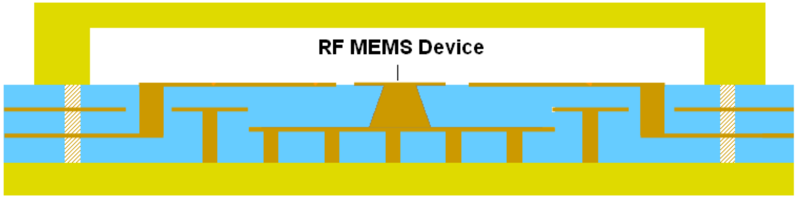


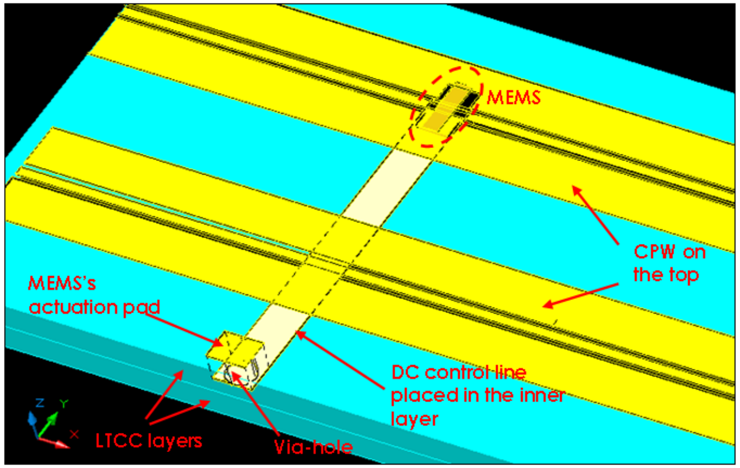


MEMS on LTCC

The design of 2x2 reconfiguration matrix module consists in a switching section composed by switching elements (MEMS) and a control section in which RF and DC lines have to be routed: routing is done using capabilities of multilayer ceramic substrate (LTCC)

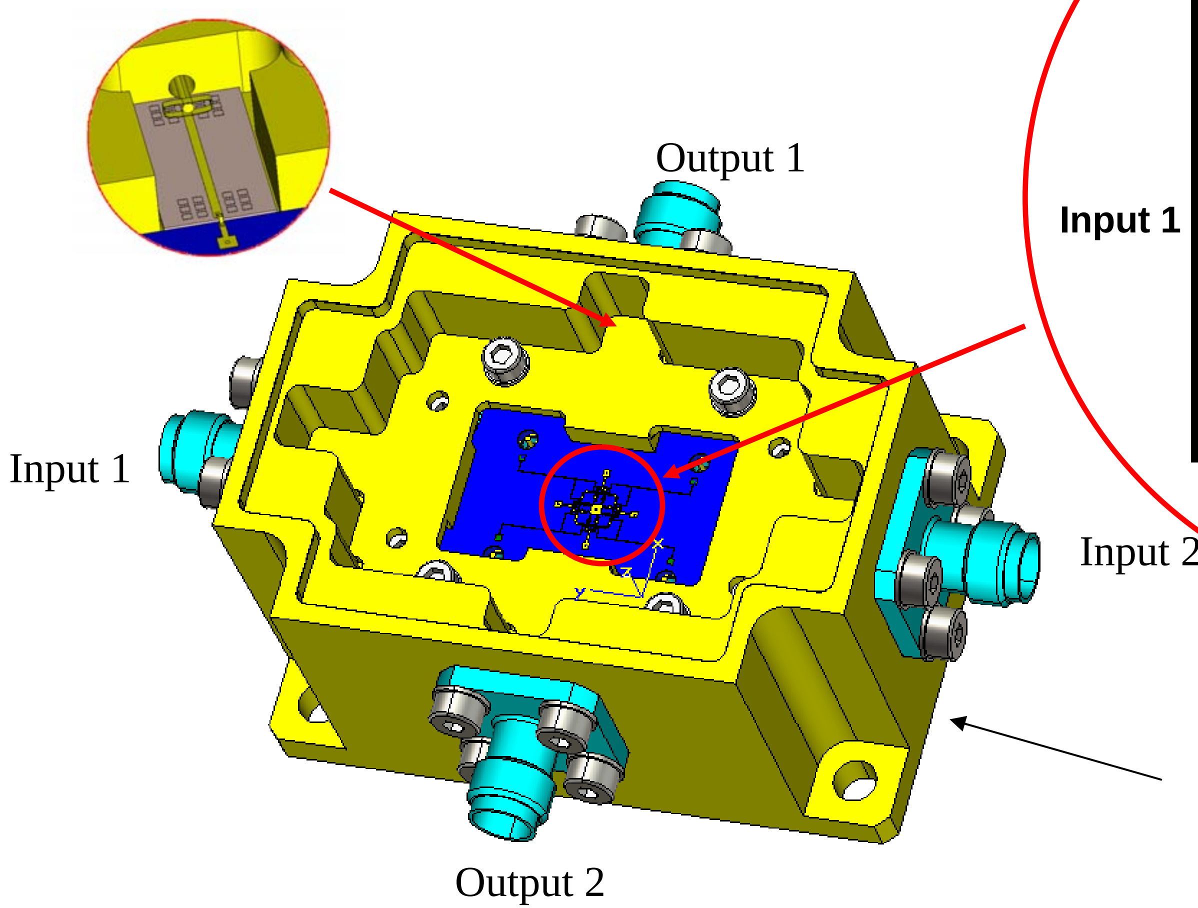
Integration of the MEMS directly on the LTCC substrate

