TSXdB.00

High Frequency Broadband Attenuators
Electrical and Thermal Test Report

Juan Ayala, Mo Hasanovic
March 15, 2021
Revision 2
(July 14th, 2021)

Table of Contents

Table of Figures

Table of Tables

Scope

The purpose of this test report is to present the electrical and thermal performance of SMT high frequency broadband attenuators covering frequencies from DC to 40 GHz (product family TSXdB.00) developed under the project DD-233610. The report will show test data collected during the tests performed on these products. Both the pre-test simulation analysis as well as the tests on real prototypes will be displayed and analyzed. For a successful evaluation of the products at high frequencies, it is of a paramount importance for the products to be mounted on the test fixture using clearly defined mounting instructions. This report contains these mounting instructions for a future reference to be used by both the internal and external users. In addition, the test procedure is included with the test equipment used and best testing practices implemented.

Thermal performance has also been presented through a simulation and a real-life test. Thermal finite element analysis (FEA) simulations are carried out to calculate the maximum power handling of the family of parts in different environments (with different mounting constituents). The power test has been conducted in a destruct fixture that was described in the report. Finally, the set of samples has been exposed to a rigorous qualification that included Group A, Group B and Group C tests as per test plan TP-9293.

The test samples passed all the qualification test requirements. The test results that will be presented in this test report are an evidence of a successful test and viability of the products to be released into customers' applications.

Specifications

The products have been designed for a broad frequency band from DC to 40 GHz. The performance is also evaluated up to 50 GHz. The product offering spans attenuation values from 0 dB to 10 dB in increments of 1 dB as well as high attenuation values of 15 dB and 20 dB. The size of the product is identical for all values, 0.060"×0.040"×0.010". These products were made using a thin film based processes on an Alumina ceramic substrate. Detailed specifications for these two products are shown in Tables and Figures below.

TSXDB.00				
ITEM	PARAMETER	REQUIREMENT	LIMITS	UNITS
1	Nominal Impedance	50 ± 10%	-	Ω
2	Frequency Range	DC – 40	-	GHz
3	VSWR (DC–20 GHz)	1.30:1	maximum	-
4	VSWR (20–40 GHz)	1.40:1	maximum	-
5	Attenuation	0 – 10 dB, 15 dB, 20 dB	minimum	dB
4	Attenuation Accuracy (DC–20 GHz)	±0.50	minimum	dB
5	Attenuation Accuracy (20–40 GHz)	±0.75	minimum	dB
8	Temperature Coefficient	±200	maximum	ppm/°C
9	Input Power	0.5	minimum	Watts
10	Operating Temperature	–55 to +150	-	°C
11	Non-Operating Temperature	–65 to +150	-	°C

Table 1. Electrical and Non-Electrical Requirements for TSXDB.00

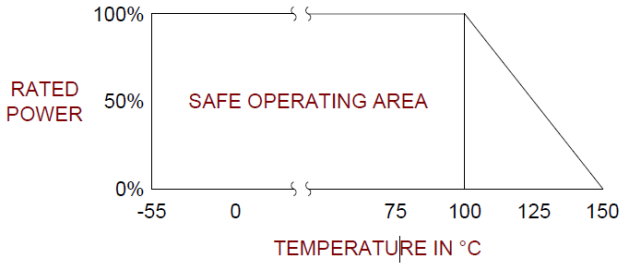


Figure 1. Power Derating at Temperature

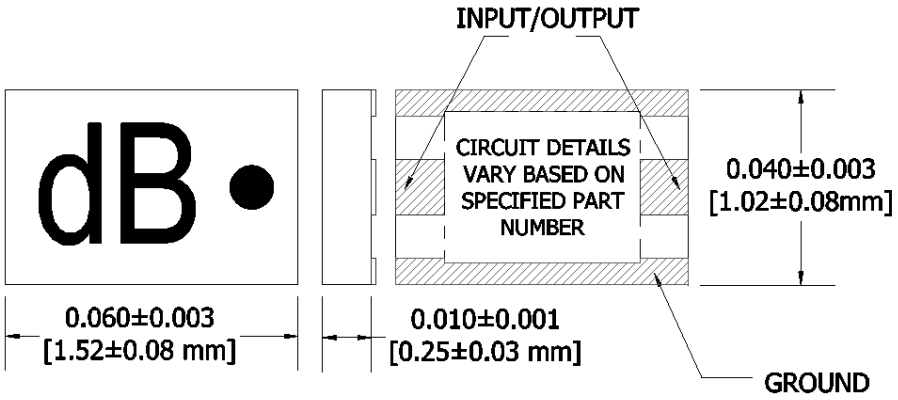
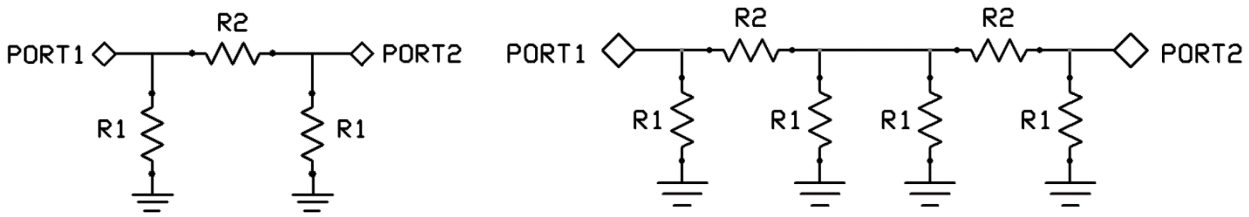


Figure 2. 2D Drawings for TSXDB.00 - Mechanical Footprint

Theory

RF attenuator, marketed by Smiths Interconnect under various product names represents an RF passive component broadly used in the industry for many applications including mobile networks, high power amplifiers, military applications, instrumentation, and many more. Broadband frequency attenuator series TSX presented in this report is applicable in wide frequency range, from DC to 40 GHz, providing attenuation of 0 to 10 dB in increments of 1 dB plus high attenuation values of 15 dB and 20 dB. The product is also characterized by its high reliability, compactness, and low-cost. For most of the values, this product is realized as a simple pi-network as shown in Figure 3. Higher attenuation values are design as a series connection of two pi-networks that produce lower attenuation value.



(a) (b)

Figure 3. Attenuator circuit model options:
(a) Pi-configuration (0 – 10 dB), (b) Double Pi-configuration (15 dB and 20 dB values)

All different models of the broadband high frequency attenuators have been modeled, simulated and tuned through iterative design process using 3D electromagnetic tools. Figure 4 shows the baseline model of TSX attenuator design in Ansys HFSS, both as a stand-alone part as well as mounted and interfacing the test fixture.

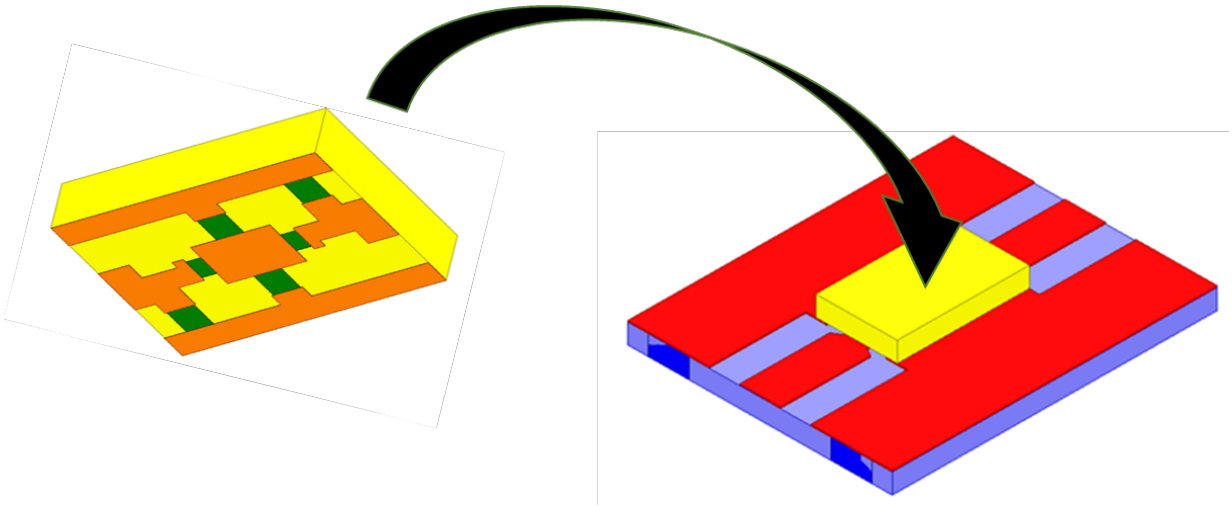


Figure 4. Electrical Model of TSX broadband high frequency attenuator, as a standalone and as mounted on the test board

After the designs have been optimized for a nominal performance, the tolerance analysis has been conducted that considered substrate thickness and dielectric constant variations, transmission line dimensional tolerances, and variations in the bulk resistivity and shape of the resistors (Figure 5).

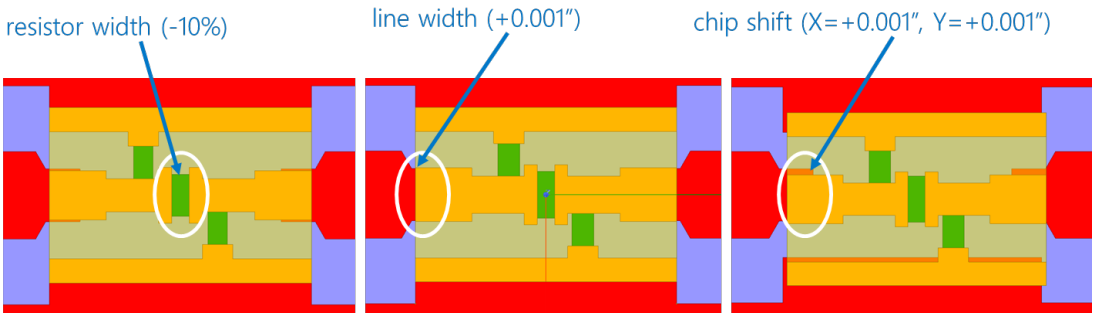


Figure 5. Positional tolerance of the chips on the application board (modeling in 3D electromagnetic software)

No out-of-spec performance has been observed during the tolerance analysis as shown on Figure 6 for three typical values of 1 dB, 6 dB, and 20 dB.

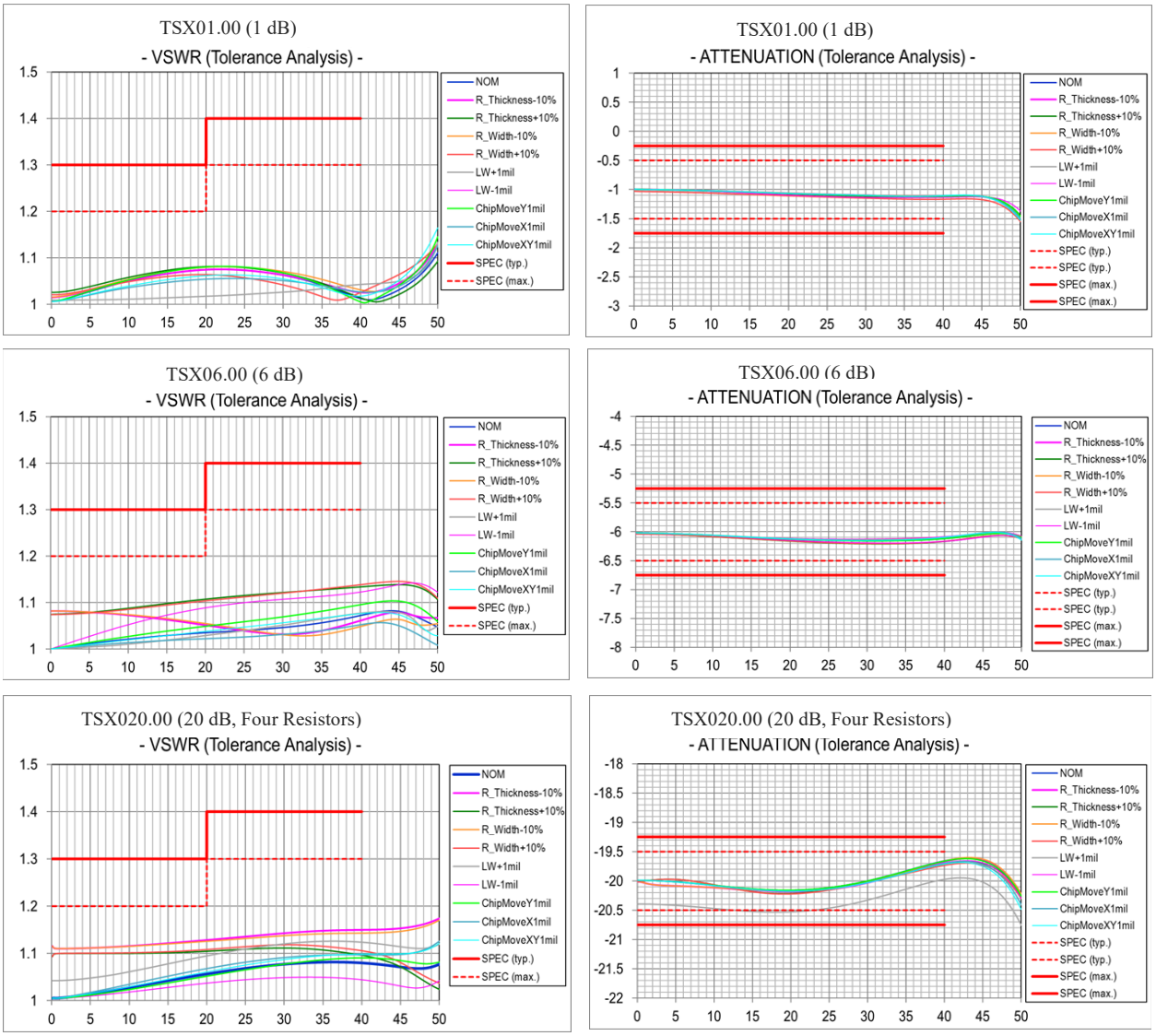
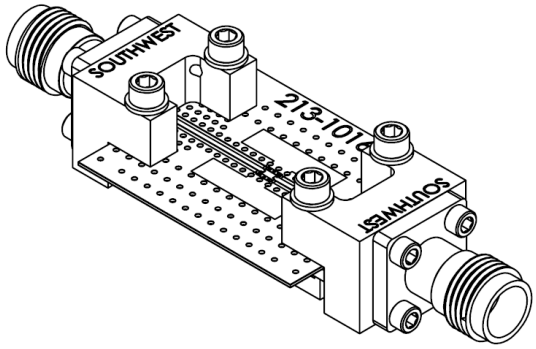
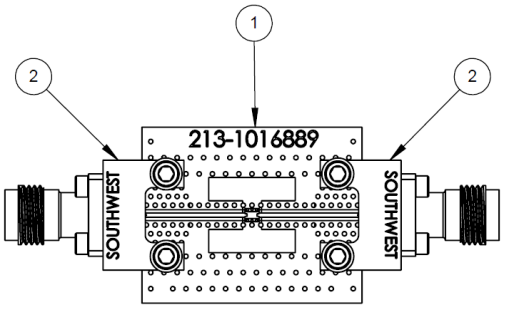


Figure 6. Electrical performance of three typical TSX attenuator values – 1 dB, 6 dB, and 20 dB

Test Fixture Choice

The test fixture that was chosen to test this product was standardized to cover all the broadband attenuator values of TSX series. The fixture consists of a test board made with Rogers 4350 (0.0133" thickness) and two Southwest field replaceable female end launch 1.85mm connectors (1892-04A-6), see Figure 7.





ITEM	PART NUMBER	DESCRIPTION	QTY.
2	240-1016890	SOUTHWEST MICROWAVE END LAUNCH CONNECTOR, 1.85mm	2
1	213-1016889	HF SMT ATTENUATOR TEST BOARD	1

Figure 7. Test Fixture used to test Developed Prototypes.

