ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-TUPRI114

PERFORMANCE OF THE TPS RF REFERENCE DISTRIBUTION LINKS

Y. S. Cheng, K. H. Hu, C. Y. Wu, C.Y. Liao, K.T. Hsu
NSRRC, Hsinchu 30076, Taiwan

Abstract

A fiber based 500 MHz RF reference distribution system with femto-second jitter and temperature drift compensation will deploy for the Taiwan Photon Source (TPS) project. The system consists of several pair's commercial available continue wave RF fiber links. Installation is performed in the 1st quarter of 2014. Characterize the performance of the install system are in proceeding. Jitter of the transfer RF reference and drift due to ambient temperature effects are investigated systematically. Instrumentations to support the measurement are also addressed. Follow up plans to revise the system configuration and work out to transfer low jitter RF reference to time-resolved experimental stations are in considered. Measurement results will be summarized in this report.

INTRODUCTION

The TPS is one of the latest generation synchrotron light sources in its final integration phase. Commissioning is scheduled in late 2014. To take advantages of latest development in last decade, commercial available fiber based transfer of continue wave RF reference and timing are chosen [1, 2]. The RF reference will be generated by a low phase noise master oscillator. The RF signal split into multiple fan-out to distribute to different locations and applications around the accelerator and experimental stations via fiber links. There are two superconducting RF station for the storage ring and one RF station for the booster synchrotron will be deployed at early operation. All of these RF stations are distributed around the 1/3 of the ring. The RF reference would need distributed to RF systems of linear accelerator, booster synchrotron, the storage ring and diagnostic stations with phase stabilize, low additive phase noise and could compensate the effects of ambient temperature change. Beam-line and experimental station which need precision timing (sub-picoseconds) for time-resolved experiments or synchronize the laser system will use via fiber link also to generate synchronization signal to accompany with event system which provide 10~20 psec drift without temperature compensation event system links.

MASTER OSCILLATOR AND SIGNAL FANOUT AND OPTICAL FIBER BASED RF REFERENCE DISTRIBUTION

The master oscillator should be low phase noise and phase continues when changing frequency. The R&S SMA-100A signal generator with SMA-B22 option [3] was chosen as master oscillator due to it meets requirements of TPS. The master oscillator takes reference from a low phase noise GPS disciplined 10 MHz rubidium clock. The master oscillator and the frequency standard installed at the equipments area (CIA, Control Instruments Area) nearby the linear accelerator. The timing master and fiber distribution of the event system are installed at the same area.

RF reference fan-out boost power of the master oscillator and split the signal in multiple outputs for various destinations with more than 30 dB isolation between ports. Output power at 15 dBm level at fan-out unit drives fiber transmitter directly. The fan-out unit is installed at a sub-rack with thermal insulation. One port of the fan-out connects to the 2nd power splitter to delivery another four 5 dBm output for timing system, linac LLRF, and diagnostic application. One of a RF reference port will connect to the event generator (EVG) on the timing system which will generated various machine clocks and trigger signals and distributed to the site which need these signals around the whole accelerator for synchronization, injection control, and synchronize experiment with the stored beam. Since the instruments rack is installed nearby the linear accelerator, one link will connect to the linear accelerator low level RF system by coaxial cable directly. The RF references for the booster synchrotron and the storage ring will be distributed by four fiber links.

The RF reference will adopt fiber based RF CW transfer system which is commercial available Libera Sync 500 [2] assures clock signal distribution with femtosecond jitter and length drift compensation. Group delay of the RF signal in the clock distribution system is stabilized by the wavelength tuning and the chromatic dispersion of the optical fiber in the forward and backward direction. The wavelength tuning is operated by means of control temperature of the distributed feedback (DFB) laser. The telecom grade DFB laser is directly modulated by the input RF signal and ensures high reliable operation of the system. Health conditions of fiber links are also monitoring by the control system. Any failures of a link can be identified easily; spare unit replacement is quickly.

