A 202 GHz Link Using Planar Transceiver Modules

Utku Soylu[1]

Amirreza Alizadeh[1], Munkyo Seo[2], Ahmed S. H. Ahmed[1], Mark J. W. Rodwell[1]

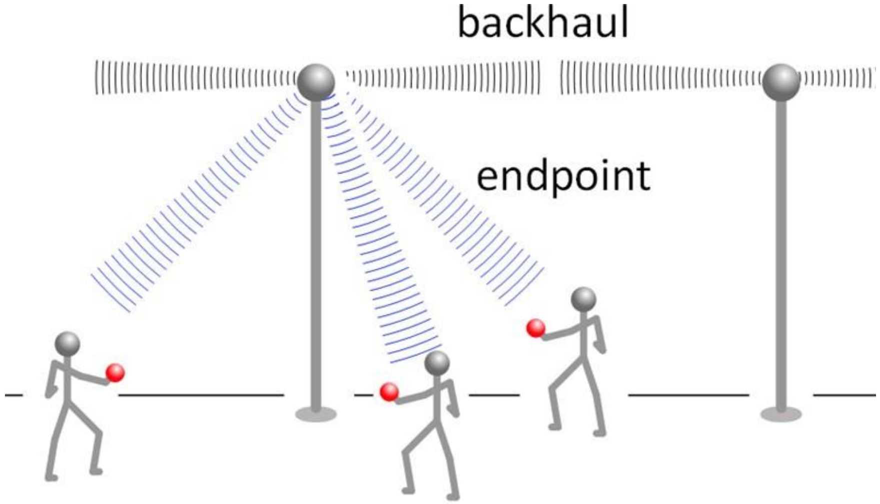
[1]ECE, University of California, Santa Barbara, USA

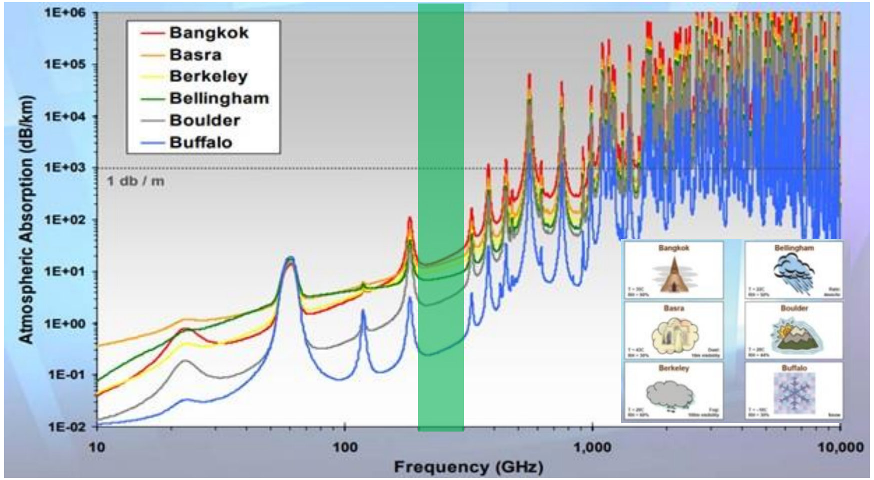
[2]ECE, Sungkyunkwan University, South Korea

200-300 GHz Wireless Backhaul

Growing demand for wireless communications: endpoint and backhaul

- Large available spectrum & massive # of parallel channels → high capacity. ☺
- High atmospheric/path losses & high blockage & poorer PA/LNA performance. ☹





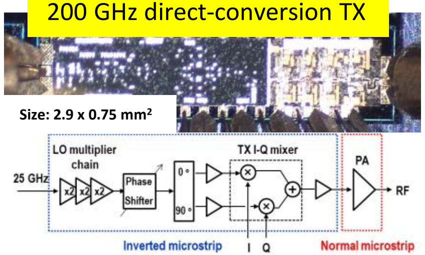
[M.Rosker, IMS2007]

200-300 GHz Wireless Backhaul

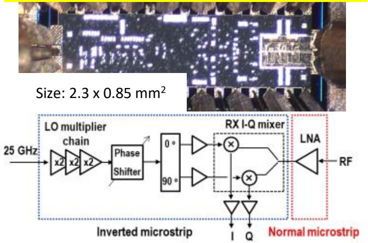
200-300 GHz backhaul: 100+ Gb/s feasible over ~km range.
→ develop 200-300 GHz transceivers

ICs → Modules → Links

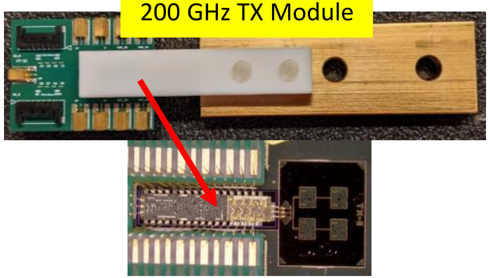
200 GHz direct-conversion TX



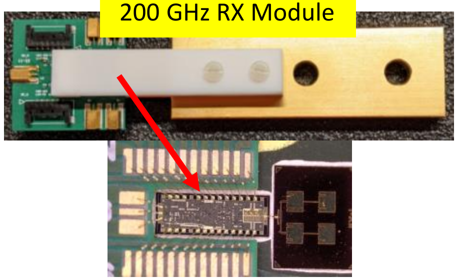
200 GHz direct-conversion RX



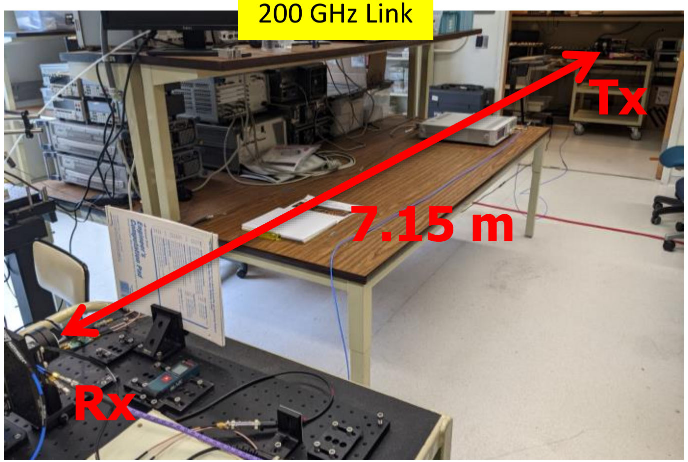
200 GHz TX Module



200 GHz RX Module



200 GHz Link



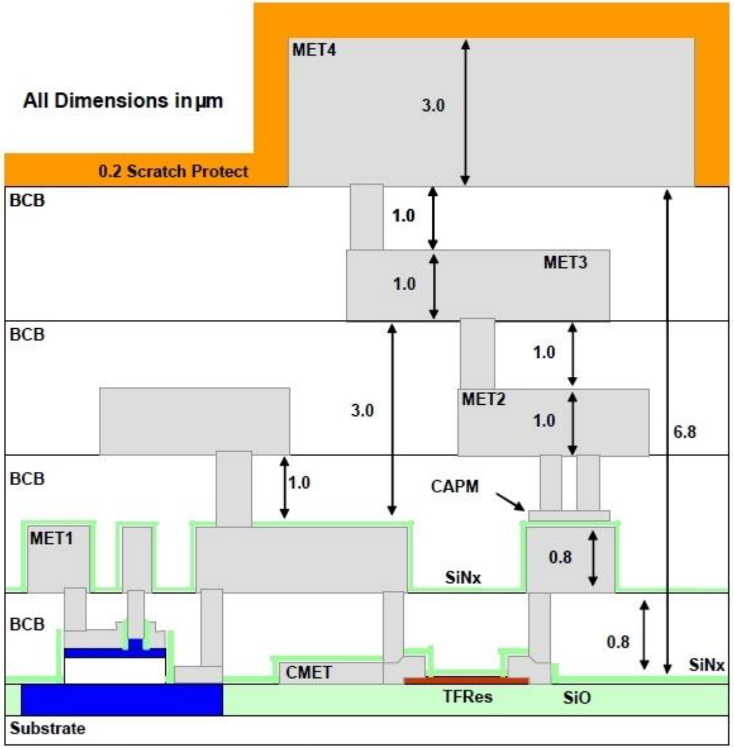
Teledyne 250 nm InP HBT

f_{max} = 650 GHz
J_{max} = 3 mA/µm
B_{VCEo}= 4.5 V

Four interconnect levels

Microstrip lines (M4 signal, M1 ground)
0.88 dB/mm, 0.9 dB/λ @ 200 GHz
1.0 dB/mm, 0.78 dB/λ @ 280 GHz

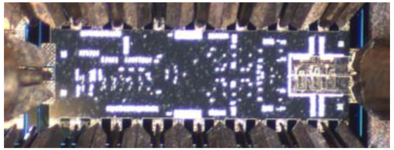
Resistors: 50 Ω/square
MIM capacitors: 0.3 fF/µm^2

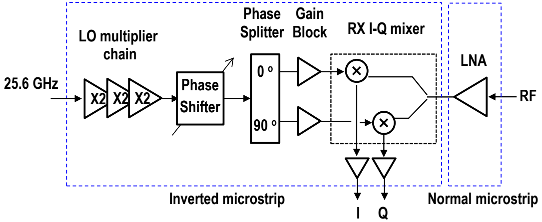


Representative cross-section of TSC250 IC technology. Drawing is not to scale.

