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SERIES L: ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Maintenance and operation – Optical fibre cable maintenance

Cable identification for the construction and maintenance of optical fibre cable networks by optical sensing techniques

Recommendation ITU-T L.316

ITU-T

ITU-T L-SERIES RECOMMENDATIONS

ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

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Recommendation ITU-T L.316

Cable identification for the construction and maintenance of optical fibre cable networks by optical sensing techniques

Summary

Recommendation ITU-T L.316 specifies cable identification for the construction and maintenance of optical cable networks. Cable identification is performed to find or trace a target cable or route by optical fibre sensing techniques under deployed conditions characterized by a number of cables.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T L.316	2022-02-13	15	11.1002/1000/14920

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Cable identification, optical fibre cable, optical sensing technique.

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Recommendation ITU-T L.316

Cable identification for the construction and maintenance of optical fibre cable networks by optical sensing techniques

1 Scope

This Recommendation specifies cable identification for the construction and maintenance of optical cable networks. Cable identification is performed to find or trace a target cable or route by optical fibre sensing techniques under deployed conditions characterized by the number of cables.

Optical fibre identification that is used to identify a particular fibre among many fibres is specified in [ITU-T L.314].

This Recommendation:

– describes functional requirements for cable identification performed on deployed optical fibre cable networks;
– gives a classification of and information on optical fibre sensing techniques;
– gives requirements for in-service cable identification without interfering with optical communication signals;
– describes procedures and system configurations for cable identification.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.652] Recommendation ITU-T G.652 (2016), *Characteristics of a single-mode optical fibre and cable*.

[ITU-T G.653] Recommendation ITU-T G.653 (2010), *Characteristics of a dispersion-shifted, single-mode optical fibre and cable*.

[ITU-T G.654] Recommendation ITU-T G.654 (2020), *Characteristics of a cut-off shifted single-mode optical fibre and cable*.

[ITU-T G.655] Recommendation ITU-T G.655 (2009), *Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable*.

[ITU-T G.656] Recommendation ITU-T G.656 (2010), *Characteristics of a fibre and cable with non-zero dispersion for wideband optical transport*.

[ITU-T G.657] Recommendation ITU-T G.657 (2016), *Characteristics of a bending-loss insensitive single-mode optical fibre and cable*.

[ITU-T L.100] Recommendation ITU-T L.100/L.10 (2021), *Optical fibre cables for duct and tunnel application.*

[ITU-T L.102/L.26] Recommendation ITU-T L.102/L.26 (2015), *Optical fibre cables for aerial application.*

[ITU-T L.103] Recommendation ITU-T L.103/L.59 (2016), *Optical fibre cables for indoor applications.*

[ITU-T L.108] Recommendation ITU-T L.108 (2018), *Optical fibre cable elements for microduct blowing-installation application.*

[ITU-T L.202] Recommendation ITU-T L.202/L.50 (2010), *Requirements for passive optical nodes: Optical distribution frames for central office environments.*

[ITU-T L.300] Recommendation ITU-T L.300/L.25 (2015), *Optical fibre cable network maintenance.*

[ITU-T L.314] Recommendation ITU-T L.314 (2018), *Optical fibre identification for the maintenance of optical access networks.*

[ITU-T L.330] Recommendation ITU-T L.330 (2020), *Telecommunication infrastructure facility management.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 optical distribution frame (ODF) [ITU-T L.202].

3.1.2 optical fibre identification [ITU-T L.300].

3.1.3 manhole [ITU-T L.330].

NOTE – This Recommendation uses the term "maintenance hole" as a synonym.

3.1.4 handhole [ITU-T L.330].

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 cable identification: Distinguishing the target cable in deployed conditions containing a number of cables by applying an optical fibre sensing technique.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

APC Angled Physical Contact

CO Central Office

DAS Distributed Acoustic Sensing

ODF Optical Distribution Frame

PC Physical Contact

5 Conventions

None.

6 Background

Optical fibre cables are the main media for telecommunication. More and more cables are being installed and operated, including duct and aerial cable.

Sharing of telecommunication infrastructures such as poles, ducts, tunnels, conduits, maintenance holes and handholes, by different operators is the new norm. In shared infrastructures, optical cable identification is essential for network construction and maintenance, to quickly find the target cable among many; it can greatly reduce the delivery and out-of-service times, and avoid incorrect handling of in-service cables.

