ULTRA-WIDEBAND & YOU!

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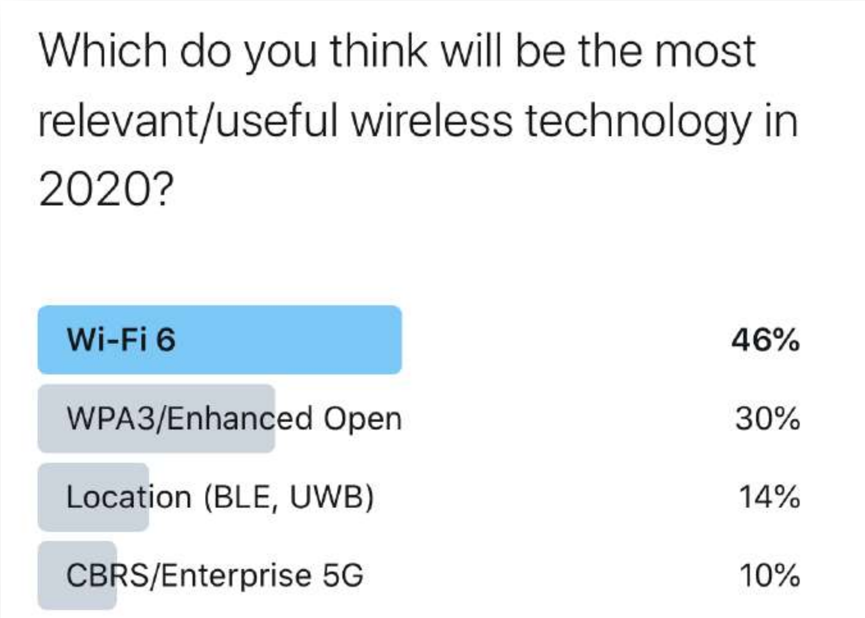
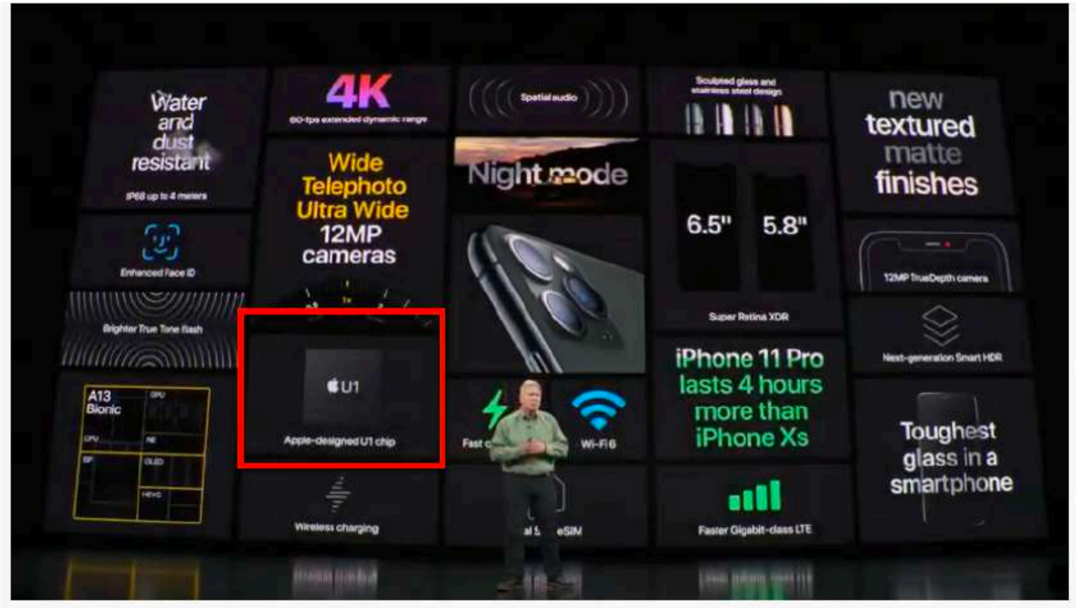
WHAT'S ON TAP FOR THE NEXT 30 MINUTES?

- What is Ultra-wideband (UWB)?
- How does UWB work?
- Use cases for UWB
- UWB product examples
- What's next for UWB?



APPLE U1 CHIP - IPHONE 11

- September 10, 2019 – Apple-designed U1 TMKA75 UWB chip in iPhone 11
  - Enhanced AirDrop
  - Improved directionality
  - UWB now in the hands of the consumer!
  - … but, what standard(s) does it comply to?!



Share. Find. Play. More precisely than ever.

Ultra Wideband technology comes to iPhone. The new Apple-designed U1 chip uses Ultra Wideband technology for spatial awareness — allowing iPhone 11 to precisely locate other U1-equipped Apple devices. Think GPS at the scale of your living room. So if you want to share a file with someone using AirDrop, just point your iPhone at theirs and they'll be first on the list.[3]

U1 module image from: https://www.techinsights.com/blog/apple-iphone-11-pro-max-teardown

WHAT IS ULTRA-WIDEBAND?

- It is ***not*** this:

https://www.verizonwireless.com/support/5g-mobile-faqs/

WHAT IS ULTRA-WIDEBAND?

- Ultra-wideband (UWB) is a pulse radio technology used in the IEEE 802.15.14 Low Rate Wireless Personal Area Network (LR-WPAN) standard*.
  - Definition: Radiation in which the 3dB bandwidth is at least 25% of its center frequency
  - Uses impulse radio with extremely short pulses (<2ns)
  - Has a very low power spectral density
  - Operates in the 3.1 to 10.6 GHz range
  - Uses very wide channels of at least 500 MHz
  - Data rates of up to 27 Mbps
- Enables measurement of the Time of Flight (ToF) of radio signals with sub-meter accuracy for ranging/location services and close-proximity communications.
  - *UWB is also specified in IEEE 802.15.6 Wireless Body Area Networks (WBANs)

WHAT PROBLEM IS UWB TRYING TO SOLVE?

- Ranging/Location Accuracy
  - Better accuracy and precision than Wi-Fi or traditional BLE for specific use cases
  - Radar applications/use cases

- Security
  - Operates in close proximity (a more secure alternative to NFC, vehicle access)
  - Relatively immune from interference and the effects of multipath
  - Protection from eavesdropping and relay attacks
    - More ideal for digital transactions and hands-free access control

HISTORY OF UWB

- UWB began it's modern life with short-range, high-speed data communications use cases
- In 2002 the FCC allowed UWB to communicate in an unlicensed fashion with strict spectral power density requirements in the 3.1 to 10.6 GHz bands.