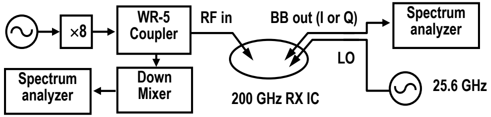
200 GHz Receiver IC

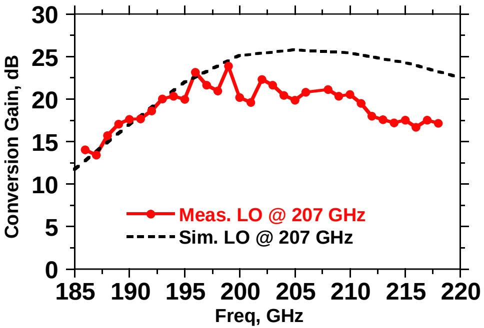
chip size: 2.3 mm x 0.85 mm

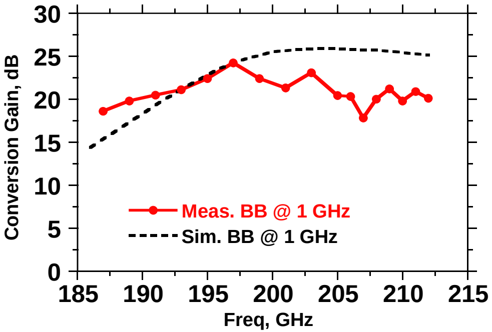


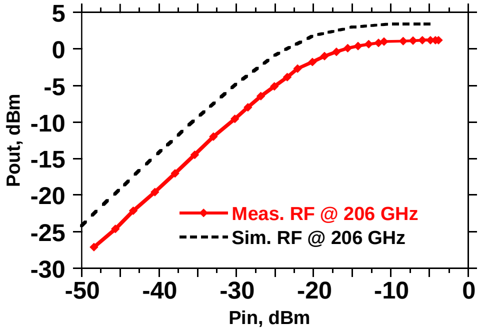


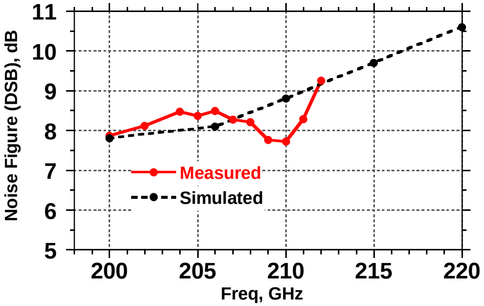
	Measured/Simulation
Peak CG	25 dB
3 dB BW	**25 GHz** / 25 GHz
P_{in1dB}	**-24 dBm**
P_{DC}	825 mW
NF	8.5 dB **/8.5 dB**
Chip Size	2.3 mm x 0.85 mm

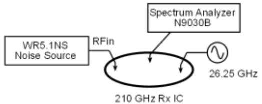












	$F_{CASCADE}$
5 um device	**6.7 dB**
1-stage LNA	**7.5 dB**
NF of Rx	**8.5-8.8 dB**

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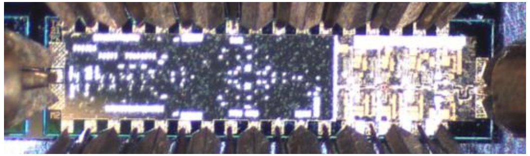
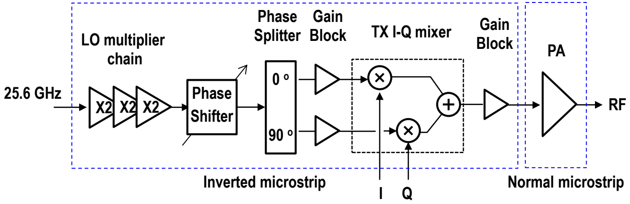
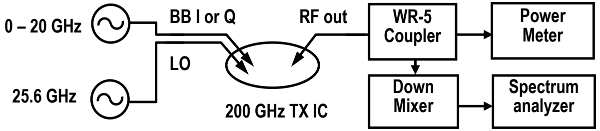
200 GHz Transmitter IC

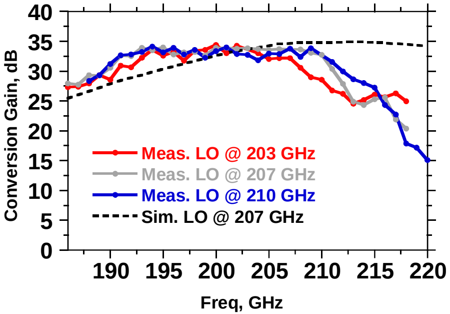
chip size: 2.9 mm x 0.75 mm

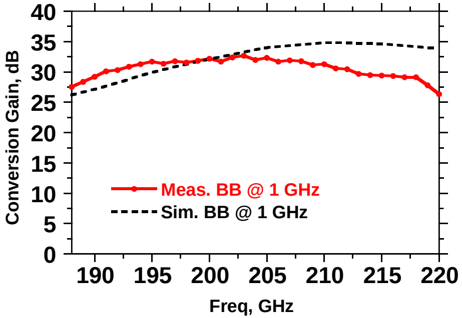


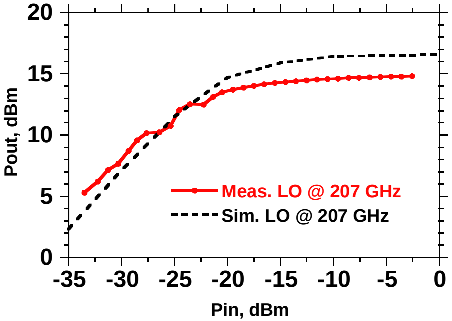


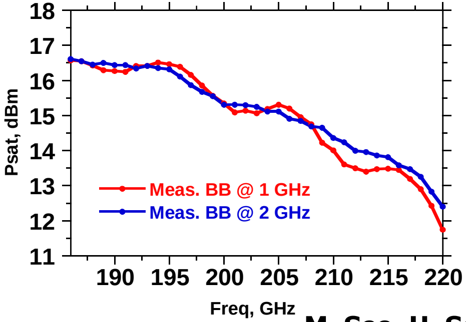
	Measured/Simulation
Peak CG	34 dB
3 dB BW	**20 GHz** / 35 GHz
P_{sat} @ 195 GHz 200 GHz	**16.5 dBm** **15.3 dBm** / 17.4 dBm
P_{DC}	1250 mW
Efficiency	**3.6%**
Chip Size	2.9mmx0.75mm











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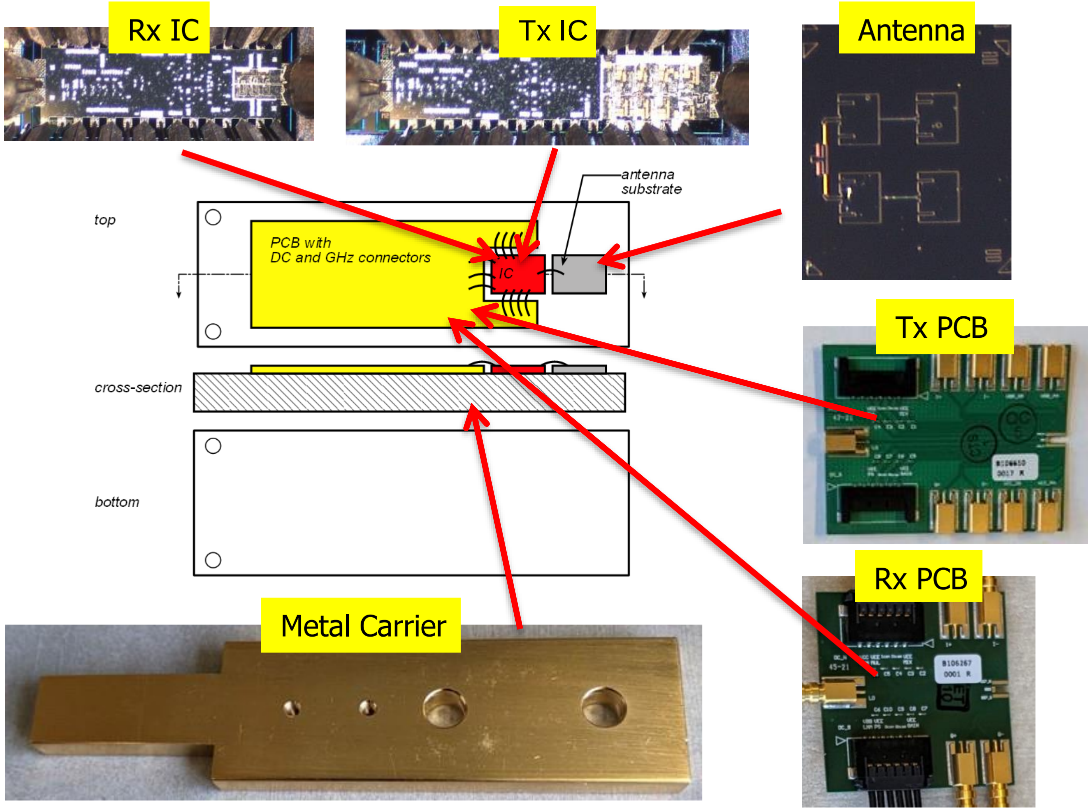
200 GHz Modules



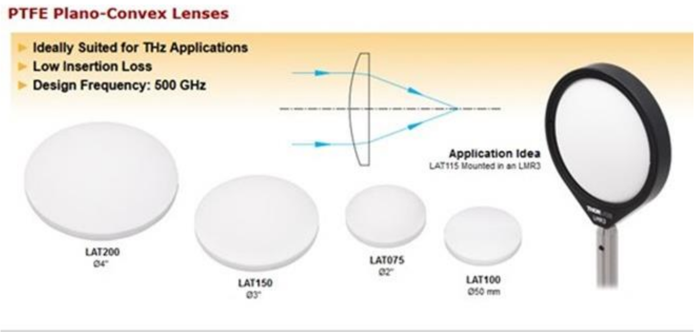
2 Major Design Principles:
Design for **Manufacturability** &
Design for **Lead Time**

Tx & Rx ICs: InP substrate, 82 um thick

Antennas: Fused silica, 50 um thick

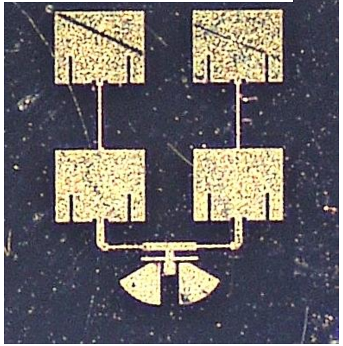
PCBs: I-Tera MT40, 8 mil thick

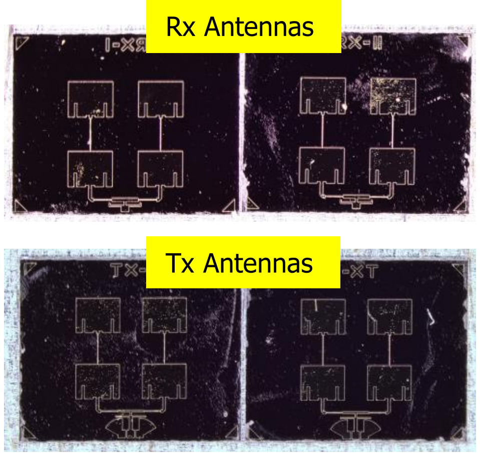
Metal Carrier: Cu with Ni/Au surface finish

