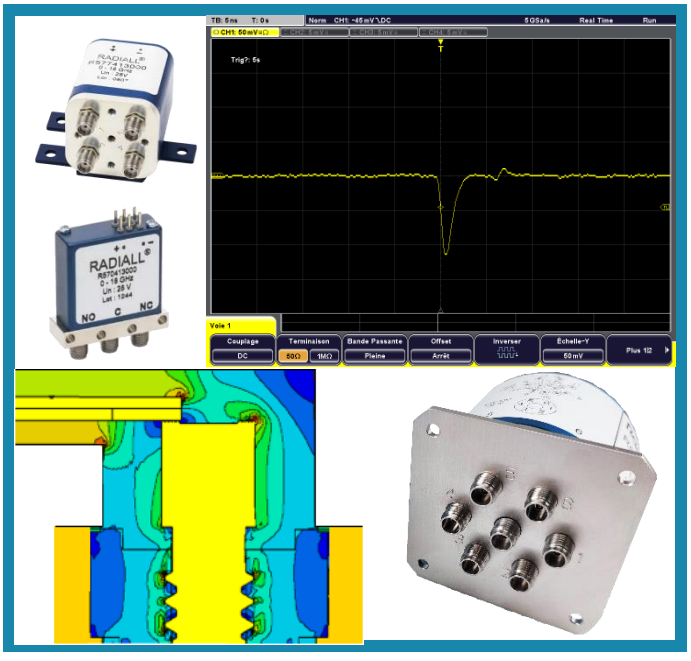
Switch Transient – Triboelectric Effect on Coaxial Switching Products



Definitions

Z_C: System's characteristic impedance (Ω)

RAMSES : RAdiall Modular System for Electromechanical Switches

TBE : TriBoelectric Effect

LNA : Low Noise Amplifier

ESD : Electro Static Discharge

ATE : Automatic Test Equipment

Introduction to Triboelectric Effect

The triboelectric effect also known as triboelectricity describes electric charge transfer between two objects when they contact or slide against each other. It can occur with different materials, or between two pieces of the same material.

In order to understand TBE on RF relays or switches, it is necessary to understand the mechanism of contact. The mechanism of contact and the TBE is strongly dependent on the material, the kinematic but also the contact forces.

TBE becomes a problem when it damages very sensitive equipment such as Low Noise Amplifier (LNA) or other electronic devices sensitive to Electro Static Discharge (ESD).

Usually, the TBE behavior does not tend to disrupt behavior of the test measurement instrument such as spectrum analyzer, oscilloscope, and there is no significant concern with damage to the test instruments, but there is concern, and in fact real cases, of damage to devices connected to test instruments.

In the case of a waveform generator, generating a signal vs. an oscilloscope that receives a signal, the user of the waveform generator may be amplifying the signal, potentially exacerbating the problem.

Switch Application (Kinematic)

The unique design of RAMSES developed by Radiall allows the RF switches to operate by moving a rectangular section contact reed inside of a rectangular cavity. These contact reeds are linked to dielectric material called “transmission pushers”. In addition, dielectric materials are also present close to RF connectors. Usually it’s a PTFE insulator. Figure 1 illustrates the RF body of RAMSES concept.

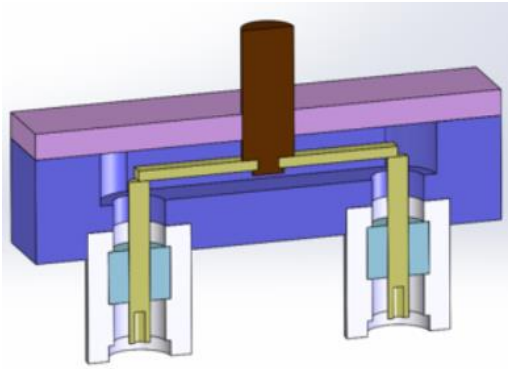


Figure 1: Contact area in RAMSES coaxial relay

In general, traditional switches of Radiall competitors operate by moving a rectangular section contact reed inside a rectangular cavity too. Like RAMSES concept, these contact reeds are linked to dielectric material “transmission pushers”. However, contact reeds are directed by guides made of insulated material according to the figure below. Figure 2 illustrates RF body of conventional competitors.

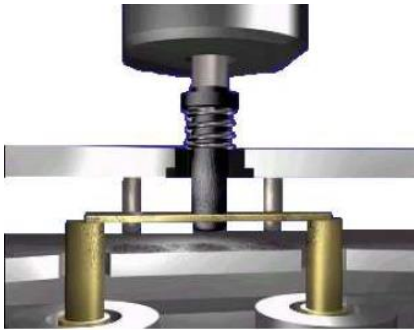


Figure 2: Contact area in traditional switch

During the switching sequences, these dielectric parts are charged with electricity and this electricity passes through the input or output connectors of the switch when the RF path moves from the open position up to the closed position.

How to capture Transients

TBE or transient voltages can be captured using high speed scope. It occurs when nothing is connected to the RF connectors of the RF relay or switch. It's a very fast transient, which is definitely repeatable. At the output of the switch, transients' level is higher than 0dBm. Figure 3 below illustrates how to capture transients using high speed scope.

