ATSC 3.0 Direct-to-Vehicle (D2V) Field Evaluation Results

Sunhyoung Kwon

Media Research Division
Electronics and Telecommunications Research Institute (ETRI)

Way to Mobile

ATSC 3.0 Solutions for Handheld DTV

ATSC 3.0 Dongle

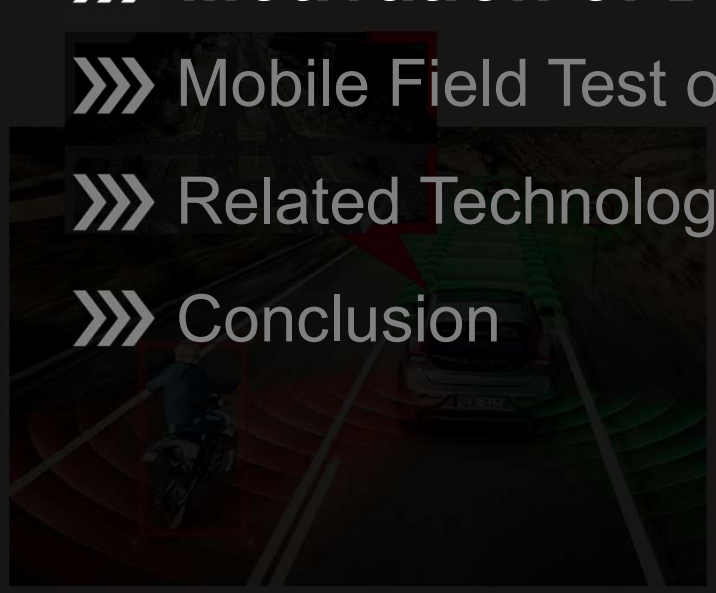
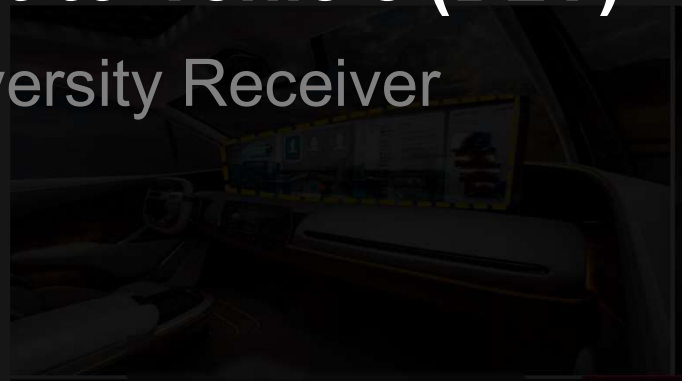
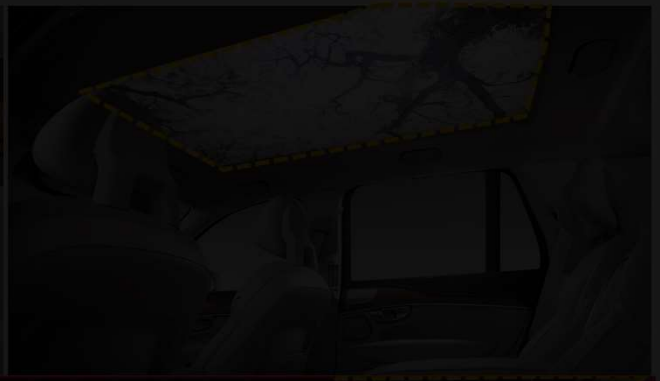
ATSC 3.0 Home-Gateway

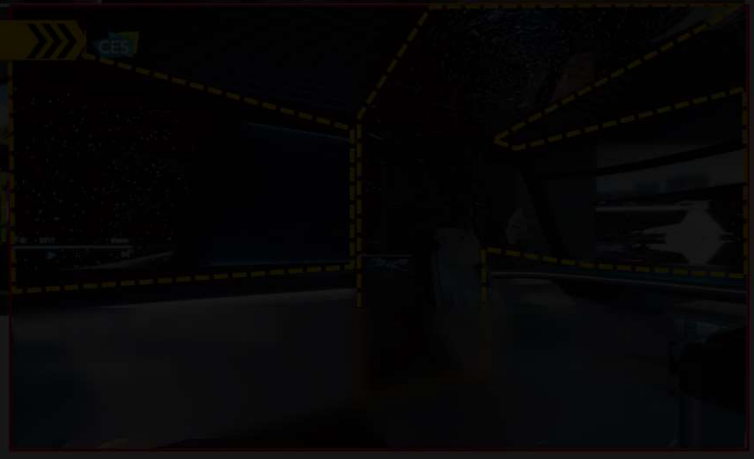
Demos – Raleigh, Maryland, Vegas, Seoul, etc.

MarkOne - SBG

ATSC 3.0
ADVANCED TELEVISION SYSTEMS COMMITTEE

- **Motivation of Direct-to-Vehicle (D2V)**
- Mobile Field Test of Diversity Receiver
- Related Technologies
- Conclusion

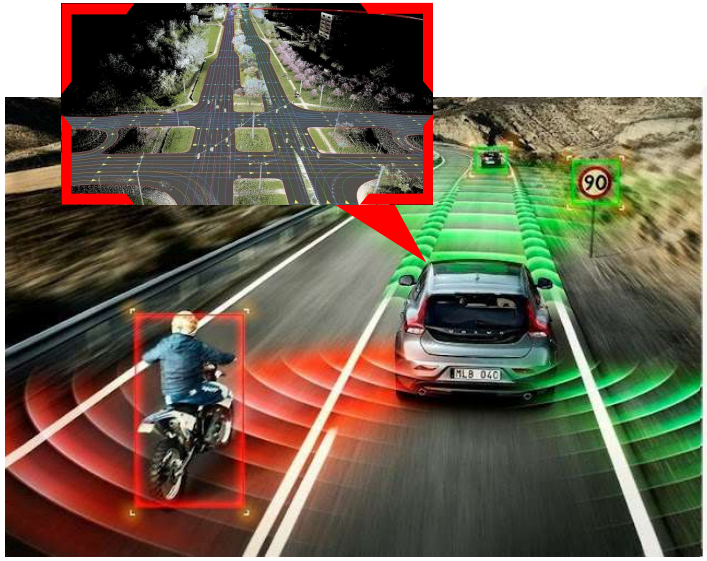






Media-in-Vehicle: Spotlight on Automotive Infotainment

Rise of Self-Driving Technology

Emerging market for Media & Entertainment (M&E) verticals



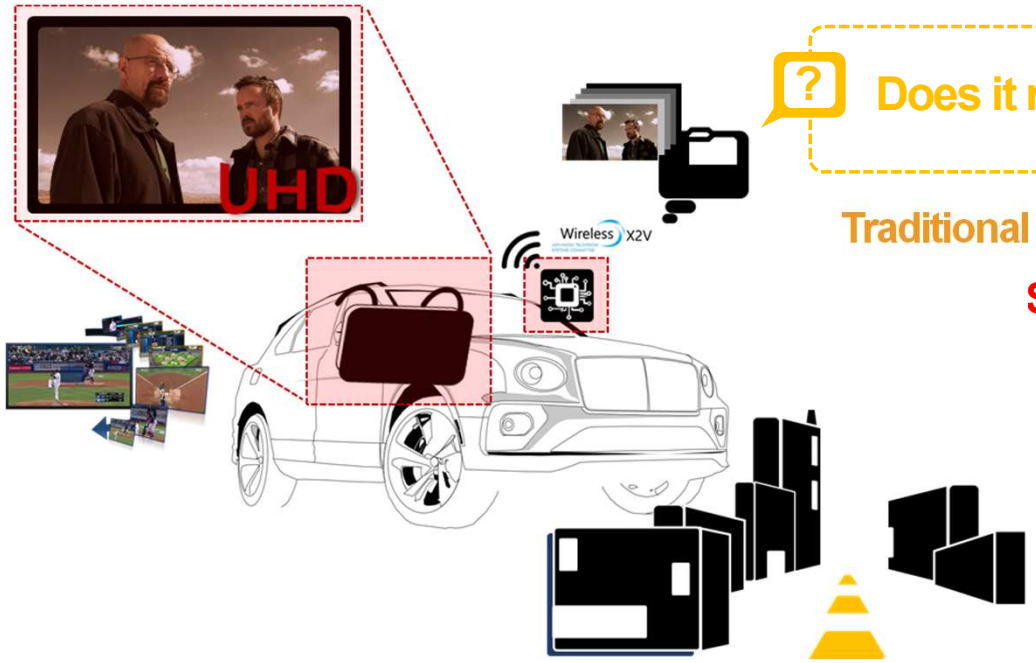
Been Free from Driving

- Display Screen Getting Larger
- Transforming into a **Moving Cinema**

Where are We at? – ATSC 3.0 for D2V

Direct-to-Vehicle (D2V) on the Table

- **ATSC 3.0 has imagined mobile broadcasting from the design stage**
  - Ultra-robust transmission mode is available
  - Short channel codes are available



Does it really work in the real world?

