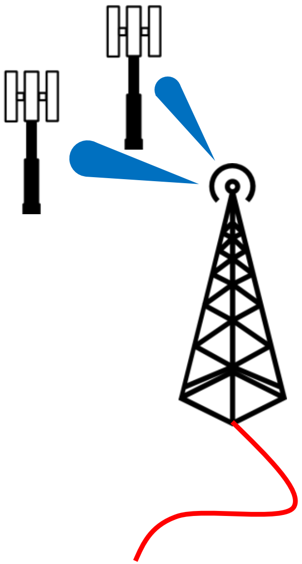
100 Gbit/s V-band Transmission Enabled by Coherent Radio-over-Fiber System with IF-OFDM Envelope Detection and SSBI Suppression

Matthias Steeg, Florian Exner, Jonas Tebart, Andreas Czylwik, and Andreas Stöhr

Motivation for 100 Gbit/s in the 60 GHz band

- 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!



UNIVERSITÄT DUISBURG ESSEN

Open-Minded

Table of Contents

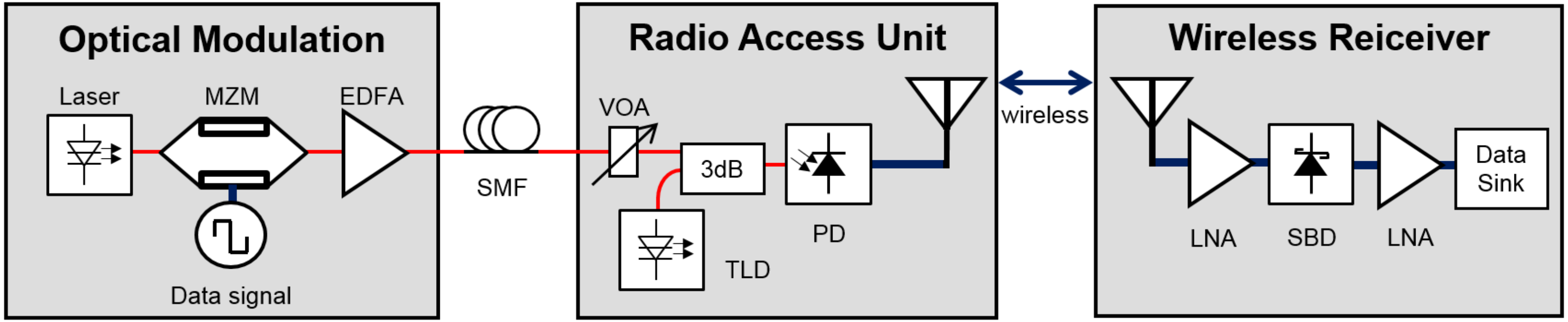
Table of Contents

- Motivation
- 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

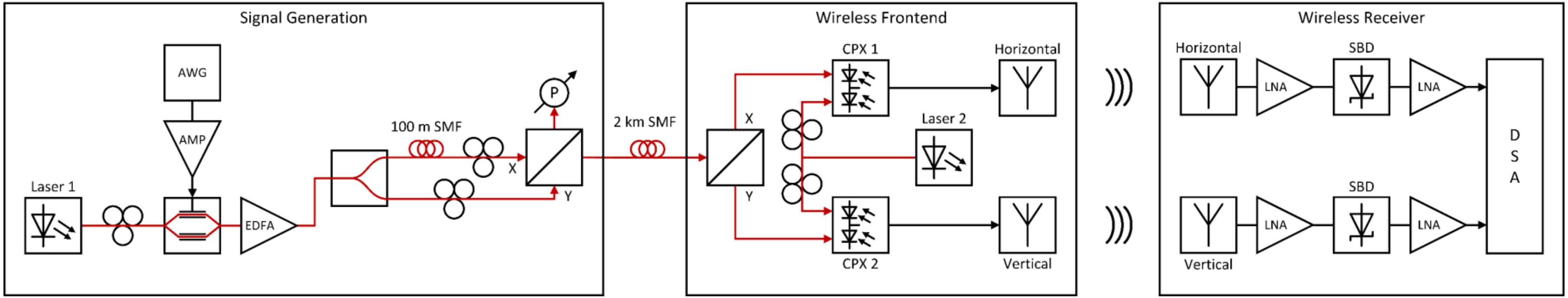
- System architecture for digital modulation and signal processing
- IF-OFDM with SSBI suppression for QAM envelope detection

