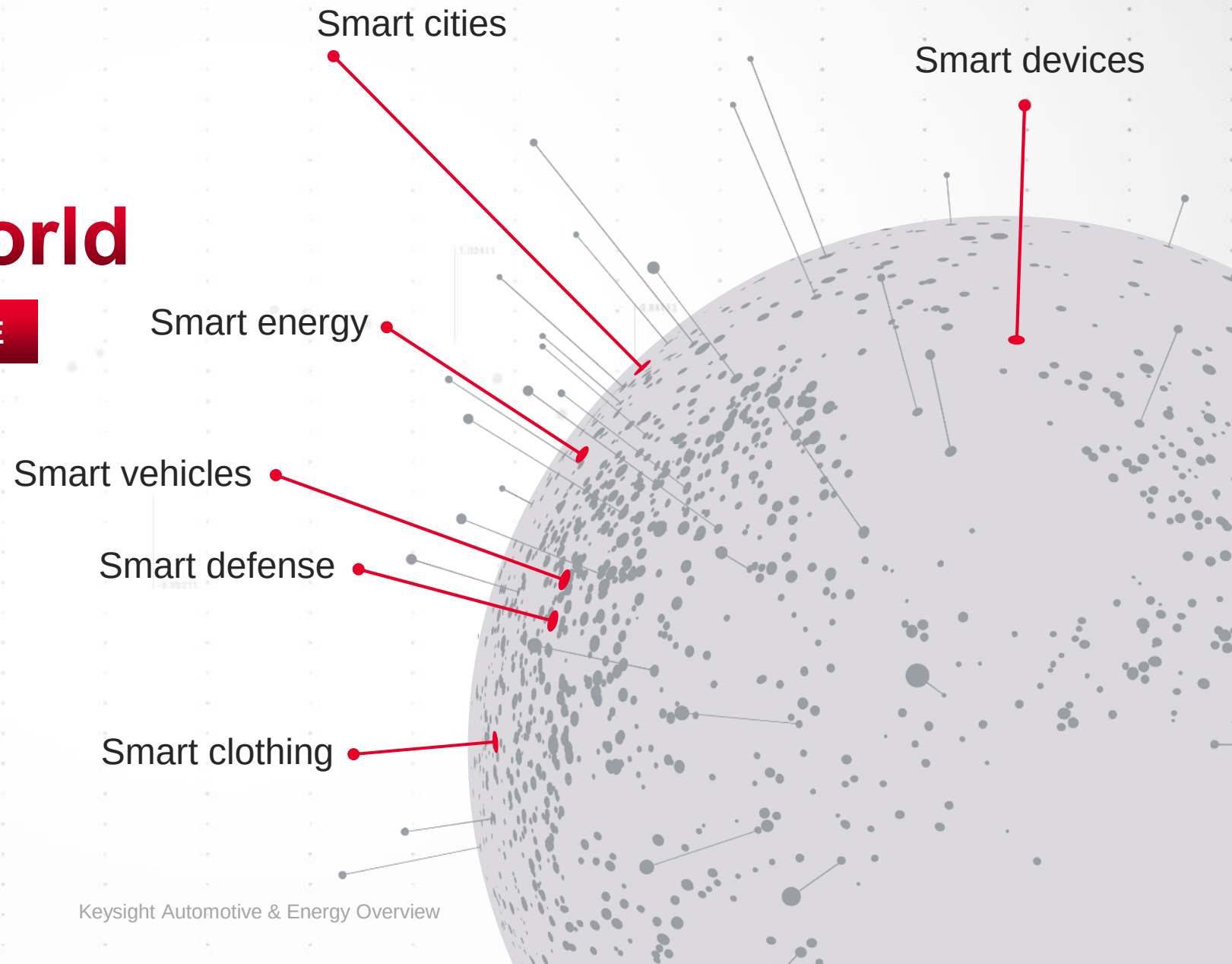
E6953A DSRC CoC Certification solution

April 2018	***2018.4.5***
/ Keysight Technologies	

Technology Connects the World

INNOVATION IS EVERYWHERE



Our Expectations Are Growing: The Car Industry

LAST 220+ YEARS (1770 – 1997)

Cugnot – Steam Powered

1770

Benz – Combustion

1885

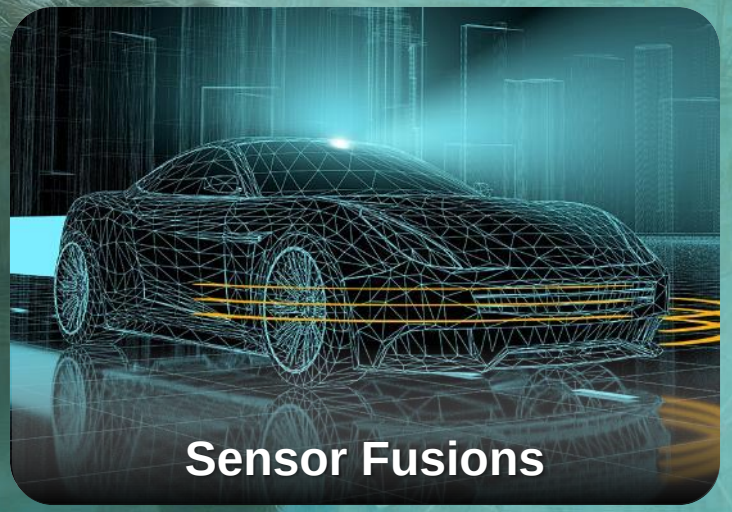
Toyota – Hybrid Electric

1997

Progress was electromechanical in the first **220+ Years**

Pace of Innovation is Accelerating

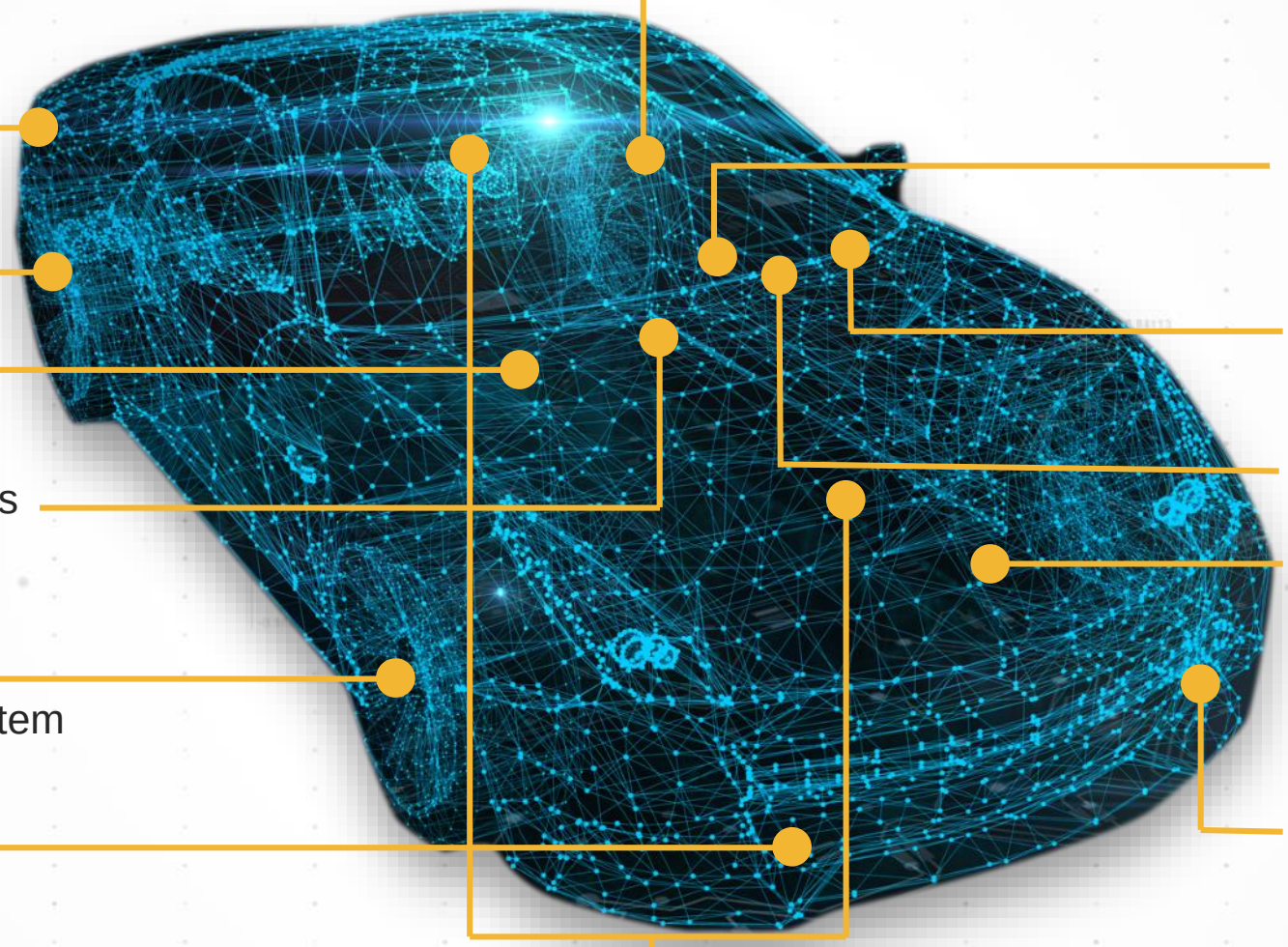
LAST 20+ YEARS



2004 → 2016 → 2020+

Innovation has completely **revolutionized** the industry

Innovations Through Multiple Technology Domains



Radar Collision Avoidance

Electronic Stability Control Module

Climate Control System

Infotainment/Navigation Modules (DVD, eCalls, Hands Free Telephony, GPS)

Anti brake Locking system
Tire Pressure Monitoring system

Emission Control Module

Power Steering Control
Rear-view camera
Backup sensors
Power Seat Control

Personnel Occupancy Detection Systems (PODS) for Air Bag systems

Remote Keyless Entry

Instrument Clusters

Fuel Injection Module
Power Train &
Engine Management
(MiL, SiL, HiL)

Adaptive Lightning Control

Hybrid Electric Vehicle
(HEV) / Electric Vehicle (EV)

Evolution of Sensors in Vehicles

Mechanical Designs Starting in 1976

- Basic electronics
- Mostly mechanical
- No connectivity

Assisted Driving Starting in 1997

- Electronic safety systems
- Integrated electronics
- Electric control units
- Infotainment

Autonomous Coming Next

- Sensor fusions
- Autonomous processing
- Auto-charging technologies
- Multi-connectivity

Technology Requirements Keep Advancing

MORE ELECTRONICS, MORE EFFICIENCY, MORE SENSORS

Electronics

- Better diagnostics
- Automotive Ethernet
- Infotainment

Batteries

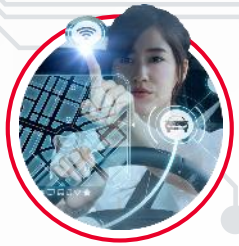
- Longer range
- Higher densities
- More eco-friendly

Connectivity

- More information
- Better safety
- Easier navigation

Sensors

- Electro-mechanical
- Driver vision
- More autonomy



Emerging Standards

More Efficient Power

Innovators Have More Dynamic Variables

TO WIN: REIMAGINE INNOVATION PROCESSES

Higher Integration

Autonomy With Safety

By 2020,
IoT markets will grow to

$470 billion

Source: Bain

By 2020,
Connected car technology will grow to

$1.6 billion

Source: Frost and Sullivan

By 2026,
the 5G market will grow to

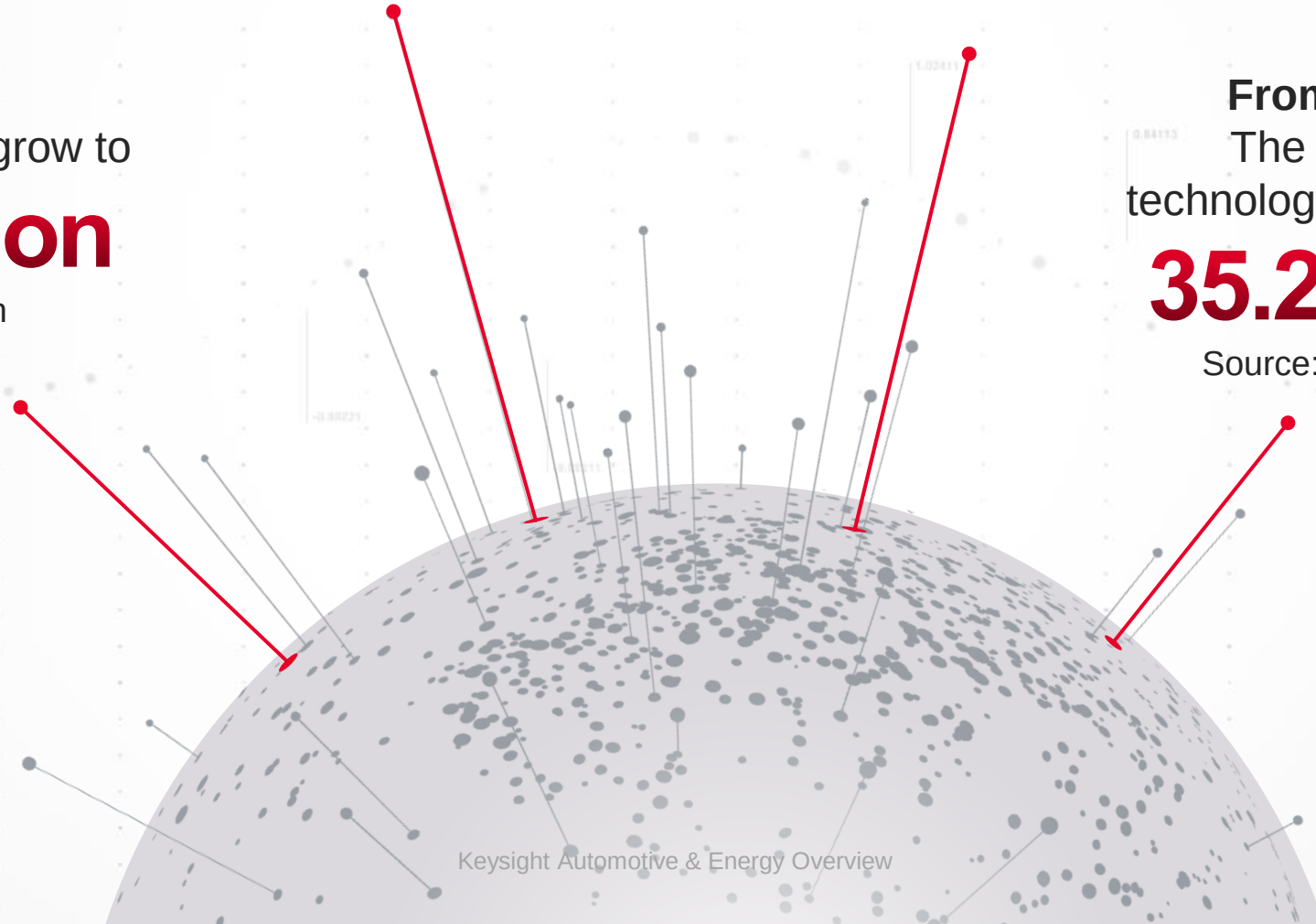
$1.2 trillion

Source: Ericsson

From 2017 to 2023,
The millimeter wave technology market will grow by

35.2% CAGR

Source: Markets and Markets



We Are at the Heart of the Revolution

Accelerating Innovation to Connect and Secure the World

WIRELESS

ENERGY

IOT

AUTOMOTIVE

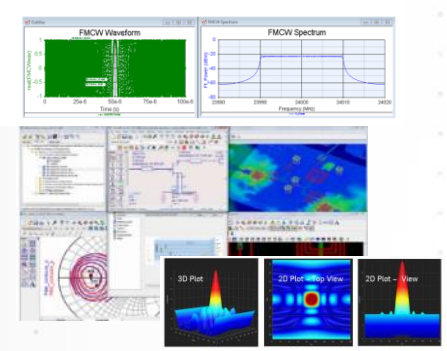
AEROSPACE & DEFENSE

NETWORKING/ CLOUD

KEYSIGHT TECHNOLOGIES

Keysight Connected Car Solutions

- *"Over Your Design and Test Lifecycle"*



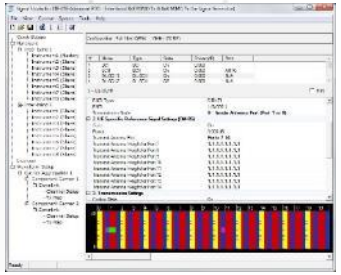
ADS / SystemVue Simulation SW

E7515A UXM Wireless Test Set

T4010S Conformance Test System

E6640A EXM Wireless Test Set

Architecture / Design → Development → Validation → Manufacturing



Signal Studio and Signal Creation Software

X-Series Signal Analyzers

X-Series Signal Generators

X-Series Oscilloscopes

Test Challenges and Requirement for V2X(DSRC)

