The Research of Analysis Strategy of Transmission Performance in Subsea Observatories

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***Abstract*—The optical network system is the information transmission channel and one of the core functional units of the subsea observatories. The operation quality of the optical network determines whether the subsea observatories could provide valuable data for marine science research directly. With the increasing number of network nodes, an increasing amount of data and transmission rate requirements puts forward severe challenges to the designers of observatories. SDH(Synchronous Digital Hierarchy) is the main means of communication of the existing famous subsea observatories. As we know, SDH, which is based on the optics/electronic/optics transition, is limited by the bottleneck in conversion rate. OTN(Optical Transport Network), which is based on WDM(Wavelength Division Multiplexing), will replace the SDH and become the main technology of next generation backbone transmission network.**

There are several different parameters which can be used to represent the running states of the optical network. In this paper, a model of transmission quality assessment is put forward, which considering both the nonlinear factors in the transmission channels and the topological structure of the subsea observatories. The parameters Q-factor(Quality factor) and BER(Bit Error Ration) are presented to describe and distinguish the running quality of the optical network of the observatories. The simulation analysis proves the rationality of the model.

Keywords—subsea observatories, model, Strategy of Transmission Performance, Analysis

I. INTRODUCTION

Building the underwater observatories, researching marine from inside at a time-continuous and fixed-point platform are the main tasks of cross-domain of Marine Science and Information Science in the new century. The subsea observatories have been one of the hottest research topics compared with the buoy and ship-based observatories, which satisfies the requirements for real-time and long term observation. Constructing a long-term operation, long sequence, multi-sensors and real-time observation network, with the stable network communication and the intelligent positioning of faults and intelligent optimization transmission are the effective ways of solving the problems[1][2][3].

The topology of the subsea observation optical network (Fig. 1) consists of the optical loop network, the primary nodes, the secondary nodes and the marine instruments.

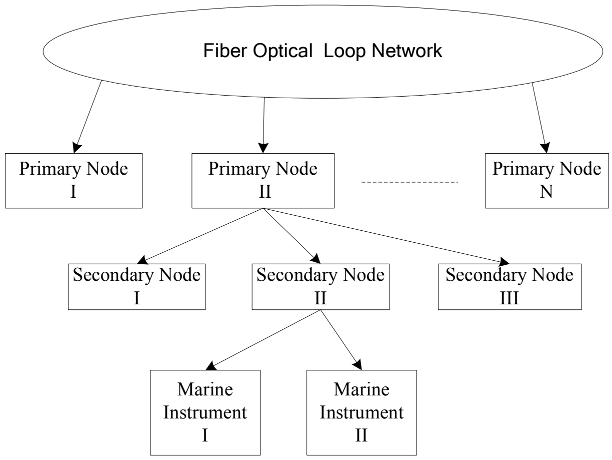

Fig. 1 the topology of the subsea observatories

The business content and the topology of the network are changing all the time. There are many factors could cause these changes, for example, opening or closing one of the marine sensors could arouse the fluctuate of the network, similarly, the data flow will decrease if there are any faults occurs at the node of the network. The network equipment themselves can also cause unstable-performance of the network, such as the increase of channels of the fiber optical network and the change of optical power of transmission. Beyond that, chromatic dispersion (CD), polarization mode dispersion (PMD), self-phase modulation (SPM) and cross-phase modulation (XPM) have an impact on the optical transmission quality. The static network performance evaluation strategy almost ignores the real-time property, furthermore, the new increase of optical channels should be recalculated along with the changes of topology of the optical network. Therefore, the static network performance evaluation strategy is not suitable for underwater observatories[4][5][6].

This paper researches the dynamics-property-analysis model of network communication of subsea observatories and puts forward the assessment criteria of transmission performance. First of all, a set of information acquisition and monitoring system model of subsea observatory network was designed, and then the performance analysis and evaluation strategy based on dynamic priority was put forward. This study is to uncover the complexity of network communication and

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the law of the failure under the precondition of the subsea observatories, improve efficiency of fault location and fault remediation in the observation networks, explore the advanced technology of the long-term stable operation and data communication[7][8].