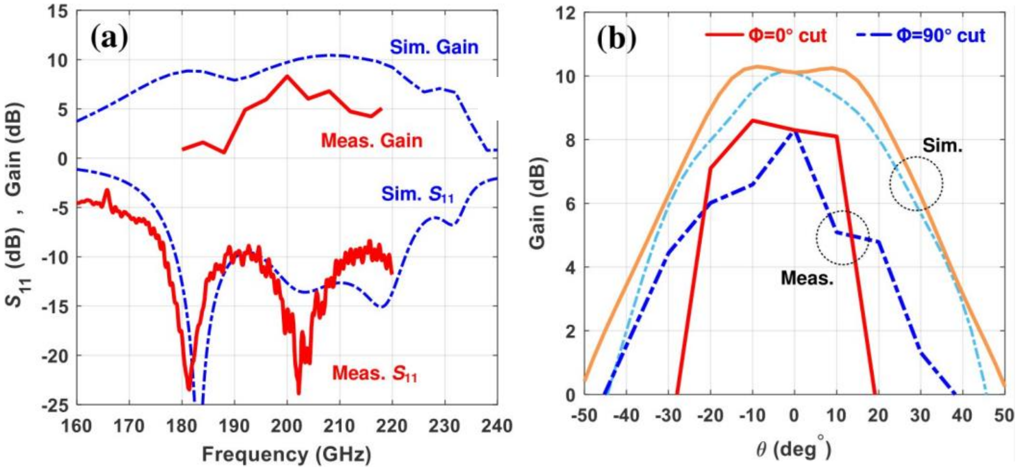


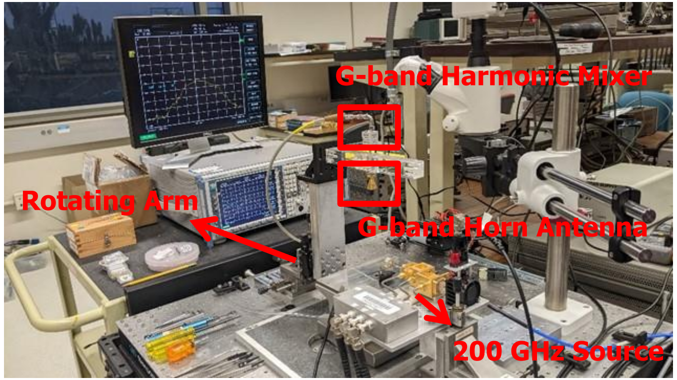
200 GHz Antennas

Size: 1.1 x 1.42 mm^2









50 um thick fused silica

Antenna gain = 8 dBi

3-dB Beamwidth is +/- 20^0 on E and H-plane

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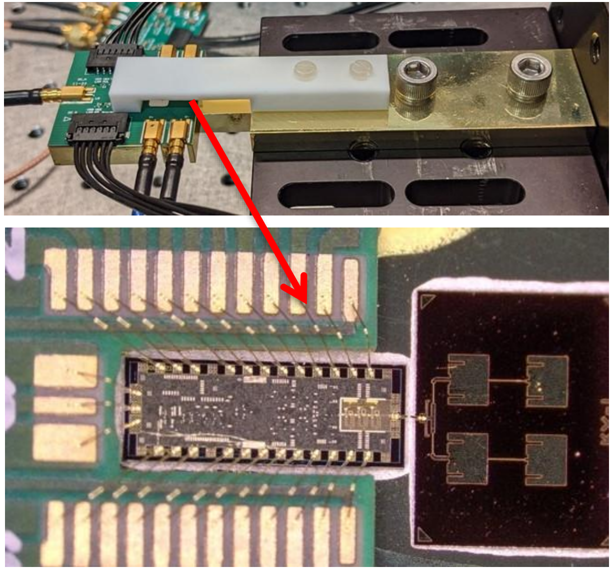
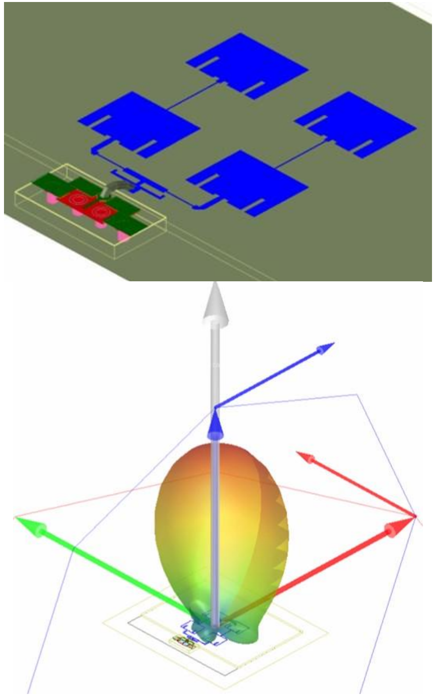
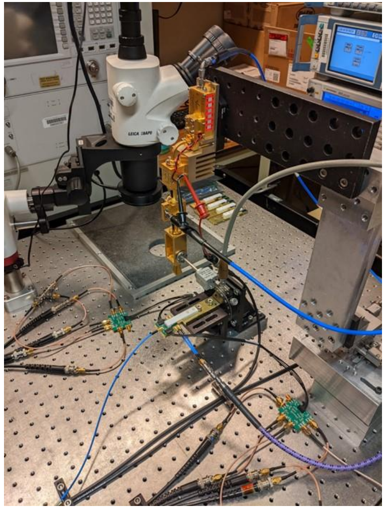
200 GHz Receiver Module

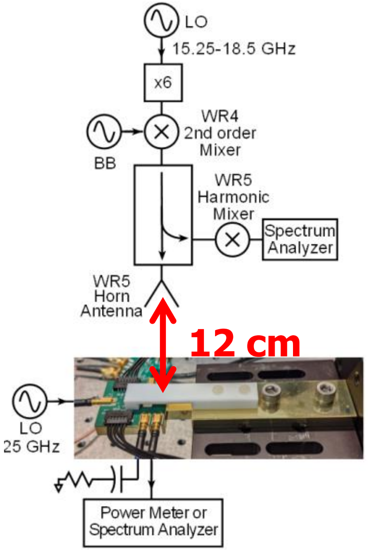




Main Lobe Direction: Theta=1.02453e-05 °, Phi=-180 °
Maximum Gain: 10.1068 dBi

Radiation Efficiency: 68.89%

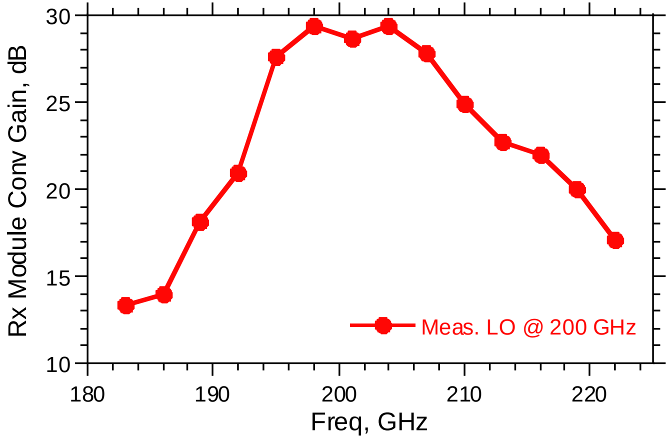




Simultaneous spectrum & power testing

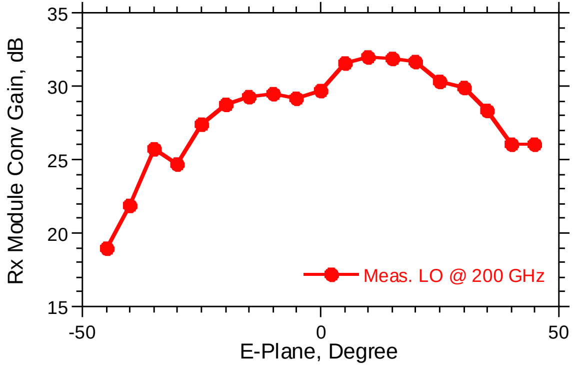
Rx Module CW Testing Results

Conversion Gain @ fixed f_{LO}



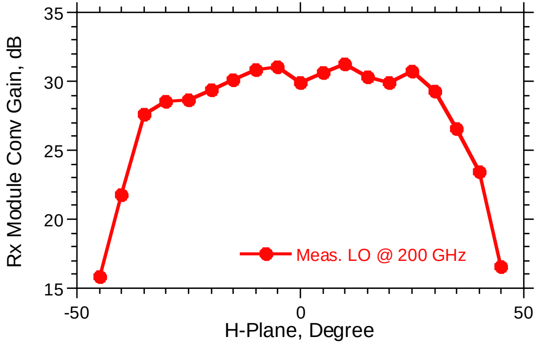
Peak conversion gain = 29.4 dB,
3-dB Modulation BW = 14 GHz

Conversion Gain @ fixed f_{LO} (f_{RF}=201 GHz)



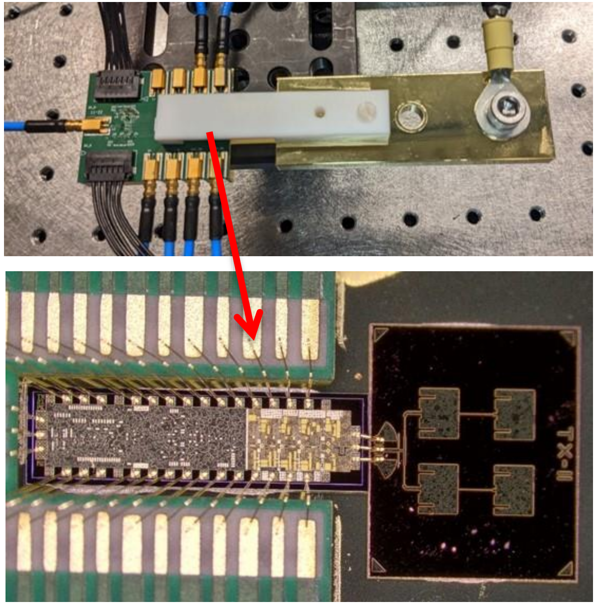
Beam is tilted by 10^0 on E-Plane,
3-dB Beamwidth = +/- 35^0

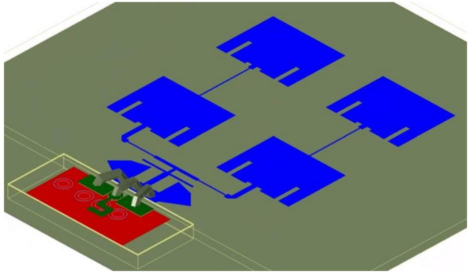
Conversion Gain @ fixed f_{LO} (f_{RF}=201 GHz)

