A Rohde & Schwarz webinar in cooperation with the FiRa Consortium

# Reinforce a seamless UWB experience by certification and over-the-air testing

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Make ideas real

# Seamless UWB experience

- Need for interoperability and quality of experience
- Continuous evolution of standards and regulation
- Ongoing efforts in setting up a certification framework (FiRa, CCC)
- Over-the air testing is becoming more important


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Certification Program Manager
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# Reinforce a seamless UWB experience by certification and over-the-air testing

# Wide adoption of UWB on smart devices driven by an open global ecosystem






UWB ALLIANCE

fira The Power to Be Precise

omlox

CARCONNECTIVITY consortium

Associate Member

Adopter Member

# UWB adoption increases within smartphones, wearables, speakers, personal trackers, and real-time location applications!

**~0.5** Ultra-Wideband (UWB) devices are expected to reach nearly **half-a-billion units in 2022**

ABI Research anticipates UWB to be incorporated in nearly one-quarter of smartphones that will ship in 2022

**≥1.0** By 2026, ABI Research forecasts there will be well over 1 billion UWB annual device shipments.

Almost every smart phone shipped in 2026 will support UWB services


*Source: ABI Research – November 2021*
*https://www.abiresearch.com/press/2022-will-mark-a-new-era-for-wireless-innovation/*

# Ultra-wideband

DARPA$_{1989}$: Signals with a fractional bandwidth ($B_f$) equal to or larger than 0.25 are classified as UWB signals

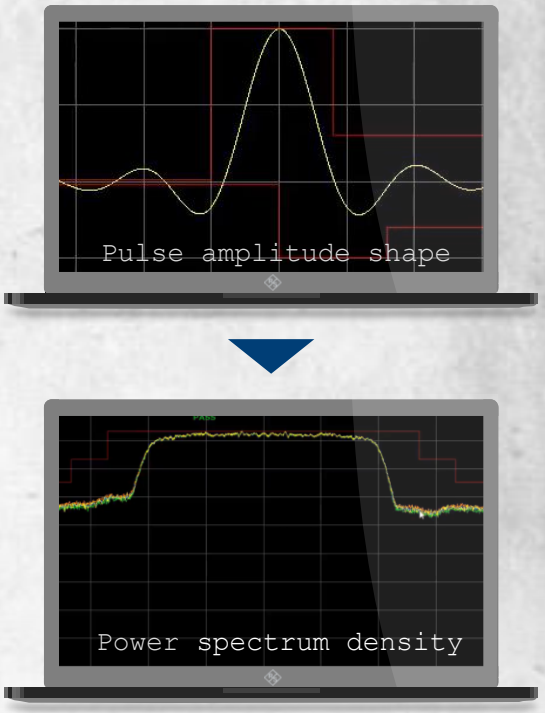
$$B_f = BW_{3dB} / f_c > 0.25$$

Fractional bandwidth ($B_f$) is the ratio of the 3 dB signal bandwidth to the center frequency

FCC$_{2002}$: A signal is considered UWB if either the -10 dB bandwidth of the signal is larger than 500 MHz or its fractional bandwidth is at least 0.2.
PSD limit of -41.3 dBm/MHz

$$B_f = BW_{10dB} / f_c = \frac{f_H - f_L}{½ (f_H + f_L)} > 0.2$$

Frequencies $f_L$ and $f_H$ are defined as the lower and higher 10 dB frequencies of the power spectrum relative to the PSD peak




Source: UWB communication systems: Conventional and 60 GHz, Shahriar Emami, Springer 2013

# Ultra-wideband (UWB) standardization: IEEE 802.15.4

| HRP UWB PHY<br>High Rate Pulse repetition frequency | | | LRP UWB PHY<br>Low Rate Pulse repetition frequency | | | | | |
|---|---|---|---|---|---|---|---|---|
| RDEV | ERDEV | | RDEV | | | ERDEV | | |
| base | BPRF | HPRF | base | extend | long-range | DF | enh. DF | DF w/ EPC |
| **Modulation**<br>BPM-BPSK<br>**Pulse Rate:**<br>3.9 MHz<br>15.6 MHz<br>62.4 MHz | **Modulation**<br>BPM-BPSK<br>**Pulse Rate:**<br>62.4 MHz | **Modulation**<br>BPSK<br>**Pulse Rate:**<br>124.8 MHz<br>249.6 MHz | **Modulation**<br>OOK<br>**Pulse Rate:**<br>1 MHz | **Modulation**<br>OOK<br>**Pulse Rate:**<br>1 MHz | **Modulation**<br>PPM<br>**Pulse Rate:**<br>2 MHz | **Modulation**<br>PBFSK<br>**Pulse Rate:**<br>1 MHz<br>2 MHz<br>4 MHz | **Modulation**<br>PBFSK<br>**Pulse Rate:**<br>1 MHz<br>2 MHz<br>4 MHz | **Modulation**<br>PBFSK-PPM<br>**Pulse Rate:**<br>1 MHz<br>2 MHz |
| 802.15.4a/z | 802.15.4z | | 802.15.4f/z | | | 802.15.4z | | |

RDEV: Ranging device
ERDEV – Enhanced Ranging Device
BPM - burst position modulation

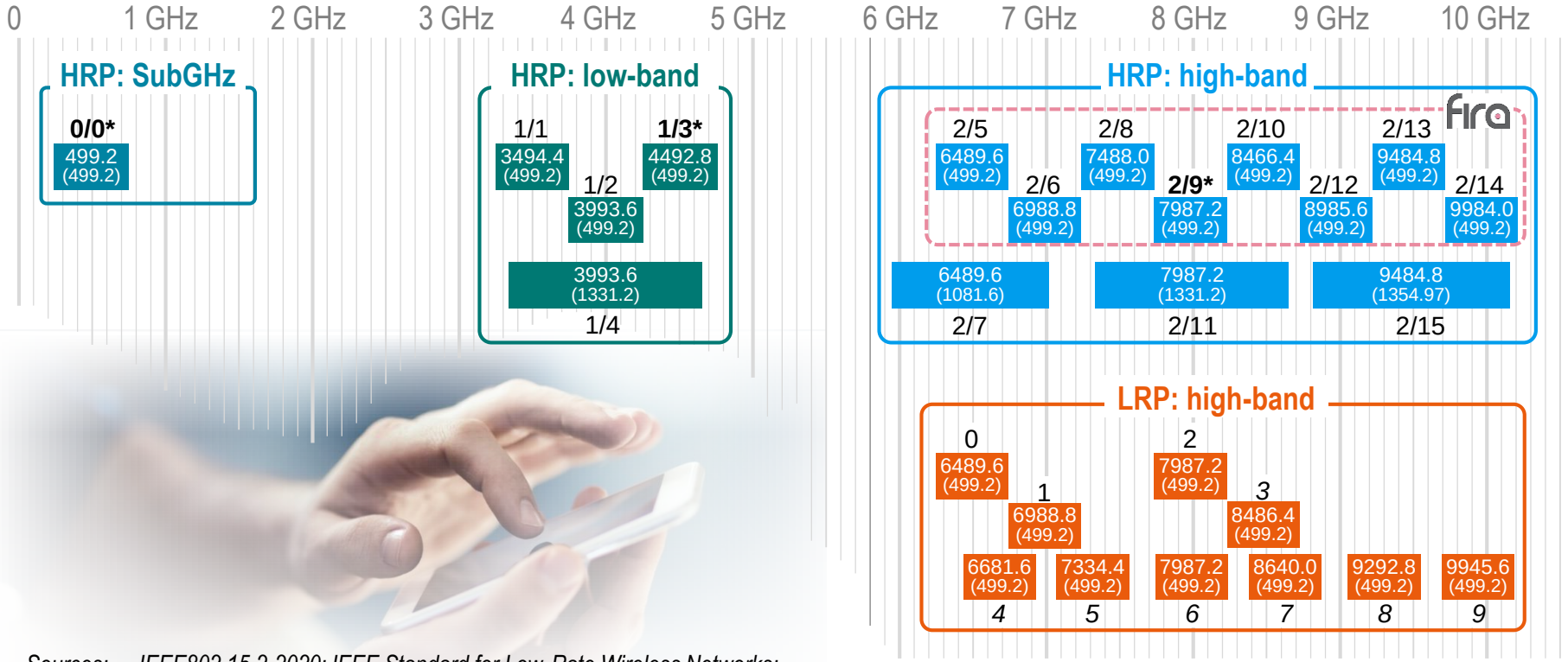
BPRF – Base pulse repetition frequency
HPRF – Higher pulse repetition frequency
PBFSK – Pulsed binary frequency shift keying

