Small form factor optical fiber connector evaluation for harsh environments

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ABSTRACT

For the past decade NASA programs have utilized the Diamond AVIM connector for optical fiber assemblies on space flight instrumentation. These connectors have been used in communications, sensing and LIDAR systems where repeatability and high performance are required. Recently Diamond has released a smaller form factor optical fiber connector called the “Mini-AVIM” which although more compact still includes the tight tolerances and the ratcheting feature of the heritage AVIM. NASA Goddard Space Flight Center Photonics Group in the Parts, Packaging and Assembly Technologies Office has been performing evaluations of this connector to determine how it compares to the performance of the AVIM connector and to assess its feasibility for harsh environmental applications. Vibration and thermal testing were performed on the Mini-AVIM with both multi-mode and single-mode optical fiber using insitu optical transmission monitoring. Random vibration testing was performed using typical launch condition profiles for most NASA missions but extended to 35 Grms, which is much higher than most requirements. Thermal testing was performed incrementally up to a range of -55°C to +125°C. The test results include both unjacketed fiber and cabled assembly evaluations. The data presented here indicate that the Mini-AVIM provides a viable option for small form factor applications that require a high performance optical fiber connector.

Keywords: space flight, fiber optic, connector, LIDAR, cable, communication, interconnection, vibration

1. INTRODUCTION

The Diamond AVIM optical fiber connector has been used for over a decade in flight environments. AVIM which stands for Aviation Intermediate Maintenance is always referenced as a fiber optic connector type from the DIN LSA (Deutsches Institut fur Normung, Lichtwellen Stecker type A or in English, Lightwave Connector type A) family of optical fiber connectors. The newly available Mini-AVIM and DMI (Diamond Miniature Interface) connectors also by Diamond provide similar features as the high performance AVIM with the added benefits of being small form factor for board mount and internal box use where long connectors and strain relief can not be accommodated. Transceiver, fiber laser technology and receiver optic technology based on small size constraints will benefit the most by the reduction in connector form factor. It is for this reason that the Mini-AVIM is being evaluated for multi-mode and single-mode optical fiber use in both fiber-based and cable-based packaging configurations. In a fiber-based termination, there are no cable materials to bond to the connector. The only bonding that is conducted is the mounting of the fiber with epoxy to the connector ferrules (which are called DMI ferrules). In a cable configuration, the compatibility of the connector subcomponents along with the upjacketing materials of the cable around the fiber needs to be considered carefully to ensure long term stable performance. If proper materials and methods are not used for cabled terminations, they will show greater insertion loss and have a high probability of failure during thermal cycling. This is due to the stressing of

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the fiber due to the combination of materials, each of which has a different Coefficient of Thermal Expansion (CTE), that are being bonded together to the connector subcomponents. As the materials flex during thermal excursions, forces are applied to the termination that can make the system fail if the grouping of materials (per their CTE's) are not compatible; this includes cable materials, epoxies, ferrules and connector body components. For this evaluation, multi-mode 100 micron core step index fiber was used for the fiber terminated condition, and single-mode SMF-28 fiber upjacketed with W.L. Gore Flexlite was used for the cabled configuration.

For background purposes, a comparison of features is presented between the high performance AVIM connector and the Mini-AVIM small form factor connector. Basic connector features of both types are keying and spring-loaded ferrules. Keyed connectors have an alignment "key" on the connector body and a mating slot on the adapter. The advantage of a keyed connector is that the connector will always interface into the adapter in the same orientation. Therefore, when mating two fibers they will always contact in the same manner, resulting in consistent connection performance. The keying feature also prevents the ferrule endfaces from rotating as the fibers are mated together, thus preventing scratching of the fibers at their endfaces. For multi-fiber ferrules, a keying feature is required to align the multiple fibers with another pair or multiple injected spots. For angled fiber polishes, used to prevent backreflections from the fiber endface getting back into the laser source, a keyed connector ensures the correct orientation of the fiber angle. Single fiber connectors that are used in free space to accept or emit a light pulse do not require keying, but still benefit from the feature during the manufacturing process and subsequent testing.

Spring-loaded ferrules use a spring mechanism behind a "floating" ferrule. When two fibers are connected, the ferrules come into contact and are held together by the springs. This method provides a controlled means of setting the force on the fibers and ferrules. On free space coupled systems, the spring is used to seat the fiber ferrule against a stop to ensure precise alignment. Due to the spring loading, the fiber ferrules are more stable over temperature and vibration.

None of the standard commercially available connectors are truly hermetic over a lifetime of 20-30 years under harsh environmental conditions. Many of the connectors or adapters use o-ring seals to provide some level of protection, and this is often claimed to be a hermetic connector. For short duration missions, (less than ~ 5 years) o-ring seals can provide a needed level of hermeticity, but gas permeation through the o-rings over time prevent this from being a long duration seal.

2. AVIM, MINI-AVIM, AND RUGGEDIZED MINI-AVIM CONNECTORS

2.1 DIAMOND AVIM CONNECTOR

The Diamond AVIM connector is the baseline connector for NASA spaceflight missions and is shown in Figure 1. Table 1 lists the missions that have used standard or customized AVIM fiber connectors. It is a keyed connector with a spring loaded ferrule. One of the primary benefits of this connector is the ratcheting mechanism on the outer connector nut that prevents the connector from backing off once attached. No additional epoxy stacking of the connector threads is needed. Extensive testing (vibration, thermal cycling, repeatability, etc) has been performed on this connector with both single-mode and multi-mode fiber and the typical insertion loss is 0.2 dB or better. [1-3] The connector can be purchased with various metal or hybrid ceramic ferrules with metal inserts. Various types of adapters are available, but the cleanable version is the NASA recommended version.

