Evaluation Report for the Amphenol-Bendix 453 Miniature Circular Connector with Mil-T-29504 Optical Termini in a Vibration Environment

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- **A2 Test Method for Insertion Loss/Optical Throughput**
- **Table II. Interferometer Measurement Results**
- **Table III. Initial Visual 400X**
- **Table IV. Baseline Insertion Loss and Optical Throughput Data**
- **Table V. Data for First Vibration Test- Thick Bracket**
- **Table VI. Data for Second Vibration Test - Thin Bracket**

Up to TVA Homepage

Back to the Library

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Abstract

The use of a multi-termini optical connector has been adopted on two GSFC programs. This connector system introduces the use of individually removable, specially polished, physically touching, optical contacts. This evaluation addresses performance of the Amphenol-Bendix "453" connector using optical contacts in a random vibration environment. The results show that this multi-termini connector performs within the manufacturer's specifications to at least 37 Grms random vibration, with thermal cycling preconditioning. Contamination was found to be generated by the connector itself, indicating the need for attention to cleanliness and the development of adequate cleaning procedures. Alignment sleeve retention force played a role in the occurrence of metal filing contamination between one of the optical contact pairs, indicating that alignment sleeve retention force should be more closely controlled. Finally, the optical contacts with less than ideal polish qualities tended to degrade over the duration of the evaluation which indicates that cleave and polish damage can lead to increased polish surface defects over the life of the optical connector. While the "453" connector was found suitable for use in environments that experience mild thermal cycling, further study of the relationship between the surface polish defects, temperature and fiber tension will show their suitability for use in more thermally stressful environments.

Table of Contents

Next Section

Up to TVA Homepage

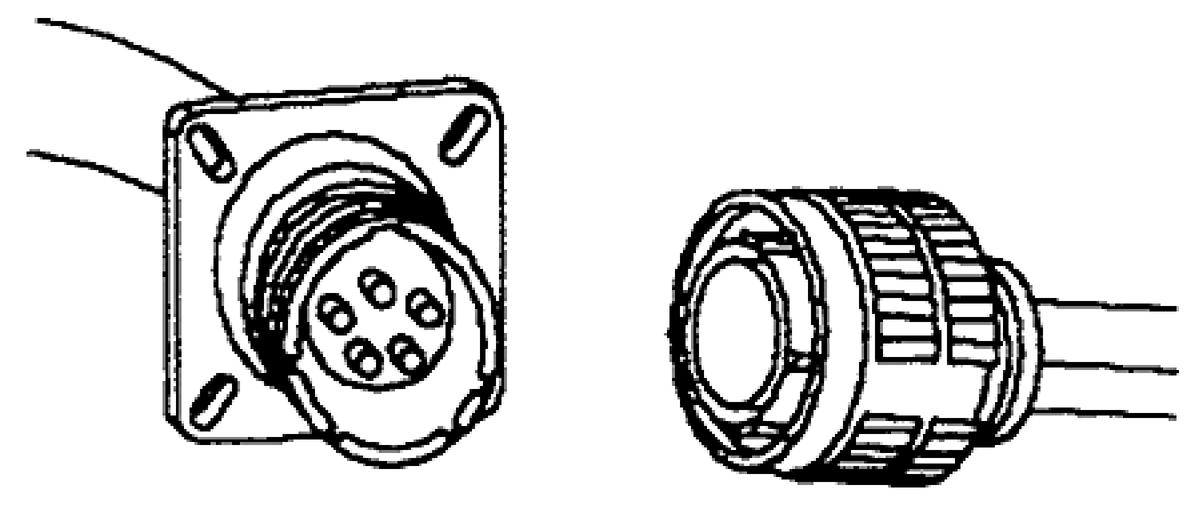
Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

1.0 Introduction

The MIL-STD-1773 optical fiber based communication bus has been qualified and successfully flown by GSFC on the SAMPEX (Solar Anomalous Magnetospheric Particle Explorer) satellite. The success of SAMPEX has led to acceptance of the MIL-STD-1773 data bus system in the XTE (X-ray Timing Experiment) satellite and on TRMM (Tropical Rainfall Measuring Mission). Each of these later projects have been able to improve on the SAMPEX bus design by modifying various parts of the system hardware. With the exception of the "453" connector and the M29504 optical termini that is described here (Figure 1 and 2), the basic passive optical components (the fiber, cable, star coupler**1**), have not changed.

Figure 1. "453" - M29504 Connector System

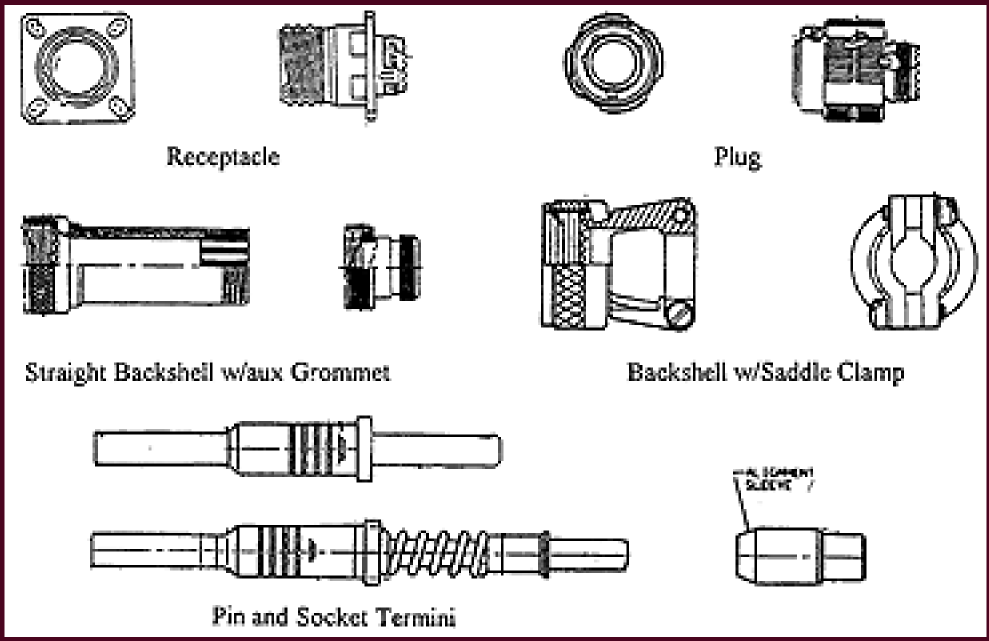


The "453" - M29504 connection system can be used to replace multiple, individual, MIL-C-83522, SMA type, single fiber connectors. This approach should improve reliability and performance by decreasing the number of individually mating connectors and by introducing a physically contacting (PC) mate at the fiber ends. SMA connectors allow an air gap between the fiber ends which limits the performance to the air gap loss (typically 0.34 dB to 2.0 dB depending on the width of separation between the fiber ends). The M29504 termini are designed and polished to eliminate the air gap between the fiber ends.

The use of "453" connectors with several optical contacts provides smaller footprint and significant reduction in hardware weight. The XTE and TRMM busses use "453" connectors with four and sixteen optical contacts. SMA connectors are still used in these systems at the active device interfaces (transmitters and receivers).

1/ Part numbers for the optical components used in the MIL-STD-1773 fiber optic bus are listed in section 51 of the GSFC Preferred Parts List, PPL-21. Design changes have been made on the transceiver unit for the TRMM mission.

Figure 2. Connector and Terminus



The "453" connector has a long history of use at GSFC for electrical applications. M29504 contacts in MIL-C-38999 connectors (military version of the 453) have been studied by such organizations as NASA-JSC's Space Station group, the Air Force's F22/Comanche Helicopter fiber optic development group and Martin Marietta Space Systems in Denver, however the actual use of "453" connectors in high reliability optical systems has been limited. These organizations have reported good performance for the MIL-C-38999 - M29504 connector with some uncertainty in the vibration area. To date, test data has not been released by these organizations because the connector, used as an optical device, is fairly difficult to test with respect to accuracy and repeatability.

Table of Contents

Next Section

Up to TVA Homepage

Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

2.0 Objective

This evaluation was done to generate performance data for the "453" - M29504 system with respect to the operational requirements and application conditions of the XTE and TRMM programs. The affect of vibration on connector performance characteristics is a significant reliability concern. Another area of interest was characterization of the physical condition of the specially polished fiber ends, since XTE and TRMM were the first to use PC polished optical contacts.

Table of Contents

Next Section

Up to TVA Homepage

Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

3.0 Part Description

The "453" connector is Amphenol-Bendix's high reliability miniature circular connector made to the performance and dimensional specifications of MIL-C-38999, the military's specification for electrical, miniature, circular, connectors. Amphenol-Bendix's "453" was designed for NASA applications with "low outgassing" materials. It is defined as environmental class (removable contacts, non-hermetic) and scoop-proof, triple start, self-locking, threaded coupling style (a.k.a. Series III) with a wall mount flanged receptacle (the connector mating occurs on the other side of the panel to which the receptacle is attached). The metal shells are electroless nickel plated aluminum. Various polymers make up the contact insert, gasket, grommet and spacer. Standard military backshells can be used with the "453" connector. In this evaluation, both a straight saddle-clamp type and a straight backshell with auxiliary grommet were used.

The M29504 optical termini conform to the MIL-T-29504/4 and /5 specifications. These termini are designed to fit in the contact cavities of the MIL-C-38999 connector as securely and reliably as size 16, MIL-C-39029 electrical contacts. MIL-T-29504/4 and /5 specifically reference MIL-C-38999 as the corresponding connector for these termini. The termini are designed with a stainless steel body and ceramic ferrule. The ceramic ferrule retains and precisely aligns the bare fiber. The fiber is captivated by heat cured epoxy in the ferrule and the rest of the optical cable components, such as the jacket and strength members, are captured by the terminus crimp sleeve and heat shrink tubing. The "socket" terminus (MIL-T-29504/5) employs a spring and stainless steel, slotted, alignment sleeve to facilitate precisely aligned, physical contact (PC) with the "pin" terminus (/4). The pin terminus is used in the receptacle-half of the connector and the socket is used in the plug-half of the connector. Amphenol-Bendix is the only QPL source for these termini. Table I in Appendix A shows manufacturer ratings for the parts tested.

The test assembly consisted of one connector pair with four contact pairs. The socket termini were housed in the plug-half and the pins were in the receptacle-half. The contacts were terminated to Brand-Rex's OC-1008 Flight Light cable which incorporates a Corning graded index (100/140 m size) radiation hard fiber. On the free ends of each of the eight cable segments was an

Amp "905" SMA connector (compliant with MIL-C-83522).

The transmitter, Honeywell's HFE 4010, was operated in continuous-+- wave mode producing a signal of 850 nm wavelength with approximately 0.16 mW (-7.95 dBm) output power.

Table of Contents

Next Section

Up to TVA Homepage

Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

4.0 Test Program

Table 1 shows environmental conditions defined for XTE and TRMM. Table 2 shows the tests used to evaluate the cable assembly and the test equipment employed. Figure 3 shows the testing flow.

Table 1. XTE and TRMM Environmental Conditions:

Temperature	-operating	0C to +5C
	-storage	-20C to +40C
Vibration (Random)	- XTE	7.87 Grms
	- TRMM	14.8 Grms

Table 2. Test Methods and Conditions

Step	Test	Conditions	Test Equipment
1	Physical Dimensions	Verify dimensions to three significant digits.	
2	Thermal Conditioning	85°C for 24 hrs (minimum) followed by -55°C for 24 hrs (minimum)	Tenney Benchmaster oven with Watlow Series 942 controller
3	Visual Inspection	Inspect the cable for evidence of degradation. Inspect fiber end faces at 200X minimum.	Janavert 30-G0685 incident light microscope, Nikon Epiphot inverted microscope, Norland Fiber Interferometer,
4	Insertion Loss	See Appendix A	Tektronix

			6711 Optical to Electrical Converter, Hewlett Packard 54501A digital oscilloscope, Noyes OPM1 Optical Power Meter, DC Power Supply, Honeywell HFE4010 transmitter, Hewlett Packard 8158B Optical Attenuator
5	Temperature Cycling	Test method EIA/TIA-455-3A. Using 50 C for max temperature and -20C for minimum temperature, 8 cycles.	Tenney Benchmaster oven with Watlow Series 942 controller with the insertion loss set-up.
6	Visual Inspection	See step 3	See step 3
7	Insertion Loss	See Appendix A	See step 4
8	Random Vibration 1	Test Method MIL-STD-1344, Condition V, 18.7 Grms, 6 minutes in each of three mutually perpendicular directions. Optical throughput shall be measured during exposure using a 0.008mW input signal. A mechanical integrity test will also be performed on the SMA to active device interface. Use bracket A in Figure 9.	B335 Shaker System Lateral Table with the Insertion Loss set-up
9	Visual Inspection	See Step 3	See step 3

10	Insertion Loss	See Appendix A	See step 4
11	Random Vibration 2	Repeat step 8 using bracket B in Figure 9.	see random vibration 1 above
12	Visual Inspection	See Step 3	See step 3
13	Insertion Loss	See Appendix A	See step 4

Figure 3. Testing Flow

Physical Dimensions

Thermal Conditioning

Visual Inspection

Insertion Loss

Temperature Cycling

Visual Inspection

Insertion Loss

Random Vibration (Bracket 1)

Visual Inspection

Insertion Loss

Random Vibration (Bracket 2)

Visual Inspection

Insertion Loss

Table of Contents

Next Section

Up to TVA Homepage

Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

5.0 Test Results and Discussion

5.1 Dimensional Measurements and Interferometer Examinations

The results of the dimensional check showed that the connectors and termini complied with the dimensions and tolerances given by the manufacturer and the associated military specifications (MIL-C-38999 and MIL-T-29504). This leads to the conclusion that the parts being evaluated are physically representative of the parts selected for use on flight hardware.

Interferometer measurements were taken for each of the eight fiber end faces to quantify their initial polish quality (shape). The intent was to create a convex shaped fiber end face centered on the fiber core. Theoretically, optical power loss is reduced with a highly concentric polish which leaves no surface discontinuities in the glass (that will cause reflection) such as cracks, pits and material contamination.

An interferometer image appears as a fringe pattern whose center, or "bull's eye" is at the center of the fiber end face polish radius (Figure 4). This "straight-on" view provides quantifiable polish offset data and can show serious damage to the glass such as crushes and large cracks. The interferometer used in this evaluation also employed a tilt function that showed physical characteristics of the fiber polish from a profile view. Known values such as the fiber size and the distance between the fringes are used to calculate the fiber protrusion (distance between highest point on the glass fiber and the highest point of the ceramic ferrule). Table II in Appendix A shows the data taken for the evaluation cable assembly and the acceptance criteria used by XTE and TRMM.