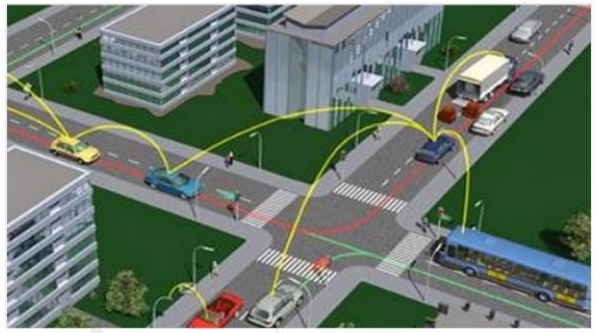
V2X – Enhanced Safety, Enabling Higher Levels of Automation

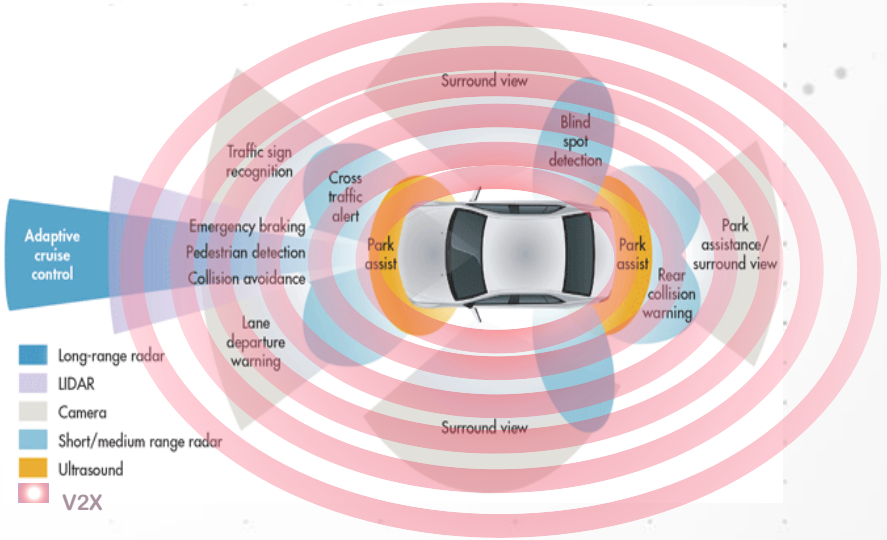
V2V, V2I, V2P, V2N …

Technology to enhance driving experience, prevent accidents and collisions, assist traffic flow, enable higher levels of automated driving.

2 wireless technologies are currently being proposed -

- ❑ DSRC (based on IEEE 802.11p)
- ❑ C-V2X (based on 3GPP Rel-14 LTE-A Pro)



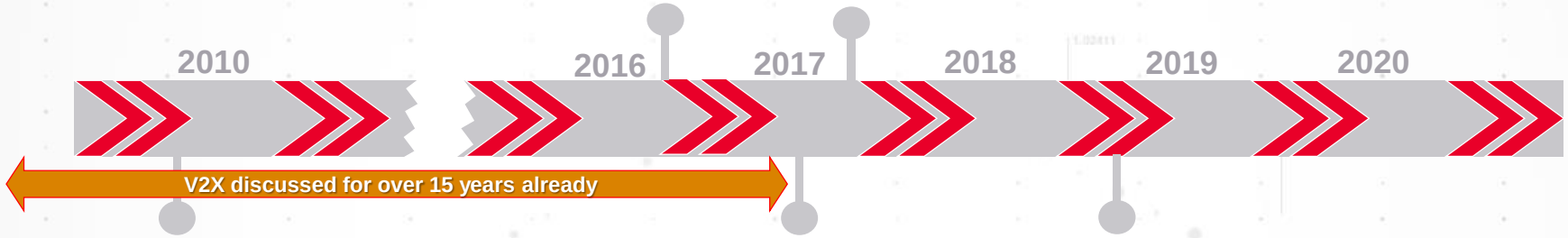


Secure V2X considered necessary for L3/L4 ADAS

V2X Standards: Global Landscape

United States
- NHTSA NPRM mandating V2V
- All new cars with DSRC by 2024

First pilots and trials (C-V2X)
- Europe, China



Basic Safety

DSRC (802.11p)
- Specs available since 2010 (discussions on ITS >13 years ago!)
- Proto devices being produced today
- Well tested, many trials, Eu/US/Ja support
- *Concerns include infrastructure costs and lack of features to support new Use Cases*

'Enhanced Safety'

LTE V2X (3GPP Rel 14)
- Specs available only since March 2017
- Main advantage:can reuse existing infrastructure to cover V2I/V2N
- V2V building on D2D (R12)
- Designed to be handle newer Use Cases
- Concerns over latency and lack of trials, congestion control

'Advanced Safety'

LTE V2X Rel-15+
- Next generation cellular technology
- Eventually will augment LTE V2X
- Backwards compatible
- Major priority is eMBB though (IoT and Automotive will be delayed)

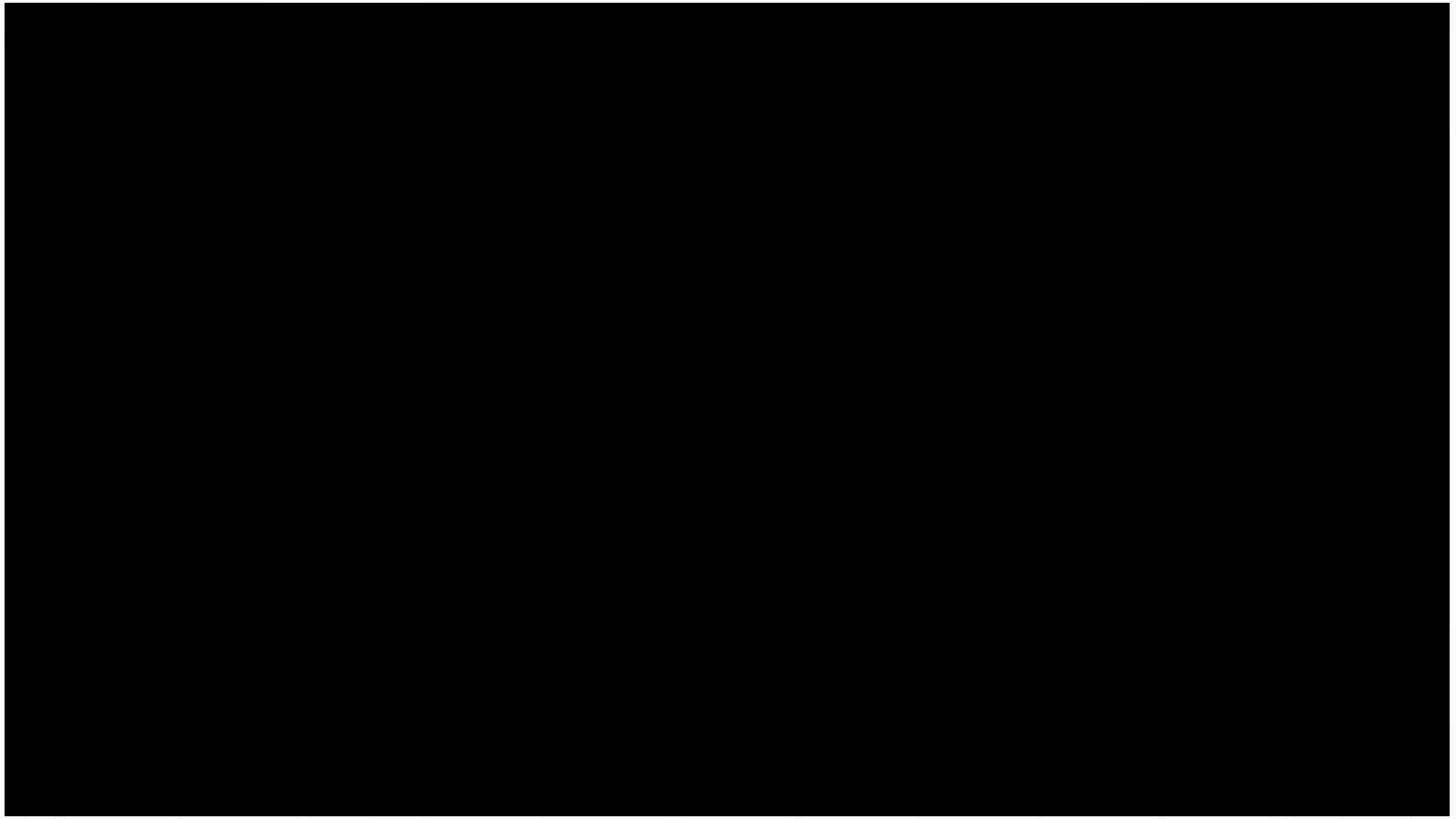
DSRC

MARKET TRENDS AND CHALLENGES

- Top 3 market trends/drivers
  - V2X close to mandatory deployment order in US
  - DSRC/WAVE/802.11p incumbent & ready standard
  - Cellular V2X being counter-proposed by Wireless heavyweights Qualcomm & Huawei, but standard not fully ready or a match to all Use Case requirements
- List top market challenges
  - Roll-out of DSRC RSU infrastructure for V2I use cases
  - Design/development of OBUs and RSUs conforming to 802.11p + relevant higher layer protocols in each region

Future Trends for Road Vehicle

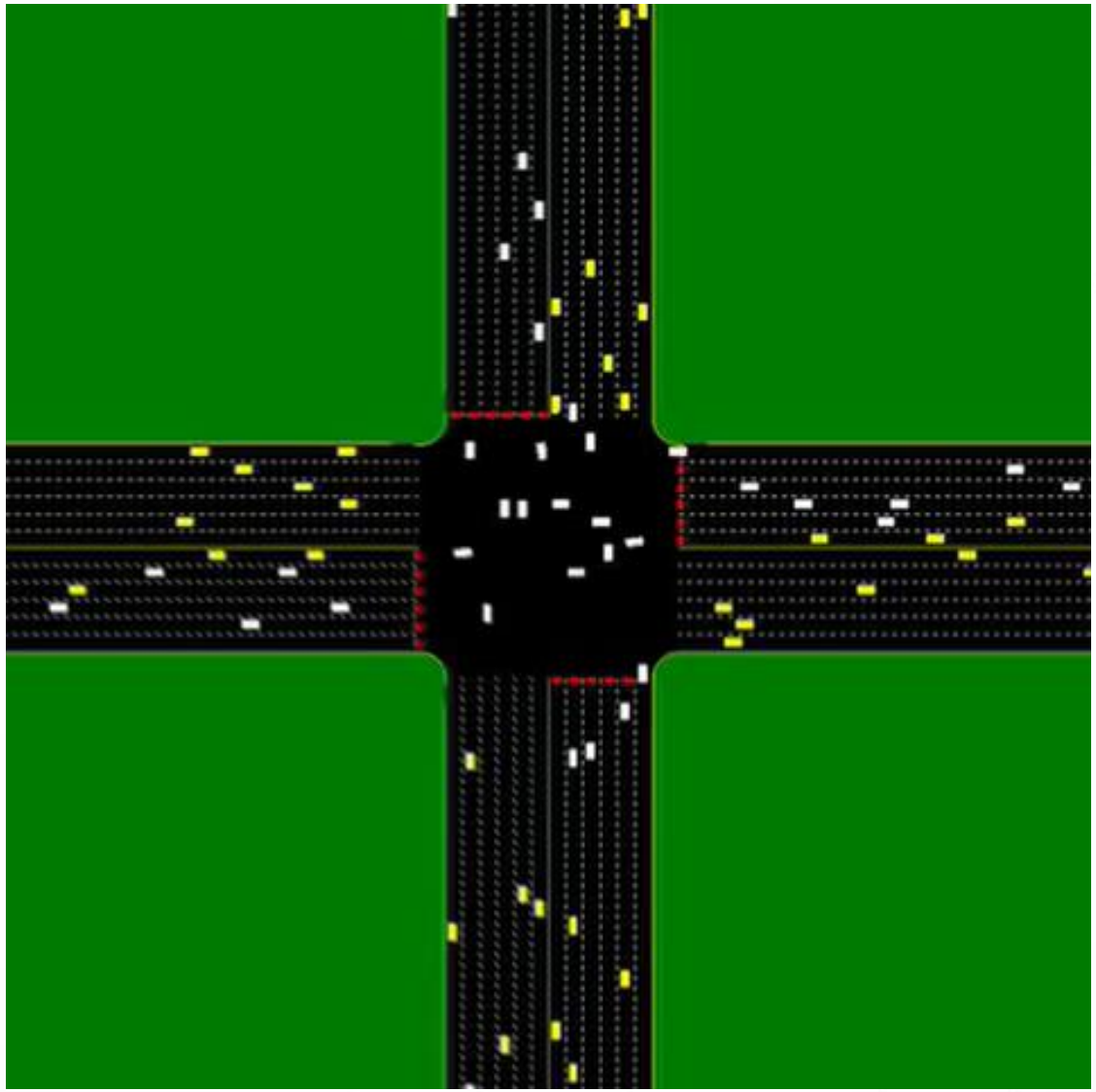
Less Air pollution, Less delay



MIT Senseable City Lab 2016

Future Trends for Road Vehicle

Less Air pollution, Less delay



Texas University
Autonomous Intersection Management
2009

E6953A DSRC CoC Certification solution

E6953A DSRC CoC Certification Test Solution

802.11p, IEEE1609.3,4, 2 Tests Cases supported: J2945/1 Tests in progress

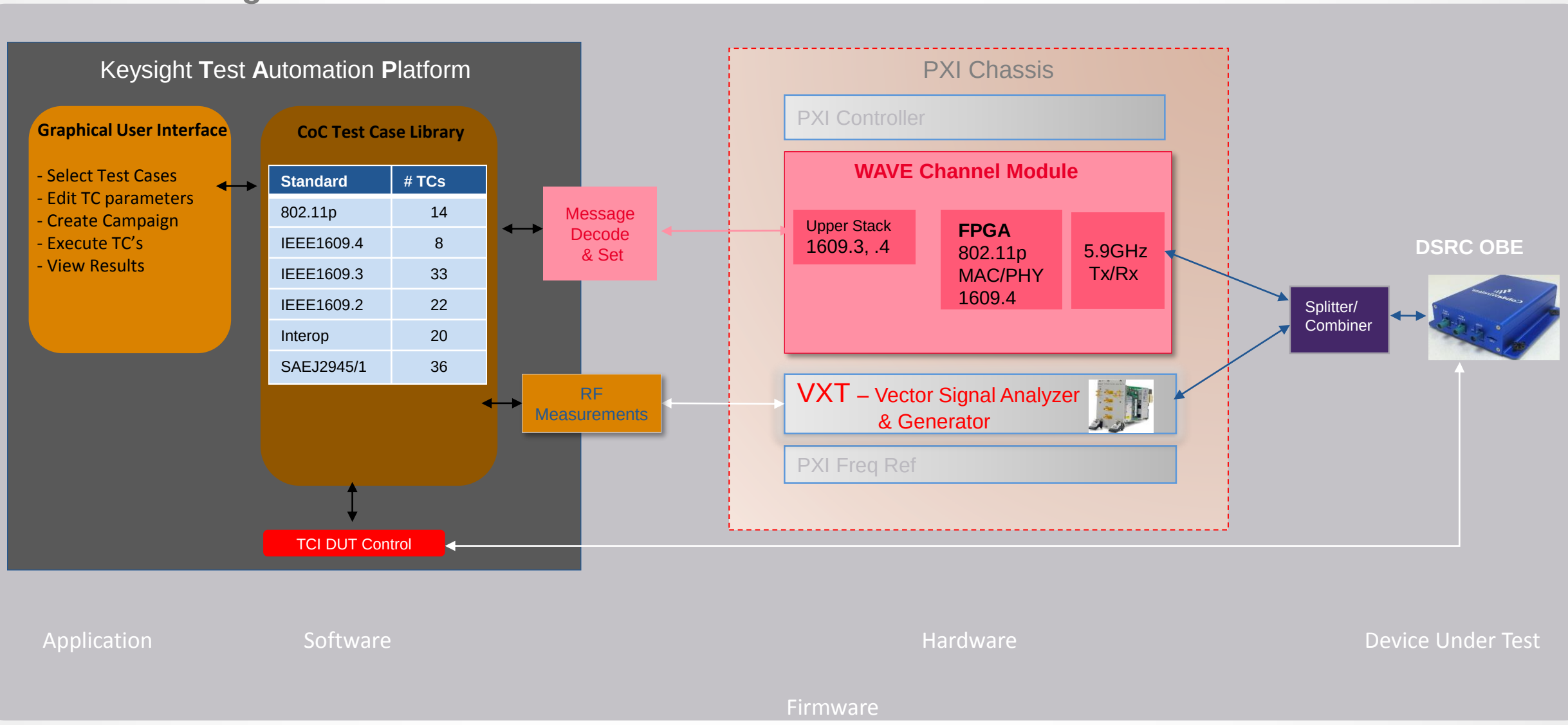
- Compact PXIe hardware
  - Keysight VXT : RF measurements + GPS source
  - WAVE Channel Module
    - CoC Test Cases require only 1 module
    - add modules for multiple simultaneous RF channels
  - Keysight PXIe Frame, Controller, Freq Ref

