The Study on Tunable-SFP for Optical Transport Network for 5G Service

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***Abstract*—**With the launch of 5G services, new networks are constantly required to increase data traffic and eliminate bottlenecks. Accordingly, the optical communication network for 5G needs to continuously evolve to a high-speed, high-capacity, infrastructure to provide high-quality service. However, due to the limited number of fiber cables, the maximum capacity extension that can be transmitted is limited. To solve this problem, a new optical transport network configuration solution must be studied. Therefore, the adoption of DWDM(Dense Wavelength Division Multiplexing) scheme, which is most advantageous for increasing the data capacity among the various optical communication network technologies proposed to date, is rapidly increasing.[1] However, because DWDM is advantageous in capacity, but requires a large number of wavelengths, DWDM SFP optical module inventory per channel can accumulate, leading to an increase in inventory costs. In order to solve this problem, we applied wavelength tunable SFP(T-SFP) which can realize more than 16 channels with one SFP module and summarized the results of study on tunable SFP.

Keywords—5G Service, Tunable-SFP, Optical Transport Network, Fronthaul

I. Introduction

The WDM system conforms to the promised wavelength and channel allocation in accordance with ITU-T G.695 CWDM(Coarse Wavelength Division Multiplexing) or G.694 DWDM as defined by the International Telecommunication Union(ITU) as an international standard.[2] In the 5G optical transport network being built by SK Telecom, various multimedia high capacity signals are transmitted through one optical fiber, and a tunable SFP is applied to improve the efficiency of the wavelength used in each service.

This is a method to maximize the efficiency by overcoming the limitation of the optical fiber and the wavelength number that can be used.In addition, the optical transport capacity can be maximized by dividing the multiservice into 16 channels within 100 GHz channel spacing within +/- 7.5 nm of one wavelength band.

In this paper, we evaluate the applied SFP, identify the operational factors of the stable optical transport network, derive objective numerical values, and propose a method to solve the weak points.

II. 5G Optical Network Architecture

For 5G service, SK Telecom is operating PON(Passive Optical Network) with wavelength tunable technology in last-mile network. This maximizes the use of transport capacity by combining wavelength division method of CWDM and DWDM. The wavelength tunable SFP has been optimized to improve the efficiency of the optical fiber and the wavelength used and the quality of the operation service by transmitting multiple large capacity services such as 4G (LTE) and 5G.

The tunable SFP used for the 5G optical transport network can use up to 16 wavelengths in the CWDM band from 1270 nm to 1610 nm. If only 12 wavelengths are used, a total of 96 lines can be constructed by implementing 8 or 16 lines per wavelength. In the PON for 5G service, a transmission rate of 10Gbps will be used per line. Figure 1 below shows the basic structure of the 5G optical transport network. Figure 2 shows the structure of the line monitoring function added here.

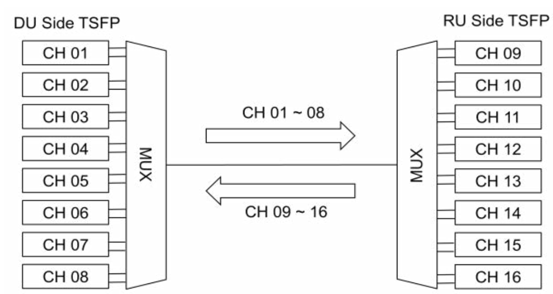

Fig. 1. 5G optical fiber direct connection network configuration

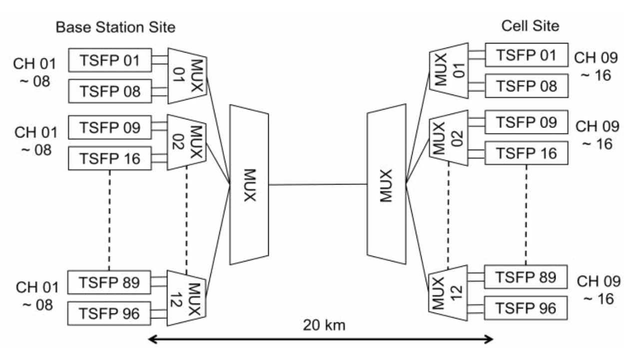

Fig. 2. 5G optical Fiber monitoring network configuration

III. Structure and Understanding of Tunable SFP

The light output from the semiconductor gain chip is diverted through the optical waveguide with the built-in thermoelectric element such as a micro heater. The transport wavelength is adjusted to a desired value according to the change of the micro heater current in the optical waveguide. In other words, the wavelength is changed by the change of the refractive index of the optical waveguide.[3][4] In order to change the refractive index, a micro heater is built in the waveguide.[5]