Distance from the master oscillator to RF stations is about 100 m to 220 m for the TPS configuration. However, to simply the cable deploy from local source and installation on cable tray with acceptable temperature compensation range (+/- 2 ^{o}C), length of all fiber cables are set at 250 m (tightly buffer fiber) at this moment. Change to loose tube fiber cable in future is planned to extend compensation range of temperature variation.

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-TUPRI114

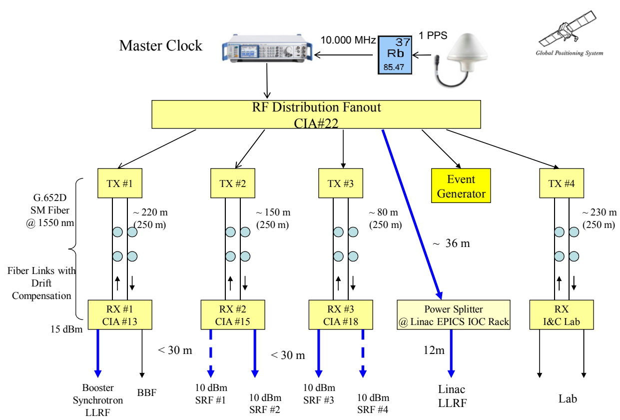


Figure 1: RF reference distribution scheme for the TPS.

CHARACTERIZATION OF THE RF REFERENCE FIBER LINKS

To characterize performance of the fiber links, tools with guarantee performance and insensitive to ambient temperature includes R&S FSUP signal source analyzer [3], Agilent E5071C vector network analyzer [4] and 600 MHz Zurich Instruments UHFLI lock-in amplifier [5] are used for the measurement.

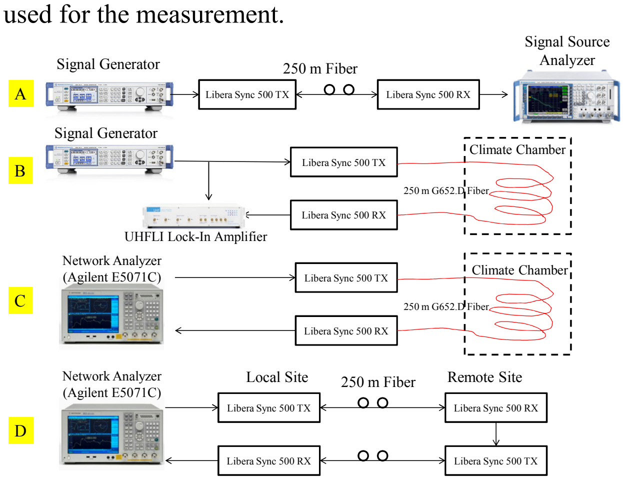
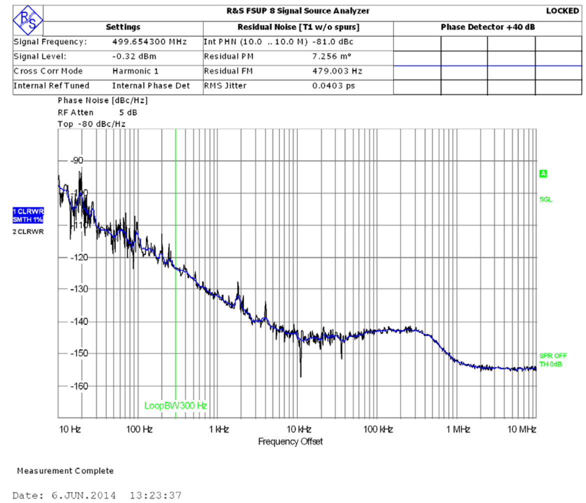
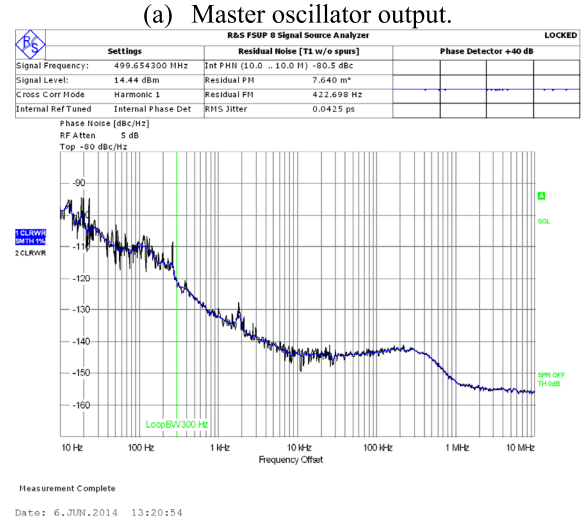