System architecture for digital modulation and signal processing



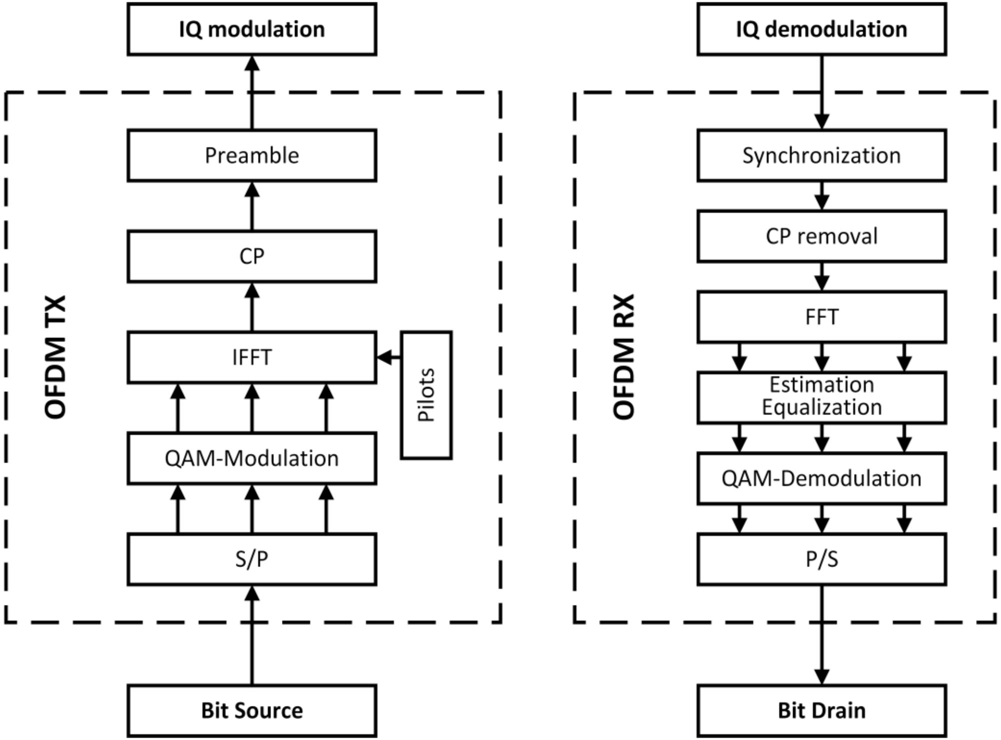
- DACs are necessary for spectral-efficient modulation and forward error correction
- But also bottleneck for highest data rate single channel transmission
- Coherent Radio-over-Fiber enables for transparent fiber fronthaul + wideband operation
- mm-wave local oscillators at transmitter and receiver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