Traditional Problem. Mobile vulnerability of linear downlink systems

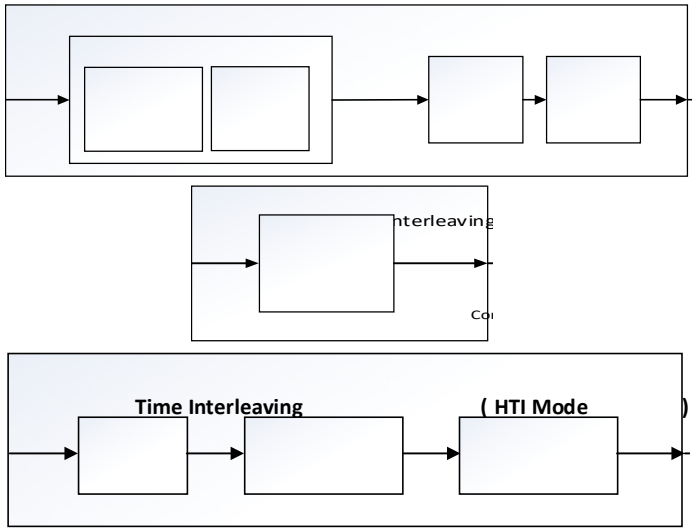
Solutions

- ✓ Enhanced robustness Powered by ATSC 3.0
- ✓ Diversity reception
  - Perfectly fits the vehicle-target plans

Diversity Technologies in ATSC 3.0 System

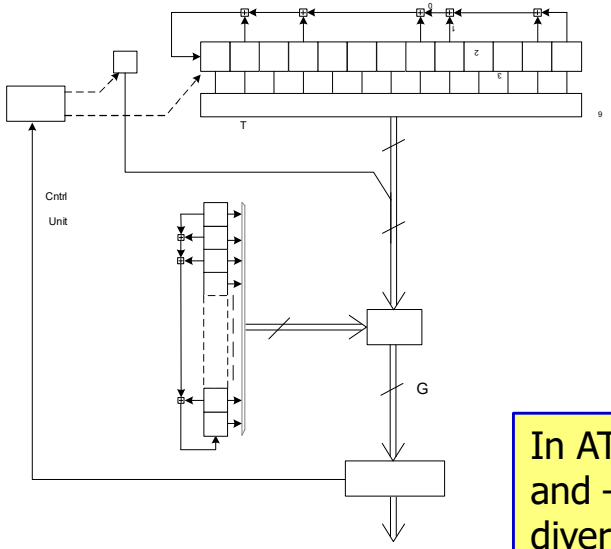
Time Diversity

- Message is spread in time by means of bit/time-interleaving, and then burst errors are avoided
- Time diversity in ATSC 3.0
  - ✓ Bit-interleaver
  - ✓ Time-interleaver (CTI or HTI)



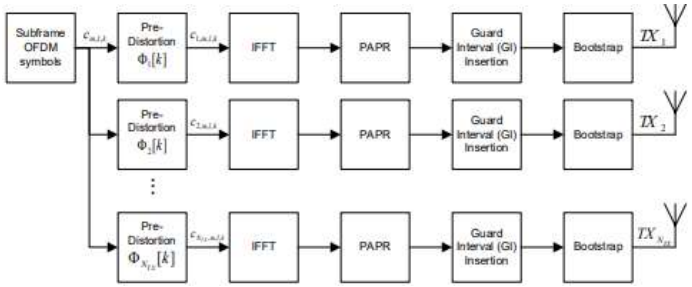
Frequency Diversity

- Message is spread in frequency by means of frequency-interleaving, and then burst errors are avoided
- Frequency diversity in ATSC 3.0
  - ✓ Frequency-interleaver



Antenna Diversity

- Message is spread in space by means of multiple antennas
- Antenna diversity in ATSC 3.0 (transmitter side)
  - ✓ SFN (single Frequency Network)
  - ✓ TDCFS (transmit diversity coded filter sets)-based MISO



In ATSC 3.0 system, there exist very well-designed and –optimized time/frequency/transmit-antenna diversity technologies. Receiver antenna diversity can further improve ATSC 3.0 system performance.

Diversity Receiver with Multiple Rx Antennas

Multi-Antenna Diversity – Installing multiple antennas in the end-device

✓ **Signal combining and compensation across the branches**

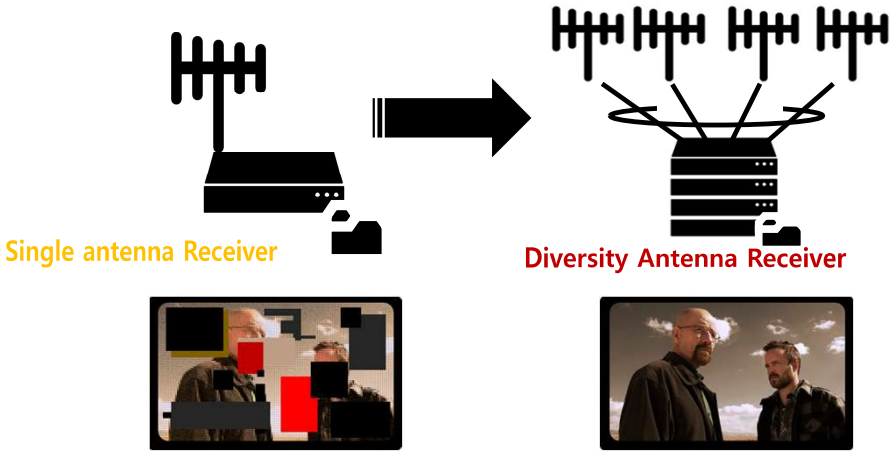
The *"Diversity"* property is preserved if the antennas are (at least) λ/2 apart from each other

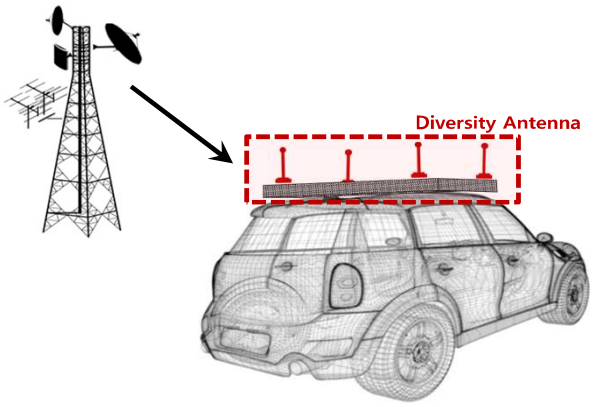
- 600 MHz **UHF**: λ/2 = **25 cm**

➡ **Challenge in physical size**

➡ **Viable use case to bring multi-antenna diversity solution into the real world:**

Vehicle-Type Rx





- Motivation of Direct-to-Vehicle (D2V)
- **Mobile Field Test of Diversity Receiver**
- Related Technologies
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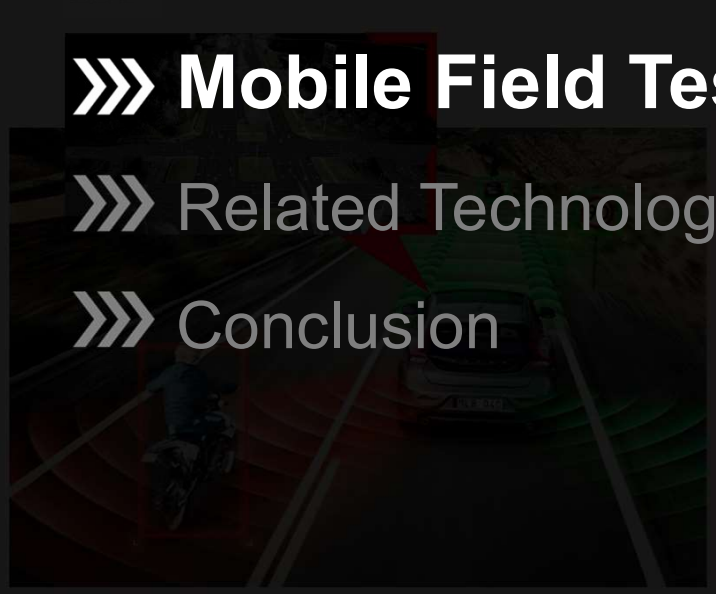
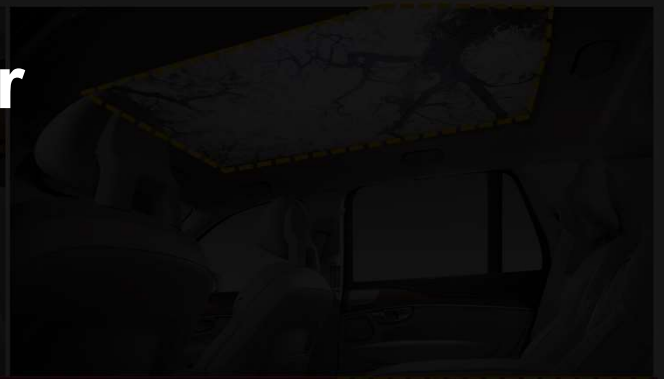
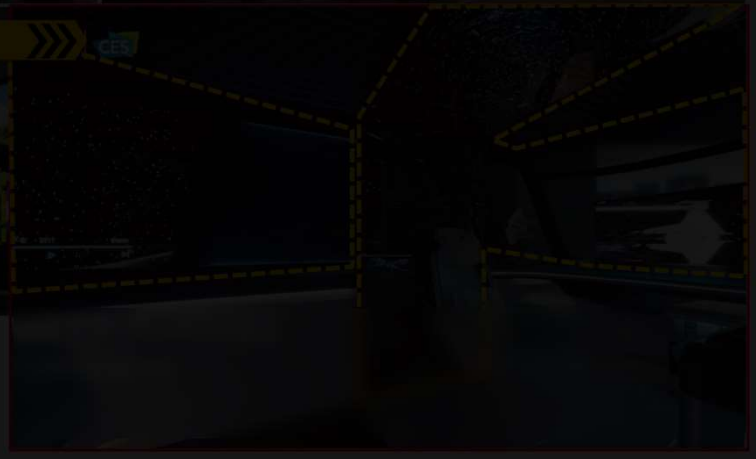