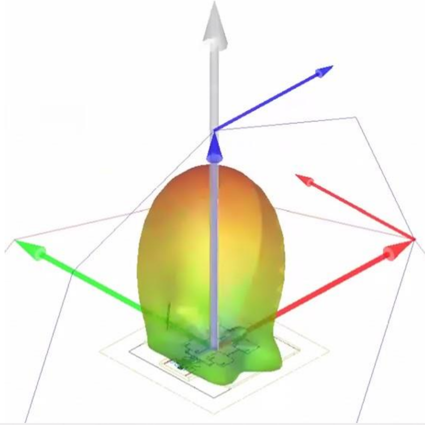


There is no beam tilt on H-Plane,
3-dB Beamwidth = +/- 35^0

200 GHz Transmitter Module



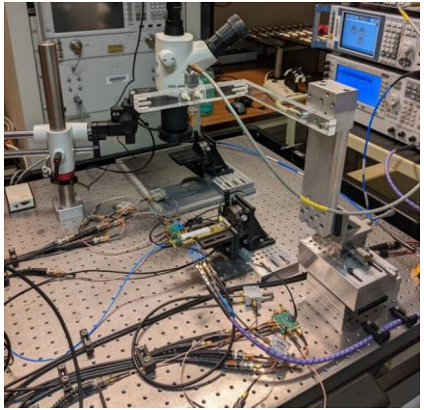


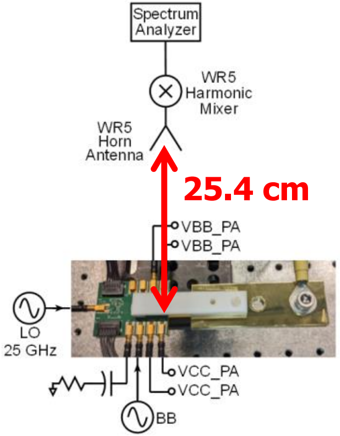


Main Lobe Direction: Theta=1.02453e-05 °, Phi=-180 °

Maximum Gain: 8.088 dBi

Radiation Efficiency: 62.10%

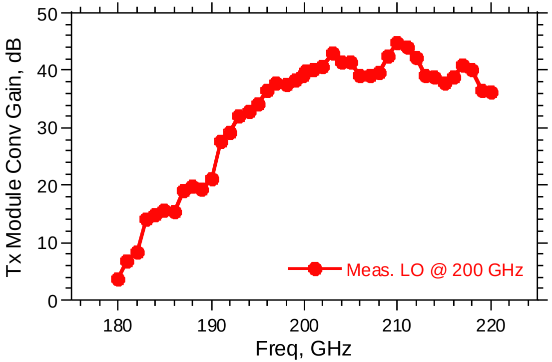




Double side band transmission

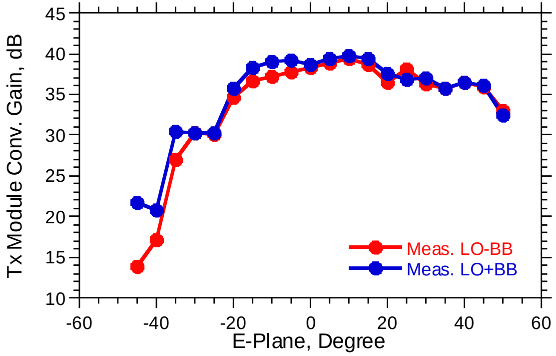
Tx Module CW Testing Results

Conversion Gain @ fixed f_{LO} (P_{BB}=-25 dBm)



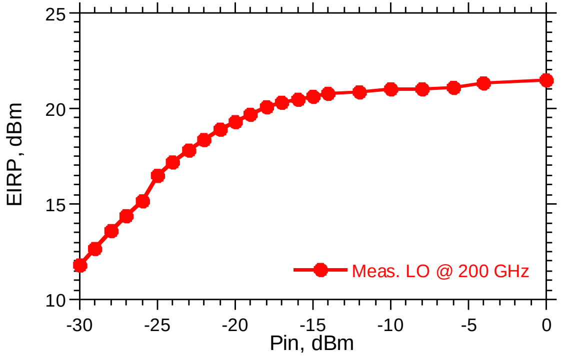
Peak conversion gain = 44.9 dB

Conversion Gain @ fixed f_{LO} =200 GHz(f_{BB}=1 GHz)



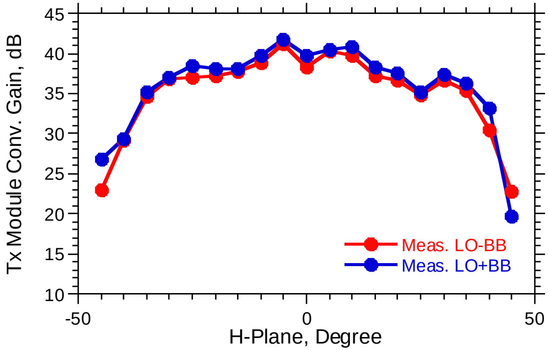
Beam is tilted by 10^0 on E-Plane, 3-dB Beamwidth = +/- 35^0

EIRP vs P_{in} @ fixed f_{LO} (f_{BB}=1 GHz)



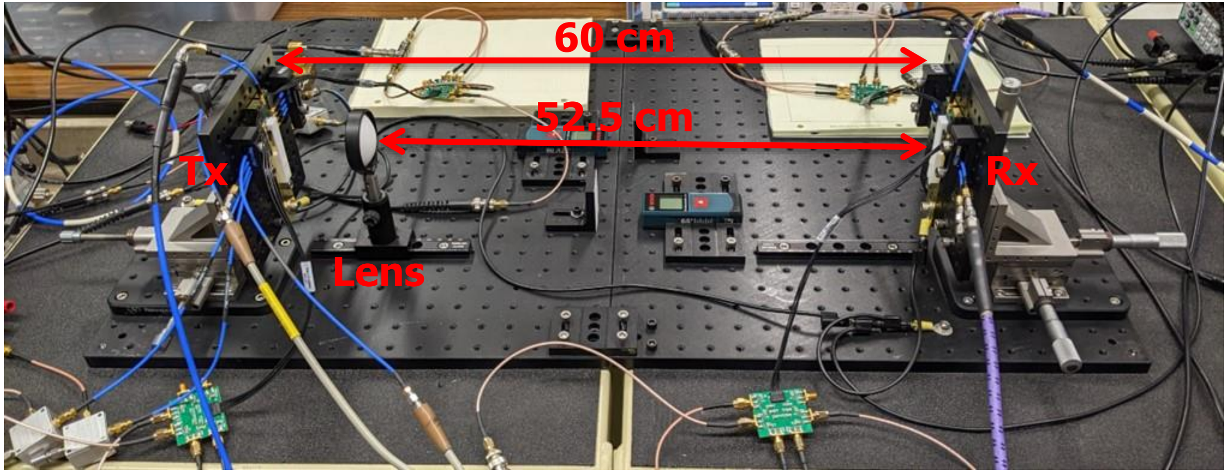
Peak EIRP = 21.5 dBm

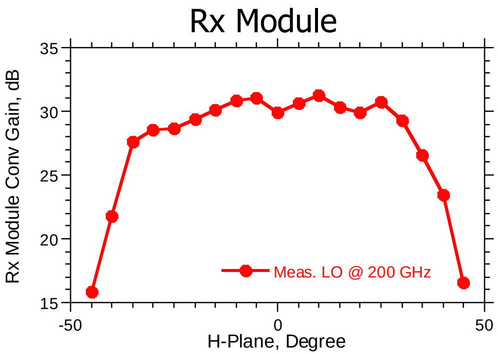
Conversion Gain @ fixed f_{LO} =200 GHz(f_{BB}=1 GHz)

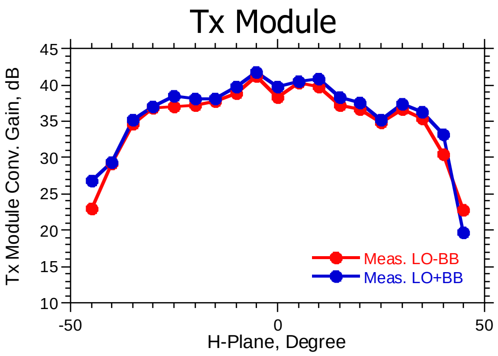


There is no beam tilt on H-Plane, 3-dB Beamwidth = +/- 35^0

Short Range Link Setup







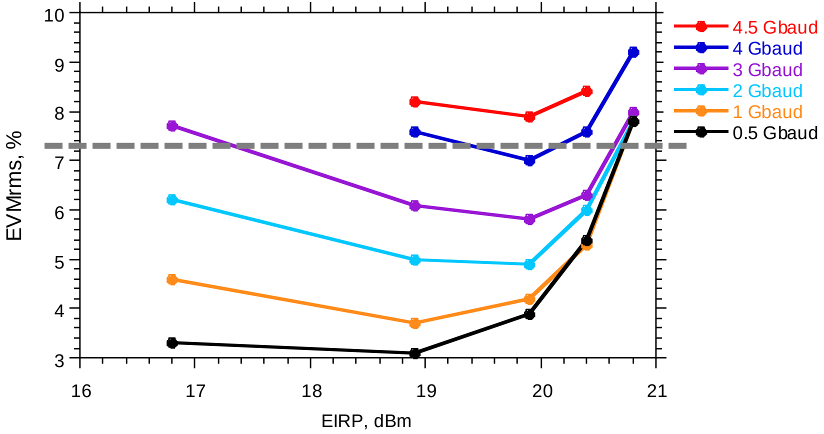
LO @ 200GHz (Tx & Rx modules shares the same synthesizer)

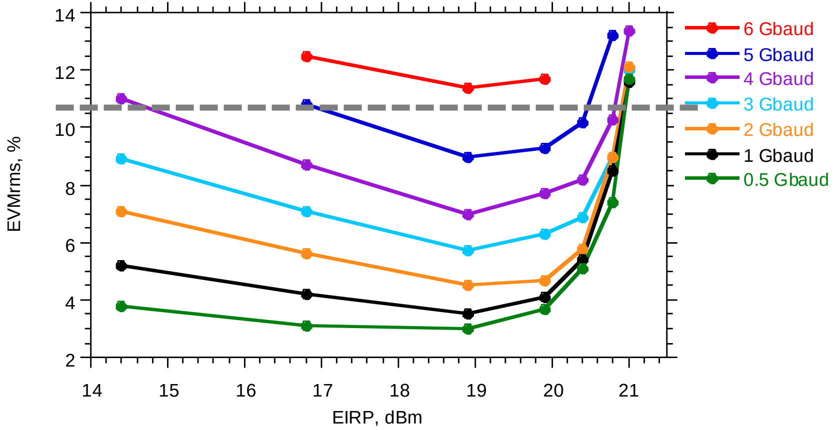
SSB w/ 6 GHz IF (upper side band), 206 GHz Carrier

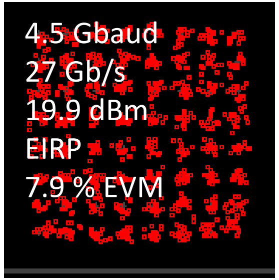
alpha = 0.35, Filter tab # = 80

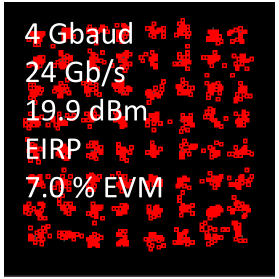
Lens @ Tx: Diameter = 50 mm, Focus = 75 mm, +/-18.7^0

