A Packaged 135GHz 22nm FD-SOI Transmitter on an LTCC Carrier

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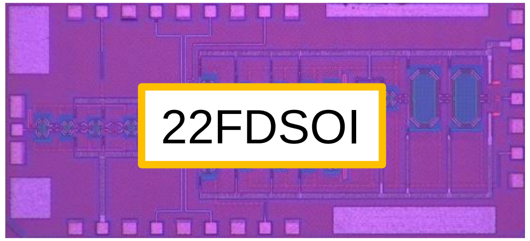
Outline

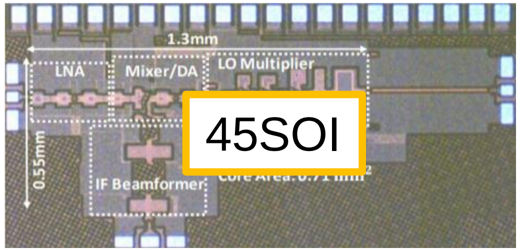
- Motivation
- Ceramic interposer design/ transition loss
- On package Antenna design
- Integrated Transmitter module on an LTCC carrier
- Link measurement
- Conclusion

Packaging technologies at sub-THz frequencies

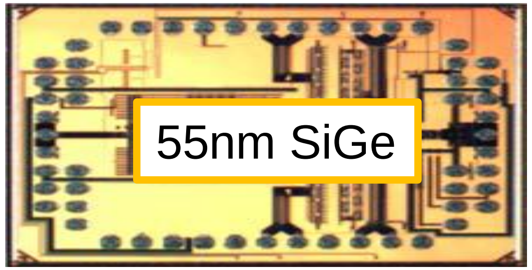
IC technologies



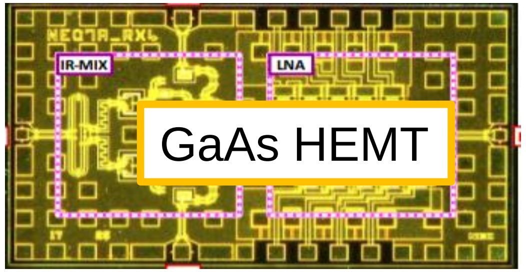
[Farid et. al.]



[Siwei et. al.]

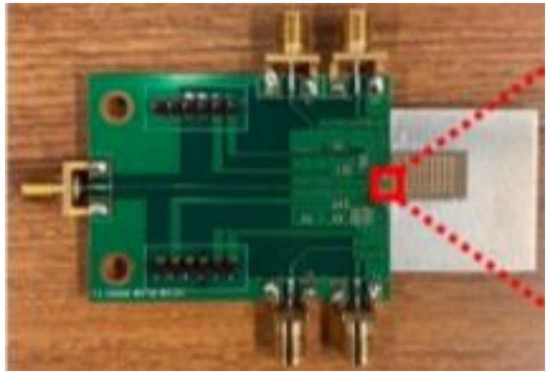


[Sawaby et. al.]



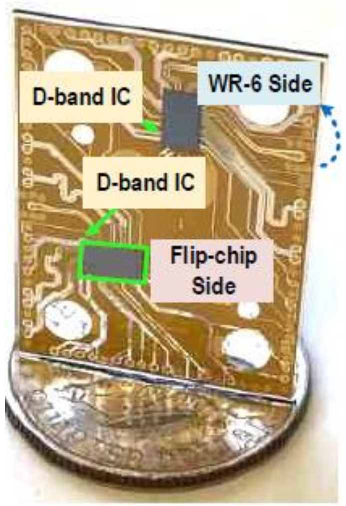
[Ito et. al.]

Packaging technologies



[Simsek et. al.]

- High performance laminate
- IL= 2.5dB @140GHz

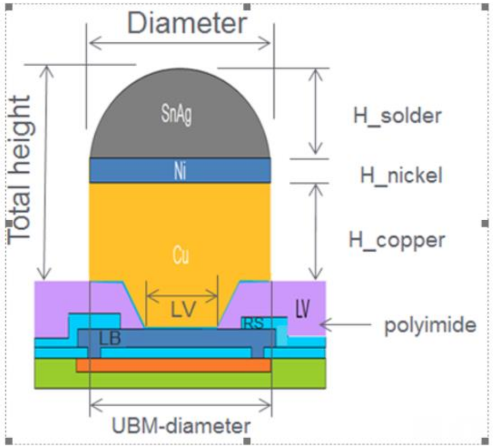


[Singh et. al.]

