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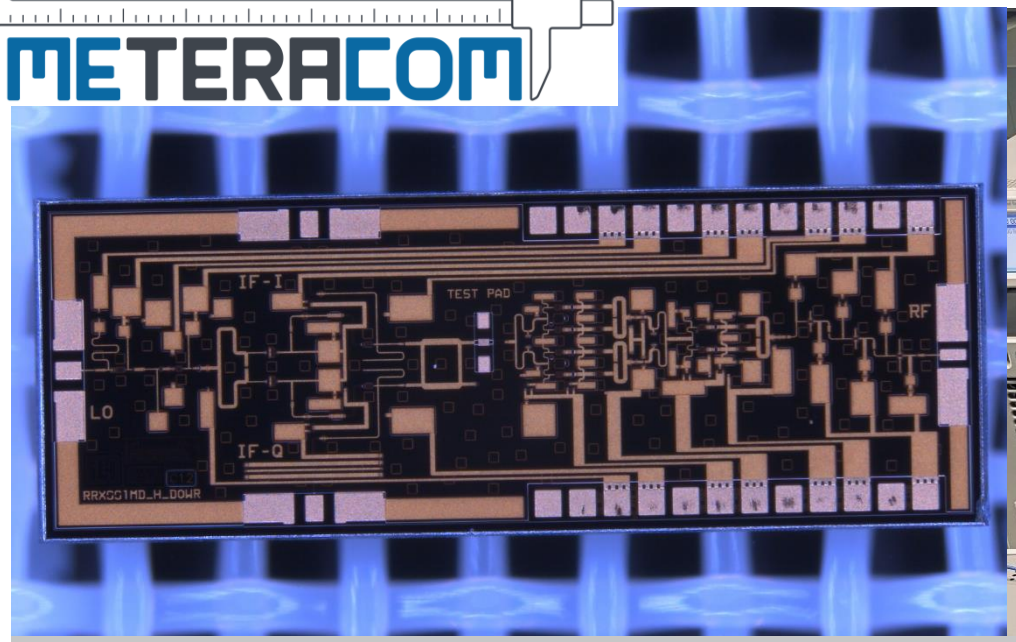
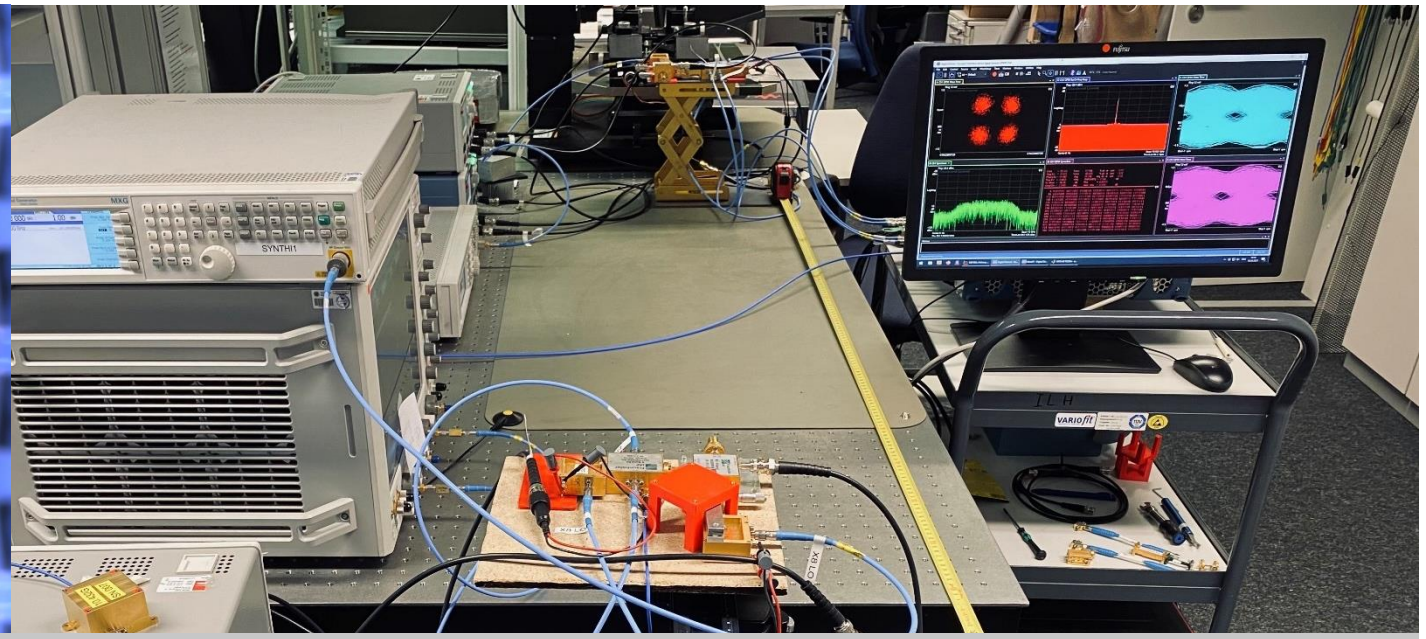
FOR 2863 Meteracom
Metrology for THz Communications

METERACOM





Sensitivity Analysis of a 280 – 312 GHz Superheterodyne Terahertz Link Targeting IEEE802.15.3d Applications

Dominik Wrana

1st International Workshop on Metrology for THz Communications, Braunschweig, 28 June 2022

Agenda

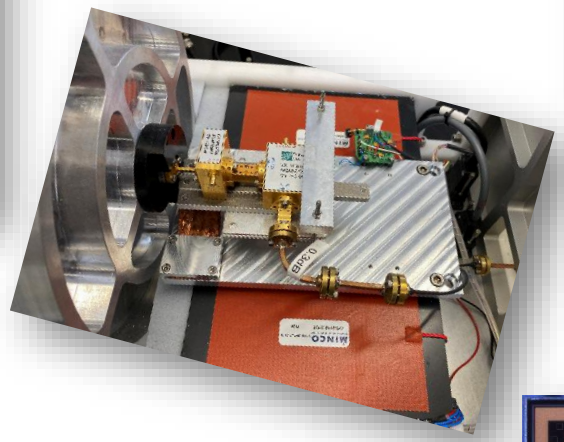
1. Motivation
2. Transmit and Receive Chipsets for THz Wireless Communication
3. Sensitivity Analysis
4. Conclusion

