Demystifying Next Generation UWB

Key features, applications and test solutions

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ROHDE&SCHWARZ

Make ideas real

Impulse radio ultra-wideband (IR-UWB)
Standardization by IEEE and driven by a strong ecosystem

2007
IEEE 802.15.4a
High-Rate Pulse Repetition HRP UWB

2020
IEEE 802.15.4z
HRP UWB enhanced ranging

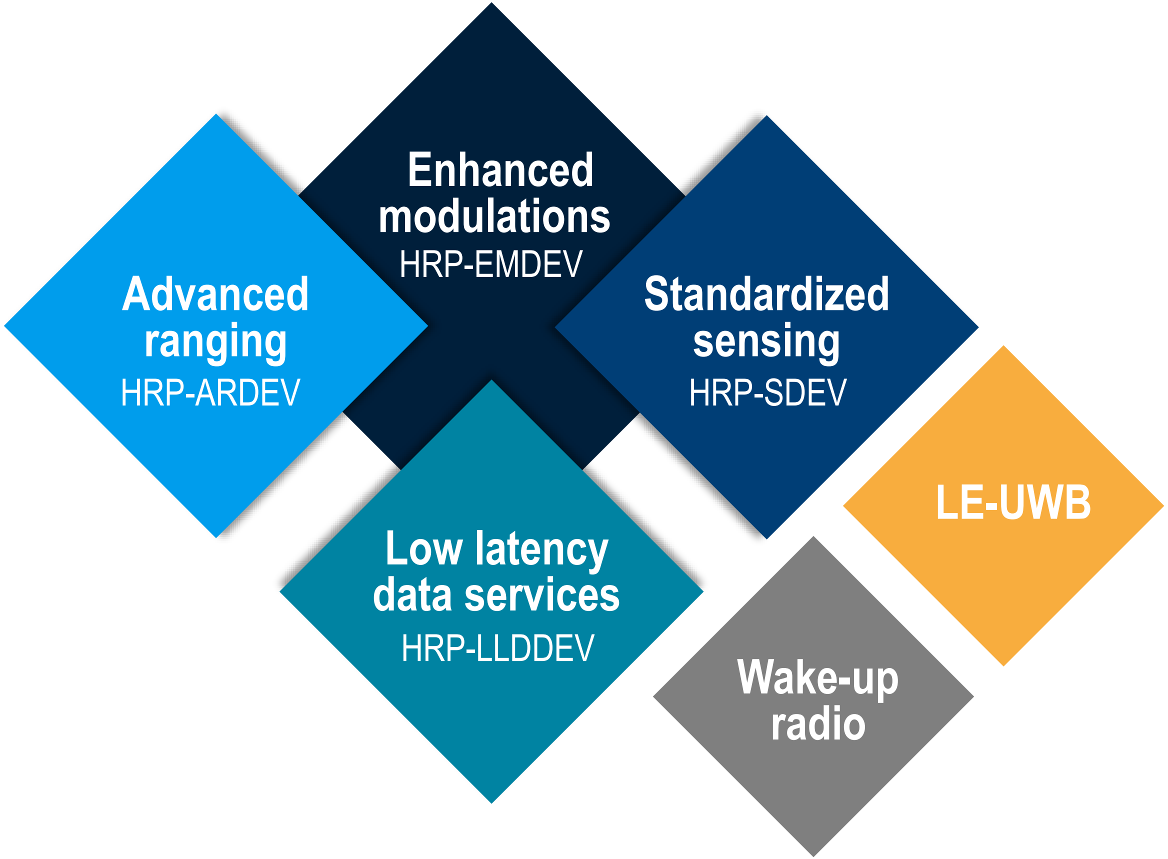
2025
IEEE 802.15.4ab
Next generation UWB

Towards the ultimate mobile user experience empowered by the next generation of UWB

Targets of IEEE 802.15.4ab task group:

- Optimized ranging performance
- New data transfer capability
- Standardized sensing capabilities
- Improved interference avoidance

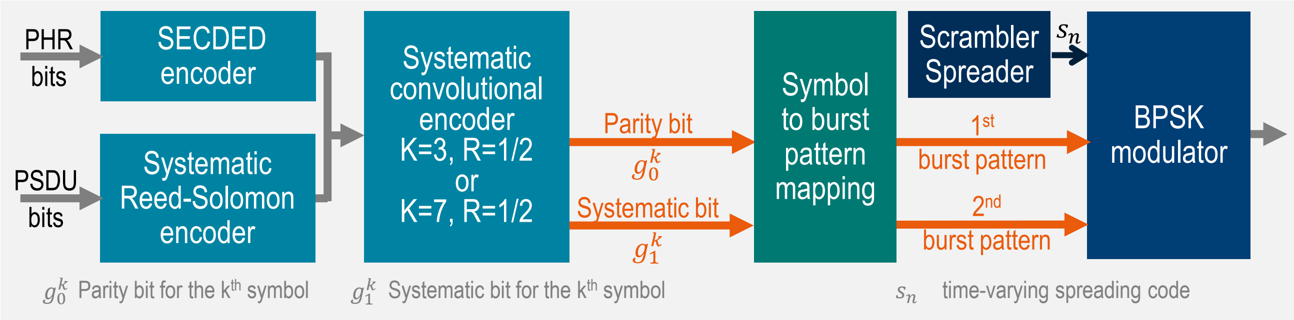
Enhanced Ultra Wideband (UWB) – IEEE 802.15.4ab