Figure 1: Diamond AVIM connector and adapter

Relevant attributes:

- Keyed connector
- Spring-loaded ferrule
- Ratcheting nut – prevents nut from backing off once installed
- Cable can be attached to back of connector for ruggedness in handling
- Custom fiber sizes available
- Baseline connector for NASA missions – flight heritage on multiple systems

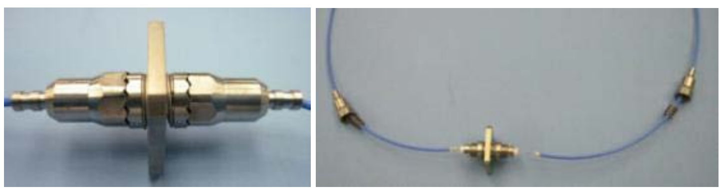
Table 1: Flight Heritage of AVIM Connector

Project	Dev	Launch	Connectors	Description	Details
Geoscience Laser Altimeter System (GLAS) on ICESAT	1998	2001	AVIM Standard Single Mode / Multi Mode / Flat Polish	Gore Flexlite SM & MM 2 Km of SM	Custom drill in ferrule, tungsten carbide shell ferrules
Mercury Laser Altimeter (MLA) MESSENGER	2001	2004	AVIM Standard, Flat Polish	330 um MM Flexlite	Custom drill in ferrule, tungsten carbide shell ferrules
Shuttle Return to Flight NEPTEC Laser Heat Tile Sensor	2003	2005	AVIM standard SM APC & SM	BICC OC1008, one sided terminations.	Standard pilz ferrule, ceramic shell
Lunar Orbiter Laser Altimeter (LOLA) on Lunar Reconnaissance Orbiter	2007	2009	AVIM array connector, 303 SS ferrule drill @ GSFC	SS larger PM AVIM for five 220 um fibers side one, fan out standard side two, Flexlite	Custom drill 220 um on fan out side, with standard AVIM tungsten carbide shell ferrules
Laser Ranging on Lunar Reconnaissance Orbiter	2007	2009	AVIM Array connector, 416 SS ferrule flower drill @ Diamond	SS larger PM AVIM for seven 440 um fibers, large custom cable	Both sides array flower pattern. Gimbal, cold, to -55 C.
Mars Science Lab, Chemcam	2008	TBD	AVIM standard custom drill ferrule for 330 um	Flexlite	Gimbal, cold, hot to 110 C
Express Logistics Carrier on ISS	2008	Nov-2009	AVIM standard custom drill for 140 um	Space Station cable & Flexlite	Pilz ceramic shell ferrules
James Webb Space Telescope	2008	GSE	FC & AVIM titanium ferrules.	No cable, cryogenic application.	Multiple sizes, multiple materials

Due to the connector design and termination process, Diamond will only sell unassembled parts to a small number of companies for performing terminations. NASA GSFC Photonics Group is among only a few manufacturers in the US that have been certified by Diamond to terminate with their products. The company also has a spaceflight division that can terminate fibers into assemblies for high reliability applications.

2.2 DIAMOND MINI-AVIM

The Diamond Mini-AVIM connector was introduced in 2010 as a smaller version of the AVIM connector. The Mini-AVIM is pictured in Figure 2 with comparisons made to the standard AVIM. In Figure 3 the drawing and piece parts are identified. The ferrule is identical to a DMI, which Diamond has been manufacturing for many years. The primary change offered by this new connector is that part of the ratcheting mechanism for securing the outer nut has been relocated onto the adapter body instead of being entirely contained in the connector itself. The adapter is manufactured such that the two ferrules "float" and are held together by the springs pressing on the back of ferrules once mated. Endface alignment between the two ferrules is maintained using a split ceramic sleeve, similar to almost all other connectors. The primary disadvantage of the Mini-AVIM is the lack of ruggedness during handling. The standard connector has no means of attaching the fiber jacketing to the ferrule or connector without epoxying the cable into the ferrule, which would lead to poor thermal performance (it would defeat the intended cable slip mechanism during thermal changes). A modified version of this connector needed to be evaluated as an alternative to when the usage of bare fiber in the termination was not enough and cable was necessary due to integration concerns.

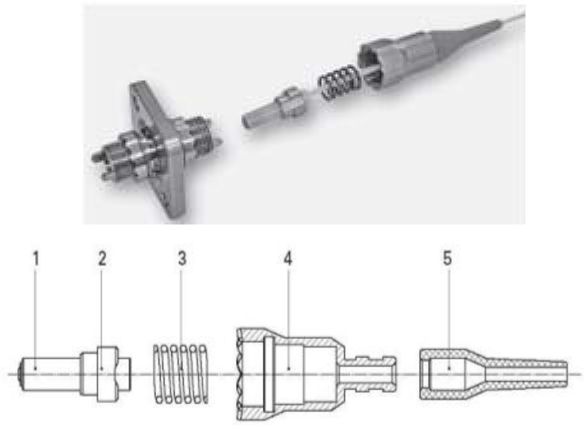


A) Mini-AVIM interconnected into a box mount adapter, B) disconnected bodies of the Mini-AVIM w/ ferrule still inserted into adapter.