Figure 2: Performance characterizes setup.

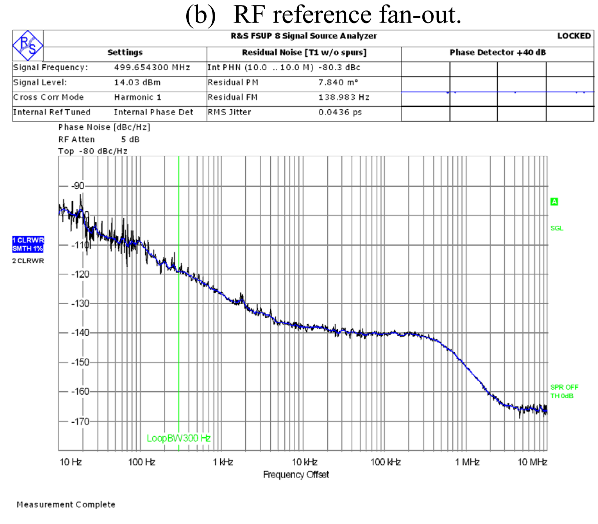
Phase noise of the master oscillator, the RF reference fan-out and Libera Sync pairs output are measured by signal source analyzer as shown in Fig. 3. Jitter of the master oscillator is less than 30 fs rms (< 0.005^{o} rms in RF phase, integrated from 10 Hz to 10 MHz) as shown in Fig. 3(a) which satisfy requirements of the TPS. Phase noise of 10 fsec additive jitter of the RF reference fan-out unit as shown in Fig. 3(b). There is about 15 fsec additive phase noise of the Libera Sync 500 link pair output as shown I n Fig. 3(c). Additive jitter of the RF fan-out unit and fiber link can be obtained by simple de-convolution as 13 fsec and 10 fsec respectively.



(a) Master oscillator output.



(b) RF reference fan-out.



(c) Libera Sync 500 fiber link output.

Figure 3: Measured SSB phase noise from 10 Hz to 10 MHz.

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-TUPRI114

The long-term drift measurement will be performed by two approaches. The first method will vector network analyzer working at RF frequency and zero span during time sweep. The phase can be read directly from the transmission measurement (phase of scattering parameter s21). Resolution can be achieved in milli-degrees when adequate averaged was taken. The second approach is compared phase by UHFLI lock-in amplifier with milli-degrees resolution when time constant set at one second when a few degrees of ambient temperature changed of these instruments. Precision phase measurement is sensitive to mechanical stability of cable, it can move to a few tens of milli-degrees if move the test cable. It should avoid move the cable during the measurement.

The long-term drift of a deploy fiber link by using two Libera Sync pairs, one pair is send the RF reference to booster RF station, the other pair the send the signal back to master clock site for measurement. Round trip phase variation is measured by the UHFLI lock-in amplifier in configuration D setup is shown in Fig. 4. The drift is combined two fiber link stability. There is not measurement device between both sites along the fiber link. It is estimated temperature variation during measurement is about ±2 °C. The measured phase drift for 6 hours are in th order of ±0.01RF phase variation corresponding to ±50 fsec timing change. The instruments installed in an open rack might suffer from the ambient temperature variation for this preliminary measurement. Further improvement is on-going.