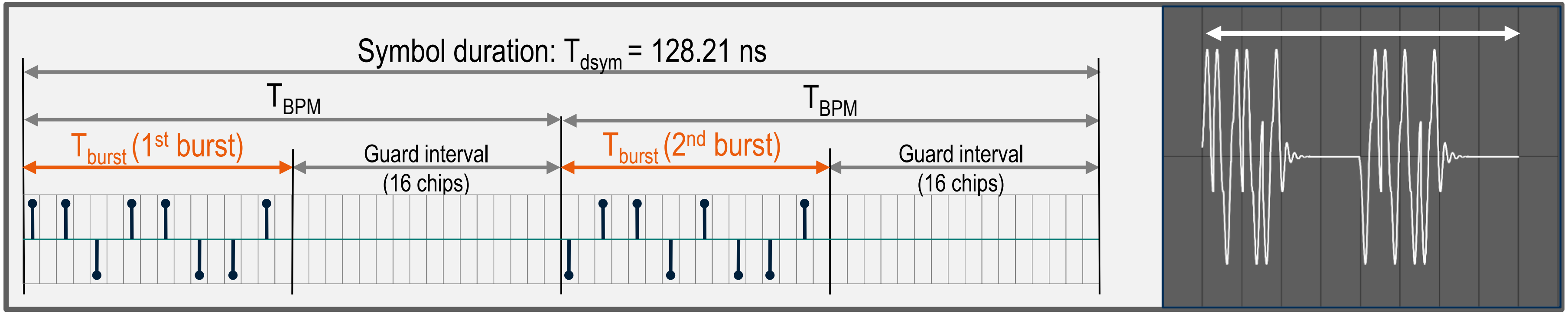
HRP-EMDEV

ENHANCED MODULATION

Short recap on 802.15.4z HPRF modulation



Constraint length (CL)	PHR bitrate	PSDU bitrate
CL3	3.9 Mbps	6.8 Mbps
CL7	7.8 Mbps	7.8 Mbps

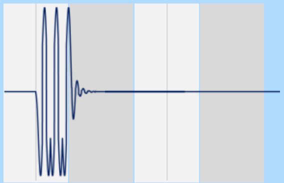


Enhanced modulation for connectivity improvements

Improved link budget and/or reduced air-time, low-power low-latency streaming, higher data-rate streaming allowing at least 50 Mbps of throughput

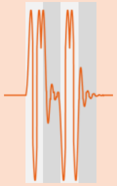
HRP-ERDEV (BPRF)

DRBMLP/HP
Symbol duration: 128 ns
Data rate: 6.8 Mbps
Coding: CL3
PRF_{PEAK}: 499.2 MHz
PRF_{MEAN}: 62.4 MHz

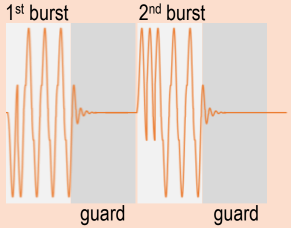


HRP-ERDEV (HPRF)

High data rate – low latency

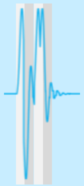


DRHM_31p2
Symbol duration: 32 ns
Data rate: 27.2/31.2 Mbps
Coding: CL3/CL7, (LDPC)
PRF_{PEAK}: 499.2 MHz
PRF_{MEAN}: 249.6 MHz



DRHM_7p8
Symbol duration: 128 ns
Data rate: 6.8/7.8 Mbps
Coding: CL3/CL7, (LDPC)
PRF_{PEAK}: 249.6 MHz
PRF_{MEAN}: 124.8 MHz

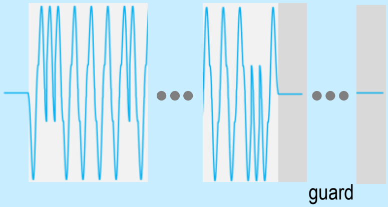
HRP-EMDEV (HPRF)



DRHM_62p4
Symbol duration: 16 ns
Data rate: 62.4 Mbps
Coding: CL7, (LDPC)
PRF_{PEAK}: 499.2 MHz
PRF_{MEAN}: 249.6 MHz

DRHM_124p8
Symbol duration: 8 ns
Data rate: 124.8 Mbps
Coding: CL7, (LDPC)
PRF_{PEAK}: 249.6 MHz
PRF_{MEAN}: 249.6 MHz

***BPSK modulation** – two bursts per symbol, two guard intervals*



DRHM_1p95
Symbol duration: 513 ns
Data rate: 1.95 Mbps
Coding: CL7, (LDPC)
PRF_{PEAK}: 249.6 MHz
PRF_{MEAN}: 124.8 MHz

Low data rate – Long range

Enhanced Ranging DEVices (ERDEV)

Enhanced Modulation DEVices EMDEV)

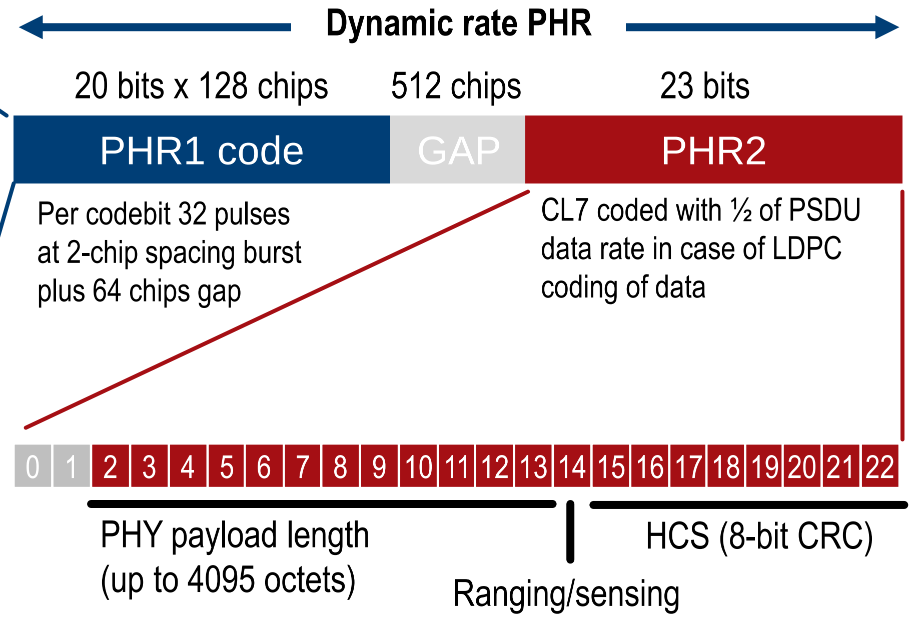
HRP-LLDDEV

LOW LATENCY DATA

Dynamic data mode enabled by PHR1 code and optional LDPC

Transmitter data rate and coding may be varied from packet to packet, depending on channel characteristics by selecting one data mode out of the supported, indicated by the PHR1 code as listed below

