Redefining testing for Bluetooth® Low Energy

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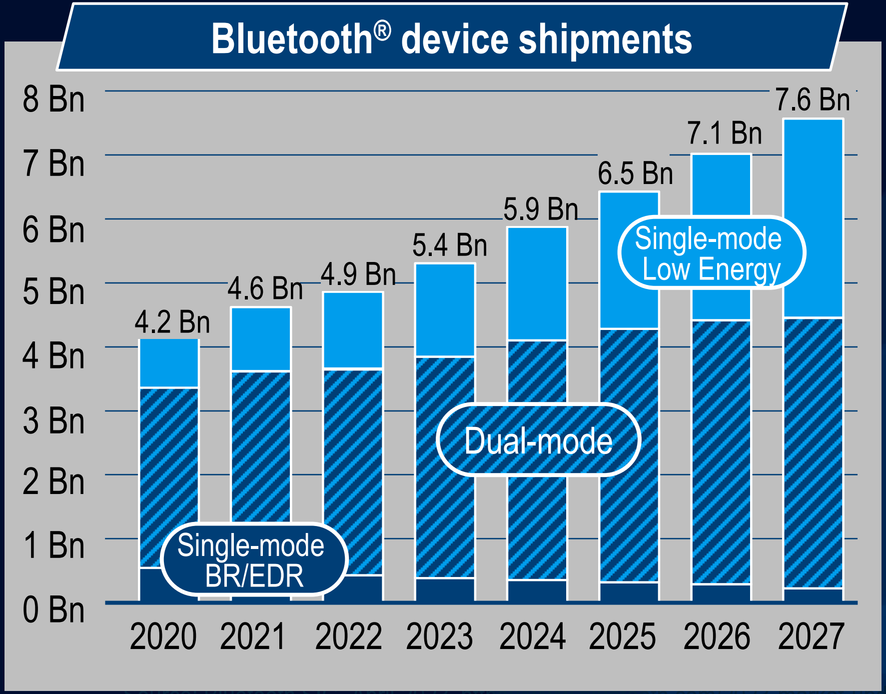
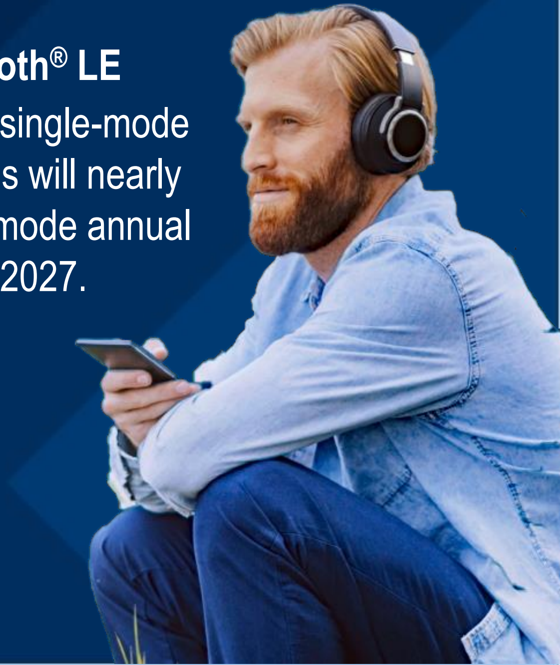
Make ideas real

Continuous growth (9% CAGR) and move from Bluetooth® BR/EDR to Low Energy expected for the next years



97% support Bluetooth® LE

Annual shipments of single-mode Bluetooth® LE devices will nearly match those of dual-mode annual device shipments by 2027.



Bluetooth® most attractive applications today & tomorrow

Bluetooth® LE evolution over the last couple of years

Speed
100% data rate improvement for low latency

Range
4x range to cover smart home or office

Broadcast
Extended advertising capabilities

Mesh
Meshed networking

Direction
Angle of Arrival and Angle of Departure

Power
Dynamic optimization of TX power

Audio
Isochronous physical channels

Bluetooth® 5.0
(2015)

Bluetooth® 5.1
(2019)

Bluetooth® 5.2
(2020)

Bluetooth® LE evolution over the last couple of years

Interference

Channel classification from peripherals

Efficiency

Connection sub-rating and updates

Advertising

Advertising efficiency improvements

Scalability

Periodic advertising with response

Security

Encrypting data in advertising packets

Ranging

High accurate & secure distance measurement

Test mode

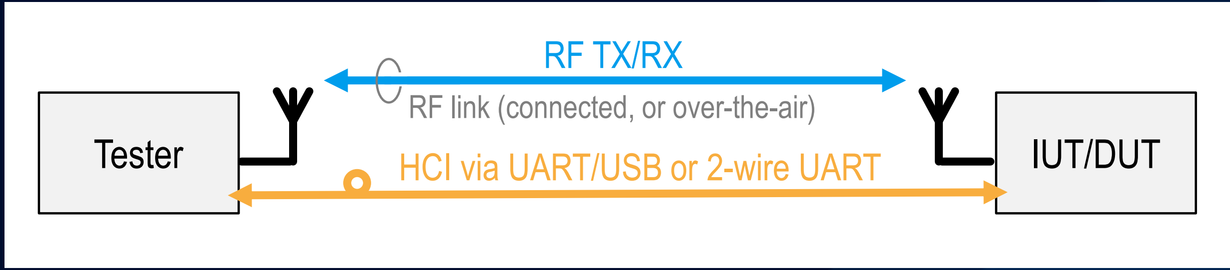
New test protocol incl. LL test control

Bluetooth® 5.3
(2021)

Bluetooth® 5.4
(2023)

New
Bluetooth® LE
Test Mode

Bluetooth® LE physical layer testing and qualification uses DTM



Direct Test Mode (DTM) provides a common interface for fast and repeatable test control, **but requires a wired connection to the Bluetooth® LE device.**

Bluetooth® LE devices are becoming more compact and are often not equipped with wired control interfaces.

