Automotive

TESTING ULTRA-WIDEBAND FOR AUTOMOTIVE APPLICATIONS

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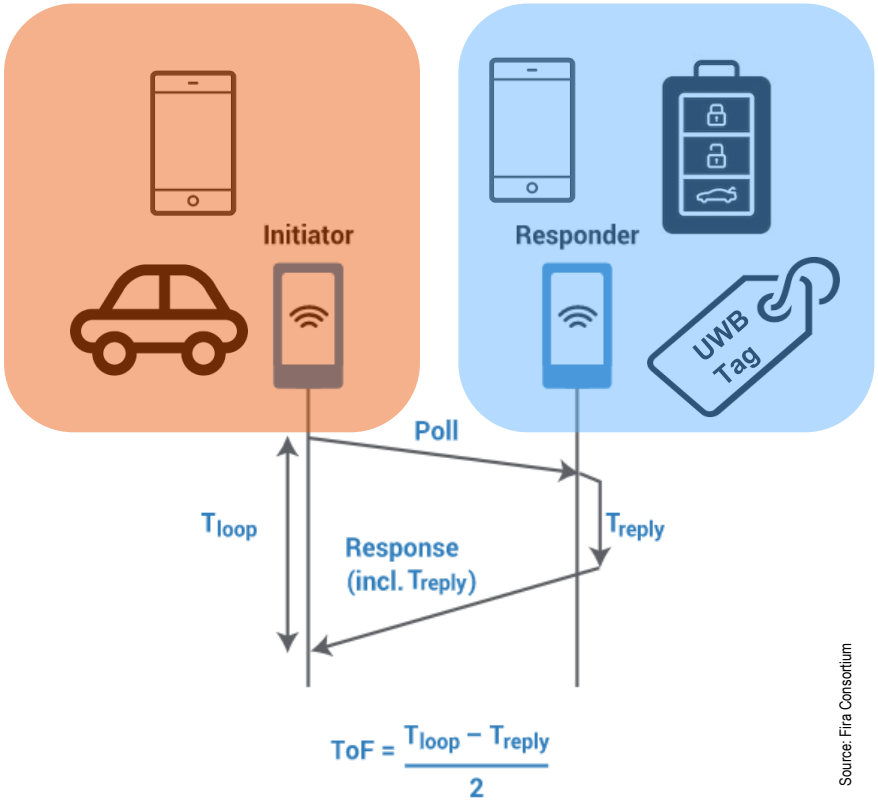
ROHDE&SCHWARZ
Make ideas real

AGENDA

- Technology, Standards and Market Overview
- Automotive Applications
- UWB Test Requirements
- Test Solutions for R&D and Manufacturing
- Conclusions

WHAT IS ULTRA-WIDEBAND ABOUT?

- The Ultra-Wideband (UWB) technology consists of narrow pulses (typically 2ns), which makes it highly immune to multi-path and interference.
- UWB uses a bandwidth between 500 MHz and 1.2 GHz (i.e. CH5 6789 MHz mainly in Automotive) . UWB is difficult to jam (relay attacks).
- The in-vehicle unit can be configured to only take action when the measured distance is less than a certain vehicle manufacturer defined value (Time-of-Flight, ToF).



Source: Fira Consortium

ULTRA-WIDEBAND ADVANTAGES FOR AUTOMOTIVE

- Proximity
  - Inside / outside vehicle detection performance close to LF 125kHz
- Radio Security
  - Effective against relay attacks due to Time-of-Flight distance detection
- HW/SW Security
  - Authentication and optimized coding
- Scalable multi-car access
- Adaptable to key sharing models
- Sharing of access credentials

Image Source: BMW AG

20 Years of ultra-wideband communication and precise ranging

In 2002 the Federal Communication Commission (FCC) finally allowed the unlicensed use of UWB systems in radar, public safety and data communication applications.

2002

WiMedia ALLIANCE

Promotes wireless multimedia connectivity and interoperability between devices in a personal area network.
First UWB spec.

wimedia.org

2005

ECMA-368
Low Rate Pulse Repetition UWB

2007

IEEE 802.15.4a
High Rate Pulse Repetition UWB

2012

IEEE 802.15.4f
Low Rate Pulse Repetition UWB

2015

IEEE 802.15.4-2015
HRP Chap. 16 & LRP Chap. 19

2018

UWB ALLIANCE

Mission to be the voice of UWB ecosystem in order to support growth of UWB techn. through e2e, vendor-agnostic interoperability.

uwballiance.org

2019

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

2020

omlox

Industry standard to integrate all existing techno-logies, such as UWB, BLE, RFID, 5G or GPS and deliver positioning data via a uniform interface.

omlox.com

2020

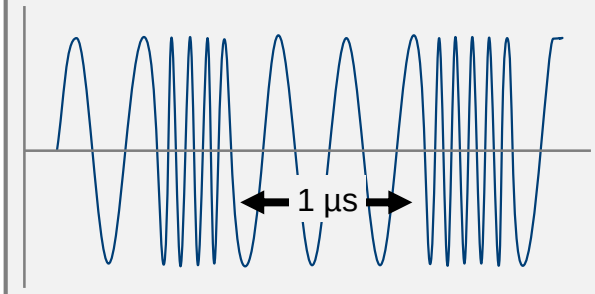
IEEE 802.15.4z
HRP/LRP UWB enhancements

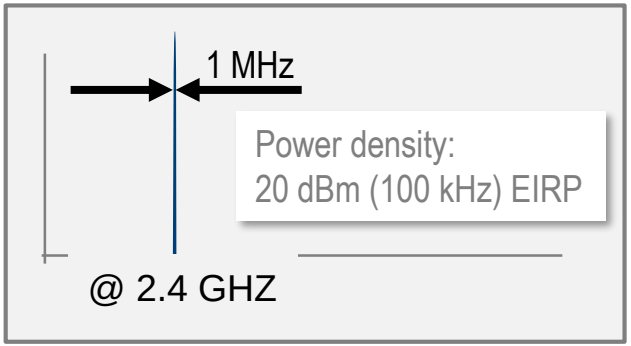
CARCONNECTIVITY consortium®

Digital Key Release 3.0 planned with UWB

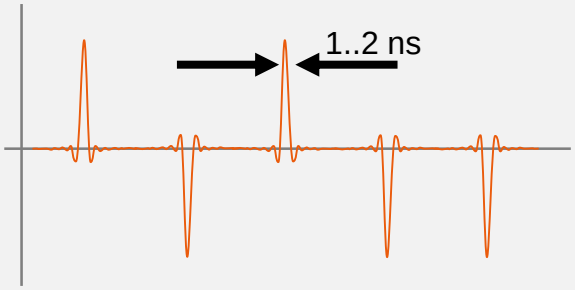
Ultra-wideband (UWB) : Low-power short signal pulses over a broad spectrum