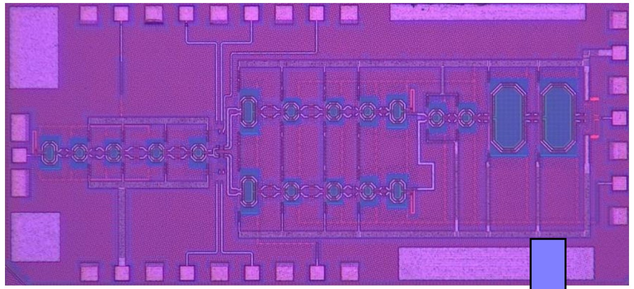
- Radio on Glass
- IL= 1dB @140GHz

Transmitter IC design

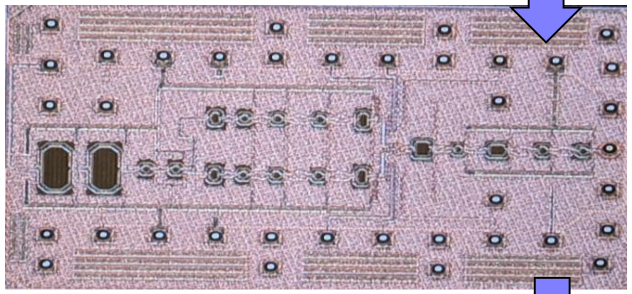
- Direct conversation transmitter using GF 22FDSOI
- Tx chip is flipchip bonded to LTCC interposer using 50μm diameter copper pillar



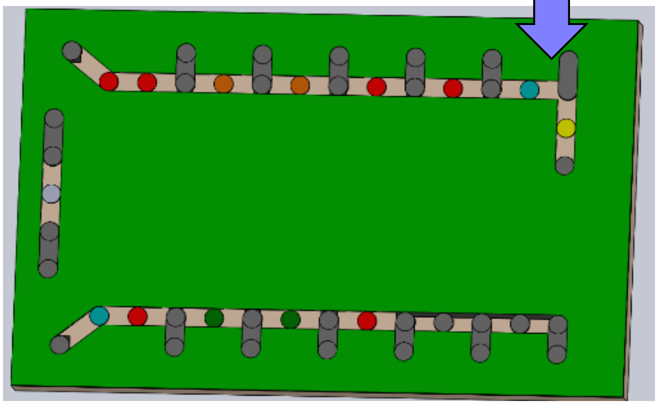
- Copper pillars are equally spaced at 175μm distance