7 Functional requirements of cable identification

With a view to realizing the efficient construction and maintenance of optical fibre cable networks, it is very important that on-site workers be able to rapidly identify a particular target cable among many on a worksite. In cable identification, an operator of optical sensing equipment in a central office (CO) monitors the intentional vibration applied by the on-site worker.

Therefore, the fundamental requirements of cable identification are as follows. Cable identification should:

– identify a target cable by measuring vibration by analysing a received optical signal from dark fibre;

– be able to monitor the intentional vibration applied to a target cable on site and also be capable of eliminating the spurious vibration created when the on-site worker handles candidate cables.;

– employ a dark fibre of the target optical cable as a sensing fibre;

– be capable of being performed without degrading optical communication signals in live fibres contained in the same cable.

7.1 System configuration

Figure 1 shows a system configuration for the cable identification. In cable identification based on the optical sensing technique, a sensing equipment operator connects the optical output of test light to a dark fibre of the target cable at an ODF in a CO. An on-site worker applies intentional vibration to one of the candidate cables. As the sensing equipment captures and analyses the vibration, the intentional vibration is clearly observed in the CO, the on-site worker can identify the target cable without any service interruption.

In general, when vibration is measured by an optical sensing technique, large capacity data of the order of gigabytes is recorded even in short periods. To decrease the measurement time, the sensing equipment operator and on-site worker are assumed to have a means of communication to synchronize hitting and recording.

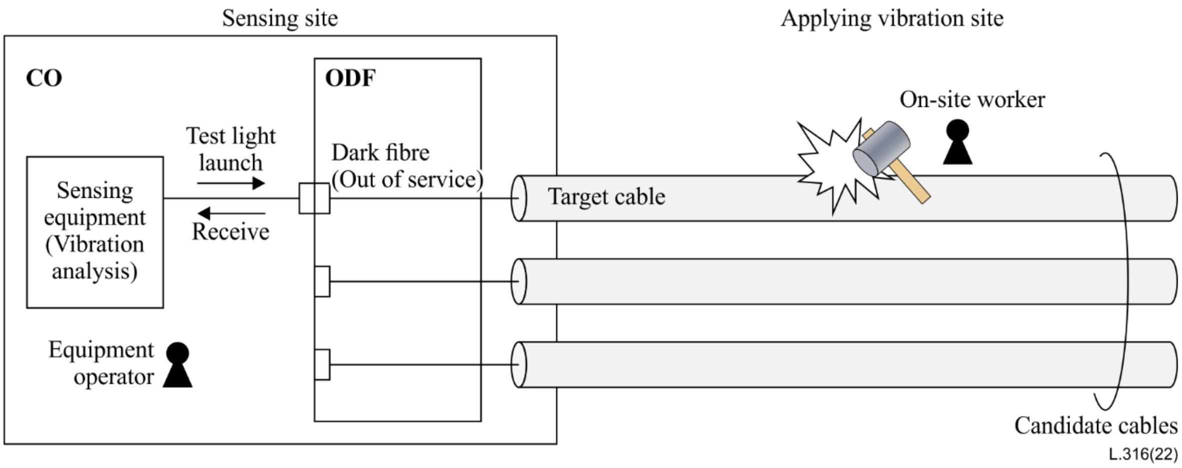

Figure 1 – System configuration of cable identification

7.2 Sensing fibre configuration

The configuration of the sensing fibre should be single star or ring topology.

7.3 Applicable areas

Applicable areas where target cable is deployed include, but are not limited to:

– underground;

– aerial;

– indoors.

7.4 Cable types

Cable identification should apply to cables of the duct, conduit, aerial and indoor types.

Cable identification should apply to the cable types specified in [ITU-T L.100], [ITU-T L.102], [ITU-T L.103] and [ITU-T L.108], which contain any number of fibres.

7.5 Fibre types

Cable identification should support the fibre types specified in [ITU-T G.652], [ITU-T G.653], [ITU-T G.654], [ITU-T G.655], [ITU-T G.656] and [ITU-T G.657].

7.6 Cable identification procedure

Cable identification using optical sensing is carried out in the following process. A sensing equipment operator in a CO connects the sensing equipment to the planned dark fibre in the target cable, and a test light is launched into the fibre directly for vibration monitoring. An on-site worker visually locates candidate cable(s) and prepares to apply intentional vibration. If necessary, adjacent cables are suitably separated to prevent vibration from being transmitted between cables. The operator in the CO and the on-site worker communicate with each other to synchronize vibration application and monitoring. When the intentional vibration is clearly captured, the target cable is most likely to have been identified. For confirmation, adjacent cables are struck to check that no vibration is captured. When the worker must trace the route of the target cable, the above steps are repeated at different locations.

