Upgrading on the Longest Legacy Repeatered System with 100G DC-PDM-BPSK

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Abstract: The largest west Africa submarine cable system cross connects 14 countries along Europe, West Africa and South Africa, was successfully upgraded to 100G systems recently. This paper describes how to lay down the solution by field trial and the delivery details on the longest legacy 11450km segment between Portugal and South Africa.

1. Introduction

In order to meet with the explosive growth of high speed data communication needs, the most effective way is using the high speed rate such as 100Gbit/s to upgrade on the legacy system deployed by 10Gbit/s and/or lower speed. The WACS (West Africa cable system) connects 14 countries and the longest legacy 11450km segment is a point to point system between Portugal and South Africa, see figure 1. Now the network design capacity has been increased from 5.12Tbit/s to 14.5Tbit/s with 100G solution. The following paper mainly describes the transmission capacity using the 100Gbit/s DC-PDM-BPSK on the longest segment.

The operation contains two steps, firstly do the field trial and the perform delivery with 100Gbit/s.

First, this paper analyses the field trial data to find out the key points which influence system capacity and performance upgraded. Then combined with the system operation feasibility and convenience, we provide advanced and cost-effective upgrade solution. Finally, it achieves 2.5Tbps capacity within 27nm operating bandwidth using 100G DC-PDM-BPSK technology on the condition that the existing channels 10Gbps services are kept.

Figure 1: WACS Map

2. Field trial

In order to verify that the initial 100G solution scheme was suitable for the project, a field trial was executed on the WACS system. The customer choose the 11450km DLS, it's one of the longest 100G submarine links in the industry and also over the whole legacy system.

The undersea link consists of transmission spans that P type fiber is spliced to N type fiber and some compensation spans using the P type fiber spliced with LMF fiber to adjust the system dispersion. 180 optical repeaters are used in this transmission link. The repeaters are with 27nm bandwidth.

Before upgraded on this 11450km segment the existing network has 24 channels 10G services and several CW (continuous Wavelength) loading channels see figure 2.

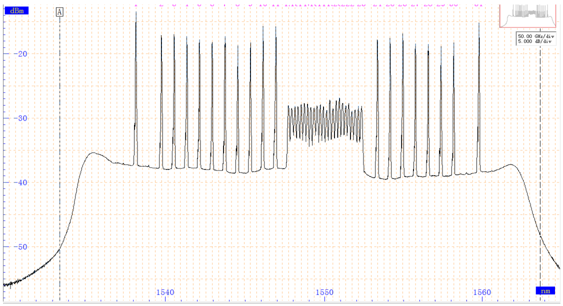

Figure 2: RX Spectrum in South Africa station before upgraded

The trial equipments are set in both cable stations and coupled with the existing equipments, the spectrum after connected 100G line cards can be seen figure 3.

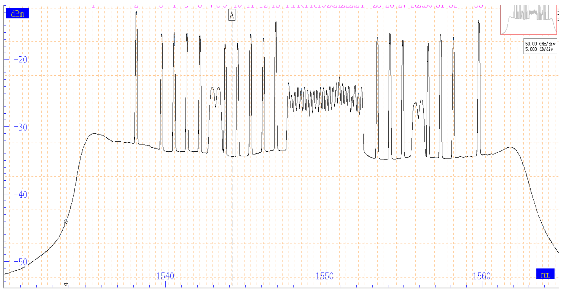

Figure 3: RX Spectrum in South Africa station after coupling two 100G BPSK

During our field trial, it has been found that the CW dummy lights which are linear polarizable had an effect on the performance stability of the 100G, this is because 100G modulation format is PDM (Polarization Division Multiplex), which is sensitive to XPolM (Cross Polarization Modulation) nonlinear effect, and directly lead to performance fluctuations that may exceed the threshold of Bit Error Rate (BER). This phenomenon was affirmed by comparing bidirectional testing that the direction from Portugal to South Africa reported burst errors with CW dummy channels, while the other direction was error free for all CW dummy channels have been replaced by ASE dummy lights. Furthermore, we did the research to verify the influence grade with different CW loading scenarios, and it showed that with reducing the number of CW, transmission performance became better and more stable.

