

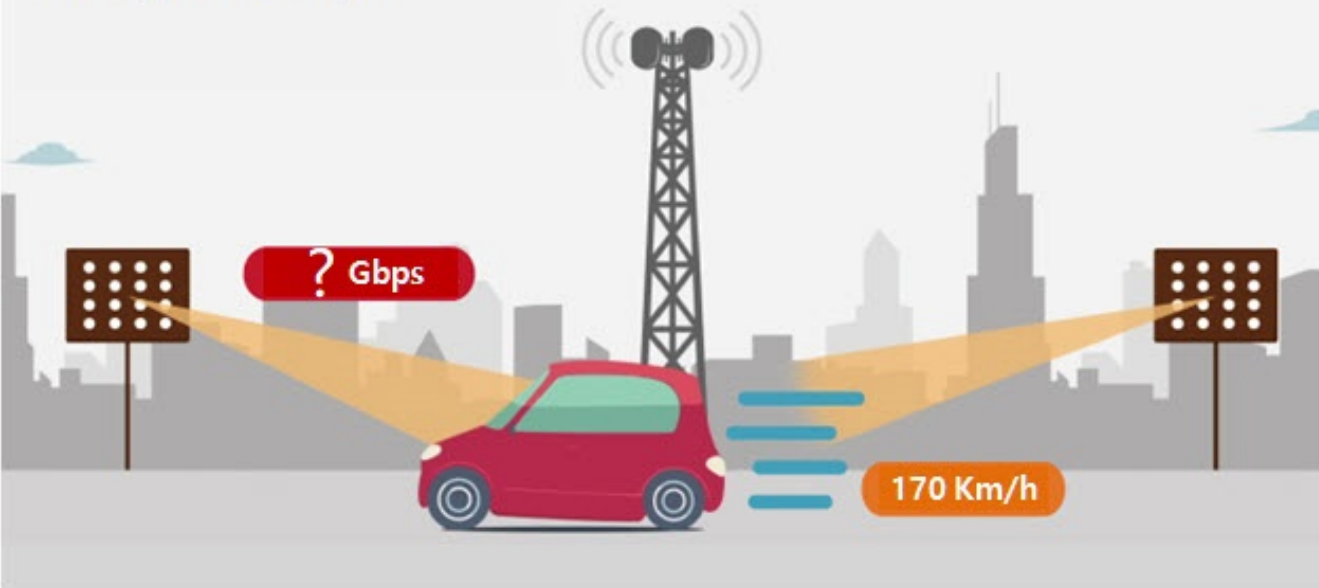


Weighing the Elephant: Testing 5G-connected cars

Fred Yu

A Test solution helps you to find answers to the critical questions

a 5G connected car
moving at 170 Km/h



5G base station



Data throughput before and after
being installed ? Moving at 170Km/h

Which antenna is better ? antenna
pattern, polarization,

Try different positions to mount
antennas?

The receivers sensitivity getting
worse ?

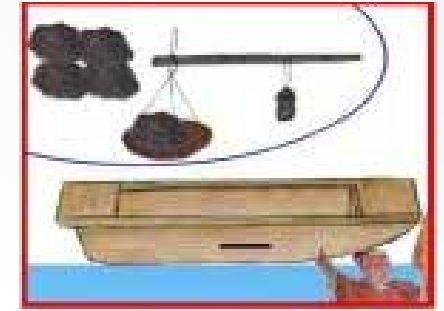
The performance is affected by FM
radio? Or some other electrical
devices ?

RTS: A smart methodology to create Channel models in a controlled OTA environment

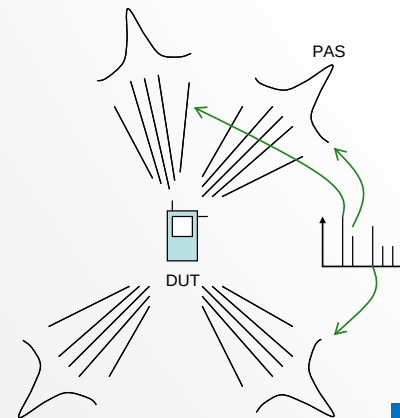
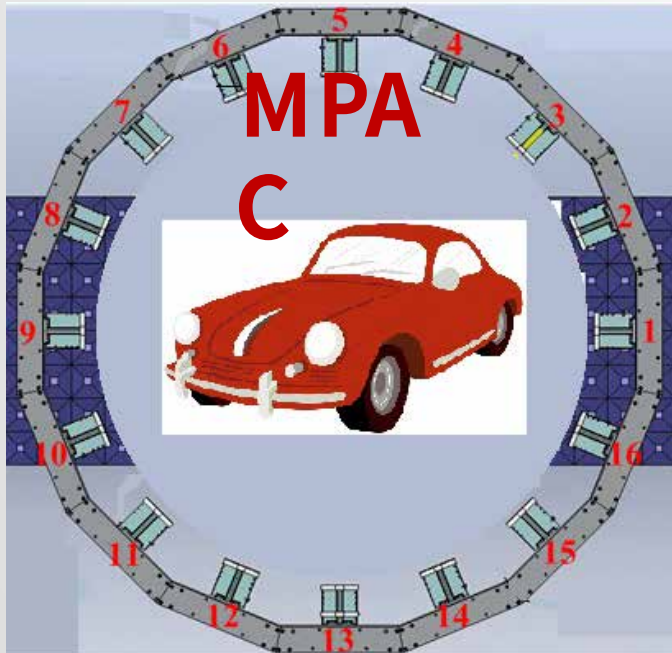
Practical ?



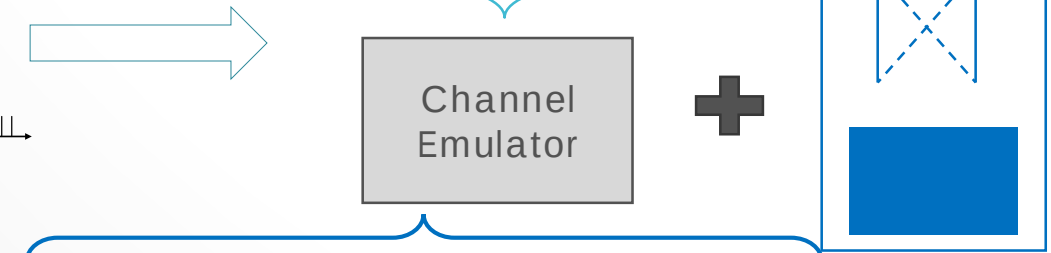
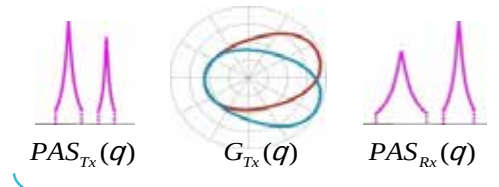
Feasible & Simple



Implementing the channel models defined by 3GPP or customers



RTS



SCME Urban Macro-Cell				
Cluster #	Delay [ns]	Power [dB]	AoD [°]	AoA [°]

MIMO OTA Measurement

Ø MPAC Method & RTS Method **RTS advantages**

3GPP TS 37.544 V14.6.0 (2018-06)

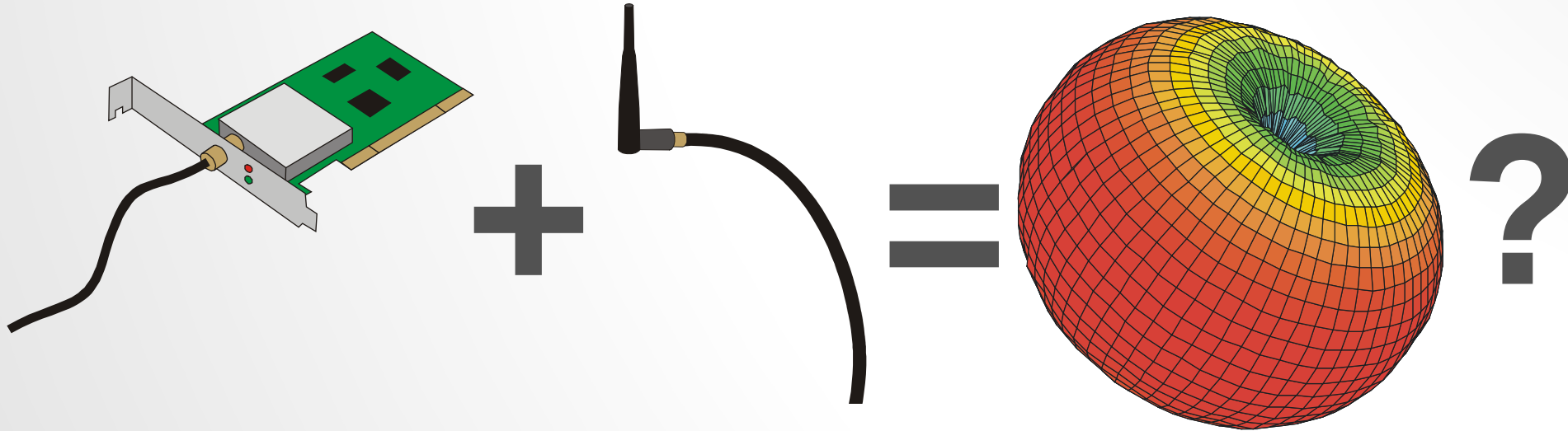
Technical Specification

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Universal Terrestrial Radio Access (UTRA) and Evolved
Universal Terrestrial Radio Access (E-UTRA);
User Equipment (UE) Over The Air (OTA) performance;
Conformance testing
(Release 14)