PPM – Pulse Positioning Modulation
EPC – Enhanced Payload capacity
BPSK - binary phase shift keying

DF – Dual frequency
OOK: On-Off Keying

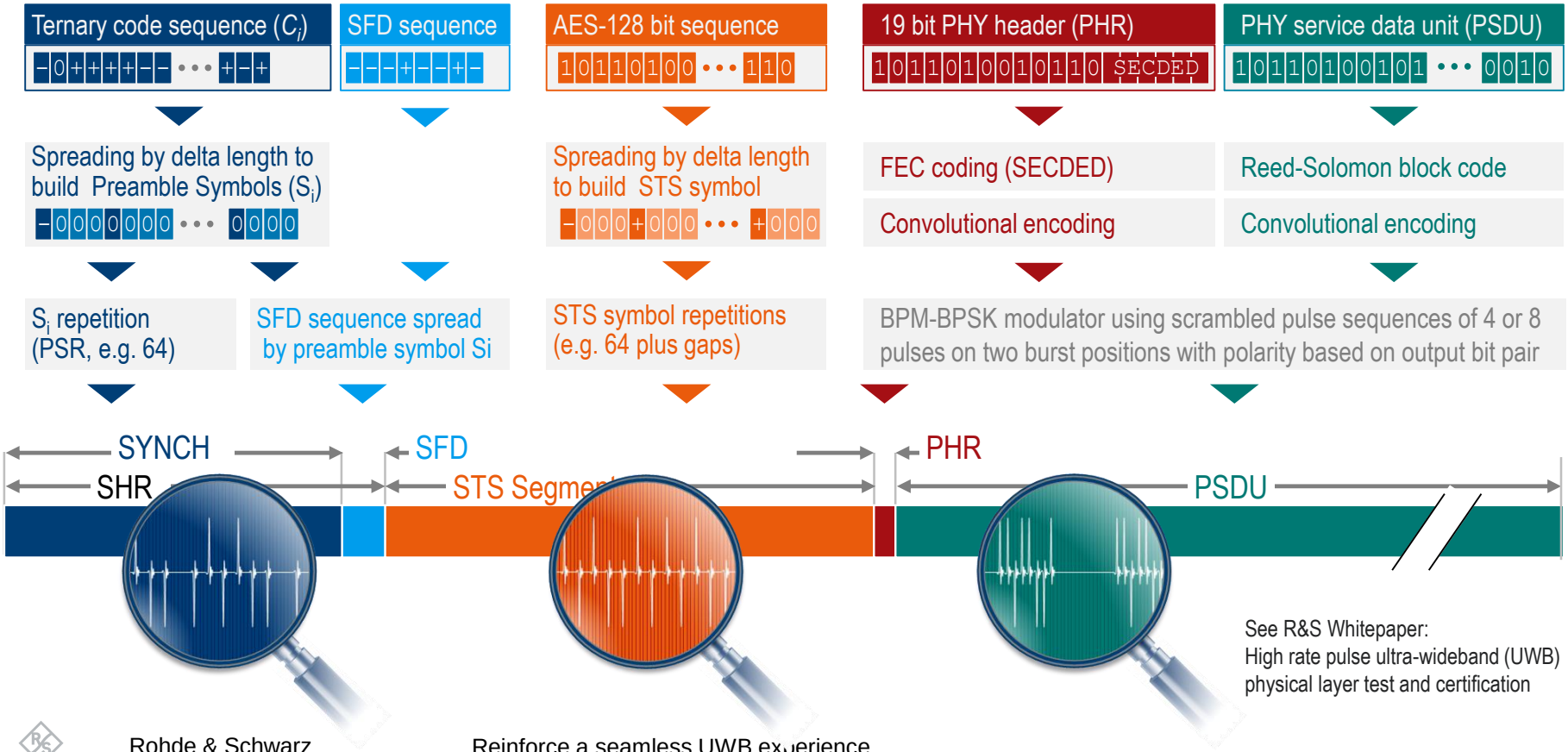
*Sources:* *IEEE802.15.2-2020: IEEE Standard for Low-Rate Wireless Networks;*
*IEEE802.15.2-2020z: Amendment 1: Enhanced Ultra Wideband (UWB) Physical Layers (PHYs) and Associated Ranging Techniques*

# UWB channel allocation based on IEEE 802.15.4z




*Sources:* *IEEE802.15.2-2020: IEEE Standard for Low-Rate Wireless Networks;*
*IEEE802.15.2-2020z: Amendment 1: Enhanced Ultra Wideband (UWB) Physical Layers (PHYs) and Associated Ranging Techniques*

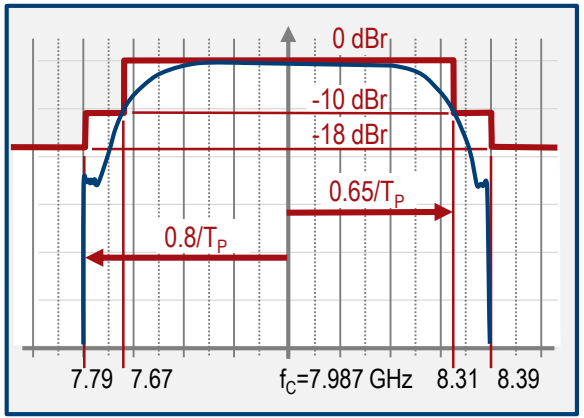
# UWB packet structure in a nutshell (HRP-ERDEV: HPRF SP2)




See R&S Whitepaper:
High rate pulse ultra-wideband (UWB) physical layer test and certification

# Specific UWB measurements based on IEEE 802.15.4z

## Transmit Power Spectrum Density

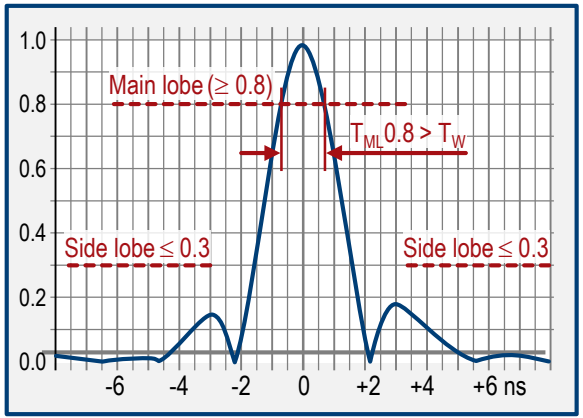



The transmitted spectrum shall be less than –10 dB relative to the maximum spectral density of the signal for

$0.65/T_P < |f - fc| < 0.8/T_P$

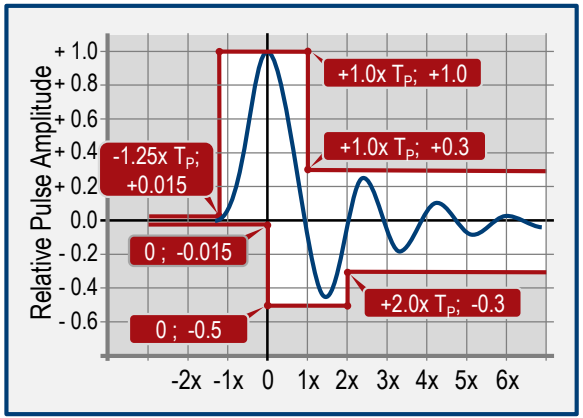
and –18 dB for $|f - fc| > 0.8/T_P$.