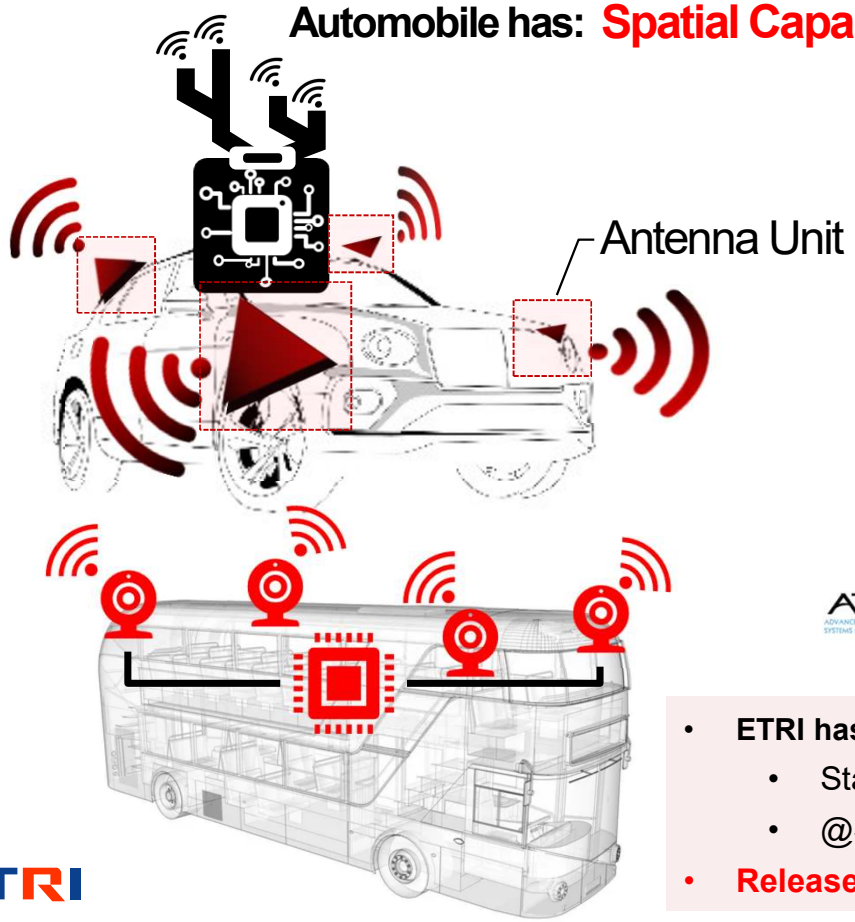


D2V over ATSC 3.0: Antenna Diversity Solution

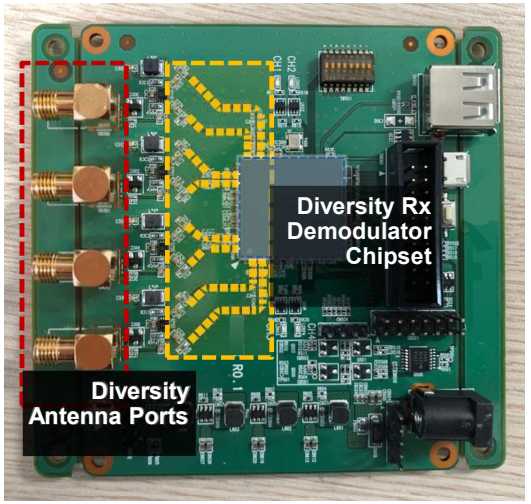
Multi-Antenna Diversity Solution for D2V

Idea. **Installing multiple antennas to enable signal combining**

Automobile has: Spatial Capacity ➡ **Makes sense!**



ATSC 3.0 **FPGA Prototype for Verification (2019)**



Chipset-Based Evaluation Board Kit (2020 ~)

- **ETRI has driven extensive field experiments to verify multi-antenna reception for D2V (’19 ~)**
  - Started from FPGA and evaluated the chipset solution also
  - @Seoul Metropolitan operating SFN, Jeju Island Experimental Network
- **Release of multi-antennas installed car is on track**

ETRI

ATSC 3.0 SFN Configuration in Seoul Metropolitan Area + Gyeonggi-do Province

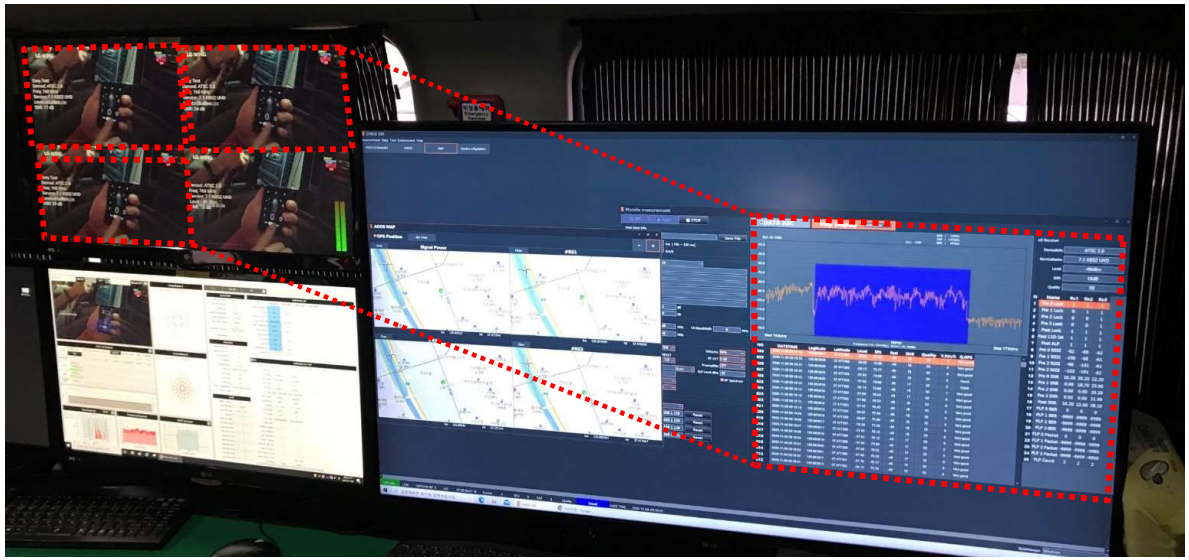
Seoul and Gyeonggi area which has 10 transmitters' SFN

10 SFN transmitters
+ one experimental site

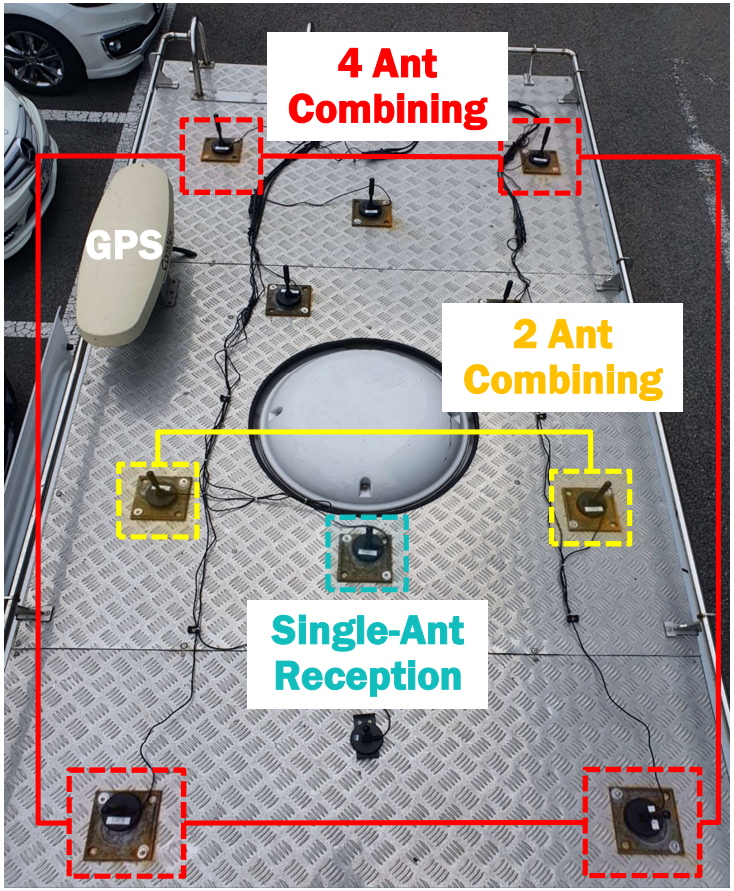
RF Frequency = 768 MHz

Measurement Environment for Multi-Antenna Solution

<Measurement Facility with Diversity Rx Sets>



<Status Monitor: Recorded in Real-Time>



<Receive Antennas on The Car Top>

*The distances between any two antennas should be larger than λ/2

PHY configuration (KBS2 On-Air | Nationwide SFN)

