DETECTION OF ABNORMAL ACTIVITIES ON SM OR MM FIBER

We demonstrate eavesdrop detection based on polarization signatures by analyzing polarization state changes at the receiver. We identify changes related to the normal operation and the ones caused by eavesdropping.

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INTRODUCTION

- Both single and multimode fibers are carrying large traffic volumes in fiber optical infrastructures
- Disruption of high density traffic is a serious threat
- Our recent work [1] shows that an optical fiber can be eavesdropped at a certain distance from the transmitter, depending on the efficiency of the tapping device. The higher efficiency the tapping device has, the lower attenuation it will introduce the harder it will be to detect by means of observing the attenuation.
- It is therefore important to detect abnormal activities exposed to fiber optical installations carrying secure or sensitive information before any attenuation can be observed.
- This demonstration will show how security threats of different kinds can be detected by observing the change in polarization state in the transmitted light.

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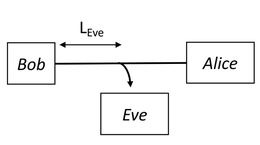
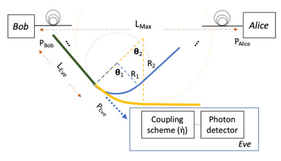
TRANSMISSION LINE

Consider Bob and Alice who are connected over an optical fiber. Eve has intentions to eavesdrop the transmitted information. In order to make a successful eavesdrop she has to first peel off the protective layers of the optical cable and release the optical fiber. Then she has to couple out the light by for example bending the fiber in a certain angle and radius [1]. The out coupled light needs to be focused to an active detector with a certain efficiency.





OUT COUPLED OPTICAL POWER

Eve is making an attempt to eavesdrop a fiber installation of LMax (km) at a distance LEve (km) from Bob. Assume a fiber attenuation of α [1/km] (10 log(α) = 0.2 dB/km).

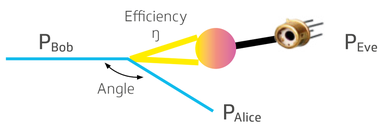
Eve is introducing an extra attenuation DEve (dB) at the receiver of Alice. The power level received by Alice is :

$P_{Alice} = P_{Bob}\ \alpha^{L_{Bob}}\ 10^{-D_{Eve}/10}$

The power level possible for Eve to detect is:

$P_{Eve} = \eta\ P_{Bob}\ \alpha^{L_{Eve}}\ (1 - 10^{-D_{Eve}/10})$

where η [%] is the efficiency of the tapping



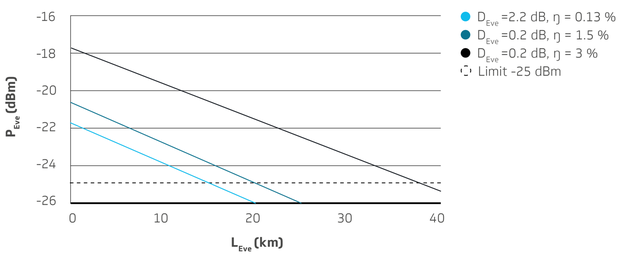
EFFICIENCY OF TAPPING

To prevent information tapping, Alice can use an OTDR and monitor the transmitted optical power. If Alice is using a resolution of 0.2 dB, she has a chance to detect small power changes. However the received optical power do normally varies more that 0.2 dB. This will in practice result in a high level of false alarms.

Assume Bob is transmitting 0 dBm, Eve has a detector with sensitivity of -25 dBm @ 10 Gbps and EDFA of 11 dB and Alice has the same receiver sensitivity as Eve.

References
[1] S.Karlsson, R.Lin, L.Wosinska, P.Monti "Eavesdropping G.652 vs. G657 fibres: a performance comparison", ONDM2022

Detected efficiant power level



- With a tapping device introducing 0.2 dB with 3 % efficiency, she can eavesdrop at 37 km from transmitter.
- With a taping device introducing 0.2 dB attenuation with an efficiency of 1.5 % she can detect the signal at 22 km from transmitter.
- With a commercial tap on device introducing 2.2 dB attenuation, Eve can detect 10 Gbps 16 km from transmitter.

Even if Eve is using an OTDR with 0.2 dB resolution to monitor the received power, it is possible for Eve to eavesdrop the installation. Because a resolution of 0.2 dB will result in a high degree of false alarms, Eve needs to find an alternative method to detect eavesdropping.

3

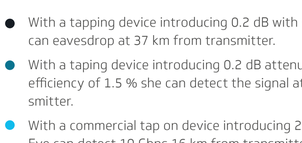
MONITORING POLARIZATION CHANGES TO DETECT EAVESDROPPING

We have shown that it is possible to eavesdrop an optical fiber without significant change in the received optical power

This demonstration will show how changes in polarization state due to vibrations can be used to detect eavesdropping.