– Software
  - Certification Test Cases in Keysight Test Automation Platform
    - Test Case construction
    - Test Case sequencing
    - Pass/Fail
    - GUI
    - Controls Wave Channel Module & VXT
  - Single platform to be expanded for future V2X test needs

– Hardware & Software options for
  - full CoC
  - RF only
  - Protocol only

Keysight E6953A DSRC Certification Solution

Functional diagram



Keysight V2X Test Platform

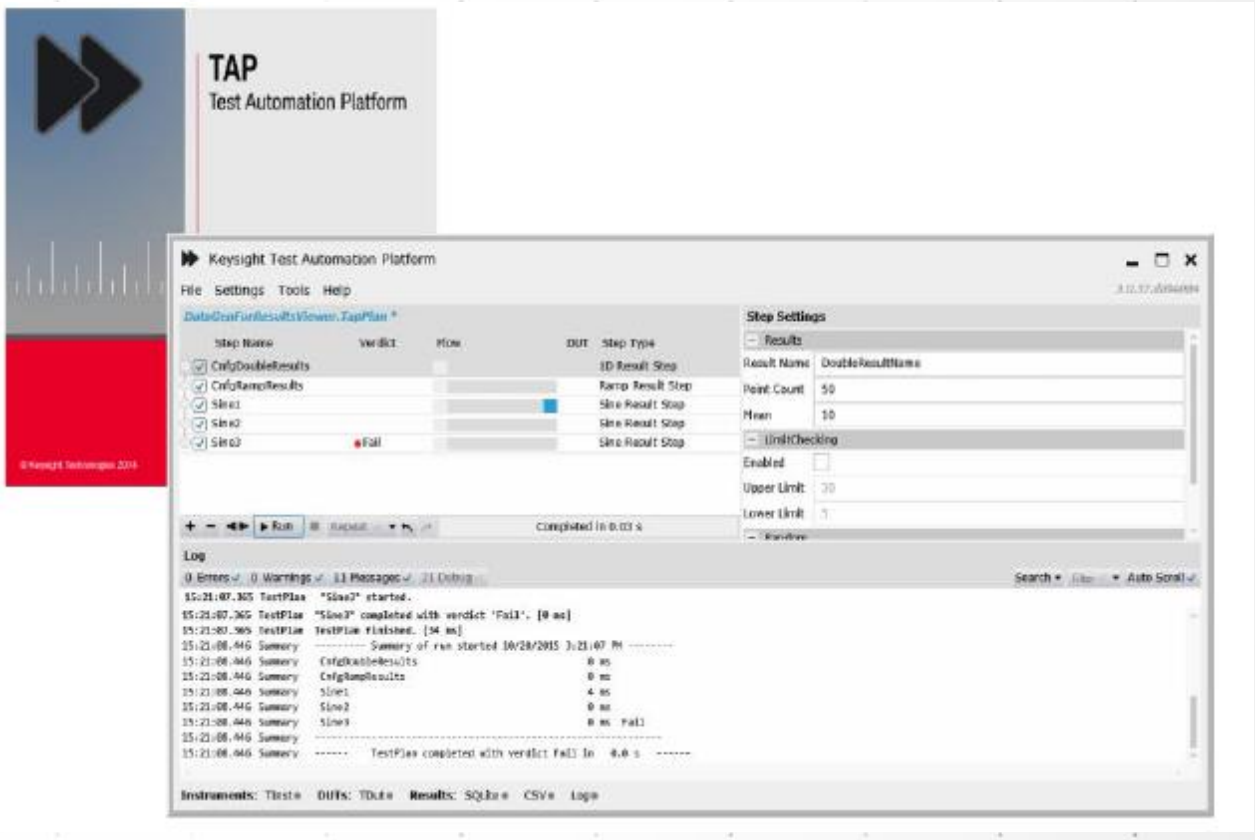
Keysight ‘TAP’ in C# - create your own ‘Plugins’

DSRC

- Modular hardware
  - include/exclude RF test
  - Channel scalability
- Raw message data reporting
- Fully functioning real-time ‘OBU’ or ‘RSU’ (configurable)
- Quick turnaround for changes & fixes to software stack

Roadmap Plans

- ITS-G5 cover
  - optional 18GHz SA for EN 302 571 5.3.4
- C-V2X



Keysight V2X Test Platform

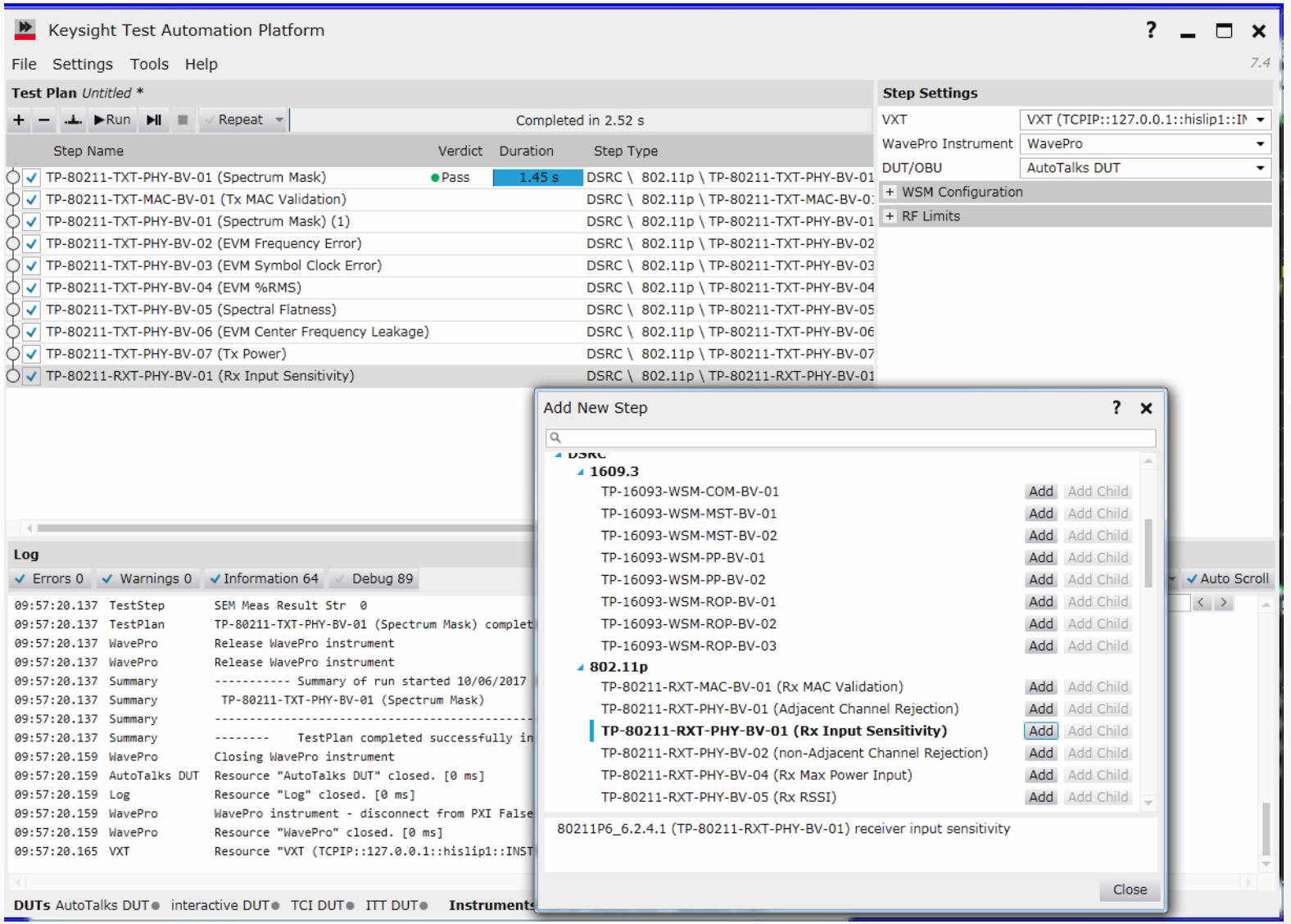
Test Automation Platform

Test Cases

- 802.11p
- IEEE1609.3
- IEEE1609.4
- IEEE1609.2
- J2945/1

Test Plans

- Parameter Sweep Loop
  - e.g. Channel, Data Rate



Keysight V2X Test Platform

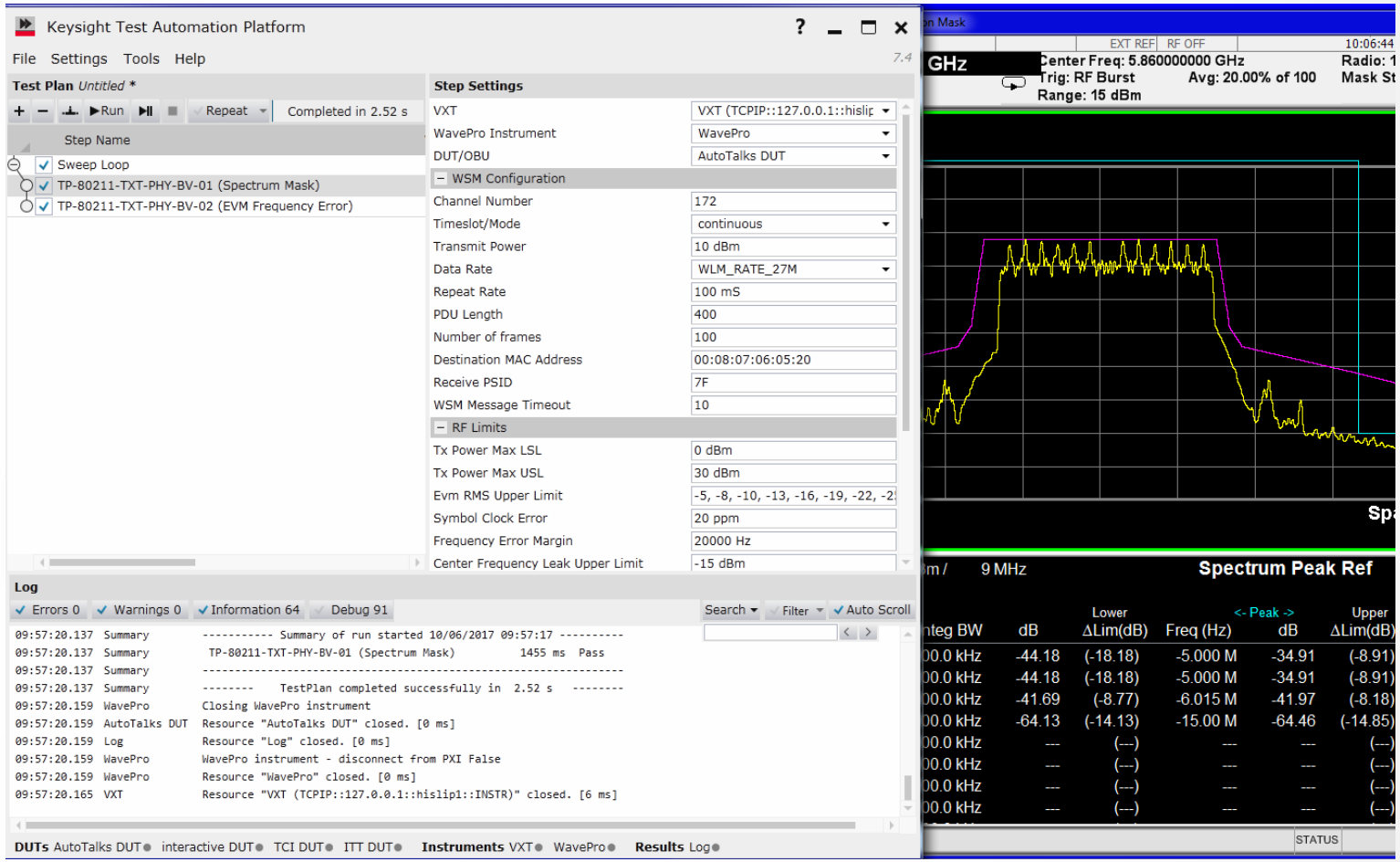
Test Automation Platform

802.11p Test Cases
- RF measurements

– using VXT hardware
  - Vector Signal Analyzer & Source

– N9077A measurement application
  - Graphical Vector Signal Analyzer

– N7617B Signal Studio
  - Arbitrary Waveform creation



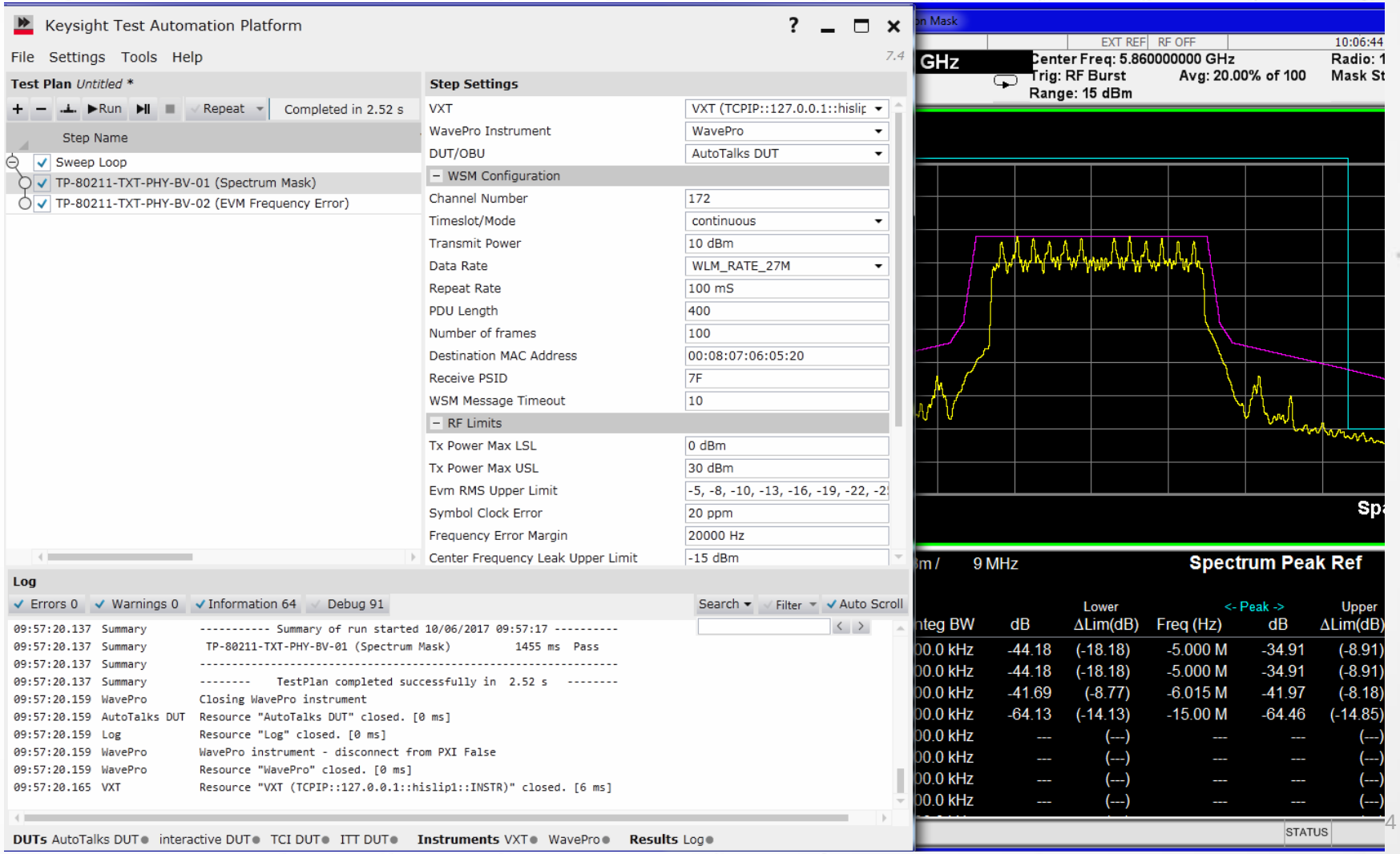
PHY layer measurements common from Keysight R&D tools, through Design Verification, Certification to Manufacturing

