Traffic interception in fiber optical video-systems

Yu E Krivenko and E I Andreeva

The Bonch-Bruevich Saint-Petersburg State University of Telecommunications, St.Petersburg, 193232, Russian Federation

Abstract. In fiber-optic video systems, as well as in optical communication systems, standard single mode optical fibers (SSMF, standard G.652) are usually used. One of the advantages of these fibers is the ability to use CWDM in a wide spectrum. At the same time, more optimal near the wave-length of 1550 nm are provided by non-zero dispersion fiber (NZDSF, standard G.655) fibers. However, as studies have shown, these optical fibers have an increased sensitivity to bending. This fact can be used to traffic interception. It is shown that fiber-optics systems with SSMF have more protection from traffic interception than systems with NZDSF. To transmit a high-confidence video signal, special techniques, such as frequency modulation, can be used, or additional noise signals can be added.

1. Introduction

The use of the optical cable in the communication systems provides such advantages as information capacity, reliability, durability, and protection. To achieve these advantages, different types, and standards of fibers are used [1-3]. However, this does not exclude the interception of the transmitted information.

Often the optimization some system parameter is associated with difficulties in maintaining the proper level of other system parameters. One of the key issues in the design of a video surveillance system is the choice of the type of optical fiber as a direct signal transmission medium. The characteristics of the optical fiber must ensure the maximum of the transmission distance on the one hand, and the protection from the interception of the transmitted information on the other. To provide the transmission a high-quality video signal, it is necessary to transmit a wide-spectrum optical signal. Therefore, to transmit such optical signal over a long distance, fibers with a low losses and low dispersion can be used, such as NZDSF – nonzero dispersion shifted fibers (standard G.655). In fiber-optic video surveillance systems, as well as in optical communication lines, standard optical fibers (SSMF, Standard Single Mode Fiber, standard G.652) are most often used. One of the advantages of these fibers is the ability to use the CWDM wavelength division multiplexing in a wide spectrum range (from 1270 to 1610 nm). At the same time, the optimal parameters for losses and dispersion in the third transparency window (near the wavelength of 1550 nm) are provided by NZDSF fibers. However, as studies have shown, these fibers have an increased sensitivity to bending. This can lead to additional losses when laying optical cables and an increased risk of unauthorized access. To mitigate these risks, the Bending Loss Insensitive Fiber (BLIF – fibers, standard G.657) can be used.

The main methods of interception relate to the formation of optical informative signals by outputting a part of the optical information signal, e. g., by removing a part of the radiation when the fiber is bended.

To study the effect of bending of an optical fiber on its characteristics, a stand was assembled, the block diagram of which is shown in Figure 1.
Experimental study of the level of bending losses was carried out by the substitution method. Testing was carried out in 2 stages. At the first stage, the spectral dependence of the level of introduced losses was recorded in a wide range of wavelengths: from 1270 to 1610 nm. CWDM SFP modules (Small Form-Factor Pluggable) were used as radiation sources. Registration of the optical signal was carried out by the differential method considering the spectral sensitivity of the photodetector [2]. Optical power measurements were carried out using a Rubin-300 stationary optical power meter. The source parameters were monitored using a Yokogawa AQ6370C optical spectrum analyzer. Results of the investigation of the bend sensitivity of the different fibers is presented in figure 2.

![Block diagram of the measuring setup](image)

**Figure 1.** Block diagram of the measuring setup: 1 – WD-multiplexor, 2 - measuring optical fiber, 3 - tested optical fibers, 4 - optical spectrum analyzer, 5 - optical power meter.

**Figure 2.** The bend loss $\alpha$ in dependence from wavelength $\lambda$. for NZDSF (standard G.655) (1), for SSMF (standard G.652) (2) and BLIF (standard G.657A2) (3) is presented. (The bend diameter is 12.5 mm.)

NZDSF has maximal bend sensitivity within studied fibers. So, this fiber has big risk of the information interception.