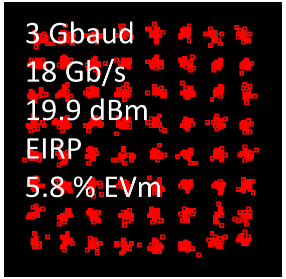
Short Range Link Experiments

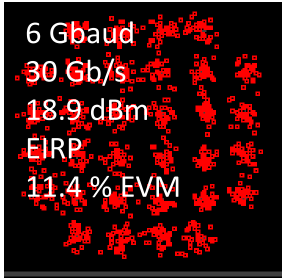


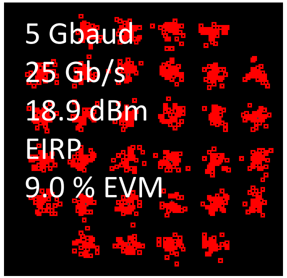


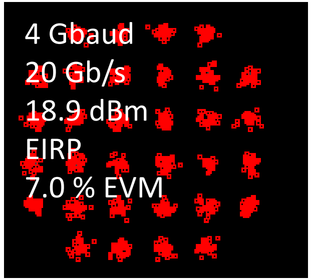








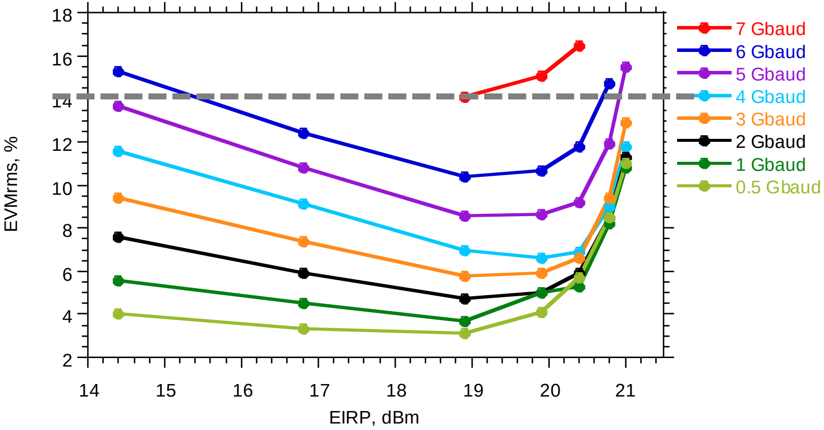


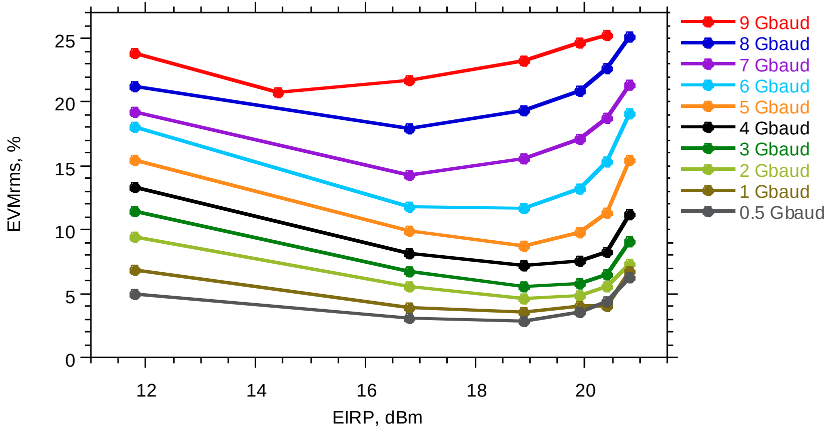


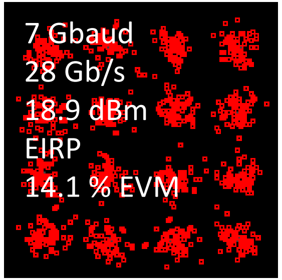
64 QAM: < 7.3 % EVMrms → BER < 1E-3

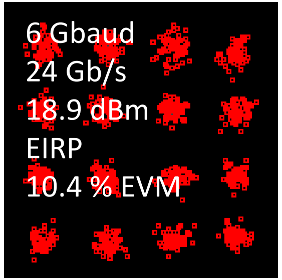
32 QAM: < 10.6 % EVMrms → BER < 1E-3

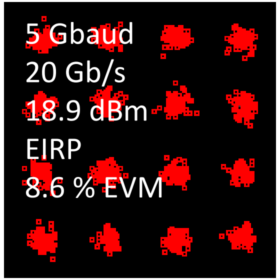
Short Range Link Experiments

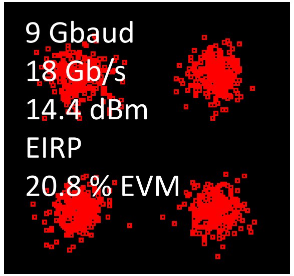


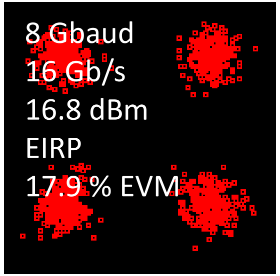


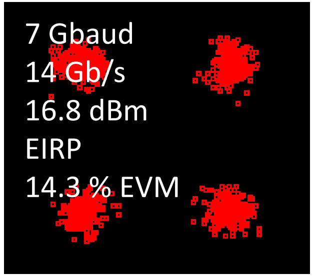








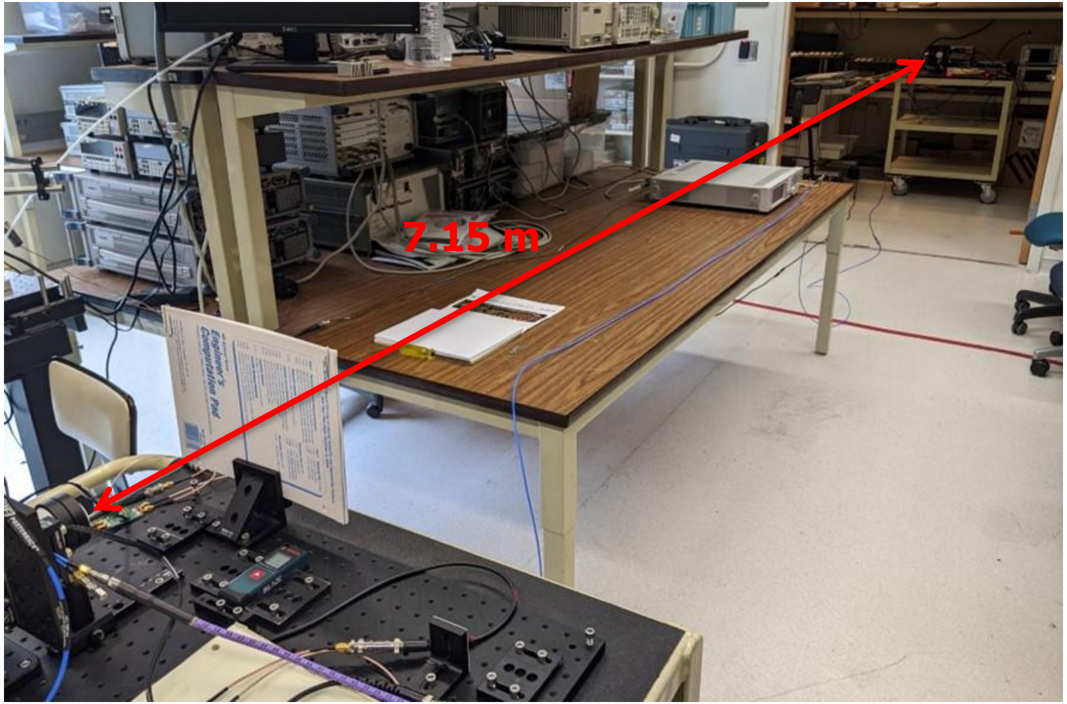




16 QAM: < 14.1 % EVMrms → BER < 1E-3

QPSK: < 31.6 % EVMrms → BER < 1E-3

Long Range Link Setup



LO @ 196GHz (Tx & Rx modules shares the same synthesizer)

SSB w/ 6 GHz IF (upper side band), 202 GHz Carrier

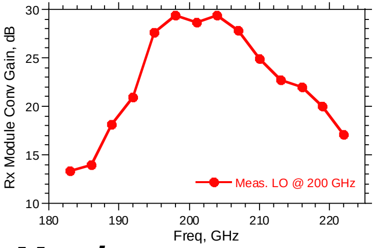
alpha = 0.35, Filter tab # = 80

Paper Attenuator: 10.4 dB

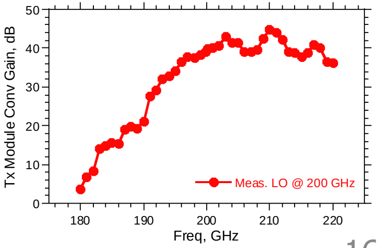
Lens: Diameter = 50 mm, Focus = 75 mm, +/- 18.7^0

