The External Mechanical Effects on the Value of Additional Losses in the Telecommunicationsfiber Optic Cables Under Operating Conditions

Ali Mekhtiyev[1,2], Felix Bulatbayev[1], Yelena Neshina[2], Eduard Siemens[3], Aliya Alkina[2] and Tatyana Shaigarayeva[1]

[1]*Faculty of Power Engineering, Automation and Telecommunications, Karaganda State Technical University, Mira, Karaganda, Kazakhstan*

[2]*Engineering School of Nondestructive Testing and Safety, Lenina, Tomsk. Russia*

[3]*Future Internet Lab Anhalt, Anhalt University of Applied Sciences, Bernburger Str. 55, 06366 Köthen, Germany*

barton.kz@mail.ru, felix4965@mail.ru, 1_neg@mail.ru, eduard.siemens@hs-anhalt.de, alika_1308@mail.ru, shaigaraeva@mail.ru

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Abstract: This article deals with the impact of optical fiber bends on the level of optical losses. The main task of this research was to carry out a series of experiments using the optical time domain reflectometer (OTDR VISA) under field operating conditions for obtaining of optical loss parameter's dependencies from different bending radii of optical fibers and from the fibers number. We have studied the processes of the occurrence of optical losses in the investigated object and elaborated deterministic models of the physics of the phenomena along with the description undelraying physical processes during the bending. As the outcome of the experiment, a number of dependencies of the optical losses intensity from the number of bends in the fiber, the radii and the wavelength is elaborated. A methodology of the calculation of the signal strength from the number of bends is given. During the work, the excessive losses were noted in case of non-compliance with the installation technology and operating rules. The results of cable research are adopted by Kazakhtelecom JSC.

1 INTRODUCTION

During the operation of the fiber optic cables mechanical loads on the cables occur, which lead to bends of the optical waveguide which in turn causes the signal attenuation and optical losses reducing the performance of the telecommunications network. Hereby the quality of the services provided to customers of Kazakhtelecom JSC is the most important criteria for the company and a special attention is payed to determination of that..

When laying fiber-optic communication cables different situations occur, which affect the technical characteristics of the fiber optic cable and the transport capacity of the telecommunications channels. The most important impact on the transport capacity has been proved to be the influence of bending parameters of optical fibers and the occurrence of losses of radiated power of the signal source in the fiber optic cable. As pointed out above, bends of a fiber-optic conductor lead inevitably to energy losses which in practice exceed the values given in the manufacturer's specifications. The loss data at such a bend radius is especially large. The signal attenuation values in optic fibers reach critical values, when the fiber optic conductor is on the verge of mechanical damage. The critical radius can be as small as a few millimeters for fibers with high numerical aperture, whereas the minimum allowable bend radius is much larger - often tens of centimetres - for single-mode fibers with large transverse mode area.

Usually the energy losses increase during the optical fiber deformation at longer wavelengths. The interference of light reflected from the cladding of the coating determines the dependency of the losses from the wavelength. The increase in fiber losses on fibre bends at long wavelengths limits the transmission range of single-mode fibers [1].

Our work was carried out of the request of Kazakhtelecom JSC and is of applied nature, whereby cables of various manufacturers are used for tests and investigations, while installation is performed by several contract organizations that are not connected by common management of operations. At the same time, there is a possibility that not all technological requirements are met during assembly work.
The main task was to carry out a series of experiments using optical time domain reflectometer (OTDR)VISAunder actual operating conditions for obtaining the multifactor dependencies with different bend radii of optical fibers and their number. The results will be used to adjust the monitoring system of Kazakhtelecom JSC.

2 RELATED WORK

A scientific analysis of similar research performed by foreign authors that work with optical fibers and develop fiber-optic sensors has been performed in [2] - [10]. Most of that relates to the use of fiber to build sensors for the mining industry.

The author's experience and research methods have been taken into account, which allowed us to choose the direction of work and achieve the originality of the research, since our task was to solve actual problems associated with the transmission of optical signals in telecommunications systems. In recent research, we have elaborated methods of investigation of optical power losses and result processing in [11].

3 THE PERFORMANCE OF THE EXPERIMENT

The accuracy of the measurements made by the OTDR meter is determined in the same way as by optical wattmeters and light-sensitive detectors of other kinds [12]. The accuracy of any optical meter depends on how close the output power of the electrical signal corresponds to the input power of the optical radiation. Most optical meters convert the incoming power of optical radiation evenly over the entire operating range into an electrical signal of the appropriate level, but the output power of the electrical signal is extremely low. During the research we used OTDR VISA (Figure 1) which is an universal measuring system for equipping the trunk stations and operating the new FTTx access technologies (PON, etc.) operating at two wavelengths of 1310 nm and 1550 nm with an additional option of the optical power meter. OTDR VISA is used in the production of fiber and fiber optic cable, the construction of fiber optic communication lines (FOCL), diagnostics and maintenance of the state of fibers, cables and fiber optic communication lines.