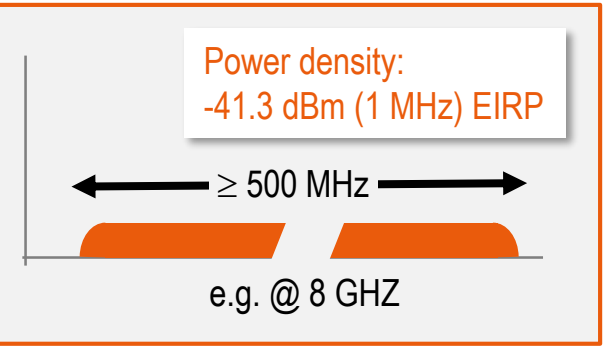
NB/WB e.g. Bluetooth GFSK

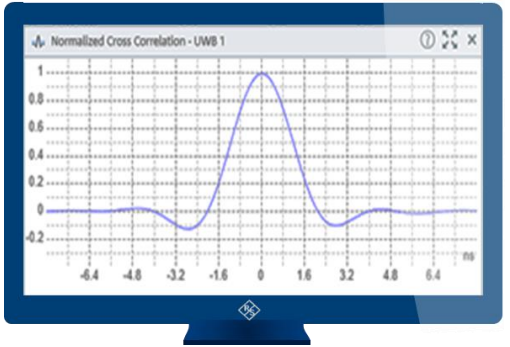


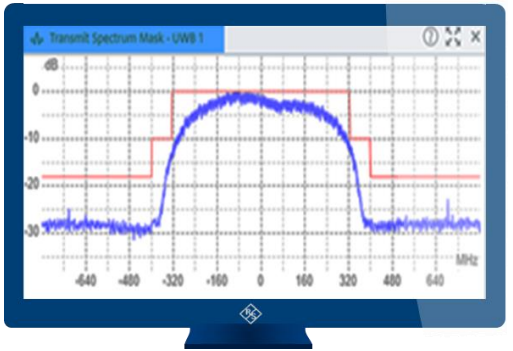


UWB pluse – Phase shift keying

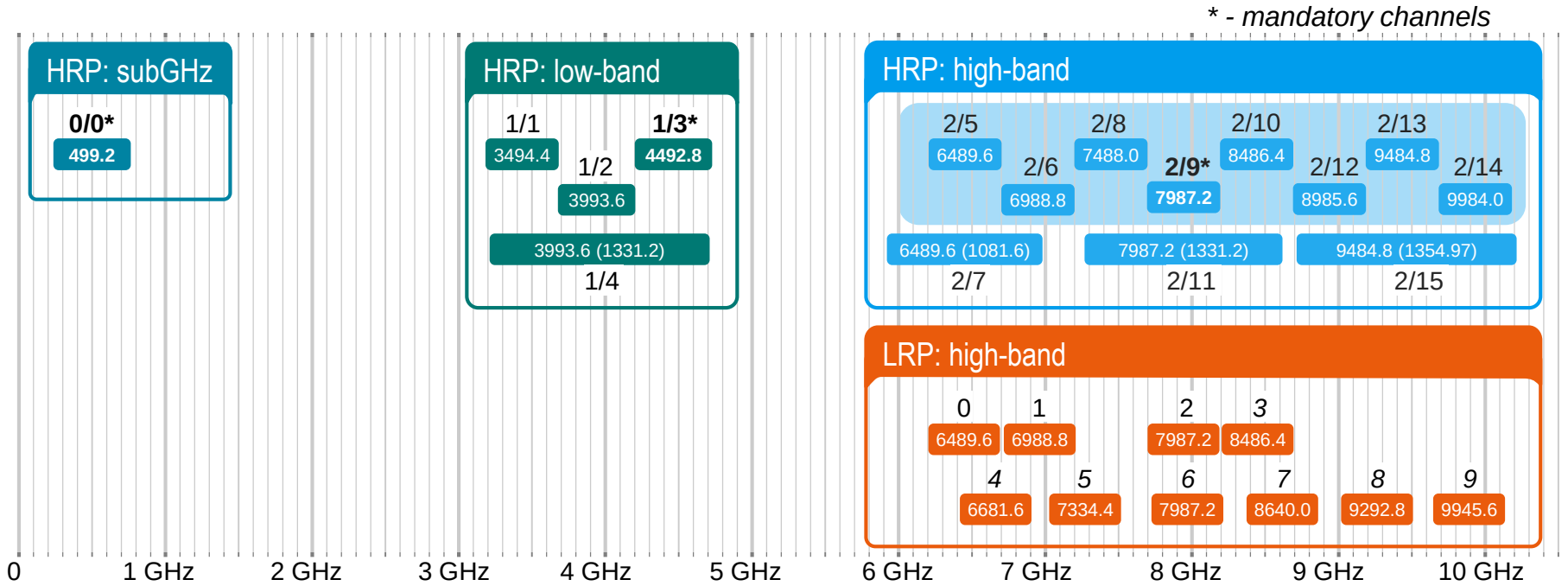




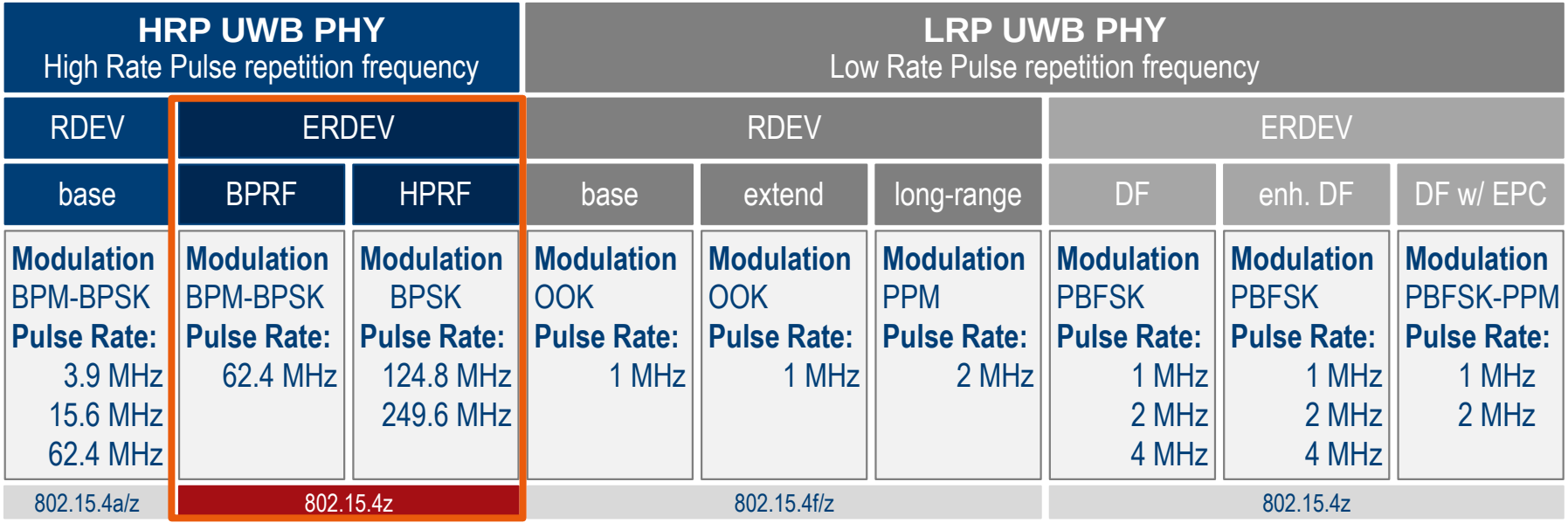




UWB channel allocation based on 802.15.4z



Impulse radio ultra-wideband (UWB) standardization: IEEE 802.15.4 (groups a, f, z)