1. Motivation

Metrology for THz communication systems

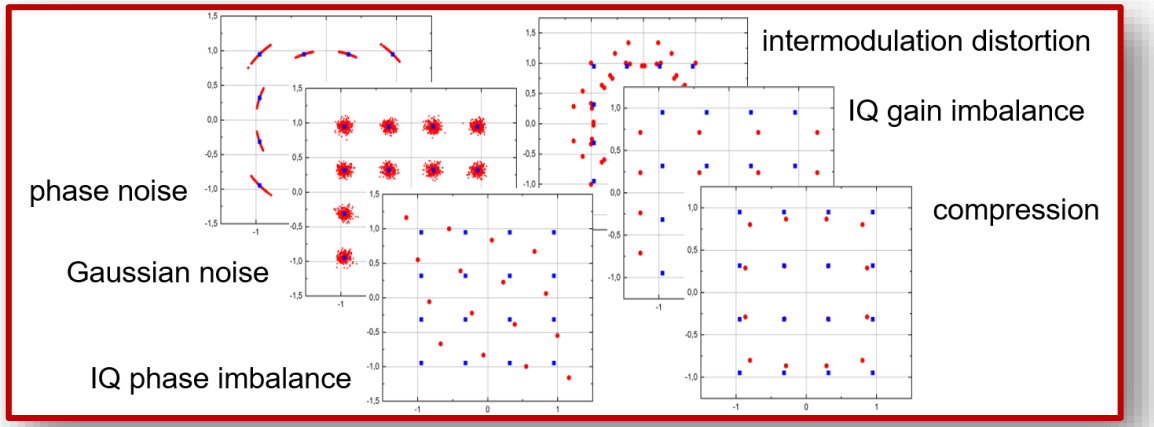
Link-Level

Component-Level

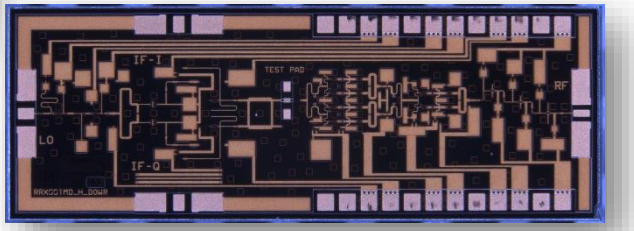


Circuit-Level

chip-level non-idealities cause signal distortion!



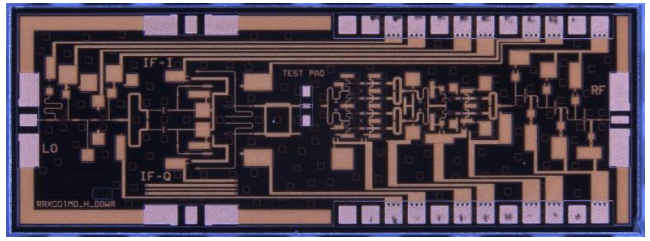
→ device characterization + sensitivity analysis to define link capabilities and optimum operation points

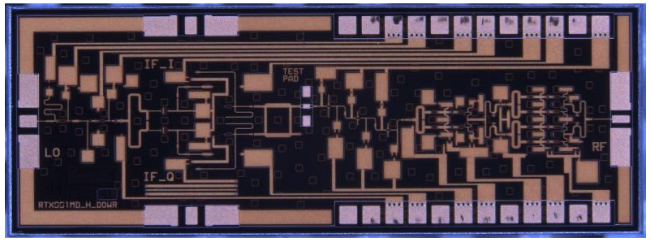


Tx / Rx Chipsets for Wireless THz Communication
MMIC Architecture

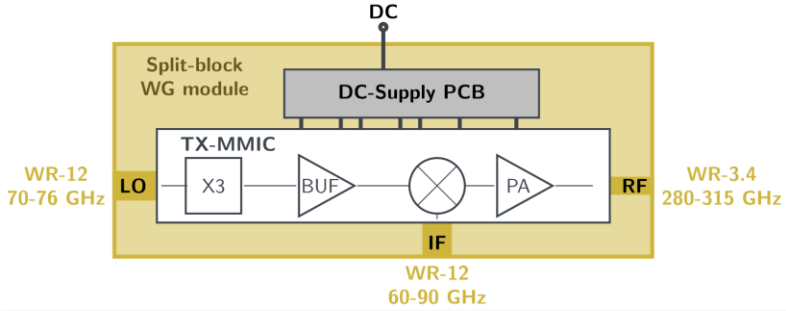
1. METERACOM-specific Tx and Rx MMICs (adopting a specification-driven top-down design approach)

