RMO1C-1

Indoor and Outdoor Millimeter Wave Systems and RF/BB SoCs

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Outline

- **Tokyo Tech mm-wave project**
- **60GHz indoor mm-wave system**
- **38GHz outdoor mm-wave system**
- **Summary**

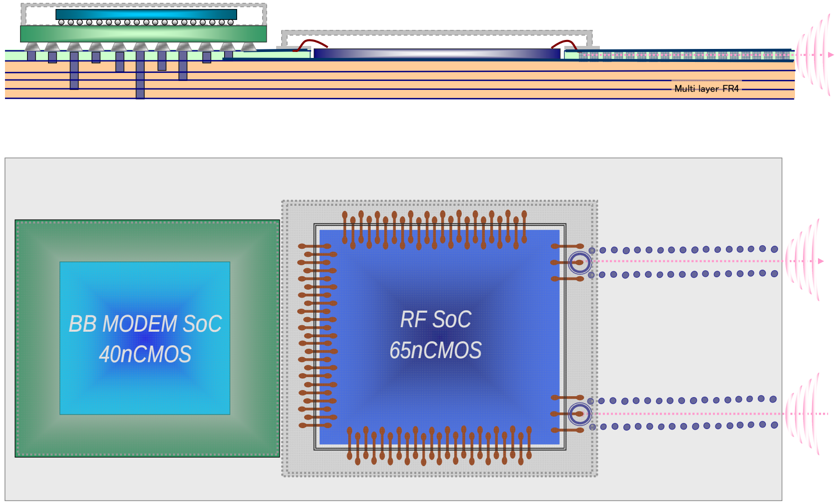
Mm-wave project

Developing mm-wave systems and SoCs to address the future wireless big bang.

FY2007-FY2011

1. 60GHz, Indoor
3-10 Gbps
-- 10m

2. 38GHz, Outdoor
0.6-1.0Gbps
1km – 4km



Project members and roles

Three labs. in Tokyo Tech. and five companies

Outdoor entrance systems (JRC)

Indoor wireless access system (Sony)

Mm-wave CMOS Rx/Tx chip and base band ADC/DAC. (Matsuzawa & Okada lab.)

GaN HPA (NEC)

Phase noise reduction by DSP (Suzuki lab. Tokyo Tech ）

Packaging, MMIC, RF-module (AMSYS)

High Gain Arrays (Ando Hirokawa lab.)

Antennas on PCB / Chip (Ando Hirokawa lab)