None of the termini polishes complied with all of the established limits, however they were considered acceptable for the needs of the evaluation. Optical time domain reflectometer (OTDR) measurements performed later in the evaluation (after the first vibration test) confirmed that all four of the fibers were making physical contact. No serious defects were found on any of the eight termini although at least one had significantly large chips in the fiber cladding outer diameter.

Figure 4. Example of an Interferometer Image (Channel 42 pin terminus)

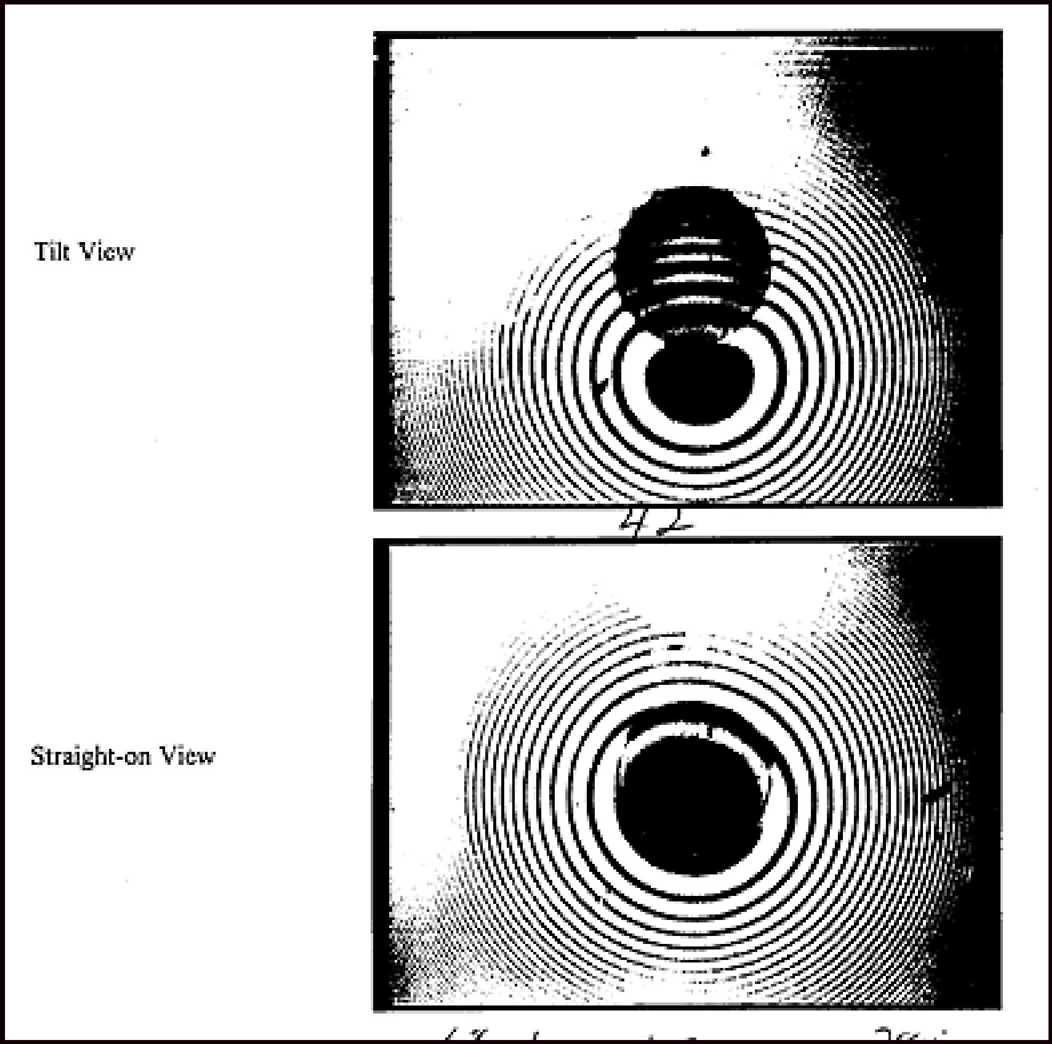


Table of Contents

Next Section

Up to TVA Homepage

Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

5.2 Thermal Conditioning

Two types of thermal conditioning were used prior to vibration testing: a temperature soak and temperature cycling. A high and low temperature soak consisting of a dwell time of 24 hours at each of the temperature extremes, -55°C and 85°C, was used to enhance the stability of the optical cable by driving marginal parts of the assembly to failure. The temperature profile used is shown in Table 3. No failures were found following the soaks however it was observed that the OC-1008 cable stiffened with exposure to high temperature (85°C is the maximum rated temperature due to the material characteristics of the optical fiber coating).

Table 3. Thermal Conditioning Temperature Profile

Transition Time (hours)	Dwell Time (hours)	Temperature °C
Start		25
0.5		85
	24	85
0.75		25
1		-55
	24	-55
0.5		25

5.2.1 Post Thermal Soak Visual Inspection

Following the thermal conditioning, a visual examination of the fiber end faces was performed at 400X, both with and without the use of backlighting. A significant number of features were noted on many of the fiber end faces and were attributed to the original termination process which left surface irregularities. Several of the end faces showed rough edges on the cladding outer diameters and pits in the core and cladding areas. One terminus appeared to have a crack or severe scratch in the fiber cladding. This feature was not seen in the interferometer photograph and is considered to be an artifact of the original polish, or a condition that might have evolved during thermal conditioning.

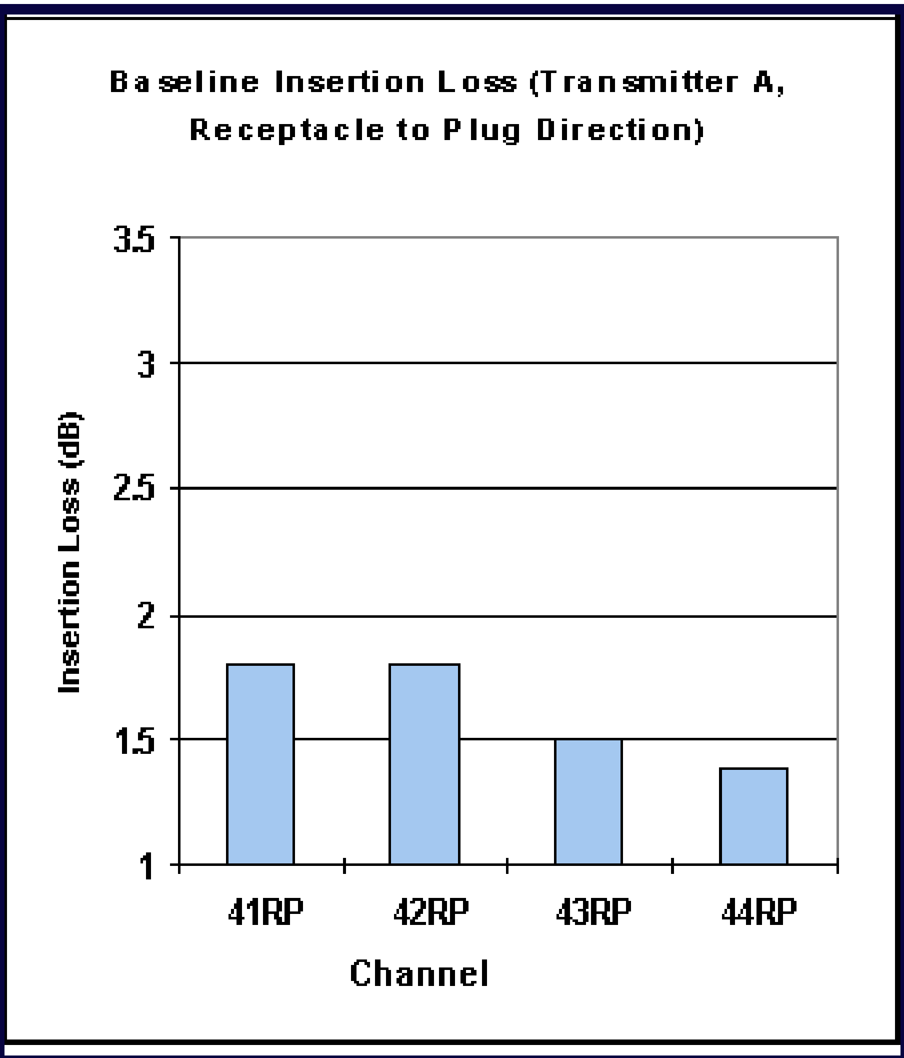
At this point in the evaluation, one cable was found broken inside the rear barrel of an SMA connector. This was attributed to insufficient capture of the cable jacket under the barrel that may have caused excessive mechanical strain to the fiber inside the SMA connector. This cable was replaced and subjected to thermal conditioning as described above. An inventory of the features found during the initial visual examination is given in Table III of Appendix A.

5.2.2 Optical Baseline Measurements (Post Thermal Soak Insertion Loss)

Over 380 measurements were taken to baseline the optical throughput for each channel, in each direction, using the sources and equipment that would be used in the vibration test. These measurements were derived from mV values read on a digital oscilloscope (using a optical to electrical converter) and were also taken directly from the display of a hand-held optical power meter (in dBm - dB referenced to mW)2.

The measurement repeatability during these tests was generally between 0 and 0.3 dB, although it varied up to 1.5 dB at times3. The "hands-on" experience showed that measurement repeatability was greatly affected by the compatibility between the threaded coupling mechanisms of the SMA connectors and the link hardware such as the connector adapters on the transceiver and on the optical-to-electrical (O/E) converter. The measurement variability associated with the connector on the O/E converter was insignificant while the connectors on the transceiver caused as much as 1.5 dB variability. The connector often became "locked" in position at some distance from the transmitter (even with the use of the 4 lb torque wrench) and could be re-mated to a position much closer to the transmitter. This aspect of connector loss seemed to be much more significant than the variability attributable to the lack of connector keying (consistent radial position with respect to the transmitter).

Figure 5



The term throughput is used when no launch cable was used in the measurement (units in dBm), as opposed to insertion loss which incorporates a launch cable and is recorded in dB. Some of the lack of repeatability of the data was due to the single fiber SMA connectors used on each of the free ends of the evaluation cable channels. The SMA connector design is non-keyed and incorporates a threaded coupling nut that can cause variation in the mate condition, in air gap width and termini radial alignment, each time the connector is mated.

The baseline insertion loss data is shown in table form in Appendix A. A graph of the insertion loss (using transmitter A, going in the receptacle to plug direction for each of the four channels) is shown in Figure 5. The data shows that the assembly provides a total insertion loss that is within the limits specified for the SMA connectors and M29504 termini combined (< 3.5 dB), for each of the four channels. The very short length of the cable contributes negligible loss to the link.

Table of Contents

Next Section

Up to TVA Homepage

Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

5.3 Thermal Cycling Test

A moderately stressful thermal cycling test was run over a four day period to further condition the cable before the vibration test and to screen out infant mortality failures and marginal devices. The optical throughput was monitored every 15 minutes during the cycling, for channel 42 in the receptacle to plug direction. This channel was selected because its large number of mating surface features indicated that it was the most likely to degrade during the test. Six times over the duration of the test, the throughput was measured for each of the three remaining channels.

The test data showed that for channel 42, the optical power transmitted did not decrease by more than 0.2 dB during periods of uninterrupted measurement. Channel 41 and 44 did not show any indication of degradation due to the temperature cycling test. The deltas calculated during and after the test indicate that the throughput remained within the established envelope of variation due to repeatability.

Channel 43 was the only channel that consistently showed increased attenuation during this test. Review of the data taken for this channel throughout the evaluation indicates that the pre-thermal cycling test insertion loss value was abnormally low and was probably due to a better than average mating condition for the SMA connectors. A more repeatable value would have been about 0.5 dB higher. Given this adjustment, the variation for channel 43 was within the repeatability envelope established during baselining. Figure 6 shows initial optical throughput and post-thermal cycling throughput for the four channels. The -7.95 dBm value corresponds to the transmitter output and -11.5 dBm corresponds to the upper limit of the cable assembly's performance rating.

5.3.1 Post Thermal Cycling Visual Inspection

Following thermal cycling, the termini were removed from the "453" connector, examined at 255X to 1000X and photographed. The visual inspection showed a significant number of new surface features in the fiber end faces, mainly on the pin side of the connection. In general, the number and size of rough spots seemed to increase. Some new crescent shaped scratches were found on some termini at the outer edge of the cladding. Table 4 gives a listing of these observations.

The termini were reinserted into the connector halves after the visual examination and it was noted that a significant amount of debris was created due to the degradation of the grommet material by the insertion/removal tool. Later examination of the connector halves also showed

Figure 6

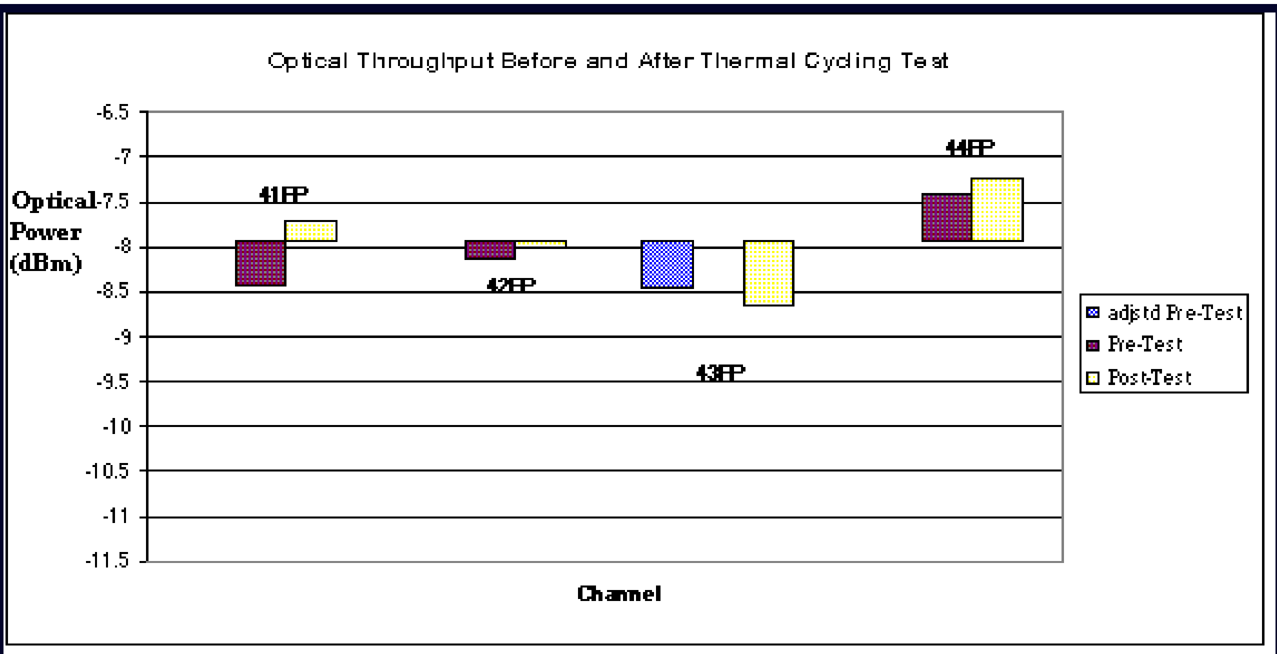


Table 4. Results of Post Thermal Cycling Visual Examination

Terminus	Description of New Features
41R (pin)	Two new rough spots at center Large scratches near radius center and near a rough spot that increased in size
41P (socket)	Several rough spots, no significant change in features present
42R (pin)	Increased number of rough spots Rough spot at crack/scratch site much larger Some lines around large crack/scratch may be micro-cracks, also one near the center.
42P (socket)	Three new large rough spots Pre-existing smaller rough spots grew in size.
43R (pin)	Increased number of rough spots especially at cladding outer diameter (OD) Scratch emanating from cladding OD
43P	No increase in feature number or size

(socket)	
44R (pin)	Increase in number of rough spots Two new scratches, one emanating from new edge chip Two large straight scratches may be new
44P (socket)	Some increase in rough spot size No significant new features

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that the insert material was breaking away and metal filings were being left behind after de-coupling the connectors and after removing the backshells (Figure 7).