Standard	Year	Data Rate	Band (GHz)	Modulation	PHY/Alliance	Use Case/benefits
802.15.3a	2002-2006	<480 Mbps	3.1-10.6	MB-OFDM	WiMedia	WirelessHD
802.15.4-2003	2003	Various	Various	Various	ZigBee, Thread etc	Low rate, low power
802.15.4a	2007	<27 Mbps	<1 & 3.1-10.6	BPM & BPSK	IR-UWB (later HRP)	Data, ranging
802.15.4-2011	2011	(Mainly editorial changes to roll-up amendments)				
802.15.4f	2012	<1 Mbps	6.3-9.2	PPM, OOK	LRP-UWB	Active RFID
802.15.4-2015	2015	<27 Mbps	<1 & 3.1-10.6	Various	HRP-UWB, LRP-UWB	Data, ranging, active RFID, access control
802.15.6	2012, 2016	<12.6 Mbps	3.1-9.7	OOK, DPSK, FM	IR-UWB, FM-UWB	Wireless Body Area Networks (WBANs)
802.15.4z	2018-	<27 Mbps	<1 & 3.1-10.6	Various	HRP-UWB & LRP-UWB; UWB Alliance, FiRa	Better ranging & security & power consumption

UWB BODIES

UWB Alliance

- Formed in December 2018
- "The mission of the UWB Alliance is to be the voice of the designers and manufacturers committed to establishing ultra wideband (UWB) technology as a significant open standards industry."
- Members include: Hyundai, Kia, Zebra, Decawave*, Alteros**, Novelda, Ubisense, Denso, Analog Devices, Apple, Samsung.

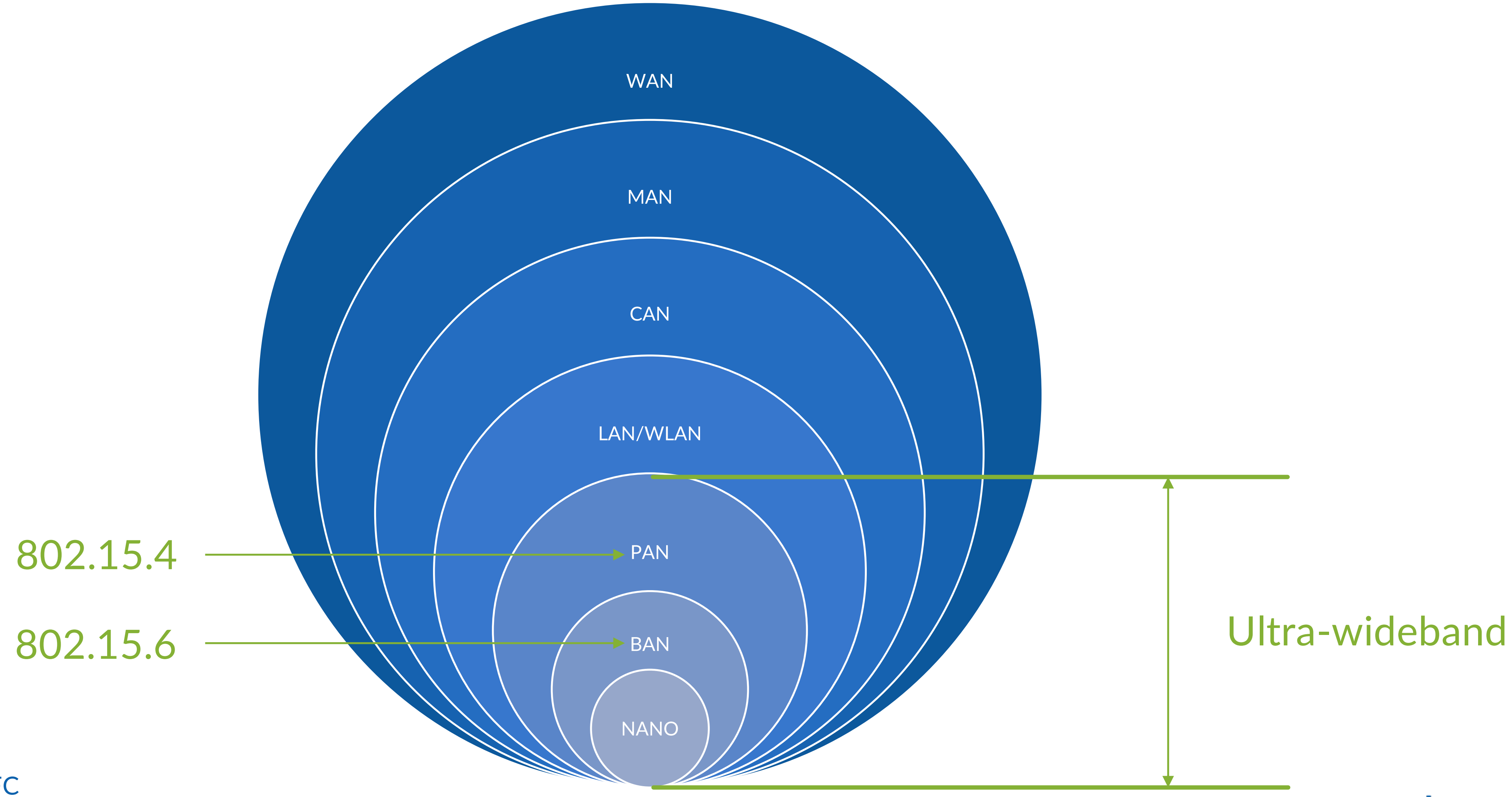
FiRa Consortium

- Formed 2019
- "Our vision is to provide seamless user experiences using the secured fine ranging and positioning capabilities of interoperable UWB technologies."
- Members include: NXP***, Samsung, Assa Abloy, Bosch, HID, Hyundai, Xiaomi, Tile, Denso.

HOW DOES UWB WORK?

- PHY – bands, channels, regulations, modulation
  - HRP-UWB
  - LRP-UWB
- MAC – channel access, frame format
- Ranging and Localization - comparison of methods

