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Installation Considerations for Rail

Introduction

Distributed fiber optic sensing techniques, such as DAS, DSS or DTS are powerful tools for the monitoring of long, linear assets. Consequently, these approaches fit perfectly with specific requirements of the railroad industry, where they can fulfill objectives in various areas:

- Tracking the position, direction, speed & length of trains
- Monitoring rolling stock defects (flat / defective wheels and defective bearings)
- Monitoring rail defects (rail breaks, rail buckling or bad welds / joins)
- Detecting trackside activity (work crews, trespassers, cable tampering)
- Detecting Rockfall and landslide events in the vicinity of the track

In each of these applications, distributed fiber optic sensing offers clear benefit in the ability to cover a wide area from a central monitoring point, and can often achieve this by repurposing spare fibers in the existing railroad communication network.

Optimum performance for any particular sensing objective is dependent on cable type, installation method, cable position and the environmental conditions of the site. This applies to both existing cables and those installed specifically for distributed fiber optic sensing.

This document provides guidance on best practice for the selection and installation of cables for fiber optic sensing in the railroad domain. In general, the most prevalent sensing technology for railroad applications is Distributed Acoustic Sensing (DAS) which monitors vibrations transmitted to the fiber from nearby energy sources – such as moving trains, people or vehicles.

Cable Selection

General

Cables should be selected according to their proposed use, which for rail is often a dual purpose of fiber optic sensing and communications, and the operational requirements of the railroad. Optical fibers should conform to ITU-T G652 or 655. The type of installation (e.g. direct buried, in conduit, aerial lashing, fence attachment, or direct rail attachment) and the environment/ground conditions may have an impact on the construction and level of protection/armor necessary to meet local regulations. Depending on various factors, the structure of the cable might affect the sensitivity and performance of the sensing system. Cable selection details should be discussed with your Distributed Fiber Optic Sensing (DFOS) supplier or industry specialists before finalizing installation.

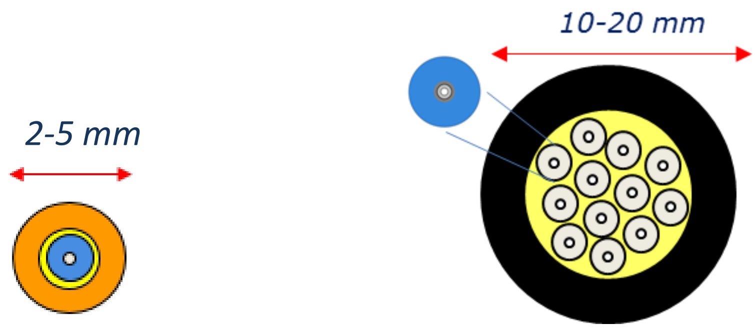

Figure 1: Tight Buffer Cable structures (Left: Tactical Cable, Right: Distribution Unit)

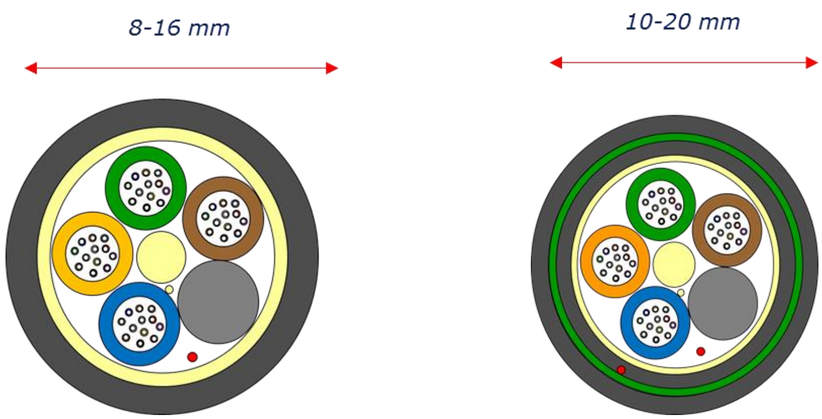

Figure 2: Loose Tube Cable structures (Left: Single Jacket unarmored, Right: Single Steel Tape Armor for Direct Burial)

Cable Core Configurations

Loose tube buffered fiber or tight buffered fiber are the most common configurations used for organizing and protecting optical fibers inside the cable core. These configurations should be designed to minimize fiber strain when the cable is under tension during placement. This helps keep optical fiber attenuation low and ensures fiber reliability post installation.

