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ANALYSIS OF THE REQUIREMENTS FOR OPTICAL CABLES FOR CONSTRUCTION OF UNDERWATER TRANSMISSION SYSTEMS

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ABSTRACT: *Analysis of the requirements for underwater transmission systems using optical fibers: The purpose of this article is to explain the fundamentals of the optical fibers for underwater placement. The specific requirements for the creation of underwater transmission systems are defined by the extreme environment. A general analysis of the current optic fiber has been conducted and their main characteristics are presented*

KEY WORDS: *Optical fiber, Underwater transmission systems*

1. Introduction

The continuous growth of internet traffic and telephone services are the main driving force for the development of higher speed transmission lines. A key element in these architectures are optical systems, which will soon be transmitting several Tbit/s information.

Optical networks that can carry 5 ÷ 7 Tbit s traffic are demonstrated. One of them with a transmission speed of 5.12Tbit/s for a distance of 300 km and 7Tbit/s at 186 km developed by "ALCATEL-LUCENT" (One of the world leaders in the field of optical technologies). Each of the two networks uses the wavelength seal (WDM) required as a basis for modern networks, as well as basic operating flows of 40Gbit / s (STM-256) [1], [3], [4].

Network operators are now struggling to build and maintain networks that provide a flexible platform for billions of services at the lowest possible cost. Many of them are underwater (due to the need for global communication) and network engineers must consider many key factors in their design and operation.

The main difference between terrestrial and underwater optical systems is the strict requirements for high reliability due to the high cost of line repairs (imposed by the aggressive physical environment). The line must withstand a pressure of 70MPa for a depth of about 4000m, also huge tensile forces and vibrations, as well as high resistance of the elements to the salinity of the water. The equipment itself includes an underwater cable, underwater amplifiers, underwater couplings and power strips. The design must also pay particular attention to the long distance that the line must cover, the speed of information transmission, as well as the possibilities for its future development and increase of transmission capacity.

2. Exposure

The optical fiber is composed of two optical media - an optical core and an optical shell (Fig. 1). They have different but similar refractive indices, and their laws of variation may not be linear functions of distance (derived or higher order).

The most important element in the optical system is the optical fiber. It provides the transmission medium for optical energy. The distance and speed of transmission along the optical line depend on its parameters. The quality of optical fibers has improved considerably in recent years.

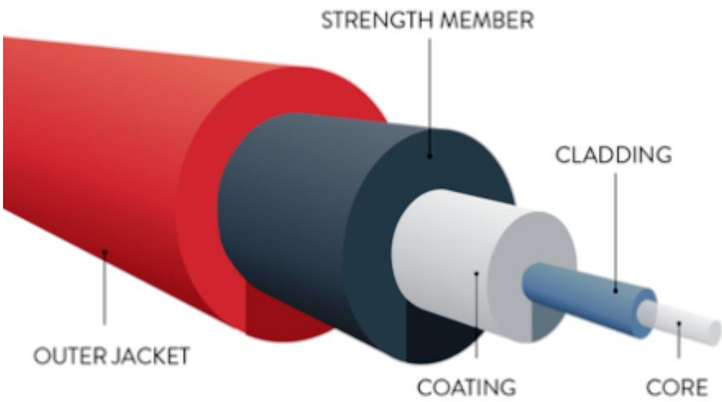

Fig. 1. Fiber optic structure

New types of fibers have been developed in accordance with the recommendation of the International Telecommunication Union ITUT G.655 for optical fibers with offset non-zero dispersion or the so-called fibers with dispersion equalization. Such a dispersion inhibits the growth of four-wave mixing, a nonlinear effect that can be particularly detrimental when using WDM Wavelength-Division Multiplexing wavelength compaction. These fibers are optimized for use in the range between 1500nm and 1600nm. They are suitable for transmission in underwater systems, in which a wavelength is transmitted over several thousand kilometers. Attractive for single-channel systems, these fibers impose serious restrictions on the transmission of several wavelengths in the area of the third window, ie. area of 1550nm.

Optical cable is one of the most important components in the underwater optical network. Its construction is shown in (Fig. 2). It consists mainly of a bumper, a cable sheath, a cable core and a power element for gripping the cable. The bumper serves to protect the cable from mechanical impacts, the cable sheath protects the cable from moisture penetration, and in the core is a steel tube in which the optical fibers are located.