Figure 3: How to capture transients using high speed scope

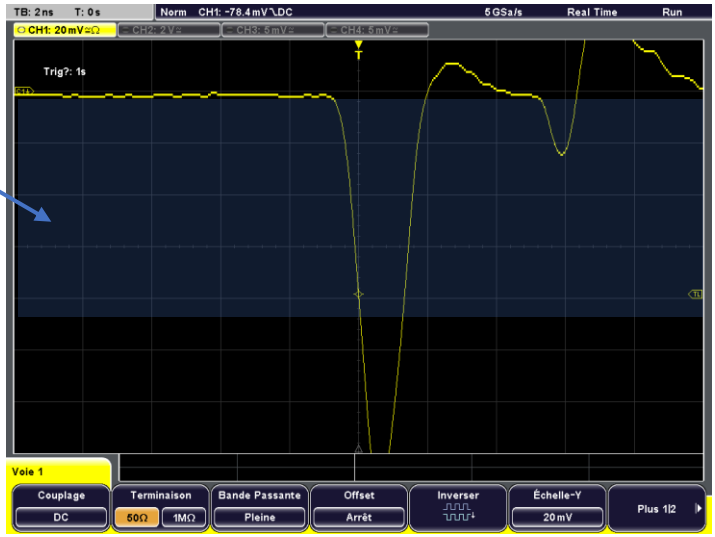
Evaluation of TBE on coaxial switches

On standard Radiall electromechanical switches the transients is close to 80mV. On the following figure 4, transient voltages induced during switching were recorded using a Rohde & Swartz oscilloscope. No occurrence of transient voltage spike was observed with minimum value between -80mV and -140mV. Measurement are made on each port of the switch with oscilloscope trigger level set to -14mV. Switching cycle rate was 1 Hz per position

Figure 4: Transient voltage induced during switching

On RF switches of Radiall competitors transients induced during the switching sequence are closed to -160mV for the first competitors and -120mV for the second competitors. It's not an exhaustive list. Figure 5 below illustrates the performances of two competitors.

Occurrences of Radiall RF switches transient, voltage spike in this area



Occurrences of Radiall RF switches transient, voltage spike in this area

Figure 5: Transient voltage induced during switching for Radiall competitors

Due to dielectric part inside RF cavity such as the guide made of dielectric material, conventionally RF switches of Radiall competitors have transient's voltages higher than Radiall RAMSES concept. Figure 6 below illustrates the transient voltage difference between Radiall RAMSES concept and Radiall's competitors.

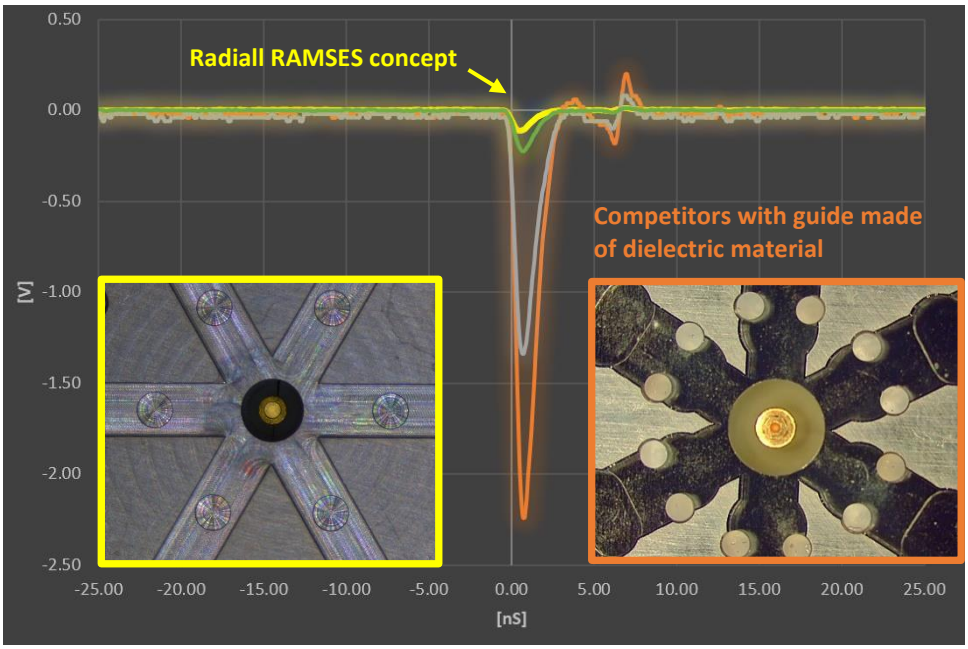


Figure 6: Transient voltage induced during switching

RF path behavior between the same product

Usually, the transients are not the same between the switch ports. It comes from the fact that the RF blade never touches the two stationary contacts area simultaneously. The first contact could be predictable due to slight asymmetries near contact area. However, it's not viable to change asymmetries of switch ports in the aim to create TBE only on desired switch ports. The following figure 7 show the transient difference between the switch ports of a SPDT fitted with SMA type connectors.