System architecture for digital modulation and signal processing



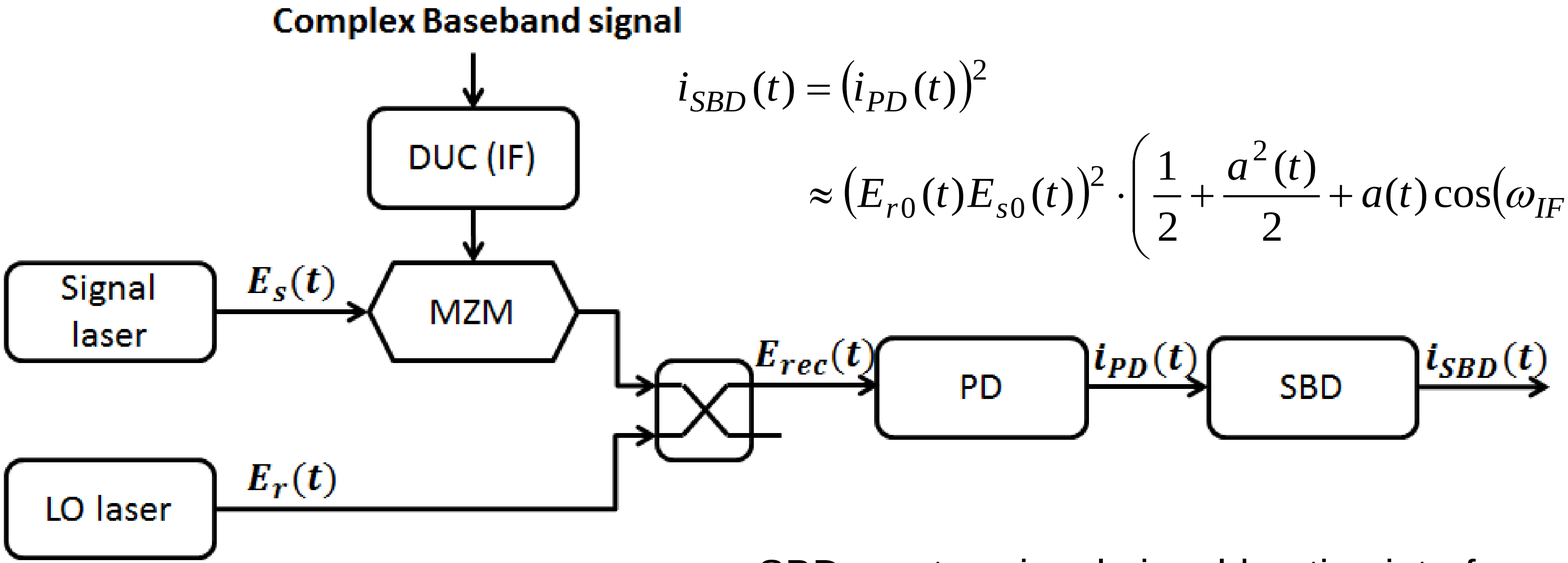
- 16 QAM IF-OFDM signals from arbitrary waveform generator (AWG)
- Dual-polarization transport in optical and wireless domain to double throughput
- 2 pairs of linear polarized horn antennas (rotated in orthogonal polarization) for wireless link
- Photonic upconversion via LO (Laser 2) and coherent photonic mixer (CPX)
- Schottky-barrier diode (SBD) envelope detection for downconversion to IF

System architecture for digital modulation and signal processing



- 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



$$i_{SBD}(t) = \left(i_{PD}(t)\right)^2$$

$$\approx \left(E_{r0}(t)E_{s0}(t)\right)^2 \cdot \left(\frac{1}{2} + \frac{a^2(t)}{2} + a(t)\cos\left(\omega_{IF}t + \theta(t)\right)\right)$$

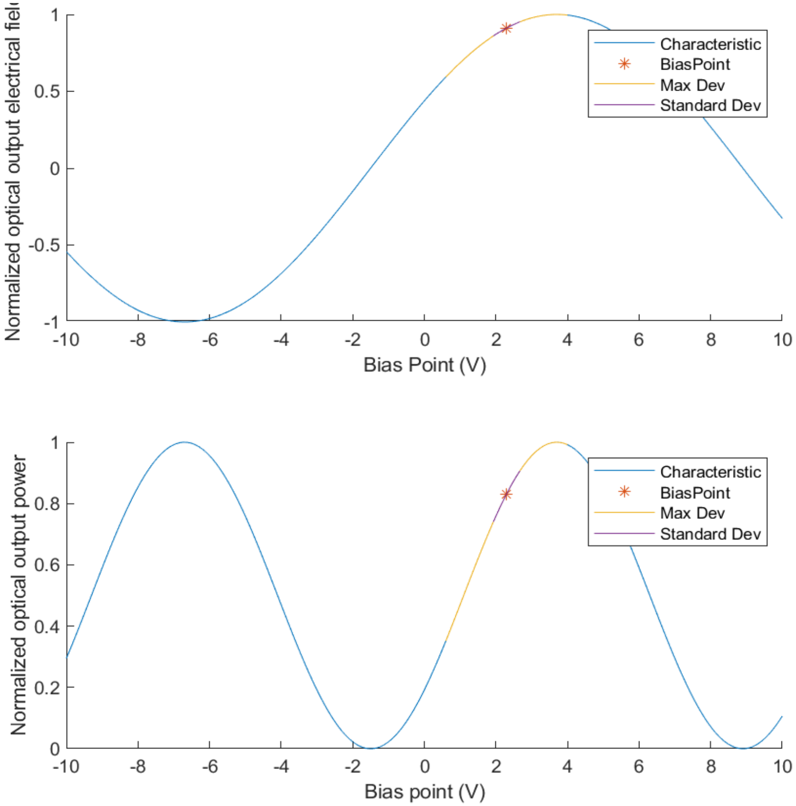
- SBD creates signal-signal-beating interference
- Avoided by IF = 1.5 x BW but at cost of spectrum