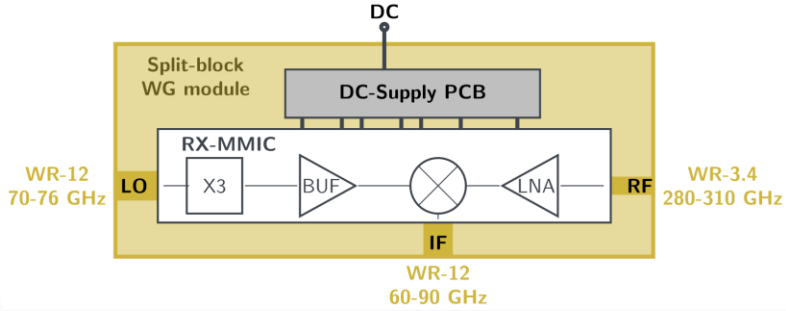
Novel BOEL 300 GHz Tx and Rx MMICs

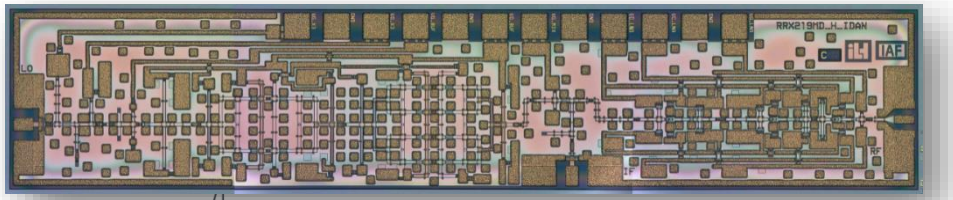


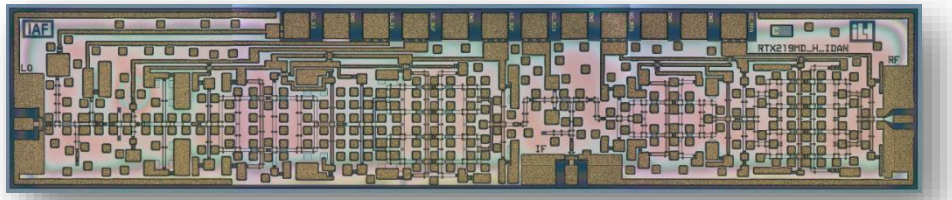


2. Superheterodyne Tx and Rx MMICs (specifically developed within the ThoR project)





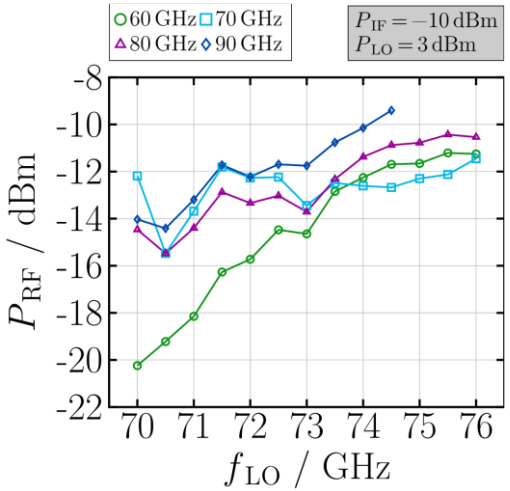


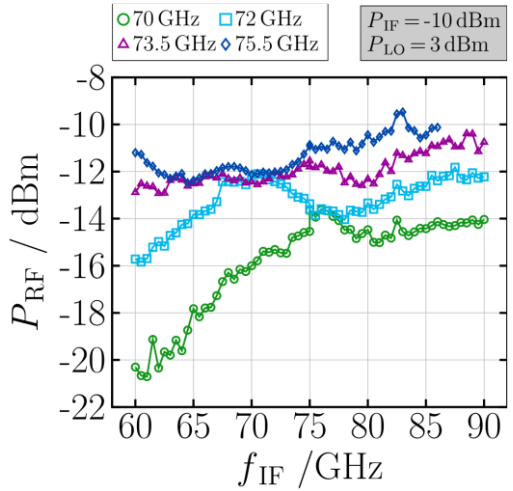


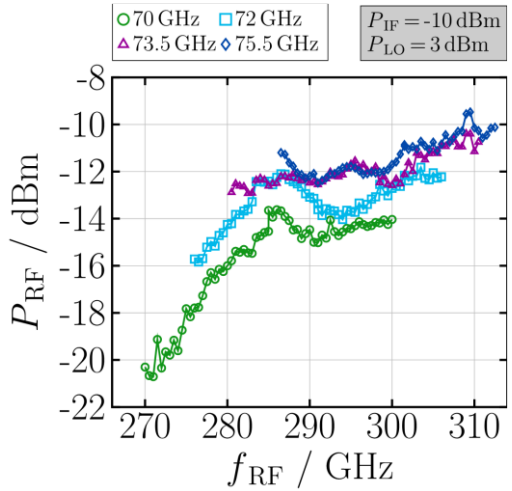
2. Superheterodyne Tx / Rx Chipset for Wireless THz Communication

