SUBMARINE SYSTEMS DESIGN BASED ON MARGIN EVALUATION

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Abstract: Submarine optical networks are responsible for the intercontinental network of terrestrial networks; therefore, it is necessary to respond to the changes in the demands of the networks.
There has been a change in the concept of reliability of submarine networks, and several changes have been suggested in new operation methods and configurations of underwater equipment.
Recent advances in optical transmission technology have led to the improvement of reception sensitivity and reduction in degradation due to transmission. Without any replacement of hardware, a modulation that allows modulation format to be changed is possible, and the combination of bit rate and reception sensitivity can be changed.
Based on a contract margin design, the conventional optical communication network system design guarantees the provision of a contract transmission capacity. Here, we demonstrate a design whereby the margin required for monitoring deterioration and operation is temporarily changed to realize the modulation format associated with optimal capacity thereby securing a margin against sudden sensitivity deterioration.
Based on a design at 8000 km transmission distance, we showed that 350 Gbit/s can be increased to 400 Gbit/s. This method is effective for transponders with relatively small granularity.
In a system including an optical branching unit in a submarine optical network, there is the danger of fiber disconnection due to impact from ships or earthquakes. If a fiber breaks, the optical power of the signal remaining in the network may rise and the signal quality may deteriorate until the fiber is repaired. Optimization of fiber nonlinear penalty compensation circuit suppresses the deterioration of signal quality caused by an increase in optical power and enables errorless transmission even before idler light level is readjusted.
This shows that the transmission capacity can be effectively changed by changing the modulation scheme in submarine networks.

1. CAPACITIY EXPANSION WITH MODULATION FORMAT OPTIMIZATION

1.1 Transmittable distance and transmission capacity

Following the increase in terrestrial communication operations, such as communication transmission, video distribution services, and data center networking, optical communication networks are required to tackle installation and enable expansion in a short period of time. Moreover, flexibility in handling the rapid change in capacity demand is important.

Submarine optical networks enable intercontinental connection of terrestrial networks; therefore, it is necessary to respond to changes in the demands of the networks.

There is also a change in the concept of reliability for submarine networks, and changes have been suggested in new operation methods and configurations of underwater equipment.

Recent developments in optical transmission technology have led to advanced technologies for improving received sensitivity and reducing degradation due to transmission. Without further hardware replacement, a modulation that allows change in modulation format is possible, and the combination of bit rate and reception sensitivity can be changed.

Based on a contract margin design, the conventional optical communication network system design guarantees provision of a contract transmission capacity is guaranteed. Here we demonstrate a novel design whereby the margin required for monitoring deterioration and operation is temporarily changed to realize the modulation format associated with optimal capacity, thereby securing a margin against sudden sensitivity deterioration.

Application of the wavelength selective switch (WSS) used in the reconfigurable optical add/drop multiplexer (OADM) of the terrestrial system to the submarine network system is also studied.

Although this may be a flexible operation and fault tolerance may be improved, the fault allocation margin may increase.

Recent developments in optical transmission technology have resulted in advanced technologies for improving received sensitivity and reducing propagation impairment. Without replacing hardware further, scientists have been able to apply a modulation that allows modulation format to be changed, and it has become possible to change the combination of bit rate and received sensitivity.

An illustration of the relationship between the transmittable distance and the transmission capacity per wave is shown in Fig. 1.1. We considered the margin necessary for the design here. In the current technology, 350 Gbit/s at 8000 km and 300 Gbit/s at 10000 km can be applied. Furthermore, 350 Gbit/s can be realized by a temporary combination of the two modulation methods. By hybrid modulation, a system with a granularity of 50 G can be configured. Changing the ratio of combination allows even smaller granularity.

