Unlocking Millimetre Wave Spectrum for 5G in Europe

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Ilmenau, Germany

5G Service Vision

Enabling the Immersive Service Experiences

Ubiquitous Health Care

Wearable/Flexible Mobile Device

Mobile Cloud

UHD Video Streaming

Smart Map/Navigation

Real-Time Interactive Game

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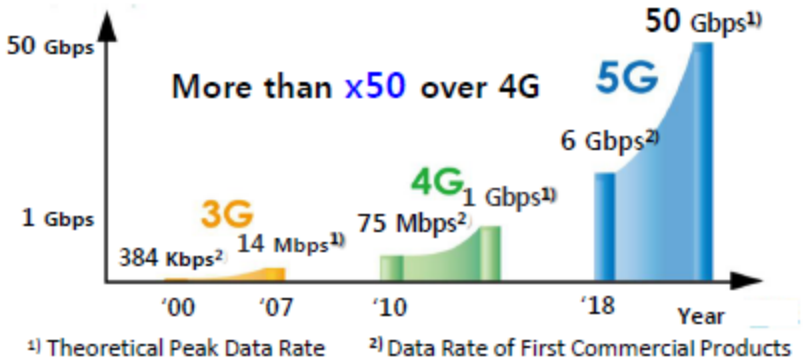
5G Key Performance Targets

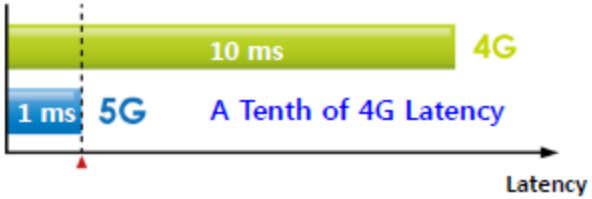
- Providing Gigabit Experience to Users Anywhere

5G Performances

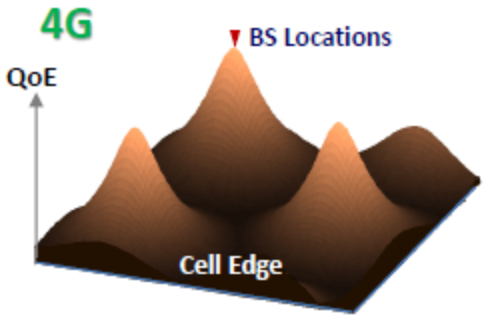
Peak Data Rate > 50 Gbps



Latency < 1 msec



Anywhere 1 Gbps



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Spectrum remains a key challenge

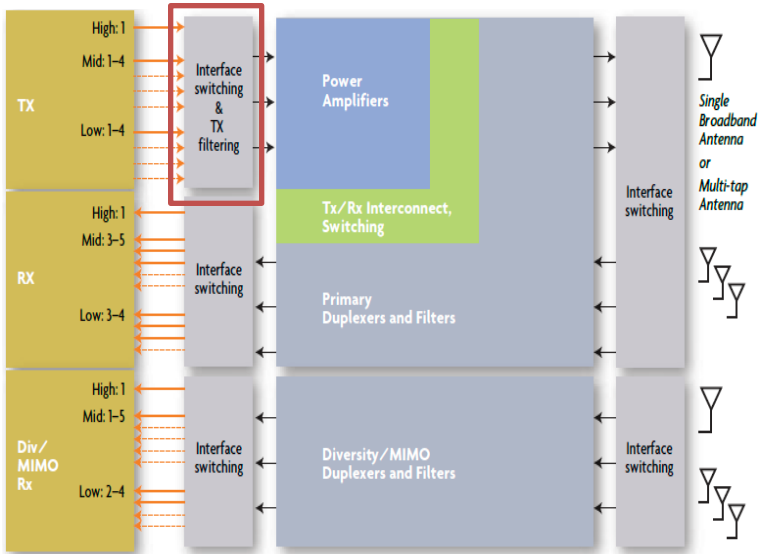
Fundamental limits in using spectrum below 7 GHz for 5G