- Ø Uncertainty analysis completed
- Ø Cost effective
- Ø Fast
- Ø Provide more useful information

▪ A.5.2	Testing environment conditions	192
▪ A.5.2.1	MPAC Positioning Guidelines	198
▪ A.5.2.2	RTS Positioning Guidelines and test zone dimensions	202

Wrong Assumption



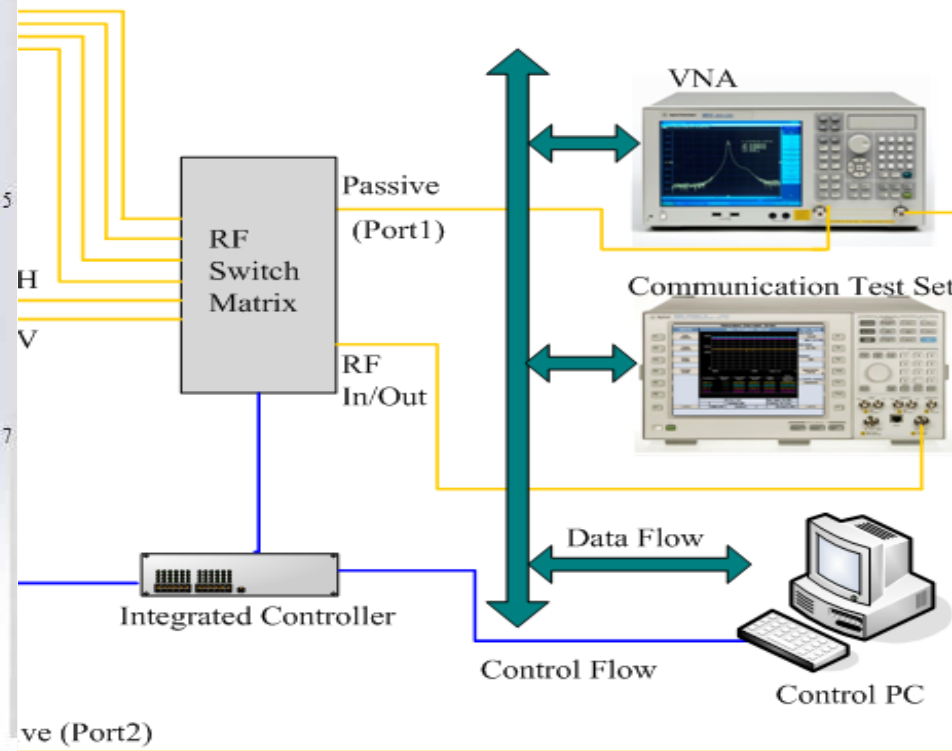
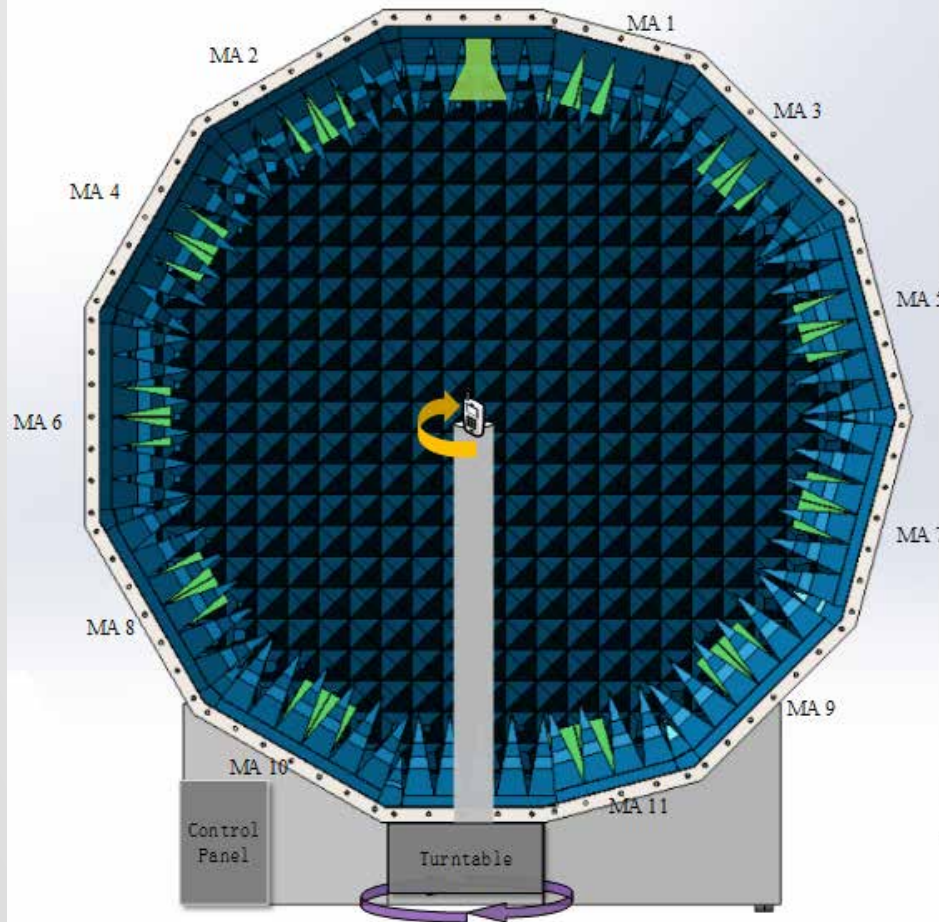
Over Performance != Conducted Test + Antenna Measurement

Note: Some devices have no external RF ports for connection.
The only way for wireless tests:

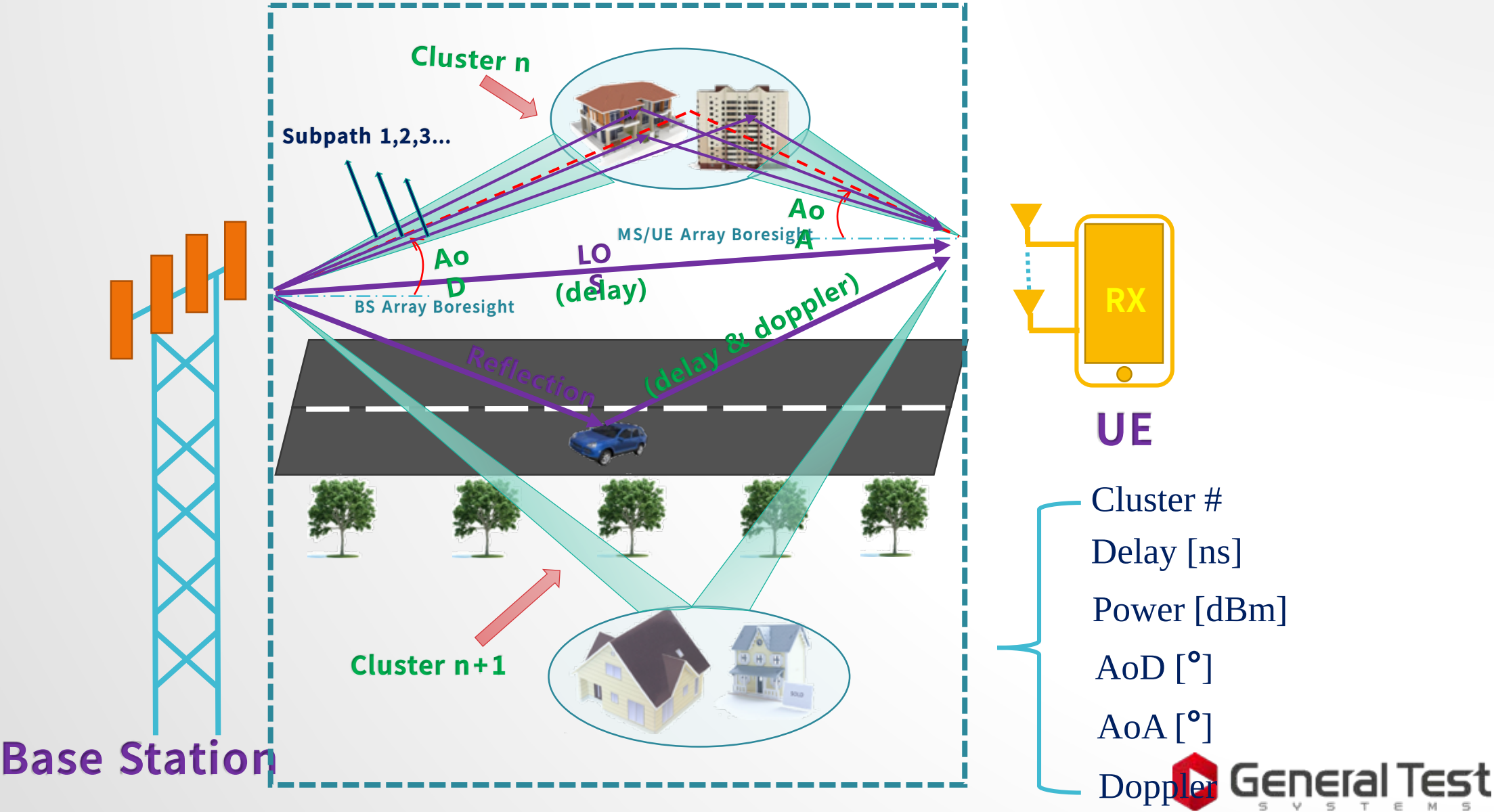
OTA

The Solution of the wireless tests

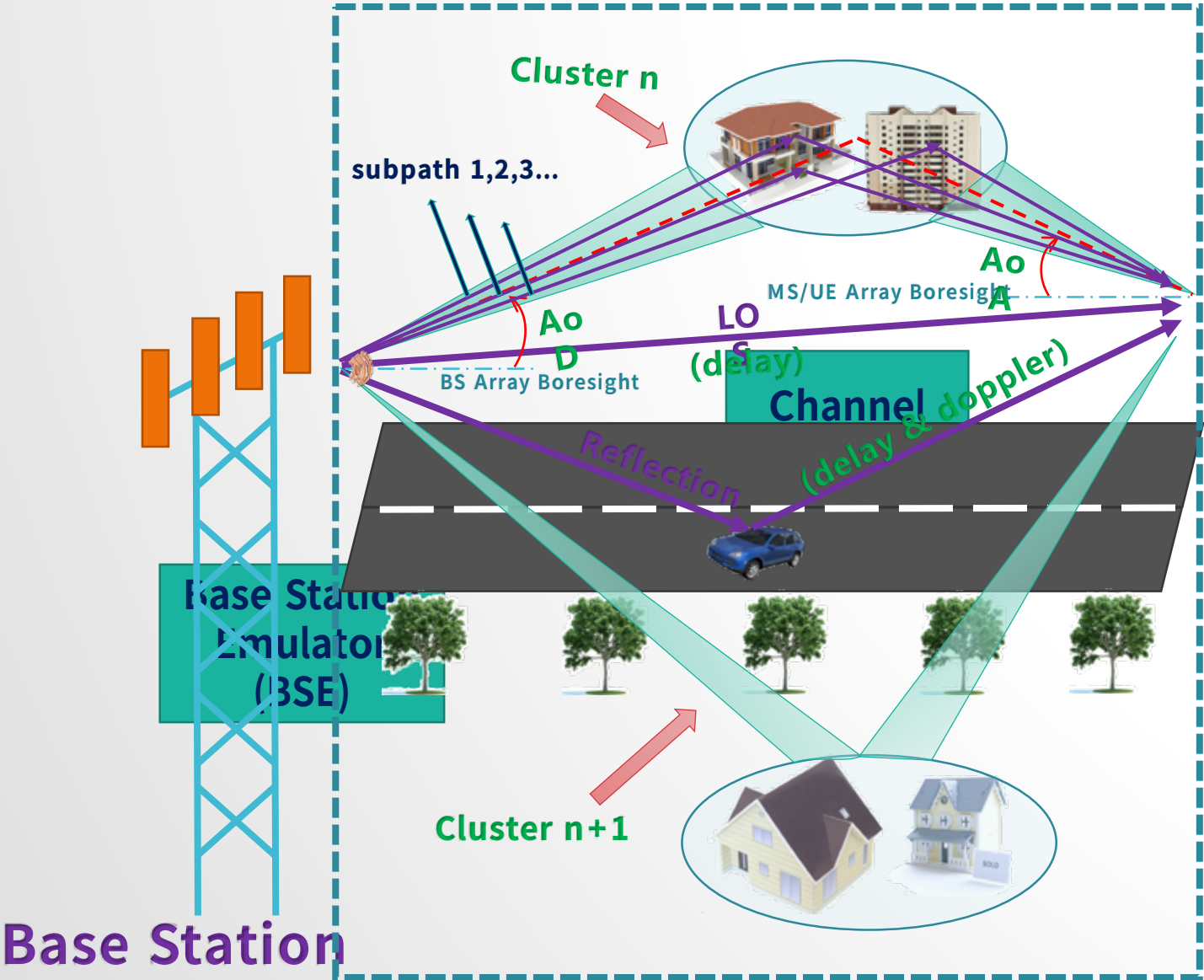
Over-the-air (OTA) test Reflect overall device performance in **real** environment



