Bluetooth® Seminar Series

Tools, Techniques, and Trends

Bluetooth LE RF Testing
Why Not Over the Air?

Ute Philipp | Product Manager | Rohde & Schwarz

86 years
of success

12.100
employees

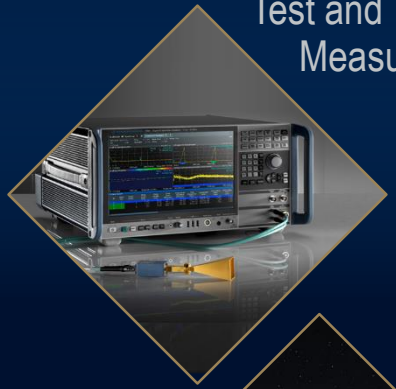
300
new products

Rohde & Schwarz - From a two-man laboratory to a global group of companies

Make ideas real

Shaping the future of communications, information and security

Test and Measurement



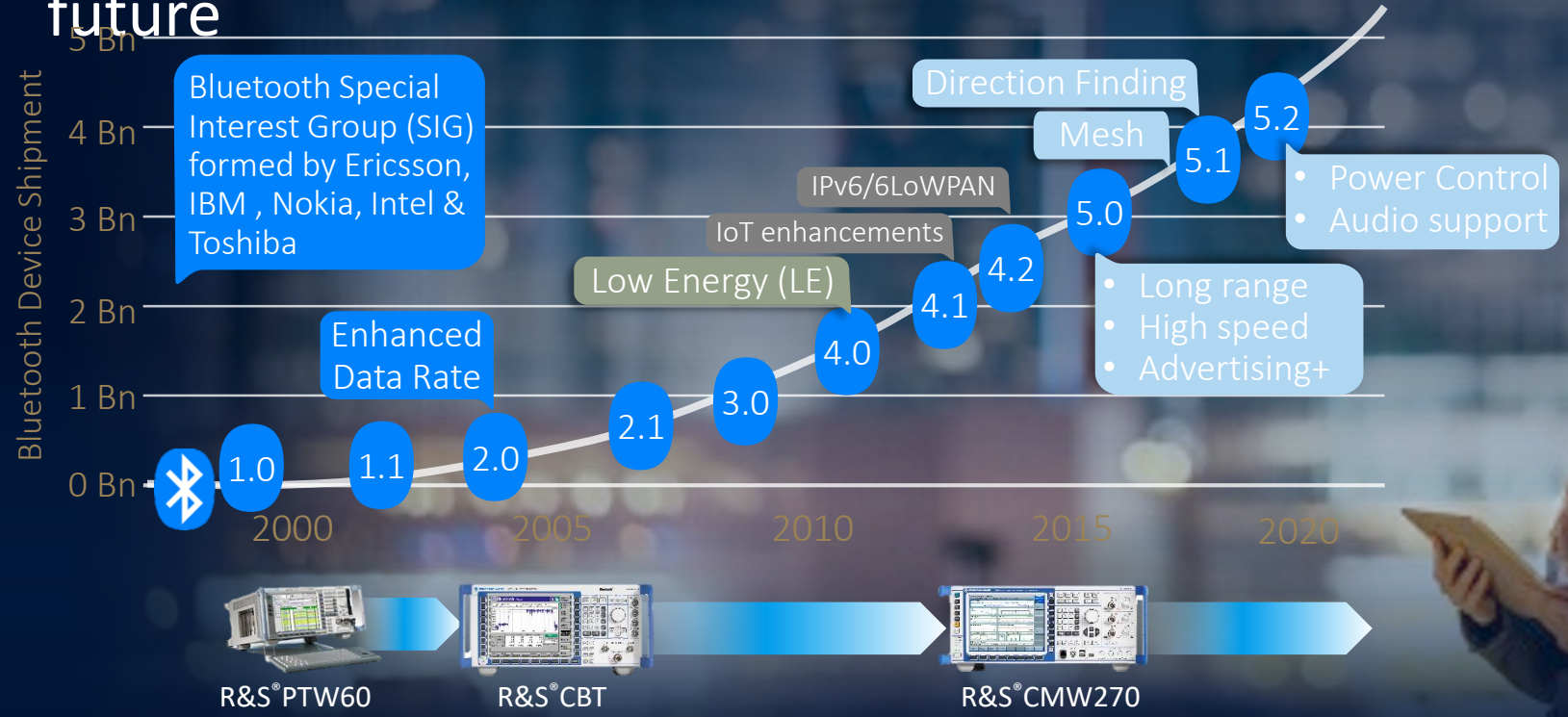
Networks and Cybersecurity

Aerospace ◆ Defense ◆ Security

Broadcast and Media

Make ideas real

We have supported the ecosystem with dedicated test solutions over the last twenty years and will do so in the future