C) Pictured Top; Cable Terminated Standard AVIM Interconnected into AVIM Cleanable Adapter, D) Pictured Bottom; Fiber Terminated Mini-AVIM Interconnected into adapter

E) Pictured Top; Cable Terminated Standard AVIM disconnected from AVIM Cleanable Adapter, F) Pictured Bottom; Fiber Terminated Mini-AVIM disconnected from adapter.

Figure 2: (A – F) AVIM & Mini-AVIM Optical Fiber Connector Configurations



POS.	DESCRIPTION	MATERIAL NAME	MATERIAL NORMS	WEIGHT (gr.)
1	Ferrule	Ceramic-Titanium	ZrO2, UNS R50250	0.27
2	DMI ring	Titanium	UNS R56400	0.09
3	Spring	Stainless steel	1.4310	0.12
4	Outside shell	Titanium	UNS R56400	0.58
5	Vacuum backed boot	Thermoplastic Elastomer TCP-ET	Hytrel 8068[1]	0.06
			Total	1.12

[1] Vacuum baked, 24h at 110°C to 125°C and 10^{-3} Torr

Figure 3: Diamond Mini-AVIM shown in detail.

<u>Relevant attributes:</u>

- Keyed connector – one larger and one smaller tab/slot
- Spring-loaded ferrule
- Ratcheting nut – prevents nut from backing off once installed
- Custom fiber sizes available
- Standard version is susceptible to handling damage
    - (see ruggedized version below)

2.3 RUGGEDIZED MINI-AVIM

When using the Mini-AVIM with a cabled configuration, the connector has some handling issues that make it very vulnerable to breaking the fiber behind the ferrule when used with a cable. For this purpose, a slightly modified version was required for termination purposes and is shown in Figure 4. It uses a sleeve in the back of the connector that allows connecting the jacket to the ferrule without having the jacket glued into the ferrule. This change prevents the weak spot behind the ferrule and prevents twisting the ferrule relative to the fiber cable. The boot is also too tight to enable mates and demates without pulling the outer jacket while it's being manipulated. A larger inner diameter boot is required to accommodate termination with W.L. Gore's Flexlite cable that measures 1.2 mm outer diameter.

Figure 4: GSFC modified Mini-AVIM connector.

These changes have been recommended to the vendor as a modification to their termination process as a result of this evaluation. Diamond agreed to work with GSFC, in order to implement these changes to their current offering and modify the outer connector nut (shown to the right in the figure above) to allow use of a Hytrel boot for fiber strain relief behind the connector. The Modified versions have been supplied by Diamond, but are currently under investigation and thus not included in this paper.

3. ENVIRONMENTAL EVALUATION OF MINI-AVIM WITH MULTIMODE FIBER

The Mini-AVIM terminated to a fiber, as an off-the-shelf product was characterized for its vibration and thermal performance earlier this year. Two versions of the board mount DMI tube and retention clip were also evaluated simultaneously. Diamond Switzerland submitted the Mini-AVIM and the DMI ferrules and retention clips in Berylium Copper and in Stainless Steel, with and without a "ruggedized" retention ring. Pictured in Figure 5 is the standard AVIM with cleanable adapter on top, the Mini-AVIM below that, the DMI ferrules and mating tube, followed by the board mount retention clips in the standard and ruggedized versions.

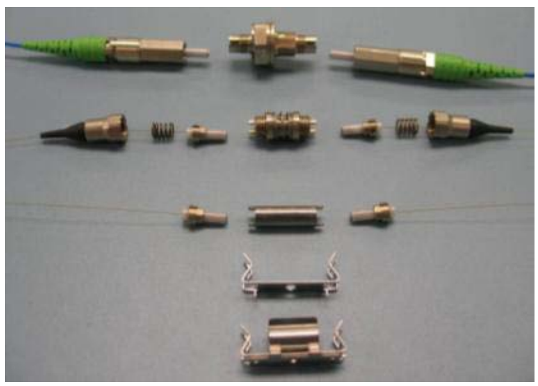


Figure 5: Standard AVIM (cable terminated), Mini-AVIM, and DMI connectors (optical fiber terminated)

The retention clips were tested for pull force retention to validate basic retention prior to random vibration stressing. Figure 6 illustrates the testing method used. The force used to pull the tube from the retention spring clips was logged for a total of 20 iterations. The results were used to calculate the average retention force for the; stainless steel standard clip at 6.6 N, the BeCu standard at 16.6 N, the stainless steel rugged version at 30.9 N and the BeCu rugged version at 44.4 N. The pull testing results were acceptable for moving on to thermal and random vibration characterizations.

Post pull testing, thermal cycling testing was conducted from -50°C to +125°C for 30 cycles with 1 hour soaks at the extremes, and a ramp rate of 1°C/min, followed by random vibration testing to 9.8, 14.1, 20 and then 34.6 Grms with insitu monitoring of optical transmission during exposure. The random vibration testing consisted of 3 minutes per axis and 3 axis configurations. Results from both tests showed that the Mini-AVIM and the DMI performed similarly to the standard AVIM. Prior to environmental stressing, all assemblies were end face inspected at 200 and 400 X magnification and tested for insertion loss to validate that the quality of the termination and performance of the assembly were within typical specifications. Thermal cycling was conducted first to validate the connector performance as well as the termination process used. Typically a thermal workmanship test is conducted on all manufactured assemblies and in this case the workmanship testing was included in 30 cycle characterization as a dual purpose test for time savings. In most cases, a non optically monitored 10 cycle thermal workmanship test is conducted followed by visual end face inspections prior to moving on to vibration and then thermal cycling.