- Limit in expanding bandwidth: Carrier aggregation degrades system performance
- Significant increase in modem cost due to increased RF front-end complexity

Performance degradation in carrier aggregation

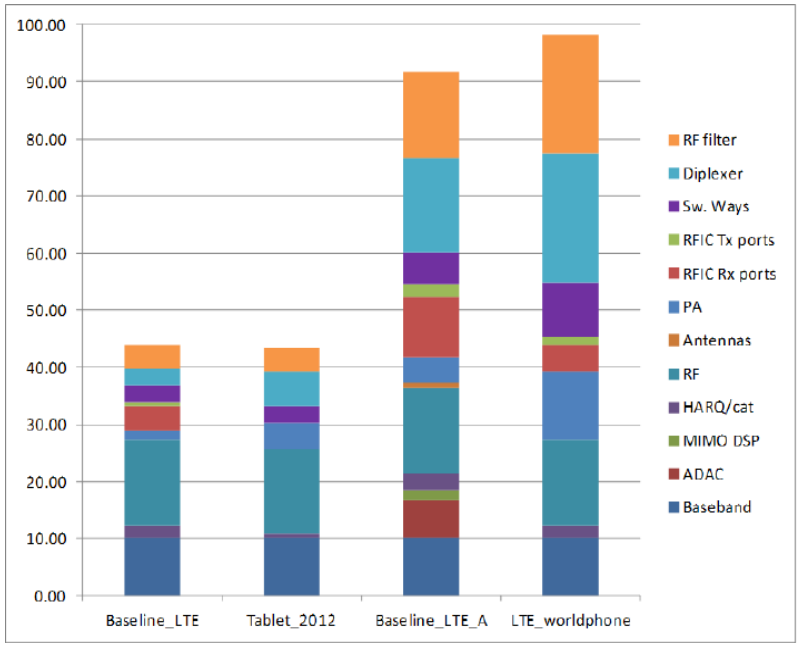
▷ **Switch loss (1dB per switch)**

▷ **Power amplifier & antenna inefficiency**



※ SiGNALS Ahead, "Improve Your [RF] Front-end in Seven Easy Steps!", May 23, 2012 Vol.8 No.6

Impact of the number of bands on the cost of LTE modems



※ *RF Front End Technology Challenges ICT KTN-Cambridge Wireless joint Position Paper, December 2012*