Back-to-back lens on Rx-module : Diameter = 50 mm, Focus = 37.5 mm, +/-34^0

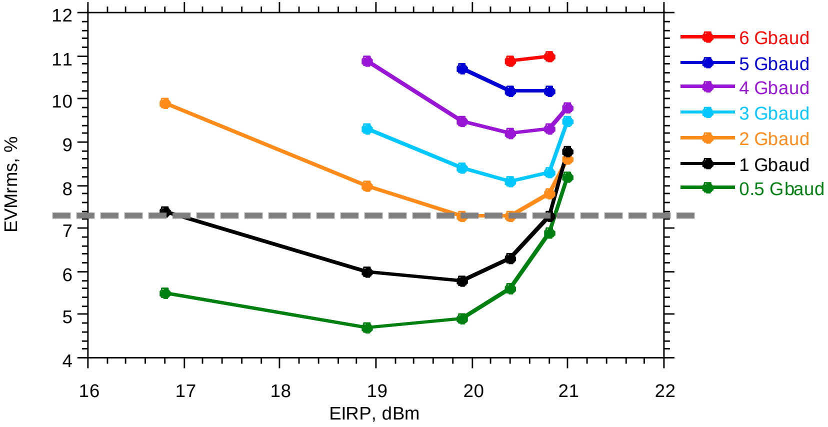
Rx Module

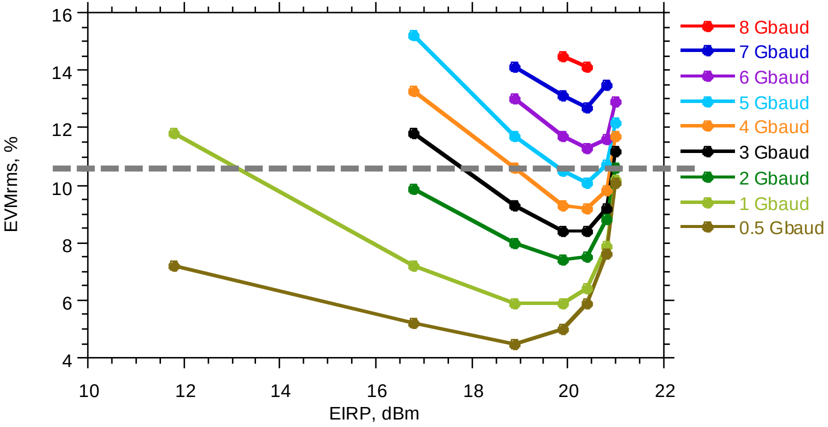


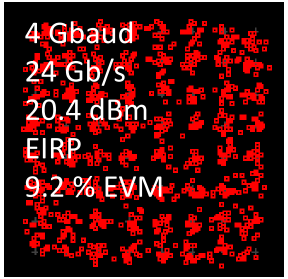
Tx Module

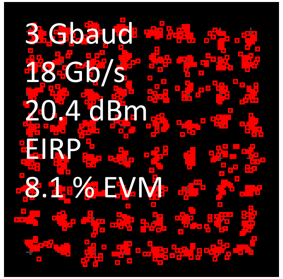


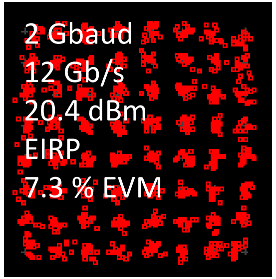
Long Range Link Experiments

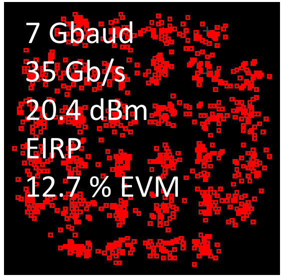


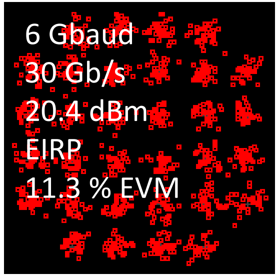


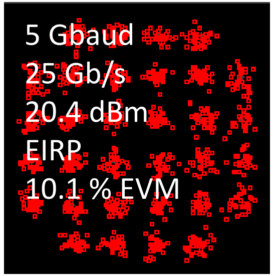








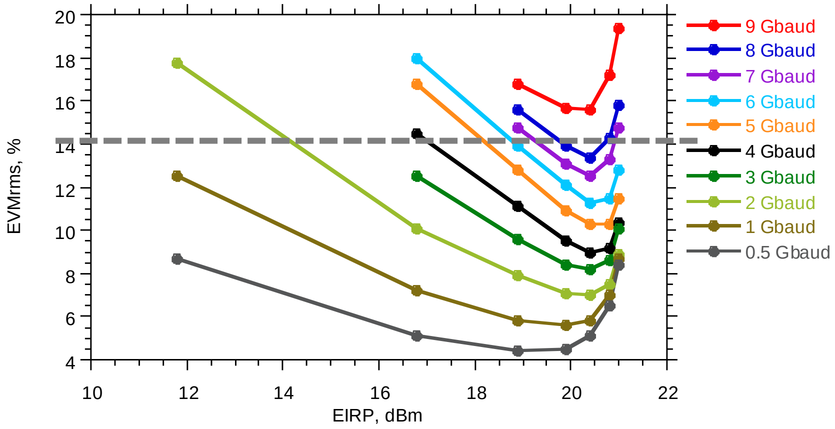


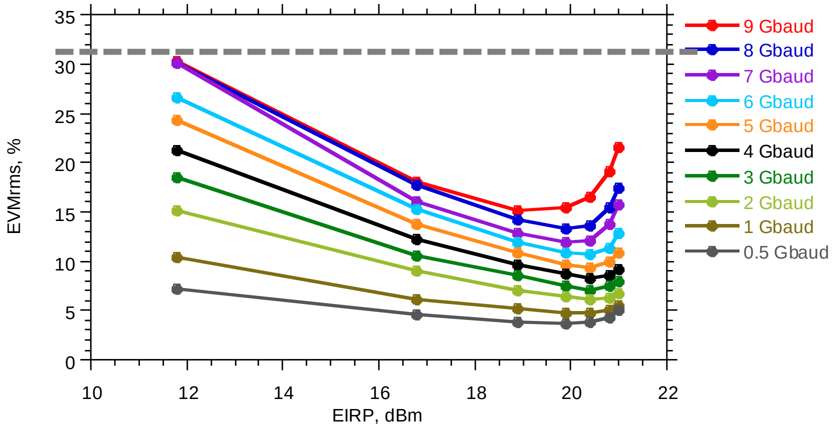


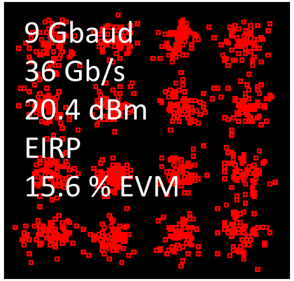
64 QAM: < 7.3 % EVMrms → BER < 1E-3

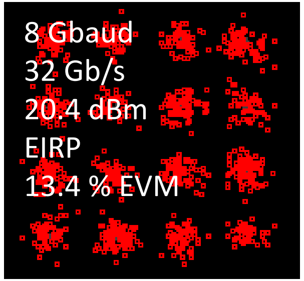
32 QAM: < 10.6 % EVMrms → BER < 1E-3

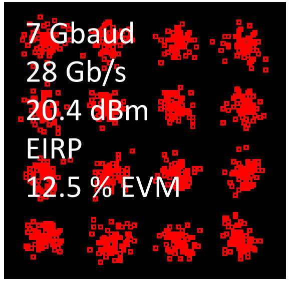
Long Range Link Experiments

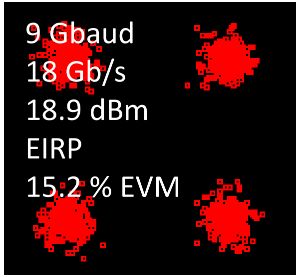


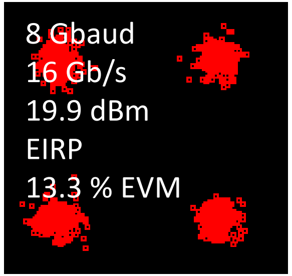


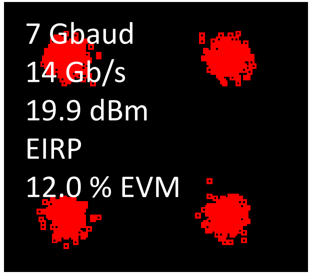










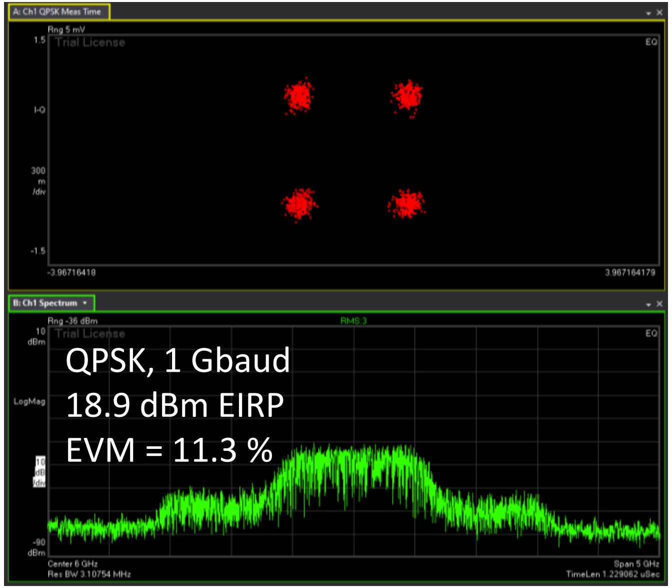


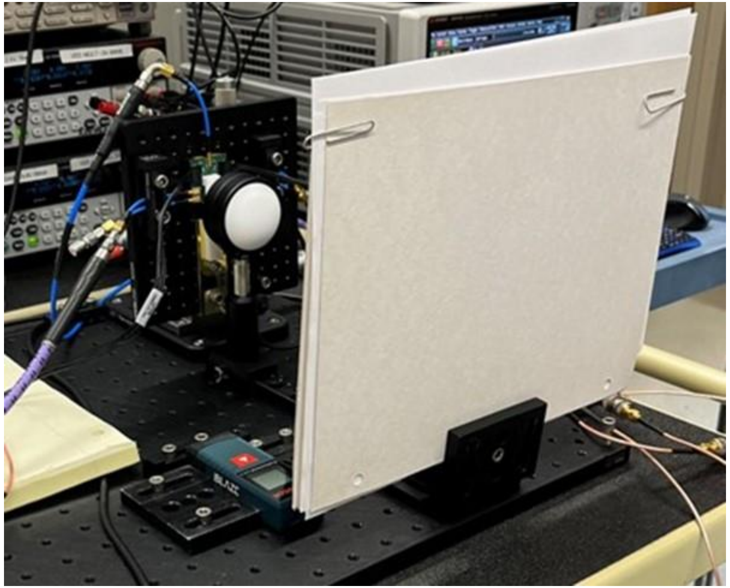
16 QAM: < 14.1 % EVMrms → BER < 1E-3

QPSK: < 31.6 % EVMrms → BER < 1E-3

Live Demo

Longer Range Link Experiments





Receiver is saturated without paper attenuator (10.4 dB attenuation)
Single lens setup: +/-18.7^0, Double lens setup: +/-34^0 (~5.2 dB)
~16 dB more signal power → **50 meters**