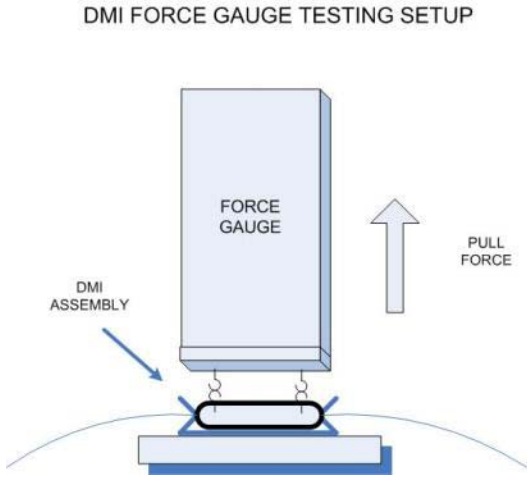


Figure 6: Sketch of Pull Force Experiment for the DMI Retention Force.

The results showed thermal-induced losses no greater than 0.2 dB (5% transmission change) and vibration-induced insertion loss changes no greater than 0.05 dB (1 % transmission change). Both tests confirmed that for multi-mode applications this connector was worth further study for space flight implementation.

3.1 Thermal Characterization of Mini-AVIM and DMI with Multimode Optical Fiber

Figure 7: Thermal cycling test set-up with insitu optical power transmission monitoring of Mini-AVIM and DMI interconnection.

Figure 7 shows the experimental set-up capturing insitu optical power transmission through the optical interconnects inside the thermal cycling chamber. The connectors were tested with both Polymicro Technologies FIP100120140 monitored at 850 nm and FVP100120140 monitored at 532 nm. The sources were the RIFOCS 752L for the 850 nm signal and a 532 nm Laser Diode. The detectors used to monitor optical transmission were the HP8166 multichannel lightwave multimeter chassis, with HP8162A modules to monitor the light at 850 nm. The Agilent 81623B with an E01 modification for operation at shorter wavelength was used to monitor optical transmission at 532 nm for the FVP fiber. Thermal cycling was conducted from -50°C to +125°C with 1 hour soaks at extremes and a ramp rate of 1°C/min for the duration of the 30 cycle test. Transmission was recorded once per minute and logged into a data file via Labview. The first data point is taken prior to the thermal test start and all data is then compared for relative insertion loss to the first point prior to thermal stress. Source drift is monitored and removed from the final data set.

The thermal-induced relative insertion loss data is graphed in Figure 8. The graph shows data that is very similar to previously gathered results of the standard AVIM from past NEPP reported evaluations.[2, 3] Visual inspections of all endfaces were conducted to be certain no cracking occurred during thermal stressing. No cracks were found at 200X.