UWB NETWORK CLASSIFICATION BY SPATIAL SCOPE



Nanoscale e.g. NFC

UWB SPECTRUM

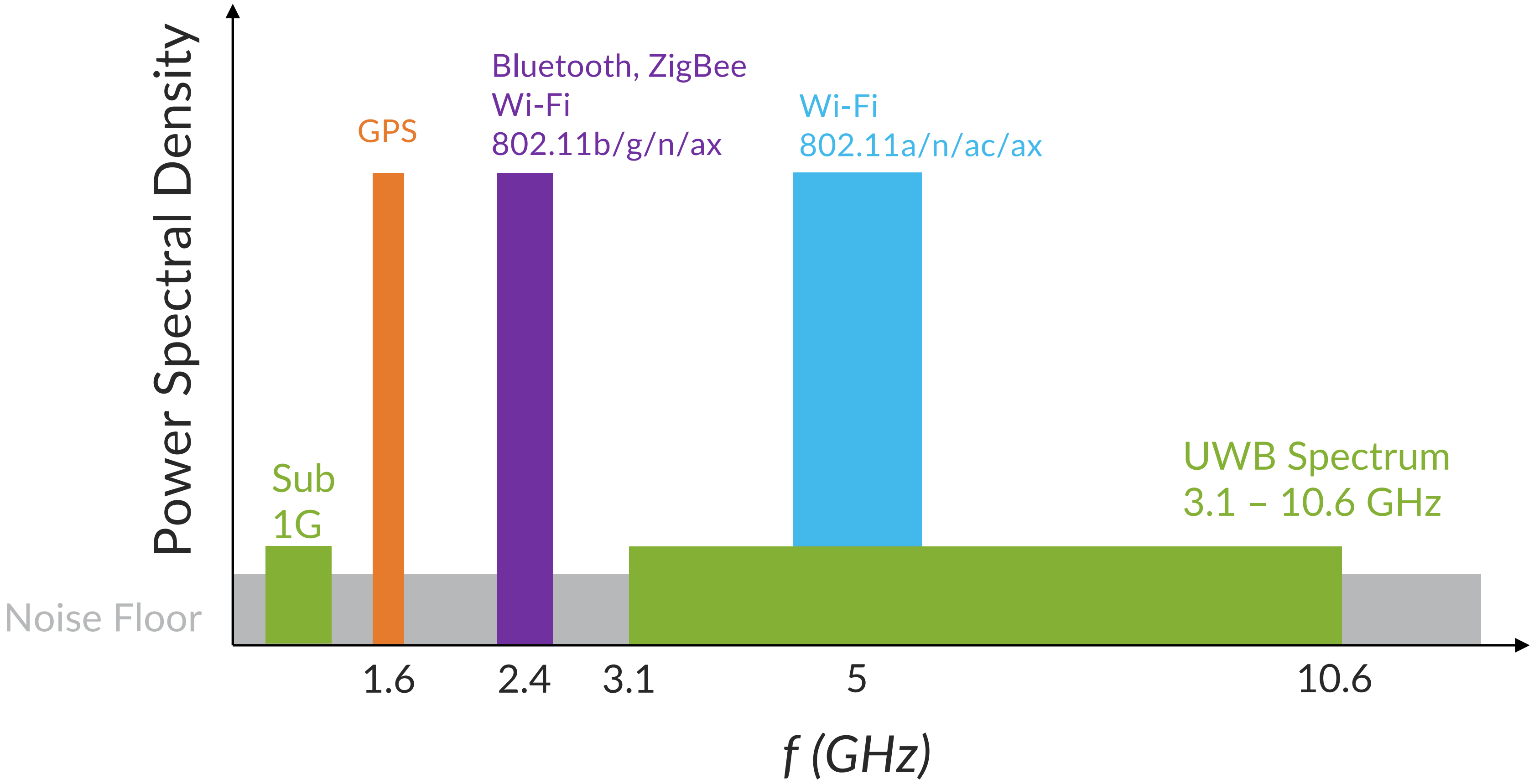
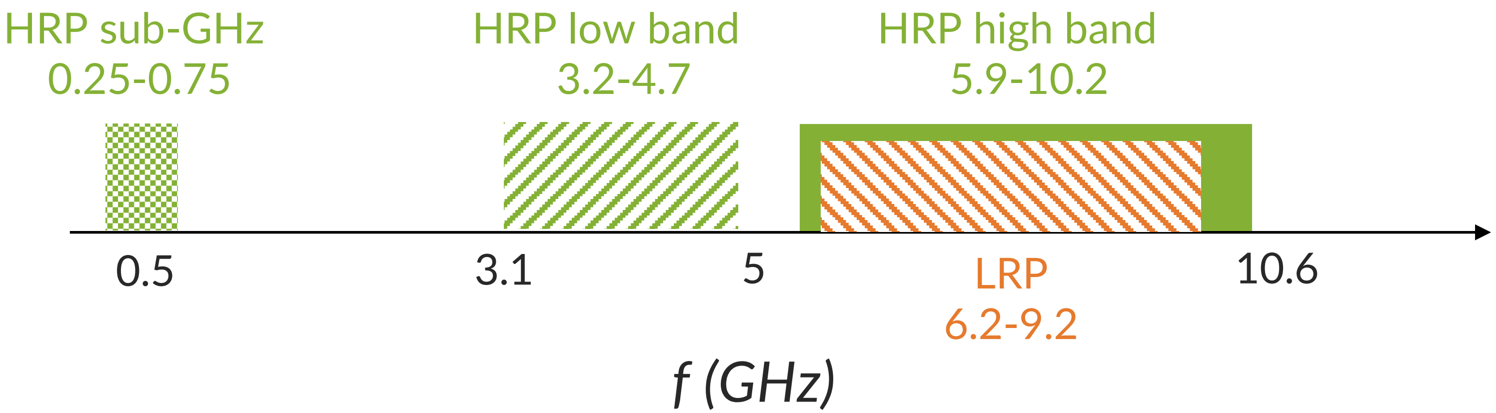


Chart modified from https://rtlsuwb.com

UWB HRP & LRP PHY BANDS



HRP = high-rate PRF (pulse repetition frequency)

LRP = low-rate PRF

UWB HRP & LRP BANDS & CHANNELS

PHY	Band Group	Channel /Band #	Center Frequency (MHz)	Bandwidth (MHz)	Mandatory/Optional
HRP	0	0	499.2	499.2	Mandatory below 1 GHz
	1	1	3494.4	499.2	Optional
		2	3993.6	499.2	Optional
		3	4492.8	499.2	Mandatory in low band
		4	3993.6	1331.2	Optional
	2	5	6489.6	499.2	Optional
		6	6988.8	499.2	Optional
		7	6489.6	1081.6	Optional
		8	7488.0	499.2	Optional
		9	7987.2	499.2	Mandatory in high band
		10	8486.4	499.2	Optional
		11	7987.2	1331.2	Optional
		12	8985.6	499.2	Optional
		13	9484.8	499.2	Optional
		14	9984.0	499.2	Optional
		15	9484.8	1354.97	Optional
LRP	n/a	0	6489.6	1730.56	Optional
		1	6988.8	2296.32	
		2	7987.2	2129.92	n/a

WHAT IS PULSE RADIO?