Frequency Response

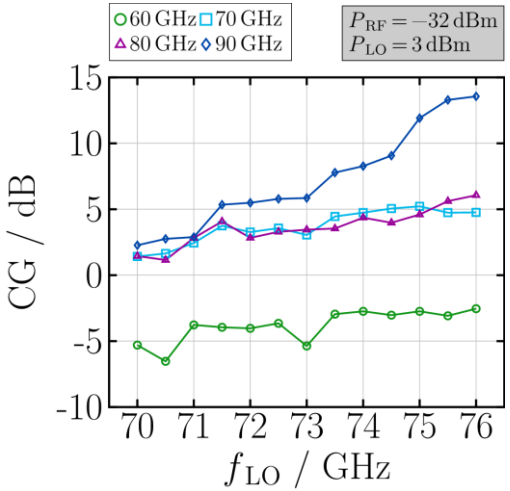
Tx

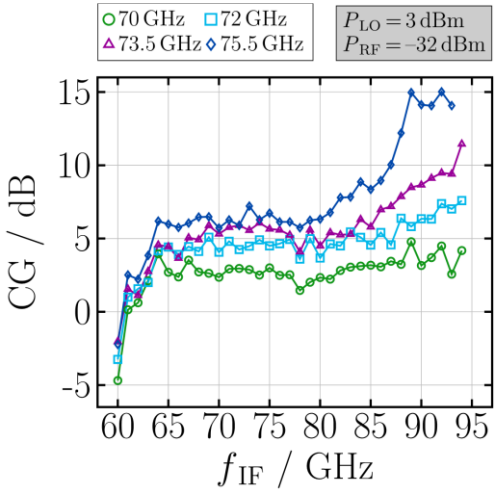


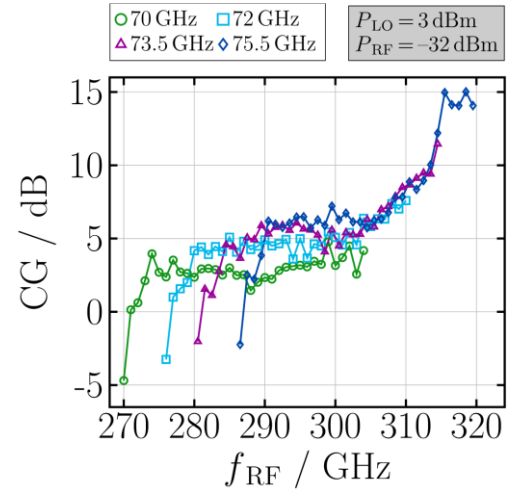




Rx

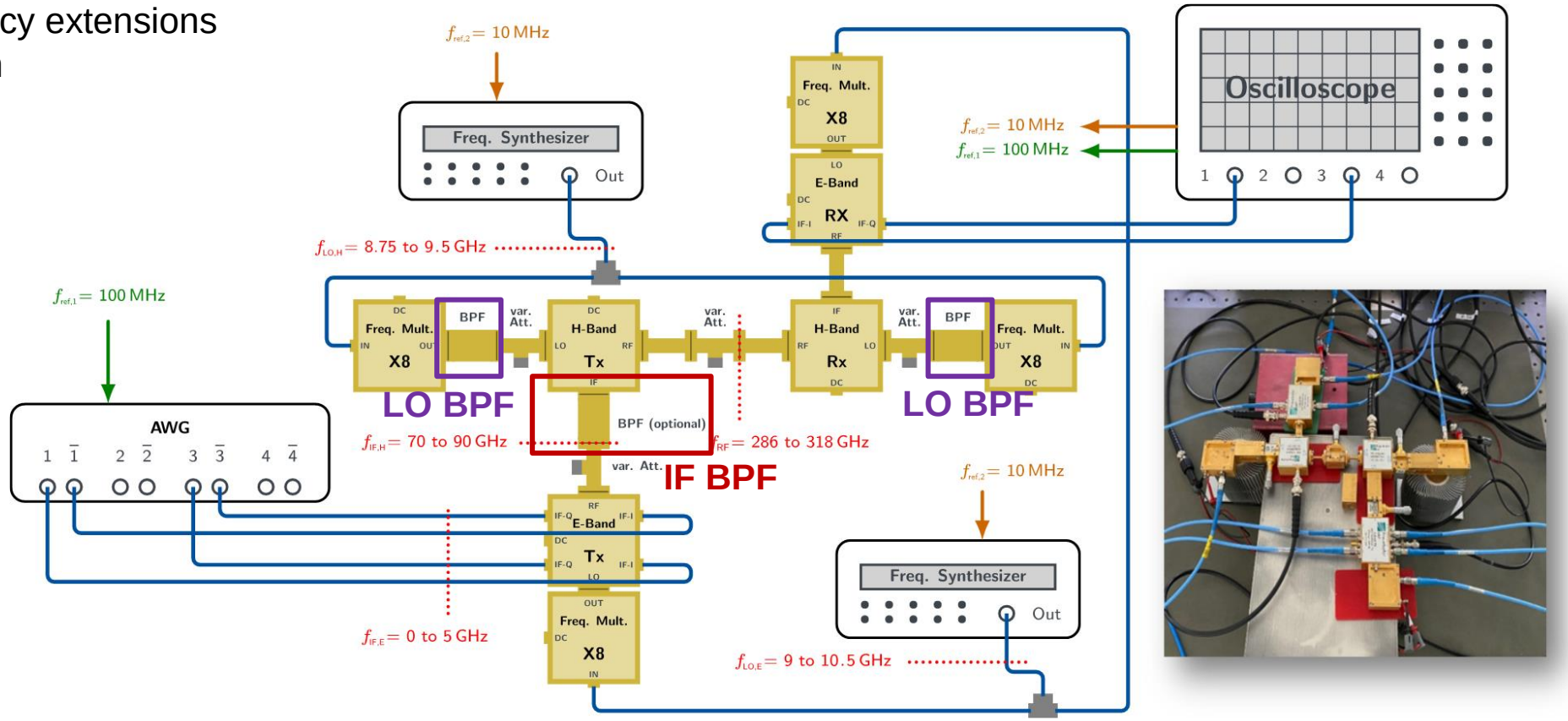






3. Sensitivity Analysis
Measurement Setup

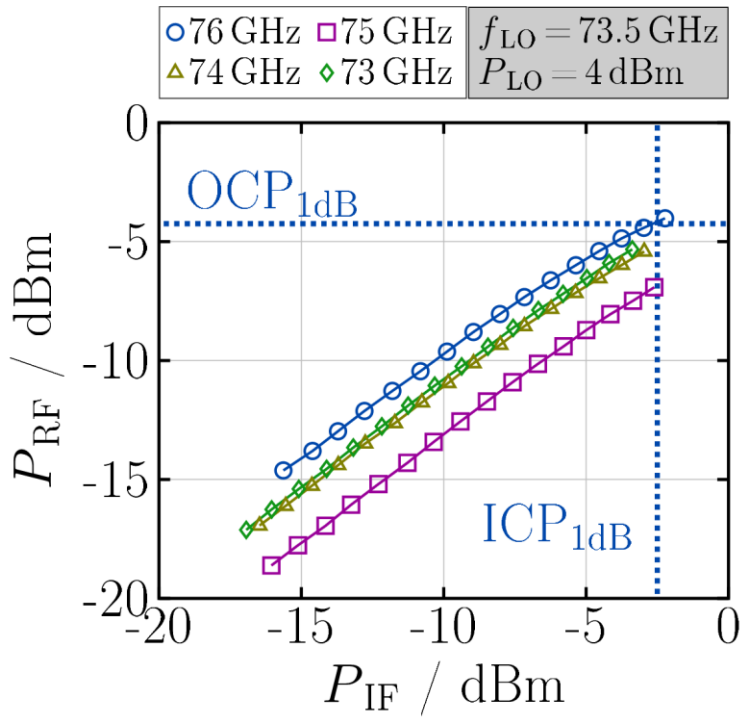
- Goals:
  I. Characterization of H-band Tx / Rx chain to find optimum operation points for wireless demonstration
  II. Analysis of the influence of chip-level impairments on signal quality
- Tx – Rx chain in back-to back configuration neglecting all air channel impairments
- Custom E-band frequency extensions
- Coherent LO generation



3. Sensitivity Analysis

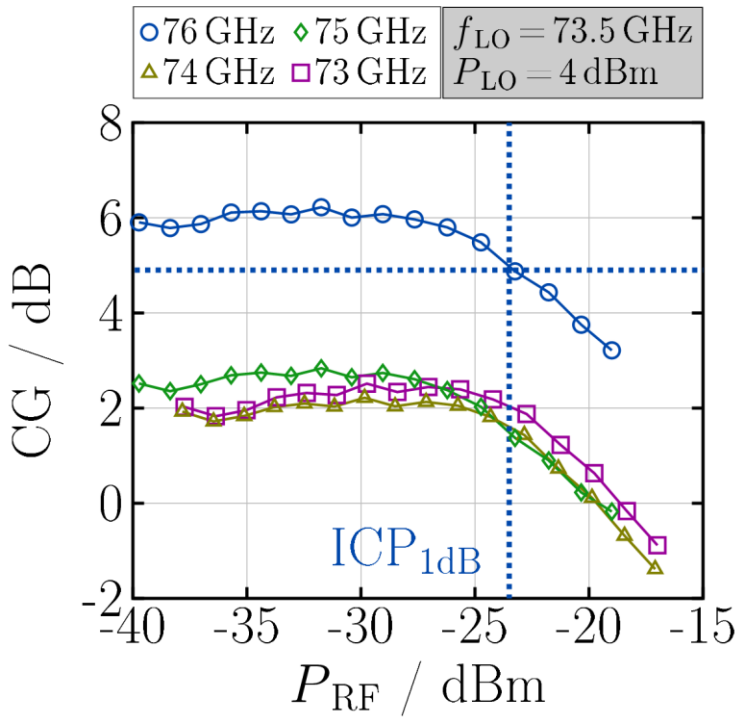
CW Measurements – Tx Linearity / Rx Sensitivity