II. Topology Structure and the Modeling

Structure design

The structure design of optical transmission layer of subsea observatories is shown in the Fig. 2. There are two shore stations, each one can be the backup of another one, the two shore stations make up the ring optical network. The OXC(Optical Cross Connectors) and OADM(Optical Add-Drop Multiplexers) are used to expend the optical channels and connect the electrical layer. The BU(branch unit) can be seen as the relay station of the communication, where the amplifier of optical is located in. In the backward position of BU is the Junction Box, which can be seen as the message rendezvous point. This overall structure is the foundation of the follow-up modeling of the optical communication system[9][10].

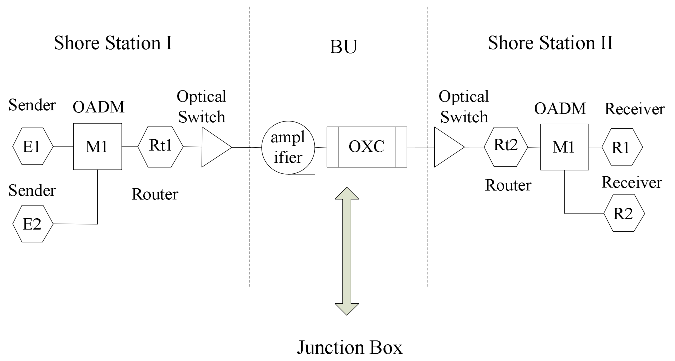

Fig. 2 the overall structure of optical network

As is shown in Fig. 3, the communication quality depends on either the network equipment themselves or the network loads. Considering this, a dynamic performance aggregate analysis mode is put forward in this paper, which taking account of interactive nonlinear distortions between amplitude and phase modulated channels. This model provides theoretical proofs for impairment aware or impairment controllable optical network designs and operations for subsea observatories. The model is described below: Assuming that the power loss of the optical signal is completely compensated by the optical amplifier, at the same time, the ASE noise caused by EDFA can be filtered by optical receiver. Under these circumstances, the optical channel of subsea observatories can be regarded as series-connection of network nodes and fiber optical sections, so the CD, PMD, SPM and XPM give rise to the impairments, the factors that affect the transmission quality are as follows:

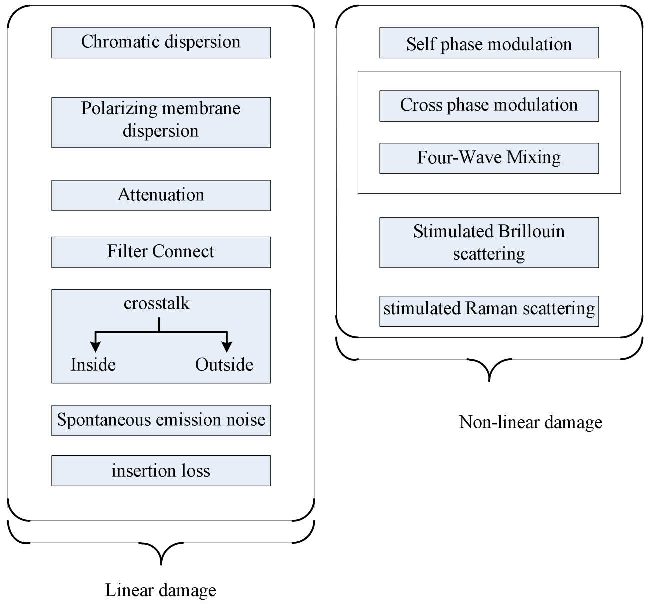

Fig. 3 factors that affect the transmission quality

MODELING

As we can see from the above analysis, there are both liner error and nonlinear error in the optical networks, so the simulation model should contain the two kinds of errors. Fig. 2 indicates that the entire optical path can be seen as the series connection of network node and optical fiber. Chromatic dispersion (CD) and polarization mode dispersion (PMD) consist of the main liner error. The nonlinear schrodinger equation in which the CD and PMD and nonlinear error are considered is presented here[11]:

$$\frac{\partial A_x}{\partial_z} + {\beta'}_x \frac{\partial A_x}{\partial_t} + \frac{i}{2}\beta'' \frac{\partial^2 A_x}{\partial t^2} + \frac{\alpha}{2} A_x = i\gamma\left(|A_x|^2 + \frac{2}{3}\left|A_y\right|^2\right) A_x \quad (1)$$

$$\frac{\partial A_y}{\partial_z} - {\beta'}_y \frac{\partial A_y}{\partial_t} + \frac{i}{2}\beta'' \frac{\partial^2 A_y}{\partial t^2} + \frac{\alpha}{2} A_y = i\gamma\left(\left|A_y\right|^2 + \frac{2}{3}|A_x|^2\right) A_y \quad (2)$$