Testing requires hardware modifications of the DUT and typical RF/antenna performance measurements are cumbersome.

Growing demand for a Bluetooth® LE test control over the Bluetooth® LE RF interface, such as know from Bluetooth® BR/EDR test mode

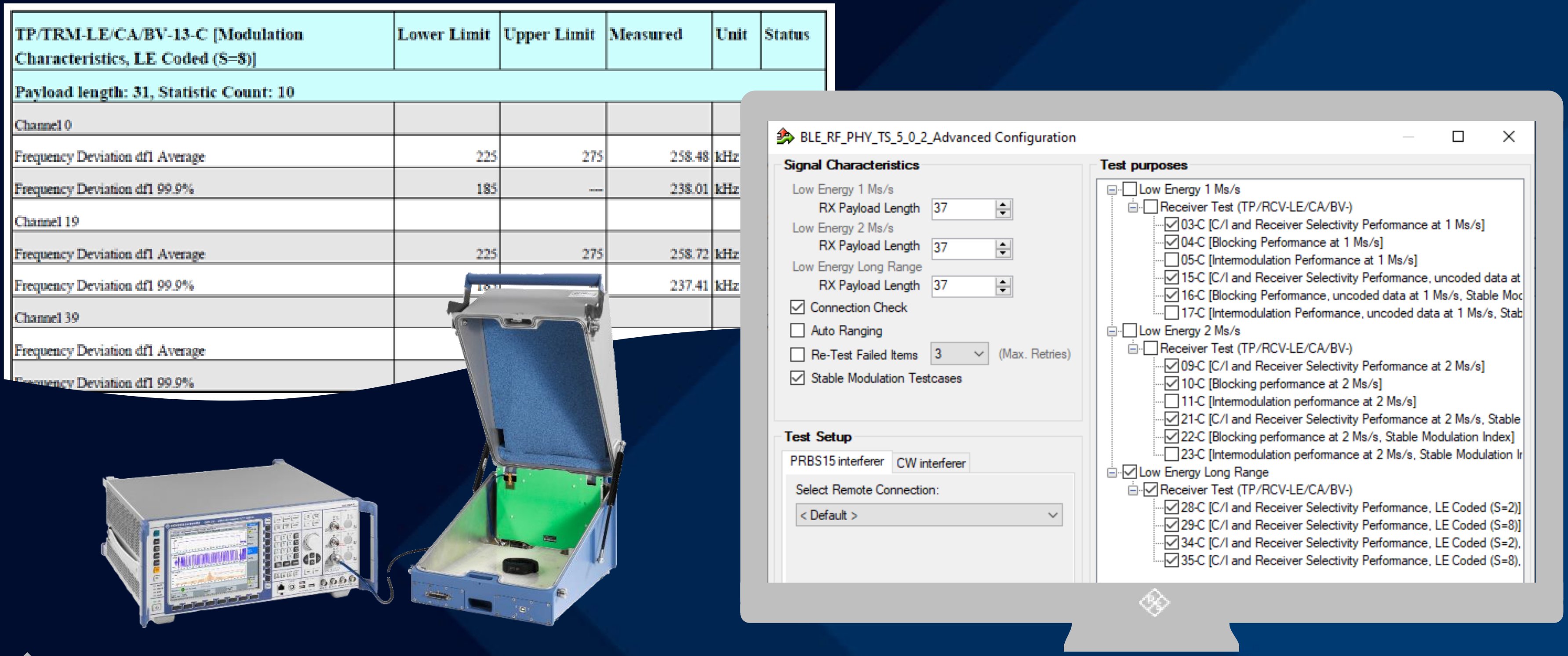
The Unified Test Protocol as enhanced alternative to the DTM

Today, LE RFPHY test cases are limited to being performed over either the 2-wire UART or Host Controller Interface (HCI) transports defined as Direct Test mode (DTM).

The new mode defines a unified and extensible control protocol for use across all existing transports and, in addition, the new OTA transport.

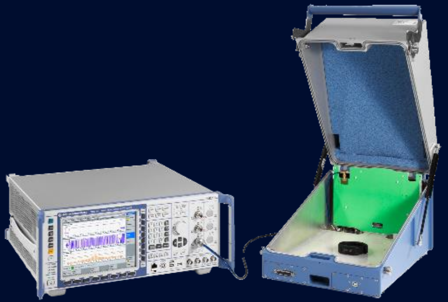
New OTA transport means that the control protocol (UTP) will be transported over the RF interface between tester and DUT (either conducted via a coaxial cable or radiated in nature).

DTM and UTP mode are supported by a comprehensive test automation software based on R&S®CMWrun



Bluetooth® LE RFPHY testing for all product testing phases

R&D, integration 〉 Pre-conformance 〉 Regulatory compliance / **Bluetooth SIG certification** 〉 Go-to market 〉 Production testing



Ensure RF performance, quality and interoperability by applying test scenarios and test case defined by Bluetooth SIG to be well prepared for the final certification.

Bluetooth® Qualification Test Facilities (BQTFs) & Bluetooth Recognized Test Facilities (BRTF) use the R&S®CMW platform.

7layers *Interlab test solution*

Applying most efficient test procedures in production to ensure final product quality and performance.

