Evaluation of Stability Performance of a Simple Time and Frequency Transfer System

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***Summary*—In this paper, we describe a simple system for the transfer of precision time and frequency signals over an optical fiber network at high accuracy. The system involves the use of small form modules for precision time and frequency transfer. As a proof-of-concept, we demonstrate the delivery of 1 Pulse Per Second (PPS) and 10 MHz signals at stability levels below 10 picoseconds (ps) and around 10^{-14} respectively, over a 15-km long G.652 single mode optical fiber within the laboratory environment, for averaging periods of 1000 second.**

Keywords—Time Transfer; Frequency Transfer; Optical Fibers

I. INTRODUCTION

Time and frequency transfer over an optical fiber link is an area of interest to timekeeping laboratories and national metrology institutes worldwide. Several of these distribution methods over a single optical fiber have been demonstrated [1, 2]. The outstanding time and frequency stability performances demonstrated is a motivation to develop a means of time and frequency transfer over existing telecom networks. For integration with existing telecom networks, solutions utilizing wavelength division multiplexing for the transmission of time and frequency signals over individual telecom channels have been proposed [3, 4]. Apart from telecom channel utilization, hardware integration is also essential, and this has led to the exploration into simple and integrable modules [4, 5].

In this paper, we will demonstrate a proof-of-concept precision transfer of a 1 Pulse Per Second (PPS) and 10 MHz signals over a single optical fiber through two small form modules. Time and frequency signals are transferred over a single optical fiber link via wavelength division multiplexing over telecom channels and their stabilities are evaluated.

II. METHODS/RESULTS

The experimental setup consists of a pair of time and frequency transfer modules (TFTMs), each occupying 1U of rack space. Each TFTM consists of electro-optic transmitters (T_X) and opto-electric receivers (R_X) and can act as a receiver or a transmitter or a transceiver. Course wavelength division multiplexors (CWDMs) are used to combine or separate the bi-directional optical signals at each TFTM. The experimental setup with the two TFTMs is as shown in Fig. 1. For simplicity, we show only the transmitters and receivers that were used. The 1 PPS and 10 MHz signals were sourced from a Cesium (CS) clock (Microsemi 5071A). All electrical cables used were of the same type and length (POMONA 5697-72). Time and frequency signals were transmitted over a 15 km long G.652 single mode optical fiber spool. The data were collected at 1s intervals over a period of 4 hours using a counter (Pendulum CNT-91). All equipment were switched on and warmed up for at least an hour before any measurements were collected. As this is only a proof-of-concept study, all devices were housed in the same area, and maintained at a temperature of 23 °C ± 2 °C and a humidity of 60 % ± 10 % relative humidity.

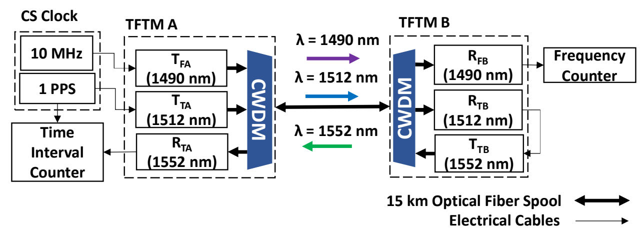

Fig. 1. Schematic of the experimental setup for time and frequency transfer.

i. TIME TRANSFER

The setup for the round-trip time transfer is shown in Fig. 1. A 1 PPS signal is transmitted over the 1512 nm wavelength channel from TFTM A over a 15 km optical fiber spool. At TFTM B, the 1PPS electrical signal output is connected to the 1 PPS transmitter of TFTM B and the optical signal is backpropagated over the 15 km optical fiber spool to TFTM A over 1552 nm wavelength channel.

We also studied the one-way time-delay as shown in Fig. 2. The frequency transfer components have been omitted from the schematic for simplicity. The one-way time delays (from TFTM A to TFTM B, and from TFTM B to TFTMA) were measured individually. The time deviation (TDEV) of the two

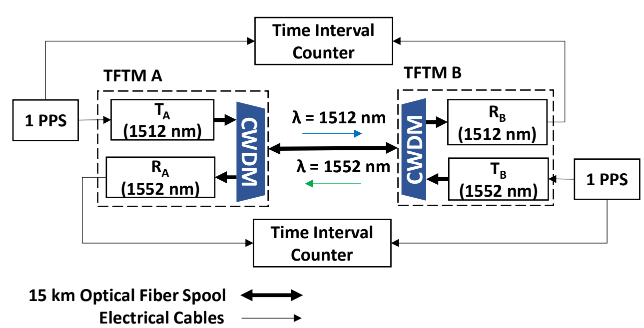

Fig. 2. Simplified schematic of the experimental setup used for one-way time delay measurement.