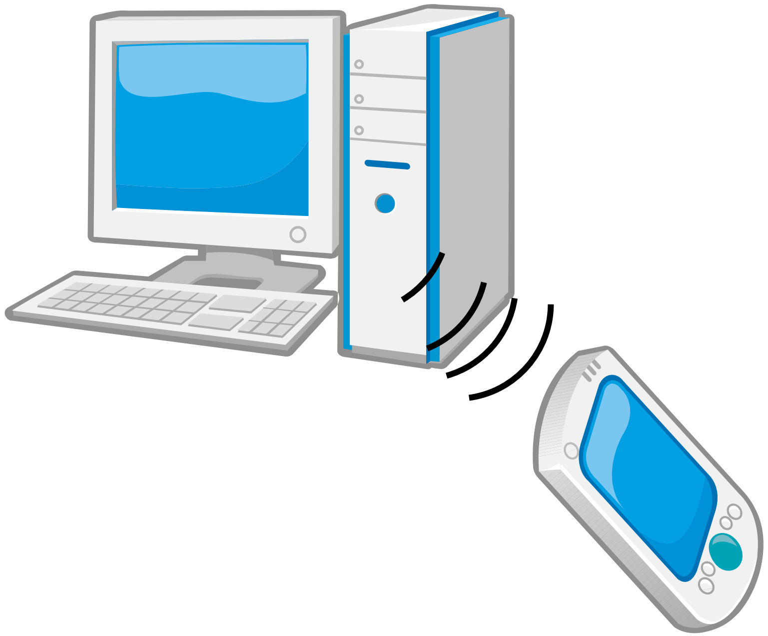
Propagation Test （Willcom）

The leader is Prof. M. Ando

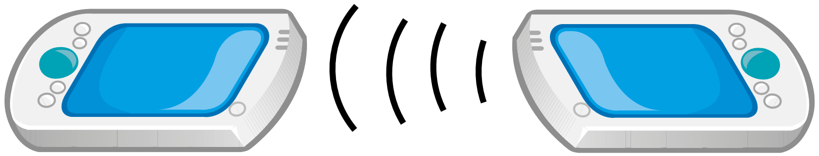
60GHz indoor mm-wave system

Indoor system: Usage model

Giga bit ultra-fast data transfer systems
Low power and small size are important



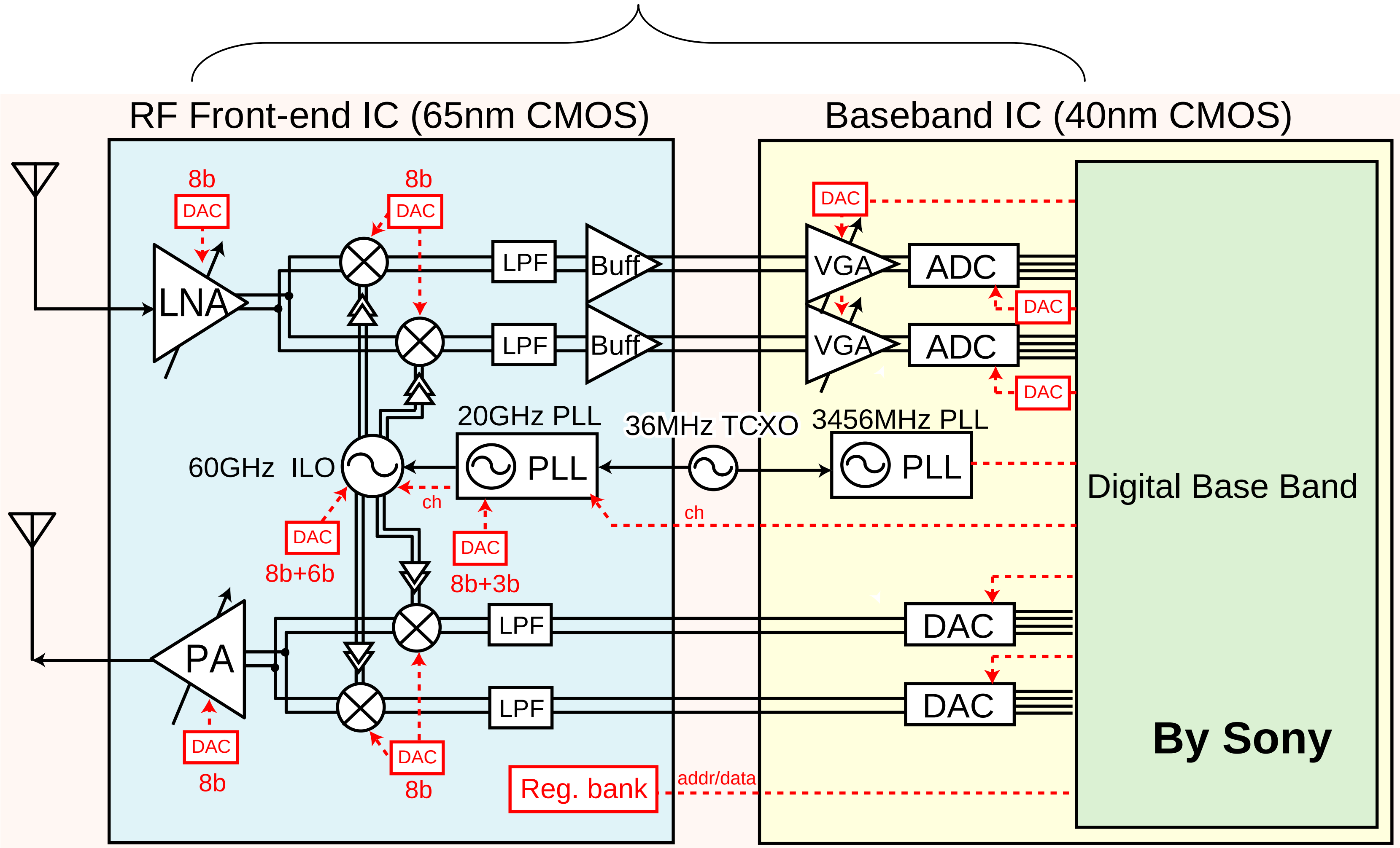
Kiosk download



Peer-to-peer

System block diagram

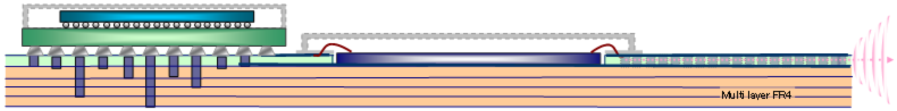
Matsuzawa and Okada lab. developing

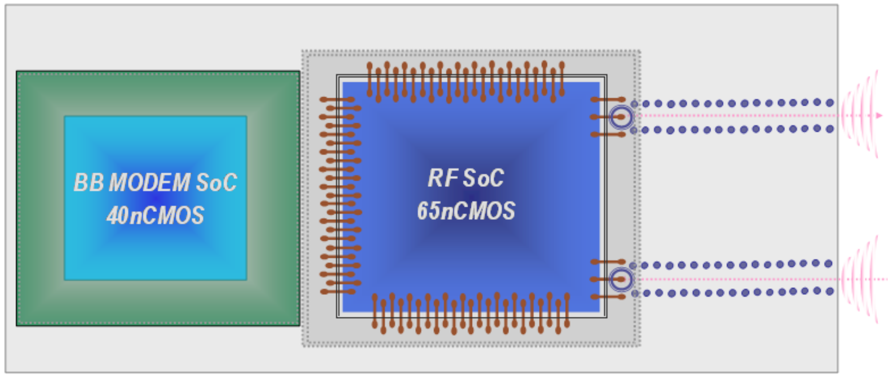


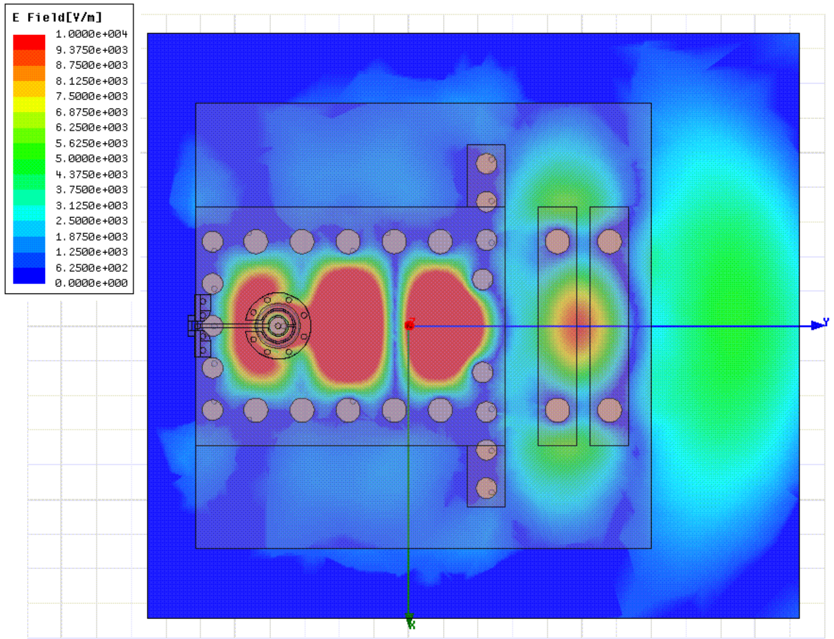
Equipment image

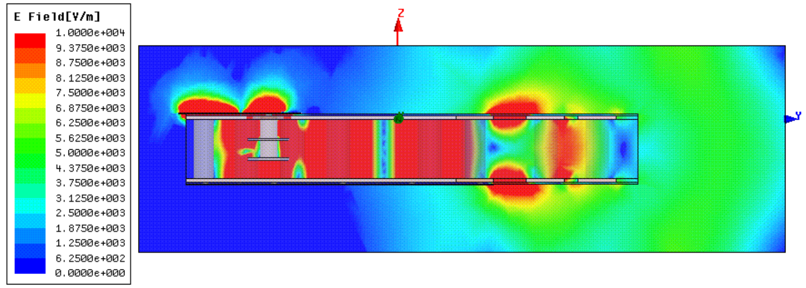
Two chips solution on one PCB with antenna

Low cost system





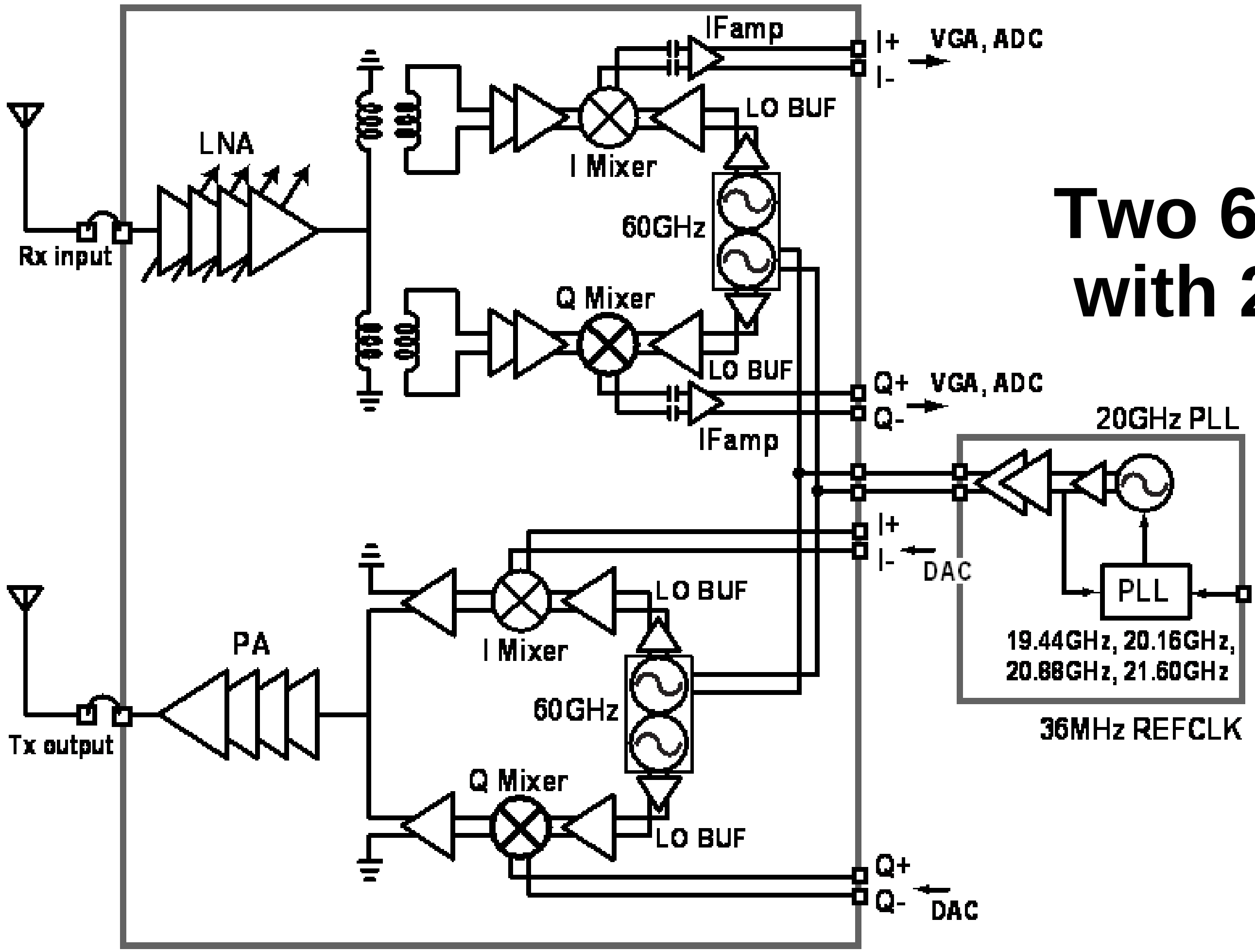




Gain: 5.6 dBi

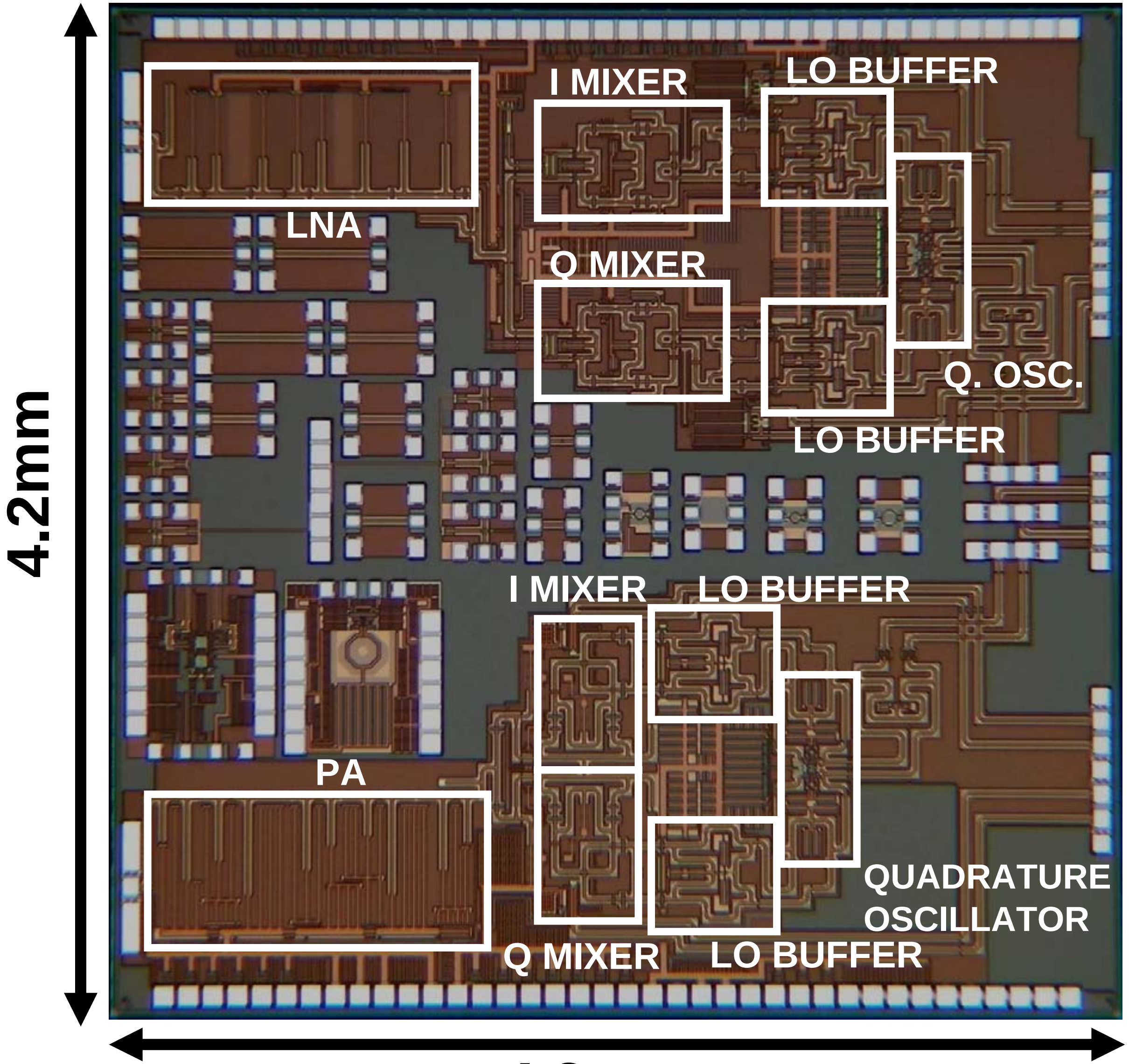
60GHz CMOS transceiver chip

A direct conversion method is employed to reduce power and complexity.