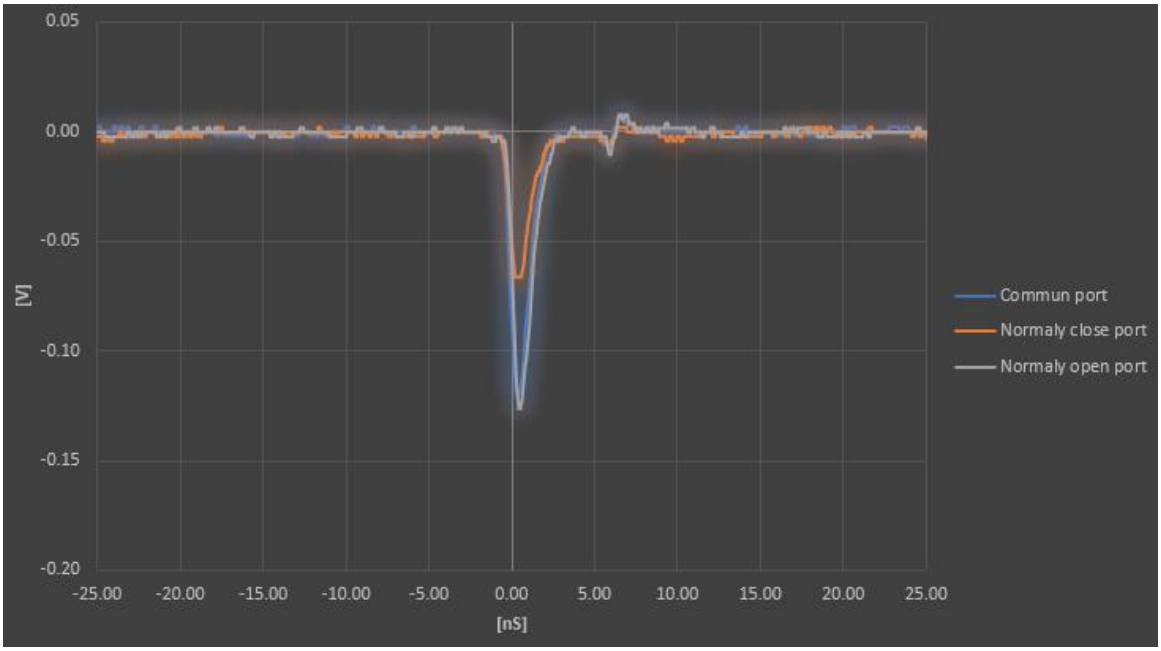


Figure 7: Transient voltage between the switch ports

Transient Repeatability

A transient repeatability campaign was performed on SPDT fitted with SMA type connectors. More than 1000 switching cycles were performed and TBE were recorded using the ATE. During this campaign transients were captured on the three SMA type connectors of the SPDT. The following figures below illustrates the results of the campaign.

Normally open SMA connector :

