Prepar Measuring the Main Parameters of Optical Transfer Media – Optical Fibers and Cables

Ivelina Balabanova

***Abstract* – Attenuation measurement is performed at a definite wavelength λ. The main part of such a device is the monochromator. Attenuation is measured using an optical time domain reflectometer (OTDR). It is based on back scattering of the signal due to Rayleigh scattering. A series of short optical pulses is input into the fiber and the reflected power is measured. Optical reflectometers are used to determine and measure distances to interruptions and cracks in optical fibers, as well as distances to splitters and connectors.**

***Keywords* – Optical reflectometer, Monochromator, Numerical aperture, Fiber absorption, Pulse dispersion**

I. Prepar Measuring the Main Parameters of Optical Transfer Media – Optical Fibers and Cables

Attenuation constant of the signal in the optical cable - α

$$\alpha = \frac{1}{\ell}.10.\log\frac{P_I}{P_O} \qquad (1.1)$$

l – cable length; P_I – input power; P_O – output power.

In the case of a cable of length l = 1 km; $n_1 = 1{,}48$; $n_2 = 1{,}46$; dc = 50 µm a beam falling at an angle of 80,6° to the optical axis will travel not 1000 m, but 1014 m, i.e. 14 meters more than a beam parallel to the optical axis.

If $V_c \approx 2.10^8\ m/s$ in a fiber of $n_1 \approx 1{,}5$ the beam delay will be:

$$td = \frac{14m}{2.10^8\ m/s} = 69\,ns \qquad (1.2)$$

The optical power is measured in watts (W), to be turned in decibels (dB)

$$dB = 10.\log\frac{P_{изм}}{P_E} \qquad (1.3)$$

$P_{изм}$ - the power measured; P_E - reference power.

For 1mW reference power

$$dB_m = 10.\log\left(\frac{P_{изм}}{1mW}\right) \text{-(absolute power).} \qquad (1.4)$$

For 1 µW reference power

$$dB_\mu = 10.\log\left(\frac{P_{изм}}{1\mu W}\right) \text{- (absolute power).} \qquad (1.5)$$

The light power losses in an element of the communication systems are:

$$L(dB) = 10.\log\frac{P_O}{P_I} \qquad (1.6)$$

The loss factor in the cable is:

$$CLF(dB/km) = \frac{P_I(dB) - P_O(dB)}{l(km)} \qquad (1.7)$$

Optical devices

Optical multimeter – measures: power in dBµ or dBm; losses in optical fibers, connectors, splitters; reflection losses, etc.

Optical power meter – measures optical power; radiation angles of laser diodes and LEDs; losses in fibers, connectors; numerical aperture, etc.

Optical ohmmeter – measures losses in the fibers.

Optical reflectometer – determines the length of optical fibers; identifies the fault location and the crack location; measures attenuation in fibers, splitters and connectors.

Optical attenuator – measures the speed of optical systems and reflection losses.

Optical spectrum analyzer – analyzes spectra of various types of light source.

Monochromator – operates in circuits for measuring the spectral dependence of the attenuation constant.

- Quantities measured in optical communications: signal attenuation in optical fibers and cables – dB/km;
- constant α of signal attenuation in the fiber – dB/km;
- radiation power of the source (absolute value);
- numerical aperture;
- pulse dispersion – ns;
- fiber absorption;
- losses in fiber connections – dB;
- losses in fiber scattering – dB;
- sensitivity of the optical receiver – A/W;
- radiation spectrum of laser diode and LED – nm, µm;
- physical and design features of fibers:
  - profile measurement;
  - diameter of the fiber core;
  - diameter of the cover.

Measurement of the signal attenuation in fibers and cables

Methods:

- comparison method for input and output signal
  - insertion loss method
  - cut – back method
- pulse method

[1]Ivelina Balabanova Technical university of Gabrovo, department: “KTT”, 8 Hadji Dimitar, Gabrovo 5300, Bulgaria, e-mail:ivstoeva@yahoo.com

♦ back scattering method by means of a reflectometer

Attenuation measurement is performed at a definite wavelength λ. The main part of such a device is the monochromator.

Fig.1.1a,b show a circuit for measurement of attenuation using the *insertion loss method*.

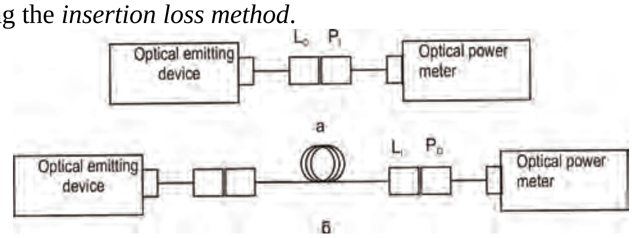

Fig.1.1

If P_I designates the optical power at the beginning of an optical fiber of length L, and P_O - at the end of the fiber, then the attenuation is:

$$a = 10.\log \frac{P_I}{P_O}, dB \qquad (1.8)$$

The attenuation constant α is:

$$\alpha = \frac{a}{L}, dB/km \quad ; \quad L \approx L_1,\ L_0 << L_1. \qquad (1.9)$$

When applying this method, a small standard piece of optical fiber of length L_0 is used (for example, up to 3 m), and the optical power meter is connected to it – Fig.1.1a. Then the meter is connected to the cable being measured of length $L_1 >> L_0$ (circuit in Fig.1.1b).