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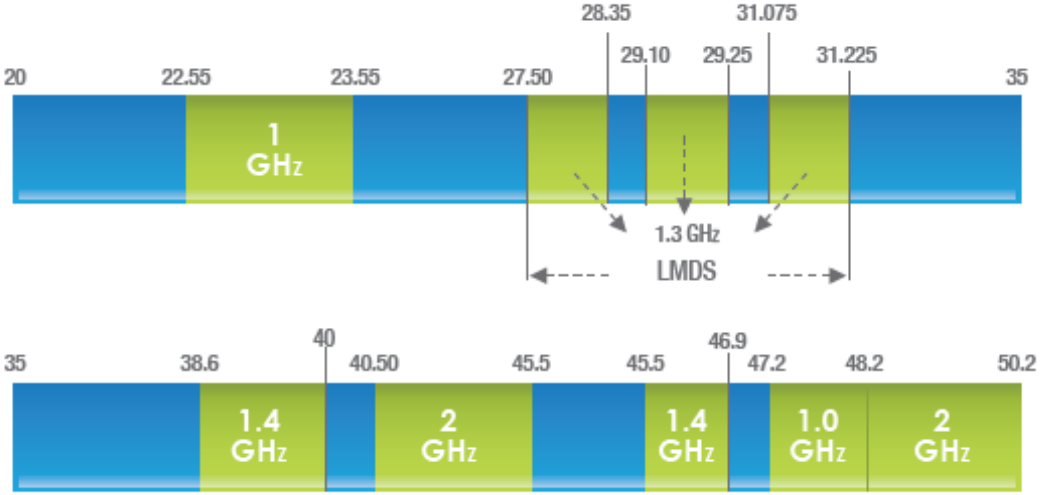
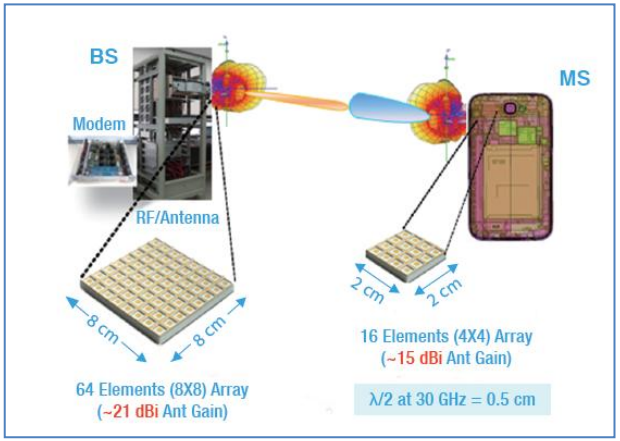
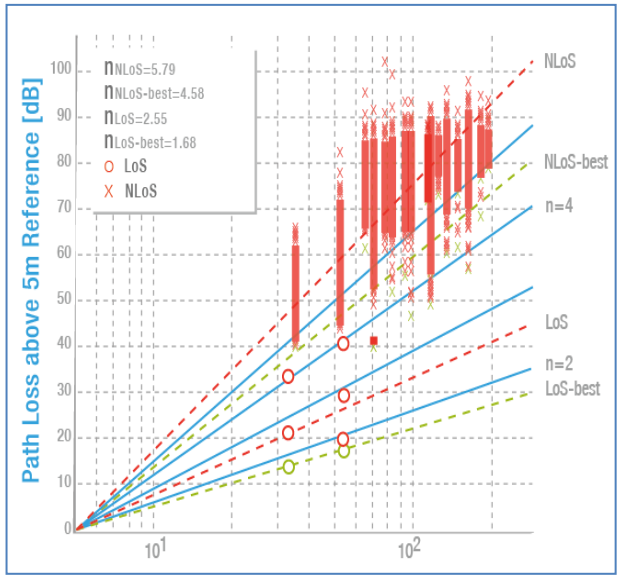
Unlocking mm-Wave spectrum for 5G





- ▷ *The mm-Wave bands provided up to 25 times more spectrum than available for 4G*
- ▷ *Very large blocks of* contiguous *spectrum to support future applications*
- ▷ *Small wave-length makes possible use of large antenna arrays for adaptive beam forming*
- ▷ *Propagation exponent is very similar to spectrum below 7 GHz, as long as beam forming is maintained between BS and terminal*