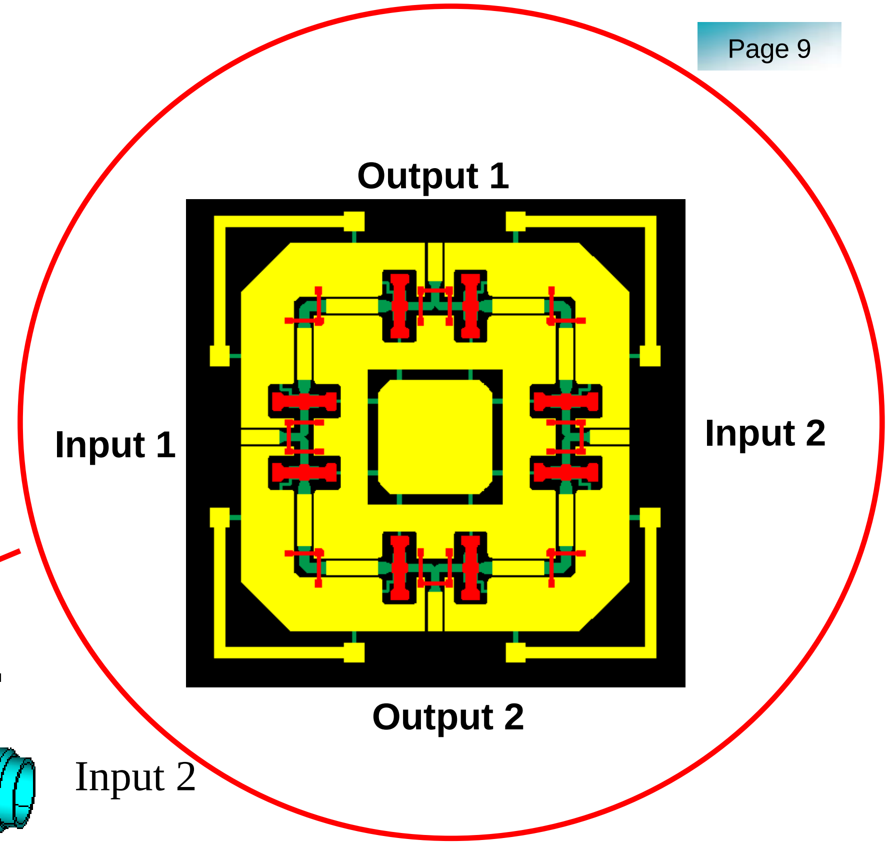




Advantages of multilayer capability to perform routing of RF lines and DC control lines.