Center Frequency		768 MHz	
Preamble Parameters	FFT Size	8K	
	Guard Interval	GI6_1536 (222 us)	
	Pilot Pattern	Dx = 4	
	L1-Basic	Mode 1	
	L1-Detail	Mode 2	
		Subframe 0 (PLP 0)	Subframe 1 (PLP 1)
Payload Parameters	FFT Size	8K	32K
	Guard Interval	GI6_1536 (222 us)	GI6_1536 (222 us)
	Number of OFDM Symbols	34	38
	Pilot Pattern	SP4_2	SP8_2
	Frequency Interleaver	ON	ON
	Time Interleaver	CTI-1024	CTI-512
	FEC Type	BCH + 16K LDPC	BCH + 64K LDPC
	Code Rate	5/15	8/15
	Modulation Order	64QAM	256QAM
	Data Rate	1.6 Mbps	17.1 Mbps
	Req. SNR (@AWGN)	6.9 dB	14.3 dB

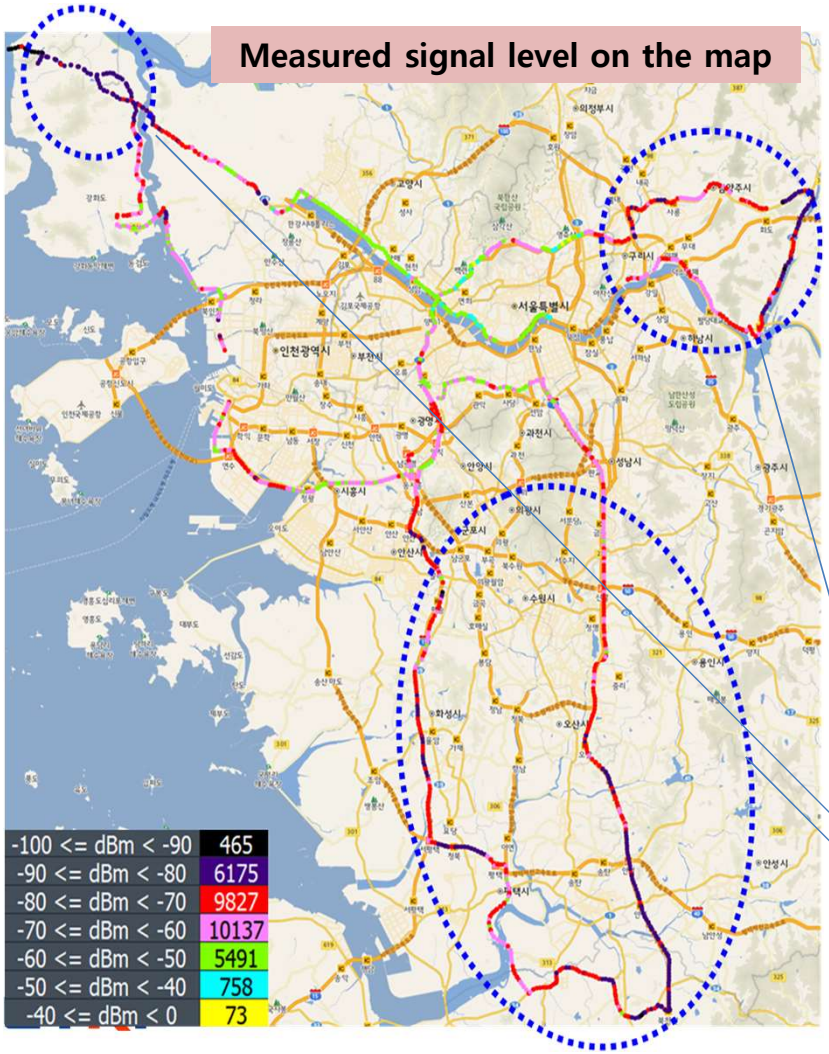
Truly Mobile-Oriented HD Service (1.6 Mbps)

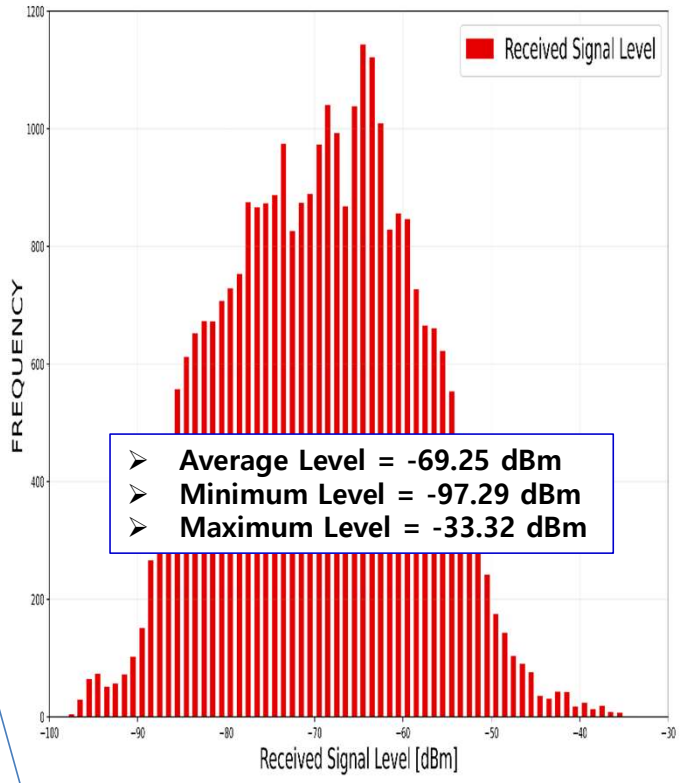
Primary Purpose: Fixed Service 4K-UHD (17.1 Mbps)

- **Field tests were conducted in the HPHT environment (Seoul Metropolitan SFN, South Korea)**
  - Operating public network (commenced in ’17)
  - Verifies feasibility in the wild