## Cross-correlation magnitude




The transmitted pulse shape p(t) shall be constrained by the shape of its cross-correlation function with a standard reference pulse

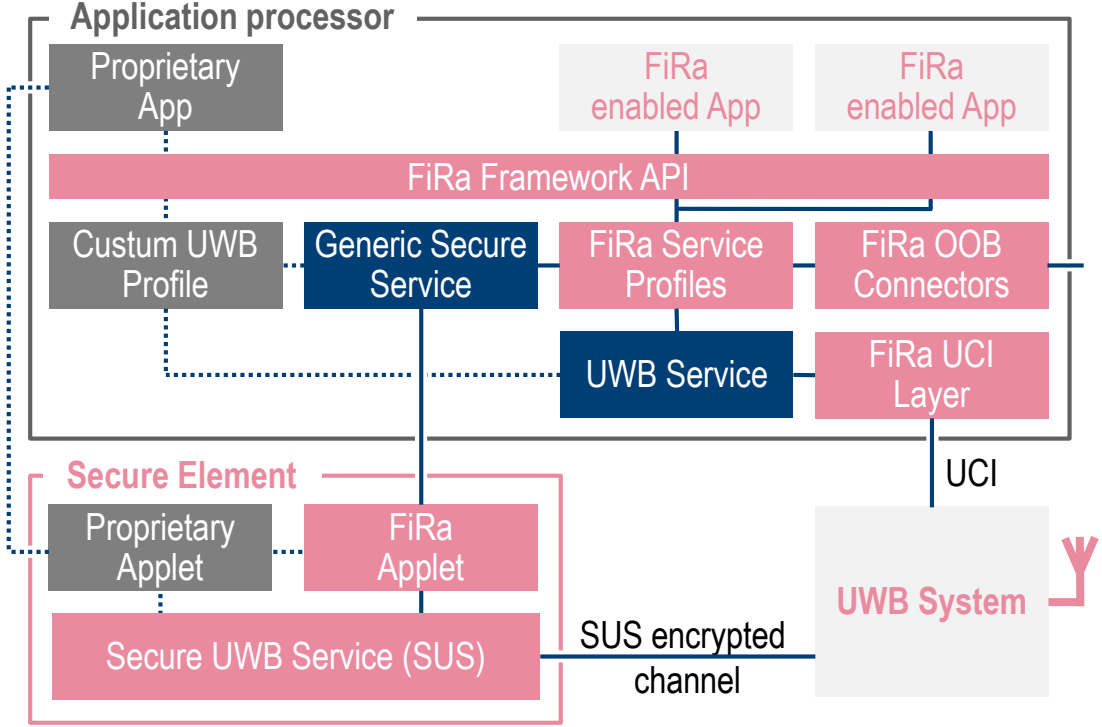
## Relative pulse amplitude




The pulse shape should be constrained by the time domain mask where the peak magnitude of the pulse is scaled to a value of one, and the time unit is pulse duration TP.

*See R&S Whitepaper: High rate pulse ultra-wideband (UWB) physical layer test and certification*

# Transforming the way we interact with our environment by enabling precise location awareness for people and devices.




fira | The Power to Be Precise

- Support the development of compelling use cases across broad business domains
- Define specifications and certify products to ensure interoperability
- Foster a robust UWB ecosystem to enable rapid technology deployment

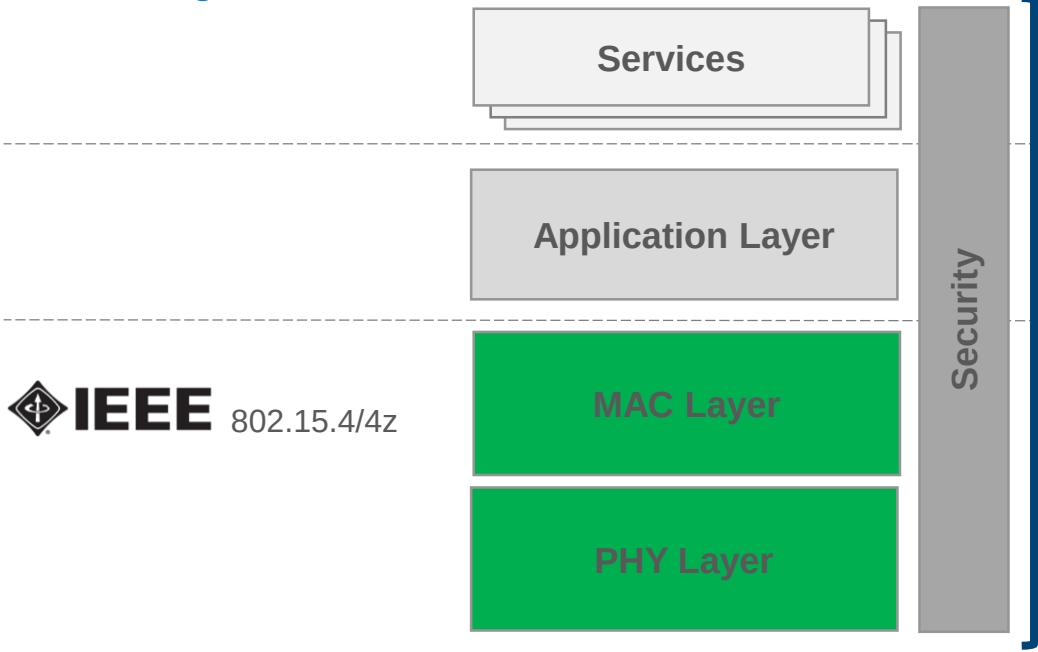
www.firaconsortium.org

# FiRa Certification

Mitch Kettrick
Certification Program Manager

# FiRa‘s Scope of Certification

## Existing Standards




IEEE 802.15.4/4z

## FiRa Consortium

**Service-specific requirements for multiple verticals**

**Mechanisms which are not within IEEE scope**

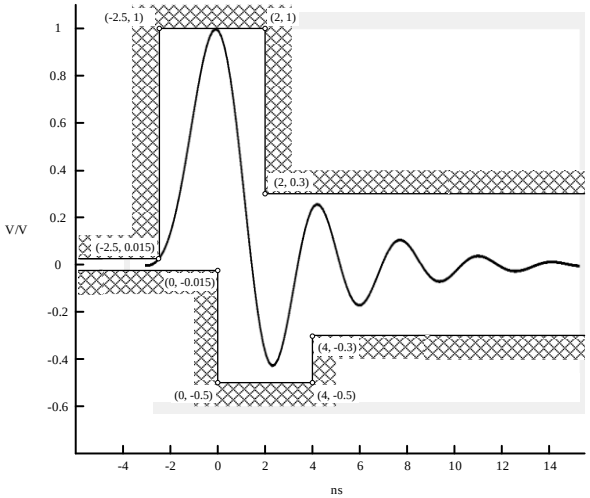
- Discovery and configuration
- Security requirements

**Conformance Standards**

- Profiled features among 802.15.4/4z PHY/MAC
  - Signaling conformance
  - Minimum performance
  - Interoperability
- Test methods/procedures
- Certification program

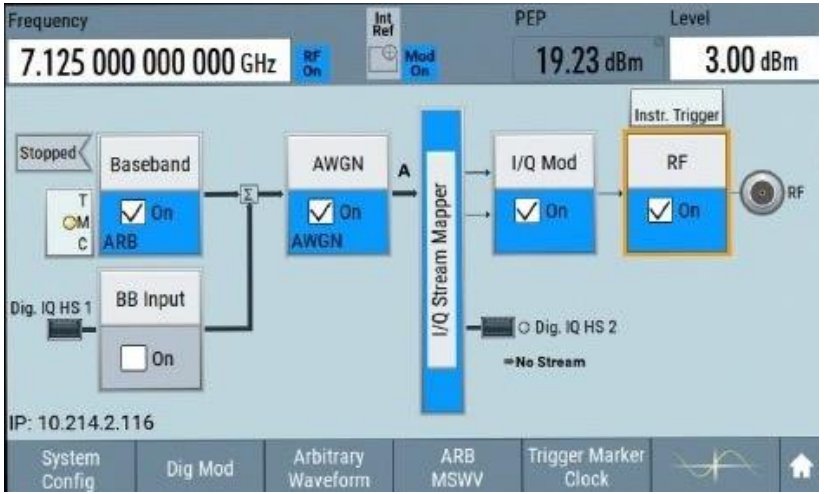
# PHY Testing - TX

- Carrier Frequency Tolerance and Pulse Timing
- Packet Format
- Power Spectral Density Mask
- Baseband Impulse Response
- Transmit Signal Quality



# PHY Testing - RX

- Packet Format
- Packet Reception Sensitivity
- Dirty Packet Test
- First-Path Dynamic Range



# Validated Test Platforms

- Test platforms go through a rigorous validation process to ensure that they meet the requirements defined by FiRa
- The latest list of validated test platforms can be found here: https://www.firaconsortium.org/certifications/fira-validated-test-tools

