

WHITE PAPER



ITU-T G.654.E Fiber, PureAdvance for Terrestrial Long-Haul Networks

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1. Introduction

Growth of global data traffic demand is driving continuous requirements for higher capacity optical transmission systems. To support these high capacity systems in terrestrial backbone networks, low attenuation and large core area fibers compliant with Recommendation ITU-T G.654.E were introduced and have been extensively deployed worldwide. G.654.E fiber is suitable for long-haul high-capacity terrestrial optical transmission links, supporting to maximize the transmission performance at minimum total system cost. Sumitomo Electric Industries, Ltd. developed and supplies PureAdvance-110 and PureAdvance-125 exhibiting ultra-low attenuation of 0.16 dB/km or less, which are fully compliant with ITU-T G.654.E.

In this whitepaper, we review ITU-T G.654.E fibers from various points of view; what G.654.E is, what the application of G.654.E is, why G.654.E fiber is suitable for terrestrial long-haul networks, and how much performance improvement will be expected. We also introduce PureAdvance-110 and PureAdvance-125, terrestrial long-haul fibers compliant with ITU-T G.654.E.

2. What is G.654.E?

G.654.E fiber is a fiber featuring low attenuation and large core area, and is best suited for terrestrial long-haul and high-capacity transmission links.

Recommendation ITU-T G.654, "Characteristics of a cut-off shifted single-mode optical fiber and cable"⁽¹⁾ describes a cut-off shifted fiber and cable which is attenuation-minimized at wavelengths around 1550 nm, and optimized for use in the C- and L-bands (1530 – 1625 nm). Since ITU-T G.654 was originally established in 1988, ultra-low attenuation and large core area G.654 fibers have been widely used in submarine cables.

G.654.E was introduced in 2016 as a new category of G.654 in order to significantly improve the optical signal-to-noise ratio (OSNR) performances to support 100 Gb/s and beyond 100 Gb/s digital coherent transmissions in terrestrial deployments. Since then, G.654.E fibers have been extensively deployed in terrestrial networks worldwide including long-haul backbone links. Table 1 shows excerpts from the attributes of ITU-T G.654.E and G.652.D. G.654.E features low attenuation and large mode field diameter (MFD), whereas the macrobending loss performance is kept as the same as that of G.652.D.

Sumitomo Electric developed and supplies terrestrial long-haul fibers, PureAdvance-110 and PureAdvance-125 fully complying with ITU-T G.654.E. By applying Sumitomo Electric's matured pure-silica core fiber technologies that have been cultivated since the first launch of submarine fibers in 1989 to the manufacturing, PureAdvance-110 and PureAdvance-125 realize ultra-low attenuation of 0.16 dB/km or less (typically 0.156 dB/km) at 1550 nm ⁽²⁾, which exhibits the world's lowest attenuation among commercial terrestrial fibers today, to the best of our knowledge. PureAdvance-110 and PureAdvance-125 also have large effective areas (A_{eff}) of 110 and 125 μm^2 typically at 1550 nm, respectively, whereas that of G.652.D standard single mode fiber (SSMF) is typically 80 μm^2 .

Table 1 Attributes of ITU-T G.654.E and G.652.D (Excerpt)

	ITU-T G.654.E	ITU-T G.652.D
Mode field diameter (MFD) @1310nm [μm]	-	8.6-9.2 (± 0.4)
Mode field diameter (MFD) @1550nm [μm]	11.5-12.5 (± 0.7)	-
Effective area (A_{eff}) @1550nm [μm^2]	Typ. 110-125*	Typ. 80*
Cable attenuation @1550nm [dB/km]	≤ 0.23 (Cabled)	≤ 0.3 (Cabled)
Macrobending loss ($r=30\text{mm}$) @1625nm [dB/100turns]	≤ 0.1	≤ 0.1
Cable cut-off wavelength [nm]	≤ 1530	≤ 1260

*: Typical value. A_{eff} is not specified in ITU-T Recommendations.

3. What is the application of G.654.E fiber?

G.654.E fiber can be used for various applications in terrestrial optical networks, including

- telecom trunk lines,
- datacenter interconnect (DCI),
- submarine cable landing,
- shallow sea cables,
- optical core along with power cable,
- repeaterless transmission systems for remote areas,
- quantum cryptographic communication systems, and
- other optical transmission systems that require low attenuation.

G.654.E fiber is also applicable to highly spectrally-efficient digital coherent DWDM transmission systems with the bit rate per channel of 100 Gb/s, 200 Gb/s, 400 Gb/s, 600 Gb/s, 800 Gb/s and beyond, in the C-band (1530-1565 nm) and L-band (1565-1625 nm).