The 1.85 mm jack (female) end launch connector used for the tests at frequencies DC – 50 GHz is shown in Figure 8. It is important to mention that the selection of the connector pin (see dimensions ϕA) on the connector (1.85 mm or 2.4 mm) affects the connector launch performance and thus must be chosen as directed.

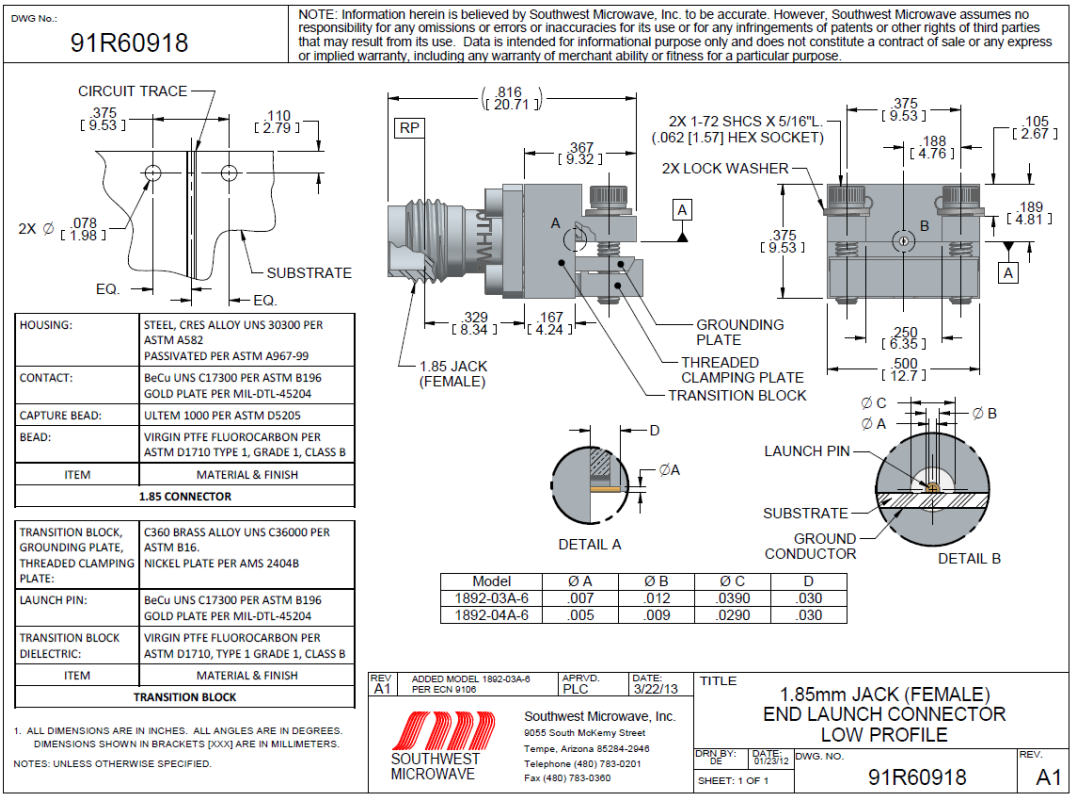


Figure 8. Southwest Microwave 1.85 mm connector used in tests at frequencies DC-42.5 GHz (drawing)

Mounting Instructions

First step in properly mounting the Thermopad for testing is to carefully inspect all the components of the test fixture to be assembled. Special attention should be given to the test board edges (Figure 18a). Common PCB manufacturing often leave rough edges that can cause fixture assembly issues. The edges of the test board can usually be cleaned up using fine grit sandpaper. (Figure 9b).

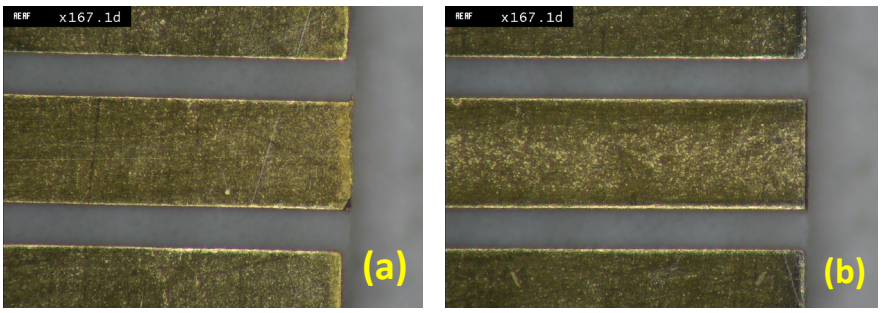


Figure 9. Test board transmission line:
(a) rough edge (before cleaning), (b) smooth edge (after cleaning)

The TSX chip attenuator should also be inspected to ensure the edges are cleanly cut and have no jagged edges prior to being installed on the test board. To avoid any potential electrical failures, the TSX chip attenuator needs to be properly positioned (centered) and soldered in place. Introduction of the solder mask around the footprint area where the chip attenuator is to be soldered helps this positional alignment. The TSX chip attenuator is soldered onto the test board using Sn96 solder. Care should be taken to insure there is no solder run-out into the area where the DUT is to be mounted.
The final step in the fixture assembly is to mount the connector to the test board. Things to look for at this step is to center the connector pin on the transmission line and to ensure the connector is flush with the edge of the test board to avoid undesired air gaps (Figure 10). Use of a microscope is essential to ensuring that the connector is mounted properly.

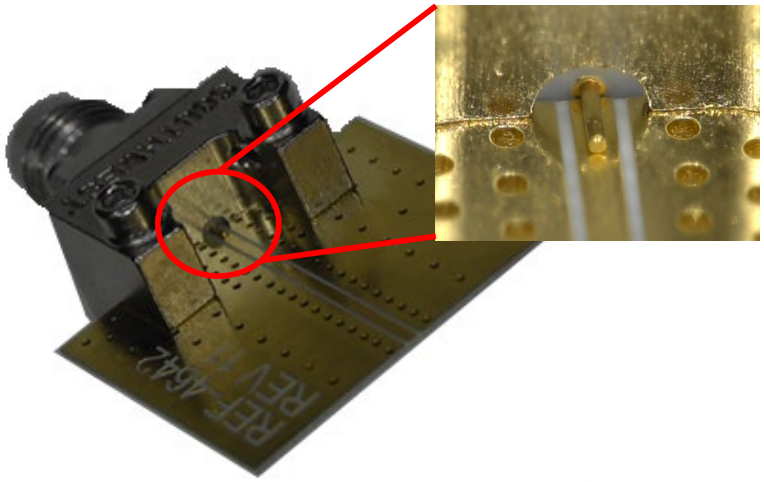


Figure 10. Connector pin alignment on the test board

Figure 11 shows details of the DUT mounting positions for the test board used to test TSX chip attenuators.

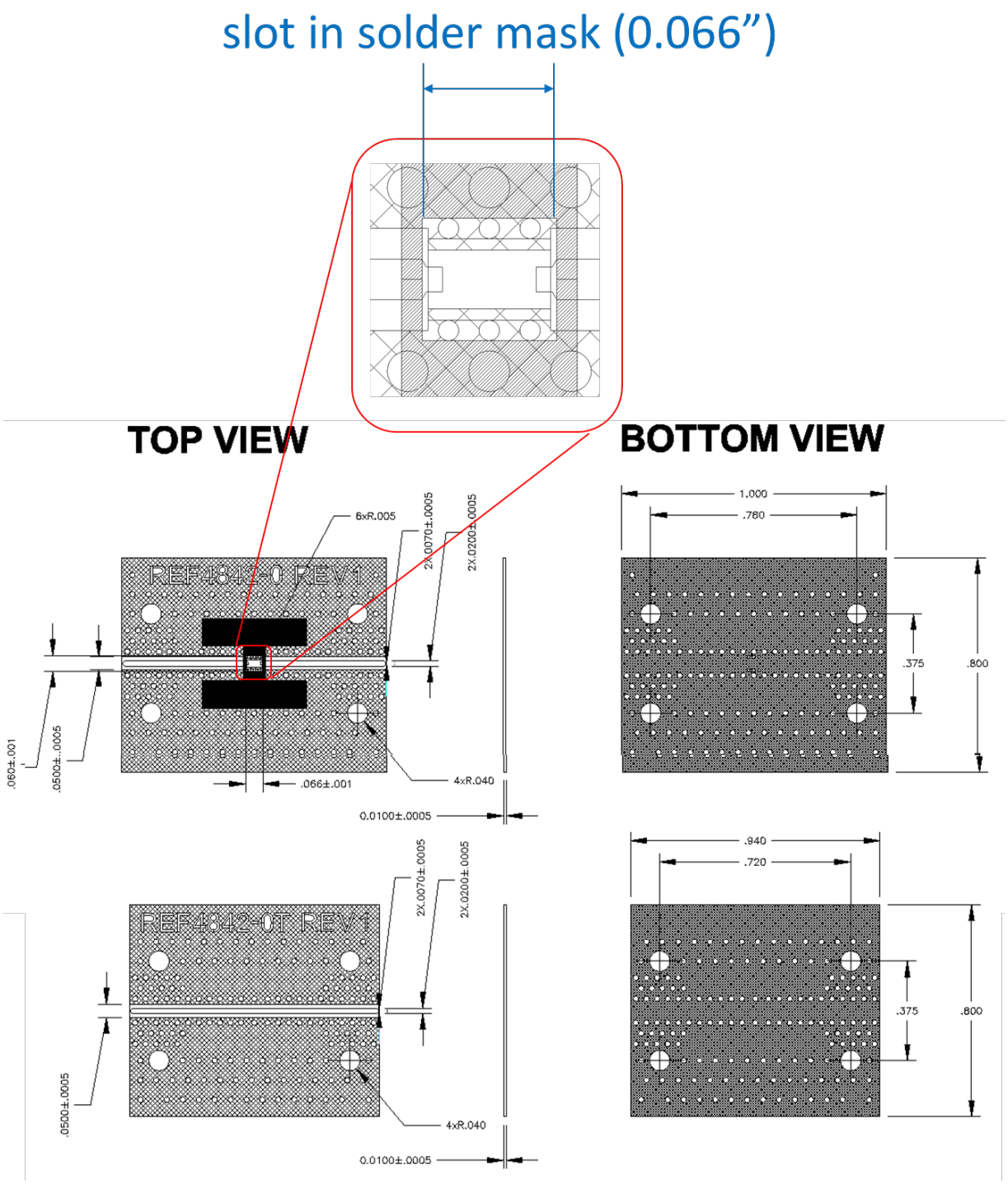


Figure 11. Detailed view of the test board used to test broadband attenuators of TSX series

The mounting instructions are shown on the block diagram (Figure 12). The fully assembled test fixture (Figure 13) consists of the test board with the DUT installed using proper mounting practices described above. The Southwest microwave connector is seen on each side of the fixture.

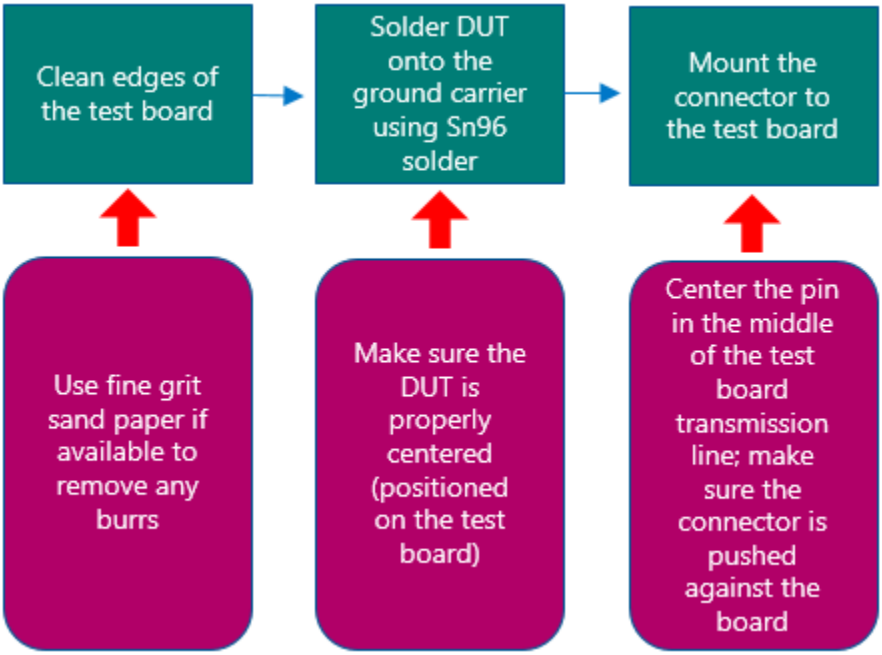


Figure 12. The Mounting instructions – Flow Chart

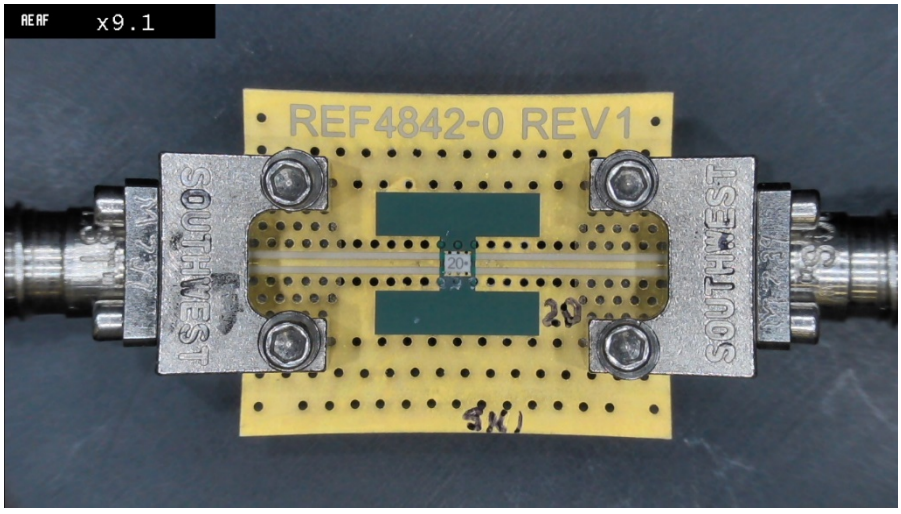
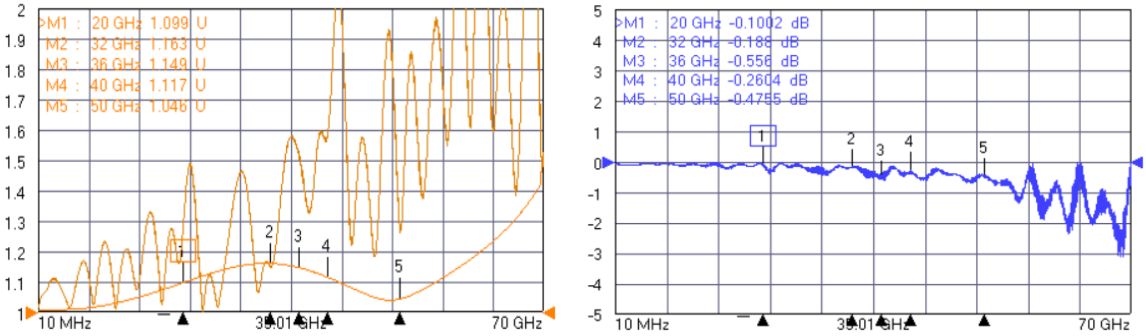


Figure 13. Fully assembled test fixture for the test of broadband high frequency attenuators of TSX series

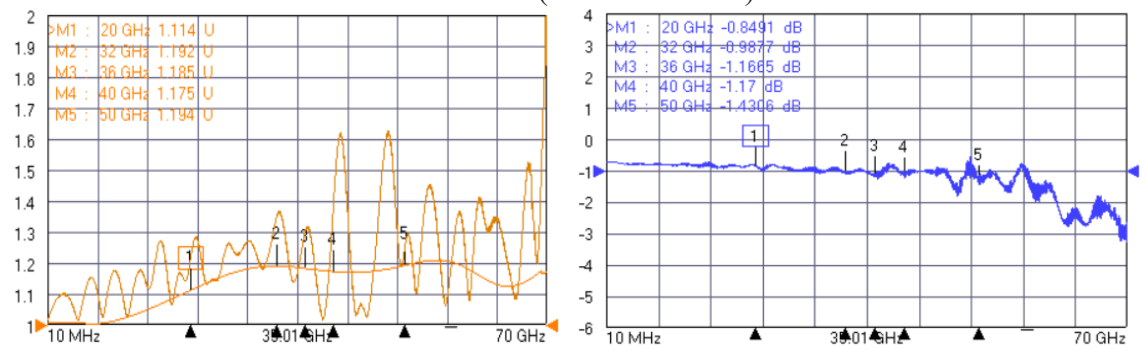
RF Test Results

Typical performance of the full product portfolio of TSXdB.00 chip attenuators is shown in Figure 14. Both VSWR (ungated) and attenuation (with the fixture loss removed) is shown. The prototypes exhibit a very repetitive VSWR performance under 1.50:1 and attenuation within ±1 dB for the entire frequency band 17 – 22 GHz.