Fig.1.2 shows measurement of attenuation in optical fibers using the *cut-back method*.

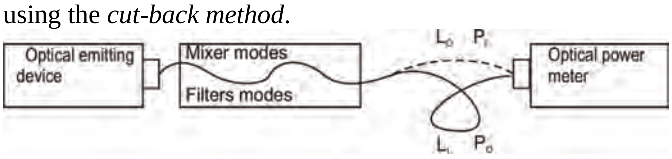

Fig.1.2

First the entire fiber of length L_1 is measured and a reading is taken of power P_O, after that a short fiber of length L_0 (1÷2 m) is cut and a reading is taken of power P_I. The attenuation constant is:

$$\alpha = 10.\log \frac{P_I}{P_O} \Big/ (L_1 - L_0), dB/km \qquad (1.10)$$

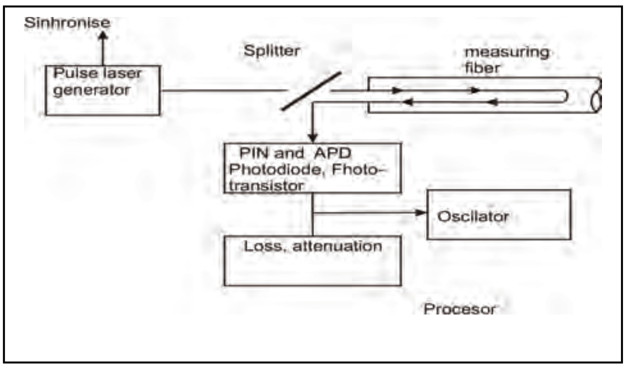

Fig.1.3

Attenuation is measured using an *optical time domain reflectometer* (OTDR).

It is based on back scattering of the signal due to Rayleigh scattering.

A series of short optical pulses is input into the fiber and the reflected power is measured.

Pulses are radiated with t_I = (10- 100) ns, and pulse power of 0,5 W at the respective λ.

The circuit of measurement using an optical reflectometer is shown in Fig. 1.3.

The optical coupler is located at an angle of 45°.

Optical reflectometers are used to determine and measure distances to interruptions and cracks in optical fibers, as well as distances to splitters and connectors. It becomes clear that access to both ends of the fiber is not necessary.

When a reflectometer is used for measurement, the results are presented graphically, by means of reflectograms.

Measuring the dependence of the optical fiber attenuation constant α on the wavelength λ. The measurement circuit is shown in Fig. 1.4.

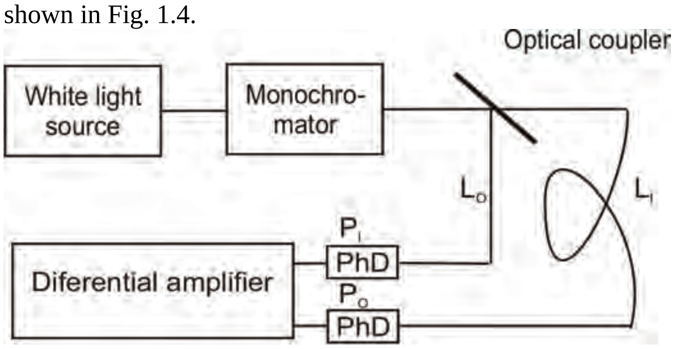

Fig.1.4

The monochromator with a diffraction grating transmits only beams of wavelength:

$$\Delta\lambda = \lambda_1 - \lambda_2 \qquad (1.11)$$

An incandescent lamp is used as a colourless light source.

Measuring the sensitivity of the receiver (R) relative to the digital error (BER) probability – Fig. 1.5

In the circuit T designates a transmitter, E/O – electro-optical, for example laser LED, and R designates a receiver.

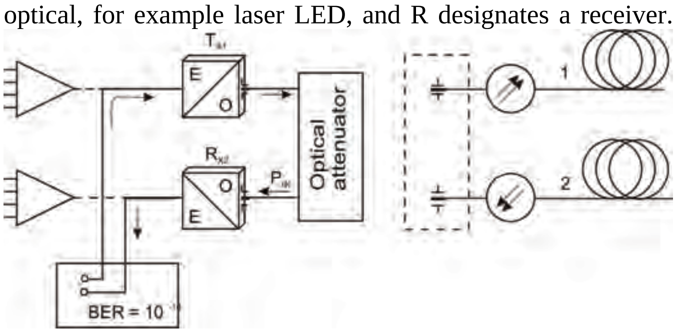

Fig.1.5

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