Novel Techniques for Optical Fiber Links beyond Current Practice

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Nowadays, optical links represent a key technology for time and frequency dissemination and remote clocks comparisons. Current techniques are based on Doppler fiber noise cancellation and enable frequency dissemination at the 10^{-19} level of uncertainty. Nevertheless, they present two important issues: the noise compensation is limited by the fiber delay[1], and bridging long distances becomes challenging due to high optical loss, low SNR at detection and high phase noise.

We propose two techniques to overcome these limitations: the first enables better performances on existing links; the second allows the length extension by a factor two along a fiber in the same conditions.

First, we developed a scheme in which the fundamental limit of a typical Doppler-stabilized link is surpassed by 6 dB. This concept is demonstrated through the well-known bounce diagram: it enables to visualize the fiber noise as a function of space and time, and gives some clues on how to minimize it.

With this scheme, two tasks are accomplished at the same time: the dissemination of an ultrastable laser at the typical delay-limited performances, and an offline processing that improves the comparison stability by a factor of 2. The results are shown in Fig. 1.

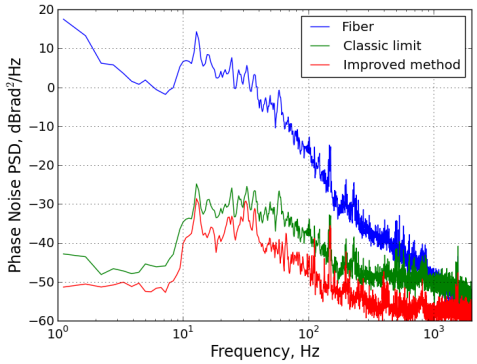

Fig. 1: The phase noise of a free-running 47 km optical link (blue line), of the signal delivered by the theoretical classic limit (green line), and the 6 dB improvement obtained by the first proposed method (red line).

Second, we introduce a different scheme, based on the optical Two-Way Phase Transfer, where two signals travel the fiber in opposite directions[2]. This scheme enables the bridging of longer distances, as the light travels the fiber only once. So, attenuation, phase noise and noise from the amplifiers have a lower impact.

These techniques represent a step forward in optical links. In particular, the bounce diagram method can be regarded as a general tool to better understand existing methods and to investigate novel approaches for time and frequency dissemination.

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[1] W. Williams, W. C. Swann, and N. R. Newbury, "High-stability transfer of an optical frequency over long fiber optic links," J. Opt. Soc. Am. B, vol. 25, p. 1284, 2008.

[2] C. E. Calosso, E. Bertacco, D. Calonico, C. Clivati, G. A. Costanzo, M. Frittelli, F. Levi, A. Mura, A. Godone, "Frequency transfer via a two-way optical phase comparison on a multiplexed fiber network," Opt. Lett., vol. 39, (2014).