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

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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

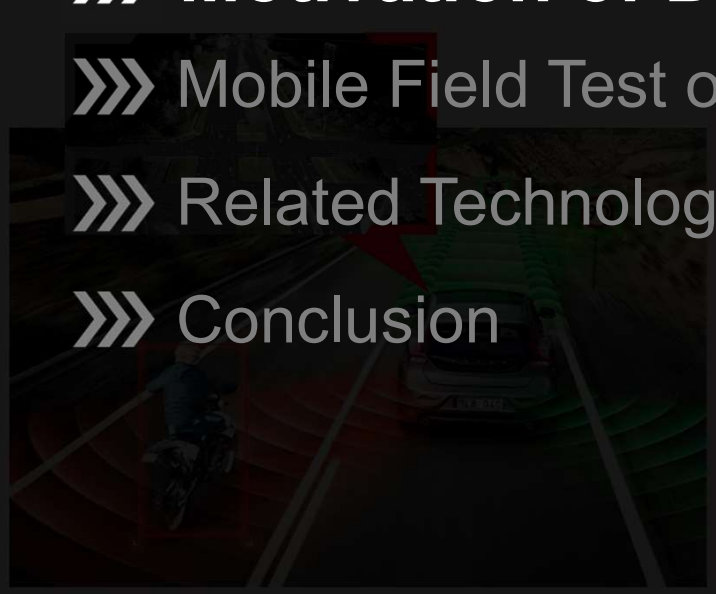
Demos – Raleigh, Maryland, Vegas, Seoul, etc.

