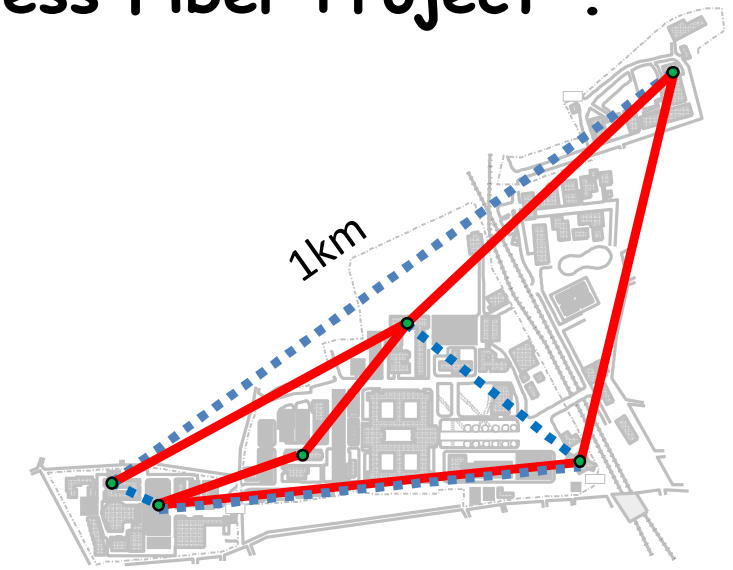
Antennas, Propagation and Transceiver IC Technologies for Millimeter Wave Radio Systems for 5G Networks.

- the Tokyo Tech Wireless Fiber Project-.



Makoto Ando

Tokyo Institute of Technology

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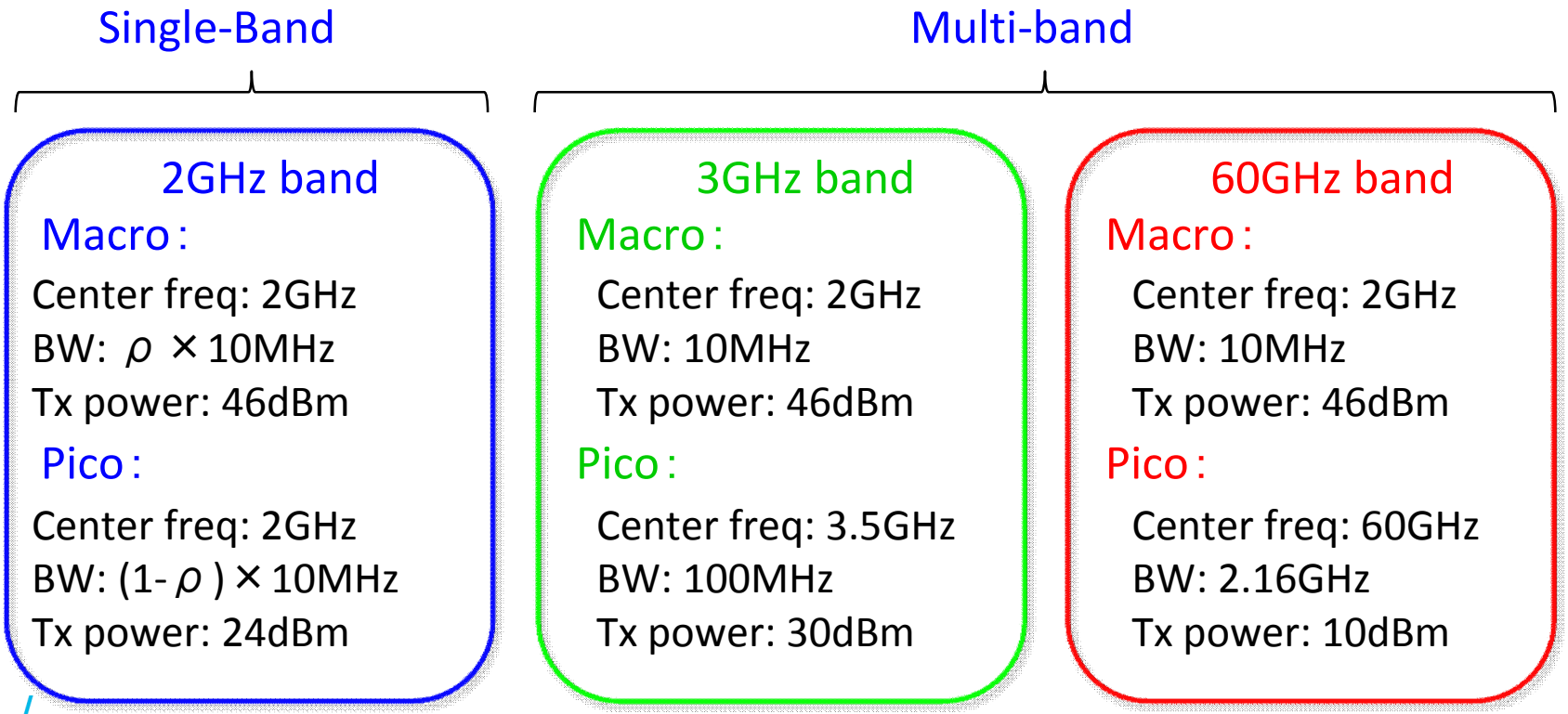
Tokyo Institute of Technology –TOKYO TECH– develops distinctive students with outstanding qualities of creativity and leadership. TOKYO TECH is making significant contributions to science and technology in many fields of expertise, creating new and powerful synergies. TOKYO TECH, being a research-based university, is dedicated to education and research, and to exploring knowledge in science and technology. Pursuing excellence, TOKYO TECH serves society and the world.