# Authorized Test Labs

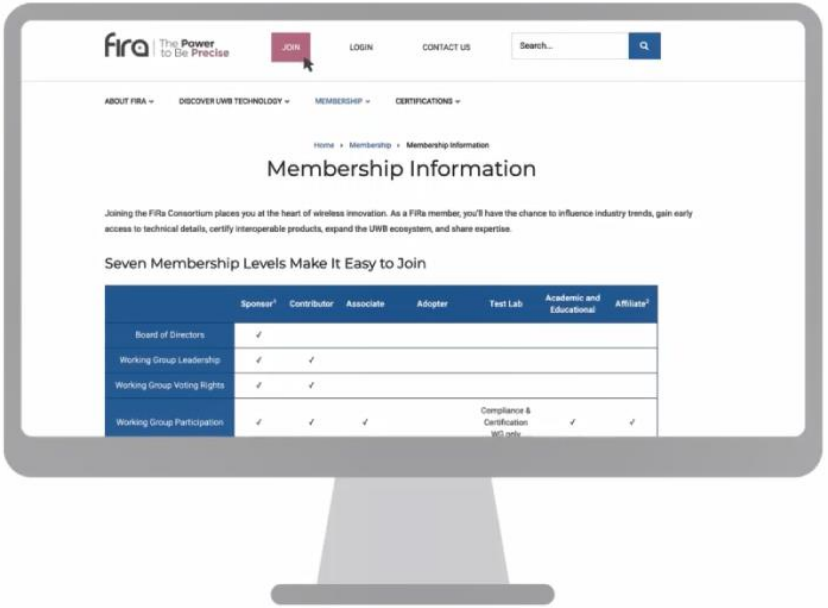
- Test labs must meet FiRa's requirements and pass an on-site audit to become authorized to perform FiRa certification testing
- The latest list of Authorized Test Labs can be found here: https://www.firaconsortium.org/certifications/authorized-test-labs

| Authorized Test Laboratory | Authorized Test Scope | Location | Contact |
|---|---|---|---|
| DT&C | MAC, PHY | South Korea | compliance@dtnc.net |
| HCT | MAC, PHY | South Korea | iopt-sales@hct.co.kr |
| SGS | MAC, PHY | South Korea | KR.FIRA@sgs.com |
| TTA | MAC, PHY | South Korea | iot@tta.or.kr |

# Certification Process

1. JOIN

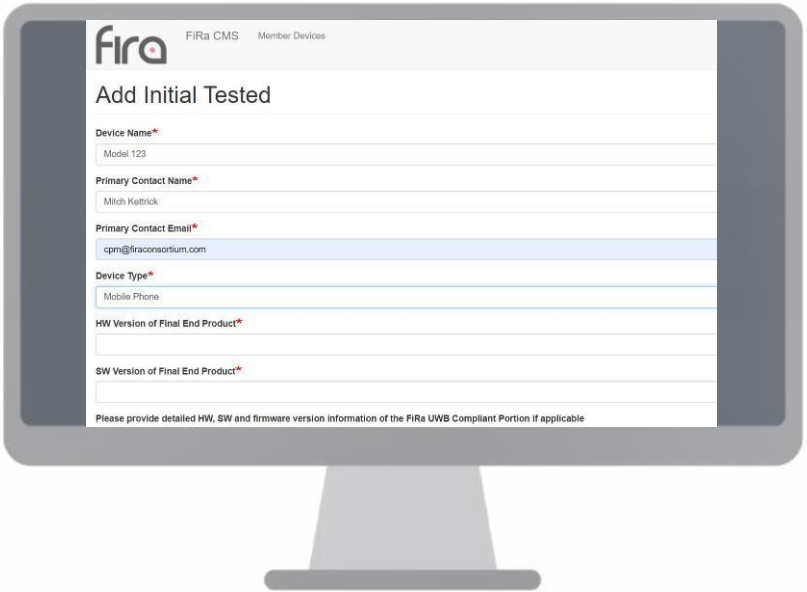
- Certification is open to FiRa members only
- Learn more and apply for FiRa membership at https://www.firaconsortium.org/membership/information



# Certification Process

2. PREPARE

- Review the device certification requirements
- Enter your device in the Certification Management System

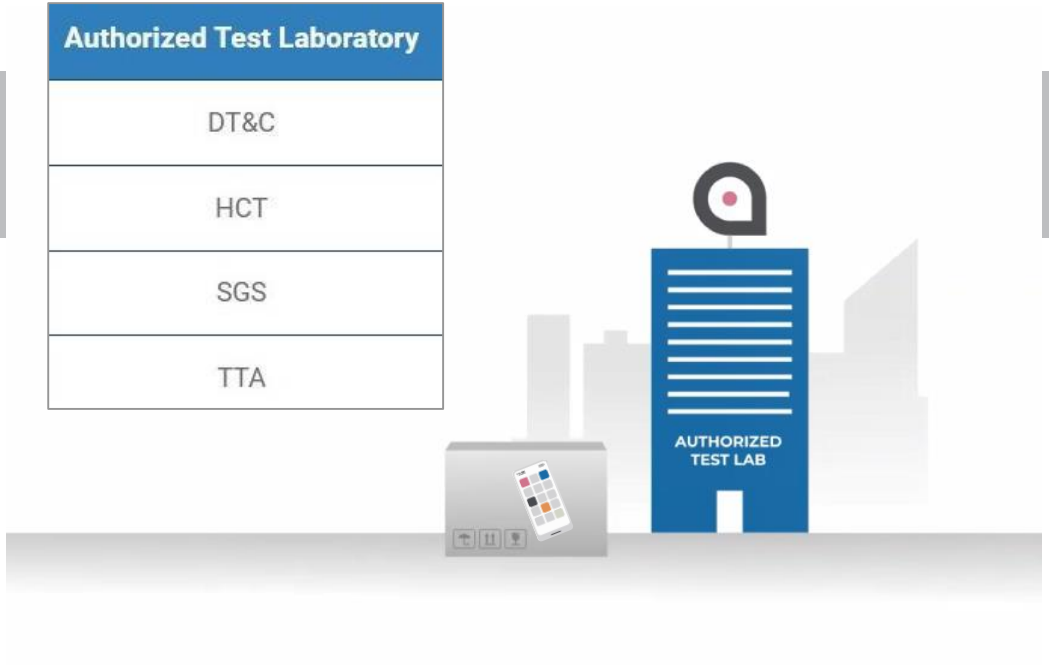


# Certification Process

3. TEST

- Submit your device to an Authorized Test Lab
- Certification testing is conducted using test platforms validated by FiRa

| Authorized Test Laboratory |
| --- |
| DT&C |
| HCT |
| SGS |
| TTA |



# Certification Process


- Resolve any issues found during testing
- Pay the certification listing fee

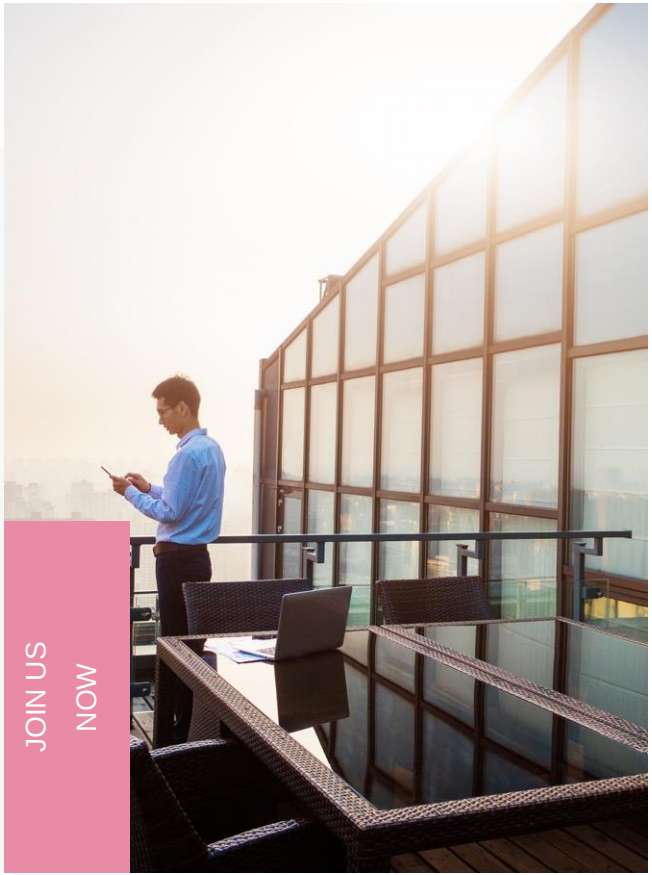

# Certification Process


- Receive a Certificate of Conformance
- Your device is listed on the certified device list on the FiRa website