Acknowledgement

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THANK YOU

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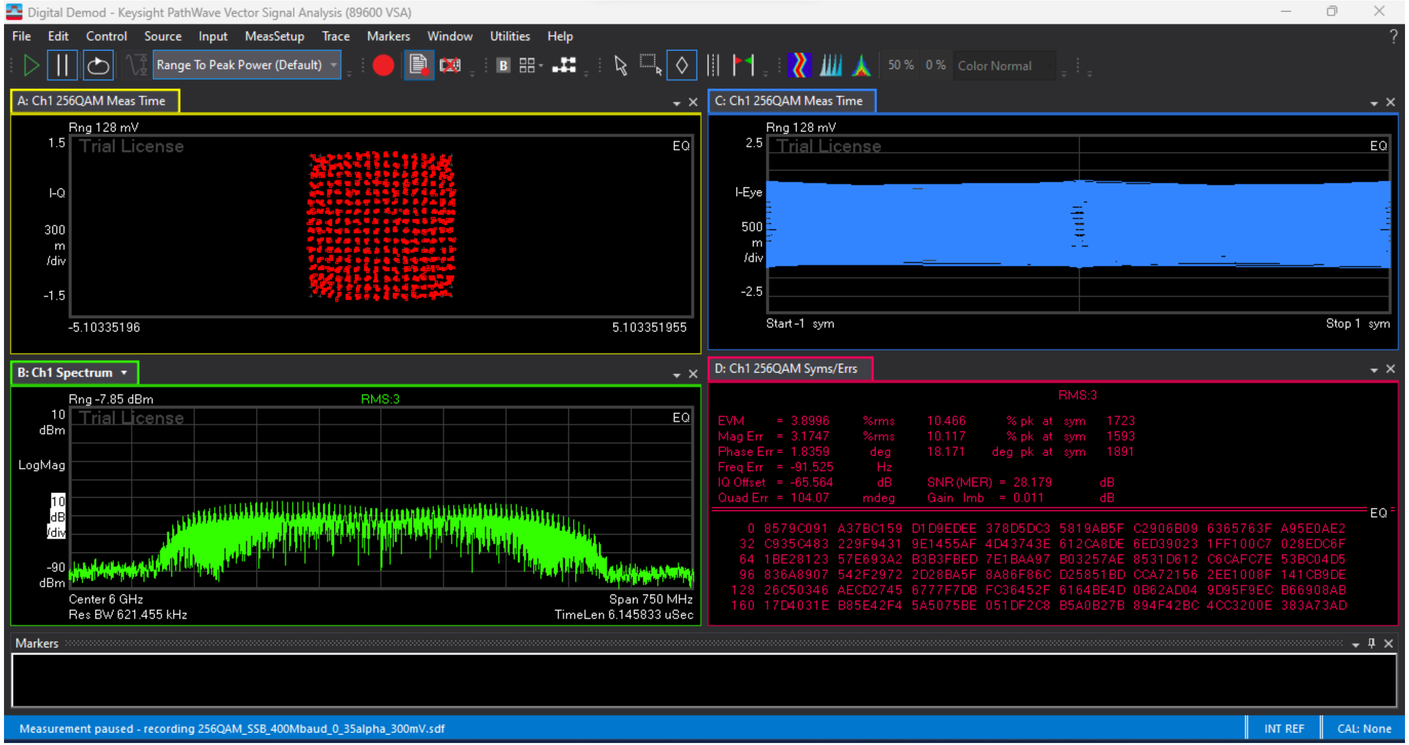
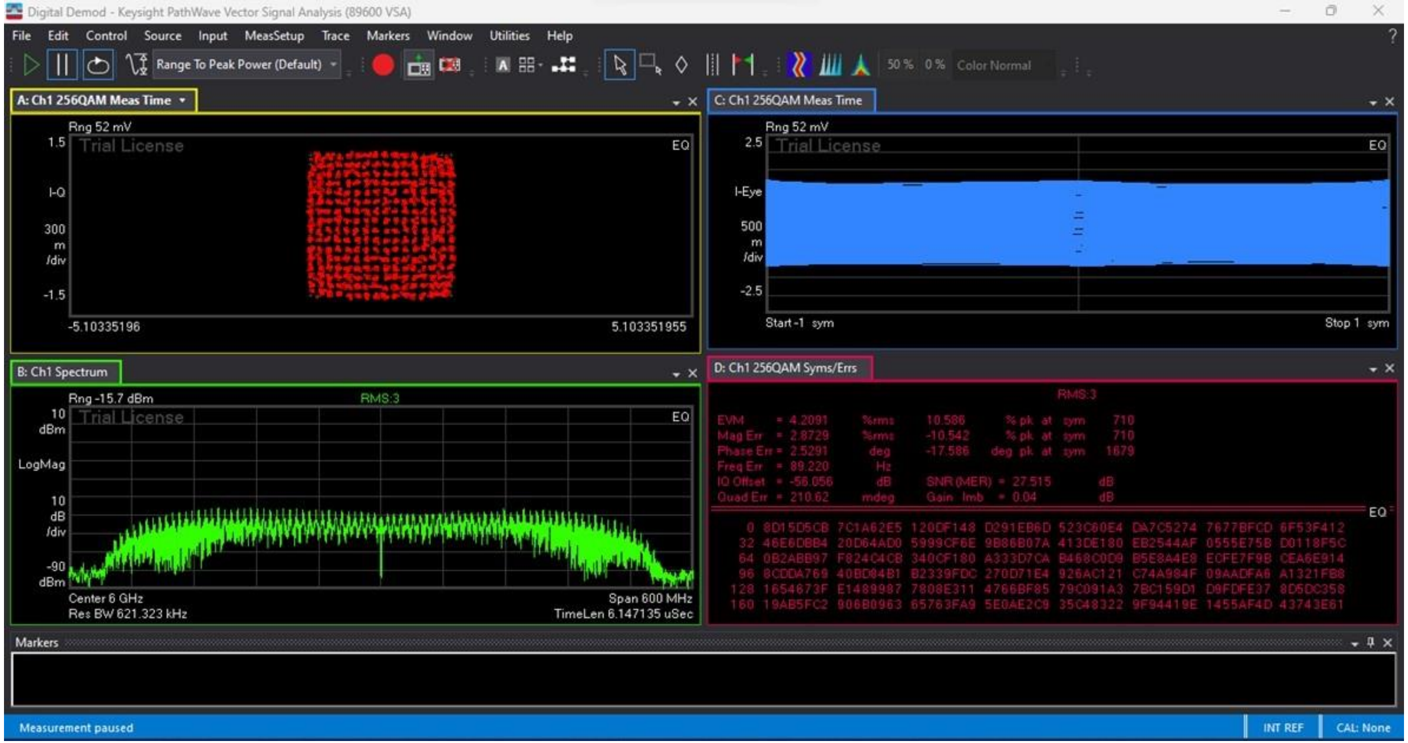
(backup files follow)

