

GR-1081 Field Installable Connectors

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GR-1081

Field Installable Connectors

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Introduction of Field Mountable Connectors (FMC)

FICs were first introduced as a field polished connector. Although the cost of the connector and equipment is not as high as a fusion splicer, the operation is delicate and requires a highly skilled technician to produce a good quality connector. Multiple parts and equipment such as a heating oven, epoxy, distilled

water, connector holder, polishing film, and polishing jig are required. In addition, the epoxy has a limited shelf life which requires careful forecasting and stock management. To prevent the polishing film from being contaminated, a clean environment for storage and operation is required.

Measure and Strip Fiber to Correct Length



Measure and mark fiber



Strip fiber to correct length

Insert Fiber into holder and cutting



Push fiber into fiber holder



Set the cleaver for cutting

Insert Fiber into Connector & Settle



Insert assembly into connector holder



Remove wedge from connector

Check Connector



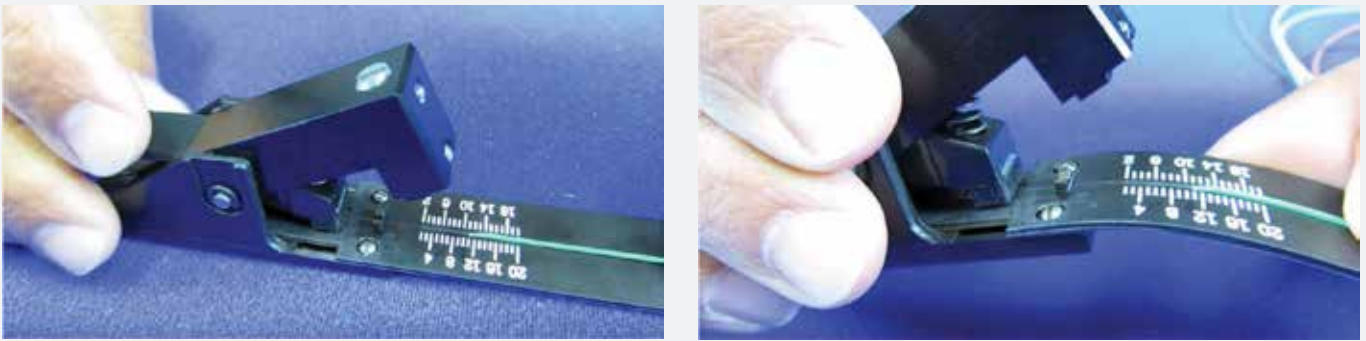
The connector is terminated



Check the termination

The FMC evolution is the introduction of a No Epoxy No Polish solution. The FMC is designed to have an optical fiber stub which is pre-cleaved and pre-polished within the connector ferrule. A mechanical splice together with a fiber guide and clamp is incorporated within the connector body. A prepared and cleaved fiber of a set length is pushed into the connector to make a physical contact with the fiber stub. Index matching gel within the connector improves the fiber interface and prevents fiber grinding on contact. The performance of the FMC termination is further improved with the introduction of precision cleavers which replaces the Score-and-Snap cleavers.

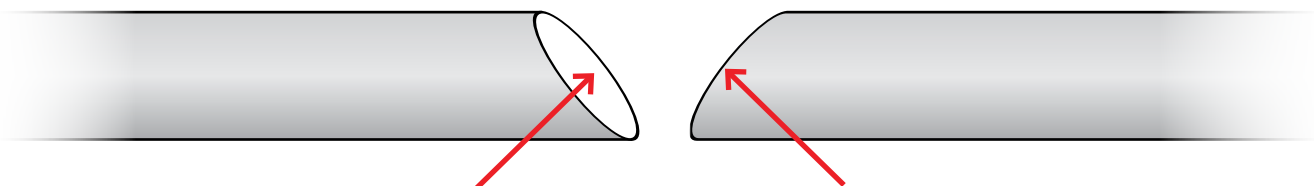
The use of Snap-and-Score Cleavers reduces FMC loss performance



As the No Epoxy No Polish FMC proved to be a very reliable and easy to install solution, multiple variations of the connector for different applications are introduced such as the FMC for 900 μ m, cords and drop cables. These included new boot designs for gripping Kevlar from cords and the outer sheath of cables for improved connector retention strength.