PHR1 Code	Coding	PHR2 data rate	PSDU data rate
0xFFFFF	LDPC	½ x 1.95	1.95
0x04CCC	CL7	1.95	1.95
0x01999	LDPC	½ x 7.80	7.80
0x070F0	CL7	7.80	7.80
0x025A5	LDPC	½ x 31.20	31.20
0x043C3	CL7	31.20	31.20
0x01696	LDPC	½ x 62.40	62.40
0x07F00	CL7	62.40	62.40
0x02A55	LDCP	½ x 124.80	124.80
0x04C33	CL7	124.80	124.80



R&S®SMW200A vector signal generator
The fine art of signal generation

Features

- One or two RF paths
- Frequencies up to 3, 6, 7.5, 12.75, 20, 31.8, 40, 44, 56 or 67 GHz
- Internal RF modulation bandwidth up to 2 GHz
- Up to 8 basebands with real time coder and ARB
- Support of all important digital standards
- Integrated fading section for channel emulation with up to 800 MHz fading bandwidth
- Support of all key MIMO fading scenarios
- Integrated GUI
- Configuration via touchscreen

The art of easy signal creation

Directly on instrument (internal)

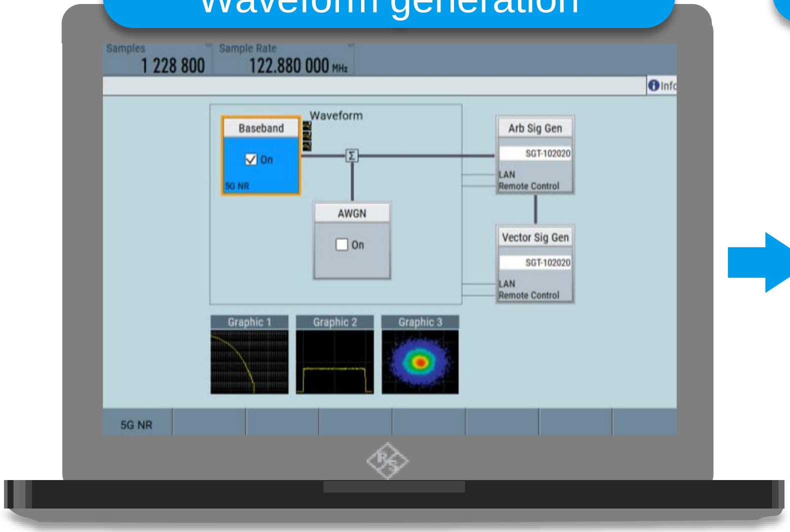
R&S®SMW200A

R&S®SMM100A

R&S®SMBV100B

Using **WinIQSIM2 PC software** (waveform playback)

Waveform generation



Waveform playback

R&S®SMW200A

R&S®SMM100A

R&S®SMBV100B

R&S®SMCV100B

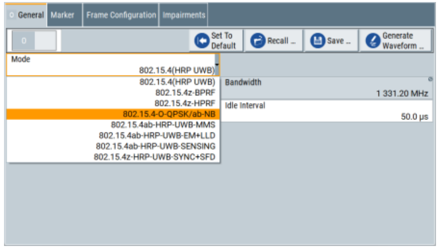
R&S®SFI100A

R&S®SGT100A

R&S®CMP200

R&S®PVT360A

UWB signal generation with R&S®SMW200A



Hardware configuration

- Wideband baseband main module
- Wideband baseband generator path A
- Baseband extension to 1 GHz
- RF path A (20 GHz)

Additionally, for 2 path version:

- Wideband baseband generator path B
- RF path B (20 GHz)

Signal creation software options

- HRP UWB option
  - BPRF, HPRF
- HRP UWB MMS option
  - Enhanced modulations
  - Low latency data
  - Multi-millisecond ranging
- HRP UWB sensing option
- IEEE 802.15.4 O-QPSK option

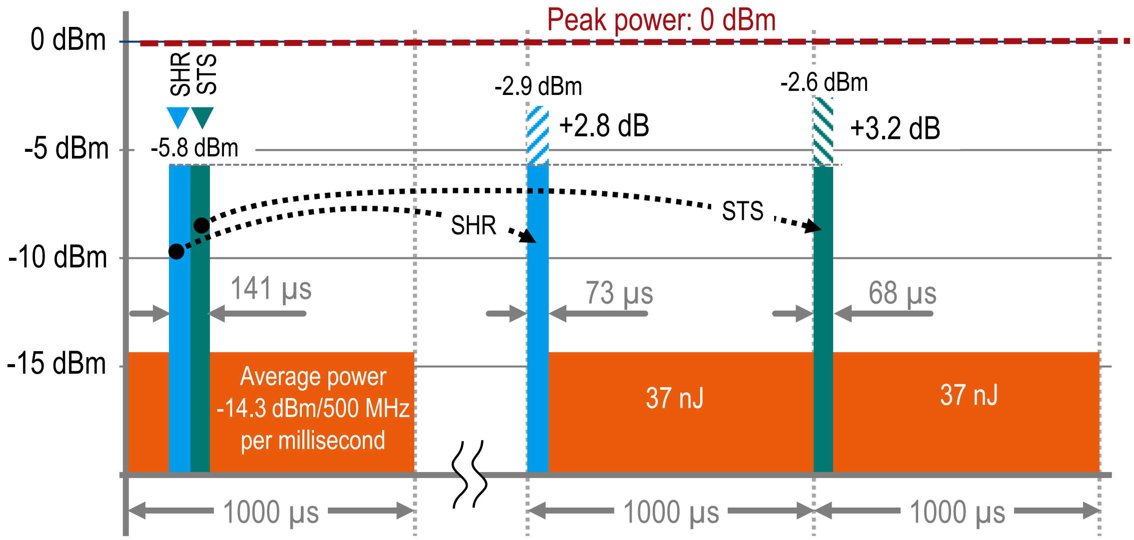
R&S®SMW200 Introduction Demo

HRP-ARDEV

ADVANCED RANGING

Improving the ranging performance by optimization of the allowed transmit power per millisecond slot

Example: Gain due to distribution of a SP3 packet over two millisecond slots



Transmit power is limited by the

- maximum **Peak Power** of 0 dBm
- **Power Spectrum Density** (PSD) of -41.3 dBm/MHz averaged over 1 ms, this corresponds for a 500 MHz channel to -14.3 dBm/ms or 37 nJ

Split of a UWB ranging packet in short fragments spanning N millisecond slots increases the energy budget to Nx 37 nJ