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

BPRF – Base pulse repetition frequency
HPRF – High 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

FOR DETAILS ABOUT IEEE 802.15.4 STANDARD AND UWB TECHNOLOGY PLEASE REFER TO OUR PREVIOUS WEBINAR

Link to webinar

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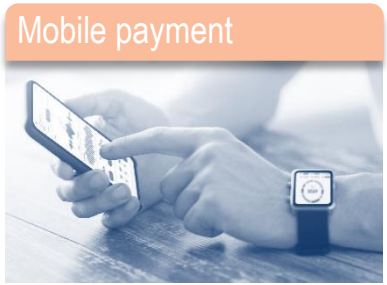
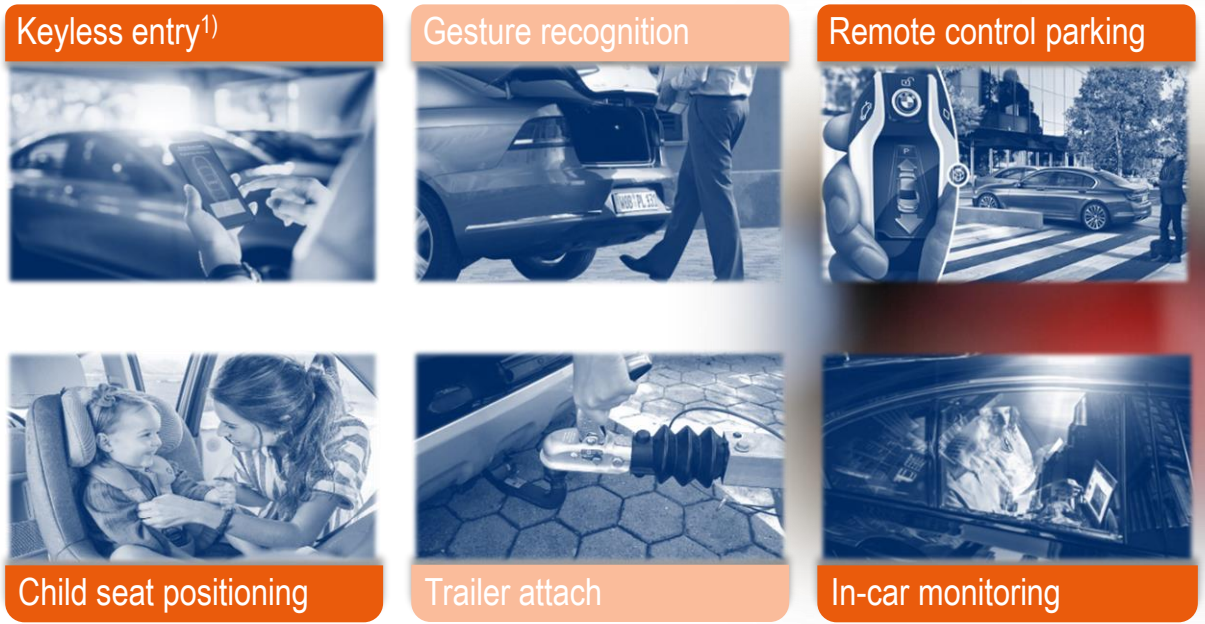
UWB on mobile devices with precise ranging and secure low-power communication



All major smartphone vendors provide UWB connectivity, e.g. iPhone 11/12, HomePod mini, Apple Watch S6 or Samsung Galaxy 20/21, Galaxy SmartTag, Google, Xiaomi and others more

UWB initially solving a keyless security problem is becoming a universal tool around the car



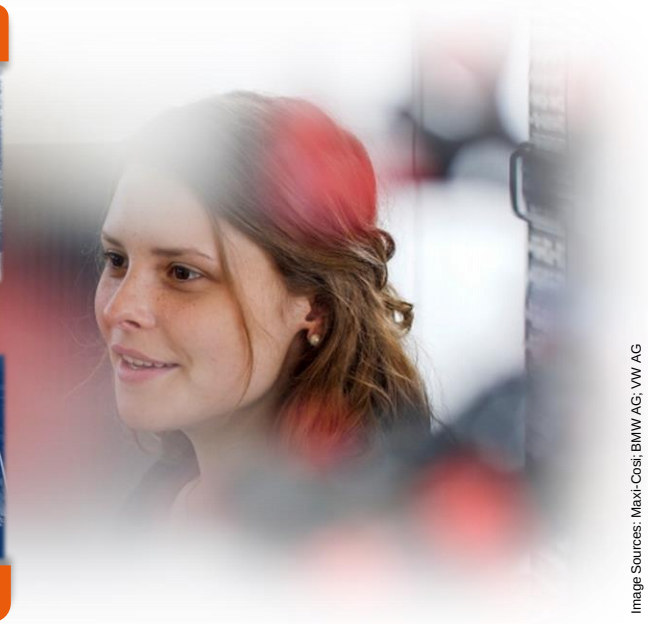


Image Sources: Maxi-Cosi; BMW AG; VW AG

[1)] The Car Connectivity Consortium (CCC) is specifying Digital Key Release 3.0 based on Bluetooth Low Energy (BLE) in combination with Ultra-Wideband (UWB).

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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
- Pulse masks / main lobe width / peak
- Pulse masks / 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
- Reception sensitivity
- Time-of-Flight/ToF & Angle-of Arrival/AoA

ETSI related documents EN 302 065 and EN 303 883

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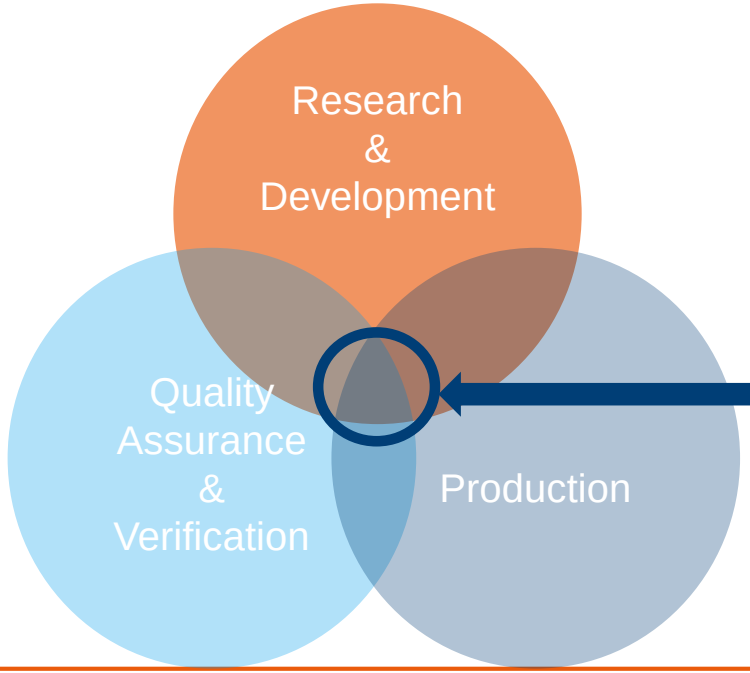
T&M APPLICATION AREAS