As a result, the voltage / current value of the heater control circuit changes due to the temperature change of the micro-heater, which changes the refractive index of the waveguide and changes to a desired wavelength.[6] The basic structure of the tunable transmitter is shown in Figure 3 below.

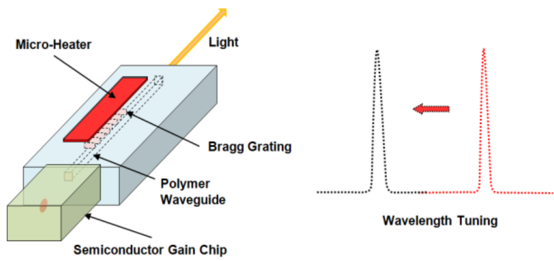

Fig. 3. Figure 3. Basic Configuration of Tunable SFP

The wavelength tunable SFP can be divided into 16 channels with 100GHz channel spacing within one wavelength band +/- 7.5nm, so that it is possible to implement a total of 8 lines or 16 lines with one SFP type, thereby allows for maximum network design and operational efficiency.

The 16 channels assigned to one wavelength band are shown in Fig. 4 below.

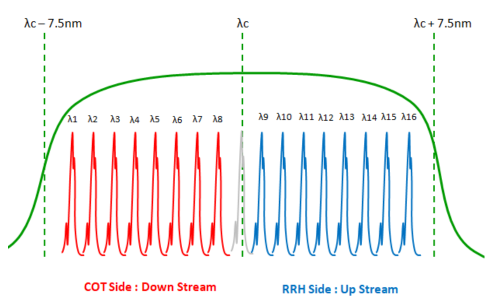

Fig. 4. Channel assignment within one wavelength band

IV. Experiment and Evaluation of Wavelength Variable SFP Method

In case of PON network for 5G service operated by SK Telecom, 16 lines communicate in two directions within one wavelength of CWDM wavelength. However, in order to eliminate the suspicion of stable wavelength tuning and locking operation for wavelength tunable SFPs, direct or indirect factors have been verified and evaluated from various perspectives.

In the case of internal / external influences, experiments and evaluations are conducted on each item as shown below, and experiments and evaluations are performed to eliminate the doubts that are currently occurring. In addition, evaluation of each item is performed by placing one SFP into the chamber using a temperature / humidity chamber and adjusting the temperature and humidity.

- Evaluation of Wavelength Stability of Variable SFP with Temperature Variation
- 20km Transmission Test Evaluation of Tunable SFP

A. *Evaluation of Wavelength Stability at Temperature Variation of Tunable SFP*

The basic evaluation scheme is shown in Fig. 5, and the temperature / humidity condition of the DUT(Device under Test) chamber is shown in Fig. 6. The source DUT and the measurement DUT are wavelength-tuned according to each channel, and the wavelength stability of the tunable SFP is evaluated by wavelength location analysis of the optical signal monitored by the optical coupler according to the channel of each wavelength band using the Optical Spectrum Analyzer. In addition, an error / alarm analyzer is used to check whether an error has occurred at the same time.

