SUCCESSFUL MASS PRODUCTION OF HIGH PERFORMANCE SUBMARINE CABLES

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Abstract: The rapid evolution of recent optical communication systems towards higher bit rates and capacity has been accelerated by the advances in transmission technologies requiring high performance levels for each element of the system. In this paper we describe the successful cabling results of submarine cable equipped with Ultra Low Loss and Ultra Large Effective Area fibers. Recently, we obtained excellent optical attenuation results for a submarine cable applying optical fibers with Aeff 150 um^2, after actual field installation. Attenuation measurement was conducted over an optical path of approximately 164 km; with an average optical attenuation of 0.152 dB/km @ 1550 nm which was the same as the optical attenuation measured on the coiled cable at the production facility.

1. INTRODUCTION

To address the demands of recent higher bit rate optical communication systems, we completed the cabling evaluation and qualification for “Ultra Low Loss” and “Ultra Large Effective Area” fibers with excellent results.

For the deployment of recent high performance optical fibers over transoceanic distances, we successfully manufactured and delivered a few thousands kilometers of submarine cables over the 2014~2018 period. One concern about utilizing such “Ultra Large Effective Area” optical fibers was “Macro/Micro Bending Losses” introduced during cabling process but, we manage to finish mass production of cables and system integration works successfully, supported with results measured on “Coiled Cable” that were not in actual installed conditions.

In this paper, we present the optical attenuation data of mass production cables equipped with large effective area fibers. In addition, we present field data of optical attenuation during/after actual cable laying operations which is very unique for actual installation measurements.

2. OPTICAL SUBMARINE CABLE DESIGN

Our cable structure’s special features are that the optical fibers are directly cabled into the 3 divided steel segments tube. To achieve manufacturing of this cable, we have developed a state-of-the-art fiber insertion technology. The 3 divided steel segment structure is followed by a layer of stranded high strength steel wires, which is then covered with seam-welded copper tape that serves as both the hermetic barrier against moisture ingress and the power feeding conductor. The LW (Light Weight) cable structure is shown in Figure 1. The LWS and major armored cable variants structure are shown in Figure 2.

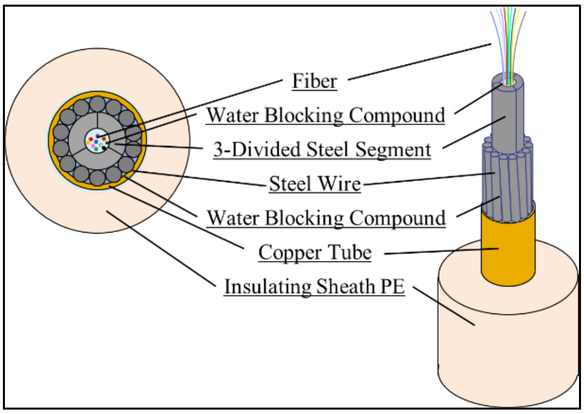

Figure 1: LW (Light Weight) Cable

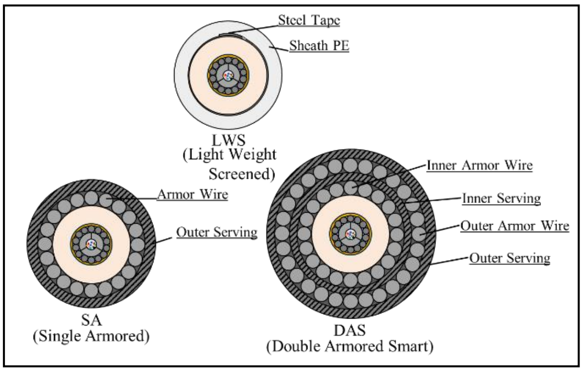

Figure 2: LWS and Major Armored Cable

3. OPTICAL ATTENUATION DATA OF MASS PRODUCED SUBMARINE CABLES

3.1. Attenuation of Cables with 130µm^2 fibers

We manufactured and delivered submarine cable equipped with 130µm^2 optical fibers over the 2014~2015 period. A summary of the mass produced cables' data is as follows;

Cabled Fiber Core Length:

approx. 118,000km

Effective Area on Average:

131.2µm^2@1,550nm

Cabled Attenuation on Average:

0.155dB/km@1,550nm (Refer to Figure 3.)