22FDX Chip micrograph



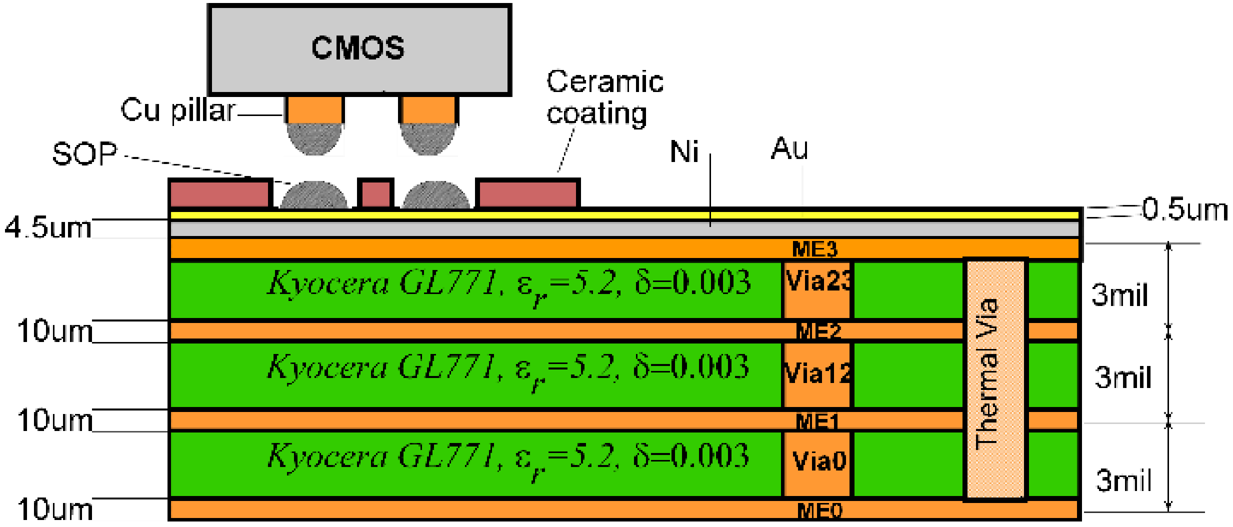
22FDX Chip with Copper pilla



PCB with copper pads

Ceramic Interposer design

- 3 dielectric layers of Kyocera GL771
- 4 metal layers (ME3 for I/Q routing and LO signal)

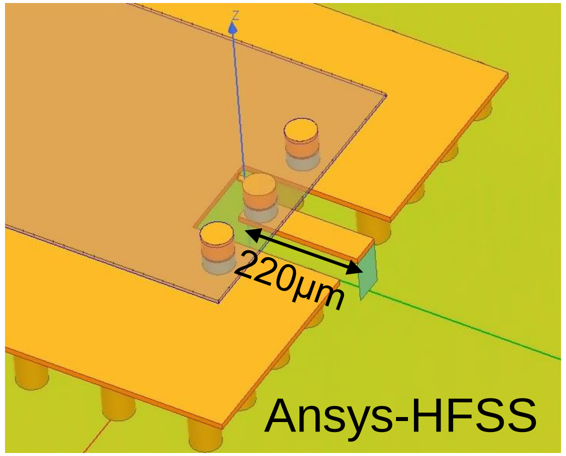


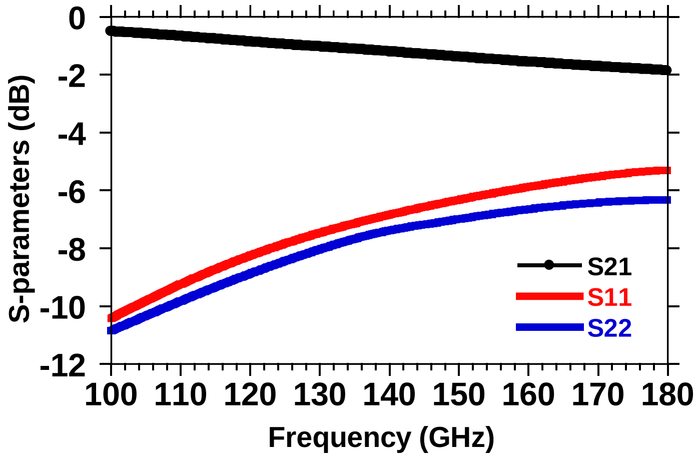
How to secure landing copper pillars precisely?

- Ceramic coat with 75µm opening
- SOP on the ceramic carrier

CMOS/Interposer transition

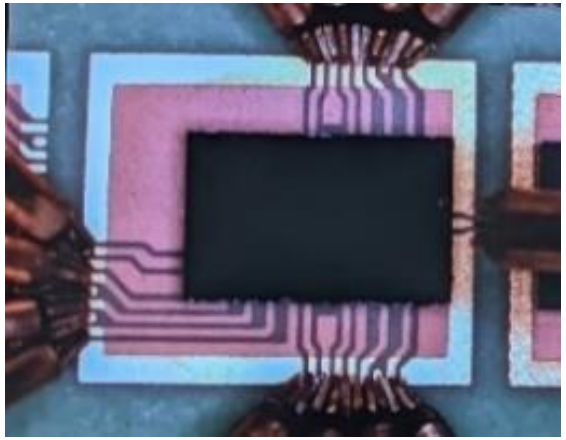
- Simulated transition loss=1.15dB at 135GHz
- Transition loss includes
  - Copper pillar
  - 220μm CPW section