Figure 1: Type of VISA OTDR.

A series of experiments was conducted to determine the dependency of the additional losses on the number of bends and the bend radius of the fiber optic conductor which can arise during its operation under normal operation conditions. A single-mode G-652 fiber with a wavelength of 1310-1550 nm was investigated.

The following initial conditions were adopted for the investigations:

- air temperature is 20 C,
- number of bends is from 1 to 10 in steps of 1,
- bend radius is in the range from 3 to 18 mm,
- length of the fiber optic cable under test is 71 m.

The blind spot of the OTDRvisa is no more than 3 m (according to the passport), the measurement method used is the measurement of optical losses on the optic fiber with an increaseed number of bends with different bend radii during the cable installation into the ground. The OTDR characteristics are: the refraction index (n) -1.4683, back-scattering coefficient (BC) -78 dB, allowed interval (dL) - 0.43 m, and the pulse length (Tp) - 10 ns [12].

Analysis parameters are: attenuation in the connections - 0.2 dB, reflection coefficient - 40 dB, fiber end - 3 dB, inner losses within the device - 0.002. During the research more than 30 types of fiber optic cable which was in operation by Kazakhtelecom JSC were examined, however three of them has been used for presenting in this work.

We have studied the processes associated with the occurrence of optical losses in the investigated object and developed deterministic models physical phenomena and the underlaying physical elementary processes in the fibers. The performed tasks where: the following: the determination (refinement) of the model parameters; d determination of the model parameters, reduction of the number of iterations. The method is based on the development results of M. M. Protodyakonov [13]. It allows working with data of uncontrolled and controlled experiments. The method is universal both in the field of application and in the variants of the model construction: the models can have the form of sum, products of partial dependencies, their combinations, with sequential neutralization of the influence of priority arguments or without it. An important advantage of the method is the possibility to estimate with an appropriate level of reliability the influence of those arguments that will be excluded from analysis in traditional methods as not significantly affecting the objective function (for example, by Fisher criterion). The results of our measurement results, repeated 10 times each, and the calculated approximations with exponential functionsxxx are presented by the dependency graphs below, whereby the parameters of the exponential functions are given for each graph, along with the correlation coefficient R between the measurement results and the respective approximations.

The measured fiber optic cable isSNR-UT-12, which is a very robust one and designed for laying intra-district and inter-building networks of cable providers of communication or cable TV. The technical parameters of the cable are shown in Table 1. Figure 2 shows the measurements results and their average loss values which were determined by means of the optical reflectometer. According to the average loss value it was constructed a dependency graph on the number of bends from the bend radius. We plotted the dependency curves of the additional losses on the number of bends at different values of the bend radii of the optical fiber. The value of the radius r for the curve is given for all three graphs as follows: 1: 3 mm, 2: 5 mm, 3: 10 mm, 4: 12 mm, 5: 15 mm, 6: 18 mm. For each radius two lines are given – a solid line with measurement points and a dashed line with the approximation, described above.

Table 1: Descriptions of SNR-UT-12fiber optic cable.

Number of optical fibers, pcs.	Attenuation coefficient, dB/km, acc. ITU-T:		Allowable tension strain, kN	Temperature range, °C	Outer diameter, mm	Weight of 1 km of cable, kg
	G.652	G.651				
2-154	0,339	0,206	1,3...2,55	-40 ... +60	6	217

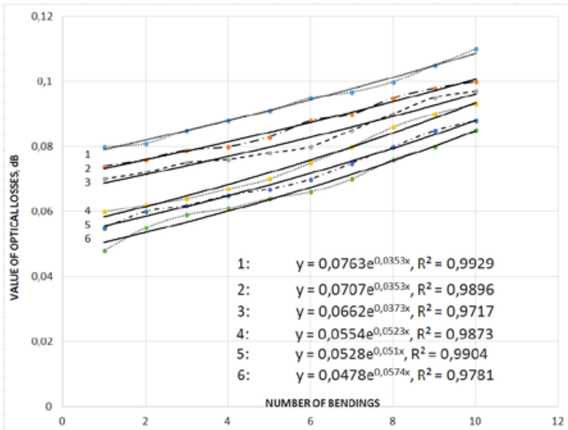

Figure 2: The value of the optical lossess of SNR-UT-12 fiber optic cable. The value of the radius r for the curves: 1: 3 mm, 2:5 mm, 3: 10 mm, 4: 12 mm, 5: 15 mm, 6-; 8 mm.

Futher the fiber optic cable M6A24, which is designed for data transmission over long distances and a high number of channels, has been analyzed. For this, the cable has to have low attenuation and dispersion and high data throughput. A single-mode fiber is used with core and shell dimensions of 8/125 µm. The wavelength is 1.3 ... 1.55 µm. The technical characteristics of the cable are presented in Table 2. Figure 3 shows the measurements results and their average loss value which was determined by means of the optical reflectometer. According to the average loss value a dependency graph has been compiled on the number of bends in dependence from the bend radius.