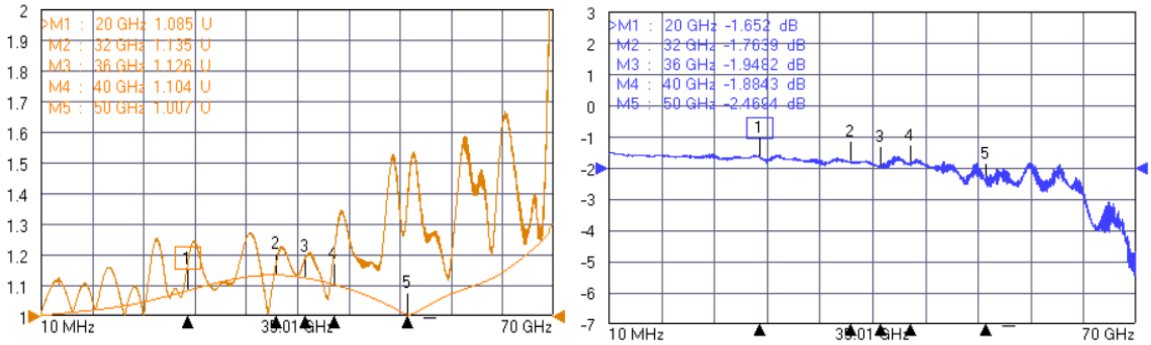
TSX00.00 (0 dB attenuator)



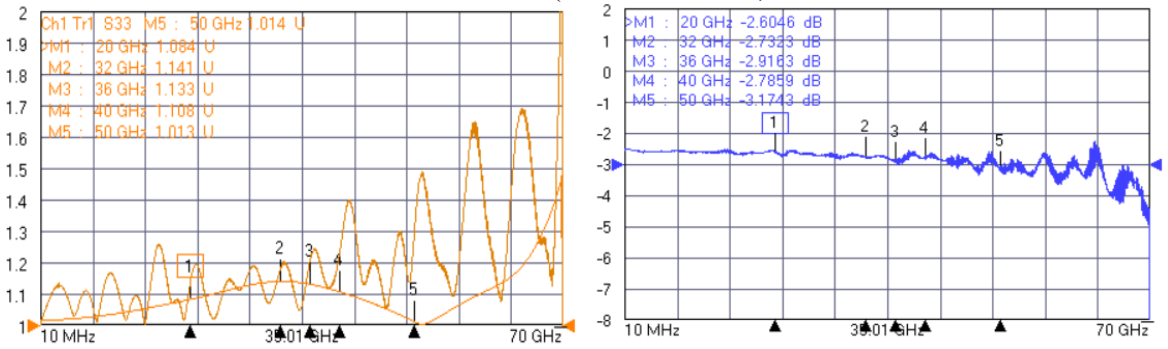
TSX01.00 (1 dB attenuator)



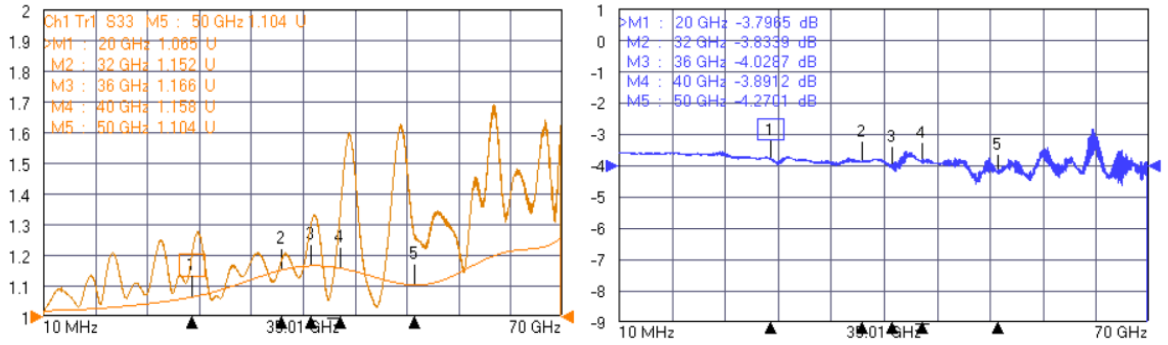
TSX02.00 (2 dB attenuator)



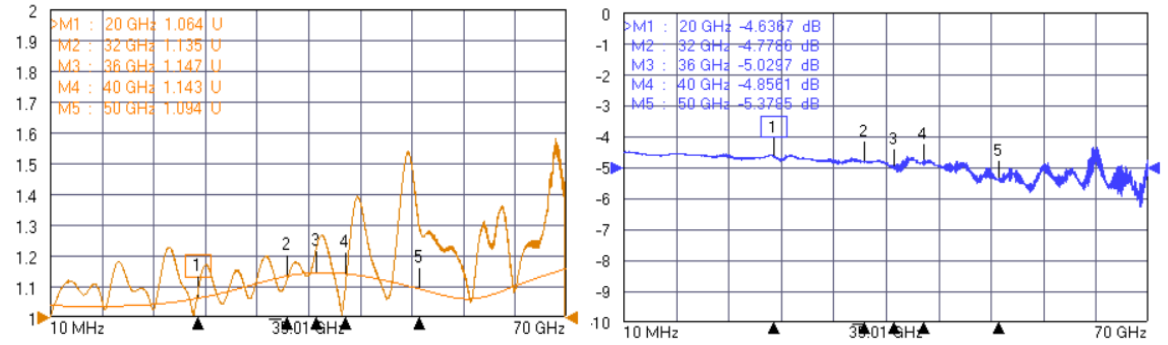
TSX03.00 (3 dB attenuator)



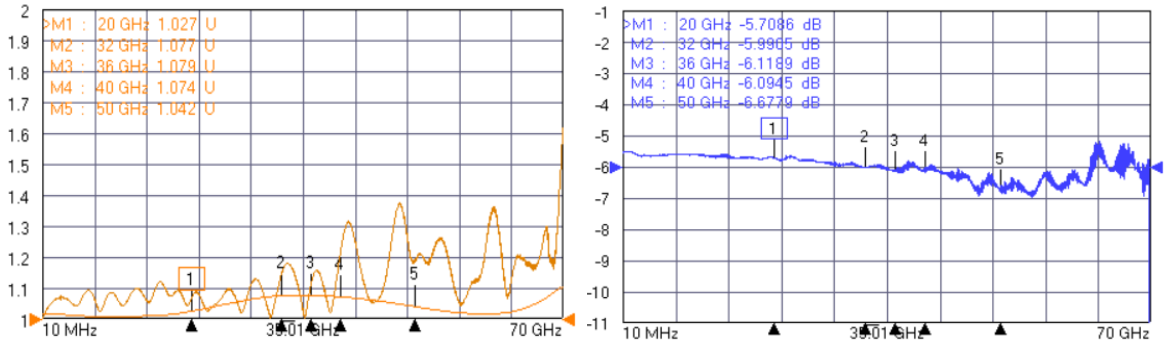
TSX04.00 (4 dB attenuator)



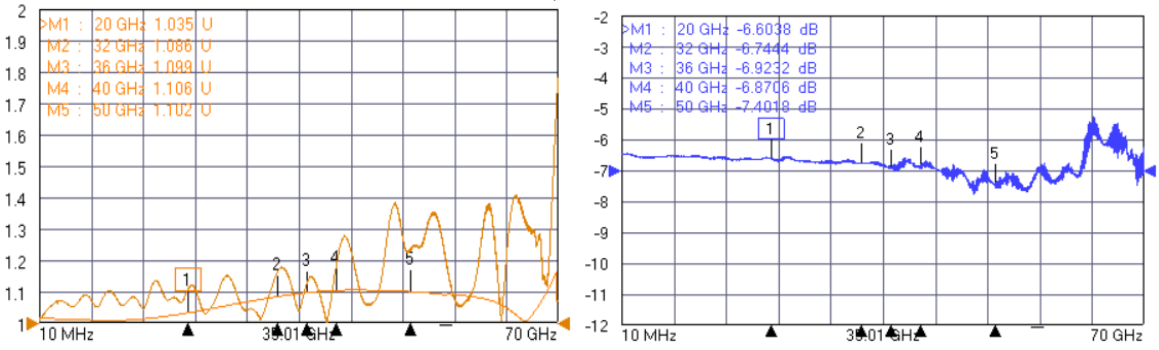
TSX05.00 (5 dB attenuator)



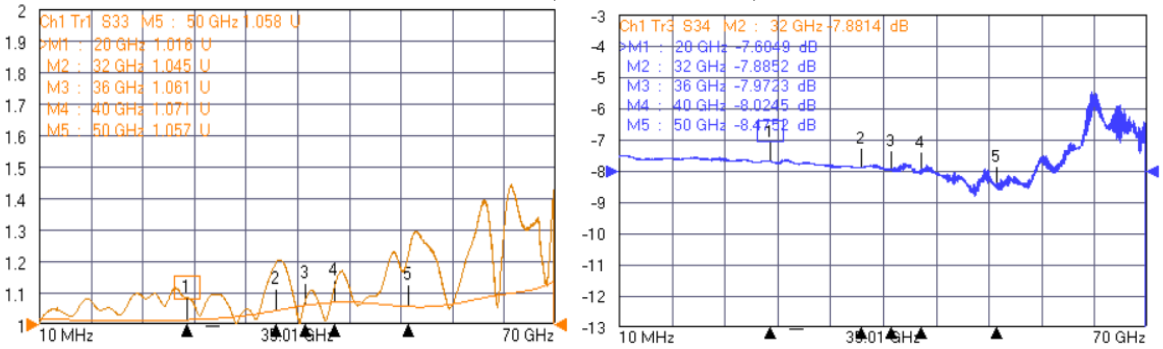
TSX06.00 (6 dB attenuator)



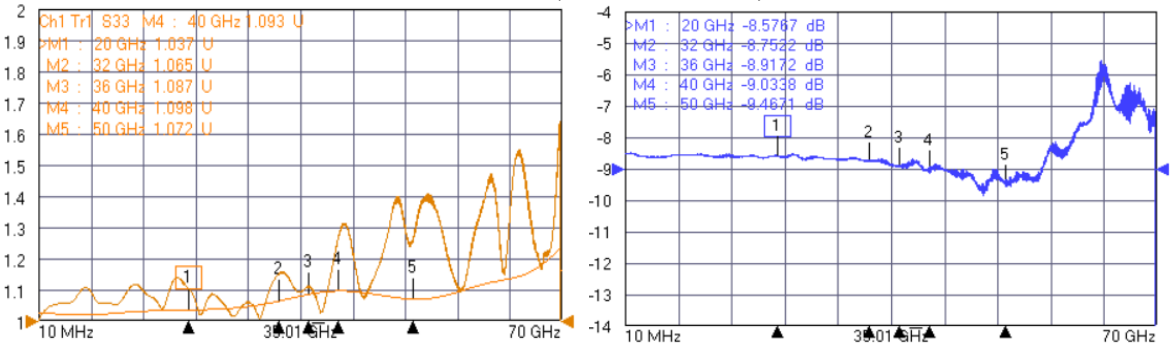
TSX07.00 (7 dB attenuator)



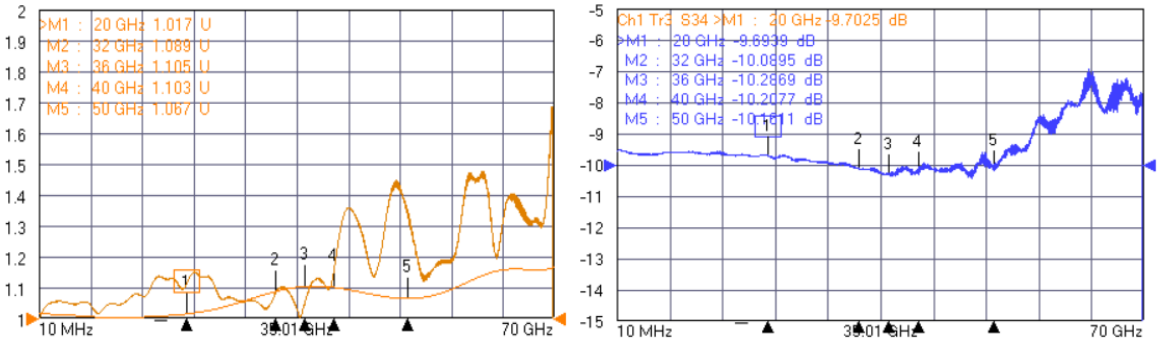
TSX08.00 (8 dB attenuator)



TSX09.00 (9 dB attenuator)



TSX10.00 (10 dB attenuator)



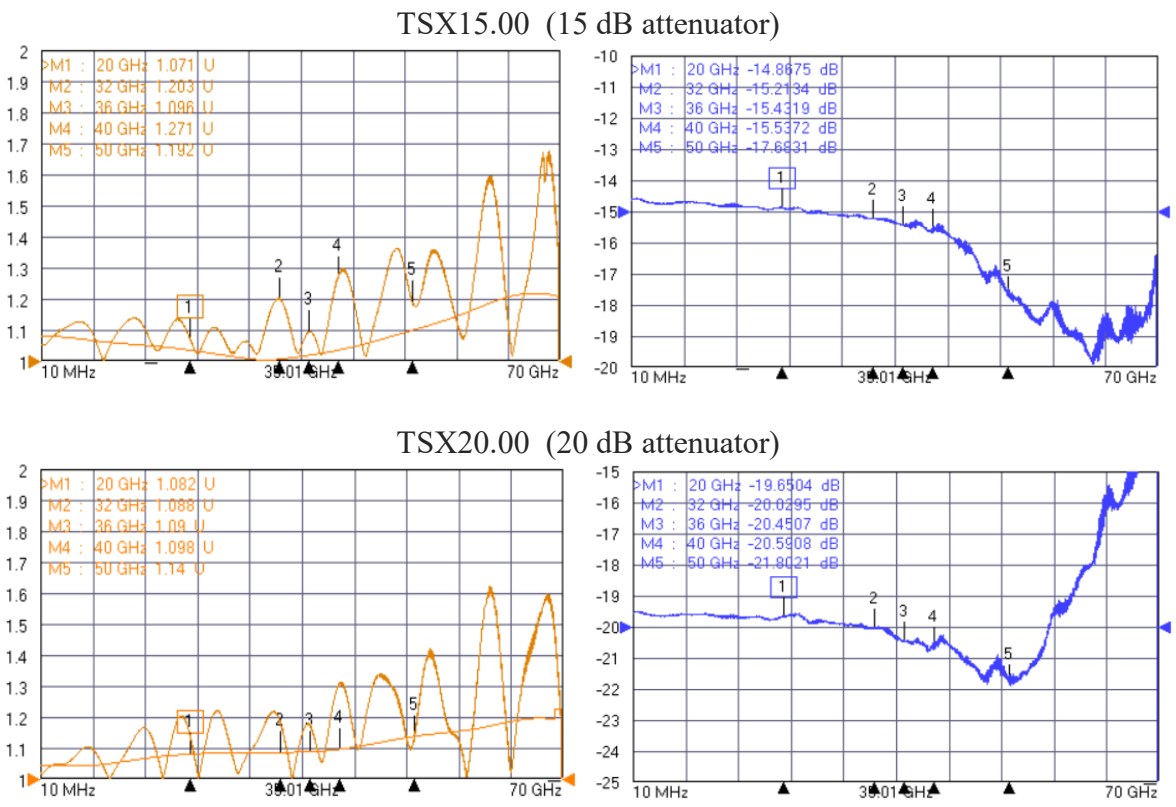


Figure 14. Typical RF performance of TSXdB.00 series: gated and ungated VSWR (left), attenuation (right)

Power Test

One device from the group (20dB) was RF tested to verify its pre-burn-in performance on an Anritsu MS4647B VNA (TE91819), see Figure 15.