Tx Linearity



- IP1dB = -4 … -2 dBm
- OP1dB = -6 … -4 dBm

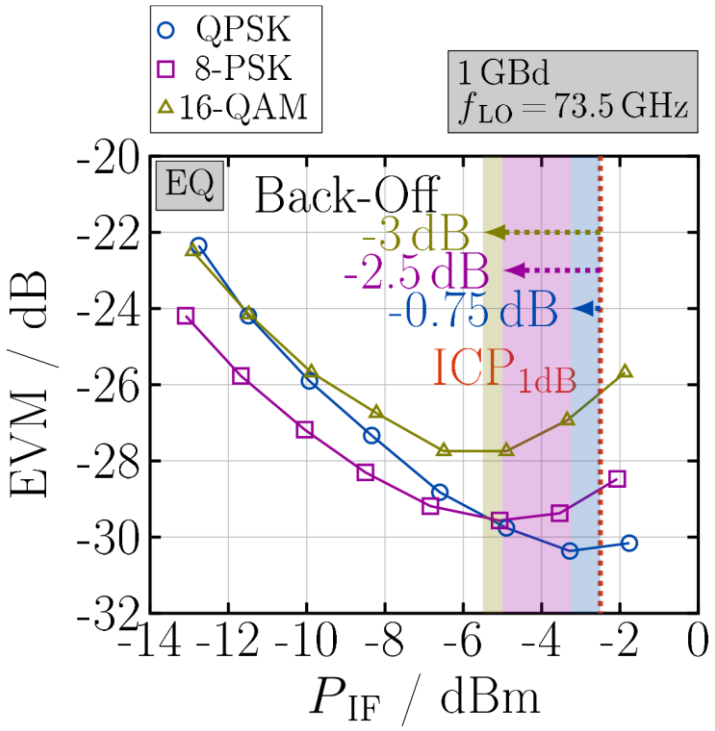
Rx Sensitivity



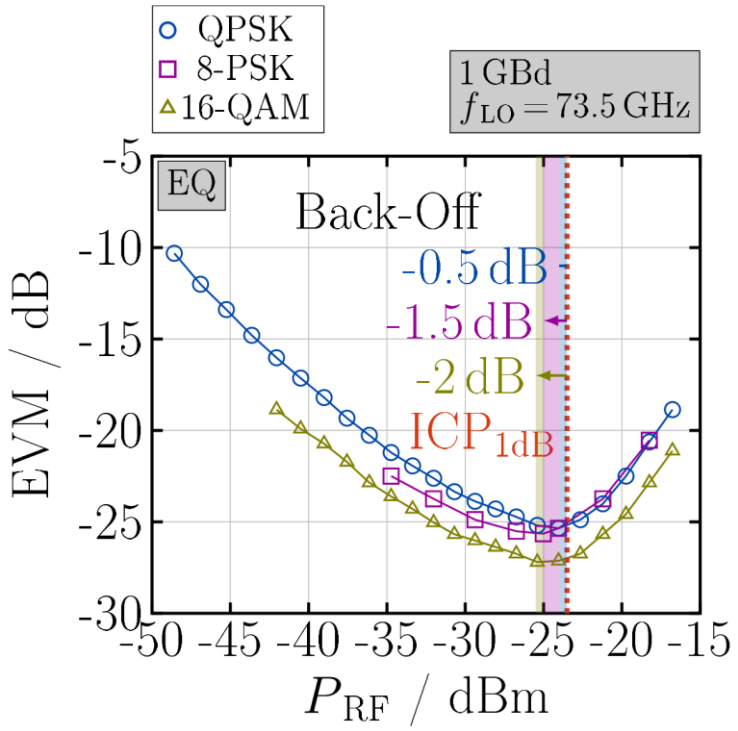
- CG = 2 … 6 dB
- IP1dB = -24 … -21 dBm

3. Sensitivity Analysis
Modulated Signal Measurements

Tx Linearity



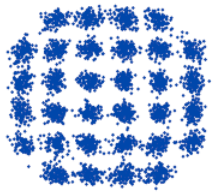
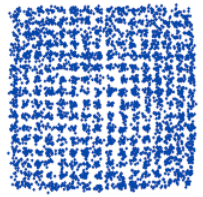
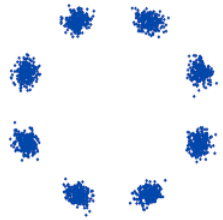
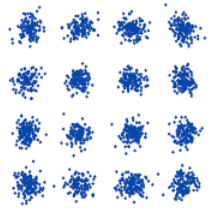
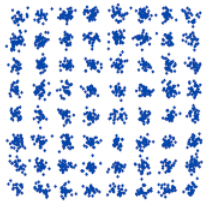
Rx Sensitivity



- Higher order modulation schemes require higher back-off from IP1dB due to higher peak-to-average power ratio (PAPR)
- Measured back-off in good accordance with theoretical derivation
- Manual adjustment of RF attenuation limits accuracy of Rx sensitivity measurement

3. Sensitivity Analysis

Selected Results – Max. Data Rate / Spectral Efficiency / IEEE802.15.3d

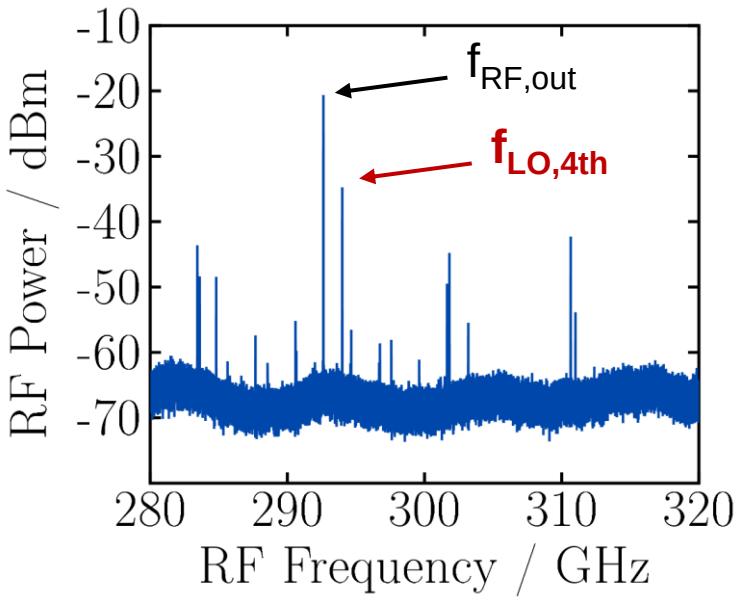
	Maximum performance		IEEE802.15.3d			
Channel ID	-	-	44	54	25	26
$f_{\mathrm{IF,center}}$ / GHz	79.1	79.25	85.7	79.1	84.6	84.6
$f_{\mathrm{RF,center}}$ / GHz	301.2	304.25	302.4	300.2	305.6	307.8
Bandwidth / GHz	8.64	1.35	4.32	8.64	2.16	2.16
Data Rate / Gbit/s	32	8	9.6	25.6	9.6	11.2
Modulation Scheme	32-QAM	256-QAM	8-PSK	16-QAM	64-QAM	128-QAM
Constellation						
EVM / dB	–23.6	–30.8	–20.9	–21.4	–27.1	–30.5
SNR / dB	19.6	26.3	20.6	19	23.5	25.6

