DESIGN, MANUFACTURE AND TEST TECHNIQUES FOR MULTIPACTOR FREE RF DEVICES

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INTRODUCTION

High reliability RF/Microwave passive components/devices are essential parts of satellite communications payloads. High power devices, placed in the transmit path of the communication link, are required to handle increasingly larger peak and average powers over the entire frequency spectrum. In addition to general high reliability requirement for any part used in space applications, these high power RF devices must be proved to be safe and free of high power related failure phenomena, such a multipactor breakdown, corona discharge, and passive inter-modulation.

Multipaction is a known phenomenon related to RF breakdown mechanism in vacuum under high power whereby an avalanche-like increase of electrons may occur due to secondary electron emission. If multipaction discharge occurs, it can generate noise and reduce the output power by increasing the mismatch loss due to return loss degradation and therefore increases the device temperature. A prolonged discharge can increase the pressure inside the unit by outgassing the walls and dielectric material. This will result in ionization in presence of the fields, which may lead to corona discharge under partial pressure and cause catastrophic failure.

Therefore, any device carrying high RF power and operating in vacuum is susceptible to multipactor breakdown and must be proved to have multipactor threshold well above the operating power by a comfortable margin, typically 6 dB. The verification can be done either by analysis or by test. ESA/ESTEC multipactor analysis tool calculates multipaction threshold and safety margin for some known structures; given the frequency, power level, impedance, minimum gap and finish material [1]. SPARK3D [2] is another multipaction analysis tool that uses the electromagnetic fields distribution obtained by full wave analysis and calculates multipaction threshold for different materials with known Secondary Emission Coefficient. When the analysis doesn’t predict enough margins, verification must be done by testing.

In this paper, both analysis and testing of some high power RF devices are presented. Examples of devices that were designed and successfully tested for multipaction at Sierra Microwave will be presented, including a WR112 waveguide circulator in X-band tested to 3000 Watts peak (600 Watts average), a VHF lumped element band pass filter tested to 80 Watts peak (4 Watts average) and an L-band coaxial isolator-combiner tested to a combined output power of greater than 755 Watts peak (378 Watts average). The design approach, multipaction mitigation methods, test methods and test results for each of these parts will be presented and discussed.

WR112 HIGH POWER CIRCULATOR

Fig. 1 shows the WR112 high power waveguide circulator operating over 7-9 GHz. The power handling requirement is 1000 Watts peak, 50 Watts average. The device was tested for multipaction up to 3000 Watts peak, 600 Watts average, with no sign of breakdown. As shown in Fig. 2, Teflon spacer was used between the Ferrites to improve matching. In addition, gaps between the waveguide housing, Ferrites and Teflon spacer were filled with a silicone RTV to prevent multipaction and to provide a conforming bond.

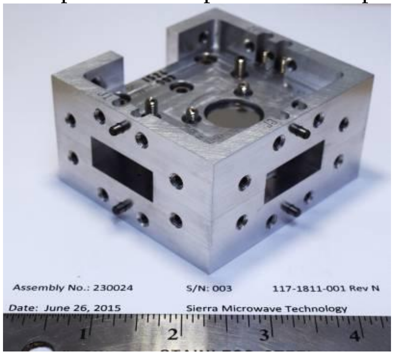


Fig. 1. WR112 Waveguide Circulator

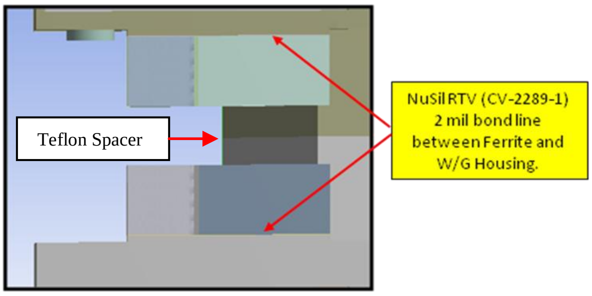


Fig. 2. Ferrite Gap Region

Circulator Multipaction Analysis

Multipaction analysis was performed with SPARK3D. The electromagnetic field distribution was obtained with HFSS. The DC magnetic field used in the circulator operation was included in the analysis. If was observed that the presence of magnetic field significantly reduces multipaction threshold. It has been shown [3] by analysis and verified by testing that parallel DC magnetic fields inhibit electron diffusion which results in lower breakdown voltage and lower multipaction threshold.

Fig. 3 shows the circulator 3-D model used for field calculation and multipaction analysis. Fig. 4 shows the breakdown threshold for different values of DC magnetic fields obtained by SPARK3D. The plots represent the electron growth (multipaction breakdown) in the Ferrite region with a power level slightly higher that the threshold values calculated, typically 10% above the threshold. It can be seen how DC magnetic field concentrates the electrons in the Ferrite region and reduces multipactor threshold. The threshold values are summarized in Table 1. The operating point of DC magnetic field is very close to 1500 Gauss.

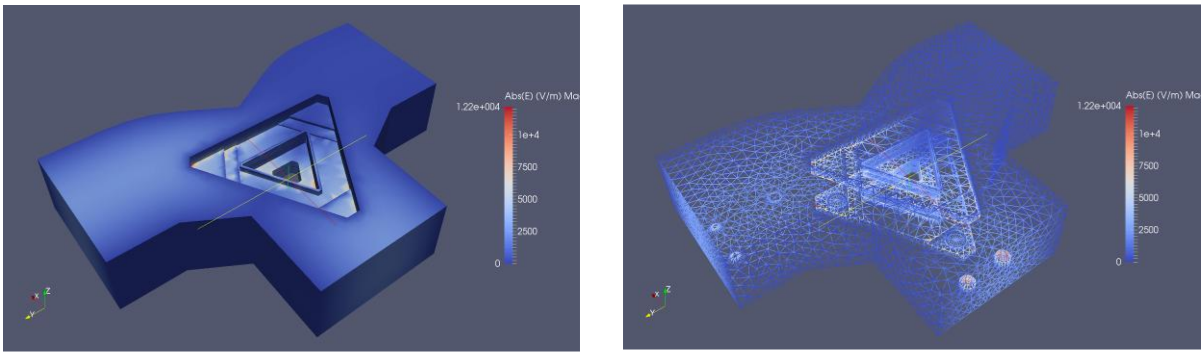


Fig. 3. Circulator 3-D Model used with HFSS and SPARK3D

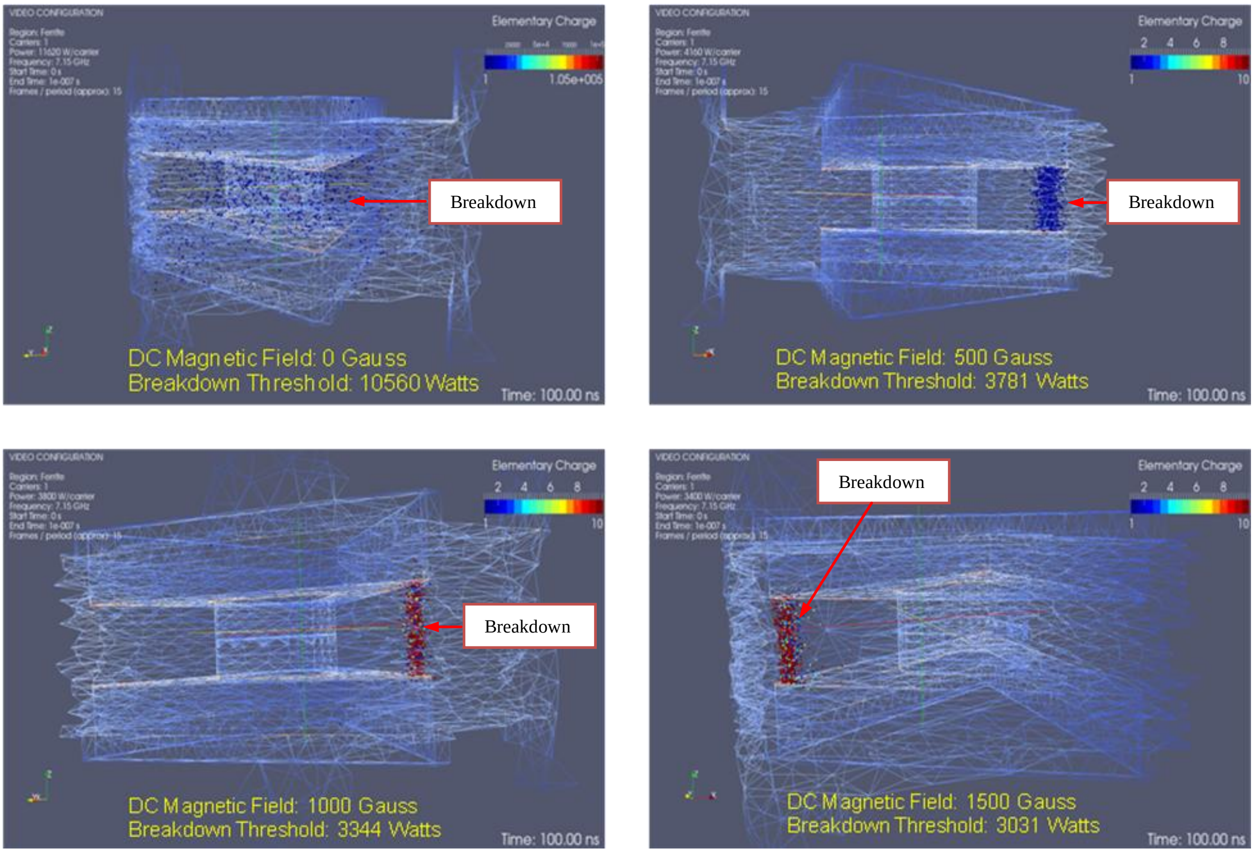


Fig. 4. Multipaction analysis of the Ferrite region, including DC magnetic field. Power levels about 10% above threshold show breakdown

Table 1. DC Magnetic Field reduces Multipaction threshold significantly

DC Magnetic Field (Gauss)	Multipaction Threshold (Watts)
0	10560
500	3781
1000	3344
1500	3031

Circulator Multipaction Testing

Test Conditions Summary

The test set-up is calibrated prior to multipaction testing. A multipaction standard is used to verify that the test set-up is capable of detecting an event when it occurs. Power level is ramped up from 1600 Watts peak, 315 Watts average to 3000 Watts peak, 600 Watts average, in 200 Watts intervals with 5 minutes dwell at each level. 30 minutes dwell at maximum power of 3000 Watts peak, 600 Watts average. Forward, reflected and output powers are continuously monitored and recorded on TMX Chart Recorder. Third harmonic signals at input and output are continuously monitored and recorded. Current Probes (Pico ammeters) are placed at all ports through the vent holes to detect possible anomalies. Several thermocouples are placed on DUT and base plate to continuously monitor and record the temperature. Thermal vacuum chamber temperature and pressure is continuously monitored and recorded on Data Acquisition Unit. Visual inspection after multipaction testing using a microscope at 10x magnification and RF test according to the test plan will finalize the test procedure.

Test parameters

Table 2. shows multipaction test parameters, including the RF signal waveform, the detection methods and number of units tested. Pictures of the test set-up with DUT and multipaction standard inside a thermal vacuum chamber are shown in Fig. 5. The positions of thermocouples, current probes, and electron sources can be seen in the pictures.

