Stable RF transmission using PLL over long-distance optical fiber

Hao Gao[1], Chenxia Liu[2], Jianming Shang[1], Ziyang Chen[3], Bin Luo[1], Song Yu[1], Hong Guo[3]

1. State Key Laboratory of Information Photonics and Optical Communications, Beijing University of Posts and Telecommunications, Beijing 100876, China
2. Department of Electronic and Communication Engineering, North China Electric Power University, Baoding 071000, China
3. State Key Laboratory of Advanced Optical Communication Systems and Networks, Department of Electronics, and Center for Quantum Information Technology, Peking University, Beijing 100871, China

E-mail: luobin@bupt.edu.cn

Stable frequency standards have important applications in gravitational wave detection, precise navigation timing, and verification of relativity principles [1-4]. Effectively utilizing the present fiber network resource to construct the stable radio frequency (RF) transfer system has been explored by many researchers. As the transmission distance is extended, the noise induced by the fiber link affects the frequency stability of the receiver signal. Phase-locked loop (PLL) is an efficient method to filter out noise and obtain the synchronous frequency signal at the receiver. In this paper, we test the performance of the frequency transfer system over long-distance optical fiber link and compare the effect of PLL on the frequency stability.

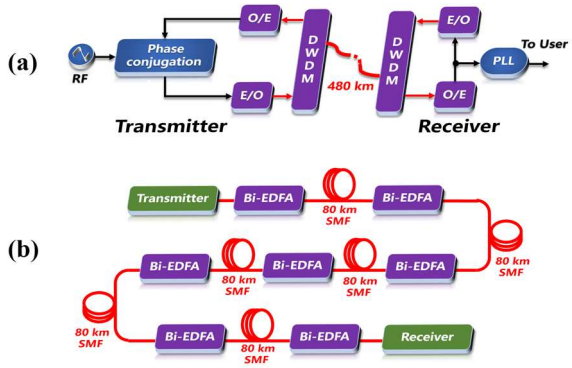

Fig.1. (a) Schematic diagram of the RF transfer system. (b) Schematic diagram of optical fiber link.

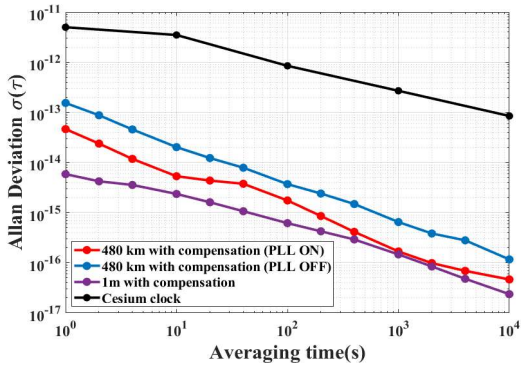

Fig.2. Measured stability of the radio frequency transfer system.

As shown in Fig.1, the experiment is carried out on a 480 km optical fiber link constructed from the cascade of 80 km fiber spools. The transmitter and receiver of the transfer system are placed at either end of the link, and bi-directional erbium-doped fiber amplifiers (Bi-EDFAs) are placed at the fiber link. The experimental results are shown in Fig. 2, when the PLL is turned off, the frequency stability of the transfer system is 4.65×10^{-14}@ 1 s and 4.66×10^{-17}@ 10,000 s. When the PLL is turned off, the frequency stability of the transfer system is 1.54×10^{-13}@ 1 s and 1.17×10^{-16}@ 10,000 s. Experimental results show that the frequency stability of the transfer system is significantly improved by the PLL for long-distance frequency transmission. The frequency stability of the synchronous frequency signal recovered from the receiver is better than that of the cesium clock, which meets the demand of long-distance frequency transmission.

References

[1] M. Zhan and X. Xie, "Precision measurement physics: physics that precision matters," National Sci. Rev. 7, 1795–1795 (2020).

[2] W. M. Campbell, B. T. McAllister, M. Goryachev, E. N. Ivanov, and M. E. Tobar, "Searching for scalar dark matter via coupling to fundamental constants with photonic, atomic, and mechanical oscillators," Phys. Rev. Lett. 126, 071301 (2021).

[3] L. Li, C. Jia, L. Zhao, J. Cheng, J. Liu, and J. Ding, "Real-time single frequency precise point positioning using sbas corrections," Sensors 16, 1261 (2016).

[4] T. Bothwell, C. Kennedy, A. Aeppli, D. Kedar, J. Robinson, E. Oelker, A. Staron, and J. Ye, "Resolving the gravitational redshift within a millimeter atomic sample (2021)," arXiv preprint arXiv:2109.12238 (2019).