Additional examinations were made of the termini mating faces including the use of the scanning electron microscope (SEM) to try to obtain evidence of origins of the rough spots that were not seen when using the optical microscopes. The SEM photographs in Figure 8 show evidence of a rough fiber surface (at 1300X). The three V shaped features can be seen on the optical microscope photograph as rough spots while equally prominent features that can be seen on the SEM photograph cannot be readily identified on the optical microscope image. This indicates that

Figure 7. Metal Filings and Insert Debris on Connector Grommet

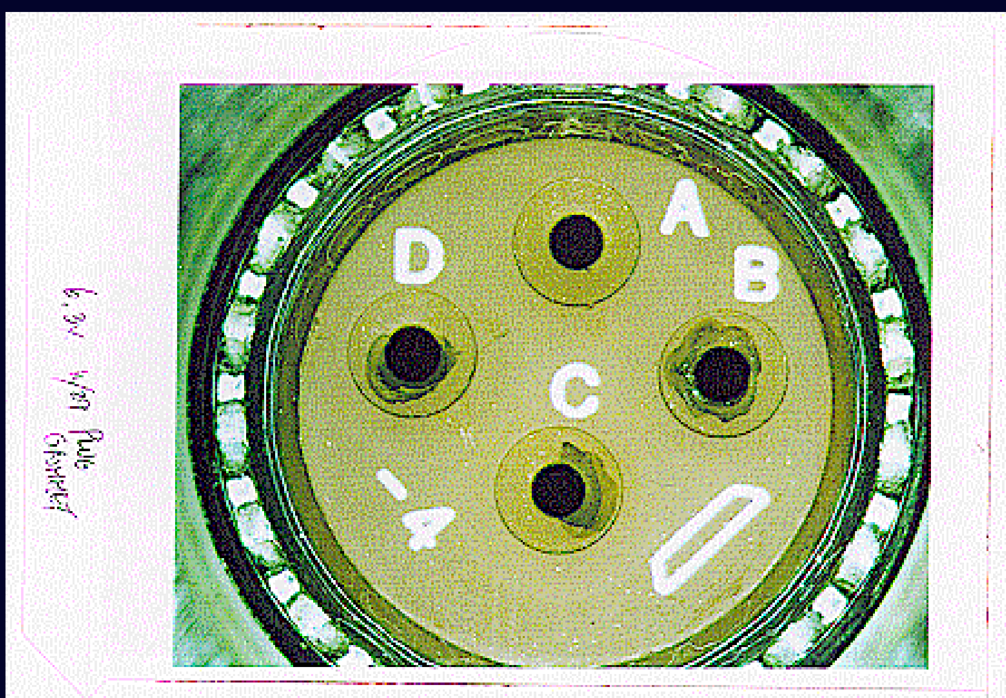
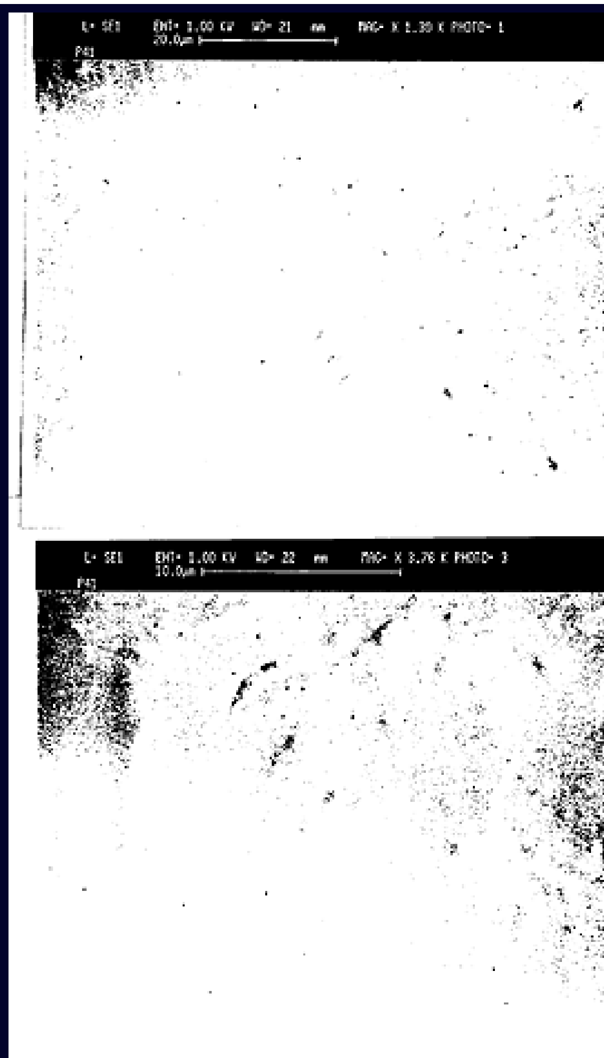


Figure 8. SEM Photograph Showing Existing Surface



Roughness Not Seen in Optical Microscope Photograph

the increase in number of rough spots could be that they are simply growing in size due to environmental conditions, including abrasion between the two glass faces during mating, to a size that is discernable by the microscope.

Another possible source of the increased feature size and new scratches could have been from abrasion by glass particles that were liberated from rough areas at the cladding outer diameter. The shapes and locations of the new scratches support this possibility.

The number and size of the features on the pin termini tended to increase while those on the socket half did not. This may be because the pins are more exposed to abrasion during insertion and removal from the connector than the sockets, the socket face being protected by the alignment sleeve.

Table of Contents

Next Section

Webster: Melanie.Ott@gsfc.nasa.gov

5.4 The First Vibration Test - Thick Bracket

A standard test method qualifying high reliability connectors was used to evaluate the connector's vibration performance. This consisted of a set-up that monitored optical throughput during a random vibration profile which provided 18.79 Grms from 20 to 2000 Hz for six minutes in each of three axes (Figure 9, x-axis was the most dynamic for the mounting bracket used). A bracket made of machined aluminum was configured to provide a fixture that was as "quiet" as possible with respect to its own vibration characteristics. The original bracket proposed in the test plan was found to be highly resonant within the test frequency range and so was not used to establish the qualification data. It was used in a subsequent vibration test described below as supplemental testing. Both brackets are shown in Figure 10.

Figure 9. Random Vibration Profile for First Test (X-Axis)

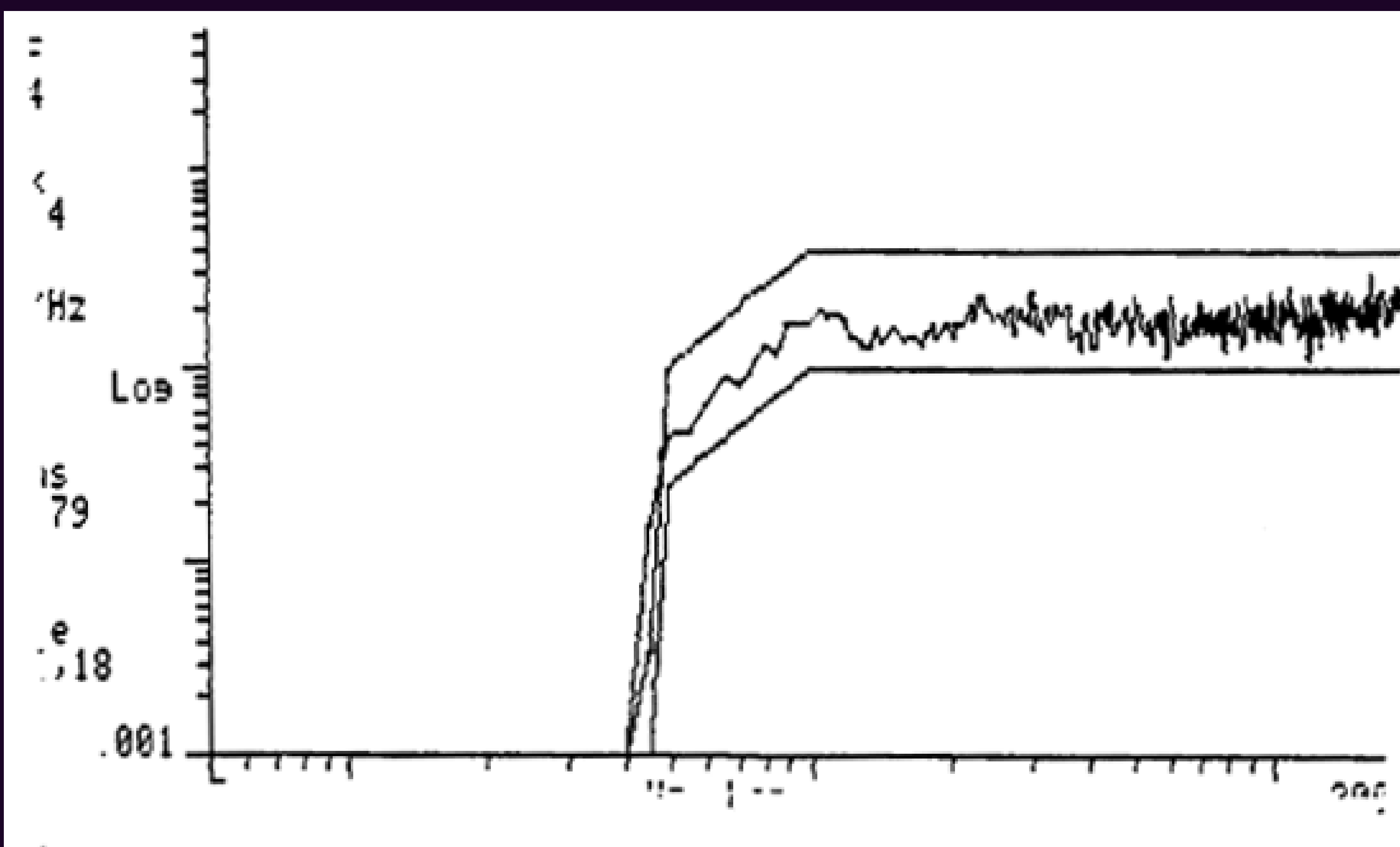
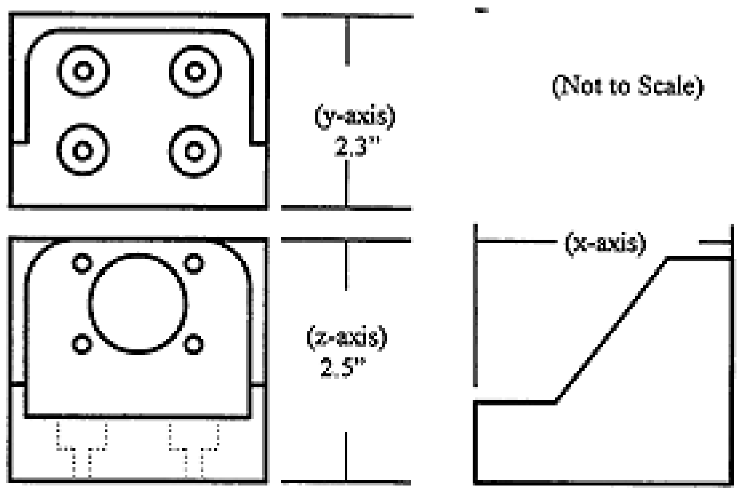
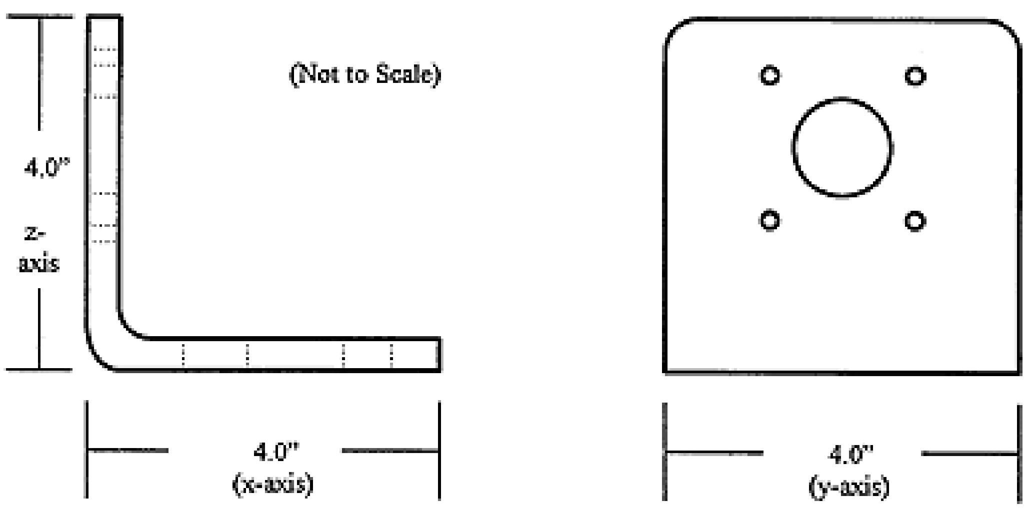