Keysight V2X Test Platform

Test Automation Platform

802.11p Test Cases
- RF measurements

– Parameter setting

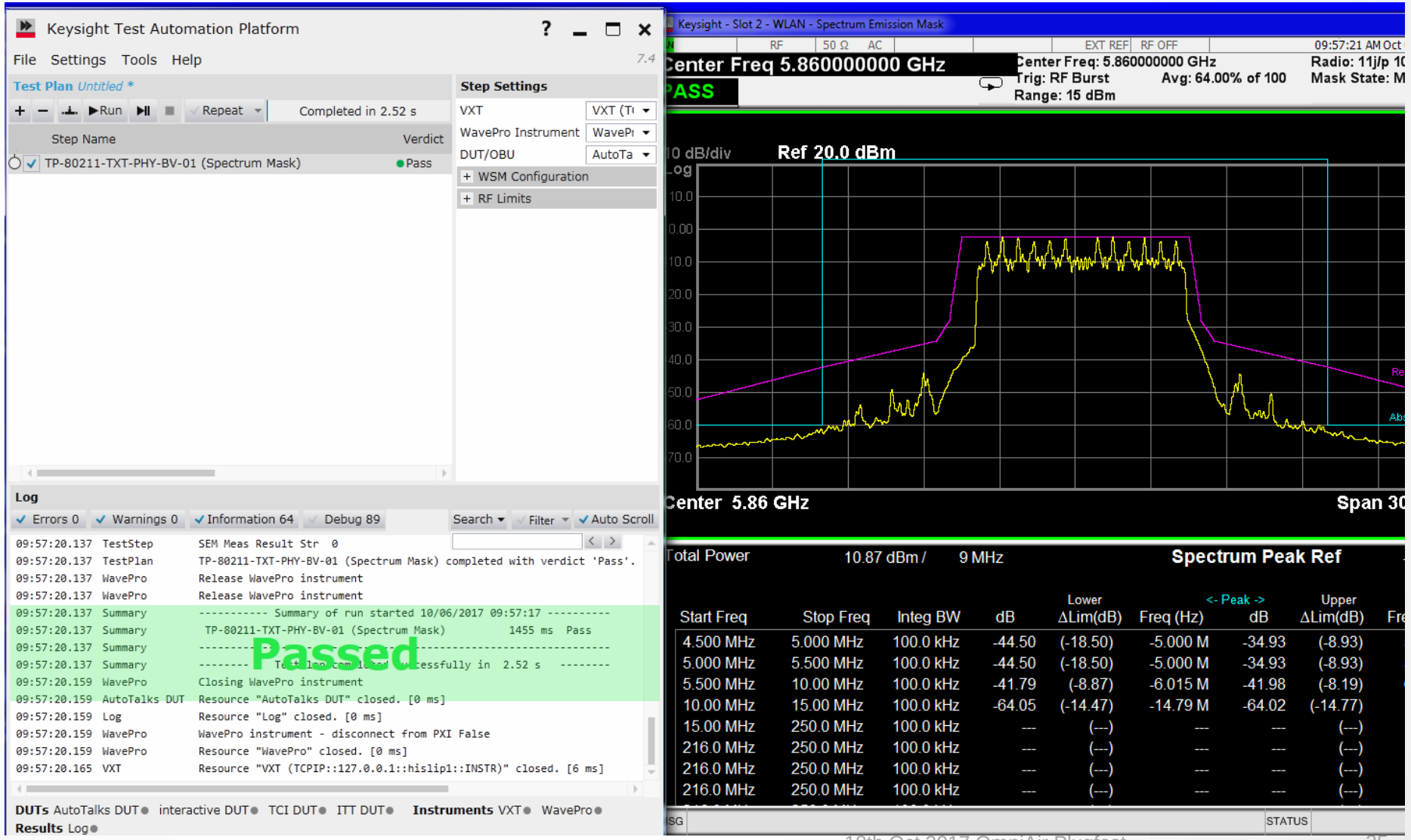


Keysight V2X Test Platform

Test Automation Platform

802.11p Test Cases

- Test Case Pass/Fail
- Graphical VSA window

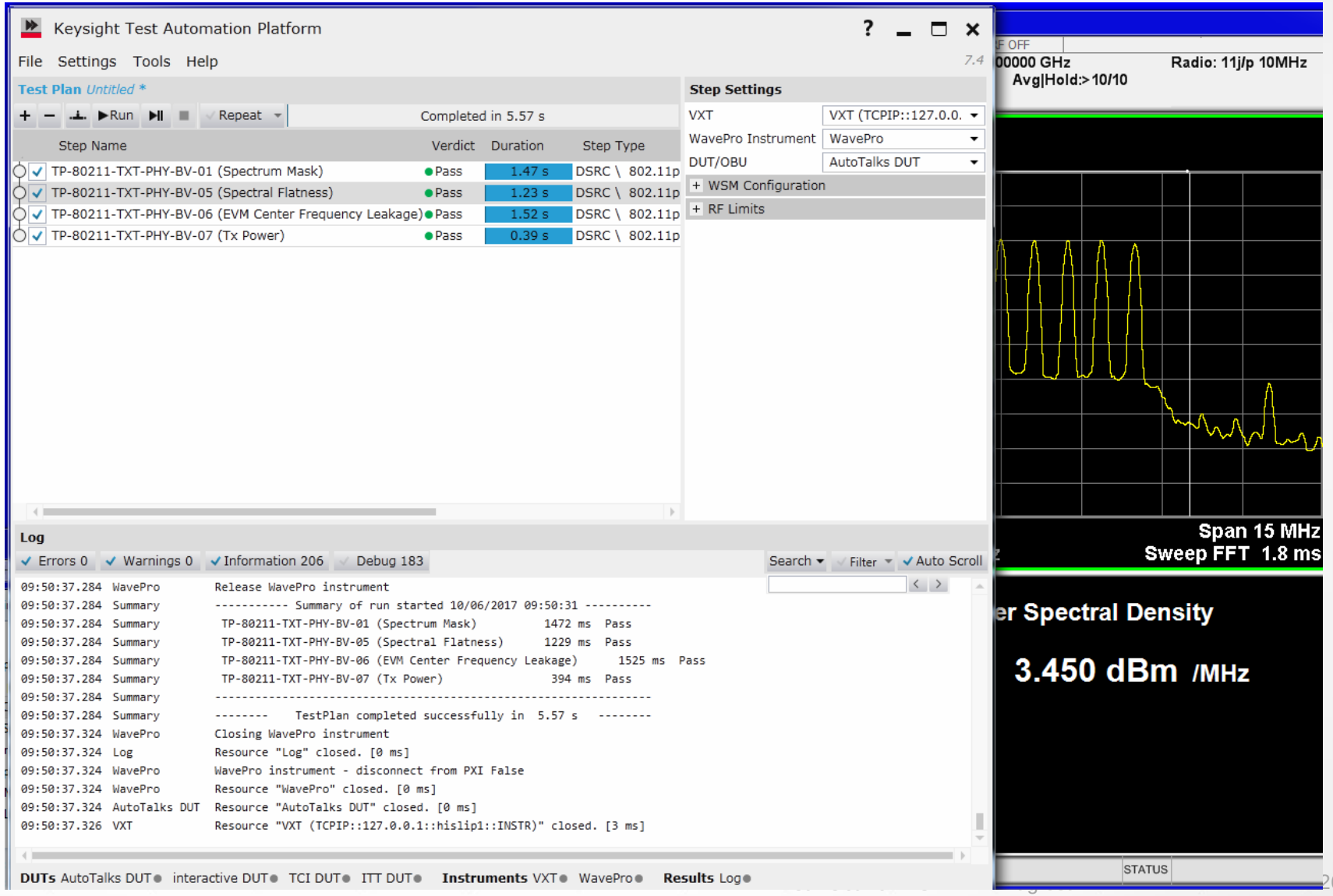


Keysight V2X Test Platform

Test Automation Platform

Sequence of Test Cases

- Test Case Pass/Fail
- Graphical VSA window

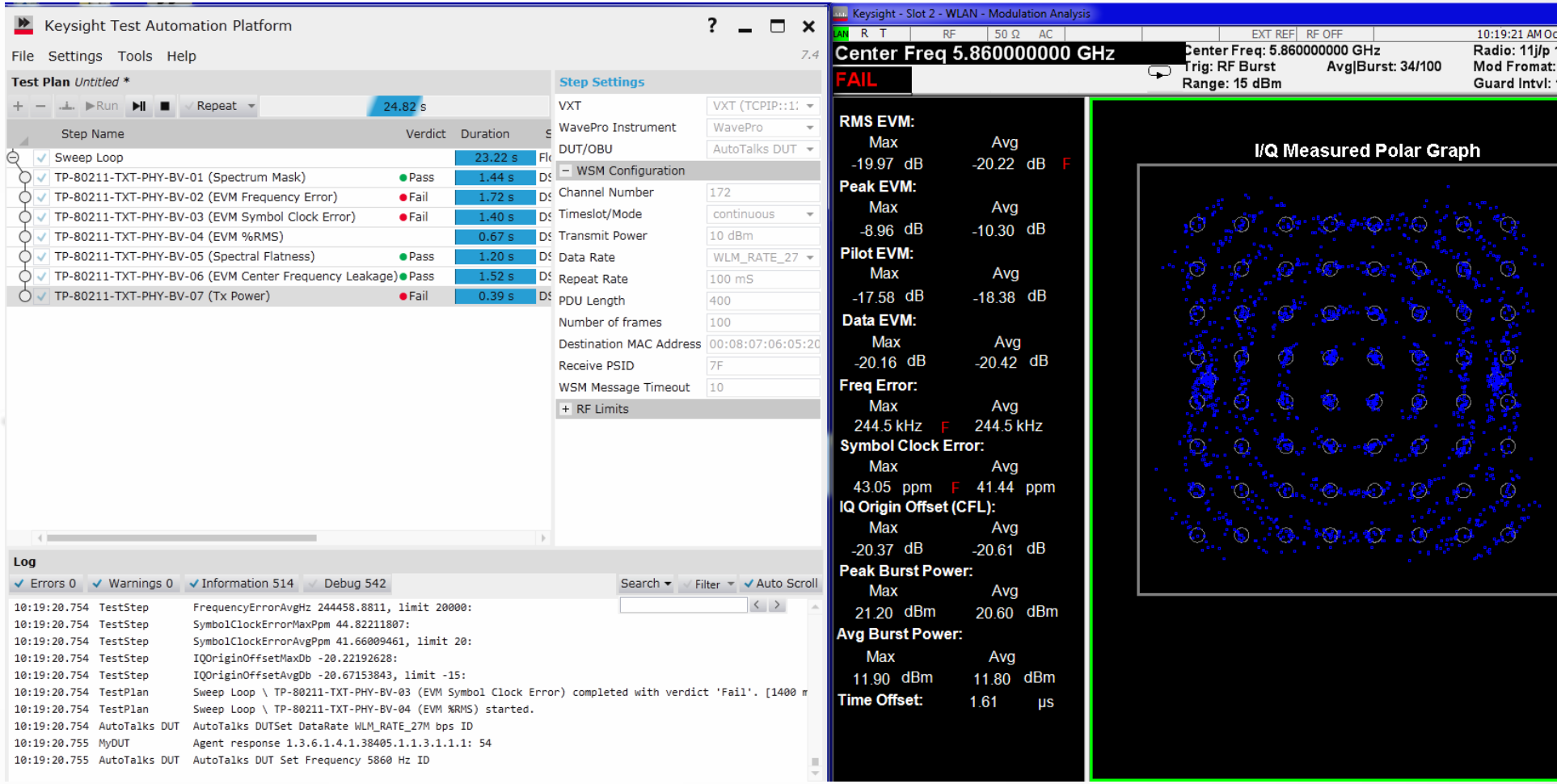


Keysight V2X Test Platform

Test Automation Platform

Looped Sequence of Test Cases

- Test Case Pass/Fail
- Graphical VSA window

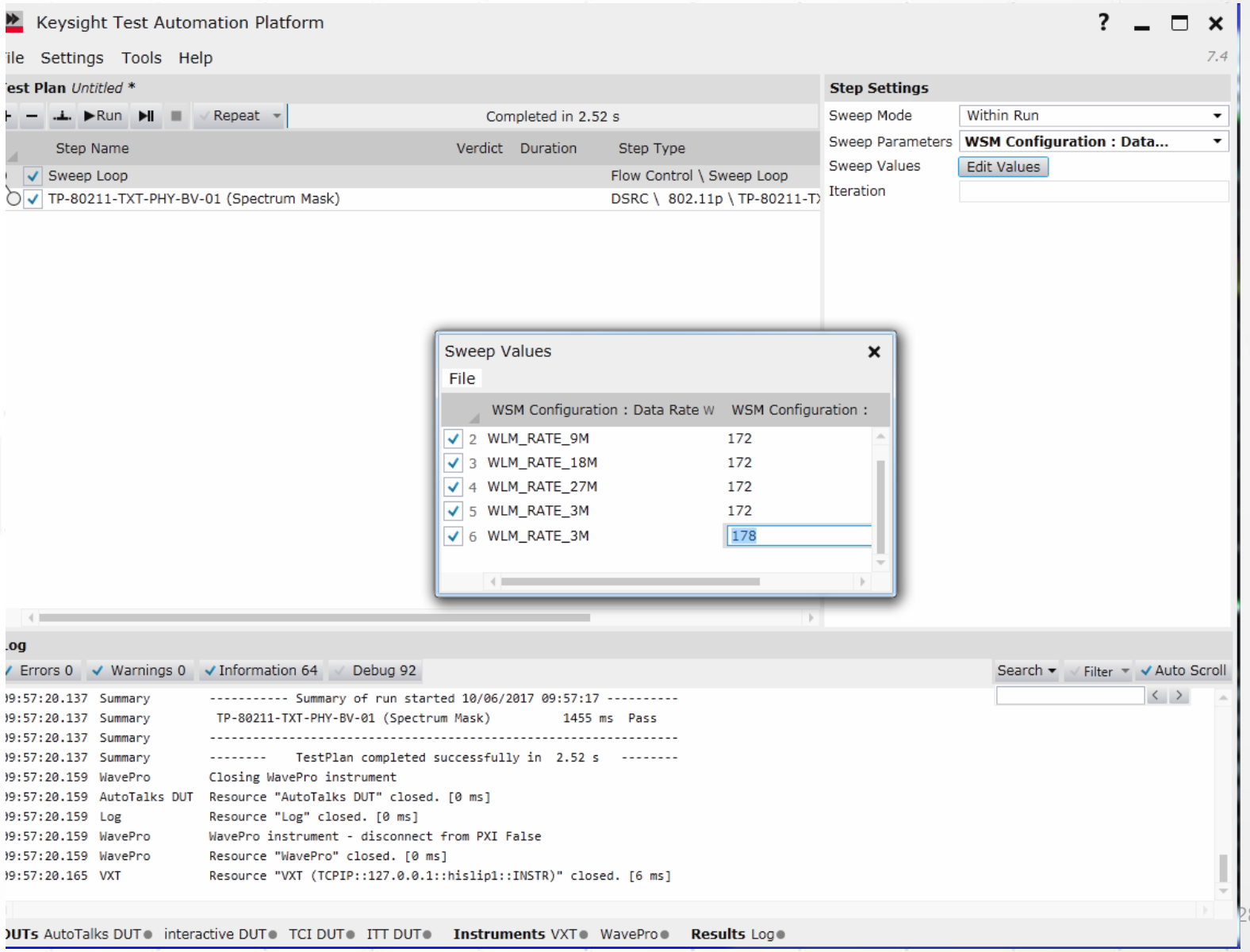


Keysight V2X Test Platform

Test Automation Platform

Sweep Loop

– On Test Case parameters
  - e.g. data rate, RF channel



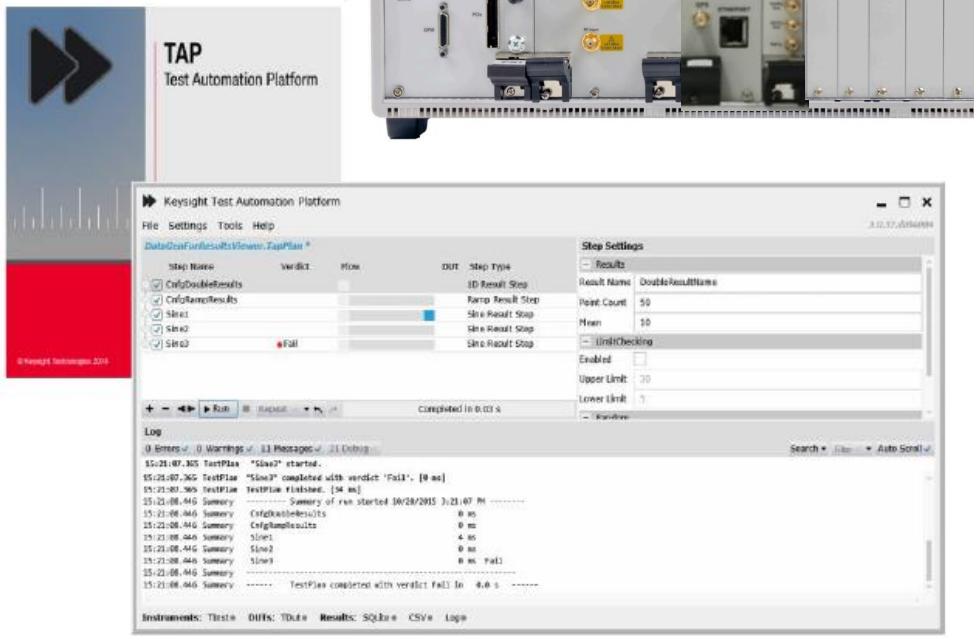
E6953A Keysight DSRC CoC Certification Tester

Covers all CoC Test Cases in single , integrated PXI frame

- 802.11p
- IEEE1609.3
- IEEE1609.4
- IEEE1609.2
- J2945/1

Up next ……

- Pre-Certification and Design Verification solution
  - Parameter flexibility to create new ‘TC’s & scenarios
- Loading, congestion, application testing
- ITS-G5
- C-V2X



Test Spec Overview – 1609.2

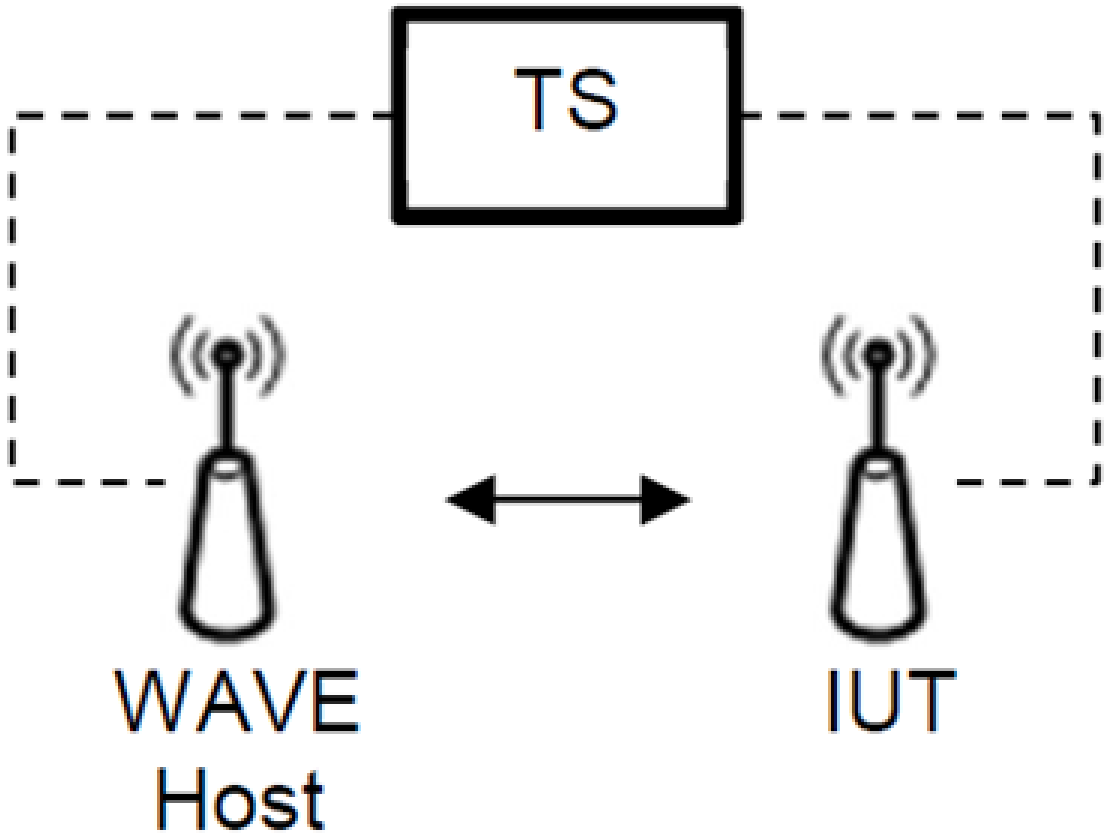
Security Service

- Conformance test specifications for Wireless Access in Vehicular Environments (WAVE)
  - Security Services Test Suite Structure and Test Purposes (TSS & TP)

Abbreviation

- TP: Test Purpose
- SPDU: Secure Protocol Data Unit
  - BSM: Basic Safety Messages
  - WSA: WAVE Service Advertisements Messages
- BI: Behavior Invalid
- BV: Behavior Valid

Test Configuration (1)



- TC: Test Configuration System
- TS: Test System
- IUT: Implementation Under Test
- --- : TS Control Interface

Initial States

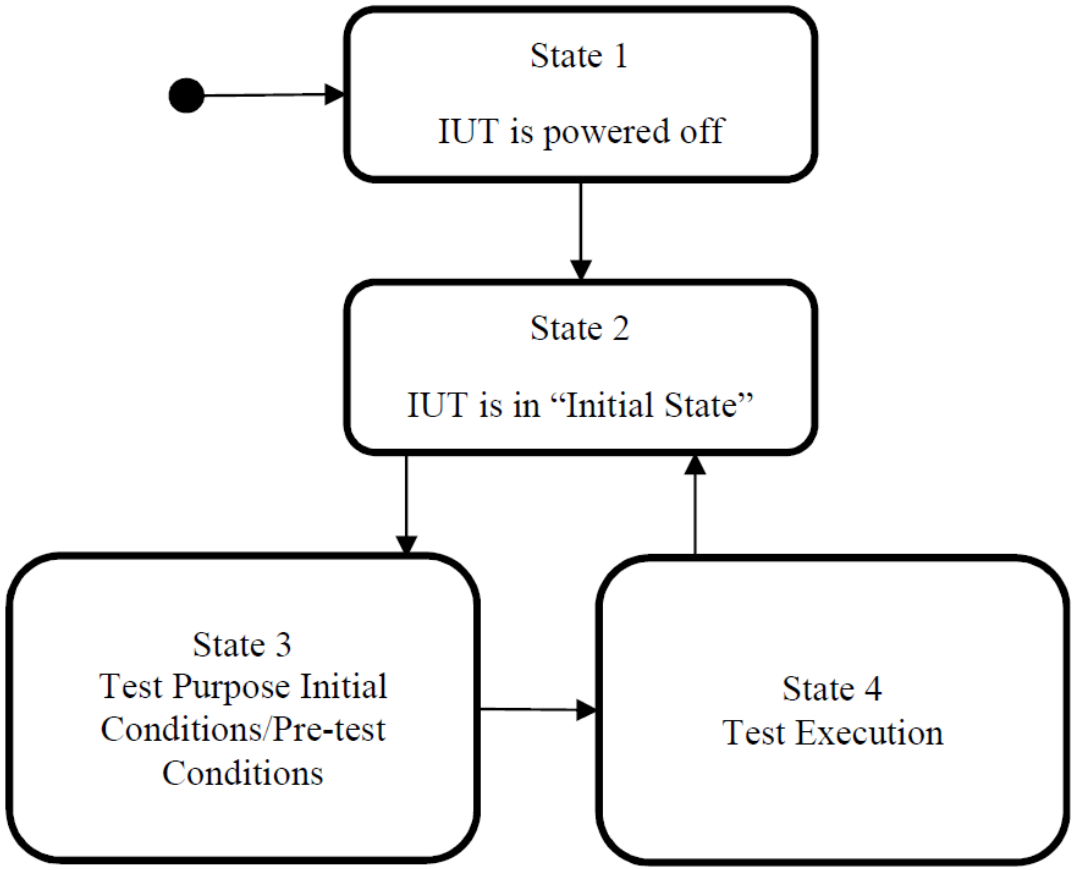


Figure 2: State Diagram

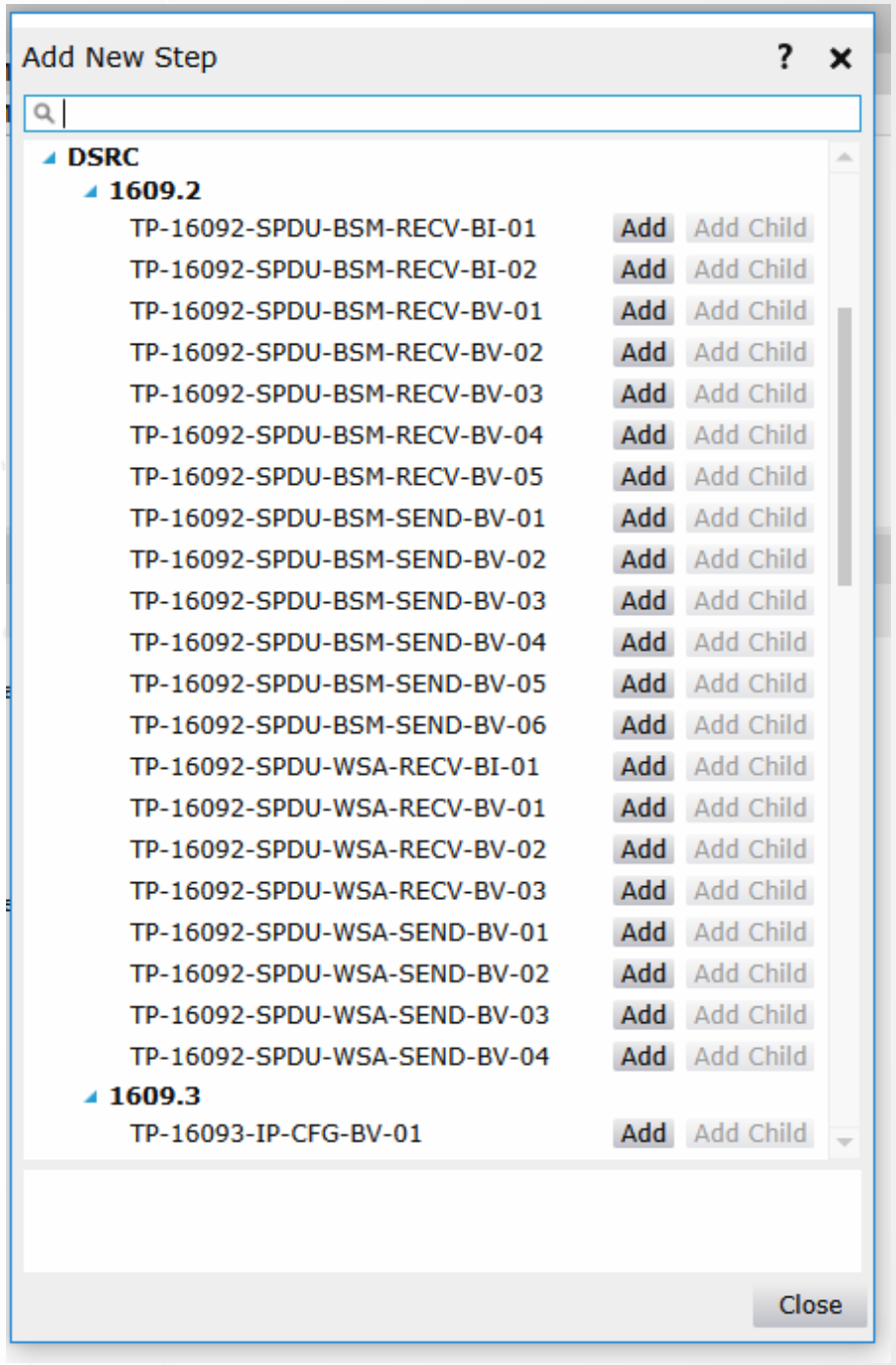
Each TP contains an initial condition.

- The IUT is powered up.
- The IUT is not transmitting or receiving messages
- The IUT is provisioned with the appropriate security credentials to enable transmission or reception of messages. That is, the IUT is configured with a valid signer credentials (certificate) as specified in SAE J2945/1 [1] and IEEE 1609.3 [5] security profiles for BSM and WSA.