With the increasing volume of data transmission of video and internet services, improved connector reflectance loss is required. APC polished FMC is introduced, however due to the flat cleave connection within the FMC, the optical reflection performance is not compliant with a Grade 1 connector of -55dB. In order to overcome this issue, a mechanical splice with angle cleaved optical fiber is introduced. The fiber stub within the FMC is cleaved at an 8 \circ angle similar to the angle of an APC connector. By using an angle cleaver, instead of a flat cleave, the optical fiber can be cleaved at an 8 \circ angle to produce an angled mechanical splice with improved the optical reflection performance to less than -60dB.

Like any cleavers in the market, angle cleavers is not able to consistently produce 8 \circ angle cleaves 100% of the time. The higher the cleave angle, the greater the angle variation. For a precision cleaver with a nominal cleave angle of 8 \circ , the cleave angle is normally distributed from 6.5 \circ to 10 \circ . This range of angle coupled with the potential keyed fiber rotation mismatch with the fiber stub in the FMC produces a core gap that will result in poorer return loss stability.



Mismatched Angled Fiber Rotation

Although the angled connection improves return loss performance, the quality of termination is still dependent on many external factors such as the skill of the installer, maintenance of the cleaver and the environment. In addition, an installation mistake made during the insertion and reinsertion of fiber into the FMC reduces the index matching gel and potentially introduce air pockets at the fiber contact point.

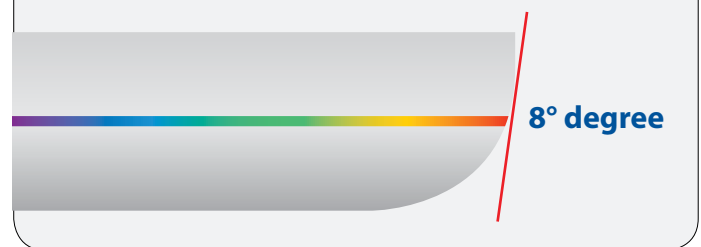
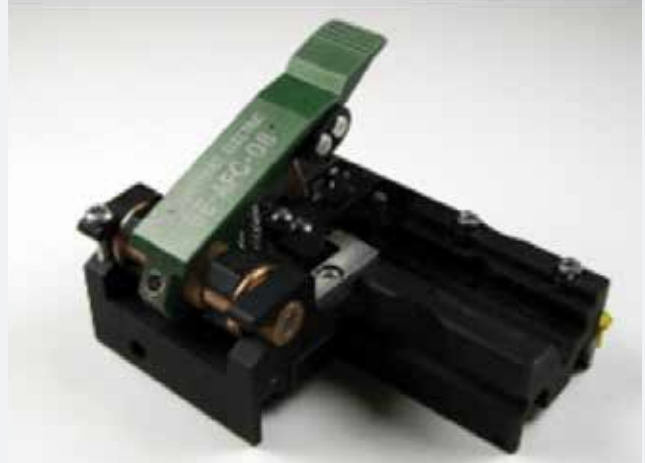
Another development of FMC caters to further improve the return loss performance of FMC by introducing a splice-on connector which is usually used for connectorizing fiber cords. This is born out of the requirement for a higher performance connector and the introduction of lower cost handheld fusion splicers. The FMC is designed to have a cleaved fiber stub at the end of the connector which is presented on a holder which fits into a fusion splicer. After splicing to the FMC, a splice protection sleeve is heated over the splice point and a connector boot is slid over the splice point.

The latest development of FMC is the SENKO's Q-XP connector which enables a high return loss and insertion loss performance when used with a unique curved angle cleave. FMC with angled cleave fiber stub requires accurate angular alignment of the cleaved fiber to maintain mechanical splice quality. The Q-XP FMC, fiber holder tool and unique curved angle cleaver are designed to enable an accurate angle alignment. During the manufacturing process, the curved angle cleave of the fiber stub within the FMC is set to a specific orientation. By using the fiber holder tool and curved angle cleaver, the curved angle cleave orientation of the fiber to be inserted is aligned with the fiber stub in the FMC which results in a low loss termination.

Although the use of the specific fiber holder tool is highly recommended, a high quality termination can still be obtained with the Q-XP FMC even if the curved angle cleaved fiber is not aligned with the fiber stub. In addition, the Q-XP FMC is also compatible with fibers with a right angled cleave without significant drop in connector performance.