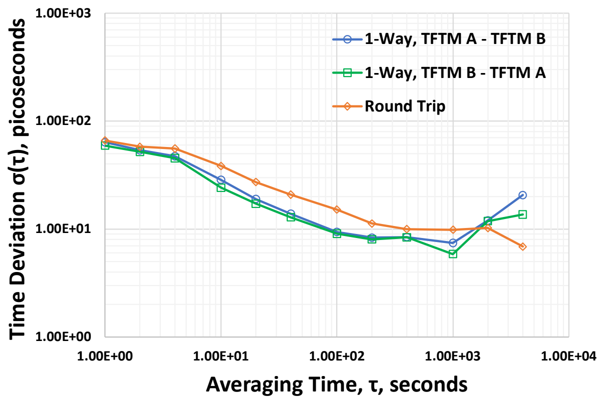

Fig. 3. Time deviation for the various time-transfer schemes.

one-way measurements (circles and squares), and round-trip (diamonds) are plotted in Fig. 3.

ii. Frequency Transfer

The setup for frequency transfer is shown in Fig. 1. A 10 MHz signal is sourced from the same CS Clock and is transferred from TFTM A to TFTM B over the 1490 nm wavelength channel. The frequency stability of the 10 MHz signal after delivered to TFTM B was measured and is shown in Fig. 4 (squares). The stability of the CS clock (circles) is included as well.

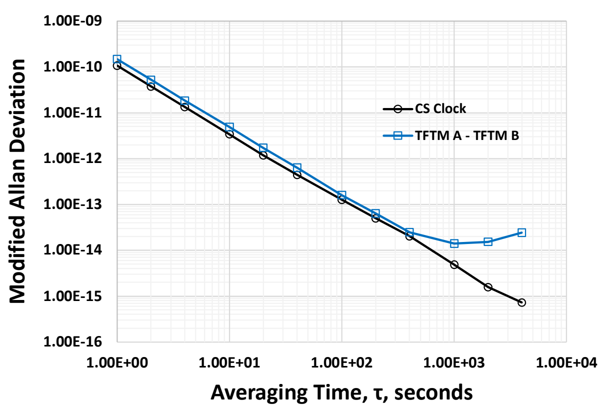

Fig. 4. Fractional frequency instability for the one-way transfer of a 10 MHz signal.

III. Discussion

The TFTMs allow for the simultaneous and bidirectional transfer of optical signals over a single optical link using CWDM. The bidirectional time signal transfer over a single optical fiber link demonstrated here would allow for the future integration of time error correction modules where a feedback signal for time error correction can be carried out over a single fiber for better link stability performances.

At present, we can observe from Fig. 3 that the stability for one-way time-transfer is below 100 picoseconds (ps) for all averaging periods and reached a value of 8 ps for an averaging period of 1000 s.

From Fig. 4, we can observe that the stability for one-way frequency transfer was below 2 x 10^{-10} Hz/Hz for all averaging periods. The stability performance also approaches that of the CS clock. For averaging periods below 400 s, it can be observed that the stability is limited by white PM noise. For averaging periods above 400 s, the stability is limited by random walk FM. This may be due to fluctuations in environment and will be the subject of future studies. The one-way frequency transfer stability reached a value of 1.5 x 10^{-14} Hz/Hz for an averaging period of 1000 s.

IV. Conclusions

We have presented here a simple time and frequency transfer solution for the delivery of 1 PPS and 10 MHz signals over an optical fiber link with high accuracy. The preliminary results indicate that precision time and frequency transfer with the stabilities at the orders of 10 ps and 10^{-14} Hz/Hz are achievable for delivery of 1 PPS and 10 MHz signals respectively, for averaging periods of 1000 s.

The results obtained demonstrate the feasibility of application of this solution for the dissemination of UTC time over a telecom network. The present work is a proof-of-concept demonstration where time and frequency correction has not been applied. The application of this method to achieve better link stability and the application of these modules to existing telecom networks will be the subject of study in future works.

Disclaimer

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