- Repeated transmissions short pulses of large bandwidth at a low power
  - Pulse repetition rates/frequency may be low or very high

- HRP-UWB – higher repetition rates

  enable data communications use cases

- LRP-UWB – lower repetition rates

  enable imaging and radar use cases

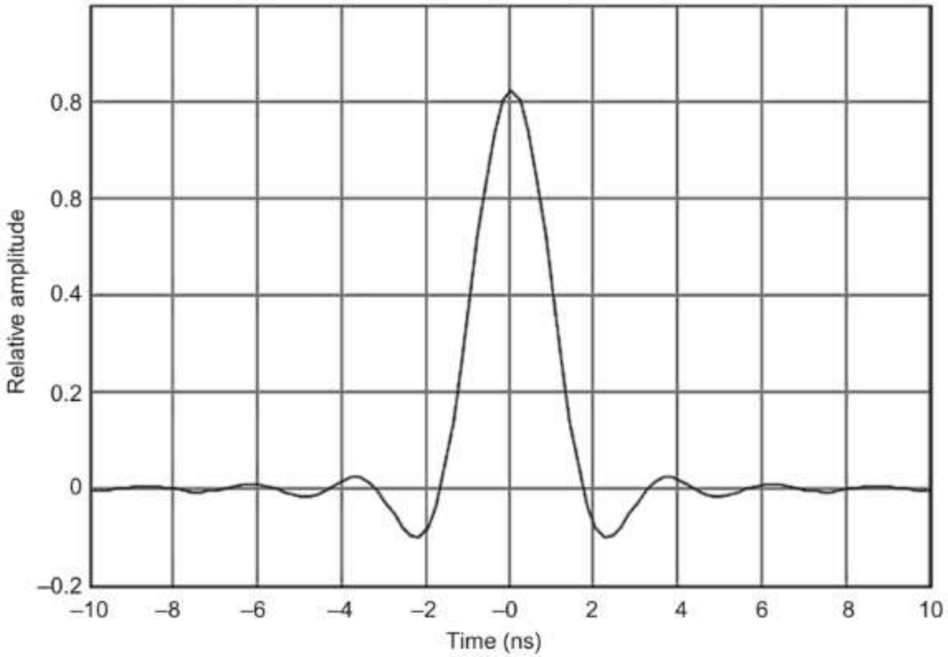


Image from: Short-range Wireless Communication, by Alan Bensky, 2019, pg. 355.

UWB RADIO REGULATIONS

- In 2002, the FCC approved of UWB in the 3.1 to 10.6 GHz range at a power spectral density of -41.3 dBm / MHz.

Country	License	Band (GHz)	Regulations
US	Unlicensed	3.1-10.6	Indoor only. Cannot be used in fixed outdoor environments.
Canada	Unlicensed	4.75-10.6	Indoor and handheld communications, vehicular radar, radar imaging applications.
Brazil	Unlicensed	3.1-10.6	Indoor communications, portable devices, medical imaging systems.
Europe	Unlicensed	3.1-10.6	Fixed indoor or mobile applications ETSI EN 302 065-1 Location tracking ETSI EN 302 065-2 (see UWB ETSI Location Tracking System Definitions next slide). Mitigation techniques required; and transmit power control required for road & rail applications.
Australia	Unlicensed	3.4-4.8, 6.0-8.4	In-ground UWB transmitters restricted to -62 dBm / MHz for 4.2-4.8 & 6.0-6.8 GHz. Must not be operated near radio-astronomy sites, nor onboard any aircraft, nor from any fixed outdoor location.
S. Korea	Unlicensed	3.1-4.8, 7.2-10.2	3.735-4.8 GHz band requires use of DAA or LDC mitigation techniques. Must not be used onboard aircraft, ships, or satellites.
Japan	Unlicensed	3.4-4.8, 7.25-10.25	3.4-4.2 GHz band requires a minimum data rate of 50 Mbps and the use of DAA mitigation techniques. 7.25-10.25 GHz band has neither of these restrictions.
Singapore	Unlicensed	3.4-9	Indoor only. 3.4-4.2 GHz restricted to -70 dBm / MHz. 4.2-4.8 GHz band requires the use of mitigation techniques.

Information from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4883398/pdf/sensors-16-00707.pdf &
https://www.decawave.com/sites/default/files/apr001_uwb_worldwide_regulations_summaryrev1.2.pdf

UWB ETSI LOCATION TRACKING SYSTEM DEFINITIONS

- ETSI EN 302 065-2 defines three types of location tracking systems:

System Type	Definition
LT1	6-9 GHz band for general location tracking of people and things. Can be used mobile (indoors or outdoors) or fixed (indoors only). Typically these are location tracking tags.
LT2	3.1-4.8 GHz band for people and object tracking as well as industrial applications at defined locations. Can be mobile or fixed, both indoor or outdoors. Operation at fixed sites and local coordination and authorization may be required to ensure there is no interference with other systems.
LAES	3.1-4.8 GHz band for locating and tracking personnel of the fire and emergency services; such as locating personnel within a building in an emergency situation.

- Transmitters of type LT1, LT2, and LAES are required to use mitigation techniques to prevent interference with other systems and devices.

Information from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4883398/pdf/sensors-16-00707.pdf & https://www.decawave.com/sites/default/files/apr001_uwb_worldwide_regulations_summaryrev1.2.pdf

UWB MITIGATION TECHNIQUES

Low Duty Cycle (LDC)

- Passive mitigation technique
- Limits the activity of the transmitter
- Maximum transmitter on time is 5 ms, and mean transmitter off time is at least 38 ms.

Detect And Avoid (DAA)

- Active Mitigation Technique
- Limits the Tx power, or defers transmission, if other transmissions are sensed (akin to Wi-Fi ED)
- Proximity to ‘victim’ system follows a zone model.
  - Different zones can have different threshold levels and corresponding Tx power levels.

HRP-UWB PHY SPECIFICATION

- The high rate pulse repetition frequency (HRP) UWB PHY consists of three frequency bands and is used for data communications up to 27 Mbps and precision two-way ranging/positioning.
- Each band has a mandatory channel support requirement, and channel bandwidths are typically 499.2 MHz but can be up to 1.3 GHz. Larger bandwidths have better multipath resistance and better ranging.
- Pulses are transmitted in bursts modulated by the polarity of the pulses (binary phase-shift keying, BPSK) and the position of the burst within a symbol period (burst position modulation, BPM).
    - Each symbol has two bits of information: one for the burst position, and one for the phase of the burst.
- Forward error correction (FEC) is performed using Reed-Solomon encoding on the PHY Protocol Data Unit (PPDU).
- Data rate is determined by number of pulses in a burst, preamble code length, modulation & coding rate, chips per burst & per symbol, symbol duration, and symbol rate – 0.11, 0.85, 6.81, and 27.24 Mbps.