Figure 10. Brackets Used for First and Second Vibration Tests

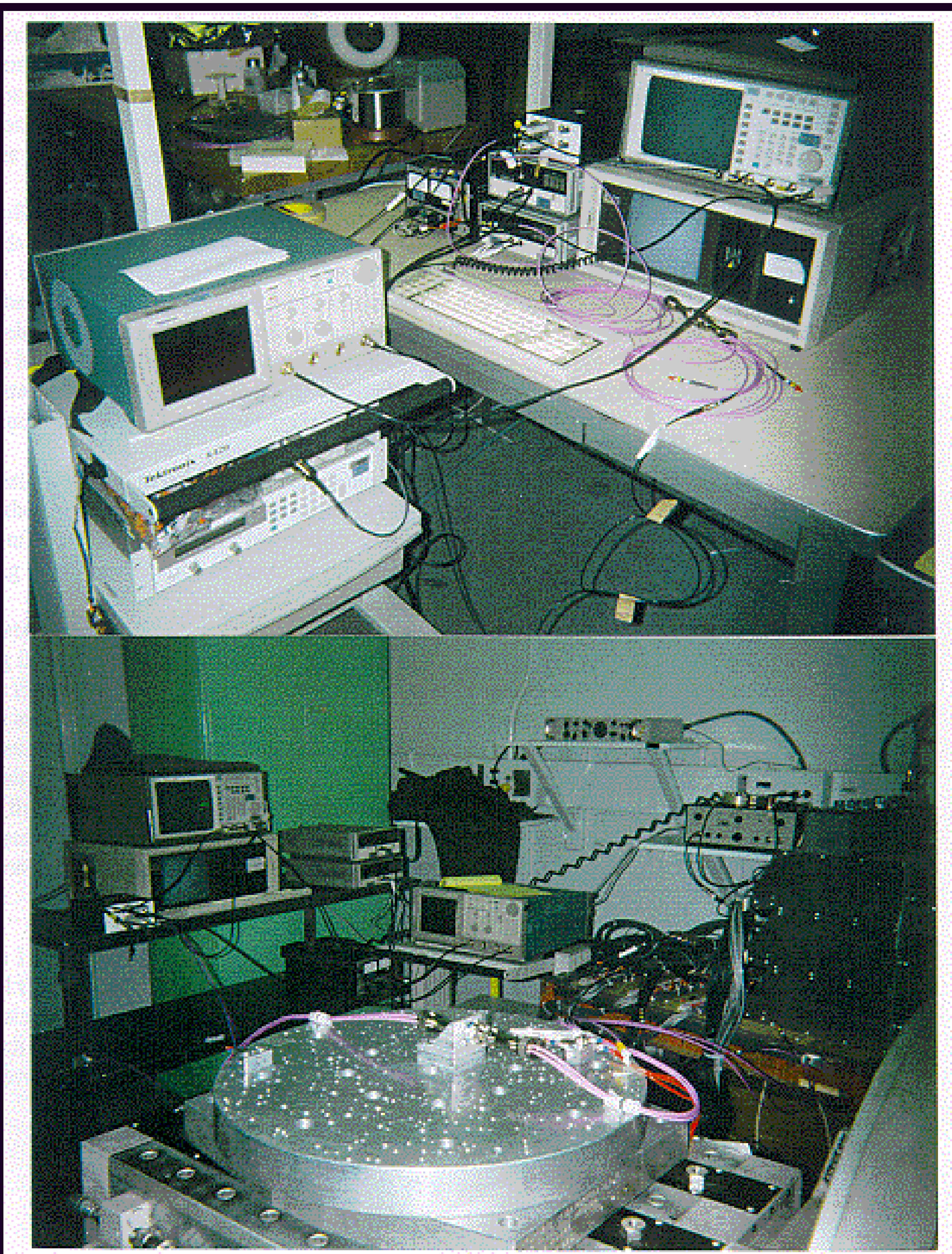


Bracket A - Used for the First Vibration Test



Bracket B - Used for the Second Vibration Test

Figure 11. Vibration Test Set-Up



The optical signal was reduced to 8W (-20.969 dBm), using an optical attenuator, to simulate a signal similar in amplitude to that expected for the actual MIL-STD-1773 application. Optical monitoring was accomplished through the use of optical to electrical converters and a Hewlett Packard 54501A digital oscilloscope driven by external software. Two optical channels were monitored during each test run. To get data for all four channels in the x-direction, the x-axis test was run twice, once monitoring channels 41 and 42 and then monitoring channels 43 and 44. A Tektronics TDS 544 digital oscilloscope was used to view the signal real-time and operated in storage mode to save throughput deviations (in mV) over the duration of the test run.

The software monitored the oscilloscope, changing from one channel to the other every five seconds. A trigger was set at a mV level equal to a 0.45 dB reduction in optical signal. When a trigger event occurred, the program would capture the Vmin value from the oscilloscope, tag it with the corresponding channel number and dump it to a data file. It would then switch to the other channel and wait for a similar trigger event. If no event occurred, the program would switch to the next channel after five seconds. At the end of every test, a false trigger event was simulated on each of the channels to verify that the program and scope were still working as intended. The vibration test set-up is shown in Figure 11.

The tests were run in an order which minimized the effects of re-mating the SMA connectors. After the connector was mounted to the bracket, it was torque striped at every coupling ring on the connector and backshell. Inspection after the test did not show any break in the torque striping or other evidence of backing-off on any of the coupling mechanisms.

The data taken for this test is given in appendix A. The only trigger events that occurred during testing using the thick bracket were on channel 41 during the first x-axis exposure. Figure 12 shows the optical throughput before the X1 test for channel 41PR, the approximate throughput values at the time of the trigger events and the throughput measured for the channel at the end of the 6 minute test. This data shows that the channel fully recovered after the trigger events while increasing in loss by as much as 1.2 dB during the events. The lack of trigger events for the rest of the five remaining axis runs and the lack of contamination on channel 41 pin and socket suggests that channel 41 physically settled into a stable alignment position due to the application of vibration and that the discontinuities observed in Figure 12 do not necessarily indicate part failure.

Figure 13 shows that after each of the six vibration tests, there were no significant decreases in optical throughput. The data is plotted, pre-test value with post-test value, in the order the channels were tested. Again, to reduce SMA repeatability effects, measurements were not taken for each channel after each axis run, but only for those runs for which they were actively monitored.

Figure 12

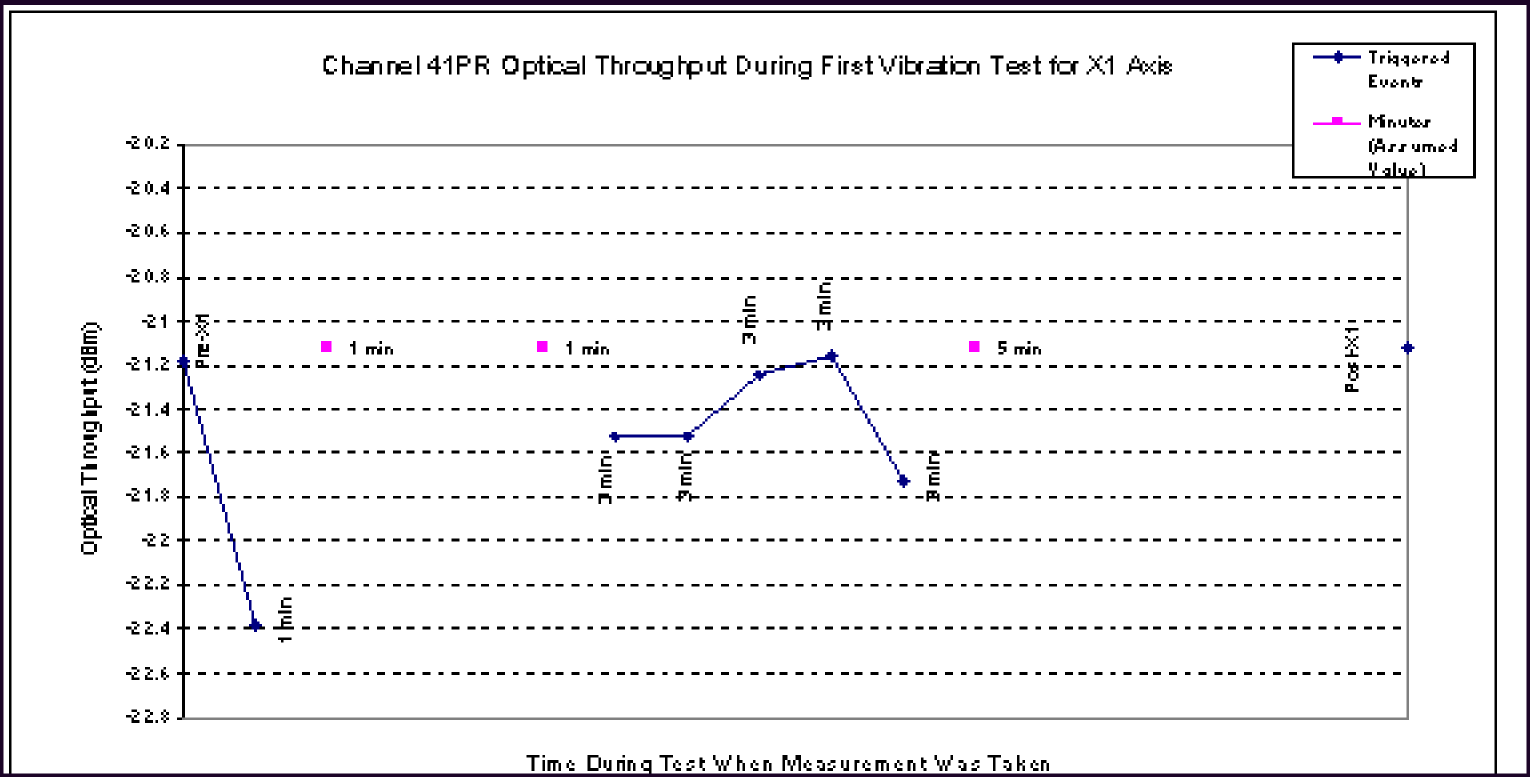
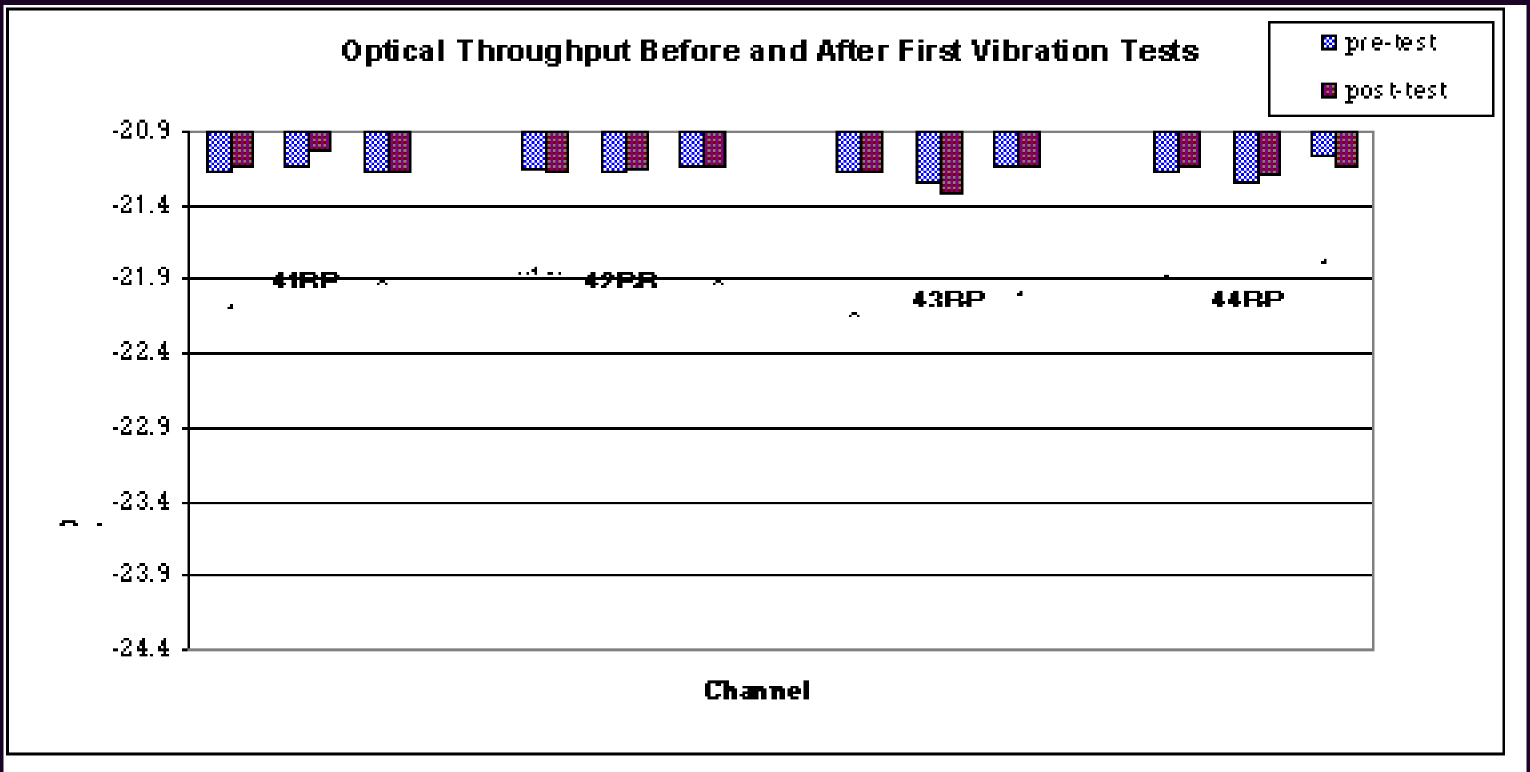


Figure 13



The second part of the vibration test was designed to determine whether the SMA connector ferrules would crush the active device lenses during vibration. The test results showed that the SMA connector ferrules did not affect the active device lenses and that no significant change occurred in throughput for the test cable. Figures 14 and 15 show that one of the two active devices subjected to the mated condition, did exhibit evidence of scratches on the metal package, but not on the glass.