4. Why is G.654.E suitable for terrestrial long-haul applications?

G.654.E fiber featuring low attenuation and large A_{eff} can significantly increase the OSNR.

OSNR, optical signal-to-noise ratio, is a power ratio of the optical signal to the noise after transmitting through an optical link. Higher OSNR is required for obtaining a better signal quality, and the required OSNR increases as the bit rate increases and/or as the transmission distance increases. For example, 7dB-higher OSNR will be required theoretically for upgrading the bit rate from 100 Gb/s QPSK to 200 Gb/s 16QAM at the same transmission distance (Fig. 1). 3dB-higher OSNR will also be required for increasing the transmission distance twofold with the same bit rate.

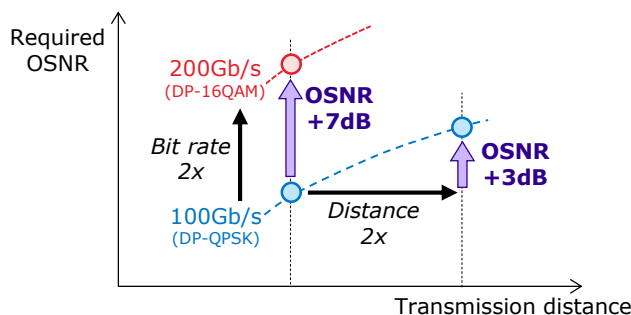


Fig. 1 Increase of required OSNR due to increase of bit rate and increase of transmission distance.

Figure 2 shows a schematic view explaining why low attenuation and large A_{eff} of a G.654.E fiber can improve the OSNR. Lower attenuation can directly increase the signal output power for the same input power. On the other hand, signal input power is limited to a certain level, because the signal quality may be degraded by nonlinear impairments in an optical fiber if the signal input power is too high. Larger A_{eff} fiber can reduce the fiber nonlinearity, and hence is more tolerant to higher input power. Therefore, both low attenuation and large A_{eff} of G.654.E fiber can effectively increase the OSNR.

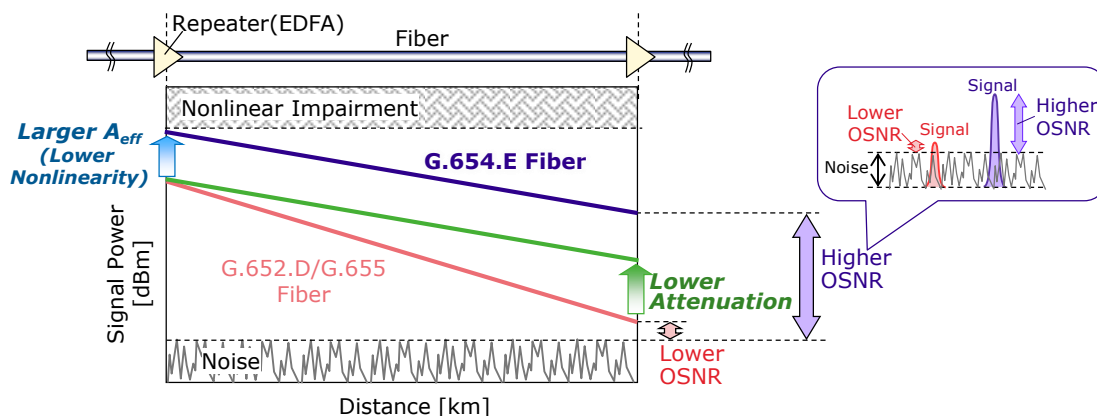


Fig. 2 OSNR improvement by lower attenuation and larger A_{eff} of G.654.E fiber.

5. How much performance improvement will be expected with G.654.E fiber?

Figure 3 gives an example of OSNR improvement (Δ OSNR) compared to G.652.D SSMF, where OSNRs for several types of fibers are calculated using Fiber Figure-Of-Merit ^{(3),(4)}. The horizontal axis is the span length between repeaters (EDFAs). From Fig.3, PureAdvance-110 and PureAdvance-125 show the best performance among the fibers at any span length. The Δ OSNR is about +2.0 to +4.0dB for the span length of 40 – 120 km.