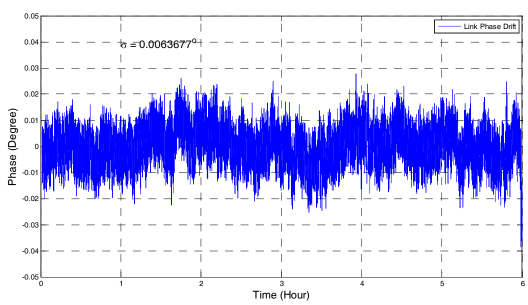
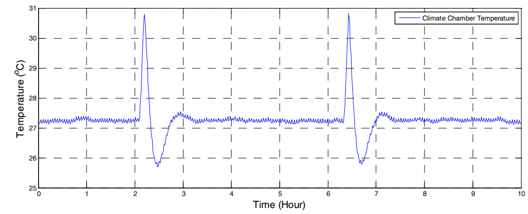
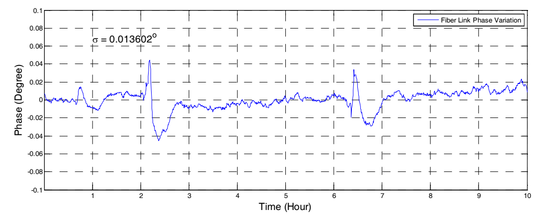


Figure 4: Six hours drift measurement by configuration B for the link from master clock to booster RF.

The long-term drift measured by the network analyzer as configuration C setup is shown in Fig. 5. The drift is combined of instruments stability and fiber link stability. The most of sensitivity is the lead cable to the instruments, the cable should be fixed. It is easy to get more than 0.1° even move the cable by hand. The measured phase drift for 10 hours are within ±0.02° of RF phase. Periodical 5 °C spike temperature variation in the climate chamber is intended to generate to explorer response of the links. The fiber is put inside the climate chamber and response to ambient temperature change to less than ±0.05° of RF phase. The link can meet required performance even extreme conditions happened.



(a) Temperature variation in climate chamber.



(b) Fiber link phase variation.

Figure 5: Ten hours drift measurement results. Above curve is the temperature inside of the climate chamber. Lower curve is the RF phase variation of the link. One degree phase changes correspondence to 5.5595 psec at RF frequency. The intended spike variation in temperature changes about 5 °C peak to peak.

SUMMARY AND FUTURE PLANS

Installation of the TPS RF reference generation and distribution are almost done. Characterize of the system are in progress. Preliminary results are summary in this report. Various key parameters include short term jitter and long-term drift were measured. Results show that the system meets requirements for TPS applications. A phase stabilized coaxial cable monitoring link will deploy soon to serve as real-time monitoring the operation of fiber link operation conditions. Customized AD8302 based phase detector will be used for online phase monitoring. Another possible application which need RF reference such as streak camera station and beamline laser systems synchronization will be distributed by the fiber link for sub-picoseconds timing will be deploy for the future expansion.

ACKNOWLEDGEMENT

Help from experts of Instrumentation Technologies especially of Sebastjan Zorzut on the various issues of Libera Sync are highly appreciated. Discussion with James Way of Zurich Instruments about usage of UHFLI lock-in amplifier is also very helpful.

REFERENCE

[1] C. Y. Wu, et al., "RF Reference Distribution and Timing System for the Taiwan Photon Source", Proceedings of DIPAC2011, TUPD86, Hamburg, Germany, 2011.
[2] Libera Sync Specifications and User's Manual.
[3] http://www.rohde-schwarz.com
[4] http://www.agilent.com
[5] http://www.zhinst.com/product/uhfli