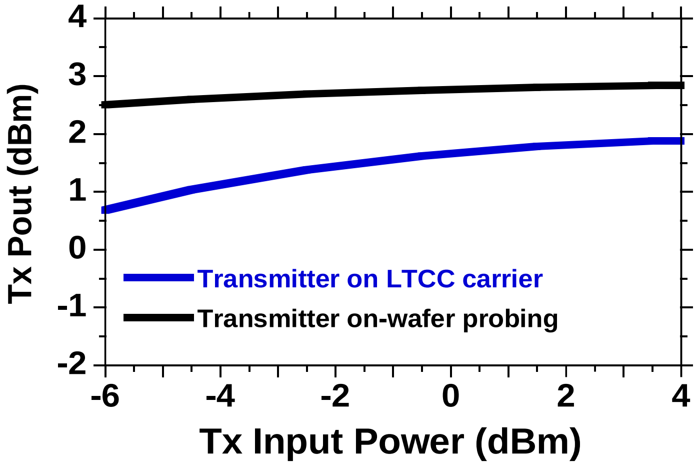




Simulated transition loss

- Measured transition loss~=0.85dB





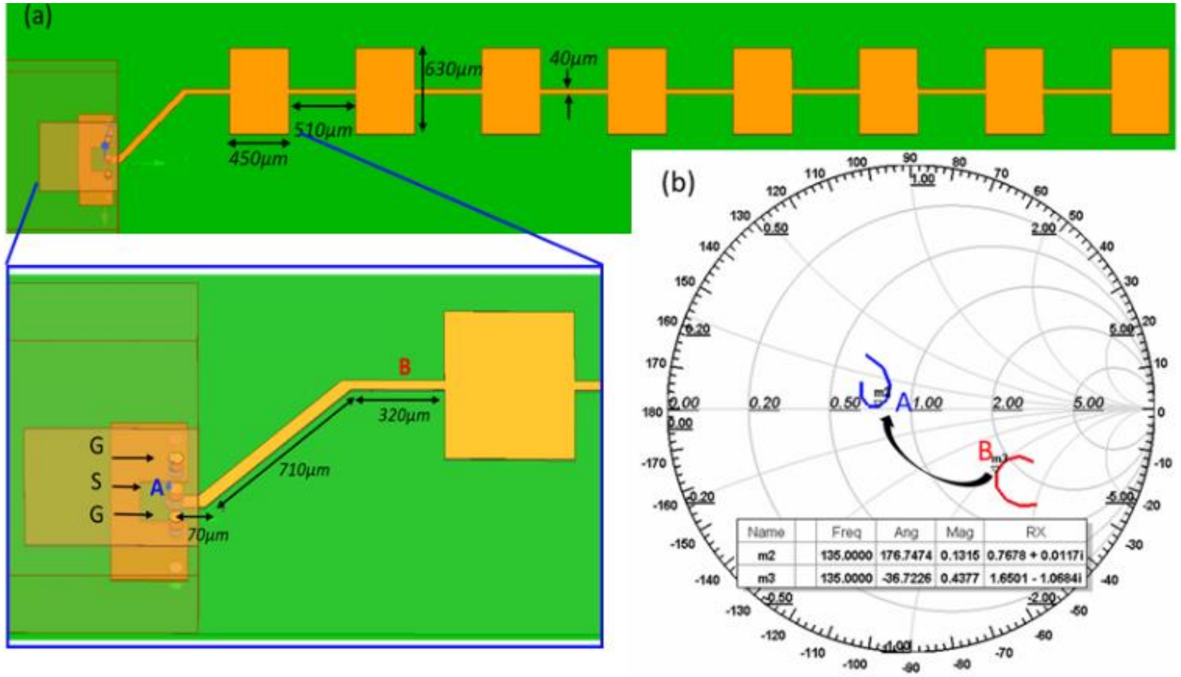
measured transition loss

Series Fed Patch Antenna on LTCC carrier

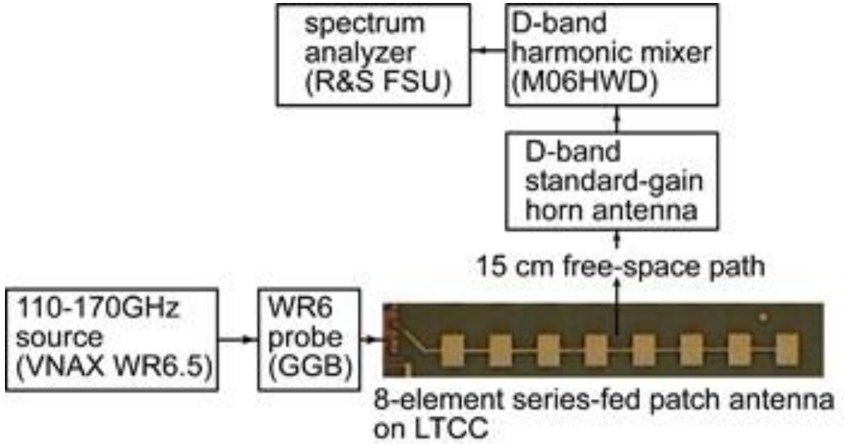