Channel Model Introduction



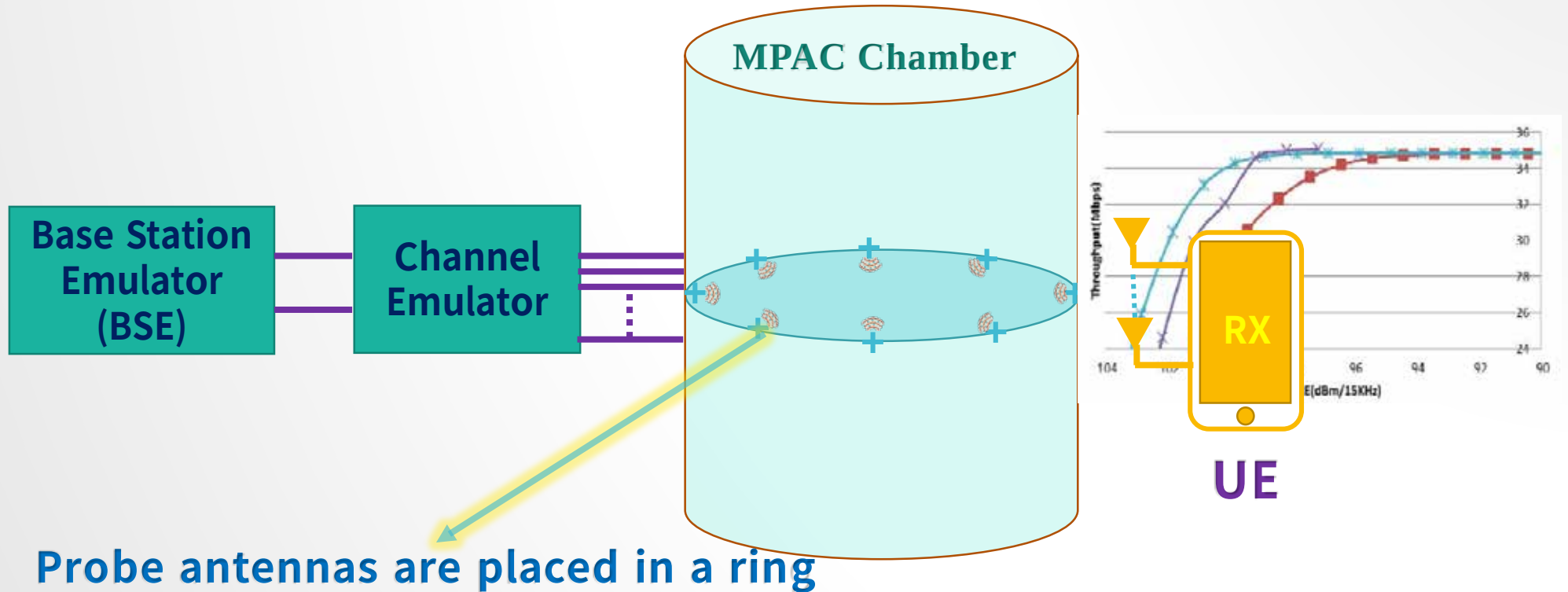
Channel Model Introduction



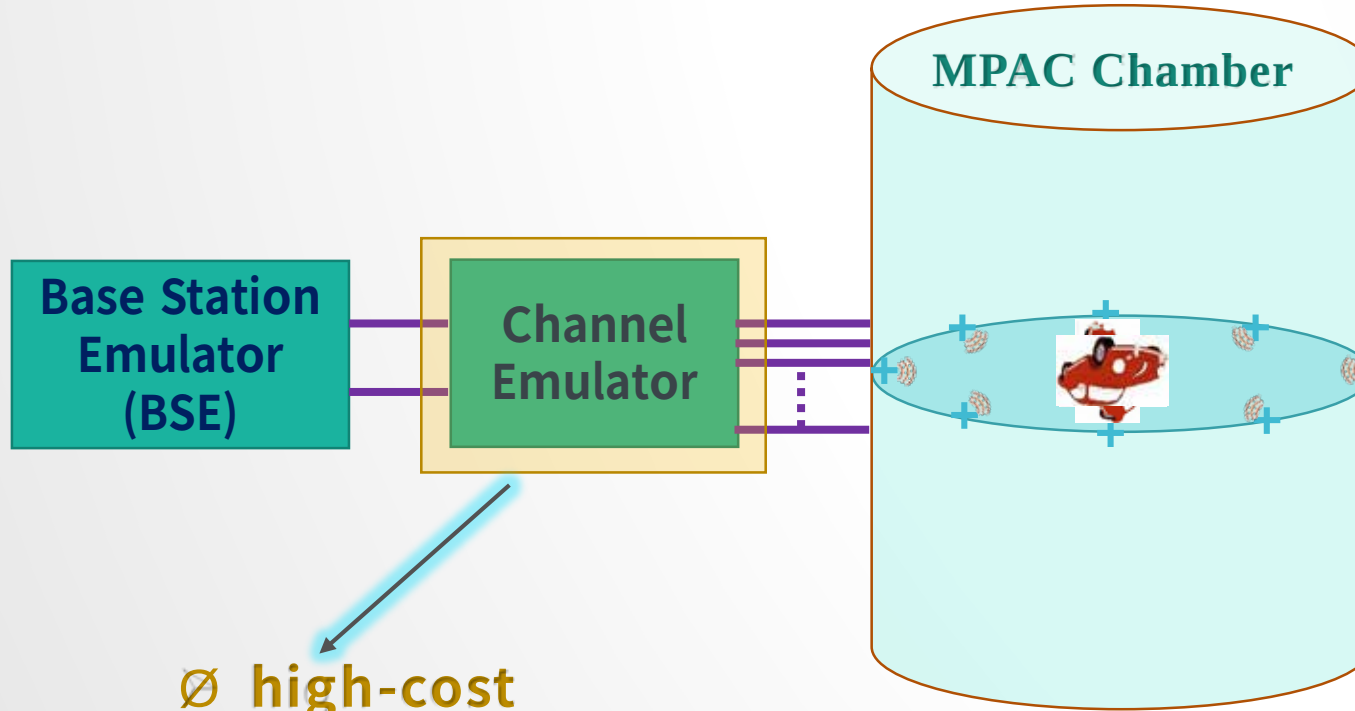
UE

- Cluster #
- Delay [ns]
- Power [dBm]
- AoD [°]
- AoA [°]
- Doppler

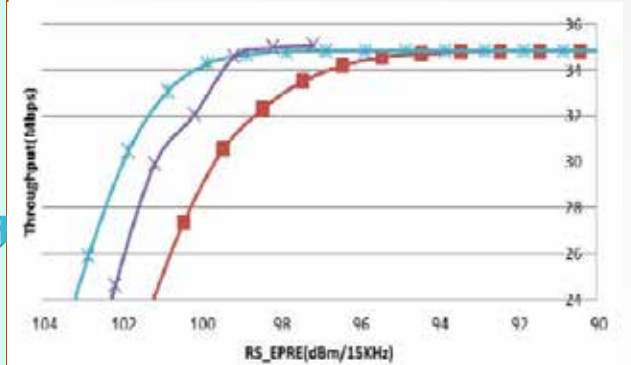
MPAC Method Introduction



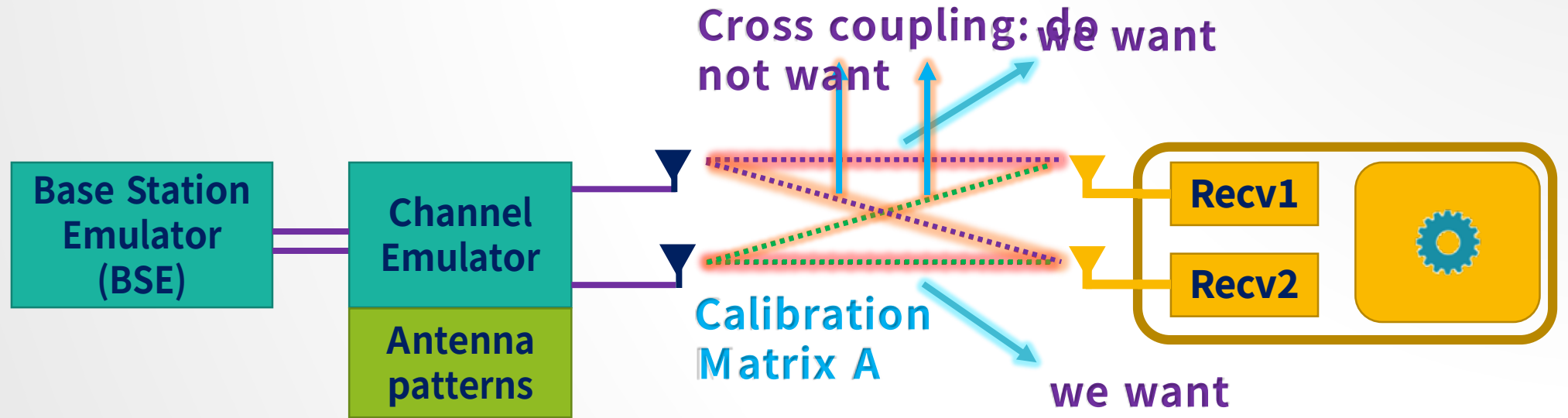
Challenges for MPAC Method



- Ø high-cost
- Ø 3D measurement: Unrealistic
- Ø Calibration Challenges: Complicated
- Ø The quiet zone size.



Radiated Two Stage (RTS) Method

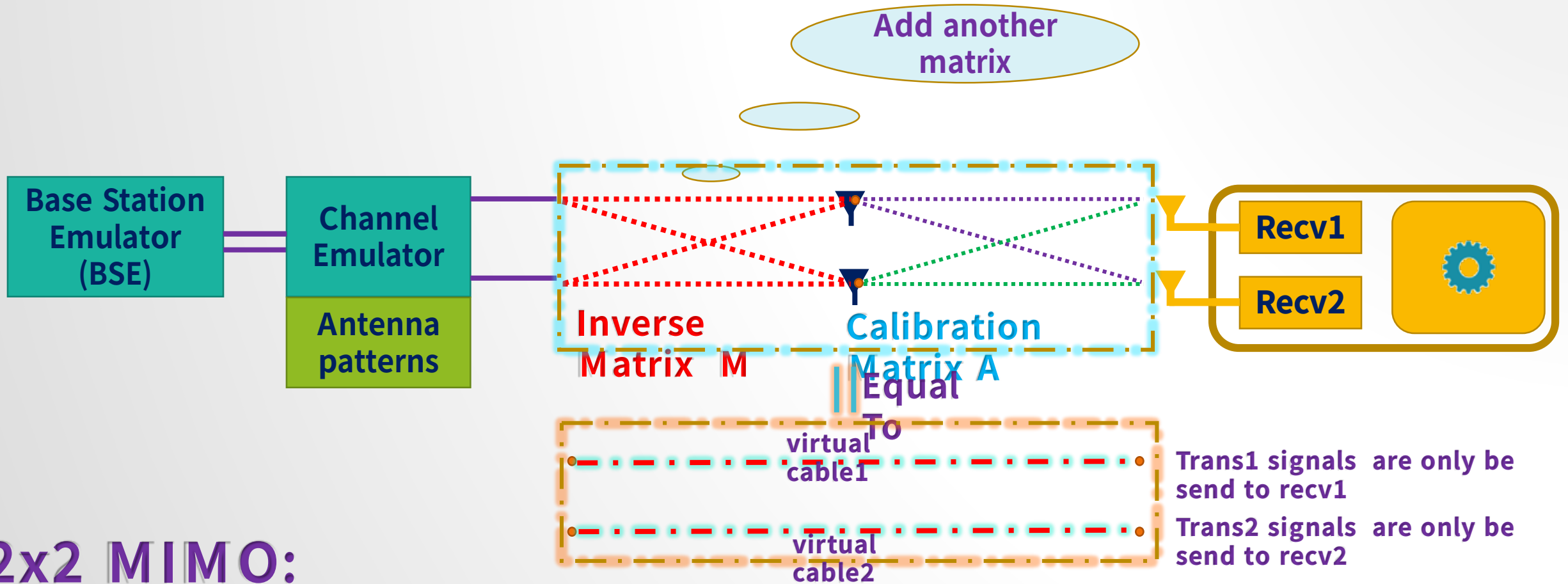


2x2 MIMO:

Step1: antenna patterns measurement

Step2:OTA Throughput Measurement

Radiated Two Stage (RTS) Method



2x2 MIMO:

Step1: antenna patterns measurement

Step2:OTA Throughput Measurement

Summary of RTS

Advantages

- Ø Uncertainty analysis completed
- Ø Cost effective
- Ø Fast
- Ø Provide more useful information

3GPP TS 37.544 V14.6.0 (2018-06)

Technical Specification

**3rd Generation Partnership Project;
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Universal Terrestrial Radio Access (UTRA) and Evolved
Universal Terrestrial Radio Access (E-UTRA);
User Equipment (UE) Over The Air (OTA) performance;
Conformance testing
(Release 14)**

obtained by this method, discovering the imperfections in the design of the device and the efficiency of MIMO systems.

Keywords—decomposition (MIMO); diagnosis; optimization

WHAT is the input and output to pass the imperfections and improve the MIMO technique is the basis of 4G and coming 5G wireless communications because of its high data rates and better quality

¹This work was supported by the Chinese Ministry of Education—China

processing, the propagation channels, the antennas system performance and etc. [1], [2]. The major challenge for MIMO OTA test is the repeatable realization of a test environment

Fast Method for OTA Performance Testing of Transmit–Receive Cofrequency Mobile Terminal

Penghui Shen, *Student Member, IEEE*, Yihong Qi, *Senior Member, IEEE*, Wei Yu, *Member, IEEE*, Fuhai Li, and Jun Fan, *Senior Member, IEEE*

Abstract—This paper provides a novel method for measuring a wireless user equipment, when the equipment uses the same frequency for both transmitting and receiving. The proposed method is based on the fact that the total radiated power (TRP) and the total isotropic sensitivity patterns are complementary for transmit-

and paper propose a technique for antenna system evaluation based on the RTS method. Besides the throughput, the antenna patterns, the ECC, the antenna imbalance and the

TIS are also two of the certification parameters for networking measurements. The OTA performance tests are significant for manufacturers and mobile operators. Moreover, the TIS test is important in the electromagnetic interference analysis of

papers for standardizations of MIMO OTA measurement [2], [11], [18]. At the end, only two methods were approved: the multi-probe anechoic chamber (MPAC) method [2], and the

multaneously of the spatial fading conditions [8]—based on wireless aspects of spreads,

[6] and the n (CTIA) ent white

Comprehensive Electromagnetic Test (CET) solution for Vehicles

CET-- EMC+OTA all-in-one test system

Measurement items			Solution features
Conventional EMC measurement			ØUnique OTA solution for vehicle MIMO test. ØCost effective solution. ØLeverage the CAPEX of current EMC chamber. ØShort lead time for CET system.
OTA measurement	SISO	GPS	
		2G, 3G, 4G cellular	
	MIMO	4G LTE	
		Wi-Fi MIMO	
	5G	Sub 6G terminal	
		Ready for future 5G	
	Phased-array antennas		
	Vehicular millimeter wave radar		