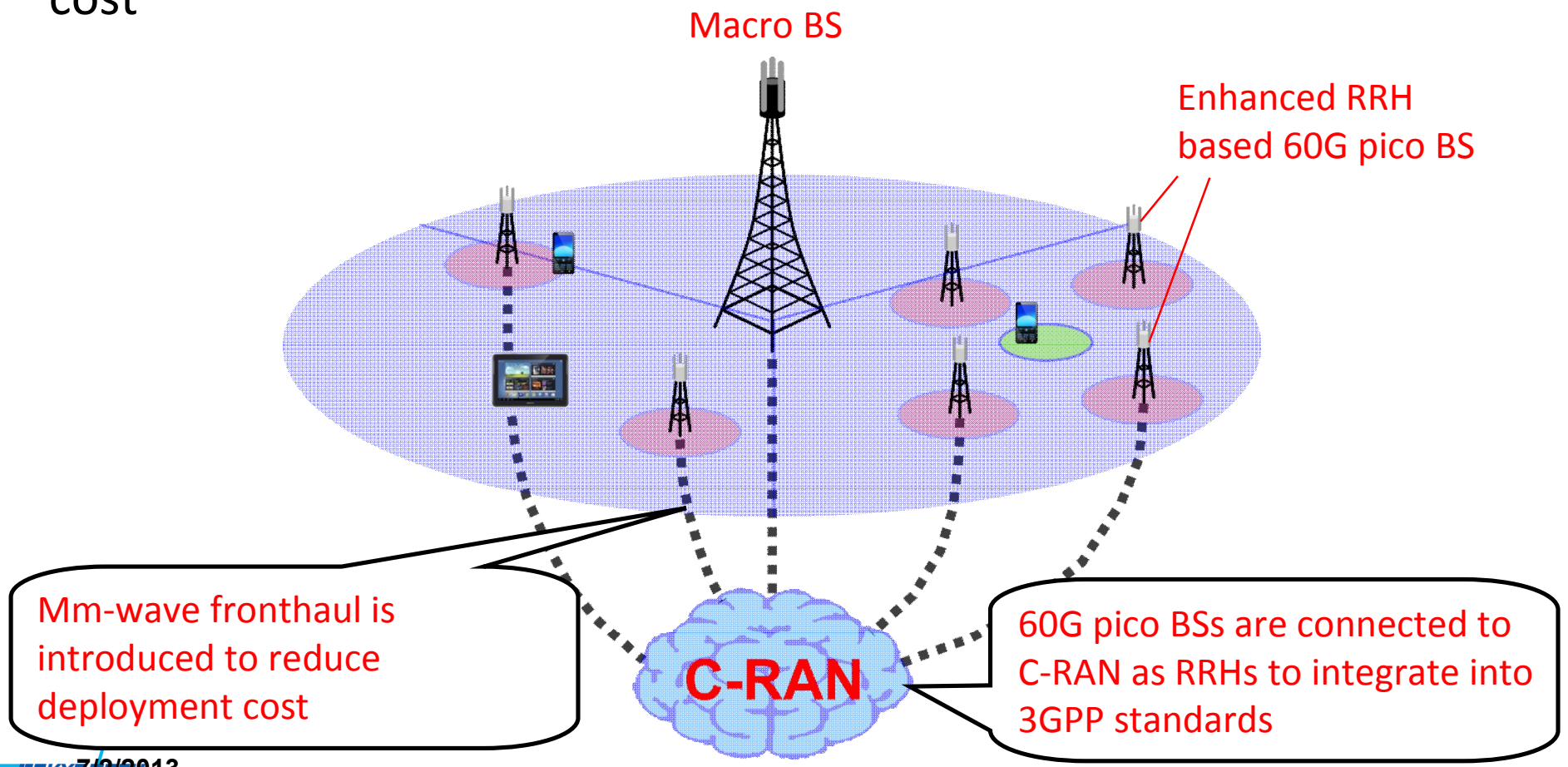
Multi-Band HetNet

- Macro-pico interference management is necessary
- Spectrum splitting loss occurs in single-band HetNet（e.g. ABS）
- Multi-band HetNet achieves BW enhancement without interference



C-RAN with MM-Wave Fronthaul

- Integrate 60G pico BSs as RRHs of C-RAN based cellular network
- mm-wave fronthaul based on enhanced CPRI to reduce deployment cost

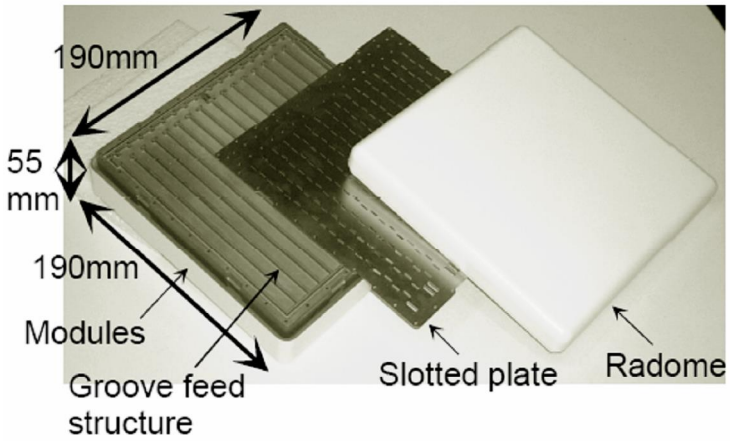


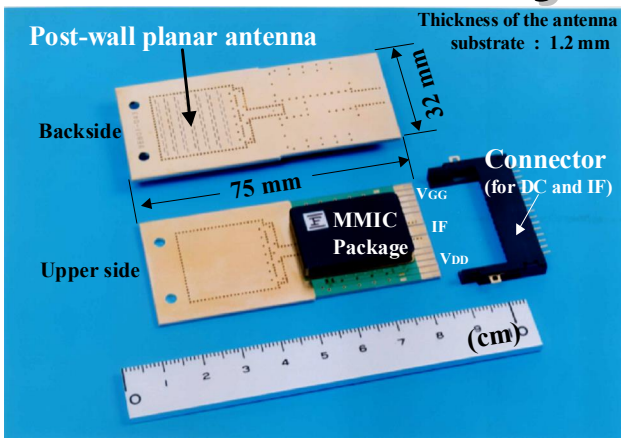
“Tokyo Tech Wireless-Fiber Project”