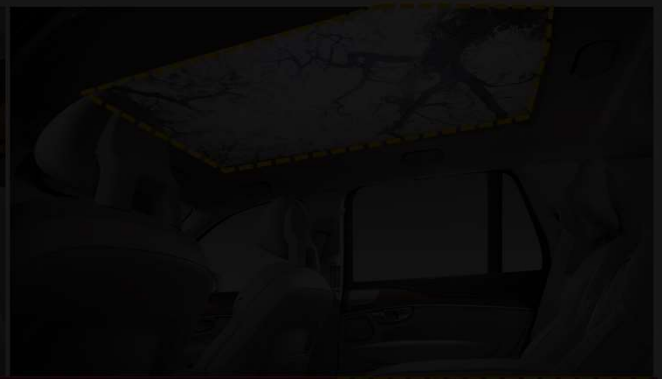
MarkOne - SBG

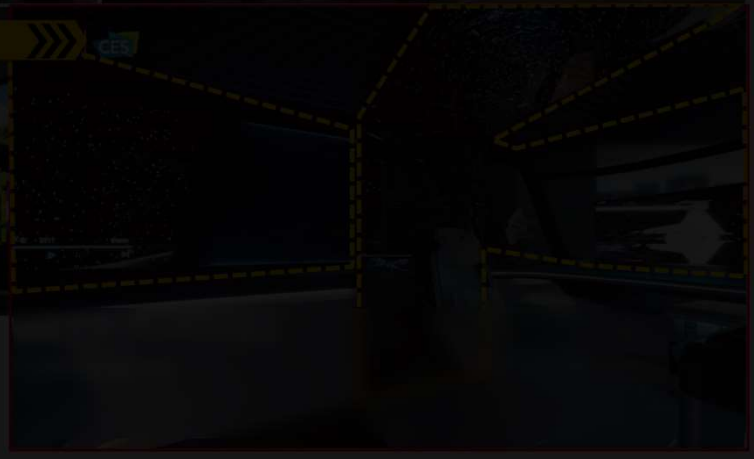
ATSC 3.0
Built-in Smartphone
Released

ATSC 3.0
ADVANCED TELEVISION SYSTEMS COMMITTEE

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



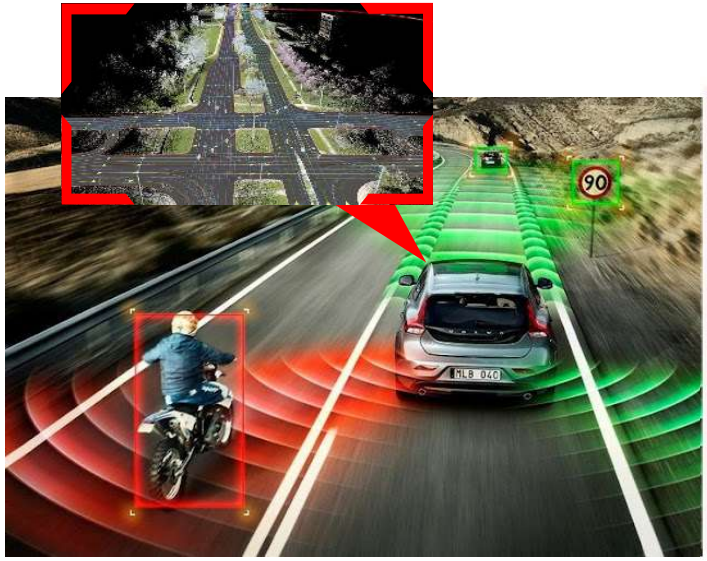




Media-in-Vehicle: Spotlight on Automotive Infotainment

Rise of Self-Driving Technology

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



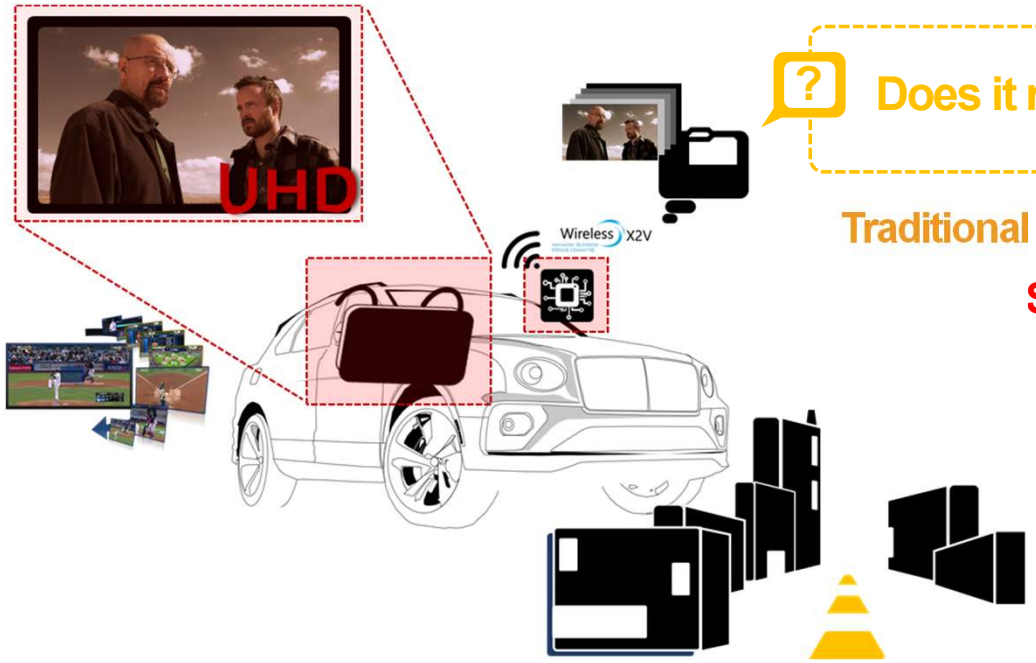
Been Free from Driving

- 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

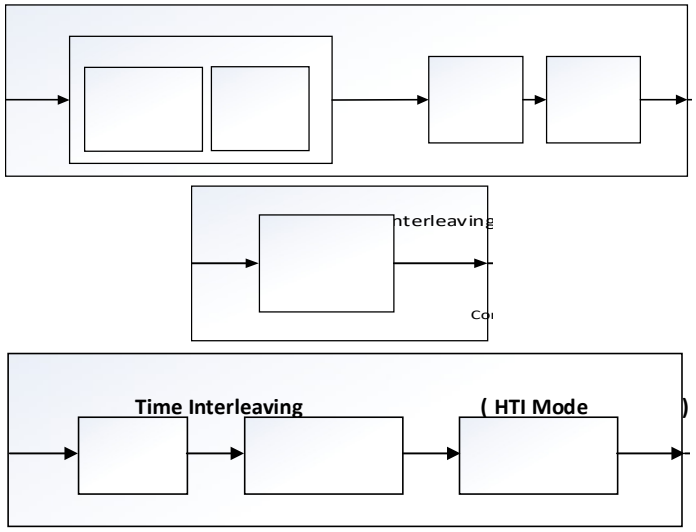
Solutions

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

Diversity Technologies in ATSC 3.0 System

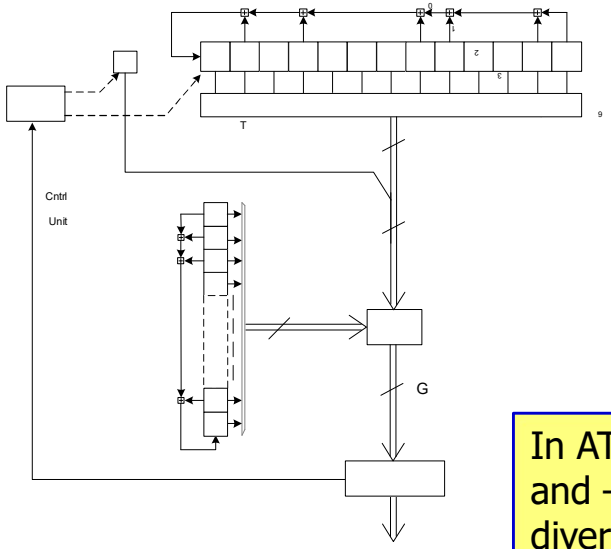
Time Diversity

- 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)



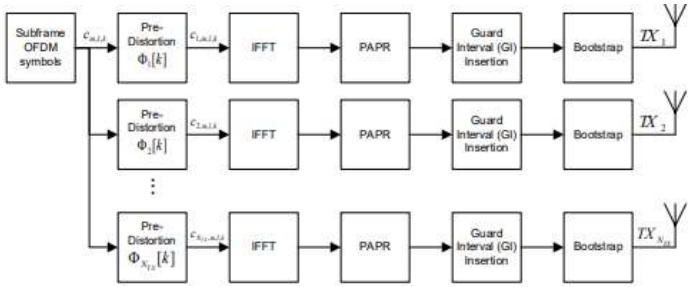
Frequency Diversity

- 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**

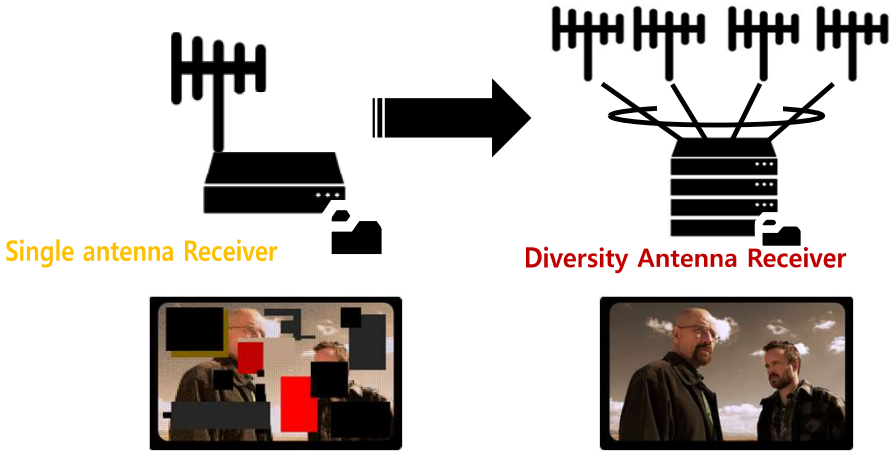
The *"Diversity"* property is preserved if the antennas are (at least) λ/2 apart from each other

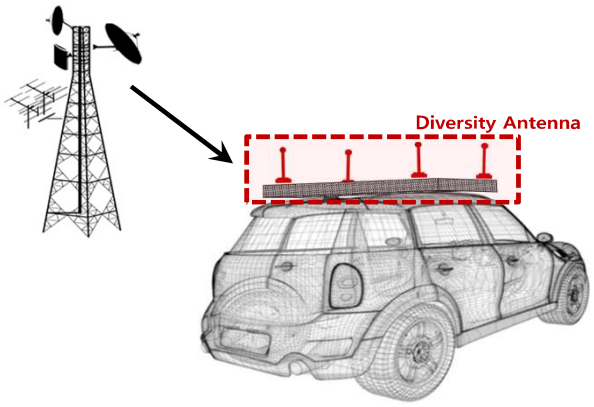
- 600 MHz **UHF**: λ/2 = **25 cm**

➡ **Challenge in physical size**

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

Vehicle-Type Rx





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- **Mobile Field Test of Diversity Receiver**
- Related Technologies
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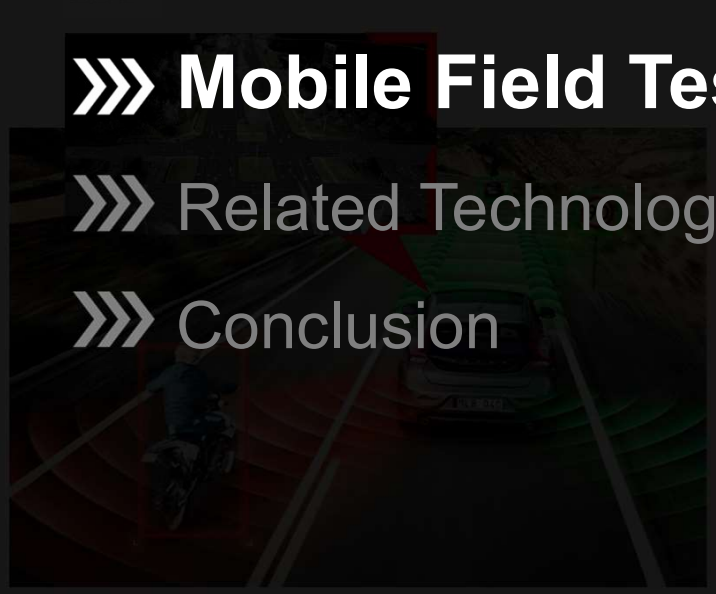
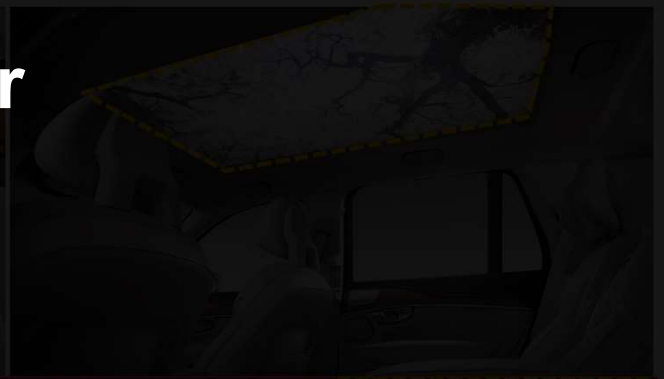
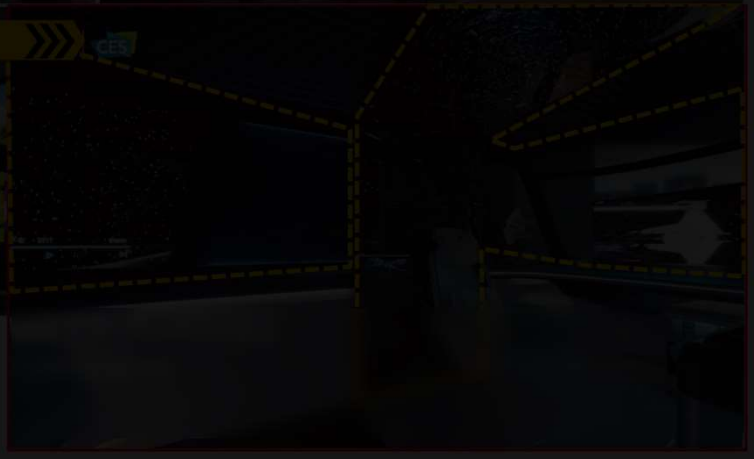