Bluetooth® Low Energy - physical layer overview

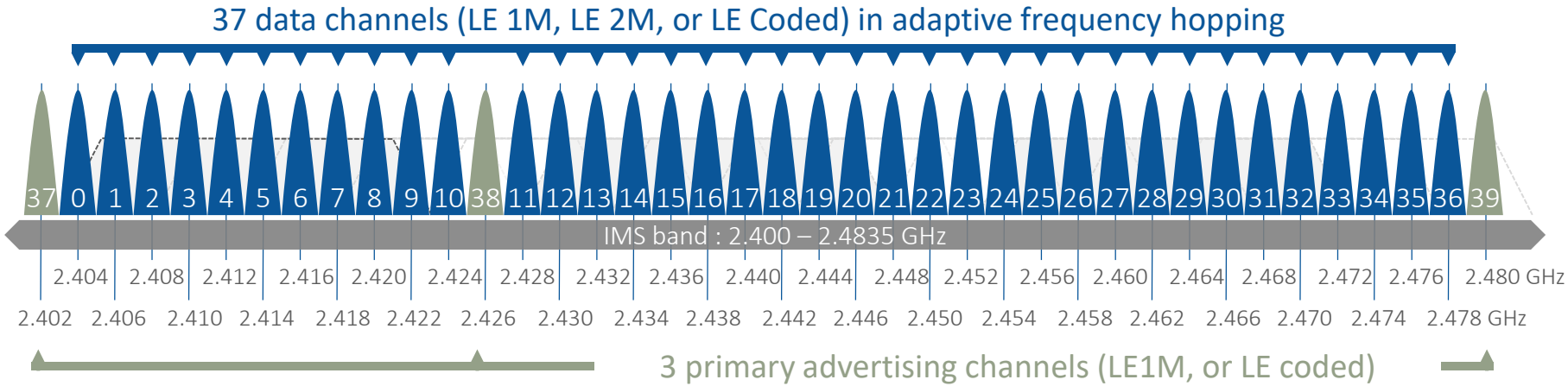
	LE 1M PHY	LE 2M PHY	LE Coded PHY w/ S=2	LE Coded PHY w/ S=8
Modulation	GFSK ΔF: 250 kHz	GFSK ΔF: 500 kHz	GFSK ΔF: 250 kHz	GFSK ΔF: 250 kHz
Symbolrate	1 MS/s	2 MS/s	1 MS/s	1 MS/s
Bitrate	1 Mbit/s	2 Mbit/s	0.5 Mbit/s	0.125 Mbit/s
Rx Sensitivity	≤ - 70 dBm	≤ - 70 dBm	≤ - 75 dBm	≤ - 82 dBm

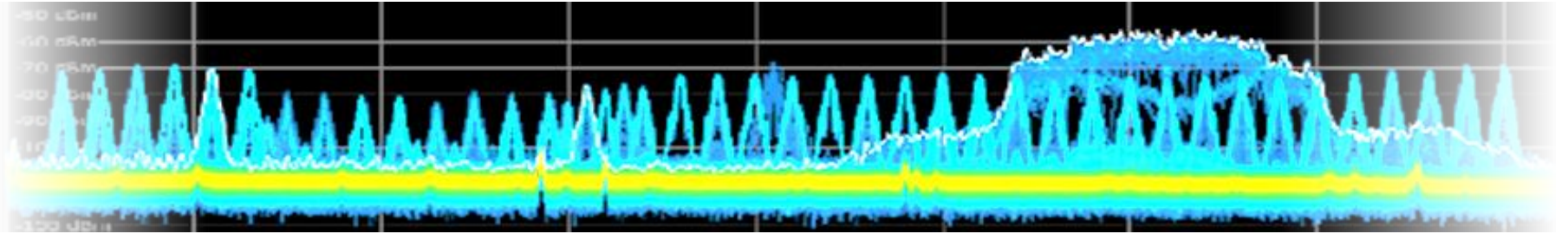
Link Layer packet format for the LE uncoded PHYs

Preamble	Access Address	PDU	CRC	CTE
1 or 2 octets	*4 octets*	*2 – 256 octets*	*3 octets*	*16 to 160 µs*