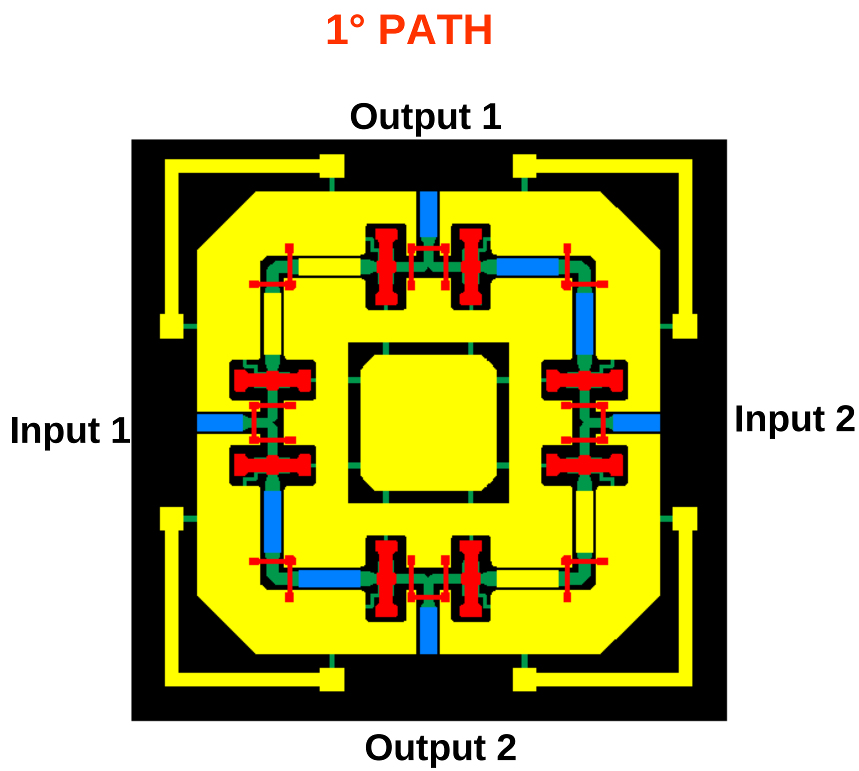
The 2x2 redundancy module

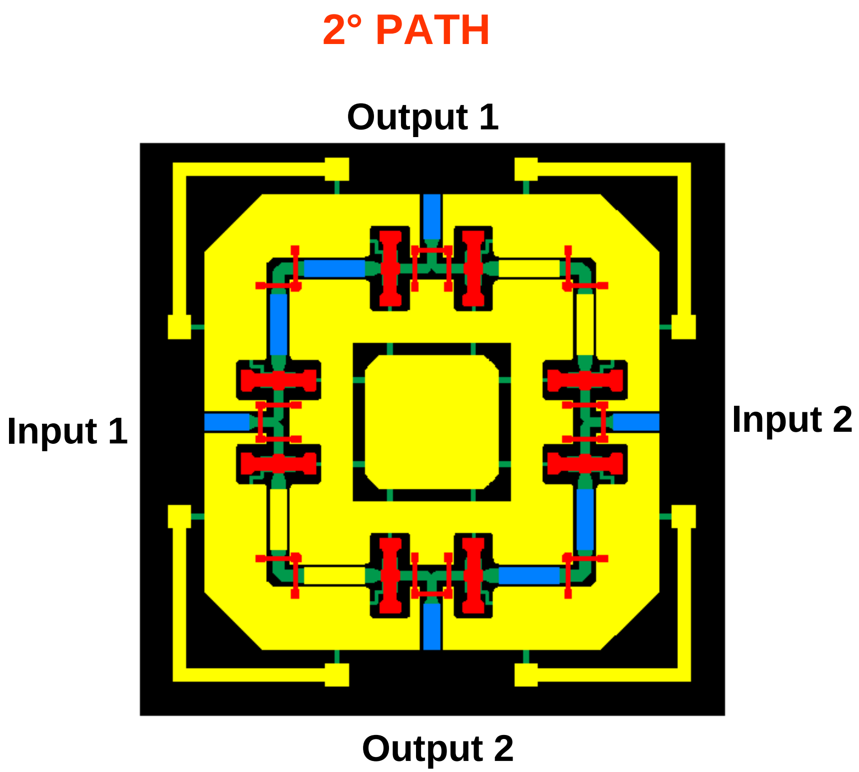


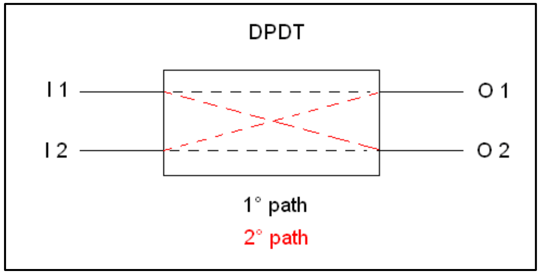


DC controls on the back side