Table 2. Multipaction Test Parameters

Parameter	Setting	Notes
Frequency	7.0 GHz	
Power	3000 W peak	600 W average
Pulse Width	100 µs, 5% duty factor	
Pressure	<1.0e-5 Torr.	
Temperature	-10 and +23 Deg. C	
Electron Source	Cs—137 Source,	3 sources, 10 µc each
Sample Rate	50 KHz	
Detection Methods	Input Return Loss, Through Power	Instant change in any two parameters and/or anomaly in Pico ammeters, as recorded on Astro Med TMX Chart Recorder
	Input/Output Third Harmonic	
	Current Probes (all ports)	
# of Samples Tested	20	

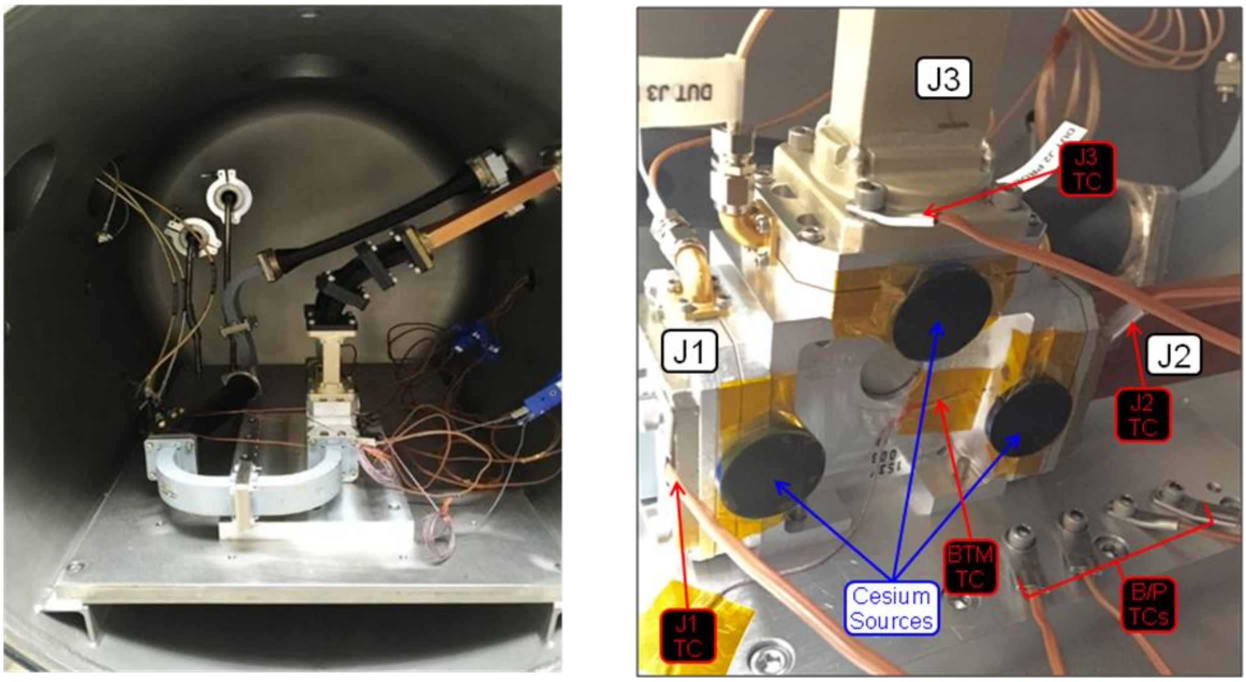
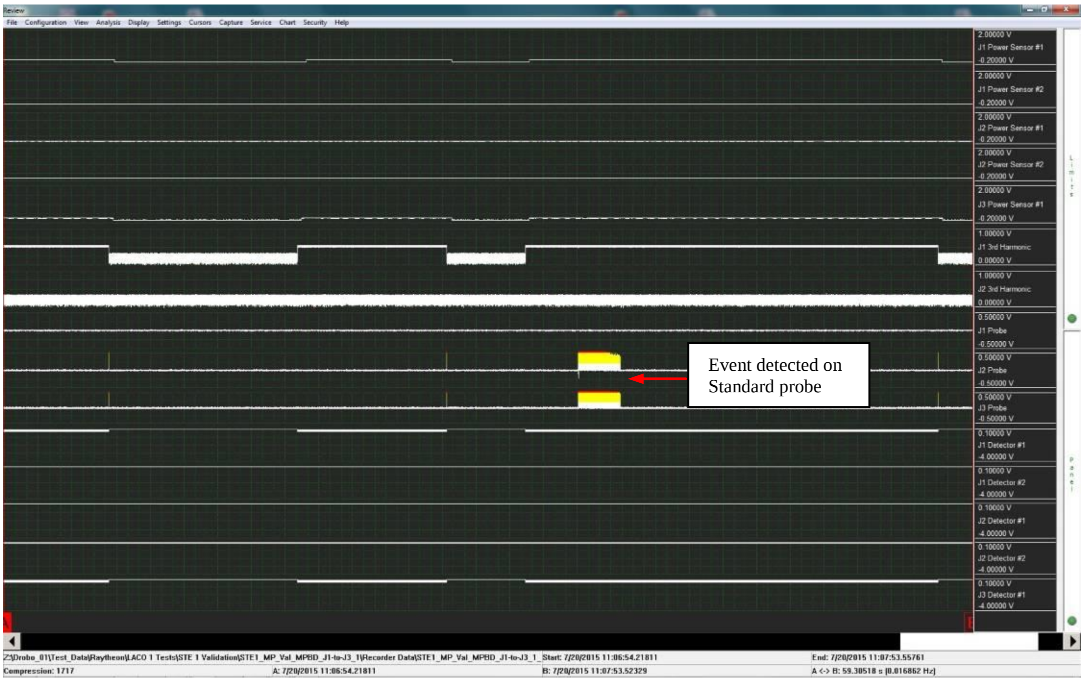


Fig. 5. Images of the circulator in the thermal vacuum chamber, including temperature sensors, current probes and Caesium electron sources

Test Results

Multipaction standard is first tested and shows a clear event detected by the probes at 600 Watts peak, see Fig. 6. The circulator is then submitted to multipaction test, using the test profile shown in Fig. 7. The profile shows the variations of power (represented by detector voltage), temperature and pressure over time during the test cycle. The test begins at -15 °C with the initial power of 1600 Watts peak, and ramped up to the maximum of 3000 Watts peak, 600 Watts average. Keeping the power at this level, the chamber temperature is then increased to +25 °C with 30 minutes dwell. No multipaction event was detected in any of the conditions tested, see Figs. 8 thru 12.



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Compression: 1717 A: 7/20/2015 11:06:54.21811 B: 7/20/2015 11:07:53.52329 A <-> B: 59.30518 s [0.016862 Hz]

Fig. 6. Multipaction test on standard showing event at 600 Watts peak

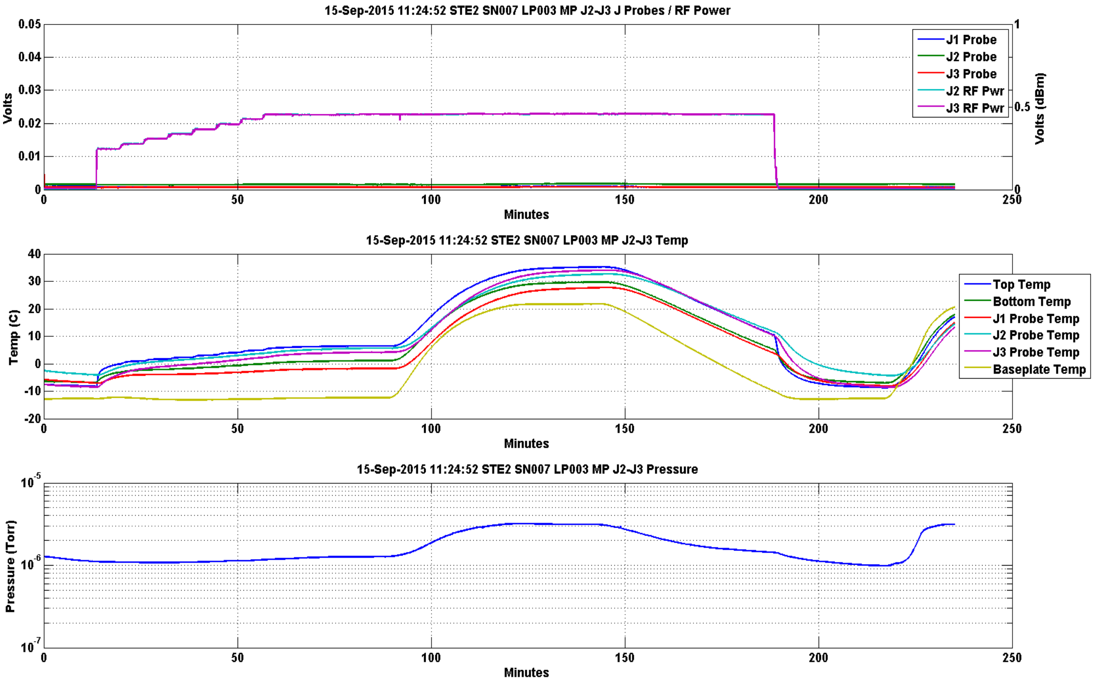
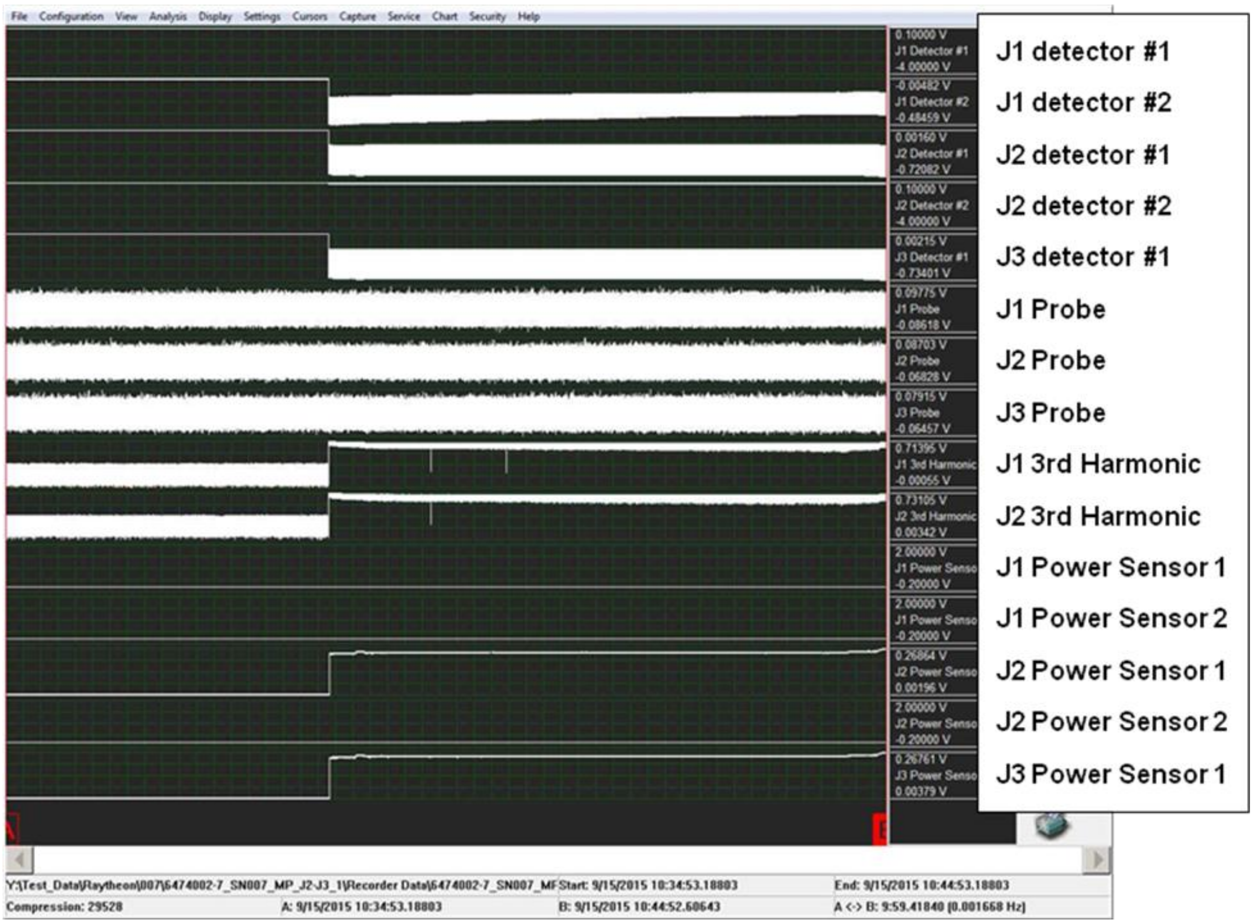