IF-OFDM with SSBI suppression for QAM envelope detection

URSI GASS 2020

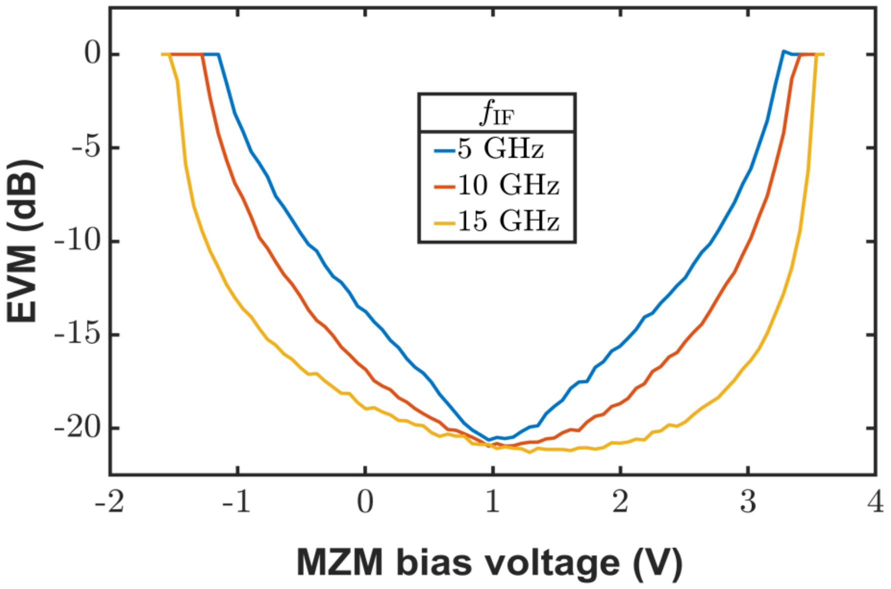
UNIVERSITÄT DUISBURG ESSEN

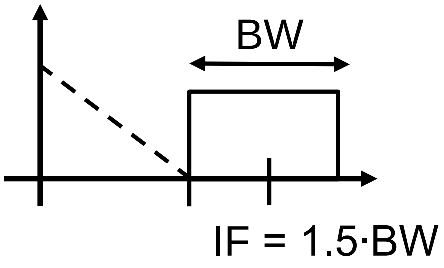
Open-Minded



- 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!

UNIVERSITÄT DUISBURG ESSEN

Open-Minded

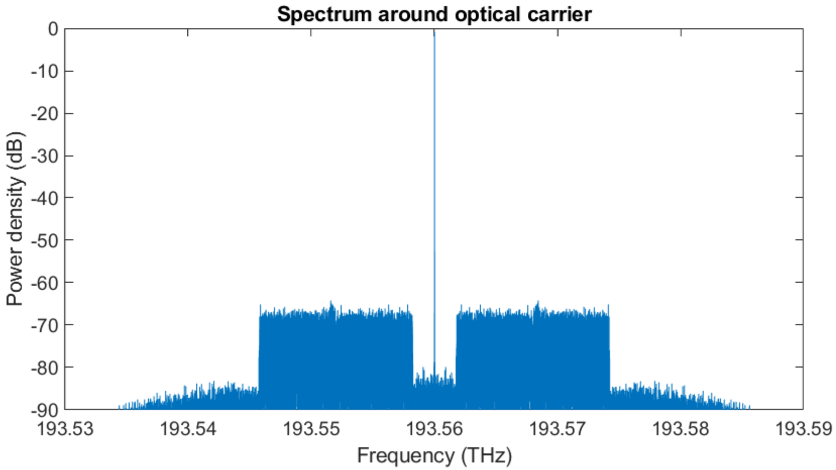
Demonstration measurements for spectral-efficient high data rate link