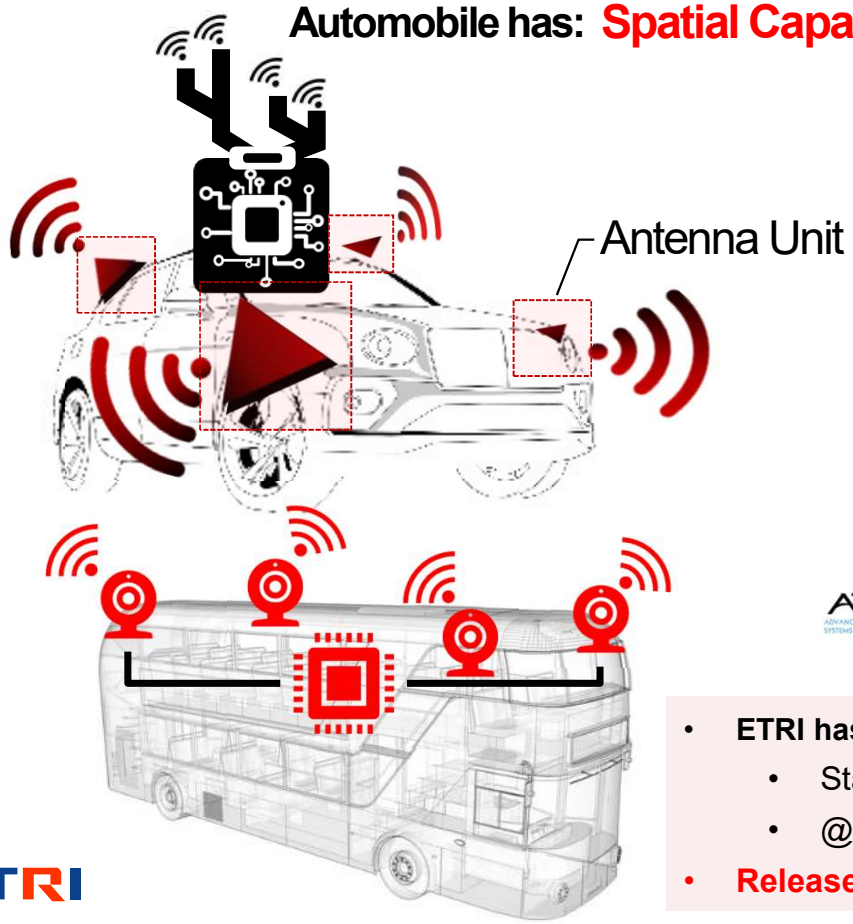


D2V over ATSC 3.0: Antenna Diversity Solution

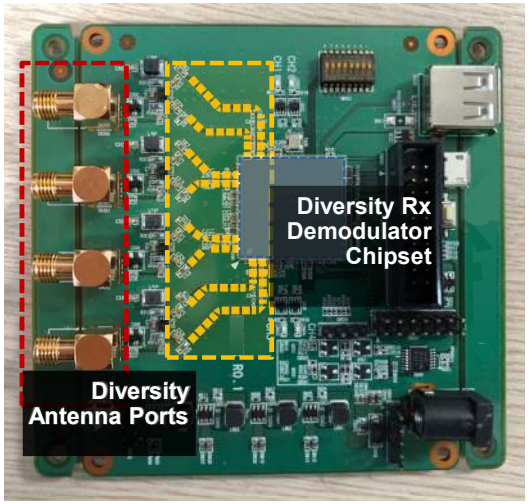
Multi-Antenna Diversity Solution for D2V

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

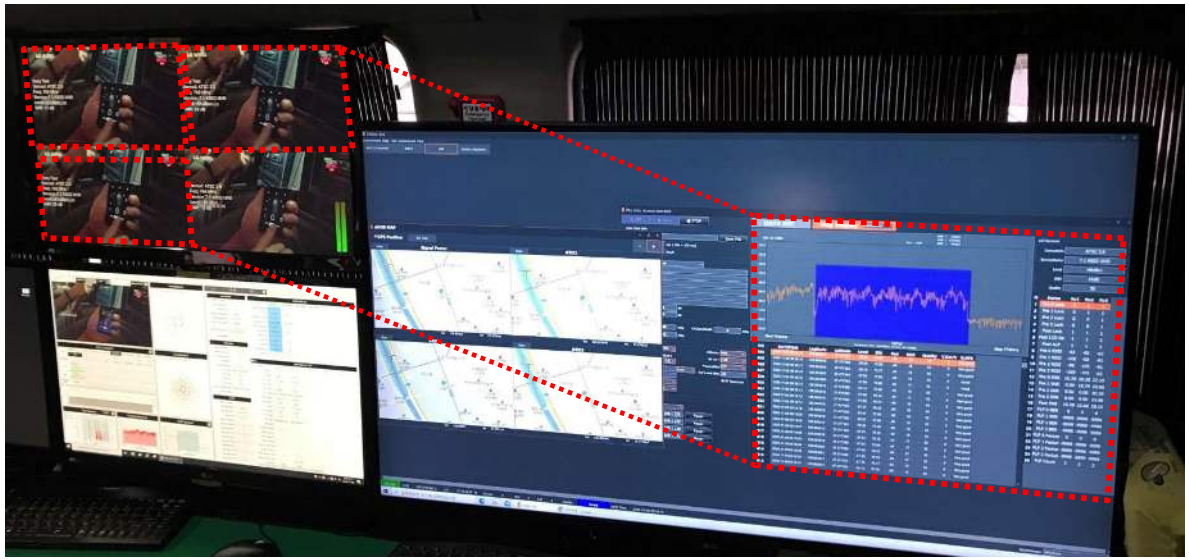
Seoul and Gyeonggi area which has 10 transmitters' SFN