2007.4-2012.3-2016.3

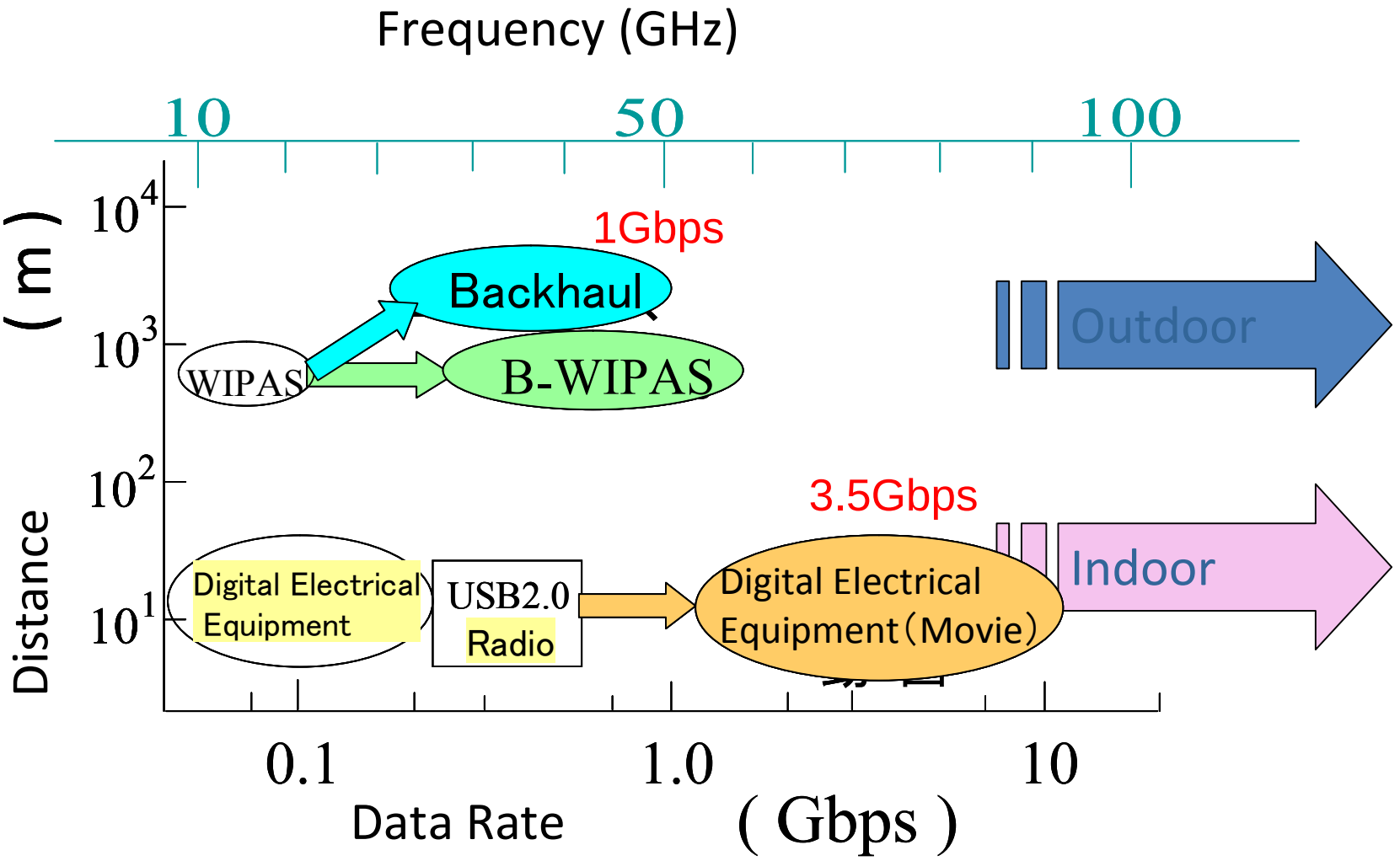
Pursuing Excellence

Background of MM-wave Project





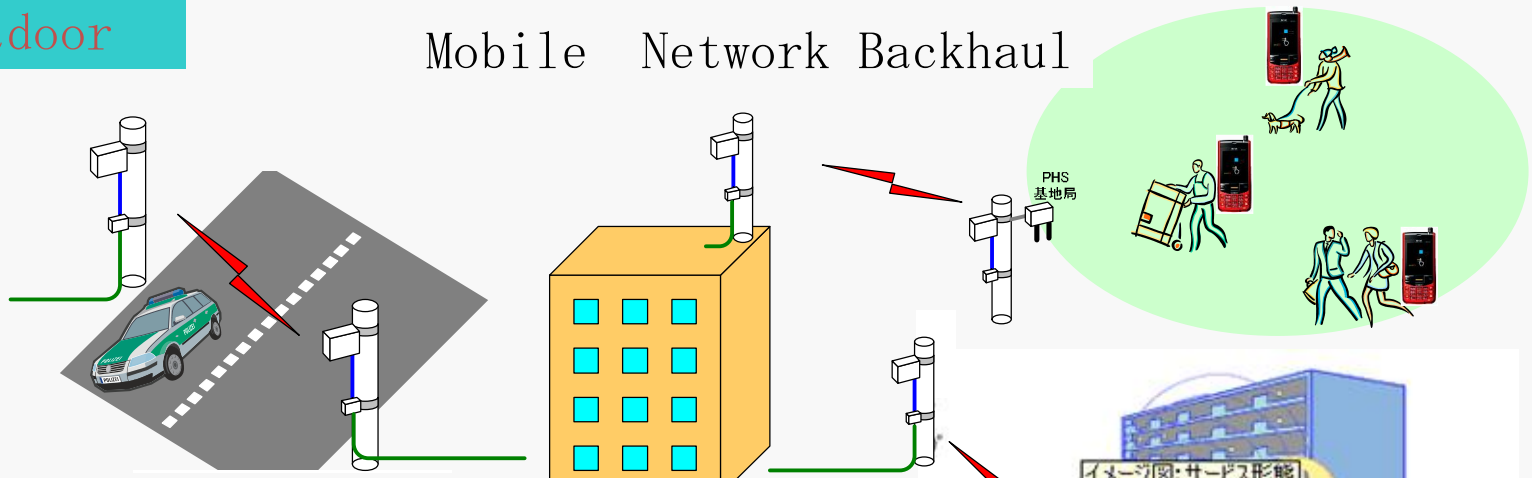
The 5 year (2007-2012) project "RF Coexisting Technology on High Speed Baseband IC for Millimeter Wave Radio Systems" was supported by Government (MIC) as well as Industry's participation. The objective was to develop RF coexisting technology on high speed baseband CMOS for Millimeter wave radio systems. Outdoor and indoor beyond Gbps were designed, the former of which was installed in Tokyo Tech campus.


Frequency (GHz)
10
50
100
(m)
10^4
10^3
10^2
10^1
Distance
1Gbps
Backhaul
WIPAS
B-WIPAS
Outdoor
3.5Gbps
Digital Electrical Equipment
USB2.0 Radio
Digital Electrical Equipment（Movie）
Indoor
0.1
1.0
10
Data Rate
(Gbps)

target usage image

Outdoor

Mobile Network Backhaul

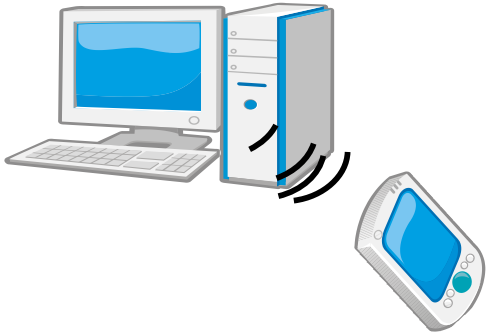


Radio Entrance

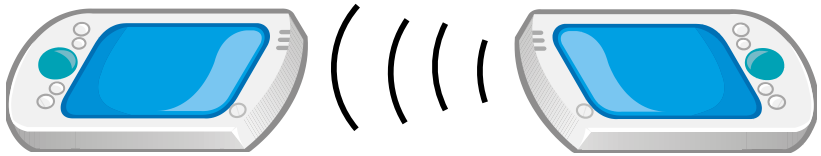
Fixed Wireless Access

Indoor

File Transfer (0～10m)