- 8-elements series fed patch antenna

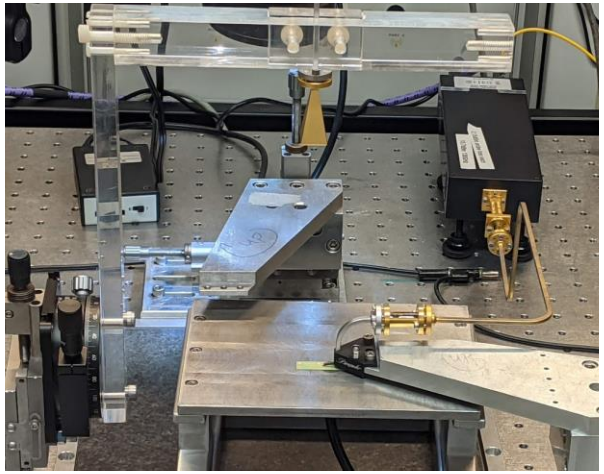
- $\frac{\lambda}{4}$ transmission line matches antenna to the transmitter 50Ω impedance

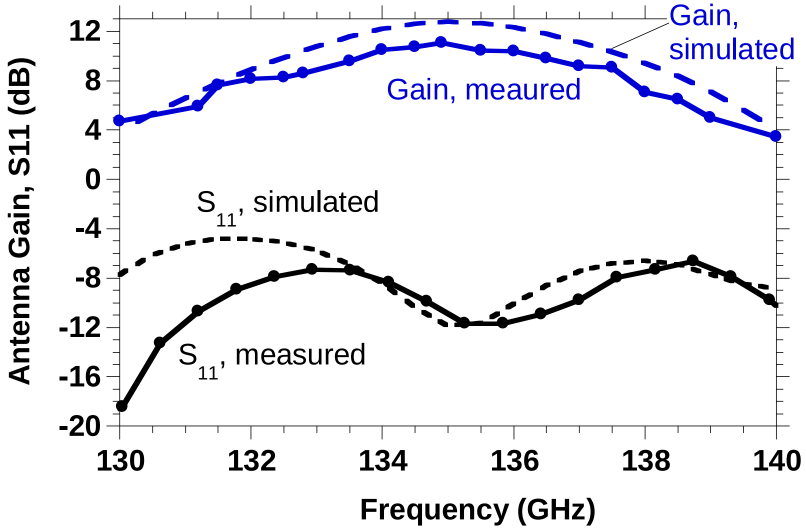
- Copper pillar transition is part of the impedance matching network