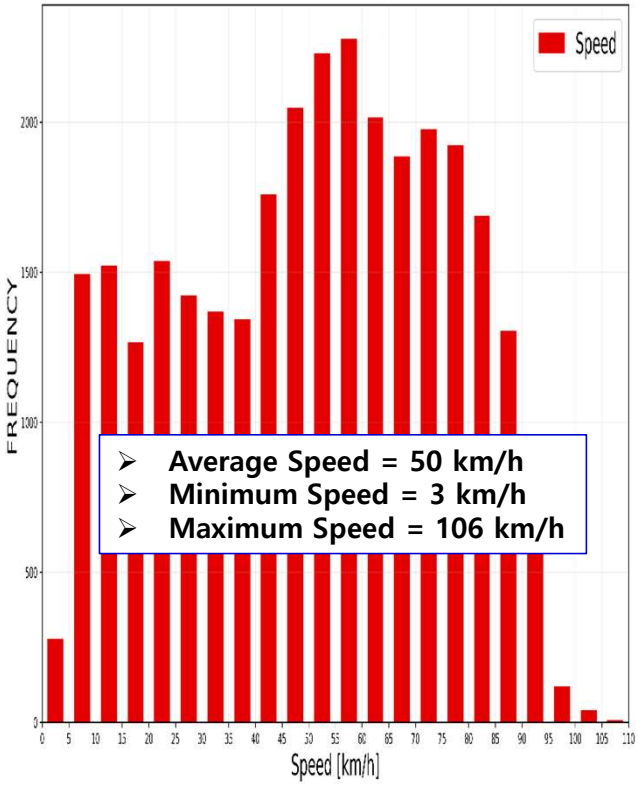
ATSC 1.0 :
19.39 Mbps @ 15.2 dB

Measured Signal Power and Speed for Mobile-Target HD





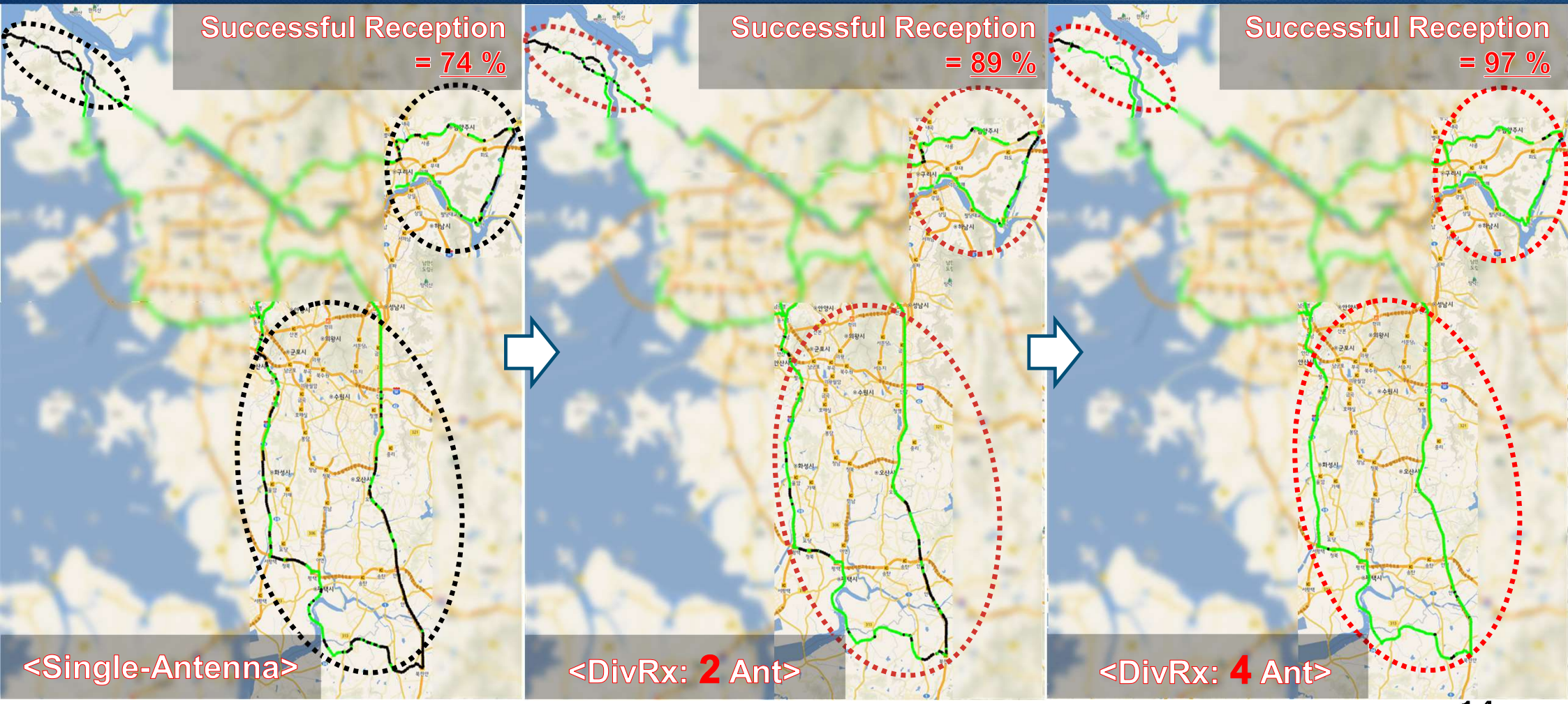
<Measured signal level distribution>



<Test Vehicle Speed Distribution>

Blue-dotted three circles have weak field strength because they are out of SFN coverage now. Especially, the low blue dotted circle belongs to a different province that doesn't have ATSC 3.0 transmitter.

QoS Improvement from DivRx: (1) Mobile-Target HD 1.6 Mbps

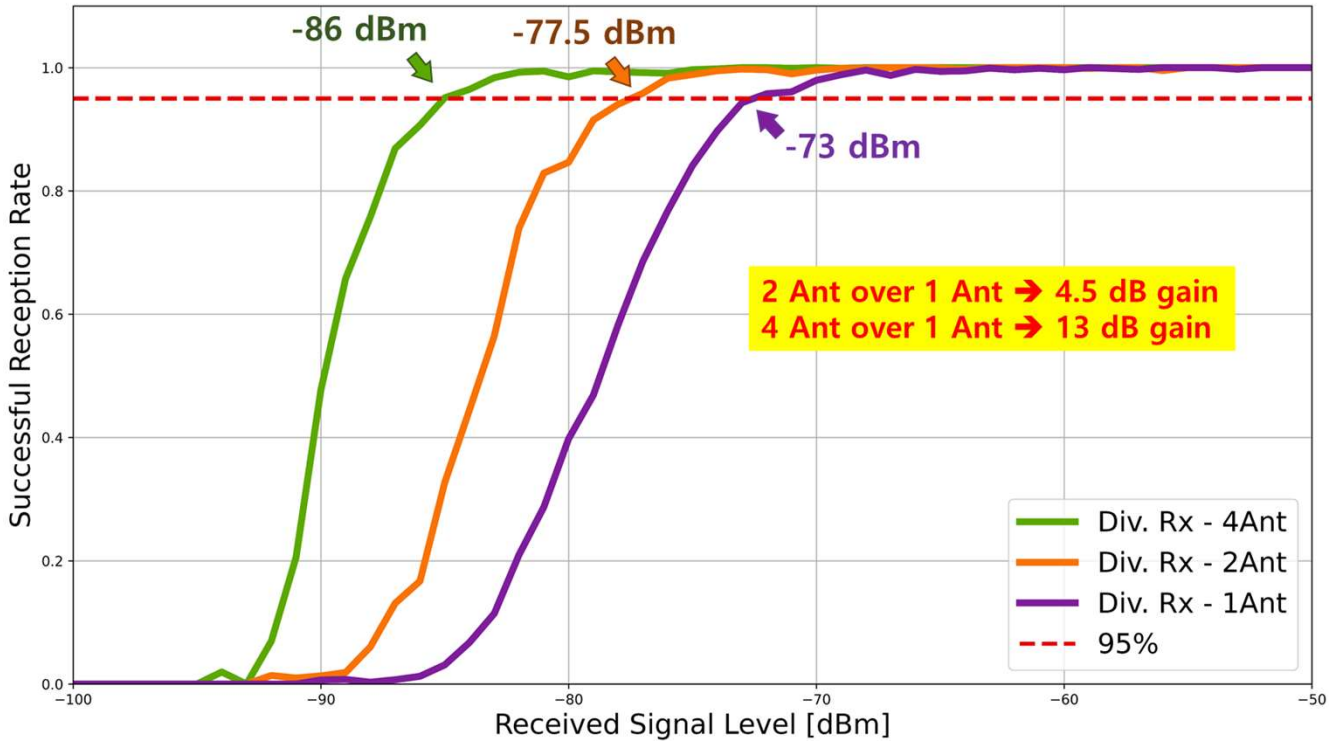


Results were recorded every second | If driving faster than 3 km/h

Reception Success or Failure (Diversity Rx – 1/2/4 Antennas) for Mobile-Target HD Service

➢ Received Signal Level vs ESR5 (erroneous second ratio)

- ESR5 (ITU-R BT.1368) is normally used for quality criteria of mobile reception. Reception success/fail is decided at every one second, i.e., if there is one hit in given one second, reception fail is recorded.

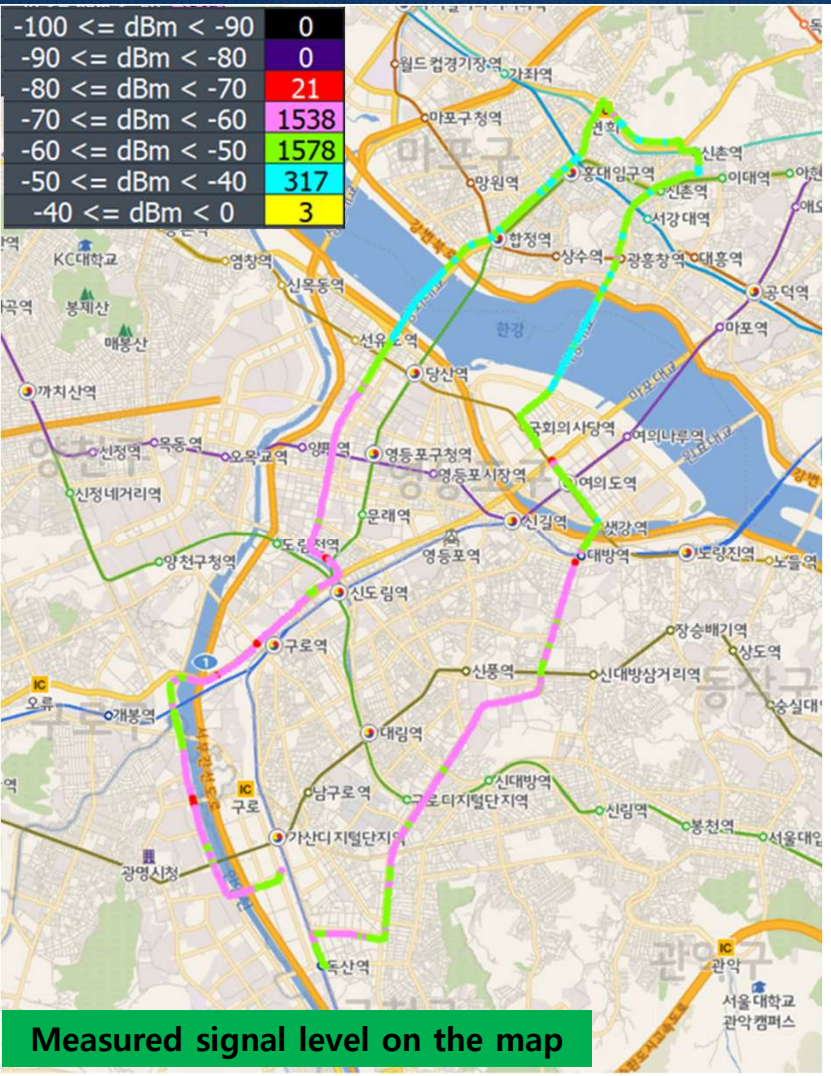


According to the test results of mobile-target HD service at Seoul and Metropolitan + Gyeonggi-do Province, diversity receiver significantly improved the reception performance:

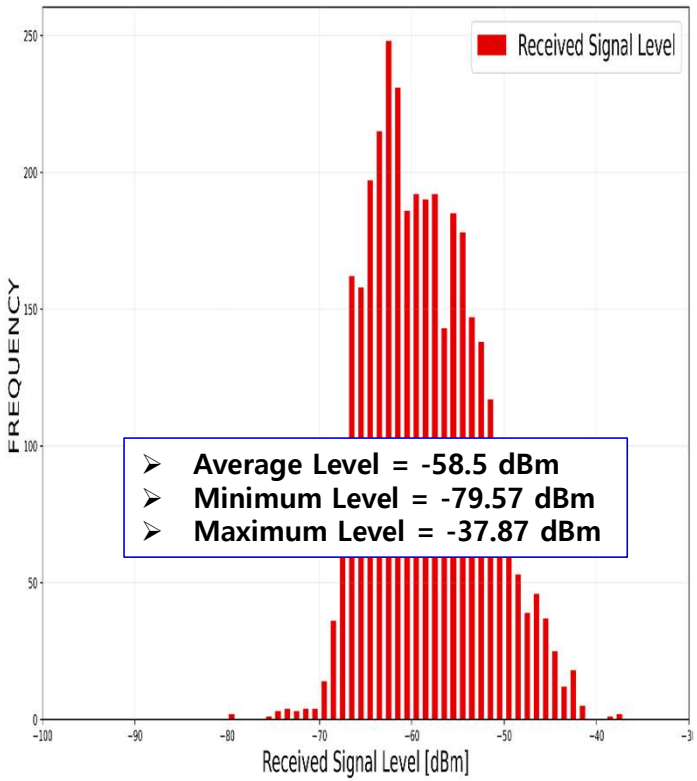
- Two antennas have around 4.5 dB gain compared to a single antenna
- Four antennas have around 13 dB gain compared to a single antenna

- **13 dB less strength is needed if end-device (vehicle) has 4 antennas**

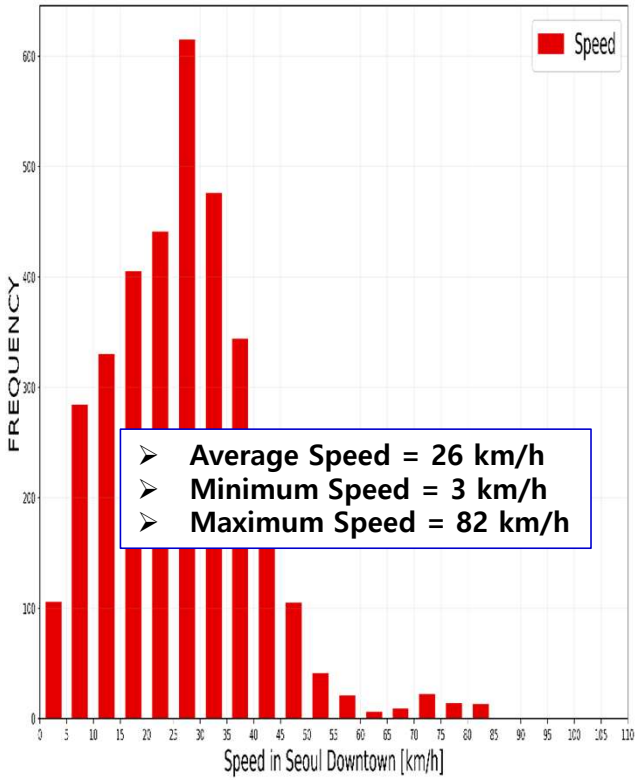
Measured Signal Power and Speed for 4K-UHD



Measured signal level on the map



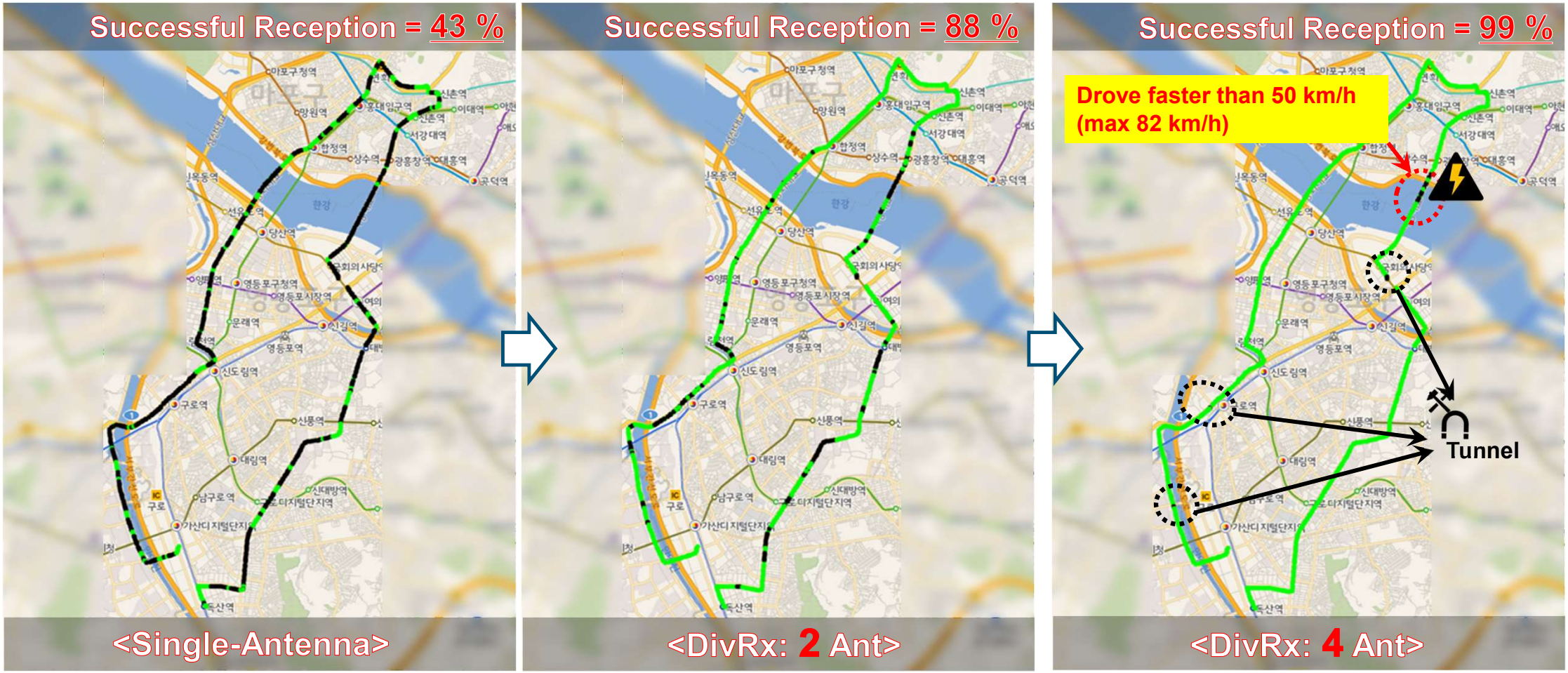
<Measured signal level distribution>



<Test Vehicle Speed Distribution>

PLP1 (designed primarily for the fixed UHD service) was measured in the Seoul downtown area under mobile conditions. Field strength is generally good enough for a successful reception due to the well-designed SFN.