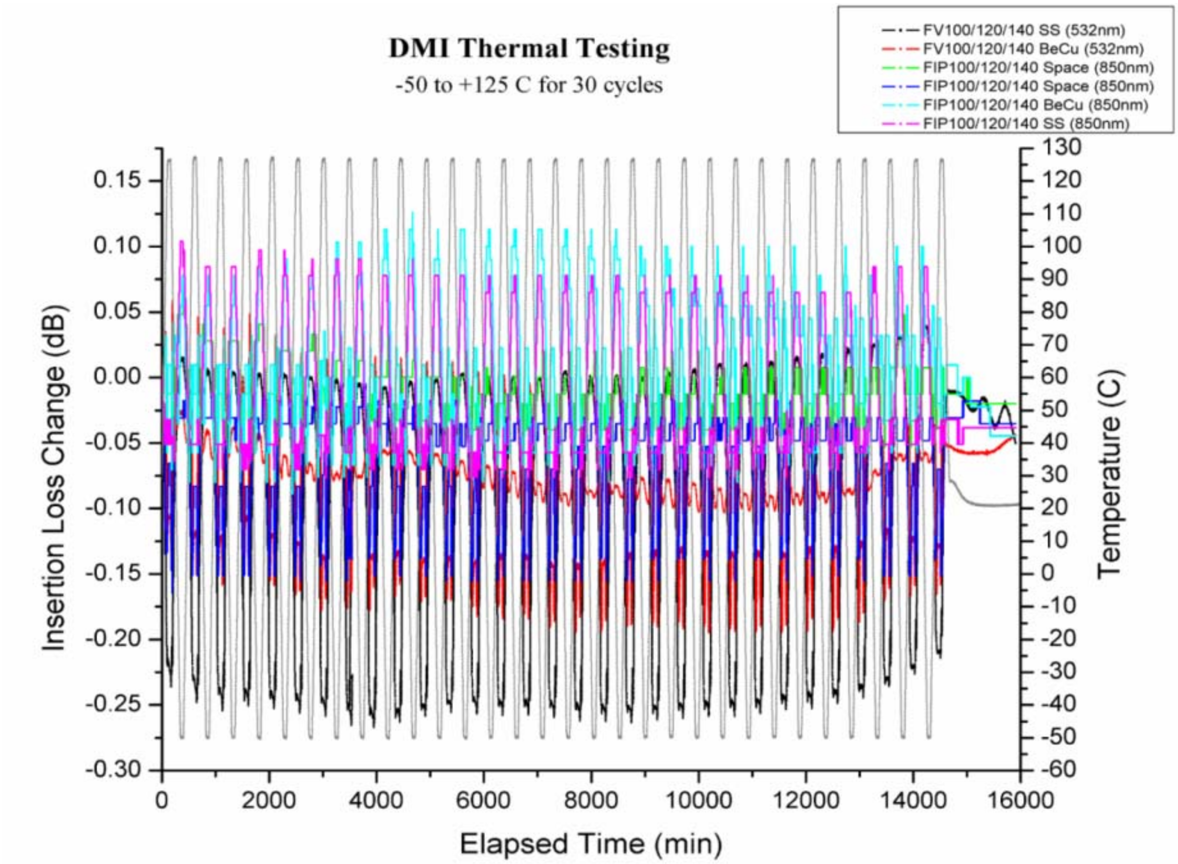


Figure 8 Thermal test results of the Mini-AVIM and DMI connector for multimode use.

3.2 Random Vibration Characterization of Mini-AVIM and DMI with Multimode Optical Fiber

Post completion of the thermal cycling testing, random vibration testing was conducted using the following profiles in order of how they appear: a) 9.8 Grms, b) 14.1 Grms, c) 20 Grms, and d) 35 Grms. The setup is pictured in Figure 9.

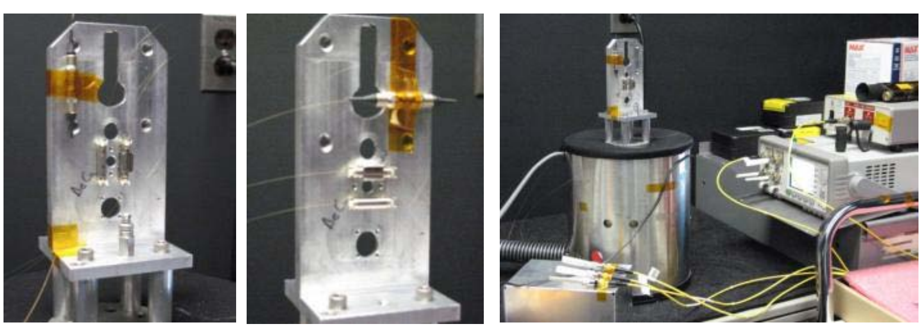


Figure 9: Z and X direction placement of vibration fixture on the vibration shaker and the random vibration insitu experimental set up.

Tables 2A – D; Random Vibration Profiles as Conducted for Insitu Random Vibration Testing

Table 2A

Frequency (Hz)	Level
20	0.013 g^2/Hz
20-50	+6 dB/octave
50-800	0.08 g^2/Hz
800-2000	-6 dB/octave
2000	0.013 g^2/Hz
Overall	9.8 grms

Table 2B

Frequency (Hz)	Level
20	0.026 g^2/Hz
20-50	+6 dB/octave
50-800	0.16 g^2/Hz
800-2000	-6 dB/octave
2000	0.026 g^2/Hz
Overall	14.1 grms

Table 2C

Frequency (Hz)	Level
20	0.052 g^2/Hz
20-50	+6 dB/octave
50-800	0.32 g^2/Hz
800-2000	-6 dB/octave
2000	0.052 g^2/Hz
Overall	20.0 grms

Table 2D

Frequency (Hz)	Level
20	0.156 g^2/Hz
20-50	+6 dB/octave
50-800	0.96 g^2/Hz
800-2000	-6 dB/octave
2000	0.156 g^2/Hz
Overall	34.63 grms

For each profile listed in Table 2, a 3 minute test was conducted for each of the 3 axes. All optical transmission data through each of the mated interconnections were logged into a file with a data point logged prior to the vibration induced stress applied as a reference point. Figure 9 shows the fixturing and shaker holding with assemblies attached for testing. All assemblies were monitored at 850 nm during vibration testing and monitored with the multichannel detectors.

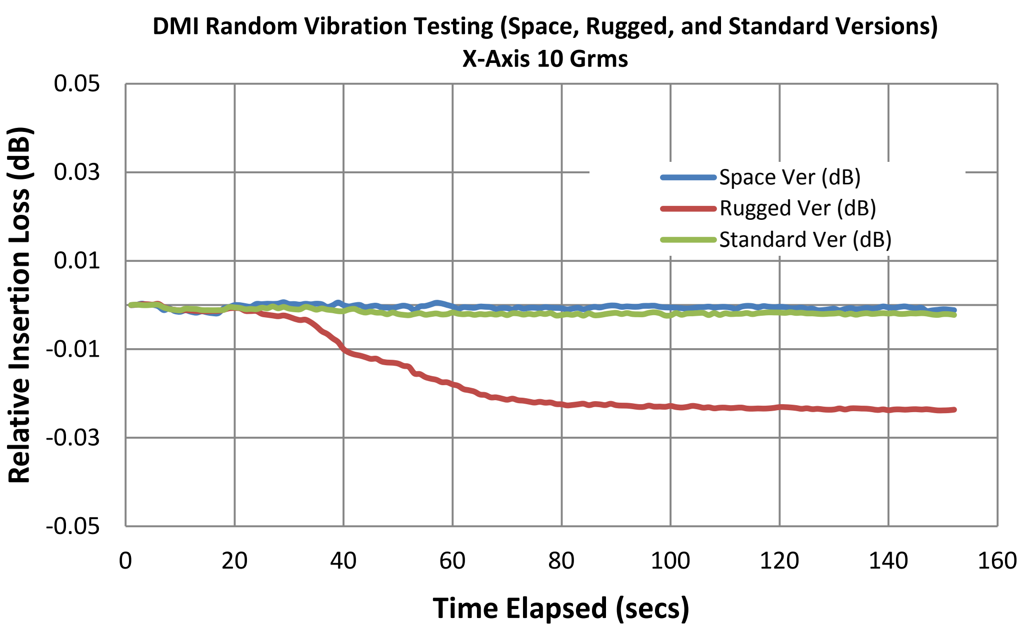


Figure 10: Worst case optical insertion loss data logged for all tests during random vibration.