Specifics for DAS

DAS

Distributed Acoustic Sensing utilizes one singlemode fiber and requires good acoustic coupling between the fiber, the cable itself, and the environment in which the acoustic events are to be detected.

So far good experiences have been made with standard single mode fiber cables which are used for telecommunication and work with wavelengths between 1540 – 1552 nanometers. The generally preferred cable specification for DAS will typically have the following features:

- Single Mode
- Tight buffered or Gel filled loose tube
- Single Jacket
- Unarmored or Single armor
- Spare dark fiber cores (generally one for every 40km monitored)

This type of cable has proven its capabilities in many different installation scenarios and up to distances of 40 kilometers (25 miles). Heavily armored cables with loose buffering or powder fill should be avoided if possible, as this type of construction may result in a reduction of sensitivity. This could cause difficulty in detecting low energy events such as walking or digging near the end of the fiber.

While most installations to date have made use of existing cables, it is expected that in the future specifically developed cables with optimized waveguides, buffering, jacketing, and/or armor could improve DAS performance.

Cable Positioning

General

There are many possibilities for how new or existing cables could be installed, and these can significantly affect performance depending on application, as explained in the following sections.

Specifics for DAS

DAS

A major factor in the quality of the acoustic signal transmitted to the fiber is the location and installation method of the cable. The distance from the fiber to the sound source must also be considered – for example 3-5 m (10-15 ft) from the track is ideal for train tracking, but may not be the best solution to detect trespassers trying to access the railroad. The influence of sound sources not of interest (false positives) to the DAS system should also be taken into account, for example road vehicles or people walking in a station area. Care should be taken to route the cable away from these areas, maintaining the system’s ability to detect and classify signals of interest.

High energy acoustic sources such as trains can be detected at a greater distance than low energy patterns like human digging or walking. In addition to distance, the type of medium through which the acoustic energy needs to travel will affect the level of vibration applied to the fiber – for example, a cable buried in loose sand will not be as sensitive as one buried in firm sand or regular soil, since the loose media will absorb some of the signal.

Cable Deployment Methodology

General

The methods used to deploy and protect the cable near a railroad will depend on local geography, environmental conditions, and regulations. These will generally be focused on protecting the cable from the weather and accidental or malicious damage, but could also have a detrimental effect on its sensing performance.

Specifics for DAS

For acoustic sensing applications, the key is finding an installation method that places the cable close to the signal of interest and protects the cable both from damage and unwanted noise sources, without unduly reducing sensitivity.

Buried cables should be bedded into the soil, infilled with the same soil type, and compacted.

Railroad Applications

The performance of different cable positions and installation methods, based on practical experience over many installations, is explained on the following pages for different railroad applications

Railroad / Asset Monitoring: Deployment Approaches

	Train Tracking	Rolling stock / track defects	Rockfall
Direct buried: *offers some insulation from background noise and good coupling to the ground.*	**BEST** performance, Optimum burial depth is 30-60 cm (1-2 ft) from the surface. With the cable buried clear of the ballast, approximately 1-5 m (3-15 ft) from the center line of the track.		**BEST** performance for rockfall impacts. Optimum burial depth is 30-60 cm (1-2 ft) from the surface. Optimally Cable should be positioned 3-10 m (10-30 ft) from the track and on the side of the rock face.
Direct buried (Single Armor)	GOOD performance – see optimum cable position/burial information above		GOOD performance – see optimum cable position/burial information above
Cable trough: *offers some insulation from background noise*	GOOD performance, with concrete trough located parallel to the track.	Performance for rolling stock/track defects unproven so far	GOOD performance for rockfall impacts on or near the trough.
Wall/Fence Mounted: *Can be subject to high levels of background noise and wind/rain – especially if the fiber is not tightly clipped*	Generally POOR performance compared to cable buried or in trough. GOOD performance is possible if wall mounted in tunnels where background noise is reduced		GOOD for detecting rocks impacting directly to the fence/wall; provided the fiber is protected from environmental wind and rain noise. POOR for events not impacting directly on the fence.
Ground/Ballast Surface	POOR performance for all applications. Installing cables unprotected on the ground should be avoided as they are more susceptible to damage and will be subject to very high levels of background noise.		
Rail Mounted: *cables clipped to the rail are easily damaged by maintenance operations and can be subject to high background noise levels*	POOR performance, cable subject to huge vibrations before, during and after train passage.		GOOD performance for detecting impacts directly on the track if the fiber is held against the rail web and protected from environmental wind and rain noise.