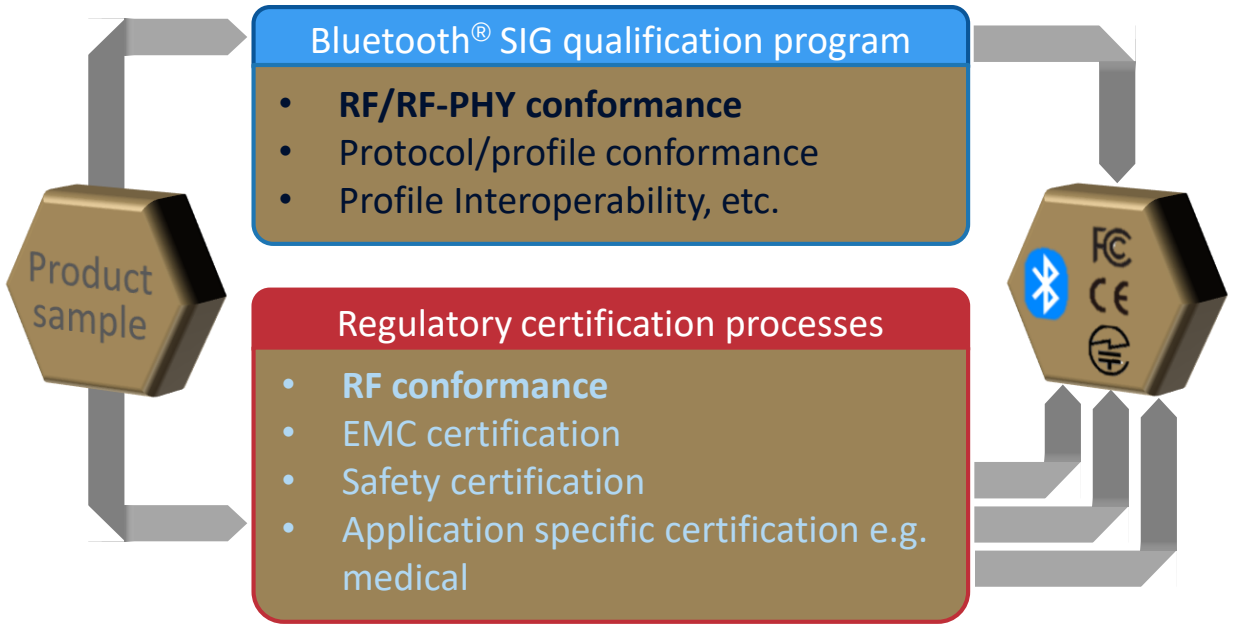
PDU – Packet Data Unit ◆ CRC – Continuous Redundancy Check ◆ CTE – Continuous Tone Extension

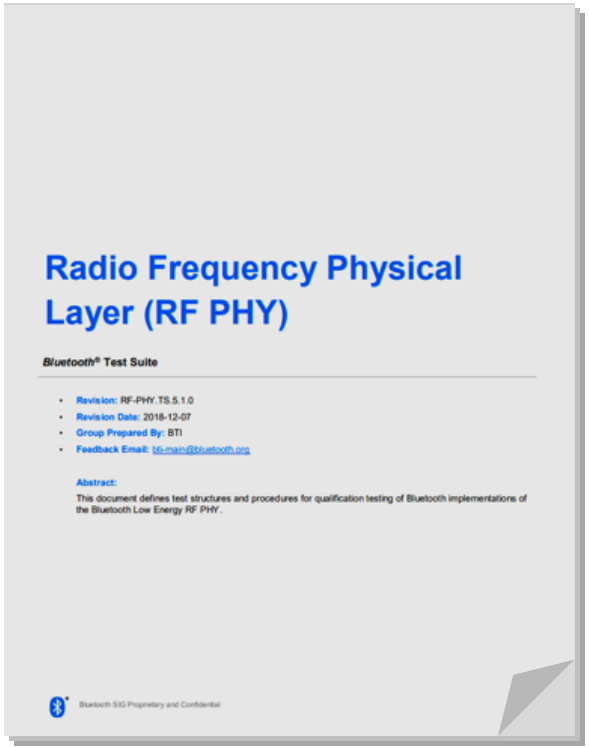
Bluetooth Low Energy – 2.4 GHz ISM spectrum use





Bluetooth® certification processes




Radio Frequency Physical Layer (RF PHY)

Bluetooth® Test Suite

- Revision: RF-PHY.TS.5.1.0
- Revision Date: 2018-12-07
- Group Prepared By: BTI
- Feedback Email: bti-main@bluetooth.org

Abstract:

This document defines test structures and procedures for qualification testing of Bluetooth implementations of the Bluetooth Low Energy RF PHY.

Bluetooth SIG Proprietary and Confidential

Bluetooth LE RF pre-qualification testing
Test Cases

Test Cases up to Rel. 5.0

BT5	Tests / Requirements	1Ms/s	2Ms/s	1Ms/s, SMI	2Ms/s, SMI	1Ms/s, S=2	1Ms/s, S=8	1Ms/s, S=2, SMI	1Ms/s, S=8, SMI
TRM-LE	Output power	01							
	In band emission	03	08						
	Modulation charachteristics	05	10	09	11		13		
	Carrier frequency offset & drift	06	12				14		
RCV-LE	Receiver sensitivity	01	08	14	20	26	27	32	33
	C/I and Receiver sensitivity	03	09	15	21	28	29	34	35
	Blocking performance	04	10	16	22				
	Intermodulation performance	05	11	17	23				
	Maximum input signal level	06	12	18	24				
	PER Report Integrity	07	13	19	25	30	31	36	37