3.2. Attenuation of Cables with 150µm^2 fibers

In 2016 we started manufacturing cables for a new transoceanic project. This submarine cable system applies an optical fiber with a typical effective area of 150µm^2. A summary of the mass produced cables' data is as follows;

Cabled Fiber Core Length:

approx. 44,000km

Effective Area on Average:

150.3µm^2@1,550nm

Cabled Attenuation on Average:

0.154dB/km@1,550nm (Refer to Figure 4.)

3.3. C+L Band Attenuation of Cables with 110µm^2 fibers

One of the ideas that can fulfill the requirements for higher capacity in the future is the C+L band optical communication systems. Usage of broader optical communication bandwidth, not only C band (1530 – 1565nm) but also L band (1565 – 1625nm), will allow expanding the available spectrum and thus allow more carrier wavelengths.

Optical attenuation data on the C+L band, wavelength range from 1530 to 1625nm, was measured and collected during the mass production of submarine cables equipped with Aeff 110 um^2 (G.654. D) fibers, commonly utilized in several submarine cable systems. This attenuation measurement was performed on dozens of cable pieces totalizing approximately 48,000km in fiber cores. Figure 5 shows the typical attenuation data of C+L band measurement.

Cabled Fiber Core Length:

approx. 48,000km

Effective Area on Average:

114.2µm^2@1,550nm

Cabled Attenuation on Average:

0.152dB/km@1,550nm

0.155dB/km@1,590nm (Refer to Figure 5.)

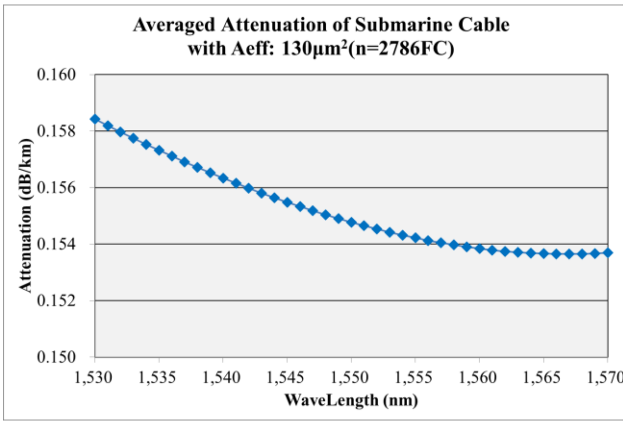

Figure 3: Averaged Attenuation vs Wavelength (Aeff: 130µm2)

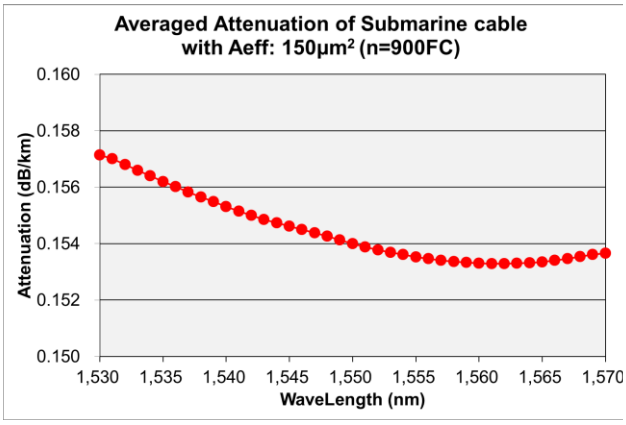

Figure 4: Averaged Attenuation vs Wavelength (Aeff: 150µm2)

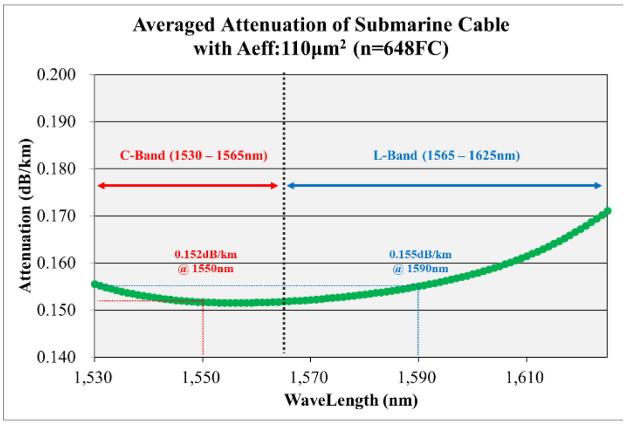

Figure 5: Averaged C+L band Attenuation vs Wavelength (Aeff: 110µm2)

4. FIELD DATA OF A CABLE WITH 150µm² FIBERS DURING/AFTER CABLE LAYING

We had a chance to measure optical attenuation during/after actual cable laying operations.