# Learn more

**www.firaconsortium.org**

- Explore the FiRa Certification Program on the FiRa website at: https://www.firaconsortium.org/certifications
- For assistance with the Certification Program, contact Mitch Kettrick at cpm@firaconsortium.com



Read New FiRa Consortium Annual Report to learn more



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to Be Precise
THANKS

# R&S®CMP200
# Wideband non-signaling test for UWB and more

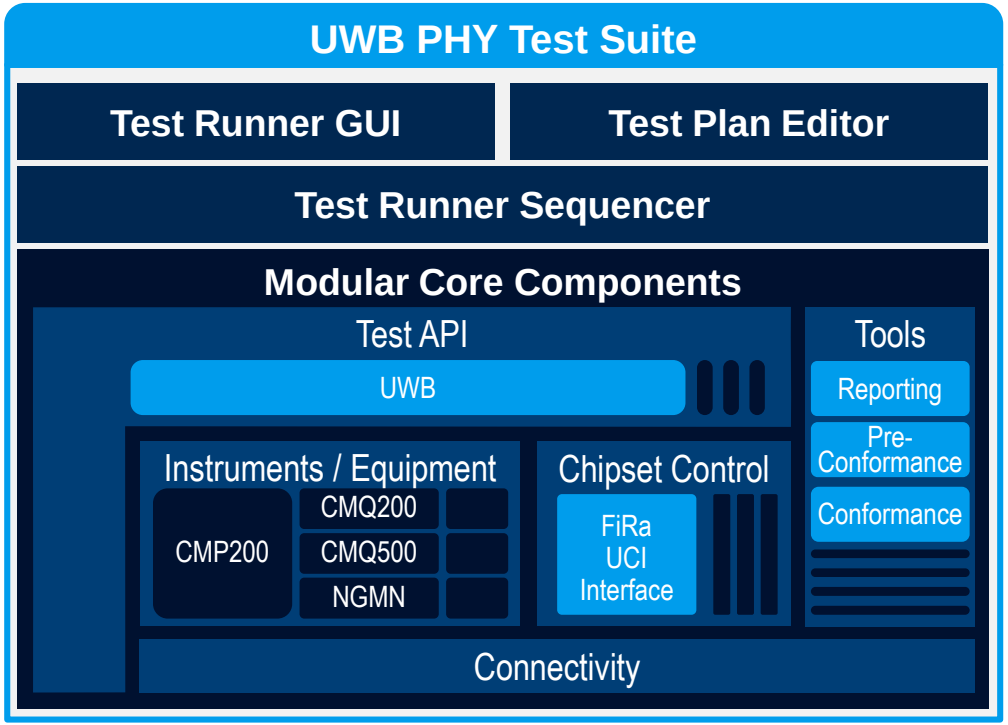
## R&S®CMP200 features

- One general purpose analyzer
  Frequency range: 4 to 20 GHz
- One ARB generator
  Replay of predefined waveforms ( -100 dBm)
  Frequency range: 6 to 20 GHz
- Three switchable ports, 1 GHz bandwidth

## Compact UWB non-signaling tester for HRP in high band

- HRP UWB PHY TX measurements (802.15.4)
  Band group 2: 6.5 to 9.5 GHz
- HRP UWB RX measurements by use of customer waveforms or R&S®WinIQSIM2
- Time of flight and angle of arrival measurements

# Tailored for UWB non-signaling R&D and conformance applications based on the R&S wireless non-signaling test solution framework




- Two supported Modi
  - Pre-Conformance
  - Conformance
- Flexible integration into any automated testing environment
- Field-proven speed of test execution
- High efficiency by simultaneous testing (smart channel)
- Insightful and easy customizable GUI for sequencing and test plan creation

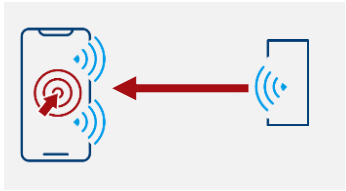

R&S®CMP200 Demo Session

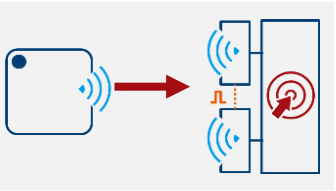
# The different techniques to estimate distance, location, …

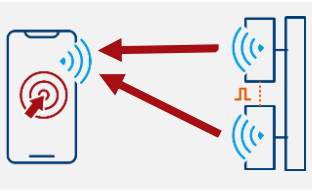
| | Bluetooth® LE | Wi-Fi® | UWB | 3GPP(4G/5G) | GNSS |
|---|---|---|---|---|---|
| **Received signal strength** | Bluetooth® 4.0 Proximity, Find me | RSSI BSSI | | RSRP/ RSRQ eCell ID NR ECID | |
| **Phase difference** | Bluetooth® 5.1 Direction Finding (AoA, AoD) | | 802.15.4z: AoA | NR DL-AoD NR UL-AoA | |
| **Time difference** | | | UL-TDOA DL-TDoA | OTDOA NR DL-TDOA NR UL-TDOA | Time difference from several satellites |
| **Propagation time** | | 802.11mc: RTT 802.11az: FTM | 802.15.4z: One way ranging Two way ranging | RTT NR Multi-RTT | Time of flight |

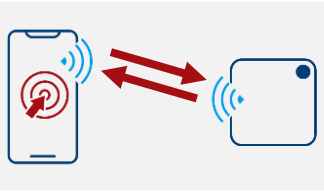
# It’s all about signal propagation time

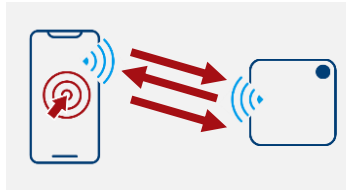
| One-way ranging (OWR) | | | Two-way ranging (TWR) | |
|---|---|---|---|---|
| Angle of Arrival (AoA) | Uplink Time Difference of Arrival (UL-TDoA) | Downlink Time Diff. of Arrival (DL-TDoA) | Single sided (SS-TWR) | Double sided (DS-TWR) |