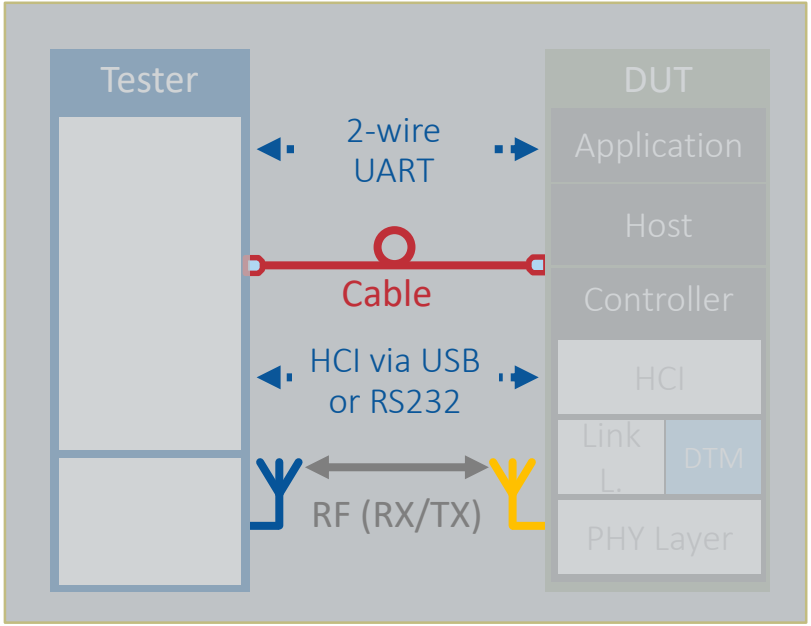
Blocking Tests

Test Cases Rel. 5.1

	Description		1 Ms/s PHY		2 Ms/s PHY	
TRM	Output Power	TRM/BV-	15		-	
	Carrier Frequency Offset and Drift with CTE	TRM/BV-	16		17	
			2us Slot	1us Slot	2us Slot	1us Slot
	TX Power Stability; AoD Transmitter	TRM/PS/BV-	01	02	03	04
	Antenna Switching Integrity; AoD Transmitter	TRM/ASI/BV-	05	06	07	08
RCV	IQ Samples Coherency; AoD Receiver	RCV/IQC/BV-	01	02	03	04
	IQ Samples Coherency; AoA Receiver	RCV/IQC/BV-	05	-	06	-
	IQ Samples Dynamic Range; AoD Receiver	RCV/IQDR/BV-	07	08	09	10
	IQ Samples Dynamic Range; AoA Receiver	RCV/IQDR/BV-	11	-	12	-

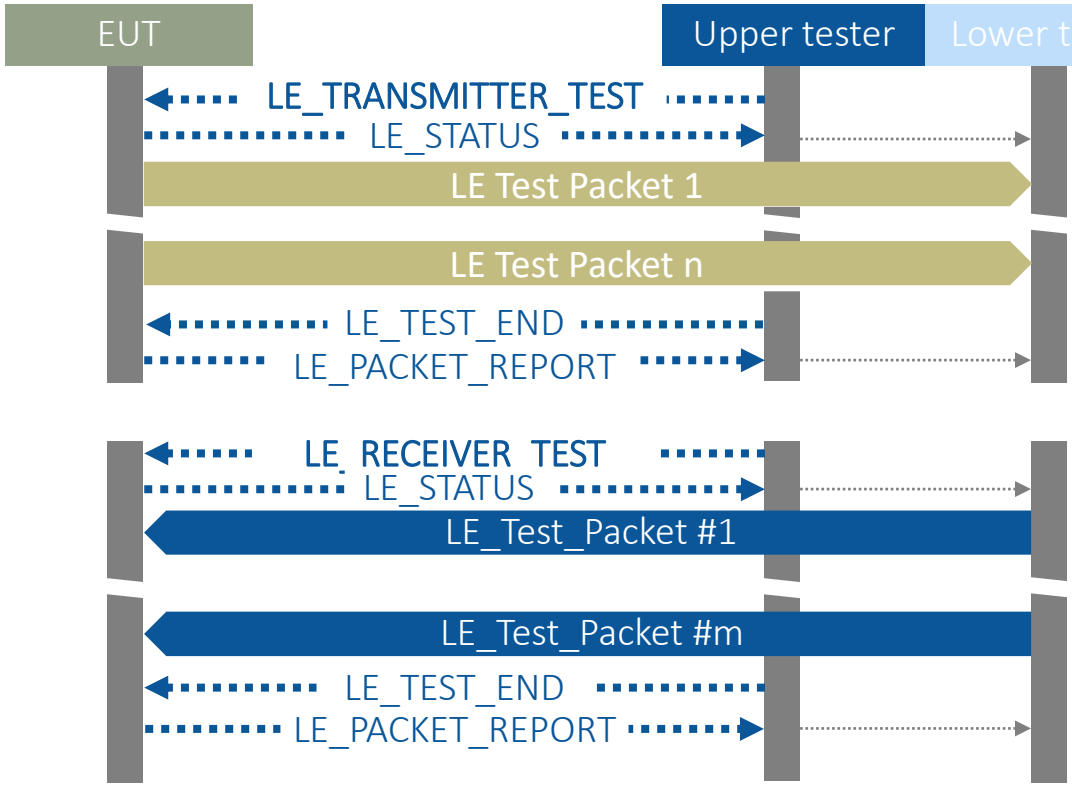
Bluetooth® LE Direct Test Mode (DTM)