Fig. 7. Circulator Multipaction Test, Input/Output Power, Temperature& Pressure Profile



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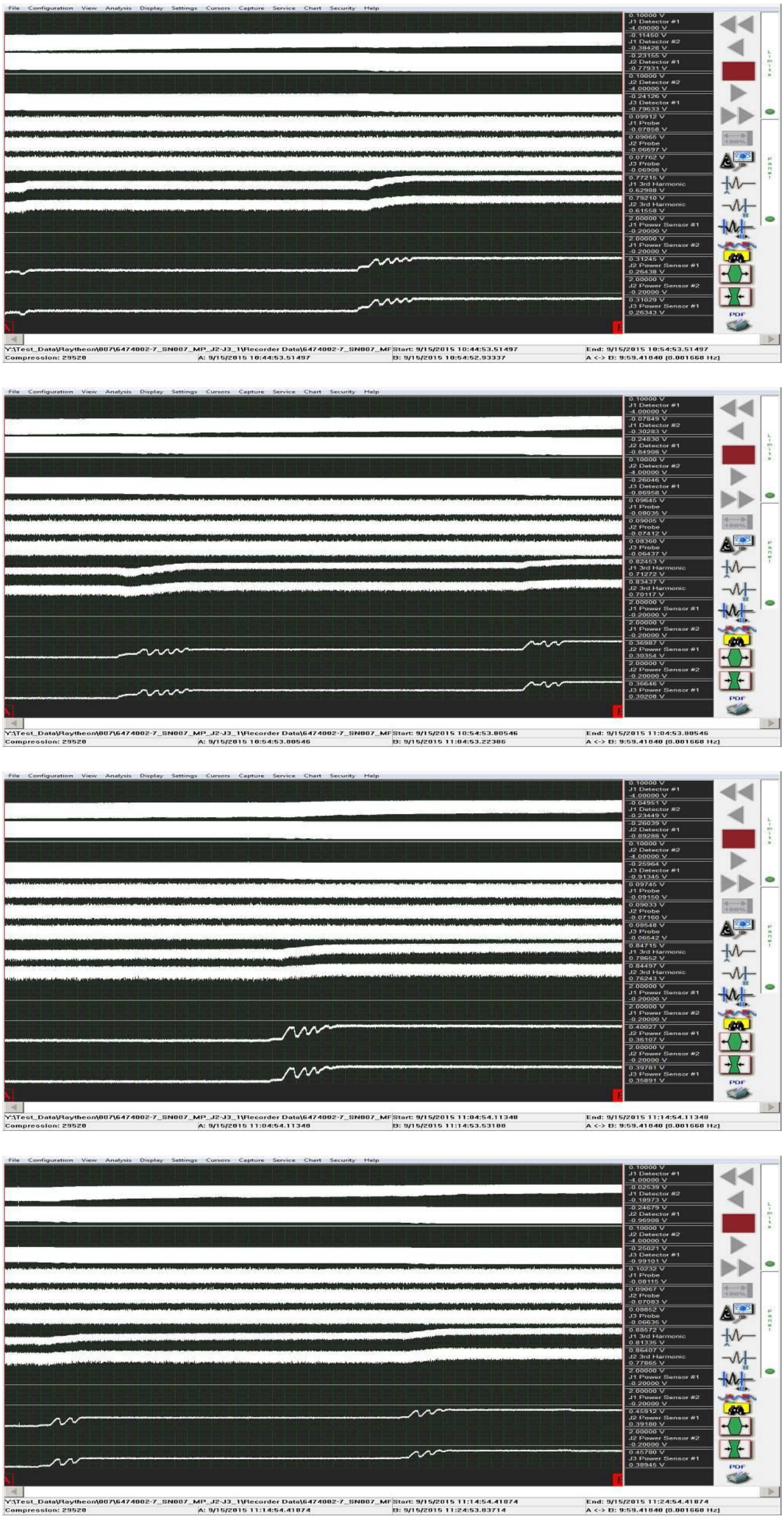
Compression: 29528 A: 9/15/2015 10:34:53.18803 B: 9/15/2015 10:44:52.60643 A <-> B: 9:59.41840 (0.001668 Hz)

Fig. 8. Multipaction Test at 7.0 GHz, -15 °C, 1600 Watts peak, no event



0.10000 V
J1 Detector #1
-4.00000 V
-0.11450 V
J1 Detector #2
-0.38428 V
-0.23155 V
J2 Detector #1
-0.77931 V
0.10000 V
J2 Detector #2
-4.00000 V
-0.24126 V
J3 Detector #1
-0.79633 V
0.09912 V
J1 Probe
-0.07858 V
0.09065 V
J2 Probe
-0.06697 V
0.07762 V
J3 Probe
-0.06908 V
0.77215 V
J1 3rd Harmonic
0.62988 V
0.79210 V
J2 3rd Harmonic
0.61558 V
2.00000 V
J1 Power Sensor #1
-0.20000 V
2.00000 V
J1 Power Sensor #2
-0.20000 V
0.31245 V
J2 Power Sensor #1
0.26438 V
2.00000 V
J2 Power Sensor #2
-0.20000 V
0.31029 V
J3 Power Sensor #1
0.26343 V

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0.10000 V
J1 Detector #1
-4.00000 V
-0.07849 V
J1 Detector #2
-0.30283 V
-0.24830 V
J2 Detector #1
-0.84908 V
0.10000 V
J2 Detector #2
-4.00000 V
-0.26046 V
J3 Detector #1
-0.86958 V
0.09645 V
J1 Probe
-0.08035 V
0.09006 V
J2 Probe
-0.07412 V
0.08360 V
J3 Probe
-0.06437 V
0.82453 V
J1 3rd Harmonic
0.71272 V
0.83437 V
J2 3rd Harmonic
0.70117 V
2.00000 V
J1 Power Sensor #1
-0.20000 V
2.00000 V
J1 Power Sensor #2
-0.20000 V
0.36987 V
J2 Power Sensor #1
0.30354 V
2.00000 V
J2 Power Sensor #2
-0.20000 V
0.36646 V
J3 Power Sensor #1
0.30208 V

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Compression: 29528 A: 9/15/2015 10:54:53.80546 B: 9/15/2015 11:04:53.22386 A <-> B: 9:59.41840 [0.001668 Hz]

0.10000 V
J1 Detector #1
-4.00000 V
-0.04951 V
J1 Detector #2
-0.23449 V
-0.26039 V
J2 Detector #1
-0.89288 V
0.10000 V
J2 Detector #2
-4.00000 V
-0.25964 V
J3 Detector #1
-0.91345 V
0.09745 V
J1 Probe
-0.09150 V
0.09033 V
J2 Probe
-0.07160 V
0.08548 V
J3 Probe
-0.06542 V
0.84715 V
J1 3rd Harmonic
0.78652 V
0.84497 V
J2 3rd Harmonic
0.76243 V
2.00000 V
J1 Power Sensor #1
-0.20000 V
2.00000 V
J1 Power Sensor #2
-0.20000 V
0.40027 V
J2 Power Sensor #1
0.36107 V
2.00000 V
J2 Power Sensor #2
-0.20000 V
0.39781 V
J3 Power Sensor #1
0.35891 V

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Compression: 29528 A: 9/15/2015 11:04:54.11348 B: 9/15/2015 11:14:53.53188 A <-> B: 9:59.41840 [0.001668 Hz]

0.10000 V
J1 Detector #1
-4.00000 V
-0.02539 V
J1 Detector #2
-0.18973 V
-0.24679 V
J2 Detector #1
-0.96908 V
0.10000 V
J2 Detector #2
-4.00000 V
-0.25021 V
J3 Detector #1
-0.99101 V
0.10232 V
J1 Probe
-0.08115 V
0.09067 V
J2 Probe
-0.07083 V
0.08852 V
J3 Probe
-0.06635 V
0.88672 V
J1 3rd Harmonic
0.81335 V
0.86407 V
J2 3rd Harmonic
0.77865 V
2.00000 V
J1 Power Sensor #1
-0.20000 V
2.00000 V
J1 Power Sensor #2
-0.20000 V
0.45912 V
J2 Power Sensor #1
0.39180 V
2.00000 V
J2 Power Sensor #2
-0.20000 V
0.45780 V
J3 Power Sensor #1
0.38945 V

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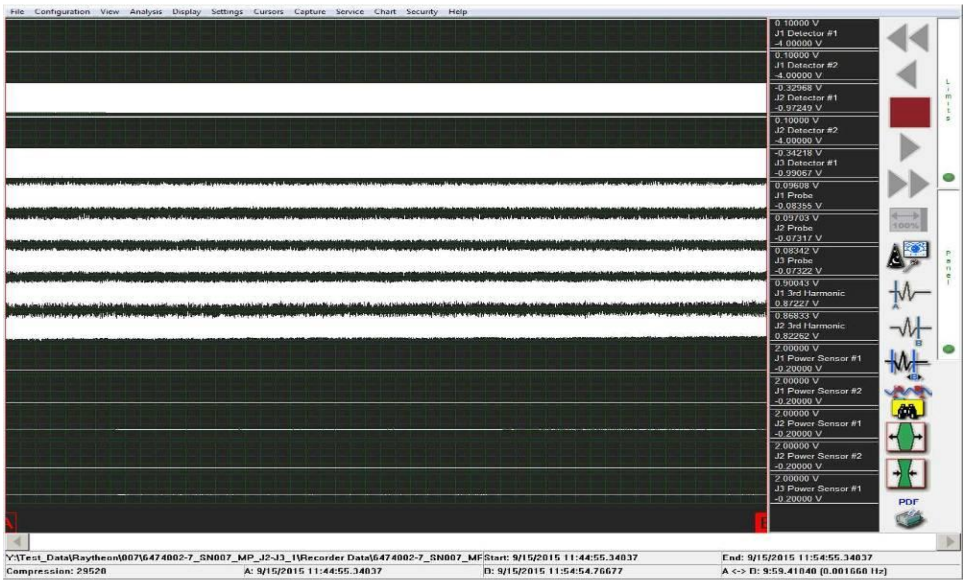
Compression: 29528 A: 9/15/2015 11:14:54.41874 B: 9/15/2015 11:24:53.83714 A <-> B: 9:59.41840 [0.001668 Hz]

Fig. 9. Multipaction Test at 7.0 GHz, -15 °C, power ramp 1600-3000 Watts Peak, no event



```
0.10000 V
J1 Detector #1
-4.00000 V
0.10000 V
J1 Detector #2
-4.00000 V
-0.32968 V
J2 Detector #1
-0.97249 V
0.10000 V
J2 Detector #2
-4.00000 V
-0.34218 V
J3 Detector #1
-0.99067 V
0.09608 V
J1 Probe
-0.08355 V
0.09703 V
J2 Probe
-0.07317 V
0.08342 V
J3 Probe
-0.07322 V
0.90043 V
J1 3rd Harmonic
0.87227 V
0.86833 V
J2 3rd Harmonic
0.82262 V
2.00000 V
J1 Power Sensor #1
-0.20000 V
2.00000 V
J1 Power Sensor #2
-0.20000 V
2.00000 V
J2 Power Sensor #1
-0.20000 V
2.00000 V
J2 Power Sensor #2
-0.20000 V
2.00000 V
J3 Power Sensor #1
-0.20000 V
```

```
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Compression: 29520   A: 9/15/2015 11:44:55.34037   B: 9/15/2015 11:54:54.76677   A <-> B: 9:59.41040 (0.001660 Hz)
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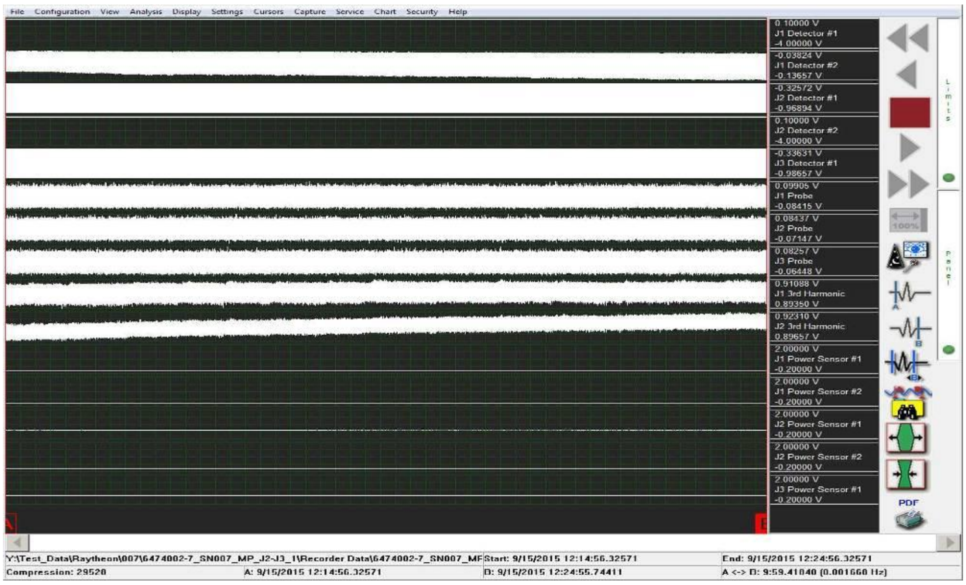
Fig. 10. Test at -15 °C, 3000 Watts peak dwell, no event