8 System requirement of cable identification

8.1 Basic principle of optical sensing techniques

Optical sensing techniques are useful for cable identification because they can measure intentional vibration on a fibre cable remotely and in real time. When intentional vibration is applied to a candidate cable by an on-site worker, the vibration causes fibre birefringence in the cable owing to the photoelastic effect, which creates phase disturbance or phase shift in the test light. The disturbed test light (or scattering of the test light) is received by optical sensing equipment through far-end reflection, fibre loopback or Rayleigh scattering, and the vibration signal is analysed. If necessary, noise (environmental vibration) in the received test light is eliminated by analysis filters (e.g., low or high pass filter). The optical sensing equipment judges whether the vibration signal is in accordance with the intentional vibration or not. Common optical sensing techniques are classified in clause 8.2.

8.2 Classification of optical sensing techniques

8.2.1 Interferometry-based technique

An interferometry-based technique is one candidate method for cable identification. Three main effects are utilized for cable identification, i.e., the birefringence of fibre (caused by the photoelastic effect), Fresnel reflection and interferometry. The end face of the fibre termination should be considered when test light reflection from the far end is used. Reflection mirrors for test light may be introduced at the far end to upgrade identification performance and capability, as the poor reflection provided by fibre cut ends or angled physical contact (APC) connectors degrades the sensitivity of the sensing system. For the configuration in Figure 2-a, one dark fibre is needed, while for that in Figure 2-b, two dark fibres are needed, with fibre loopback at the far-end.

The advantage of adopting the interferometry-based technique is high sensitivity and quick responsiveness, as the received test light is analysed directly. Furthermore, the equipment configuration is relatively simple.

The disadvantage of the technique is that the received test light generally does not have distance information, hence noise arising from environmental vibration experienced over the entire cable cannot be eliminated easily.

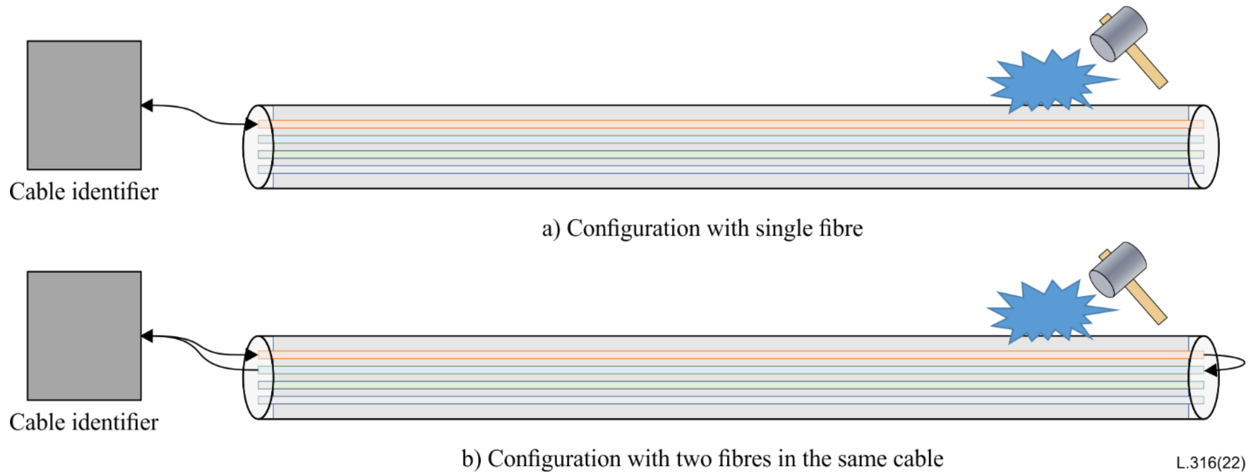

Figure 2 – Interferometry-based cable identification

8.2.2 Reflectometry-based technique

A reflectometry-based technique is another candidate method for cable identification, in which, as shown in Figure 3, the vibrations at any point are analysed by comparing the intensity or phase of the received Rayleigh scattering of the test light. If the distance to a vibration application site is roughly known, environmental vibrations at unnecessary points can be eliminated based on the distance information.