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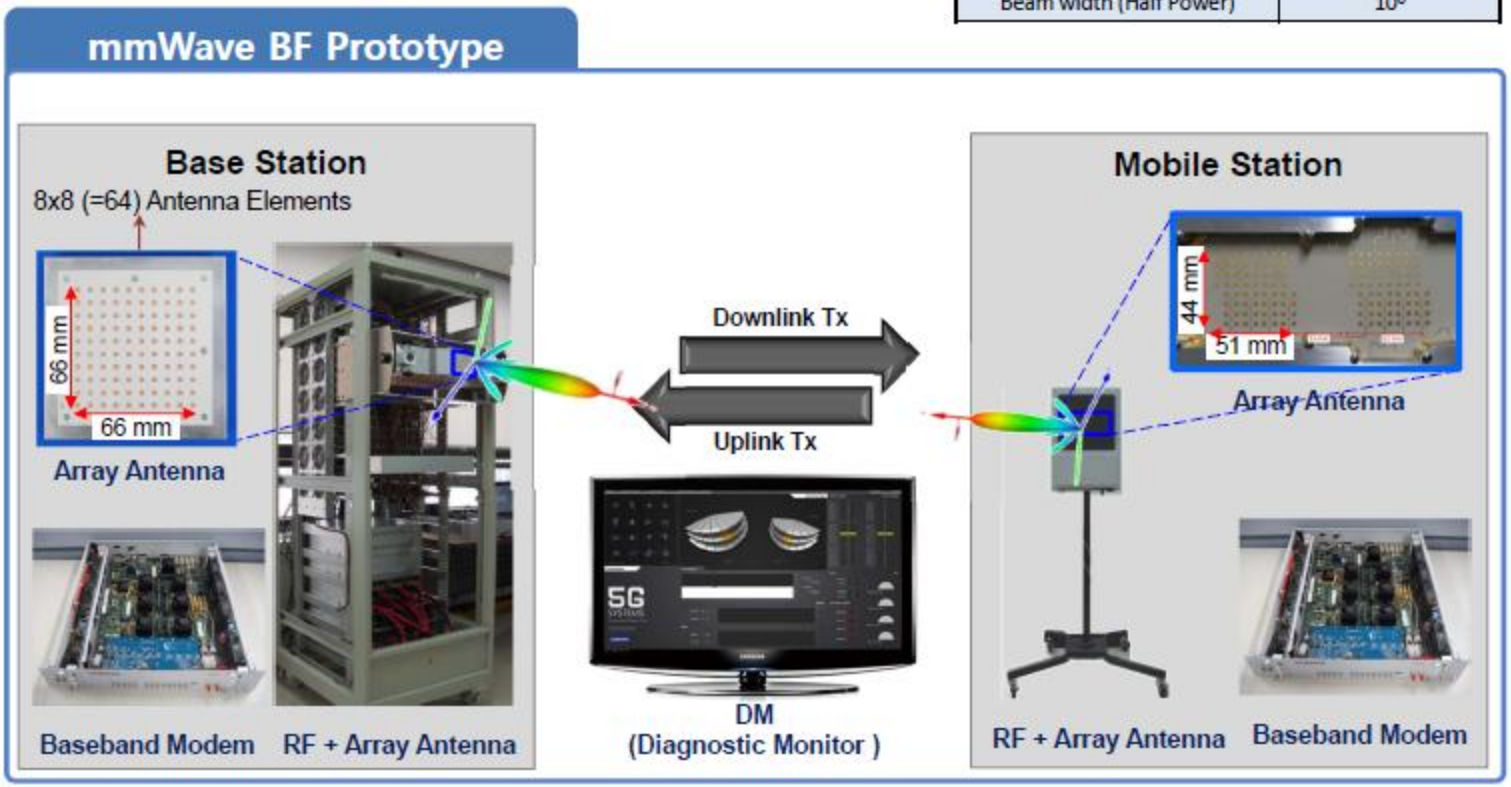
mmWave mobile communication prototype

- **World's First mmWave Mobile Technology**
  - Adaptive array transceiver technology operating in the millimeter-wave frequency bands for outdoor cellular

Carrier Frequency	27.925 GHz
Bandwidth	500 MHz
Max. Tx Power	37 dBm
Beam width (Half Power)	10°



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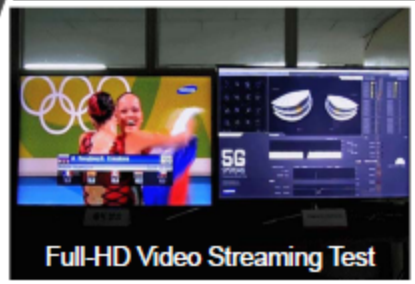
- **Performance Tests of mmWave OFDM Prototype**
  - OFDM system parameters designed for mmWave bands
  - Indoor & outdoor measurements performed for data rates and transmission ranges

System Parameters & Test Results

PARAMETER	VALUE
Carrier Frequency	27.925 GHz
Bandwidth	500 MHz
Duplexing	TDD
Array Antenna Size	8x8 (64 elements) 8x4 (32 elements)
Beam-width (Half Power)	10°
Channel Coding	LDPC
Modulation	QPSK / 16QAM

PARAMETER	VALUE	REMARKS
Supported Data Rates	1,056Mbps 528Mbps 264Mbps	
Max Tx Range	Up to 2Km @ LoS	>10 dB Tx power headroom