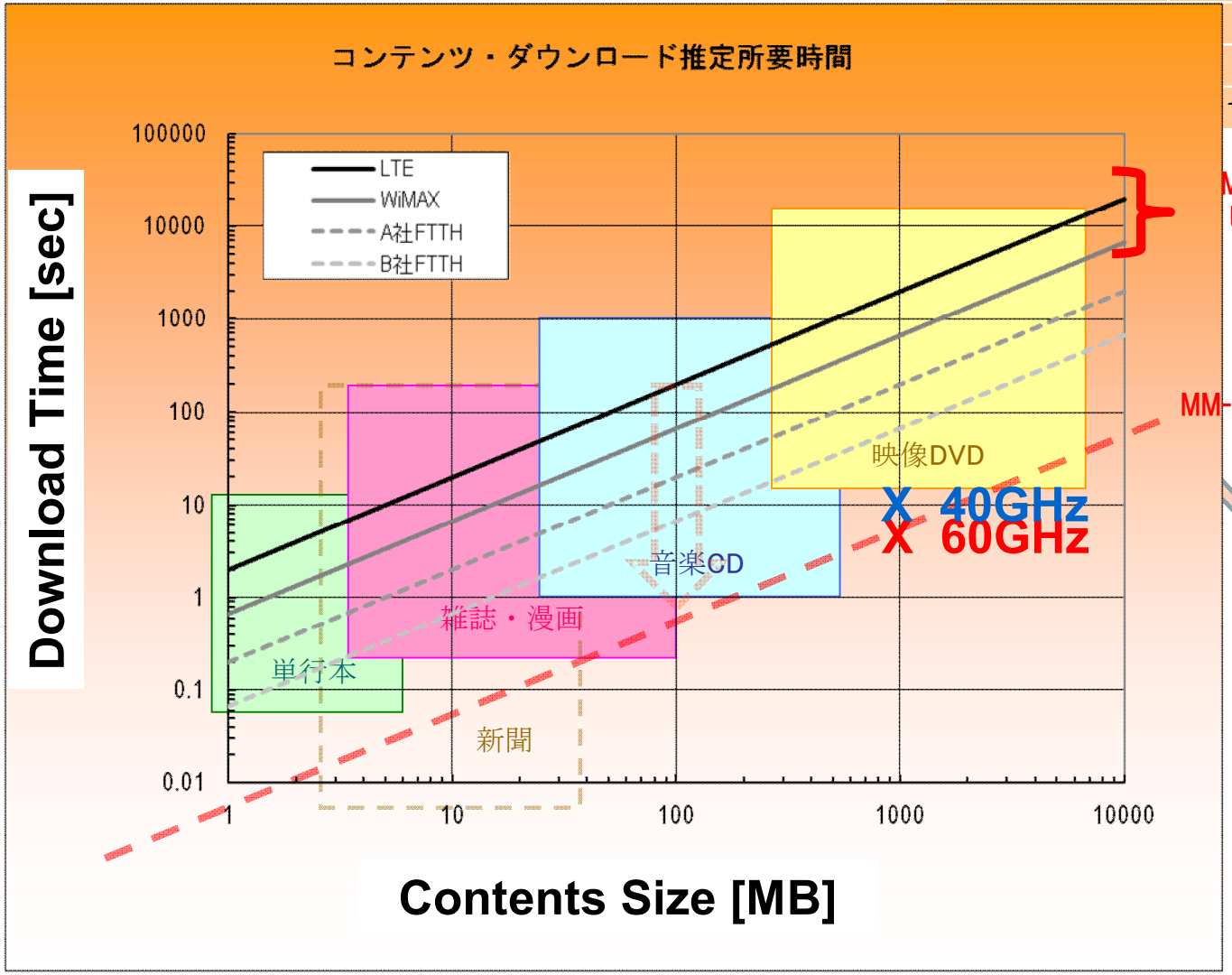
Kiosk download



Peer-to-peer

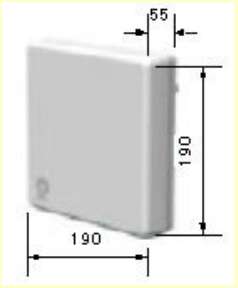
Time required for contents download via wireless systems

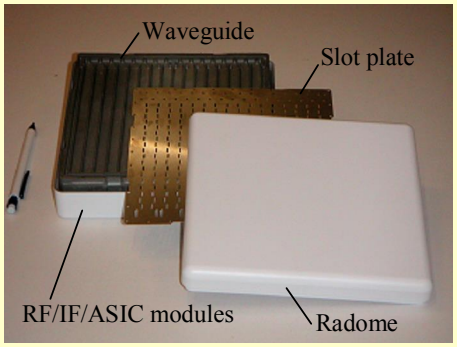
2011年1月 Measured average speed	
WiMAX	12 Mbps
	4 Mbps
	40 Mbps
	120 Mbps

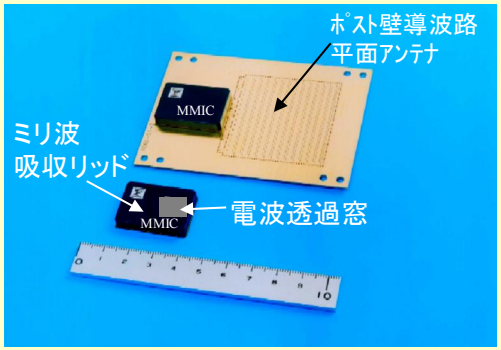


1GB: 3sec->1.5sec

DVD: 13sec->7sec







Medium Range Outdoor Entrance Radio Systems (JRC)

Short Range Indoor Wireless Access System (Sony)

System Spec. ↓ ↑ IC

System Spec. ↓ ↑ IC

"RF Coexisting Technology on Silicon CMOS Radio Systems" (Tokyo Tech)

High Speed Baseband IC for Millimeter Wave

Phase Noise Compensation by Digital Signal Processing (Tokyo Tech)	Phase Noise Compensation by Digital Signal Processing (Tokyo Tech)
Packaging, MMIC, RF Module (AMSYS)	Packaging, MMIC, RF Module (AMSYS)
GaN HPA (NEC)	
Outdoor System Equipment (JRC)	Indoor System Equipment (Sony)
High Gain Arrays (Tokyo Tech.)	Antennas on PCB / Chip (Tokyo Tech)
Propagation Test (Willcom, KDDI lab)	Indoor Demonstration (Sony)

CMOS chips development

chip size (mm x mm)
power consumption (mW)

feasibility study
for indoor syst.

	RF (Tokyo Tech)	BB (Tokyo Tech + Company)
Step 1	90 nm 43 mm² 600 mW	90 nm 98 mm² 450 mW
Step 2	65 nm 38 mm² 560 mW	65 nm 53 mm² 300 mW
Future Study	40 nm 35 mm² 560 mW	40 nm 30 mm² 200 mW

2007
2008
2009~
2009~

Outdoor syst.