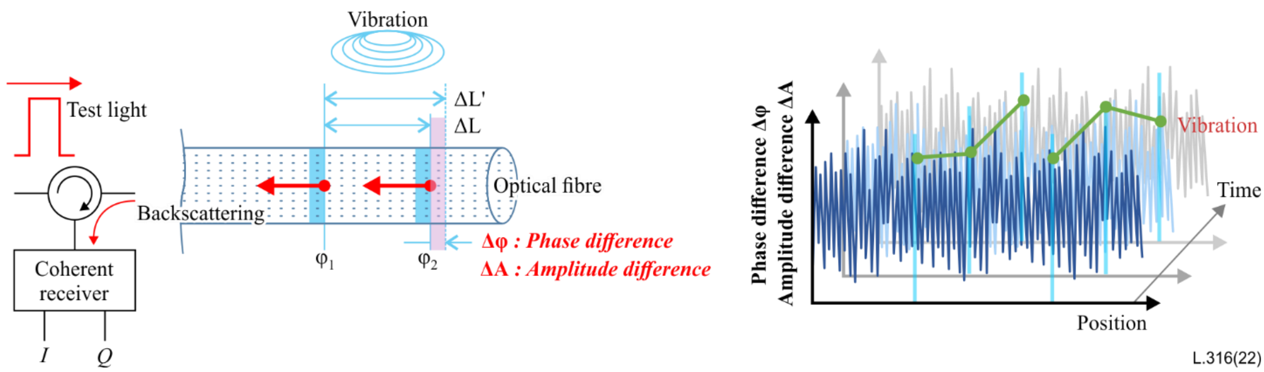

Figure 3 – Reflectometry-based cable identification

The advantage of adopting the reflectometry-based technique is that cable identification can be performed more accurately via multidimensional analysis by referring to the distance information in addition to the vibration analysis. Furthermore, this technique is applicable to a single dark fibre configuration without requiring far-end reflection or fibre loopback.

The disadvantage is its relatively low sensitivity, because the vibration signal is analysed from the Rayleigh scattering, which has very small power. Furthermore, the configuration of the sensing equipment might not be simple, and complicated signal processing degrades responsiveness.

8.3 Optical performance

8.3.1 Distance measurement range

The distance measurement range is the maximum distance (specified in length units) from the sensing equipment along the fibre within which the vibration signal can be measured under specified conditions with adequate performance. The distance range is expected to be at least 10 km for outdoor cable identification.

NOTE – Since the distance measurement range varies greatly depending on vibration conditions, environmental noise, cable installation site, etc., it is preferred that customer and manufacturer confirm the conditions of cable identification.

8.3.2 Identification light

Test light is usually launched at the end of an optical fibre in the CO. Due to the use of a dark fibre, an arbitrary wavelength can be selected for the test light. A 1 550 nm wavelength is preferred given its lower loss with propagation distance, which could support longer working distances at the same launch power of test light.

The output power and signal to noise ratio of test light are highly related to the identification working distance and capability.

8.3.3 Optical return loss

The return loss at dark fibre connections is recommended to be higher than 40 dB, because multiple reflections along the dark fibre cause noise in the received test light. Of particular note, the return loss at the connection between the sensing equipment and ODF yields a dead zone, typically of several hundred metres.

8.4 Interference with vibration applied to the cable

The intentional vibration applied to a cable should minimize the disturbance on active service being carried by the cable. Permanent damage to cables should, of course, be avoided. The on-site worker applying the vibration to a candidate cable should adequately separate adjacent cables to prevent the vibration from being transferred to any adjacent cable.

The intentional vibration with modulated frequency can be monitored more clearly by using a frequency band different from that of environmental vibration, the major causes of which are traffic and wind. Thus, the modulated frequency of the intentional vibration is recommended to avoid the frequency band of 1 to 90 Hz. Note that the modulated frequency must be less than the detectable frequency band of the optical sensing equipment.

Appendix I

Cable identification application in China

(This appendix does not form an integral part of this Recommendation.)

I.1 Application of cable identification

Nowadays, sharing of telecommunications infrastructure among different operators, such as poles, ducts, tunnels, maintenance holes and handholes, has become a major trend.

In shared infrastructure, optical cables identification is essential for network maintenance, to quickly find a target cable among several or dozens of cables, which could reduce out-of-service time greatly, and avoid incorrect handling of in-service cables.

Optical cable identification is mainly used for regular inspection in cable network maintenance and emergency cable repairs of damage caused by human activities, accidents or natural hazards. Especially in the latter case, it is important to locate, identify and repair the target cables.

Several optical cable identification methods have been used.