Product Life Cycle



802.15.4/z specific measurements

Defined in IEEE 802.15.4 incl. 802.15.4z

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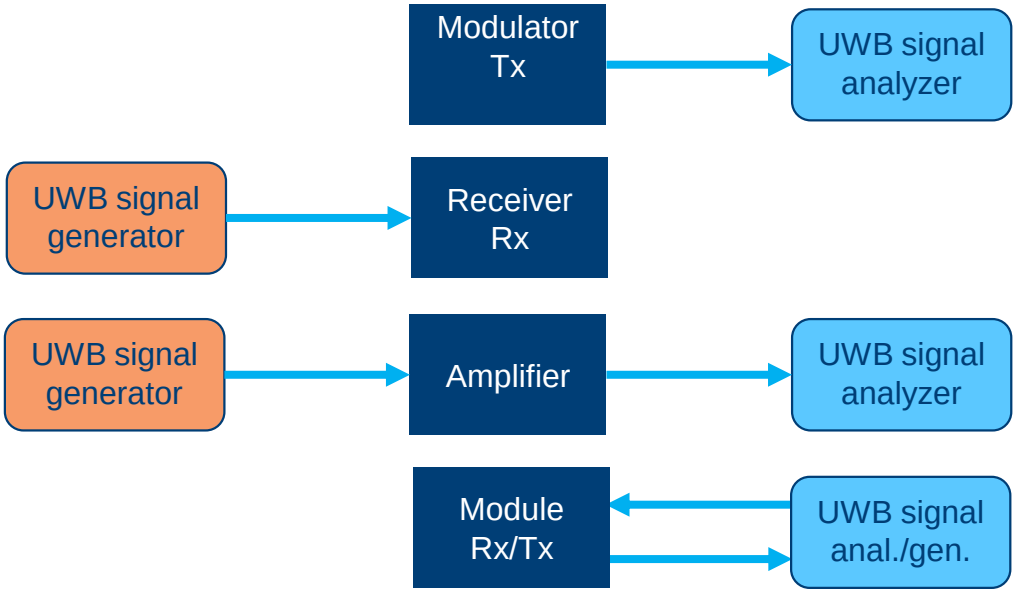
T&M APPLICATIONS

R&D of UWB modulators

R&D of UWB receivers

R&D of UWB amplifiers

R&D of UWB modules



TEST SOLUTIONS FOR R&D

- UWB signal generation and analysis
  - R&S®SMM100A/SMW200A signal generators
  - R&S®FSW26 spectrum analyzer
  - R&S®RTP oscilloscope
  - R&S®VSE 2.0 signal analysis software

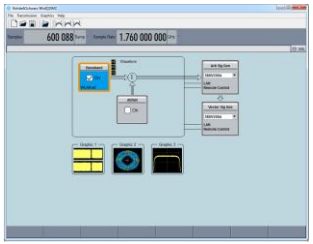
HRP UWB SIGNAL GENERATION

R&S®SMW200A

- Frequency range from 100 kHz to 12.75 GHz
  - Support of all HRP UBW bands
- RF modulation bandwidth up to 2 GHz
  - Support of all mandatory and optional HRP UWB channels
- Optional fading simulation and AWGN generator
- Works also with R&S®WinIQSIM2

R&S®SMM100A

- Frequency range from 100 kHz to 12.75 GHz
  - Support of all HRP UBW bands
- RF modulation bandwidth up to 1 GHz
  - Support of all mandatory HRP UWB channels
- Works also with R&S®WinIQSIM2



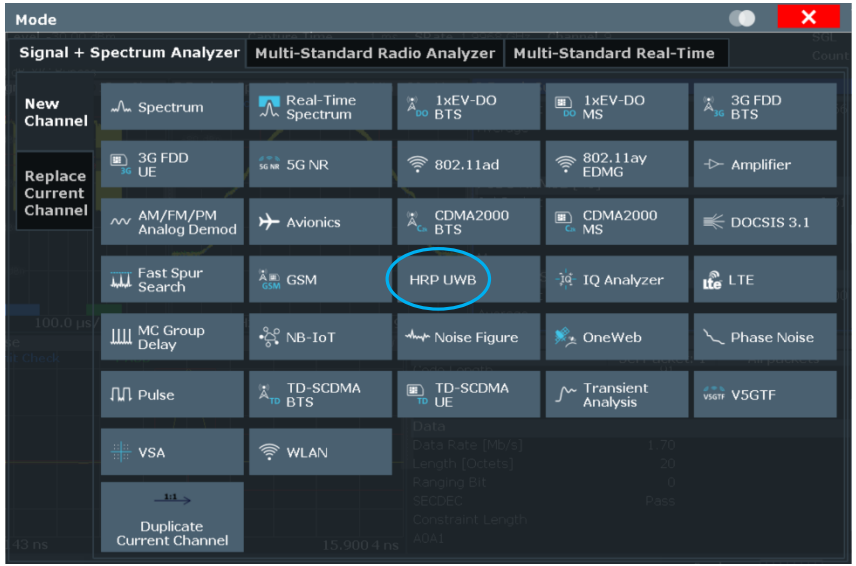
R&S®WinIQSIM2

HRP UWB SIGNAL ANALYSIS WITH R&S®FSW26

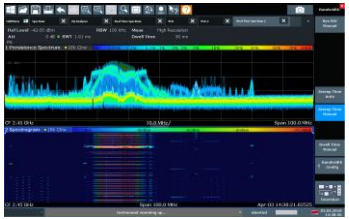
R&S®FSW26

- Frequency range from 10 MHz (DC: 2 Hz) to 26.5 GHz
  - Support of all HRP UBW bands
- RF modulation bandwidth up to 2 GHz
  - With **R&S®B1200** support of all mandatory HRP UWB channels
  - With **R&S®B2001** support of all mandatory and optional HRP UWB channels
- Excellent phase noise and DANL characteristic
- Wide range of applications and standards
- HRP UWB measurements with **R&S®FSW-K149** option