Where, A_x and A_y are the pulse envelope slowly varying amplitude of the signal in two polarization direction, ${\beta'}_x$ and ${\beta'}_y$ are the differential group delay, β'' is the group velocity dispersion coefficient, α is the attenuation parameter. Let the nonlinear parameter $\gamma = n_2\omega_0/A_{eff}C$, $n_2 = 2.6 \times 10^{-16}\ cm^2/W$ is the Kerr coefficients. Let the optical fiber effective cross-sectional area $A_{eff} = 50\ \mu m^2$. We assume that dispersion and nonlinear effects together while the light field propagates a short distanceΔz , we have:

$$\mathrm{A}(\mathrm{z} + \Delta\mathrm{z}, \mathrm{t}) \approx \exp\left(\Delta\mathrm{z}\widehat{D}\right)\exp\left(\Delta\mathrm{z}\widehat{N}\right)\mathrm{A}(\mathrm{z}, \mathrm{t}) \quad (3)$$

Where, $\widehat{D}$ is the differential operator, represents the dispersion and absorption of the liner medium; $\widehat{N}$ is the nonlinear parameter, represents the nonlinear effects of optical transmission in the process of pulse. Let $\Delta z = 10^{-2}$km. The positive and negative Fourier-Transform will be used in every step, that cause a great amount of calculation[12]. So, the average speed $\overline{V_g} = \frac{1}{\beta'} = \frac{1}{\beta'_x + \beta'_y}$ is introduced in this paper to get a simplified calculation:

$$\frac{\partial A_x}{\partial_z} + \frac{\beta'_x-\beta'_y}{2}\frac{\partial A_x}{\partial T} + \frac{i}{2}\beta''\frac{\partial^2 A_x}{\partial T} + \frac{\alpha}{2}A_x = i\gamma\left(|A_x|^2+\frac{2}{3}|A_y|^2\right)A_x \qquad (4)$$

$$\frac{\partial A_y}{\partial_z} + \frac{\beta'_x-\beta'_y}{2}\frac{\partial A_y}{\partial T} + \frac{i}{2}\beta''\frac{\partial^2 A_y}{\partial T^2} + \frac{\alpha}{2}A_y = i\gamma\left(|A_y|^2+\frac{2}{3}|A_x|^2\right)A_y \qquad (5)$$

The step length is considered to be in 0.5 km order of magnitude in order to reduce the times of Fourier-Transform. In every Δz, The optical fiber can be seen as many segments of PM(polarization-maintaining) short optical fibers, Each small section of the PM fiber exists coupling angle. The attenuation of the fiber and EDFA amplification effect are both neglected in this paper under the consideration of simplified calculation[13]. Let $\beta' = (\beta'_x - \beta'_y)/2$, the liner part in the frequency domain of (4) and (5) are:

$$\frac{\partial A}{\partial_z} + ib'\sigma\omega A - \frac{i}{2}\beta''\omega^2 A = 0 \quad (6)$$

Where, $\sigma = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$, $\mathrm{A} = (A_x + A_y)^t$. In the small step, $\mathrm{h} = \Delta z/N$, (6) can be indicated as:

$$\mathrm{A(z+h,\omega)} = e^{\frac{i}{2}\beta''\omega^2 h}\begin{bmatrix} e^{-ib'h\omega} & 0 \\ 0 & e^{ib'h\omega} \end{bmatrix}\mathrm{A(z,\omega)} \qquad (7)$$

