Field Test of Communication Cable for Environmental Monitoring

Chuanbiao Zhang*[1,2], Xiongyan Tang[1,2], Guangquan Wang[1,2], Shikui Shen[1,2], He Zhang[1,2], Yanbiao Chang[1,2], Junzhong Cao[3]

1. State Engineering Research Center of Next Generation Internet Broadband Service Applications, Beijing 100033, China
2. China Unicom Research Institute, Beijing 100033, China
3. China Unicom Tianjin Branch, TianJin 300020, China
E-mail address: zhangcb65@chinaunicom.cn

Abstract: A routing section of the communication cable in the live network is used, combined with distributed optical fiber sensing equipment, for long-term monitoring, and through data recording, to achieve a variety of dynamic event response analysis.

1. Introduction

As more and more communication optical cables are laid to provide users with quality services, cable resource management and effective use has become important, people have developed a variety of new means for cable maintenance, such as the widely used OTDR technology, analysis of fiber link characteristics, used in optical network troubleshooting and maintenance. In addition, due to the continuous development and maturity of optical fiber sensing technology, optical fiber resources can be used not only for the transmission media of optical fiber communication, but also for the sensing media of optical fiber sensors. Researchers have proposed that the integration of communication and sensing functions can be realized by using optical fiber resources [1,2]. Based on the needs of operators themselves and combined with distributed monitoring technology, active perception of optical fiber status, such as optical cable resource visualization and optical fiber fault monitoring, can improve the operation and maintenance efficiency of optical networks and improve user experience [3,4]. Using fiber optic cable resources to realize the sensing and monitoring function, generally speaking, is to collect and process the scattered signals of different optical fibers, and extract the useful characteristics of optical fiber links. It is common to realize distributed optical fiber sensing systems based on backscattered light signals, such as Rayleigh scattering, Raman scattering and Brillouin scattering. Researchers have conducted extensive research, such as distributed vibration sensors, distributed temperature and strain sensors, etc. [5-7].

In order to achieve a better integration of distributed sensors and optical cables in the live network, it is necessary to conduct test analysis on the current optical cable resources in the live network. In this paper, through the field test, combined with a variety of installation types of cable resources in the network test analysis, such as overhead cable, wall cable, pipe well cable, etc. The field test characteristics of different optical fiber states are analyzed, the spectral response of optical fiber scattering in different environments is analyzed, and the potential application of optical fiber resources in environmental monitoring and urban dynamic detection is studied.

2. Field test and related data analysis

2.1. Optical fiber routing status monitoring and positioning

In the test, we selected a cable span in the actual network, approximately 8 km in length, from the test room as the starting endpoint, connected to a distributed vibration sensor via fiber jumper. The optical cable is led out from the machine room and fixed on the outer wall through a steel fixture. Then it is elevated through two communication poles in the courtyard of the test site, and finally enters the underground pipe well and leads to another office end along the road, as shown in Fig. 1. In this test, the acquisition spectrum of the instrument is about 125 MHz, the wavelength of the laser light source is 1550 nm, and the amount of data collected every day is about 12GB. It is worth mentioning that the optical cable route we selected, and the routing direction in some pipe Wells, happened to be accurately determined through this test. The optical cable routing used in this experiment has undergone various types of installation environments. In order to analyze the response of optical fiber scattered signals to vibration events in different environments, several typical optical cable locations were selected for testing.

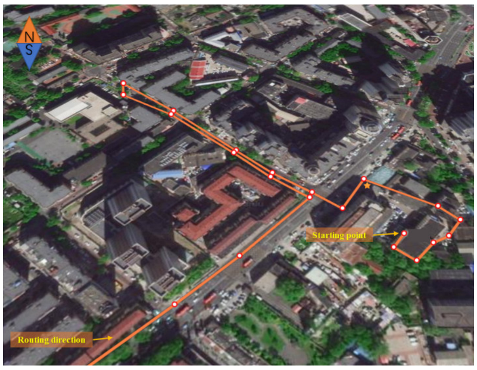

Fig. 1 Schematic diagram of optical cable routing.