DEMO SETUP FOR THE NEW UTP MODE

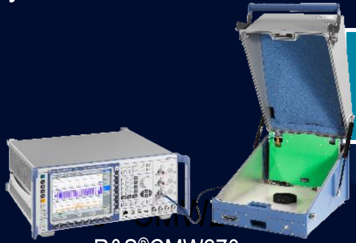
New Bluetooth® LE Test Mode

- One unified test protocol (UTP) applicable for three different transport channels
- UTP will allow execution of RFPHY test cases as specified for Bluetooth LE for devices supporting this optional feature
- Future implementation will be limited to UTP using HCI and OTA transport only
- Beta version is already available for validation on the R&S®CMW270/500

Always using the best solution to test Bluetooth® Low Energy

	Covered channels	Control transport
Standalone Test Mode Vendor specific test control	40	UART
Primary Advertiser Mode Quick & easy functional test	3	(LE Radio)
LE Direct Test Mode Standardized test mode	40	UART
LE Unified Test Protocol Mode Standardized test mode	40	LE Radio
Connected Mode Easy to use channel tests	37	(LE Radio)

Design → Verification → (Pre-) conformance → Manu- facturing



R&S®CMW270

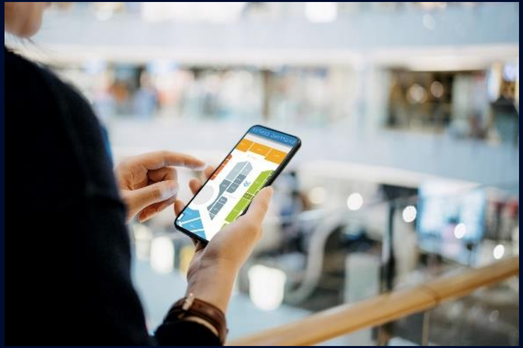
R&S®CMW100

Bluetooth® LE

Channel Sounding

Closing the gap for secure ranging and localization services with a new secure ranging technique for Bluetooth® LE

Localization and tracking



- Item finding
- Asset tracking
- Smart home

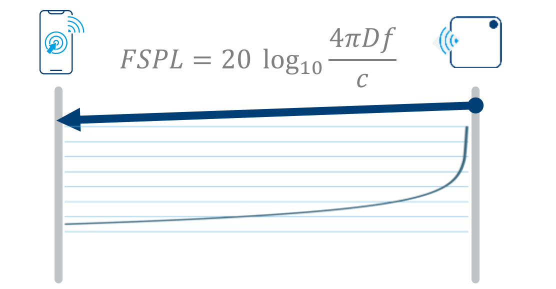
Secure proximity

- Keyless entry
- Door looks
- Building access

◆ Accurate distance estimation under real-world conditions
◆ Robust against security attacks
◆ Simplified setup
◆ Standardized & interoperable

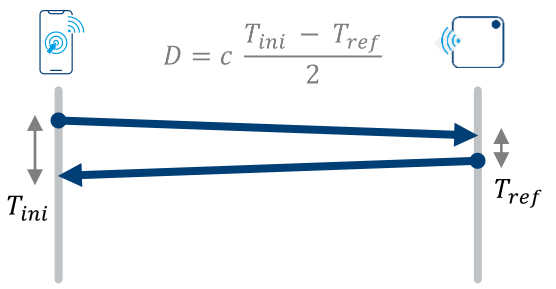
Distance estimation based on path loss or propagation delays

Received signal strength



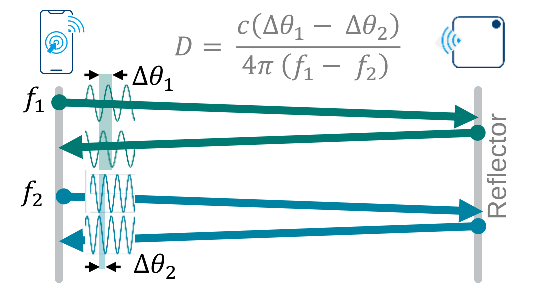
- Distance estimation based on free space path loss (FSPL) modelling
- Values vary due to multipath fading and shading, interference etc.
- Adequate for simple tracking, presence or navigation services

Round trip time (RTT)



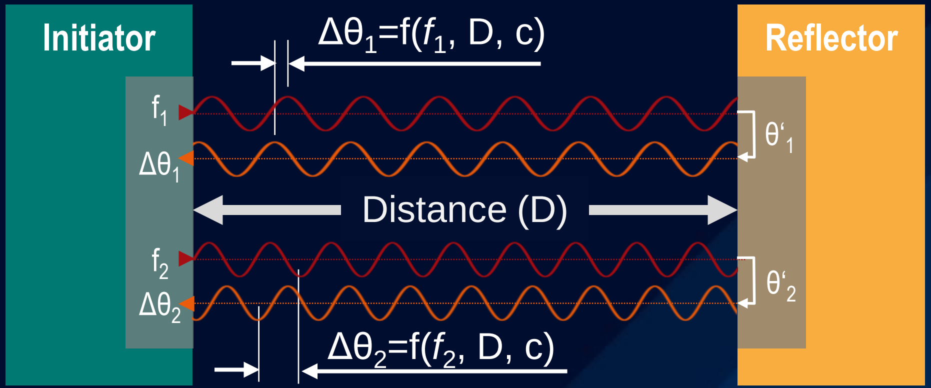
- Based on propagation delay of wireless signals
- Requires accurate time (30 cm/ns) measurements of the shortest path
- Appropriate for wide range of secure ranging services

Phase based ranging (PBR)



