OPTIME - time and frequency dissemination system based on fiber optical network

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OPTIME project

Description of OPTIME project

The OPTIME proposes a solution that allows end users to obtain ultra-precise time and frequency signals without incurring huge costs for the purchase their own atomic clocks, and receive the service related to laboratories generating international atomic time scales, to witch any precise time must be referred.

The OPTIME system is based on three main elements:

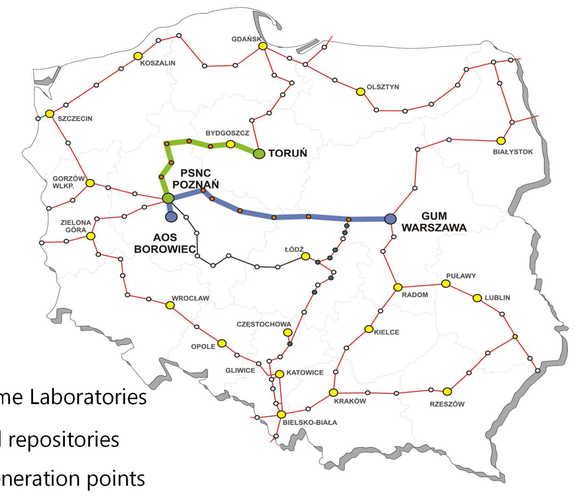
- Reference time and frequency laboratories,
- Local time and frequency repositories,
- Fiber optical network.

Time and frequency reference laboratories provide time-frequency signals to the OPTIME system. Local repositories – synchronized to these laboratories – are responsible to maintain time-frequency signals during any failures caused by lost of connection with laboratories. Fiber optical network with specialized transmission equipment transfers time and frequency signals between laboratories, repositories and end-users.

Topology of OPTIME system

System OPTIME consists:

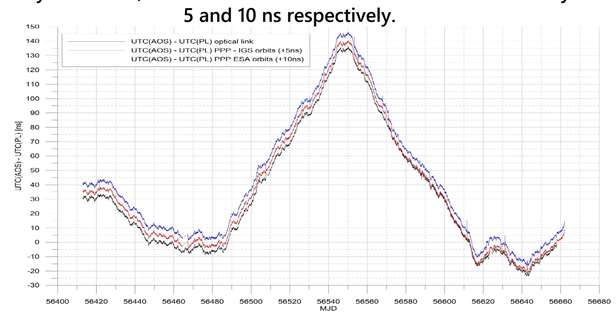
- 2 Time and Frequency Laboratories – the first one is located at GUM in Warsaw and generates UTC(PL) time scale, the second one is located at AOS in Borowiec and generates UTC(AOS) time scale;
- 2 Local Repositories which are under construction – the first one is located at PSNC in Poznan, the second one is located at FAMO in Torun;
- 2 fiber optical links 720 km long – the first 420 km long link is operational 2.5 years, the second one 300 km long is under construction;



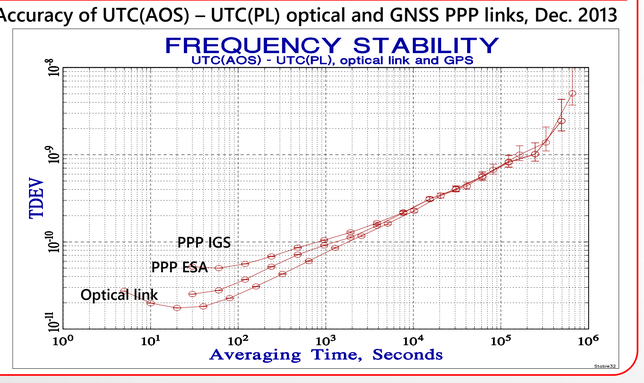
Optical link GUM – AOS

- 2.5 years of successful operation of the optical link between Central Office of Measures (GUM) in Warsaw and Astrogeodynamical Observatory (AOS) in Borowiec near Poznan, the first optical fibre connection between UTC(k) laboratories.
- This link allows for a continuous real-time comparisons of the UTC(PL) and UTC(AOS) time scales with unprecedented accuracy.
- In July 2013 BIPM conducted a series of calibrations using their GNSS mobile station and optical-fiber link. AOS-PL optical fibre link is being taken into consideration in the process of establishing novel methods and techniques for time scale comparisons for the realization of UTC and TAI.
- Upper figure on the right presents results of UTC(AOS) - UTC(PL) differences from May 2013 till December 2013. The OPTIME optical link is compared to GNSS phase measurements, post-processed using Precise Point Positioning method.
- For the computations, (CSRS-PPP ver. 1.05/03812/2012-02-07) software by Natural Resources Canada was used. The PPP results were obtained using two different sets of precise ephemerides and satellite clocks from IGS and ESA. The results obtained with ESA orbits show slightly better accuracy then the IGS ones.
- Time stability calculations show that optical link achieves better precision and stability for short averaging times, up to about 10^4 seconds.
- The short term stability of the results obtained for the optical link is, seriously limited by Austron 2055A phase microstepper used for the realization of UTC(PL) at GUM. This will be improved at the end of 2014, by the application of the phase femto-stepper and active H-maser as a source of UTC(PL). Also measurement noise of the Stanford SR-620 used at the AOS increases the instability of the link, It is planed to replace it with a new WAT counter of picoseconds precision.
- It is verified, (see diagram) that the AOS-GUM 420 km optical link assures synchronization of time scales with 20 ps precision in real time. The obtained stability of frequency transfer is in the range of a few x 10^{-17} for one day averaging.