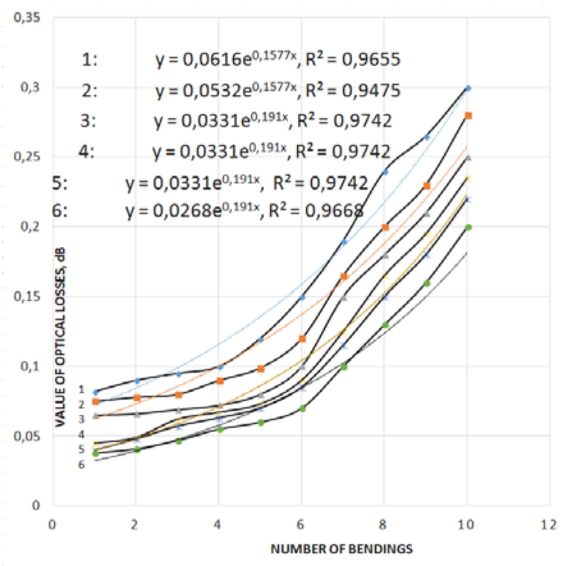

Figure 3: Value of additional losses of M6A24 fiber optic cable. The value of the radius r for the curve: 1-3 mm, 2: 5 mm, 3: 10 mm, 4: 12 mm, 5: 15 mm, 6: 18 mm.

Table 2: Descriptions of M6A24 fiber optic cable.

Number of optical fibers, pcs.	The attenuation coefficient, dB/km		Allowable tension strain, kN	Temperature range, °C	External diameter, mm	Weight of 1 km of cable, kg
	G.652	G.651				
2-156	0,20	0,67	1,3 ... 2,55	-40 ... +60	14,9	215

In a next series, the OKLSM-12-FF fiber optic cable, designed for laying in cable channels, pipes, blocks, collectors has been investigated. The technical characteristics of the cable are shown in Table 3. Figure 4 shows the measurement results and the average loss values. According to the average loss value a dependency graph on the number of bends from the bend radius has been conducted.

Table 3: Descriptions of OKLSM-12-FF fiber optic cable.

Number of optical fibers, pcs.	The attenuation coefficient, dB/km		Allowable tension strain, kN	Temperature range, °C	External diameter, mm	Weight of 1 km of cable, kg
	G.652	G.651				
2-144	0,22	0,7	1,5...3,5	-40 ... +60	14,4	194

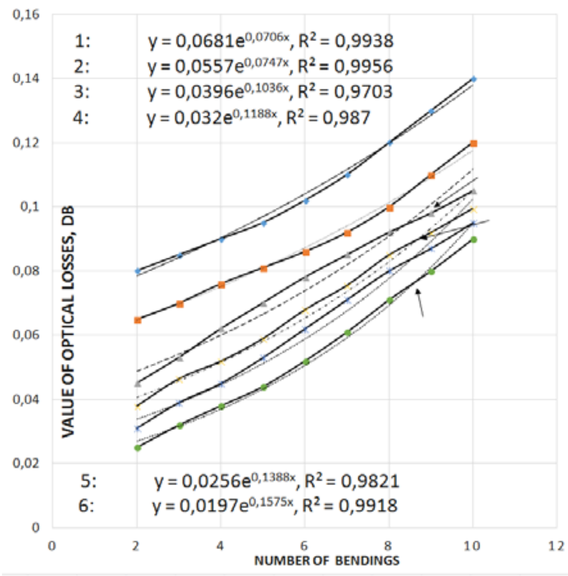

Figure 4: Value of additional losses of OKLSM-12-FF fiber optic cable. The value of the radius r for the curve: 1: 3 mm, 2: 5 mm, 3: 10 mm, 4: 12 mm, 5: 15 mm, 6: 18 mm

The performed tests and measurements have shown that under normal operating conditions not all technical characteristics of the manufacturers correspond to the claimed ones. Additional optical losses arising from mechanical effect on them may be higher than the normative ones, even if the manufacturer indicates that the cable is not susceptible to mechanical bends and deformations.

Based on the research, the recommendations on the selection of fiber optic cables for use at Kazakhtelecom JSC have been made.

4 CONCLUSIONS

During the experiments, a number of dependencies of the increase in additional losses are established with an increase in the number of fiber bends and a decrease in the bend radius, and also with an increase in the wavelength of the optical range of the light source. This analysis is new and is not yet known to be performed by other research groups. The results allow to make ajustments for more accurate results of reports of telecommunication devices sent to the central server in the monitoring system to assess the overall transmission quality situation. In the event of an increase in optical losses, the information is sent to the operator desk for making appropriate decisions.

During the work, excessive losses were noted in case of non-compliance with the installation technology and operating rules. Recommendations for elimination of points of massive optical losses were made which were sent to the management of this telecommunications company to eliminate the issues. The database has been gathered and put on the server in the monitoring system to assess the quality of the telecommunications network. This research was conducted with the participation of teachers, undergraduates and representatives of the technical service of Kazakhtelecom JSC.

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