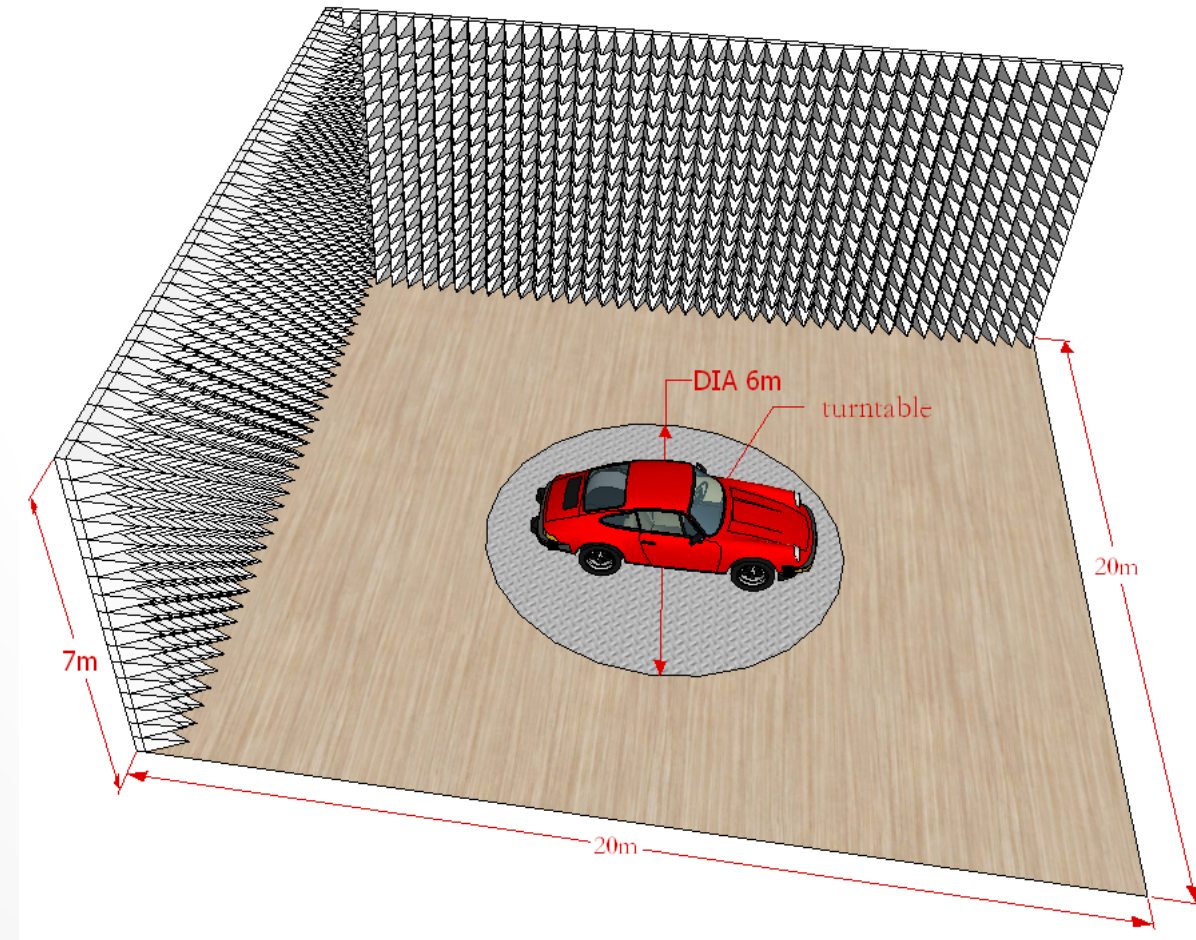
Existing EMC chamber (example)

Characteristics of a typical EMC chamber

- Ø Size: 20m×20m×7m (L*W*H) ;
- Ø Turntable: 6m (D) ;
- Ø The top and four walls covered by EMC absorber:
 - Ø ~20dB @600MHz~6GHz;
 - Ø ~15dB @20GHz~80GHz;
- Ø Metal floor (including the turntable)

The existing EMC chamber does not meet the requirements for OTA

- Ø Quite zone
- Ø Size (measurement distance)
- Ø Methodologies



Key Technical points to upgrade EMC system to CET test system

Challenges	
A. Quiet zone	BIG quiet zone to host the vehicle under test.
	Minimize reflection inside the quiet zone to meet requirements of SISO/MIMO/mmW test.
	Maintain the EMC test requirements unaffected.
	Fast switch between EMC and OTA test.
B. Absorbers	All-band absorbers covering the frequency band of EMC (30MHz~18GHz) , cellular OTA (600MHz~6GHz), 5G and millimeter wave (18GHz~90GHz).
	East to assembly and de-assembly.
C. Sampling frame	Host multi-probe antennas for MIMO test.
	High resolution sampling capability.
	Easy to install and uninstall.
D. Probe antenna	High gain, high CPR.
	Low RCS, low cross coupling.
	Symmetrical beam.
E. Methodologies	Fast methods for SISO.
	Fast and accurate methods for vehicle 3D MIMO throughput test.
	NF-FF transformation (with and without phase measurement).
	DUT offset compensation algorithms.

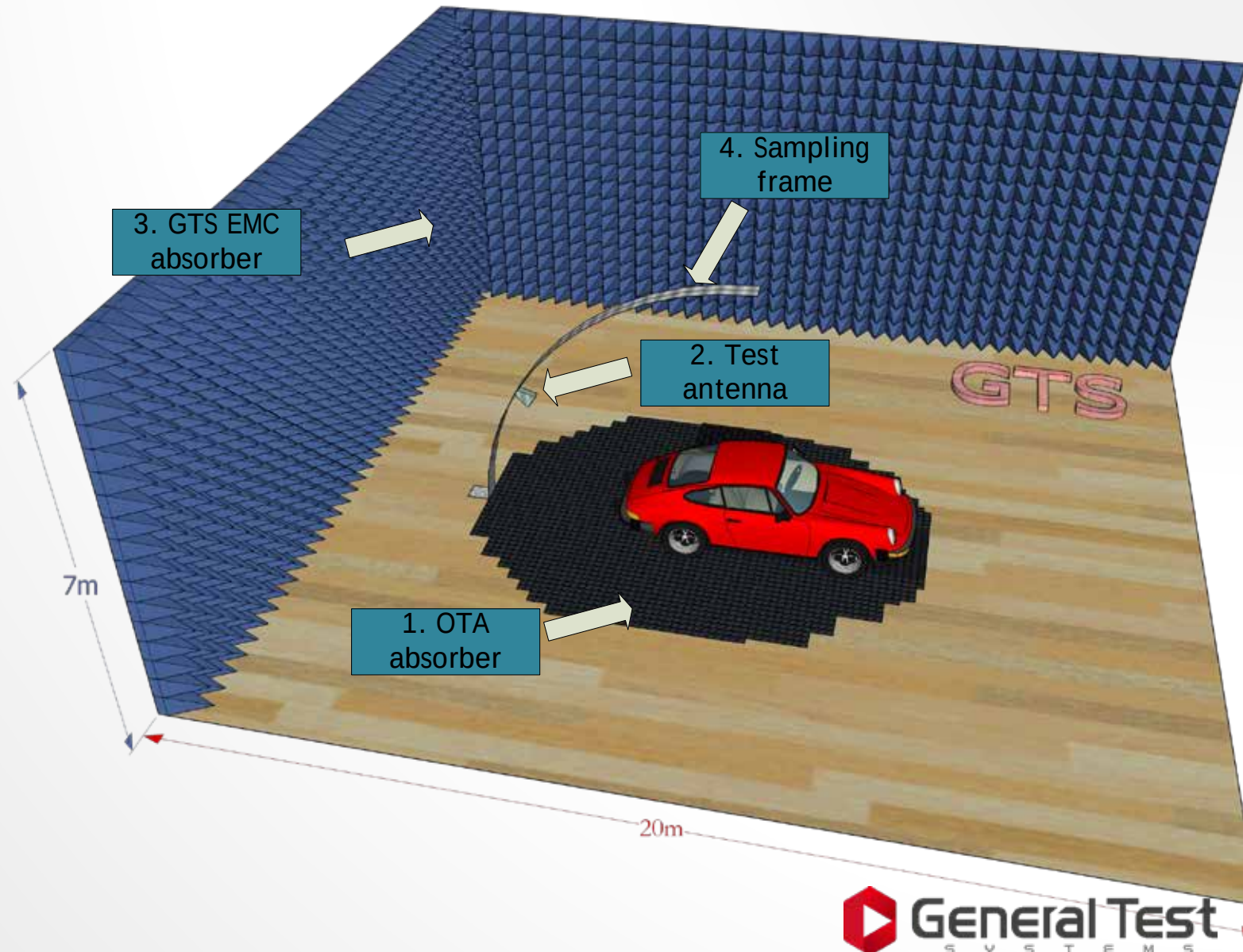
WHAT NEEDS TO BE DONE ?