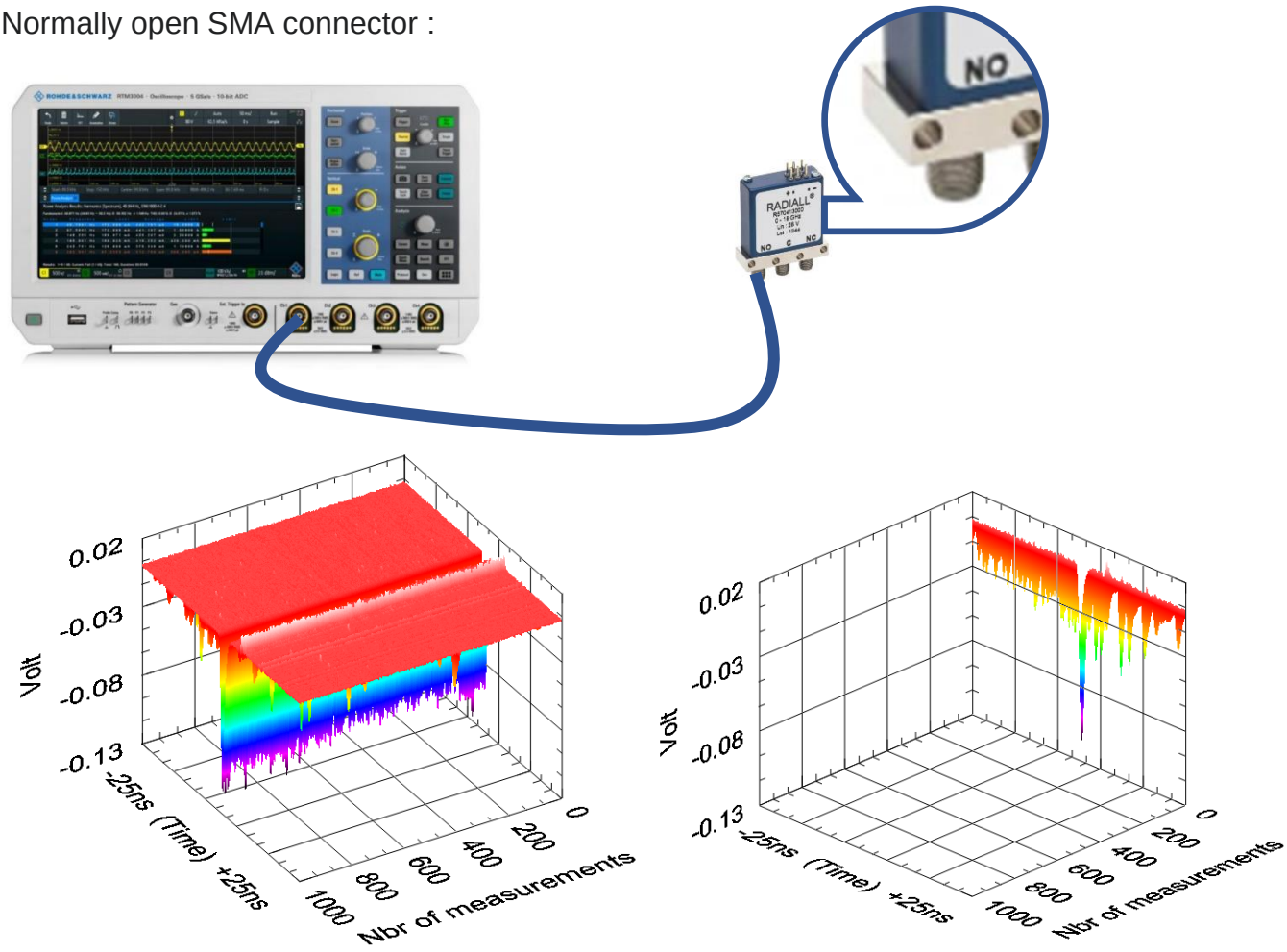


Figure 8: Transient voltage induced during switching on normally open connector

Normally closed SMA connector :