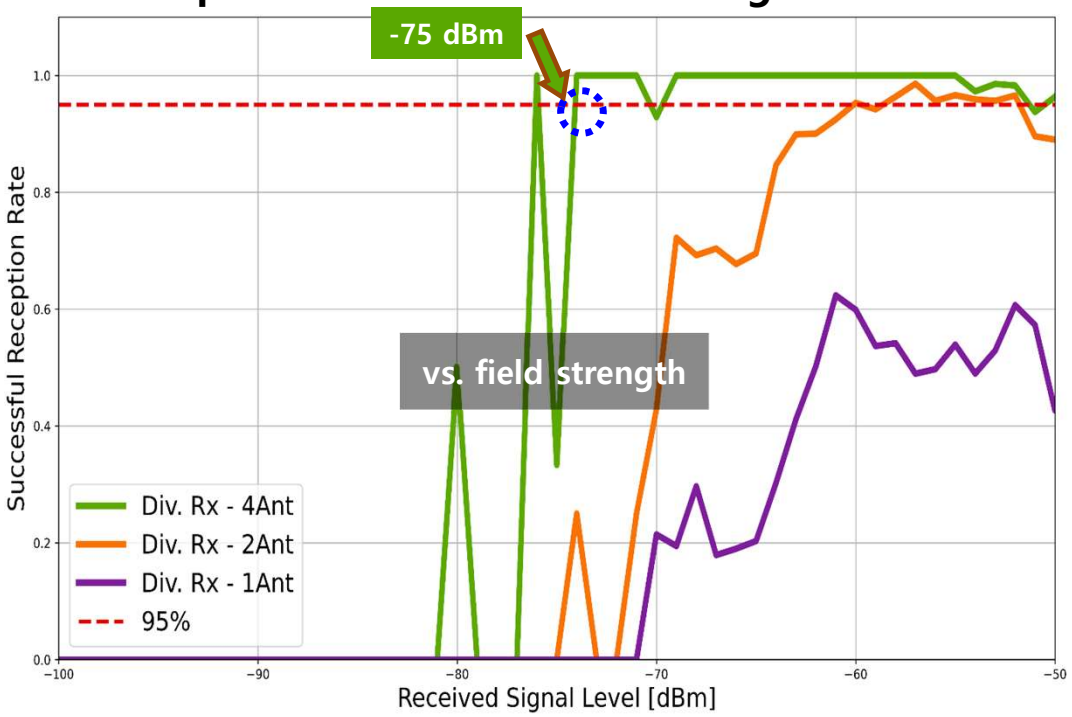
QoS Improvement from DivRx: (2) 4K-UHD 17.1 Mbps



Applying 16k-FFT would make it work much better in high-speed environment

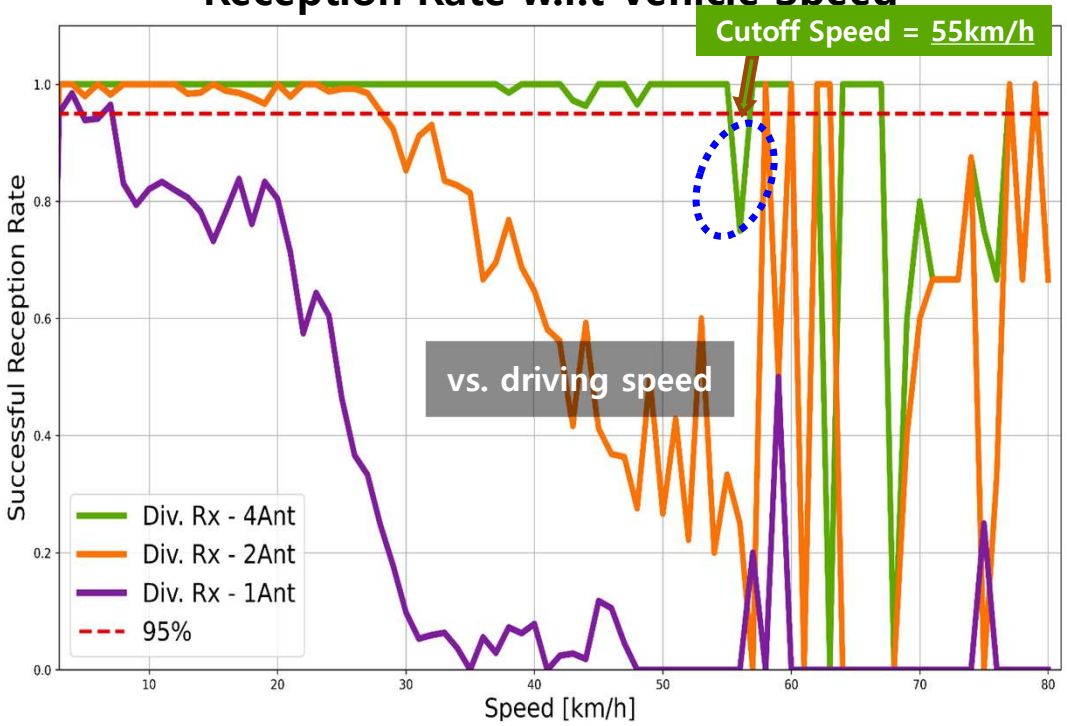
Reception Success or Failure (Diversity Rx – 1/2/4 Antennas) for 4K-UHD Service

Reception Rate w.r.t Received Signal Level



- **Only DivRxs brought mobile UHD feasible**

Reception Rate w.r.t Vehicle Speed



- **Mobile UHD could be viable for city-drive**
  - Ex. City bus are restricted to 50 km/h

➡ **16k-FFT would make it much better**

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- Mobile Field Test of Diversity Receiver
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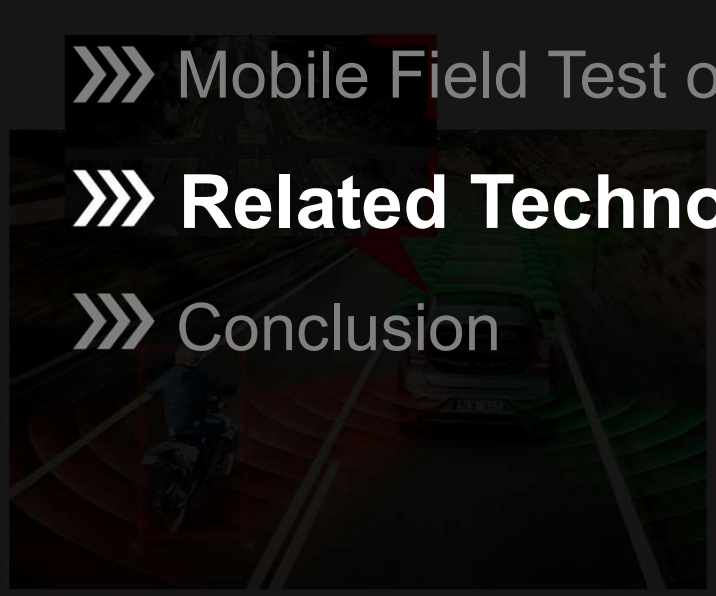
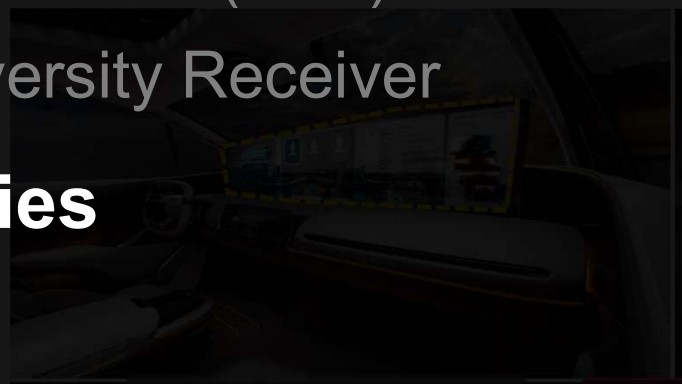
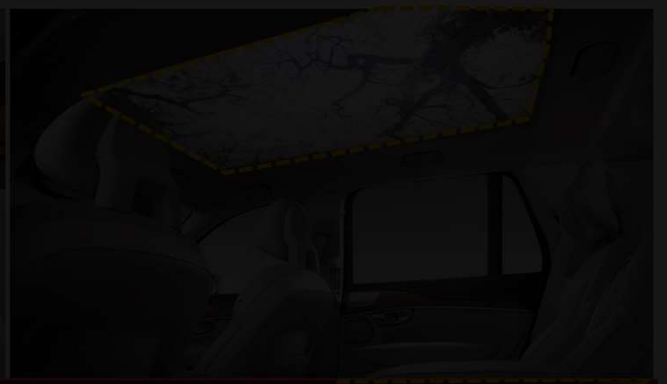
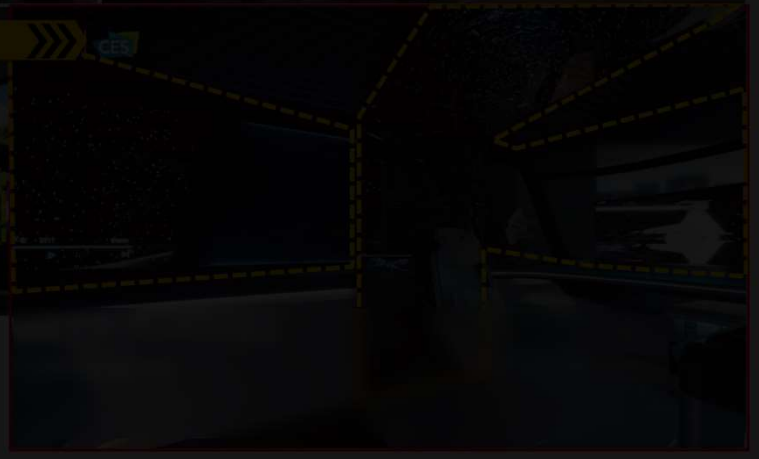
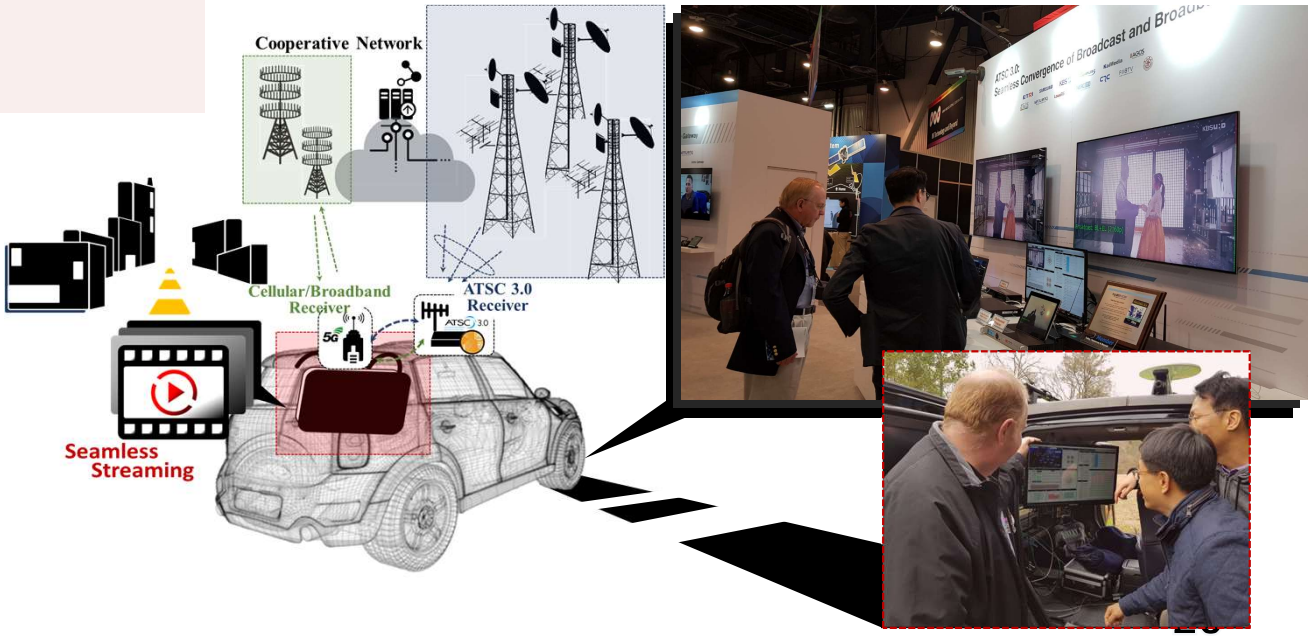