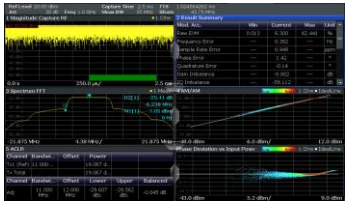
HRP UWB SIGNAL ANALYSIS WITH R&S®FSW26



Selection of standard and measurement application by mode menu



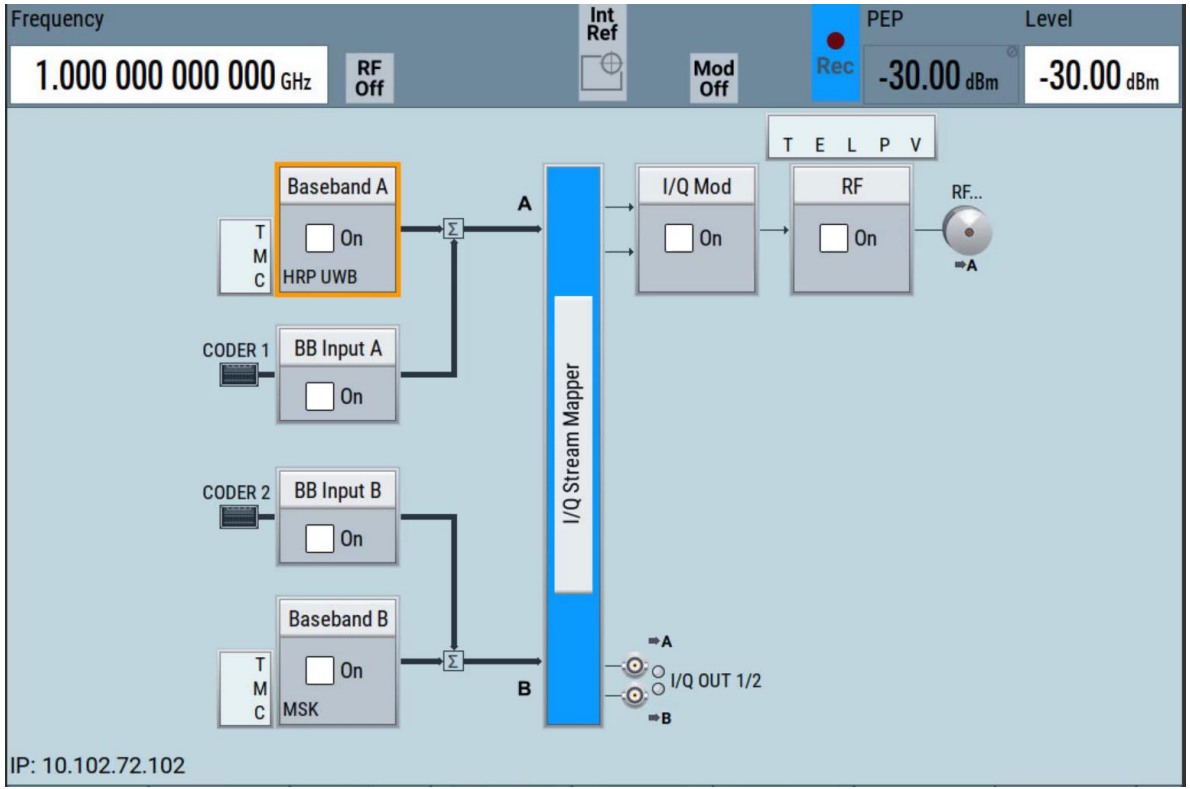
Real-time spectrum analysis up to 800 MHz of bandwidth



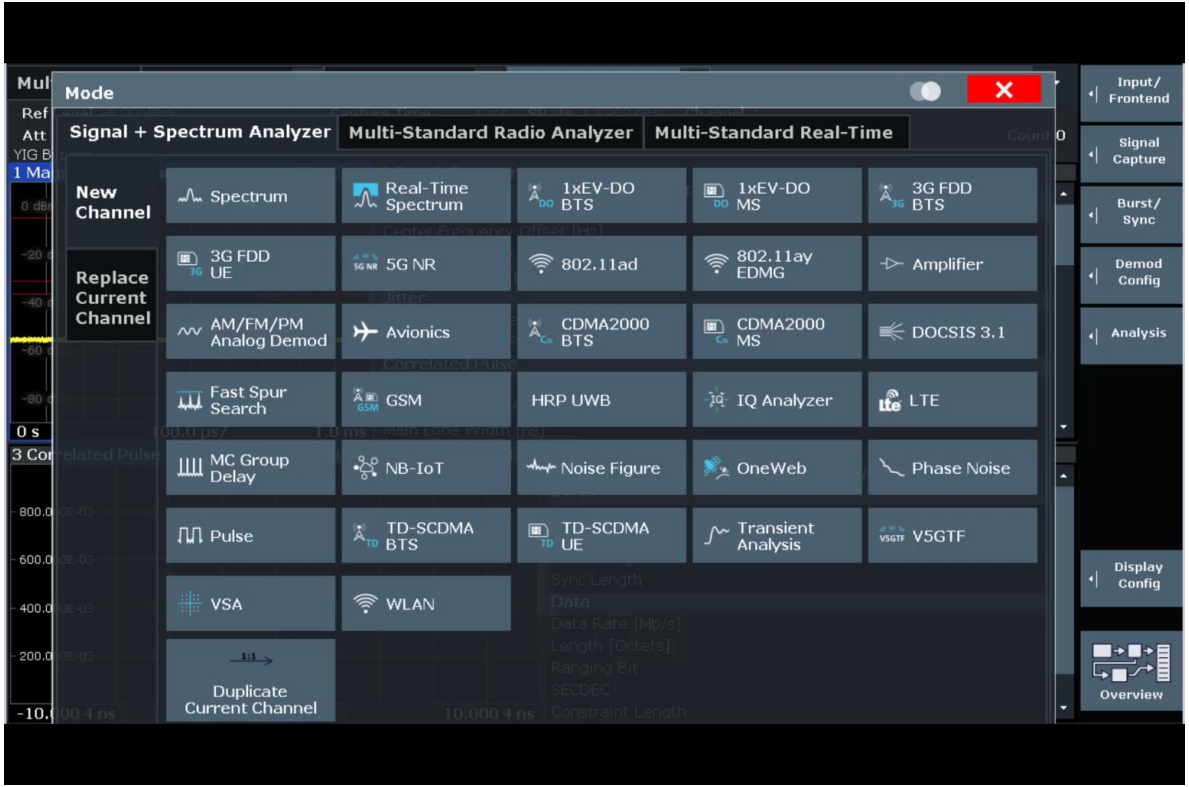
Amplifier measurements

Phase noise measurement

PRACTICAL DEMO WITH R&S®SMW AND R&S®FSW



PRACTICAL DEMO WITH R&S®SMW AND R&S®FSW



R&S OSCILLOSCOPES FOR UWB SIGNAL ANALYSIS

Advanced Trigger Capability

- Advanced detection of pulses/ pulse sequences
- All trigger types up to full bandwidth

Bandwidth up to 16 GHz

- Full coverage for all UWB channels
- Possibility to capture out-of-band emissions

Excellent RF performance

- Flat frequency response (e.g. +/- 0.25 dB for RTP)
- Powerful FFT for spectral measurements