-- STEP 1: HARDWARE UP-GRADATION

Create Quiet Zone for OTA test inside EMC chamber

Hardware up-gradation to create the quiet zone for OTA test inside the EMC chamber

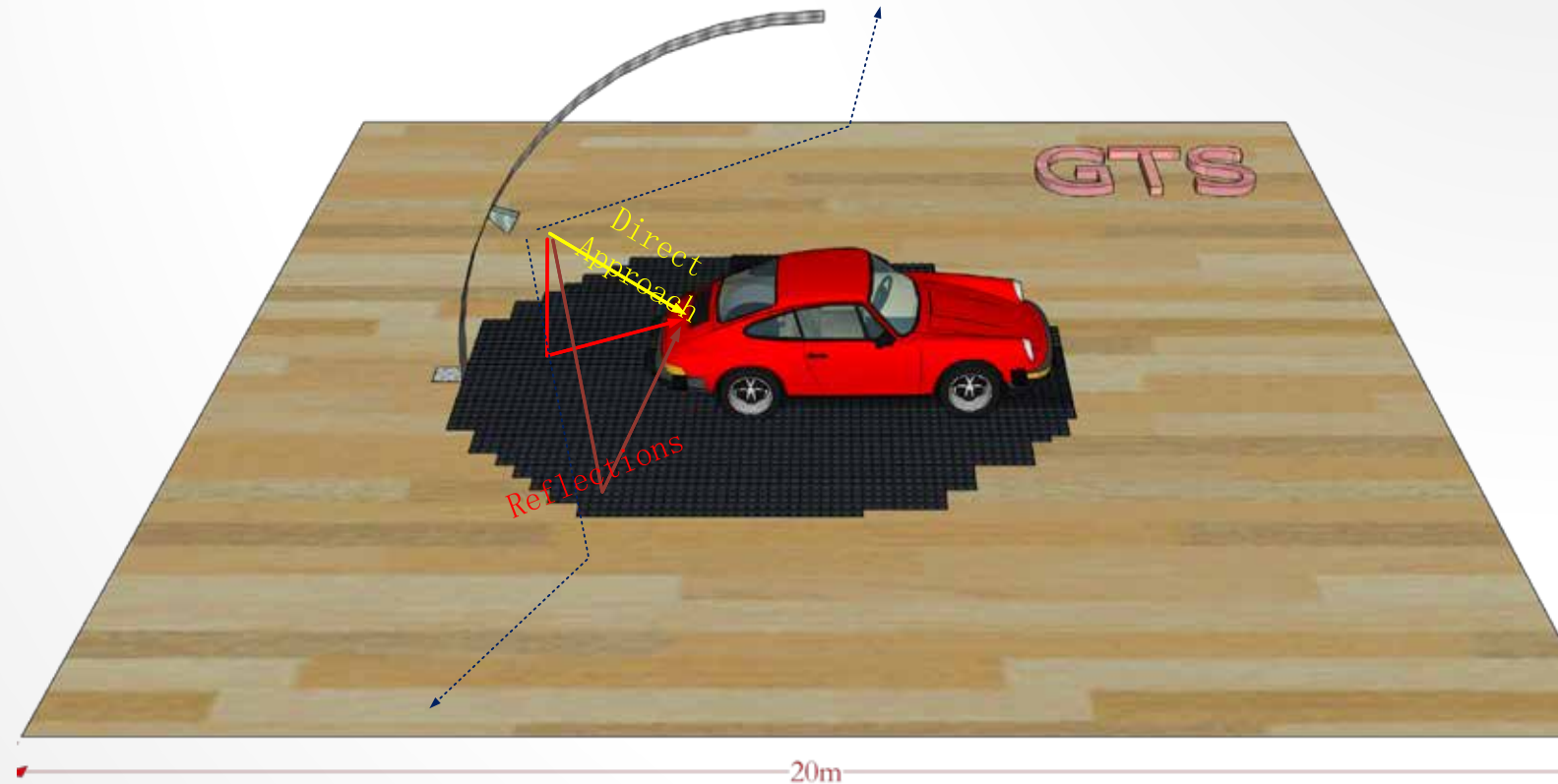
- Ø New EMC+OTA absorber installed on the wall to minimize the reflection if necessary based on EM simulation.
- Ø Microwave Absorber used on the floor. EPP absorber, easy to deploy.
- Ø Sampling Frame hosting probe antennas.
- Ø High performance Probe antennas and microwave components.



Reflection inside the quiet zone for OTA

- Ø The yellow line indicates the direct link between the DUT and the Probe antenna
- Ø Single reflection from the floor to the DUT (the red lines) is minimized by the absorbers installed.
- Ø Multi-reflections, from the floor to the wall and bounced back to the DUT (the black lines), is too weak to be taken into consideration.
- Ø The reflection must be minimized to meet the OTA requirements:

Items	Reflection	Contributed errors (typical)
SISO	-20dB	$\pm 0.2\text{dB}$
MIMO	-25dB	$\pm 0.3\text{dB}$
5G, phased-array antennas, MMW radar	-35dB	$\pm 0.2\text{dB}$



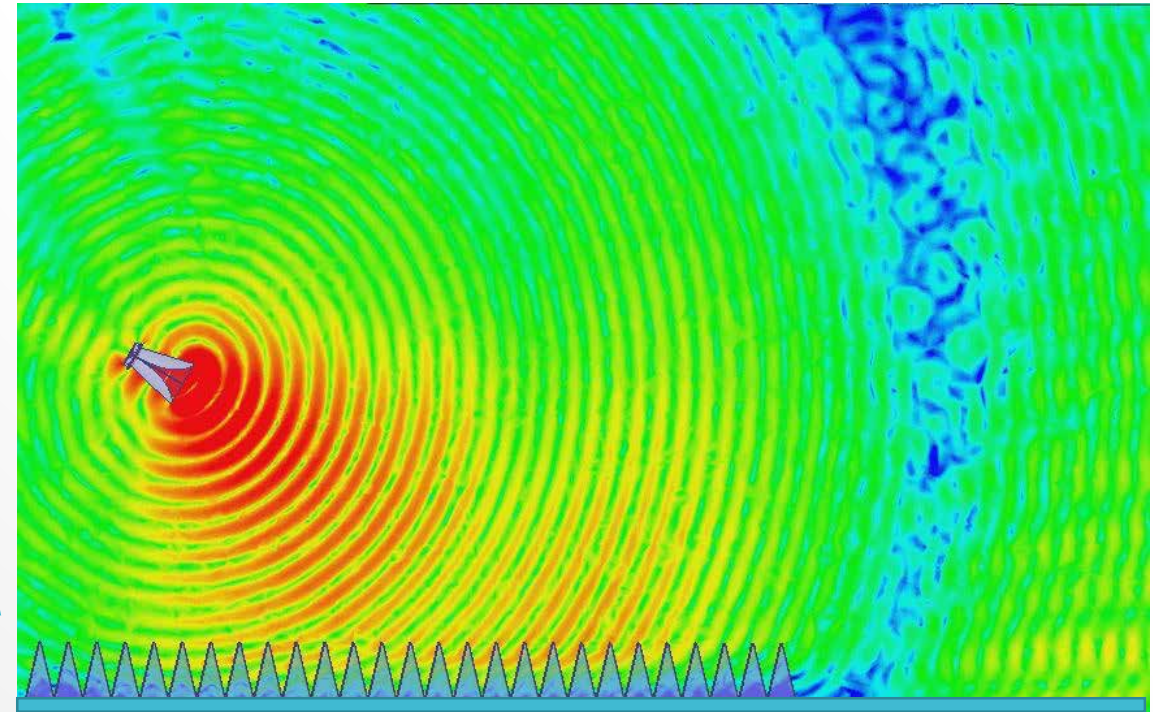
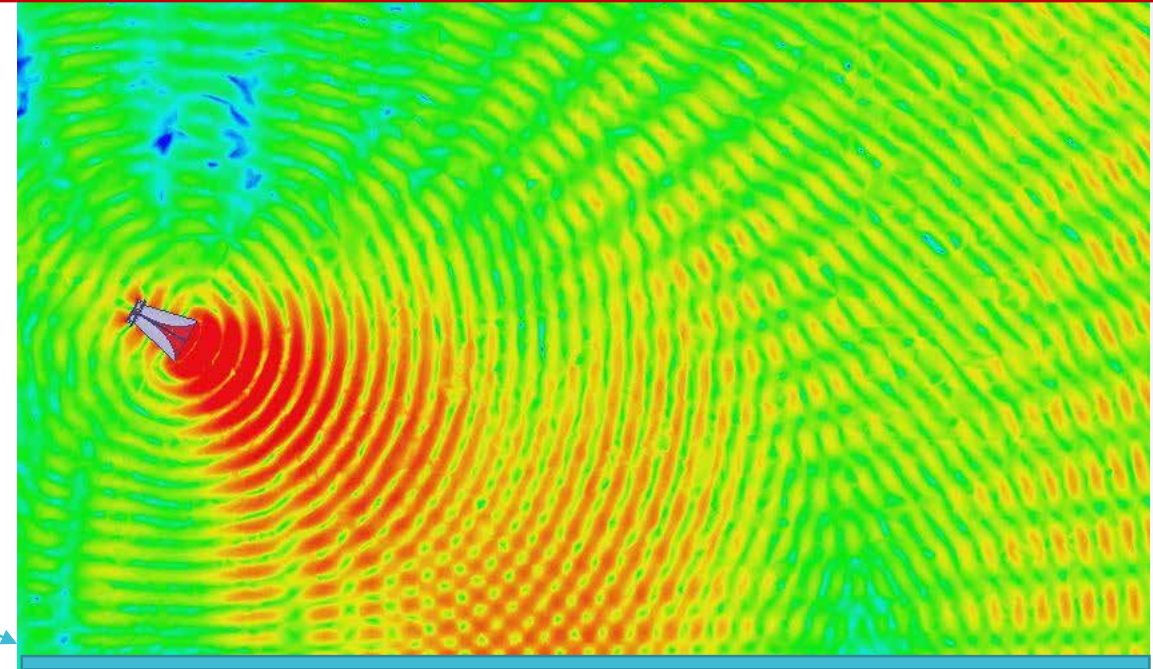
Reflection evaluation method

Computing the reflection levels under two conditions:

Ø without the absorbers on floor (EMC chamber with metal floor);

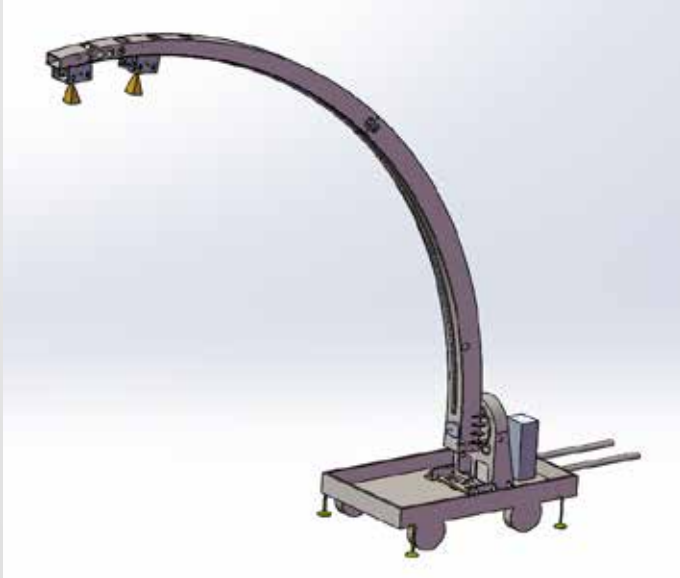
Ø with GTS absorbers on the floor.