Figure 4 shows the effect of CW in our laboratory loop experiment. The severe performance fluctuation can be observed as indicated in part (b), which is actually the combination of two test scenarios. It can be explained as follows: for the CW DFB has tens MHz low frequency and behaviors like low frequency intensity modulation in time domain, when transmitting it will cause XPolM effect which results in tens MHz SOP (status of polarization) rotation. However the tens MHz frequency of CW dummies cause the same time scale SOP rotation of transmitted signal, but DSP can't track such high frequency SOP variation and thus causes severe performance fluctuation. The horizontal axis is the number of data capture and vertical axis is the corresponding BER for each set of data recorded.

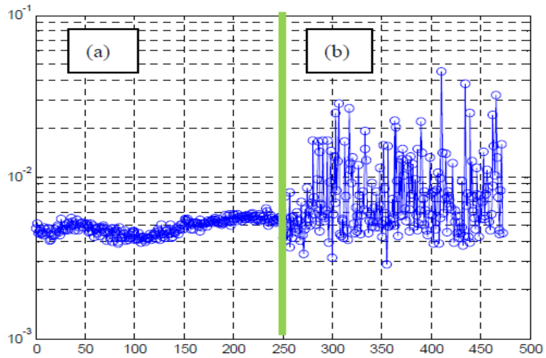

Figure 4: Effect of CW in Lab experiment, (a) 36 ASE dummy; (b) 24 CW DFB dummy

Combined with the trial results and lab research, finally a solution is given that replace all the CW loading channels with our ASE dummy lights which is generated from filtering the amplifier output for the ASE lights are non-polarizable.

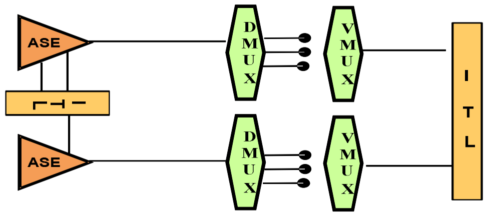

Figure5: ASE dummy light configuration typical setup

Searching optimal single channel launch power into the fiber has been done too. It's noticed that nonlinear factors dominate the performance while OSNR budget is enough on the legacy system. This can be a guide for the delivery that power is set at the optimal value.

The pre-compensate CD (Chromatic Dispersion) is very important in the dispersion managed link system. Normally half of the system residual CD is pre-compensated at the transmit side. At the beginning we set 180km positive DCM (Dispersion Compensation Module) in the main path and then tuned the single channel DCM to search the best BER performance with the optimal pre-compensated DCM value. Figure 6 gives an example of pre-compensated DCM searching test.

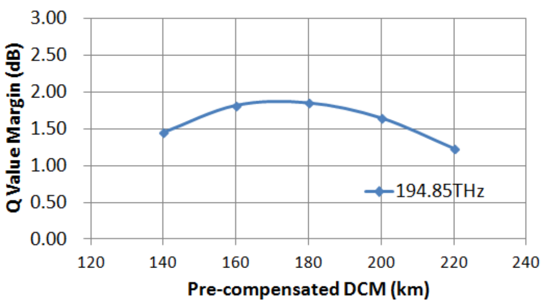

Figure 6: Pre-compensated DCM searching test

Data shows 180km DCM in the main path is most suitable for the whole bandwidth, just several channel wavelengths may need a few more positive/negative DCM. The residual CD can be compensated by the DSP (Digital Signal Processing) in coherent receiver. Figure 7 shows the optimal pre-compensated DCM test results.