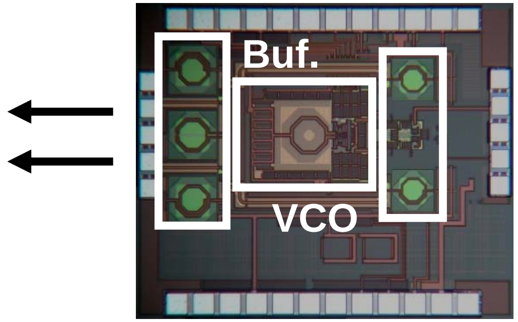


Two 60GHz QILOs with 20GHz PLL

Die Photo



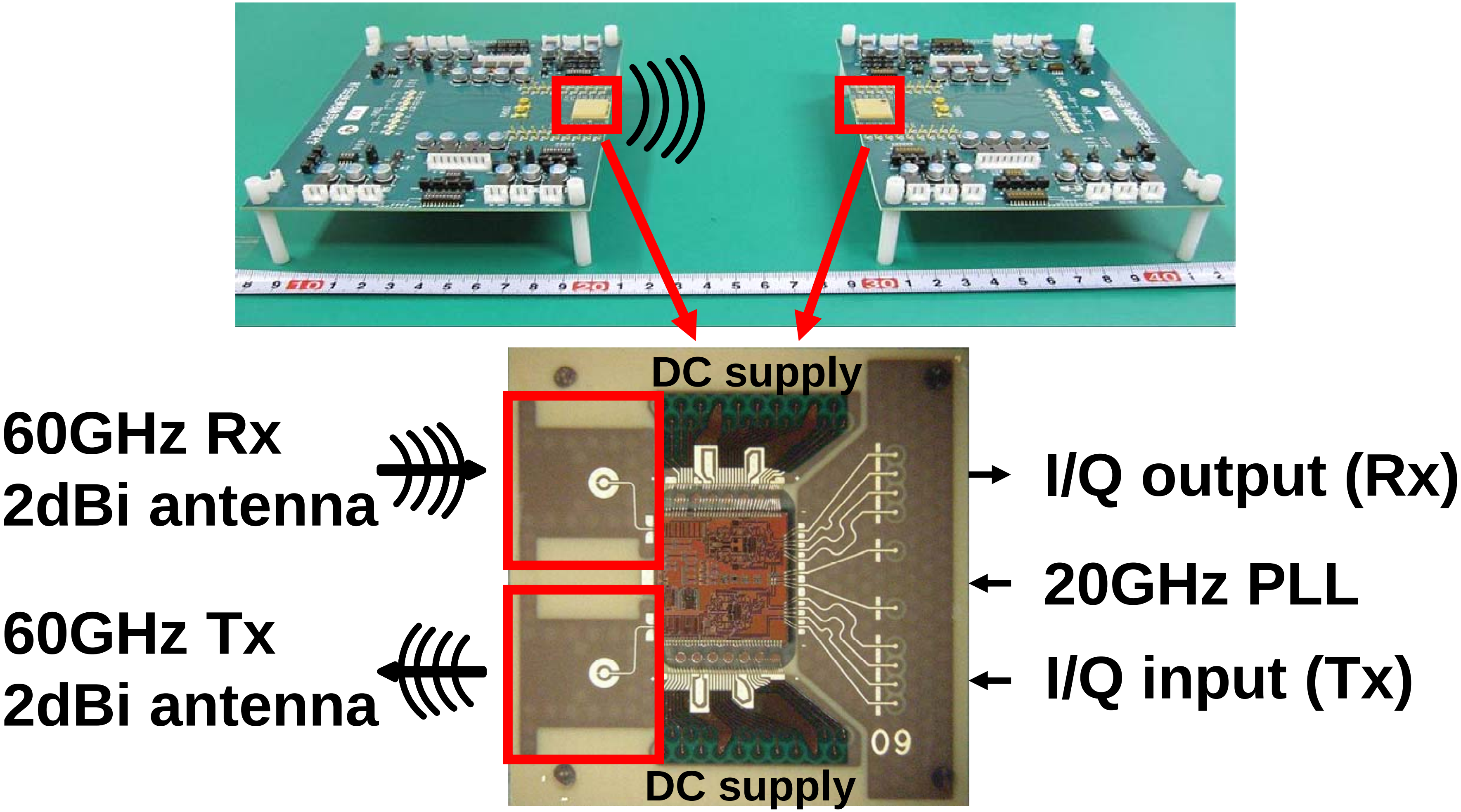
65nm CMOS
Rx:3.8mm^2
Tx:3.5mm^2
PLL:1.2mm^2



20GHz PLL

Communication test setup

Low gain antenna in package is used for the test



Basic performance

Low power, low phase noise, and low NF

Tx	
CG	18.3dB
P_{1dB}	9.5dBm
P_{SAT}	10.9dBm
PAE	8.8% (only for PA)
P_{DC}	186mW

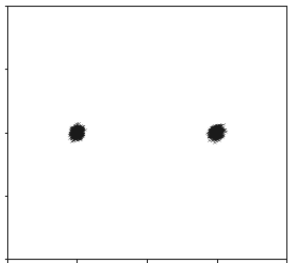
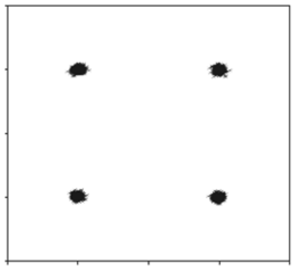
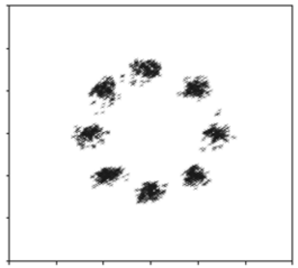
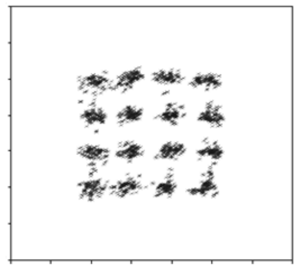
Rx	
CG	17.3dB (high-gain mode) 4.7dB (low-gain mode)
NF	<6.8dB (high-gain mode)
IIP3	-5dBm (only for LNA)
P_{DC}	106mW

PLL	
Frequency	17.9-21.2GHz
Phase Noise through Tx @60.48GHz	-94.2dBc/Hz @1MHz-offset
Ref. spur	<-58dBc
P_{out}	-2dBm
P_{DC}	66mW

The total Pd of system involving base band chip is about 500mW

Modulation Characteristics

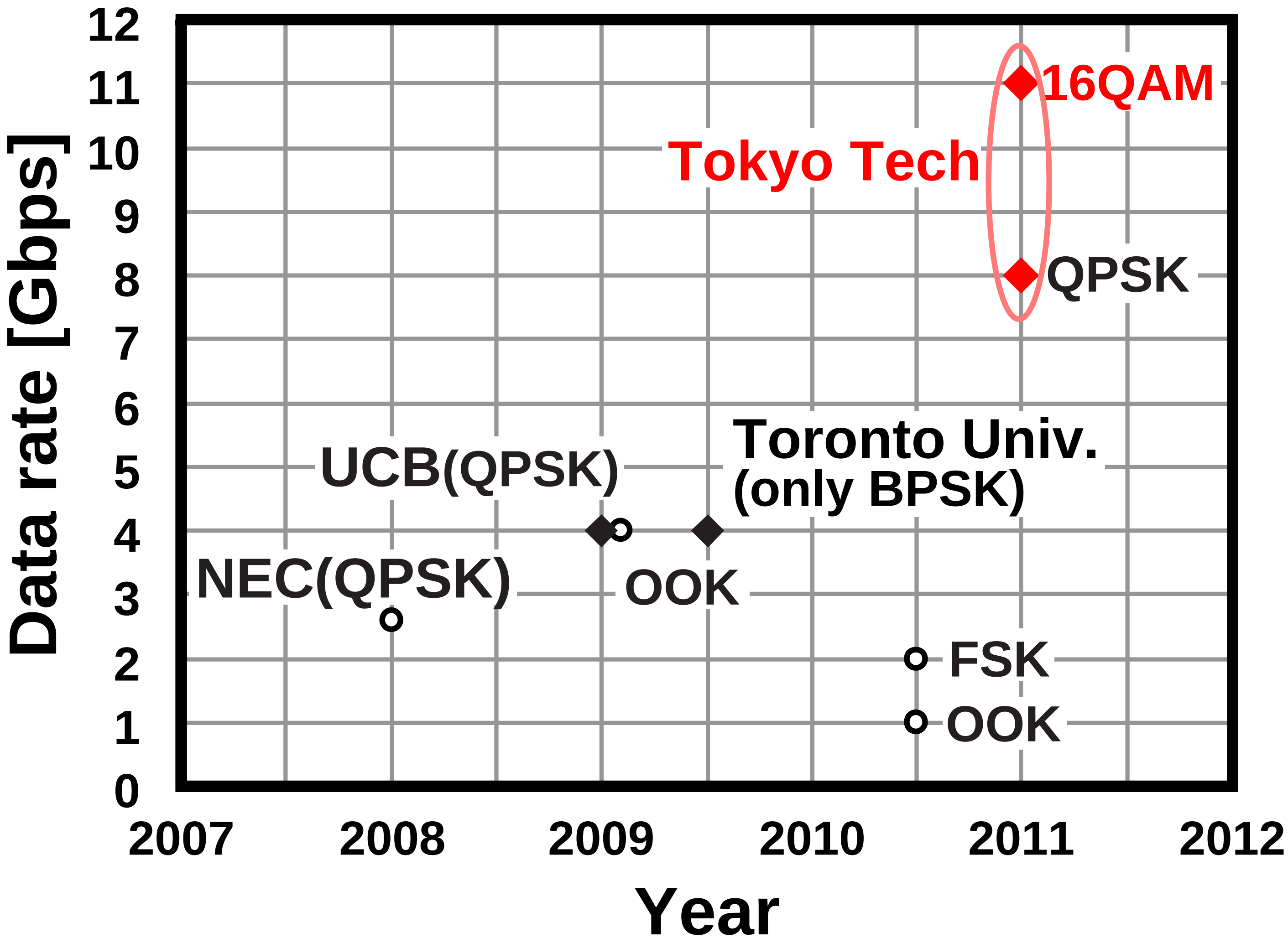
Realizes every modulations for IEEE 802.15.3c.