Calculate out the minimum area required to be covered.



Components

1. Sampling frame

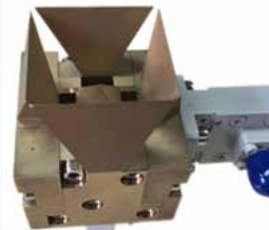


2. Measurement Antenna



400MHz~6GHz

18GHz~80GHz



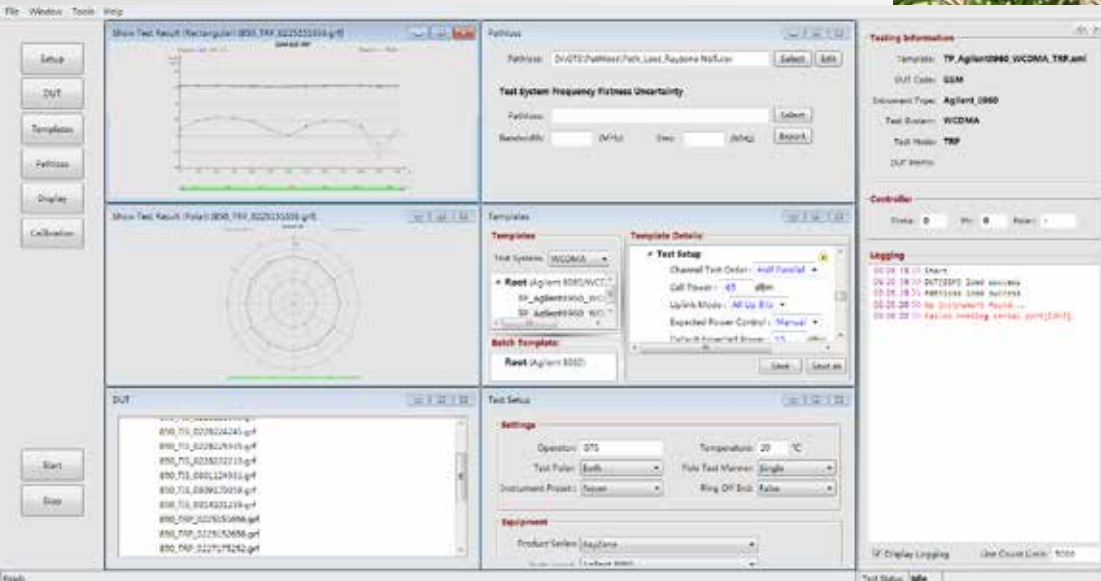
3. Absorbing material



All required components are ready to use.

Instruments and setups

Ø Setups: PC + Keysight UXM for MIMO



WHAT NEEDS TO BE DONE ?

-- STEP 2: METHODOLOGIES

SISO OTA measurement

GTS has lots of contributions on fast and accurate test methods for 2G, 3G, 4G, WiFi SISO, GPS, IoT and so on, which have been implemented on GTS's OTA test system.

Y. Qi, P. Jarmuszewski, Q. Zhou, M. Certain, and J. Chen, "An Efficient TIS Measurement Technique Based on transactions on instrumentation and measurement, vol. 59, no. 9, pp. 2414-2419, 2010.

P. Shen, Y. Qi, W. Yu, F. Li, and J. Fan, "Fast and Accurate TIS Testing Method for Wireless User Equipment Electromagnetic Compatibility, vol. 58, pp. 887-895, 2016.

P. Shen, Y. Qi, W. Yu, F. Li, and J. Fan, "Fast Method for OTA Performance Testing of Transmit-Receive Co on Electromagnetic Compatibility, vol. 58, pp. 1367-1374, 2016.

Y. Qi, W. Yu, "Unified Antenna Temperature," IEEE Transactions on Electromagnetic Compatibility, vol. 58, pp. 1425-1431, No. 5, June 2016.

Y. Qi, J. Wu, Z. Zhang, L. Liu, W. Yu, A. Orlandi, J. Fan, and Z. Yang "Objective Total Isotropic Sensitivity Measurement," IEEE Transactions on Electromagnetic Compatibility, vol. 59, pp. 1671-1676, 2017.

P. Shen, Y. Qi, W. Yu, F. Li, and J. Fan, "Fast and Accurate TIS Testing Method for Wireless User Equipment With RSS Reporting," IEEE transactions on Electromagnetic Compatibility, vol. 58, pp. 887-895, 2016.

Z. Liu, Y. Qi, F. Li, W. Yu, and J. Fan, "Fast Band-Sweep Total Isotropic Sensitivity Measurement," IEEE transactions on Electromagnetic Compatibility, vol. 58, pp. 1244-1251, 2016.

TABLE II. COMPARISONS					
Protocol	Method	TIS (dBm)	Diff. (dB)	Period (mins)	Times
LTE	power-stepping	-96.10	0.30	20	4
	BER-curve based	-96.40		5	
Wi-Fi	power-stepping	-82.71	0.49	88	8.8
	co-frequency	-83.20		10	
GPS	power-stepping	-108.40	0.23	60	12
	RSS-based	-108.63		5	

All algorithms are protected by patents

MIMO OTA measurement

RTS method is a fast, accurate and cost efficient test solution for MIMO OTA. Proposed by GTS in 2014, RTS is now acknowledged as standard test plan in 3GPP TS 37.544 in March 2018.

Within the two recognized MIMO OTA test method in 3GPP, RTS is the only one suitable for vehicle test.

W. Yu, Y. Qi, K. Liu, Y. Xu, and J. Fan, "Radiated Two-Stage Method for LTE MIMO User," IEEE transactions on Electro 1691-1696, Dec. 2014.

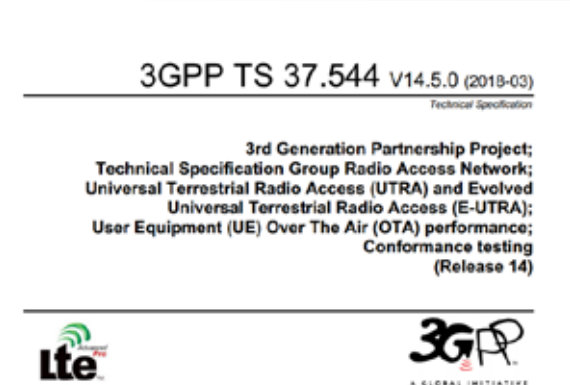
P. Shen, Y. Qi, W. Yu, and F. Li, "Inverse Matrix Auto-Search Technique for the RTS MIMO OTA Test—Part 1: Theory," Compatibility, vol. 59, pp. 1716-1723, 2017.

P. Shen, Y. Qi, W. Yu, and F. Li, "Inverse Matrix Auto-Search Technique for the RTS MIMO OTA Test—Part 2: Validation Electromagnetic Compatibility, accepted and to be published.

P. Shen, Y. Qi, W. Yu, and F. Li, "Eliminating RSARP Reporting Errors in the RTS Method for MIMO OTA Test," IEEE transactions on Compatibility, vol. 59, pp. 1708-1715, 2017.

P. Shen, Y. Qi, W. Yu, J. Fan, Z. Yang, and S. Wu, "A Decomposition Method for MIMO OTA Performance Evaluation," IEEE transactions on Electromagnetic Compatibility, accepted and to be published.

Wei Yu, Yihong Qi, method and device for testing performance of wireless terminals, US 9614627, 2015.



All algorithms are protected by patents

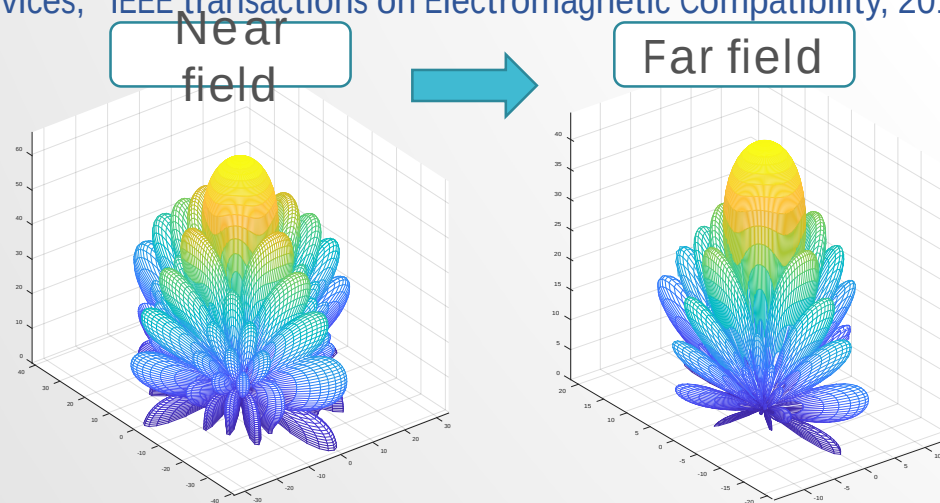
5G, array antenna, and MMW OTA measurement

A source re-construction method is used for the 5G, array antenna and MMW OTA measurement (near field to far field transformation).