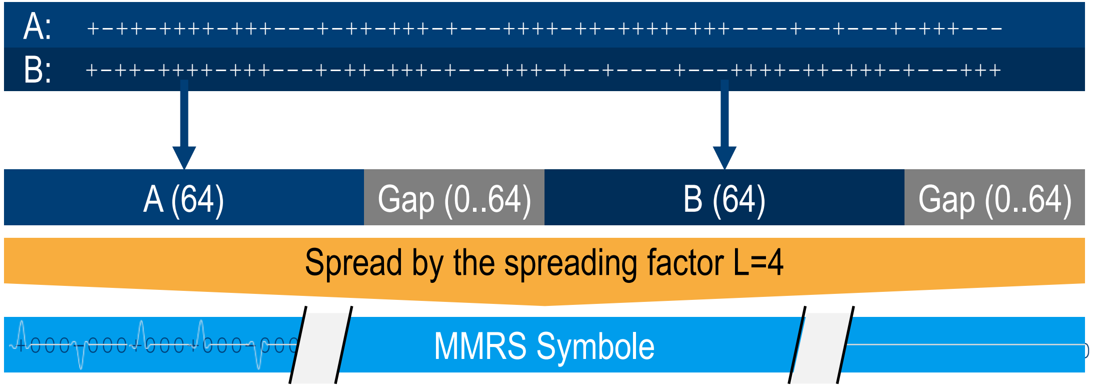
Moreover, it allows longer ranging pulse sequences to improve receiver sensitivity.

Ranging Sequence Fragment (RSF) consists of a repetition (32, 40, 48, 64, 128, or 256) of MMRS symbols

- Each RSF consists of a repetition (MSR: 32, 40, 48, 64, 128, or 256) of a selected **Multi-Millisecond Ranging Sequence (MMRS)** symbol.
- MMRS symbol is formed using code sequence (128) split in two halves, with an optional gap, inserted after both code halves, spread by the spreading factor L=4.
- Each RSF of a packet use the same MMRS symbol with the same MSR.

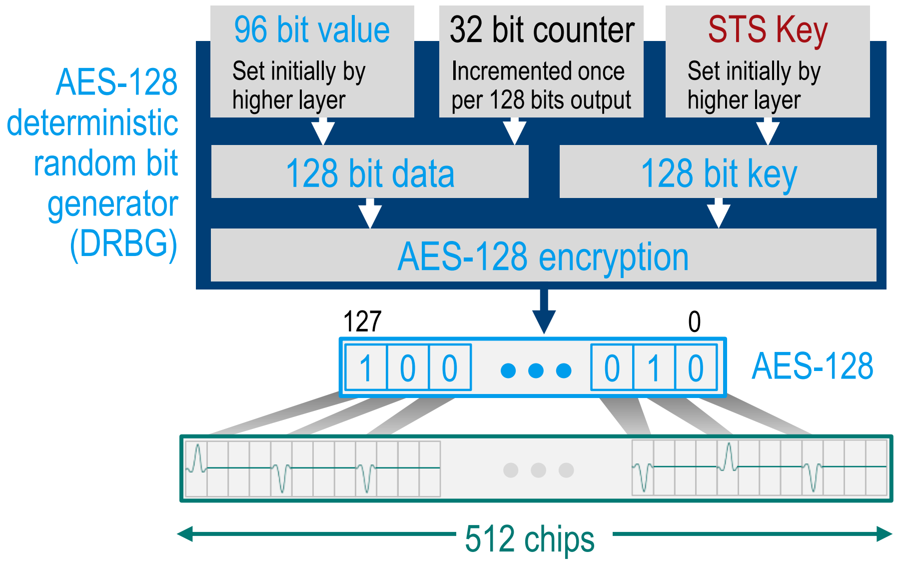
Select one out of 16 possible length-128 code sequences

(length-91 ternary codes, or the length-127 ternary codes may optionally be employed)



Note that a larger gap size leads a smoother spectrum which enables higher energy efficiency. Therefore, it is recommended to use a GAP size between 30 and 64, but a rather low MSR of 32 or 40 ⇨ Recommended RSF duration of around 60 µs to reduce also the chance of collision to other packets.

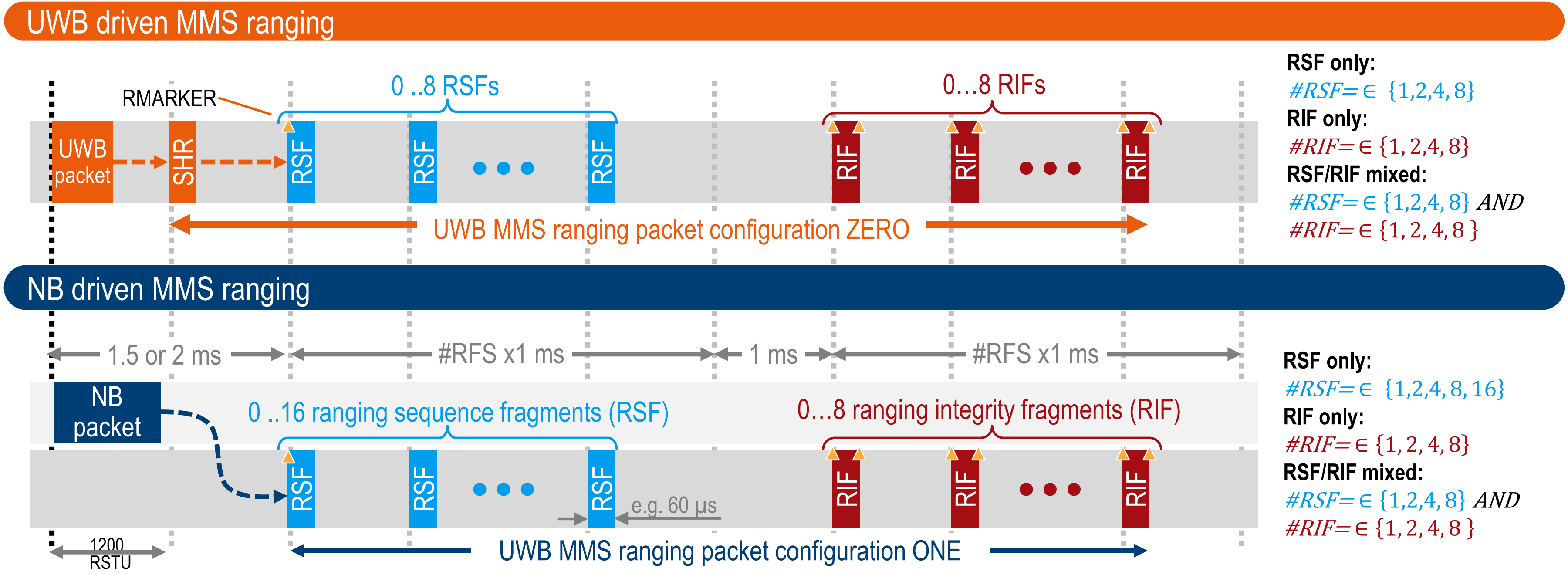
Ranging Integrity Fragment (RIF) based on a sequence of scrambled timestamp sequence (STS)