There are other FMC development such as the stripping-free FMC and automated FMC assembly machine, however such FMC solutions were difficulty in mass manufacturing or introduce a proprietary connector type which is not readily adopted by the industry.

Unique curved angle cleave

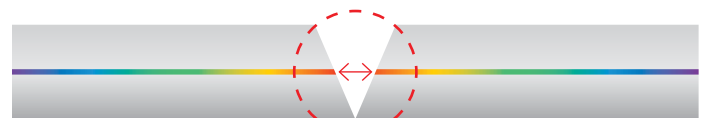


Key Aligned



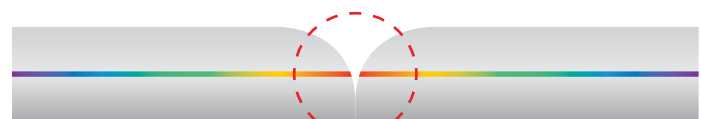
Best case scenario

Key NOT Aligned with standard angle cleaver



Air Gap
Loss increase

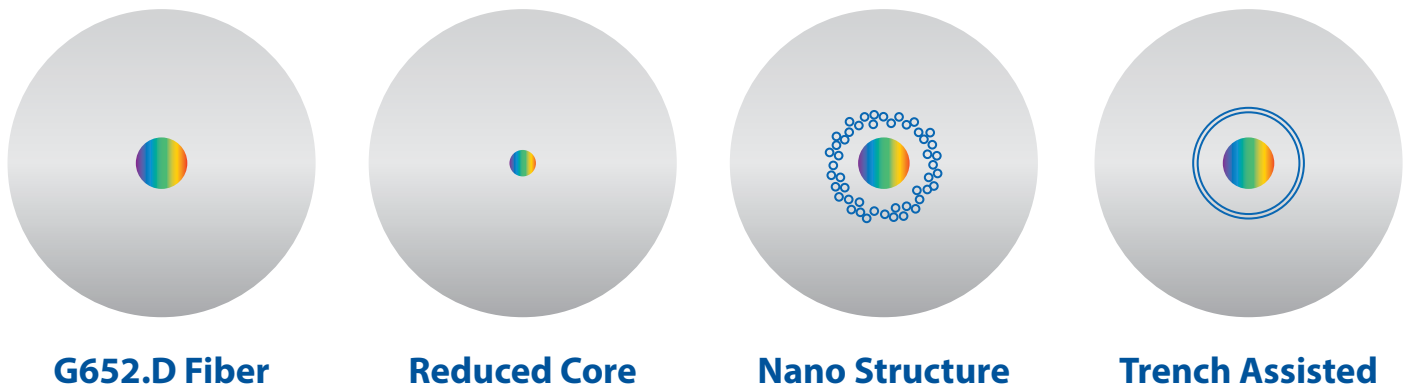
Key Alignment not required with SENKO cleaver



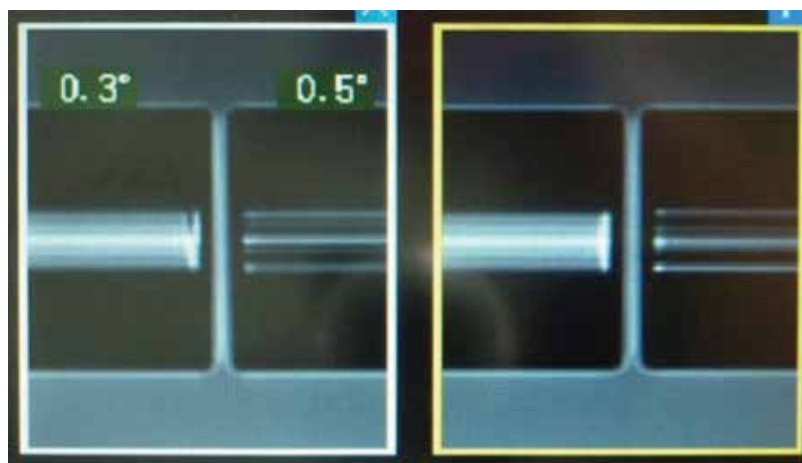
Minimum Air Gap
Better Optical performance in any case

Field Installable Connector Compatibility

The deployment of bend insensitive fibers such as the G657.A2 fiber is increasing especially in the drop and internal premise cabling. Although many fiber manufacturers are able to produce bend insensitive fiber that is compliant with the ITU-T recommendation, manufacturers deploy different fiber designs and index profile to achieve the low bending loss feature. Some examples of fiber designs are the trench assisted fiber, Nano structured design and a reduced core design. The Mode Field Diameter (MFD) for each of these fiber designs are different and this causes the mechanical or fusion splicing of a different fiber type to have an effect on the optical reflection as well as Insertion Loss performance. Another important point to note is that there are G657.B3 fibers which are not fully compatible with G652.D fiber, thus it is important to understand the type of fibers deployed in the network and the FMC fiber stub.