Figure 10 is an example graph of data collected on the three assemblies under test during the 9.8 Grms Test. This example was a representative of the worst case seen among the entire data set.

Table 3 shows the summary of results gathered from random vibration induced stressing of the optical assemblies under test. All data collected showed no losses greater than .05 dB during random vibration induced stressing. Again, the Mini-AVIM and DMI interconnected assemblies performed very similar to the standard AVIM.

Table 3 Random Vibration Insertion Loss Monitoring of all Assemblies.

DMI SPACE VERSION				DMI RUGGED VERSION				DMI STANDARD VERSION			
Axis	grms Level	Max IL	Avg IL	Axis	grms Level	Max IL	Avg IL	Axis	grms Level	Max IL	Avg IL
X	10grms	-4.850E-04	6.609E-04	X	10grms	-1.622E-02	2.941E-04	X	10grms	-1.661E-03	7.603E-05
Y	10grms	-8.267E-05	2.207E-04	Y	10grms	4.174E-04	9.817E-04	Y	10grms	-3.616E-04	2.460E-04
Z	10grms	1.223E-03	1.875E-03	Z	10grms	1.185E-05	3.408E-04	Z	10grms	1.509E-03	2.422E-03
X	14.1grms	-1.607E-03	9.443E-05	X	14.1grms	-1.302E-02	1.676E-05	X	14.1grms	-2.476E-03	1.315E-04
Y	14.1grms	6.594E-04	1.275E-03	Y	14.1grms	-2.353E-03	0.000E+00	Y	14.1grms	3.692E-04	1.157E-03
Z	14.1grms	-3.111E-02	1.449E-03	Z	14.1grms	-2.321E-03	1.785E-04	Z	14.1grms	-4.063E-03	8.008E-05
X	20grms	-1.102E-02	0.000E+00	X	20grms	-9.868E-03	0.000E+00	X	20grms	8.592E-02	1.041E-01
Y	20grms	-1.061E-02	2.058E-03	Y	20grms	-5.173E-03	2.328E-04	Y	20grms	-8.479E-03	7.375E-05
Z	20grms	-1.998E-02	3.549E-04	Z	20grms	1.163E-03	4.677E-03	Z	20grms	3.211E-03	6.775E-03
X	34.6grms	6.491E-03	1.095E-02	X	34.6grms	4.117E-03	7.596E-03	X	34.6grms	2.726E-03	6.822E-03
Y	34.6grms	2.436E-03	6.342E-03	Y	34.6grms	6.716E-03	1.040E-02	Y	34.6grms	-5.936E-04	6.045E-03
Z	34.6grms	2.956E-02	3.565E-02	Z	34.6grms	3.575E-03	4.895E-03	Z	34.6grms	-1.167E-02	1.398E-04

4. ENVIRONMENTAL EVALUATION OF MINI-AVIM WITH SINGLEMODE CABLE

After the multimode terminated optical connector testing with the Mini-AVIM was completed, the test for usage of the Mini-AVIM with single mode fiber and cable began. The goal was to determine what compatibility issues existed with the Mini-AVIM if elected to be used for a non box application which would require packaging with a cabled fiber. For these tests, the Mini-AVIM was thermally stressed for a longer duration. As shown in Figure 4, the Mini-AVIM was terminated with SMF-28 optical fiber in W.L. Gore Flexlite cable. The termination process required a modification of the connector kit as provided by Diamond such that the fiber would not break during integration and de-integration. Diamond has agreed to make final modifications to the connector kit based on the results of this evaluation to accommodate the Flexlite cable into a termination ready kit.

Once end face visual inspections and interferometry were complete, all assemblies were tested for insertion loss before being assigned to the test group. Some assemblies with a non modified version of the connector were tested using the same random vibration profiles in Table 2 for the 20 and 35 Grms levels. The modified versions were tested for thermal response to evaluate the Mini-AVIM for performance over thermal cycling for single-mode applications and the modified configuration for thermal stability.

For random vibration the unmodified version of the Mini-AVIM was used and the assembly is pictured in Figure 11a, while the modified version used for thermal testing is pictured in Figure 11b. For safe integration and general high performance use purposes, the cable needed to be terminated into the connector in a manner represented in Figure 11b. The fiber needed to be terminated into the ferrule with epoxy but separated from the bonding of the jacket outer layers such that a 1 mm slip of the fiber inside of the jacketing would be maintained for thermal stability purposes. In order to accommodate the ruggedization behind the ferrule, the connector shell had to be enlarged enough to handle the added kynar tubing surrounding the outer jacket. In enlarging the connector shell, the back of it was removed due to the tight inner dimension of the shell at that location. The boot in both cases of the configurations in Figure 11 was removed for integration purposes since, once put on, it could not easily be removed and was too tight to be used with the outer jacket of the Flexlite cable which is 1.2 mm in diameter on its outer layer.