- Phase differences (θ_1, θ_2) between transmitted and reflected signals on different carriers (f_1, f_2) supported by RTT
- Appropriate for wide range of secure ranging services

Channel sounding applying phase based ranging (PBR) for high accurate distance measurements (HADM)



Total phase change over distance D

$$D = \frac{c\,\Delta\theta_i}{4\pi\, f_i}$$

Limited by wavelength

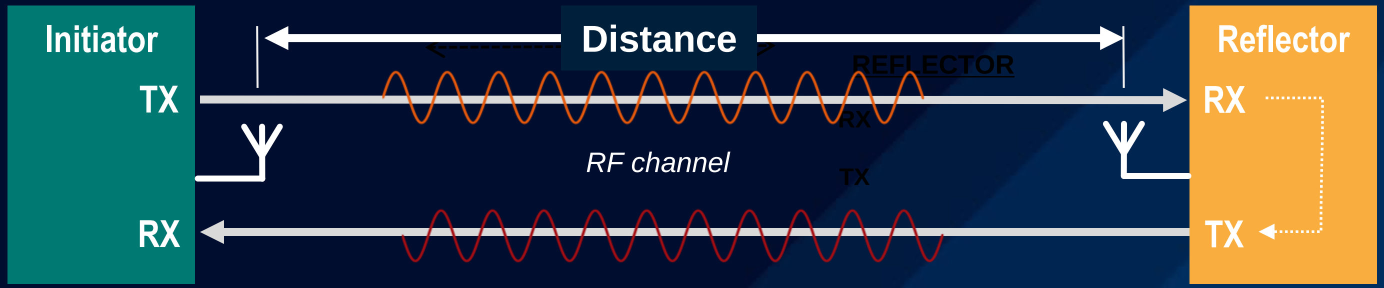
$D_{max} = \frac{c}{2f_i}$ e.g. 6 cm

$$D = \frac{c(\Delta\theta_1 - \Delta\theta_2)}{4\pi\,(f_1 - f_2)}$$

Distance wrap

$D_{max} = \frac{c}{2\Delta f}$ e.g. 150 m, Δf = 1 MHz

Channel sounding ranging concept



Initiator and reflector can have a single antenna possibility or more antennas.

Phase Based Ranging (PBR)

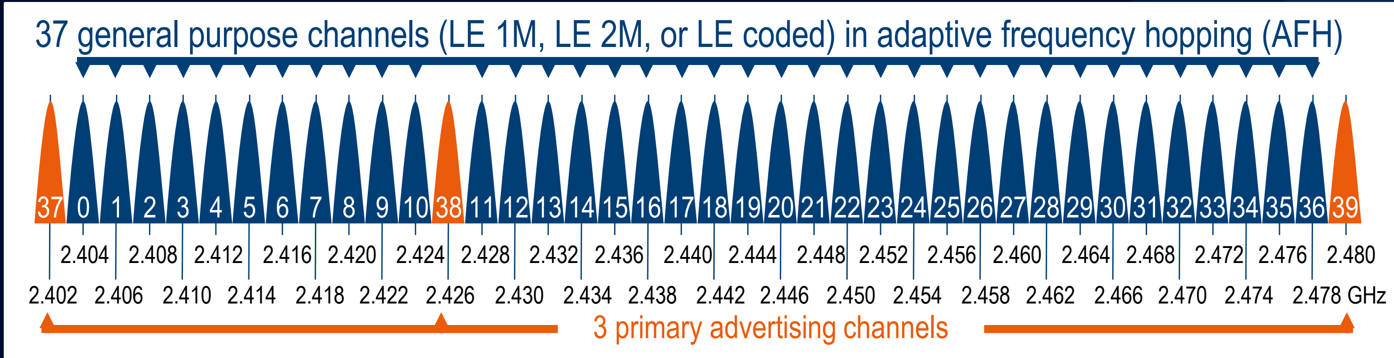
- Distance estimation based on phase and amplitude information
- Devices transmitting tones and performing IQ measurements
- Cryptographically scrambled ASK modulation is employed for the tones to enhance integrity

&

Round Trip Time (RTT)

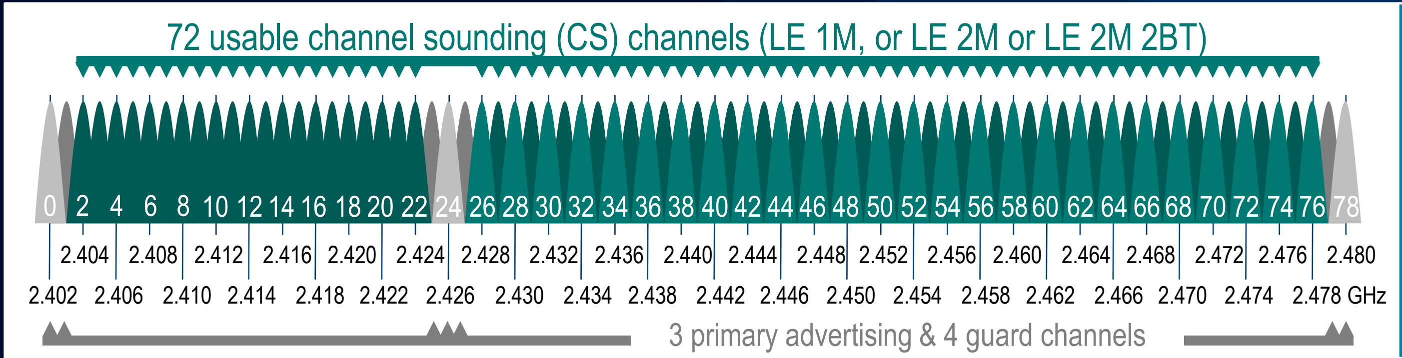
- Distance estimation based on the time period (RTT - aka ToF) of transmission and reception
- Devices are measuring ToD and ToA time stamps
- Cryptographically scrambled packets are exchanged between two devices