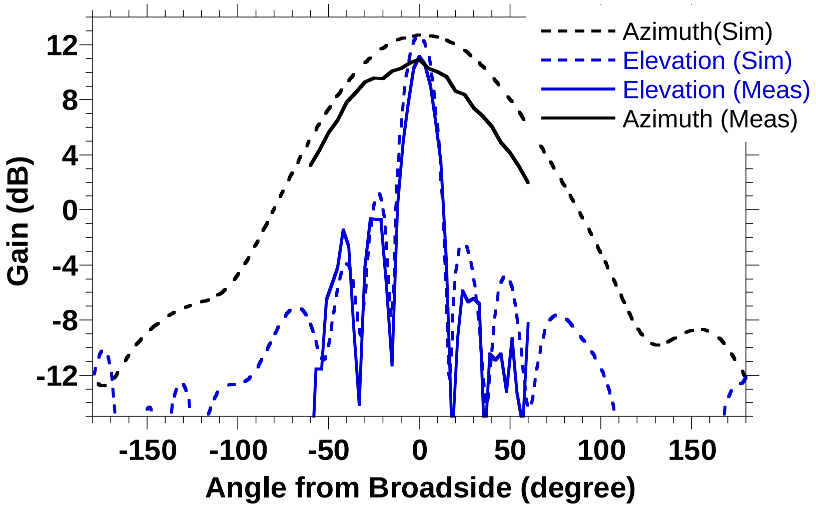


Measured Antenna performance





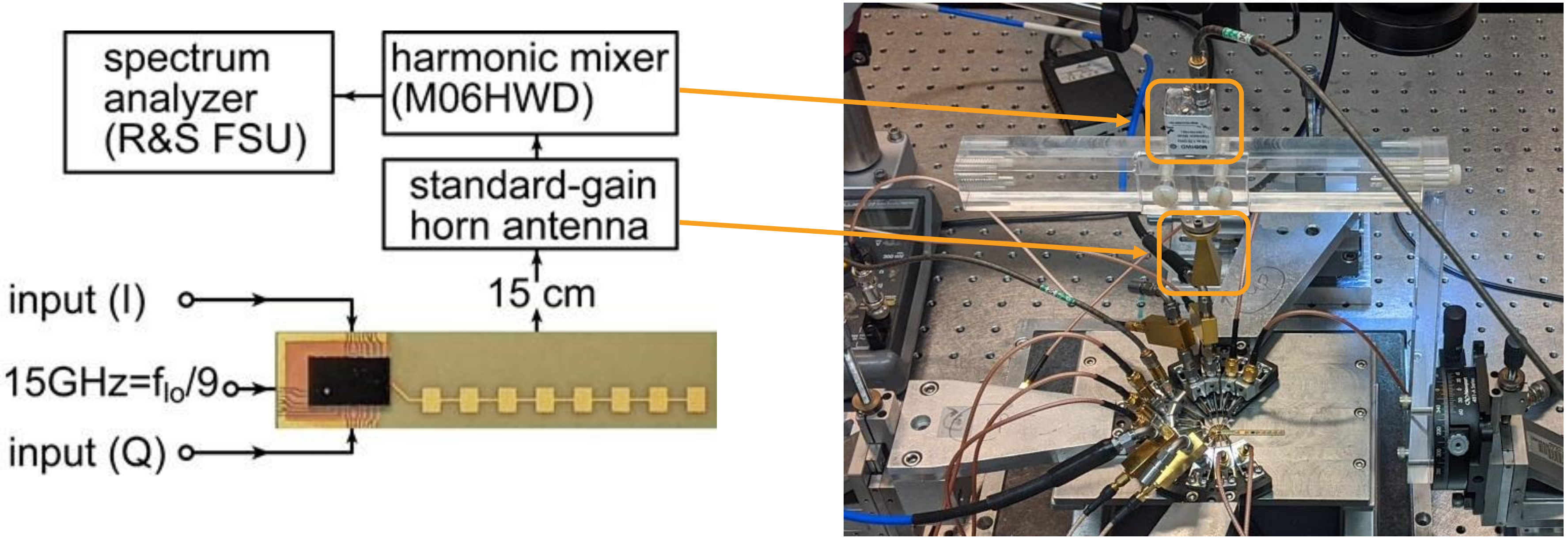




- 11dB gain, 5.5GHz bandwidth

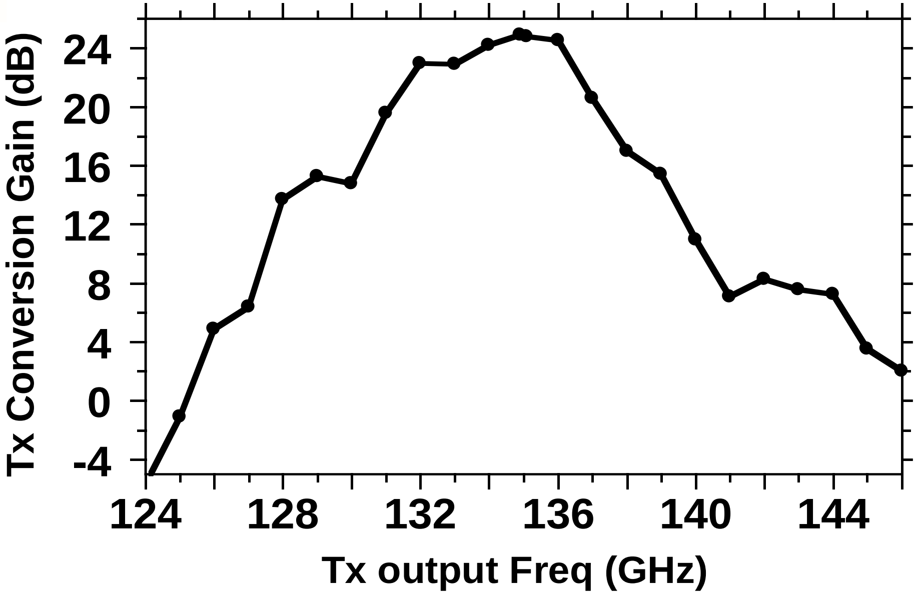
- 12º E-plane 3-dB beam width
- Sidelobes suppressed by 12-dB