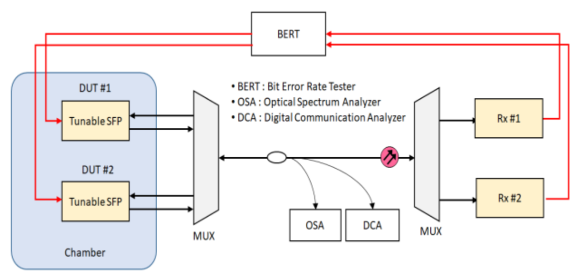

Fig. 5. Wavelength stability evaluation scheme

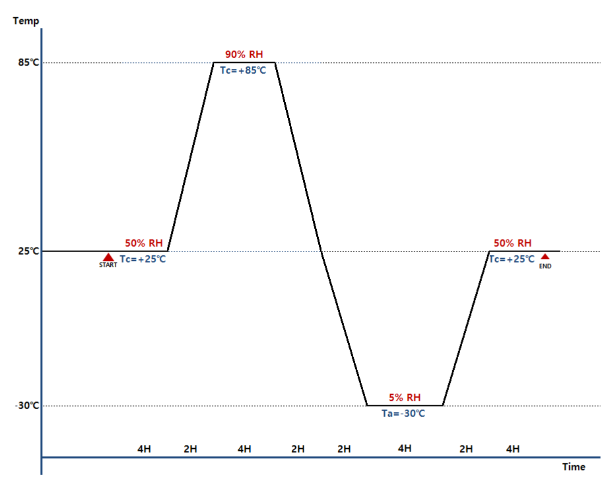

Fig. 6. 24hrs Chamber on / humidity condition of measured DUT

Two DUT samples for measurement were used, channel 5 of 1330nm and channel 12 of 1510nm. The center wavelength of channel 5 of the first sample 1330nm is 1327.652 nm, and the range of wavelengths to be satisfied is +/- 0.16 nm(min1327.492 nm, max1327.812 nm) considering the passing range(+/- 0.2nm) of the multiplexer. The center wavelength of channel 5 of the second sample 1510nm is 1505.336nm, and the range of wavelengths to be satisfied is +/- 0.16 nm(min 1505.176nm, max 1505.496nm) considering the passing range(+/- 0.2nm) of the multiplexer.

As a result of the evaluation, the wavelength of the measured DUT is stably maintained within +/-0.16 nm. Also, as shown in Fig. 8, no error has occurred in the error/alarm analyzer and it is confirmed that it operates stably.

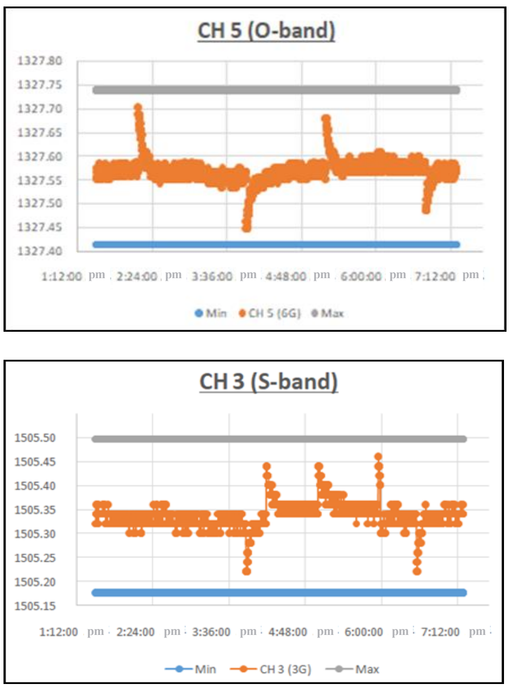

Fig. 7. Wavelength stability evaluation result

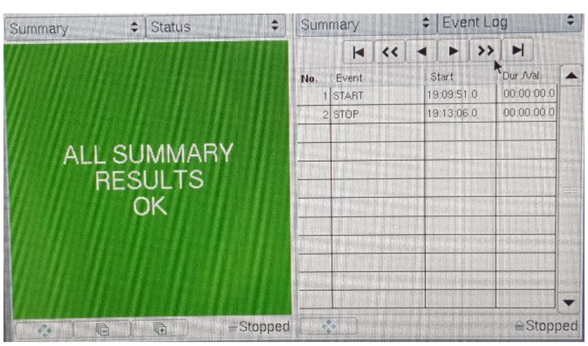

Fig. 8. Error / alarm status

B. 20km Transmission Test Evaluation of Tunable SFP

The basic evaluation scheme is shown in Fig. 9, and the temperature / humidity conditions of the DUT chamber are the same as in Fig. 6

The source DUT and the measurement DUT fix the wavelength for each channel, and the optical signal intensity monitored through the optical coupler for each channel is subjected to transmission sensitivity test and 20Km transmission test through optical power meter. Also, an error / alarm analyzer is used to simultaneously check whether an error has occurred or not.