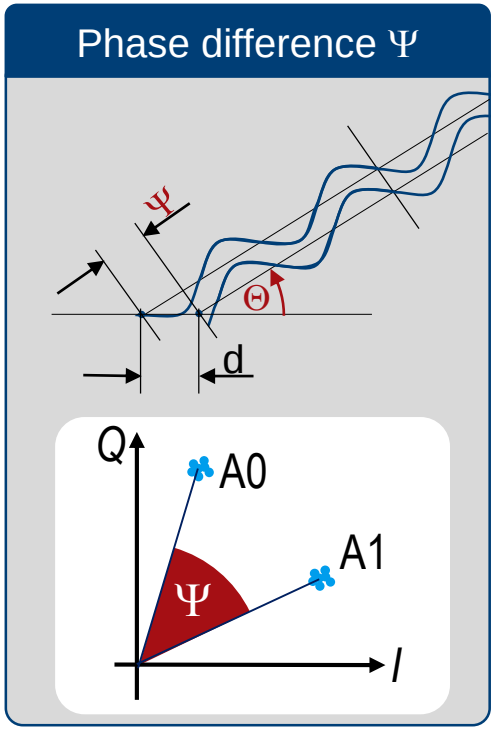
Up to 4 phase coherent channels

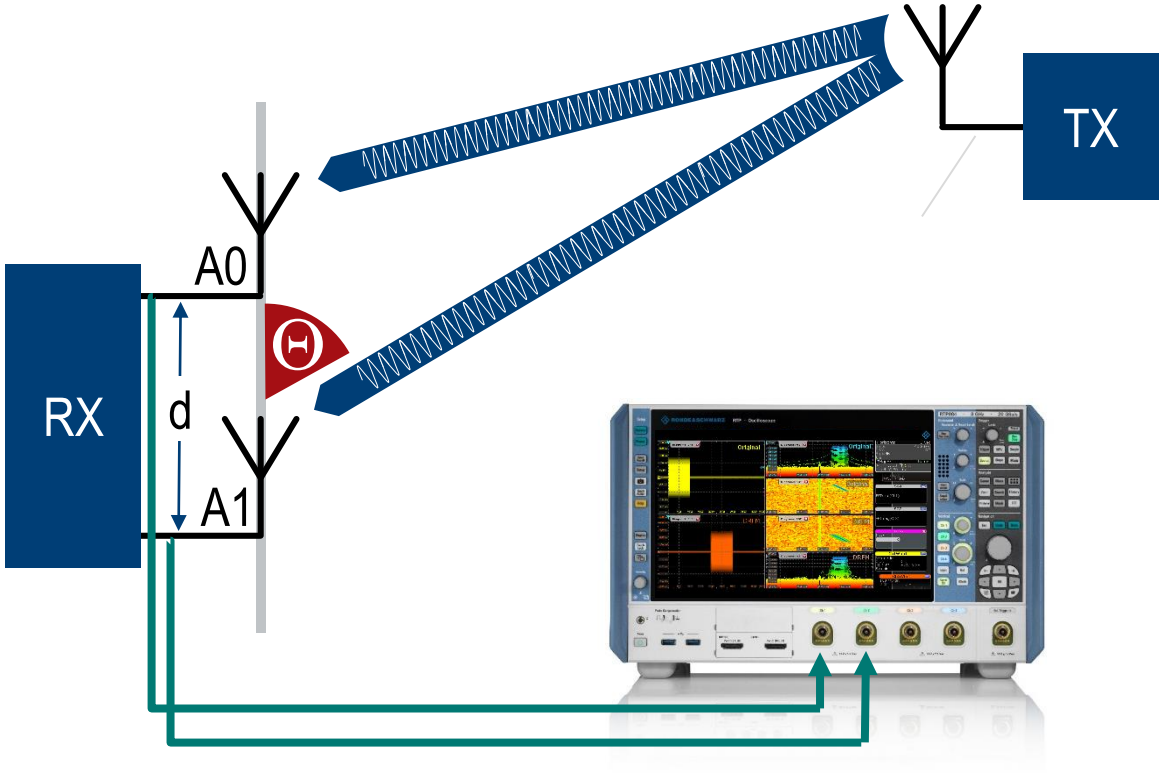
- Allows accurate phase difference measurements for AoA determination
- System-level debugging by combining multiple measurements

Vector signal analysis

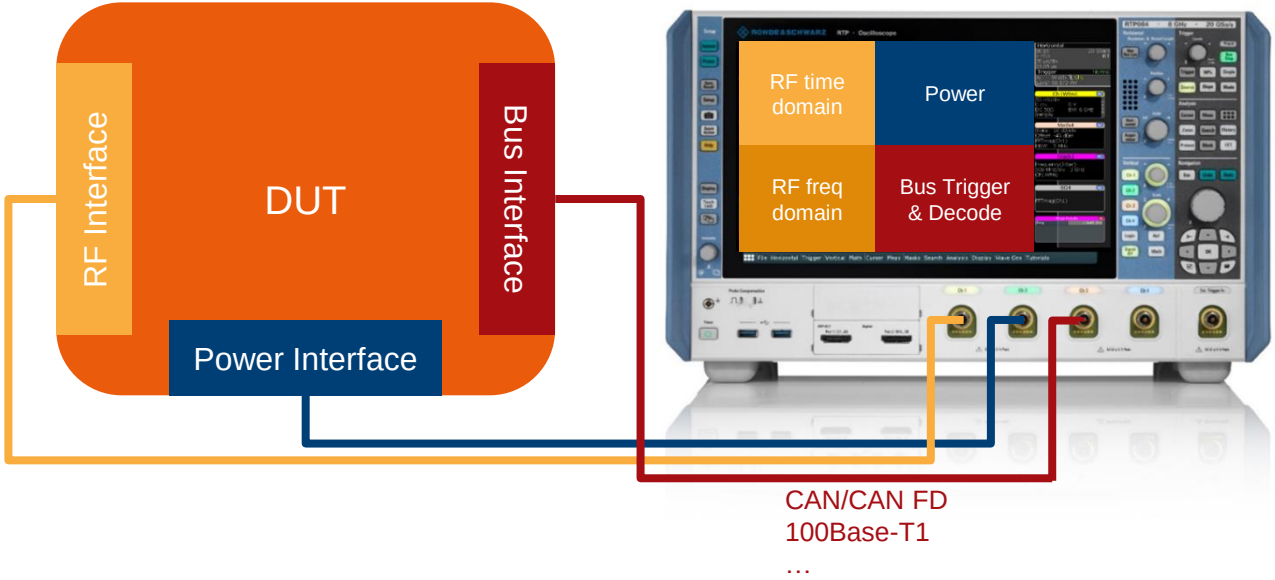
- Powerful R&S®VSE 2.0 software
- R&S®VSE-K149 UWB application

Angle of Arrival (AoA) estimation based on phase difference





MULTI-DOMAIN ANALYSIS FOR SYSTEM-LEVEL DEBUGGING



System-level Debugging

- Combine multiple measurements from different DUT interfaces on the same screen
- Look for possible correlations to determine causes of signal anomalies

TEST SOLUTIONS FOR R&D AND PRODUCTION

- UWB Non-signaling Tests including ToF Measurements
  - R&S®CMP200 radio communication tester

R&S ONE-BOX TEST SOLUTION FOR UWB

CMP200 General Features

- 1xVSA + 1xARB
- Analyzer Frequency Range 4 to 20GHz
- Generator Frequency Range 6 to 20GHz
- 1GHz Bandwidth, 3x Ports

UWB TX measurements

- HRP UWB PHY measurements
  (based on IEEE 802.15.4-2015 Chapter 16)
- Bandgroup 2: 6.5 to 9.5 GHz