Figure 3: Best practice cable deployment methods for Railroad applications.

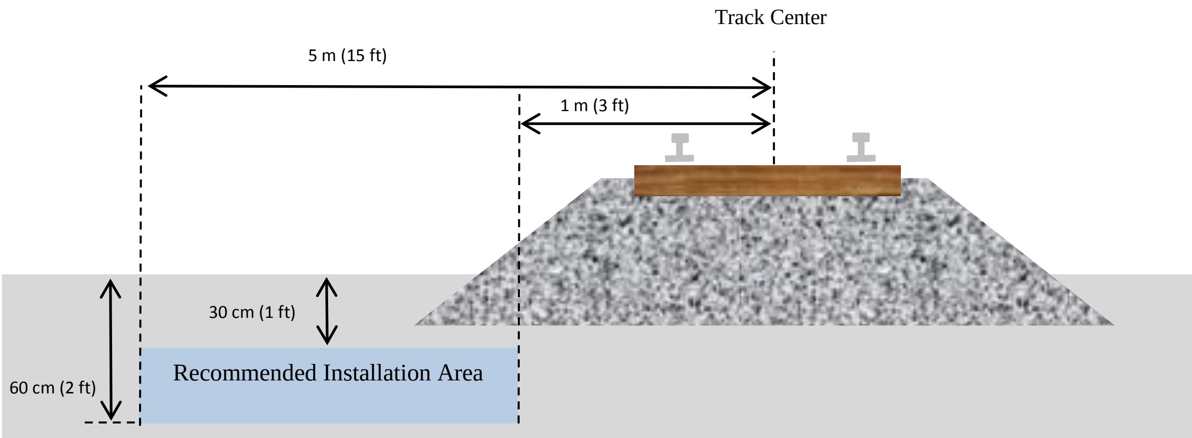

Figure 4: Recommended installation area for direct buried fiber optic cable for Train Tracking, Track/Rolling Stock monitoring

Security & third-party intrusion

For security applications where the aim is to detect third party intrusion, cable positioning must be based on the area to be protected. This may also dictate the method, depending on what is possible along the perimeter to be monitored.

Performance/Best practice - Security

	Security/Third Party Intrusion
Direct buried: *offers some insulation from background noise and good coupling to the ground.*	**BEST** performance for detection of trespassers. Optimum burial depth is 30-60 cm (1-2 ft) from the surface. Cable should be positioned as close as possible to perimeter of the area where the threat needs be detected.
Direct buried (Single Armor)	GOOD performance for detection of trespassers – see optimum cable position/burial information above
Cable trough: *offers some insulation from background noise*	GOOD for detecting people walking on top of the cable trough. BEST for detecting opening of the trough or tampering with cables inside.
Wall/Fence Mounted: *Can be subject to high levels of background noise and wind/rain – especially if the fiber is not tightly clipped*	GOOD for detecting trespassers climbing the fence/wall to which fiber is mounted. POOR for intrusions not impacting directly on the fence/wall or detecting walking patterns.
Ground/Ballast Surface	POOR performance for all applications. Installing cables unprotected on the ground should be avoided as they are easily damaged and will be subject to very high levels of background noise.
Rail Mounted: *cables clipped to the rail are easily damaged by maintenance operations and can be subject to high background noise levels*	Generally POOR, but can be GOOD for detecting trespassers walking directly on the ties.

Figure 5: Best practice cable deployment methods for Railroad security applications

FOSA Technology Committee contributors:

FOSA thanks the efforts of the technology committee Task Force for Installation Considerations for the preparation of this document.

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Please visit www.fiberopticsensing.org for further information on the application of fiber optic sensing