Transoceanic Transmission over 11,450km of Installed 10G System by Using Commercial 100G Dual-Carrier PDM-BPSK

Ling Zhao, Hao Liu, Jiping Wen, Jiang Lin, Yanpu Wang, Xiaoyan Fan, Jing Ning
Email: zhaoling0618@huaweimarine.com

Huawei Marine Networks Co., Limited / HuaWei Bld., No.3 Xinxi Rd., Shang-Di Information Industry Base, Hai-Dian District Beijing 100085, P.R. China

Abstract: We demonstrate the transmission of 100Gbps DC-PDM-BPSK over deployed 11,450km transoceanic dispersion-managed link with EDFA amplification. The mixed transmission of 10G/100G traffic is mandatory. All upgraded channels can meet the final acceptance standard with robust stability. In addition, we show that simulation plays an essential role in the process of system capacity prediction and upgrade. The differences in *Q*-factor after transmission between simulation and test are within 0.4 dB. This is a successful demonstration of upgrade from 10G to 100G over one of the longest transoceanic networks.

1. INTRODUCTION

Nowadays, with the explosive growth of the high speed data communication, broadband connections services, and broadband video, network capacity needs to increase in line with such bandwidth hungry applications. It is well known that, there exists a tradeoff between network capacity and reach, high capacity on short distances or low capacity on long distances. How to improve both capacity and reach has attracted considerable attention.

So many researchers and scholars from worldwide different organizations devote themselves to seeking for the possibility about long distance with huge capacity. Some related academic papers have been reported in these years. 20chs 100Gbps PDM-QPSK tranmit 14400km link with 100km single type fiber spans, there is no system margin[1]. 106chs 200Gbps PDM-16QAM transmit 10290km with about 60km single type fiber spans[2]. 50Gbps PDM-QPSK transmit 10080km system with about 60km single type fiber spans to demonstrate the mitigation of intra-channel nonlinearities [3]. From those papers, there is one thing that should be pointed out. Most of researches are only suitable for single fiber systems which use ultra-low attenuation and large effective area fibers. So far the majority of the existing submarine cable systems that have requirements about capacity upgrade are not such kind of sytems. These systems still operate in 10G, 40G, and partial 100G services. With the advent of advanced technology and ever-increasing demand for network capacity, there will be several upgrades on the installed submareine transmission links by using more advanced modulation format during the system design life cycle of 25 years. Compared with building a new system, upgrading the existing systems partially or fully to higher bit rate systems by deploying innovative modulation formats is one of the most effective and low cost viable alternatives.

In this paper, we demonstrate the transmission of 100Gbps dual-carrier polarization division multiplexed binary phase shift keying (DC-PDM-BPSK) over deployed transoceanic dispersion-managed links with EDFA amplification on the West Africa Cable System (WACS). Simulation, as a key role of capacity estimator, has positive and significant contributions on the test or system upgrade. The consistency of transmission performance between simulation and test results has also been proven by comparing some key parameters in the following sections.

2. NETWORK DESCRIPTION

Commissioned in 2012, WACS is the largest submarine cable directly linking Southern Africa to Europe, and it is the culmination of investment by eighteen leading international operators and regional carriers. This submarine cable system links fourteen countries in total with two or four fiber pairs , and the longest link has a total length of 11,450km from South Africa to Portugal. An overall connectivity configuration topology is illustrated in Figure 1.