Constellation	 1585 points	 3170 points	 4755 points	 6340 points
Modulation	BPSK	QPSK	8PSK	16QAM
Data rate 2.16GHz-BW	1.76Gb/s	3.52Gb/s	5.28Gb/s	7.04Gb/s
EVM	-18dB (-24dB with DFE)	-18dB (-28dB with DFE)	-17dB	-17dB
Distance (BER < 10^{-3})	0.5–274cm	0.5–270cm	0.5–20cm	0.5–17cm

8Gb/s(QPSK) and 11Gb/s(16QAM) @ wider-BW

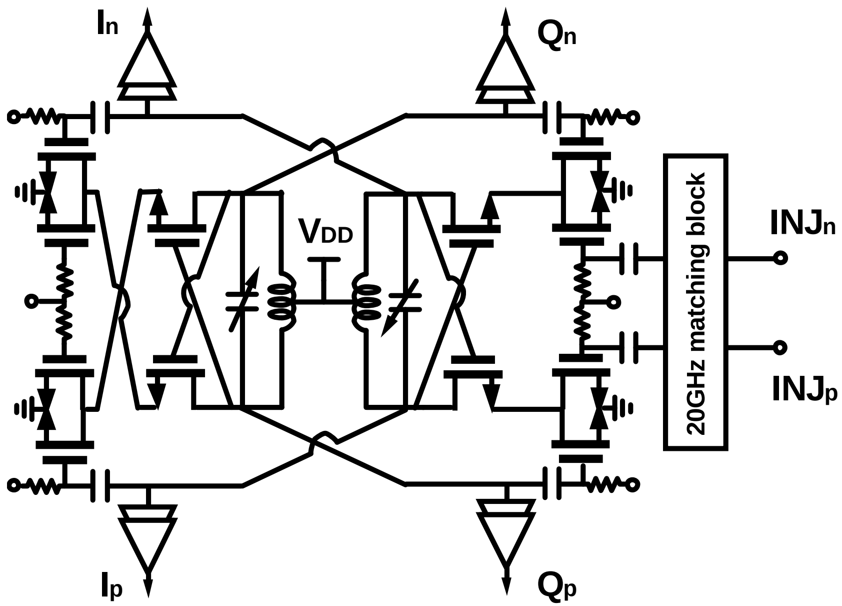
Progress of data rate in 60GHz

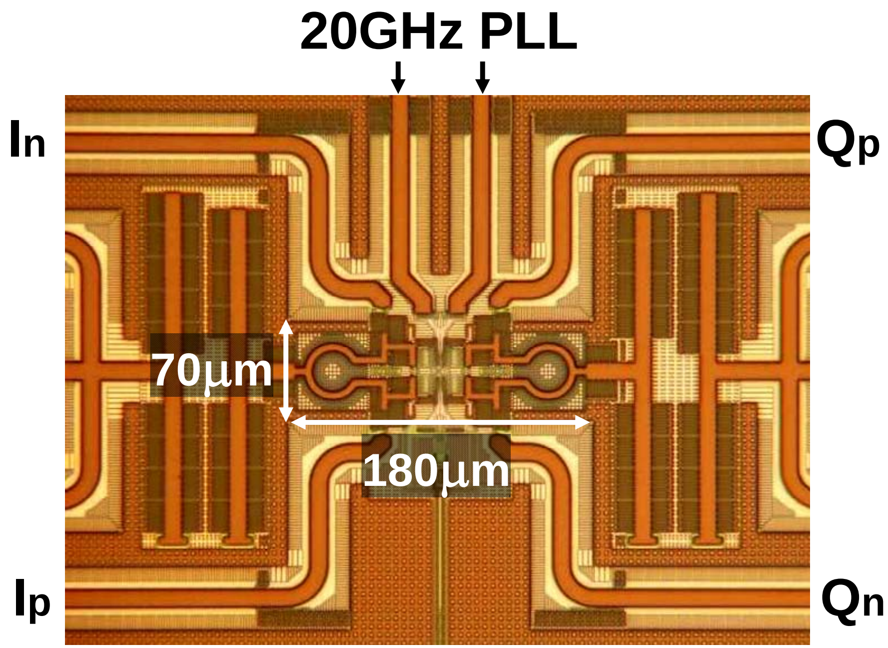
The transceiver attained over 10Gbps



Key technology: Quadrature ILO

Quadrature injection locked 60GHz oscillator with 20GHz PLL
Low phase noise of -96dBc/Hz @1MHz.

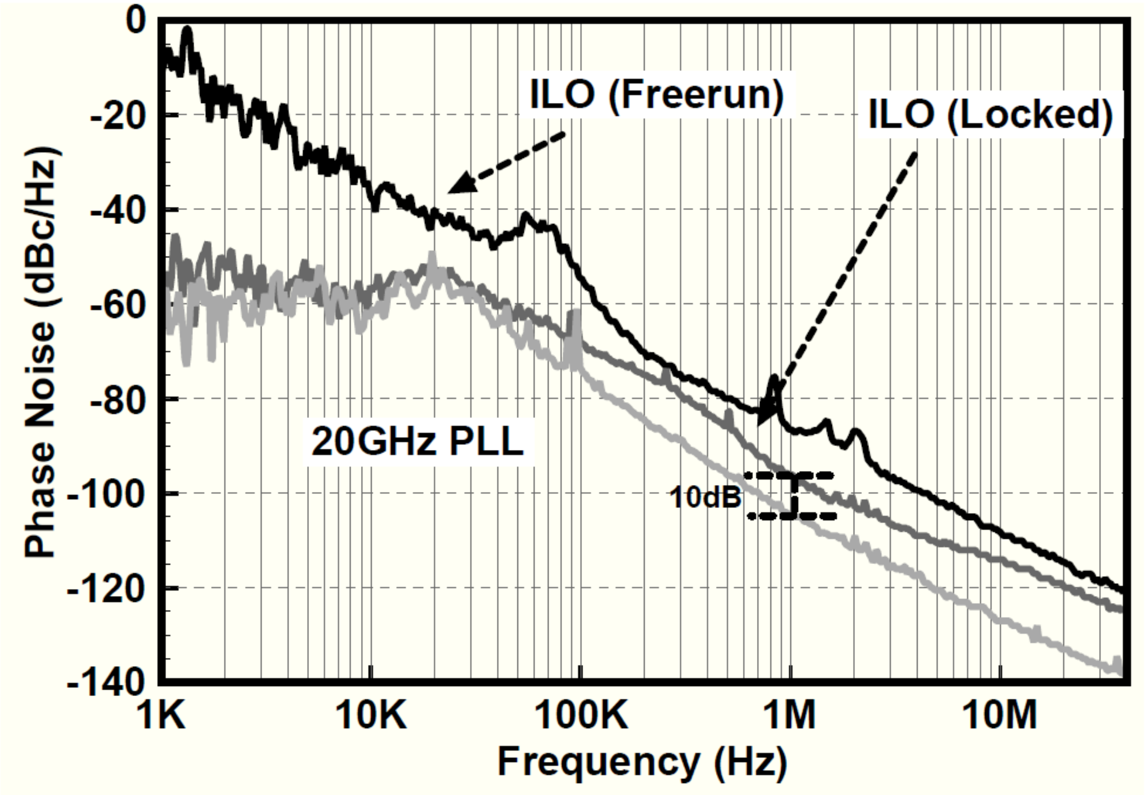




60GHz Quadrature PLL

Best phase noise is achieved.