Figure 14. Transmitter B Before Vibration Test

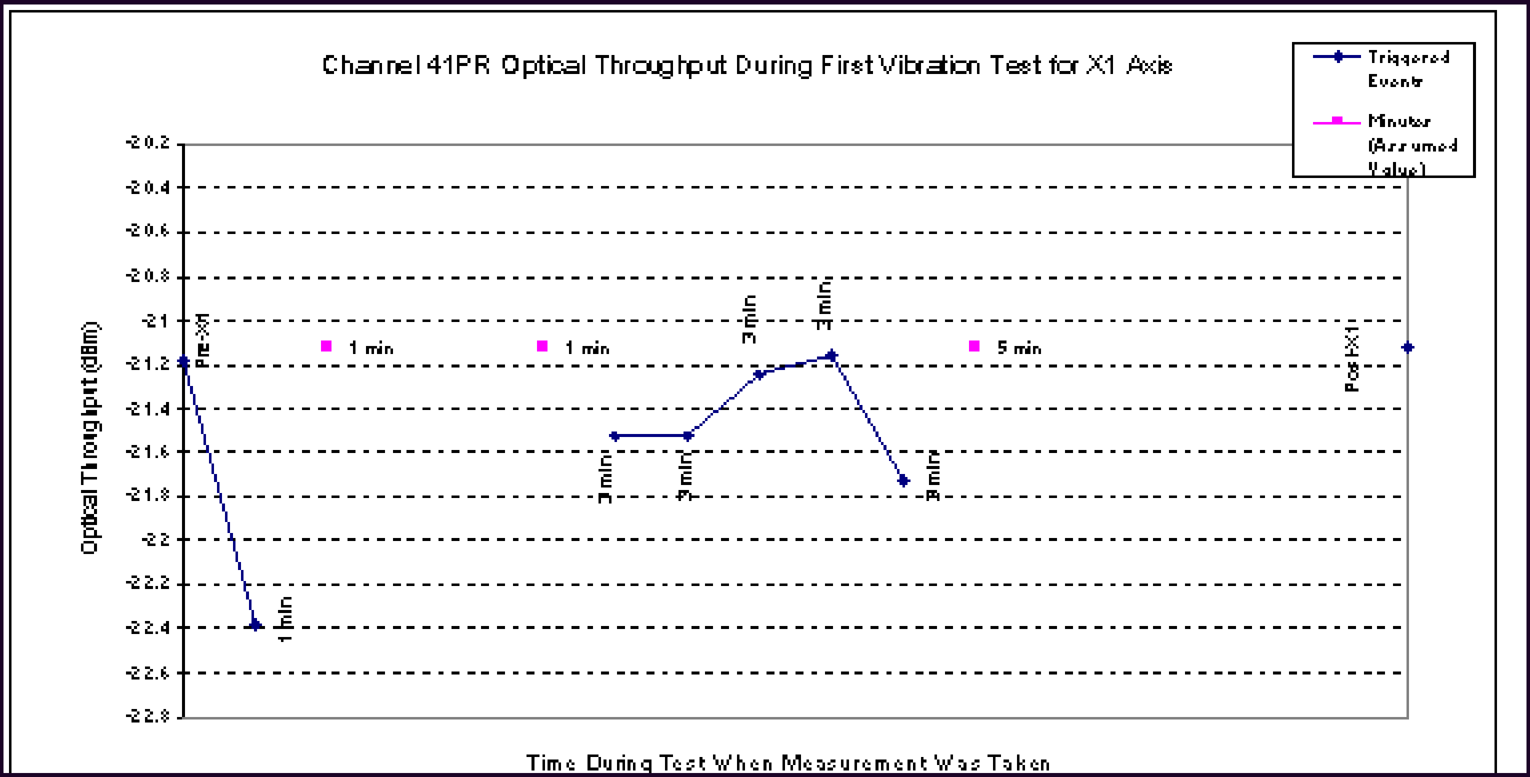


Figure 15. Transmitter B After Vibration Test

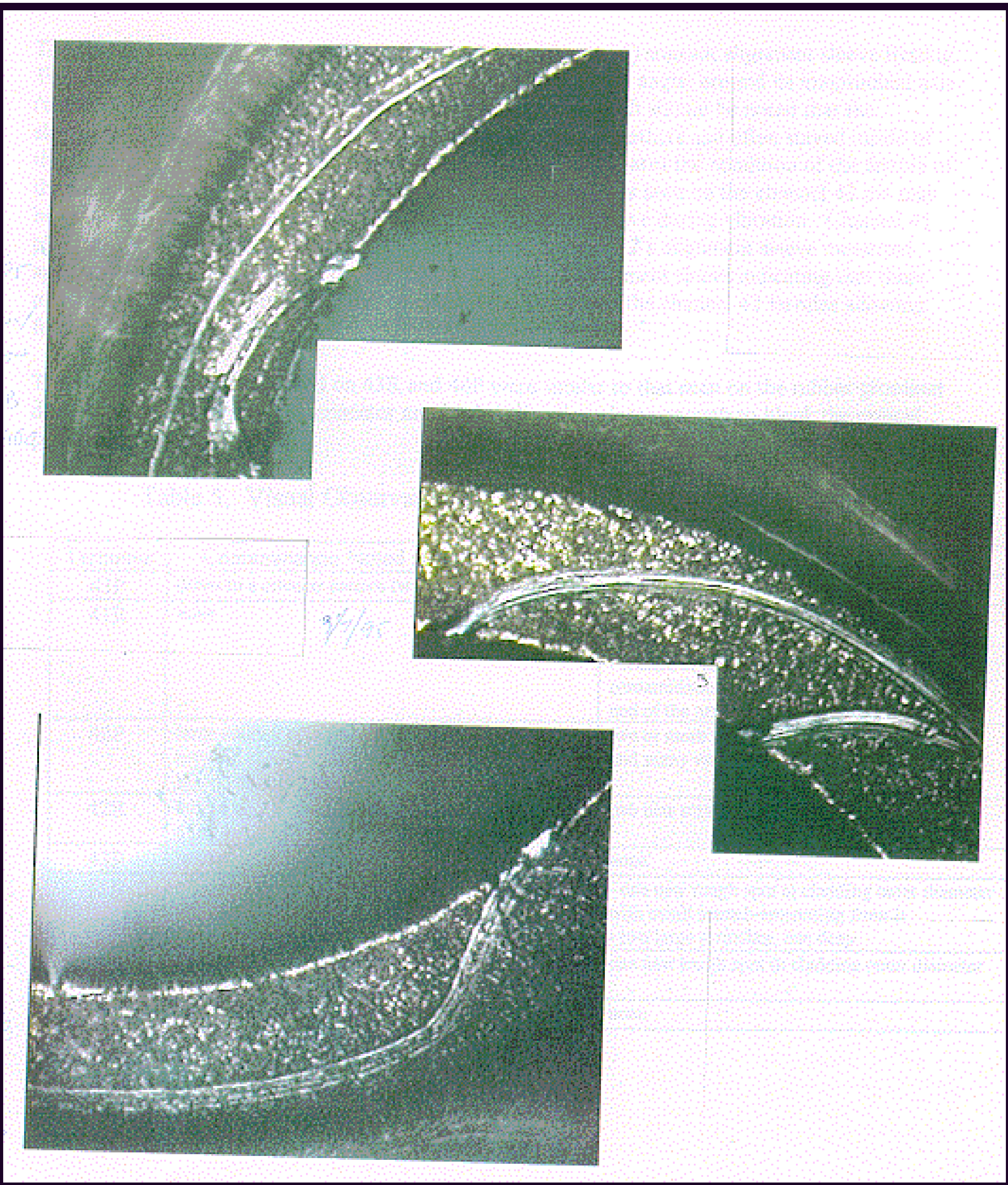


Table of Contents

Next Section

Up to TVA Homepage

Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

5.4.1 Visual Examination Following the First Vibration Test

Following the vibration test using the thick bracket, the termini were removed and photographed before and after cleaning. Table 5 summarizes the observations following the first vibration test.

The size and shape of the metal filings found on 42P (Figure 16) suggest alignment sleeve fretting. This fretting occurs when the terminus revolves at some minute angle, around its longitudinal axis (without rotation) abrading the inside of the alignment sleeve. It should be noted that the alignment sleeve for channel 42 was noticeably looser than the others and often stayed inside of the connector when the termini was extracted. Figure 17 compares the condition of the ferrule of the pin for channel 42 and the pin for channel 41. The scratches seen on the channel 42 pin may be indicative of that circular motion inside of the alignment sleeve during vibration. Channel 41 pin does not show these scratches. The slot width of channel 42's alignment sleeve measured approximately 19% larger than the slot on the channel 41 alignment sleeve indicating that there may have been less of a retaining force between the sleeve and the channel 42 ferrules allowing ferrule movement.

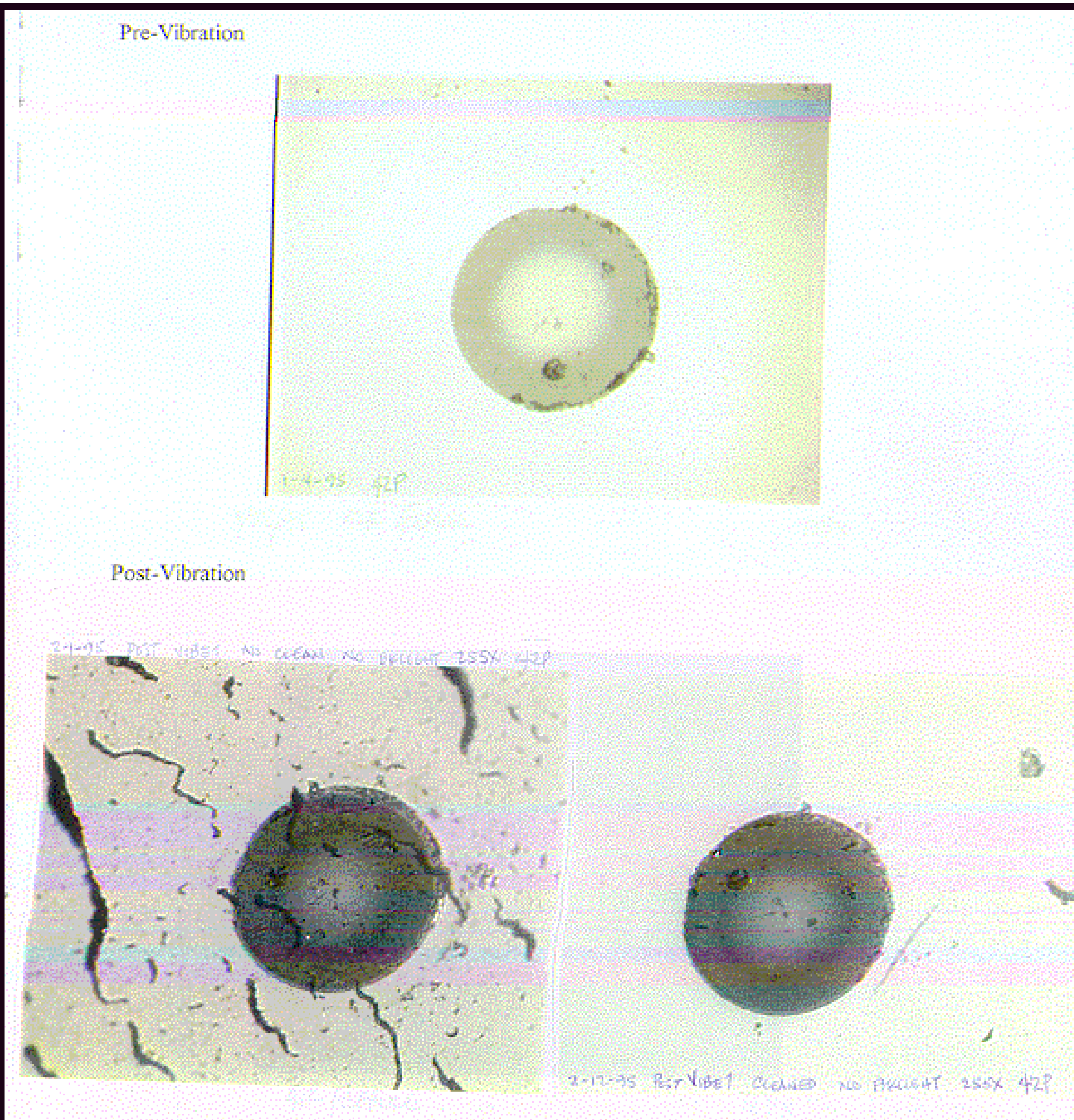
The metal contamination found on 43R and 44P were similar to that seen on the rubber grommet due to abrasion between the connector and backshell and are large enough to block the optical path.

Table 5. Visual Observations Following the First Vibration Test

Terminus	Contamination Noted Before Cleaning	New Features Found After Cleaning
41P	drops in a circular pattern (water vapor)	none
41R	none	- scratch similar in appearance to existing scratches - feature at cladding outer diameter may be contamination or a rough spot, located at one end of the new scratch
42P	large amount of **metal filings** of sizes ranging between approximately	two or more new rough areas in the fiber core and many very small

	200 m x 4 m to specks less than 1 m square.	rough spots
42R	large amount of small **metal pieces** in the range of 4 m square, most much smaller	two new scratches
43P	several drops (water vapor)	none
43R	- large **metal pieces** found on the ceramic ferrule (50 m x 100 m) on fiber core. - a few drops (water vapor)	- one new rough spot at cladding outer diameter with small scratch emanating from it - two large scratches, one deep
44P	- one large **metal piece** on ferrule (20 m square) - drops in circular pattern (water vapor)	one new rough spot in cladding outer diameter
44R	pre-existing alcohol residue	none

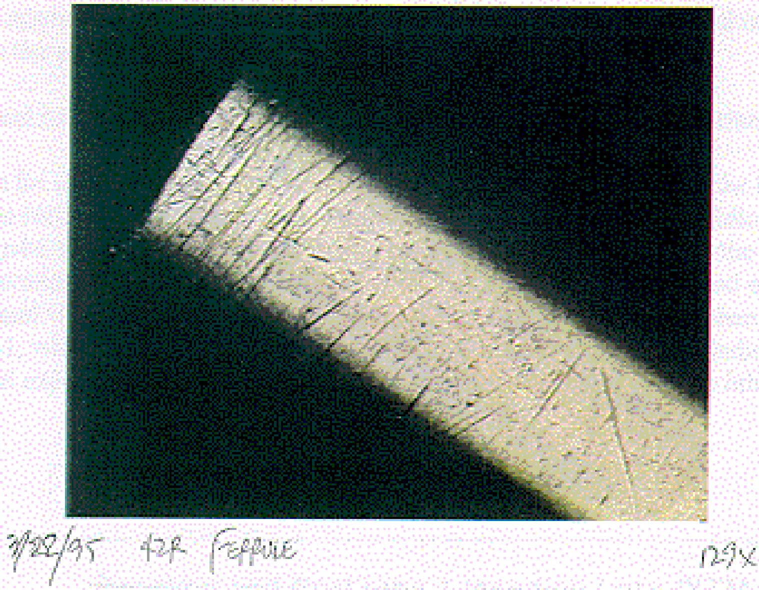
Figure 16. Pre- and Post Vibration Visual Examination (255X) 42P

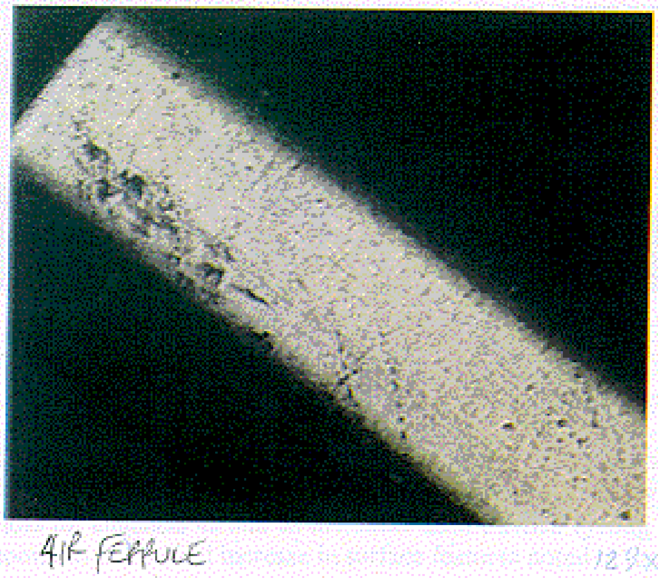


Pre-Vibration

Post-Vibration

Figure 17. Ceramic Ferrules of 42R and 41R After Vibration Testing





Following the visual examination, the termini shrink tubing was re-worked. The original shrink tubing had lost its ability to adequately support many of the termini. This degradation was due to the large number of times the termini had been inserted and removed. Following reinsertion of the termini into the connector, an optical time domain reflectometer measurement was taken for each channel. The results showed that all four were making physical contact when the connector was fully mated. A small reflection was found approximately 8 inches from the end of the SMA connector on the plug side of channel 44.