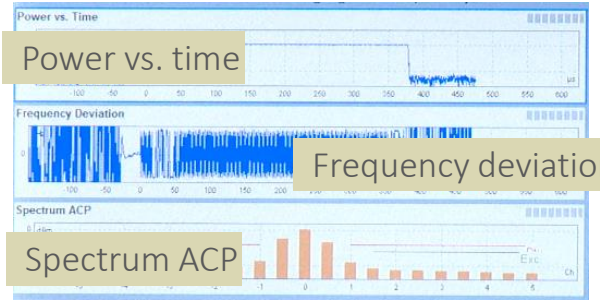
- DTM was introduced in Bluetooth® 4.0 specification together with Bluetooth® LE
- Standardized non-signaling test mode with defined test interface and uniform commands
- DTM allows fast testing on all channels
- DTM works independent from the tested radio interface, but needs a wired connection to the DUT

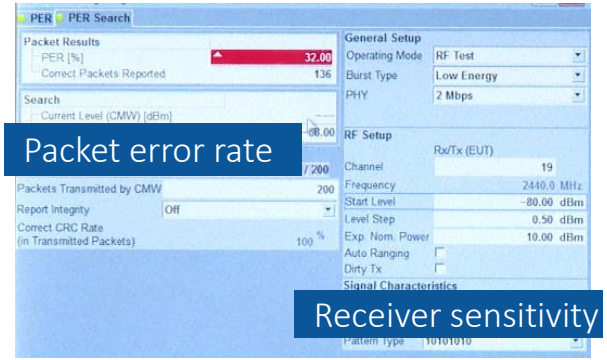


DUT: device under test | EUT: equipment under test

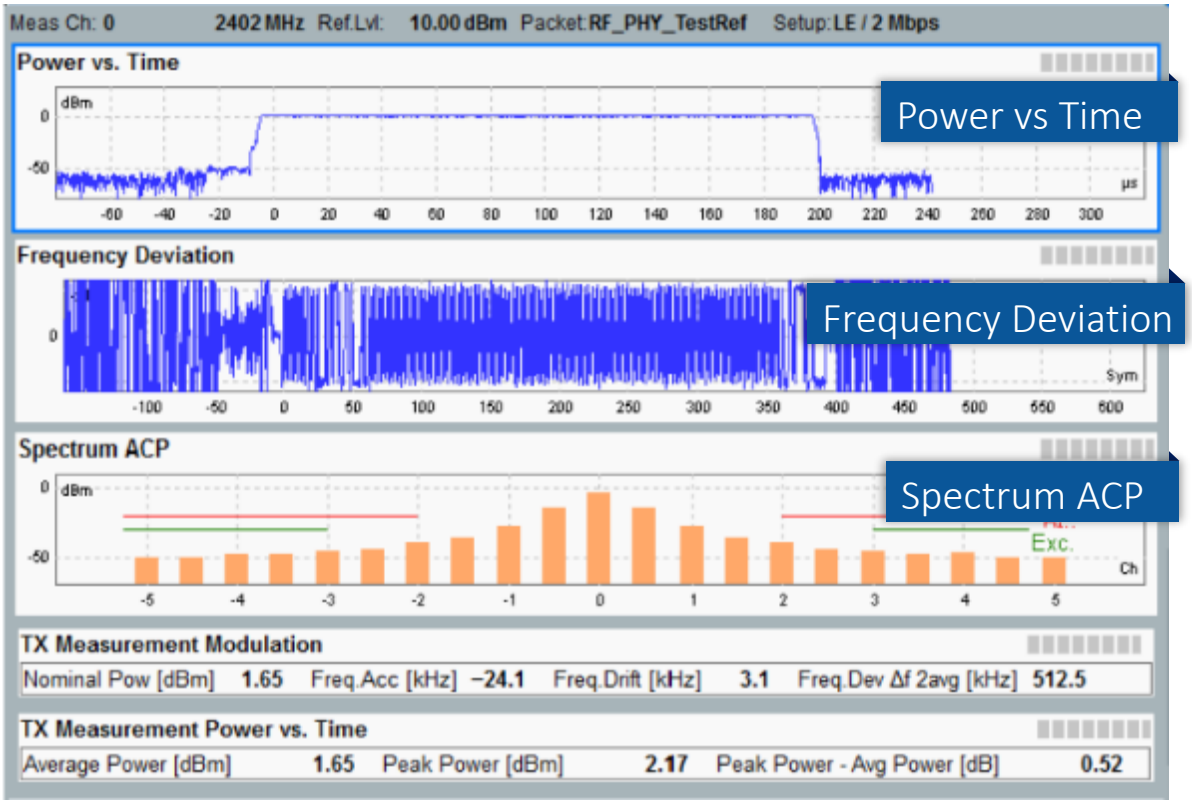
Direct Test Mode (DTM) use for RX and TX tests







Typical Bluetooth® LE RF Transmitter measurements



Typical Bluetooth® LE RF Receiver measurements

PER | PER Search

Packet Results

PER [%]	0.53
Correct Packets Reported	1492

Packets Transmitted: 1500 / 1500

Packets Transmitted by CMW	1500
Report Integrity	Off
Correct CRC Rate (in Transmitted Packets)	100 %