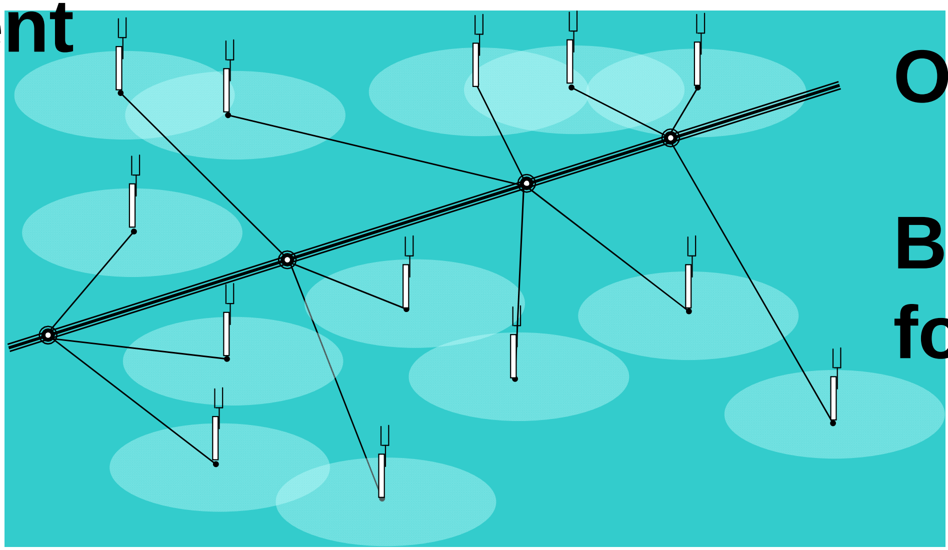
58-63GHz, -96dBc/Hz-1MHz offset



38GHz outdoor mm-wave system

Role of outdoor mm-wave

Current

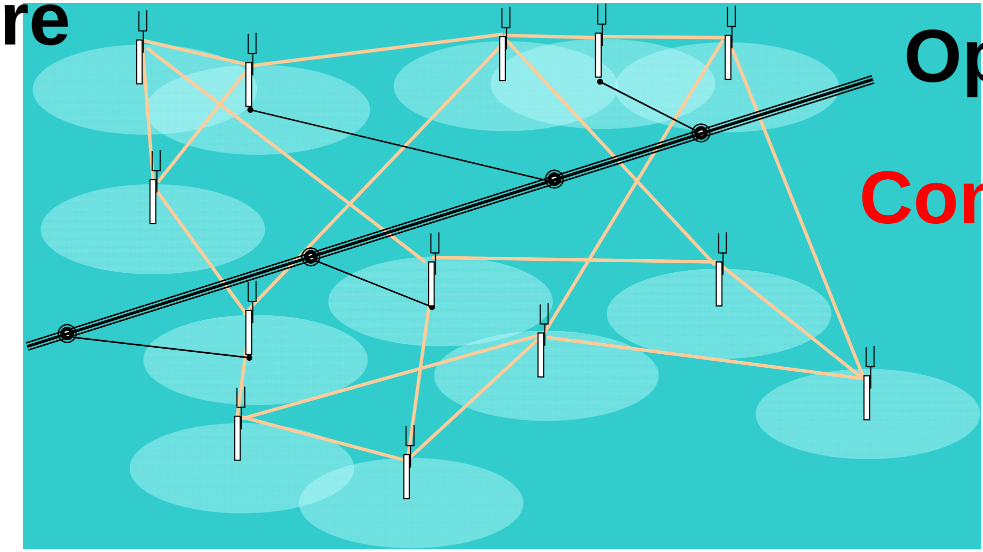


Optical fiber

Base stations for WiFi and WiMAX

Not flexible

Future



Optical fiber

Connect with mm-wave

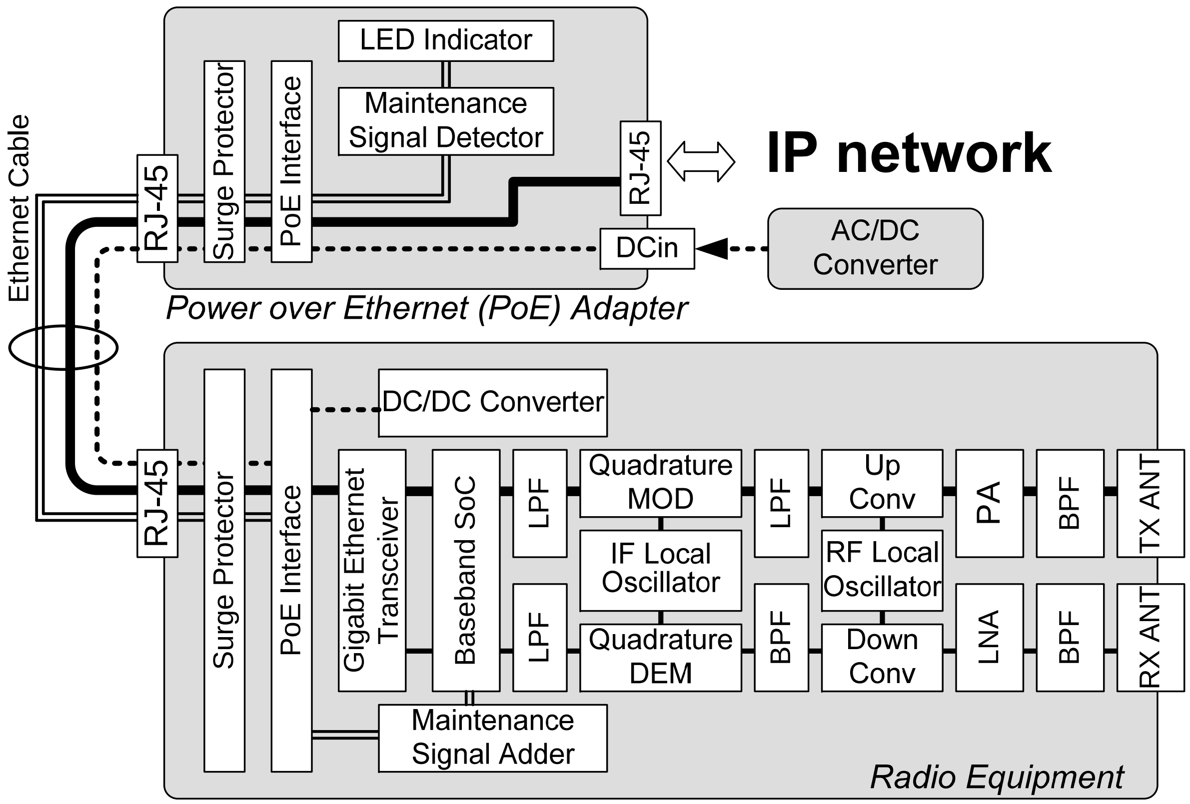
Very flexible

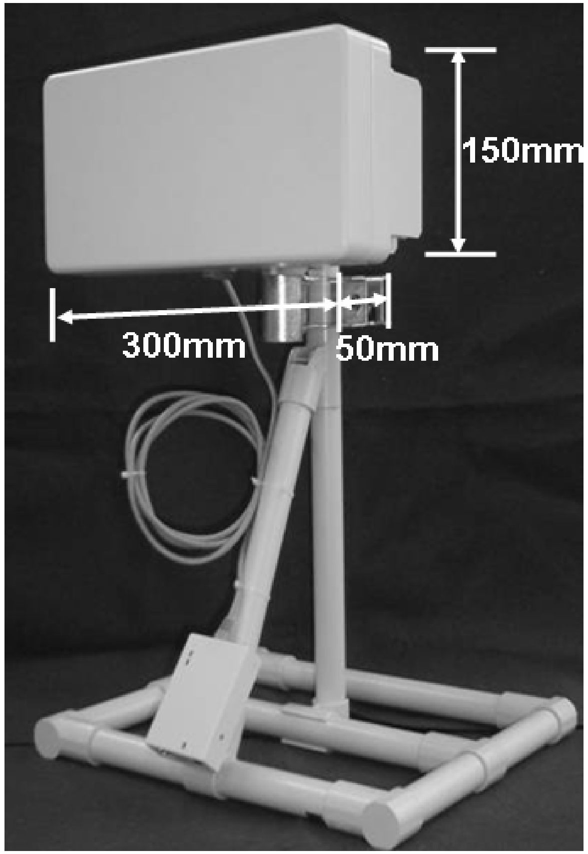
38GHz outdoor mm-wave system

Already realized 1Gbps outdoor mm-wave systems

System configuration

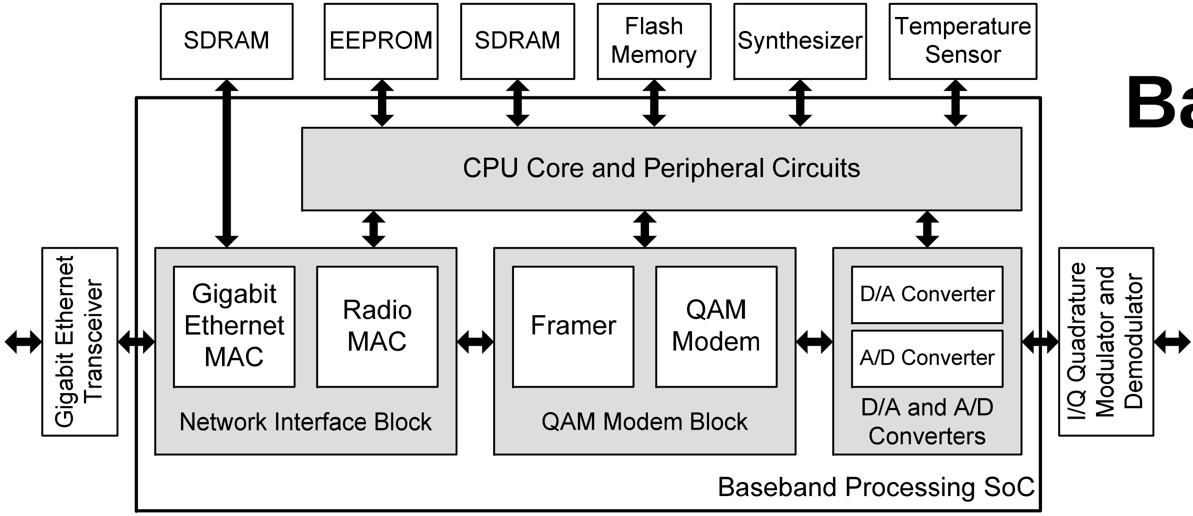
Compatible with Gbit Ethernet
Hole system is integrated with planar antenna



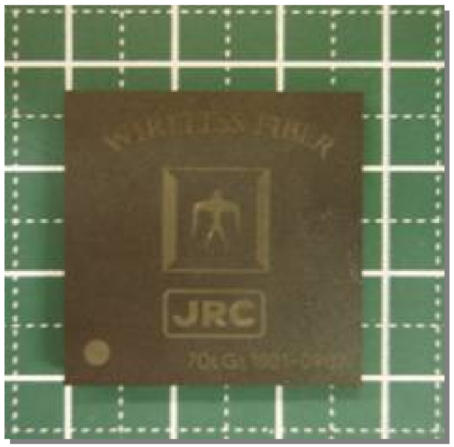


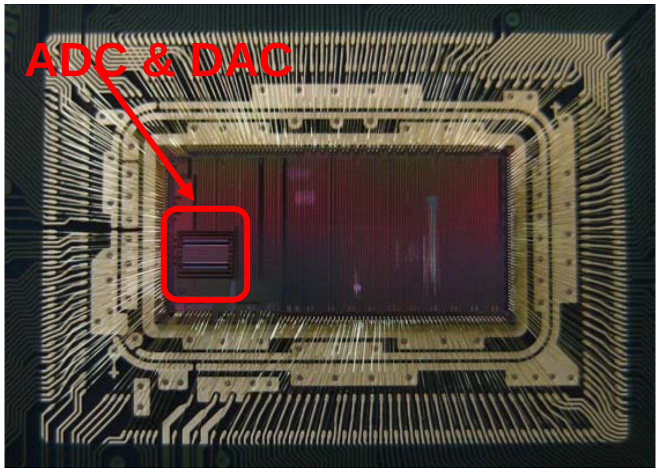
Mixed signal BB SoC

A mixed signal SoC has been developed to realize 64QAM (1Gbps) with BW of 260MHz.