TP Naming convention

Identifier	TP-<root>-<gr>-<sgr>-<x>-<nn> or TP-<root>-<gr>-<x>-<nn> when no <sgr>	
	<root> = root	16092
	<gr> = group	$SPDU_{BSM}$
		$SPDU_{WSA}$
	<sgr> =sub- group	SEND
		RECV
		CERTCH
	<x> = type of testing	BV
		BI
	<nn> = sequential number	

1609.2
Secure Basic Safety Message
Secure Wave Service Advertisement message
Send Message
Receive Message
Change Certificate
Valid Behaviour tests
Invalid Syntax or Behaviour Tests
01 to 99



Ex) TP-16092- SPDUBSM-SEND-BV-05

- Validate that a SPDU BSM containing a certificate digest is signed using a valid digital signature computed over entire payload using ecdsaP256Signature type.

Pre-test conditions			
• The IUT is being initialized			
Test Sequence			
Step	**Type**	**Description**	**Verdict**
1	Configure	The IUT is configured to transmit more than one $SPDU_{BSM}$ per second	
2	Stimulus	The IUT transmits $SPDU_{BSM}$	
3	Verify	The IUT transmitted $SPDU's_{BSM}$ contains ***signer*** containing ***digest*** indicating ***HashedId8*** where HashedId8 is referenced to pre-loaded certificate on the IUT and containing ***verificationkeyIndicator*** (KEY)	Pass/Fail
4	Verify	$SPDU_{BSM}$ Signature contains ***ecdsaP256Signature*** indicating ***r*** and ***s*** values verifiable using KEY.	Pass/Fail

```
10:50:02.884  DEMO DUT   Resource "DEMO DUT" opened. [0 ms]
10:50:02.884  TestPlan   TP-16092-SPDU-BSM-SEND-BV-05 started.
10:50:02.884  TestStep   DSRCStep Base class RUN
10:50:03.142  TestStep   DUT transmitted SPDU'sBSM signer digest = HashedId8
10:50:03.142  TestStep   SPDUBSM Signature ecdsaP256Signature = r and s values
10:50:03.142  TestPlan   TP-16092-SPDU-BSM-SEND-BV-05 completed with verdict 'Pass'. [257 ms]
10:50:03.142  Summary    ----------- Summary of run started 03/20/2018 10:50:02 ----------
10:50:03.142  Summary     TP-16092-SPDU-BSM-SEND-BV-05                    257 ms  Pass
10:50:03.142  Summary    ------------------------------------------------------------------
10:50:03.142  Summary    --------    TestPlan completed successfully in  0.26 s   --------
10:50:03.204  Log        Resource "Log" closed. [0 ms]
```

Pass!!