Channel sounding applies a channel map with 1 MHz spacing



Bluetooth® LE physical channel map

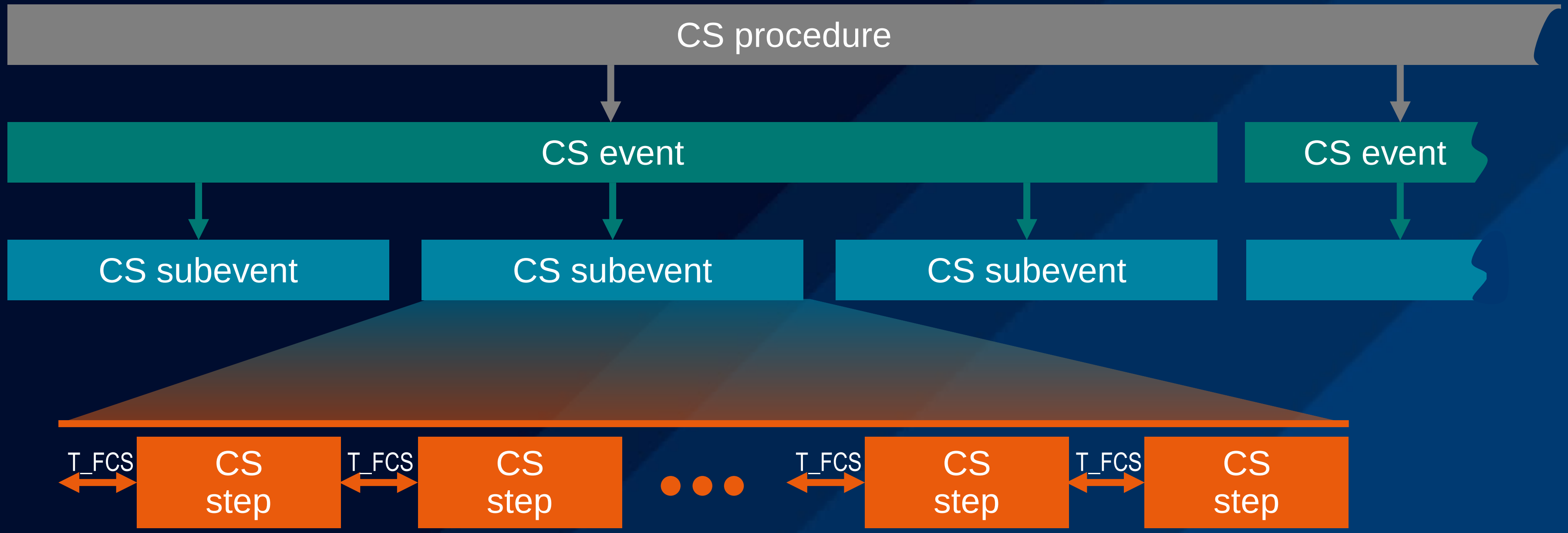
- 2 MHz spacing
- 3 primary advertising channels
- 37 general purpose channels



CS channel map

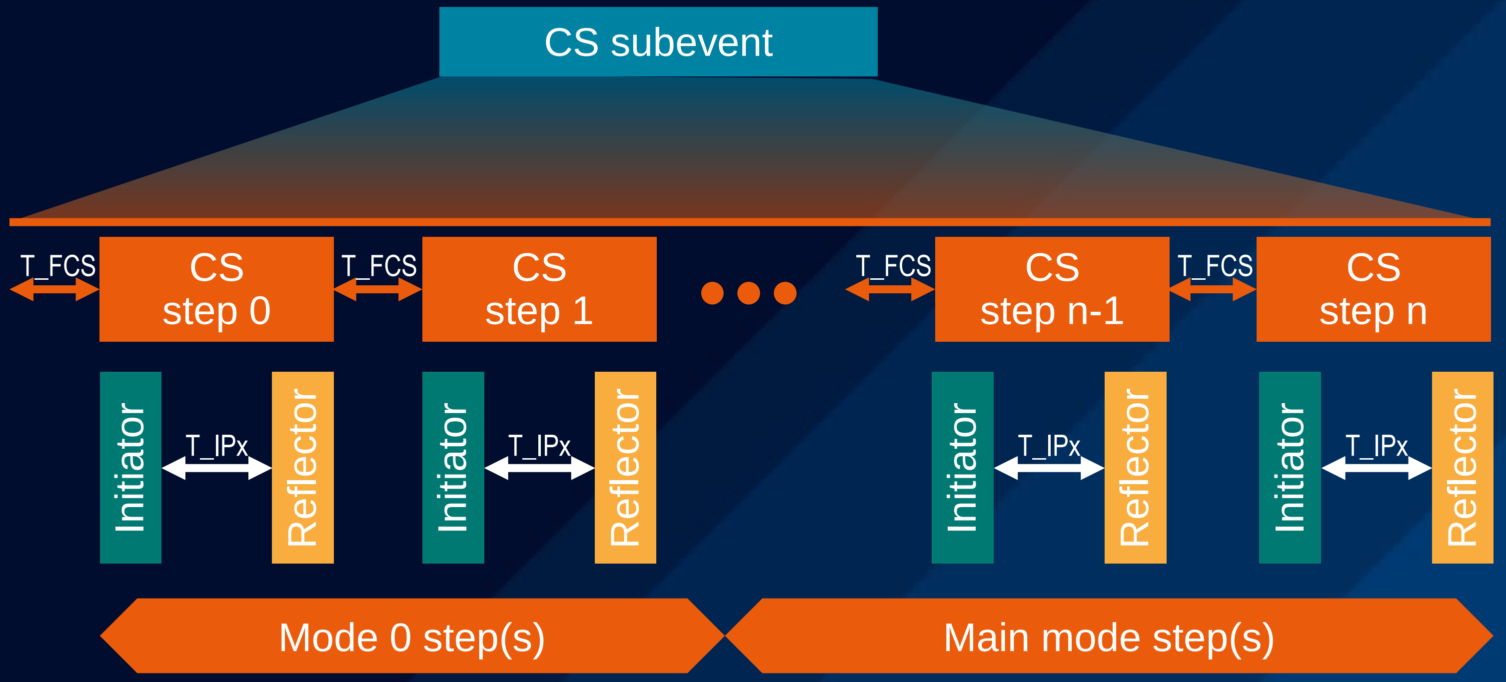
- 1 MHz spacing
- 72 CS channels
- No use of primary advertising and guard channels
- Optional CS companion signals in nearby channels