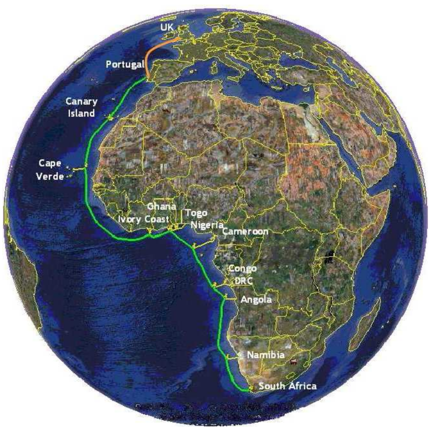

Figure1: Connectivity Configuration

Throughout the longest upgraded link, some branch units (BU) to different countries have been passed through. Two types of fibers, namely D+ and D-, are mainly applied with fixed proportional distribution in most transmission spans. Periodic dispersion compensation span is necessary and placed with another kind of positive dispersion fiber. The output power of EDFA between any two spans is allowed to be changed to achieve the optimum performance. In this ultra-long optical communication system, the bandwidth is about 27nm. There are 24 existing 10G DPSK services within about 5nm working bandwidth in the system, which is located in the middle band. Some continuous wave (CW) tones are discretely distributed in the rest of the bandwidth, sharing the total launch power from repeaters.

3. SYSTEM CONFIGURATION

In the project, the whole system was composed of 100G, 10G, and Amplified Spontaneous Emission (ASE) dummy channels. Eleven 100G channels using DC-PDM-BPSK modulation format were upgraded to satisfy the requirement of capacity. These new services occupied 22 standard ITU-T wavelengths. The subcarrier channel spacing is regarded as 50GHz whose baud rate is about 34 Gbaud/s. Combined with some dummy lights, a mixed transmission with the existing 10G DPSK was achieved by couplers. Keeping the position of 10G unchanged, 100G and ASE dummy were configured in both sides of 10G DPSK. The Figure 2 shows a general end-to-end upgraded system configuration diagram.

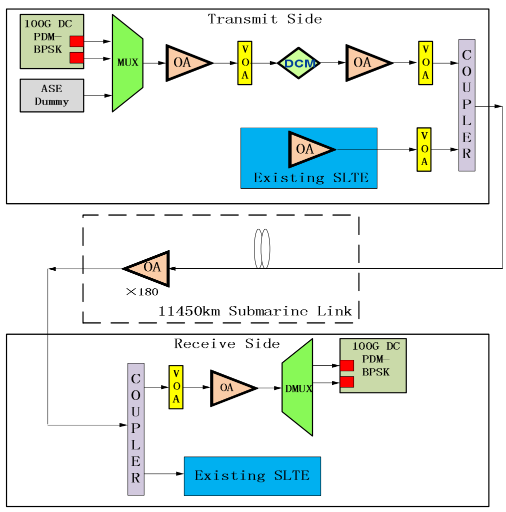

Figure2: System Configuration Diagram

100G DC-PDM-BPSK boards have been used in this system. Its common working principle diagram is shown in Figure 3. Advanced DSP techniques used in 100G board are applied to eliminate noise and nonlinear effects caused by transmission after coherent detection and receiving. At the transmitting terminal, Tx-DSP algorithms and spectral shaping techniques are introduced at the same time， which can not only increase the transmission bandwidth, but also reduce the nonlinear penalty and lower filtering penalty caused by the increased bit rate. At the receiver, it has compensation capability for CD and PMD, which can remove time-delay induced by the DCMs.

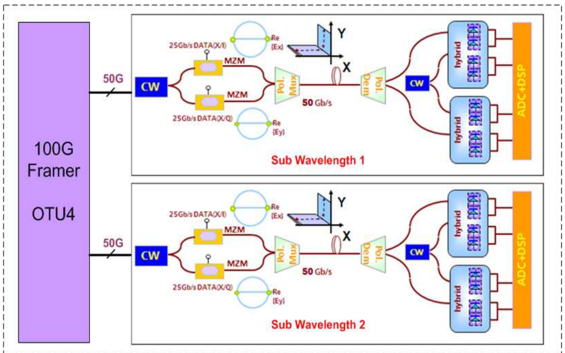

Figure3: DC-PDM-BPSK Principle Diagram

4. TEST RESULTS

In the case of making the performance of the existing 10G services stable, some key procedures such as pre-emphasis adjustment, DCM optimization, dummy light configuration scheme and 100G service location have been completed so as to ensure the *Q* values of all 100G service at a higher level.