Base band SoC

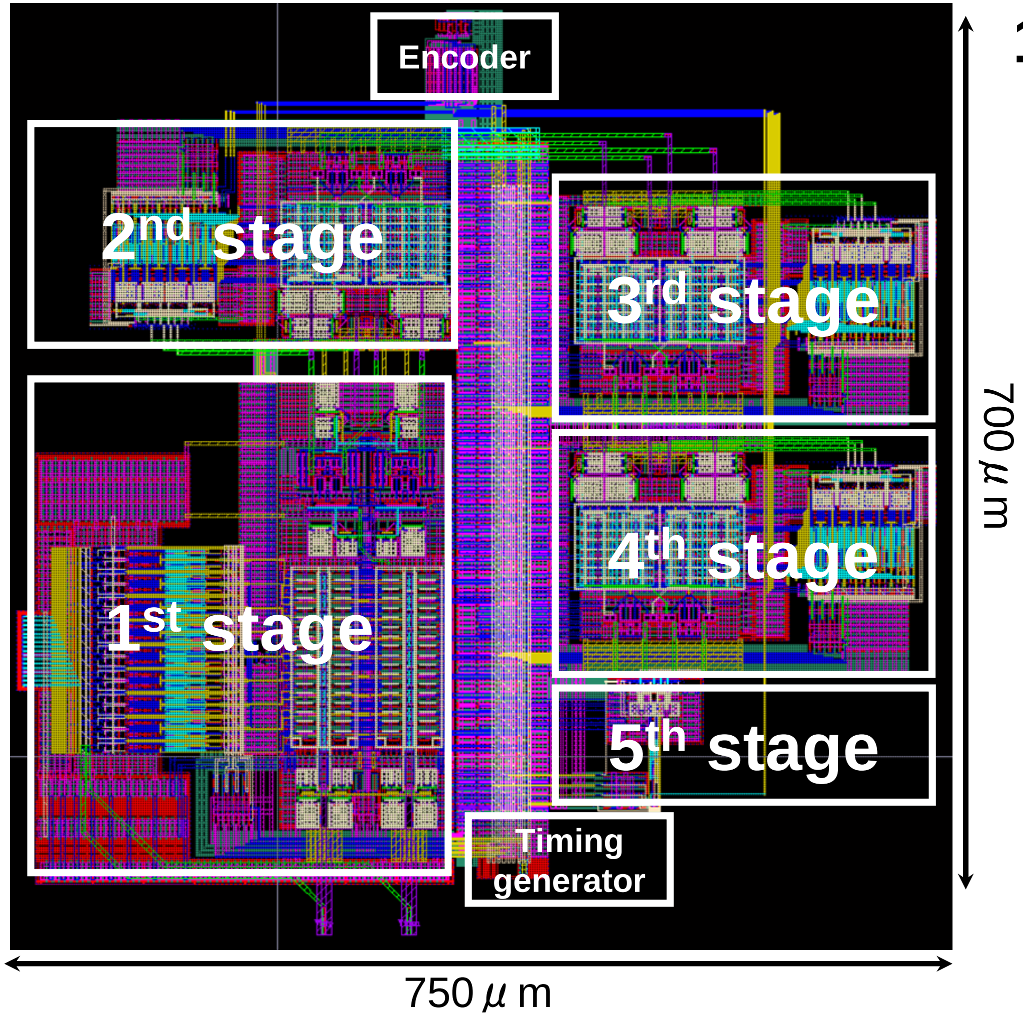




90nm CMOS
40M Transistors

Developed ADC

Developed new 10b ADC to address 64 QAM.



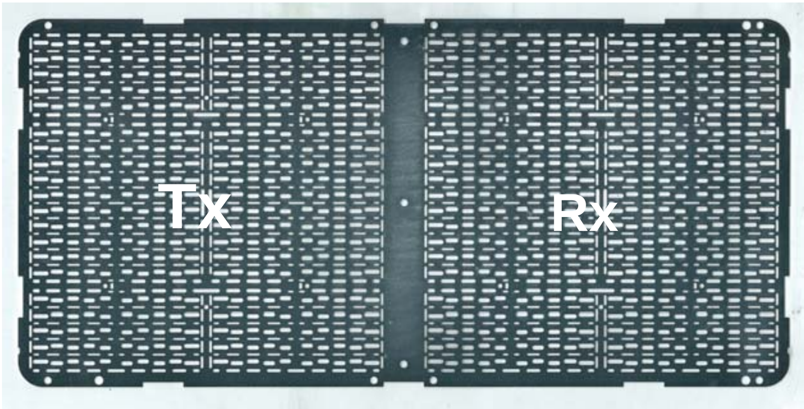
10b, 320 MSps, 40mW ADC

New ADC architecture

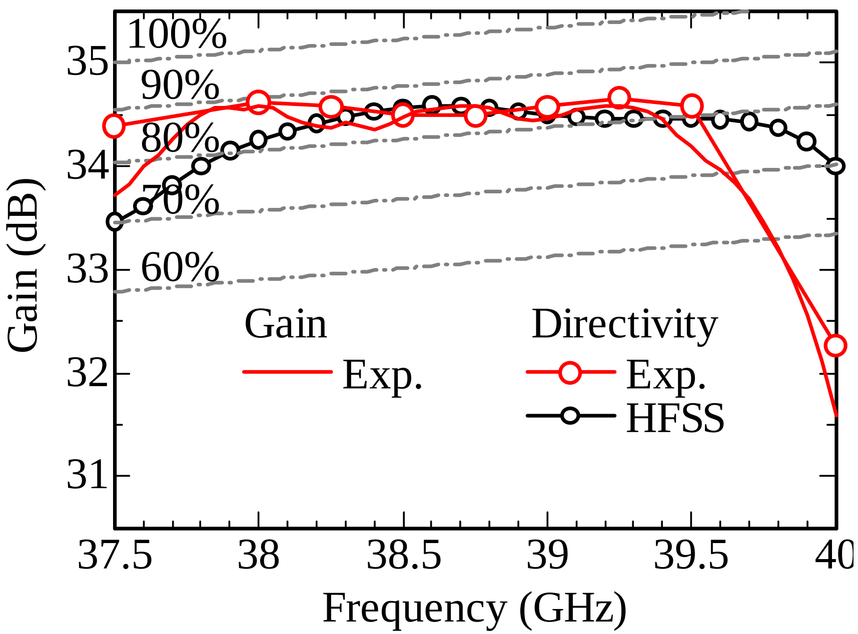
No interleaving
No double sampling
No OpAmp
No calibration

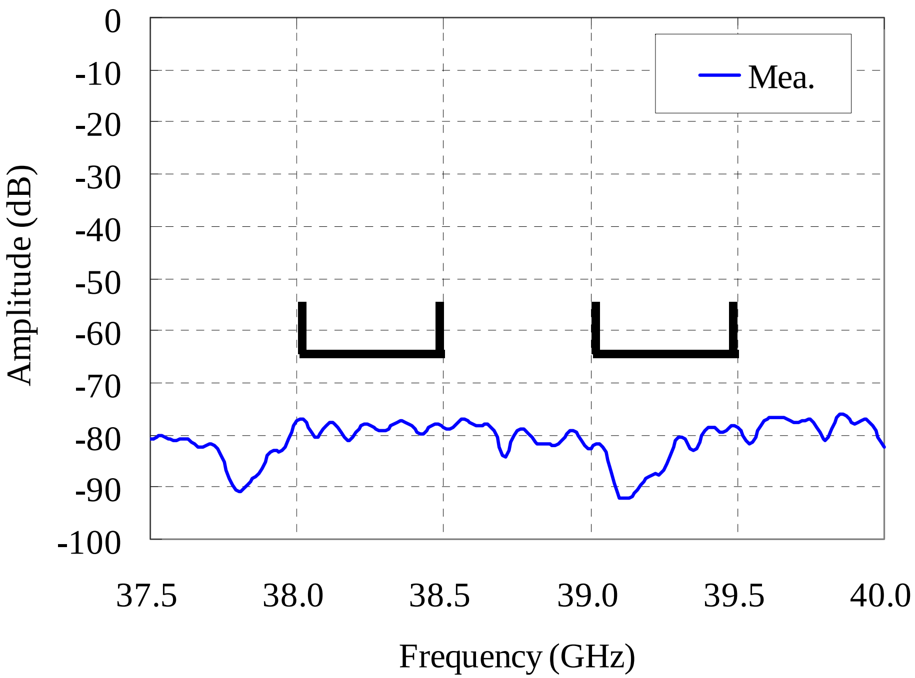
38GHz High gain planar antenna

Developed high: gain and isolation planer antenna



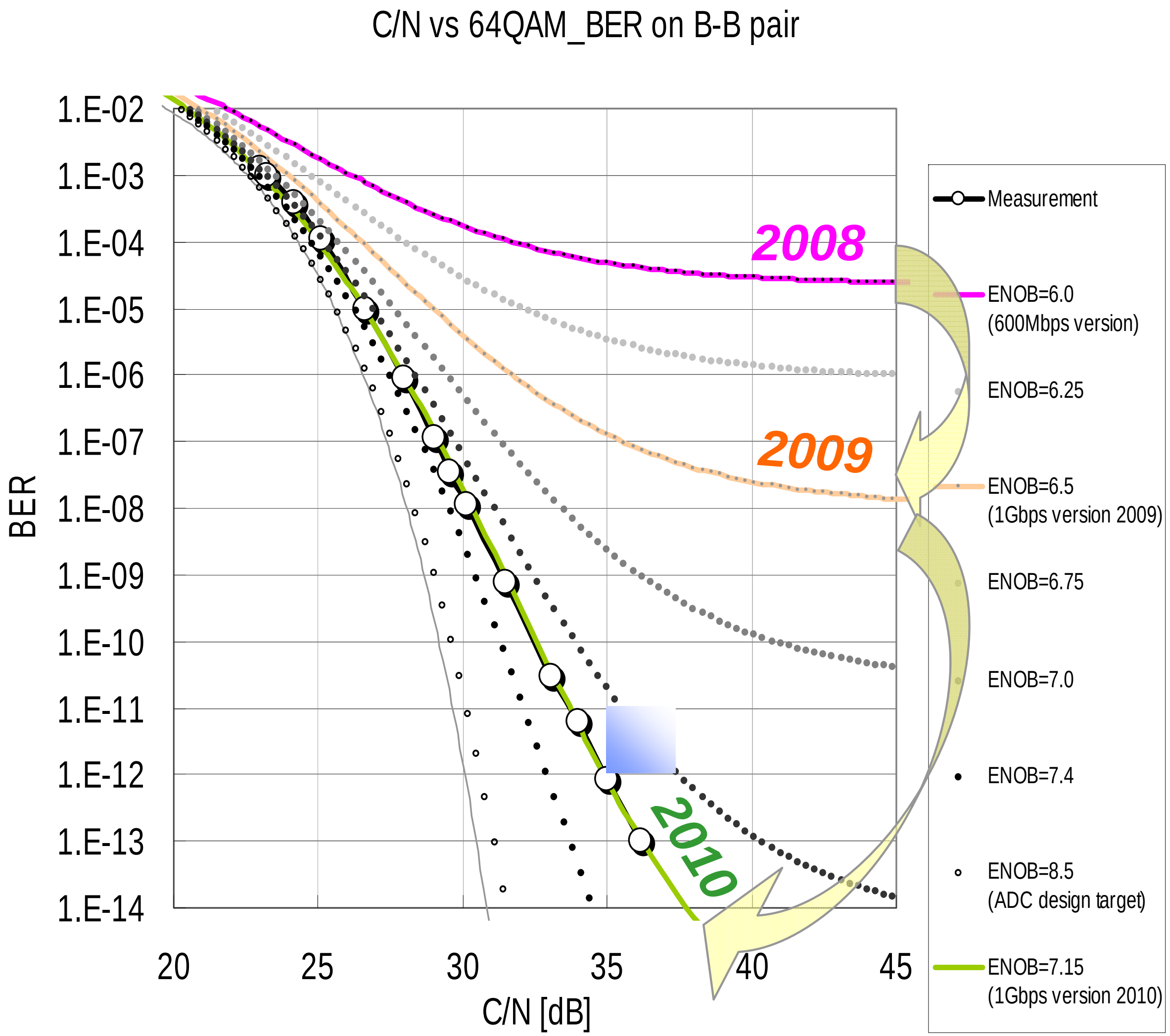
Gain：34.58dBi@38.75GHz
Efficiency：84.9%
Tx/Rx Isolation: 75 dB