Considering the stochastic coupling between each small section of the PM fiber, the linear function transfer matrix of the optical fiber $\mathrm{T(\omega)} = e^{\frac{i}{2}\beta''\omega^2\Delta z}M(\omega)$, we get $M(\omega)$:

$$M(\omega) = \prod_{n=1}^{N}\begin{bmatrix} e^{-i(\frac{\Delta\emptyset}{2}+\emptyset_n)} & 0 \\ 0 & e^{\frac{\Delta\emptyset}{2}+\emptyset_n} \end{bmatrix}\begin{bmatrix} \cos\theta_n & \sin\theta_n \\ \sin\theta_n & \cos\theta_n \end{bmatrix} \quad (8)$$

Where, $\Delta\emptyset = \sqrt{3\pi h/8}\,D_{PMD}\omega$ is the Phase difference in every section fiber caused by PMD, $D_{PMD} = 2b'\sqrt{8h/3\pi}$. $\emptyset_n$ and θ_n are the additional phase and coupling angle uniform distribution on $[0, 2\pi)$. The Fast Fourier Transform(FFT) is used in every step of calculation. There would be a large amount of calculation if $M(\omega)$ be calculated in every frequency point. Because $M(\omega)$ is a slowly varying function(compared with the angular frequency), so that $M(\omega)$ needed be calculated in a few frequency, and then do the calculus of interpolation to it[14].

III. Evaluating Indicators of Network Performance:

As discussed above, transmission loss including linear loss and nonlinear loss

Optical Signal Noise Ratio (OSNR) and Bit Error Rate (BER) are introduced in this paper to identify the transmission quality. The concept of tolerance value is referenced in this paper. The communication system can be regarded as "robust" when the OSNR is bigger than the tolerance value of the end signal. The OSNR is calculated through the formula:

$$\mathrm{OSNR} = 58\mathrm{dB} + \mathrm{P}_1 - NF - L_1 - 10\log(N)$$

"P1 "is the power of source optical fiber, "NF" is the noise figure of the amplifiers, "N" is the cross section number of fiber.

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IV. Conclusions

The numerical simulation results are close to the eye diagrams at the end of the transmission channels from the experiment, the validity of the simulation model was confirmed also, which laid a solid foundation for the numerical optimization of all optical system.

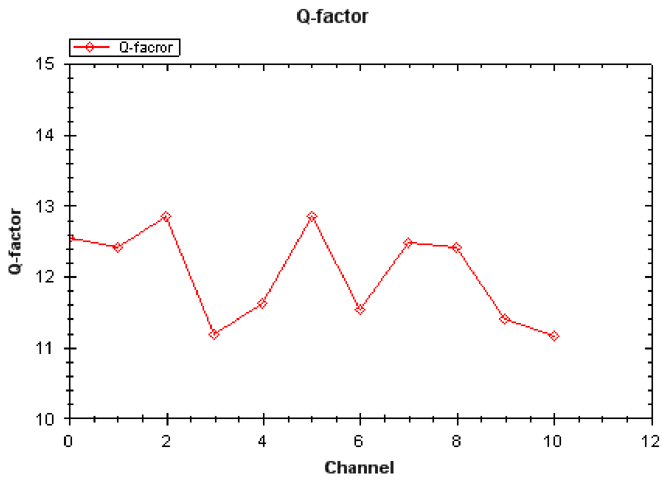

Fig. Q-factor simulation results

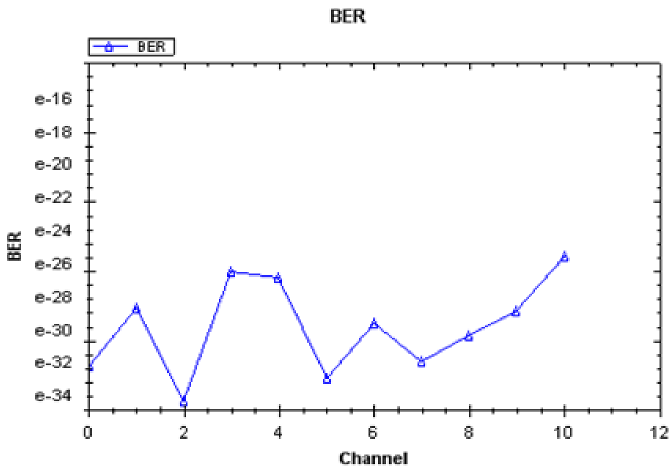

Fig. 5 BER simulation results

Acknowledgment

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