Studio sperimentale dell’impatto di ridotte spaziature inter-canale sulla trasmissione di un super-canale a 1Terabit/s

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Aims of the work

High spectral efficiency is needed to generate Terabit “super-channels” for a future Terabit Ethernet Standard. It can be obtained by:

- Higher order modulation formats (QAM 8-16)
- Decreasing the channel spacing (OFDM, Co-OFDM)

Co-OFDM operates with sub-carriers spaced at the Baud rate

- 1T/s Co-OFDM transmission over 7200km has been recently demonstrated (Record Spectral Efficiency x Distance of 27000 km·b/s/Hz)

However, Co-OFDM requires a complex transceiver architecture:

- Frequency synchronization of the sub-carriers
- Symbol transition alignment and a broadband RX

Here, we investigate a novel technique to generate 1Tb/s Superchannel by multiplexing sub-carriers close to Baud-Rate spacing using optical spectral reshaping to minimize cross-talk
CONCEPT: Before combining into a Superchannel the sub-carriers are narrow-filtered (high order Gaussian filter) to remove the cross talk.
This approach is also known as “Nyquist-WDM” (G. Bosco et al., “Performance Limits of Nyquist-WDM and CO-OFDM in High-Speed PM-QPSK Systems”, to appear in Photonics Technology Letters).
OSNR penalty vs. carrier spacing

Contour plot for BER = $4 \cdot 10^{-3}$ (Baud Rate = 27.75 Gbaud)

Spacing of 1.2 penalty-free

In this work channel spacing of 1.1 and 1.2 x Baud Rate is investigated
Sub-carriers generation at 1.1xBaudRate

\[ \Delta f = 27.5\text{GHz} \quad (1.1\times \text{Baud Rate}) \]

Waveshaper transfer function

- **Power (dB)**
- **B.W. = 27GHz**
- **2nd order SuperGaussian filter**

1Tb/s Superchannel spectrum

- **Power (dB)**
- **275GHz**
- **10ch. \times 100Gb/s at 1.1BaudRate**
Sub-carriers generation at 1.2xBaudRate

- 50Gb/s QPSK Transmitter
- Synthesizer Frequency Shifter
- 10ch. x 100Gb/s at 1.2BaudRate

Δf = 30GHz (1.2xBaud Rate)

- 25Gb/s PPG
- Nested MZ
- Pol-Mux
- Optical filter

Waveshaper transfer function

- BW = 29GHz
- 2nd order SuperGaussian filter

1Tb/s Superchannel spectrum

- 300GHz
- 10ch. x 100Gb/s at 1.2BaudRate

λout = λ1+(λ1+Δf)...

.....+(λn+Δf)
Back to back sensitivity for 5\textsuperscript{th} carrier

<table>
<thead>
<tr>
<th>Sensitivity (3×10^{-3}) measured on a single sub-carrier at 25 GBAud:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 15 dB for Waveshaper BW = 29GHz (channel spacing 1.2 B\textsubscript{R})</td>
</tr>
<tr>
<td>• 15.1 dB for Waveshaper BW = 27GHz (channel spacing 1.1 B\textsubscript{R})</td>
</tr>
</tbody>
</table>
Test-bed: Installed transmission fiber

Photon Labs
Politecnico of Turin

Installed SSMF fibre rings
Metro network Fastweb

<table>
<thead>
<tr>
<th>Length (km)</th>
<th>Loss (dB/km)</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x40</td>
<td>0.245</td>
<td></td>
</tr>
<tr>
<td>2x20</td>
<td>0.235</td>
<td>16.14</td>
</tr>
<tr>
<td>2x10</td>
<td>0.264</td>
<td></td>
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</tbody>
</table>

City of Turin
1Tb/s Transmission over installed fibre

FASTWEB SMF dark fibre installed in the city of Turin
Span length 63.6km (42Km + 21.6Km) Loss 18dB
The maximum reach: from 2600 km to 2200 km when carrier spacing is reduced from 1.2 to 1.1 x Baud rate due to inter-channel nonlinearity.
Recent developments

- Experimental results of transmission of PM-QPSK Terabit superchannels over Pure-Silica-Core Fiber (PSCF) with Raman amplification
  - 30 Gbaud, 33 GHz spacing (1.1 x baud-rate)
We have experimentally demonstrated the generation of a Terabit Superchannel using a novel multi-carrier transmitter based on sub-carriers spectral reshaping to minimize cross-talk.

Superchannel transmission experiments have demonstrated:
- Maximum reach of 2600 km over SMF + EDFA only
- Maximum reach increased to 10000 km over PSCF + hybrid Raman/EDFA amplification

Our experiments show that, thanks to optical carrier reshaping at the transmitter, a spectral efficiency close to Co-OFDM can be achieved with a simpler transceiver architecture.
Acknowledgments

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