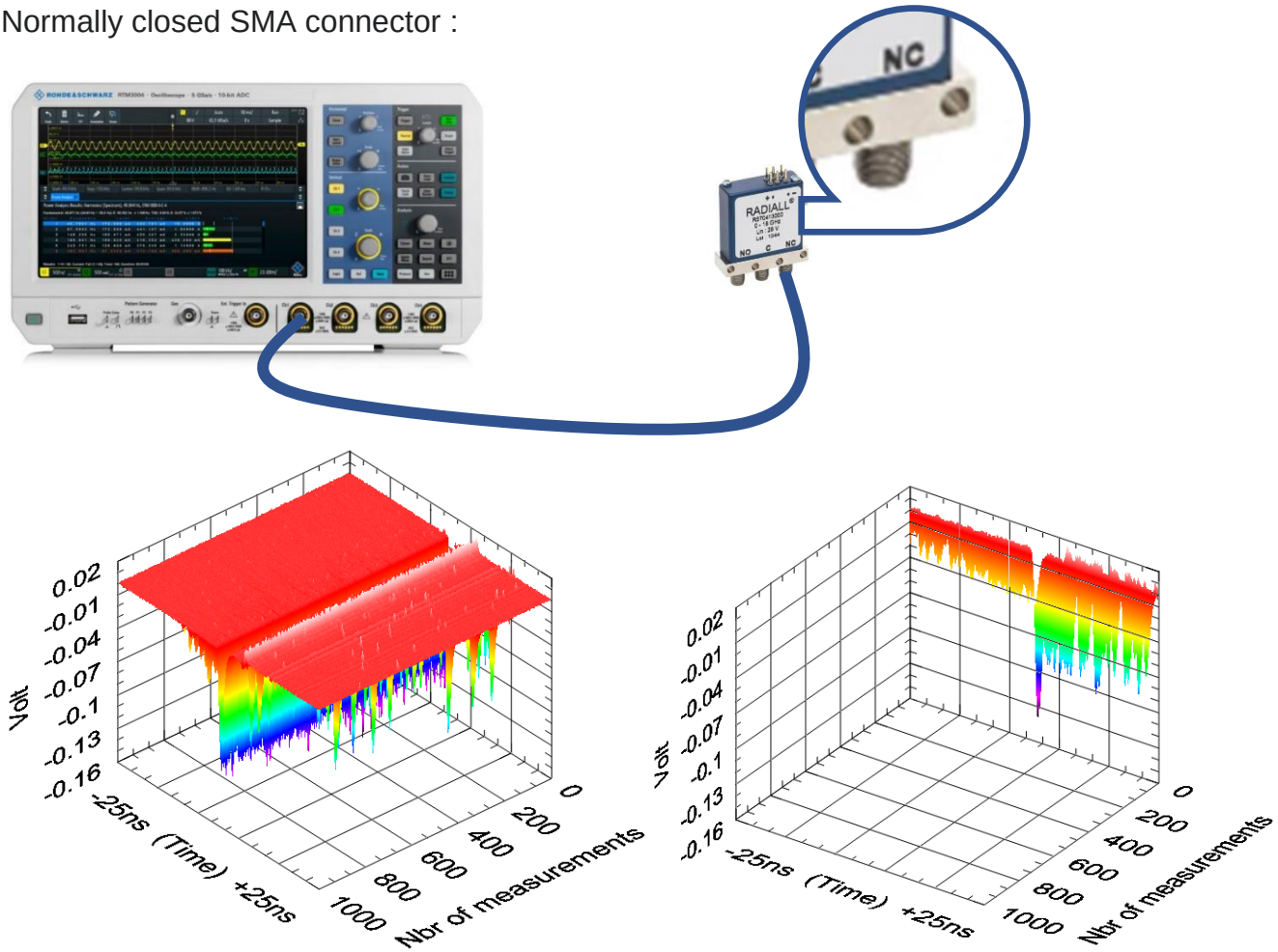


Figure 9: Transient voltage induced during switching on normally close connector

Common SMA connector :

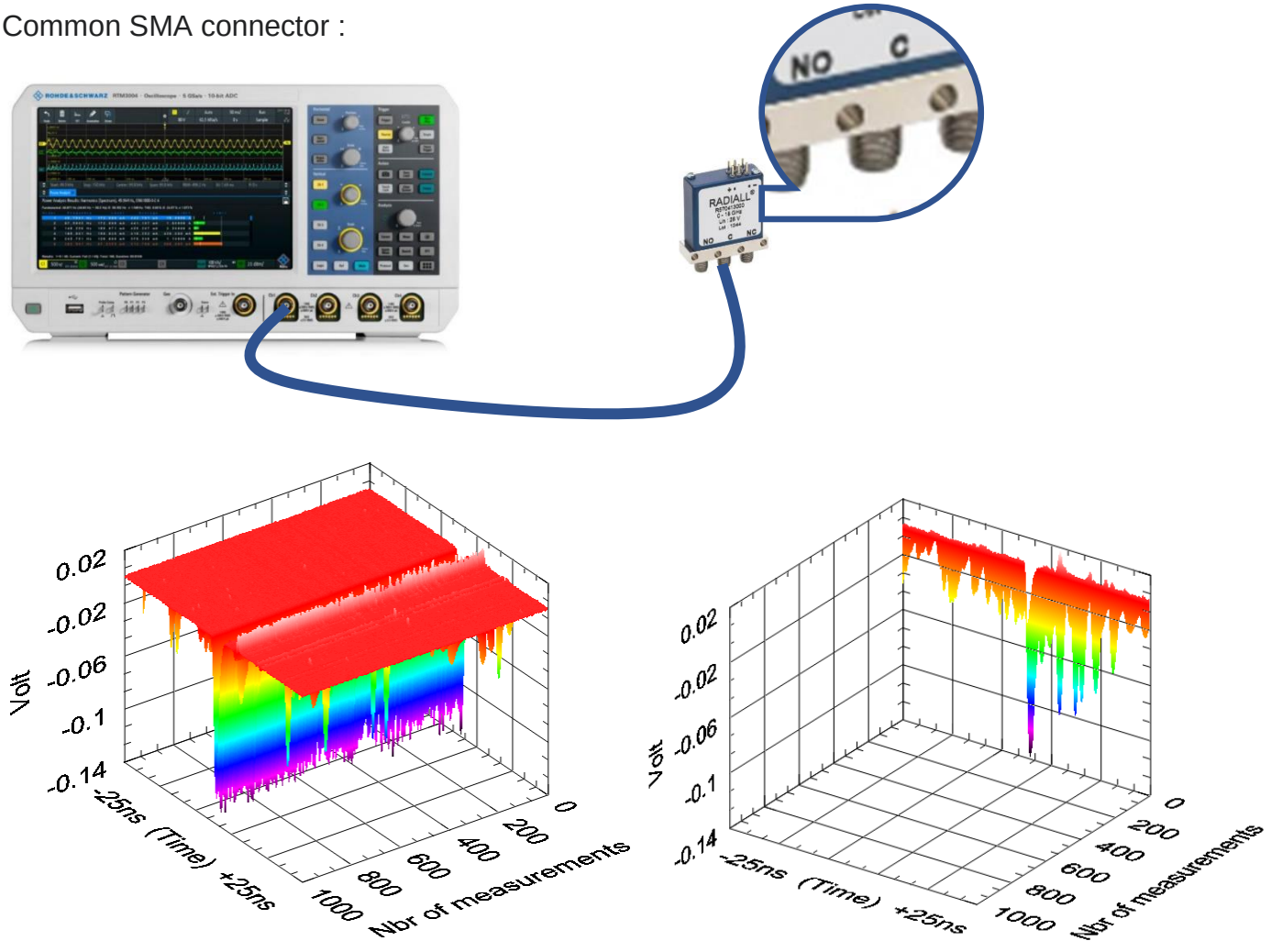


Figure 10: Transient voltage induced during switching on common connector

TBE are very fast and definitely repeatable at each output/input of the switch.

Transient repeatability over temperature

The transient repeatability campaign was also performed under temperature. The aim was to extract the behavior of the transient on one port of the switch between -25°C up to +75°C.