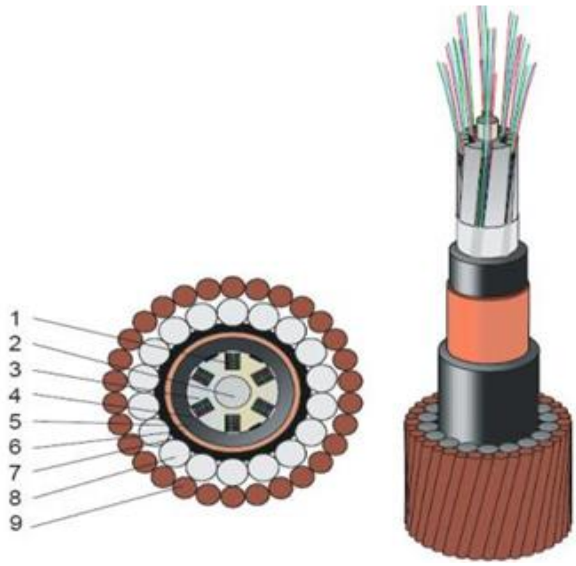

Fig. 2. Cross section of an underwater optical cable

Underwater systems use mainly three types of cables - with thick armor, lightly armored and without armor. The first type of cable construction is used for connection between water and land, where the risk of mechanical damage is greatest due to the high transport and vital activity. Therefore, maximum structural strength is required. The second type is applied for relatively shallow waters (up to 1000m), where the activity is relatively weaker. The third type of construction, which is not armored and very light, is used at depths (1000m to 8000m), where due to high pressure and lack of sunlight there is almost no life, and any other type of activity is unthinkable [2], [5], [6].

Submarine optical cables must meet the following conditions:

- low residual voltage on the fiber after its placement in the cable <0.05%;

— high mechanical resistance of the steel tube providing insignificant pressure on the fibers when bending the cable;
— high waterproofing;
— resistance to tension and side effects;
— good mechanical and optical indicators when connecting construction lengths;
— high insulating resistance of the dielectric of the composite conductor for remote power supply.

Table 1. Basic parameters of the optical cable

Cable type	LW	SA	DA
Nominal tensile force (KN)	42	156	196
Maximum tensile force (KN)	60	186	264
Outer diameter (mm)	14	26	35
Weight in air (kg/m)	0.44	1.6	3.5
Weight in water (kg/m)	0.28	1	2.4
Maximum number of fibers	24	24	24

One of the main parameters of the fiber is the attenuation coefficient - it determines the energy losses in the fiber from the distance and the intrinsic dispersion of the fiber, which leads to the expansion of the pulses propagating along the fiber. Optical networks, unlike other types of cable networks, are characterized by relatively low attenuation (0.2-0.35dB / km), but for long distances of several thousand kilometers it takes a significant value, which is 300 - 400dB, and must be compensated. For optical cables, the attenuation can be expressed by the attenuation factor:

$$\alpha(dB/km) = -\frac{10}{L}\log 10\,(\frac{P_{OUT}}{P_{IN}}) \quad (1)$$

Where POUT is the optical power at the end of the fiber, PIN is the power at the beginning of the fiber and L is the length of the fiber; For individual wavelengths in the range from 1535nm to 1560nm the dispersion can be calculated by the formula:

$$D(\lambda) = \left\{\frac{D(1565nm)-D(1530nm)}{29} * (1665nm - \lambda)\right\} + D(1565nm) \quad (2)$$

Suitable for the construction of underwater communication systems is the TrueWave XL optical fiber in accordance with the recommendation of ITUT -

G.655, manufactured by "Lucent Technologies". It is a special single-mode optical fiber with a wide effective area, developed for application in optical systems (Table 1) operating in the range (1500nm -1600nm), low attenuation coefficient 0.20db / km (1550nm) compared to the standard 0, 35db / km uncompensated negative dispersion for the C range, inhibiting the development of four-wave mixing (non-linear effect, quite undesirable in DWDM systems) and high strength.

For synchronous digital hierarchy (SDH) and wavelength compression (WDM), fibers can be used for wavelengths above 1550nm. The maximum attenuation increase must be applied to the maximum operating wavelength (ie * 1580 nm). Losses at this wavelength can be predicted by measuring at 1550nm and by spectral modeling of the losses or by statistics for a specific fiber type. It can be performed as an alternative and qualifying test at longer wavelengths.

3. Conclusion

The article presents a general analysis of the requirements of optical cables for the construction of an underwater optical system. At this stage in the development of communication systems, the only technology that provides the ability to transmit a huge amount of information on the order of several (Tbit/s) over long distances (>1000km) are optical systems. With their huge transmission potential, they manage to meet all the requirements of the moment.

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