Many fusion splicer manufacturers have developed selectable splice functions which changes the splice parameters such as arc duration and power level depending on the type of fibers to be spliced. Some fusion splicers even have auto detection of the fiber type. Using such functions will improve on the splice quality for a splice-on FMC. However it does not change the MFD profile of the fibers spliced and the fiber mismatch will remain. A mechanical splice type FMC however is more susceptible to reduced splice performance due to fiber mismatch. In addition to not having any fiber specific adjustment nor the micro alignment of the fiber core or cladding.



G652.D and G657.A2 Fiber in a Fusion Splicer

Connector Quality

GR-326-CORE (Generic Requirements for Singlemode Optical Connectors and Jumper assemblies) was initially created by Bellcore and continues to evolve as one of the more popular standards in the telecommunications industry. GR-326-CORE was written as part of Telcordia's General Requirement series to be consistent with the Telecommunications Act of 1996 and it is intended to be the industrial specifications for long haul high-speed applications such as telecommunications and cable TV.

With the introduction of FMC with increasing deployment in FTTH networks, part of the connector assembly process is passed on to technicians in the field which expands the assembly variables such as installer skill level, external assembly environment and the introduction of optical loss from an additional contact point. GR-1081-CORE (Generic Requirements for Field-Mountable Fiber Optic Connectors) is introduced to complete the assessment of variables with reference to the GR-326-CORE standard.

The tests outlined in GR-1081-CORE aims to determine the FMC performance, service life and reliability based on the Service Life Test and Extended Service Life Test outlined in the GR-326-CORE standard. Understanding that FMC is assembly, there is an increased Insertion Loss from the joining a fiber to a stub-fiber in a connector housing. Such an FMC is identified as a Multiple Jointed Connector Assembly. Referencing the GR-326-CORE Service Life Test criteria, the Maximum Loss and Mean Loss threshold level is increased by 0.2dB. The Service Life Test outlined in GR-1081-CORE is a series of test procedures and requirement.

GR-1081-CORE Service Life Test

TEST TYPE

FMC Assembly



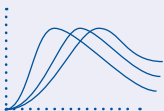
As the FMC is designed to be installed in the field, the quality of the connector will be affected by the technician's level of skill and care during the assembly process. As part of the assembly test, two operators, one designated by the FMC supplier and another designated by the testing house, are tasked to assemble at least 10 FMC at three different temperatures to simulate a hot climate, cold climate and room temperature condition.

In addition, depending on the FMC assembly type, the time to install must not exceed the following:

- 15 minutes for an FMC designed for termination to an optical cord or cable
- 12 minutes for an FMC designed for termination to a 900µm or 250µm fiber.

All the assembled FMC are numbered with their install condition noted as they will be used for the subsequent tests.

Wavelength Dependency



The wavelength dependency test is performed only on Multi Jointed Connector Assembly type FMC. This test is to ensure the wavelength performance is not affected by the splicing of two fibers. Using the connectors from the FMC Assembly Test, two assembled FICs are terminated and the Insertion Loss of the connection is measured from 1260nm to 1360nm in steps of 5nm. The peak-to-peak variation in loss within the wavelength range must not exceed 0.2dB.








At least 10 FMC from each installation temperature condition must pass this test in order to have sufficient samples to proceed to the next test stages.