- A deterministic random bit generator (DRGB) is used to generate a non-repeating sequence across all the RIF fragments of the packet, and the pulses are spread by the spreading factor L=4.
- Each RIF in the packet shall have the same length from one of the following permitted lengths:
  32, 64, 128, or 256 in units of 512 chips.

Length	#Chips	RIF Duration
32	16384	32.8 µs
64	32768	65.6 µs
128	65536	131.3 µs
256	131072	262.6 µs

Multi-millisecond (MMS) supported configurations: NB or UWB driven: RSF only, RIF only or RSF/RIF mixed



UWB driven MMS ranging:

RSF only:
$\#RSF = \in \{1,2,4,8\}$

RIF only:
$\#RIF = \in \{1,2,4,8\}$

RSF/RIF mixed:
$\#RSF = \in \{1,2,4,8\}$ *AND*
$\#RIF = \in \{1,2,4,8\}$

NB driven MMS ranging:

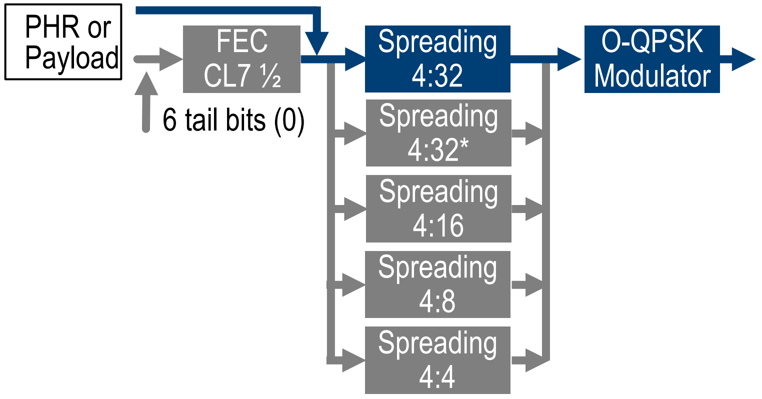
RSF only:
$\#RSF = \in \{1,2,4,8,16\}$

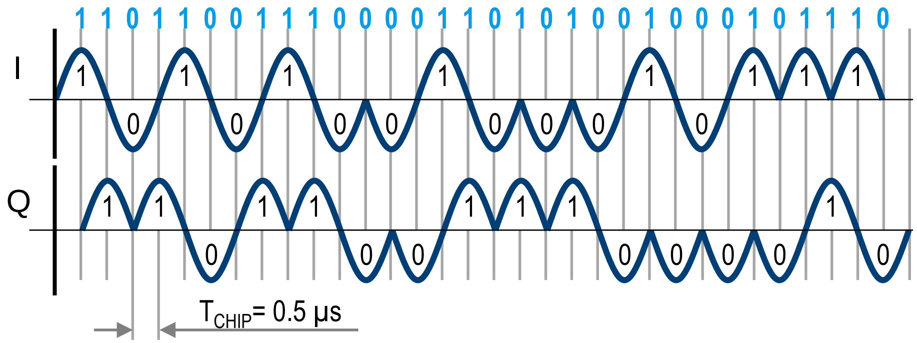
RIF only:
$\#RIF = \in \{1,2,4,8\}$

RSF/RIF mixed:
$\#RSF = \in \{1,2,4,8\}$ *AND*
$\#RIF = \in \{1,2,4,8\}$

RMARKER is defined as the peak of the first pulse in the first RSF in the packet; RIF RMARKERs are defined for each RIF fragment, as the peak of the first/last pulse in the RIF

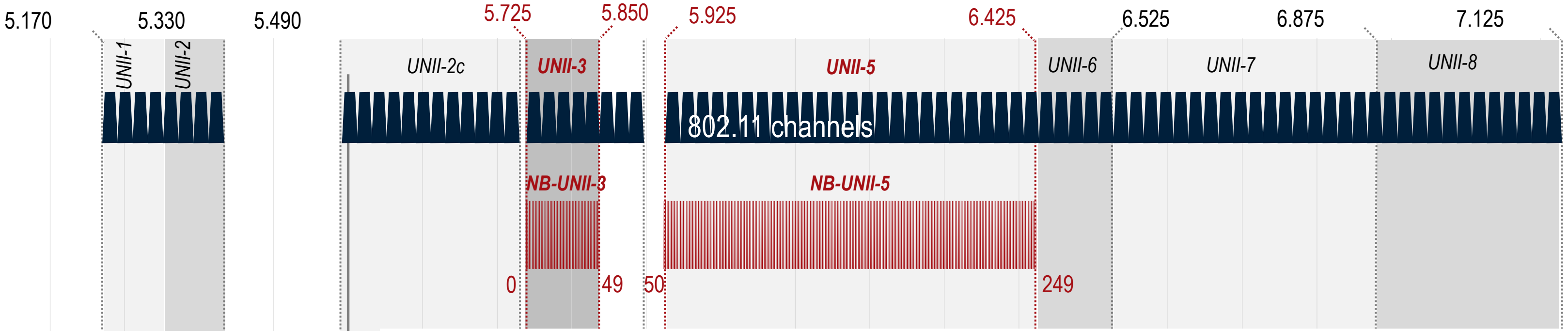
Narrow-band channel: Spreading and O-QPSK modulation