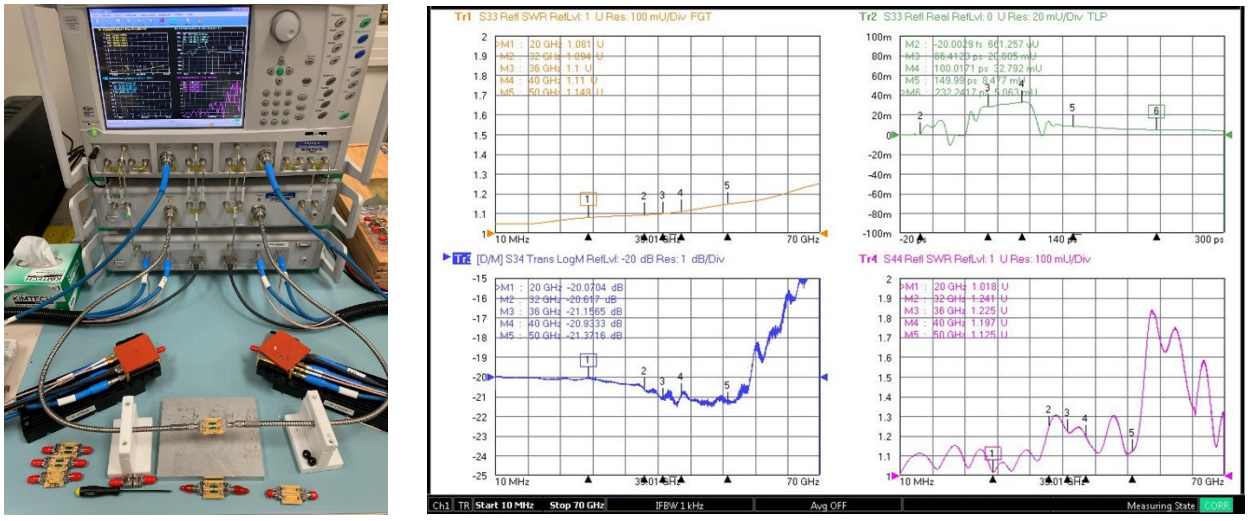


Figure 15. Pre-burn RF test of a typical 20 dB broadband attenuator: test setup (left), tested RF performance (right)

The device was then DC resistance tested using an Extech EX505 DMM (TE92005) to calculate DCA. The device was then mounted onto an aluminum block with Nitrous oxide thermal compound and placed on an Aluminum heatsink. Input DC Power and the output load (32-1036 at 49.8Ω) were connected via cables, with the input being cut to connect to the power supply leads (Figure 16).

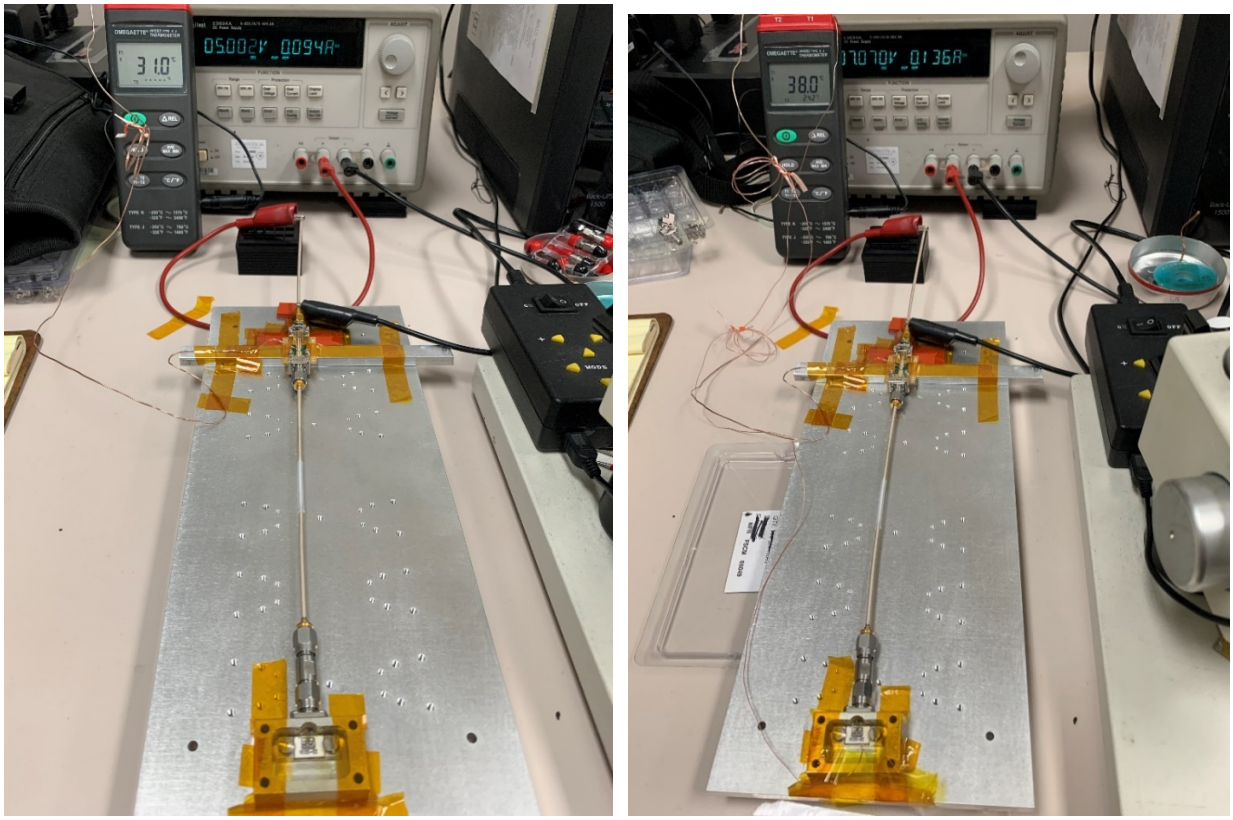


Figure 16. 20dB chip attenuator burn-in setup shown at half-power at .5Watts (right) and at full-power of 1 Watt (left)

A K-type thermocouple was placed on the top surface of the device (hottest external spot)
This temperature was recoded using an Omega HH303 thermometer (TE 30080) along with the input voltage and current from the HP E3634A Precision Power Supply (TE10965). The device underwent 15hrs at .5W with a 38-minute power ramp and experienced absolutely no change in DC Resistance after 2Hrs stabilization period. The device then underwent 405hrs at 1.0W with a 3.5hr power ramp and experienced a -.43% change in DC Attenuation after a >2Hrs stabilization period (Figure 17).

DUT # 1		Initial DCR	Final	% Δ DCR	Δ DCR ppm
RAB	Series	82.50	82.30	-0.24	-2424
RAC	Parallel	51.60	51.50	-0.19	-1938
RBC	Parallel	51.60	51.70	0.19	1938
	Ze	50	50		
	Zin	50.55	50.43		
	Zout	50.55	50.62		
	DCA (dB)	19.89	19.80		
	% Δ DCA	-0.43	%		

DATE / TIME	E.T. (Hrs.)	VOLTS	AMPS	OHMS	WATTS	TOP TEMP	Comments
7/9/20 5:52 PM	0:00:00	2.24	0.039	57.44	0.09	24.2	
7/9/20 5:54 PM	0:02:00	3.16	0.058	54.48	0.18	25.5	
7/9/20 5:56 PM	0:04:00	3.87	0.072	53.75	0.28	27.3	
7/9/20 5:58 PM	0:06:00	4.47	0.084	53.21	0.38	29.1	
7/9/20 6:00 PM	0:08:00	5	0.094	53.19	0.47	31	
7/9/20 6:30 PM	0:38:00	5	0.094	53.19	0.47	31.9	
7/10/20 9:15 AM	15:23:00	5	0.094	53.19	0.47	31.9	Stop test. Measure DCA after 2Hr cool down. No Change
7/10/20 11:20 AM	0:00:00	5	0.094	53.19	0.47	28.3	Restart test. Ramp up to 1W.
7/10/20 11:25 AM	0:05:00	5.47	0.104	52.60	0.57	30.8	
7/10/20 11:35 AM	0:15:00	5.47	0.104	52.60	0.57	32.8	
7/10/20 12:10 PM	0:50:00	5.47	0.104	52.60	0.57	33	
7/10/20 12:12 PM	0:52:00	5.92	0.113	52.39	0.67	34	
7/10/20 1:02 PM	1:42:00	6.32	0.121	52.23	0.76	34.6	
7/10/20 1:03 PM	1:43:00	6.32	0.121	52.23	0.76	35.5	
7/10/20 1:55 PM	2:35:00	6.7	0.129	51.94	0.86	36	
7/10/20 1:56 PM	2:36:00	6.7	0.129	51.94	0.86	37.1	
7/10/20 2:50 PM	3:30:00	7.07	0.136	51.99	0.96	37.7	
7/10/20 2:51 PM	3:31:00	7.07	0.136	51.99	0.96	38.5	
7/10/20 3:10 PM	3:50:00	7.07	0.136	51.99	0.96	39.3	
7/10/20 5:00 PM	5:40:00	7.07	0.136	51.99	0.96	39.5	Bumped T-Couple & Reposition.
7/10/20 5:30 PM	6:10:00	7.07	0.136	51.99	0.96	39.5	Adjusted values.
7/13/20 8:30 AM	69:10:00	7.07	0.136	51.99	0.96	39.5	
7/13/20 5:05 PM	77:45:00	7.07	0.136	51.99	0.96	39.8	
7/14/20 9:45 AM	94:25:00	7.07	0.136	51.99	0.96	39.8	
7/14/20 5:30 PM	102:10:00	7.07	0.136	51.99	0.96	40.1	
7/15/20 3:30 PM	124:10:00	7.07	0.136	51.99	0.96	40.6	
7/16/20 11:30 AM	144:10:00	7.07	0.136	51.99	0.96	42.3	
7/27/20 12:00 PM	408:40:00	7.07	0.136	51.99	0.96	43.3	Stop Test.

Figure 17. Data log of Burn-in: time, voltage, current, power, resistance*, and DUT top temperature (* = calculated).*

The device underwent a final post-burn-in RF test to further confirm there was no damage to the device due to the Burn-in (Figure 18). Note that the same connectors were used throughout the test and never removed. As Figure 18 shows, there was no observable degradation in the RF performance of the DUT in the post-burn test. Based on the data provided we can conclude that the broadband high frequency attenuator, TSX family can handle 1 Watt of power when properly mounted.

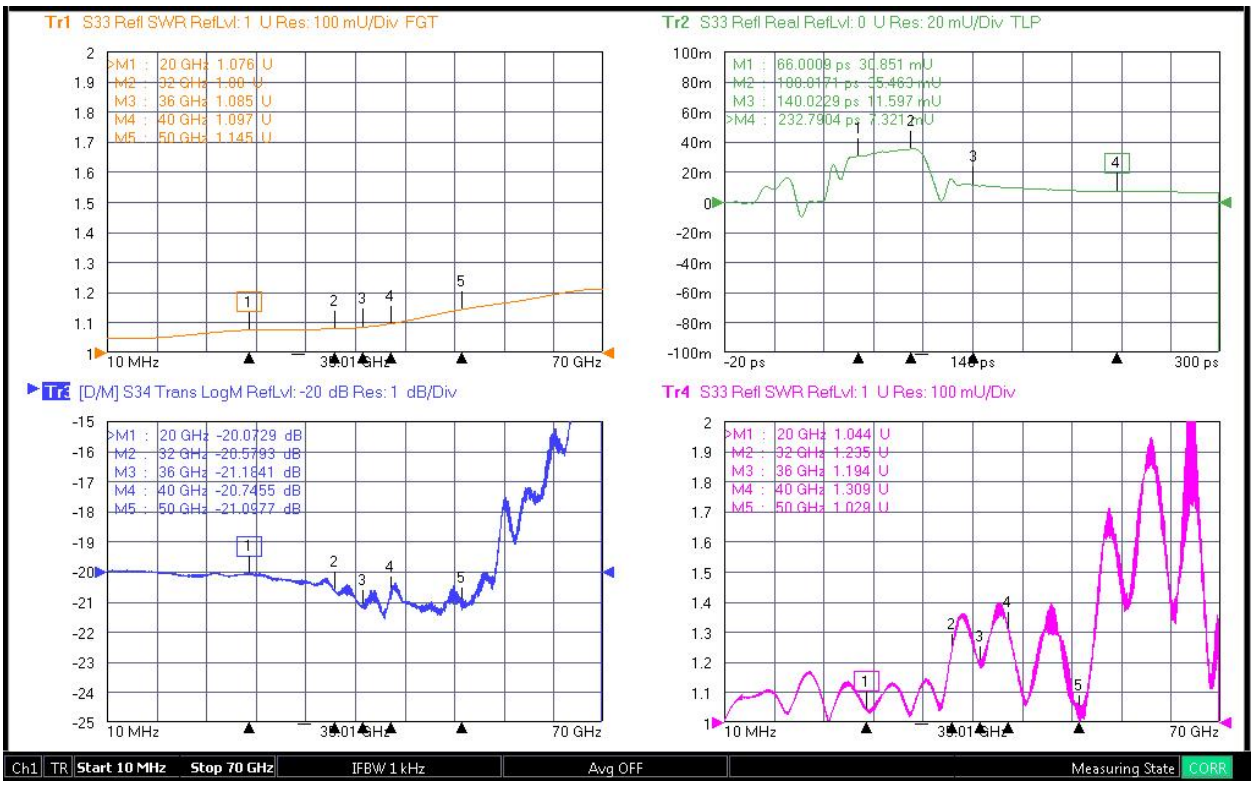


Figure 18. Post-burn-in RF Performance: gated VSWR (Tr1), ungated VSWR (Tr4), Attenuation (Tr3), Time Domain (Tr2)

Qualification Test

The purpose of this test was to subject the broadband high frequency attenuators of TSX series to the conditions as specified in the test plan TP-9293 and qualify them internally for the markets to be served. Five representative samples from the high, mid and low attenuation values selected for the Qualification Test: 3dB, 6dB, & 20dB represented the entire part family. Group A inspection was performed on 100% of the lot. Group B and C inspections were performed in the following quantities – three representative samples of each value for Group B and two representative samples of each value for Group C. Tests not performed in this qualification were considered by similarity to other products of similar materials and construction that have successfully undergone such tests. The Specification Control Drawing (SCD, see Table 1) of the device was the governing document for all specification limits for each test, with any exceptions noted in the test plan TP-9293. Qualification testing references MIL-PRF-55342 for Class L devices with the exceptions noted in the test plan TP-9293. Devices were mounted on destruct fixturing in order to facilitate performance of the required tests. Removable RF connectors were mounted only when RF test was called out. Test frequencies were defined DC to 50 GHz in increments of 10 GHz. Change in resistance incurred by tests performed was noted (if any) and used for the specification risk assessment and the final device rating. All electrical tests were conducted at DC as power handling is the main concern for the qualification. RF performance was verified at the end of each test group. Figure 19 shows the qualification test flow chart.