Short Range Link Experiments



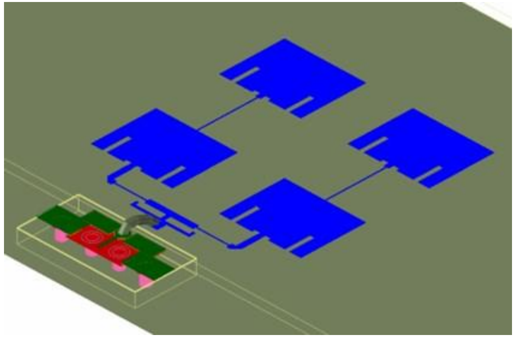
256 QAM, 400 Mbaud @ 18.9 dBm EIRP

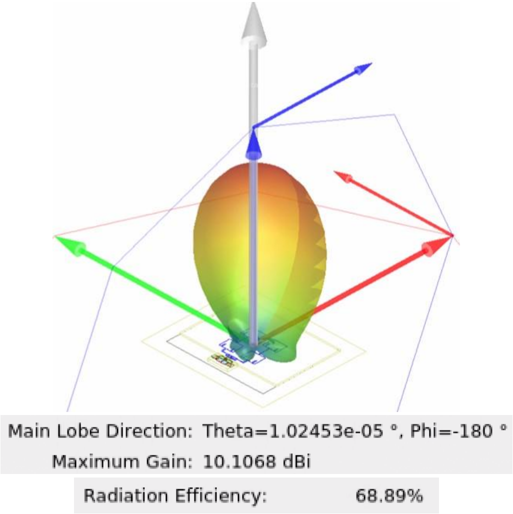
Long Range Link Experiments

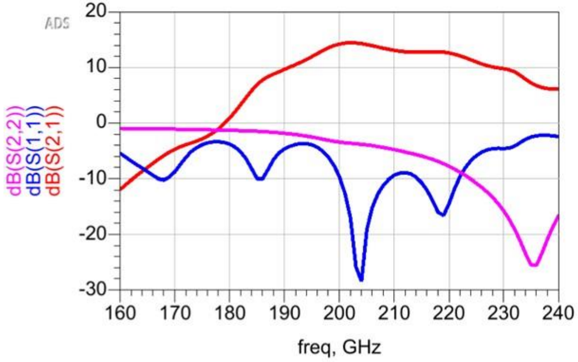


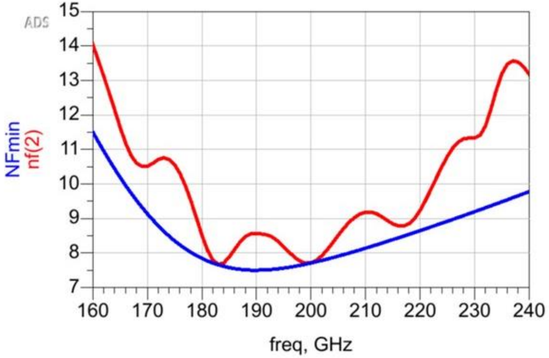
256 QAM, 400 Mbaud @ 18.9 dBm EIRP

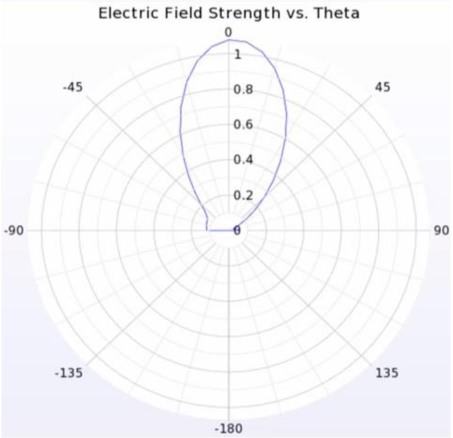
Antenna-Receiver Transition

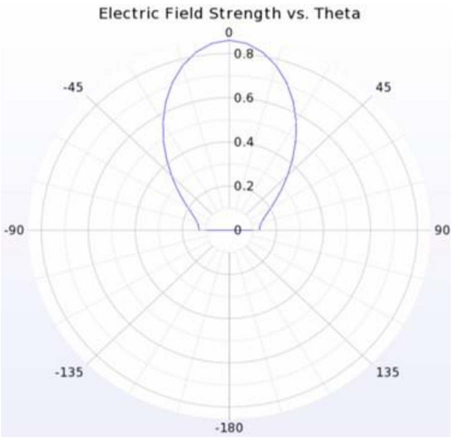




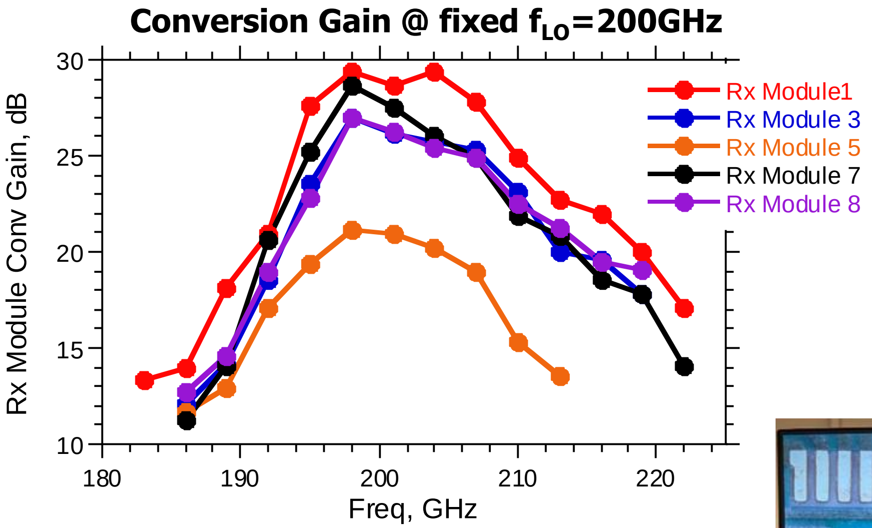


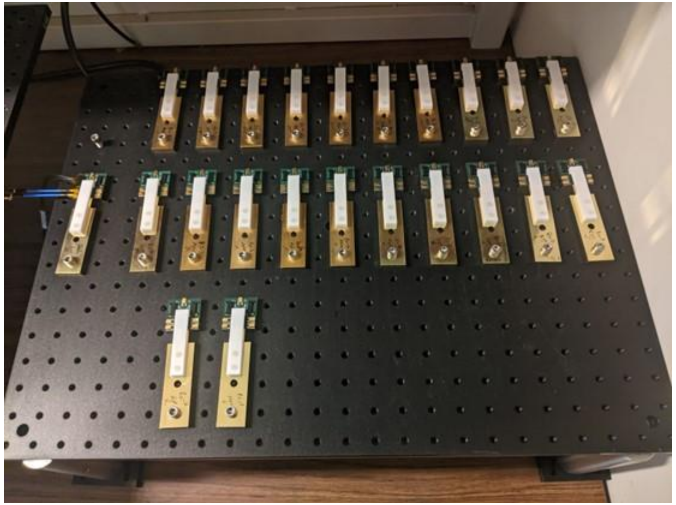


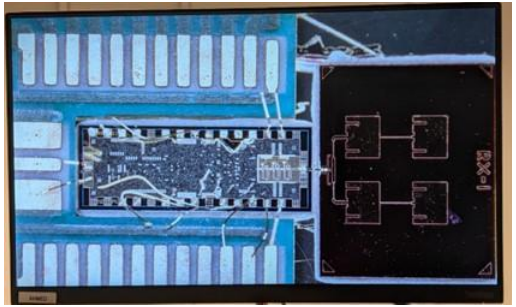


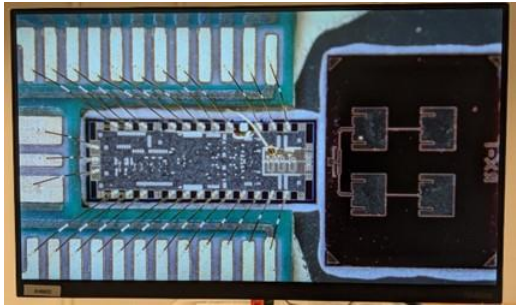


Rx Module Testing Results

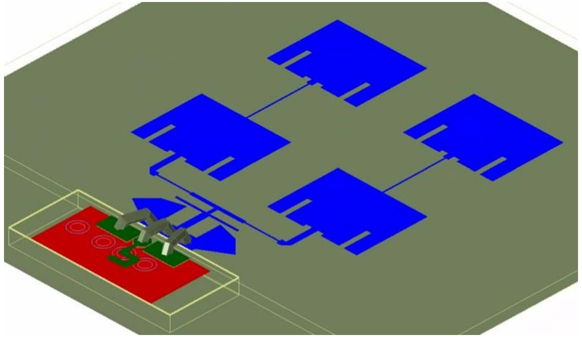


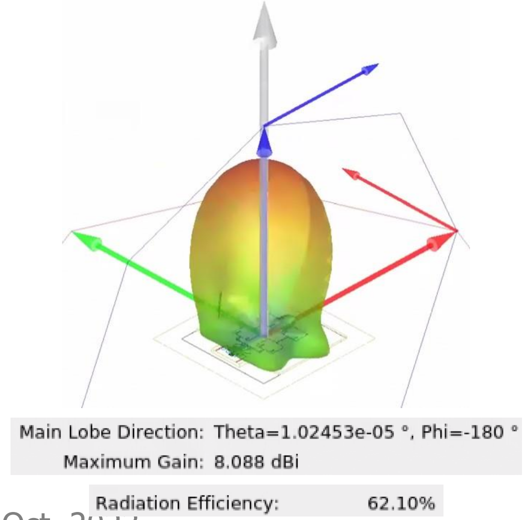


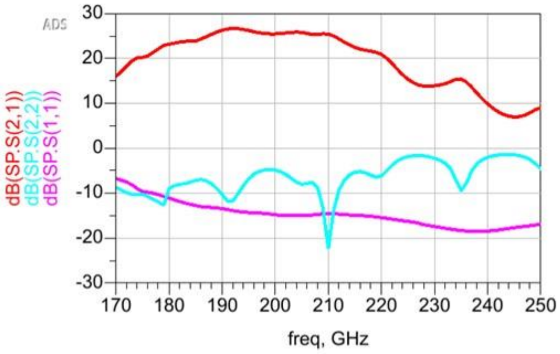


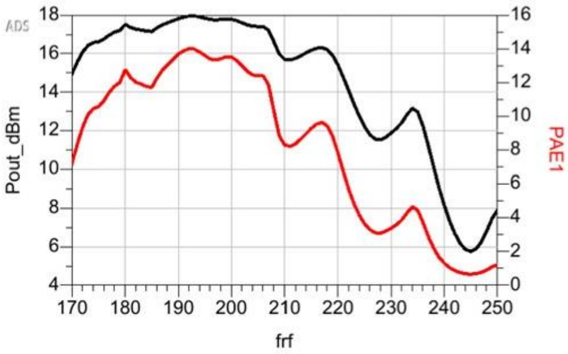


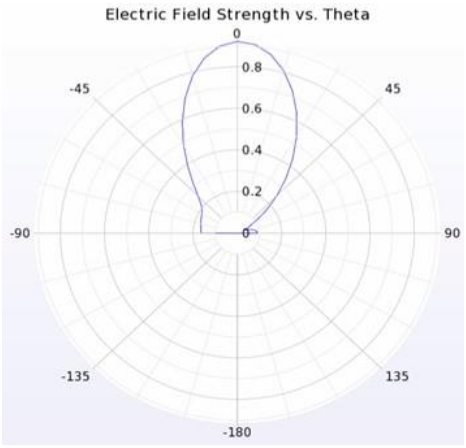
Antenna-Transmitter Transition

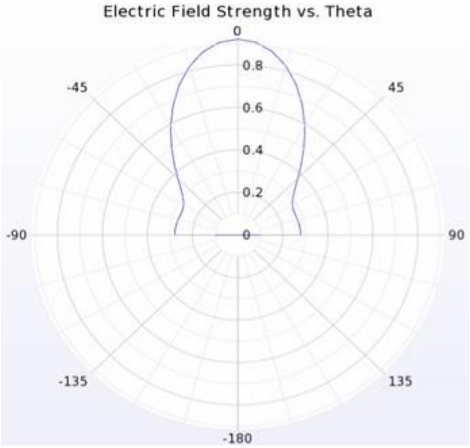




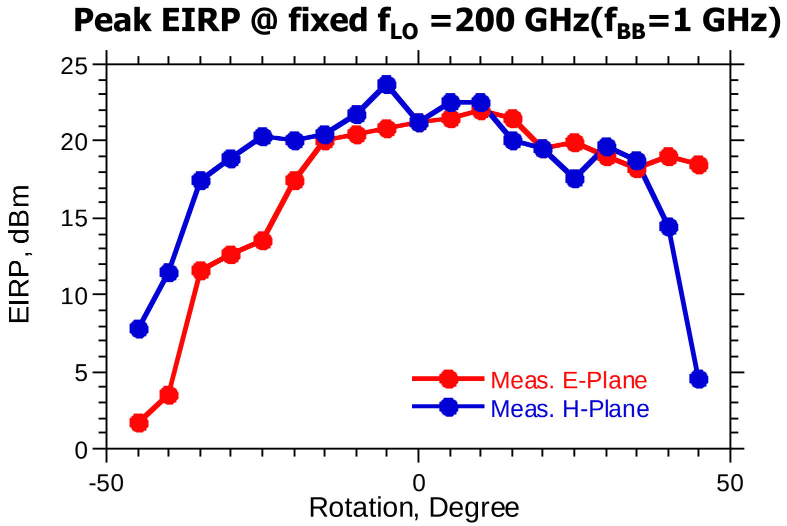


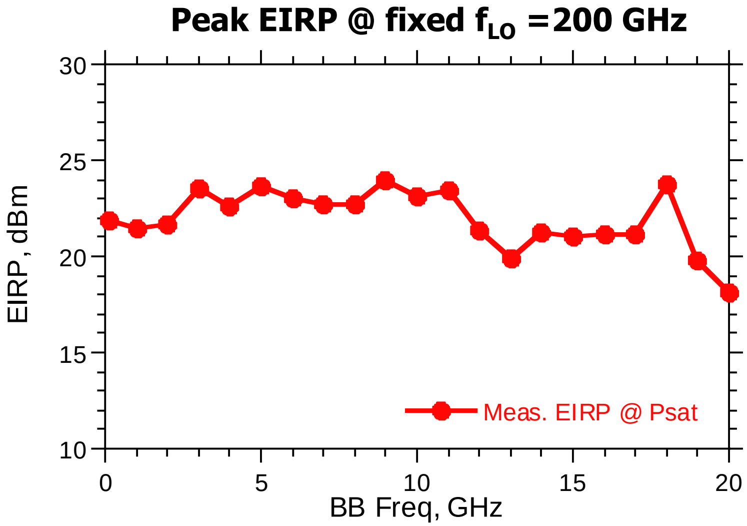






Tx Module Testing Results





Beam is tilted by 10^0 on E-Plane,
There is no beam tilt on H-Plane.

Flat peak EIRP response.

Tx Module Testing Results