Common SMA connector :

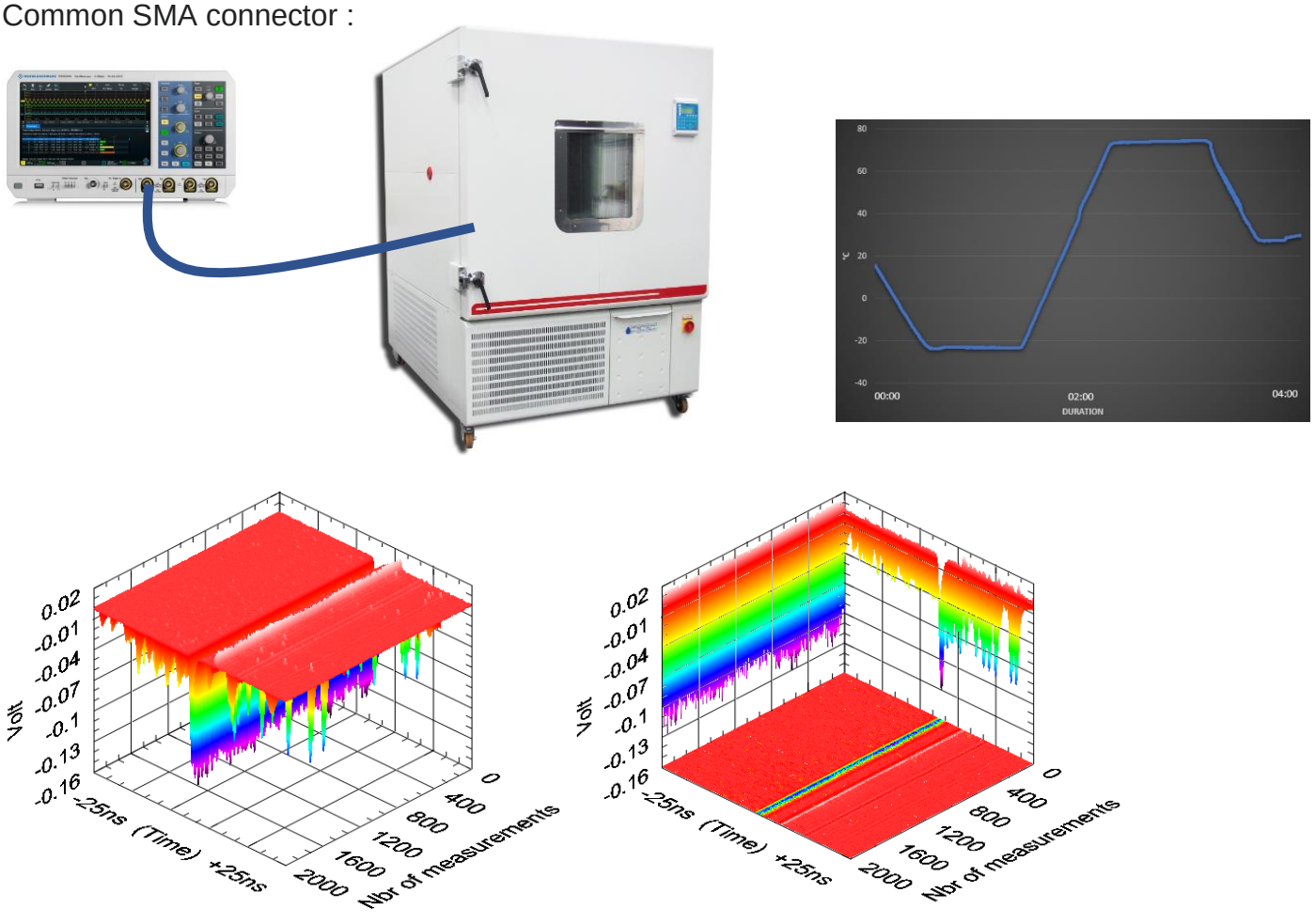


Figure 11: Transient voltage induced during switching over temperature cycle

TBE is repeatable over temperature cycle

How to reduce transient voltage

As you could see previously, the transient is very fast. The duration of the transient voltage reaches 5 ns.

A DC shunt can be used to block transient but TBE can pass through the parallel resistance of the DC shunt component. Unfortunately, the problem remains the same.

A DC block can be used too but as the spectral density of the transient is very fast, the TBE can pass through the series capacitor of the DC block. Even with DC block with a 10pF capacitor.

Low pass filters can be use but unfortunately, it reduces the bandwidth of the RF path.

First solution to reduce transient voltage is to use metallic parts instead of dielectric parts close to the RF pusher. The aim is to link the RF pusher to the ground plane of the product using conductive material. The following figure 12, shows the diagram kinematics of patented RAMSES concept with the concerning parts subject to the metallic conversion.