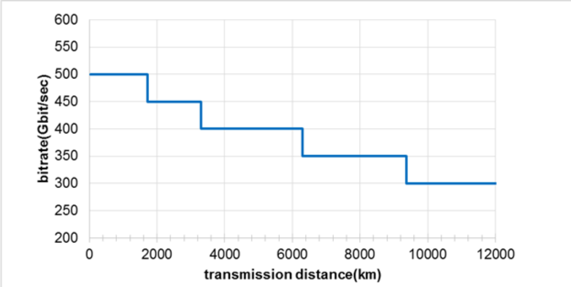

Fig. 1.1. Transmittable distance vs transmission capacity

1.2 Temporary margin reduction

In addition to the initial characteristic variation, the margin considers the temporary characteristic deterioration of the system, the characteristic change for a relatively short time, and the margin for maintenance. Deleting temporary margins can be estimated by physical monitoring at terminal stations, analyzing phenomena, and estimating signs of deterioration.

After system operation, the initial characteristic variation becomes clear. The margin of cable repair does not need to be used until cable fault occurs, and time deterioration can also be slightly mimicked by delimiting the period.

The re-examination of margin is often used to extend the regenerator section on terrestrial systems. On the other hand, in a submarine system with fixed segment length, the transmission capacity can be temporarily increased by changing to a modulation scheme with large capacity. When a cable fails or when it becomes necessary to review aged deterioration, it is necessary to return to the original design configuration.

A non-allocated margin for a design at 8000 km transmission distance is shown in Fig. 1.2.

There is a positive margin of +0.6 dB at 350 Gbit/s, but it is insufficient by 1 dB to set it to 400 Gbit/s. By design, it is possible to change to 400 Gbit/s by using the margin for maintenance.

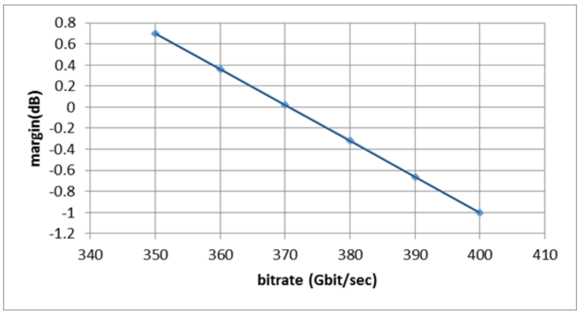

Fig. 1.2. Non-allocated margin for design at 8000 km transmission distance

1.3 Granularity

To increase the capacity with this method, the granularity of the modulation scheme plays a role.

When the granularity is large, a temporary modification of large margin is required to change to a modulation method with large capacity.

The relationship between the maximum modification amount and granularity size is shown in Fig. 1.3. If the granularity is small, the correction margin required for changing the modulation scheme is small. On the other hand, to prepare a modulation method with a small grain size, it is necessary to improve the functionality of the transponder, and optimization is also necessary.

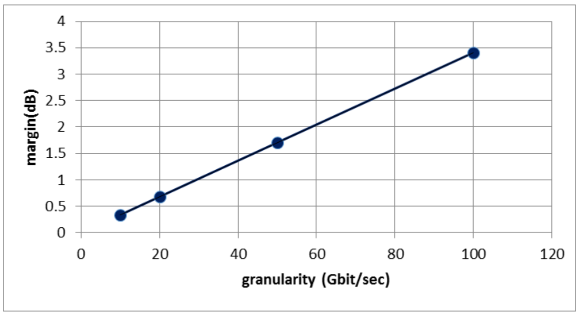

Fig. 1.3. Granularity and maximum correction margin

2. REDUCTION OF PENALTY WHEN FIBER RUNS OUT

In the submarine cable system, to optimize long-distance transmission, the optical repeater is optimized on the assumption of operation with constant light input/output so that a high optical signal to noise ratio (OSNR) can be obtained. When the wavelength on which the signal is placed is less than the design light input, idler light is prepared to enter the repeater. Recent systems cut ASE light with WSS and use it as the idler light of the required band and power.

An OADM configuration using WSS is also introduced for light branching of submarine cable. In addition, there is one that performs multiplexing/demultiplexing with a fixed wavelength filter.

In the OADM configuration, when the fiber on the trunk side is broken, the power level of the signal input from the branch side rises, and the signal quality may deteriorate due to optical nonlinearity phenomenon.

In the system with the WSS-OADM configuration, by changing the transmission characteristics of the optical branch WSS and inserting the idler light from the branch side, it is possible to suppress an increase in the power level of the optical signal from the branch side.