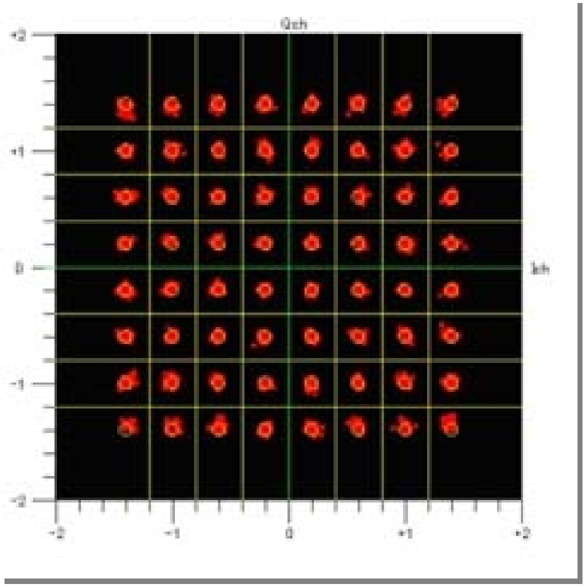




BER vs. SNR

BER for 64QAM has been reduced to the ideal

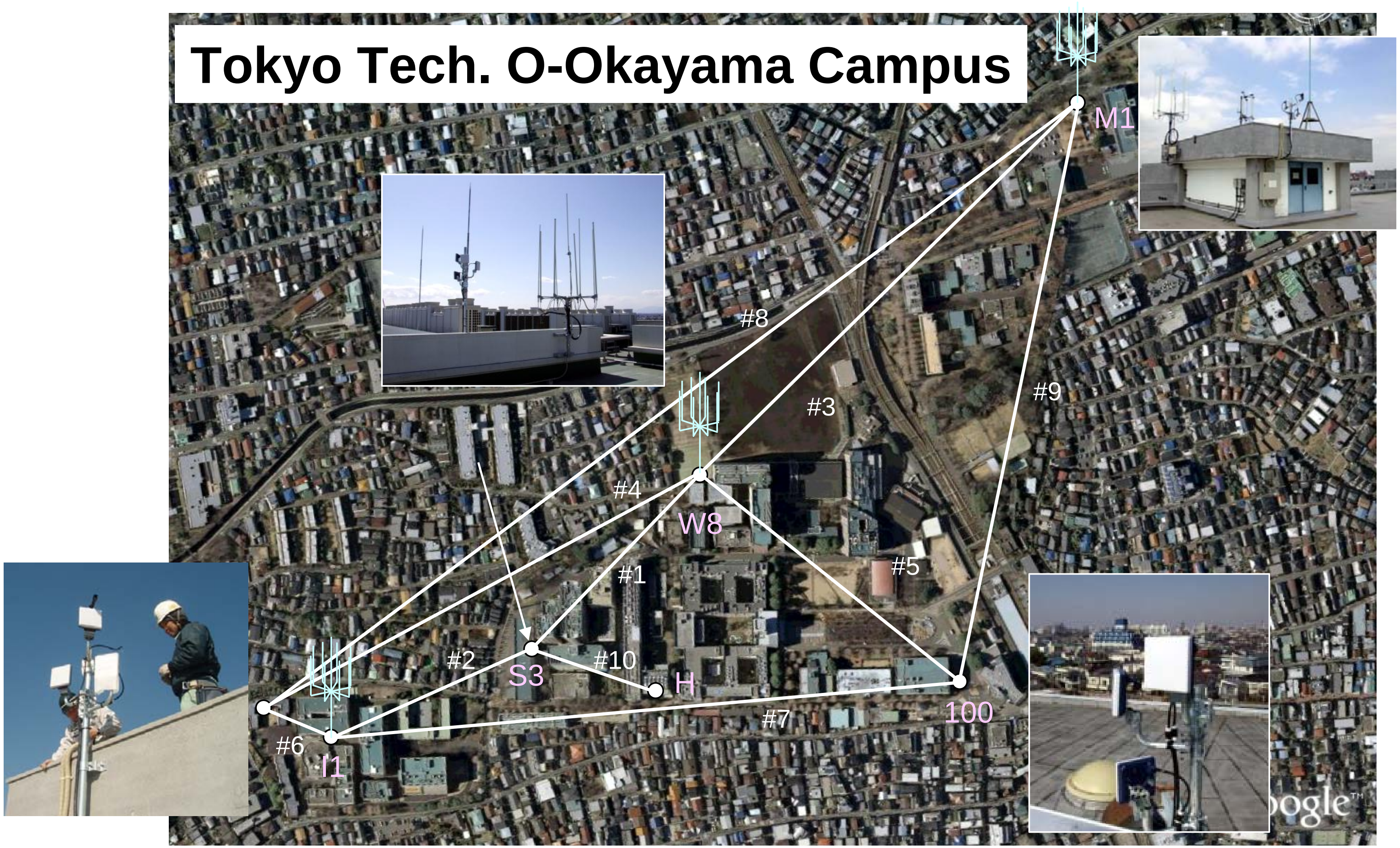




Tokyo Tech. Model Network

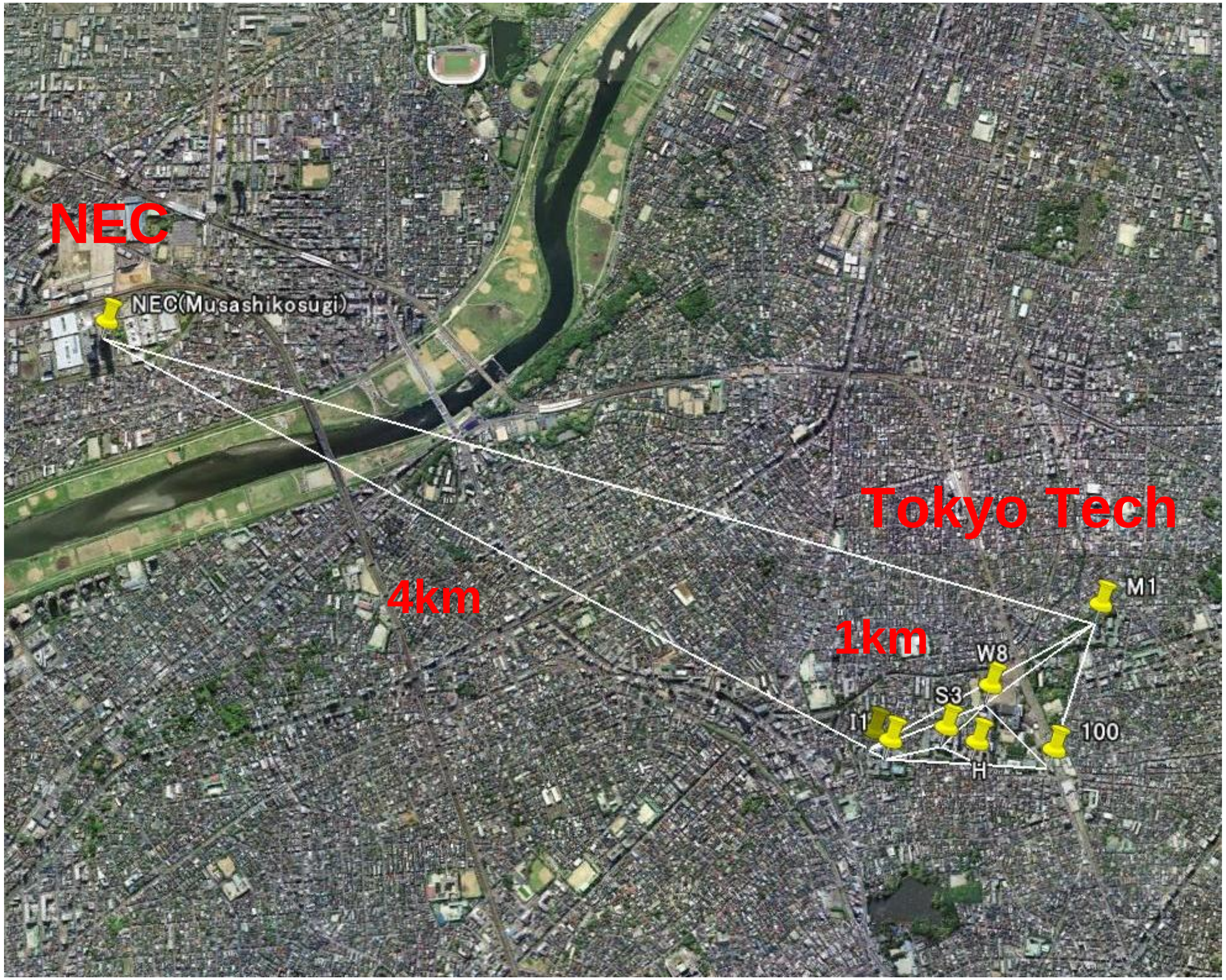
25

Ten mm-wave base stations in our campus



Expand the area to NEC (4km)