HRP-UWB DATA RATES

Channel Number	Peak PRF MHz	Bandwidth MHz	Preamble Code Length	Modulation & Coding: Viterbi Rate	Modulation & Coding: RS Rate	Modulation & Coding: Overall FEC Rate	Data Symbol Structure: #Burst Positions per Symbol N_{burst}	Data Symbol Structure: # Hop Bursts N_{hop}	Data Symbol Structure: # Chips Per Burst N_{cpb}	Data Symbol Structure: #Chips Per Symbol	Data Symbol Structure: Burst Duration T_{burst} (ns)	Data Symbol Structure: Symbol Duration T_{dsym} (ns)	Data: Symbol Rate (MHz)	Data: Bit Rate Mb/s	Data: Mean PRF (MHz)
{0:3, 5:6, 8:10, 12:14}	499.2	499.2	31	0.5	0.87	0.44	32	8	128	4096	256.41	8205.13	0.12	0.11	15.60
	499.2	499.2	31	0.5	0.87	0.44	32	8	16	512	32.05	1025.64	0.98	0.85	15.60
	499.2	499.2	31	0.5	0.87	0.44	32	8	2	64	4.01	128.21	7.80	6.81	15.60
	499.2	499.2	31	1	0.87	0.87	32	8	1	32	2.00	64.10	15.60	27.24	15.60
{0:3, 5:6, 8:10, 12:14}	499.2	499.2	31	0.5	0.87	0.44	128	32	32	4096	64.10	8205.13	0.12	0.11	3.90
	499.2	499.2	31	0.5	0.87	0.44	128	32	4	512	8.01	1025.64	0.98	0.85	3.90
	499.2	499.2	31	0.5	0.87	0.44	128	32	2	256	4.01	512.82	1.95	1.70	3.90
	499.2	499.2	31	1	0.87	0.87	128	32	1	128	2.00	256.41	3.90	6.81	3.90
{0:3, 5:6, 8:10, 12:14}	499.2	499.2	127	0.5	0.87	0.44	8	2	512	4096	1025.64	8205.13	0.12	0.11	62.40
	499.2	499.2	127	0.5	0.87	0.44	8	2	64	512	128.21	1025.64	0.98	0.85	62.40
	499.2	499.2	127	0.5	0.87	0.44	8	2	8	64	16.03	128.21	7.80	6.81	62.40
	499.2	499.2	127	0.5	0.87	0.44	8	2	2	16	4.01	32.05	31.20	27.24	62.40
{4, 11}	499.2	1331.2	31	0.5	0.87	0.44	32	8	128	4096	256.41	8205.13	0.12	0.11	15.60
	499.2	1331.2	31	0.5	0.87	0.44	32	8	16	512	32.05	1025.64	0.98	0.85	15.60
	499.2	1331.2	31	0.5	0.87	0.44	32	8	2	64	4.01	128.21	7.80	6.81	15.60
	499.2	1331.2	31	1	0.87	0.87	32	8	1	32	2.00	64.10	15.60	27.24	15.60
{4, 11}	499.2	1331.2	127	0.5	0.87	0.44	8	2	512	4096	1025.64	8205.13	0.12	0.11	62.40
	499.2	1331.2	127	0.5	0.87	0.44	8	2	64	512	128.21	1025.64	0.98	0.85	62.40
	499.2	1331.2	127	0.5	0.87	0.44	8	2	8	64	16.03	128.21	7.80	6.81	62.40
	499.2	1331.2	127	0.5	0.87	0.44	8	2	2	16	4.01	32.05	31.20	27.24	62.40
7	499.2	1081.6	31	0.5	0.87	0.44	32	8	128	4096	256.41	8205.13	0.12	0.11	15.60
	499.2	1081.6	31	0.5	0.87	0.44	32	8	16	512	32.05	1025.64	0.98	0.85	15.60
	499.2	1081.6	31	0.5	0.87	0.44	32	8	2	64	4.01	128.21	7.80	6.81	15.60
	499.2	1081.6	31	1	0.87	0.87	32	8	1	32	2.00	64.10	15.60	27.24	15.60
7	499.2	1081.6	127	0.5	0.87	0.44	8	2	512	4096	1025.64	8205.13	0.12	0.11	62.40
	499.2	1081.6	127	0.5	0.87	0.44	8	2	64	512	128.21	1025.64	0.98	0.85	62.40
	499.2	1081.6	127	0.5	0.87	0.44	8	2	8	64	16.03	128.21	7.80	6.81	62.40
	499.2	1081.6	127	0.5	0.87	0.44	8	2	2	16	4.01	32.05	31.20	27.24	62.40
15	499.2	1354.97	31	0.5	0.87	0.44	32	8	128	4096	256.41	8205.13	0.12	0.11	15.60
	499.2	1354.97	31	0.5	0.87	0.44	32	8	16	512	32.05	1025.64	0.98	0.85	15.60
	499.2	1354.97	31	0.5	0.87	0.44	32	8	2	64	4.01	128.21	7.80	6.81	15.60
	499.2	1354.97	31	1	0.87	0.87	32	8	1	32	2.00	64.10	15.60	27.24	15.60
15	499.2	1354.97	127	0.5	0.87	0.44	8	2	512	4096	1025.64	8205.13	0.12	0.11	62.40
	499.2	1354.97	127	0.5	0.87	0.44	8	2	64	512	128.21	1025.64	0.98	0.85	62.40
	499.2	1354.97	127	0.5	0.87	0.44	8	2	8	64	16.03	128.21	7.80	6.81	62.40
	499.2	1354.97	127	0.5	0.87	0.44	8	2	2	16	4.01	32.05	31.20	27.24	62.40

Table from: IEEE Std 802.15.4-2015

LRP-UWB PHY SPECIFICATION & DATA RATES

- The low rate pulse repetition frequency (LRP) UWB PHY consists of three channels corresponding to three transmission modes. LRP-UWB is used for RFID applications (and ranging in 802.15.4z).
- Either on-off keying (OOK) or pulse position modulation (PPM) is used to modulate the symbols depending on the mode of transmission. Symbols are composed of one or more bursts of UWB pulses.
  - Optional Location Enhancing Information postamble (LEIP) – sequence of pulses at the defined PRF for measuring RTT to determine distance.
- Base mode – highest data rate
- Extended mode – balance of data rate and sensitivity
- Long-range mode – best sensitivity

Mode	PRF (MHz)	DataRate as used in MCPS-DATA primitives	Data rate	Modulation
Long-range mode	2.0	1	31.25 kb/s	PPM
Extended mode	1.0	2	250 kb/s	OOK
Base mode	1.0	3	1 Mb/s	OOK

Table from: IEEE Std 802.15.4-2015

UWB CHANNEL ACCESS METHODS

- 802.15.4 Standard
  - Validation of successful reception of a frame with an acknowledgement is *optional*.
  - Access to the medium can be either scheduled or contention-based (ie random access).
    - CSMA-CA (slotted or unslotted) can be used.
    - ALOHA or slotted ALOHA mandatory for UWB as CCA is difficult on low-power UWB
      - Random Access, used by HRP-UWB & LRP-UWB for active RFID blink frames.
- CCA
  - HRP-UWB shall use one of the CCA modes defined in 802.15.4 PHY requirements (ie CSMA/CA or TDMA) or shall report a busy medium upon detecting a preamble symbol.
    - Channel can be used by multiple users as long as preamble code and PRF are different.
  - HRP-UWB receiver energy detection (ED) measurement can input into DAA mitigation

UWB FRAMING

802.15.4 MAC Frame Format

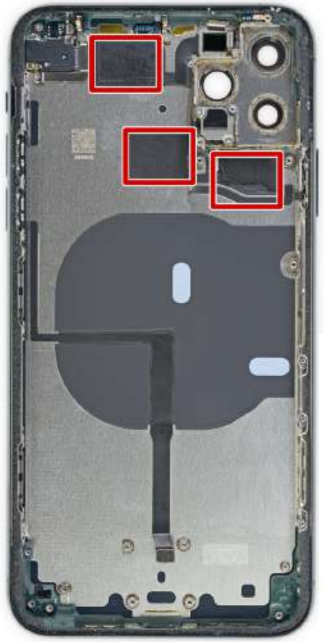
	Frame Control	Sequence Number	Addressing Fields				Auxiliary Security Header	IE Headers / IE Payload	Frame Payload	FCS
			Destination PAN ID	Destination Address	Source PAN ID	Source Destination Address		IEs		
Bytes	1/2	0/1	0/1	0/2/8	0/1	0/2/8	Variable	Variable	Variable	2/4

- Data communication and distance measuring requires precise synchronization between terminals.
  - Synchronization preamble in HRP-UWB PPDU SHR header, constructed from one of two lengths of preamble code (either 31 or 127 symbols).