Y. Qi, G. Yang, L. Liu, J. Fan, A. Orlandi, H. Kong, W. Yu, and Z. Yang, "5G Over-the-Air Measurement Challenges: Overview," IEEE transactions on Electromagnetic Compatibility, vol. 59, pp. 1661 - 1670, 2017.

P. Gong, L. Liu, Y. Qi, W. Yu, F. Li, and Y. Zhang, "Multiphasic Analysis of Millimeter-Wave Absorber with High-Power Handling Capability," IEEE transactions on Electromagnetic Compatibility, vol. 59, pp. 1748 - 1754, 2017.

F. de Paulis, A. Orlandi, J. Wu, Y. Qi, and C. Olivieri, "Applicability of Cylindrical Near-Field to Far-Field Transformation to OTA and EMC Measurements of 5G Equipment and Devices," IEEE transactions on Electromagnetic Compatibility, 2017.

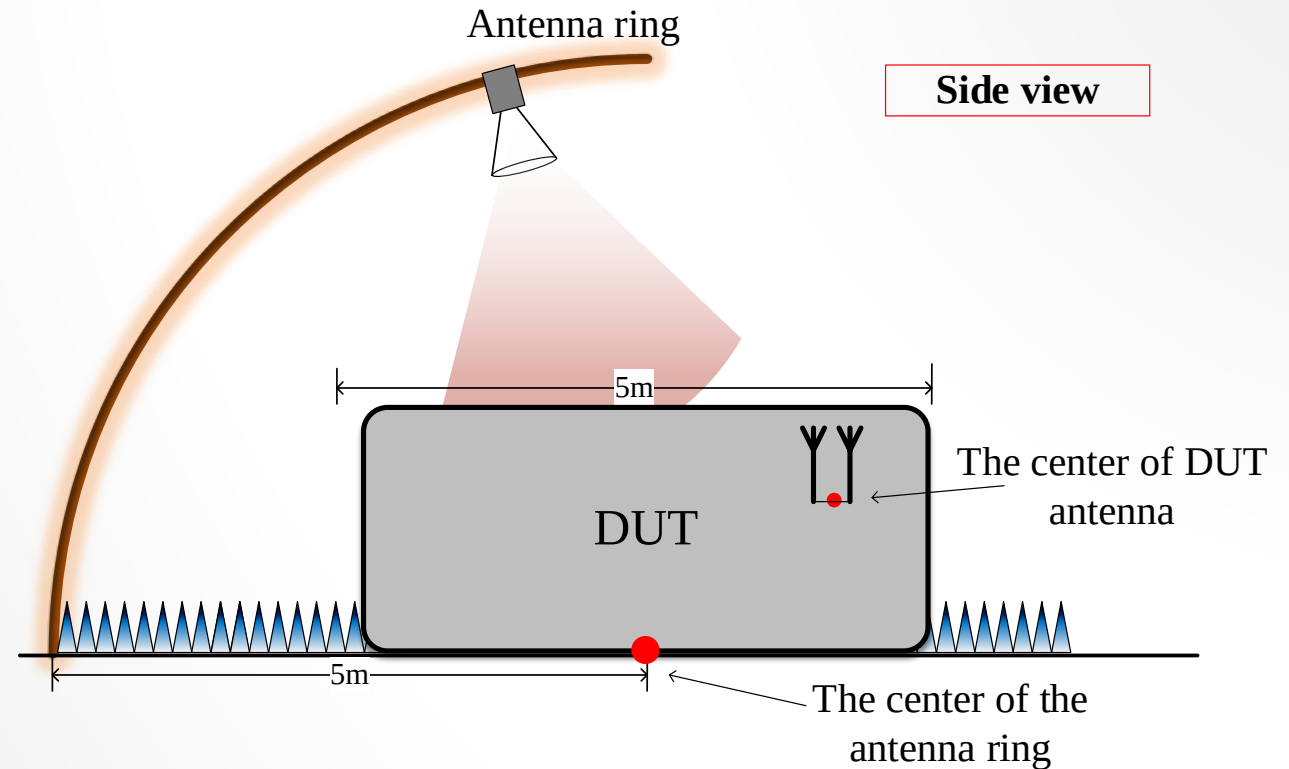


All algorithms are protected by patents

DUT offset compensation algorithm

Ø Challenge in the vehicle OTA test:
in most cases the DUT may be off-centered from the center of the turntable.

Ø Solution: Source re-construction method proposed by GTS



Y. Wang, S. Wu, Z. Yang, P. Shen, and J. Fan, "Studying the effects of location offset on the evaluation of MIMO performance based on the radiated two-stage (RTS) method," 2017 IEEE International Symposium on Electromagnetic Compatibility & Signal/Power Integrity (EMCSI), pp. 464-469, 2017.

All algorithms are protected by patents

Line of OTA systems to test Antenna/Receiver



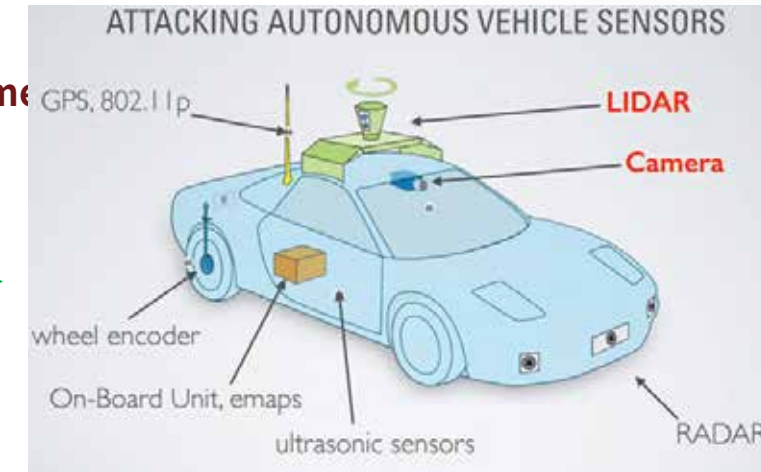
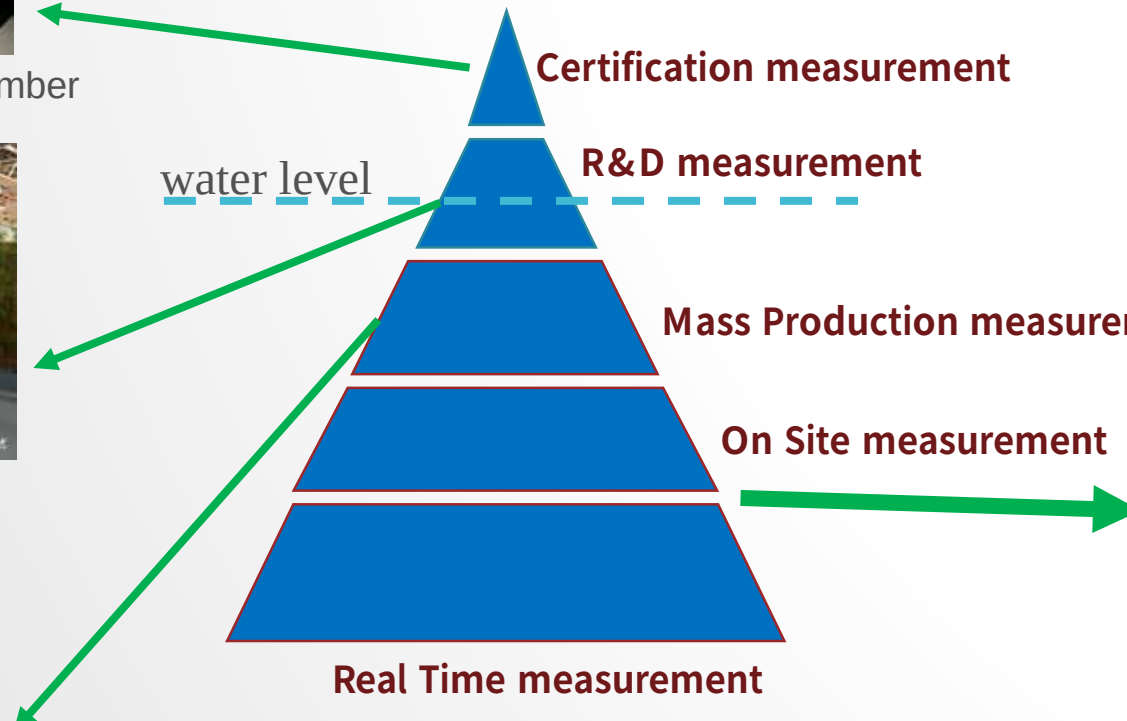
Dart-9000B
China first CTIA certification chamber



RayZone 2800
MIMO OTA chamber



Rayline 600
Mass Production measurement





Accurate · Simple · Fast · Agile