Table of Contents

Next Section

Up to TVA Homepage

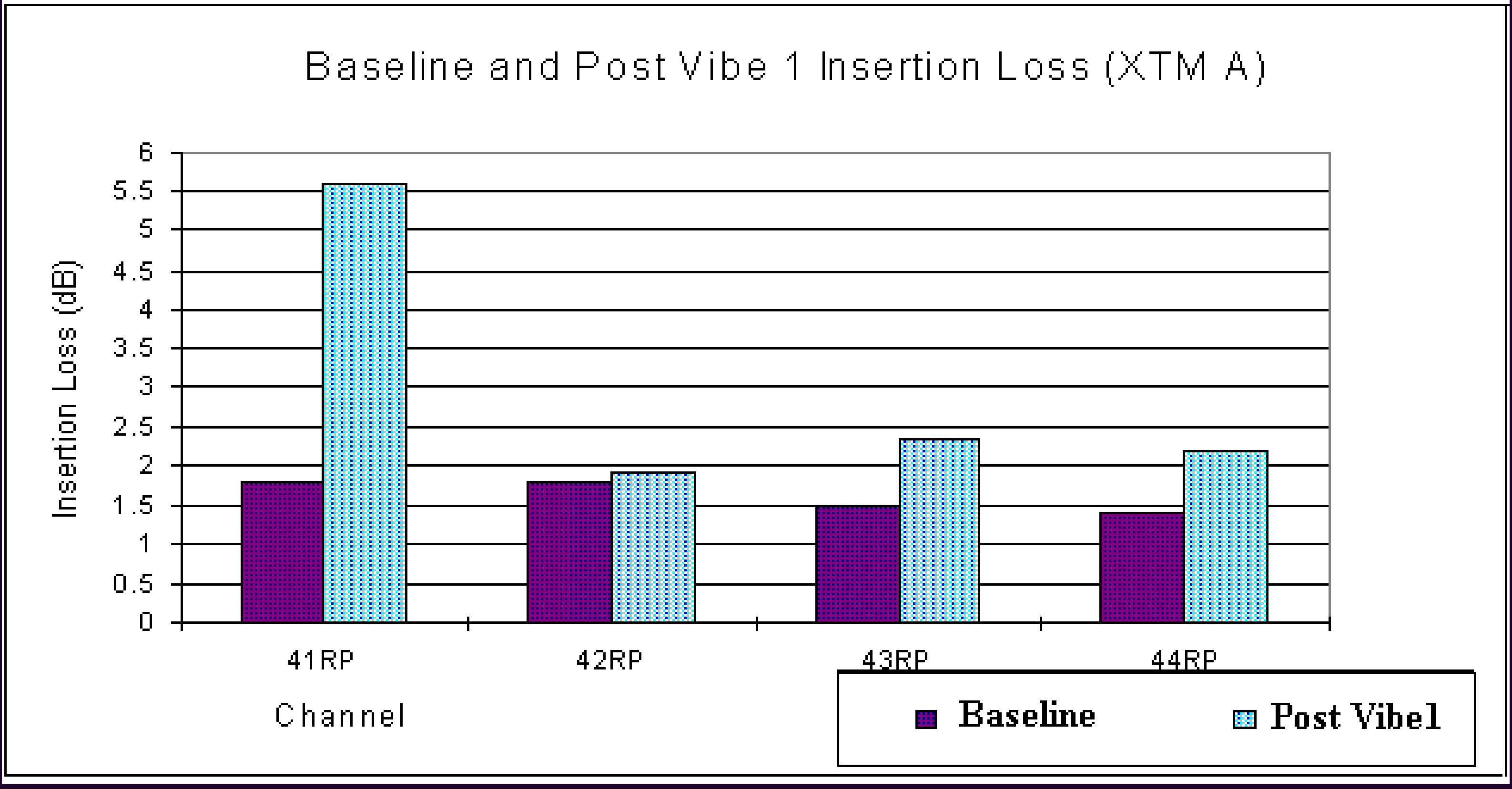
Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

5.4.2 Optical Measurements Following the First Vibration Test (Vibration 1)

Insertion loss for the evaluation cable is shown in Figure 18 which compares the baseline value with the value recorded after the termini were reinserted into the connector, following post-vibration visual examinations and shrink tubing rework. This data represents the combined effects of repeated termini insertion and removal, handling, SMA non-repeatability and exposure to the temperature and vibration environments on channel loss stability. The large change in loss shown for channel 41, which was not seen immediately following the vibration test, indicates that the environmental exposures probably had less affect on the channel loss than the other factors noted above.

Figure 18



Although channels 42 through 44 showed a change in insertion loss between 0.1 and 0.8 dB, they stayed well below the manufacturer's ratings of 3.5 dB maximum. A review of the data indicates that the insertion loss for channels 43 and 44 increased after thermal cycling by about 0.2 dB which may correspond to the overall increase in surface features noted at that time. The factors noted above such as repeatability, handling and changes in radial alignment between the terminus pairs may account for an additional portion of the 0.8 dB increase in insertion loss. It is interesting to note that even though the fiber end faces for both the pin and socket for channel 42 saw significant increase in surface features over the duration of the test, channel 42's optical data was the most stable throughout the testing.

Table of Contents

Next Section

Up to TVA Homepage

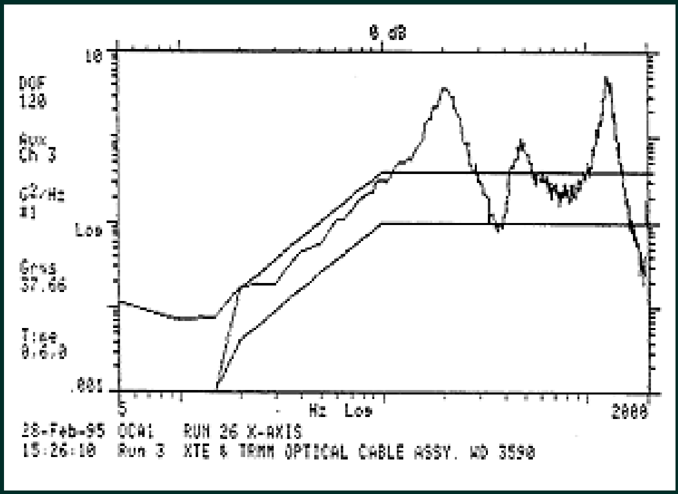
Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

5.5 Supplemental Testing: The Second Vibration Test Using the Thin Bracket

The second vibration test was run to see if any catastrophic failures would occur due to a less than stable mounting bracket. It was run in exactly the same way as the first test except that the original bracket, described in the test plan (Figure 10), was used. Figure 19 shows the vibration profile extended to the bracket when using the same test conditions as those used in the first vibration test. The resonant peaks and resulting increase in total force extended to the connector resulted from the physical design of the bracket; namely the thin sides, the height and the lack of side support. The total force of this test was 37.66 Grms.

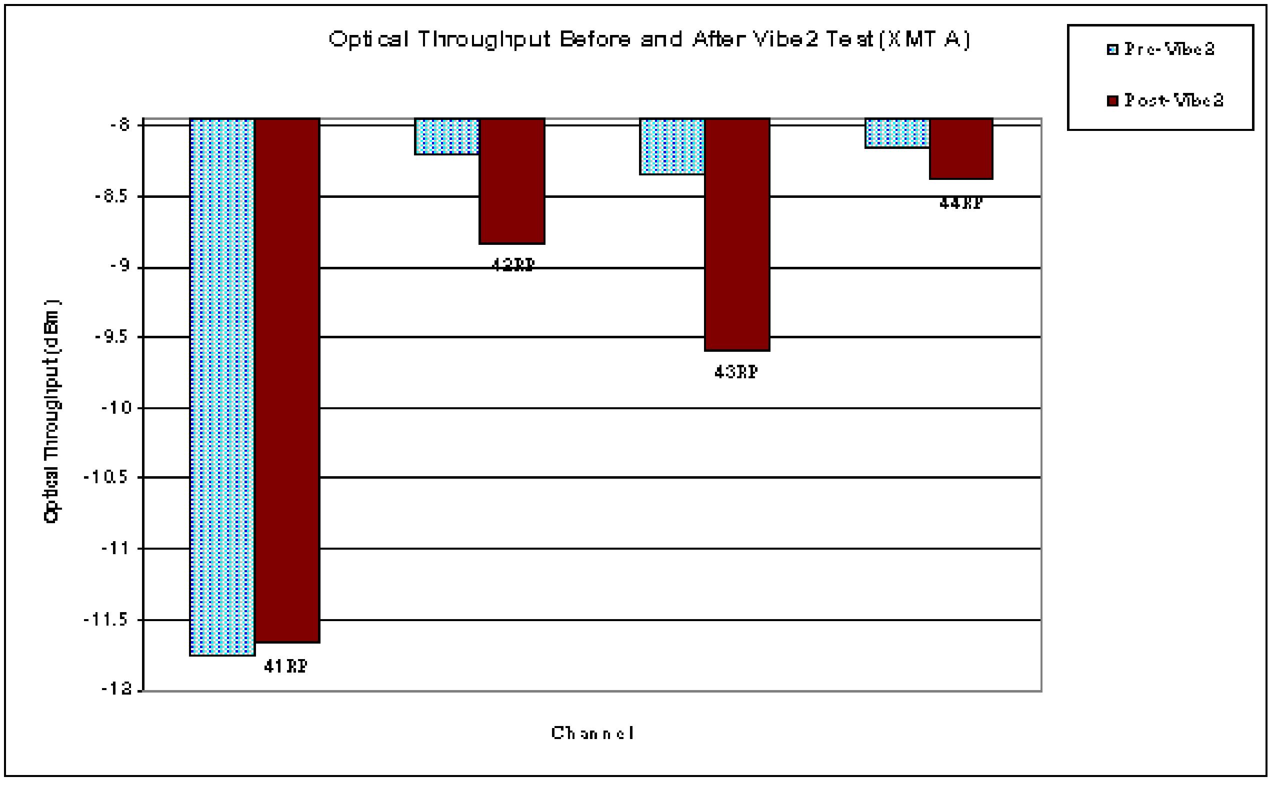
Figure 19. Vibration Profile for the Thin Bracket



No trigger events were found during the first five runs (X1, X2, Y1, Y2, Z1). During the last z-axis test (Z2), several trigger events (momentary loss in excess of 0.5 dB) occurred for channel 43 during the first minute of the six minute test. Data for the second vibration test is provide in appendix A. No backing-off from the connector or backshell was noted and there was no disruption to the torque striping.

Figure 20 compares optical power throughput measurements taken before and after the second vibration test (-11.5 dBm represents the maximum loss rating and -7.95 dBm the launch power). Channel 43 experienced the most degradation (1.2 dB) due to the second vibration test. Figure 20 data was taken before the termini were visually examined and cleaned.

Figure 20



5.5.1 Visual Examination Following the Second Vibration Test

After the second vibration test, the termini were removed and photographed at 255X magnification before and after cleaning. Table 6 lists the results of visual observations incuding contamination found before the termini were cleaned compared to the post Vibration (1) photographs.

Although some contamination was observed on most of the fiber end faces, the amount and particle sizes were significantly smaller than noted after the first vibration test. With the exception of the rough spots noted on the channel 42 pin and socket, no new features evolved. No large contamination or defect was found on either the pin or socket of channel 43 that could explain the trigger events noted during the last vibration run or the increase in loss (1.2 dB) measured after the test.

Table 6. Visual Observations Following the Second Vibration Test

Terminus	Contamination Noted Before Cleaning	New Features Found After Cleaning
41P	none	none
41R	residue smear (material unknown)	four large scratches
42P	very small amount of particulate	large

	contamination (may be metal)	rough area at cladding/core interface (half the total core size)
42R	large amount of small **metal** **particles** in the range of 4 m square, most much smaller	large rough area at cladding/core interface (half the total core size)
43P	very small particles (may be metal)	none
43R	residue smear (material unknown)	none
44P	small amount of smear material	none
44R	very small particles (may be metal)	none

The rough spots described for the channel 42 fiber end faces are interesting in that they are very different than the dark rough spots noted on the end faces throughout the evaluation and are much larger. They do not appear to have depth like all of the other rough spot features but possess the texture of small cracks or scratches. More analysis is required to identify the exact nature and cause of all the rough spots, scratches and other unidentifiable features.

Table of Contents

Next Section

Up to TVA Homepage

Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

6.0 Conclusions

The evaluation showed that this fiber optic connector system, when subjected to 18 Grms of random vibration, will not suffer a catastrophic failure. It should be noted that a substantial amount of metal contamination evolved on the termini which had the loosest alignment sleeve. Similar contamination was not found on the three remaining termini pairs. This suggests that there should be a limit set for the "insertion force" or "retention force" of the alignment sleeve with each of the mating termini. A measurement of the retention force of the alignment sleeves on the three unaffected termini pairs would give a indication of an acceptable value.

Another source of large sized contamination seemed be the backshell where debris freely moved to the mating area during termini insertion or due to handling. This contamination debris- metal flakes and ground pieces of grommet and insert material - must be removed. Attempts to remove the visible material (on the outer surfaces of the connector) were not very successful. This indicates that some type of cleaning procedure should be developed for use with these connectors (when using optical termini), especially after the termini have been inserted. Improvement of the insertion and removal mechanisms, the tools, internal retention mechanism or termini clearance space inside the connector, would likely reduce the occurrence of the organic debris.