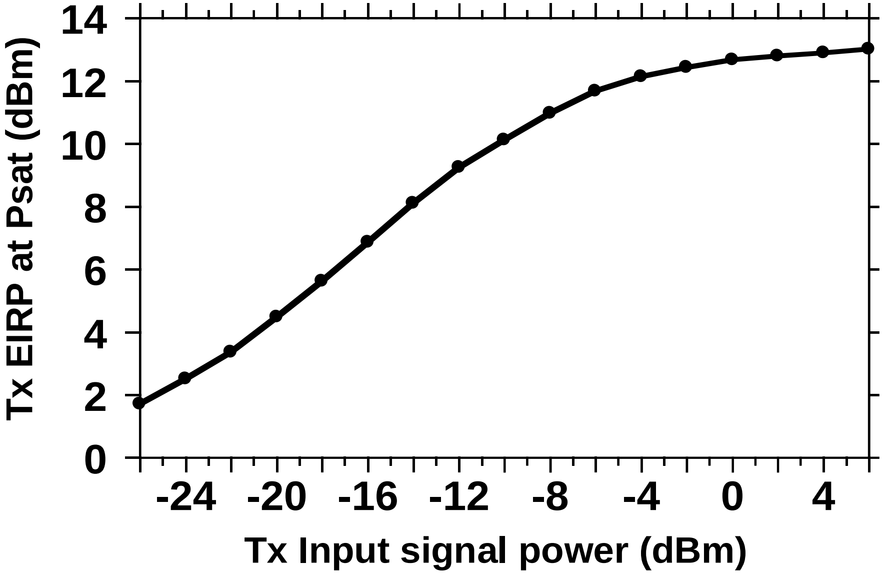
Integrated Transmitter module testing



- Tx Input signal swept from 0.1G to 10GHz (either I or Q)
- LO signal fixed at 135GHz
- Tx upper sideband captured using Harmonic mixer and spectrum analyzer