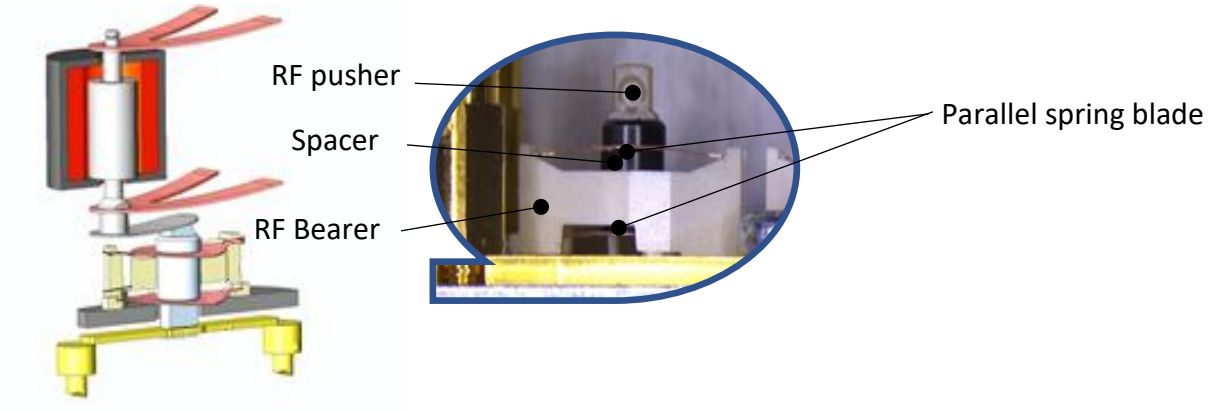


Figure 12: Parts subject to metallic conversion

The TBE campaign was done on several products. The aim was to demonstrate the grounding of each metalized dielectric part close to the RF pusher. The following figure 13 shows an example of the transient difference for the same RF path with grounding parts of bearer and spacer.

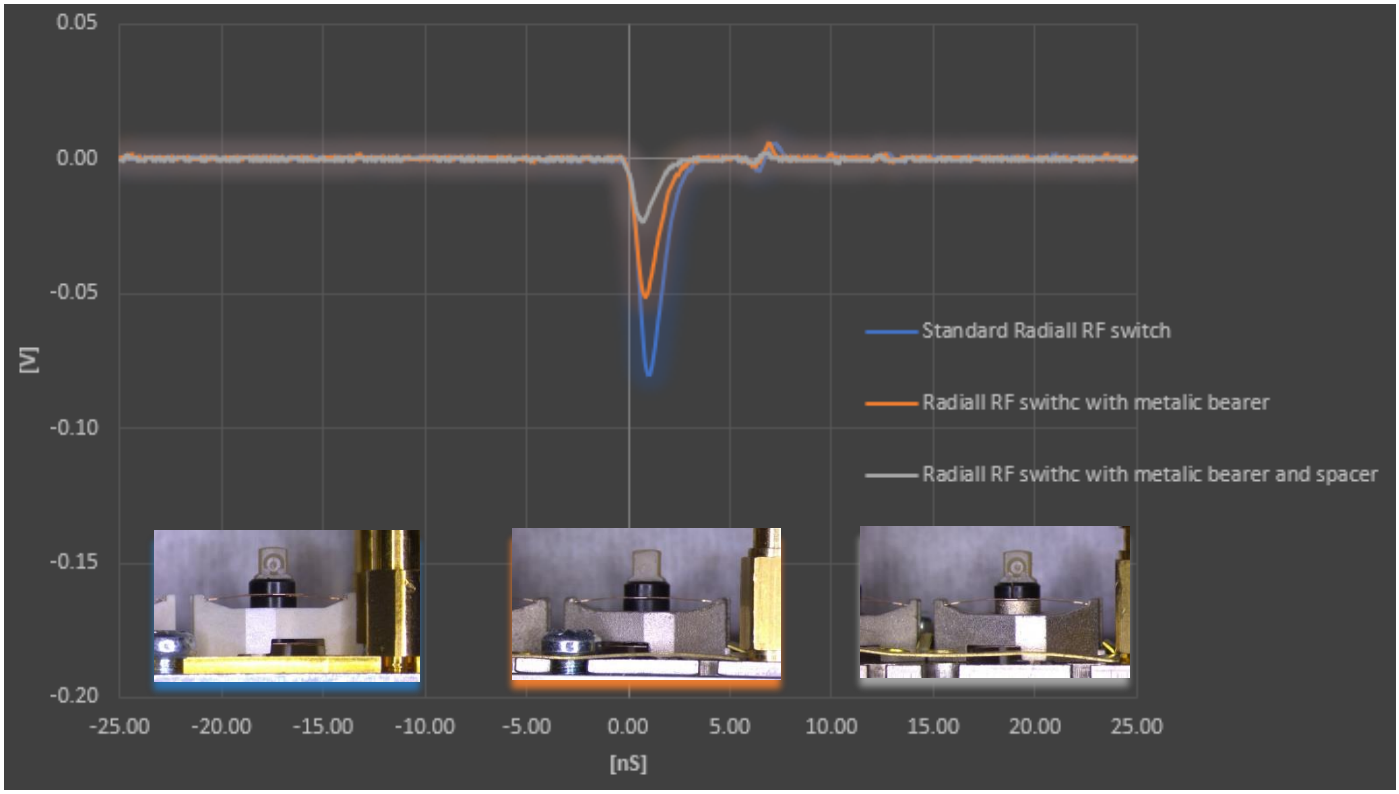


Figure 13: Transient vs parts subject to metallic conversion

With metallic parts close to the RF pusher, transients decreases from 80mV up to 20mV. However, transients are always present and repeatable.