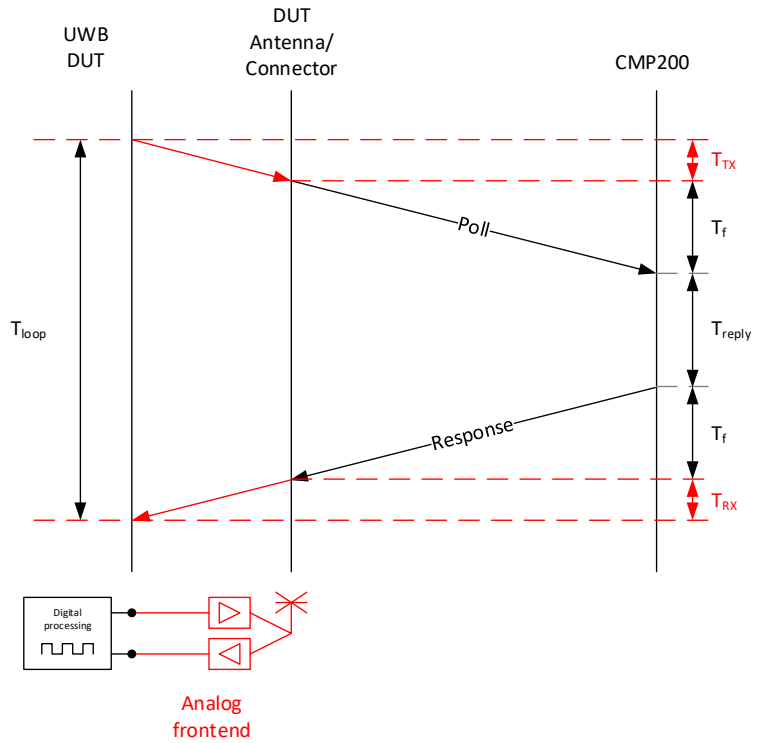
General purpose(GPRF) Generator

- ARB generator function; replay of predefined waveforms / Chipset specific, -90dBm
- CW signals

General purpose(GPRF) TX measurements

- IQ vs Slot
- FFT Spectrum Analyzer
- IQ Recorder
- Power measurements

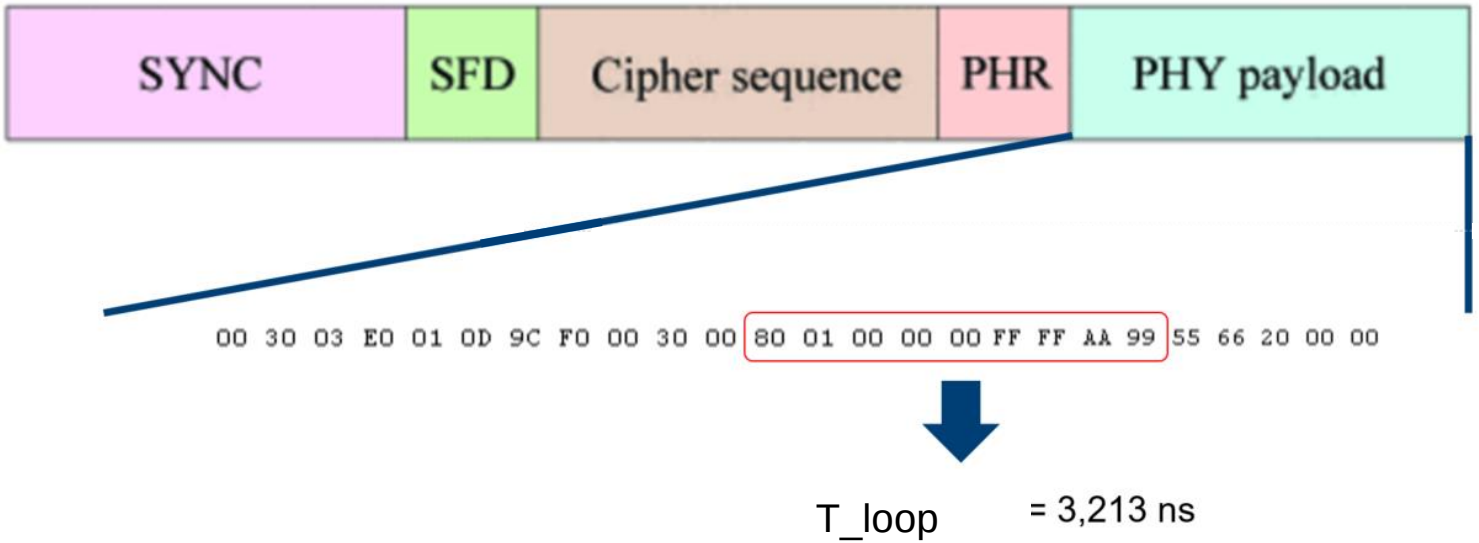
DUT INITIATED CALIBRATION



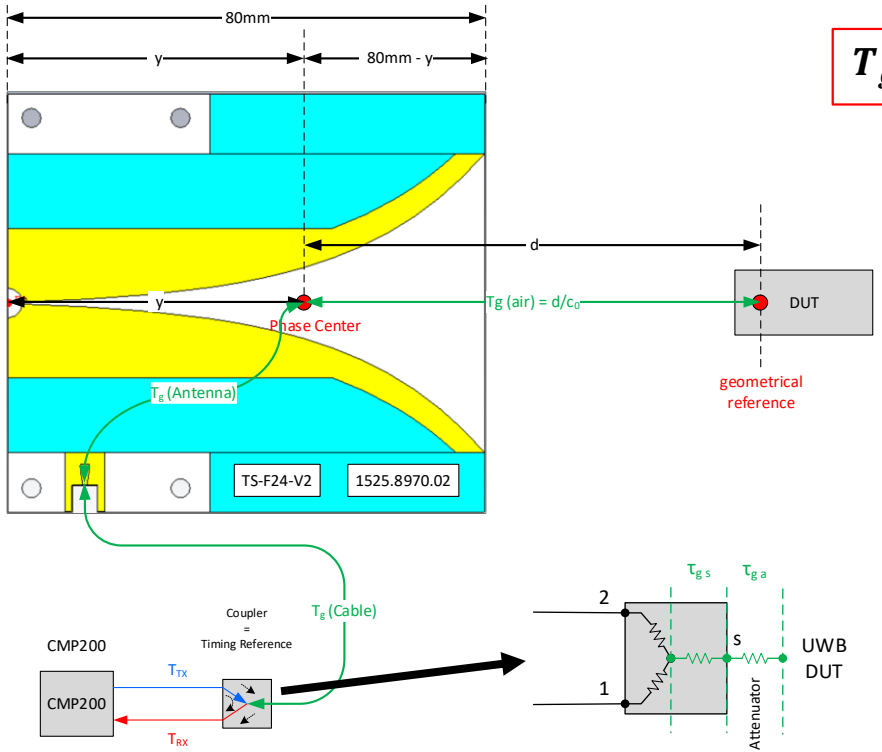
- DUT sends poll packet
- CMP200 responds
- CMP200 measures T_{Reply} (high accuracy ps range)
- Clock Error / Frequency Error is measured as well. T_{loop} can be corrected accordingly

DATA DECODING

Decode payload into Bit stream and read out information needed for the Time-of-Flight procedure