```
0.10000 V
J1 Detector #1
-4.00000 V
-0.03824 V
J1 Detector #2
-0.13657 V
-0.32572 V
J2 Detector #1
-0.96894 V
0.10000 V
J2 Detector #2
-4.00000 V
-0.33631 V
J3 Detector #1
-0.98657 V
0.09906 V
J1 Probe
-0.08415 V
0.08437 V
J2 Probe
-0.07147 V
0.08257 V
J3 Probe
-0.06448 V
0.91088 V
J1 3rd Harmonic
0.89350 V
0.92310 V
J2 3rd Harmonic
0.89657 V
2.00000 V
J1 Power Sensor #1
-0.20000 V
2.00000 V
J1 Power Sensor #2
-0.20000 V
2.00000 V
J2 Power Sensor #1
-0.20000 V
2.00000 V
J2 Power Sensor #2
-0.20000 V
2.00000 V
J3 Power Sensor #1
-0.20000 V
```

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Compression: 29520   A: 9/15/2015 12:14:56.32571   B: 9/15/2015 12:24:55.74411   A <-> B: 9:59.41040 (0.001660 Hz)
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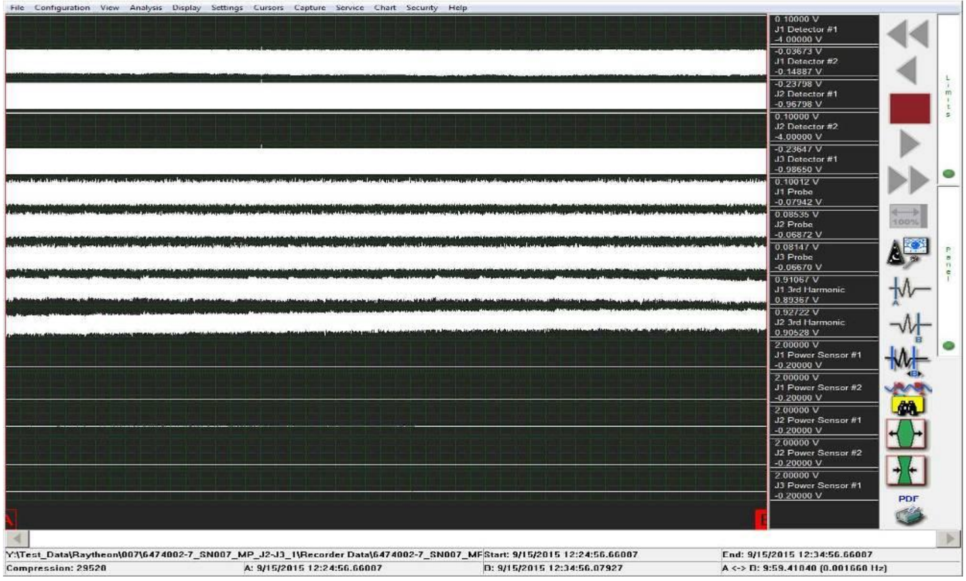
Fig. 11. Test at 3000 Watts peak during temperature transition, no event



```
0.10000 V
J1 Detector #1
-4.00000 V
-0.03673 V
J1 Detector #2
-0.14887 V
-0.23798 V
J2 Detector #1
-0.96798 V
0.10000 V
J2 Detector #2
-4.00000 V
-0.23647 V
J3 Detector #1
-0.98650 V
0.10012 V
J1 Probe
-0.07942 V
0.08535 V
J2 Probe
-0.06872 V
0.08147 V
J3 Probe
-0.06670 V
0.91067 V
J1 3rd Harmonic
0.89367 V
0.92722 V
J2 3rd Harmonic
0.90528 V
2.00000 V
J1 Power Sensor #1
-0.20000 V
2.00000 V
J1 Power Sensor #2
-0.20000 V
2.00000 V
J2 Power Sensor #1
-0.20000 V
2.00000 V
J2 Power Sensor #2
-0.20000 V
2.00000 V
J3 Power Sensor #1
-0.20000 V
```

```
Y:\Test_Data\Raytheon\007\6474002-7_SN007_MP_J2-J3_1\Recorder Data\6474002-7_SN007_MF  Start: 9/15/2015 12:24:56.66087  End: 9/15/2015 12:34:56.66087
Compression: 29520   A: 9/15/2015 12:24:56.66087   B: 9/15/2015 12:34:56.07927   A <-> B: 9:59.41040 (0.001660 Hz)
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Fig. 12. Test at +25 °C, 3000 Watts peak dwell, no event

BANDPASS FILTER DESIGN

Fig. 13 shows the schematic of the bandpass filter. It is a lumped element design in the 150-250 MHz frequency band with Pseudo-elliptic response achieved by 10 poles and one transmission zero. The filter uses air core inductors and ceramic single layer capacitors. Coils are made of pure Silver with minimum unloaded Q of 125 at 85 °C. Ceramic capacitors are 0.010” or 0.025” thick with much higher Q, typically >2000. Mounting base is made of a controlled expansion alloy to reduce thermal stress on shunt capacitors. Coils are placed in individual cavities inside the housing to improve Q and avoid direct coupling between them. Inductors are soldered on Copper-Tungsten carriers which are soldered onto the shunt capacitors to achieve high Q and robust attachment. See Fig. 14.

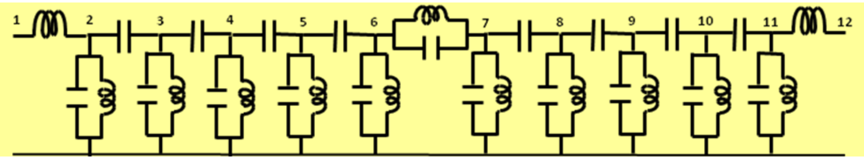


Fig. 13. Schematic of the bandpass filter

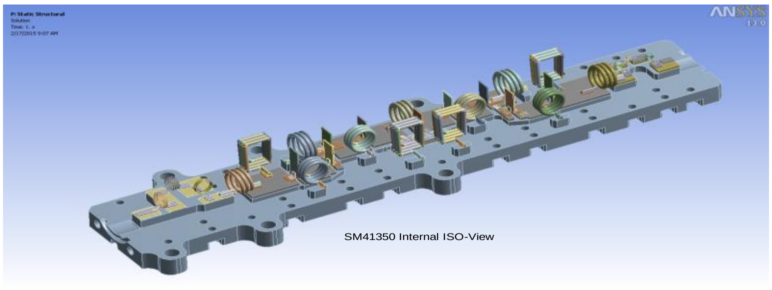


Fig. 14. Filter assembly with housing, cover and connectors removed

High Power and Multipaction –Free Design

Table 3 shows peak voltages at different nodes with 37.5 Watts peak power. The voltages are calculated at *Fc* = 200 MHz and at frequencies of maximum group delay, (141 MHz and 256 MHz). Maximum voltage build-up is 128 Volts, occurring at node 4 at 141 MHz. This voltage value is well below the breakdown voltage of all the material in the filter, but it’s not known if it will not cause a multipactor breakdown; therefore the device must be protected.

To protect the filter against multipaction, it will be filled with a syntactic foam with high breakdown voltage (2.5KV/mm). Multipaction is not possible with dielectrically impregnated RF cavities due to the free mean path of the electron being much smaller than the physical gap. Theoretically, over the pass band frequency (150-250 MHz), gaps smaller that 0.037” will not multipact; however all gaps will be filled with syntactic foam or with layers of silicone RTV. RTV filling must be confined to small regions to minimize iso-thermal mechanical stresses. Due to the large organic load in the filter, substantial venting must be used to allow for outgassing and prevent a corona discharge. Both the foam and RTV are considered infinite sources of gas. Figs. 15 and 16 show the pictures of the filter before and after adding the foam.

Table 3. Peak voltages at different nodes of the filter

Peak Voltage (Volts)	Node Number, Refer to Schematic											
Frequency	1	2	3	**4**	5	6	7	8	9	10	11	12
@ 141 MHz	27	43	116	**128**	117	93	90	77	60	43	24	21
@ 200 MHz	41	48	61	**65**	59	63	60	62	57	53	47	39
@ 256 MHz	54	80	112	**124**	122	113	76	68	57	44	32	23

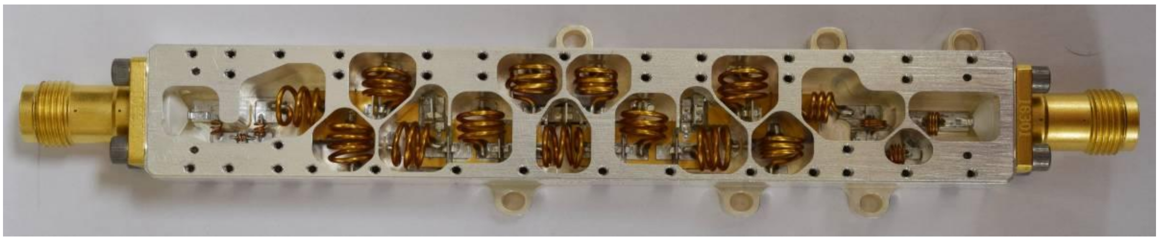


Fig. 15. Filter with cover removed, before adding foam

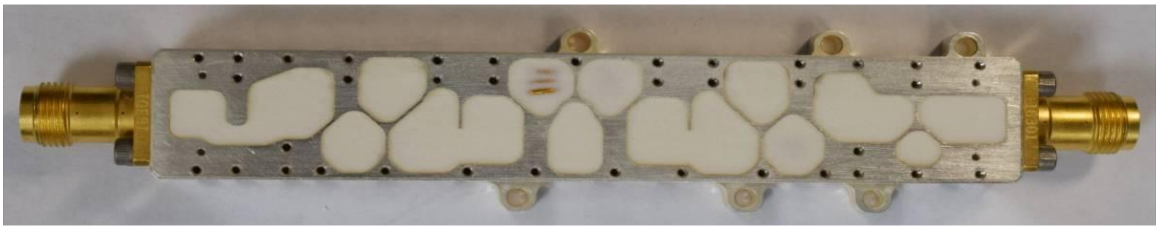


Fig. 16. Filter with cover removed, foam-filled

Band pass Filter Multipaction Testing

Test Conditions

The test set-up is calibrated prior to multipaction testing. A multipaction standard is used to verify that the test set-up is capable of detecting an event when it occurs. Power level is ramped from 10 Watts peak to 80 Watts peak with 5 minutes dwell at each level. 30 minutes dwell at maximum power of 80 Watts peak, 4 Watts average. Forward, reflected and output powers are continuously monitored and recorded on TMX Chart Recorder. Return loss null and third harmonic signals at input and output are continuously monitored and recorded. Current Probes (Pico ammeters) are placed at the input and output of the filter through the vent holes to detect possible anomalies. Several thermocouples are placed on DUT and base plate to continuously monitor and record the temperature. Thermal vacuum chamber temperature and pressure are continuously monitored and recorded on Data Acquisition Unit. Multipaction test is followed by a visual inspection using a microscope at 10x magnification and RF test according to the test plan to ensure the device shows no sign of degradation or damage during the test.