Full-HD Video Streaming Test

Measurements with DM

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Test Results – Range

Outdoor Line-of-Sight (LoS) Range Test

- Error free communications possible at 1.7 km LoS with > 10dB Tx power headroom
- Pencil BF both at transmitter and receiver supporting long range communications

LoS Range

☐ **Support wide-range LoS coverage**

✓ 16-QAM (528Mbps) : BLER 10^{-6}

✓ QPSK (264Mbps) : Error Free

BLER : Block Error Rate QPSK : Quadrature Phase Shift Keying QAM : Quadrature Amplitude Modulation

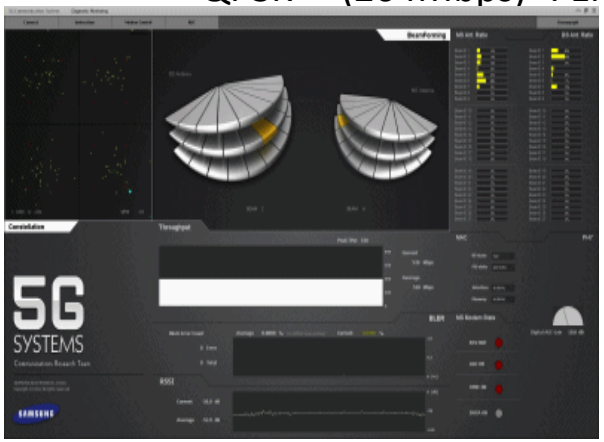
Test Results – Mobility

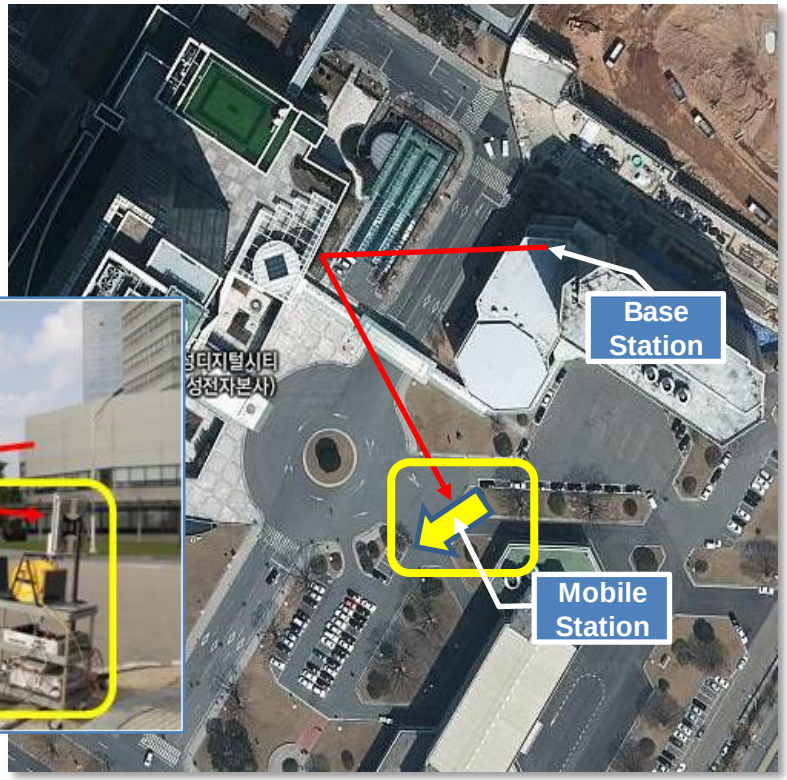
- **Outdoor Non-Line-of-Sight (NLoS) Mobility Tests**
  - **Adaptive Joint Beamforming & Tracking Supports 8 km/h Mobility even in NLOS**