10 SFN transmitters
+ one experimental site

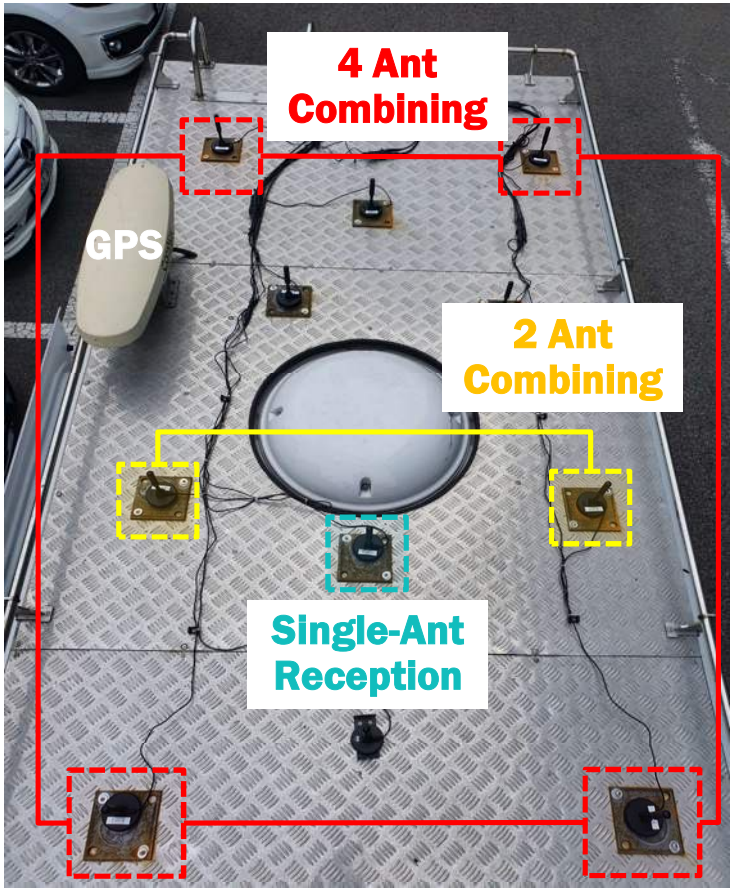
RF Frequency = 768 MHz

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

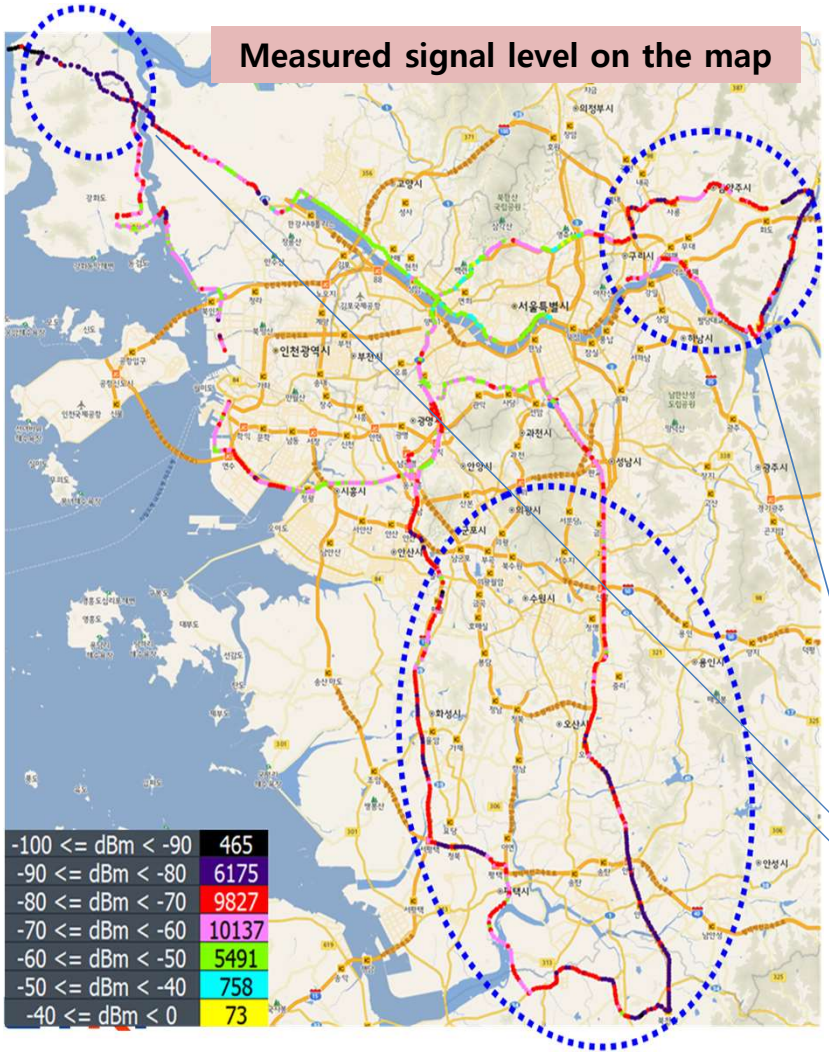
Truly Mobile-Oriented HD Service (1.6 Mbps)

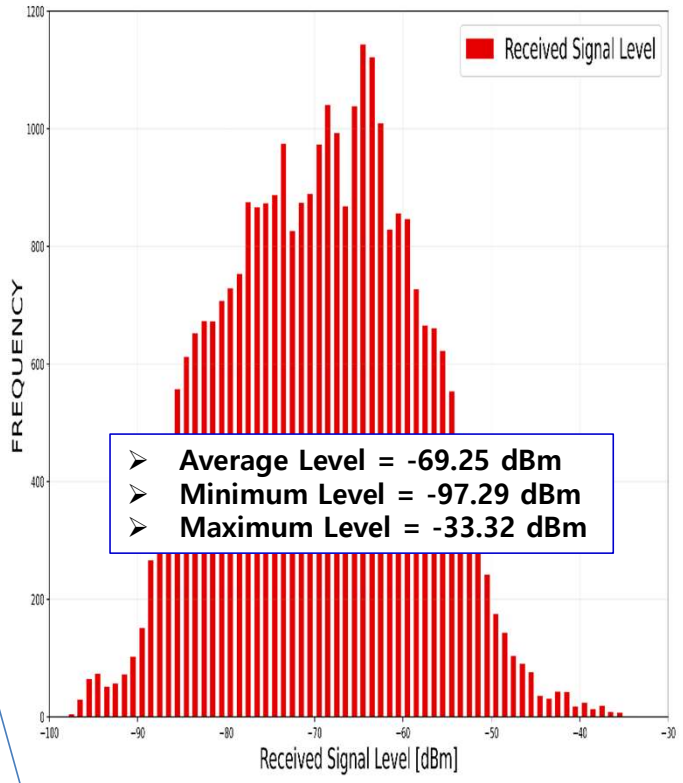
Primary Purpose: Fixed Service 4K-UHD (17.1 Mbps)