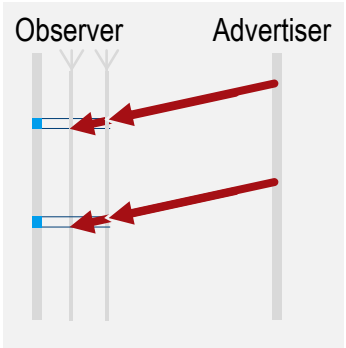


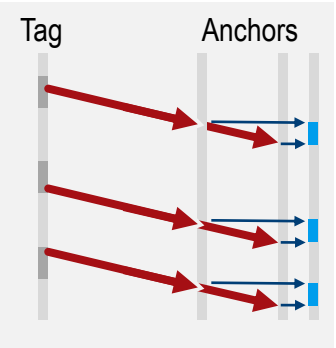


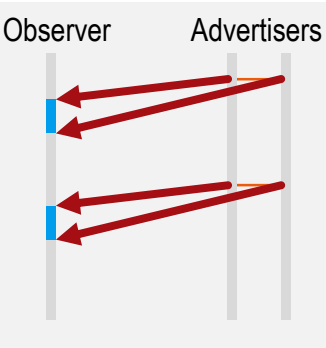


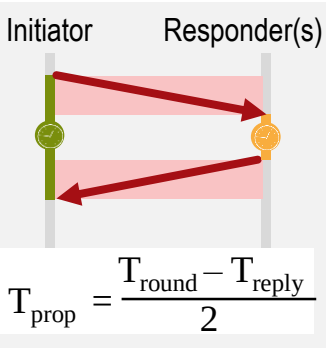


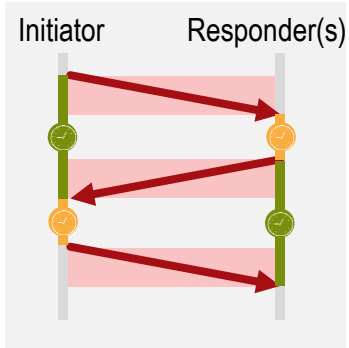




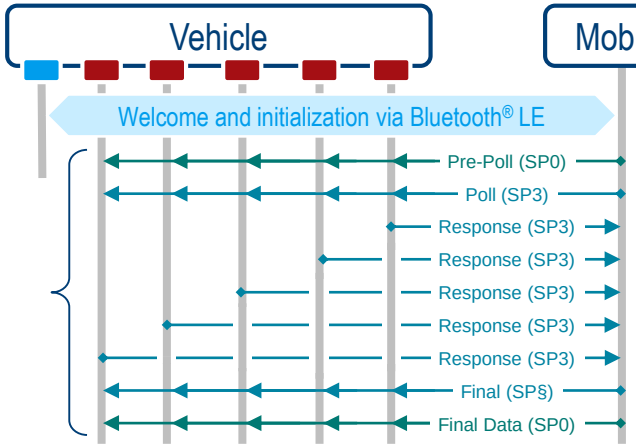



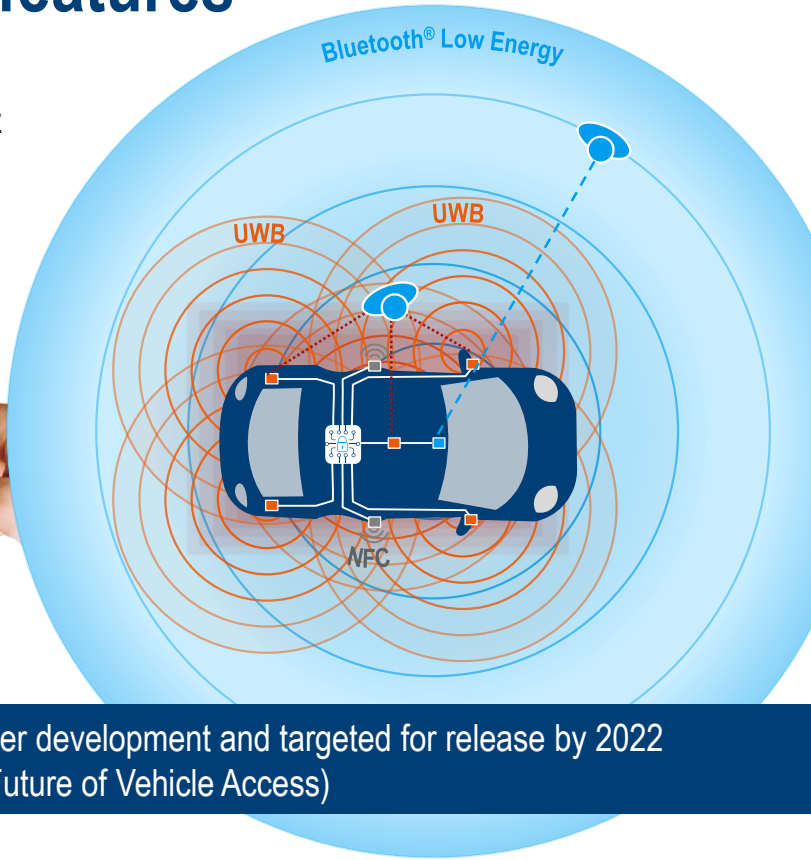



# CCC Digital Key Release 3.0 adds hands-free, location-aware keyless access and location-aware features

The CCC has adopted the UWB secure ranging technology based on High Rate Pulse repetition frequency (HRP) standardized in IEEE 802.15.4z in combination with standard Bluetooth® Low Energy connectivity.

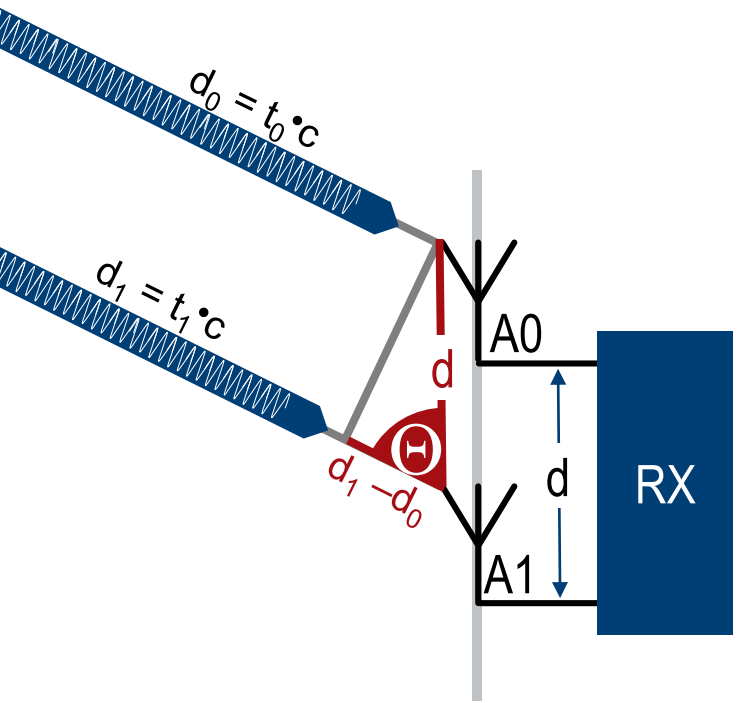


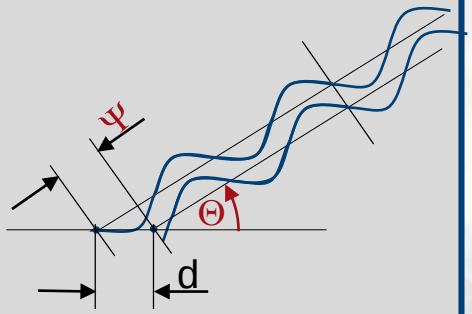

Rohde & Schwarz member of CARCONNECTIVITY consortium®

The CCC Digital Key certification program is under development and targeted for release by 2022 (see CCC Whitepaper " CCC Digital Key – The Future of Vehicle Access)

# Angle of Arrival (AoA) based on phase difference measurement




## Phase difference Ψ




λ: Wavelength

d: Antenna distance (d< λ/2)

Ψ: Phase difference

$$\Theta = \arccos\left(\frac{\psi\lambda}{2\pi d}\right)$$

# Antennas play a crucial role for the RF performance

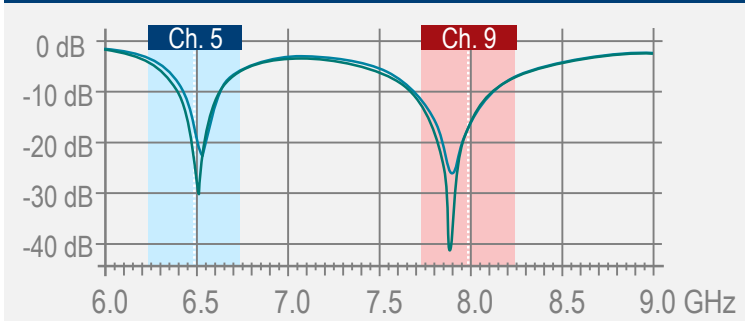
**Antenna characteristics** on several channels over channel bandwidth of more than 500 MHz due to frequency dependencies of the properties:

- Matching
- Efficiency
- Gain
- Directivity
- Group delay

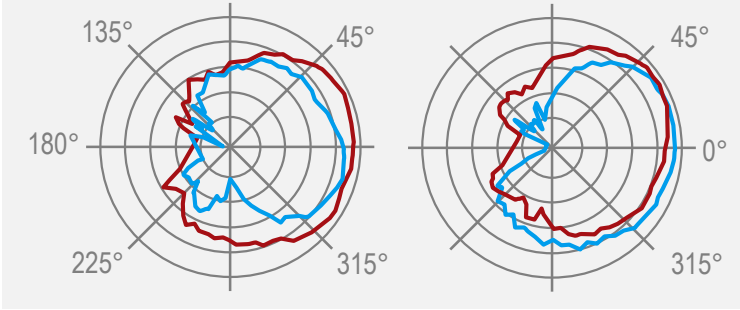
Impact of final **device design**

- Antenna coupling
- Antenna feeding
- Ground plane
- Housing, ….