Test Spec Overview – 1609.3

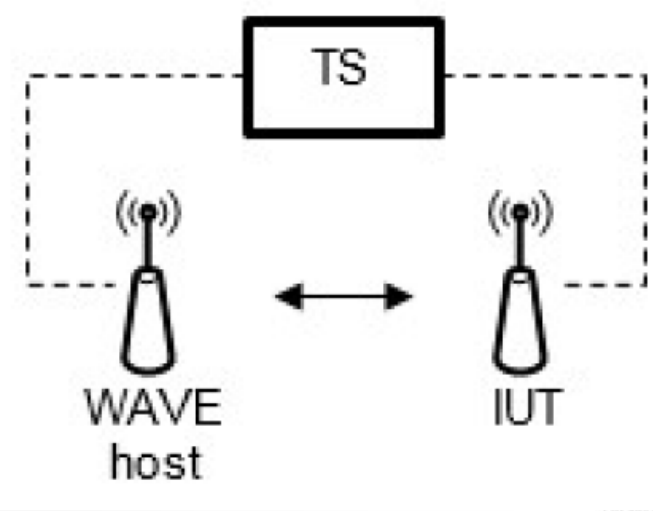
Networking Service

Conformance test specifications for Wireless Access in Vehicular Environments (WAVE) — Networking Services Test Suite Structure and Test Purposes (TSS & TP)

Document Mnemonics:

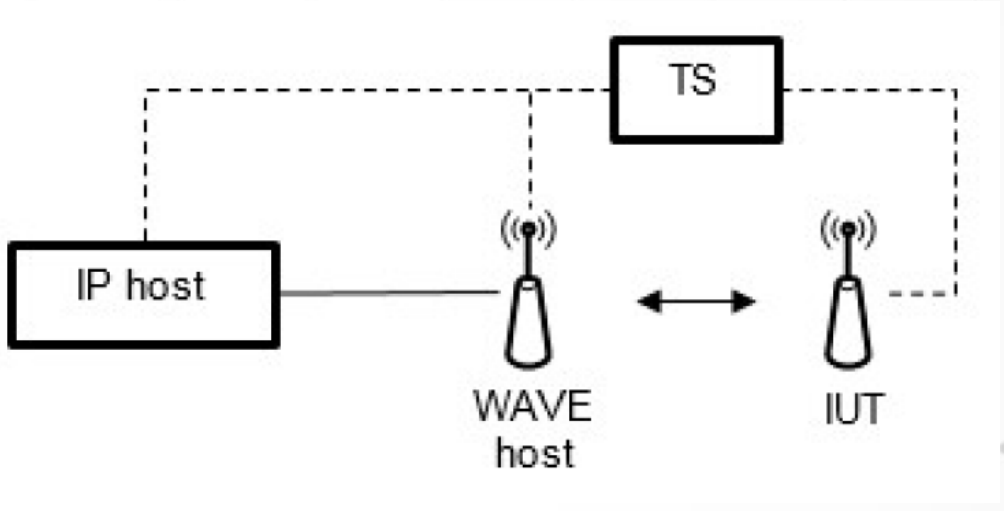
- WSM: WAVE Short Messages

Test Configuration



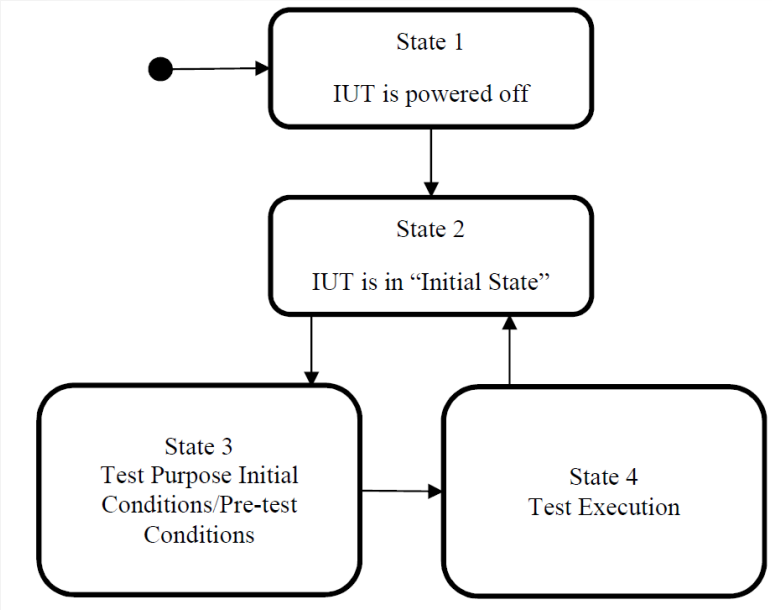
- TC: Test Config (1) – sending receiving WSM

--- TS Control Interface



- TC: Test Config (2) – IPv6 Host Communications

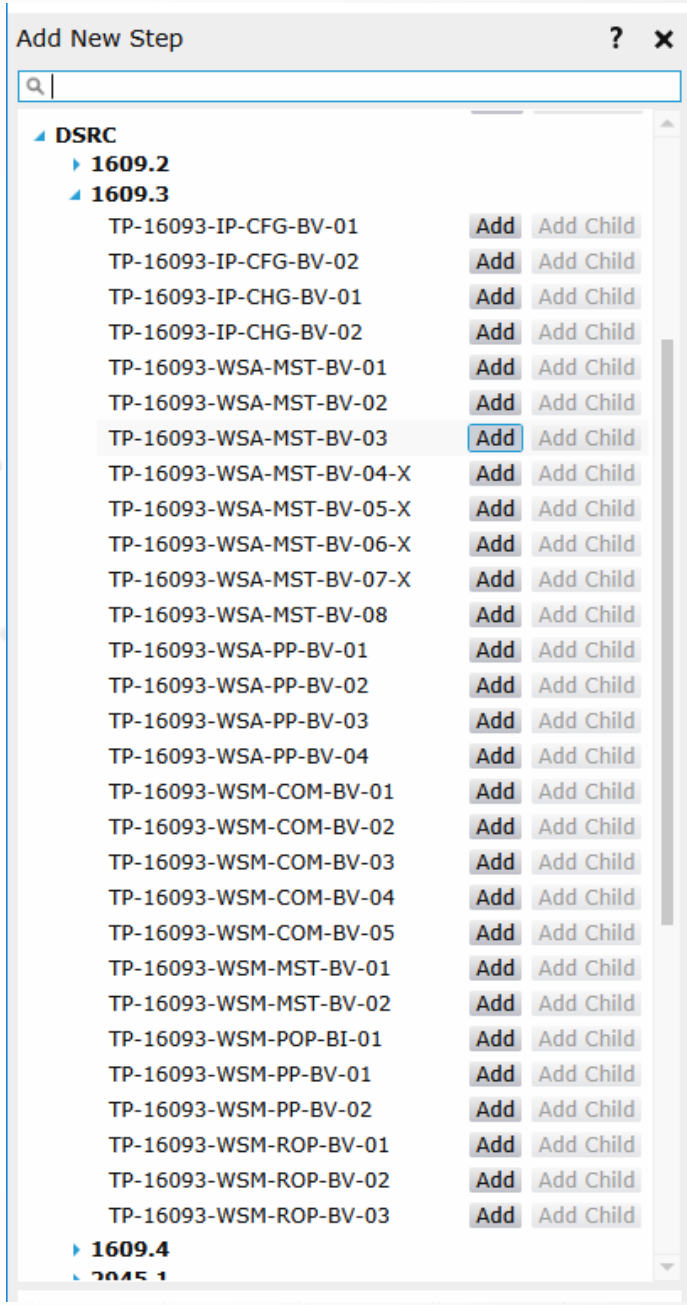
Initial States



- Test Environment and Test System has reached room temperature (21 degrees Celsius +/- 5 degrees).
- No external DSRC units within range of IUT, DSRC Packet Capture Tool, and DSRC Reference Unit are transmitting outside of the test setup.
- The IUT is powered up
- Radio interface is initialized but does not transmit or receive messages over any DSRC channels
- Radio acquired and locked its position based on GNSS
- MAC address is assigned to the DSRC interface
- Unless otherwise stated, the IUT is not transmitting
- Unless otherwise stated, Congestion Control is disabled
- The IUT is provisioned with any required security credentials to enable transmission or reception of messages over DSRC
- The IUT is running Certification Interface Application

TP Naming conversion

<root> = root	16093	
<gr> = group	WSM	WAVE Short Messages
	WSA	WAVE Service Advertisements
	IP	Internet Protocol
<sgr> =sub- group	CFG	Configuration
	CHG	Service Change
	COM	Communications
	MST	Message Structure
	POP	Protocol Operation
	PP	Packet Processing
	ROP	Radio Operation
<x> = type of testing	BV	Valid Behavior tests
	BI	Invalid Syntax or Behavior Tests
<nn> = sequential number		01 to 99



Ex) TP-16093-WSM-ROP-BV-01

- Verify that the IUT will transmit WSM containing valid WSM-N-Header including WAVE Info Element Extension ‘Channel Number’ and matching the actual channel used by the IUT.

Test Sequence			
Step	**Type**	**Description**	**Verdict**
1	Configure	The IUT is configured to transmit **WSM_nExt** in Table 7-2 using channel ‘*pChannel*’ and include WAVE Element Extension fields ‘Channel Number’.	
2	Stimulus	The IUT transmits WSM	
3	Verify	The IUT transmitted WSM	Pass / Fail
4	Verify	WSM N-Header contains ‘Subtype/Option Indicator/WSMP Version’ indicating ‘0x0B’ (Subtype=0, Opt Ind = 1, Version = 3)	Pass / Fail
5	Verify	WSM N-Header contains ‘Wave Info Element’ contains ’Count’ matching the number of ‘Wave Info Element’ included in the message (>= 1, cannot be ‘0’)	Pass / Fail
6	Verify	WSM N-Header contains ‘WAVE Info Element’ containing ‘WAVE Element ID’ indicating ‘15’ (Channel Number)	Pass / Fail
7	Verify	WSM N-Header contains ‘WAVE Elem Length’ indicating ‘1’	Pass / Fail
8	Verify	WSM N-Header contains ‘WAVE Elem’ data indicating the Channel Number value equal to ‘*pChannel*’	Pass / Fail
9	Procedure	Repeat steps 1-8 for other values of ‘*pChannel*’ listed in Section 4.1.1.1.	

```
11:29:40.495  Log       Resource "Log" opened. [0 ms]
11:29:40.496  TestPlan  TP-16093-WSM-ROP-BV-01 started.
11:29:40.496  TestStep  DSRCStep Base class RUN
11:29:40.758  TestStep  getWSMPHeader() Subtype = 0
11:29:40.758  TestStep  getWSMPHeader() Option indicator = 1
11:29:40.758  TestStep  getWSMPHeader() WSMP Version = 3
11:29:40.758  TestStep  getWSMPHeader() N Header WAVE Info Element Count = 0
11:29:40.758  TestStep  getWSMPHeader() Channel Number = 172
11:29:40.758  TestPlan  TP-16093-WSM-ROP-BV-01 completed with verdict 'Pass'. [
11:29:40.758  Summary   ----------- Summary of run started 03/20/2018 11:29:40
11:29:40.758  Summary    TP-16093-WSM-ROP-BV-01                          261 m
11:29:40.758  Summary   ------------------------------------------------------
11:29:40.758  Summary   --------    TestPlan completed successfully in  0.26 s
```

Test Spec Overview – 1609.4

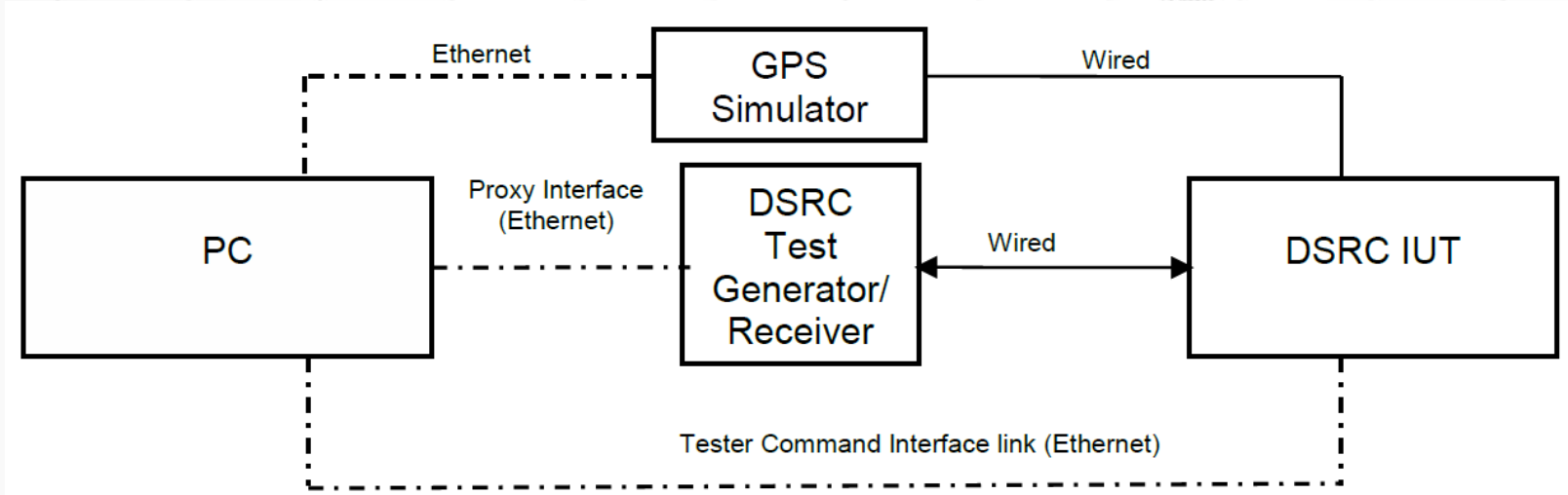
Multi-Channel Operation

Conformance test specifications for Wireless Access in Vehicular Environments (WAVE)

— Multi-channel Operation Test Suite Structure and Test Purposes (TSS & TP)

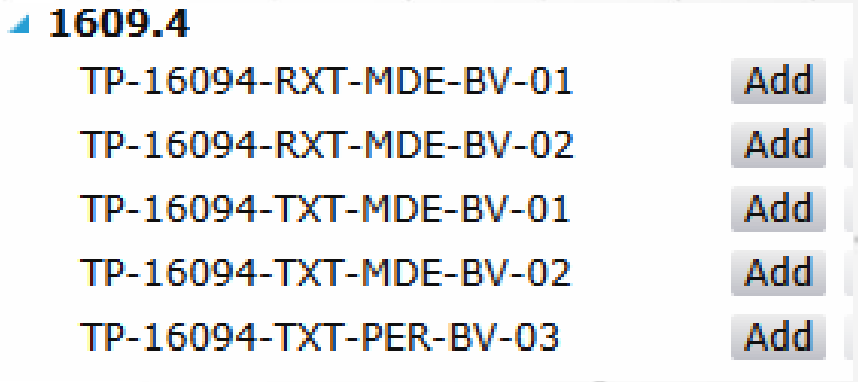
Test Configuration

- TC(1)



TP Naming Conversion

<root> = root	16094	
<gr> = group	RXT	Receive
	TXT	Transmit
<sgr> =sub- group	MDE	Channel Access Mode
	PER	Performance
	IP6	IPv6
	BV	Valid Behavior tests
<x> = type of testing	BI	Invalid Syntax or Behavior Tests
<nn> = sequential number		01 to 99



Ex) TP-16094-RXT-MDE-BV-01

- Transmit WSMs in continuous channel mode (non-switching) and verify IUT receives the transmitted messages.