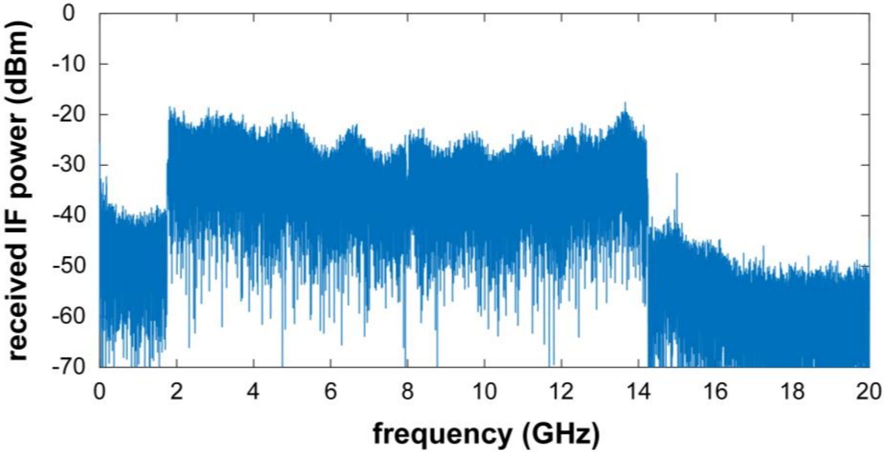
Demonstration measurements for spectral-efficient high data rate link

URSI GASS 2020

UNIVERSITÄT DUISBURG ESSEN

Open-Minded





- Simulated flat double sideband transmission spectrum after MZM
- Power balancing between carrier and sidebands for SINR

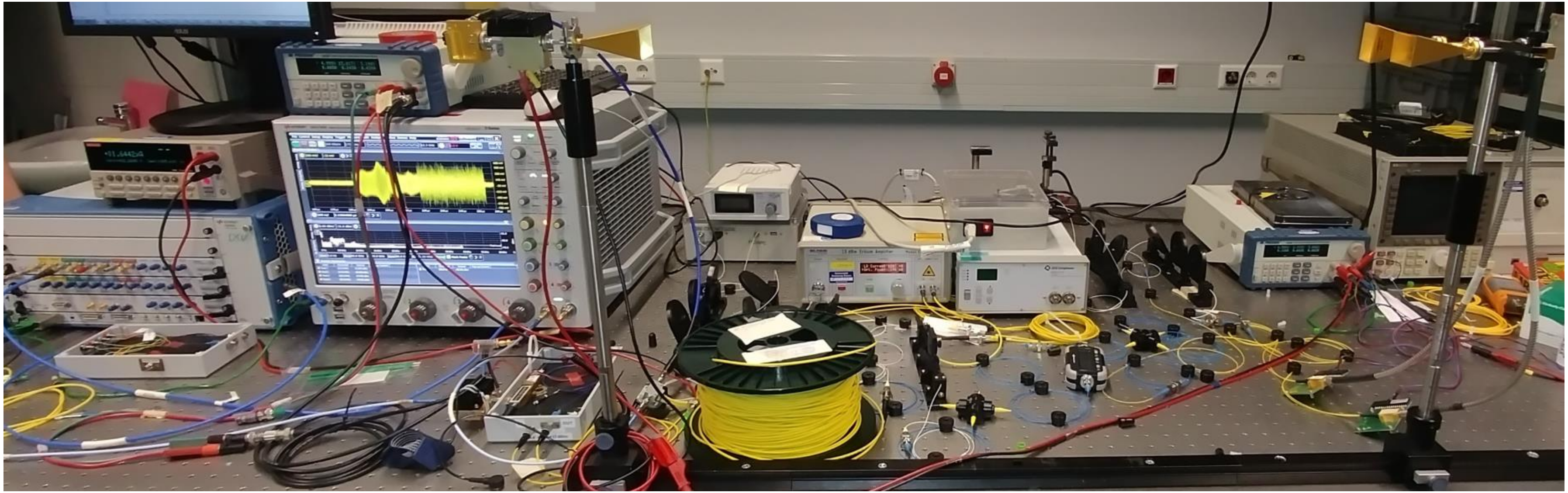
- OFDM provides channel estimation for demodulation of the wideband signal
- Received spectrum shows frequency selectivity