In systems with CWDM, traffic interception can be carried out on channel splitting devices. Adjacent channel isolation is nearly 30 dB. Non-adjacent channel isolation is nearly 40 dB. So transmitted signal can be registered in different output channel. To test the possibility of intercepting traffic, a stand was assembled, figure 3. The part of the experimental setup is shown in figure 4. The possibility of intercepting traffic at the demultiplexor output has been experimentally confirmed.
**Figure 3.** Block diagram of the measuring setup: 1 – WD-multiplexor, 2 - WD-demultiplexor, 3 - optical power meter, 4 - optical spectrum analyzer, 5 - optical fiber.

**Figure 4.** Experimental setup: CWD-multiplexor, CWD-demultiplexor, Yokogawa AQ6370C optical spectrum analyzer, optical fiber.

**Figure 5.** Optical signal at input (a) and output (b) optical fiber with dispersion $D = 2$ ps/nm/km. Signal wavelength: $\lambda = 1470, 1490, 1530$ and $1550$ nm. Distance 20 km.
In WDM systems, part of the transmitted signal can fall into the adjacent spectral channel due to FWM (Four Wave Mixing). The simulation was carried out in the OptiSystem program. The optical signal was fed into the spectral channels of the CWDM grid: 1470 and 1490, 1530 and 1550 nm. After passing the effective loss manifestation length $L_{\text{eff}} = 20$ km, signals due to the original ones were observed in the adjacent spectral channels. The level of these signals is 53 ... 55 dB lower than that transmitted in NZDSF and 55 ... 60 dB lower than that transmitted in SSMF (figure 5). This fact reflects the difference in the nonlinearity coefficient of these optical fibers. Standard optical fibers are characterized by greater protection from unauthorized access then NZDS fibers.

### Table 1. Nonlinear fiber coefficient.

| Fiber      | $A_{\text{eff}}$, $\mu$m$^2$ | $n_2$, $10^{-20}$ m$^2$/W | $n_f/A_{\text{eff}}$, $10^{-10}$ W$^{-1}$ | $\gamma=(2m_2/\lambda A_{\text{eff}})$, W$^{-1}$km$^{-1}$ |
|------------|-------------------------------|--------------------------|---------------------------------|---------------------------------|
| SSMF       | 80                            | 2.35                     | 2.94                            | 1.2                             |
| NZDSF      | 55                            | 2.6                      | 8.7                             | 3.5                             |

$A_{\text{eff}}$ – the effective core area  
$n_2$ – nonlinear refractive index  
$\gamma$ - nonlinearity coefficient

### 2. Conclusion

It is experimentally confirmed that NZDS-fibers (with low dispersion) of the G.655-standard are characterized by increased sensitivity to bending, as result of which they require greater security to avoid interception of the transmitted signal traffic. NZDSFs provide more long-distance transmission of video signal. At that time SSMFs provide greater protection against traffic interception. It has been shown experimentally that interception of the transmitted signal traffic can occur in the CWDM system.

The question of the penetration of the fraction of the transmitted signal into adjacent channels in WDM-system due to nonlinear effects is investigated. Comparative analysis shows that a standard optical fiber (SSMF) has a higher protection, while the signal transmission range can be increased using a dispersion-shifted fiber (NZDSF). To transmit a high-privacy video signal, special modulation methods, such as frequency modulation, can be used, or additional noise signals can be added.

### References

[1] Andreev D, Andreeva E, Sergeev A and Sumkin V 2020 Influence of Optical Cable Bending in Fiber Optic Systems Video Surveillance and Subscriber Access with Spectral Multiplexing *APINO Proc.* 1 pp 57–61

[2] Andreeva E, Valyukhov V and Kuptsov V 2019 High-Quality Video Transmission Over Fiber-Optic Network with CWDM-Technique *APINO Proc.* 1 pp 56–60

[3] Andreeva E, Valyukhov V and Kuptsov V 2018 Fibre Optics CCTV Systems and Security Alarms *APINO Proc.* 1 pp 57–61