Test Parameters

Table 4. shows multipaction test parameters, including the RF signal waveform, the detection methods and number of units tested. Pictures of the test set-up with DUT and multipaction standard inside a thermal vacuum chamber are shown in Figs. 17 and 18. Thermocouples, current probes, and electron sources can be seen in the pictures.

Table 4. Multipaction Test Parameters

Parameter	**Setting**	**Notes**
Frequency	150 MHz and 250 MHz	
Power	80 W peak	4 W average
Pulse Width	2ms, 5% duty factor	
Pressure	<1.0e-5 Torr.	
Temperature	-45 and +85 Deg. C	
Electron Source	Cs—137 Source,	3 sources, 10 µc each
Sample Rate	10 KHz and 10 Hz	
Detection Methods	Input Return Loss Nulling	Instant change in any two parameters and/or anomaly in Pico ammeters, as recorded on Astro Med TMX Chart Recorder
	Input/Output Third Harmonic	
	Vent Hole Current Probes	
# of Samples Tested	10	

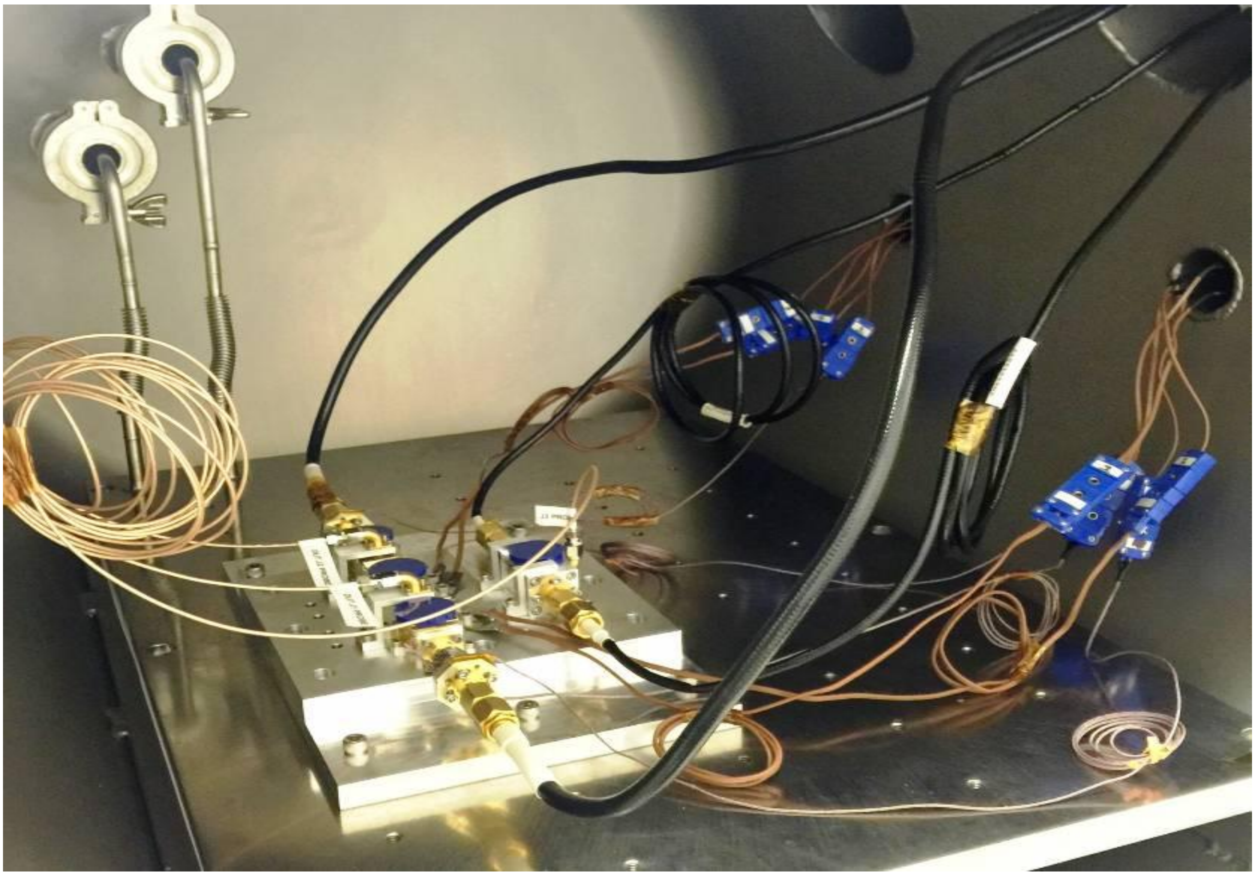


Fig. 17. Picture the filter and multipaction standard in thermal vacuum chamber

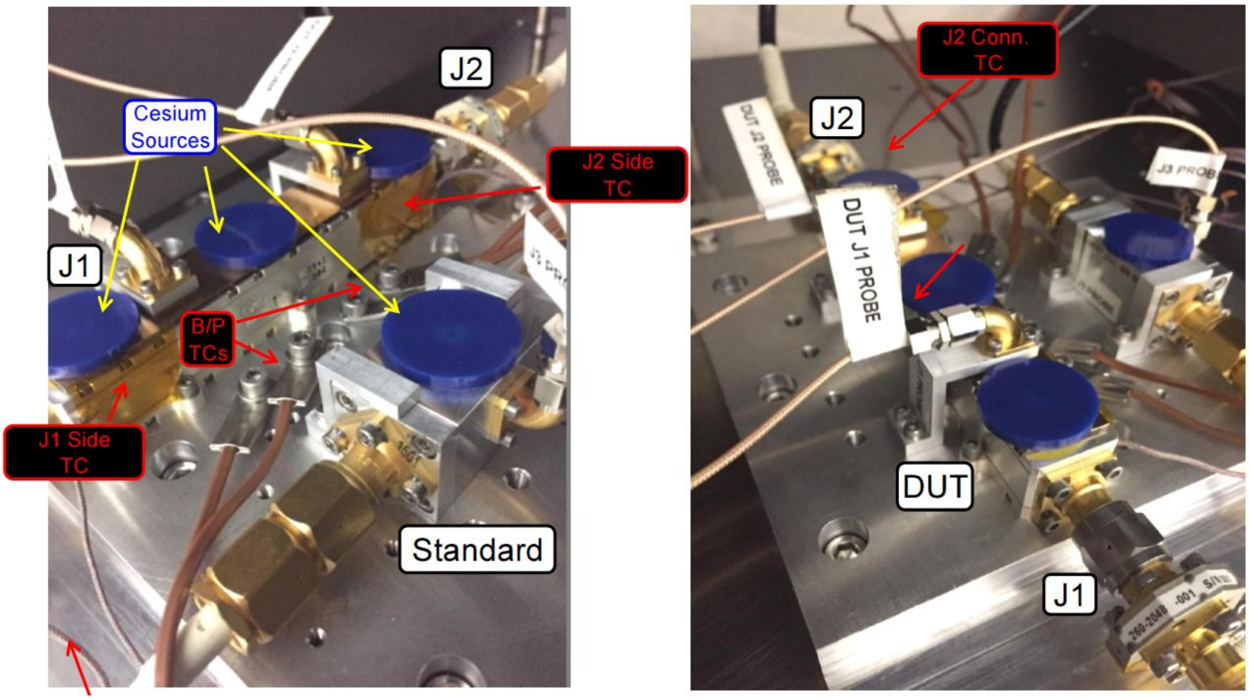
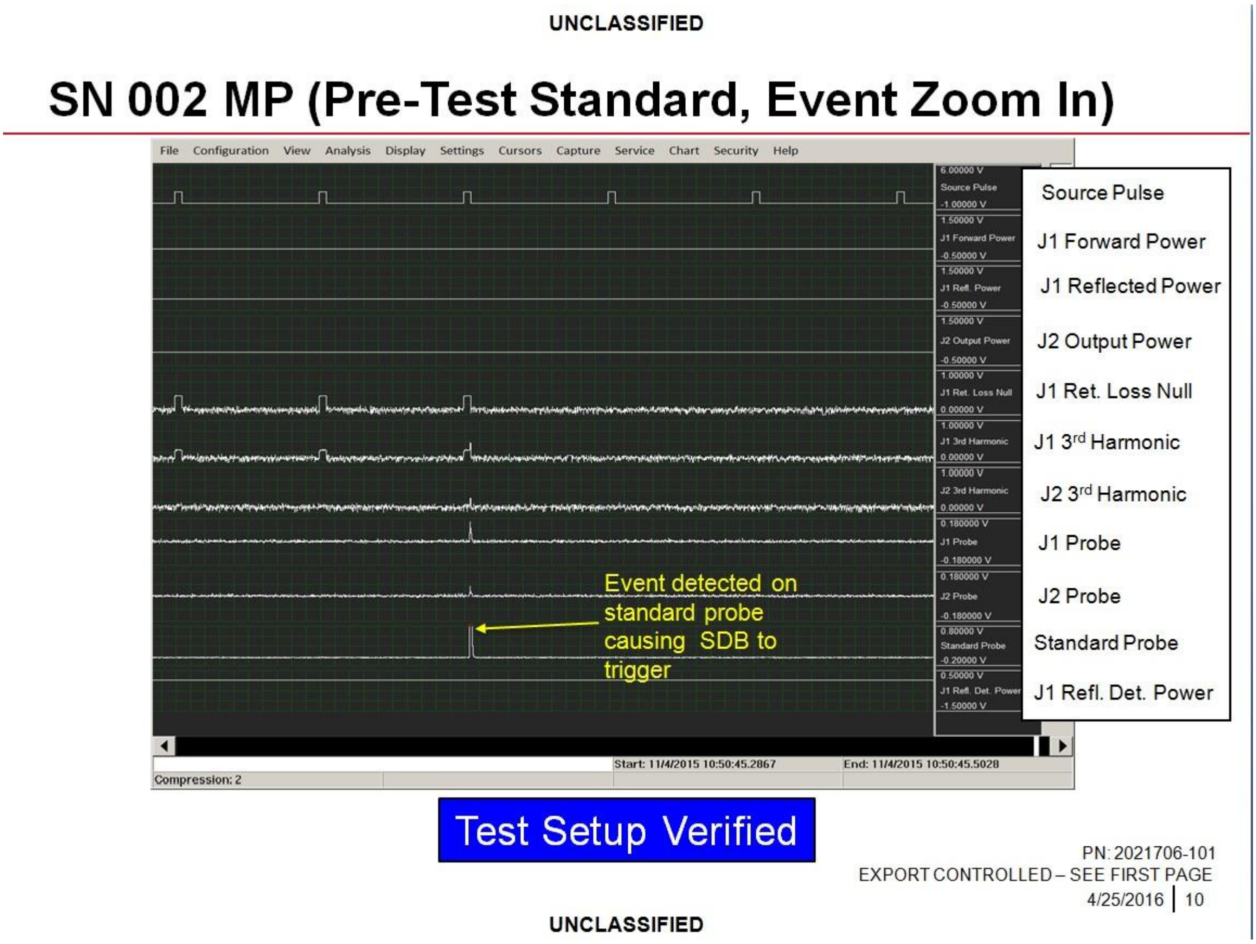


Fig. 18. Images of the unit in the thermal vacuum chamber, including temperature sensors, current probes and Cesium 137 seed electron sources

Test Results

Multipaction standard is first tested and shows an event at 6.93 Watts peak detected by the probes, see Fig. 19. The filter is then submitted to multipaction test, using the test profiles shown in Figs. 20 and 21. The profiles show the variations of power, temperature and pressure over time during the test cycle. The test begins at -45 °C with the initial power of 10 Watts peak, and ramped up to the maximum of 80 Watts peak, 4 Watts average. Keeping the power at this level, the chamber temperature is then increased to +85 °C with 30 minutes dwell. No multipaction event was detected in any of the conditions tested, see Figs. 22 thru 25.