Config #	SHR			PHR			Payload			Duration (min Poll)	Mandatory optional
	SYNCH	SFD	Spreading	FEC	Symbols	Spreading	FEC	Spreading	Rate		
1	**8**	**2**	**32**	**No**	**2**	**32**	**No**	**32**	**250 kbps**	**544 µs**	**M**
2	4	2	32	Yes	7	8	Yes	8	500 kbps	312 µs	O
3	4	2	32	Yes	7	8	No	8	1000 kbps	212 µs	O
4	8	2	32	Yes	7	16	Yes	16	250 kbps	592 µs	O
5	4	2	32	Yes	7	4	Yes	4	1000 kbps	204 µs	O
6	8	2	32	No	2	32*	No	32*	250 kbps	544 µs	O
7	8	2	32	Yes	7	16	Yes	16	250 kbps	592 µs	O
8	4/8	2	32	See SFD pattern to select configuration 1..5					varies	varies	O

Up to 250 possible NB channels in UNII-3 and UNII-5



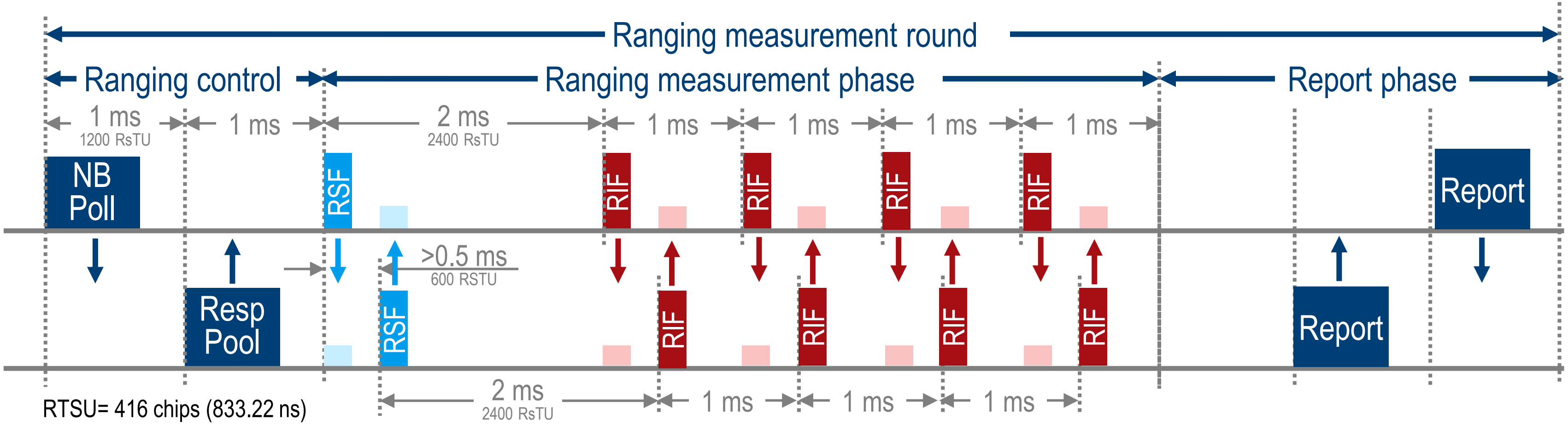
$f_n = 5726.25\ \mathrm{MHz} + \mathrm{k} \times 2.5\ \mathrm{MHz},\ (0 \leq \mathrm{k} \leq 49)$, in the UNII-3 band, and

$f_n = 5926.25\ \mathrm{MHz} + (k - 50) \times 2.5\ \mathrm{MHz},\ (50 \leq \mathrm{k} \leq 249)$, in the UNII-5 band.

- If LBT is required before a transmission, either for regulatory reasons or as a coexistence mechanism, then the device shall perform CCA before each O-QPSK PHY transmission.
- The NB channel selection/switching is performed independently by initiator and responder based on an exchanged NB channel list and a pseudo-random number generating (PRNG) using the actual ranging block index and seed value.

Interleaved narrowband assisted multi-millisecond ranging to improve link budget (long-range, high attenuation)

A new ranging scheme designed to overcome the sensitivity bottleneck imposed by the very low transmit level permitted by regulation in the case of long-range line-of-sight and short-range highly attenuated first path.



RTSU= 416 chips (833.22 ns)

R&S®SMW200 / CMP200 Demo about MMS

Ready for the future UWB testing
with the best-in-class test solution based on R&S®CMP200

FIRA CERTIFIED

FAST

AUTOMATED

VALIDATED

PRECISE

- Fully validated for FiRa Physical Layer Certification
- Supports physical security testing, new NRMSE and CCC 3.0
- Automated multi-DUT testing in manufacturing with smart channel and UWB head
- Comprehensive AoA test and validation solution with the R&S®ATS800R shielding chamber and a specifically designed positioner
- Ready to test NBA-MMS as defined in IEEE 802.15.4ab already today

FiRa 3.0 PHY layer certification highlights

- Covering now the results from the NRMSE tiger teamwork
- Couple of clarifications and adjustments e.g. good packet count
- Now including the validation of security certification test cases
- CCC related UWB physical layer test for CCC digital key 3.0

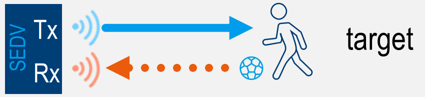
Fully automated FiRa validated PCTT test solution

HRP-SDEV

SENSING

Sensing use cases and nomenclature

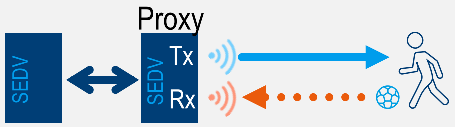
Mode 0: Mono-static



Mode 1: Bi-static

Mode 2: Multi-static

Mode 3: Sensing by Proxy



Sensing initiator:
an SDEV that initiates an RF sensing session with one or more other SDEVs.