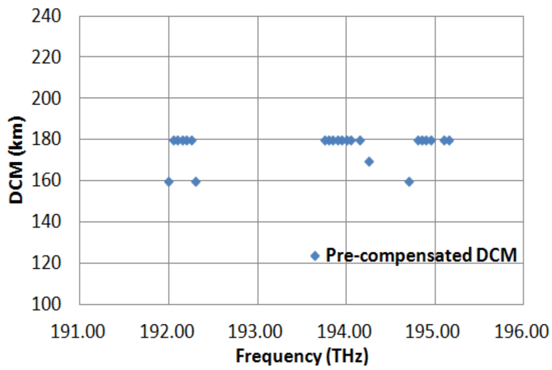

Figure 7: Measured BER performance versus CD

In field trial we also noticed that all the amplifiers in the existing SLTE (Submarine Line Terminal System) were working with power lock mode. When the CW channels were removed, the leaving 10G power would be allocated the total power, so the power for each channel would be very high before injecting into the submarine cable. And there is a fixed attenuator set after the last transmitting optical amplifier. On this circumstance, even the new adding power from our upgrading equipments was tuned to the highest level, the power ratio of 10G was also very high that not only performance of 10G degradated much, but also it was hard to adjust the upgrading channels' power. So it's suggested that the existing fixed attenuator after the last amplifier at transmit side should be replaced with a VOA (Variable Optical Attenuator), which is beneficial to adjust the power ratio between existing and new adding equipments. That will not affect the performance of existing running services, and good for the next upgrade with lowest risk in the future.

3. Implement setup

Figure 8 shows the schematic of delivery configuration setup. At the transmit side, 11pcs 100G DC-PDM-BPSK and some ASE dummy lights are combined using MUX board (integrated VOA for each channel), and a total 180km DCM modules are added between two optical amplifiers to pre-compensate residual CD. At the end two VOA ports (integrated in one board) are added separately after our last OA (Optical Amplifier) and existing SLTE OA to adjust the power ratio. At the receive side signals go out from DMUX board to the input ports of 100G coherent line boards.

Figure 9 shows the spectrum after upgraded, it can be seen that all the CW lights have been removed and 100G channels and ASE dummy lights are added within the 50GHz ITU standard grid. The frequencies of 100G are from 191.95THz to 192.60THz and from 194.80THz to 195.15THz.

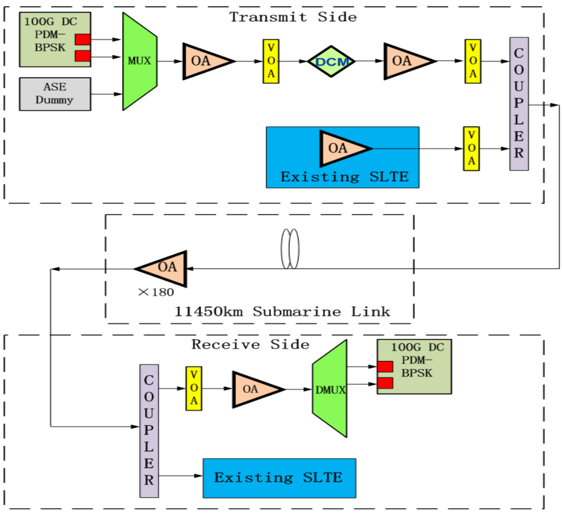

Figure 8: Schematic of configuration setup

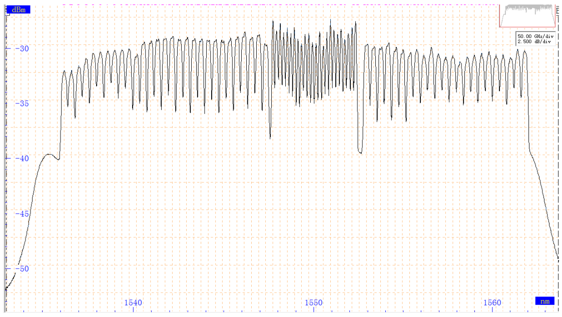

Figure 9: RX Spectrum in South Africa station after upgraded

4. Delivery process and results

In order to reduce the cutting down time of services to minimum and monitor the running 10G performance during the upgrading time, it's required that replace the existing fixed attenuator with VOA and recover the 10G services first, then remove the CW while adding 100G or ASE dummy step by step though adjusting the two VOA to balance the power. The whole upgrade process works very well.

After upgraded on the 11450km segment, the existing 10G Q values are all above the requirement commissioning Q line, results of relative Q values comparing with commissioning Q in figure 10.