Figure 11 a) Non modified version of termination to the Mini AVIM with SMF-28 in Flexlite, b) Modified version of the terminated Mini-AVIM with SMF-28 in Flexlite.

4.1 Random Vibration Characterization of the Mini-AVIM Cabled with SMF-28

Random vibration testing was conducted with the cabled single-mode fiber terminated into the Mini-AVIM. The 20 and 35 Grms levels in Table 2 were used to conduct 3 minutes duration tests for each of the 3 axes. As performed previously for the multi-mode version, the optical transmission was monitored actively for changes due to mechanical stressing.

As can be seen in Figure 12b, the Mini-AVIM boot was not used during this testing because of the amount of handling involved in changing orientation three times for two different profiles which involved multiple mates and demates. For random vibration testing, the HP 815525M module at 1310 nm was used as the laser diode source and the HP81532A power sensor module was used as the detector in an HP 8153A Lightwave multimeter instrument. The testing setup is shown in Figure 12a. During random vibration exposure the optical power transmission was monitored and recorded and later converted to vibration induced insertion loss.


Figure 12a) Random vibration testing set-up with insitu monitoring for the Mini-AVIM unmodified version. b) close up of the Mini-AVIM attached to the interconnection adapter on the vibration fixture.

Figure 13 represents a worst case for all the data captured. It is evident that even in the worst case that under the stress of random vibration that the relative insertion loss is below 0.03 dB (0.7 % change in transmission).

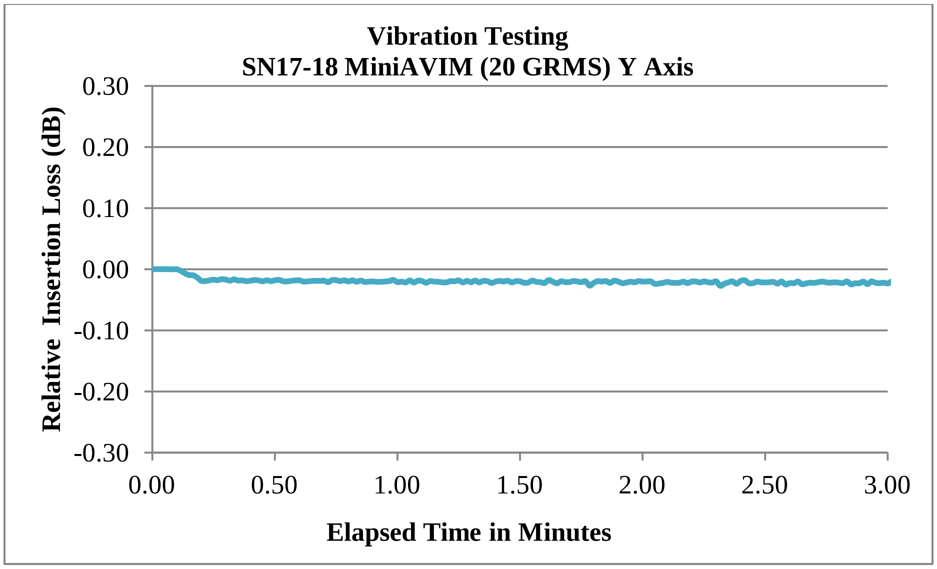


Figure 13: Example graph of in-situ random vibration induced insertion loss. This example represents the worst case data set collected during both the 20 & 35 Grms tests.

The results show no values more than 0.03 dB during or after vibration exposure for both the 20 Grms and 35 Grms level tests for the three mated pairs under test. These results for the Mini-AVIM with single mode fiber are similar to the multimode fiber characterization where the relative insertion loss was less than 0.05 dB (1% change in transmission).

4.2 Thermal Characterization of Mini-AVIM with Cabled SMF-28

The modified version shown in Figure 11b was tested for thermal response. The thermal testing setup is shown in Figure 14. Instead of performing the usual 10 thermal cycle workmanship test, the thermal test was started and the optical throughput monitored for any indication of workmanship related issues. Thermal cycling included 30 cycles of -30°C to +85°C followed by 70 cycles of -55°C to +125°C at a ramp rate of 1°C /min and dwells at extremes of 1 hour each. Two versions of the "ruggedized" modified termination were tested during thermal cycling. In the case of the "ruggedized" version RV01 as it is designated, it is the packaging configuration shown in figure 11b. In the case of all three mated pairs, the thermally induced relative insertion loss changes by around 0.20 dB (~5% change) during the first 30 cycles and increases to 0.30 dB (~7% change) during the next 70 thermal cycles. The change in insertion loss at the very beginning of the test is typical for what occurs during thermal workmanship testing (small gains are frequently seen as the mechanical structures move as a result of CTE) and as mentioned previously the workmanship part of the testing that usually goes unmonitored was included here to validate the termination process. A room temperature sample was run as well to monitor for set up power changes. Some of the gathered data for the Mini-AVIM is shown in Figure 15.