Mobility Support in

☐ **Mobility support up to 8 km/h at outdoor NLoS environments**

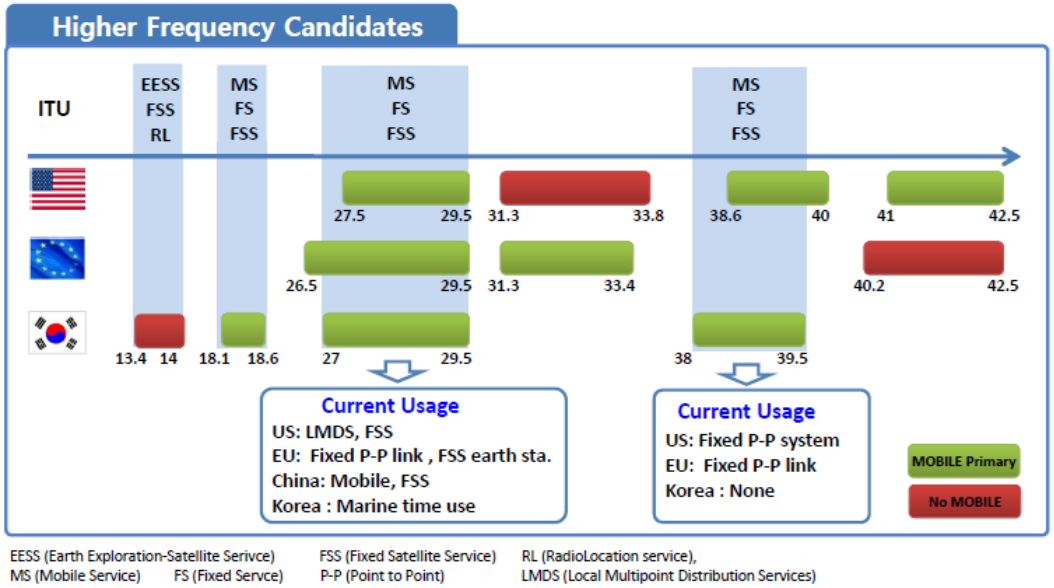
- ✓ 16-QAM (528Mbps) : BLER 0~0.5%
- ✓ QPSK (264Mbps) : Error Free

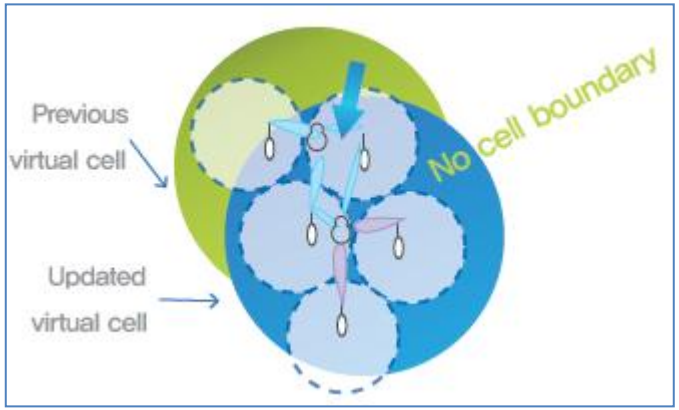




[DM Screen during Mobility Test]

Mm-wave 5G opportunities & research challenges





Advanced cooperation between base stations to realize virtual cell concept ("edge –less" user experience)

Multi-tier and multi-frequency network architectures including mm-wave overlay

- ▷ *The lower mm-Wave bands are already allocated to other services (mobile backhaul, Satellite)*
- ▷ *Feasibility of sharing need to be researched*
- ▷ *Sharing mechanism will be required, e.g. cognitive radio techniques, databases , interference cancellation*
- ▷ *Opportunity to develop shared use of mm-Waves for both backhaul and access, hence enabling fast spectrum release*

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In summary

- **Samsung is putting significant resources into collaborative 5G R&D in Europe, H2020 (5G PPP), 5GIC (UK)**
  - Building consensus on challenges and solutions
  - Global standards and harmonization
  - re-grow Europe's status as the leader in cellular technology
- **MmWave shows exceptional promise as a key component for 5G**
  - Order of magnitude improvements in system capacity leading to ***significant cost/bit reduction***
  - Support of cost-efficient wireless backhaul for ***network scalability*** and advance cooperation ("edgeless" user experience)
  - Many remaining challenges and great opportunities for high-impact R&D