- Maximum datarate of 32 Gbit/s (BW limited by E-band freq. extension)
- Sufficient linearity to support up to 256-QAM
- Compliance with the IEEE802.15.3d frequency standard

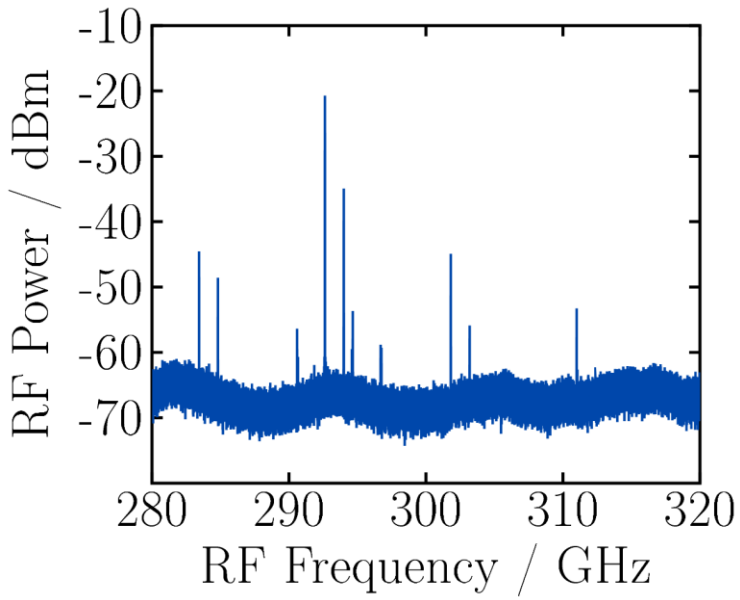
3. Sensitivity Analysis
Analysis of Spurious Tones in the RF Domain

- Measured RF spectra at output of Tx module
- Conditions: $f_{LO,in}$ = 73.5 GHz → $f_{LO,3rd}$ = 220.5 GHz / $f_{LO,4th}$ = 294 GHz
  $f_{IF,in}$ = 72.125 GHz, $P_{IF,in}$ = -18 dBm
  $f_{RF,out} = 3 \cdot f_{LO,in} + f_{IF,in}$ = 292.625 GHz