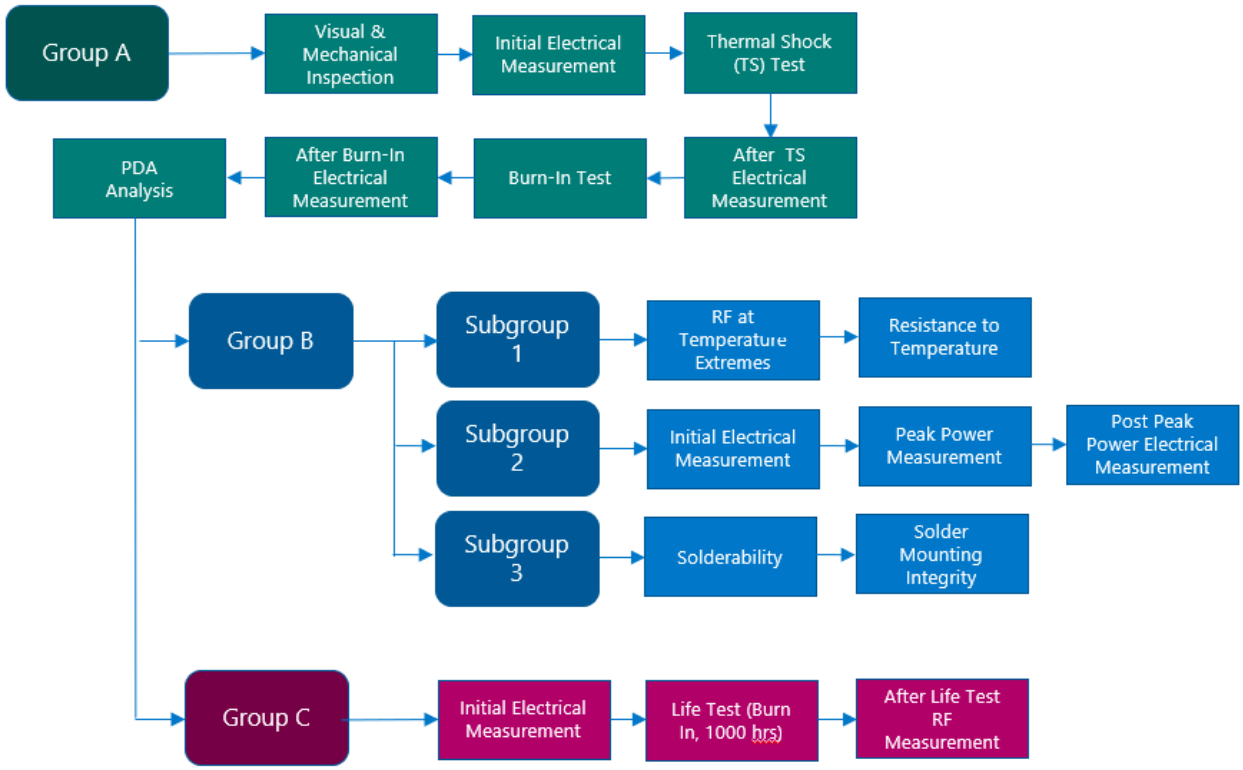


Figure 19. Flowchart of Test Procedure

GROUP A INSPECTION (15 samples; 5 pcs of each 3 dB, 6 dB, 20 dB)

Five representative samples of 3 dB, 6 dB, and 20 dB attenuators were selected and mounted to their appropriate PCB carriers for test. Test Board RF Connectors might have been removed to prevent possible damage incurred by test and replaced for post-test RF measurements.

Visual Mechanical Inspection Results

The materials, design, construction, physical dimensions, markings and workmanship were verified to be in accordance with applicable requirements per the appropriate SCD.

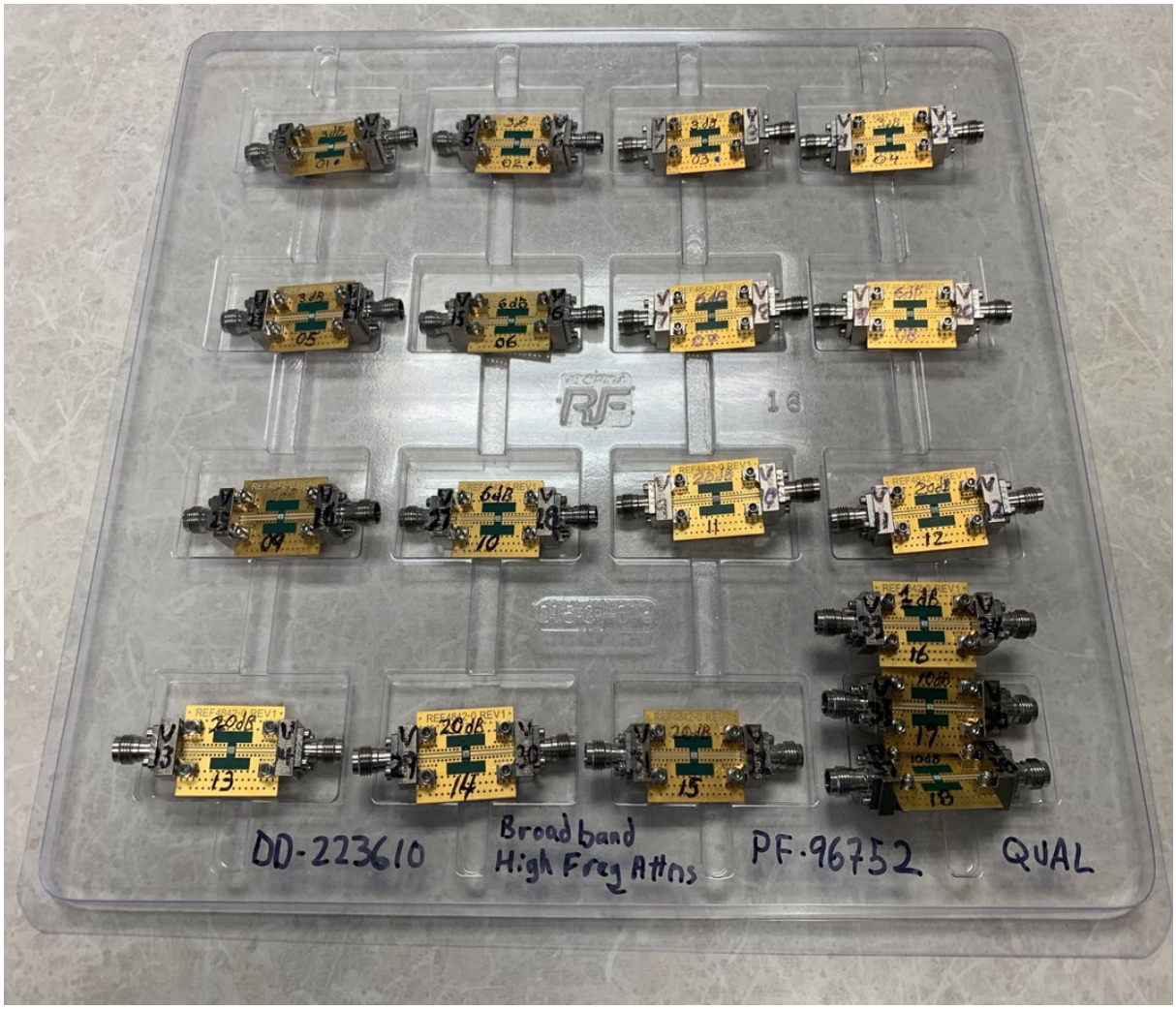


Figure 20. Group A inspection lot: test fixtures with the connectors installed

Initial Electrical (INI) Test Results

VSWR and attenuation at the mid band were measured and recorded according to the frequency band of the part number at 23°C ± 3°C. The S-parameters were recorded at minimum, across the device's frequency band. Acceptance limits for VSWR and attenuation as per SCD (see Table 1) adjusted for the test fixture (test board and test connector) impact. All samples of the Group A passed initial RF test (see Table 2).

TSX Series, Qualification Acceptance Testing, TP-9293

smiths interconnect
bringing technology to life

Project / WO:	DD-233610 / PF-96572
Part #:	TSX0604XX.00X
Description:	High Frequency Broadband Attenuator
Test Plan:	TP-9293
Test Stage:	2.2.1
Test Descr:	Initial RF (INI)
Test Equip:	Anritsu MS4647B VNA TE91819
Operator:	JA
Start Date:	11/9/2020
End Date:	11/13/2020

Results PASS

Specifications:		≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz	≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz
Part Value	**Attn (dB)**	**VSWR :1**	**VSWR :1**	**VSWR :1**	**Attn Tol. (±) (dB)**	**Attn Tol.(±) (dB)**	**Attn Tol. (±) (dB)**
TS060403.00F	-3.0	1.20	1.30	1.50	0.50	0.75	1.05
TS060406.00F	-6.0	1.20	1.30	1.50	0.50	0.80	1.32
TS060420.00F	-20.0	1.20	1.30	1.50	0.50	0.90	1.80

TS060403.00F

Frequency	VSWR :1	VSWR :1	VSWR :1	VSWR :1	VSWR :1	ATTN dB	ATTN dB	ATTN dB	ATTN dB	ATTN dB
(GHz)	**01**	**02**	**03**	**04**	**05**	**01**	**02**	**03**	**04**	**05**
0.01	1.02	1.02	1.01	1.01	1.02	-2.50	-2.51	-3.18	-3.05	-3.00
10	1.04	1.04	1.02	1.07	1.05	-2.62	-2.60	-3.06	-3.12	-3.07
20	1.08	1.09	1.09	1.16	1.14	-2.68	-2.60	-3.21	-3.11	-3.12
30	1.14	1.15	1.16	1.21	1.25	-2.63	-2.65	-3.31	-3.16	-3.25
40	1.11	1.13	1.15	1.18	1.27	-2.82	-2.88	-3.50	-3.31	-3.60
50	1.01	1.01	1.05	1.06	1.20	-3.16	-3.23	-3.79	-3.79	-3.94

TS060406.00F

Frequency	VSWR :1	VSWR :1	VSWR :1	VSWR :1	VSWR :1	ATTN dB	ATTN dB	ATTN dB	ATTN dB	ATTN dB
(GHz)	**06**	**07**	**08**	**09**	**10**	**06**	**07**	**08**	**09**	**10**
0.01	1.02	1.02	1.02	1.03	1.04	-5.52	-5.70	-5.50	-6.15	-6.12
10	1.01	1.01	1.01	1.04	1.03	-5.62	-5.61	-5.60	-6.11	-6.12
20	1.03	1.03	1.02	1.05	1.06	-5.61	-5.67	-5.60	-6.06	-6.12
30	1.07	1.07	1.08	1.08	1.09	-5.67	-5.86	-5.64	-6.12	-6.23
40	1.07	1.07	1.12	1.08	1.09	-6.07	-6.16	-6.09	-6.45	-6.67
50	1.04	1.03	1.06	1.03	1.05	-6.63	-6.65	-6.56	-7.15	-7.32

TS060420.00F

Frequency	VSWR :1	VSWR :1	VSWR :1	VSWR :1	VSWR :1	ATTN dB	ATTN dB	ATTN dB	ATTN dB	ATTN dB
(GHz)	**11**	**12**	**13**	**14**	**15**	**11**	**12**	**13**	**14**	**15**
0.01	1.05	1.03	1.05	1.03	1.04	-19.50	-19.50	-19.50	-20.00	-20.00
10	1.05	1.05	1.06	1.05	1.05	-19.50	-19.60	-19.60	-20.00	-20.00
20	1.07	1.08	1.10	1.09	1.09	-19.60	-19.60	-19.60	-20.00	-20.00
30	1.07	1.09	1.11	1.10	1.11	-19.70	-19.80	-19.70	-20.20	-20.10
40	1.08	1.10	1.15	1.10	1.13	-20.60	-20.60	-20.60	-20.90	-20.80
50	1.09	1.14	1.18	1.10	1.16	-21.40	-21.80	-21.40	-20.90	-21.10

Note: One 1dB and two 10dB devices were tested in Group A, outside of the Test Plan, as there were extra connectors

Specifications:		≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz	≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz
Part Value	**Attn (dB)**	**VSWR :1**	**VSWR :1**	**VSWR :1**	**Attn Tol. (±) (dB)**	**Attn Tol.(±) (dB)**	**Attn Tol. (±) (dB)**
TS060401.00F	-1.0	1.20	1.40	1.80	0.50	0.75	1.00
TS060410.00F	-10.0	1.20	1.40	1.80	0.50	0.75	1.00

TS060401.00F

Frequency	VSWR :1	ATTN dB
(GHz)	**16**	**16**
0.01	1.03	-1.46
10	1.05	-0.84
20	1.15	-0.96
30	1.22	-1.06
40	1.15	-1.55
50	1.18	-1.97

TS060410.00F

Frequency	VSWR :1	VSWR :1	ATTN dB	ATTN dB
(GHz)	**17**	**18**	**17**	**18**
0.01	1.03	1.03	-9.73	-9.57
10	1.02	1.02	-9.59	-9.63
20	1.01	1.01	-9.55	-9.58
30	1.03	1.04	-9.50	-9.59
40	1.03	1.08	-10.10	-10.30
50	1.06	1.05	-9.77	-9.85

Table 2. Group A Initial Electrical Test Results – Summary

Below is a plot of the thruline used to normalize the test fixture loss. It can be observed that the response becomes less stable at frequencies above 37GHz.

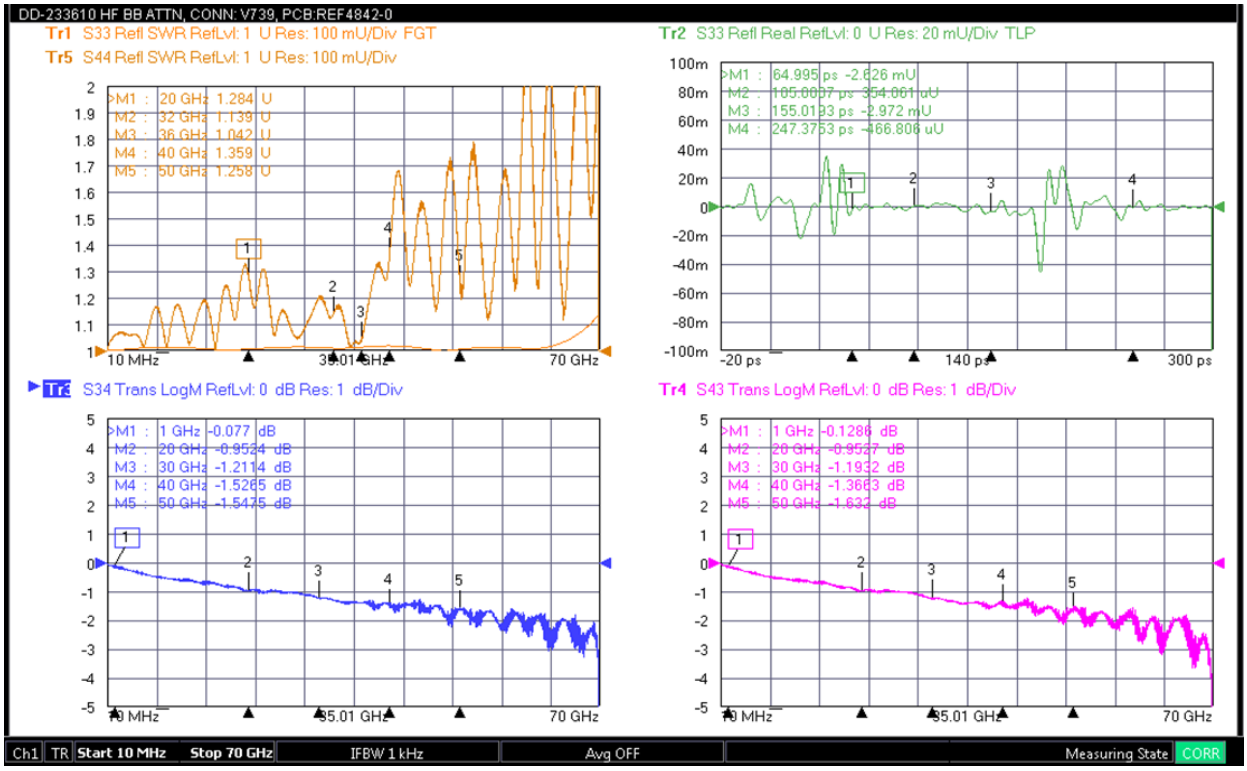


Figure 21. Thruline test fixture RF performance

Thermal Shock

The inspection lot samples were exposed to 10 cycles of thermal shock, -55°C to +125°C in accordance with MIL-STD-202, Method 107 (see Table 3). The equipment used for the test consisted of Thermotron, model ATS-30-4-4 with the asset tag # TE90075.