During manufacture, cables should be marked for identification on the sheath at regular intervals. The markings can sometimes be two-dimensional matrix codes. However, during the lifetime of cables, the markings could become indistinct a long time after installation, making identification difficult.

Information about the cable could be printed or manufactured on passive label tags attached to cables, in maintenance holes, handholes, poles, tunnels or ducts, which can be read by an on-site worker during the cable maintenance. Missing tags or incorrect attachment can cause confusion in cable identification.

To enhance passive tags, tags with radio frequency identifier chips attached to or embedded in cables have been introduced, from which cable information can be read by special equipment carried by on-site maintenance workers.

These methods also have drawbacks of one kind or another; a more effective and precise method based on external effects has been introduced in China.

I.2 Interferometry-based cable identification and working principle

Interferometry-based cable identification methods are commonly used by network maintenance in China for quick cable identification, when a cable is knocked, the knock can be transferred as an audio or video signal through interferometry to maintenance workers in a CO.

This method works based on the interference effect.

In the single fibre scenario shown in Figure I.1-a, the signal is launched from the interferometer into the fibre of a target cable, reflected back at the far end of the cable and finally detected by the interferometer. When the cable is knocked, the detected interference signal changes as a result of the knock, therefore the target cable can be identified.

Two fibres within the same cable can also be used, as shown in Figure I.1-b.

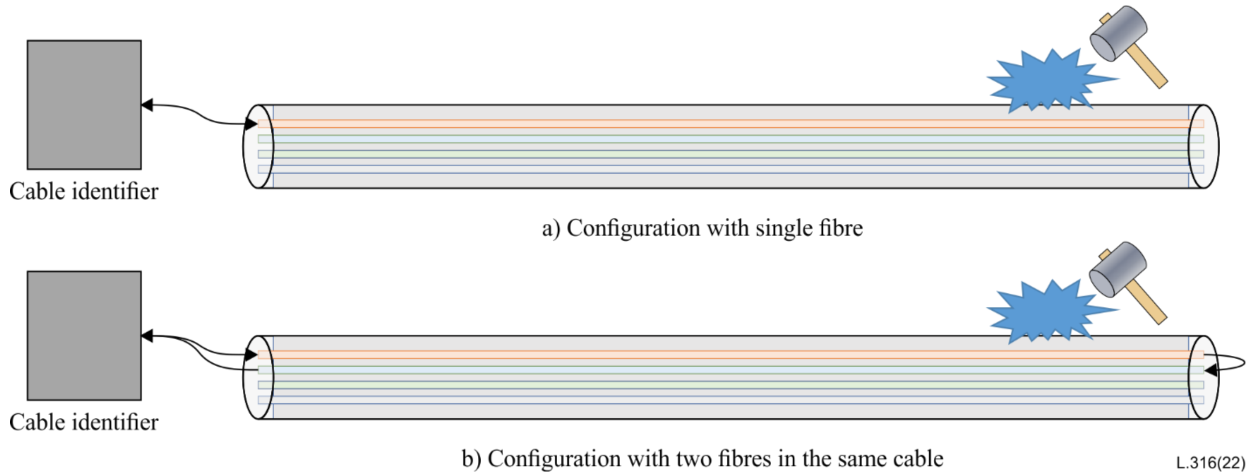

Figure I.1 – Interferometry-based cable identification

For single fibre method, the reflection of far end is very important, sometime a reflector may be needed to enhance the signal reflection. Using two fibres in same cable which are interconnected far end could avoid this problem.

I.3 Identification ability and applicable scenarios

The signal wavelength of cable identifier could work in different bands, while C band preferred as lower loss along the cable, such as 1550 nm.

The detected length depends on the output power and sensitivity of the identifier, including outdoors and indoors application.

Typically, the key specifications of optical fibre cable identifier are as follows.

– Centre wavelength: 1 310 nm or 1 550 nm;

– Optical output power: ≥ −5 dBm;

– Distance measurement range: ≥ 10 km.

The output identification results could be audio or video on the identifier.

For single fibre method, there should not be larger reflection during the fibre link, which would affect the identification performance.

And the cable should be terminated in far end ODF using physical contact, not APC.

The knock on the cable could be generated by different ways, including hammer, handheld motor, etc.

Crosstalk would happen when the cables are too close to each other, therefore, when knock, the cable should be separated certain distance with other cables.

This method is applicable for different cables installations, including duct, aerial, and tunnel, and applicable for different fibres.

Appendix II

Cable route identification application in Japan

(This appendix does not form an integral part of this Recommendation.)