UWB Antenna charachteristics (S11)

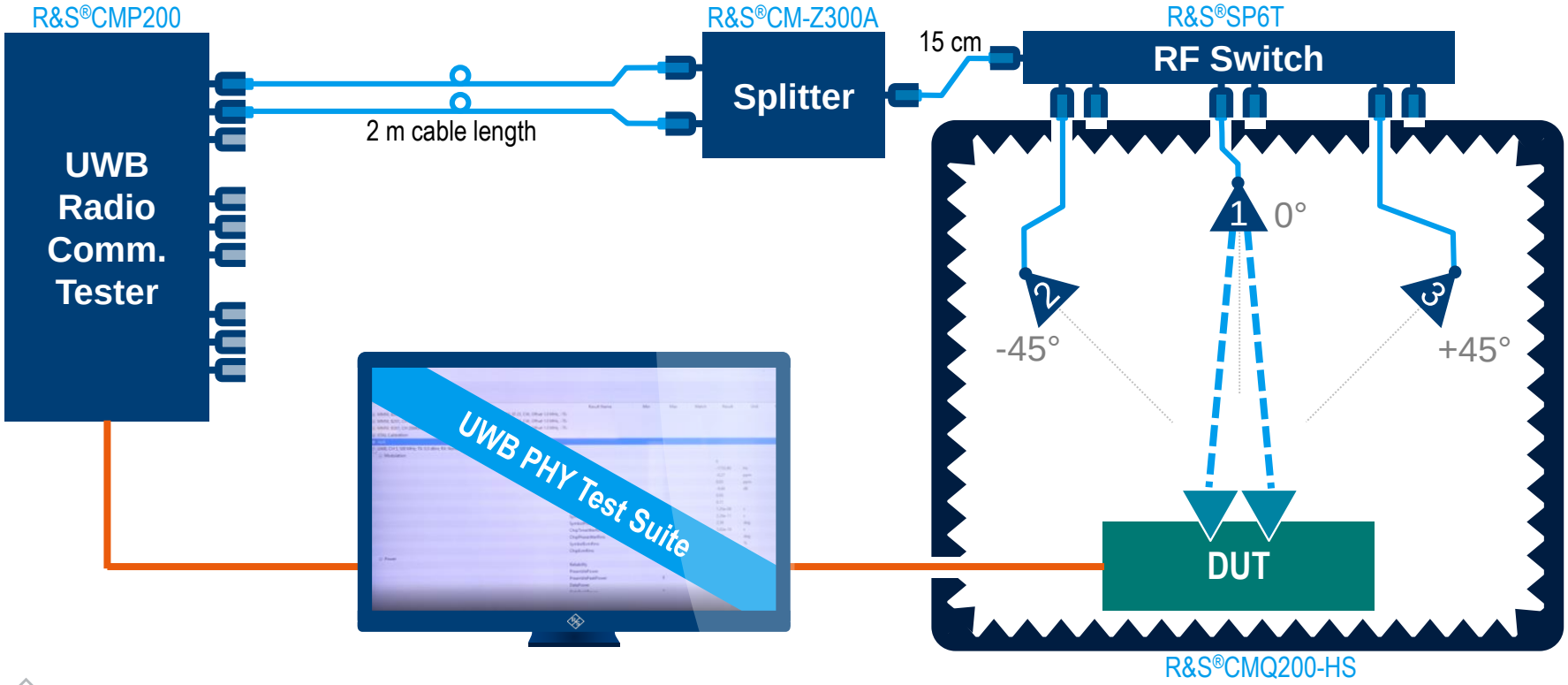



UWB Antenna characteristics (antenna gain)

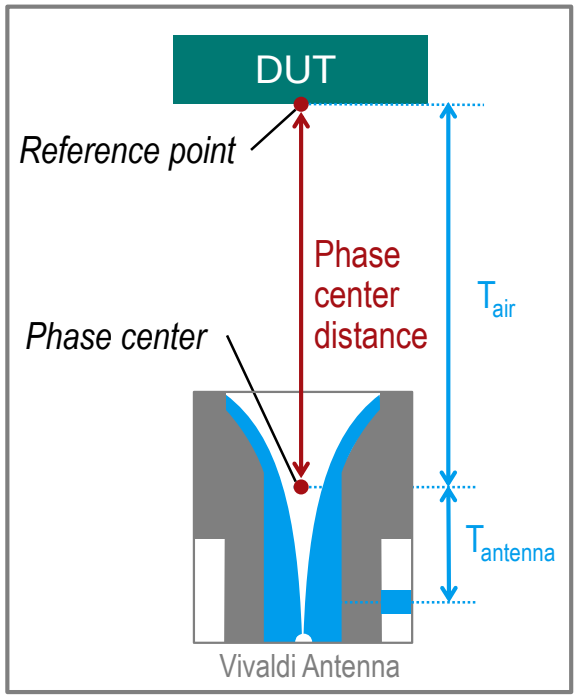


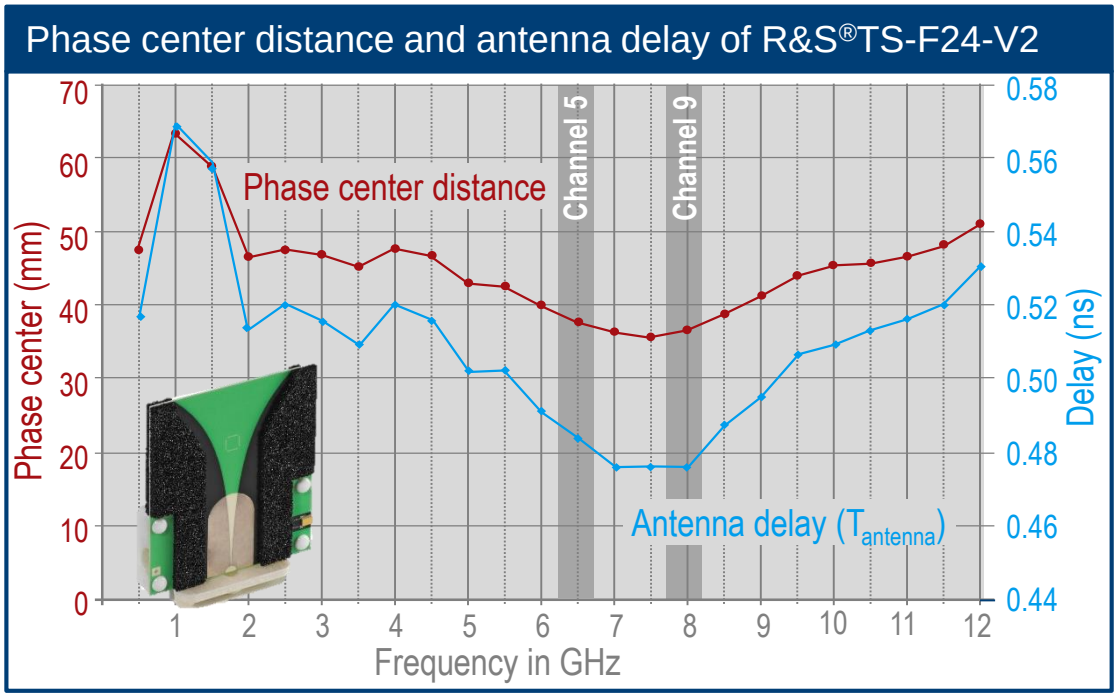

Source: Master Thesis Daniela Lutz @ Rohde & Schwarz

# Typical UWB setup for OTA test with multiple antennas (recommended for ToF and AoA measurements)



# Phase center position as well as the internal antenna delay are dependent on the frequency



# Performing over-the-air measurements at the shortest possible range length

## Fraunhofer distance ($r_{Fr}$)

Fraunhofer distance concerns the whole radiation pattern of the antenna which may be overly conservative in some cases

$$r_{Fr} = \frac{2D^2}{\lambda}$$

$\lambda$ – *Wavelength*
$D$ – *largest dimension of the radiator*

## Benoit „Derat“ distance ($r_{De}$)

If we are concerned with the **main beam only**, the Fraunhofer distance can be replaced by the so called "Derat" distance, defined as the distance where the radiation density in the peak direction of a standard gain horn (SGH) antenna lies within 0.5 dB of the EIRP at infinite far field condition

