Time and Frequency Transfer Using Amplified Optical Links

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Time and frequency transfer over optical fiber is a rapidly developing area of research and experimental deployment. In dependence on utilized technology, shorter optical links up to about 100 km (reached distance depends on link attenuation and available power budget) might be utilized without amplification, however optical amplification is unavoidable for longer links. Majority of methods utilize two-way transfer that might be implemented either on a pair of unidirectional fiber or in a single bidirectional fiber. Most accurate methods require fully symmetrical path in both direction including all amplifiers. Standard telecommunication grade optical amplifiers are designed for unidirectional operation – obviously, they can be adapted for amplification of bidirectional traffic, however new issues can appear:

- dealing with different power of both input signals,
- delay symmetry in both directions,
- filtering of unwanted wavelengths,
- influence of reflection and back-scattering.

List of common optical amplifiers includes: Erbium-doped fiber amplifier (EDFA), Semiconductor optical amplifier (SOA), Raman amplifier, and Brillouin amplifier. We made laboratory tests with standard types of optical amplifiers in symmetrical bidirectional setup. The evaluation includes also experience with EDFA, SOA and Raman amplification experimentally performed in our time and frequency transfer infrastructure on both dedicated "dark" fiber and fiber shared with standard data traffic.

Although our time and frequency transfer infrastructure currently utilizes EDFAs, we proved that SOA amplifiers are also suitable for bidirectional amplification of modulated optical signal. Distributed Raman amplifiers can be deployed in links with very long fiber spans but they can interact with other channels in shared fiber. Brillouin amplifiers were not subject of our tests as they are unable to amplify modulated signal due to their very narrow band, however they may be used for frequency transfer based on CW (continuous waveform) carrier.

Our paper also provides overview of time and frequency transfer issues related to optical amplifiers. Finally, we compare our experience with long distance time transfer in amplified optical links with other known time transfer systems.