Integrated Transmitter module

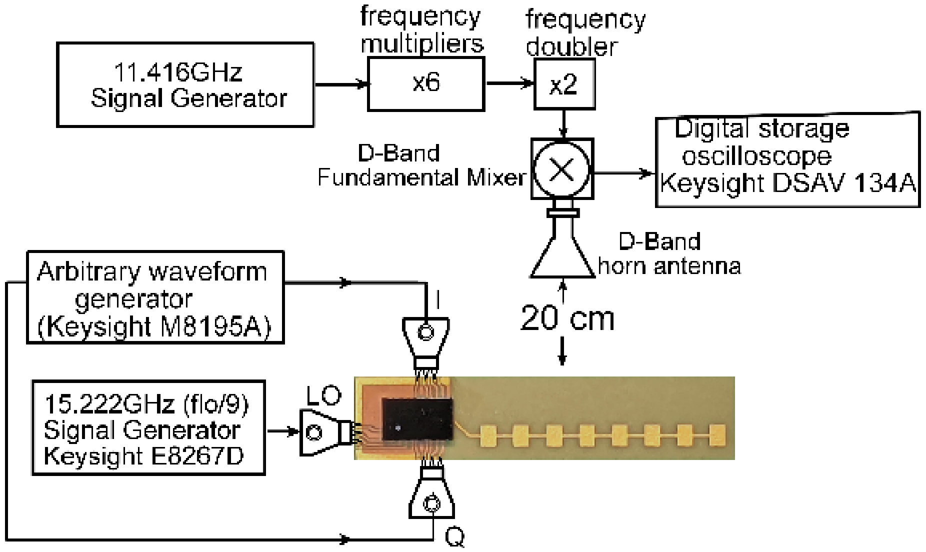


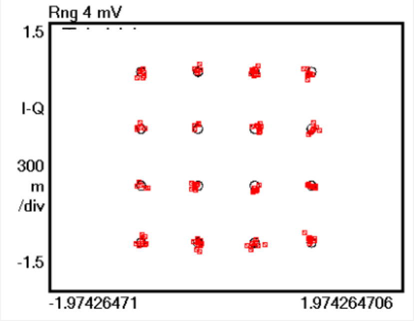
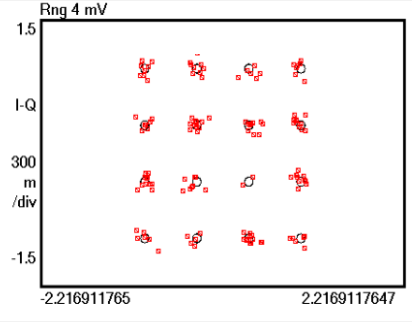


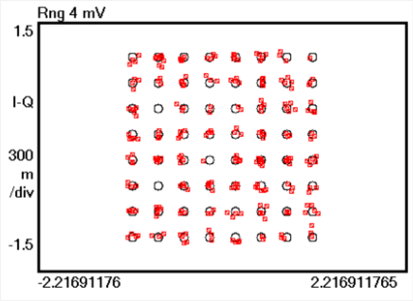
- Module has 6GHz 3-dB modulation BW
- Conversion gain=24dB
- EIRP at Psat =12.8dB / EIRP at P1dB=8.4dB

Module Link Measurement

- Transmitter (I,Q) data driven by AWG at 2GHz IF
- EVM measurements with equalization at DSO.



16QAM (6dB-BO)	
1GBaud	4GBaud
	
5.44% RMS	9.2% RMS

64QAM (8dB-BO)	
1GBaud	2GBaud
	
5.6% RMS	7.4% RMS

Comparison with state of the art

	Sawaby [SSCL 2018]	Singh [RFIC 2020]	Simsek [RWS2020]	**This Work**
Package	RO4350	Radio on Glass	Astra MT77	LTCC GL771
IC Tech	55nm SiGe HBT	0.13µm SiGe-BICMOS	45nm CMOS SOI	22nm FDSOI
Antenna Integration	No	No	Yes	Yes
Frequency (GHz)	110-150	115-155 135-170	142-147	131-137
EIRP at Psat	-	-	14dBm/ channel	13dBm
Tx-Psat	-0.5dBm	13dBm	2dBm	1.95dBm
Tx Pdc (mW)	220	1350 2100	-	210
Package Loss	3dB	1dB	2.5dB	0.85~1.1dB
Supported Modulation	QPSK	256QAM	BPSK	64QAM

Conclusion

- High performance package with loss transition loss <1dB at 135GHz
- Transmitter module has 6GHz 3-dB BW limited by series fed patch antenna BW
- EIRP at psat=13dBm (limited by the CMOS TX output power of 2dBm)

Acknowledge

- Kyocera Japan for LTCC carrier fabrication
- Kyocera San Diego for module assembly
- GF for free access to 22FDX technology and free access to GF advanced copper pillars

Questions?