Time and radio frequency transfer using the optical ELSTAB system

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Main difference between frequency and time dissemination

**Frequency dissemination**

- Distributed frequency
- Reference frequency $f_0$

$$f = 5 \text{ MHz}, 10 \text{ MHz}, ..., \text{ optical frequency } (~194 \text{ THz})$$

$$\Delta f(t) = f_0 \frac{d\tau(t)}{dt}$$

Delay should be constant

**Time SCALE dissemination**

- Distributed time scale
- Original time scale

1 PPS (Pulse Per Second)

UTC$_k$ scale

The delay should be constant and known
ELSTAB fiber T/F distribution system

ELectronically STABbilized fiber T/F distribution system

System developed by AGH University of Science and Technology
Current status

- T&F users
- T&F repository
- UTC Laboratories
- DWDM T&F links
- Dark Fibre T&F links
- PIONIER Network
Time and Frequency dissemination - areas of responsibility

Source of signals (UTCₖ LABs)

PIONER Network (managed by the PSNC)

End Users
UTC\textsubscript{k} LABs are responsible for:

- Maintaining the time and frequency reference clocks
- Generation of reference signals (1 PPS and 10 MHz)
- Absolute time calibration (determination of total link delay)
PSNC is responsible for:

- Fibre optic network maintenance
- Management and monitoring of T&F transfer devices (Local + Remote + EDFAs)
- Support in time calibration (for cascaded links)
Management and monitoring of T&F transfer devices

Parameters monitored at the Local (transmitting) module:

- Presence of input signals (1 PPS, 10 MHz)
- Received optical signal level
- System status (status of proper operation of the stabilization system)

Using a time interval counter (TIC)

it is also possible:

- Measure/monitor the round trip time delay
- Perform calibration measurements
Parameters monitored in BiDir EDFA amplifiers:

- Levels of optical input and output signals
- Amplifier Gain
- Amplifier pump current
- Module temperature

Modifiable parameters:

- Operation mode, Gain, pump current

Possibility to transfer T&F+OC in a single fibre (the same amplifiers)
Parameters monitored at the Remote module:

- Received optical signal level
- System status
  (state of the stabilisation system)
Management and monitoring of T&F transfer devices

Communication interfaces/protocols:

- Access via „out of band” and/or „in band” channel
- SSH
- SNMP v2c/v3, SNMP Traps
- Access to device management with different authorisation levels
- Local or radius user authentication
- Event logging, syslog server ...
Example of SNMP monitoring
Time calibration

All the calibration measurements are done at the local side only

Basic calibration formulas:

\[ \tau_{\text{REF} \rightarrow \text{OUT}} = \frac{1}{2} \left[ \tau_{\text{REF} \rightarrow \text{RET}} + \left( \tau_{F \rightarrow F} - \tau_{F \rightarrow B} \right) + \tau_C \right] \]

\[ \tau_{\text{UTC}(k) \rightarrow \text{OUT}} = \tau_{\text{UTC}(k) \rightarrow \text{REF}} + \tau_{\text{REF} \rightarrow \text{OUT}} \]

Fiber forward-backward asymmetry:

\[ \tau_{F \rightarrow F} - \tau_{F \rightarrow B} = D_T \left( \lambda_F - \lambda_B \right) + \frac{4 \omega A_E}{c^2} + \tau_{\text{BIR}} \]

Local & remote modules asymmetry:

\[ \tau_C = \left( 2 \tau_{\text{REF} \rightarrow \text{OUT}} - \tau_{\text{REF} \rightarrow \text{RET}} \right) \]

Source: https://www.clonets.eu/clonets-posters0.html?&no_cache=1&cid=6513&did=15429&sechash=d24f500e
Delay compensation

Calibration formulas:

\[ \tau_{UTC(k)\rightarrow OUT} = \tau_{UTC(k)\rightarrow SRC} + \tau_{SRC\rightarrow REF} + \tau_{REF\rightarrow OUT} \]

\[ \tau_{UTC(k)\rightarrow OUT_A} = \tau_{REF\rightarrow OUT} - \tau_{ADV} \]

Source: https://www.clonets.eu/clonets-posters0.html?&no_cache=1&cid=6513&did=15429&sechash=d24f500e
Performance

Example:

- Stability of 615 km long-distance transfer using ELSTAB
  - Fiber delay fluctuations: 100 ns pp
  - Output signal fluctuations: 30 ps pp

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Time (1 PPS) and Frequency (10 MHz) dissemination

Work in Progress

- T&F Repository - level I
- T&F Repository - level II
- T&F Dissemination Network:
  - Future international connections
  - PIONIER Network
Optical Carrier dissemination

Work in Progress

- Optical carrier distributing point
- Points of access to the optical carrier

Optical Carrier Network:
- Toruń - Poznań evaluated link
- Poznań - Warszawa, Poznań - Wrocław links
- Future international connections
- PIONIER Network
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