100 Gbit/s V-band Transmission Enabled by Coherent Radio-over-Fiber System with IF-OFDM Envelope Detection and SSBI Suppression

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Global surge in demand for high-speed broadband, especially (fixed) wireless access

For front- and backhauling of 5G cells, 100 Gbit/s wireless links are needed

>100 Gbit/s only realized in (sub-)mm-wave bands

FCC allocation provides 14 GHz spectrum (57-71 GHz) in V-band around 60 GHz

In contrast to THz-bands (>100 GHz) V-band technology allows for longer wireless reach!
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Fiber-wireless dual-polarization V-band transmission system using envelope detection
  - System architecture for digital modulation and signal processing
  - IF-OFDM with SSBI suppression for QAM envelope detection

Demonstration measurements for spectral-efficient high data rate link

Conclusion
Fiber-wireless V-band transmission system using envelope detection

• System architecture for digital modulation and signal processing
• IF-OFDM with SSBI suppression for QAM envelope detection
DACs are necessary for spectral-efficient modulation and forward error correction
But also bottleneck for highest data rate single channel transmission
Coherent Radio-over-Fiber enables for transparent fiber fronthaul + wideband operation
mm-wave local oscillators at transmitter and receiver adds phase noise
IF-OFDM and envelope detection are employed due to phase noise insensitivity
System architecture for digital modulation and signal processing

- 16 QAM IF-OFDM signals from arbitrary waveform generator (AWG)
- Dual-polarization transport in optical and wireless domain to double throughput
- 2 pairs of linear polarized horn antennas (rotated in orthogonal polarization) for wireless link
- Photonic upconversion via LO (Laser 2) and coherent photonic mixer (CPX)
- Schottky-barrier diode (SBD) envelope detection for downconversion to IF
Digital OFDM (de-)modulation
IQ data is then upconverted to IF by the AWG
IF-OFDM signal is modulated onto optical carrier via standard Mach-Zehnder modulator (MZM)
SBD downconversion to IF retaining phase information
Signal is captured at IF by digital sampling oscilloscope (DSA)
IF-OFDM with SSBI suppression for QAM envelope detection

Complex Baseband signal

\[ i_{SBD}(t) = (i_{PD}(t))^2 \]
\[ \approx (E_{r0}(t)E_{s0}(t))^2 \cdot \left( \frac{1}{2} + \frac{a^2(t)}{2} + a(t)\cos(\omega_{IF}t + \theta(t)) \right) \]

- SBD creates signal-signal-beating interference
- Avoided by IF = 1.5 x BW but at cost of spectrum
IF-OFDM with SSBI suppression for QAM envelope detection

- MZM has non-linear (sinusoidal) transfer function
- Biasing conditions define linearity, power loss etc.
- Optimization has to include input power level, bias point and over non-linear channel elements in transmit chain
- Here, MZM is used to optimize SIR and SNR balancing after the SBD
IF-OFDM with SSBI suppression for QAM envelope detection

- MZM biasing conditions can alter power relation between carrier and sideband
- Sideband creates signal and SSBI
- Carrier only mixed to IF-OFDM signal by the SBD
- SIR management possible!

\[ \text{IF} = 1.5 \cdot \text{BW} \]
Demonstration measurements for spectral-efficient high data rate link
Demonstration measurements for spectral-efficient high data rate link

- Simulated flat double sideband transmission spectrum after MZM
- Power balancing between carrier and sidebands for SINR
- OFDM provides channel estimation for demodulation of the wideband signal
- Received spectrum shows frequency selectivity
Demonstration measurements for spectral-efficient high data rate link

- 60 GHz fiber-wireless transmission setup with running experiment
- 2 Tx antennas fed by CPXs (right) and rotatable Rx antenna (left)
Demonstration measurements for spectral-efficient high data rate link

- 12.5 GHz bandwidth OFDM signal at IF of only 8 GHz
- >20 dB weaker out-of-band power density, no significant interference detected
- +/- 3 dB fluctuation of the EVM per subcarrier due to frequency selectivity of the channel
Demonstration measurements for spectral-efficient high data rate link

- Average EVM of both polarizations is -16.2 dB
- 16 QAM signal is received with a BER of $2.4 \times 10^{-3}$ → below the $3.8 \times 10^{-3}$ limit for 7% overhead HD-FEC
- 100 Gbit/s transmission in the 60 GHz band is achieved with ~7 bit/s/Hz spectral efficiency
Conclusion & Outlook

- Motivation: Provision of 100 Gbit/s links in the 60 GHz band
- Analog coherent RoF for wideband fiber-wireless transmission
- Utilization of IF-OFDM signals for QAM detection via envelope detectors
- MZM bias point optimization to combat non-linear distortion as well as SSBI generated by the SBD downconversion
- IF reduction to 8 GHz allows high bandwidth transmission in the 60 GHz band
- Doubling the throughput by fiber-wireless dual-polarization transmission
- 100 Gbit/s transmission achieved with 16 QAM and 12.5 GHz bandwidth dual-polarization signals
Thank you for your attention!
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