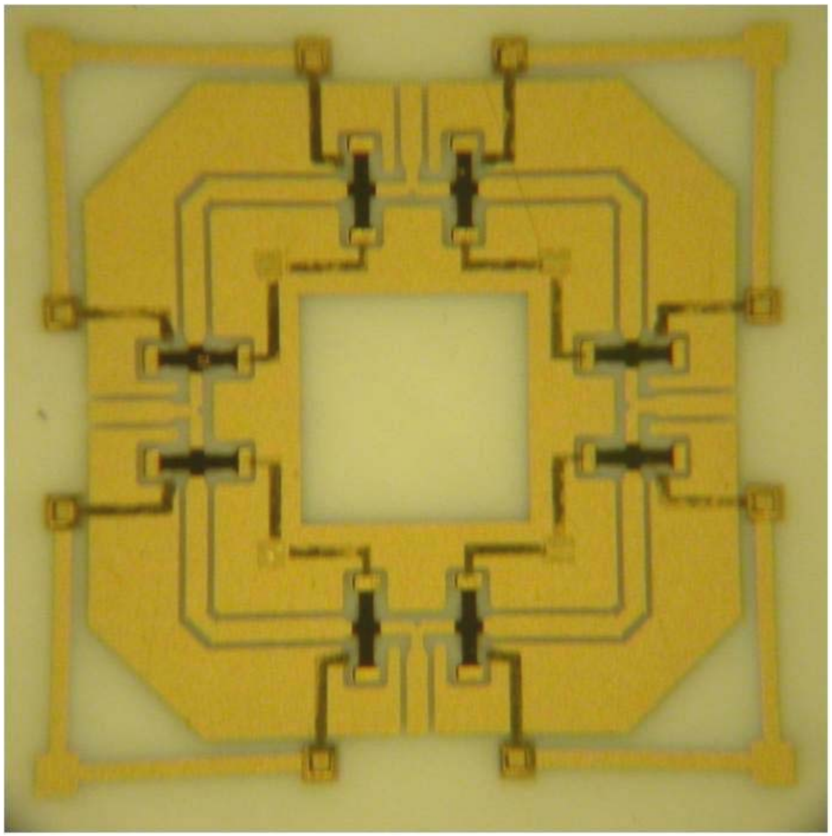
The 2x2 redundancy module

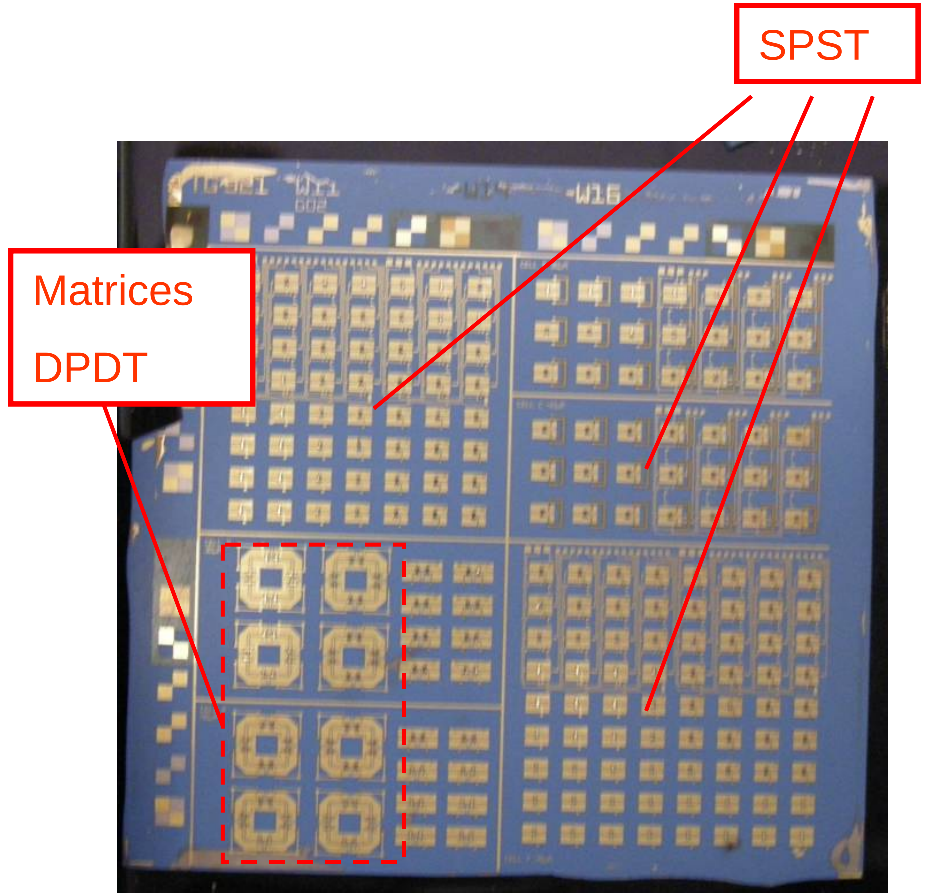






Manufactured structures





ELECTRICAL MEASUREMENTS