UNCLASSIFIED

SN 002 MP (Pre-Test Standard, Event Zoom In)

Event detected on standard probe causing SDB to trigger

Start: 11/4/2015 10:50:45.2867

End: 11/4/2015 10:50:45.5028

Compression: 2

Test Setup Verified

PN: 2021706-101

EXPORT CONTROLLED – SEE FIRST PAGE

4/25/2016 | 10

UNCLASSIFIED

Fig. 19. Multipaction test on standard showing event at 6.93 Watts peak

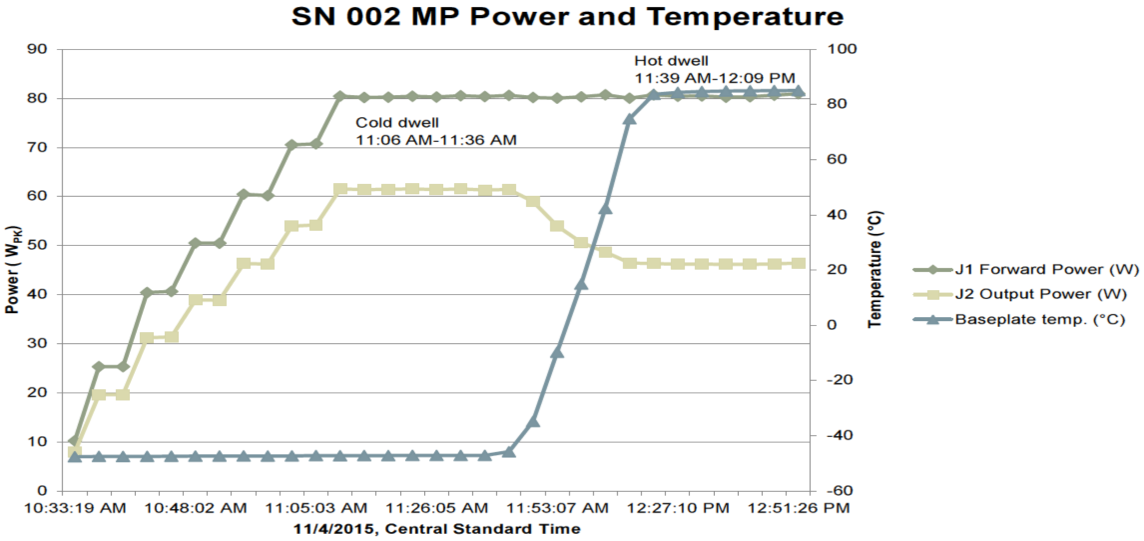


Fig. 20. BPF Multipaction Test, Input/Output Power and Temperature Profile

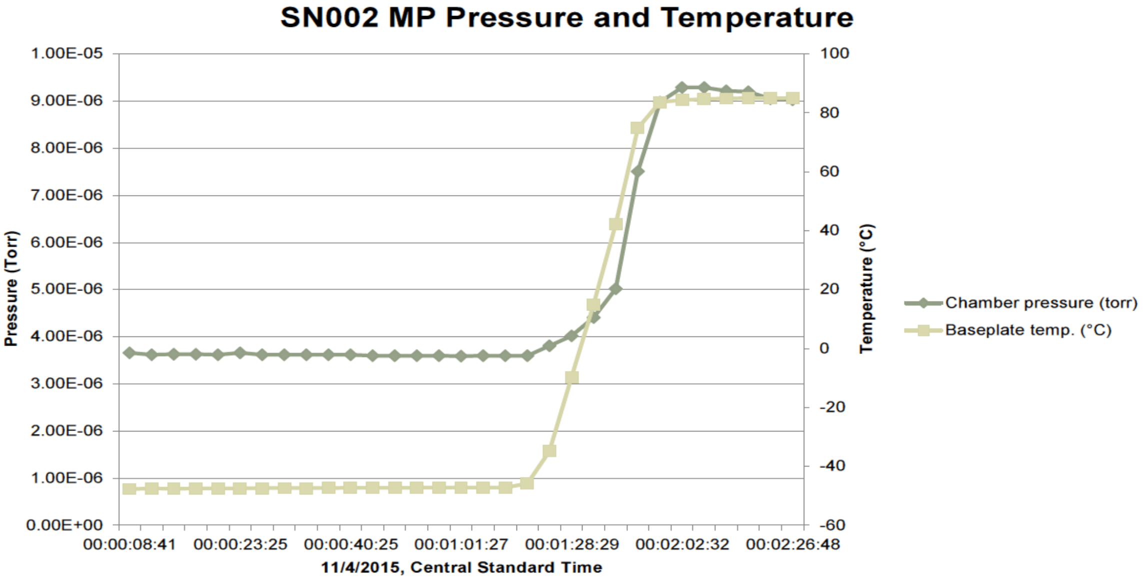
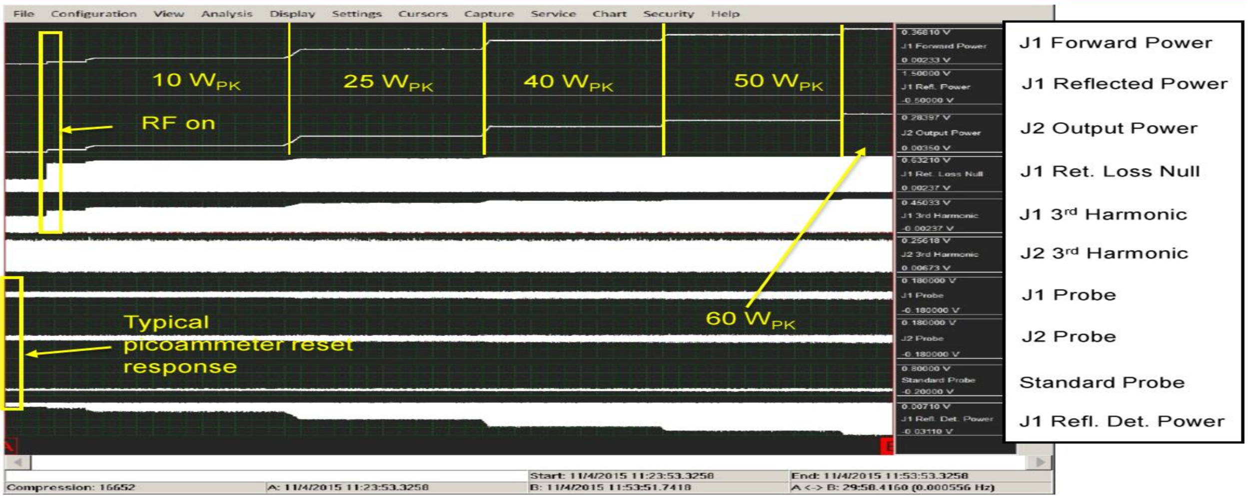
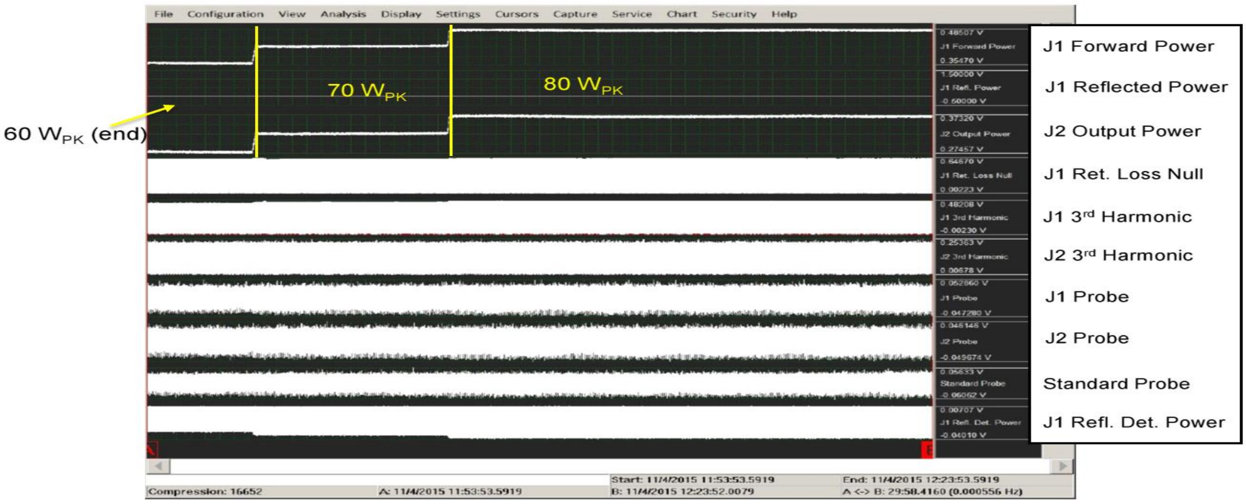


Fig. 21. BPF Multipaction Test, Pressure and Temperature Profile



Start: 11/4/2015 11:23:53.3258
End: 11/4/2015 11:53:53.3258
Compression: 16652
A: 11/4/2015 11:23:53.3258
B: 11/4/2015 11:53:51.7418
A <-> B: 29:58.4160 (0.000556 Hz)

Fig. 22. Test at -45 °C, from 10 to 60Watts peak



Start: 11/4/2015 11:53:53.5919
End: 11/4/2015 12:23:53.5919
Compression: 16652
A: 11/4/2015 11:53:53.5919
B: 11/4/2015 12:23:52.0079
A <-> B: 29:58.4160 (0.000556 Hz)

