UWB automotive trends, challenges and over the air test solutions

Nikola Serdar
Product Manager

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Agenda

- UWB Ecosystem, Market and Usecases
- R&S CMP200 & UWB Challenges
- R&S OTA Solutions
- UWB Outlook

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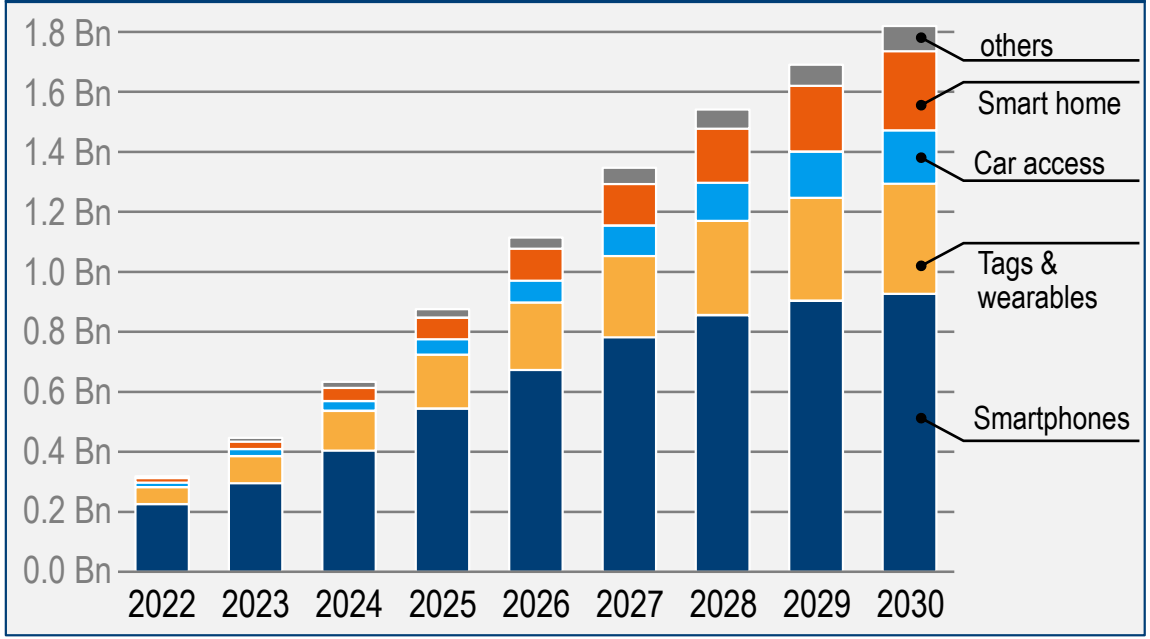
Global forecast: More than 300 M UWB units shipped in 2022 and more than 1.8 Bn units shipped by 2030.

UWB shipment forecast from Techno Systems Research Co. Ltd.



https://www.eetasia.com/global-uwb-market-shipment-to-reach-317-million-units-in-2022/

Consumer devices available

Samsung:
Galaxy Note 20 Ultra,
Galaxy Z Fold 2,
S21 Series (S21 +, S21 Ultra),
Galaxy Z Fold 3,
Galaxy S22 Series (S22+, S22 Ultra) and
Samsung Galaxy smart tag+
Apple:
iPhone 11/12/13 Series,
Apple watch 6/7 Series and Airtag.
Xiaomi: Mix 4
Google: Pixel 6 Pro

Ultra-wideband standard driven by a strong ecosystem

IEEE 802.15.4a
High Rate Pulse Repetition UWB

IEEE 802.15.4f
Low Rate Pulse Repetition UWB

IEEE 802.15.4z
HRP/LRP UWB enhancements

IEEE 802.15.4ab
Next generation UWB

2007 2012 2018 2019 2020 2020 2021 (2024)

UWB

UWB ALLIANCE

Mission to be the voice of UWB ecosystem in order to support growth of UWB technology through end2end, vendor-agnostic interoperability

uwballiance.org

Fira The Power to Be Precise

Provide seamless user experiences using the secured FIne RAnging and positioning capabilities of inter-operable UWB technology

firaconsortium.org

omlox

Industry standard to integrate existing technologies such as UWB, BLE, RFID, 5G or GPS in order to deliver positioning data via a uniform interface

omlox.com

CARCONNECTIVITY consortium

Digital Key Release 3.0 specification – which combines NFC, Bluetooth LE and UWB to enable secure passive keyless access and engine start

carconnectivity.org

FiRa Consortium: the scope of use cases

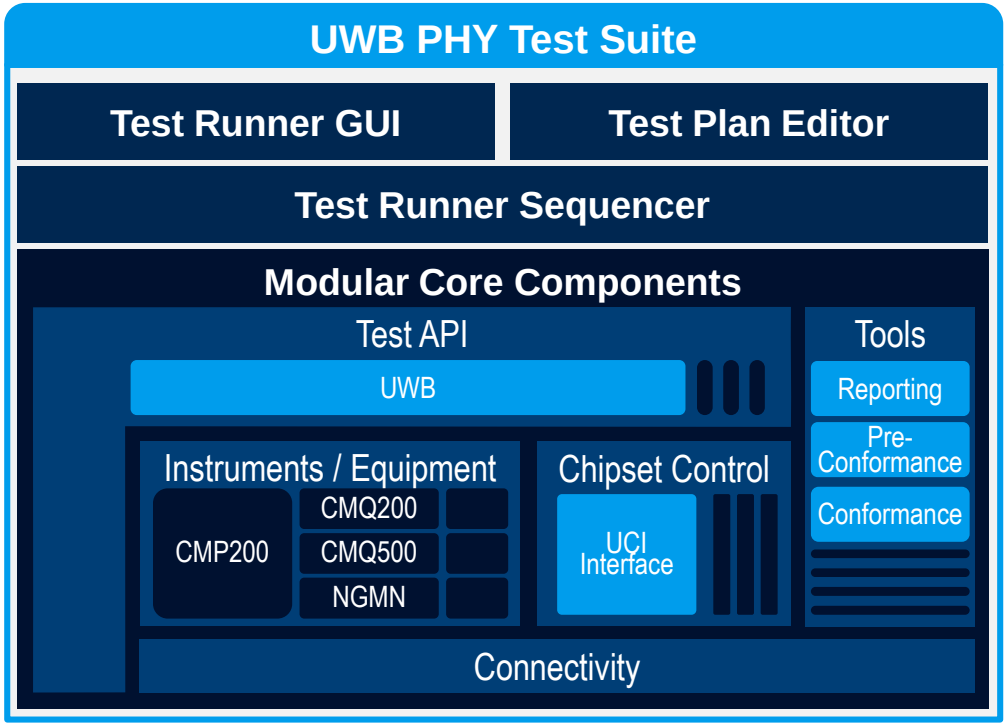
SMART CITIES & MOBILITY		SMART BUILDING & INDUSTRIAL		SMART RETAIL		SMART HOME & CONSUMER	
Indoor Navigation	V2X* and Autonomous Driving	Social Distancing	Asset Tracking	Tap-Free Mobile Payment	Targeted Marketing	Point and Trigger Controller App	Gesture-Based Control
Vehicle Digital Key (Standardized by CCC)	Ticket Validation (Public Transport Services)	Controlled Access	Find Equipment	Unmanned Store Access	Drone-Controlled Delivery	Residential Access Control	VR Gaming and Group Play
Rider Identification (Private Transport Services)	Reserved Seat Validation	Physical Access Control	Patient Tracking	Foot Traffic and Shopping Behavior Analytics	In-Vehicle Payment	Easy (Logical) Access to Personal Devices	Find Someone/ Something Nearby
Transportation Sharing (Find a Bike or Scooter Nearby)	Transportation Fare Payment	Indoor Navigation	Teleconference System	Exhibition Attendee Management		AR Gaming	Presence-Based Device Activation
Ride Sharing (Precise Positioning)	eID Validation in Crowded Environments	Employee Gathering in Emergencies	Proximity-Based Patient Data Sharing				
Driverless Valet Parking and Pick-Up	Parking Garage Access Control						