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

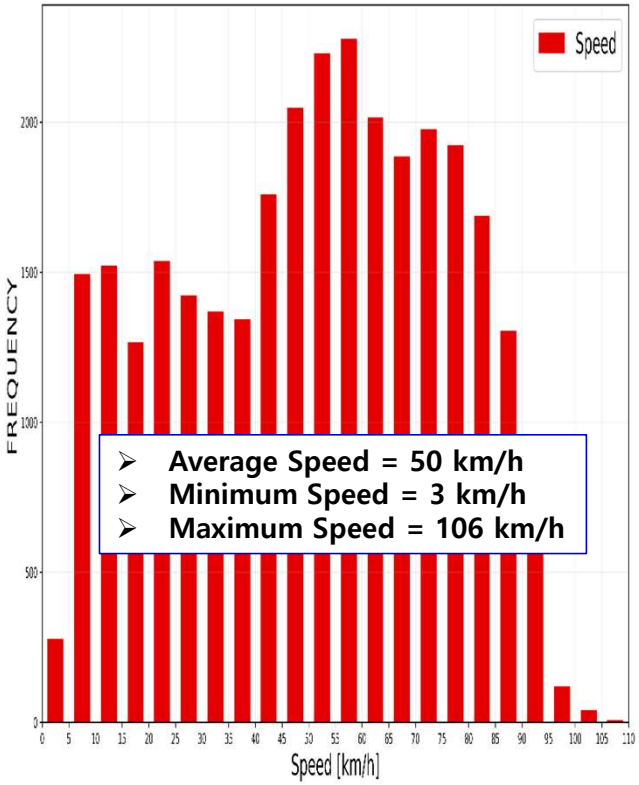
ATSC 1.0 :
19.39 Mbps @ 15.2 dB

Measured Signal Power and Speed for Mobile-Target HD





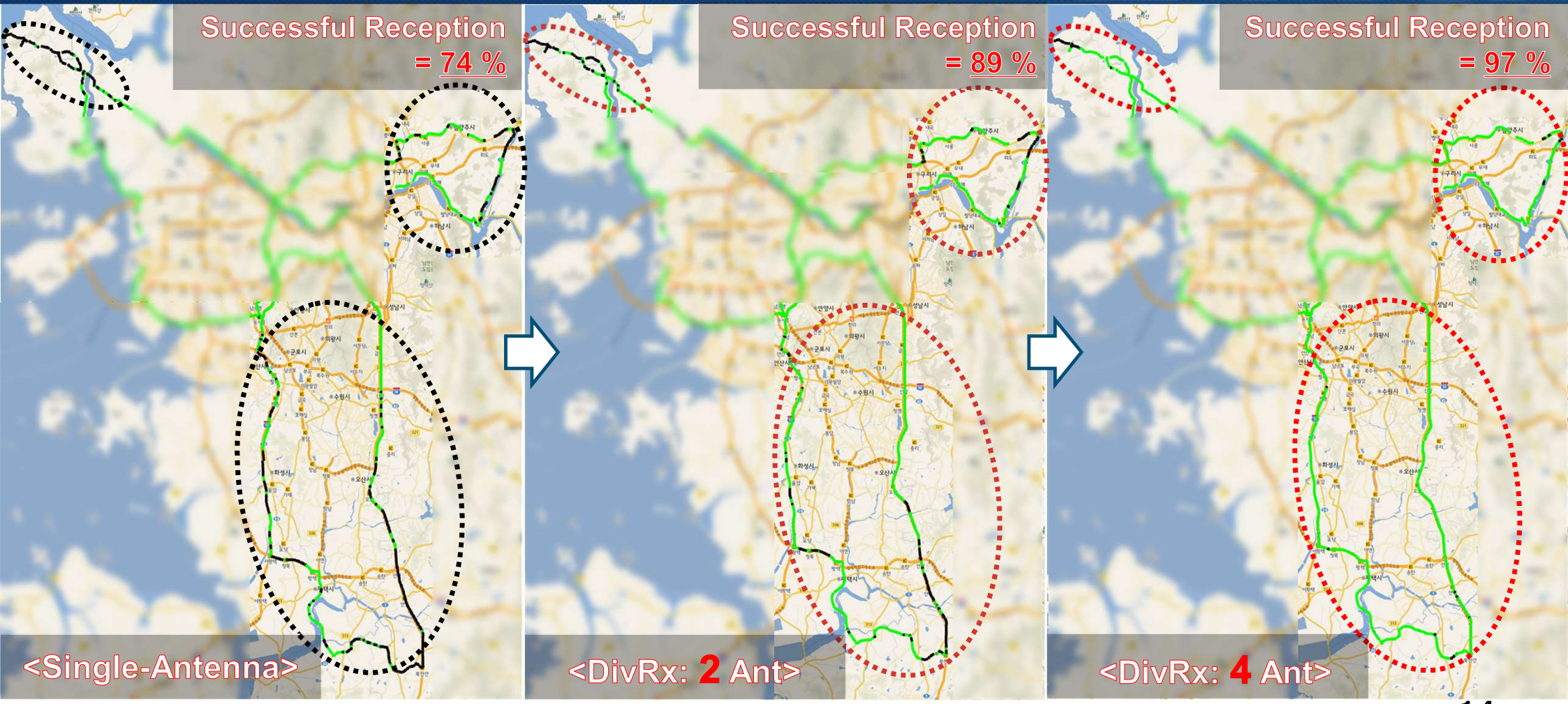
<Measured signal level distribution>



<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

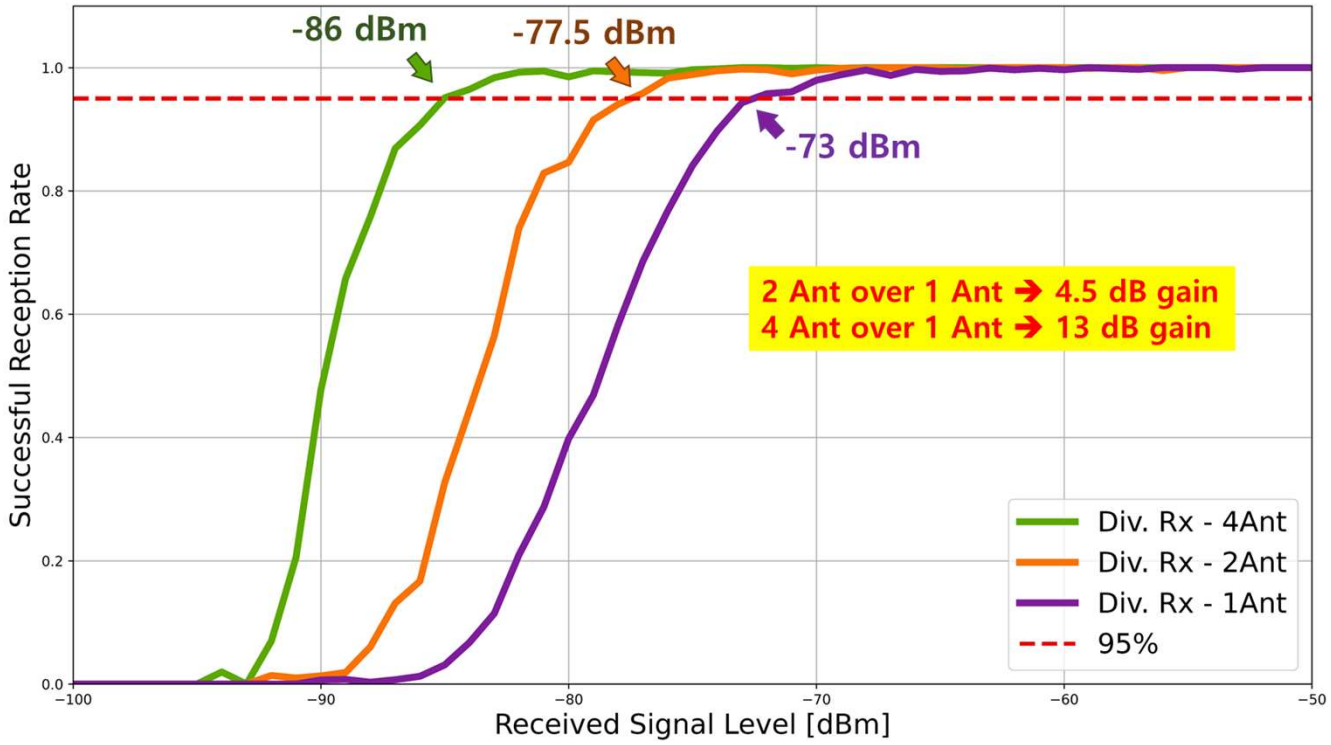


Results were recorded every second | If driving faster than 3 km/h

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.

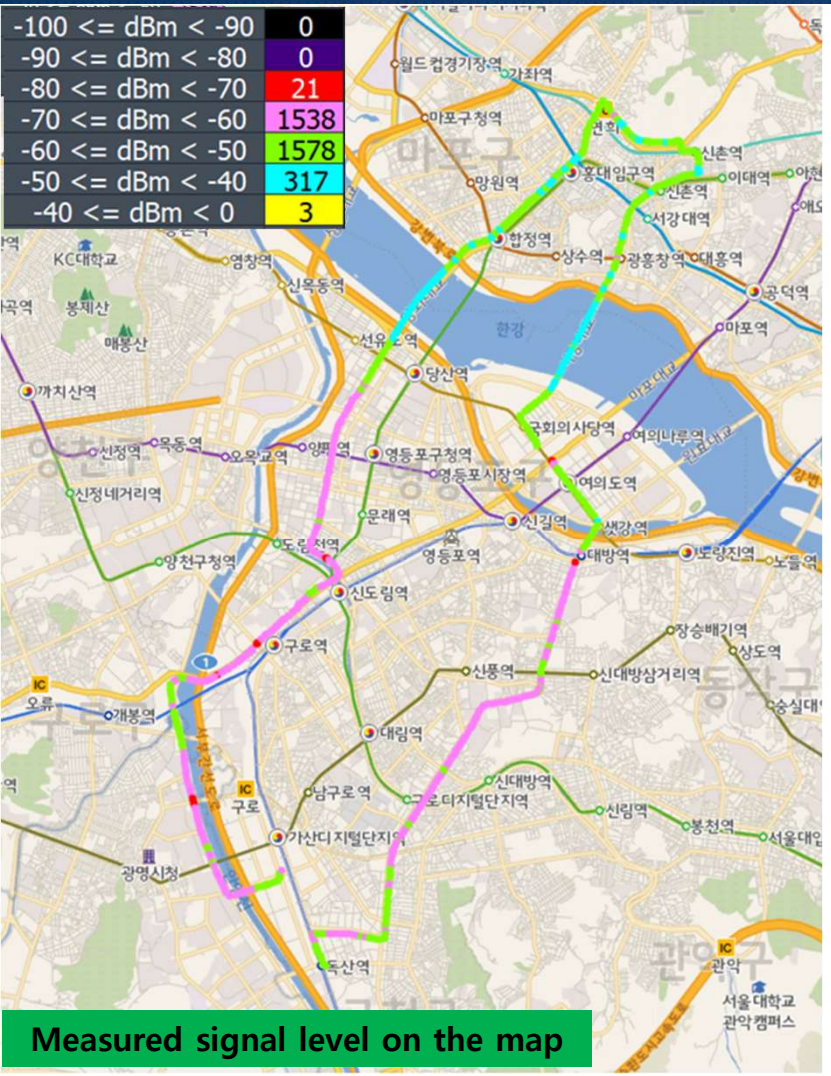


According to the test results of mobile-target HD service at Seoul and Metropolitan + Gyeonggi-do Province, diversity receiver significantly improved the reception performance:

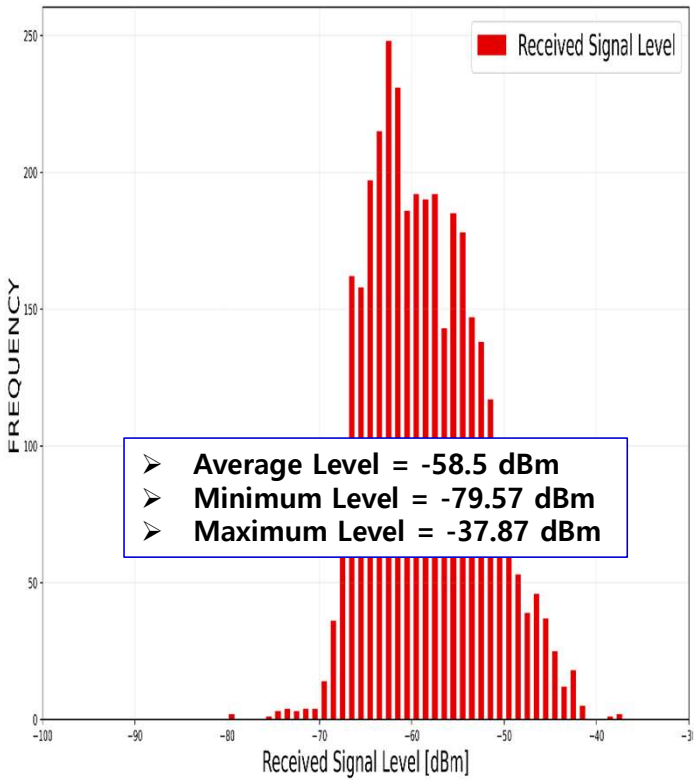
- Two antennas have around 4.5 dB gain compared to a single antenna
- Four antennas have around 13 dB gain compared to a single antenna

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

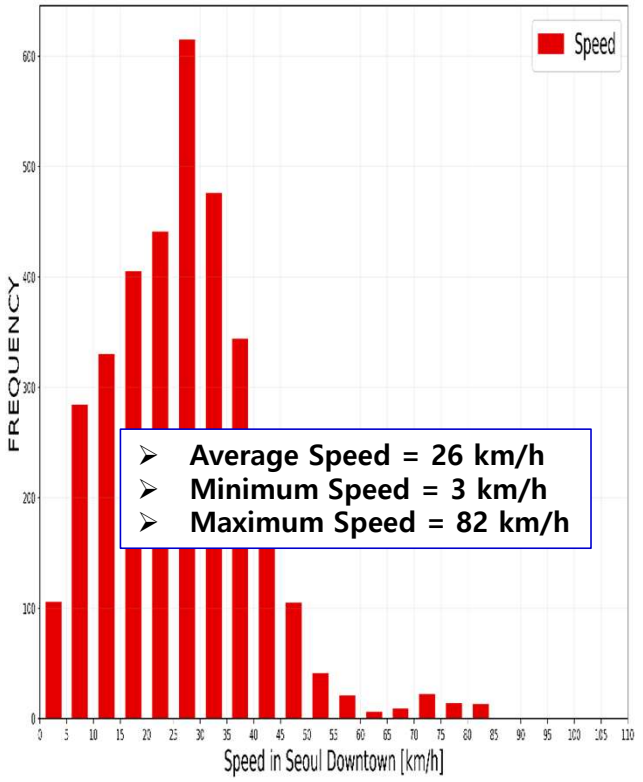
Measured Signal Power and Speed for 4K-UHD



Measured signal level on the map



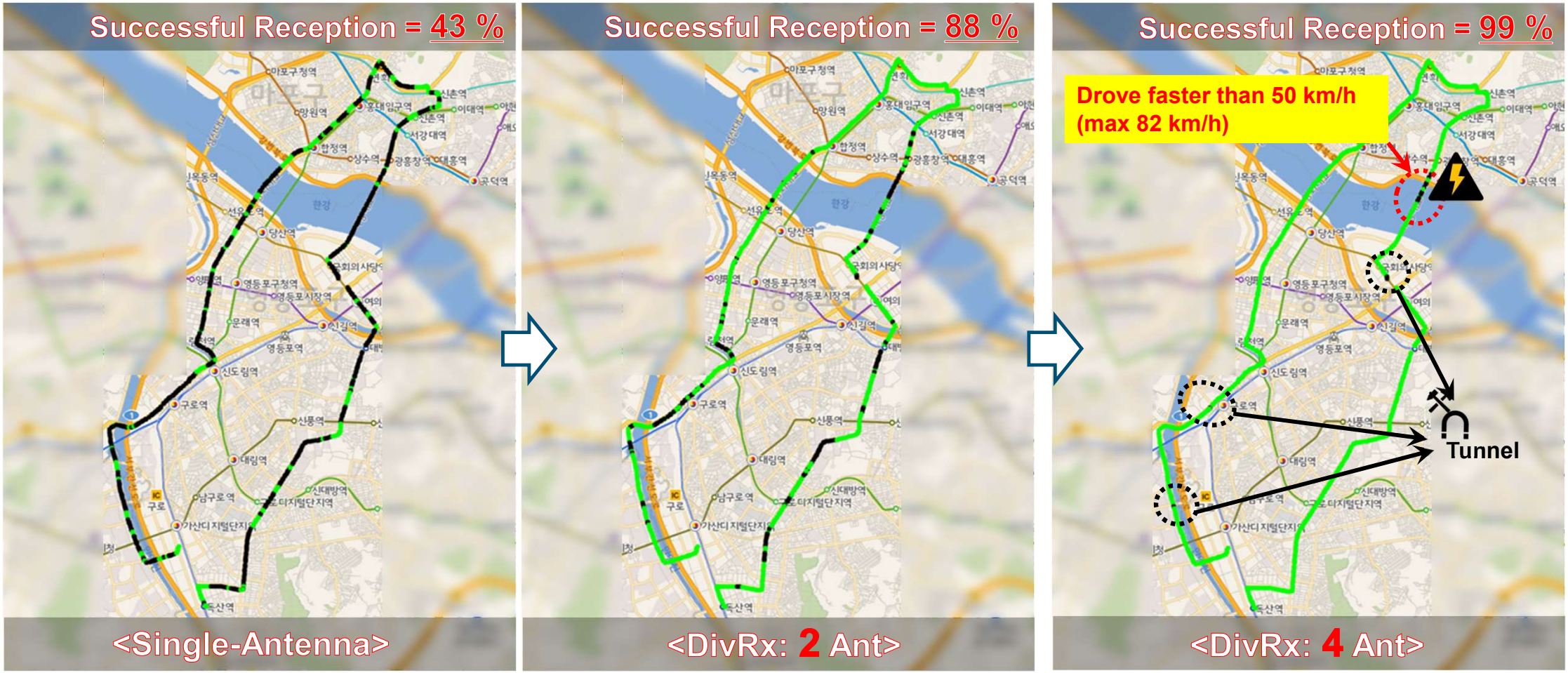
<Measured signal level distribution>



<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.