Fig. 23. Test at -45 °C, from 60 to 80 Watts peak

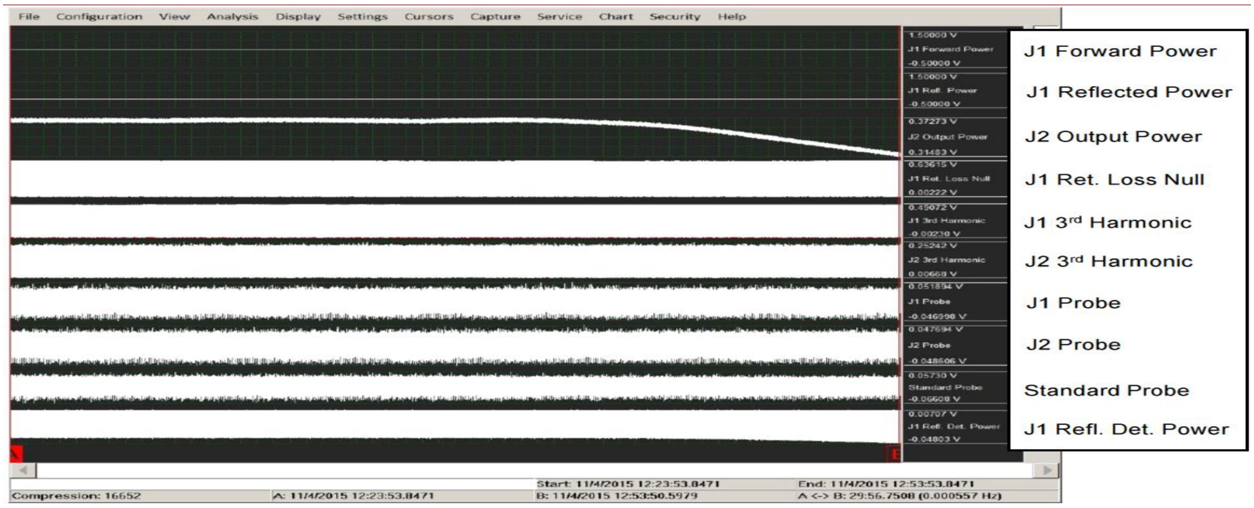


Fig. 24. Test during Cold to Hot Transition, 80 Watts peak

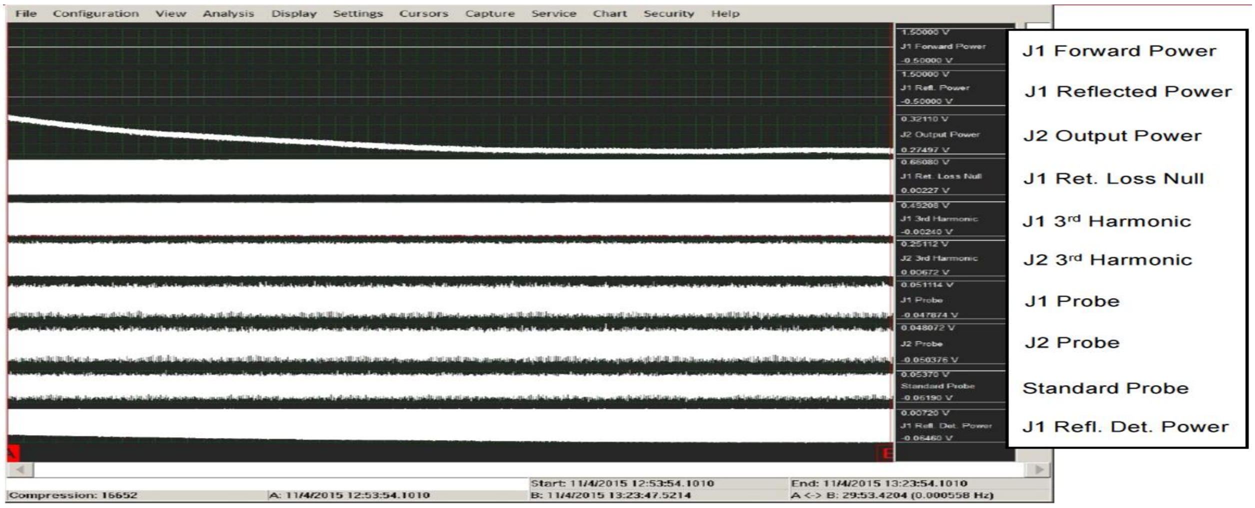


Fig. 25. Test at +85 C, 80 Watts peak dwell showing no event

HIGH POWER L-BAND ISO-COMBINER

Fig. 26 shows a picture o f the iso-combiner. The schematic is presented in Fig. 27. It is a 3-port device comprised of apower combiner and two isolators, one at each input port. The Iso-combiner is required to handle 400 Watts combined average power and it was tested for multipaction with combined input power up to 755 Watts peak with no evidence of multipaction breakdown.

Fig. 26. Iso-Combiner Picture

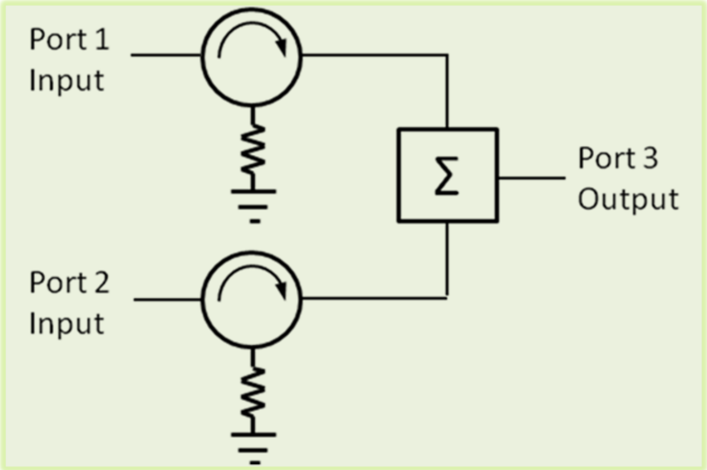


Fig. 27. Iso-Combiner Schematic

Iso-Combiner Multipaction Analysis

Power Combiner Multipaction Analysis

EM simulation with CST Microwave Studio was performed to obtain electric field distribution of the combiner and calculate the peak voltages over critical gaps with 3170 Watts CW (200 Watts+12 dB) power at each input port. Fig. 28 shows the position of voltage monitors in the analysis. The two highest voltages correspond to monitor 1 and 2. Voltage monitor 1 in the connector area shows 696.0 volts peak corresponding to gap, d=2.48 mm, and voltage monitor 2 in the combiner area has 741.6 volts peak with d=3.24 mm. The corresponding breakdown voltage thresholds will be 241.9 volts and 316.3 volts respectively, at F=1.55 GHz (using V=63xFxd for Silver) which will result in negative safety margins. This indicates that an unprotected device would multipact with the specified power levels.

Isolator Multipaction Analysis

The minimum gap in the isolator is the distance between the circuit trace and termination carrier, 0.731 mm. At 1.55 GHz, Fxd = 1.133 GHz·mm and the peak voltage V_P for aluminum will be 33.7 V, using ESA/ESTEC calculator and the maximum safe power is calculated to be 22.71 Watts, with Z = 50 ohms (the highest impedance in the isolator). This represents -24.47dB margin over the 3170 Watts CW requirement. Thus without protection, the isolator would multipact with the specified power level. To increase multipaction threshold, the iso-combiner is filled with a syntactic foam with high breakdown voltage (2.5KV/mm). The foam will block any free path of secondary electron that may be released from the surface due to high RF power. In addition, thin layers of silicone RTV will be used to fill any gap between different parts of the device. RF connectors will be TNC Wedge type known to have high breakdown threshold.

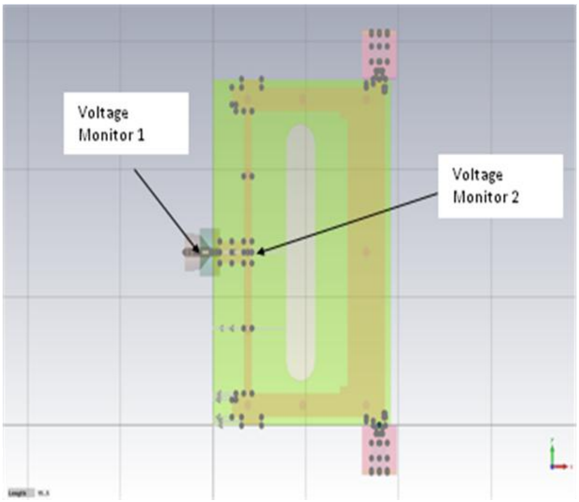


Fig. 28. Voltage Monitors for Iso-Combiner Multipaction Analysis

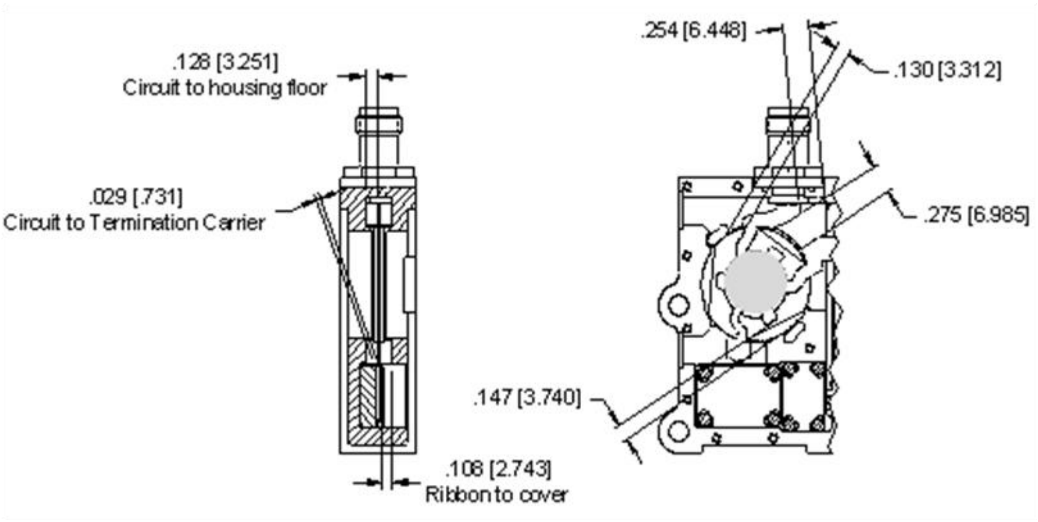


Fig. 29. Isolator section showing minimum gap of 0.731 mm between circuit and termination carrier

Iso-combiner Multipaction Testing

Test Conditions

The test set-up is calibrated prior to multipaction testing. A multipaction standard is used to verify that the test set-up is capable of detecting an event when it occurs. Each input power level is ramped up from 50 Watts peak to 400 Watts peak, in 50 Watts intervals with 10 minutes dwell at each level. 60 minutes dwell at maximum power of 400 Watts peak. Forward, reflected and output powers are continuously monitored and recorded on TMX chart Recorder. Return loss null and third harmonic signals at input and output are continuously monitored and recorded. Several thermocouples are placed on DUT and base plate to continuously monitor and record the temperature. Thermal vacuum chamber temperature and pressure is continuously monitored and recorded with Data Acquisition Unit. Visual inspection after multipaction testing using a microscope at 10x magnification and RF test according to the test plan will finalize the test procedure.

Test Parameters

Table 5. shows multipaction test parameters, including the RF signal waveform, the detection methods and number of units tested. A picture of the test set-up inside the thermal vacuum chamber is shown in Fig. 30, including thermocouples, and electron sources.

Table 5. Multipaction Test Parameters

Parameter	**Setting**	**Notes**
Frequency	1575 MHz	
Power	755 W peak	378 W average
Pulse Width	2ms, 50% duty factor	
Pressure	<1.0e-5 Torr.	
Temperature	-5, +25 and +85 Deg. C	
Electron Source	Cs—137 Source,	3 sources, 10 µc each
Detection Methods	Dual Return Loss Nulling	Instant change in any two parameters as recorded on Astro Med TMX Chart Recorder
	Input/Output Return Loss	
	Dual Input/Output Third Harmonic	
# of Samples Tested	2	