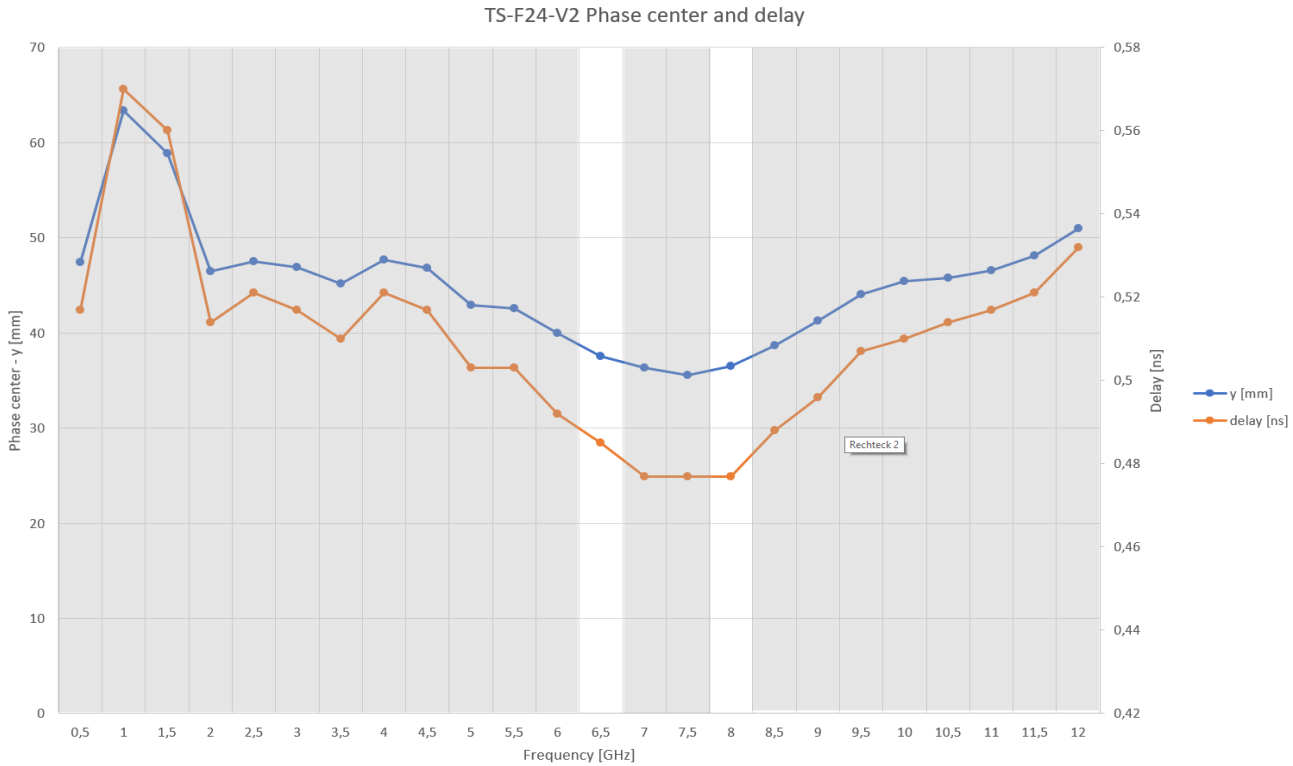
OTA SETUP WITH VIVALDI ANTENNA



$$T_g = T_{gs} + T_{ga} + T_{g\,(cable)} + T_{g\,(antenna)} + T_{g\,(air)}$$

T_{gs}	: 120ps
T_{ga}	: 100ps
$T_{g\,(cable)}$	: has to be known. Keep this cable short to minimize impact.
$T_{g\,(antenna)}$	: 483ps
d	: distance from antenna phase center (right edge -43mmm) to DUT
c_0	: speed of light, 299.792.458 m/s

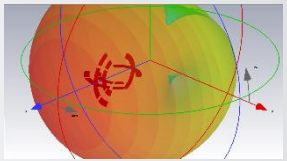
FREQUENCY INFLUENCE ON PHASE CENTER



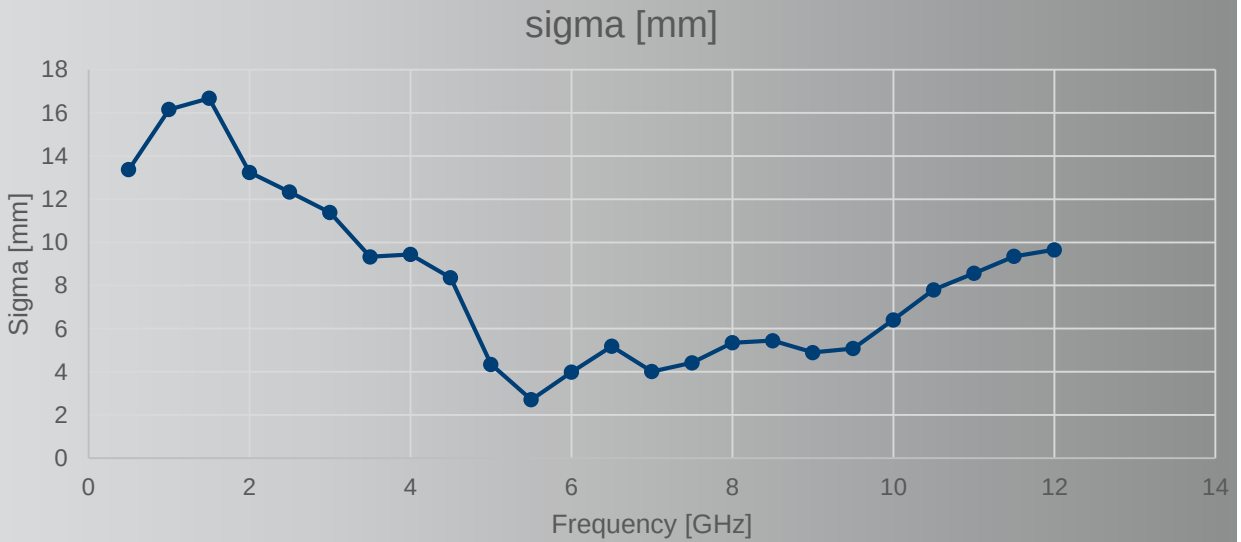
- Phase Center difference has not much impact if we only look at the important channels.
- We took the average for our calculation.

SIGMA OF PHASE CENTER

- Sigma describes the uncertainty of the phase center in terms of a radius of a sphere



- Valid for +/- 15° from boresight



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CONCLUSIONS

- Digitalization is a key driver for the next generation of vehicle access. UWB is implemented in all major new smartphones, and enables multitude applications.
- UWB HRP is transitioning from lab to mass production. Standardization and interoperability is ensured via IEEE, FiRa and together with BLE by the Car Connectivity Consortium.
- Testing requirements are defined in IEEE 802.15.4 with the specific enhancement IEEE 802.15.4z for e.g. secure communication.
- Signal Generators, Signal Analyzers and Oscilloscopes enable accurate UWB measurements dedicated for R&D applications.
- The CMP200 is a UWB test solution for R&D and production. It covers all the important test fields such as Tx, Rx, ToF and AoA measurements with state-of-the-art accuracy.
- Rohde & Schwarz collaborates with leading industry partners to provide excellent UWB test solutions ensuring consistent device-to-device performance based on IEEE 802.15.4z

http://www.rohde-schwarz.com/automotive
http://www.rohde-schwarz.com/wireless/UWB

EVERYTHING YOU NEED FOR UWB TESTING

UWB Signal Generation

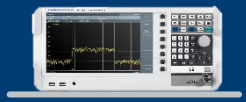
R&S®SMW200A

R&S®SMM100A

Embedded design and power

R&S®RTM3000

R&S®NGM200



R&S®FPC1500

R&S®FSW26
with B1200 / B2001/ K149

R&S®RTP134/164

UWB Spectrum & signal analysis

R&S®CMP200

R&S®CMQ200/500

R&S®TS7124

UWB non-signaling tests incl. ToF

Automotive

TEST IT. TRUST IT.