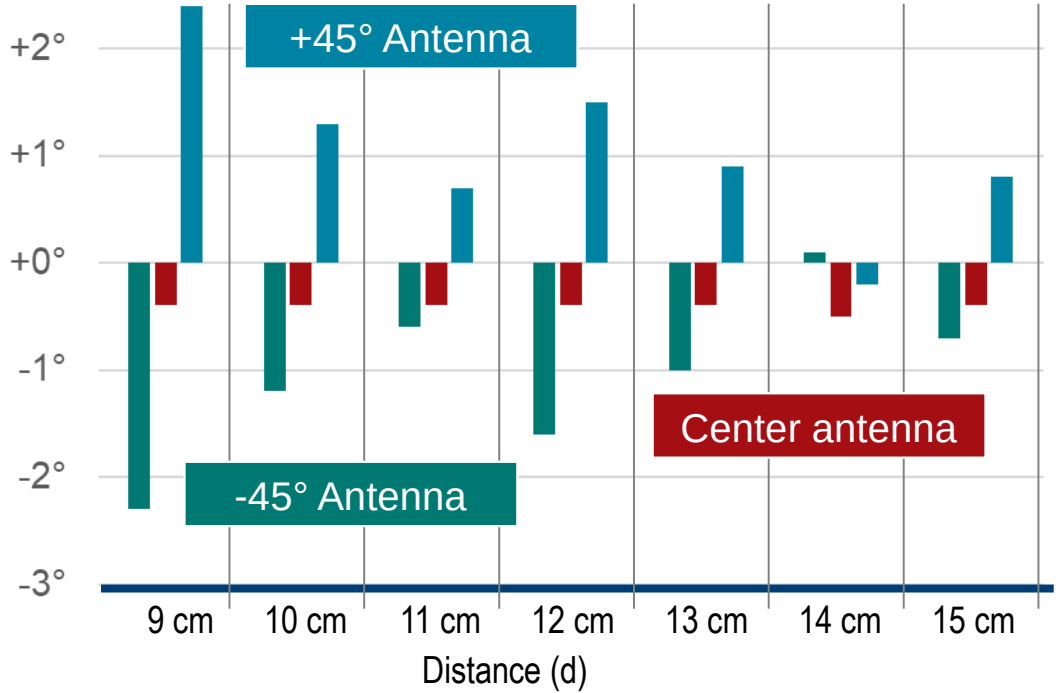
$$r_{De} = \lambda \left(\frac{\pi D}{\lambda}\right)^{0.8633} \left[0.1673 \left(\frac{\pi D}{\lambda}\right)^{0.8633} + 0.1632\right]$$

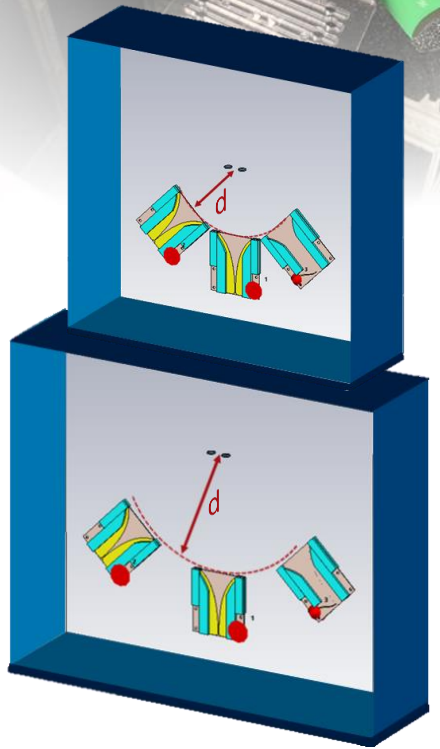

*Benoît Derat, Gerhard F. Hamberger, Fabian Michaelsen;*
*Shortest range length to measure the total radiated power; IET Microwaves, Antennas & Propagation, Volume 13, Issue 15, December 2019, p. 2584 – 2589*
*Alex J. Yuffa, Marc A. Valdez, Benoît Derat;*
*On convergence of the upper bound on the ratio of gain to quality factor; to appear on the proceedings of AMTA21*

# Effects on R&S®TS-F24 far field regions


| *D = 70 mm* | $r_{Fr}$ | $r_{De}$ |
|---|---|---|
| Channel 5 @ 6489.6 MHz | ~ 21 cm | ~ 14 cm |
| Channel 9 @ 7987.2 MHz | ~ 26 cm | ~ 16 cm |

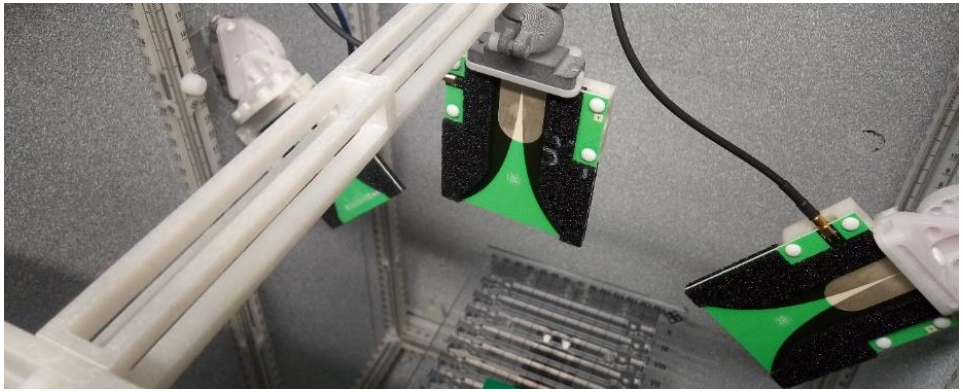
# Simulations of AoA measurement errors dependent on the distance to the antennas



# R&S®CMQ200-HS shielding cube designed for multi-antenna OTA testing for UWB in combination with the R&S®CMP200

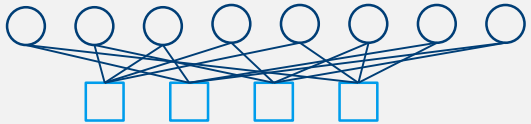
- New member of the R&S® CMQ200/500 family for a frequency range of 0.3 to 14 GHz
- High shielding support of 80 dB
- Perfectly suited for multi-antenna setups required for UWB AoA measurements



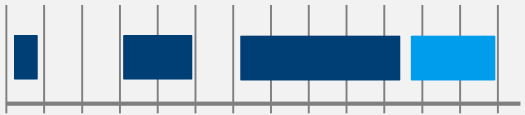
# AoA Demo Session

# Study Group 4ab: UWB next generation

802.15.4ab enhances the Ultra Wideband (UWB) physical layers (PHYs) medium access control (MAC), and associated ranging techniques while retaining backward compatibility with enhanced ranging capable devices (ERDEVs).

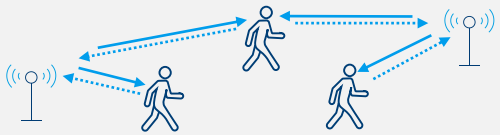


Additional coding, preamble and modulation schemes



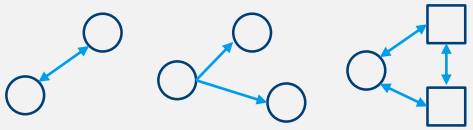
Additional channels and operating frequencies

Improvements to accuracy, precision and reliability ranging



Sensing capabilities to support presence detection and mapping

Low-power low-latency and high data-rate streaming functionalities

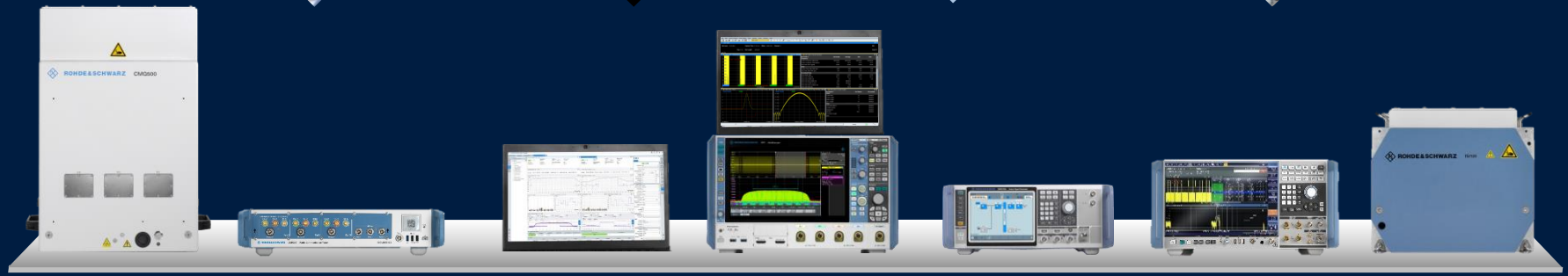


Support for P2P, P2M, and station-to-infrastructure protocols

# UWB test and measurement solutions for all phases of the product lifecycle from the experts







R&S®CMQ500/200 R&S®CMP200 UWB PHY Test Suite R&S®RTP+VSE R&S®SMM100 R&S®FSW26 R&S®TS7124

# Worthwhile to read or watch …




Discover the secrets of UWB based on IEEE 802.15.4z


Testing ultra-wideband for automotive applications

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# thank YOU