Before the system was upgraded, a lot of preparation work was done. The DCM values at the transmitting terminal needed to be evaluated by the simulation results. Because the EDFA power is adjustable, the total EDFA launch power should be adjusted to a suitable value to obtain the optimum performance of the existing services and 100G signals based on previous simulation results. Wavelength allocation is also an important influential factor that would determine the performance for 100G service. In order to achieve better *Q* values and lower transmission impairments, blue and red band were chosen to configure 100G services, considering system spectral features, characteristics of system link dispersion configuration, field trial performance for each channel, influences of 10G DPSK and dummy lights. Beyond these items, as dummy lights, CWs are put into use to reduce the power of 10G service channels before upgrading. If they are used in a coherent system, the coherent signal may experience cross-polarization modulation (XPolM) caused by CW idlers, which would cause the rotation of state of polarization (SOP), and induce serious performance fluctuation for the transmitted coherent signal. So finally the ASE dummy is selected as the dummy light for this upgrade, which are configured in unoccupied channels. This configuration is not only convenient for next system upgrade, but also reduces the dummy light influences on coherent modulation format. All preparation works mentioned in the previous part for system upgrade are mainly guided by simulation results.

During the system upgrading phase, the higher *Q* values after transmission were obtained by adjusting DCM and launch power for each channel. The performance of each 100G channel had been recorded. When the upgrade was finished, in the direction from South Africa to Portugal, the tested average *Q* and worst *Q* after transmission had a differential within 0.2dB, with reserved enough margins over FEC Limit. On the opposite direction, *Q* difference of the average case and the worst case was about 0.3dB with good margins. Furthermore, the values of five sigmas were no greater than 0.2 dB through a single channel 24-hour BER test for two directions. Figure 4 shows the fluctuation scope between calculated mean *Q* and recorded instantaneous *Q* at different moment within one day. The vertical axis stands for the differences of every monitored *Q* and mean *Q*(0 denotes mean *Q*). In the figures RSA is South Africa station, and POR is Portugal station. The mixed transmission of 10G/100G traffic is mandatory. All upgraded channels can meet the final acceptance standard with robust stability.

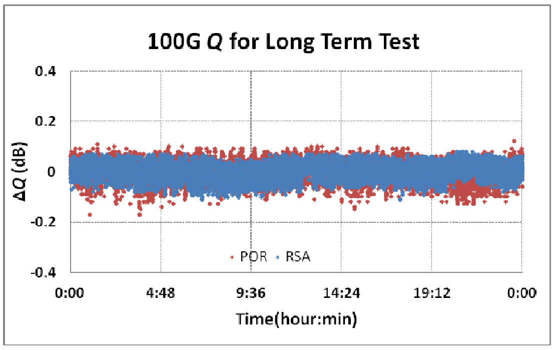

Figure4: Bi-directional 24-hour *Q* Test

While ensuring the successful upgrade of 100G, the performance of the existing 10G also needs to be stable without suffering any interference caused by neighboring 100G and ASE. Therefore, the performance of all 10G DPSK has been monitored for 48 hours for two directions after upgrade.

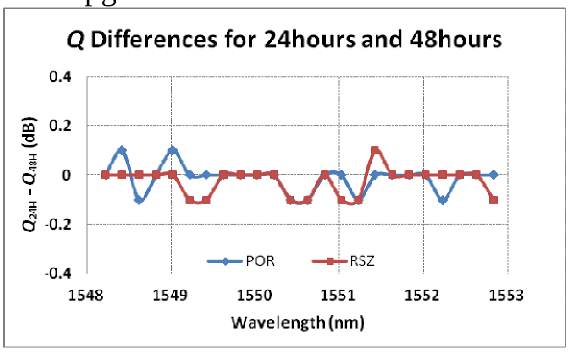

Figure5: Bi-directional *Q* Values for 10G DPSK

The *Q* values for two moments at 24 hours and 48 hours have been recorded with slight fluctuation of less than 0.2dB for each channel. The stability feature can be viewed in Figure 5. Above all, the whole system keeps a stable performance for both 100G DC-PDM-BPSK and 10G DPSK.