Image from: Design for IoT | Peter Mackenzie | WLPC Prague 2019

UWB ANTENNAS

- Distributed antennas
  - Increases transmission range
  - MIMO increases data rates
- Microstrip antennas
  - Low profile, low cost, easy to fabricate
- Wideband monopole
- Flexible wearable antennas for WBAN



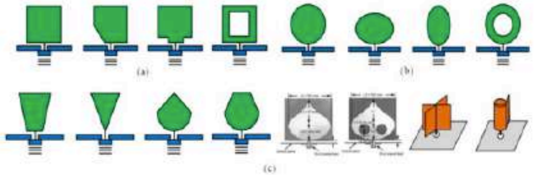


Figure 2. Modified shape planar antennas for UWB applications (a) rectangular, (b) circular and elliptical, (c) other shapes.

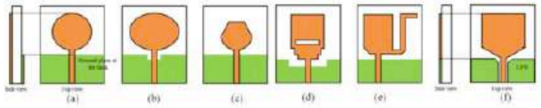


Figure 3. Planar PCB or printed antenna designs [8]-[20].

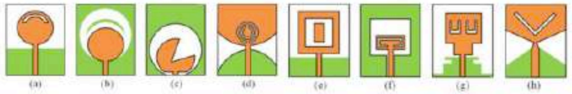


Figure 4. Printed antenna designs with single bandstop functions [21]-[28].

iPhone 11 image from: https://www.ifixit.com/Teardown/iPhone+11+Pro+Max+Teardown/126000
UWB antenna shapes from: https://www.researchgate.net/publication/272150882_UWB_Antennas_for_Wireless_Applications

UWB RANGING & LOCALIZATION

- UWB Ranging and Localization Components
  - Anchor (fixed unit) – measures location of mobile units
  - Tag (mobile unit) – in motion
  - Location engine/server
- Various algorithms for measurement

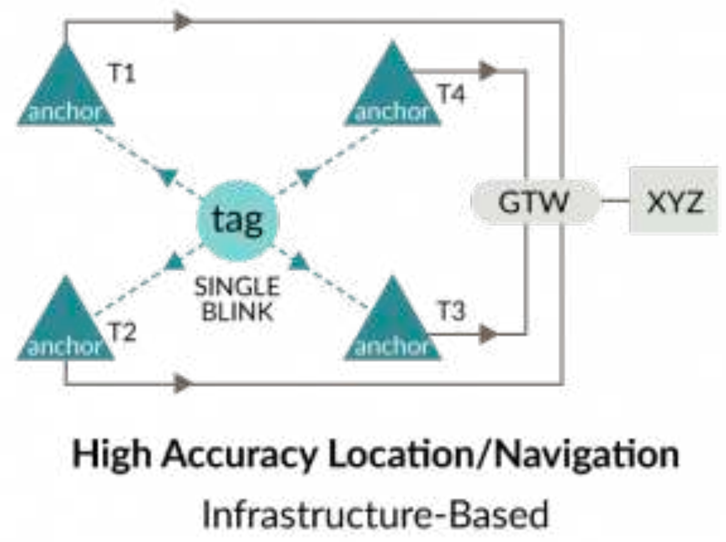


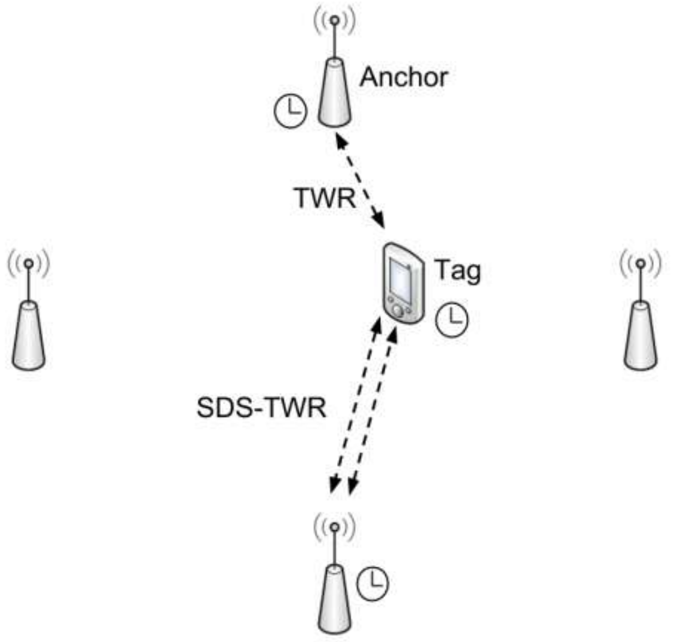
Image from: https://www.decawave.com/technology1/