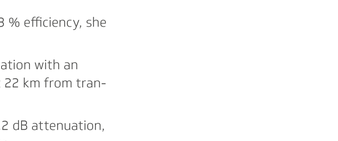
Manipulations on the fiber not detectable by measurement of the power level, can be noticeable by change in the polarization state.

Transformation of the Poincare sphere



Note.1: US patent 5,349,458 9/1994

Magnitude of polarization = f{X,Y,Z} Relaxed fiber

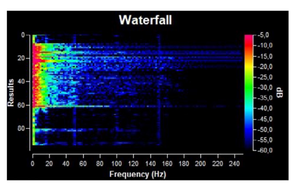


4

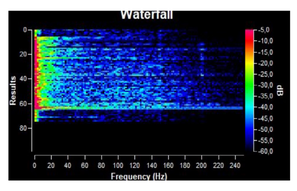
MOVEMENT OF SM G.657 FIBER COMPARED TO OM3 FIBER

In data centers or between data centers of today even OM3 fibers are carrying traffic with capacity of multiple Gbps.

The signatures below are generated by holding the fiber still in hand 2 cm above the table.



SM G.657



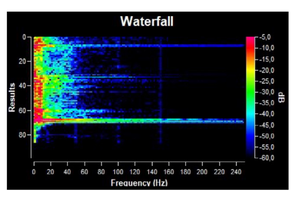
MM OM3

- We can see strong signal strength in the lower frequency range from the G.657 fiber.
- The OM3 fiber show weaker signal strength in the lower frequency range, but stronger at the higher frequencies.

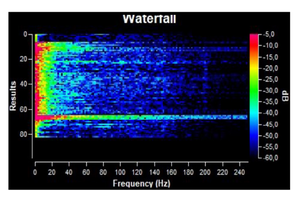
MOVEMENT OF SM G.657 FIBER COMPARED TO OM3 FIBER

Signature due to bending without exceeding an extra attenuation of 0.2 dB

The signatures below are generated by bending the fiber 60 deg, with bend radius 2 mm, and holding still in hand.



SM G.657



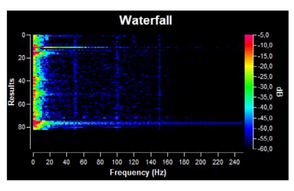
MM OM3 fiber

- We can see strong fluctuations in signal strength at lower frequency range when the G.657 fiber is bent to 60 degrees and with 2 mm bend radius.
- The OM3 fiber show weaker signal strength in the lower frequency range, but stronger at the higher frequencies.

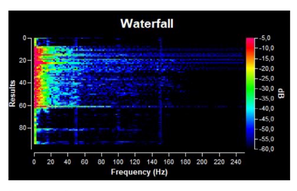
5

MANIPULATION OF MILITARY TACTICAL FIBER CABLE COMPARED TO BARE FIBER (1)

Holding still in hand a Tactical fiber cable with G.657 fiber and a bare G.657 fiber



Tactical fiber cable

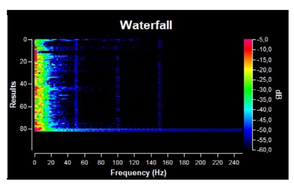


Bare G.657 fiber

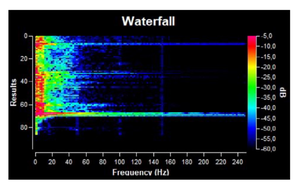
It is possible to detect the difference by handling the tactical cable and compare with a bare fiber.

MANIPULATION OF MILITARY TACTICAL FIBER CABLE AND BARE FIBER (2)

Bending angle 60 degrees and bend radius 2 mm



Military Tactical fiber cable, introducing 0 dB attenuation



Bare G.657 fiber, introducing 0.2 dB attenuation.

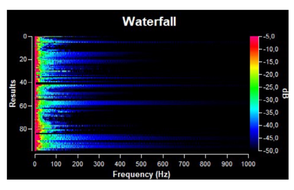
It is possible to detect the difference in signature between tactical cable compared and a bare fiber.

6

REMOVING PROTECTIVE LAYERS

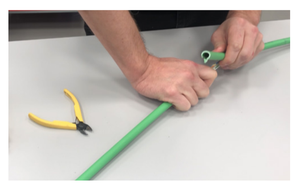
To eavesdrop an fiber optical cable it is absolutely necessary to remove the protective layers of the cable.

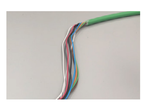
The activity of removing the layers took approx. six minutes and generated the signature below.



We can observe strong magnitude at frequency below 50 Hz.

The extra optical attenuation that Alice can measure is negligible.