Link Fira

fira | The Power to Be Precise

VALIDATED PHY LAYER CERTIFICATION TEST TOOL (PCTT)

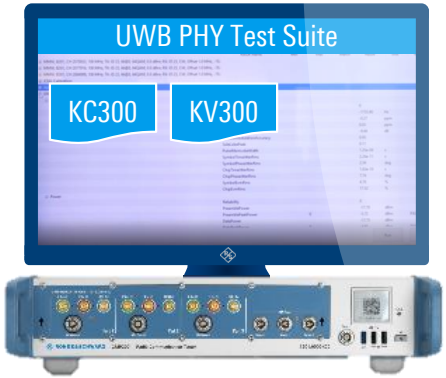
Tailored for UWB non-signaling R&D applications based on the R&S wireless non-signaling test solution framework



- 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

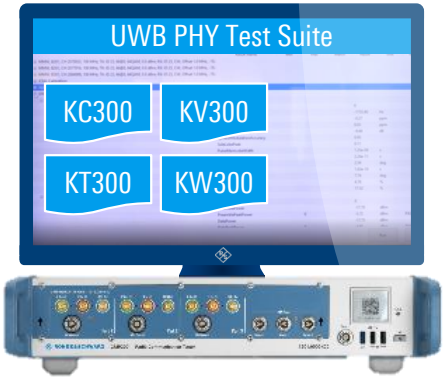
New UWB test solution based on FiRa validated certification solution creates great solutions in the UWB ecosystem

UWB PHY Test Suite
Conformance



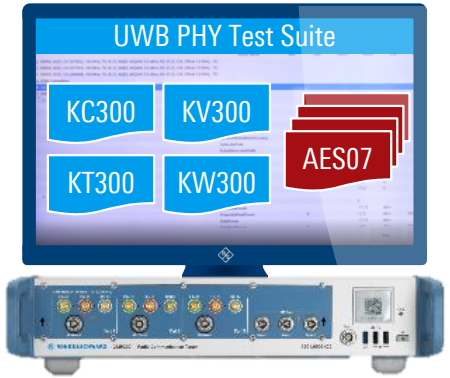
FiRa authorized test labs | Conformance test labs

UWB PHY Test Suite
Research & Development



Chipset design & validation | Device design & validation | Pre-Conformance test labs

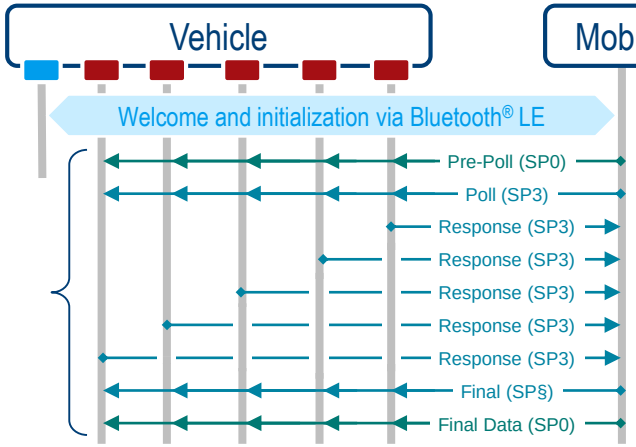
UWB PHY Test Suite
R&D Automation

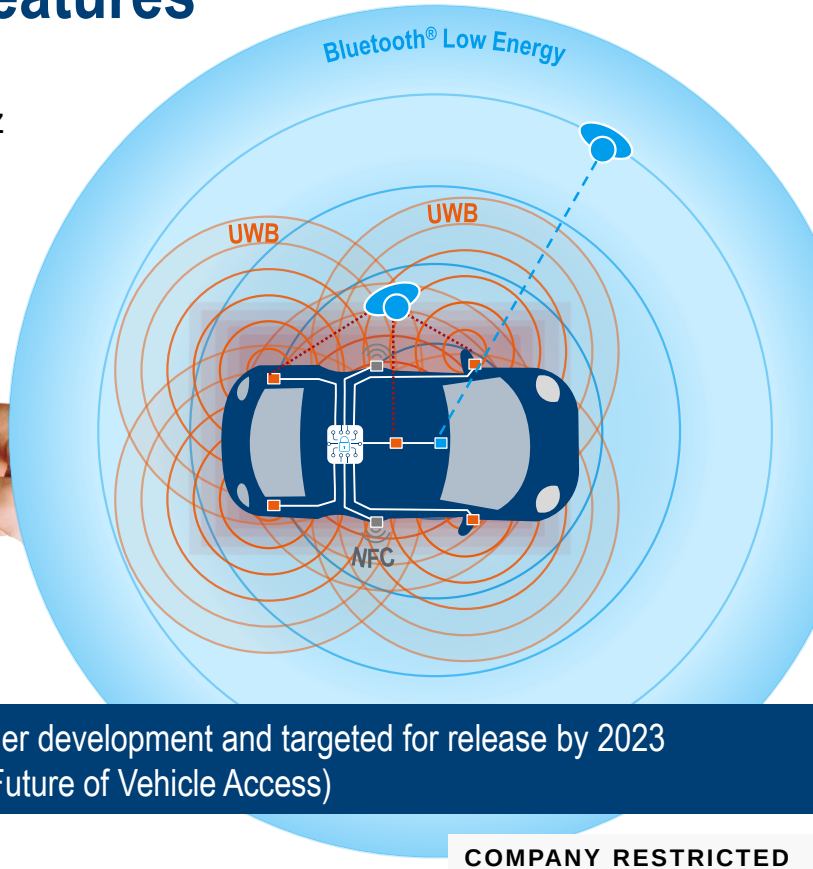


Chipset design & validation | Device design & validation | Pre-Conformance test labs

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.