General Setup

Operating Mode	RF Test
Burst Type	Low Energy
PHY	Long Range
Coding Scheme	S8

RF Setup

Rx/Tx (EUT)

Channel	19
Frequency	2440.0 MHz
Tx Level (CMW)	−82.00 dBm
Exp. Nom. Power	10.00 dBm
Auto Ranging	☐
Dirty Tx	☑

Signal Characteristics

Packet Type	RF_PHY_TestRef
Payload Length	37 byte(s)
Pattern Type	PRBS9

What we learned over the last years in using DTM

Works very well for pre-conformance and conformance testing, but …

- test setups tend to become more complicated,
- sometimes it is hard to find a plug for the control cable,
- control cabling could influence the RF measurements

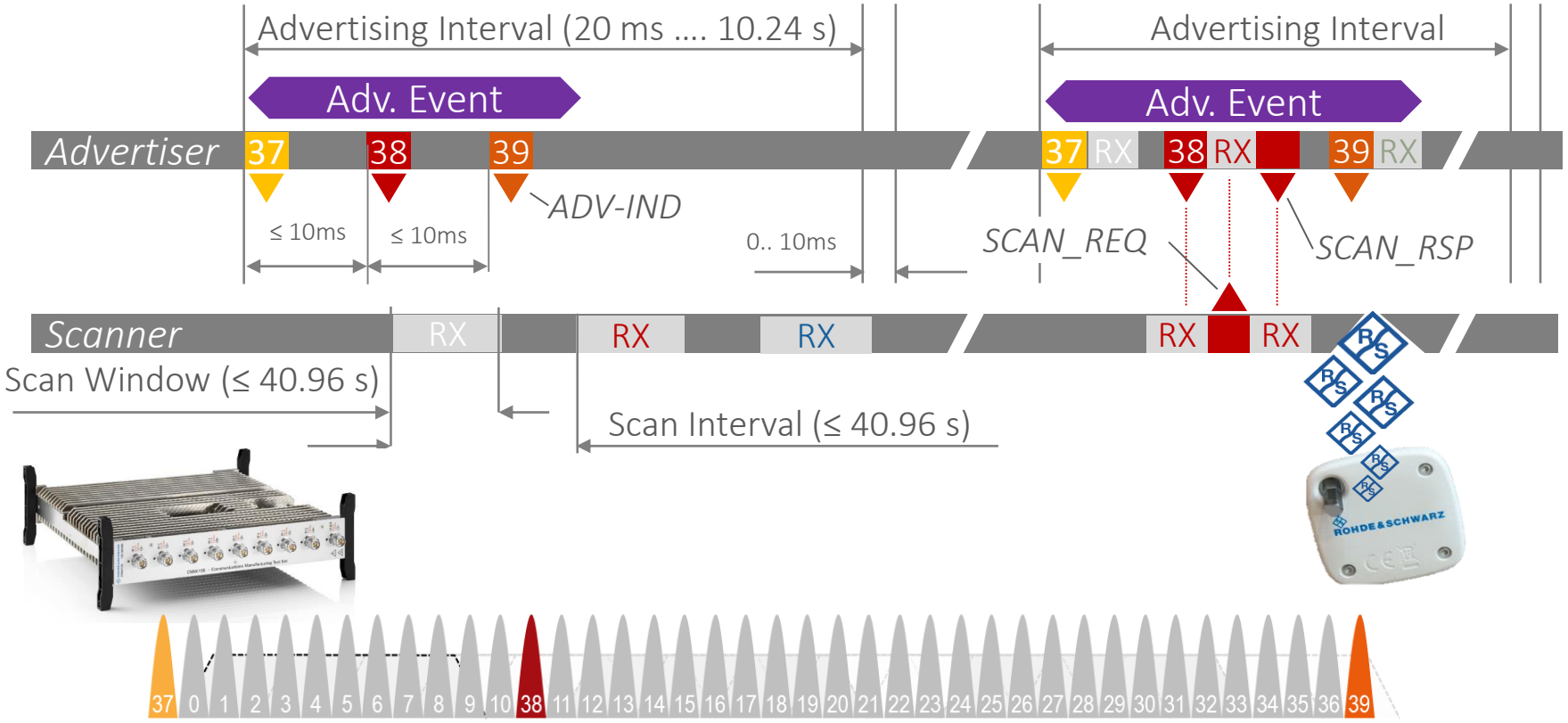
Can we simply unplug the control cable?