COMPARISON OF UWB RANGING ALGORITHMS

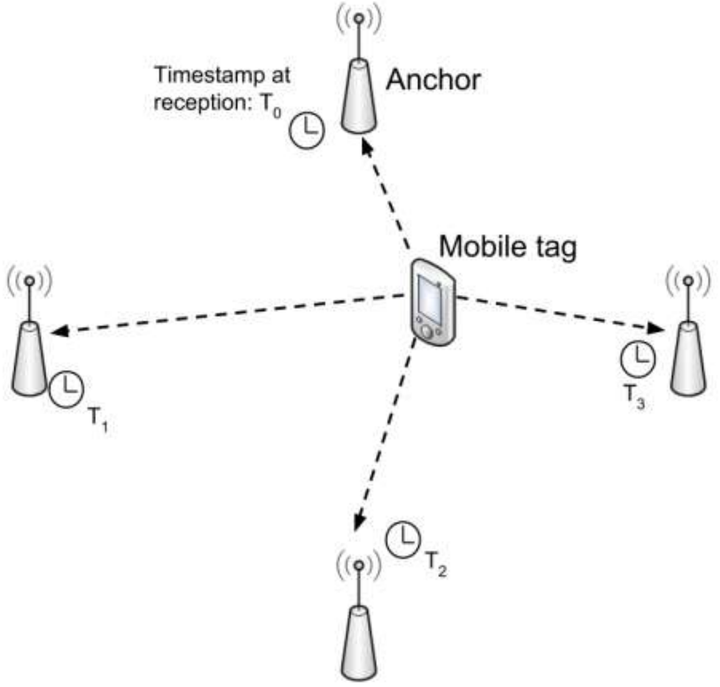
Algorithm	Summary	Pros	Cons
Two Way Ranging (TWR)	• Distance = ToF x (speed of light) • Requires exchange of 3 messages between Anchor & Tag	• Doesn't require time synchronization • Two-way communications enables data & control	• Requires knowledge of Anchor addressing, difficult to scale • Coverage limited by distance to Master Anchor (<20m) • Increased computation required, decreases battery life
Angle of Arrival (AoA)	• Measures position based on intersection of multiple signals	• Lower requirement in terms of clock precision/synchronization	• Complex deployment requiring many antennas
Phase Difference of Arrival (PDoA)	• Combines TWR with bearing measurement	• Less infrastructure required • Relative positioning between two devices	• Requires two antennas • Location error isn't constant
Time Difference of Arrival (TDoA)	• Precise measurement of time difference between blink/beacon signals arriving to Anchors	• Tag doesn't communicate directly with Anchors, so don't need to know addressing • Improved battery life • More scalable due to reduced configuration required	• Anchors require precise time synchronization

Information from www.decawave.com, www.sewio.net, and https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4883398/pdf/sensors-16-00707.pdf

COMPARISON OF UWB RANGING ALGORITHMS



Two Way Ranging
(TWR)



Time Difference of Arrival
(TDoA)

Images from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6022048/pdf/sensors-18-01875.pdf

UWB USE CASES

- Secure Access Control
  - Smart car access with smartphone for keyless entry and remote start
  - Can be combined with BLE for wake-up/initialization prior to secure ranging.
- Secure Wireless Payments
  - More secure than NFC, and can leave smartphone in pocket
- Location-based Services
  - Asset tracking in high density environments
  - Proximity of small objects
  - Sports & Fitness Tracking
    - Tracking of players and athletes on a field/arena
- Healthcare
  - Medical radar
  - Wireless health sensors (WBAN)

UWB USE CASES – FIRA CONSORTIUM

	Smart Home and Enterprises	Smart Cities and Mobility	Smart Transportation	Consumer	Smart Retail	Industry 4.0 and Healthcare
Hands-Free Access Control	• Residential access control • Restricted enterprise access	• Parking garage • Vehicle digital key (standardized by CCC)	• Rider identification (private transport services)	• Logical access control	• Unmanned store access	• Barrier-free and restricted access control
Location-Based Services	• Employee mustering in emergencies	• Bike sharing	• Ride sharing • Reserved seat validation	• AR gaming	• Indoor navigation • Foot traffic and shopping behavior analytics	• Asset tracking • Patient tracking
Device-to-Device (Peer-to-Peer) Applications	• Conference systems	• Drone-controlled delivery • V2X*, autonomous driving	• Ticket validation (public transport services)	• VR gaming and group play • Find someone nearby	• Targeted marketing • Tap-free remote payment	• Proximity-based patient data sharing • Find equipment

*Connected Vehicle-to-Everything Communication

Image from: https://www.firaconsortium.org/discover/use-cases/

UWB PRODUCTS – RECOGNIZE THIS?

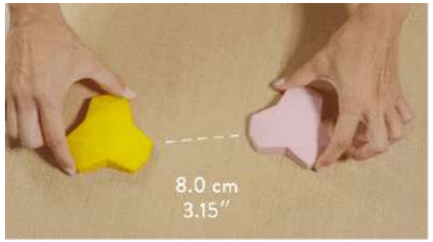
Belkin UWB CableFree USB Hub from 2006!

UWB PRODUCTS – LOCATION / ASSET TRACKING

- Zebra UWB Solution
  - Virtual planning tool
  - ATEX & IS tags
  - Sport tracking

- Ubisense Dimension4
  - IP40/54/69K
  - Various form factors
  - TDoA + AoA

- Estimote Location UWB Beacon
  - BLE, UWB
  - Estimote Automapping
  - Uses TWR

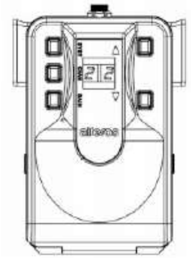


- Humatics
  - REST API
  - Uses proprietary ALOHA & TDMA MAC

- RealTrac
  - Underground mining
  - IP rated
  - APIs

UWB PRODUCTS – HEALTHCARE & AUDIO

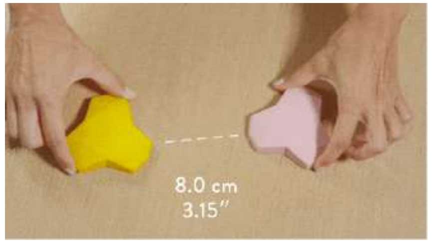
- Alteros UWB Wireless Mic System
  - Operates at 6.5 GHz
  - Transceivers mesh together
  - TDMA used for channel access



- ARIA Sensing
  - “World’s smallest UWB radar”
  - Detect gestures & breathing
  - Debuted at CES2020

- Novelda/XeThru X4 UWB Radar
  - Sleep & respiration monitoring
  - Occupancy sensing
    - Inmate monitoring
    - HVAC, lighting, security

- Estimote Location UWB Beacon
  - BLE, UWB
  - Estimote Automapping
  - Uses TWR



UWB PRODUCTS – SECURE ACCESS

- Continental + NXP
  - Secure vehicle access, digital key
  - Car Connectivity Consortium (CCC)
  - Debuted at CES2020

- Volkswagen + NXP
  - Secure vehicle access, digital key
  - Car Connectivity Consortium (CCC)
  - Remote control parking, indoor navigation
  - Accessory mounting (ie trailer)
  - Debuted at CES2020

APPLE UWB & RADIO PATENTS

Refine Search IN/"HAMMERSCHMIDT, Joachim"