However, in a system with ADM configuration using a fixed filter, sufficient idler light cannot be newly inserted from the branch side.

For a system in which a high Q value cannot be obtained by optical nonlinearity, a nonlinear compensation circuit is designed to suppress nonlinear degradation and obtain a high Q value in a high OSNR state obtained with high optical power [1]. Even when the optical power rises following the disconnection of the fiber, degradation of the Q value can be suppressed by setting the parameters of the compensation circuit from the monitoring system and activating the circuit.

Figure 2.1 illustrates the effect of the nonlinear compensation circuit in the DMF. The nonlinear compensation circuit improves the Q value by about 1 dB at the point where it is about 2 dB higher than the optimum signal power without circuit operation. Even in the case of a power rise of about 4 dB from the optimum signal power, a Q value close to the optimum Q value in the case of no circuit operation can be secured, and communication in normal operation can be made up to cable repair.

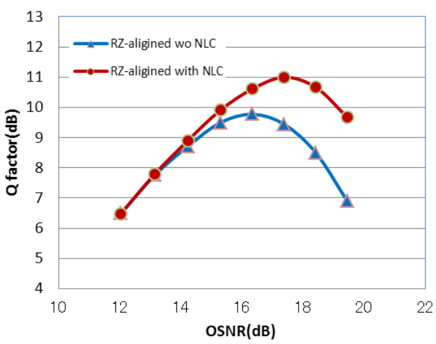

Fig. 2.1. Transmission characteristics using nonlinear compensation

3. CONNECTION WITH TERRISTRIAL NETWORK

Submarine networks must also be optimized along with terrestrial networks.

In the case of the configuration as shown in the Fig. 3.1, let station_1 (S1) and station_2 (S2) be one group and station_3 (S3) and station_4 (S4) be another; they are all on the same shore, but the groups are separated by the sea. The case of the complete graph is shown in Fig. 3.1, as well as the case of using the SW within the submarine cable.

When the S1–S3 section is sufficiently longer than the S1–S2 section, the cable length difference between the former and the latter networks becomes smaller.

The former, S1–S3, can occupy the signal band of the fiber.

The latter can change the allocation of capacity from S1 to S3 and S4.

By concentrating on either of S3 and S4, the signal band for two fibers can be used, and the temporary capacity change can be addressed.

To change the margin when going through T2, the temporary margin change mentioned can be applied.

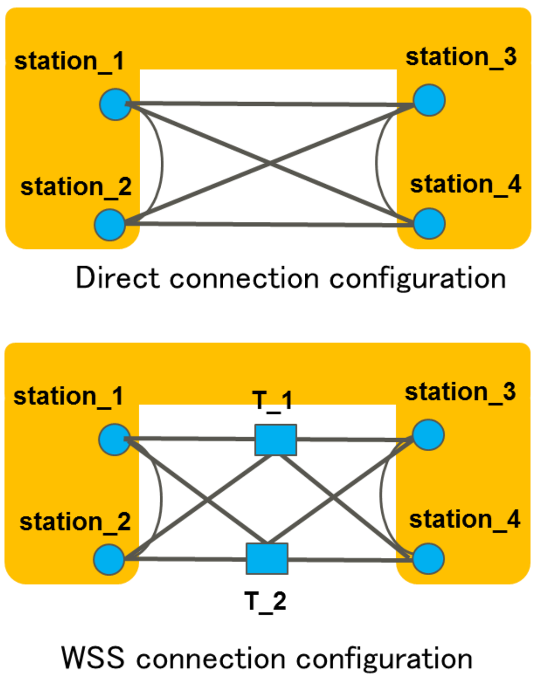

Fig. 3.1. Submarine network model

4. CONCLUSION

We showed that communication capacity can be expanded by temporarily decreasing the margin.

Using a nonlinear compensation circuit, we showed that the penalty associated with power rise at fiber failure can be reduced.

5. REFERENCES

[1] Suboptic2016 Nakamoto *et al*., "Improvement of submarine system transmission using 100 Gbit/s DP-QPSK with legacy fiber types by utilizing nonlinear compensation algorithm"