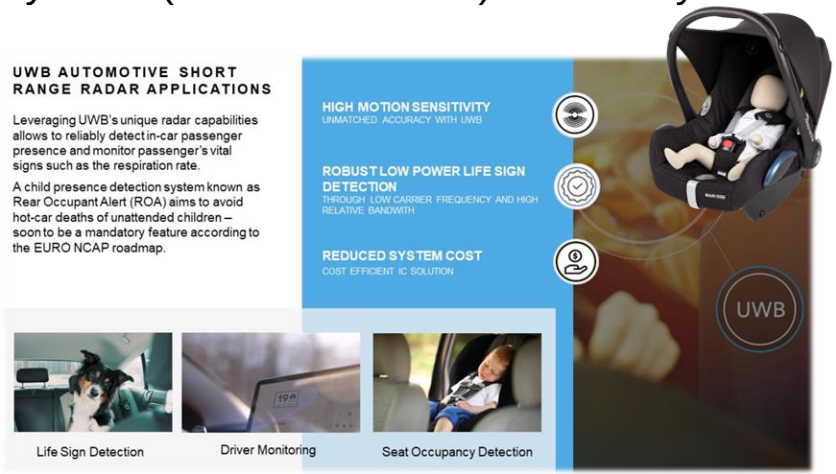


Rohde & Schwarz member of CARCONNECTIVITY consortium®

The CCC Digital Key certification program is under development and targeted for release by 2023 (see CCC Whitepaper " CCC Digital Key – The Future of Vehicle Access)

Major Upcoming Use Case in Automotive- Child Presence Detection

- NXP`s UWB Trimension™ NCJ29D6 IC (Ranger5) enables secure ranging (AoA) and ultra short-range radar (**UWB Radar**, 6-8GHz)
- Vital sensing applications are not only addressed by UWB (IEEE 802.15.4ab) but also by Wi-Fi (IEEE 802.11bf), and 60 GHz radar.
- In-cabin radar will be part of future European NCAP regulations.
- Devisions and MSs (WIC, AUT) investigating customer requirements and test solutions.



UWB Radar Motion Detection Link NXP

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R&S®CMP200 – UWB device testing

CMP200 features

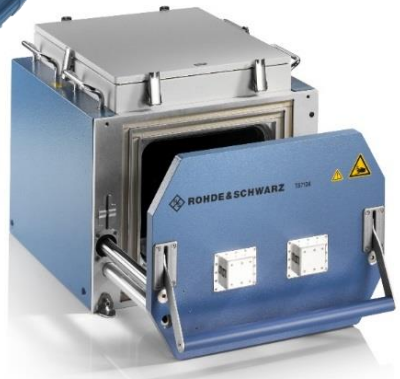
- One general purpose analyzer
  Frequency range: 6 to 20 GHz
- One ARB generator
  Replay of predefined waveforms
  Frequency range: 6 to 20 GHz
- Three switchable ports with smart channel support, 1 GHz bandwidth

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
- New CMQ200-HS from 0.3 – 14GHz @ 80dB shielding
-

R&S®CMP200

R&S®CMQ200 - HS



Typical PHY measurements for HRP UWB devices

Defined in IEEE 802.15.4 incl. 802.15.4z

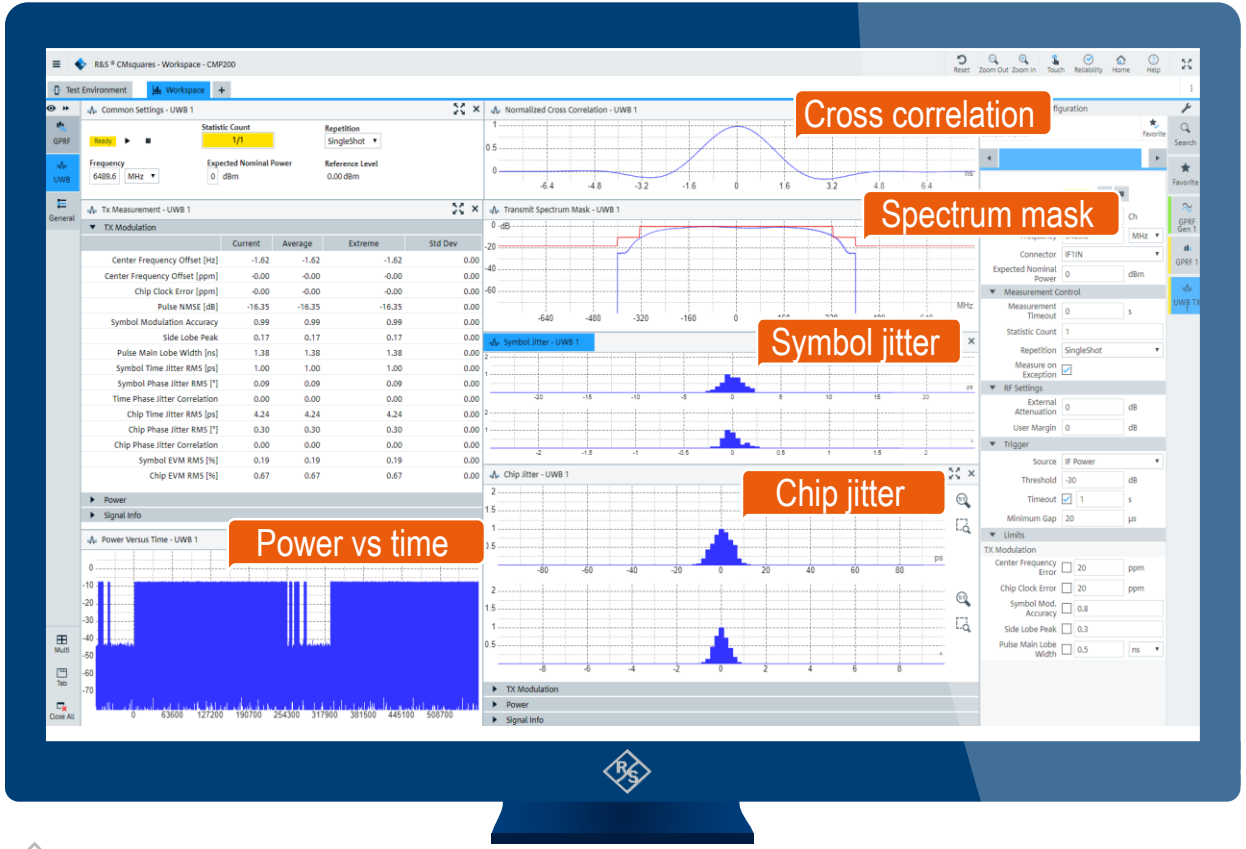
- Regulatory requirements: Maximum allowable output power spectral density e.g. FCC/ETSI[1] -41.3dBm/MHz
- Baseband impulse response:
  - Normalized cross-correlation (main/side lobe limits)
  - Pulse amplitude mask
- Transmit power spectral density mask
- Chip rate clock and chip carrier alignment accuracy of ± 20 × 10^{-6}
- Transmit center frequency tolerance of ± 20 × 10^{-6}