Electrical (DC) measurements have been performed:

1) Pull-in voltage in the range 25-35V

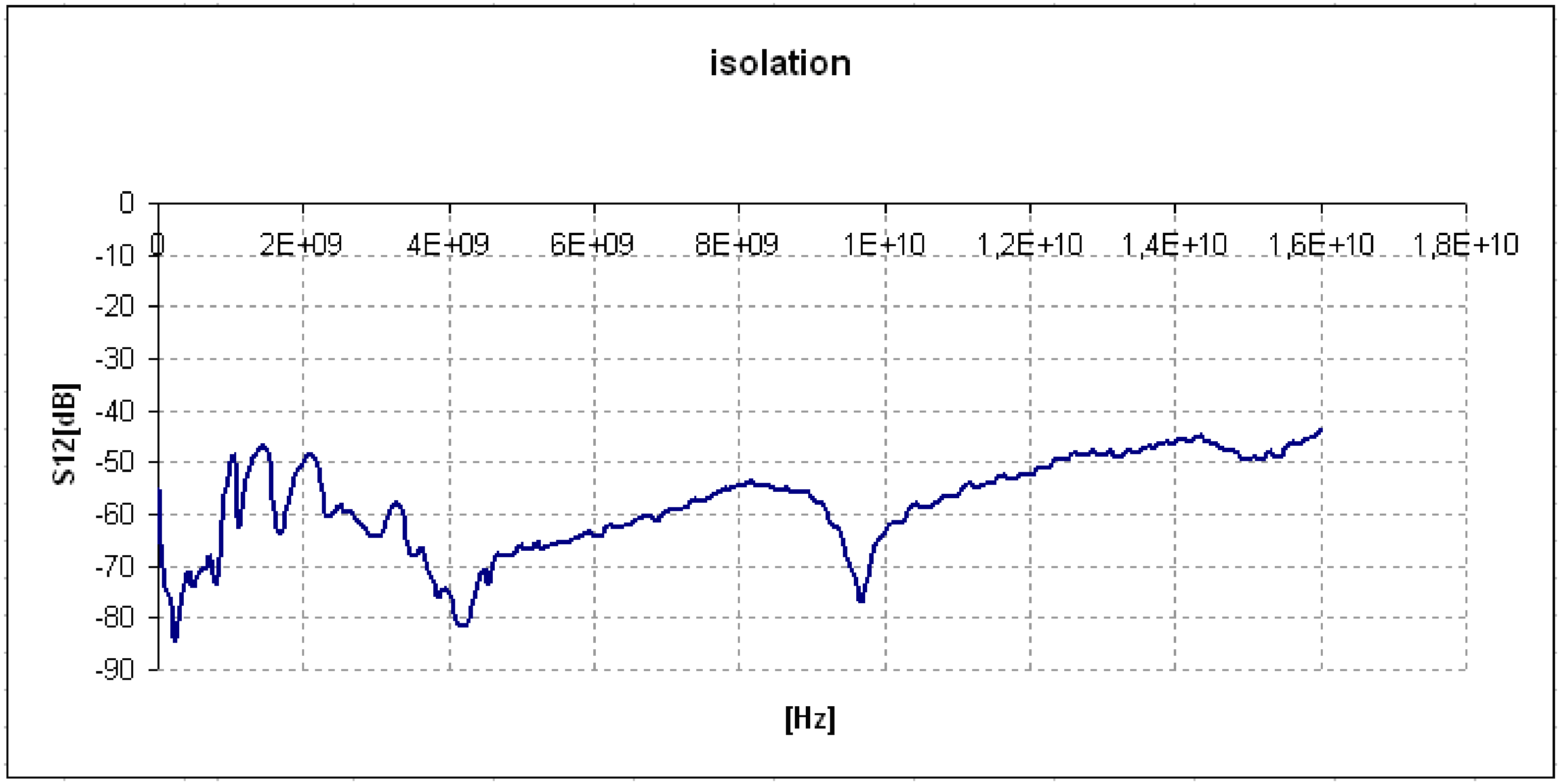
2) Contact resistance in the range 0.1-1.0 ohm