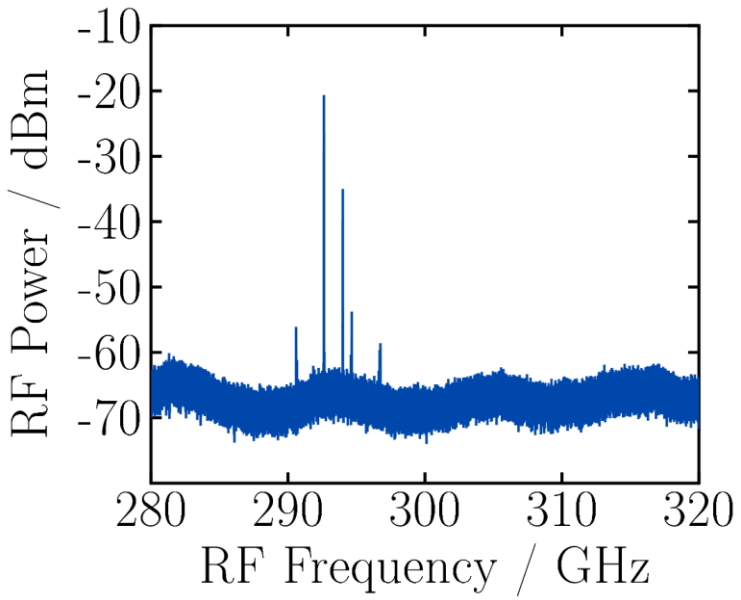
no BPF



with IF BPF



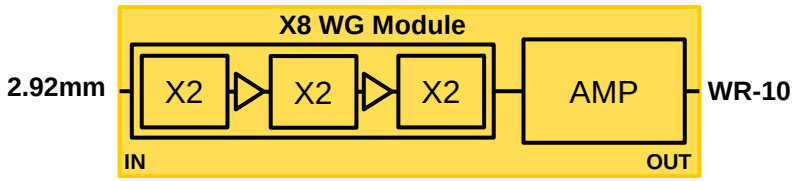
with IF + LO BPF



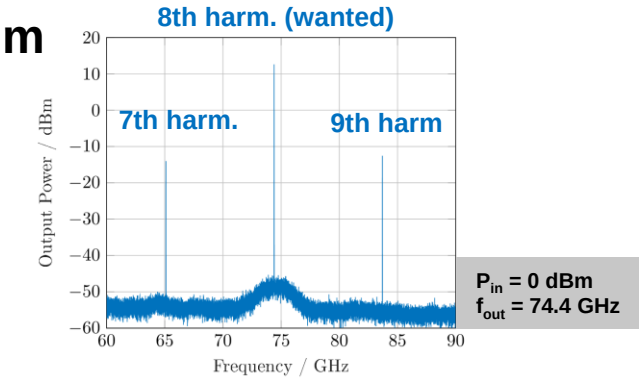
3. Sensitivity Analysis

Analysis of Spurious Tones in the RF Domain – LO Generation with X8 Module

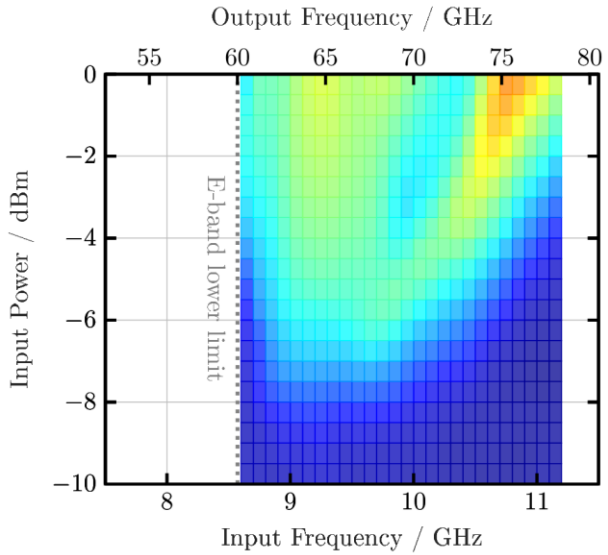
Blockdiagram



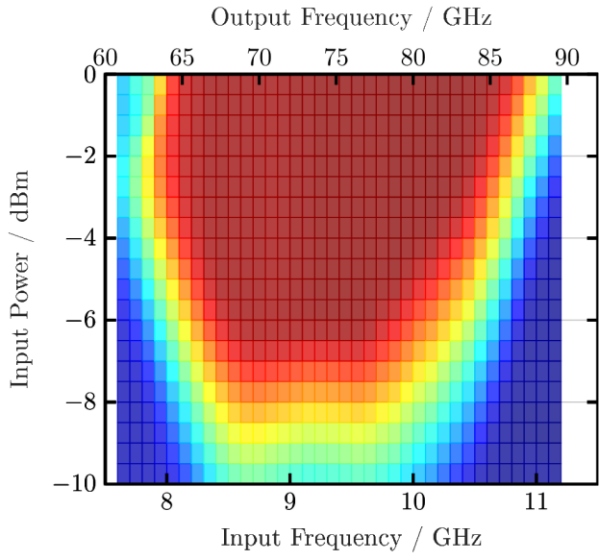
Output Spectrum



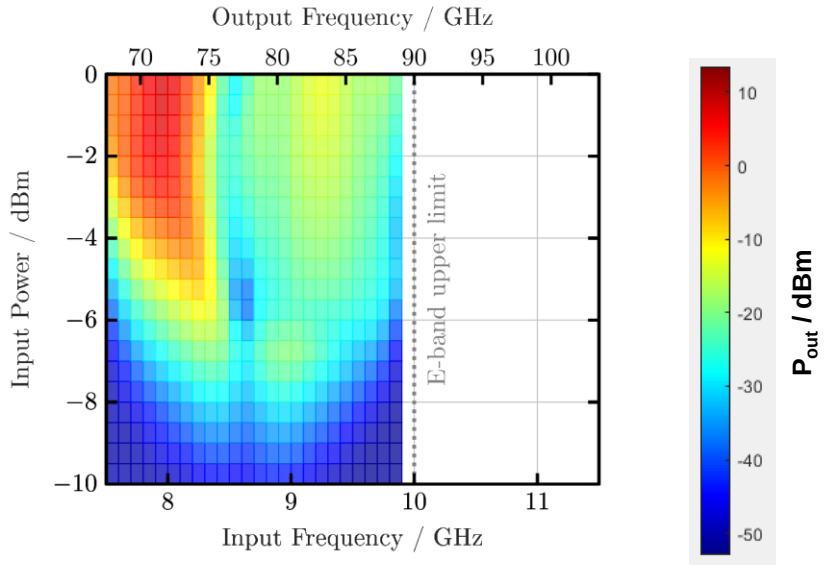
P_{out} 7th Harmonic



P_{out} 8th Harmonic



P_{out} 9th Harmonic



3. Sensitivity Analysis
Analysis of Spurious Tones in the RF Domain

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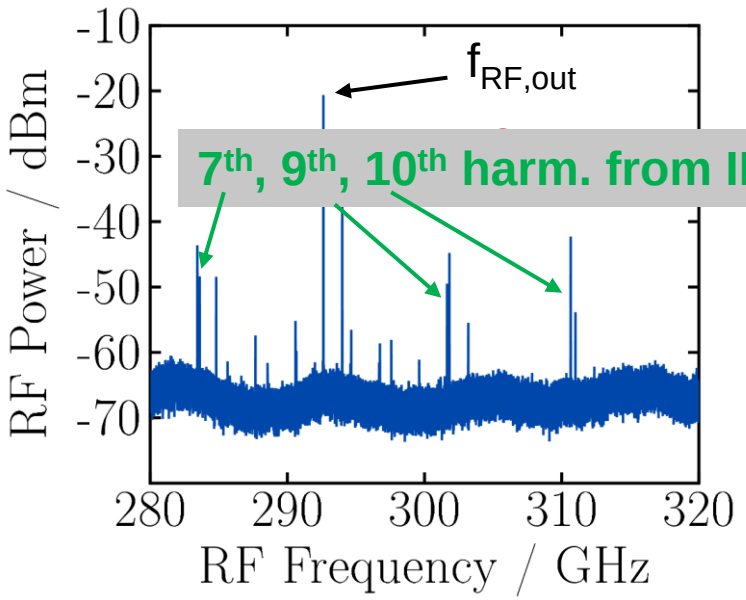
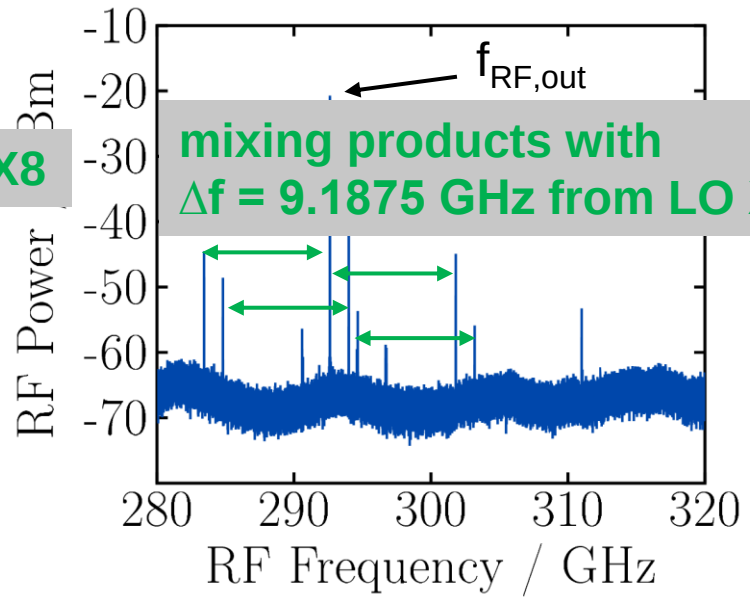
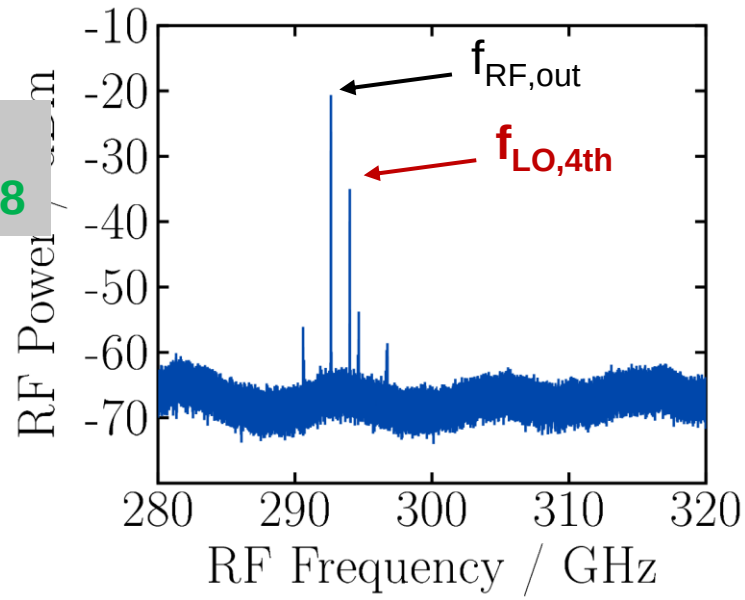
no BPF