First, the optical cable fixed on the external wall is tested. By creating vibration events, the spectrum response is observed. As shown in Fig. 2 (a), the response of multiple vibration events can be clearly observed, and the vibration response has a certain influence range of about 8 m. In the figure, the horizontal coordinate is the number of sampling points, the actual interval is 1.6 m, and the vertical coordinate is the frame rate, each frame is 0.05 s. In addition, 176 m on the way, is the optical fiber mechanical connection, strong reflection caused by the event blind area, about 40 m, and can be optimized by improving the receiver. In contrast, when the vibration occurs on the overhead optical cable, the influence range of the vibration will increase, as shown in Fig. 2 (b), about 15 m. The overhead optical cable in the test is located between two cement poles, the height of the poles is about 10 m, and the distance between the poles is about 30 m, as shown in Fig. 2 (c). Vibration is generated by striking the bottom of the poles. And the duration of the vibration can be observed to increase.

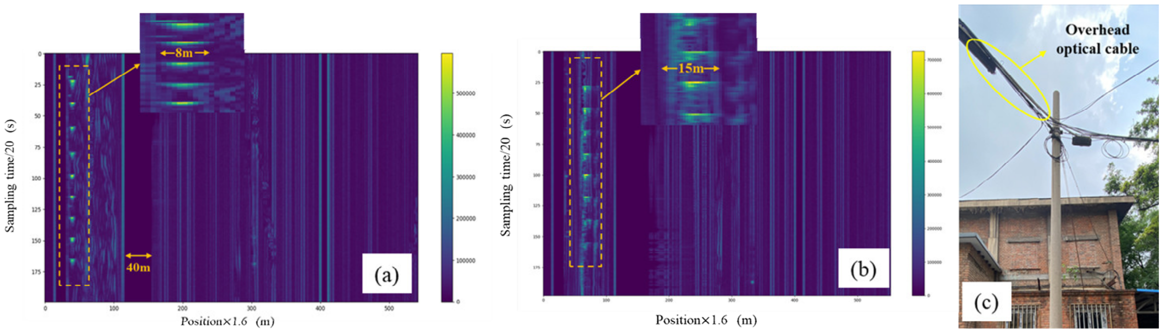

Fig. 2 Response to vibration events, (a) fixed to the wall, (b) overhead cable, (c) overhead cable fixed pole.

For the optical cable installed in pipe wells, vibration events were generated by tapping the manhole cover and the asphalt roadside near the manhole cover respectively. The vibration response was shown in Fig. 3 (a), (b). Due to the large absorption of vibration conduction on the ground, the response intensity was weak. In addition, it was found in the test that when vibration events were applied to some pipe Wells, the scattered signal of the echo occurred in different locations at the same time, and the vibration response was highly consistent in time, but the strength of the signal was different, as shown in Fig. 3 (c). It can be determined that this is the same fiber optic cable route, which is repeated through the pipe well and verified and compared with the fiber optic cable resource data. It also verified this phenomenon. This is very helpful for determining the cable routing.

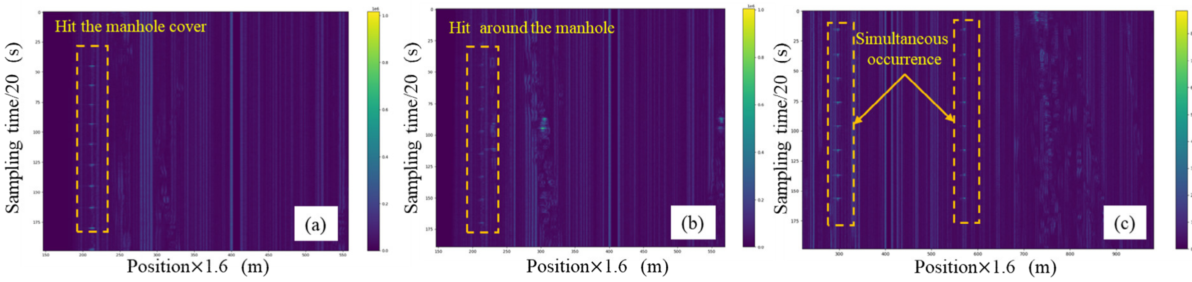

Fig. 3 Vibration response of the cable installed in the tube well (a) tapping the well cover (b) tapping around the well cover (c) repeated passing.

2.2. Urban road dynamic monitoring

In the experiment, we analyzed the obtained spectrum data, and found that the optical cable routing section located on the roadside would be affected by the traffic flow and produce a characteristic spectrum response. In the above analysis, we also observed some tracks with slopes on the spectrum diagram. In order to further analyze this phenomenon, we selected the spectrum waterfall data of different time periods, as shown in Fig. 4. When the vehicle passes over the cable section, a certain vibration is generated, which is transmitted to the cable, and as the vehicle moves, the frequency spectrum waterfall diagram will show the speed characteristics of the vehicle.