5. SIMULATION VERIFICATION

Throughout the project from bidding to delivery, the simulation plays an essential role in the process of system capacity prediction and upgrade. The multifunctional simulation platform can support end-to-end system transmission, aligning with both commercially used and predictable future products. It can provide a mixed configuration scheme for 10G, 40G, 100G, even for those higher bit rate 8QAM, 16QAM formats, such as 300G and 400G. In order to meet the requirements for those complex networks combining submarine with land cables, the simulation platform can satisfy both submarine cable communications systems and land cable systems.

Aiming at doing fast and accurate estimation response of system performance and capacity, the simulation platform has been updated and maintained by continually carrying out theory analysis and experimental verification. It provides a fundamental system solution for new building and upgrade system considering different kinds of terminal configurations, transmission effects and underwater system designs. When one simulation finishes, OSNR, *Q* values and nonlinear penalties would be achieved by statistic analysis. There is no doubt that WACS is a good example. After upgrading this 11,450km submarine link, a series of comparisons between test and simulation have been carried out.

The simulated average OSNR after transmission is about 13dB, which is in good agreement with the test result. In addition, the *Q* values of simulation and test are compared. Through this ultra-long transoceanic submarine cable link, the difference of *Q* factor after transmission is within 0.4dB. The *Q* differences for twenty-two wavelengths are shown in Figure 6. This is typically one of the successful experiences about comparisons of simulation and test.

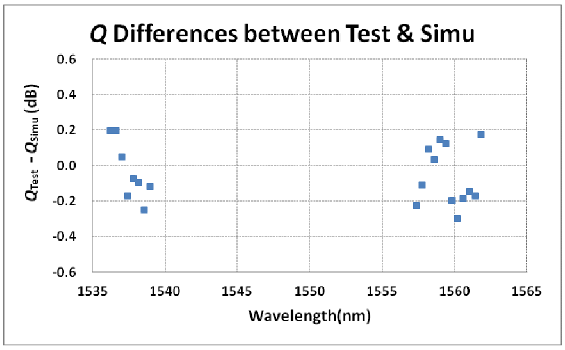

Figure6: *Q* Differences between Simulation and Test

6. CONCLUSIONS

Successful upgrade, from 10G to 100G transmission technology over the installed 11,450 km WACS network, demonstrates that the existing long haul subsea dispersion managed network is capable of supporting the next-generation and future transmission technology, which is not only compatible with existing 10Gbps services, but also meets users' demands for bandwidth growth and system stability. Throughout the project from bidding to delivery, the simulation also plays an essential role in the process of system capacity prediction and upgrade. The comparisons between simulation and test have been carried out after upgrading. The *Q* difference after 11,450km transmission is within 0.4dB. The simulation results are in good agreement with tests.

7. REFERENCES

[1] John D. Downie, et al., Transmission of 256 Gb/s PM-16QAM and 128 Gb/s PM-QPSK Signals over Long-Haul and Submarine Systems with Span Lengths Greater than 100 km, ECOC 2013, Tu.1.D.3.

[2] J.-X. Cai, O. V. Sinkin, H. Zhang, et al., Nonlinearity Compensation Benefit in High Capacity Ultra-Long Haul Transmission Systems, ECOC 2013, We.4.D.2.

[3] S. FUJISAWA, T. NAKANO et al., Demonstration of the Mitigation of Intra-Channel Nonlinearities based on Inter-Polarization Digital Frequency Offsetting with 50Gb/s PM-QPSK signal over 10,080km transmission, ECOC 2012, Mo.1.C.2.