Sensitivity enhancement in distributed acoustic sensors by operation at 850-nm wavelength

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In this work, we show that the SNR in distributed acoustic measurements can be enhanced by employing a coherent OTDR configuration operating at 850 nm wavelength, instead of the more conventional 1550 nm wavelength. The proposed approach has the advantage that it is can be adopted in already deployed fiber-optic cables.
Keywords: Distributed acoustic sensors

1. Introduction

Distributed acoustic sensors exploit the Rayleigh scattering in conventional optical fibers, in order to detect any vibration or acoustic disturbance impinging upon the fiber. The operation relies on the interference between the single scatterers inside the pulse length: in presence of an acoustic disturbance, the relative distance among the various scatterers change, affecting the backscattered signal. Therefore, this signal can be used to perform acoustic measurements [1]. In analogy with the conventional Optical Time-Domain Reflectometry (OTDR), these techniques are commonly referred to as Coherent-OTDR. In C-OTDR sensors, the sensitivity to external disturbance can be improved by either acting on the sensing fiber [2-4], or the interrogation system. The latter solution is advantageous as it can be applied to existing fiber-optic cables [5]. In this work, we propose the use of a C-OTDR operating at 850 nm, instead of the more conventional 1550 nm wavelength, in order to enhance the Rayleigh backscattered signal and thus improve the Signal-to-Noise Ratio (SNR).

2. Theoretical and experimental results

When a short pulse of light is injected at one end of a single-mode optical fiber, the power received at the launch end is proportional to $\alpha_S \times B_S$, where α_S is the Rayleigh scattering coefficient, and B_S is the Rayleigh capture fraction. The Rayleigh scattering coefficient exhibits an inverse fourth-power dependence on the operation wavelength, therefore it increases when decreasing the wavelength. On the other hand, the Rayleigh capture fraction B_S is also wavelength-dependent. Finally, one show consider that, for a given vibration amplitude the phase change at λ = 850 nm is nearly twice the phase change at λ = 1550 nm. Combining all three effects, one concludes that the SNR increases by $\approx$ 10 dB when moving from 1550 nm to 850 nm. Note that this value refers to the case in which the disturbance acts near the pulse launch end. For increasing distances, operation at 850-nm suffers from higher optical loss. However, from simple calculations one may conclude that operating at 850-nm is advantageous over 1550-nm, for sensing distances up to ≈ 3 km.
In order to validate experimentally our analysis, we have performed a number of tests using two C-OTDR setups, one operating at 850-nm and another one operating at 1550nm. Details on the setups can be found in Ref. [6]. As an example, we compare in Fig. 1 the results obtained with the two setups, when applying a 150 Hz vibration at z ≈ 105 m, at a spatial resolution of 5-m. From the graphs, it is clear that the 850-nm measurement detects the vibration more clearly. In particular, the experimental SNR, calculated as the ratio between the 150-Hz spectral component at the vibrated position, and the average amplitude of the signal across the fiber length, was 19.4 dB for the 850-nm sensor, and 12.4 dB for the 1550-nm sensor. The SNR difference (7.0 dB) should be further increased by 4.8 dB, which was the measured unbalance between the path losses in the two setups. The overall SNR enhancement is thus 11.8 dB, which is in a reasonable agreement with the theoretical expectations.

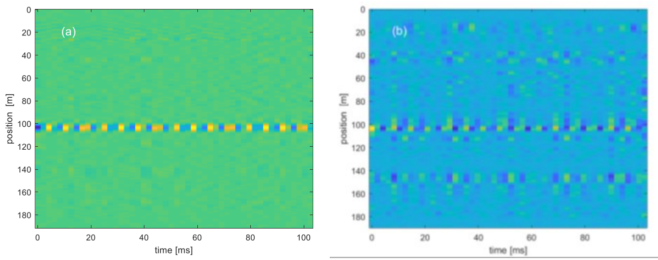

Fig. 1 Distributed vibration detected using the 850-nm sensor (a) or the 1550-nm sensor (b)

Acknowledgements

This work has been partly funded by University of Campania "Luigi Vanvitelli" (Premialità Valere2018).

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