Three vehicle tracks were selected for analysis, and the speed of the three vehicles was obtained, which were 3.3 m/s, 3.5 m/s and 4.2 m/s, respectively. Moreover, it can be observed that the spectral response intensity generated by the three vehicles passing by is different, which is because the actual road is multi-lane, so the vehicle type and the distance between the vehicle passing by and the cable tube well are also different, as shown in Fig. 4 (b), (c). In addition, it can be found from the figure that there are two points in each of the two tracks with strong vibration response, and the positions of the two points are the same. We guess that this is because the car happens to pass the manhole cover, and the wheel causes strong vibration events, that is, the red break line marked in the figure.

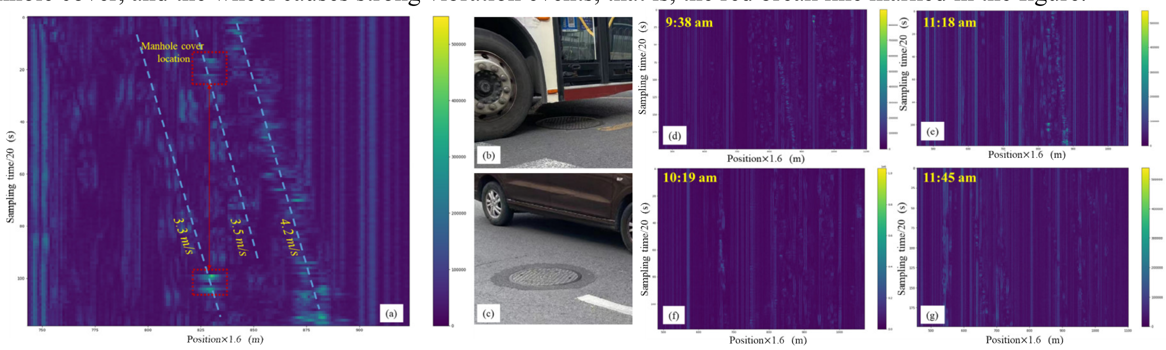

Fig. 4 Vibration response of vehicle passing by (a) response track, (b) wheel passing by manhole cover, (c) wheel passing by manhole cover, (d)-(g) dynamic monitoring at different times.

We also analyzed the traffic flow dynamics in different time periods and found that the traffic flow was also very different at different time points, as shown in Fig. 4 (d)-(g). In addition, it can be found from the figure that the monitored traffic flow state is only one-way traffic, which is also corresponding to the actual road state. This section of optical cable route is located at the edge of the right one-way lane, so only traffic in a single direction passes through. This phenomenon can be used to realize the dynamic monitoring of the city, analyze the activity status of different areas of the city, and provide real-time dynamic data for urban traffic management and other applications. A wide range of monitoring data can be obtained by adding only a few hardware devices.

3. Conclusion

In this paper, we use a section of optical cable routing in the actual network to carry out field tests of distributed optical fiber sensing monitoring, and obtain the response data of optical cables under different vibration conditions, such as overhead optical cables and optical cables in tube wells, and combined with the vehicle dynamic monitoring test, to study the value of distributed sensing technology in the application of urban dynamic monitoring. It is believed that with the gradual advancement of standardization research, this technology will gradually develop and mature.

Acknowledgment

This work is jointly supported by the China National Key R&D Program (No.2022YFB2903300).

4. References

[1] "Cable identification for the construction and maintenance of optical fibre cable networks by optical sensing technique" Recommendation ITU-T L.316:2022.
[2] Yan Y, et al. "Distributed optical fiber sensing assited by optical communication techniques," J. Light. Technol. 2021, 39(12): 3654-3670.
[3] Wellbrock G A, et al. "First field trial of sensing vehicle speed, density, and road conditions by using fiber carrying high speed data," Proc. OFC. Th3A.5 (2020).
[4] Ip E, Fang J, et al. "Distributed fiber sensor network using telecom cables as sensing media: technology advancements and applications," J. Opt. Commun. Netw. 2022, 14(1): A61-A68.
[5] Zinsou R, et al. "Recent progress in the performance enhancement of phase-sensitive OTDR vibration sensing systems," Sensors, 2019, 19(7): 1709.
[6] e Silva M S P, et al. "Evaluation of fiber optic Raman scattering distributed temperature sensor between–196 and 400° C," IEEE Sens. J. 2020, 21(2): 1527-1533.
[7] Bai Q, et al. "Recent advances in Brillouin optical time domain reflectometry," Sensors, 2019, 19(8): 1862.