Comparison of UTC(AOS) – UTC(PL) optical and GNSS PPP links, May-Dec. 2013, the results for IGS and ESA orbits are shifted by 5 and 10 ns respectively.



Accuracy of UTC(AOS) – UTC(PL) optical and GNSS PPP links, Dec. 2013



Active delay stabilization

Solution

Two-way signal transmission in single fiber, plus two electronic variable delay lines (forward and backward), plus phase detector constitute the DLL (Delay Locked Loop) feedback system. Provided that the fiber propagation delay changes equally in both directions, and both delay lines have identical tuning characteristics, the DLL stabilizes the forward (input-output) delay.

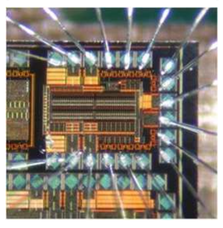
Functionality

In contrary to standard two-way systems, our solution delivers stabilized and calibrated replica of source signals, thus may be described as a virtual atomic clock at the end of the fiber. Besides metrological applications, as clock comparisons, the system may be used for time and frequency distribution to the users not maintaining their own clocks.

Experimental Validation

The results given herein were obtained in the loop configuration, with both sides of the fiber in the same laboratory. The signals outgoing the system were referred to the source (input) clock. The fibers were both a field-deployed ones around Krakow, and also the spooled ones placed in a chamber in which temperature variations was forced.

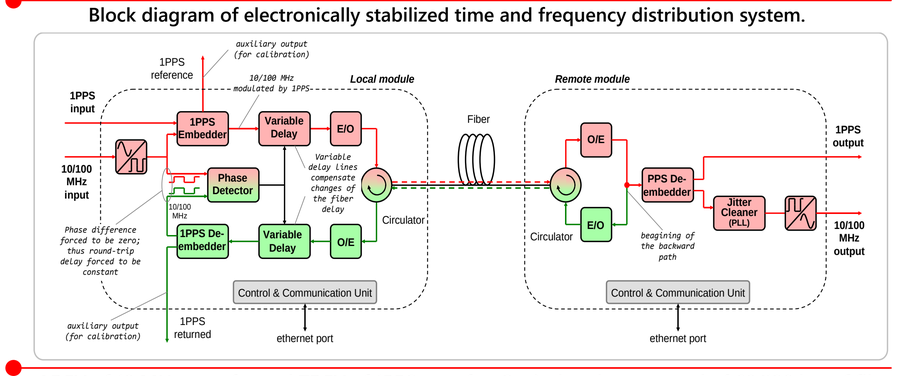
Application Specific Integrated Circuit containing the pair of precisely matched variable delays.



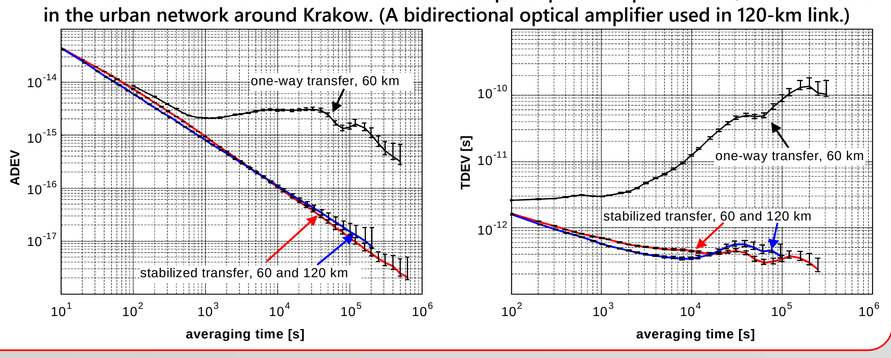
Verifications of time transfer calibration

fiber length and dispersion		difference between direct measurement and calibration
19km	82ps/nm	6 ps
20km	-23ps/nm	4 ps
50.5km	834ps/nm	13 ps
69km	1130ps/nm	11 ps
60km	1020ps/nm	6 ps
480km	7050ps/nm	35 ps

Block diagram of electronically stabilized time and frequency distribution system.



ADEV of 10 MHz transfer and TDEV of 1PPS transfer. Optical path composed of 60/120 km of fiber in the urban network around Krakow. (A bidirectional optical amplifier used in 120-km link.)



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