Additional measurements

- Chip/symbol clock jitter analysis
- Chip/symbol phase jitter analysis
- Main lobe width / peak
- Side lobe width / peak
- Transmit signal quality using a normalized root mean square error (NRMSE) metric
- Chip/Symbol EVM
- Preamble/data Power
- Power vs Time
- Receiver sensitivity
- …

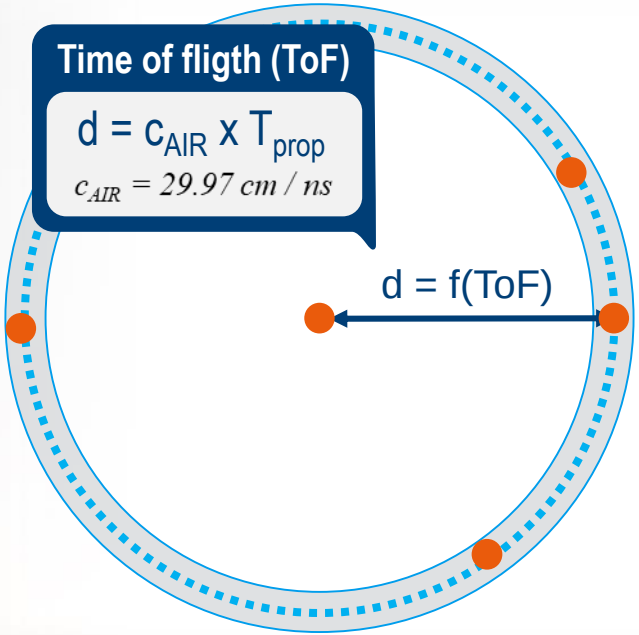
(HRP UWB PHY measurements, based on IEEE 802.15.4-2015 Chapter 16)

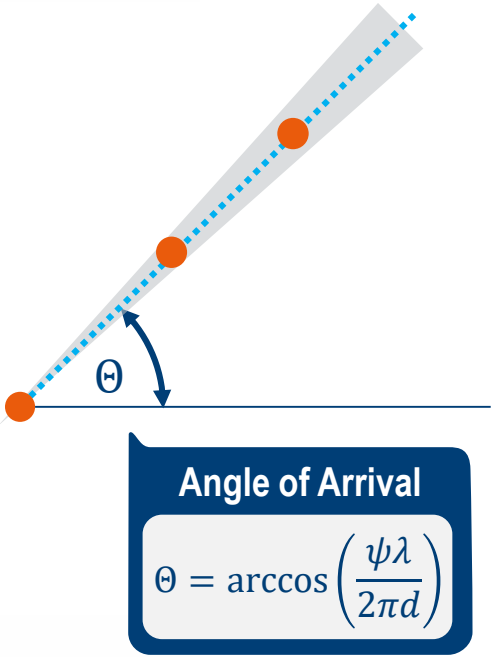
HRP UWB transmitter measurements with R&S®CMP200