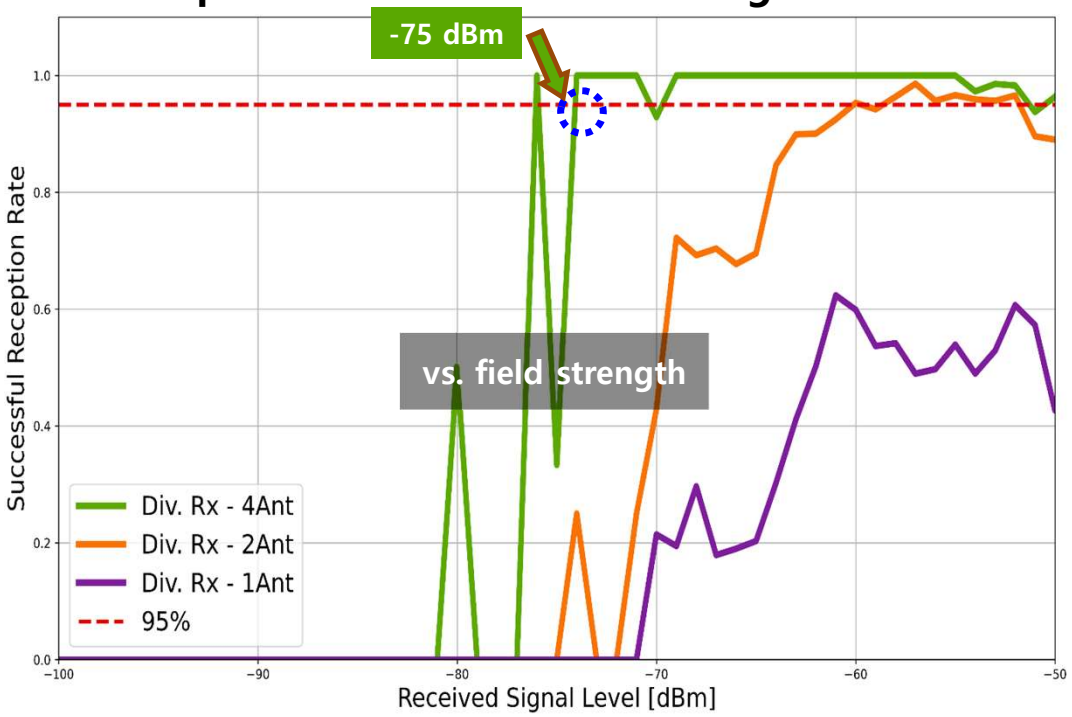
QoS Improvement from DivRx: (2) 4K-UHD 17.1 Mbps



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

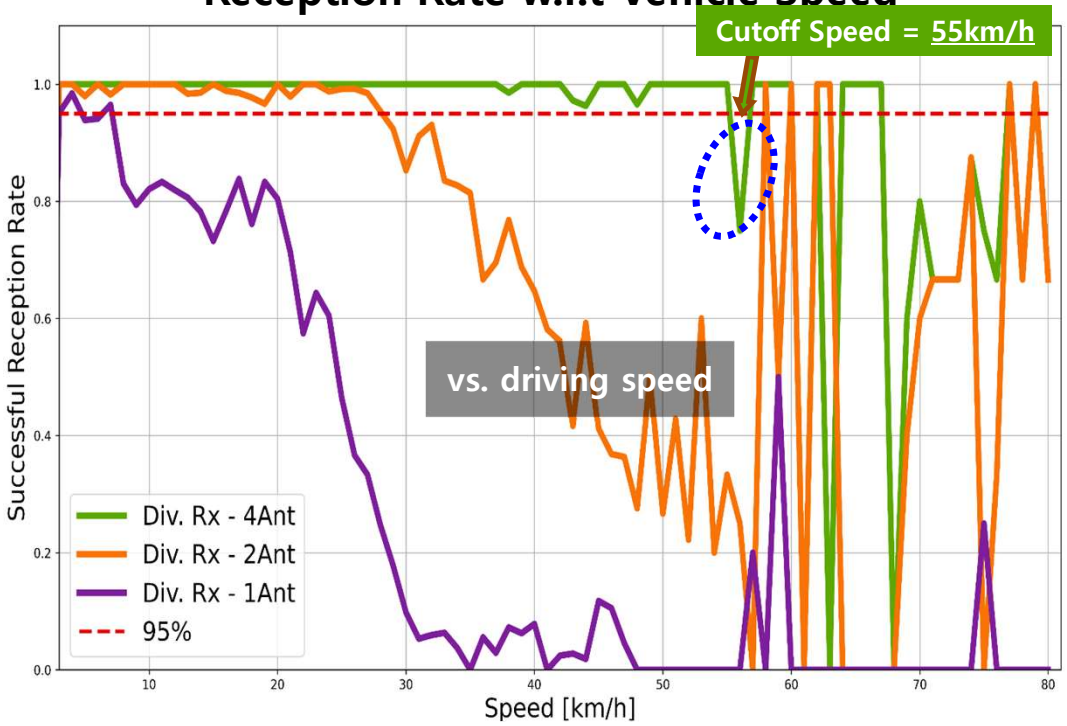
Reception Success or Failure (Diversity Rx – 1/2/4 Antennas) for 4K-UHD Service