Mechanical shock and vibrations (pre-evaluation test):

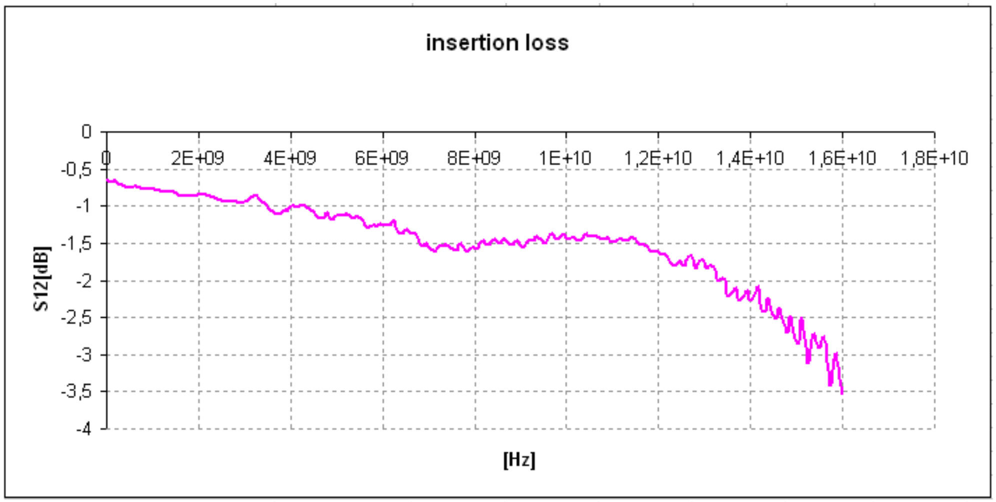
1) No variations in pull-in values have been noticed after mechanical shocks (1500g)

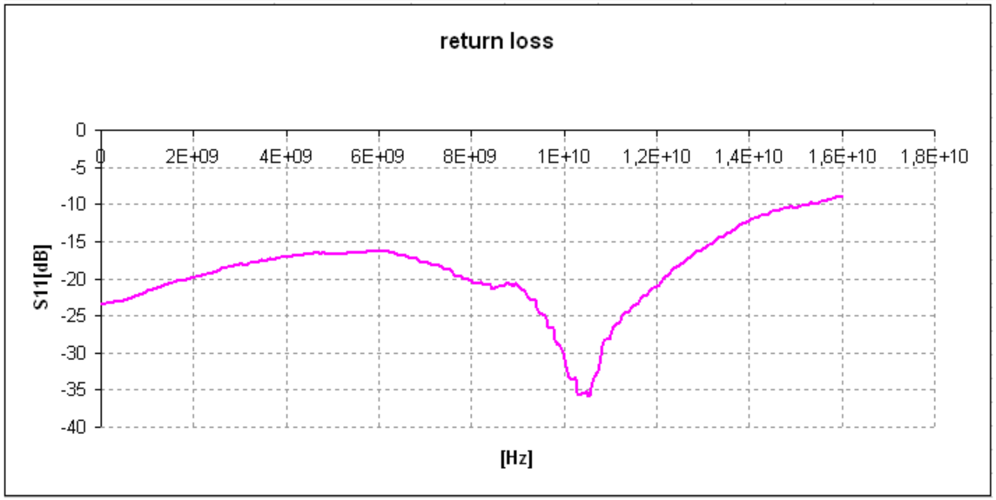
2) No variations in pull-in values have been noticed after mechanical vibrations (20 Hz-2000 Hz)

RF characterization of DPDT in off-state: isolation



RF characterization of DPDT in on state: return loss and transmission





Conclusions:

- Set-up of manufacturing process for MEMS devices on LTCC substrates has been specifically done for space application.

- Design of the devices has been oriented to redundancy applications @ 10 GHz (long time actuation status).

- Single MEMS have been first produced with results in line with the expectation.

- A 2x2 reconfiguration switch matrix has been arranged on a single substrate using LTCC capabilities (DPDT)

- Future activities: packaging and pre-evaluation for space qualification