CS procedures, subevents, steps



T_FCS Time for Frequency Change Spacing

CS procedures, subevents, steps

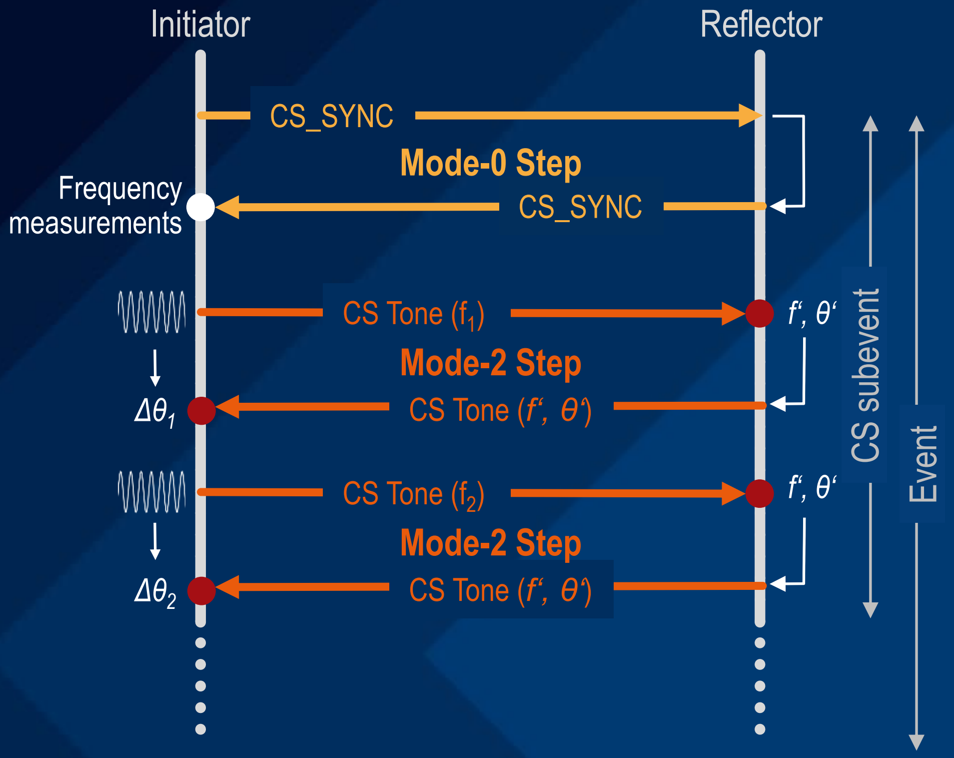


T_FCS Time for frequency change spacing
T_IPx Time for interlude period

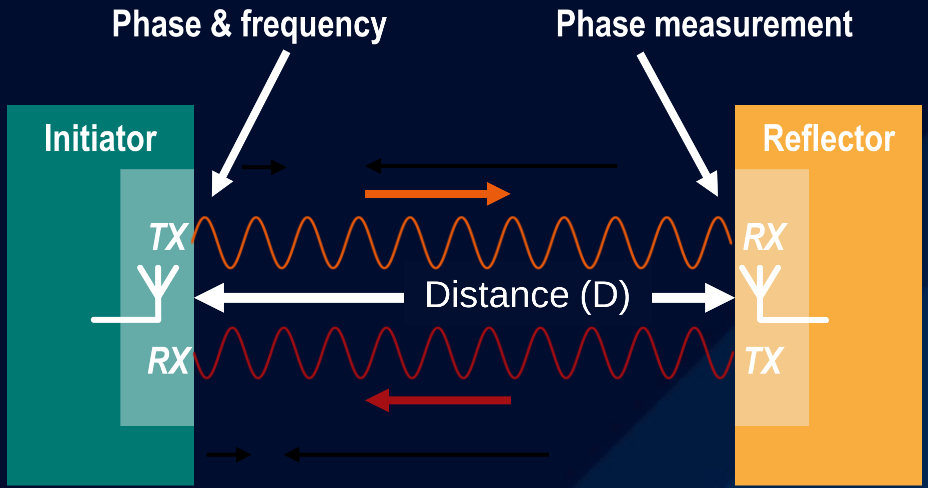
Principle of channel sounding (CS) for high accurate distance measurements (HADM)

There are four different CS step modes:

- Mode-0: measuring frequency offset (calibration)
- Mode-1: measuring RTT,
- Mode-2: measuring phase rotations
- Mode-3: measuring both RTT and phase rotations



RFPHY test specification coverage

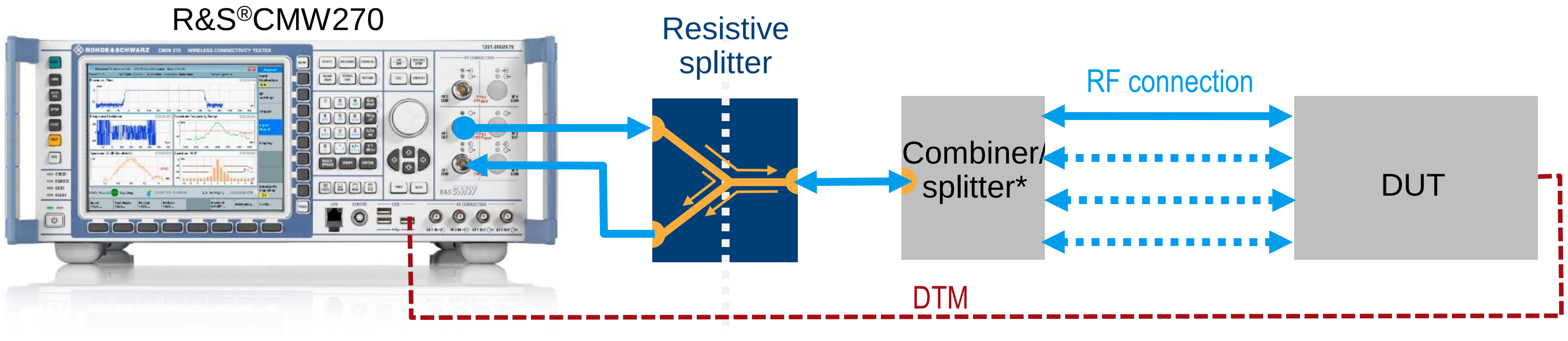


Phase Stability (transmit)
Ensure that the phase of the transmitted CS signal is acceptable stable over the phase measurement period.

Phase Measurement Accuracy (receive)
Ensure that the phase measurement accuracy is within acceptable limits during the phase measurement period.

Step Mode, Frequency Verification
This test verifies the average frequency of each of the mode transmissions within the CS sub-event are aligned with the initial frequency offset measurement.

Modulation accuracy for CS signals and RX/TX antenna switching integrity are common aspects

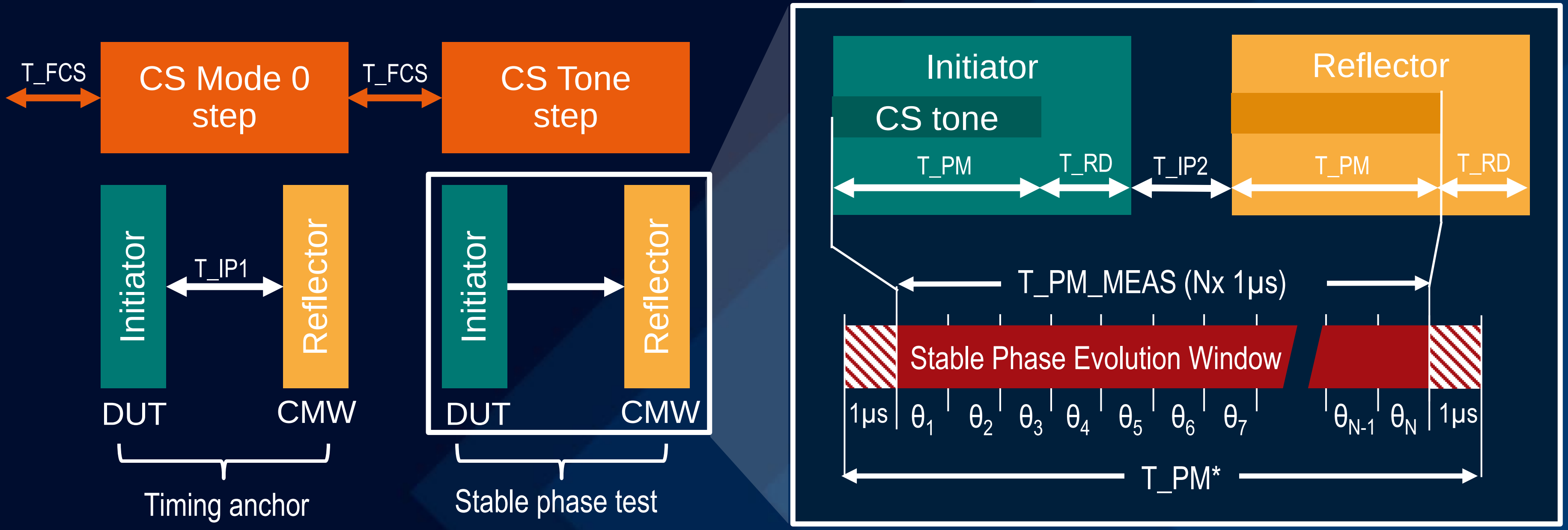


* Only required for multi-antenna configurations

CHANNEL SOUNDING DEMO SETUP – PHASE STABILITY

Stable phase test using a special test mode

Verifies that the devices carrier phase remains stable for a certain period by testing a number of absolute phase values



Bluetooth® LE Channel Sounding

- Applying a combination of phased based ranging (PBR) and round trip time (RTT) measurements incl. security features