New Product Measurement

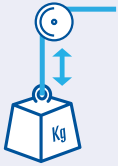


The New Product Measurement test is to randomly select samples submitted for testing to simulate normal product supply rather than the supply of improved performance product for testing and qualification purposes. Two FMC are terminated and the Insertion Loss is measured. The performance criteria is as follows:

- Maximum Loss Requirement to be $\leq 0.60\text{dB}$
- Mean Loss Requirement to be $\leq 0.40\text{dB}$
- Reflectance Requirement to be:
 - $\leq -40\text{dB}$ for UPC connectors
 - $\leq -60\text{dB}$ for APC connectors

<p>Thermal age</p> 	<p>The Thermal Age Test is considered the least extreme of the environmental tests in terms of stress applied, and is intended to simulate and accelerate the processes that may occur during shipping and storage of the product. Connectors are subjected to a temperature of 85oC with uncontrolled humidity for a duration of 7 days. Insertion Loss and Reflectance measurements taken before and after testing.</p>
<p>Humidity Aging</p> 	<p>Humidity aging is designed to introduce moisture into the connector and to determine the effect that the moisture has on the samples. This test is performed at the elevated temperature of 75oC for 7 days, while the connectors are exposed to 95%RH.</p>
<p>Thermal Cycle</p> 	<p>During thermal cycling, the temperature fluctuates over an expansive range, subjecting the product to extreme heat and cold. Thermal cycling involves changing the ambient temperature of the connector from 75oC to -40oC over the course of 3 hours. Heavy stresses and strains will be applied to each of the materials in the product. Material that make up the FMC and the optical fiber will expand and contract with the changing temperature. This test will also expose any weaknesses in the termination as well as the material design of the connector. Uneven expansion and contraction can lead to fiber cracks or breakage.</p>
<p>Vibration</p> 	<p>In a vibration test, the products being tested are mounted to a “shaker” which will vibrate along the principal axes of the FMC. This simulates the vibration experienced when the connector is mounted on in a closure or cabinet which is close to sources of vibration such as traffic. This test is performed for 2 hours with an amplitude of 1.5mm. A continuous sweeping frequency is applied between 10Hz and 55Hz at a rate of 45Hz per minute.</p>
<p>Flex</p> 	<p>The Flex Test is applied only for FMC designed for terminated to cords or cables. This test is not applicable to FMC that are terminated to 900µm buffer tube fiber or 250µm fiber. The flex test is performed to simulate stresses on the FMC boot which is designed to function as a strain relief when the cord or cable is flexed over the lifetime of the FMC. A poorly designed boot may be uncoupled from the connector body or not provide sufficient strain relief to prevent fiber breakage. A load is applied on the cord or cable and the FMC termination is subjected to flex rotation from 0o, 90o, 0o, -90o and back to 0o for 100 cycles.</p>
<p>Twist</p> 	<p>The twist test puts a rotational strain on the fiber, which tests the strength by which it is coupled with the connector. In addition, the adequacy of the crimp will also be tested. This, like the flex test, will help to identify weaknesses in the termination process. A load is applied on the cord, cable or fiber. The fiber is rotated about the axis of the fiber for a set amount of revolutions back and forth for 9 cycles.</p>
<p>Proof</p> 	<p>Proof testing simulates the occurrence of a sudden tug on the fiber in the field. This test ensures the strength of the latching mechanism of the connector, as well as the crimp strength on the fiber, cord or cable to ensure that the assembly will not break or detach from the adapter. A load is applied to the fiber, cord or cable in the condition of a straight pull and a 90o side pull.</p>

TWAL Transmission with Applied Tensile Load



The TWAL test is performed to reflect the effects of an applied load to the FMC transmission performance. This is to simulate loads that may be applied to connections in the field during network installation and operation such as opening and closing of patch panel shelves. TWAL testing will stress the samples by applying different weights at angles of 0°, 90° and 135°. The series of weights used depends on the media type of the cordage, as well as the connector form factor. Small Form Factor (SFF) connectors are subjected to a more extensive range of measurements.

Impact



The Impact test is performed to simulate accidental dropping of the FMC during installation or operation and to verify that the connector is not damaged. The cord of the FMC is clamped at 1.5m from the connector. A concrete block is placed at the bottom of the clamp where the connector will come into contact with it when dropped. The FMC is lifted to the level of the clamp so that when it is released, it will swing towards the concrete block. This test is repeated for a total of 8 impacts.

Durability



Durability testing is designed to simulate the repeated use of a connector. This test involves the mating and de-mating of the connector for a total of 200 times at different heights to simulate the FMC use on in a cross connect rack. Optical measurements are taken at termination intervals without connector end-face cleaning and with end-face cleaning. This test can potentially identify any problems with the design and/or material flaw in the connection, such that any part of the connector may experience heavy strain from repeated terminations.