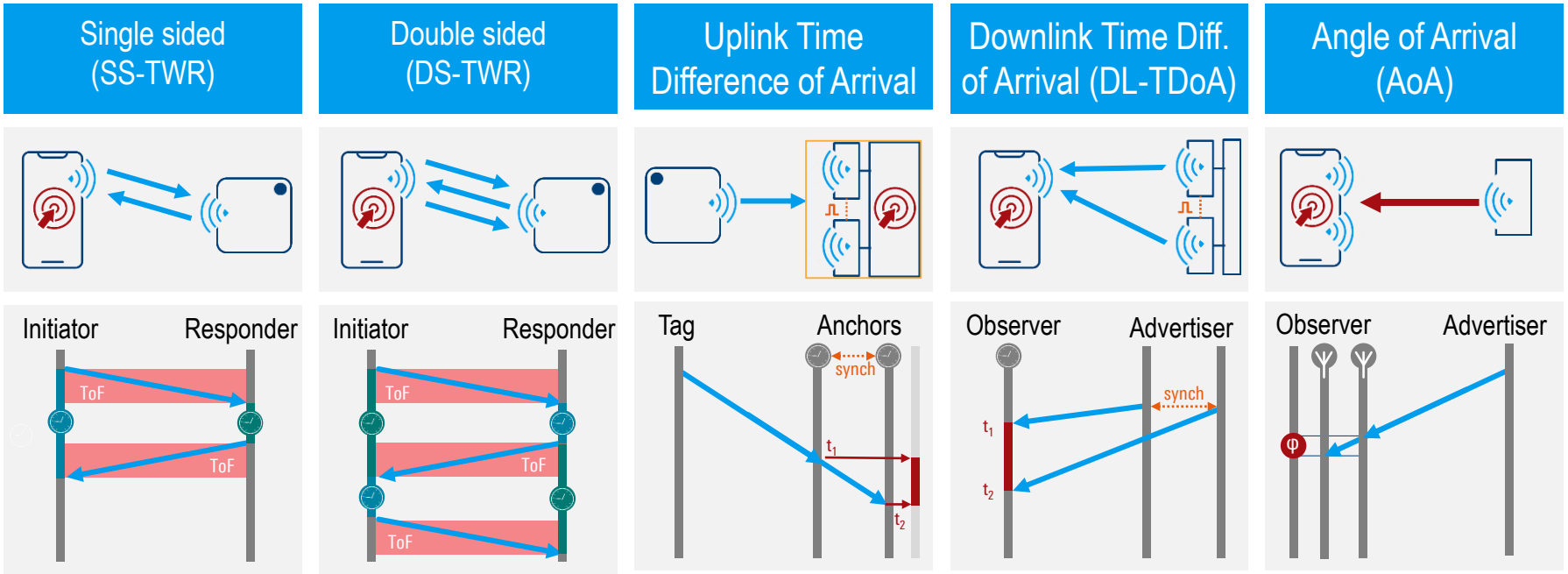
R&S®CMP200

Fine ranging/positioning with UWB

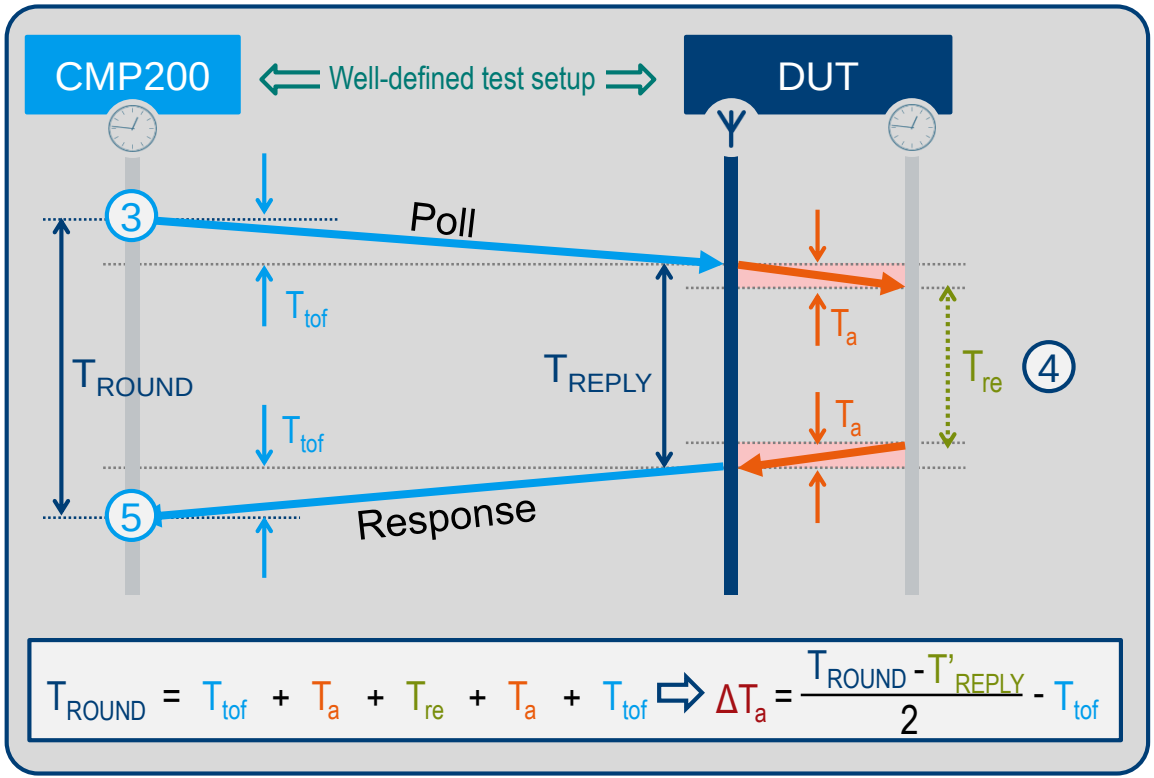




UWB ranging and positioning is all about absolute/relative signal propagation time(s)

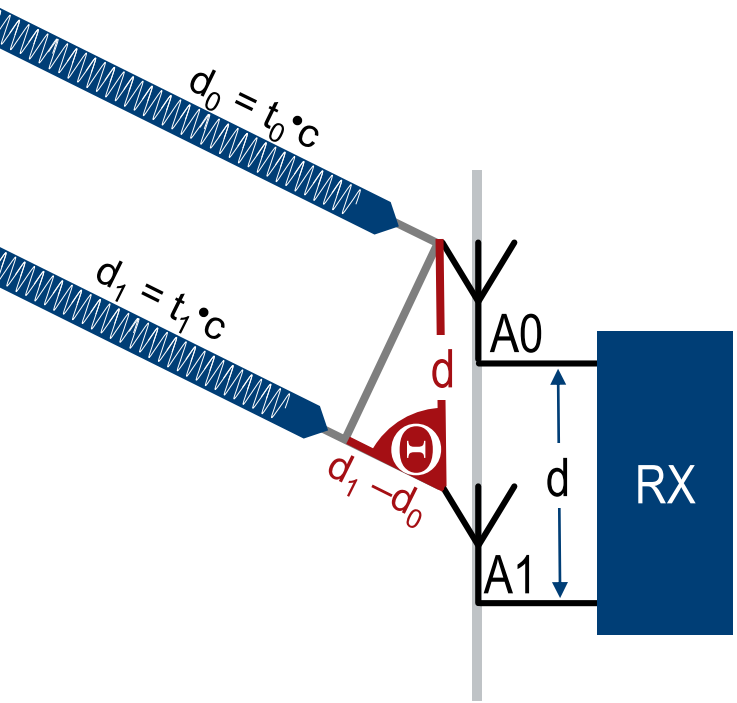


How does R&S®CMP200 initiated calibration works

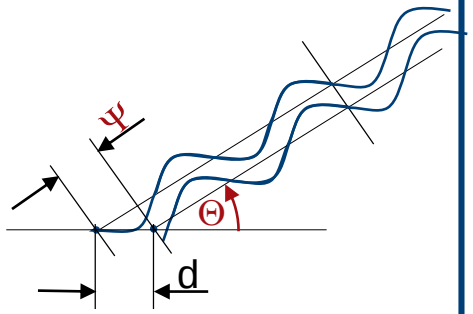


1. Put CMP200 analyzer into continuous-capturing mode
2. Set DUT into „anker mode“
3. CMP200 sends poll packet
4. DUT responds and measures T'_{REPLY}
5. CMP200 measures T_{ROUND} as well as clock and frequency error of the response to correct T'_{REPLY} accordingly
6. ΔT_a can be calculated based on the measured and expected T_{tof} values

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

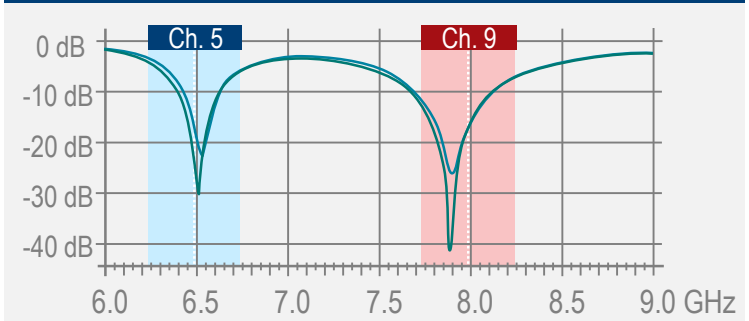
Antenna characteristics on several channels over channel bandwidth of more than 500 MHz due to frequency dependencies of the properties:

- Matching
- Efficiency
- Gain
- Directivity
- Group delay

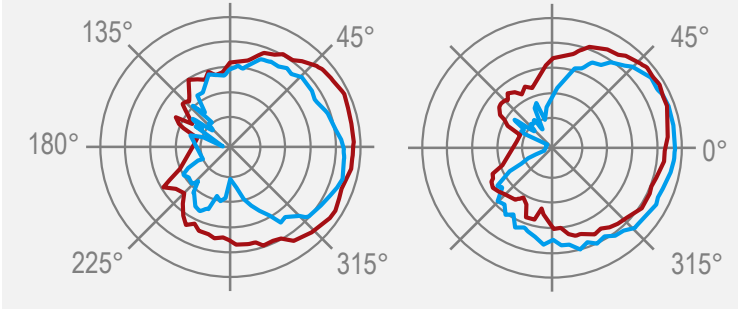
Impact of final **device design**

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

UWB Antenna charachteristics (S11)