IP Broadcast Can Do More

Cooperative Casting over IP: Seamless Mobile Empowered by Broadcast-Broadband Dual Connection

- **Seamless handover based on dual-connectivity**
  - Get video packet from *broadband* whenever DTT signal is *expected* to be lost (predictive handover) ➡ **Based on PHY signal status**
  - **IP-based interworking**
- **SVC** makes videos more sustainable and versatile
  - Dynamic transition between video qualities

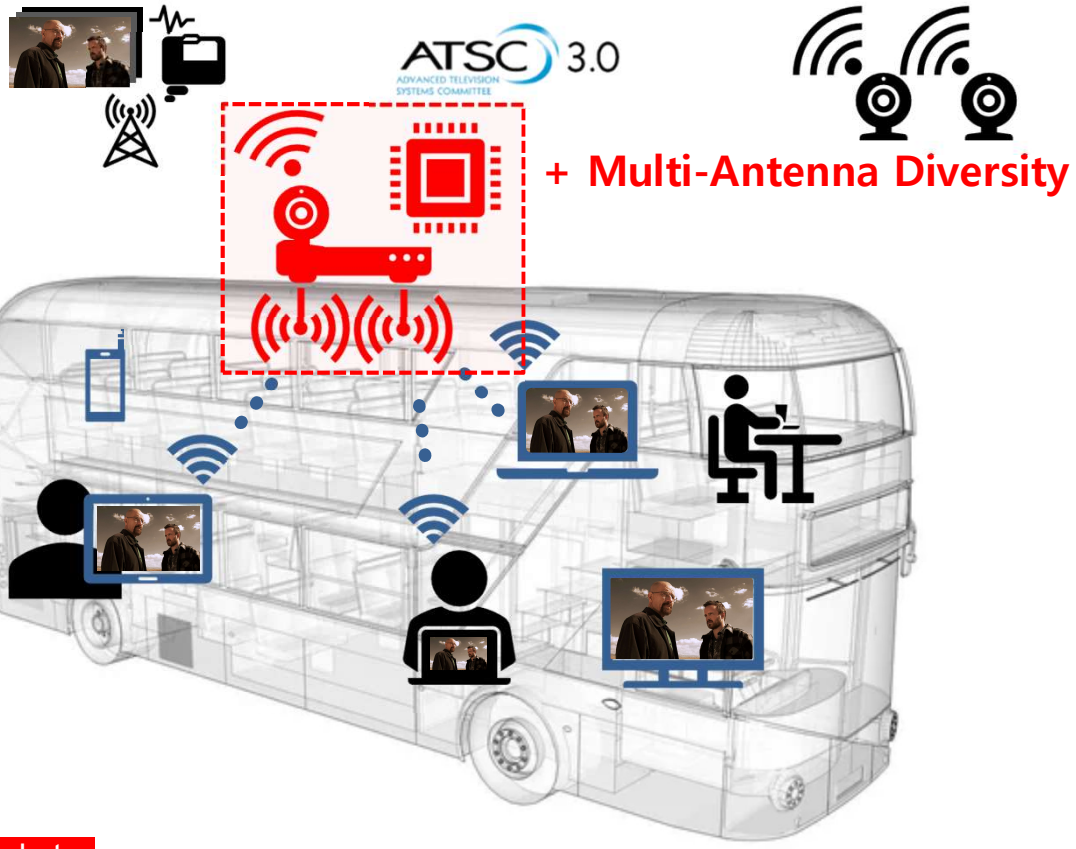


*Scalable video coding (e.g., Scalable HEVC, SHVC)

More Ways to D2V

Vehicle-Mounted Gateway over IP: TV Re-Distribution for Passengers

- **ATSC 3.0-to-WiFi Forwarding in Real-Time**
  - D2V momentum created by the IP broadcast standard, ATSC 3.0
  - Efficient way to serve simultaneous experience to the passenger group
- Add on: **Multi-antenna diversity** solution for improved reliability
  - Mass-transportation = More spatial capacity for Multi-Antenna



Previous Step: Home-Gateway

ATSC 3.0 Home-Gateway

Demos – Raleigh, Maryland, Vegas, Seoul, etc.

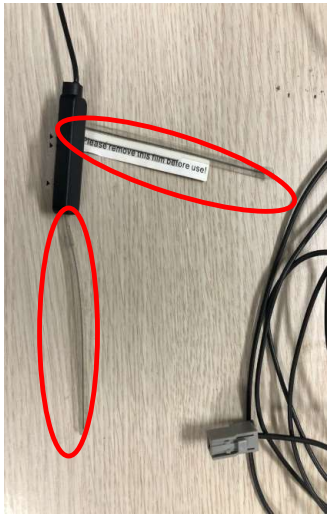
Conclusion

- We investigated the mobile performance, especially in automobile, of the latest ATSC 3.0 diversity receiver according to the number of antennas
  - Field tests were conducted in Seoul and Metropolitan area, South Korea
- According to the test results, diversity receiver significantly improved the reception performance
  - Field tests under the well-designed SFN: PLP0 (8K-FFT, 1.6Mbps@6.9dB) and PLP1 (32K-FFT, 17.1Mbps@14.3dB)
    - PLP0 (designed for mobile HD service): Single antenna (74%), Two-antennas div (89%), Four-antennas div (97%)
      - Four- and two- antennas diversity receiver has 4.5 dB and 13 dB gains compared to a single antenna receiver, respectively.
      - Well-designed SFN provides a better performance gain compared to a single transmitter.
    - PLP1 (designed for fixed UHD service): Only four-antennas diversity receiver provides acceptable performance of PLP1 under mobile conditions. However, its performance was significantly degraded when the speed is over 50km/h.

Conclusion

- Further extensive field test, equipped with commercial vehicle-targeted built-in antennas, are scheduled for commercialization of the ATSC 3.0 diversity receiver.

Glass mount antenna for vehicle



Tape-type antenna for vehicle

Thank you for your attention!