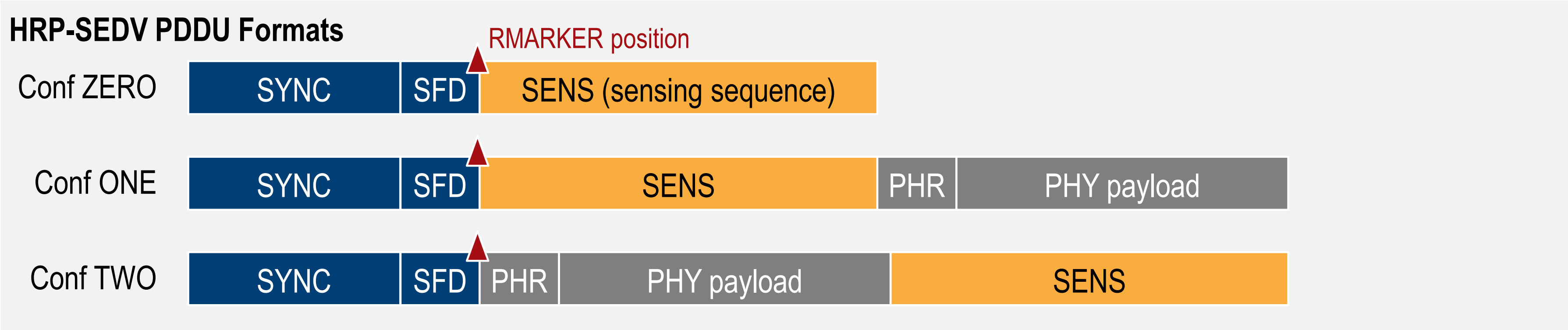
Sensing responder:
an SDEV that responds to a sensing initiator.

Sensing transmitter:
an SDEV that sends a PPDU to enable channel estimation for sensing purposes.

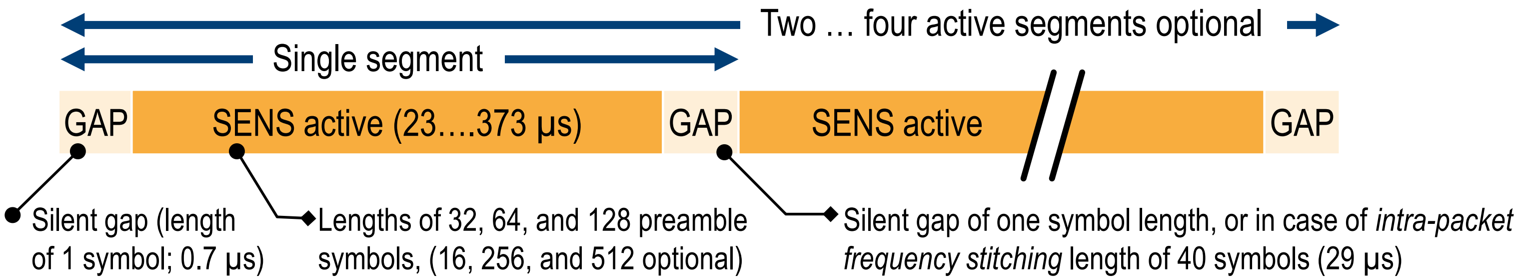
Sensing receiver:
an SDEV that receives a PPDU from the transmitter and performs channel estimation for sensing purposes.

Sensing requesting device:
an SDEV that requests the sensing CIR measurement report in a proxy application.

Sensing packet and SENS field formats

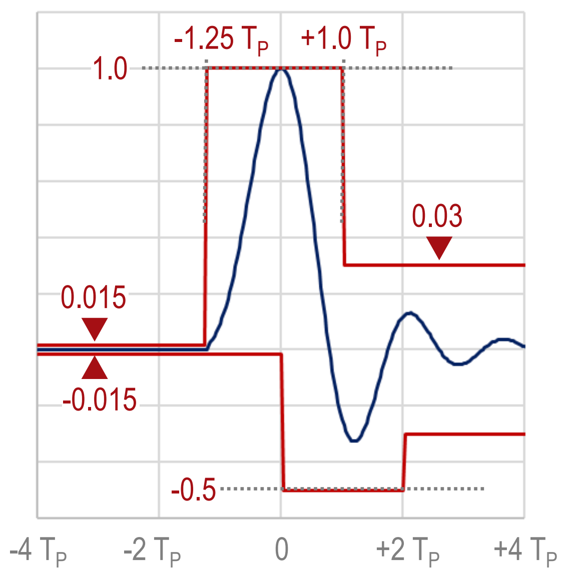


The SENS field constructed by same preamble code as used for the SYNC and SFD in the packet.
HPRF mode symbols using length 91 ternary codes (spreading L=4) shall be supported. Optional for conf ZERO length 127 code



New pulse shape for sensing applications with new requirements for baseband impulse response incl. mask

Ranging-pulse time domain mask

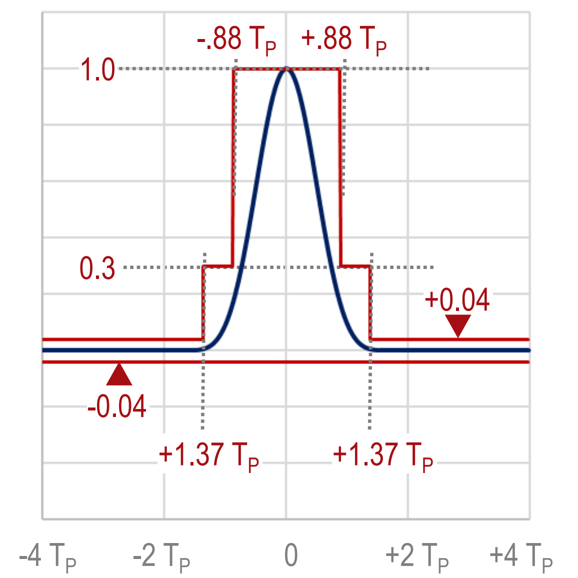


The new sensing pulse with both min. precursor/postcursor energy. A time-bounded Kaiser pulse (β = 10) that should be use for entire sensing packet.

$$r(t) = \begin{cases} \dfrac{I_0\left[\beta\sqrt{1-\left(\frac{2t}{L}\right)^2}\right]}{I_0[\beta]}, & |t| \leq \frac{L}{2} \\ 0, & |t| > \frac{L}{2} \end{cases}$$

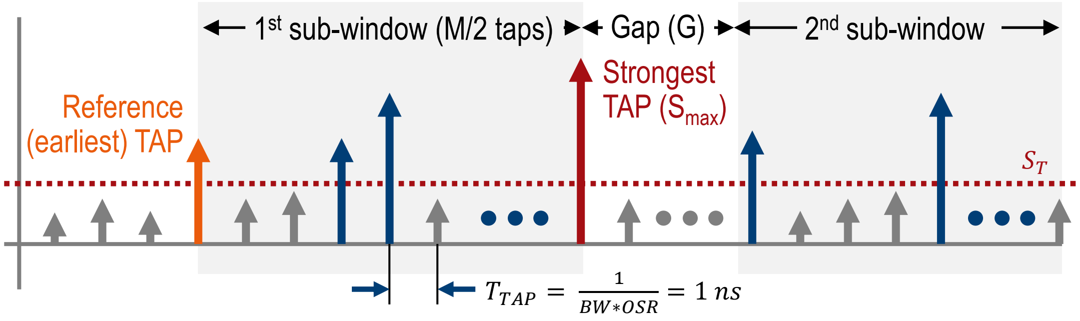
The transmitted pulse shape p(t) should be constrained by a symmetric time domain mask.