UWB Antenna characteristics (antenna gain)



Source: Master Thesis Daniela Lutz @ Rohde & Schwarz

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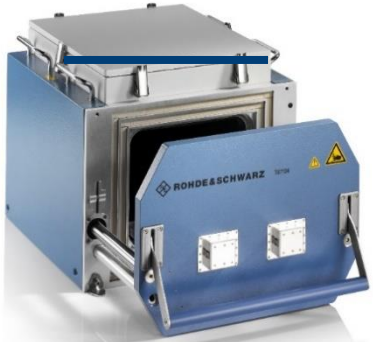
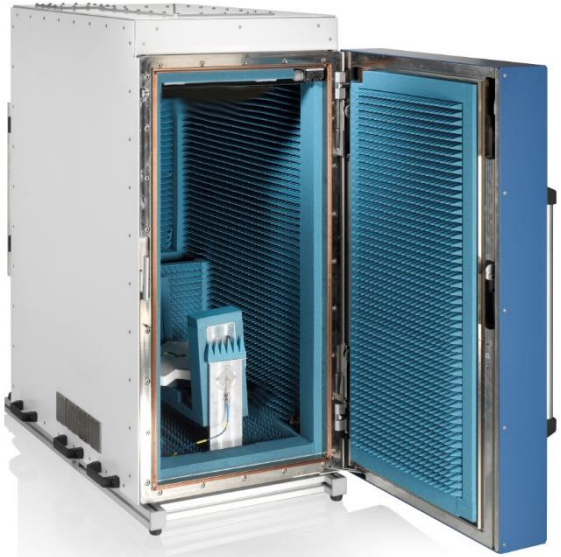
R&S®TS7124



R&S® CMQ200 HS

R&S® ATS800R



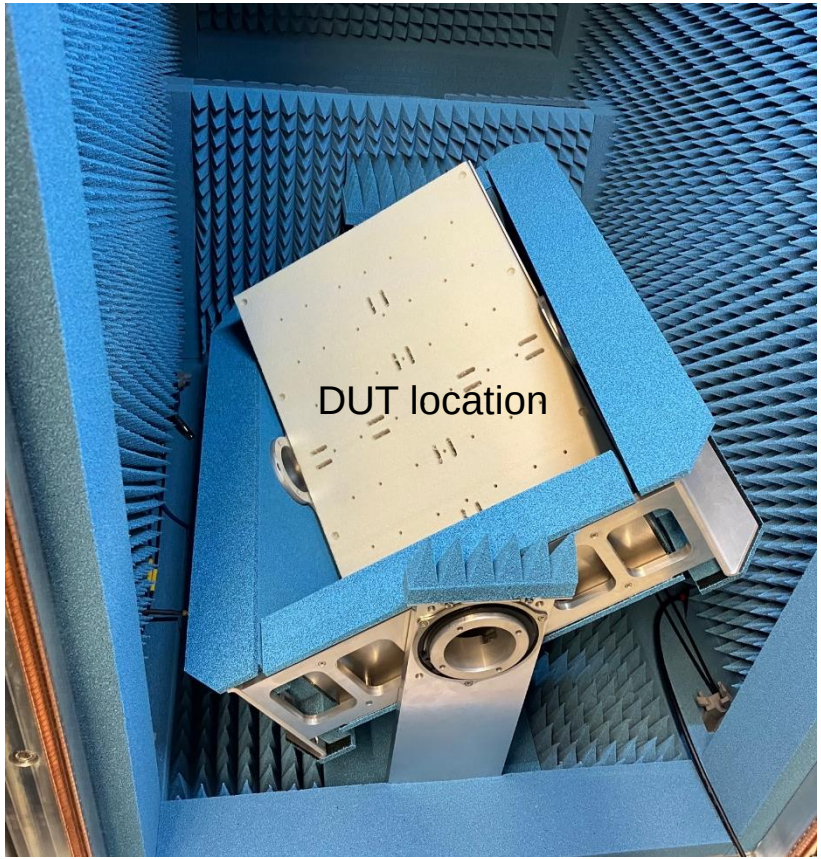
UWB RF test solution with R&S chambers

ATS800R
compact CATR test chamber on a rack

- Key Features & Benefits
  - Footprint of 0.7 m^2
  - Easily transportable on wheels
  - High shielding effectiveness
  - 12HU space for instruments in optional rack
  - Flexible in use and setup
    - With rack
    - Benchtop
    - On wheels but without rack
    - As shield box (no reflector/feed but absorber cover)

ATS800R – motorized Tilt/Tilt Positioner (under development)

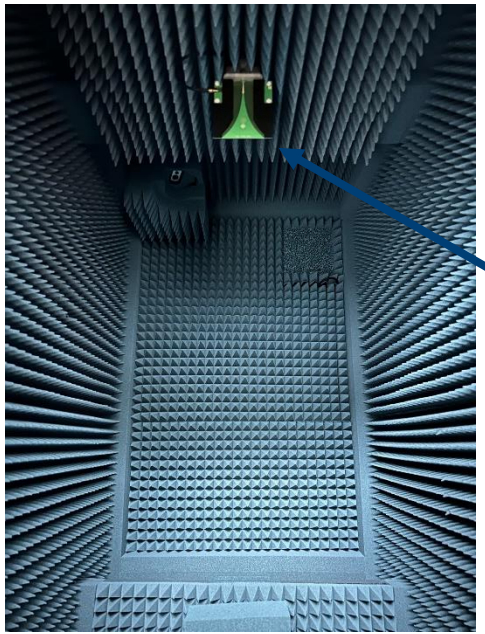
- Positioner with two perpendicular tilting planes
  - Compared to alternative positioner CATR-P3DR polarization match to feed antenna is kept while moving DUT in both planes
  - Requirement for AoA measurement in UWB
  - Also important for phase/polarization oriented DUTs such as radar (compare ATS1500C positioner)
  - Max. DUT size: 27cm x 41cm
  - Max. DUT weight: 2.5kg centered



Ats800r –DFF (Antenna)

- Flexible antenna holder in center above DUT location
- Antenna can be interchanged easily

DFF antenna on top (under development)



DFF antenna examples

0.7…18GHz

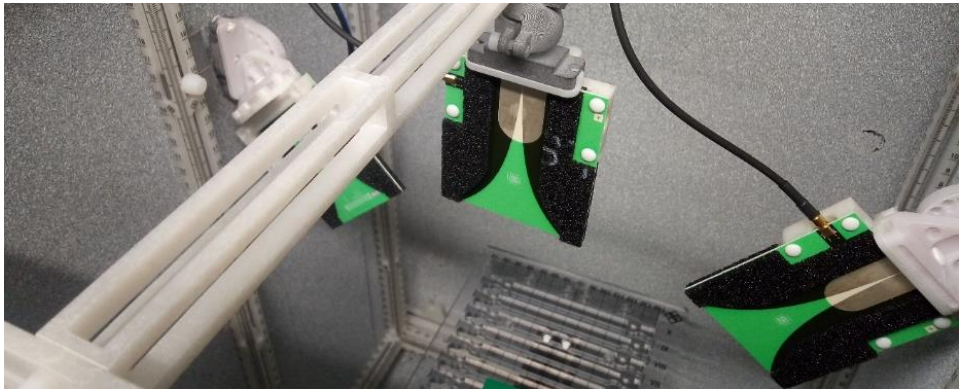
2.4…18GHz

1.7…18GHz CP


UWB TESTING FOR
FIRA CERTIFICATIO
TION
COMPANY RESTRICTED

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 CMQ 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