II.1 Introduction

Japanese operators have deployed massive amounts of optical fibre cables to provide optical information technology services. Latest servicing requirements focus on maintenance efficiency rather than construction cost. Cost-effective maintenance is necessary to develop an accurate facilities database. However, some portion of the database contains mismatch to actual cable route and maintenance hole location. Database mismatching of underground optical cabling routing has been a cumbersome burden when trying to localize a target cable or facility for maintenance. To improve database accuracy, optical vibration sensing has been implemented for route identification of deployed optical fibre cable.

II.2 Configuration

Figure II.1 shows the configuration of an optical cable identification with a distributed acoustic sensing (DAS) system, which senses optical vibration based on reflectometry. In a CO, a DAS system is connected to a fibre of the target cable in an optical distributing frame. The on-site worker applies intentional vibration by hitting maintenance hole covers that are assumed to follow the cable route. By analysing intentional vibration data, the actual cabling route and distance from the office to the hit maintenance hole can be obtained. In this measurement, vibration can be detected even when the maintenance hole is submerged. Thanks to cabling root identification, the maintenance target cable and facility can be easily identified without maintenance hole cover opening.

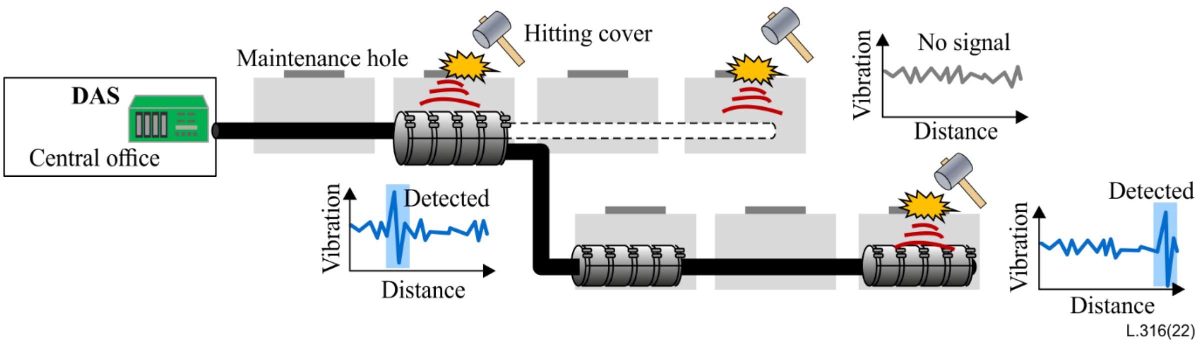

Figure II.1 – Optical fibre cable route identification with reflectometry-based optical vibration sensing

II.3 Optical performance

Figure II.1 shows a typical optical configuration of DAS implementing coherent optical time domain analysis. Optical pulses are output as the test light, and backscattered light from an optical fibre is received by coherent detection. When vibration is applied to the optical cable, the optical phase and intensity of the backscattered light change. Further, the distance to the vibration point can be measured by the reception time of the backscattered light whose phase or intensity are greatly changed.

When analysing vibration data produced by hitting a maintenance hole cover using a DAS that performs coherent detection, 15 dBm or more is required for the input light. In searching for a cable route that passes over a distance of over 20 km, or near a road with heavy traffic noise, it is desirable to launch an optical pulse of about 25 dBm at peak power to enhance signal to noise ratio.

The optical pulse width should be desirably less than 100 ns. It is necessary to have a spatial resolution that allows discrimination from other facilities (maintenance hole or handhole) existing near the maintenance hole that is hit.

II.4 Interference with vibration applied to the cable

Due to the slight cable vibration caused by the sound when an on-site worker hits the maintenance hole cover, interference with in-service links is not expected. However, if a metal maintenance hole cover is hit with a metal hammer, it causes noise pollution in the surroundings. Therefore, the use of a rubber hammer is recommended.

II.5 Cable identification procedure

In the ODF of the CO, the DAS is connected to an optical fibre not being used for communication services. The DAS operator and the on-site worker who hits the maintenance hole cover communicate with each other by telephone to synchronize the vibration measurement and the blow to the maintenance hole cover. When vibration due to the blow is detected, it can be confirmed that the measuring cable passes through the maintenance hole that is hit. It is possible to reduce noise such as traffic vibration by analysing a detected signal according to a predetermined hitting schedule. The on-site worker moves to the next maintenance hole and repeats the same process to trace the route of the underground cable without opening the maintenance hole cover.

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