Connector Installation



The connector installation test is performed to simulate a space constrained enclosure such as a cabinet. The FMC is terminated onto an adapter which is mounted on a vertical plane. A panel is placed at 70mm apart from the and parallel to the adapter mounting plane. The loss of the FMC is measured when the panel is in position.

Damage Criteria

At the end of the test sequence, the Wavelength Dependency Test is performed again to ensure consistent FMC loss performance. The FMC is further for physical damage that might impair the performance of the connector. Visual inspection is performed to identify any physical distortion, cracks, corrosion or debris.

Loss performance of the FMC after the completion of all tests must be as follows:

- The permanent Insertion Loss increase must not be more than 0.5dB.
- The permanent Reflection increase must not be more than 5dB.

GR-1081-CORE Reliability Assurance

To ensure the continuous performance and compliance of the FMC for the lifetime of the network and continuous supply of compliant product, Reliability Testing is to be performed every 2 years. The test regime is based on the Extended Service Life Test as outlined in the GR-326-CORE standard.

The FMC is subjected to thermal aging, humidity and thermal cycle tests for an extended period of time of up to 2,000 hours (83 days) and up to 5,000 hours (208 days) for more FMC performance information. In addition, 5 additional tests are introduced which are the Salt Spray, Airborne Contaminants, Dust, Groundwater Immersion, and Immersion/Corrosion Test.

Salt Spray



Salt Spray is performed to simulate the environment close to the ocean. This test involves the connector being exposed to a high concentration of Sodium Chloride (NaCl) over a period of 168 hours (7 days). After the test, the optical performance of the FMC is measured and 5 connectors are disassembled to inspect for signs of corrosion.

Airborne Contaminants



The Airborne Contaminants Test is performed to simulate the FMC reaction and performance in a polluted environment. Two sets of FMC is prepared with one set being mated and another set unmated but capped. The FMC under test are stored in a chamber where 4 types of volatile gasses with varying concentrations is introduced and held for 20 days to simulate prolonged exposure to these elements.

Dust



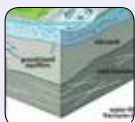
Dust particles can seriously impair optical performance. A single speck of dust when positioned on the fiber core on the connector end face can totally block optical transmission. In a worse case, dust particles can also be burnt from the laser transmission to permanently damage the connector core. Over time, dust particles will find their way onto the optical connection. While the dust particles are not difficult to remove, the cleaning process involves disconnecting the connector, which disrupts transmission as well as further expose the connector to contaminants. The dust test involves the intense exposure of dust of specified particle sizes in order to determine if there is a risk of any particle contaminating the ferrule end faces.

Groundwater Immersion



FMC deployed in underground plant may be exposed to immersion in a variety of fluids if the seals around the enclosure fails. This test involves the exposure of mated and unmated but capped FMC to chemicals that are commonly found in sewage treatment and agricultural fertilization. The FMC under test is introduced to chemicals such as detergent, chlorine, fuels and ammonia for a period of 7 days. The optical performance of the FMC is measured before and after the test.

Immersion/Corrosion



This test sets out to determine the effects of prolonged immersion in water on the materials used to construct the FMC. Both mated and unmated FMC are fully immersed in deionized or distilled water for 2 weeks. The reflectance of the FMC is measured after the test. In addition, the end face geometry of the ferrule is measured to detect any ferrule deformation. If the ferrule is not geometrically stable during this test, it may be an indication of a flaw in the zirconia material used in the ferrule. Unmated connectors are checked for Fiber Dissolution, which involves checking to see if the fiber core has not recessed too far into the fiber cladding.

Future Market of Field Installable Connector

With the increased deployment speed of high-speed enterprise networks and data centers, the requirement for optical fiber terminations has significantly increased to provide tens of thousands of connections in a single data center. The traditional termination method of using single connectors becomes a barrier to expand the number of connections due to the physical space limitations. In addition, the need to manage individual cables and cords becomes a management nightmare and are potential failure points which is difficult to locate.

In 2010, high speed 10, 40 and 100GbE ports represents only 3% of all ports sold by manufacturers. This has increased to a 75% market share by year 2015, with 40 and 100GbE ports accounting for 25% of the ports sold. To meet the increase in demand, MPO connectors are deployed to increase the number of fiber connections while maintaining the physical footprint.