The termini with the most rough cladding outer diameter seemed to degrade the most significantly with respect to surface scratches and the number and size of rough spots.. The terminus side not protected by the alignment sleeve during insertion into the connector, tended to show a greater increase in surface features though some of the termini pairs (both halves) did not change at all. This suggests that polishes (or coating removal) which leave rough edges will most likely degrade with handling.

Although surface defects in the glass fiber should be avoided for long term reliability, the results of this evaluation did not link their presence with short term degredation in optical performance. The mild thermal preconditioning enabled at least one defect to grow into a crack. More rigorous conditioning performed on the cables may produce more cracks.

Both vibration tests showed that this connector system is capable of withstanding as much as 37 Grms without failing. The change in optical loss ranged between none and 1dB (generally the specification limit).

Table of Contents

Next Section

Up to TVA Homepage

Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

7.0 Recommendations

It is recommended that this part, the "453" connector and M29504 termini, should continue to be listed in the GSFC PPL for use in applications where the thermal excursions are generally mild with respect to the temperature rating of the optical cable. This connector system should be adequate for vibration environment below 37 Grms, provided the alignment sleeves meet a minimum retention force with the termini ferrules. This force should be quantified. It is important to understand how the connector will be mounted and any additional force that will be extended to the connector during vibration as a result of the mounting configuration.

It is extremely important to understand sources of contamination that may interfere with the light path and physical mate of the termini. Contamination that is sufficiently large or sufficiently prevalent can cause temporary signal loss. Therefore, adequate cleaning techniques must be used to remove the contaminating material from the connector. This is difficult given the configuration of the socket contacts in particular. Further, the materials on the rear of the connector (resilient grommet and epoxy) seem to retain particulate contamination, such as metal shavings, which makes it difficult to keep the connector clean.

The goal with PC polish is to provide a fiber end that is convex and as free as possible of surface discontinuities. The termini pairs tested here had a range of polish qualities from good to poor, though none showed a degradation in optical performance that could be directly associated with the fiber end face surface. Some of the photographs suggest that large cladding edge chips can grow in size with multiple matings and thereby free glass particles that can pit or scratch the glass surface. A reliability analysis should be performed to better quantify the relationship between the types and characteristics of the surface features observed here and the long term connector optical performance. A life test utilizing thermal and tensile stress on the cable could be used in an attempt to determine time to failure for termini with significant defects.

The connector insert and grommet was significantly degraded during this evaluation. This degradation may be due to a combination of terminus insert/removal cycling, the build up of epoxy and shrink tubing on the terminus (preventing proper operation of the removal tool) or an ineffective insert/removal tool. Although the degradation of the grommet and insert did not seem to affect the optical performance of the connector, it did contribute greatly to the contamination situation. All efforts should be made to greatly reduce the insert/removal cycles when using optical termini in this connector and to be aware of the limitations this problem extends to the termination process (choice of materials and other limitations on the amount of material used at the termini rear barrel).

Table of Contents

Next Section

Up to TVA Homepage

Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

8.0 Acknowledgments

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Table of Contents

Next Section

Up to TVA Homepage

Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

Appendix A

Table of Contents

Up to TVA Homepage

Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

TABLE I. Part Ratings

Part Type	Part Number	Operating Temp Range (C)	Insertion Loss (dB) at 850 nm	Change in IL due to low temp (or temp cycle)	Vibration Level	Minimum Bend Radius	Coupling Torque (in-lb)
SMA Connector	Amp FSMA 905	-65 to +85	1.49	-	20 Gs sine	-	4
Termini	M29504/04-4050 (and -4044)	-65 to +150	2.0	mechanical criteria only	15 Gs sine	-	-
Multi-Termini Connector	Amphenol Bendix/TVS06RF-13-4P(453) and receptacle half	-65 to +200	1.5	-	60 Gs sine, 41 Gs Random	-	16
Backshell w/Strain Relief saddle clamp: auxiliary grommet:	620HS011M13 377HS025M136G-186 (3") and 377HS025M134G-186 (2")	-65 to 200	-	-	60 Gs sine, 41 Gs random	-	-
Cable	Brand-Rex/OC-1008	-55 to +85	10 dB/km	-	-	2 in	-
Epoxy	Tra-Con BA-F253 BIPAX	-60 to +175	-	-	-	-	-
Shrink Tubing	FIT-130-1/8 Mylar (Alpha Wire Corp)		-	-	-	-	-

Table of Contents

Index of Appendix A

Up to TVA Homepage

Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

Test Method for Insertion Loss/Optical Throughput:

Remove all equipment dust caps and dry wipe lenses (very gently). Dry wipe all connector terminations at least once before making measurements. Verify unusual measurements by re-wiping terminations and lenses. Dry wipe all dust caps before replacing them on the connectors or optical equipment.

Each segment of the launch cables should be measured independently and then concatenated as it will be used during the vibration test. To determine the throughput, attach the cable, or link, of interest as shown below - between emitter source A (or B) and the O/E converter. The oscilloscope data is given in mV. Convert to dBm by dividing by 5, taking the log10 and multiplying by 10. Control measurements should be taken at the beginning of each measurement session using the D80-D90 control cable, the SMA-ST adapter cables (used on attenuator) and the evaluation channels without launch cables. A control measurement should also be taken for each evaluation channel by using the SMA-ST adapter cables as launch cables. Data should be taken with the attenuator set to zero. The attenuation setting should then be recorded for a 0.008mW throughput.

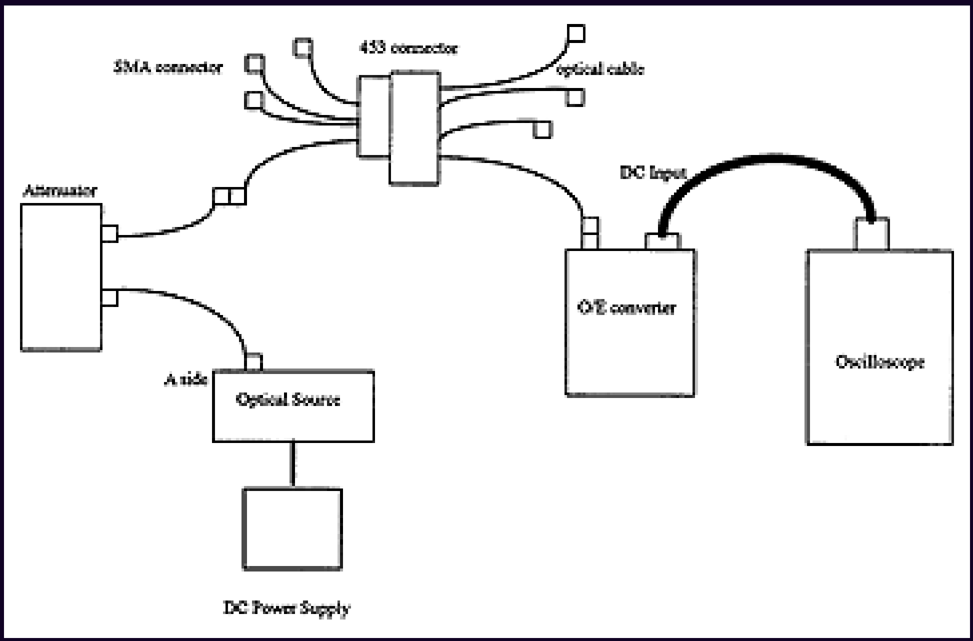

Table of Contents

Index of Appendix A

Up to TVA Homepage

Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

Table II. Interferometer Measurement Results

Terminus Type	Serial Number	Connector Half	Radius of Curvature (mm)	offset (microns)	Protrusion (microns)
	Requirement minimum		10	> 0	-
	Requirement maximum		20	0.2	35
socket	41	Plug	5.3	0.3	14
pin	41	Receptacle	9.3	0.08	40.8
socket	42	Plug	6.86	0.27	28
pin	42*	Receptacle	6.45	0.25	18.2
socket	43	Plug	4.1	0.27	35
pin	43	Receptacle	4.4	0.3	

33.6

socket	44	Plug	8.2	0.08	28
pin	44	Receptacle	16.5	0	8

---

* Data taken for hand polished terminus. See visual examination results in Appendix A.

Table of Contents

Index of Appendix A

Up to TVA Homepage

Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

Table III Initial Visual 400X

Type	SN	Conn Half	Features: chip in cladding OD 1	rough spots in cladding	rough spots in core	scratches	deep scratch or cracks	notes taken during visual exam 2
SMA	41	Plug	very small	1 med	-	-	-	small chip in OD 1:30, rough spot at 9:45
socket	41	Plug	2 - large	1 med, a few small	7 med, many small	-	-	trail of seven rough spots across center 2:30 to 8:30, one in cladding 10:30, two at OD 5:30 and 8:00, @40 smaller rough spots
pin	41	Recpt	rough edge	1 large, 3 med, numerous small	2 medium, numerous small	one	-	large rough spot at 6:30, med ones at 9:30, 11:30, 12:30, center 3:30, 5:30, polishing scratch center 5:30 to OD 10:00, >100 small rough spots
SMA	41	Recpt	-	-	-	several, 1 deep	-	polishing scratches, one deep at 7:30
SMA	42	Plug	-	2 med	-	several light	-	two very small nicks at 2:00 & 4:45, Med rough spots at 2:00, 9:30, light polishing scratches, dark spot at 10:00 is dirt

socket	42	Plug	rough edge	1 med	1 large	several light	-	large pit at 1:00 center, rough spots at OD, 11:00 - 2:30, large rough area at 11:00, small rough spot at edge of polishing scratch at 300, > 50 small rough spots
pin	42	Recpt	2 large	2 med, 1 at crack/ scratch site	1 med, 3 at crack/ scratch site, many small	several	1 large	crack or deep scratch from 12-900, hand polish scratches, 3 rough spots at middle of crack, scratch (or crack) through center w/rough spots at center, med rough spots at 12:00, 2:30, 3:30, 6:00, 9:00, chip in OD at 3:00 & 8:45, >60 small rough spots
SMA	42	Recpt	-	-	-	1 small	-	smooth OD, many polishing scratches
SMA	43	Plug	-	1	-	2 light	-	no anomalies (dark spot is dirt), light polishing scratches
socket	43	Plug	some	16 med, several small	4 med	several, light	-	some OD roughness, pits at 1:00, 6:15, 6:45, 8:15, 8:30, 9:15, 10:00, 11:00, 11:15, 12:00, >35 small rough spots, light polishing scratches
pin	43	Recpt	very	many	1 large, 3	1 (may	-	heavy pitting at OD edge, large rough

rough associated med, very be a
spot at center 12:00, med rough spots
with edge few small crack)
at 1:00, 6:00, 6:30, scratch (or
chips
crack) at 4:30, @10 small rough spots

SMA 43 Recpt - 1 - several, -
smooth OD, several light polishing
light
scratches

SMA 44 Plug - - - several, -
no anomalous features noted
light

---

socket 44 Plug some 1 med, several, -
large chips in OD 8:45, 10:00, med
roughness several light
rough spots at 9:15 in core, > 50
2 chips small
small rough spots in core

---

pin 44 Recpt rough, 1 large, - several, -
large rough spots at 8:00, rough OD
3 chip very few light
w/chips at 3:00, 5:30, 7:45, 9:00,
areas small
light polishing scratches, 3 small

rough spots

SMA 44 Recpt - - - - -
no anomalous features noted

SMA M 1 some several some light -
@ 10 small rough spots
(short) small small

SMA M 2 some several - light
@ 10 small rough spots
(short) small

---

1 OD: Outer Diameter

2 Numbers represent radial position of the anomaly (clock position).

Table of Contents

Index of Appendix A

Up to TVA Homepage

Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

Table IV. Baseline Insertion Loss and Optical Throughput Data

Transmitter	Launch Cable	Evaluation Cable Section	Throughput in dBm	Insertion Loss of Evaluation Cable Section (dB)*	Eval Cable Section/Source
A	11/9-10/12	none	-9.84		
A	11/9-10/12	41 Plug to Receptacle	-10.83	0.99	41PR/A
A	none	41 Plug to Receptacle	-7.76		
A	11/9-10/12	41 Receptacle to Plug	-11.64	1.80	41RP/A
A	none	41 Receptacle to Plug	-8.86		
B	11/9-10/12	none	-9.72		
B	11/9-10/12	41 Plug to Receptacle	-9.51	-0.21	41PR/B
B	none	41 Plug to Receptacle	-8.70		
B	11/9-10/12	41 Receptacle to Plug	-11.20	1.49	41RP/B
B	none	41 Receptacle to Plug	-8.66		

A	11/9-10/12	none	-9.84	
A 42PR/A	11/9-10/12	42 Plug to Receptacle	-11.60	1.76
A	none	42 Plug to Receptacle	-8.29	
A 42RP/A	11/9-10/12	42 Receptacle to Plug	-11.60	1.80
A	none	42 Receptacle to Plug	-8.57	
B	11/9-10/12	none	-9.72	
B 42PR/B	11/9-10/12	42 Plug to Receptacle	-11.10	1.42
B	none	42 Plug to Receptacle	-8.86	
B 42RP/B	11/9-10/12	42 Receptacle to Plug	-11.20	1.44
B	none	42 Receptacle to Plug	-8.87	

A	11/9-10/12	none	-9.84	
A 43PR/A	11/9-10/12	43 Plug to Receptacle	-11.46	1.62
A	none	43 Plug to	-8.63	

		Receptacle		
A 43RP/A	11/9-10/12	43 Receptacle to Plug	-11.34	1.50
A	none	43 Receptacle to Plug	-8.42	
B	11/9-10/12	none	-9.72	
B 43PR/B	11/9-10/12	43 Plug to Receptacle	-11.05	1.33
B	none	43 Plug to Receptacle	-8.42	
B 43RP/B	11/9-10/12	43 Receptacle to Plug	-11.01	1.29
B	none	43 Receptacle to Plug	-8.89	

A	11/9-10/12	none	-9.84	
A 44PR/A	11/9-10/12	44 Plug to Receptacle	-11.20	1.32
A	none	44 Plug to Receptacle	-7.92	
A 44RP/A	11/9-10/12	44 Receptacle to Plug	-11.20	1.39
A	none	44 Receptacle to Plug	-7.65	

B	11/9-10/12	none	-9.84	
B 44PR/B	11/9-10/12	44 Plug to Receptacle	-10.90	1.23
B	none	44 Plug to Receptacle	-8.56	
B 44RP/B	11/9-10/12	44 Receptacle to Plug	-10.90	1.23
B	none	44 Receptacle to Plug	-8.52	

* Eval Cable Section Insertion Loss = Loss for the SMA connector pair + loss for the given "453"-M29504 pair.Table V. Data for First Vibration Test - Thick Bracket