Although C-OTDR and spectrum measurement prior to installation is generally carried out to inspect system performance, measurement of optical attenuation during actual deployment conditions is unprecedented and a very unique challenge.

4.1. Cable

The submarine cable was equipped with optical fiber having large effective area of 150µm². The mechanical length of the submarine cable was approximately 82km that was finished with different types of protection. DAS: 2km, SA: 8km, LWS: 72km are applied on a 82km LW piece (Figure 6).

1fp of 150µm² fiber is used for measurement. We made a "loop splice" in the coupling housing of repeater, thus the length of fiber for measurement is double of cable length, approximately 164km. At the factory, this submarine cable was manufactured in "one piece" with inspection conducted at every step of manufacturing to allow tracing of any in-process variation. Also, submarine cable was coiled in a cable tank with a diameter of 15m, which is similar to that of cable ship for installation. However, during cable loading operations, we needed to cut this cable due to a typhoon approach to allow the cable ship to avoid the storm. Finally additional on-board Joint Box (JB) was inserted to re-build the cable span (Figure 7).

The submarine cable was laid from landing site towards open seas (Direct landing installation) within specified pulling tension (Figure 8), water depth is 0 to 3,800m as shown on the Bottom Profile of Figure 9. (The cable tension is carefully monitored during installation to control the touch down point as to follow the bottom profile.

Therefore cable tension value changes due to the various parameters (cable weight in water, catenary length, laying angle, ship speed, sea swell, etc.) that are measured to drive cable handling equipment on board. The cable tension has its highest value on top of the sheave, where also cable elongation is large and the risk of affecting the transmission properties of the fiber is a concern.)

Optical attenuation measurements were conducted by "Cut-Back Method" and "Two-Way OTDR" during and after the cable laying operation.

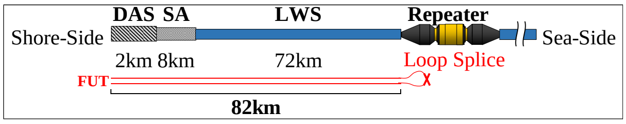

Figure 6: Submarine Cable Configuration, at Factory (before loading)

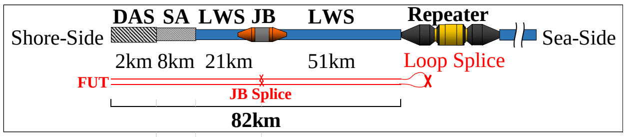

Figure 7: Submarine Cable Configuration, as Laid

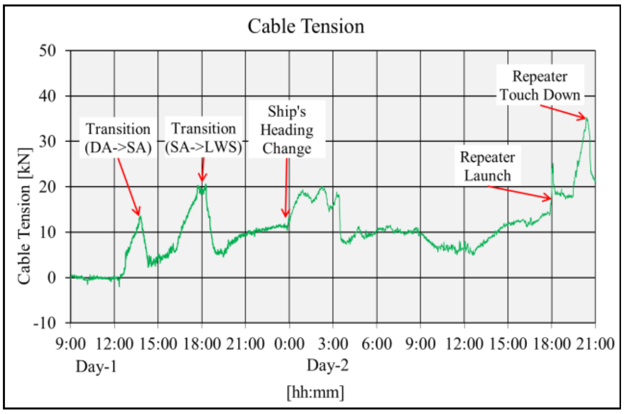

Figure 8: Cable Tension

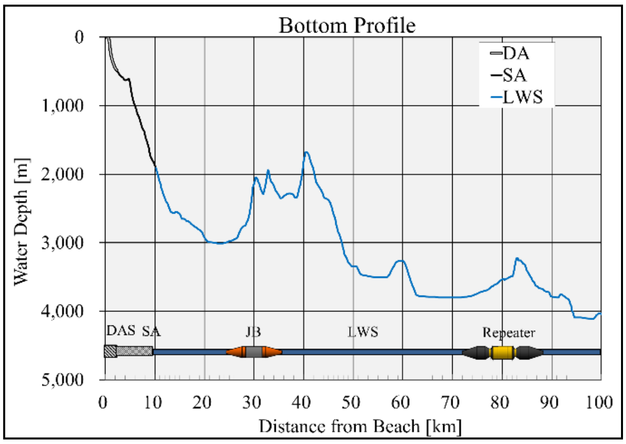

Figure 9: Bottom Profile

4.2. Measurement results

Optical attenuation measurement results are shown in Table 1. Optical attenuation at Factory, for reference, was measured on the cable coiled and without on-board JB. Attenuation During/After laying include extra value due to on-board JB inserted to re-build span (2 splices are added). The on-board JB splice loss in total (2 splices) was 0.09dB, which was measured by two-way OTDR. Optical spectral attenuation curves at different stages of the cable installation are shown in Figure 10. A small variation (attenuation increase) during laying was confirmed, and the attenuation increase is presumed to be caused by laying tension applied to the submarine cable portion between seabed touch down point and cable ship.