	PUB. APP. NO.	Title
1	20190273636	SECURE TRAINING SEQUENCE SYMBOL STRUCTURE
2	20190199398	TIME INSTANT REFERENCE FOR ULTRA WIDEBAND SYSTEMS
3	20190103661	Wireless Earphone Antennas
4	20190007093	Pulse Shaping Interoperability Protocol for Ultra Wideband Systems
5	20180097521	Method and Apparatus for Calibration of Voltage Controlled Oscillator
6	20180091340	MOST LIKELY ESTIMATION SYSTEMS AND METHODS FOR CODED GMSK
7	20180084456	Real-time Relay of Wireless Communications
8	20180048350	MULTIBAND BLUETOOTH
9	20130177891	AUDIO-VISUAL LEARNING SYSTEM
10	20120311173	Dynamic Wireless Channel Selection And Protocol Control For Streaming Media
11	20120309321	Synchronized calibration for wireless communication devices
12	20120307814	Polling using B-ACK for occasional back-channel traffic in VoWIFI applications
13	20120307746	Fair Channel Allocation for Multiple Clients
14	20110299618	MULTIPLE-BRANCH WIRELESS RECEIVER
15	20110051791	Methods and Systems for Calibrating for Gain and Phase Imbalance and Local Oscillator Feed-Through
16	20100246656	Methods and systems for soft-bit demapping
17	20090304124	REDUCED-COMPLEXITY MULTIPLE-INPUT, MULTIPLE-OUTPUT DETECTION
18	20090199076	ACKNOWLEDGEMENT MESSAGE MODIFICATION IN COMMUNICATION NETWORKS
19	20090143030	PROGRAMMABLE TRANSMITTER
20	20090117858	RECEIVE CONFIGURATION ADAPTATION FOR WIRELESS TRANSCEIVERS
21	20080310487	Single-chip wireless tranceiver
22	20080175189	TRANSMIT SCHEME ADAPTATION FOR WIRELESS DATA TRANSMISSIONS
23	20080130773	MULTIPLE-BRANCH WIRELESS RECEIVER
24	20070110180	Configurable bit interleaving
25	20070110178	Configurable de-interleaver design
26	20070077969	Maximum likelihood detection for MIMO receivers
27	20070036246	Methods and systems for soft-bit demapping
28	20070036245	Methods and systems for soft-bit demapping
29	20070025474	Receiver IQ imbalance calibration
30	20070025433	Methods and systems for calibrating for gain and phase imbalance and local oscillator feed-through
31	20070002878	Multiple protocol wireless communication baseband transceiver
32	20060291583	Programmable transmitter
33	20060269003	Method and apparatus for frequency domain compensation of DC offset in an orthogonal frequency division multiplexing system
34	20060253765	Acknowledgement message modification in communication networks
35	20060209994	MLD demapping using sub-metrics for soft-output MIMO detection and the like
36	20060209977	Global minimum-based MLD demapping for soft-output MIMO detection
37	20060104390	Reduced-complexity multiple-input, multiple-output detection
38	20050288062	Method and apparatus for selecting a transmission mode based upon packet size in a multiple antenna communication system
39	20050255815	Multiple-branch wireless receiver
40	20050163236	Transmission method and apparatus in a multiple antenna communication system
41	20040151146	Multi-branch OFDM transceiver
42	20040151145	Channel estimation for an OFDM transceiver
43	20030144032	Beam forming method
44	20030130012	Method and device for evaluating an uplink radio signal

Image from https://www.quora.com/What-is-the-new-Apple-U1-chip-and-why-is-it-important/answer/Brian-Roemmele @BrianRoemmele

APPLE UWB PATENTS AND USE CASES

- Peer-to-peer Services
  - AirDrop "So far we know the unlicensed UWB in the Apple iPhones transmits on two different frequencies - 6.24 GHz and 8.2368 GHz" (These are HRP-UWB Channels 5 and 10)
- Spatial/directional awareness (AR?)
- Asset Tracking
  - Find AirPods? AirTags?
- Apple HomeKit
  - Connected wall outlets/switches/controls
- Apple Health
  - Improved biometrics
  - New ecosystem of connected health sensors
- Apple Car??? iOS 13.4 enables CarKey API to lock/unlock/start

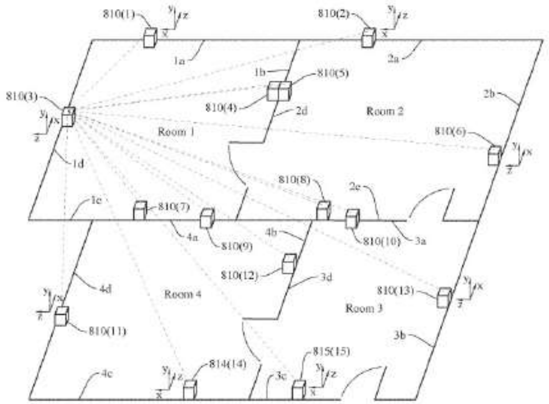
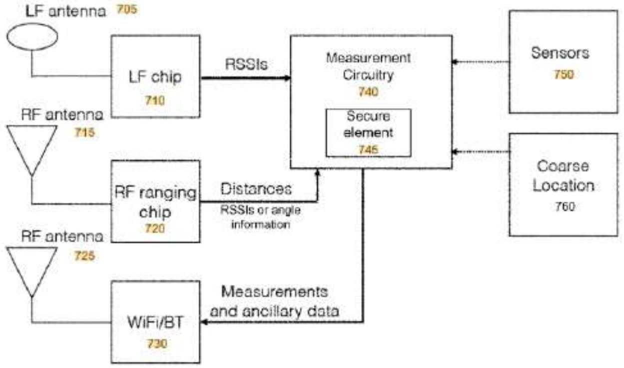


FIG. 8



Quotation from https://www.ifixit.com/Teardown/iPhone+11+Pro+Max+Teardown/126000?utm_source=everythingrf

WHAT'S NEXT FOR UWB?

- Education
  - CWSA/CWISA, CWIP/CWICP
    - Shouldn't be focused on only a subset of 802.15.4 (i.e. ZigBee, Thread, LoRaWAN)
  - Many articles and papers on UWB, some out of date
- Standardization
  - 802.15.4z – standard for secure ranging and access
  - 802.15.6 – Wireless Body Area Networks
- Large Scale Adoption
  - Will Apple lead the charge?
- Openness
  - Apple developer ecosystem
  - Open APIs in existing UWB vendor products

LOCATION, LOCATION, LOCATION

- Bluetooth Low Energy
  - vBLE is king (just ask the WiFi Ninjas 😉)!
    - Easy to deploy, scalable, cost-effective and easy to manage
    - Bluetooth is standards-based
    - Bluetooth 5.1 brings Angle-of-Arrival and Angle-of-Departure for even greater accuracy
- Wi-Fi
  - 802.11az – Next Generation Positioning
    - Still a lot of work to be done, years away
    - Wi-Fi location services requires very high density = $$$$$

Mist Expands Vision of Universal Standards-Based Indoor Location

Robust Wi-Fi platform leverages IoT, ultra-wideband, radar, LiDAR, ESL, Wi-Fi and Bluetooth LE to deliver more use cases with scale and accuracy

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February 20, 2020 07:45 ET | **Source:** Mist Systems, Inc.

Profile
Mist Systems, Inc.

NEW MIST PARTNERSHIPS FOR UWB RTLS!

- **Sewio**
  - Various tags and sensors
  - Flow analysis & heatmap
  - API
  - Planning tool

- **Quarion Atlar-5D**
  - 6000 tag reads per second
  - Heatmap/spaghetti diagram software

QUARION TECHNOLOGY INC.

- **inpixon**
  - Various tags and sensors
  - APIs & SDK

inpixon Indoor Intelligence

THANK YOU

https://www.mist.com

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