Table of Contents

Index of Appendix A

Up to TVA Homepage

Back to the Library

Webster: Melanie.Ott@gsfc.nasa.gov

Table V. Data for First Vibration Test - Thick Bracket

	Date	XTMR	cable	attenuator	attenuator setting	cable	cable	O/E	HP Data Vmin (V)	Monitor Scope Data dBm (min)	Vmax (V)	Tektronix Storage Scope Hi (V)	Lo (V)	Pk-Pk (V)	Mean (V)
Pre-X1	013095	A	UnLbld	1344130	0	Lbld	-	B010279	0.514	-9.881	0.515				
Pre-X1	013095	A	UnLbld	1344130	0	Lbld	41P/R	B010279	0.336	11.707	0.342				
Pre-X1	013095	A	UnLbld	1344130	9.33	Lbld	41P/R	B010279	0.038	21.178	0.041			0.0084	
Post-X	013095	A	UnLbld	1344130	9.33	Lbld	41P/R	B010279	0.039	21.124	0.041	0.0438	0.0358	0.008	0.04006
Post-Y	013095	A	UnLbld	1344130	9.33	Lbld	41P/R	B010279	0.039	-	0.04243	0.0438	0.0362	0.0076	0.0398
Pre-Y2	013095	A	UnLbld	1344130	9.33	Lbld	41P/R	B010279	0.038	-	0.0414				
Pre-X2	013195	A	UnLbld	1344130	9.33	Lbld	41P/R	B010279	0.038	21.160	0.042				
Pre-Z2	013195	A	UnLbld	1344130	0	Lbld	41P/R	B010279	0.430	10.658	0.436				
Pre-Z2	013195	A	UnLbld	1344130	10.39	Lbld	41P/R	B010279	0.038	21.178	0.041	0.0434	0.0354	0.008	0.0393
Post-Z	013195	A	UnLbld	1344130	10.39	Lbld	41P/R	B010279	0.038	21.178	0.041	0.0426	0.035	0.0076	0.03892
Pre-X1	013095	B	11/9	1340113	0	10/12	-	B010278	0.523	9.802	0.527				
Pre-X1	013095	B	11/9	1340113	0	10/12	42P/R	B010278	0.372	11.286	0.376				
Pre-X1	013095	B	11/9	1340113	9.79	10/12	42P/R	B010278	0.038	21.160	0.041			0.0104	
Post-X	013095	B	11/9	1340113	9.79	10/12	42P/R	B010278	0.038	21.178	0.042	0.0432	0.0356	0.0076	0.0390
Post-Y	013095	B	11/9	1340113	9.79	10/12	42P/R	B010278	0.038	21.160	0.041	0.0436	0.036	0.0076	0.0397
Pre-Y2	013195	B	11/9	1340113	9.79	10/12	42P/R	B010278	0.040	21.020	0.042				
Pre-Z2	013195	B	11/9	1340113	0	10/12	42P/R	B010278	0.349	11.568	0.352				
Pre-Z2	013195	B	11/9	1340113	9.48	10/12	42P/R	B010278	0.039	21.125	0.041	0.0432	0.0348	0.0084	0.0388
Post-Z	013195	B	11/9	1340113	9.48	10/12	42P/R	B010278	0.039	21.125	0.041	0.0428	0.0352	0.0076	0.0387
Pre-Y2	013195	A	UnLbld	1344130	0	Lbld	-	B010279	0.516	-9.863	0.521				

Pre-Y2	013195	A	UnLbld	1344130	0	Lbld	43R/P	B010279	0.387	11.108	0.392				
Pre-Y2	013195	A	UnLbld	1344130	9.98	Lbld	43R/P	B010279	0.038	21.178	0.041	0.0434	0.0354	0.008	0.03916
Post-Y2	013195	A	UnLbld	1344130	9.98	Lbld	43R/P	B010279	0.038	21.178	0.041	0.0426	0.0354	0.0072	0.03898
Pre-X2	013195	A	UnLbld	1344130	9.98	Lbld	43R/P	B010279		*21.238*	0.0426	0.0356	0.0076	0.03816	
Post-X2	013195	A	UnLbld	1344130	9.98	Lbld	43R/P	B010279		*21.308*	0.0426	0.035	0.0076	0.03882	
Pre-Z1	013195	A	UnLbld	1344130	0	Lbld	-	B010279	0.564	-9.477	0.569				
Pre-Z1	013195	A	UnLbld	1344130	0	Lbld	43R/P	B010279	0.433	10.626	0.439				
Pre-Z1	013195	A	UnLbld	1344130	10.41	Lbld	43R/P	B010279	0.039	21.125	0.041	0.043	0.0354	0.0076	0.03924
Post-Z1	013195	A	UnLbld	1344130	10.41	Lbld	43R/P	B010279	0.036	21.125	0.042	0.0434	0.036	0.0072	0.03964
Pre-Y2	013195	B	11/9	1340113	0	10/12	-	B010278	0.511	-9.907	0.515				
Pre-Y2	013195	B	11/9	1340113	0	10/12	44R/P	B010278	0.375	11.250	0.378				
Pre-Y2	013195	B	11/9	1340113	9.8	10/12	44R/P	B010278	0.038	21.178	0.041	0.044	0.0356	0.0084	0.03948
Post-Y2	013195	B	11/9	1340113	9.8	10/12	44R/P	B010278	0.037	21.125	0.041	0.0444	0.0364	0.0084	0.03974
Pre-X2	013195	B	11/9	1340113	9.8	10/12	44R/P	B010278		*21.238*	0.0428	0.0356	0.0072	0.03954	
Post-X2	013195	B	11/9	1340113	9.8	10/12	44R/P	B010278		*21.192*	0.0432	0.036	0.0072	0.03964	
Pre-Z1	013195	B	11/9	1340113	0	10/12	-	B010278	0.524	-9.801	0.527				
Pre-Z1	013195	B	11/9	1340113	0	10/12	44R/P	B010278	0.350	11.550	0.532				
Pre-Z1	013195	B	11/9	1340113	9.47	10/12	44R/P	B010278	0.039	21.072	0.041	0.0432	0.0348	0.0084	0.0396
Post-Z1	013195	B	11/9	1340113	9.47	10/12	44R/P	B010278	0.039	21.125	0.041	0.0428	0.0344	0.0084	0.03866

Table of Contents

Index of Appendix A

Up to TVA Homepage

Back to the Library

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Table VI. Data for Second Vibration Test - Thin Bracket

HP Monitor Scope Data — Tektronix Storage Scope Data

	Date	XTMR	cable	attenuator	attenuator setting	cable	cable	O/E	Vmin (V)	dBm	Vmax (min)	Hi (V)	Lo (V)	Mean (V)	Pk-Pk (V)	(V)
Baseline	022895	A	Unlbl	1344130	0	lab	-	10279	0.499	-10.013	-9.734					
Baseline	022895	A	Unlbl	1344130	9.8	lab	-	10279	0.053	-19.747						
Baseline	030195	A	Unlbl	1344130	0	lab	-	10279	0.541	-9.662	-9.694					
Baseline	030195	A	Unlbl	1344130	9.8	lab	-	10279	0.058	-19.355						
Baseline	030195	A	Unlbl	1344130	0	lab	-	10279	0.534	-9.718	-9.751					
Baseline	030195	A	Unlbl	1344130	9.8	lab	-	10279	0.057	-19.469						
Baseline	030295	A	Unlbl	1344130	0	lab	-	10279	0.523	-9.809	-9.699					
Baseline	030295	A	Unlbl	1344130	9.8	lab	-	10279	0.056	-19.508						
Baseline	022895	B	11/9	1340113	0	10/12	-	10278	0.525	-9.792	-9.755					
Baseline	022895	B	11/9	1340113	9.8	10/12	-	10278	0.056	-19.547						
Baseline	030195	B	11/9	1340113	0	10/12	-	10278	0.441	-10.545	-9.677					
Baseline	030195	B	11/9	1340113	9.8	10/12	-	10278	0.048	-20.223						
Baseline	030195	B	11/9	1340113	0	10/12	-	10278	0.521	-9.825	-9.761					
Baseline	030195	B	11/9	1340113	9.8	10/12	-	10278	0.055							

```
-19.586

Baseline   030295  B      11/9     1340113        0 10/12    -       10278  0.529
-9.759 -9.712

Baseline   030295  B      11/9     1340113      9.8 10/12    -       10278  0.057
-19.469



Pre-x1     022895  A      Unlbl    1344130        0 lab      41RP    10279  0.399
-10.985

Pre-x1     022895  A      Unlbl    1344130     9.66 lab      41RP    10279  0.040
-21.020  0.043  0.044  0.036 0.040   0.008

Post-x1    022895  A      Unlbl    1344130     9.66 lab      41RP    10279  0.043
-20.674  0.046  0.048  0.040 0.044   0.008

Pre-y2     030195  A      Unlbl    1344130        0 lab      41RP    10279  0.135
-15.702

Pre-y2     030195  A      Unlbl    1344130     6.07 lab      41RP    10279  0.039
-21.072  0.043  0.044  0.036 0.040   0.009

Post-y2    030195  A      Unlbl    1344130     6.07 lab      41RP    10279  0.040
-20.984  0.042  0.043  0.036 0.040   0.007

Pre-z1     030195  A      Unlbl    1344130        0 lab      41RP    10279  0.166
-14.802

Pre-z1     030195  A      Unlbl    1344130     6.16 lab      41RP    10279  0.039
-21.072  0.043  0.046  0.036 0.042   0.010

Post-z1    030195  A      Unlbl    1344130     6.16 lab      41RP    10279  0.041
-20.819  0.046  0.048  0.040 0.044   0.008

Pre-x1     022895  B      11/9     1340113        0 10/12    42RP    10278  0.165
-14.828

Pre-x1     022895  B      11/9     1340113     6.02 10/12    42RP    10278  0.040
-21.020  0.043  0.044  0.036 0.040   0.008

Post-x1    022895  B      11/9     1340113     6.02 10/12    42RP    10278  0.040
-21.020  0.043  0.045  0.036 0.041   0.009

Pre-y2     030195  B      11/9     1340113        0 10/12    42RP    10278  0.324
-11.891

Pre-y2     030195  B      11/9     1340113     9.58 10/12    42RP    10278  0.041
-20.919  0.041  0.044  0.036 0.039  0.0088

Post-y2    030195  B      11/9     1340113     9.58 10/12    42RP    10278  0.041
-20.833  0.041  0.044  0.035 0.040   0.008
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Pre-z1     030195  B      11/9     1340113         0 10/12    42RP    10278  0.351
-11.537

Pre-z1     030195  B      11/9     1340113       9.5 10/12    42RP    10278  0.039
-21.072  0.042  0.043  0.035 0.039   0.008

Post-z1    030195  B      11/9     1340113       9.5 10/12    42RP    10278  0.038
-21.160  0.043  0.043  0.035 0.039   0.008

Pre-x2     022895  A      Unlbl    1344130         0 lab      43PR    10279  0.304
-12.168

Pre-x2     022895  A      Unlbl    1344130      8.69 lab      43PR    10279  0.040
-21.020  0.043  0.044  0.038 0.041   0.006

Post-x2    022895  A      Unlbl    1344130      8.69 lab      43PR    10279  0.040
-20.969  0.043  0.046  0.036 0.041   0.010

Pre-y1     022895  A      Unlbl    1344130      8.69 lab      43PR    10279  0.040
-21.020  0.043  0.046  0.038 0.041   0.008

Post-y1    022895  A      Unlbl    1344130      8.69 lab      43PR    10279  0.039
-21.072  0.043  0.044  0.036 0.040   0.007

Pre-z2     030295  A      Unlbl    1344130         0 lab      43PR    10279  0.315
-12.013

Pre-z2     030295  A      Unlbl    1344130      8.97 lab      43PR    10279  0.040
-21.020  0.043  0.043  0.036 0.040   0.007

Post-z2    030295  A      Unlbl    1344130      8.97 lab      43PR    10279  0.038
-21.178  0.042  0.045  0.036 0.040   0.010

Pre-x2     022895  B      11/9     1340113         0 10/12    44PR    10278  0.326
-11.864

Pre-x2     022895  B      11/9     1340113      9.08 10/12    44PR    10278  0.039
-21.072  0.043  0.044  0.036 0.040   0.009

Post-x2    022895  B      11/9     1340113      9.08 10/12    44PR    10278  0.039
-21.125  0.041  0.043  0.034 0.039   0.009

Pre-y1     022895  B      11/9     1340113      9.08 10/12    44PR    10278  0.039
-21.125  0.042  0.043  0.034 0.039   0.009

Post-y1    022895  B      11/9     1340113      9.08 10/12    44PR    10278  0.039
-21.125  0.041  0.044  0.034 0.0386  0.010

Pre-z2     030295  B      11/9     1340113         0 10/12    44PR    10278  0.348
-11.574

Pre-z2     030295  B      11/9     1340113      9.47 10/12    44PR    10278  0.039
-21.125  0.042  0.044  0.034 0.039   0.010

Post-z2    030295  B      11/9     1340113      9.47 10/12    44PR    10278  0.037
```

-21.286 0.040 0.042 0.034 0.038 0.008

PostVib2	030295	A	-	-	-	-	41RP	10279	0.341	-11.667	0.345
PostVib2	030295	A	-	-	-	-	41PR	10279	0.322	-11.907	0.325
PostVib2	030295	A	-	-	-	-	42RP	10279	0.655	-8.828	0.655
PostVib2	030295	A	-	-	-	-	42PR	10279	0.685	-8.634	0.689
PostVib2	030295	A	-	-	-	-	43RP	10279	0.550	-9.584	0.555
PostVib2	030295	A	-	-	-	-	43PR	10279	0.518	-9.850	0.521
PostVib2	030295	A	-	-	-	-	44RP	10279	0.726	-8.380	0.730
PostVib2	030295	A	-	-	-	-	44PR	10279	0.669	-8.736	0.673
PostVib2	030295	A	-	-	-	-	C60-C9	10279	0.898	-7.456	0.903
PostVib2	030295	B	-	-	-	-	41RP	10279	0.321	-11.926	0.326
PostVib2	030295	B	-	-	-	-	41PR	10279	0.322	-11.907	0.326
PostVib2	030295	B	-	-	-	-	42RP	10279	0.679	-8.670	0.684
PostVib2	030295	B	-	-	-	-	42PR	10279	0.683	-8.643	0.688
PostVib2	030295	B	-	-	-	-	43RP	10279	0.541	-9.651	0.547
PostVib2	030295	B	-	-	-	-	43PR	10279	0.546	-9.617	0.550
PostVib2	030295	B	-	-	-	-	44RP	10279	0.637	-8.948	0.641
PostVib2	030295	B	-	-	-	-	44PR	10279	0.898	-7.456	0.626
PostVib2	030295	B	-	-	-	-	C60-C9	10279	0.911	-7.393	0.916

Table of Contents

Index of Appendix A

Up to TVA Homepage

Back to the Library

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