Far field threshold definitions

Fraunhofer distance (r_{Fr})

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

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

λ – *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 antenna lies within 0.5 dB of the EIRP at infinite far field condition

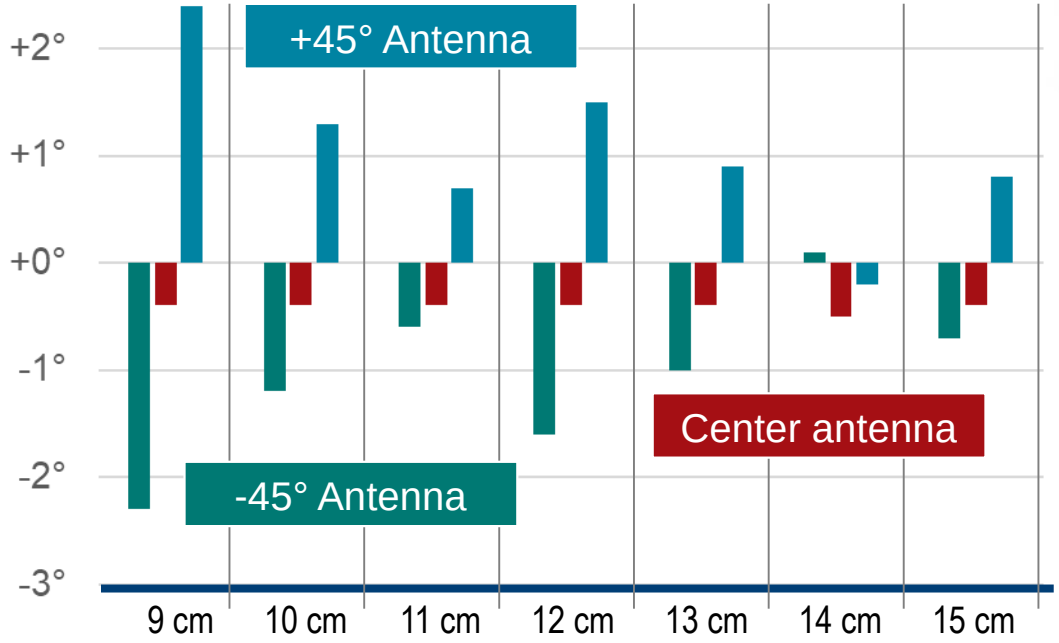
$$r_{De} = \lambda \left(\frac{\pi D}{\lambda}\right)^{0.8633} \left[0.1673 \left(\frac{\pi D}{\lambda}\right)^{0.8633} + 0.1632\right]$$

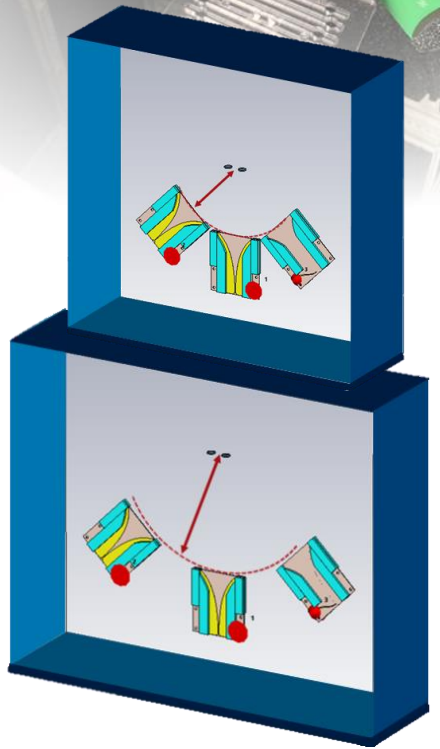
D = 70 mm	r_{Fr}	r_{De}
Channel 5 @ 6489.6 MHz	~ 21 cm	~ 14 cm
Channel 9 @ 7987.2 MHz	~ 26 cm	~ 16 cm

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

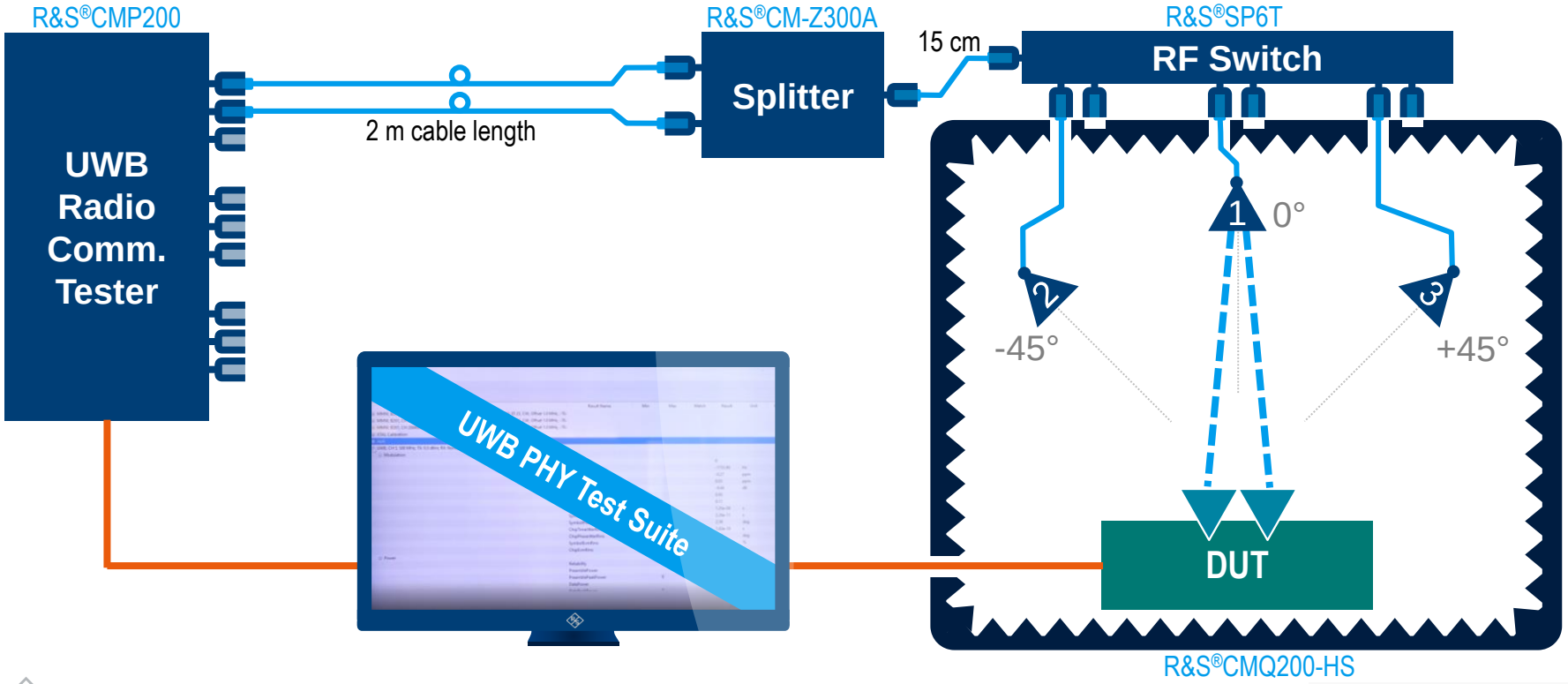
Alex J. Yuffa, Marc A. Valdez, Benoît Derat; On convergence of the upper bound on the ratio of gain to quality factor; to appear on the proceedings of AMTA21