Use the **advertising** procedure to test on advertiser channels

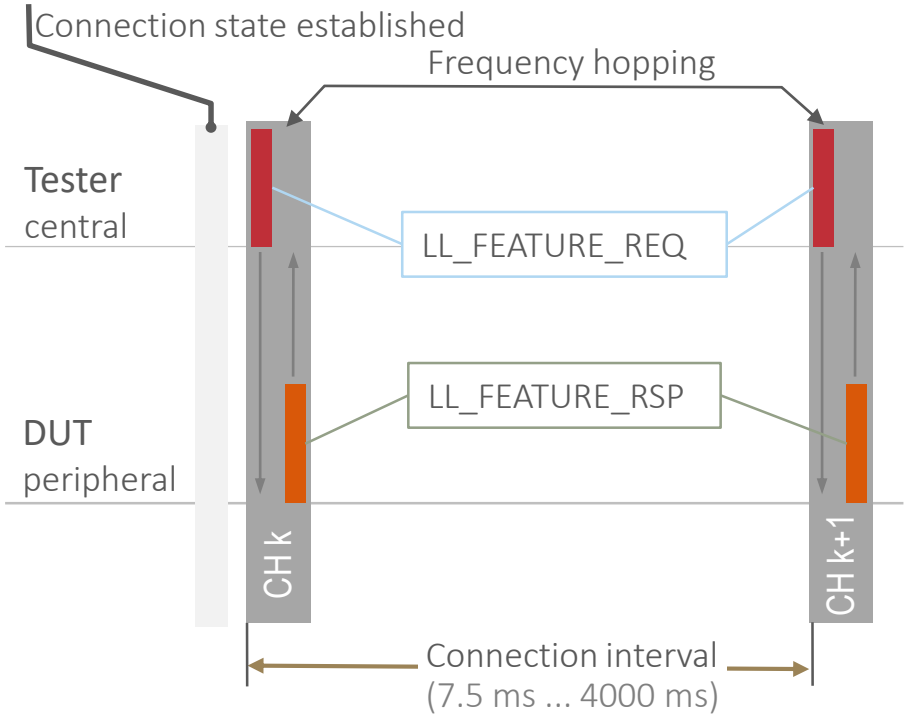
Perform measurements on data channels in **connected state**

Adapt direct test mode to a **radio-controlled** Bluetooth LE **test mode**

Use of advertising communication for functional testing



Bluetooth® LE Connected Mode

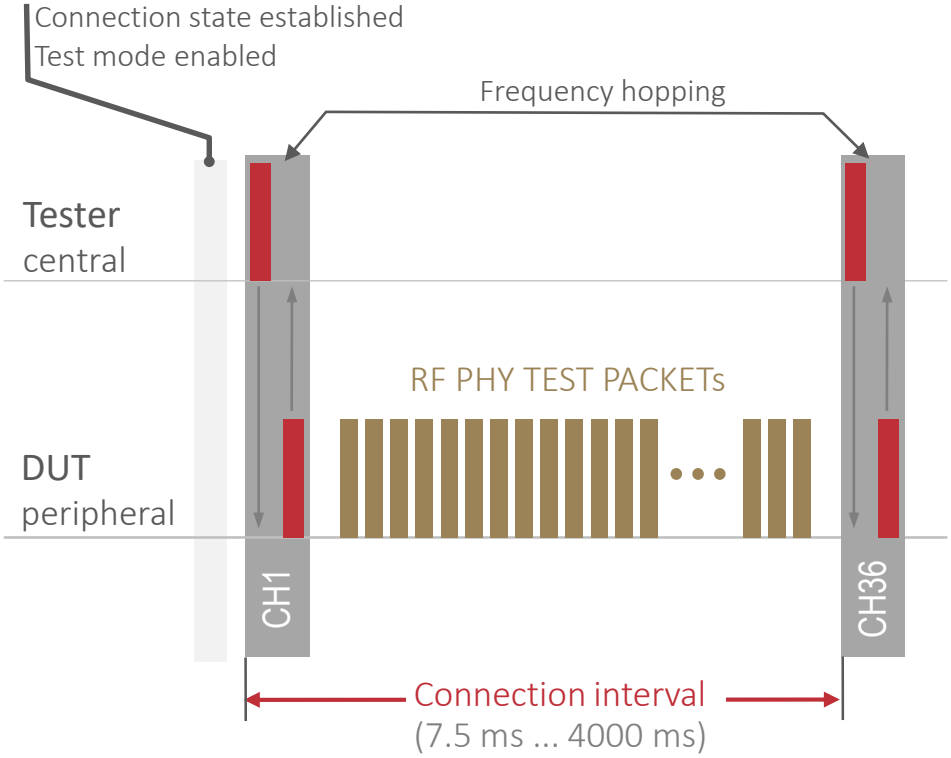


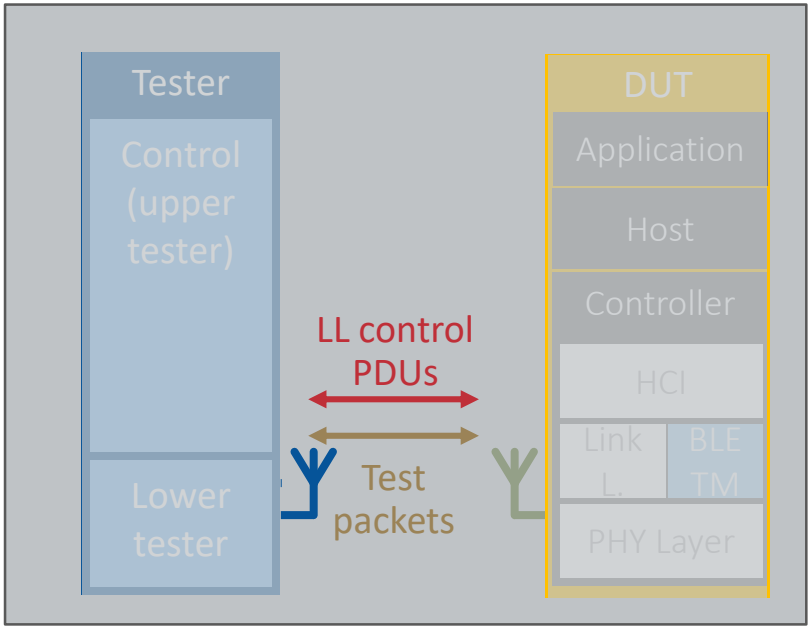
Allows testing of all data channels in frequency hopping sequence with the option to tests only data channels