How to suppress transient voltage

The approach to test and sort out the standard RAMSES switch is not viable. In order to suppress definitively TBE, Radiall has developed specific product with several adjustments such as specific RF cavity, closing plate, RF blades and specific parallelogram blade too.

These adjustments allow Radiall to completely suppress the transient generated into the RF body. Behavior is very good. After adjusting the trigger window to 10mV instead of 50mV for better sensitivity, there is no triggered event after cycling more than 100 switching cycles. The figure 14 shows that there is no triggered event after cycling.

Figure 14: No triggered event

This specific SPDT product without any transient has typical RF performances close to 26.5GHz on standard product. The figure 15 illustrates the RF performances up to 26.5GHz of SPDT without transients.

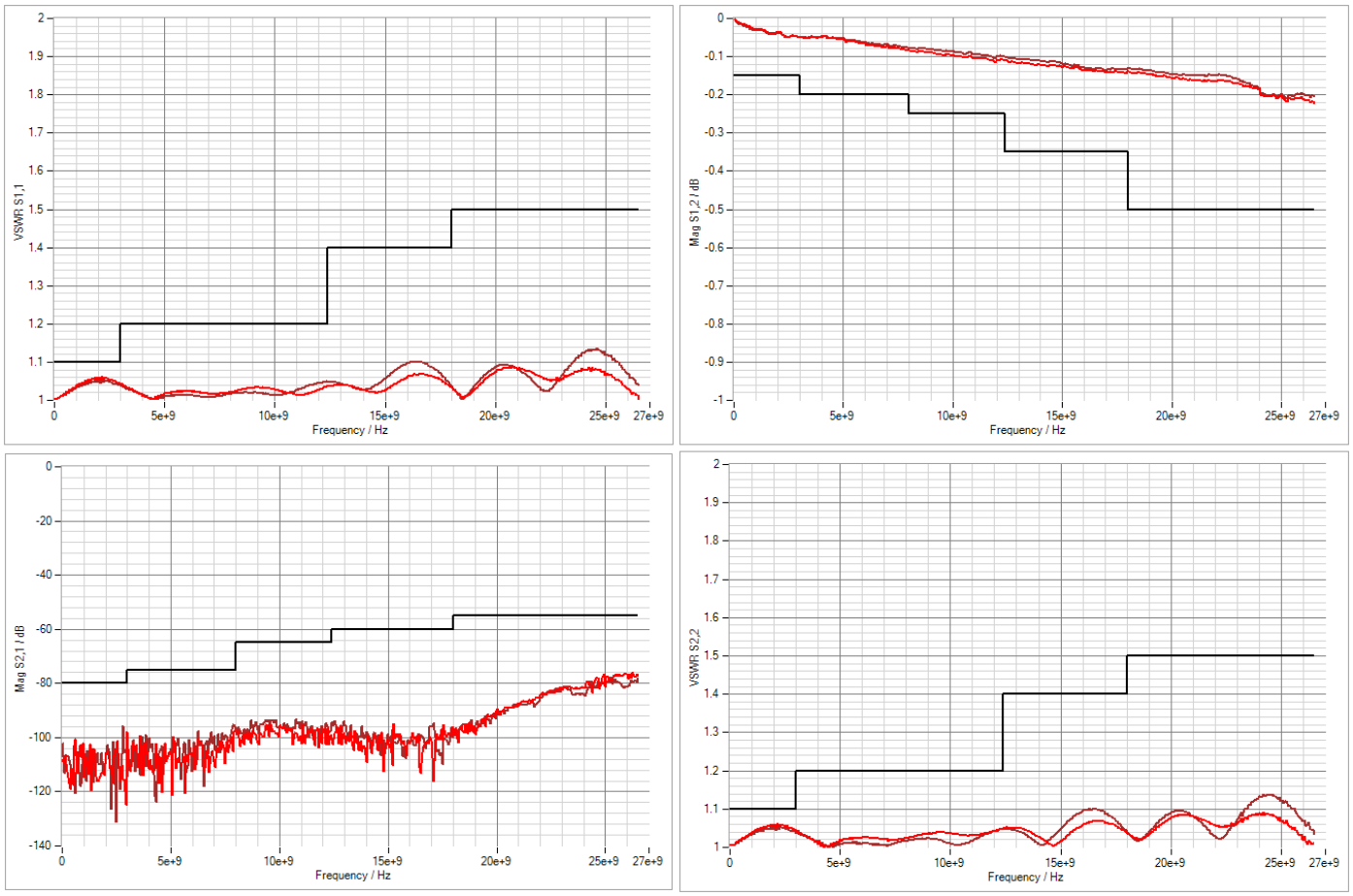


Figure 15: RF performances of specific SPDT without transient

Using the same technology, other products such as DPDT and SPnT can be developed upon request to suppress transient.