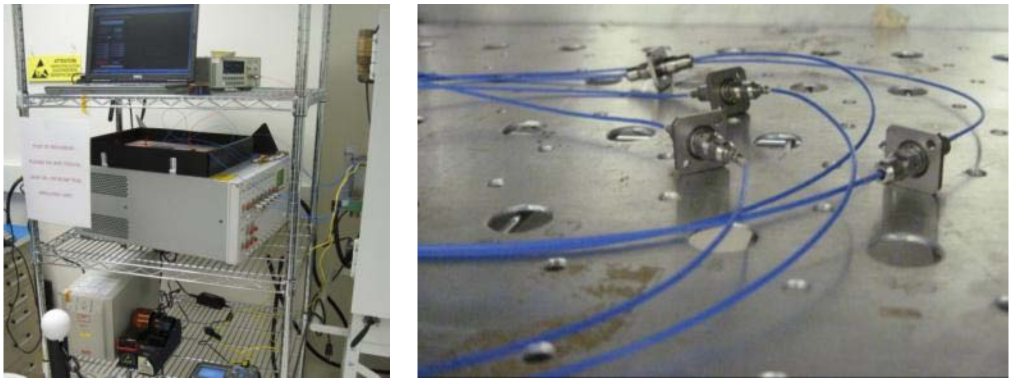


Figure 14 a) Thermal testing setup for insitu monitoring of Mini-AVIM mated pairs during thermal cycling, b) Close up view of assemblies in the thermal chamber.

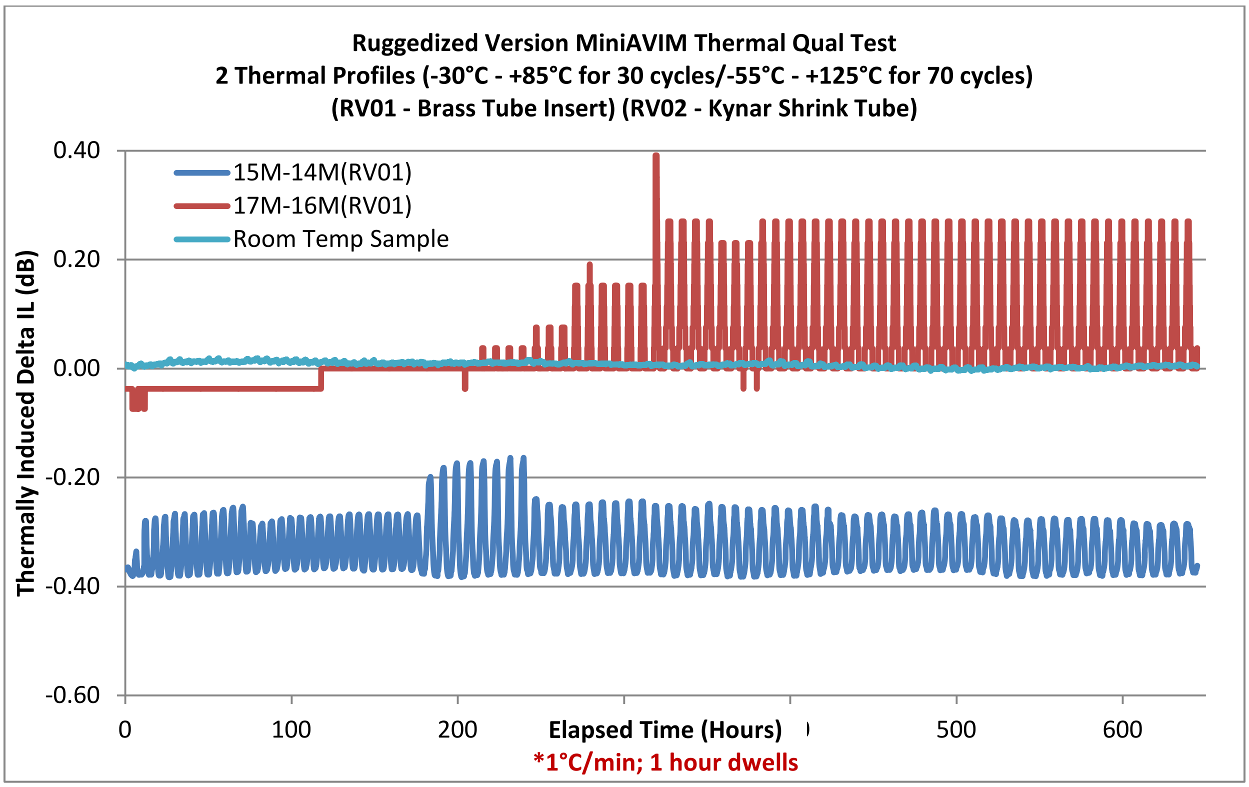


Figure 15: Thermal cycling induced relative insertion loss for Mini-AVIM mated pairs with SMF-28 optical fiber in Flexlite cable.

This single-mode fiber data is identical to the expected performance for a standard AVIM terminated with multimode fiber cable. These results show that this connector could be used in the modified version for typical thermal and vibration environments with single mode optical fiber. Upon receipt of the Diamond modified Mini-AVIM, additional thermal testing can be conducted to validate the Flexlite configuration with the updated connector shell and boot.

CONCLUSIONS

The Mini-AVIM performance was evaluated for vibration and thermal induced losses. In studies performed with multi-mode fiber terminated to the connector, the Mini-AVIM performed similarly to the standard flight heritage AVIM. When the connector was tested in configuration with W.L. Gore Flexlite challenges arose due to the dimension mismatch between the connector shell and boot, and the outer diameter of the Flexlite cable. In a modified version allowing for the cable jacketing to be accommodated, the connector performed well in mated pairs with SMF-28 and performed as the standard AVIM would under similar conditions. Although the larger version of the Mini-AVIM shell will need further evaluation, so far all results indicate that the Mini-AVIM could provide a viable option for space flight applications using both multi-mode and single-mode optical fiber.

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