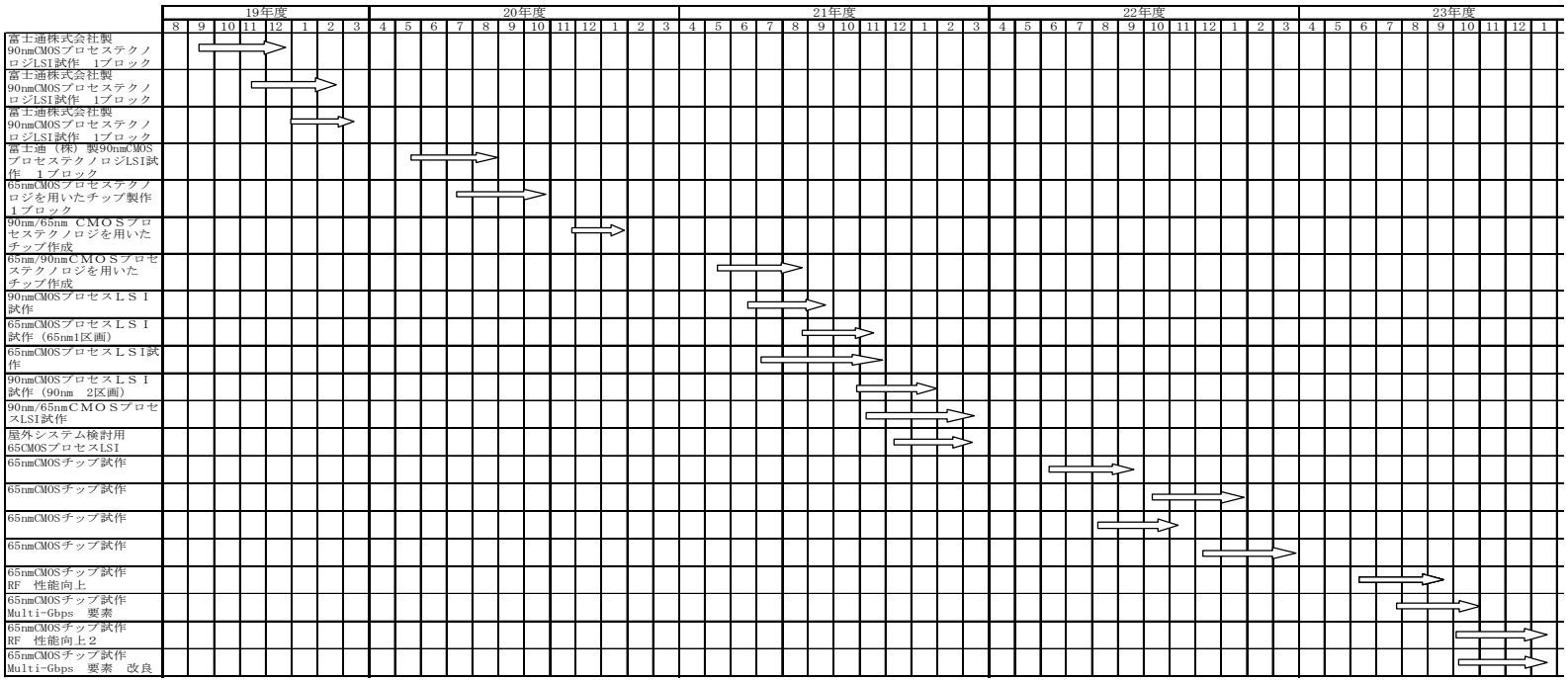
F.Y.2009
38 GHz
600 Mbps
1 km

Indoor syst.

40 nm
(system integrated as including CPU, MAC, interface)
30 mm², 500mW

F.Y.2011
60GHz
2.5 Gbps
1 m

History of CMOS Fabrication



Short-range system spec. example

Item	Specification	Unit	Note
Ch./Transmit mode	IEEE802.15.3c base		Symbol rate：1.728Gsps
Transfer distance	≦1	m	Max. distance ≦ 3m
Modulation	π /2 – QPSK Single carrier		Transmission rate：3.456Gbps
Error correction	LDPC(1440, 1344)		Information rate：3.225Gbps
Tx. Output power	3	mW	(4.8dBm), @3dB back-off
Tx /Rx Antenna gain	>6	dBi	Each (for bi-directional transmission)
Rx NF	<10	dB	
Rx input level	-60 ～ -25	dBm	5cm～3m transmit distance range
Phase noise	< -85	dBc/Hz	@1MHz offset
ADC effective bit	>5	bit	
power consumption	<500	mW	Module power total (RF+BB)
Chip size	<3 x3	mm2	RF/BB each chip
Required C/N	8.5	dB	@BER=1e-6, LDPC(1440, 1344)

Global COE International Symposium PICE

The International Workshop of Millimeter Wave Wireless Technology and Applications

December 6, 2010, Tokyo Institute of Technology, Japan

In corporation with Ministry of Internal Affairs and Communications

APS IEEE MTT-S SSCS APMC 2010 Dec.7-10 YOKOHAMA JAPAN EiC

Session 1: Key Note Speech Chair: Prof. K. Araki

- (9:00-9:20) Prof. Makoto Ando (Tokyo Tech., Japan)
- (9:20-9:40) Prof. Akira Matsuzawa (Tokyo Tech., Japan)
- (9:40-10:15) Prof. Asad Abidi (UCLA, USA)

Session 2: Research & Development in the World Chair: Prof. K. Okada

- (10:35-11:10) Prof. Roberto Sorrentino (Univ., Perugia, Italy)
- (11:10-11:45) Prof. Shuzo Kato (Tohoku Univ., Japan)
- (11:45-12:20) Prof. Wei Hong (Southeast Univ., China)

- (12:20-13:40) Poster Session (Royal Blue Hall)
  and Technical Demo (Corridor)

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Session 3: Millimeter-wave Comm. Systems Chair: Mr. Taniguchi

- (13:40-14:15) Ph.D Yorgos Palaskas (Intel, USA)
- (14:15-14:50) Prof. Shiban K. Koul (IIT Delhi, India)
- (14:50-15:15) Mr. Fumio Ozawa (JRC, Japan)
- (15:15-15:40) Dr. Makoto Noda (Sony, Japan)

Session 4: Constituent Technologies Chairs: Prof. J. Hirokawa
Prof. K. Fukawa

- (16:00-16:35) Dr. Sohrab Emami (Sibeam, USA)
- (16:35-17:10) Prof. Jri Lee (Natl. Taiwan Univ., Taiwan)
- (17:10-17:45) Dr. Duixian Liu (IBM Watson, USA)
- (17:45-18:05) Prof. Jiro Hirokawa (Tokyo Tech., Japan)
- (18:05-18:25) Prof. Kenichi Okada (Tokyo Tech., Japan)
- (18:25-18:45) Dr. Satoshi Suyama (Tokyo Tech., Japan)