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
- **Related Technologies**
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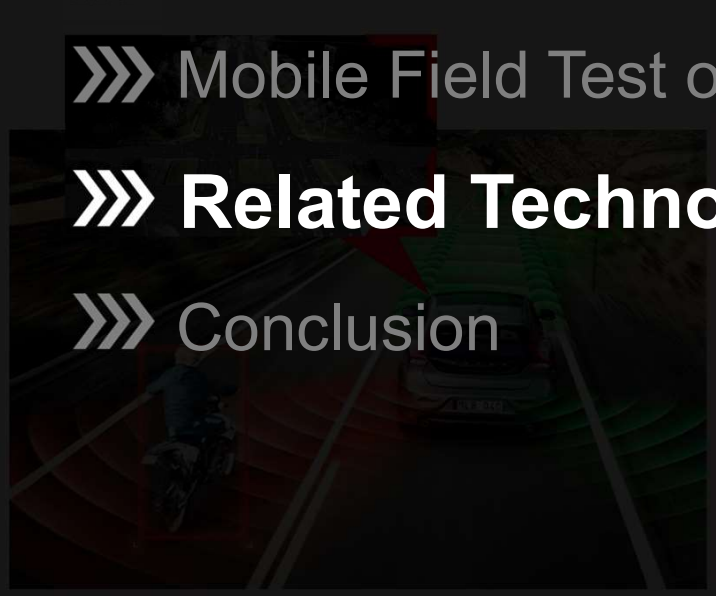
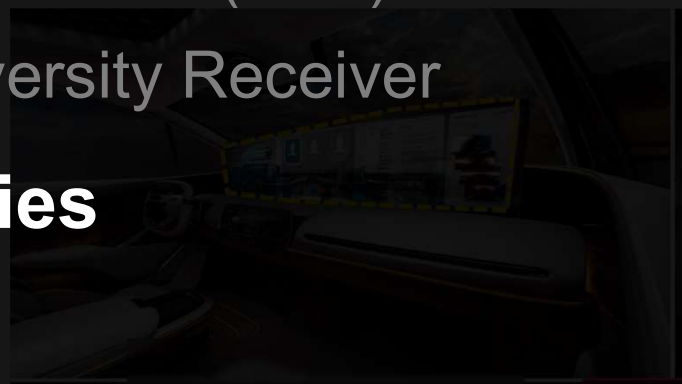
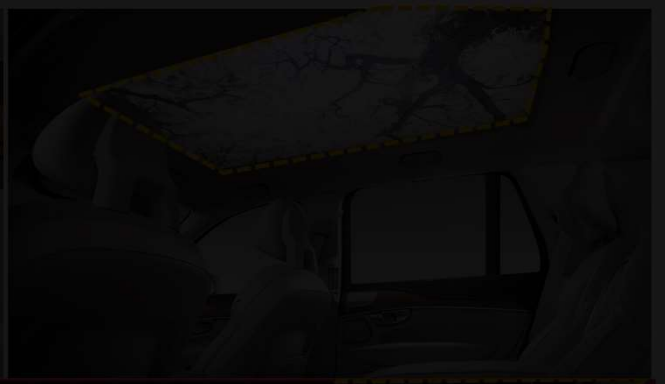
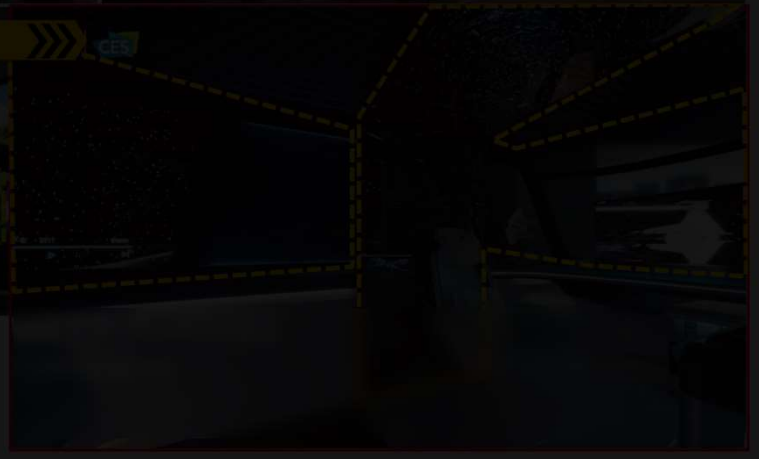
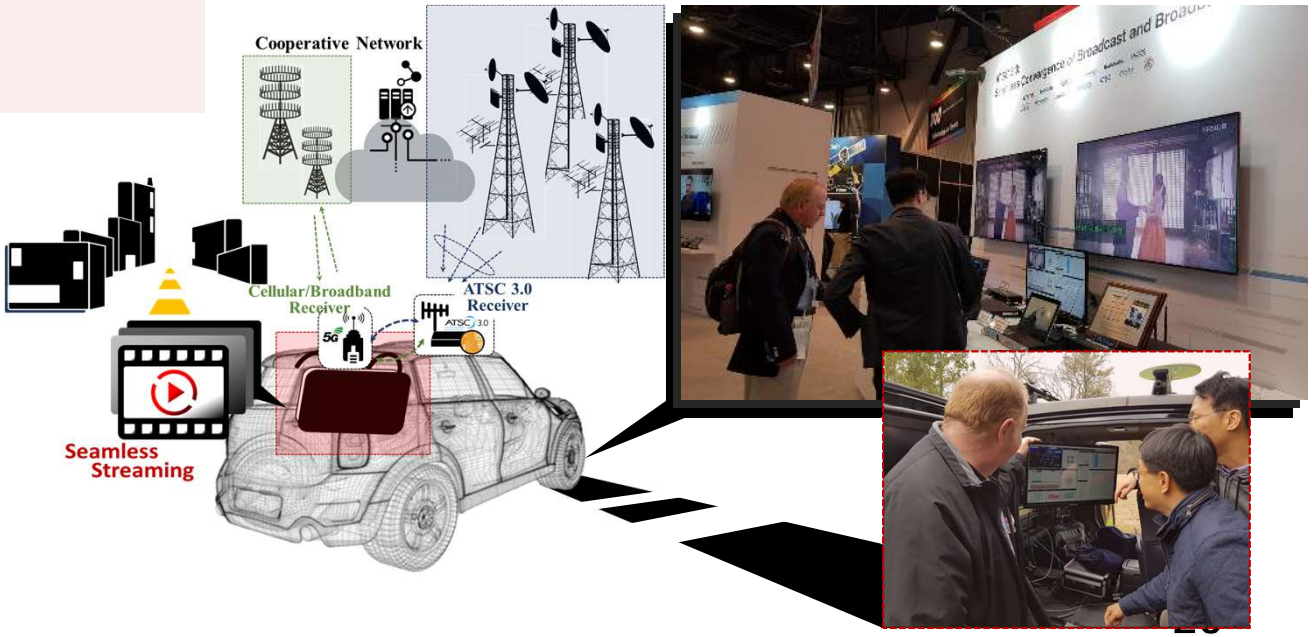






IP Broadcast Can Do More

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

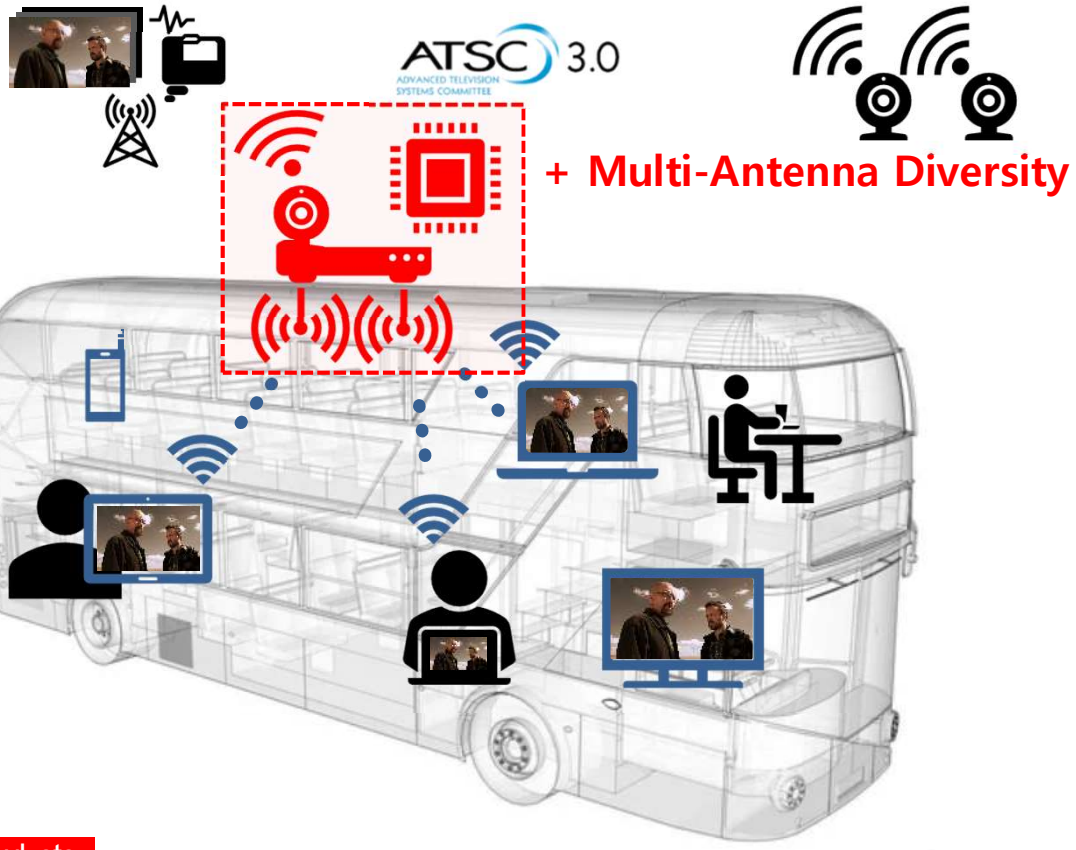


*Scalable video coding (e.g., Scalable HEVC, SHVC)

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.

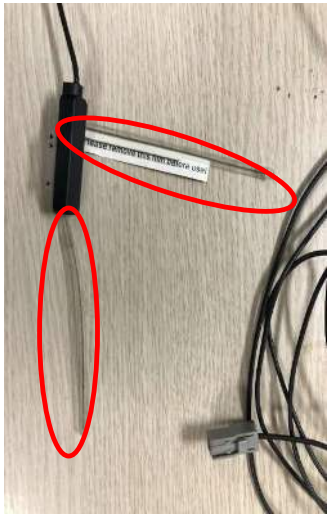
Conclusion

- 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!