Demonstration measurements for spectral-efficient high data rate link

URSI GASS 2020

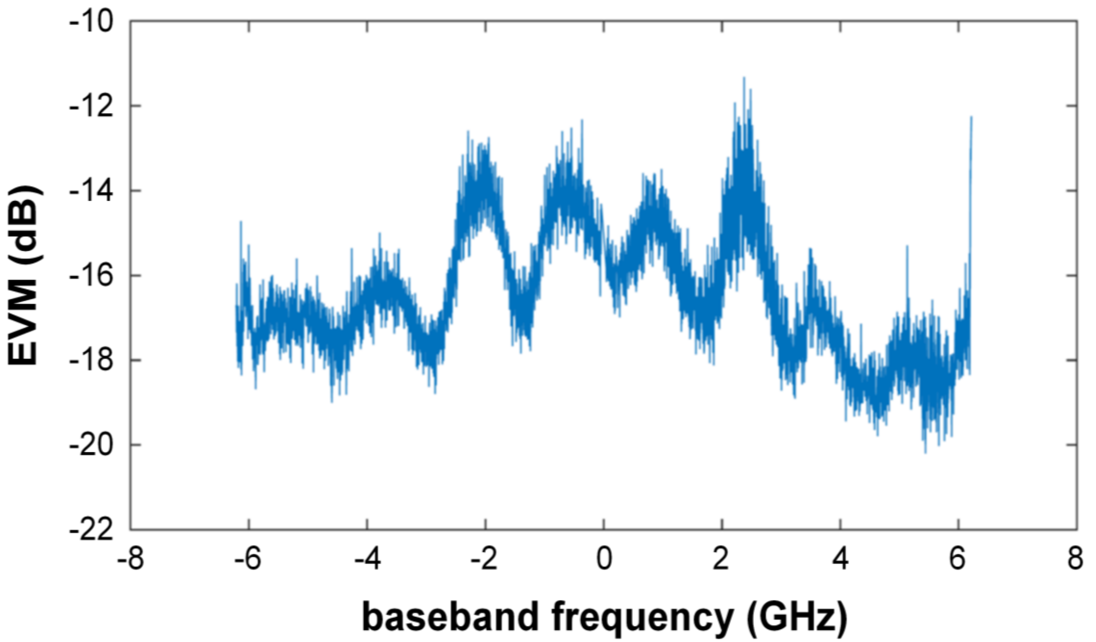
UNIVERSITÄT DUISBURG ESSEN

Open-Minded



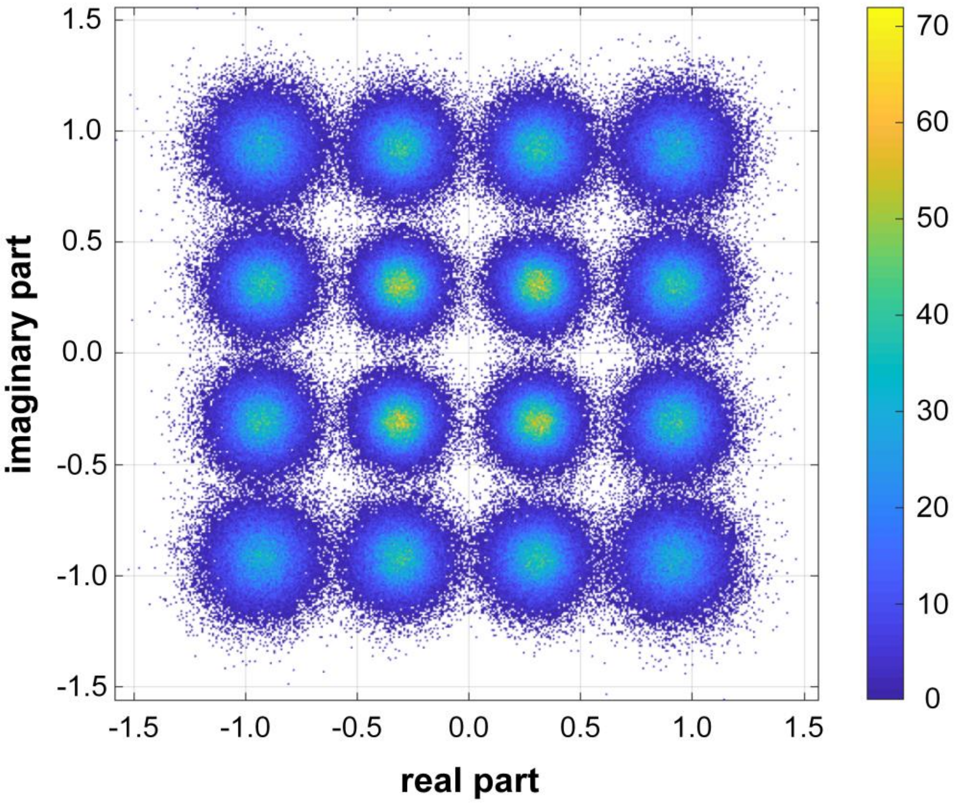
- 60 GHz fiber-wireless transmission setup with running experiment
- 2 Tx antennas fed by CPXs (right) and rotatable Rx antenna (left)

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 2.4×10^{-3} → below the 3.8×10^{-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!

Acknowledgement & References

Financial support by the DFG within the “Tera50+” project as part of the SPP1655 program “Wireless 100 Gbit/s and beyond”

1. L. Li et al., “The path to 5G: mmWave aspects,” Journal of Communications and Information Networks, 1, 2, August 2016, pp. 1-18, doi: 10.1007/BF03391553.
2. T. Nagatsuma, G. Ducournau, and C. Renaud, “Advances in terahertz communications accelerated by photonics,” Nature Photonics, 10, June 2016, pp. 371-379, doi: 10.1038/nphoton.2016.65.
3. Federal Communications Commission (FCC), “Use of Spectrum Bands Above 24 GHz for Mobile Radio Services,” Federal Register, 81, 219, 14 Nov. 2016, pp. 79894-79945, www.govinfo.gov/content/pkg/FR-2016-11-14/pdf/2016-25765.pdf.