STEP	TEMPERATURE (ºC)	TIME (MINUTES)
1	-55 (+0/-3)	15 min.
2	+25 (+10/-5)	5.0 max.
3	+125 (+3/-0)	15 min.
4	+25 (+10/-5)	5.0 max.

Table 3. Thermal Shock temperature levels and exposure times

After Thermal Shock Electrical (ATS) Test Results

VSWR and attenuation at the mid band were measured and recorded according to the frequency band of the part number at 23°C ± 3°C. The s-parameters were recorded at minimum, across the device's frequency band. Acceptance limits for VSWR and attenuation as per SCD (see Table 1) adjusted for the test fixture (test board and test connector) impact. All samples of the Group A passed post-thermal shock RF test (see Table 4).

TSX Series, Qualification Acceptance Testing, TP-9293

smiths interconnect
bringing technology to life

Project / WO:	DD-233610 / PF-96572									
Part #:	TSX0604XX.00X									
Description:	High Frequency Broadband Attenuator									
Test Plan:	TP-9293									
Test Stage:	2.2.3									
Test Descr:	After Thermal Shock (ATS) RF							**Results**	**PASS**	
Test Equip:	Anritsu MS4647B VNA TE91819									
Operator:	JA									
Start Date:	11/12/2020									
End Date:	11/16/2020									

Specifications:		≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz	≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz
Part Value	**Attn (dB)**	**VSWR :1**	**VSWR :1**	**VSWR :1**	**Attn Tol. (±) (dB)**	**Attn Tol.(±) (dB)**	**Attn Tol. (±) (dB)**
TS060403.00F	-3.0	1.20	1.30	1.50	0.50	0.75	1.05
TS060406.00F	-6.0	1.20	1.30	1.50	0.50	0.80	1.22
TS060420.00F	-20.0	1.20	1.30	1.50	0.50	0.90	1.80

TS060403.00F

Frequency	VSWR :1	VSWR :1	VSWR :1	VSWR :1	VSWR :1	ATTN dB	ATTN dB	ATTN dB	ATTN dB	ATTN dB
(GHz)	**01**	**02**	**03**	**04**	**05**	**01**	**02**	**03**	**04**	**05**
0.01	1.01	1.01	1.00	1.04	1.02	-2.54	-2.53	-3.03	-3.02	-3.01
10	1.04	1.04	1.03	1.07	1.05	-2.61	-2.56	-3.07	-3.06	-3.05
20	1.08	1.09	1.10	1.18	1.14	-2.73	-2.68	-3.14	-3.17	-3.19
30	1.13	1.15	1.17	1.24	1.24	-2.74	-2.76	-3.21	-3.27	-3.23
40	1.10	1.12	1.15	1.20	1.27	-2.88	-2.98	-3.45	-3.48	-3.74
50	1.01	1.01	1.04	1.07	1.20	-3.17	-3.38	-3.81	-4.02	-4.04

TS060406.00F

Frequency	VSWR :1	VSWR :1	VSWR :1	VSWR :1	VSWR :1	ATTN dB	ATTN dB	ATTN dB	ATTN dB	ATTN dB
(GHz)	**06**	**07**	**08**	**09**	**10**	**06**	**07**	**08**	**09**	**10**
0.01	1.02	1.02	1.02	1.03	1.04	-5.55	-5.53	-5.59	-6.24	-6.06
10	1.01	1.01	1.00	1.04	1.03	-5.60	-5.60	-5.60	-6.10	-6.09
20	1.03	1.03	1.02	1.05	1.06	-5.68	-5.71	-5.67	-6.13	-6.15
30	1.08	1.06	1.08	1.08	1.09	-5.81	-5.84	-5.79	-6.27	-6.31
40	1.08	1.06	1.12	1.08	1.09	-6.11	-6.14	-6.16	-6.38	-6.49
50	1.04	1.03	1.06	1.02	1.05	-6.72	-6.68	-6.62	-7.15	-7.21

TS060420.00F

Frequency	VSWR :1	VSWR :1	VSWR :1	VSWR :1	VSWR :1	ATTN dB	ATTN dB	ATTN dB	ATTN dB	ATTN dB
(GHz)	**11**	**12**	**13**	**14**	**15**	**11**	**12**	**13**	**14**	**15**
0.01	1.05	1.05	1.05	1.03	1.04	-19.50	-19.60	-19.50	-20.00	-20.00
10	1.05	1.05	1.06	1.05	1.05	-19.50	-19.60	-19.60	-20.10	-20.00
20	1.08	1.08	1.10	1.09	1.08	-19.60	-19.70	-19.60	-20.10	-20.00
30	1.07	1.09	1.11	1.10	1.11	-19.90	-20.10	-19.90	-20.20	-20.20
40	1.08	1.10	1.15	1.11	1.13	-20.60	-20.60	-20.60	-20.90	-20.80
50	1.09	1.14	1.18	1.11	1.16	-21.50	-21.80	-21.50	-21.00	-21.10

Note: One 1dB and two 10dB devices were tested in Group A, outside of the Test Plan, as there were extra connectors

Specifications:		≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz	≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz
Part Value	**Attn (dB)**	**VSWR :1**	**VSWR :1**	**VSWR :1**	**Attn Tol. (±) (dB)**	**Attn Tol.(±) (dB)**	**Attn Tol. (±) (dB)**
TS060401.00F	-1.0	1.20	1.40	1.80	0.50	0.75	1.04
TS060410.00F	-10.0	1.20	1.40	1.80	0.50	0.75	1.00

TS060401.00F

Frequency	VSWR :1	ATTN dB
(GHz)	**16**	**16**
0.01	1.03	-0.74
10	1.05	-0.80
20	1.15	-0.98
30	1.22	-1.08
40	1.15	-1.49
50	1.19	-2.04

TS060410.00F

Frequency	VSWR :1	VSWR :1	ATTN dB	ATTN dB
(GHz)	**17**	**18**	**17**	**18**
0.01	1.03	1.03	-9.58	-9.61
10	1.02	1.02	-9.60	-9.63
20	1.02	1.01	-9.60	-9.65
30	1.04	1.04	-9.63	-9.69
40	1.03	1.08	-10.20	-10.30
50	1.04	1.05	-9.82	-9.92

Table 4. Group A Post Thermal Shock Electrical Inspection Results

Bake (100% de-rated burn-in):

The devices were subjected to a 100-hour stabilization at 150°C. This test is the equivalent of a 100% de-rated power burn in.The equipment used in the test – Fischer Scientific Isotemp oven with an asset tag # TE91660 and Omega HH502 thermometer with an asset tag TE40080. The entire lot was placed in the appropriate burn in fixture for the product family (Figure 22). The fixture was placed in the appropriate temperature controlled preheated chamber. The power was

turned on and 168-hour test started. The temperature was monitored periodically to ensure test is not disrupted. After 168 hours had been concluded, the parts were removed from the chamber and stabilized at the room temperature until tray was cool (1 hour min).

.

Figure 22. Burn-in test Equipment – Fischer Scientific Isotemp oven and Omega HH502 thermometer

After Burn-in Electrical Test Results

VSWR and attenuation at the mid band were measured and recorded according to the frequency band of the part number at 23°C ± 3°C. The s-parameters were recorded at minimum, across the device's frequency band. Acceptance limits for VSWR and attenuation as per SCD (see Table 1) adjusted for the test fixture (test board and test connector) impact. All samples of the Group A passed post-bake RF test (see Table 5).

TSX Series, Qualification Acceptance Testing, TP-9293

smiths interconnect
bringing technology to life

Project / WO:	DD-233610 / PF-96572
Part #:	TSX0604XX.00X
Description:	High Frequency Broadband Attenuator
Test Plan:	TP-9293
Test Stage:	2.2.5
Test Descr:	After Burn-In (ABI) RF
Test Equip:	Anritsu MS4647B VNA TE91819
Operator:	JA
Start Date:	11/23/2020
End Date:	11/26/2020

Results PASS

Specifications:		≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz	≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz
Part Value	**Attn (dB)**	**VSWR :1**	**VSWR :1**	**VSWR :1**	**Attn Tol. (±) (dB**	**Attn Tol.(±) (dB**	**Attn Tol. (±) (dB**
TS060403.00F	-3.0	1.20	1.30	1.50	0.50	0.75	1.05
TS060406.00F	-6.0	1.20	1.30	1.50	0.50	0.80	1.30
TS060420.00F	-20.0	1.20	1.30	1.50	0.50	0.90	1.80

TS060403.00F

Frequency	VSWR :1	VSWR :1	VSWR :1	VSWR :1	VSWR :1	ATTN dB	ATTN dB	ATTN dB	ATTN dB	ATTN dB
(GHz)	**01**	**02**	**03**	**04**	**05**	**01**	**02**	**03**	**04**	**05**
0.01	1.02	1.01	1.01	1.03	1.02	-2.70	-2.57	-2.97	-2.96	-2.97
10	1.04	1.04	1.03	1.01	1.05	-2.63	-2.57	-3.05	-3.08	-3.07
20	1.08	1.09	1.09	1.07	1.14	-2.70	-2.67	-3.12	-3.12	-3.18
30	1.13	1.14	1.17	1.16	1.24	-2.73	-2.91	-3.20	-3.20	-3.42
40	1.10	1.12	1.20	1.20	1.27	-2.82	-2.94	-3.38	-3.42	-3.70
50	1.01	1.01	1.16	1.17	1.20	-3.21	-3.23	-3.74	-3.80	-4.01

TS060406.00F

Frequency	VSWR :1	VSWR :1	VSWR :1	VSWR :1	VSWR :1	ATTN dB	ATTN dB	ATTN dB	ATTN dB	ATTN dB
(GHz)	**06**	**07**	**08**	**09**	**10**	**06**	**07**	**08**	**09**	**10**
0.01	1.02	1.02	1.02	1.04	1.04	-5.55	-5.73	-5.53	-6.01	-6.00
10	1.01	1.01	1.01	1.04	1.03	-5.60	-5.62	-5.61	-6.12	-6.09
20	1.03	1.02	1.02	1.05	1.06	-5.69	-5.76	-5.70	-6.15	-6.15
30	1.07	1.06	1.08	1.08	1.09	-5.82	-5.98	-5.81	-6.33	-6.30
40	1.08	1.06	1.12	1.07	1.09	-6.16	-6.36	-6.16	-6.69	-6.62
50	1.04	1.03	1.06	1.02	1.05	-6.76	-6.73	-6.65	-7.21	-7.30

TS060420.00F

Frequency	VSWR :1	VSWR :1	VSWR :1	VSWR :1	VSWR :1	ATTN dB	ATTN dB	ATTN dB	ATTN dB	ATTN dB
(GHz)	**11**	**12**	**13**	**14**	**15**	**11**	**12**	**13**	**14**	**15**
0.01	1.04	1.05	1.05	1.04	1.04	-19.50	-19.60	-19.90	-20.00	-20.00
10	1.06	1.05	1.06	1.07	1.05	-19.50	-19.60	-19.50	-20.10	-20.00
20	1.10	1.08	1.10	1.13	1.09	-19.50	-19.70	-19.70	-20.00	-20.00
30	1.12	1.09	1.12	1.16	1.11	-19.80	-20.00	-19.90	-20.20	-20.20
40	1.13	1.10	1.16	1.18	1.13	-20.60	-20.80	-20.80	-20.90	-20.80
50	1.14	1.14	1.18	1.19	1.16	-21.30	-21.70	-21.50	-20.90	-21.00

Note: One 1dB and two 10dB devices were tested in Group A, outside of the Test Plan, as there were extra connectors

Specifications:		≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz	≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz
Part Value	**Attn (dB)**	**VSWR :1**	**VSWR :1**	**VSWR :1**	**Attn Tol. (±) (dB**	**Attn Tol.(±) (dB**	**Attn Tol. (±) (dB**
TS060401.00F	-1.0	1.20	1.40	1.80	0.50	0.75	1.04
TS060410.00F	-10.0	1.20	1.40	1.80	0.50	0.75	1.00

TS060401.00F

Frequency	VSWR :1	ATTN dB
(GHz)	**16**	**16**
0.01	1.03	-0.69
10	1.05	-0.83
20	1.15	-0.97
30	1.22	-1.08
40	1.15	-1.45
50	1.19	-2.01

TS060410.00F

Frequency	VSWR :1	VSWR :1	ATTN dB	ATTN dB
(GHz)	**17**	**18**	**17**	**18**
0.01	1.03	1.03	-9.60	-9.58
10	1.02	1.02	-9.61	-9.62
20	1.02	1.01	-9.64	-9.68
30	1.05	1.04	-9.73	-9.78
40	1.03	1.07	-10.30	-10.40
50	1.04	1.04	-9.86	-9.97

Table 5. Group A Post Burn In Electrical Test Results – Summary

Percent Defective Allowable (PDA) Analysis Results

Percentage Defective Allowable (PDA) Analysis was performed on the Group A inspection lot. The defective percentage was calculated to be 0% which is below an acceptable 5% (see Figure 23). It was concluded that the inspection lot that was subjected to the test passed the Group A testing and could be moved over to the Group B test stage.

smiths interconnect

PDA Analysis Report

Shop Order	DD-233610/PF-96572	Date	11/26/20
Part Number	TSX0604XX.00X	Done by	JA

Initial quantity	18	= q
PDA required by SCD / TP.	5.00%	= PDA
Defects prior to testing process	0	= d1
Qty rejected by 100% visual QC		
Qty rejected during initial electrical		
Missing pieces		
Quantity entered to the testing process	18	Q = q - d1
Defects not related to the testing process	0	= d2
Broken pieces		
Missing pieces	0	
Defects related to the testing process	0	= d3
VSWR over spec		
Attenuation over spec		
Attenuation below spec		
Delta over spec		
Delta below spec		
Total defectives after testing process	0	D = d2 + d3
Final quantity	18	F = Q - D
Defective percentage in the order	0.00%	P = D / Q
RESULT	PASS	P < PDA

Figure 23. PDA Analysis - Results

GROUP B INSPECTION (9 samples; 3 pcs of each 3 dB, 6 dB, 20 dB)

Devices from the Group A inspection were divided into Electrical and Mechanical subgroups. Each subgroup (1, 2, 3) consisted of three (3) devices, one (1) from each value. No Group B failures were allowed.

SUBGROUP 1 (3 devices, 1 from each value) TEST RESULTS

VSWR and attenuation were measured and recorded at the low, mid and high frequencies band according to the frequency band of the part number at -55°C +0°-3°C, 23°C ±3°C, and +125°C +3°-0°C. S-Parameters were recorded at minimum, across the device's frequency band. Acceptance limits were established as per SCD (see Table 1). All three samples of the Group B, Subgroup 1 passed RF test at temperature extremes (see Table 6).