Step	Type	Description	Verdict
1	Configure	IUT to receive WSM messages in continuous channel mode on '*pChannel*'	
2	Configure	Test Equipment to transmit WSMs in continuous channel mode on '*pChannel*' with '*pDataRate*' at '*pWSMRepeatRate*'.	
3	Stimulus	Test Equipment to continuously transmit WSM messages	
4	Verify	IUT receives WSM messages available on '*pChannel*' at every '*pWSMRepeatRate*'.	PASS / FAIL
5	Procedure	Repeat steps 1-4 for each supported value of '*pDataRate*' in Table 4-2	
6	Procedure	Repeat steps 1-5 for each supported value of '*pChannel*' in Table 4-1	
7	Configure	The IUT to initial state	

```
12:31:41.938  WavePro   Resource "WavePro" opened. [0 ms]
12:31:41.938  TestPlan  TP-16094-RXT-MDE-BV-01 started.
12:31:41.939  TestStep  DSRCStep Base class RUN
12:31:52.271  TestStep  WSM message received on Channel 0
12:31:52.271  TestStep  DEMO DUT receives WSM messages on Channel 172 with data rate WLM_RATE_6M at every 20 messages per second TRUE
12:31:52.271  TestPlan  TP-16094-RXT-MDE-BV-01 completed with verdict 'Pass'. [10332 ms]
12:31:52.271  Summary   ---------- Summary of run started 03/20/2018 12:31:41 ----------
12:31:52.271  Summary    TP-16094-RXT-MDE-BV-01                          10332 ms  Pass
12:31:52.271  Summary   ------------------------------------------------------------------
```

Test Spec Overview – J2945/1

V2V Safety

Conformance test specifications for SAE J2945/1

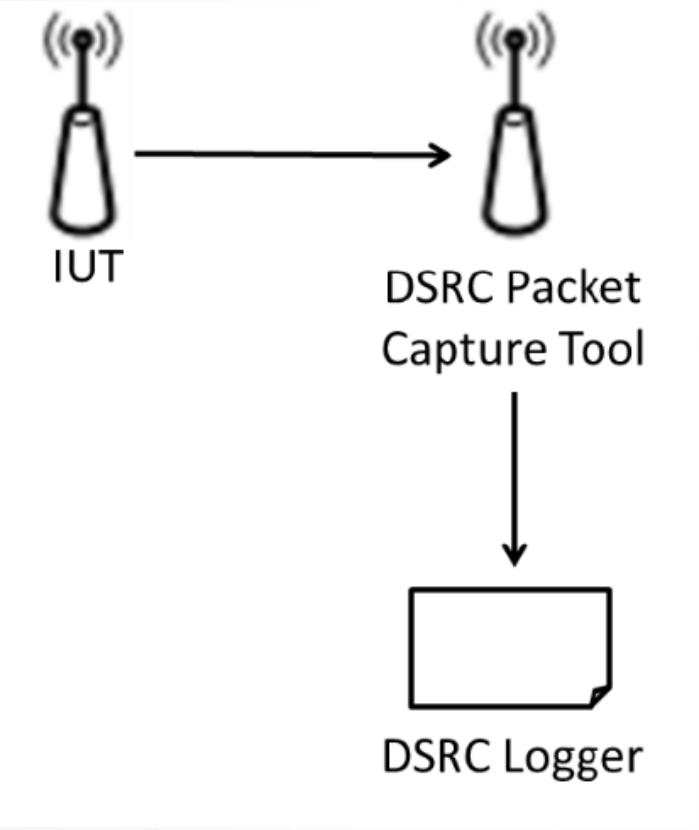
- On-board System Requirements for V2V Safety Communications

Test Suite Structure and Test Purposes (TSS & TP)

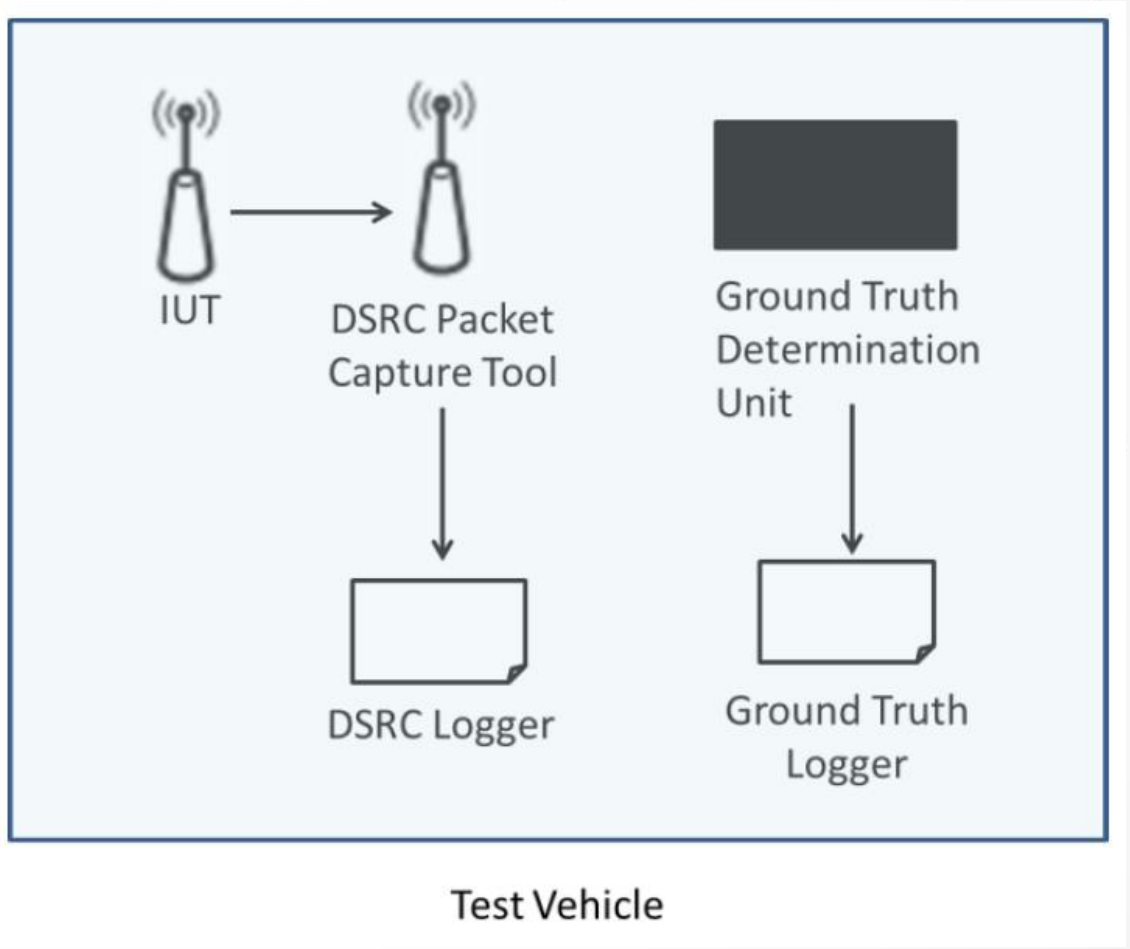
SAE: Society of Automotive Engineers

SCMS: Security Certificate Management System

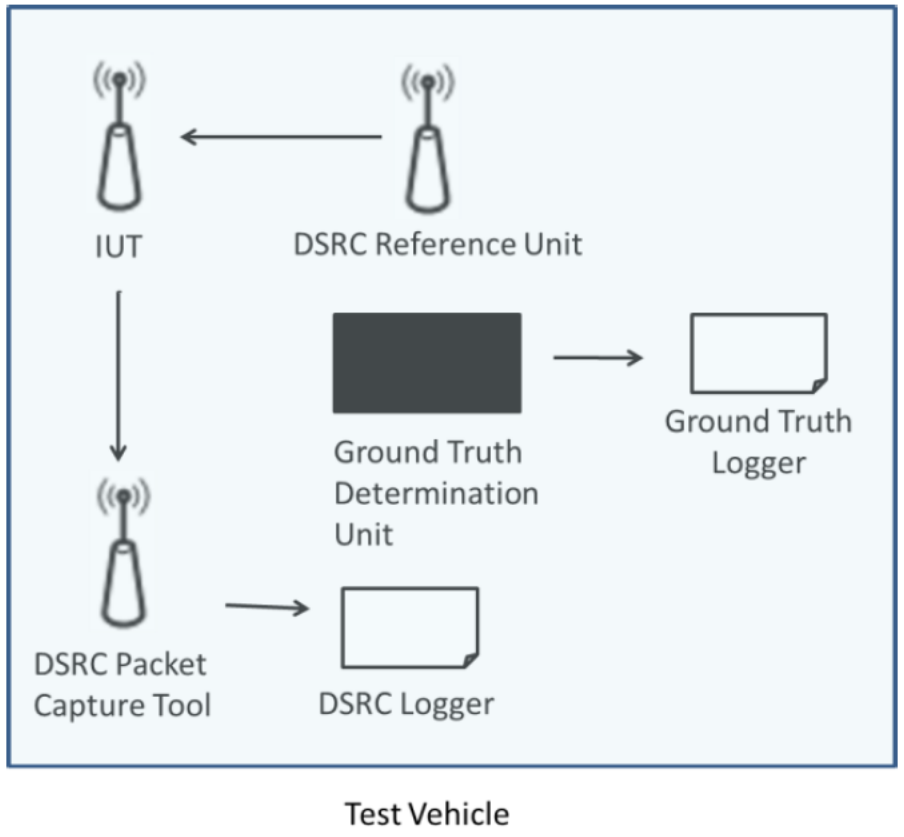
Test Configuration



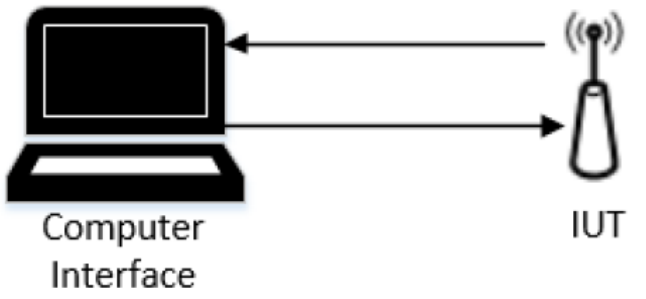
TC (1)



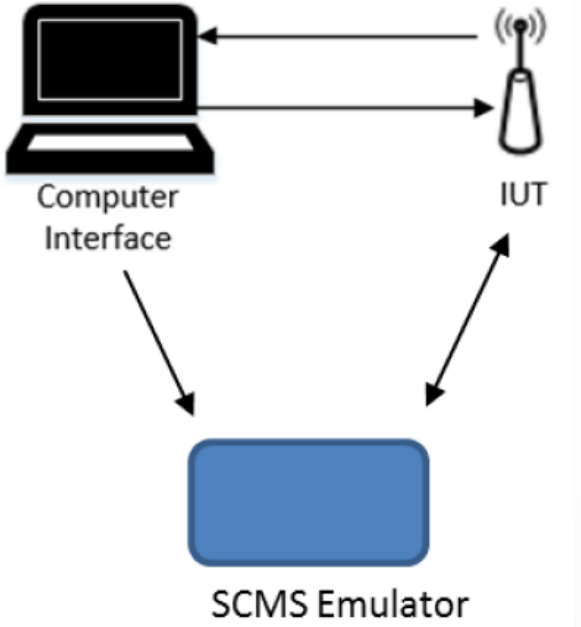
TC (2)


IUT
DSRC Reference Unit
Ground Truth Determination Unit
Ground Truth Logger
DSRC Packet Capture Tool
DSRC Logger
Test Vehicle

- TC (3)


Computer Interface
IUT

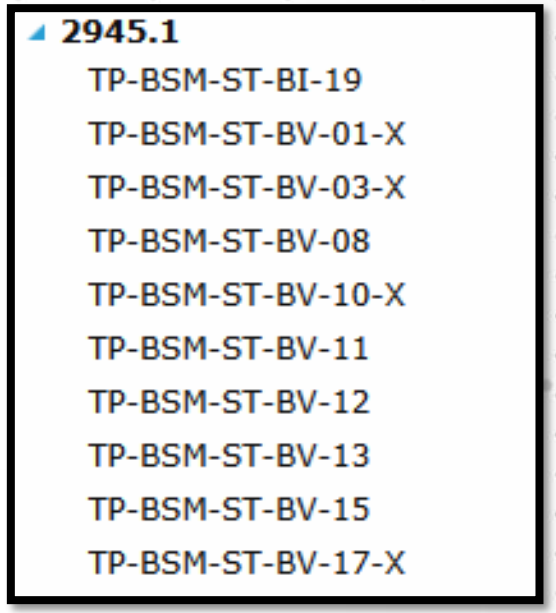
- TC (4)


Computer Interface
IUT
SCMS Emulator

- TC (5)

Naming Conversions

<root> = root	BSM	
<gr> = group	SV	Stationary Vehicle
	MV	Moving Vehicle
	LD	Local Data
<x> = type of testing	BV	Valid Behaviour tests
	BI	Invalid Syntax or Behaviour Tests
<nn> = sequential number		01 to 99

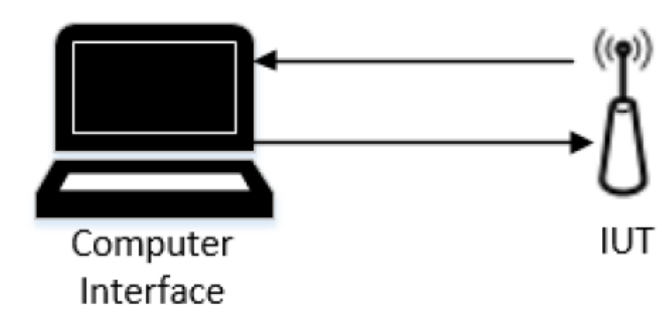


BSM: Basic Safety Messages

TP-BSM-MV-BV-17-X

- Verify certificate is not changed during event conditions unless the certificate expires

Step	Type	Description	Verdict
1	Verify	The IUT transmits BSMs with the DE_VehicleEventFlags element not included	Pass / Fail
2	Stimulus	One critical set of **Event Flag** from Section 7.6 is set	
3	Verify	The IUT transmits BSM containing full security certificate	Pass / Fail
4	Verify	The certificate of the BSM Transmitted in Step 1 and the BSM Transmitted in Step 3 are identical	Pass / Fail
5	Stimulus	The certificate expiration time passes while the **Event Flag** set remains persistent	
6	Stimulus	vCertChangeInterval time passes while the **Event Flag** set remains persistent	
7	Stimulus	The IUT transmits at least one BSM	
8	Verify	The certificate of Step 6's BSM and Step 3's BSM are different	Pass / Fail
9	Procedure	Steps 1 – 7 are repeated for all critical event sets from Section 7.6	



- TC (4)

```
13:02:47.822  TestPlan  Sweep Loop started.
13:02:47.833  TestStep  Running child steps with BSM Configuration \ Event Flag = ABSactivated
13:02:47.834  TestPlan  Sweep Loop \ TP-BSM-ST-BV-17-X started.
13:02:47.834  TestStep  DSRCStep Base class RUN
13:02:48.101  TestStep  Event flag ABSactivated (2000) is set = TRUE
13:02:48.101  TestPlan  Sweep Loop \ TP-BSM-ST-BV-17-X completed with verdict 'Pass'. [267 ms]
13:02:48.101  TestStep  Running child steps with BSM Configuration \ Event Flag = TractionControlLoss
13:02:48.101  TestPlan  Sweep Loop \ TP-BSM-ST-BV-17-X started.
13:02:48.101  TestStep  DSRCStep Base class RUN
13:02:48.353  TestStep  Event flag TractionControlLoss (1000) is set = TRUE
13:02:48.353  TestPlan  Sweep Loop \ TP-BSM-ST-BV-17-X completed with verdict 'Pass'. [251 ms]
13:02:48.353  TestStep  Running child steps with BSM Configuration \ Event Flag = StabilityControlActivated
13:02:48.353  TestPlan  Sweep Loop \ TP-BSM-ST-BV-17-X started.
13:02:48.353  TestStep  DSRCStep Base class RUN
13:02:48.655  TestStep  Event flag StabilityControlActivated (0800) is set = TRUE
13:02:48.655  TestPlan  Sweep Loop \ TP-BSM-ST-BV-17-X completed with verdict 'Pass'. [302 ms]
13:02:48.655  TestStep  Running child steps with BSM Configuration \ Event Flag = HardBraking
13:02:48.655  TestPlan  Sweep Loop \ TP-BSM-ST-BV-17-X started.
13:02:48.655  TestStep  DSRCStep Base class RUN
13:02:48.956  TestStep  Event flag HardBraking (0010) is set = TRUE
13:02:48.956  TestPlan  Sweep Loop \ TP-BSM-ST-BV-17-X completed with verdict 'Pass'. [302 ms]
```