With the use of MPO connectors, the continuous connector performance is critical. Any single connector downtime may result in the loss of a 100GbE port. Due to the critical nature of the port, the whole physical link must be subjected to minimal risk of damage which includes the proper management of cord length. The best way to manage cord slack is to not have any slack at all. This means having custom made MPO patch cords with specific cord lengths.

Factory terminated MPO connectors will provide the best optical performance but the cost and lead-time to get a custom length patch cord may take weeks. The process of getting custom made patch cords is as follows:

- The technician will have to accurately measure the required cord length for every termination, ensure the correct polarity and quantity of patch cords to provide the correct order information to the supplier.
- The manufacturer will have to manufacture, test and ship the patch cords to the technician.
- The technician will have to sieve through the supply to ensure that the correct patch cord is terminated to the correct ports.

Any single mistake in the whole process may result in having to re-order new patch cords which will cause significant project delays.

The introduction of splice-on MPO connectors enables the technician to assemble their own custom length MPO patch cord on site. This reduces the installation time and the risks from having a factory manufactured patch cord. Splice-on MPO connectors from reputable suppliers have been tested to have relatively similar loss profile from a factory terminated connector and available for the different types of optical fibers deployed such as singlemode, OM2, OM3 and OM4.

Summary

The adoption of the GR-1081-CORE standard provides an assurance of not only optical performance but also the reliability of the product throughout the lifetime of the network. The use of quality material is only part of the process in producing a quality FMC. The detailed FMC design and manufacturing process needs to be closely monitored to ensure quality. Ease of field assembly is also critical to enable technicians of all skill level to be able to successfully assemble and terminate an FMC.

With the increase in FTTH subscribers, more reliable premise connections need to be established at a faster rate. There is clearly a need for high quality and low cost Field Installable Connectors that are simple to assemble. Mechanical splicing and splice-on connectors is successfully deployed in many Asia Pacific countries and have been in service for over 10 years. The introduction of FMC that employs a mechanical splicing mechanism in Japan has seen the reduction in tooling cost by 90% and an overall reduction of installation cost by 50%. Such experiences indicate that the proper deployment of reliable FMC helps network operators to achieve a higher penetration rate. To support this increase in bandwidth consumption, data centers and enterprise network have seen a significant growth and migration to 40 and 100GbE ports. The deployment of splice-on MPO connectors will provide the technicians and managers with more control over their optical fiber infrastructure to support this growth.



References

- GR-1081-CORE: Generic Requirements for Field-Mountable Optical Fiber Connectors
- GR-326-CORE: Generic Requirements for Single Mode Optical Connectors and Jumper Assemblies
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- GR-264-CORE: Generic Requirements for Optical Fiber Cleavers
- GR-765-CORE: Optical Splices and Splicing Systems
- TIA-568C.3: Optical Fiber Cabling Components Standard
- FTTH Council APAC: <http://www.ftthcouncilapac.org>
- Jerry D. Jackson, "Mechanical Splice With Keyed Angle Cleave Fibers", 3M business white paper.
- Makoto Iwamatsu, Manabu Tabata, Yuya Kurosaka and Masashi Ishihara, "Optical Fiber Angle Cleaver", Fujikura Technical Review, 2011.
- Compatibility of Low Bend Singlemode Fibers, Huber Suhner white paper, October 2011

Biography



Dr. Bernard HL Lee is currently the Regional Technology Director at SENKO Advanced Components. He started his career in optical communications when he was appointed as a Senior Research Office for the European Union IST project known as DAVID in 2000. In 2003, he joined Telekom Malaysia R&D where he has held various technical and management positions there including the Head of Photonic Network Research and also Head of Innovation and Communications. Bernard then joined the parent company, Telekom Malaysia (TM) in 2010 as the Assistant General Manager of the Group Business Strategy Division where he oversees the company's business direction. Bernard obtained his RCDD accreditation in 2016. Bernard is also a member of the International Electrotechnical Commission (IEC), the Institute of Engineering and Technology (IET) and was also the Director of the Board of the Fiber-To-The-Home Council APAC. He is currently the Malaysia Country Chair for BICSI Southeast Asia.



Eric Staley is a Product Manager at SENKO Advanced Components and has been with the company since 2007. Prior to joining SENKO, he was involved in Sales with a major cable assembly manufacturer, a national distributor of electrical and communication products and has over 20 years of experience in the fiber optic industry.

GR-1081 FIELD



INSTALLABLE CONNECTORS

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