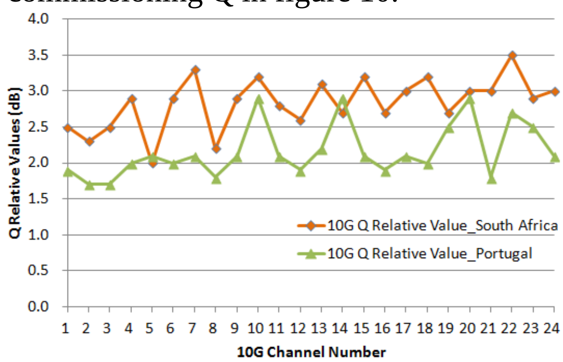

Figure 10: Existing 10G Q relative values comparing with commissioning Q after upgraded

The launch power per channel is set at the optimal value searched during the field trial. To keep all of the service channels working at the best performance, we use pre-emphasized method by adjusting the

VOA of MUX at the transmit end. After optimizing, the 100G channels OSNR are distributed from about 11.5dB to 14dB, see figure 11.

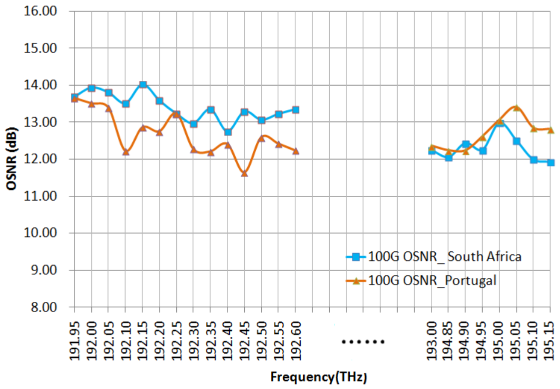

Figure 11: OSNR of 100G PDM-BPSK

100G Q value margins are from 1.8dB to 3.0dB while the TVSP (Time Varying System Performance) has been taken into account in figure 12. Q margins of the lowest channel 192.60THz are 1.88dB in South Africa and 1.80dB in Portugal respectively compared with the FEC threshold, which do compelety meet with the power budget requirement provided before project delivey.

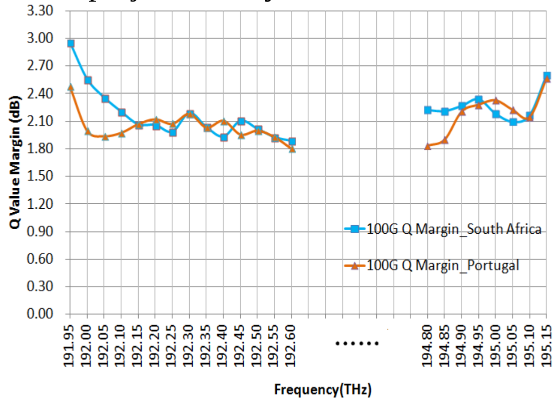

Figure 12: Q value margins of 100G PDM-BPSK (deducted TVSP)

The Q values fluctuation of 100G have also been monitored, the biggest channel fluctuation 5sigma values are 0.42dB and 0.34dB respectively in South Africa and Portugal. Here shows the biggest fluctuation channels in both stations in figure 13.

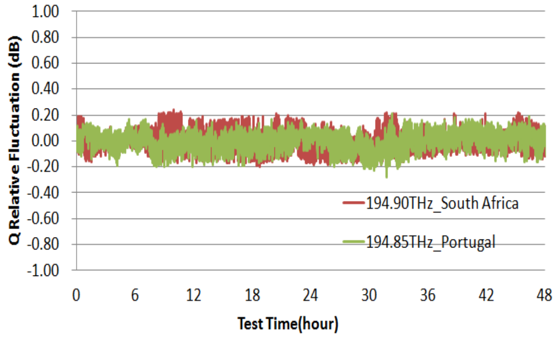

Figure 13: Q values fluctuation of 100G PDM-BPSK

5. Conclusion

In August of 2014, the field trial is demonstrated the submarine transmission feasibility in the field trial over 11450km using 100G DC-PDM-BPSK modulation format. During the field trial process, we also find out the key points that affect the system performance and provide the best upgrading scheme for the system.

In 2015, the optical submarine line equipments are manufactured, factory acceptance tested, shipped, installed and commissioned to the 14 countries for upgrading and expending the whole system capacity. It is excited that 100G DC-PDM-BPSK products are successfully delivered on this longest legacy segment reach to 11450km.

The successful of the trial and project delivery show that 100Gbit/s equipments can be absolute competent for transmitting over ultra long-haul submarine cable.