IF BPF



IF + LO BPF

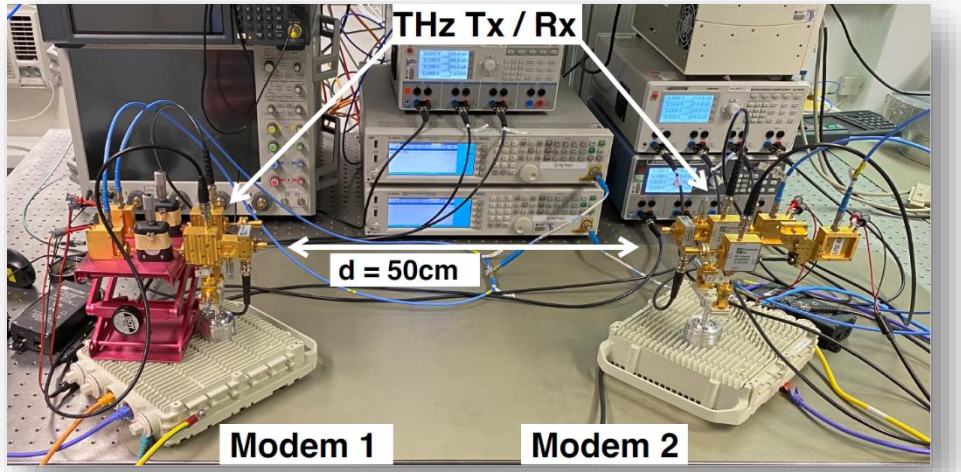


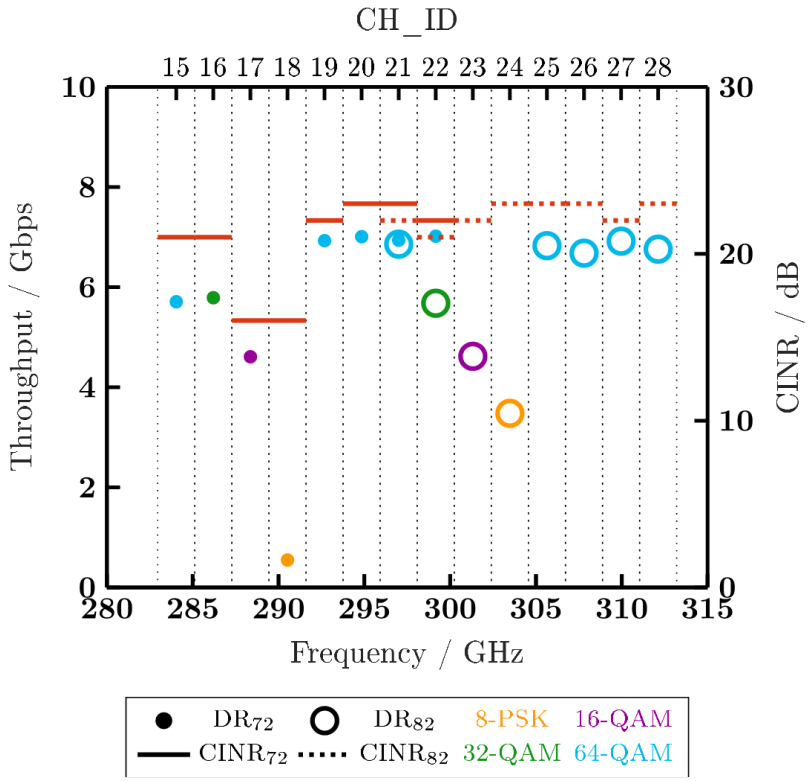
→ **even with spectrally pure IF and LO input signals unwanted spurious tones are present!**

3. Sensitivity Analysis

Analysis of Spurious Tones in the RF Domain – Effect on Transmission Quality

- Short-range wireless transmission experiment using E-band modems
- Full-duplex link
- Channel bandwidth of 2 GHz





- 4th harmonic of freq. tripler causing severe in-band interferences in channels 16, 17, and 18.
- Channel center frequencies: 286.2 / 288.36 / 290.52 GHz
- Used corresp. f_{LO}: 71.358 / 72.078 / 72.798 GHz
- Resulting 4th harm. frequencies: 285.43, 288.31 and 291.19 GHz

4. Conclusion

- Fully-integrated superheterodyne Tx / Rx chipset was shown

- Performed sensitivity analysis indicates
  I. optimum operation points
  II. Max. achievable data rate
  III. use of higher order modulation schemes is possible
  IV. Feasable link distance for long-range demonstration

- severness of spurious tones arising from non-ideal LO and IF signal generation demonstrated in wireless transmission experiment

Thank you very much for your Attention

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