Challenge for 4km mm-wave communication

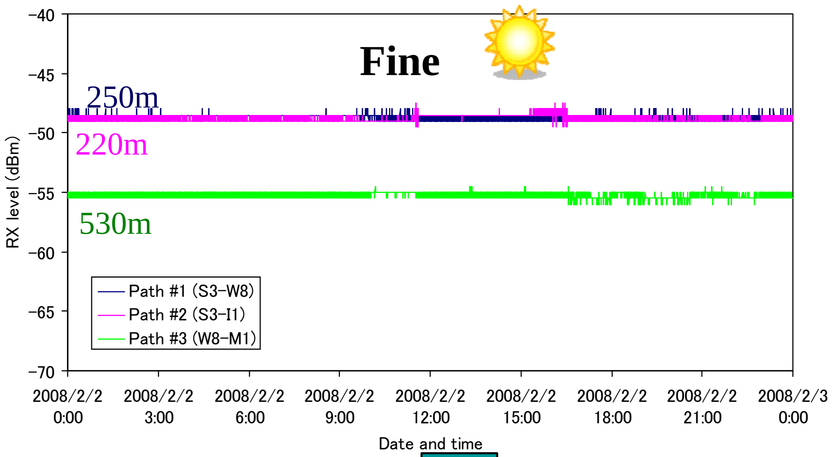


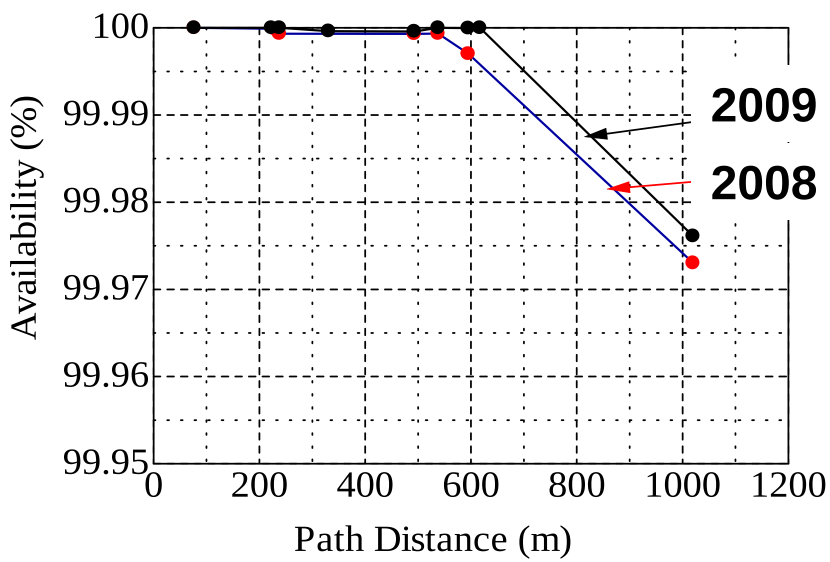
Model network in Tokyo

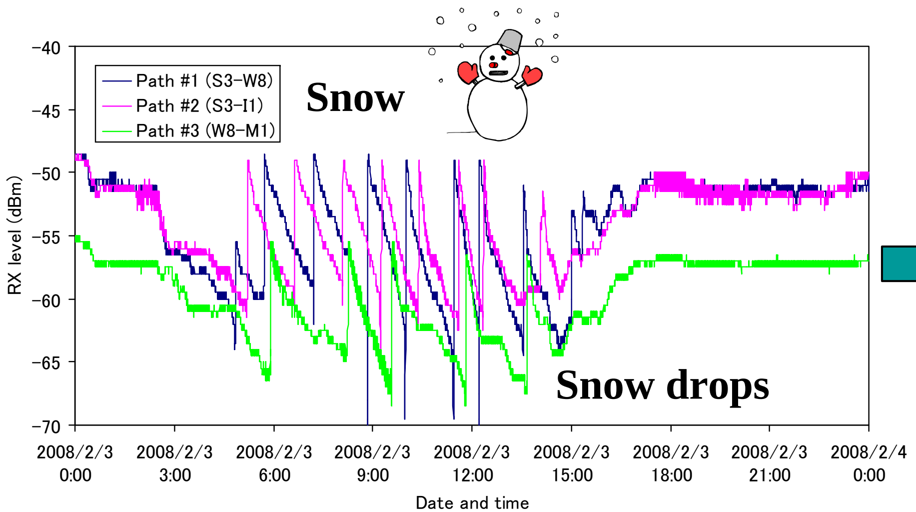
Outdoor mm-networks can cover the Tokyo metropolitan area

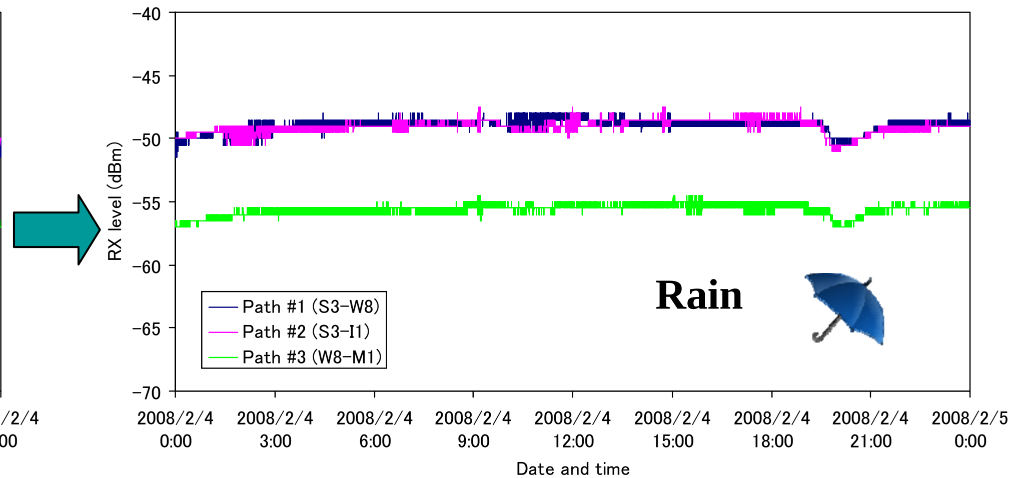
Weather variation and availability

Watch weather and mm-wave network condition



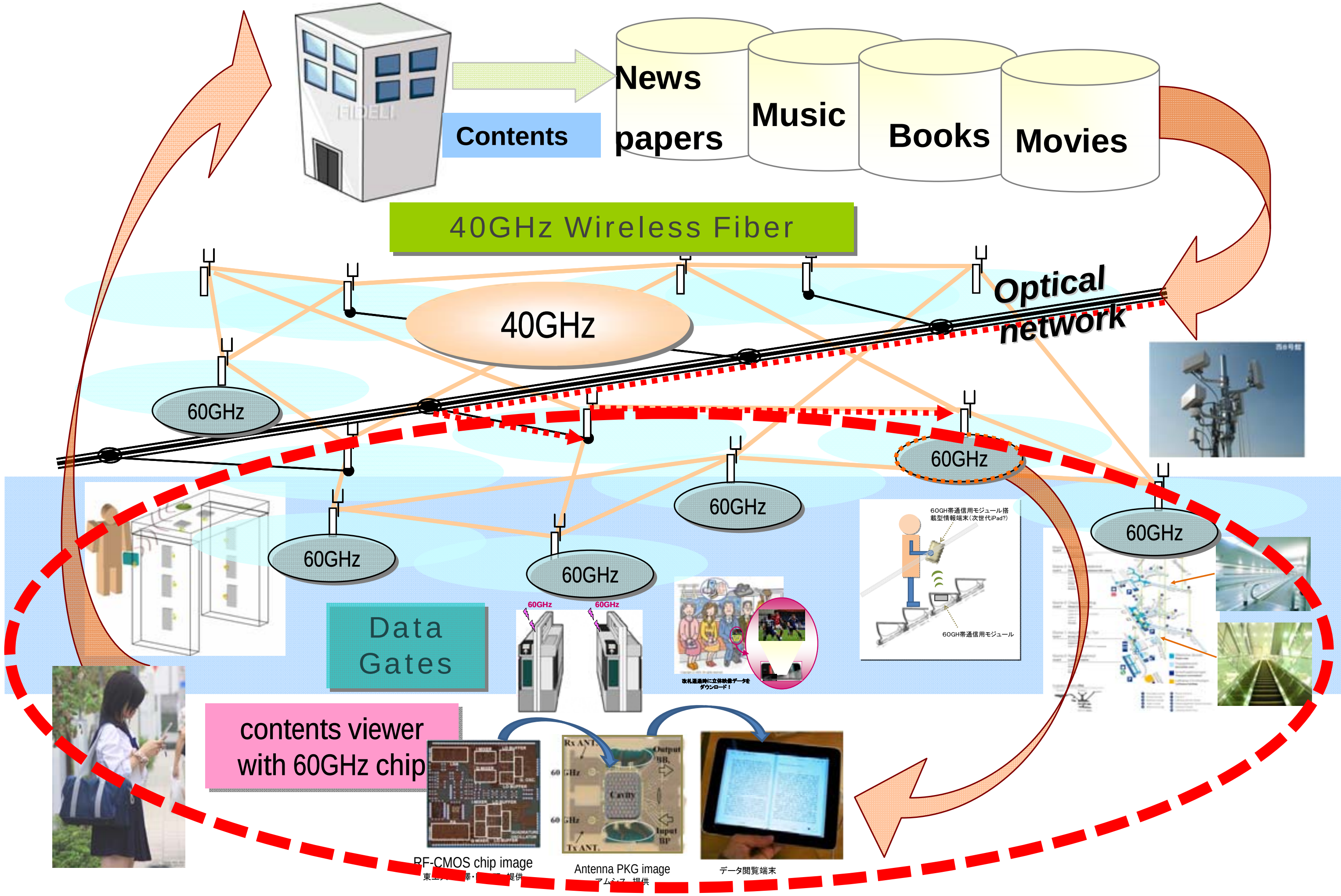






Future UHS network with mm-wave

Mm-wave will realize real high speed networks collaborating with optical and wireless technology



Summary

- **Tokyo Tech now developing 60GHz indoor and 38GHz outdoor systems, CMOS RF and ADC/DAC for BB chips**

- **60GHz CMOS direct conversion transceiver chip attained 11Gbps data rate**

- **38GHz 1Gbps outdoor mm-wave system attained 1Gbps data rate with bandwidth of 260MHz for 4km distance communication**

Acknowledgement

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Backup slides for questions