Transceiver tests:
Tester sends Feature Request packets to DUT and DUT shall respond with Feature Response packets which can be used for related measurements.

Receiver Tests
Tester sends Feature Request packets to DUT with defined power and is looking for responses from the DUT to determine PER

World's first radio-controlled Bluetooth® LE Test Mode

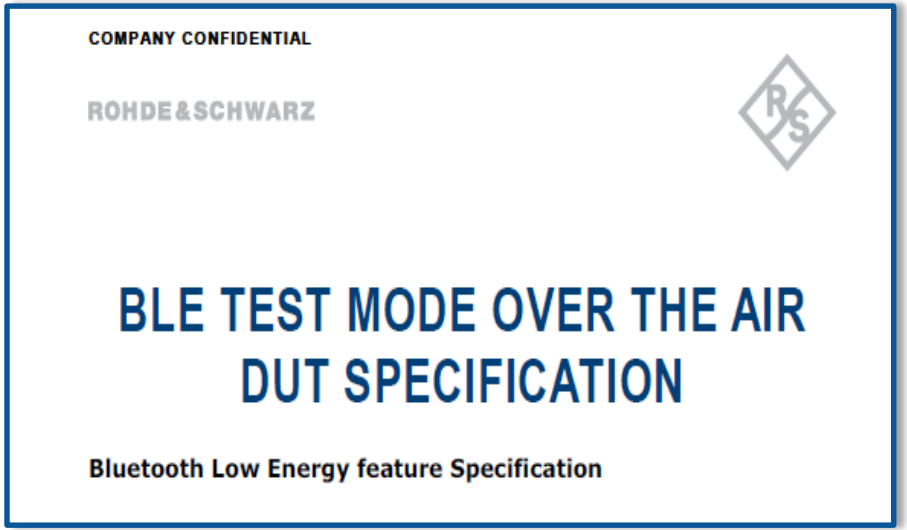




Demo

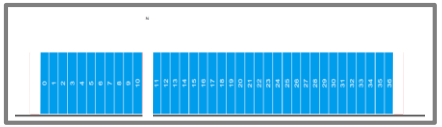
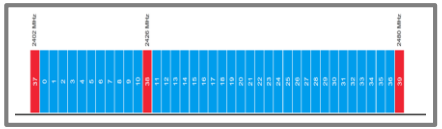
Bluetooth **LE** Test Mode

Implementation Details



- **All test cases** within the BLE RF-PHY-TS Test Specification **are possible**
- RF-PHY-TS compliant Transmitter and Receiver Tests for EUTs **without wired control interface**
- Requires changes to the EUT stack to facilitate this test mode
  - 5 new HCI commands and 4 new HCI events
  - 4 new bits in the LE Event Mask
  - 8 new LL Control PDUs (4 pairs of Request/Response)

Bluetooth LE RF test methods

	BLE Advertiser testing Mode	BLE Signaling Connected mode	DTM & BLE Test Mode
			
Test Strategy	Based on Scan Request/ Response packets	Feature request/response packets are measured only	RF Test PHY packets are measured
RF tests	on advertiser channels	on data channels	on all channels
Meas. speed	depends on DUT advertiser interval	depends on DUT connection interval	very fast
Pre-conf. tests	Not possible	Not possible	Possible
	CMW-KD611	**CMW-KS601/720**	**CMW-KS601/KS720 + KS611/KS721**

What is the difference?

	Direct Test Mode	BLE Test Mode (BLE-TM)
Test setup	☹ Complicated due to cabling	☺ Easy to use
Test control	😐 DUT control via cable	☺ Radio link layer controlled
Test coverage	☺ Test of **all** BLE channels	☺ Test of **all** BLE channels
Conformance tests	☺ All defined test cases	☺ All defined test cases
Prerequisite	😐 DTM support of the DUT	😐 BLE-TM support of DUT
Add. measurements	n/a	☺ Bit error rate (BER)

Several possibilities to test and verify Bluetooth® Low Energy

Non-signaling Mode
Vendor specific test procedure

Direct Test Mode
Standardized non-signaling test

Advertiser Mode
Quick & easy functional test

Connected Mode
Easy to use channel tests

BLE Test Mode
Standard-conform testing

R&S® CMW270

Test automation and reporting available with R&S®CMWrun

R&S® CMW100

Company Logo Here

Thank you!

Questions?

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