TSX Series, Qualification Acceptance Testing, TP-9293

smiths interconnect
bringing technology to life

Project / WO:	DD-233610 / PF-96572					
Part #:	TSX0604XX.00X					
Description:	High Frequency Broadband Attenuator					
				Results	**PASS**	
Test Plan:	TP-9293					
Test Stage:	3.1.1					
Test Descr:	RF at Temperature Extremes					
Test Equip:	Anritsu 37369D VNA (TE 91590), Thermonics T-2500E Temp forcing system (TE40071), Omega HH502 Thermometer (TE10					
Operator:	JA/ BP					
Start Date:	12/16/2020					
End Date:	12/16/2020					
Specifications:		**≤ 20GHz**	**20GHz - 40GHz**	**40GHz - 50GHz**	**≤ 20GHz**	**20GHz - 40GHz**
Part Value	**Attn (dB)**	**VSWR :1**	**VSWR :1**	**VSWR :1**	**Attn Tol. (±) (dB)**	**Attn Tol.(±) (dB)**
TS060403.00F	-3.0	1.20	1.30	1.50	0.50	0.75
TS060406.00F	-6.0	1.20	1.30	1.50	0.50	0.75
TS060420.00F	-20.0	1.20	1.30	1.56	0.65	0.75
TS060403.00F						
Frequency	**VSWR :1**	**VSWR :1**	**VSWR :1**	**ATTN dB**	**ATTN dB**	**ATTN dB**
(GHz)	**125C**	**25C**	**-55C**	**125C**	**25C**	**-55C**
0.01	1.02	1.02	1.02	-3.01	-2.98	-2.99
10	1.14	1.14	1.16	-3.13	-3.03	-2.98
20	1.13	1.13	1.23	-3.23	-3.09	-3.00
30	1.14	1.15	1.19	-3.44	-3.23	-3.11
40	1.22	1.20	1.26	-3.73	-3.35	-3.30
TS060406.00F						
Frequency	**VSWR :1**	**VSWR :1**	**VSWR :1**	**ATTN dB**	**ATTN dB**	**ATTN dB**
(GHz)	**125C**	**25C**	**-55C**	**125C**	**25C**	**-55C**
0.01	1.02	1.01	1.02	-6.02	-6.01	-6.02
10	1.16	1.16	1.18	-6.16	-6.09	-6.01
20	1.06	1.09	1.14	-6.20	-6.07	-5.95
30	1.16	1.10	1.15	-6.41	-6.20	-6.05
40	1.09	1.15	1.10	-6.65	-6.46	-6.15
TS060420.00F						
Frequency	**VSWR :1**	**VSWR :1**	**VSWR :1**	**ATTN dB**	**ATTN dB**	**ATTN dB**
(GHz)	**125C**	**25C**	**-55C**	**125C**	**25C**	**-55C**
0.01	1.02	1.01	1.00	-19.42	-19.37	-19.41
10	1.12	1.11	1.08	-19.56	-19.48	-19.36
20	1.15	1.23	1.23	-19.64	-19.55	-19.36
30	1.07	1.09	1.04	-19.91	-19.73	-19.43
40	1.18	1.06	1.15	-20.67	-20.57	-20.05

Table 6. Group B – Subgroup 1 Electrical Test Results – Summary

Group B, Subgroup 1 devices were also tested for their resistance to temperature characteristic in accordance with MIL-STD-202, Method 304. The following details and exceptions applied:

a. Reference temperature: Room ambient temperature.
b. Test temperatures:
   Step 1: Room temperature.
   Step 2: -55°C.
   Step 3: Room temperature.
   Step 4: +125°C.
c. Accuracy of temperature measurement: Devices shall be maintained within 3˚C of each test temperature for a period of 30 to 45 minutes.

Acceptance limits were established as per SCD (see Table 1). All three samples of the Group B, Subgroup 1 passed the resistance to temperature characteristics test (see Table 7).

TSX Series, Qualification Acceptance Testing, TP-9293 smiths interconnect bringing technology to life

Project / WO:	DD-233610 / PF-96572
Part #:	TSX0604XX.00X
Description:	High Frequency Broadband Attenuator
Test Plan:	TP-9293
Test Stage:	3.1.2
Test Descr:	Resistance Temperature Characteristics
Test Equip:	Agilent E4461A DMM (TE40020), Thermonics T-2500E Temp forcing system (TE40071), Omega HH502 Thermometer (
Operator:	JA/AM
Start Date:	1/7/2021
End Date:	1/11/2021

Specifications:				**Results**	**PASS**
	Attn	**Rab (Ω)**	**Rac / Rbc (Ω)**		
Attn (dB):	3 dB	17.5	152.00		
	6 dB	33	85		
	20 dB	81.82	51.01		
Tol. (±):	0.5 dB				
Tol. (±):	0.75 dB				
DCR Tol. (±):	5.0 %				
Zin / Zout:	50 Ω				
PPM (±):	200 /°C				

Ref #	**Attn value**	**Rab (Ω)**	**Rac (Ω)**	**Rbc (Ω)**	**Rab (ppm/C)**	**Rac (ppm/C)**	**Rbc (ppm/C)**
SN04_25C	3dB	17.28	152.38	152.34	**Δ25C to -55C**	**Δ25C to -55C**	**Δ25C to -55C**
SN04_-55C	3dB	17.43	153.38	153.85	**105.60**	**82.36**	**123.90**
SN04_125C	3dB	17.23	151.09	150.65	**Δ25C to 125C**	**Δ25C to 125C**	**Δ25C to 125C**
SN04_25C	3dB	17.28	152.38	152.35	**31.35**	**85.51**	**112.91**
SN09_25C	6dB	33.64	83.56	83.74	**Δ25C to -55C**	**Δ25C to -55C**	**Δ25C to -55C**
SN09_-55C	6dB	33.97	84.08	84.55	**124.11**	**77.34**	**120.46**
SN09_125C	6dB	33.21	83.04	83.04	**Δ25C to 125C**	**Δ25C to 125C**	**Δ25C to 125C**
SN09_25C	6dB	33.47	83.52	83.56	**77.68**	**57.20**	**62.62**
SN11_25C	20dB	79.66	50.53	50.58	**Δ25C to -55C**	**Δ25C to -55C**	**Δ25C to -55C**
SN11_-55C	20dB	80.30	50.95	51.01	**101.69**	**103.15**	**105.27**
SN11_125C	20dB	78.95	50.09	50.13	**Δ25C to 125C**	**Δ25C to 125C**	**Δ25C to 125C**
SN11_25C	20dB	79.66	50.53	50.59	**89.55**	**88.04**	**91.16**

Table 7. Group B – Subgroup 1 Resistance to Temperature Test Results – Summary

SUBGROUP 2 (3 devices, 1 from each value) TEST RESULTS

Subgroup 2 consisted of three (3) devices, one (1) of each value which have completed Group A. The samples were subjected to a 10 µs pulse at a 10% duty cycle (1 millisecond period), pulsed DC Voltage of an amplitude equivalent to ten times the maximum power as specified in the SCD (10W). The samples were properly terminated and mounted to a suitable heatsink (see Figure 24) for a duration of 1.0 ± 0.1 hour in each direction per MIL-DTL-3933, Method 4.7.11.7. The units were allowed to stabilize at 25°C ± 5°C for 1-hour minimum before conducting electrical measurements. Acceptance limits were established as per SCD (see Table 1). All three samples of the Group B, Subgroup 2 passed the peak power test (see Table 8).

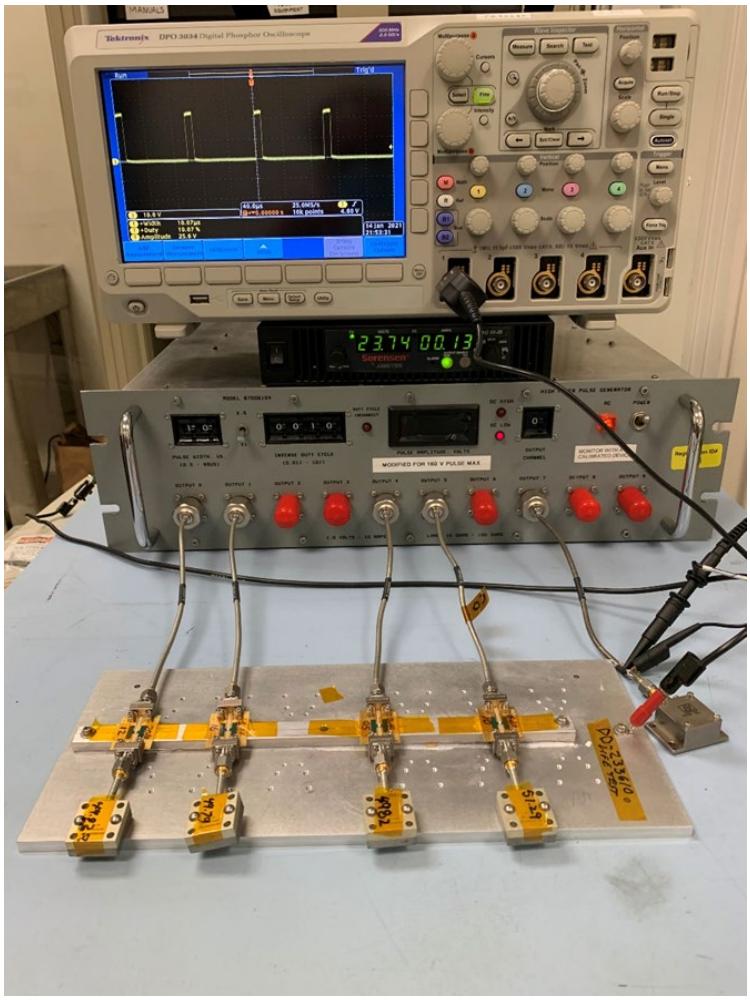


Figure 24. Test setup for the peak power test

TSX Series, Qualification Acceptance Testing, TP-9293

smiths interconnect
bringing technology to life

Project / WO:	DD-233610 / PF-96572						
Part #:	TSX0604XX.00X						
Description:	High Frequency Broadband Attenuator						
					Results	**PASS**	
Test Plan:	TP-9293						
Test Stage:	3.2.2 Peak Power						
Test Descr:	Before and After Peak Power (12.5W) RF						
Test Equip:	Tektronix DPO3034 (TE90685), EMC 87006104 High Power Pulse Generator, Sorensen XG33-25 DC Power Supply						
Operator:	JA						
Start Date:	1/13/2021						
End Date:	1/14/2021						

Specifications:		≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz	≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz
Part Value	**Attn (dB)**	**VSWR :1**	**VSWR :1**	**VSWR :1**	**Attn Tol. (±) (dB)**	**Attn Tol.(±) (dB)**	**Attn Tol. (±) (dB)**
TS060403.00F	-3.0	1.20	1.30	1.50	0.50	0.75	1.05
TS060406.00F	-6.0	1.20	1.30	1.50	0.50	0.80	1.30
TS060420.00F	-20.0	1.20	1.30	1.50	0.50	0.90	1.80

TS060403.00F	**BPP**	**BPP**		**Δ APP**	**APP**	**APP**
Frequency	**VSWR :1**	**ATTN dB**		**Δ ATTN dB**	**VSWR :1**	**ATTN dB**
(GHz)	**05**	**05**		**05**	**05**	**05**
0.01	1.02	-3.01		0.03	1.02	-2.98
10	1.05	-3.06		-0.01	1.05	-3.07
20	1.14	-3.04		-0.05	1.14	-3.09
30	1.24	-3.17		0.02	1.24	-3.15
40	1.27	-3.50		-0.05	1.27	-3.55
50	1.20	-3.96		-0.01	1.20	-3.97

TS060406.00F	**BPP**	**BPP**		**Δ APP**	**APP**	**APP**
Frequency	**VSWR :1**	**ATTN dB**		**Δ ATTN dB**	**VSWR :1**	**ATTN dB**
(GHz)	**10**	**10**		**10**	**10**	**10**
0.01	1.04	-6.01		-0.01	1.04	-6.02
10	1.03	-6.10		0.00	1.03	-6.10
20	1.05	-6.09		0.01	1.06	-6.08
30	1.09	-6.24		0.05	1.09	-6.19
40	1.09	-6.66		0.14	1.09	-6.52
50	1.05	-7.25		0.06	1.05	-7.19

TS060420.00F	**BPP**	**BPP**		**Δ APP**	**APP**	**APP**
Frequency	**VSWR :1**	**ATTN dB**		**Δ ATTN dB**	**VSWR :1**	**ATTN dB**
(GHz)	**12**	**12**		**12**	**12**	**12**
0.01	1.05	-19.50		0.00	1.05	-19.50
10	1.05	-19.60		0.10	1.05	-19.50
20	1.08	-19.50		-0.04	1.08	-19.54
30	1.09	-19.70		0.10	1.09	-19.60
40	1.10	-20.60		0.20	1.10	-20.40
50	1.14	-21.70		0.00	1.14	-21.70

Note: One 1dB was tested, outside of the Test Plan, to test the peak power handling ability of the smallest series resistor in the family.

Specifications:		≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz	≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz
Part Value	**Attn (dB)**	**VSWR :1**	**VSWR :1**	**VSWR :1**	**Attn Tol. (±) (dB)**	**Attn Tol.(±) (dB)**	**Attn Tol. (±) (dB)**
TS060401.00F	-1.0	1.20	1.40	1.80	0.50	0.75	1.04

TS060401.00F	**BPP**	**BPP**		**Δ APP**	**APP**	**APP**
Frequency	**VSWR :1**	**ATTN dB**		**Δ ATTN dB**	**VSWR :1**	**ATTN dB**
(GHz)	**16**	**16**		**16**	**16**	**16**
0.01	1.03	-0.74		0.02	1.03	-0.71
10	1.05	-0.81		-0.01	1.05	-0.82
20	1.15	-0.94		0.06	1.15	-0.88
30	1.22	-1.02		0.10	1.22	-0.92
40	1.15	-1.38		0.04	1.15	-1.34
50	1.19	-1.99		0.00	1.19	-1.99

Table 8. Group B – Subgroup 2 Peak Power Test Results – Summary

SUBGROUP 3 (3 devices, 1 from each value) TEST RESULTS

Solder Mounting Integrity (Die Shear) Test Results:

Devices were soldered to a suitable substrate. A 2-kilogram force was applied to the chip edge for 30 seconds per MIL-PRF-55342, Method 4.8.13. The devices were then visually inspected for any evidence of mechanical damage. As indicated in Table 9, the subgroup 3 devices passed the test.

TSX Series, Qualification Acceptance Testing, TP-9293

smiths interconnect
bringing technology to life

Project / WO	DD-233610 / PF-96572
Part #:	TSX0604XX.00X
Description:	High Frequency Broadband Attenuator
Test Plan:	TP-9293
Test Stage:	3.3.2
Test Descr:	Solder Mounting Integrity (Die Shear)
Test Equip:	Chatillon Force Tester
Operator:	TFM
Start Date:	1/13/2021
End Date:	1/13/2021
Results:	Pass

3 dB	**2kg for**
SN	**30 secs**
03	**PASS**

6 dB	**2kg for**
SN	**30 secs**
06	**PASS**

20dB	**2kg for**
SN	**30 secs**
13	**PASS**

Table 9. Group B, Subgroup 2 Solder Mounting Integrity Test Results - Summary

GROUP C INSPECTION (6 samples, 2 samples per value from Group A):

The Group C inspection lot consisted of six (6) devices, two (2) from each value, that have successfully completed the Group A Inspection test and were then subjected to the Life test as described in the TP-9293. No failures were permitted.

Life Test (1000 hr. Burn-In):

The properly terminated devices were subjected to a DC voltage equivalent to the max power in the SCD (1W) with a base temperature not to exceed 100°C ± 5°C for a duration of 1000 ± 4 hours. The units were allowed to stabilize at 25°C ± 5°C for 1-hour minimum before conducting electrical measurements. RF Test measurements were made after 250, 500, and 1000 hours (± 8 hours). The test setup is shown in Figure 25.
The devices were visually examined for any evidence of mechanical damage which was not observed. VSWR and attenuation at the mid band were measured and recorded according to the frequency band of the part number at 23°C ± 3°C. The s-parameters were recorded at minimum, across the device's frequency band. Acceptance limits for VSWR and attenuation as per SCD (see Table 1) adjusted for the test fixture (test board and test connector) impact. All six samples of the Group C passed the post life test (see Tables 10–12).