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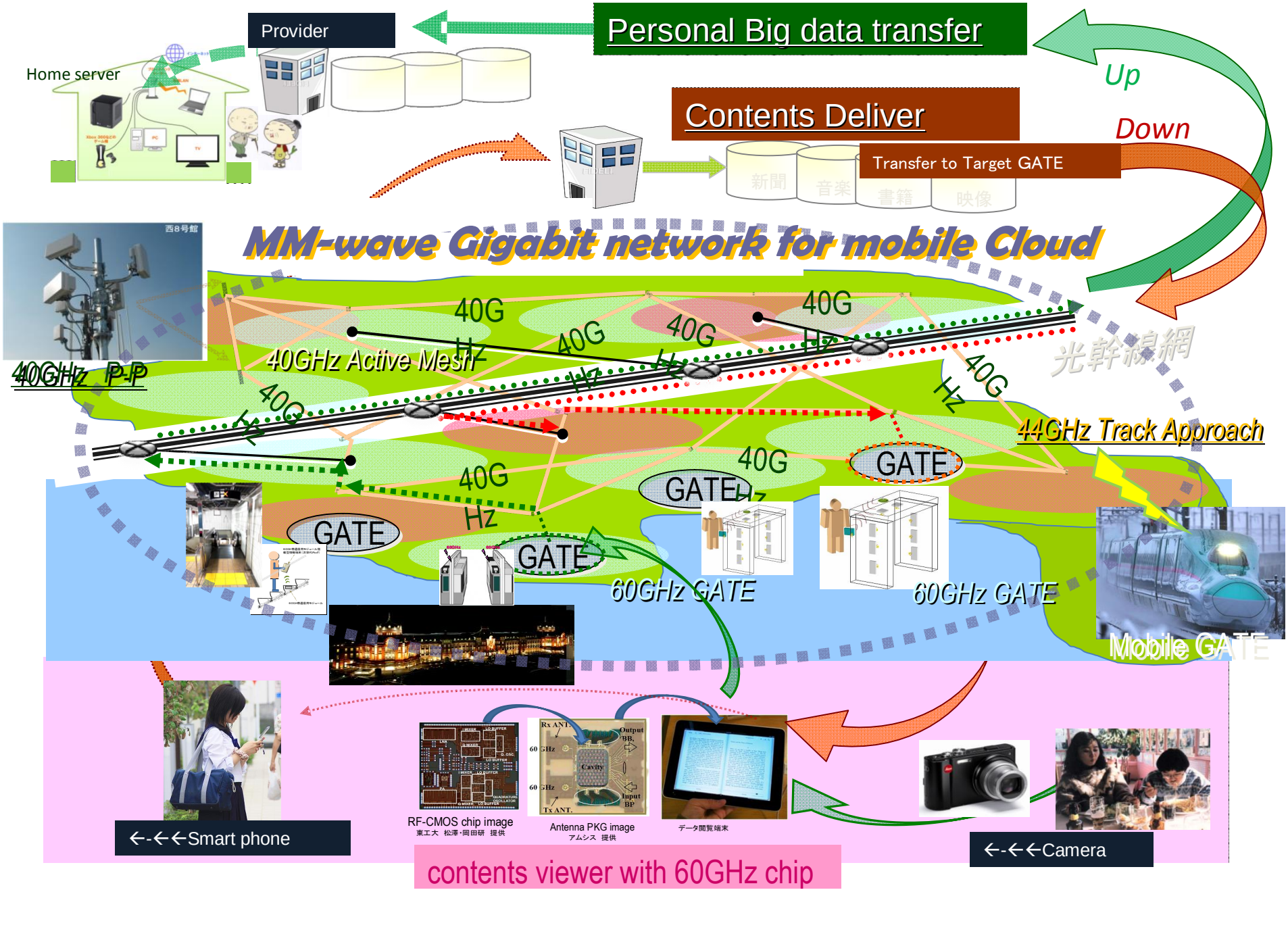
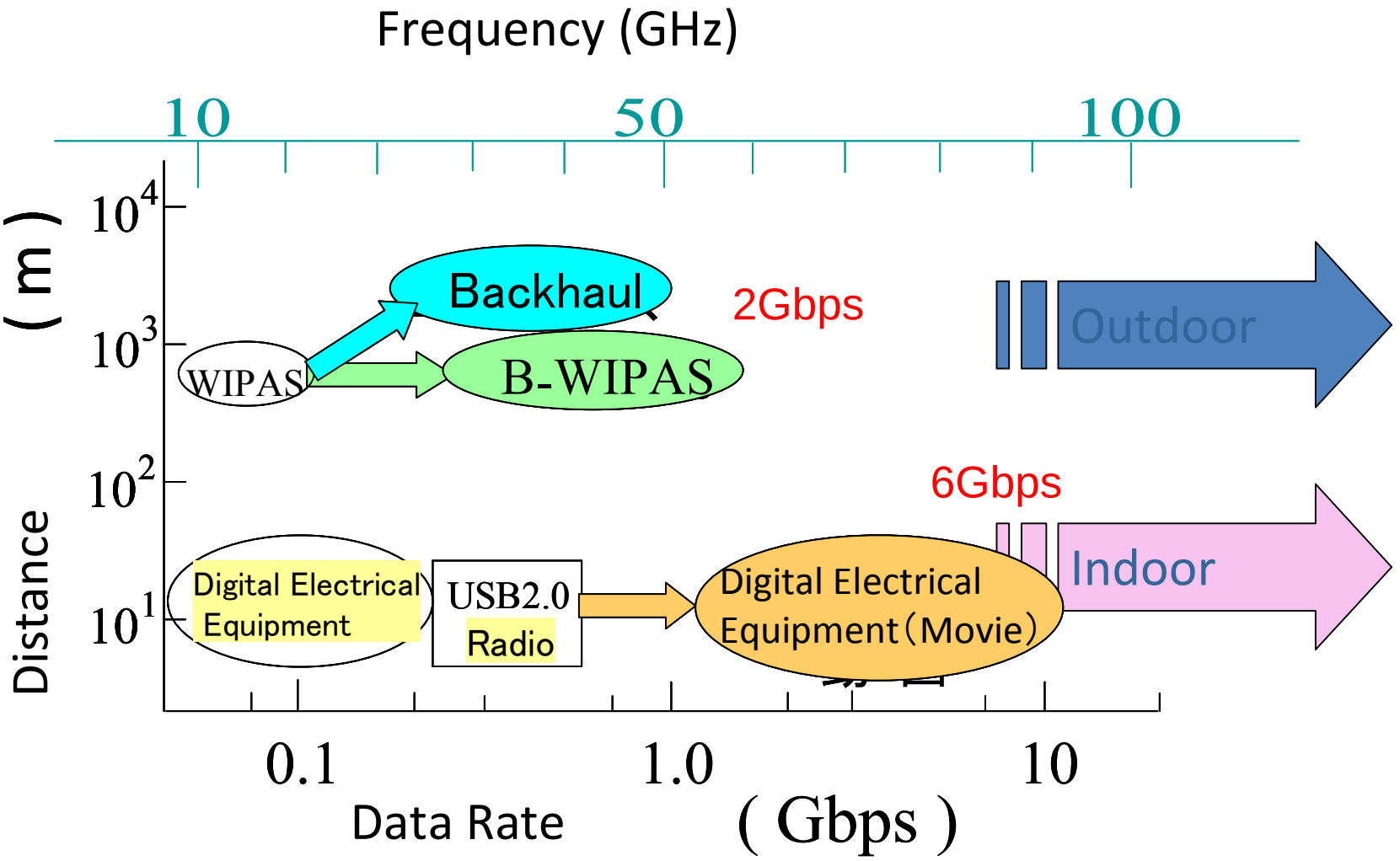
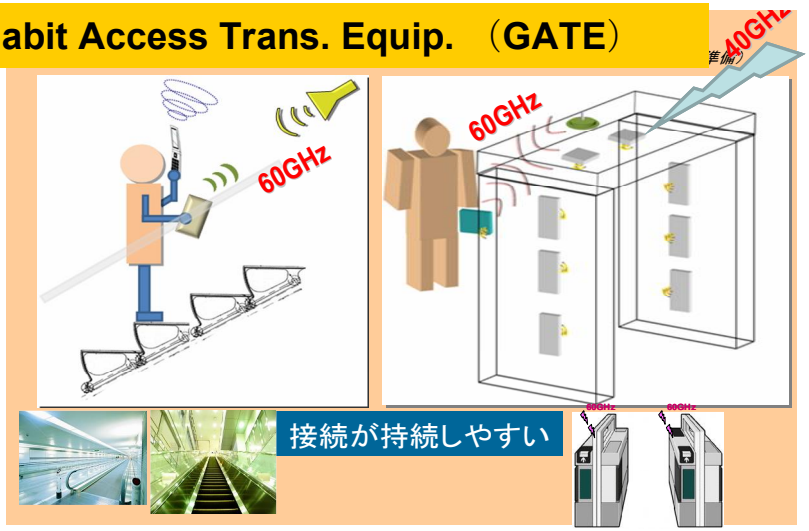
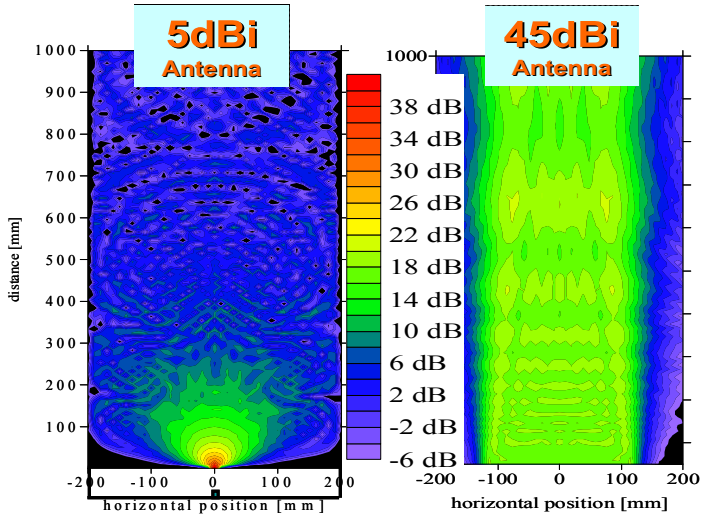
MM-wave Gigabit network image 40GHz & 60GHz