4. X. Pang et al., “260 Gbit/s photonic-wireless link in the THz band,” 2016 IEEE Photonics Conference (IPC), Waikoloa, HI, USA, 2-6 Oct. 2016, pp. 1-2, doi: 10.1109/IPCon.2016.7830951.
5. T. Harter et al., “110 -m THz wireless transmission at 100 Gbit/s using a Kramers-Kronig Schottky barrier diode receiver,” 2018 European Conference on Optical Communication (ECOC), Rome, Italy, 23-27 Sept. 2018, pp. 1-3, doi: 10.1109/ECOC.2018.8535174.
6. R. Chuenchom et al., “E-Band 76-GHz Coherent RoF Backhaul Link Using an Integrated Photonic Mixer,” Journal of Lightwave Technology, 34, 20, October 2016, pp. 4744-4750, doi: 10.1109/JLT.2016.2573047
7. M. Freire Hermelo, P.-T. Shih, M. Steeg, A. Ng’oma, and A. Stöhr, “Spectral efficient 64-QAM-OFDM terahertz communication link,” Optics Express, 25, 16, 2017, pp. 19360-19370, doi: 10.1364/OE.25.019360.
8. C. Lin et al., “V-band gapless OFDM RoF system with power detector down-conversion and novel Volterra nonlinear filtering,” Optics Letters, 42, 2, 2017, pp. 207-210, doi: 10.1364/OL.42.000207.
9. Z. Li et al., “Direct-detection 16-QAM Nyquist-shaped subcarrier modulation with SSBI mitigation,” 2015 IEEE International Conference on Communications (ICC), London, UK, 8-12 June 2015, pp. 5204-5209, doi: 10.1109/ICC.2015.7249150.