In the portion where tension/elongation is applied the condition of optical fiber temporarily changes and sensitively reacts. The optical attenuation increase due to "Microbending" occurred when fibers move and compress against each other. After laying operation, optical attenuation decreased to the same level measured at factory. We continued our measurements for 5 days after repeater laying and confirmed that optical attenuation along the entire measurement window was very stable. Also we measured optical attenuation during/after laying operation by OTDR at 1550nm (C-Band) and 1625nm (L-Band). Measurement result at 1550nm is shown in Figure 11. Before shipment, approximately one year has passed since cable manufacturing completion, with no increase in optical attenuation confirmed by pre-shipment measurement. Results shown in Figure 10 and Figure 11 prove that cable attenuation during laying is consistent with the ones measured at the factory and no additional feature nor irregular section appeared during handling of the cable.

	Optical Attenuation (dB/km)		Remarks
	@1550nm	@1590nm	
At Factry	0.153	0.154	Reference
During Laying	0.154	0.156	including JB-Spl.
After Laying	0.152	0.154	including JB-Spl.
After 5days	0.152	0.154	including JB-Spl.

Table 1: Optical Attenuation Results

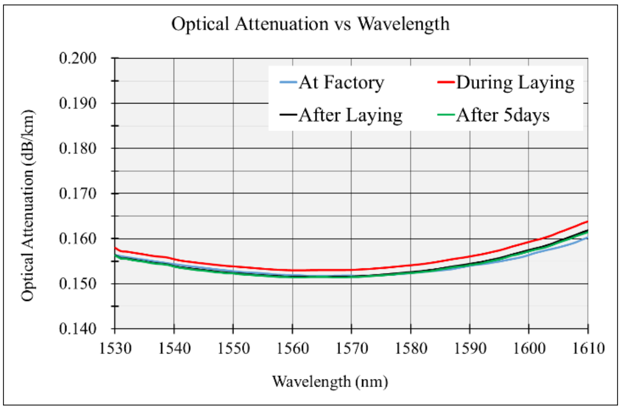

Figure 10: Optical Attenuation vs Wavelength

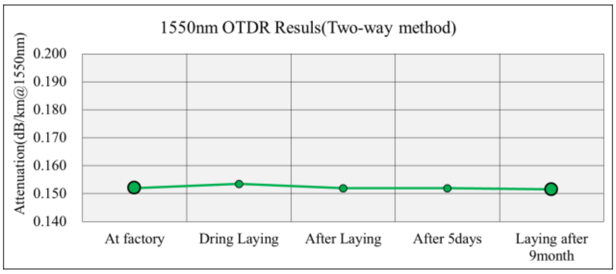

Figure 11: 1550nm OTDR Results (Two-way method)

5. CONCLUSION

We succeeded in the mass-production of submarine cable applying “Ultra Low Loss” and “Ultra Large Effective Area” fibers for one of the first transoceanic optical communication systems deploying such high performance optical fibers.

In addition, we also confirmed the mass production performance over C+L band of submarine cables equipped with Aeff 110 um^2, aiming to expand the available optical communication bandwidth. The results confirmed that at 1590nm the optical attenuation of multiple fiber core and standard deviation were at the same level as that at 1550nm. This fact on C+L band verification is a big step moving forward to achieve the C+L band transmission ready submarine cables.

Finally, we obtained excellent optical attenuation results for submarine cable equipped with optical fibers with effective area of 150μm^2 after actual laying operations. Optical attenuation at 1550nm was 0.152dB/km, the same value as is confirmed on “coiled cable” at factory. With all those data sets, we confirmed that optical attenuation was very stable throughout the time period from system assembly completion to field installation. Additionally cable joints and coupling are sufficiently robust to withstand laying and handling without degrading the optical performance of the system.

These results show that our cable design is capable of delivering all the properties of high end optical fibers to realize high bit rate systems of 100Gb/s and higher.

6. ACKNOWLEDGMENT

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7. REFERENCES

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