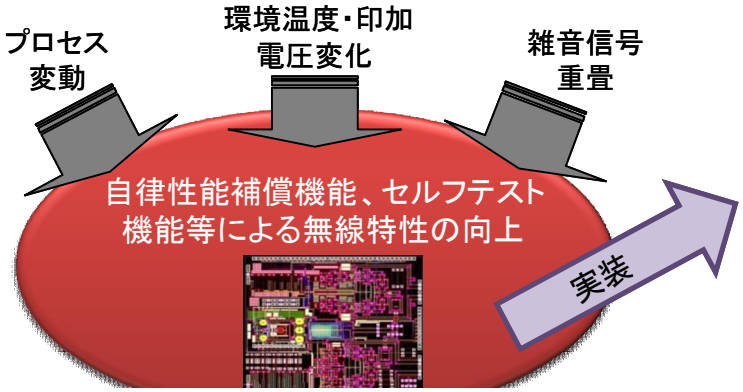

Frequency (GHz)
10
50
100
(m)
10^4
10^3
10^2
10^1
Distance
Backhaul
2Gbps
WIPAS
B-WIPAS
Outdoor
6Gbps
Indoor
Digital Electrical Equipment
USB2.0 Radio
Digital Electrical Equipment（Movie）
0.1
1.0
10
Data Rate
(Gbps)

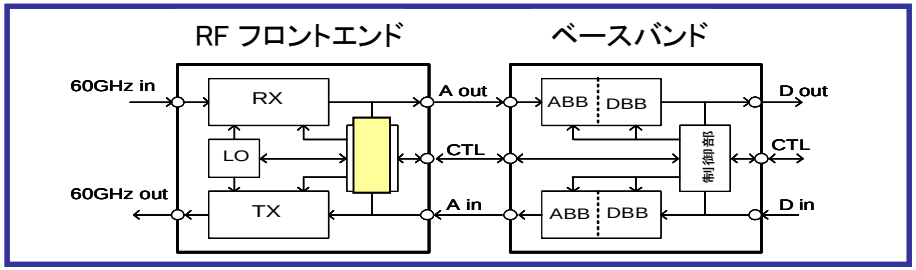
Gigabit Access Trans. Equip. （GATE）





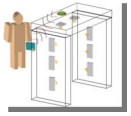
○ Highly Intelligent CMOS 60GHz RF Frontend and BB Chip