Sensing pulse time domain mask

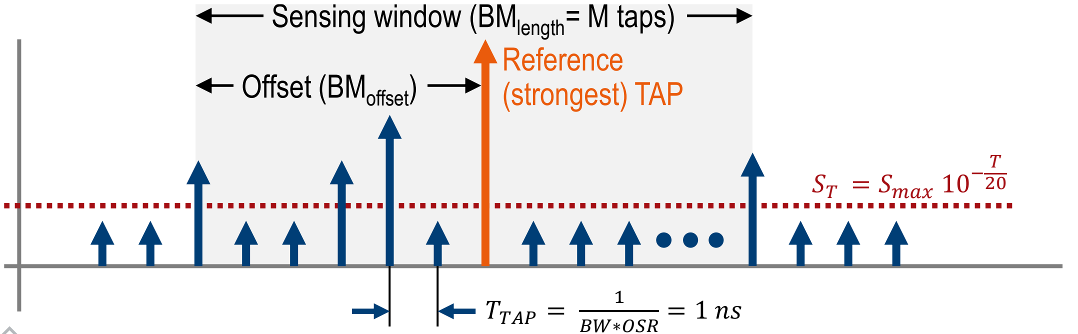


Sensing reports channel impulse response (CIR) per RX antenna and sensing segment

Example: Earliest Ref tap and two sub-windows with bitmal gap



Example: Strongest Ref tap and single sensing window



Optional target reports reporting RSSI, delay, velocity, or AoA of defined targets

$M = \{32, 64, 128, 256\}$

$S_{max} = Amplitude\ of\ strongest\ TAP$

$T = Amplitude\ threshold\ in\ dB$

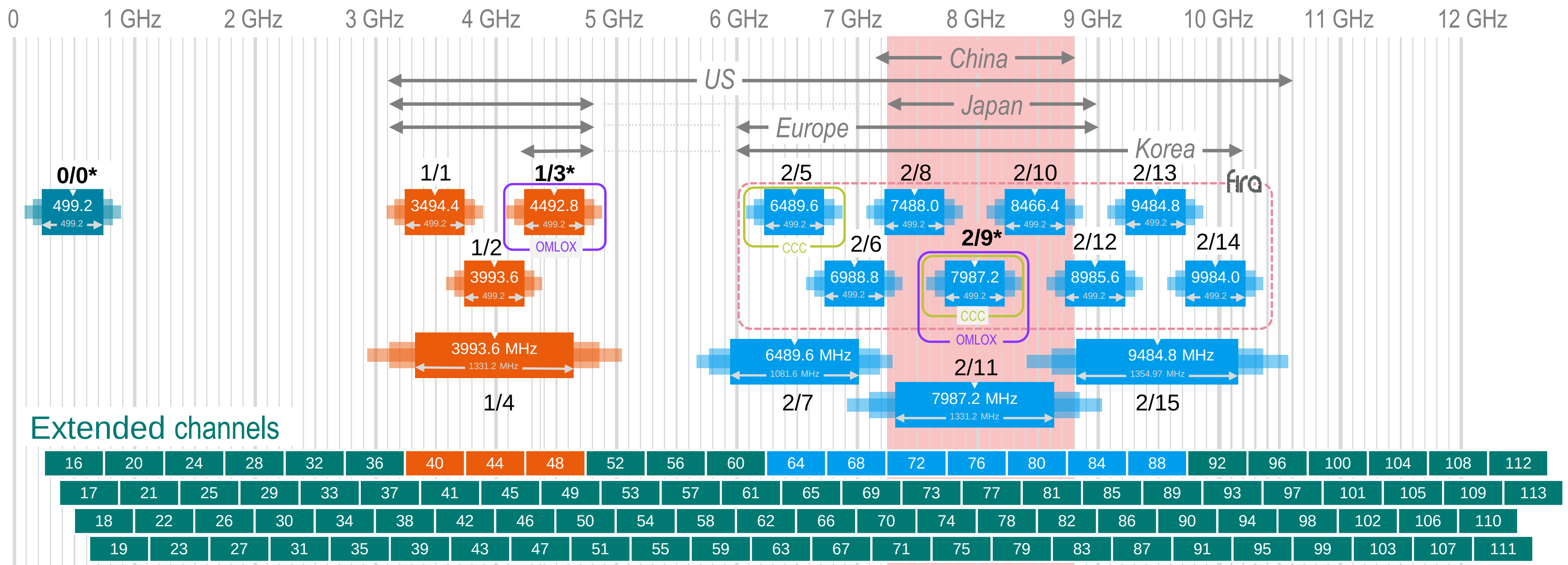
$S_T = Amplitude\ threshold$

$OSR = Over\ sampling\ rate$

$BW = Aggregated\ signal\ BW$

R&S®SMW200 Demo: UWB Sensing Packet generation

Mandatory, optional and extended channels



$$f_c = 499.2\text{ MHz} + (N_c - 16) \times 124.8\text{ MHz}$$

In addition to channels 0..15 defined for the three band groups, the HRP-EMDEV includes an optional capability to support a set of overlapping 499.2 MHz channels with 124.8 MHz spacing. While these are intended primarily to support the optional frequency stitching capability of the HRP-SDEV, they may offer some possibility to mitigate against interference between co-existent UWB networks where the participating devices all support the same additional channel bands.

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

R&S®ATS800R R&S®CMQ200 HS R&S®CMP200 UWB PHY Test Suite R&S®RTP+VSE R&S®SMM100A R&S®FSW26 R&S®TS7124

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