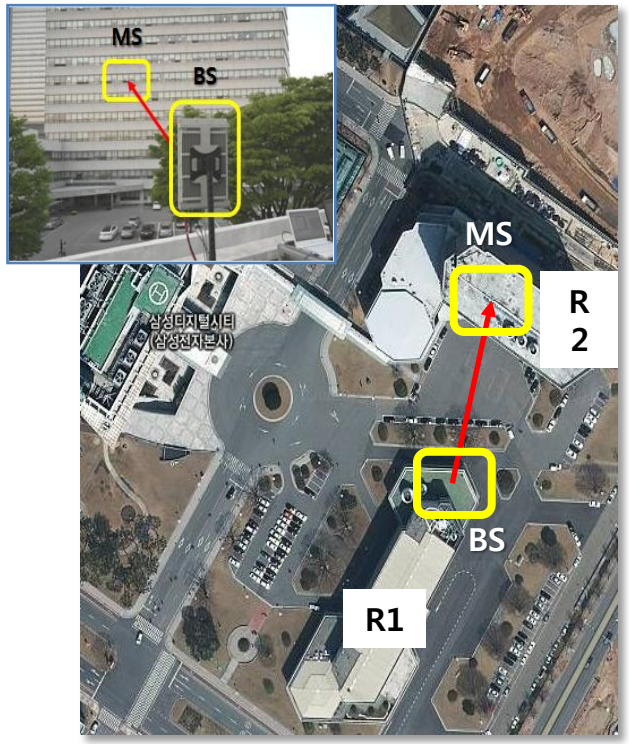
Outdoor-to-Indoor Penetration Tests

- Most Signals Successfully Received at Indoor MS from Outdoor BS
- Outdoor-to-indoor penetration made through tinted glasses and doors

Outdoor to Indoor #1

☐ **Signal measured inside office on 7th FL of R2**

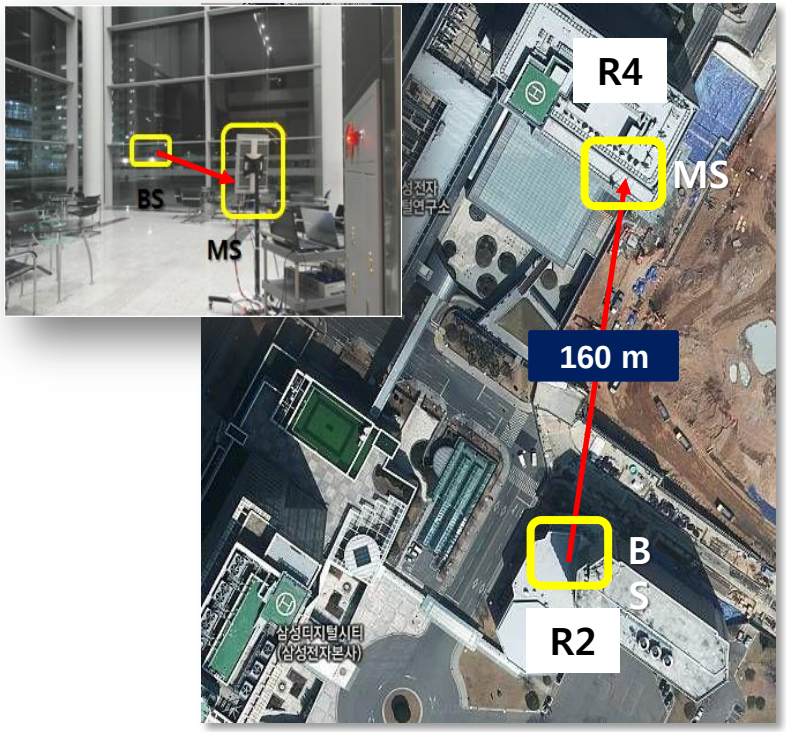
- QPSK : BLER 0.0005~0.6% (Target : < BLER 10%)



Outdoor to Indoor #2

☐ **Signal measured inside the lobby at R4**

- QPSK : BLER 0.0005~0.3% (Target : < BLER 10%)



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