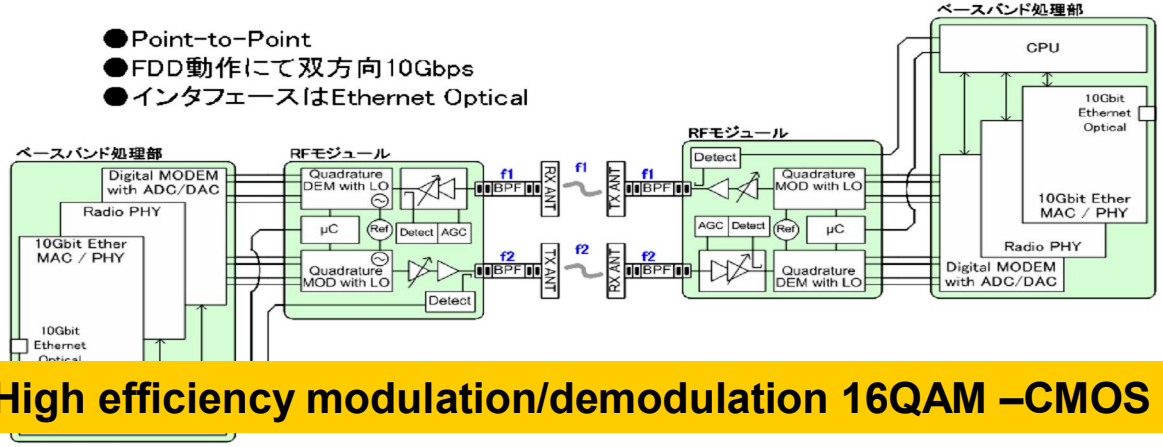
搭載

携帯端末



無線アクセスゲート

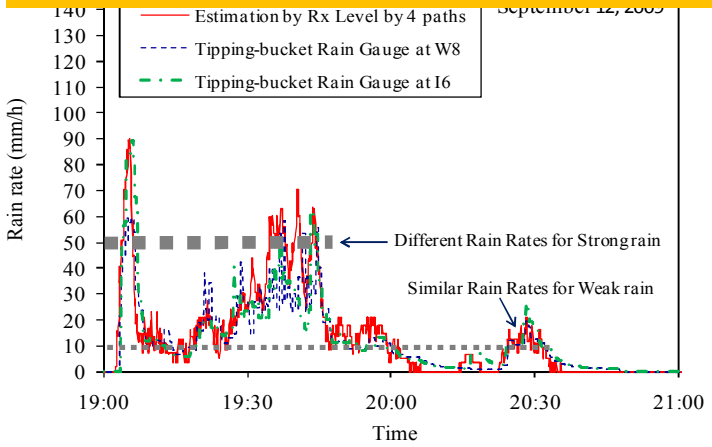
- Point-to-Point
- FDD動作にて双方向10Gbps
- インタフェースはEthernet Optical

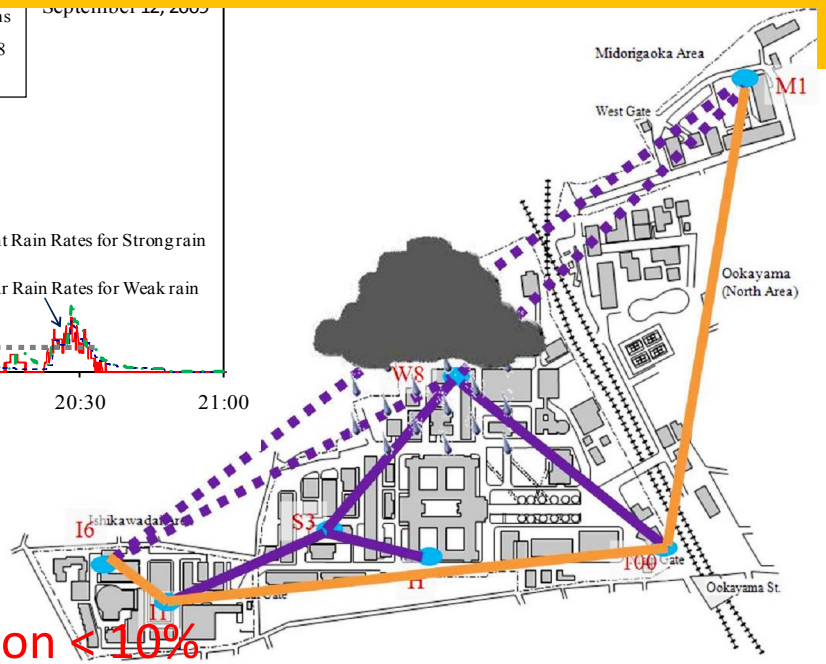


6Gbps, 0.5W, GATE

High efficiency modulation/demodulation 16QAM –CMOS Phase noise, IQ-imb., Propagation

Network operation, Proactive routing against Rain

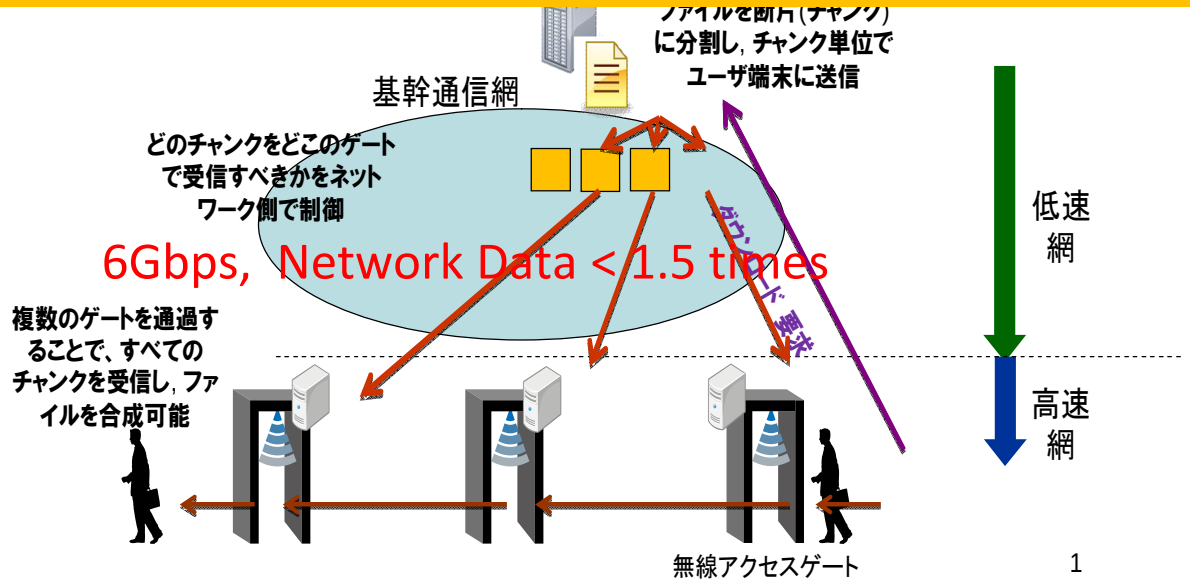




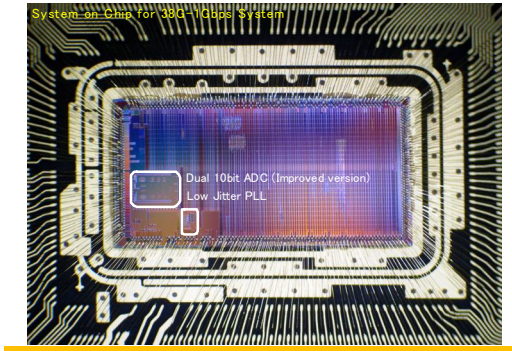
Throughput reduction <10%

40GHz 64QAM DDD System
1Gbps x 2

Network operation, Gate data handling in the network



1Gbps x2, 260MHz



実績
10bit
ADC

AD Cov. 12bit 800Msps for DDD System 1.6w→0.15w