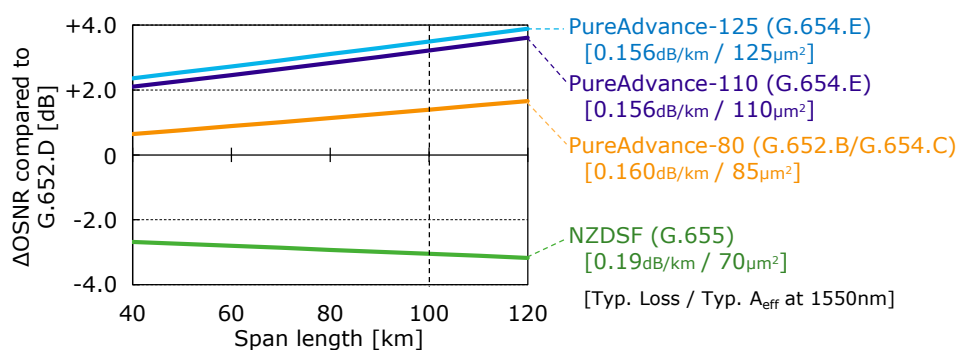


Fig. 3 OSNR improvement for G.654.E and other fibers compared to G.652.D SSMF.

Calculated transmission distance for 200 Gb/s 16QAM DWDM signals on each fiber with the span length of 100 km is shown in Fig.4. The result shows that PureAdvance-110 and PureAdvance-125 enable much longer distance by a factor of 2.1 compared to G.652.D SSMF, and by 4.2 compared to NZDSF, respectively.

Ultra-low attenuation G.654.E fiber is beneficial for constructing high quality transmission systems at a low overall cost. An example of the scenario is shown in Fig. 5. Here we consider a transmission link with the reach of 1,000 km and the span length between repeaters of 100km, where 200 Gb/s DWDM

signals are transmitted. G.652.D SSMF of which transmission distance is limited to 530 km as shown in Fig. 4 will require one regenerator station to transmit the signals over the 1,000 km reach. On the other hand, PureAdvance-110 or PureAdvance-125 can transmit 200 Gb/s signals more than 1,000 km without regenerator station. Since regenerator equipment is needed for each DWDM channel, a huge number of regenerator equipment (number of DWDM channels x number of fibers in cable x number of cables) are needed at one regenerator station. Therefore, PureAdvance-110 and PureAdvance-125 enable to construct long-haul optical transmission systems at a low overall cost, by reducing the required number of regenerator stations.

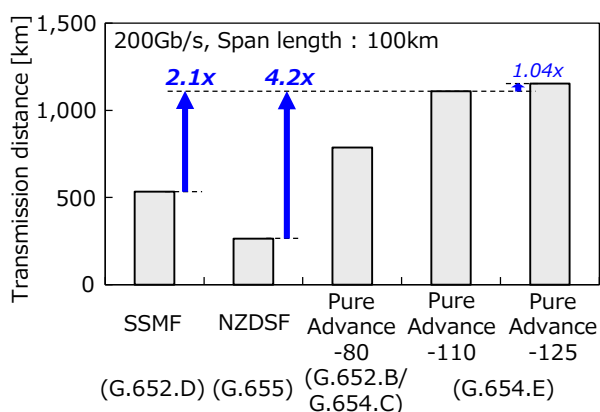


Fig. 4 Transmission distance of 200Gb/s signals for G.654.E and other fibers.

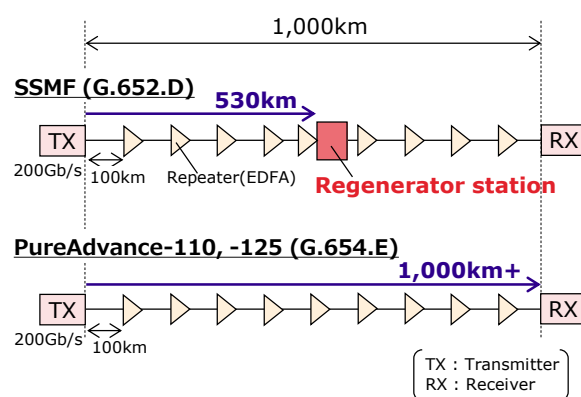


Fig. 5 Example of application scenario of G.654.E fiber; 200Gb/s transmission link.

6. Conclusion

ITU-T G.654.E fiber has low attenuation and large core area, enabling to effectively improve the OSNR of a transmission link, and is the best suited for high-capacity terrestrial networks. Sumitomo Electric's ultra-low attenuation ITU-T G.654.E fibers, PureAdvance-110 and PureAdvance-125 are beneficial for constructing terrestrial long-haul high-capacity optical transmission systems at a low cost.

PureAdvance is a trademark or registered trademark of Sumitomo Electric Industries, Ltd.

References

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