Figure 25. Test setup for the Group C life test

TSX Series, Qualification Acceptance Testing, TP-9293

smiths interconnect
bringing technology to life

Project / WO:	DD-233610 / PF-96572
Part #:	TSX0604XX.00X
Description:	High Frequency Broadband Attenuator
Test Plan:	TP-9293
Test Stage:	4.2.2
Test Descr:	Life Test 250Hrs (1W)
Test Equip:	Anritsu MS4647B VNA TE91819
Operator:	JA
Start Date:	12/4/2020
End Date:	12/4/2020

Specifications:		≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz	≤ 20GHz	20GHz - 40GHz
Part Value	**Attn (dB)**	**VSWR :1**	**VSWR :1**	**VSWR :1**	**Attn Tol. (±) (dB)**	**Attn Tol.(±) (dB)**
TS060403.00F	-3.0	1.20	1.90	1.50	0.50	0.75
TS060406.00F	-6.0	1.20	1.50	1.50	0.50	0.80
TS060420.00F	-20.0	1.20	1.30	1.50	0.50	1.10

TS060403.00F					**0 - 250 Hrs**	**1 - 250 Hrs**		
Frequency	**VSWR :1**	**VSWR :1**	**ATTN dB**	**ATTN dB**	**Δ ATTN dB**	**Δ ATTN dB**	**Δ ATTN dB**	**Δ ATTN dB**
(GHz)	**01**	**02**	**01**	**02**	**01**	**02**	**01**	**02**
0.01	1.01	1.01	-2.51	-2.51	-0.01	-0.01	-0.01	-0.01
10	1.05	1.03	-2.66	-2.64	0.01	-0.03	0.01	-0.03
20	1.10	1.05	-2.80	-2.89	0.23	0.25	0.23	0.25
30	1.21	1.23	-2.67	-2.78	-0.18	-0.06	-0.18	-0.06
40	1.62	1.83	-2.56	-2.59	-0.25	-0.35	-0.25	-0.35

TS060406.00F					**0 - 250 Hrs**	**1 - 250 Hrs**		
Frequency	**VSWR :1**	**VSWR :1**	**ATTN dB**	**ATTN dB**	**Δ ATTN dB**	**Δ ATTN dB**	**Δ ATTN dB**	**Δ ATTN dB**
(GHz)	**07**	**08**	**07**	**08**	**07**	**08**	**07**	**08**
0.01	1.01	1.01	-5.50	-5.51	-0.02	-0.03	-0.02	-0.03
10	1.03	1.02	-5.68	-5.58	0.11	-0.06	0.11	-0.06
20	1.03	1.02	-5.99	-5.81	0.35	0.13	0.35	0.13
30	1.11	1.10	-6.08	-5.81	0.26	-0.04	0.26	-0.04
40	1.41	1.32	-6.20	-5.93	0.07	-0.26	0.07	-0.26

TS060420.00F					**0 - 250 Hrs**	**1 - 250 Hrs**		
Frequency	**VSWR :1**	**VSWR :1**	**ATTN dB**	**ATTN dB**	**Δ ATTN dB**	**Δ ATTN dB**	**Δ ATTN dB**	**Δ ATTN dB**
(GHz)	**14**	**15**	**14**	**15**	**14**	**15**	**14**	**15**
0.01	1.03	1.04	-20.00	-20.00	0.00	0.00	0.00	0.00
10	1.08	1.07	-20.00	-20.00	-0.10	0.00	-0.10	0.00
20	1.12	1.07	-20.10	-20.00	0.10	0.10	0.10	0.10
30	1.16	1.12	-20.30	-20.20	0.00	0.00	0.00	0.00
40	1.24	1.20	-20.60	-20.40	-0.50	-0.70	-0.50	-0.70
						-0.11		

Note: One 1dB and two 10dB devices were tested in Group A, outside of the Test Plan, as there were extra connectors

Specifications:		≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz	≤ 20GHz	20GHz - 40GHz
Part Value	**Attn (dB)**	**VSWR :1**	**VSWR :1**	**VSWR :1**	**Attn Tol. (±) (dB)**	**Attn Tol.(±) (dB)**
TS060410.00F	-10.0	1.20	1.40	1.80	0.50	0.75

TS060410.00F					**0 - 250 Hrs**	**1 - 250 Hrs**		
Frequency	**VSWR :1**	**VSWR :1**	**ATTN dB**	**ATTN dB**	**Δ ATTN dB**	**Δ ATTN dB**	**Δ ATTN dB**	**Δ ATTN dB**
(GHz)	**17**	**18**	**17**	**18**	**17**	**18**	**17**	**18**
0.01	1.02	1.02	-9.55	-9.58	-0.03	-0.02	-0.03	-0.02
10	1.01	1.02	-9.55	-9.65	-0.06	-0.04	-0.06	-0.04
20	1.03	1.02	-9.66	-9.85	0.07	0.22	0.07	0.22
30	1.06	1.06	-9.58	-9.75	0.02	0.00	0.02	0.00
40	1.10	1.16	-9.96	-10.20	-0.34	-0.30	-0.34	-0.30

Table 10. Post 250 hours of Life Test Electrical Results - Summary

TSX Series, Qualification Acceptance Testing, TP-9293

smiths interconnect
bringing technology to life

Project / WO:	DD-233610 / PF-96572
Part #:	TSX0604XX.00X
Description:	High Frequency Broadband Attenuator
Test Plan:	TP-9293
Test Stage:	4.2.2
Test Descr:	Life Test 500Hrs (1W)
Test Equip:	Anritsu MS4647B VNA TE91819
Operator:	JA
Start Date:	12/16/2020
End Date:	12/17/2020

Specifications:		≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz	≤ 20GHz	20GHz - 40GHz
Part Value	**Attn (dB)**	**VSWR :1**	**VSWR :1**	**VSWR :1**	**Attn Tol. (±) (dB)**	**Attn Tol.(±) (dB)**
TS060403.00F	-3.0	1.20	1.30	1.50	0.50	0.75
TS060406.00F	-6.0	1.20	1.30	1.50	0.50	0.80
TS060420.00F	-20.0	1.20	1.30	1.50	0.50	1.10

TS060403.00F								
Frequency	**VSWR :1**	**VSWR :1**	**ATTN dB**	**ATTN dB**	**250 - 500 Hrs Δ ATTN dB**	**250 - 500 Hrs Δ ATTN dB**	**0 - 500 Hrs Δ ATTN dB**	**0 - 500 Hrs Δ ATTN dB**
(GHz)	**01**	**02**	**01**	**02**	**01**	**02**	**01**	**02**
0.01	1.01	1.01	-2.52	-2.50	0.01	-0.01	0.00	-0.02
10	1.05	1.02	-2.70	-2.84	0.04	0.20	0.05	0.17
20	1.11	1.06	-2.88	-2.93	0.08	0.04	0.31	0.29
30	1.24	1.19	-2.88	-2.84	0.21	0.06	0.03	0.00
40	1.36	1.50	-3.20	-3.04	0.64	0.45	0.39	0.10

TS060406.00F								
Frequency	**VSWR :1**	**VSWR :1**	**ATTN dB**	**ATTN dB**	**250 - 500 Hrs Δ ATTN dB**	**250 - 500 Hrs Δ ATTN dB**	**0 - 500 Hrs Δ ATTN dB**	**0 - 500 Hrs Δ ATTN dB**
(GHz)	**07**	**08**	**07**	**08**	**07**	**08**	**07**	**08**
0.01	1.01	1.01	-5.54	-5.51	0.04	0.00	0.02	-0.03
10	1.02	1.02	-5.68	-5.65	0.00	0.07	0.11	0.01
20	1.03	1.02	-6.02	-5.84	0.03	0.03	0.38	0.16
30	1.04	1.10	-6.16	-5.84	0.08	0.03	0.34	-0.01
40	1.05	1.13	-6.44	-5.95	0.24	0.02	0.31	-0.24

TS060420.00F								
Frequency	**VSWR :1**	**VSWR :1**	**ATTN dB**	**ATTN dB**	**250 - 500 Hrs Δ ATTN dB**	**250 - 500 Hrs Δ ATTN dB**	**0 - 500 Hrs Δ ATTN dB**	**0 - 500 Hrs Δ ATTN dB**
(GHz)	**14**	**15**	**14**	**15**	**14**	**15**	**14**	**15**
0.01	1.04	1.04	-20.00	-20.00	0.00	0.00	0.00	0.00
10	1.07	1.06	-20.00	-20.00	0.00	0.00	-0.10	0.00
20	1.10	1.07	-20.20	-20.10	0.10	0.10	0.20	0.20
30	1.12	1.10	-20.40	-20.40	0.10	0.20	0.10	0.20
40	1.12	1.07	-21.00	-20.70	0.40	0.30	-0.10	-0.40
						0.12		

Note: One 1dB and two 10dB devices were tested in Group A, outside of the Test Plan, as there were extra connectors

Specifications:		≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz	≤ 20GHz	20GHz - 40GHz
Part Value	**Attn (dB)**	**VSWR :1**	**VSWR :1**	**VSWR :1**	**Attn Tol. (±) (dB)**	**Attn Tol.(±) (dB)**
TS060410.00F	-10.0	1.20	1.40	1.80	0.50	0.75

TS060410.00F								
Frequency	**VSWR :1**	**VSWR :1**	**ATTN dB**	**ATTN dB**	**250 - 500 Hrs Δ ATTN dB**	**250 - 500 Hrs Δ ATTN dB**	**0 - 500 Hrs Δ ATTN dB**	**0 - 500 Hrs Δ ATTN dB**
(GHz)	**17**	**18**	**17**	**18**	**17**	**18**	**17**	**18**
0.01	1.02	1.02	-9.56	-9.59	0.01	0.01	-0.02	-0.01
10	1.00	1.01	-9.65	-9.70	0.10	0.05	0.04	0.01
20	1.01	1.03	-9.73	-9.93	0.07	0.08	0.14	0.30
30	1.06	1.05	-9.63	-9.88	0.05	0.13	0.07	0.13
40	1.11	1.13	-10.10	-10.50	0.14	0.30	-0.20	0.00

Table 11. Post 500 hours of Life Test Electrical Results - Summary

TSX Series, Qualification Acceptance Testing, TP-9293

smiths interconnect
bringing technology to life

Project / WO:	DD-233610 / PF-96572
Part #:	TSX0604XX.00X
Description:	High Frequency Broadband Attenuator
Test Plan:	TP-9293
Test Stage:	4.2.2
Test Descr:	Life Test 1000Hrs (1W)
Test Equip:	Anritsu MS4647B VNA TE91819
Operator:	JA
Start Date:	12/4/2020
End Date:	1/8/2020

Specifications:		≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz	≤ 20GHz	20GHz - 40GHz
Part Value	**Attn (dB)**	**VSWR :1**	**VSWR :1**	**VSWR :1**	**Attn Tol. (±) (dB)**	**Attn Tol.(±) (dB)**
TS060403.00F	-3.0	1.20	1.30	1.50	0.50	0.75
TS060406.00F	-6.0	1.20	1.30	1.50	0.50	0.80
TS060420.00F	-20.0	1.20	1.30	1.50	0.50	1.10

TS060403.00F

Frequency	VSWR :1	VSWR :1	ATTN dB	ATTN dB	Δ ATTN dB	Δ ATTN dB	Δ ATTN dB	Δ ATTN dB
(GHz)	**01**	**02**	**01**	**02**	**01**	**02**	**01**	**02**
0.01	1.01	1.01	-2.51	-2.52	-0.01	0.02	-0.01	0.00
10	1.05	1.01	-2.65	-2.63	-0.05	-0.21	0.00	-0.04
20	1.10	1.05	-2.81	-2.87	-0.07	-0.06	0.24	0.23
30	1.21	1.19	-2.70	-2.80	-0.18	-0.04	-0.15	-0.04
40	1.25	1.30	-2.62	-2.57	-0.58	-0.47	-0.19	-0.37

TS060406.00F

Frequency	VSWR :1	VSWR :1	ATTN dB	ATTN dB	Δ ATTN dB	Δ ATTN dB	Δ ATTN dB	Δ ATTN dB
(GHz)	**07**	**08**	**07**	**08**	**07**	**08**	**07**	**08**
0.01	1.02	1.01	-5.52	-5.52	-0.02	0.01	0.00	-0.02
10	1.02	1.02	-5.65	-5.62	-0.03	-0.03	0.08	-0.02
20	1.03	1.02	-5.94	-5.83	-0.08	-0.01	0.30	0.15
30	1.04	1.09	-6.05	-5.84	-0.11	0.00	0.23	-0.01
40	1.01	1.16	-6.32	-5.97	-0.12	0.02	0.19	-0.22

TS060420.00F

Frequency	VSWR :1	VSWR :1	ATTN dB	ATTN dB	Δ ATTN dB	Δ ATTN dB	Δ ATTN dB	Δ ATTN dB
(GHz)	**14**	**15**	**14**	**15**	**14**	**15**	**14**	**15**
0.01	1.04	1.04	-20.00	-20.00	0.00	0.00	0.00	0.00
10	1.07	1.05	-20.00	-20.00	0.00	0.00	-0.10	0.00
20	1.10	1.08	-20.10	-20.00	-0.10	-0.10	0.10	0.10
30	1.12	1.10	-20.30	-20.20	-0.10	-0.20	0.00	0.00
40	1.09	1.11	-21.00	-20.50	0.00	-0.20	-0.10	-0.60

Note: One 1dB and two 10dB devices were tested in Group A, outside of the Test Plan, as there were extra connectors

Specifications:		≤ 20GHz	20GHz - 40GHz	40GHz - 50GHz	≤ 20GHz	20GHz - 40GHz
Part Value	**Attn (dB)**	**VSWR :1**	**VSWR :1**	**VSWR :1**	**Attn Tol. (±) (dB)**	**Attn Tol.(±) (dB)**
TS060410.00F	-10.0	1.20	1.40	1.80	0.50	0.75

TS060410.00F

Frequency	VSWR :1	VSWR :1	ATTN dB	ATTN dB	Δ ATTN dB	Δ ATTN dB	Δ ATTN dB	Δ ATTN dB
(GHz)	**17**	**18**	**17**	**18**	**17**	**18**	**17**	**18**
0.01	1.02	1.02	-9.54	-9.61	-0.02	0.02	-0.04	0.01
10	1.02	1.01	-9.60	-9.68	-0.05	-0.02	-0.01	-0.01
20	1.06	1.03	-9.74	-9.88	0.01	-0.05	0.15	0.25
30	1.11	1.06	-9.67	-9.75	0.04	-0.13	0.11	0.00
40	1.05	1.07	-9.66	-10.20	-0.44	-0.30	-0.64	-0.30

Table 12. Post 1000 hours of Life Test Electrical Results - Summary

Qualification Test – Summary and Conclusion

The high frequency broadband attenuator family, TSX series, consists of thirteen values ranging from 0 dB to 20 dB. Samples of all values have been tested; the test results presented in this test report are evidence of the performance that meets the required specifications.

A rigorous qualification testing as per TP-9293 has also been performed on a 15-piece inspection lot of the three designs (3 dB, 6 dB, 20 dB). The three designs are chosen as "extremes" covering the entire range of attenuation values. The test consisted of Group A, Group B, and Group C testing; the devices were subjected to thermal shock, burn in test, RF test at temperature extremes, solder mount integrity test, and life test. The results of these qualification tests have been presented in this report. As shown, the inspection lot passed all the specifications as required by the TP-9293 and corresponding SCD. It has therefore been determined that **the products under the qualification test of the product family TSXDB.00 are qualified to be released into a full production**.

Other designs in this product family whose samples have not been subjected to the qualification test have been characterized by the identical bill of materials and processing router as the previously qualified products. In other words, these designs share the identical constitutive material list and identical set of processing steps used to make them. The only difference is in geometrical shapes of the metalized and resistive features on the front surface of the ceramic substrate. By similarity with the qualified designs, it is determined that these designs **can also be qualified to be released into a full production**.