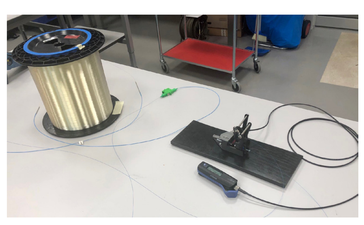


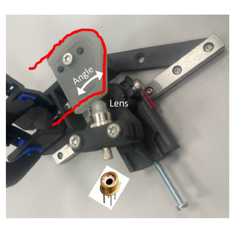
TAPPING DEVICE OUT COUPLING OPTICAL POWER FROM G.657 FIBER

Assume Eve is eavesdropping a G.657 fiber at a certain distance from the transmitter.

After removing the protective layers of the cable, without breaking the fiber, Eve is using a tapping device that focus part of the out coupled power on an active detector with high efficiency.

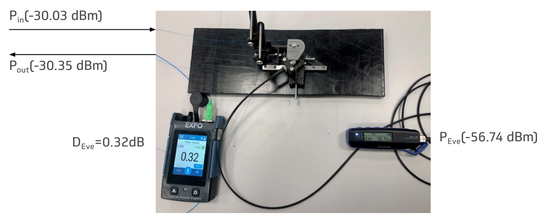
Eve must manage all this without introducing to much loss of optical power at the receiver of Alice.





TAPPING DEVICE TO COUPE OUT OPTICAL POWER FROM A G.657 FIBER

In this demonstration Eve is bending the fiber to an angle of 60 degrees over bend radius of 2 mm focusing part of the out coupled light to a MM fiber with 200 um diameter. With the efficiency of 3 % she can detect -56.74 dBm of transmitted optical power, provided the input power of -30.03 dBm to the tapping device.

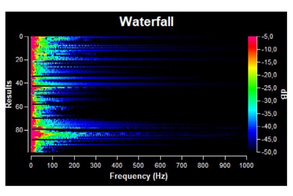


RESULTS

SIGNATURE DURING TAPPING ACTIVITY ON G.657 FIBER

Generated signature during tapping activity introducing an attenuation at Alice of 0.32 dB.

The signature has strong magnitudes at low frequencies, i.e., up to 50 Hz

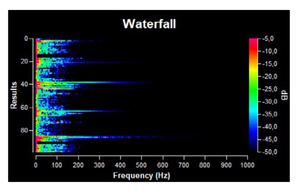


SIGNATURE DURING TAPPING ACTIVITY ON G.652 FIBER

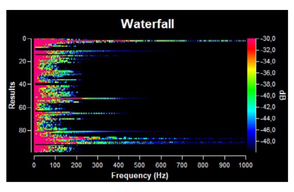
Generated signature with a commercial tapper introducing an attenuation at Alice of 1.84 dB.

Received optical power at Eve of -48.98 dBm, resulting in an efficiency of 0.031 %.

The signature has lower magnitudes compared to a tapper with angle 60 degrees over bend radius of 2 mm



Magnitudes between -5 dB and -50 dB



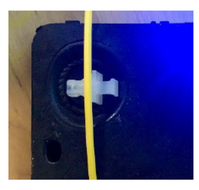
Magnitudes between -30 dB and -50 dB

7

RECOGNIZING SIGNATURES ORIGINATING FROM VIBRATIONS IN THE SURROUNDING ENVIRONMENT

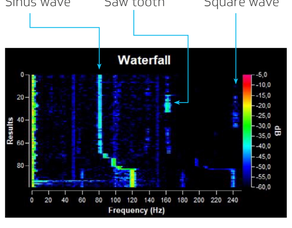
External activities, such as excavators cutting the cable by accidence, can constitute a treat to a fiber optical installation. This kind of activities generates vibrations that can be picked up by the fiber cables in the installation. Signatures could be used to alarm for threatening activities.

Tone from the loudspeaker at 80 Hz, increasing to 120 Hz



Loud speaker generating sound wave vibrating a optical cable

Sinus wave Saw tooth Square wave



HANDLING OF BARE FIBERS COMPARED TO OPTICAL CABLES

The signature from a G.657 fiber exposed to the sound waves from the loud speaker is about 30 dB stronger than signature generated with the vibrations picked up by the cable

Tone from the loudspeaker at 80 Hz, increasing to 120 Hz

Loud speaker generating sound waves on G.657 fiber

Sinus tone Saw tooth Square wave

8

CONCLUSIONS

We have shown that it is possible to seamlessly eavesdrop a single mode G.657 fiber by introducing an extra attenuation which is within a normal optical system margin.

Methods to detect polarization changes can be used to detect eavesdropping attempts.

We have shown that polarization effects provide signatures related to external physical activities that can be recognized. It can also be used to minimize the risk for damaging the fiber cable installation and generate alarms when external activates treating to cut the optical cable are going on.

Future activities include AI and ML methods to recognize the signatures.

ACKNOWLEDGEMENTS

This work was supported by Vinnova and FMV in the frame of CELTIC-Next AI-NET PROTECT.

Special acknowledgment to Micropol Fiberoptics AB for providing the experimental setup