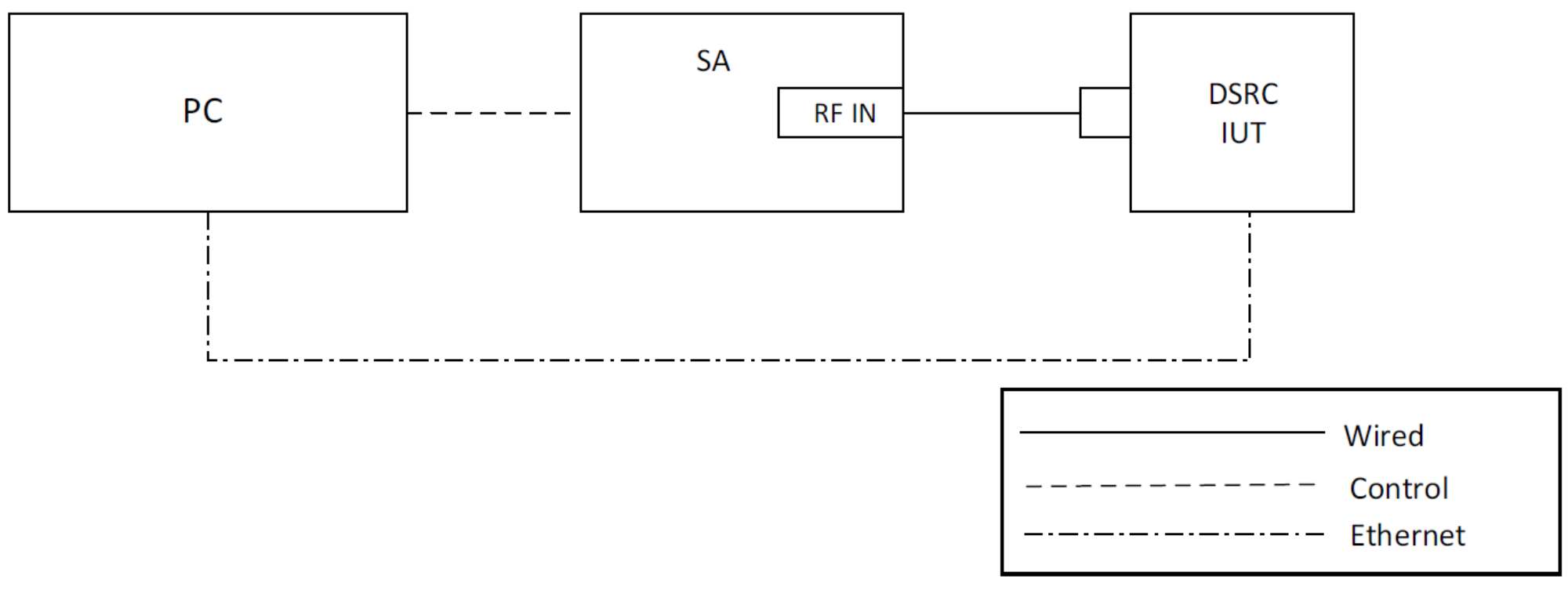
Test Spec Overview – 802.11

- Conformance test specifications for Wireless Access in Vehicular Environments (WAVE)
  - — 802.11 Test Suite Structure and Test Purposes (TSS & TP)

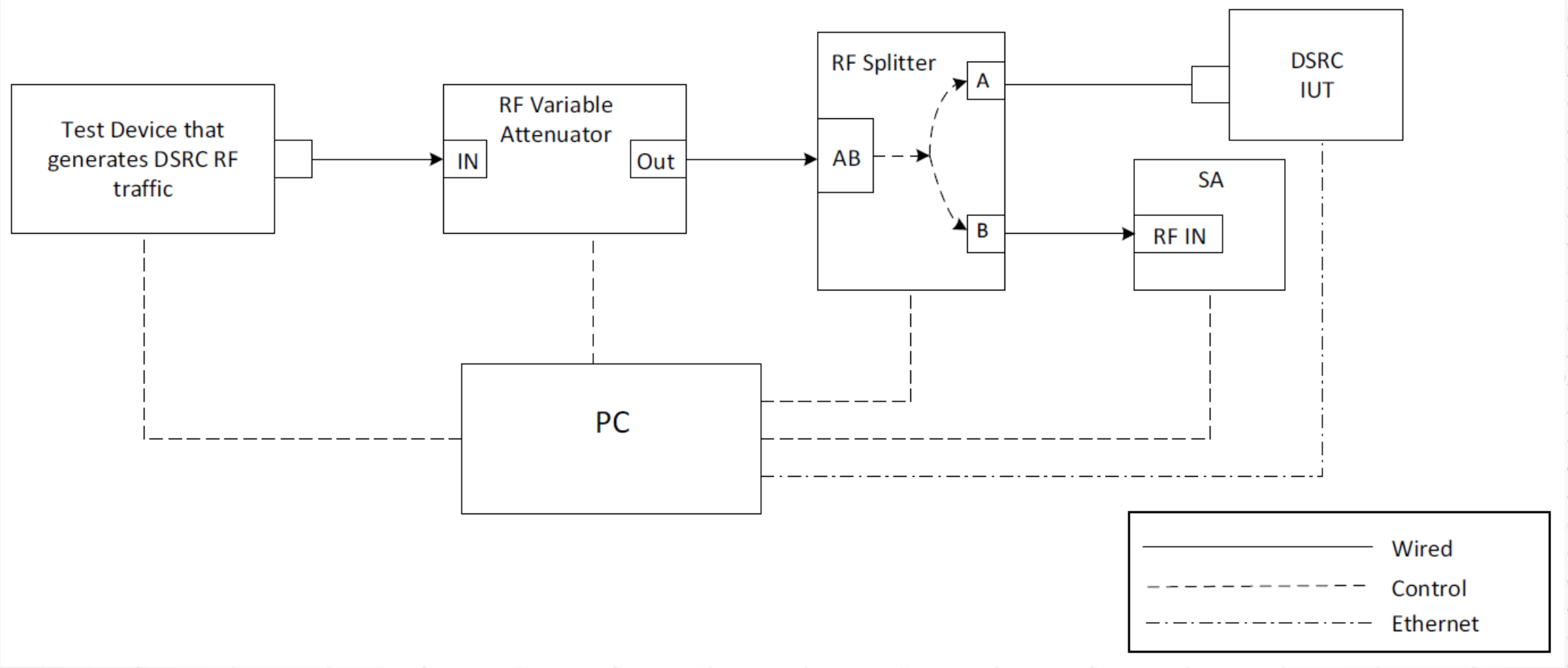
SA: Signal Analyzer

VST: Vector Signal Transceiver

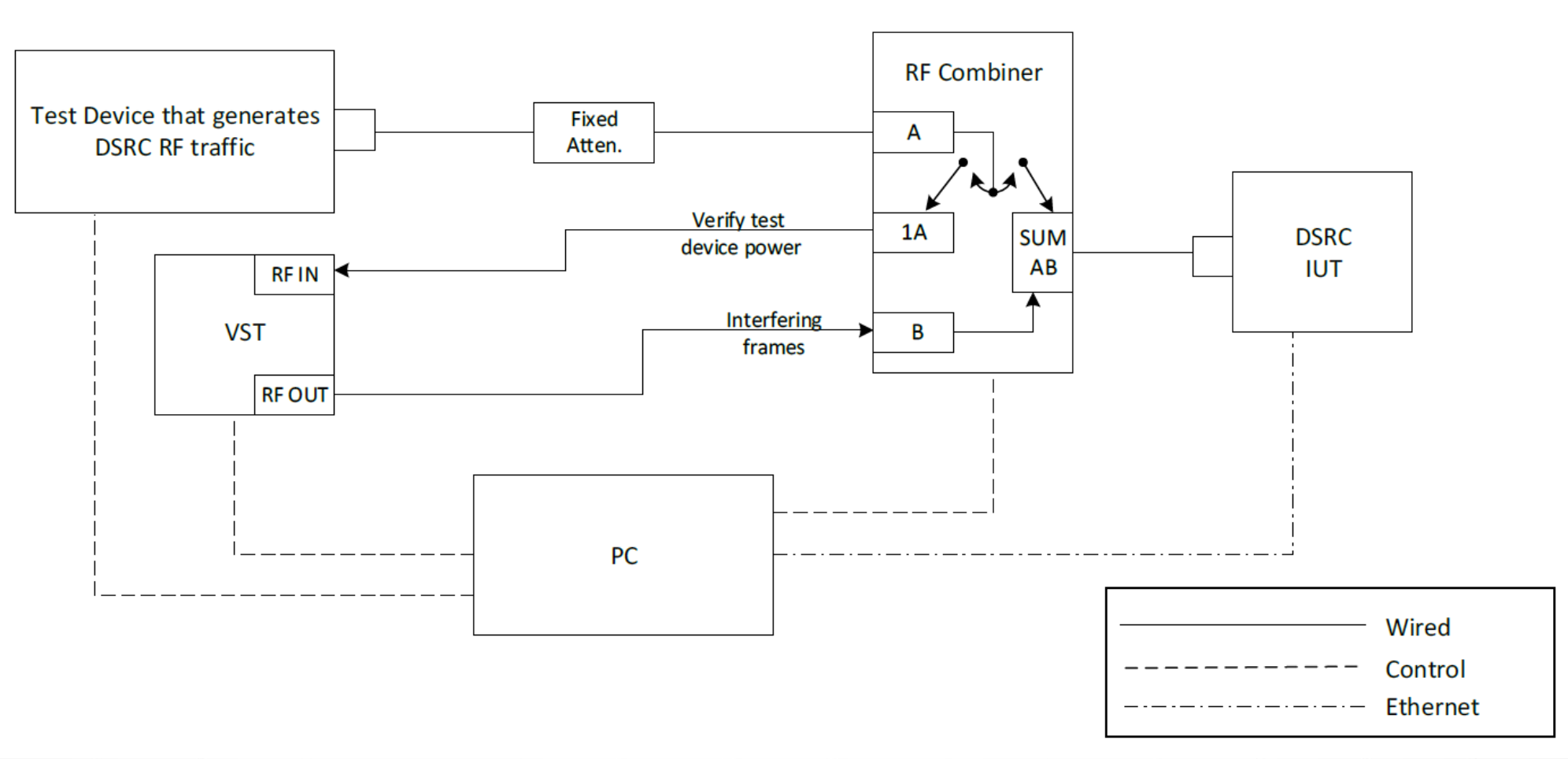
Test Configuration 1



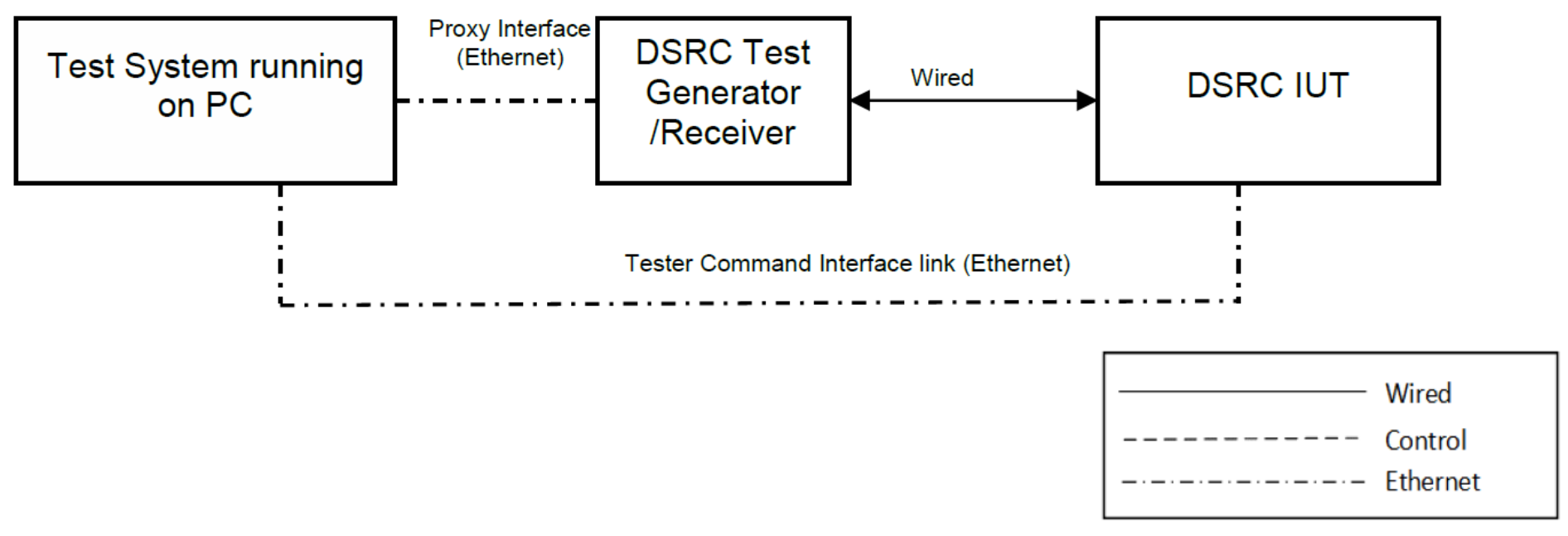
Test Configuration 2



Test Configuration 3



Test Configuration 4



Naming Conversion

<root> = root	80211	
<gr> = group	RXT	Receive
	TXT	Transmit
<sgr> =sub- group	MAC	Medium Access Control Layer
	PHY	Physical Layer
	BV	Valid Behavior tests
<x> = type of testing	BI	Invalid Syntax or Behavior Tests
<nn> = sequential number		01 to 99

- **802.11p**
  - TP-80211-RXT-MAC-BV-01 (Rx MAC Validation)
  - TP-80211-RXT-PHY-BV-01 (Rx Input Sensitivity)
  - TP-80211-RXT-PHY-BV-02 (Adjacent Channel Rejection)
  - TP-80211-RXT-PHY-BV-03 (non-Adjacent Channel Rejection)
  - TP-80211-RXT-PHY-BV-04 (Rx Max Power Input)
  - TP-80211-RXT-PHY-BV-05 (Rx RSSI)
  - TP-80211-TXT-MAC-BV-01 (Tx MAC Validation)
  - TP-80211-TXT-PHY-BV-01 (Spectrum Mask)
  - TP-80211-TXT-PHY-BV-02 (EVM Frequency Error)
  - TP-80211-TXT-PHY-BV-03 (EVM Symbol Clock Error)
  - TP-80211-TXT-PHY-BV-04 (EVM %RMS)
  - TP-80211-TXT-PHY-BV-05 (Spectral Flatness)
  - TP-80211-TXT-PHY-BV-06 (EVM Center Frequency Leakage)
  - TP-80211-TXT-PHY-BV-07 (Tx Power)

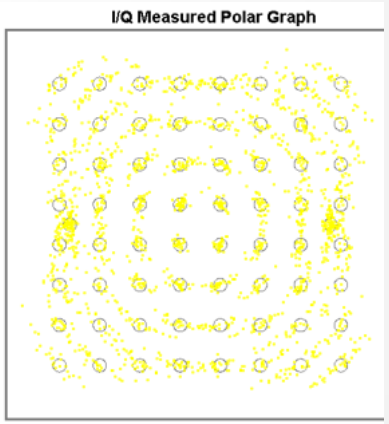
Ex) TP-80211-TXT-PHY-BV-04

- Verify the relative constellation RMS error and transmit modulation accuracy of IUT is within conformance limit

3	Verify	The Signal Analyzer captures *pNumberOfFrames* frames, demodulates the signal and computes EVM indicating value not greater than the values as shown in table below.	PASS / FAIL

Relative Constellation Error Table Vs Data Rate

Coding Rate	Modulation	Date Rate (MBPS)	Relative Constellation Error (dB)	Error Vector Magnitude (EVM) (% RMS)
½	BPSK	3	-5	56.2
¾	BPSK	4.5	-8	39.8
½	QPSK	6	-10	31.6
¾	QPSK	9	-13	22.3
½	16-QAM	12	-16	15.8
¾	16-QAM	18	-19	11.2
2/3	64-QAM	24	-22	7.9
¾	64-QAM	27	-25	5.6




Thanks!