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





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



UWB testing Applications

	UWB Testing			
	R&D		Production	
	Conducted	Over-the-air	Conducted	Over-the-air
TX	✓		✓	✓
RX	✓	Ongoing	✓	✓
ToF	✓		✓	✓
AoA	✓		(✓)	✓

2023*

2023*

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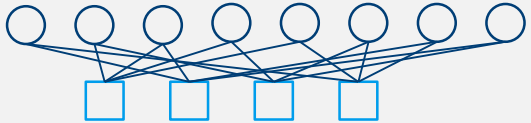
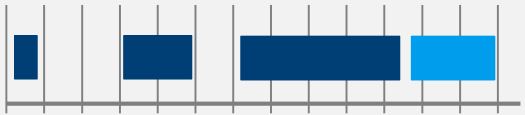
Study Group 4ab: UWB Next Generation

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).

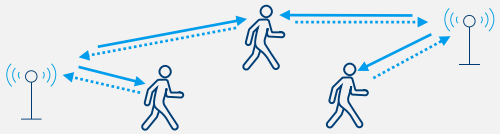


Additional coding, preamble and modulation schemes



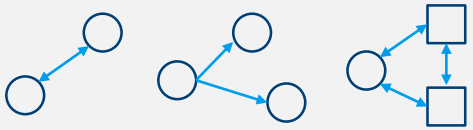
Additional channels and operating frequencies

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

Application note for Ranger 4

Application Note

AUTOMOTIVE UWB DEVICE TESTING OVER THE AIR

Calibration and Verification Solution

Products:

- R&S®CMP200
- R&S®CMQ200 HS
- R&S®CMQ500
- R&S®WMT
- R&S®WinIQSIM2
- R&S®CM-Z300A

Yong Shi | 1SL394 || Version 1e | 03.2023

http://www.rohde-schwarz.com/appnote/1SL394

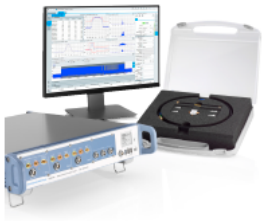
Worthwhile to read ....

HIGH RATE PULSE ULTRAWIDEBAND PHYSICAL LAYER TESTING AND CERTIFICATION

White paper | Version 01.00 | Yong Shi

SIMPLIFY FiRa™ CERTIFICATION FOR YOUR UWB DEVICE

The validated UWB PHY test suite for the R&S®CMP200 radio communication tester simplifies FiRa™ Consortium PHY conformance testing.



The physical layer requirements and certification test cases are derived from the related HRP UWB standard specified in IEEE 802.15.4 clause 15 and complemented by FiRa™. FiRa™ focuses on enhanced ranging devices (ERDEV) supporting both modes: base pulse repetition frequency (BPRF) and high pulse repetition frequency (HPRF) in the high band (band group 2) for 499.2 MHz channels as specified in the latest standard amendment IEEE 802.15.4z. For conformance testing, a couple of transmitter and receiver test cases were specified aimed at improving interoperability, quality and performance.

FiRa™ PHY test case coverage for BPRF and HPRF modes:

Transmitter tests
- Check of transmitted packet format
- Power spectral density mask
- Carrier frequency tolerance
- Pulse timing
- Baseband impulse response
- Transmit signal quality (NRMSE)

Receiver tests

The value of conformance testing for interoperability

Seamless interoperability of UWB devices is of utmost importance for the success of UWB applications such as keyless entry, asset finding, sensing and navigation. It is essential to ensure a safe and effective user experience. The certification program established by the FiRa™ Consortium builds the cornerstone to drive i across the industry.

FiRa™ conformance testing

The FiRa™ certification program is intended interoperability of UWB devices which use flight (ToF) ranging measurements on differ

The certification program includes physical formance testing that needs to be executed authorized test laboratories (ATL) using FiRa test tools such as the UWB PHY test suite f R&S®CMP200.

hwarz is a PHY ts conformance d by the FiRa™ by the FiRa™ , is based on aster that sup- al generation

Application Card | Version 01.00

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UWB FOR ENHANCED RANGING DEVICES

UWB HRP channel allocation | Power spectral density | Impulse response

UWB HRP-ERDEV PPDU formats | SHR generation | STS generation

Modulation scheme of HRP-ERDEV in BPRF mode | Modulation schemes of HRP-ERDEV in HPRF mode

Time of flight (ToF) measurement | Phase difference measurement

UWB TEST AND MEASUREMENT SOLU

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Worthwhile to watch …

Discover the secrets of UWB based on IEEE 802.15.4z

Testing ultra-wideband for automotive applications

Reinforce a seamless UWB experience

UWB Training offered by Schooling department

Startseite > Trainings

R&S®UWB (Pre-)Conformance Test with CMP200

What you receive

- meet the real world experts
- hands on
- up to date developements
- R&S certification

Seminar Info

Date: 1/31/23, 9:00 AM - 2/1/23, 5:00 PM
Location: R&S Technology Academy, Mühldorfstraße 15, 81671 München, Deutschland
Language: english
ID: 3725.1306.40

In den Warenkorb

Kasdepke Thomas 1ATL

Topics

- Introduction to HRP UWB RDEV Physical Layer (IEEE802.15.4-2020)
- Introduction to HRP UWB ERDEV Physical Layer (IEEE802.15.4z)
- Introduction to UWB ranging concepts
- CMP200 operation concept
- FiRa consortium physical layer test concept
- UWB RF conformance tests with R&S®CMP200 UWB PHY Test Suite
- Pre-conformance tests with modified FiRa consortium test plans

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