- Allows simplified operation with a single antenna or multi-antenna operation

- Introducing a new channel map with 1 MHz spacing and an optional LE 2M 2BT physical layer

- Will specify a couple of new RFPHY test cases to ensure reliability and accuracy

- Will be available on R&S®CMW – upgrade with software options only

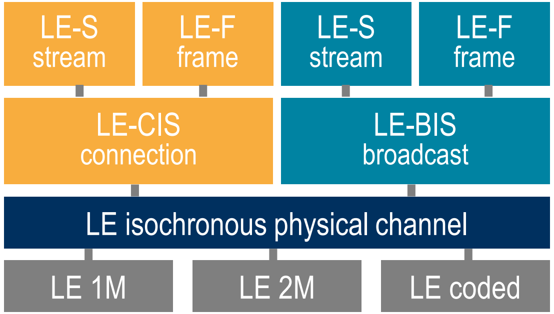
Bluetooth® LE
Audio

Bluetooth® 5.2: Native Bluetooth® LE audio support for several applications …

LE isochronous channels

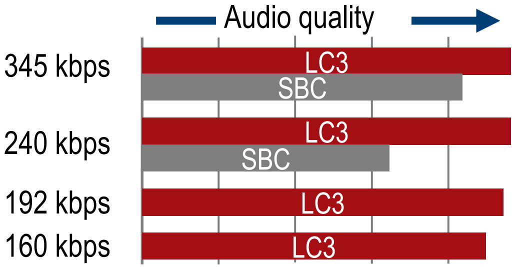
Allows communication of time-bound data to one or more devices for time-synchronized processing.

- Multi-channel audio streaming incl. hearing aids
- Audio broadcasting

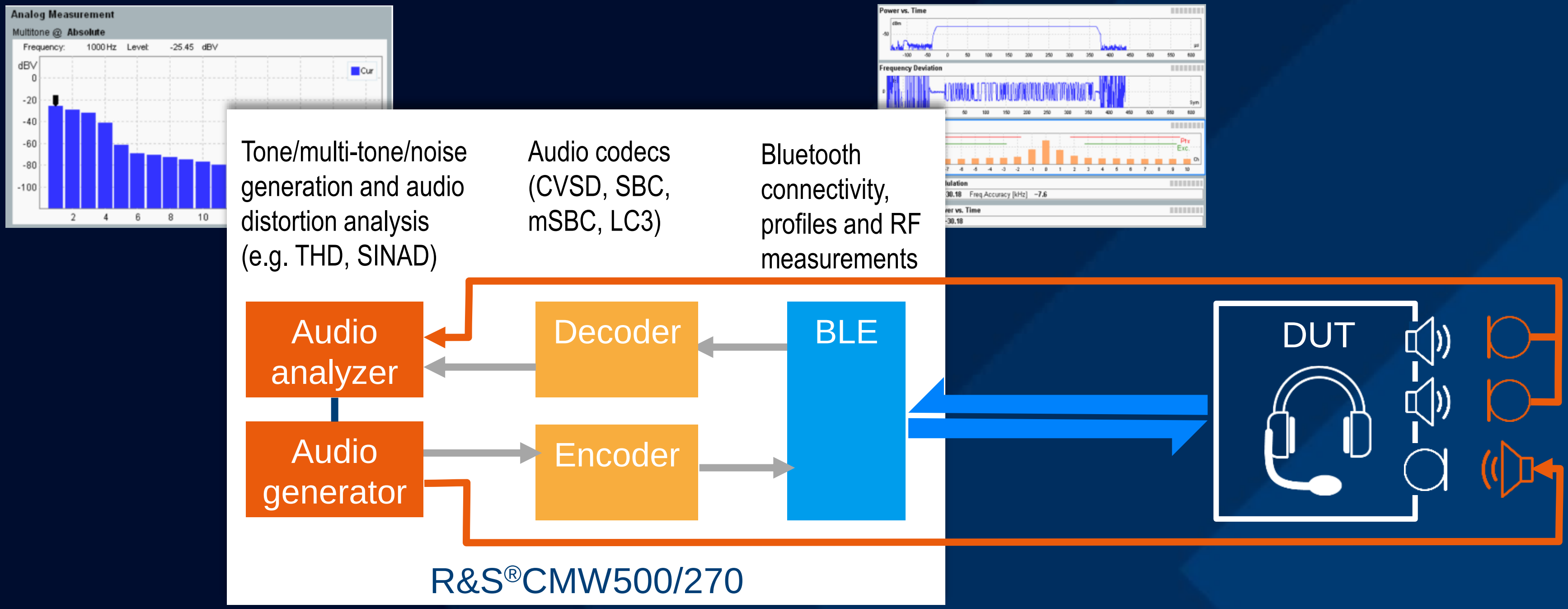


LC3 audio codec

The new low complexity codec developed by Fraunhofer IIS is optimized for high-resolution music streaming operating at low latency, low computational complexity and low memory footprint.



Ensuring Bluetooth® LE Audio performance and quality by combining measurement applications



Upcoming Bluetooth® LE features with high relevance for high-end audio and more

High Data Throughput	Hyper Length	Higher Frequency Bands
Intends to support data rates up to 8 Mbps. By applying higher modulation schemes and/or higher symbol rate (wider channels).	Upcoming high-quality music and multi-channel audio applications, ask for payload carried per unit media frame of more than 251-byte.	Improve connection quality, density, performance and coexistence by using mid-band spectrum, including the 6 GHz band.

Bluetooth® test solutions for the product life cycle

More information
https://rohde-schwarz.com/bluetooth

thank
YOU

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