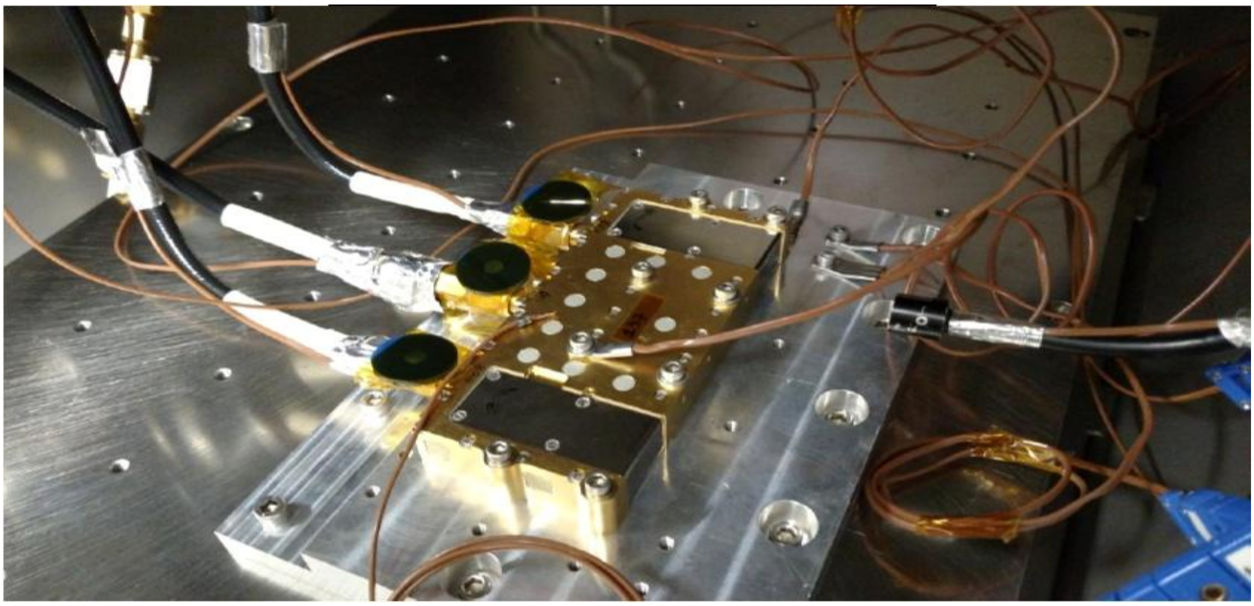
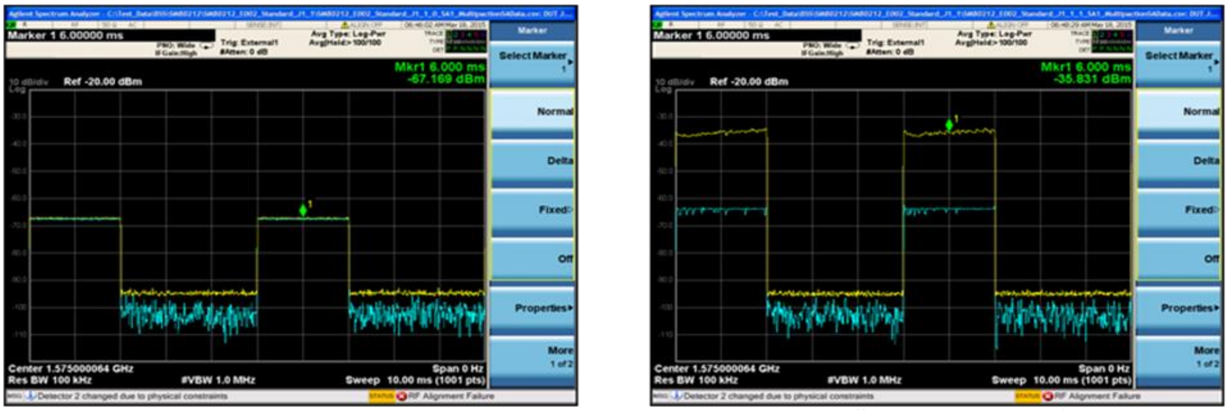


Fig. 30. Picture of iso-combiner in the thermal vacuum chamber, including temperature sensors and Cesium 137 electron sources

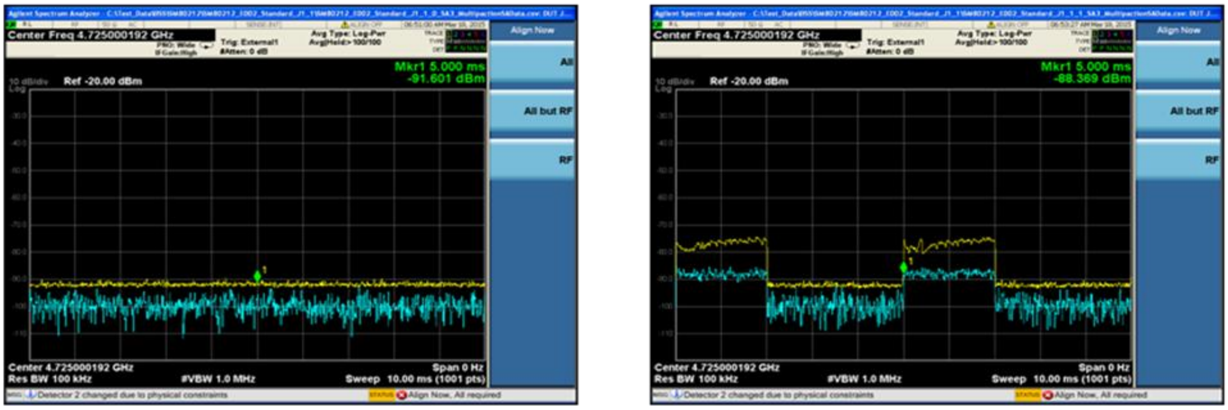
Test Results

Multipaction standard is first tested and shows an event at 70 Watts peak; picked up in return loss null and third harmonic levels, see Fig. 31. Then, the DUT is submitted to multipaction test. The test is done at three different temperatures, namely, -5, +25 and +85 °C with the initial power of 50 Watts peak, and ramped up to the maximum of 1014 Watts peak. Keeping the power at this level, the chamber temperature is increased to +85 °C with 60 minutes dwell. No multipaction event was detected in any of the conditions tested, see Figs. 32 and 33.



Return Loss Null Input, 5 Watts

Return Loss Null Input, 70 Watts Multipaction Event



Third Harmonic Input, 5 Watts

Third Harmonic Input, 70 Watts Multipaction Event

Fig. 31. Multipaction test on standard showing event at 70 Watts peak

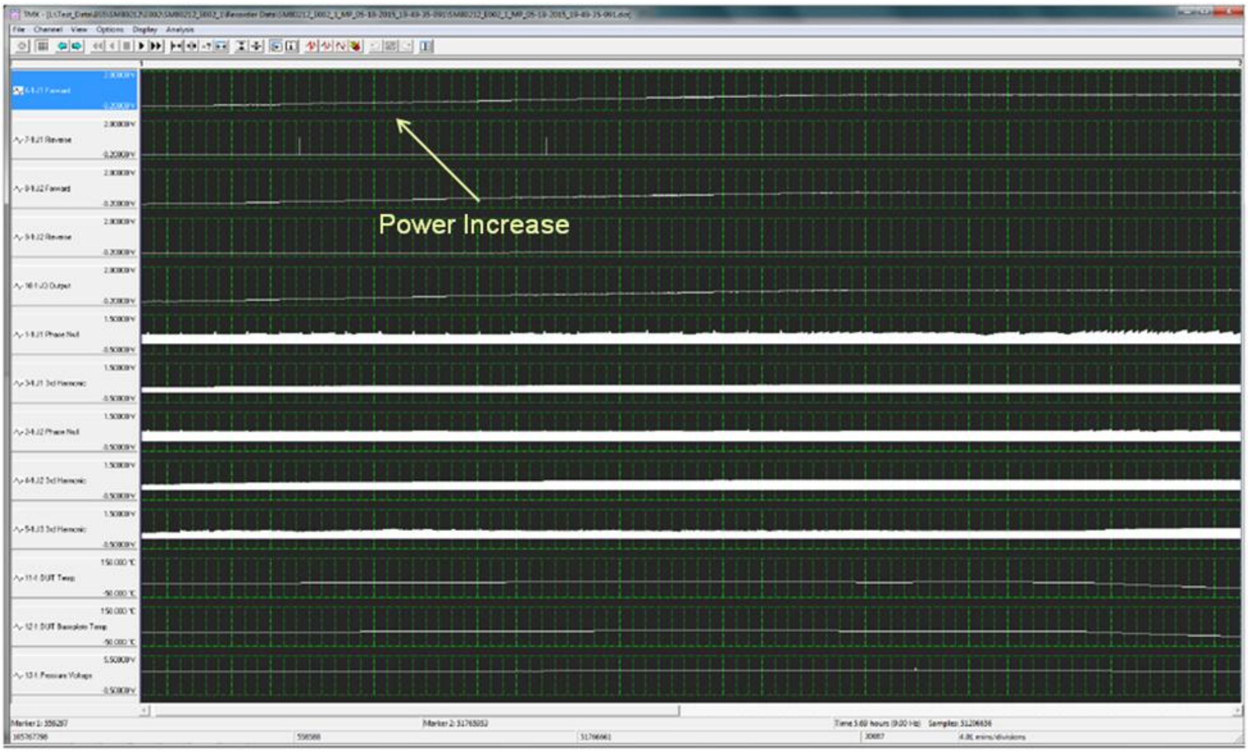


Fig. 32. Multipaction test on DUT during power ramp showing no event

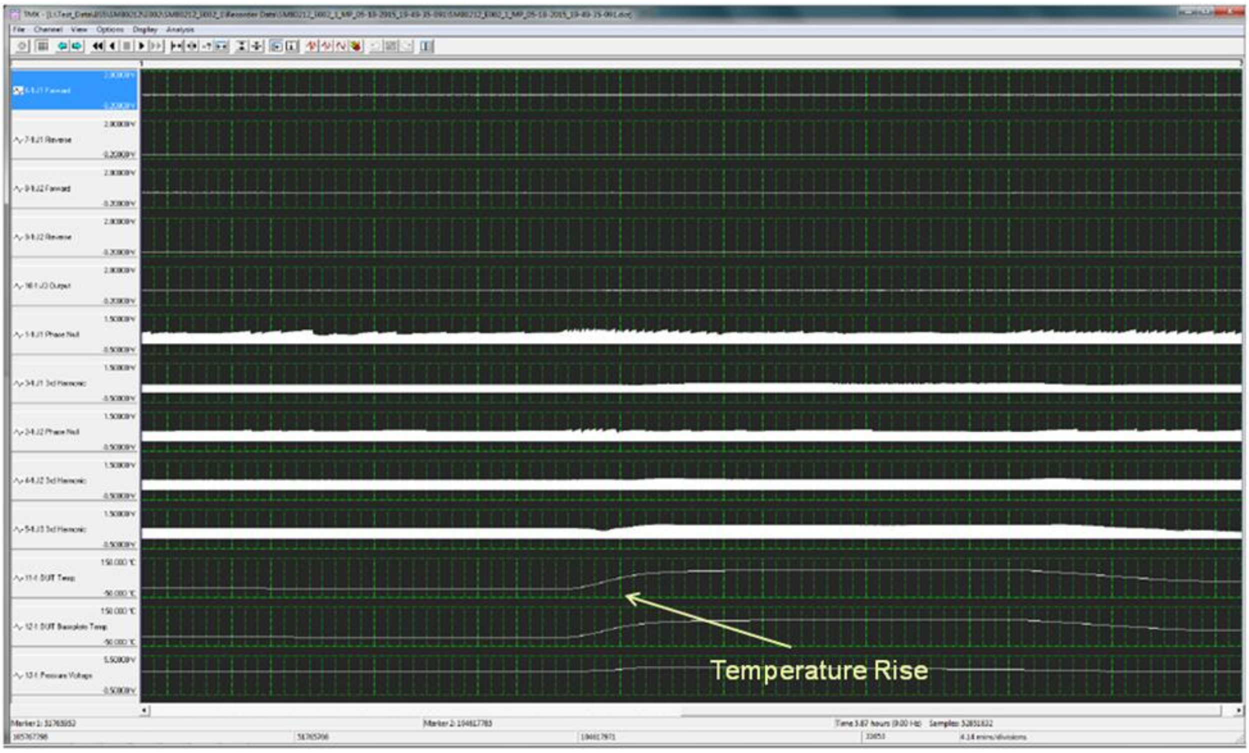


Fig. 33. Multipaction test on DUT. 60 min. dwell at maximum power and maximum temperature showing no event

REFERENCES

[1] ESA/ESTEC Multipactor Calculator, Issue 1.6, April 2007.

[2] SPARK3D is a Multipaction and corona analysis software developed by Aurorasat.

[3] A.A. Hubble, A.D. Farkas, R. Spektor, P.T. Partridge, A.M. Langford and T.P. Graves, "Diffusion-Limited Resonant Electron RF Breakdown", MULCOPIM 2014

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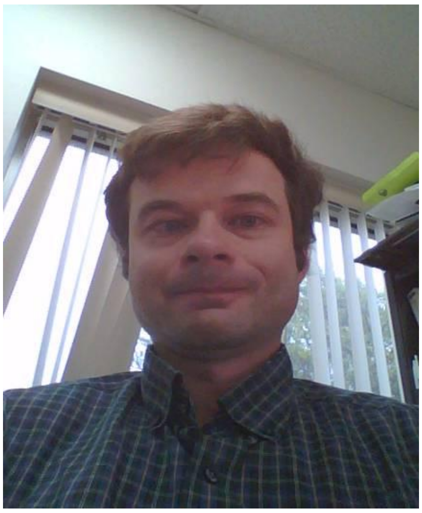

James Haas