For reference, the optical fiber loss of the actually installed SFP is 0.4dB/km in O-BAND and 0.2dB/km in C-BAND. In addition, chromatic dispersion is little in the O-band, but it is 17 ps/nm /km in the C-band and there is about 2dB of optical loss in order to transmit 20Km at 6Gbps of C-BAND. On the other hand, in order to transmit 20 km at C-band 10Gbps, optical dispersion compensation must be performed using DCF (Dispersion Compensation Fiber) or EML (External Modulated Laser)[7][8]

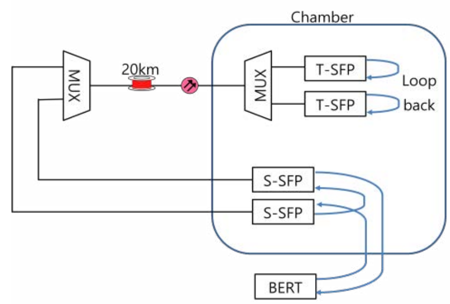

Fig. 9. 20km transmission test evaluation configuration

Measured DUT samples were used at a total of two types: 3Gbps and 6Gbps of 1510nm. As a result of the basic characteristics of the first sample, 3Gbps of 1510nm, optical output power was 5.4dBm, ER was 7.4dB, and Mask Margin was 45.2%. As a result of the basic characteristics of the second sample, 6Gbps, optical output power was 5.3dBm, ER was 5.6dB, and Mask Margin was 30.8%. This result satisfies both optical output power of +2.0 ~ + 8.0dBm, ER> 4dB, and mask margin> 10%.

The result was evaluated by measuring the Transmission Eye diagram characteristic of the measured DUT as shown in Fig. 10 below.

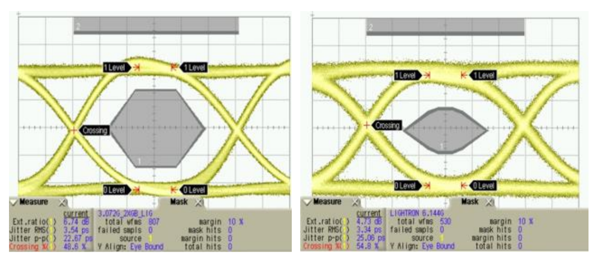

Fig. 10. Eye Diagram evaluation result of measured DUT(left: 3Gbps, right: 6Gbps)

Also, in the optical cable transmission test of 20 km, the measurement DUT confirmed the error free under the Ber10^{-12} reception sensitivity condition. It satisfies the reception sensitivity of 3Gbps<-27.5dBm and 6Gbps<21.5dBm. The error was evaluated as shown in Table 1 below. We also confirmed that no error occurred in the error/alarm analyzer.

TABLE I. RECEIVE SENSITIVITY OF MEASUREMENT DUT AND EVALUATION RESULT OF 20KM TRANSMISSION

Bit Rate	Rx Input Power (dBm)	Measuring time	Error Free
3Gbps	-28.5	7 minutes 29 seconds	OK
	-29.0	7minutes 10seconds	OK
	-28.5	7minutes 11seconds	OK
	-28.5	6minutes 45seconds	OK
6Gbps	-24.5	3minutes 10seconds	OK
	-24.5	3minutes 9seconds	OK
	-23.0	3minutes 5seconds	OK
	-22.5	3minutes 9seconds	OK

V. CONCLUSION

The PON network for 5G service built by SK Telecom is equipped with 3Gbps and 6Gbps tunable SFP. This will be a reference for 5G optical transport network for over 10Gbpstunable SFP application in the future.

This reduces the burden on optical module stock, reduces operating costs, increases network wavelength efficiency, and overcomes the limitations of wavelength management.

However, for 5G optical transport network service, it is necessary to review the potential obstacles to wavelength tunable errors in advance. Therefore, in this paper we have looked at these potential obstacles and found that there are no problems.

In order to increase the wavelength stability between DU(Digital Unit) and RU(Remote Unit) when applying tunable SFP to 5G network, it is necessary to maintain more than +/-0.2nm to pass the band-pass range of the multiplexer set to 100GHz channel spacing. If the channel spacing is narrowed to less than 100, it must be verified in advance whether there is a wavelength stability problem that may occur during operation.

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