WiFi, 5G, oder lieber UWB?

Die Buchstabensuppe der drahtlosen Protokolle lesen und verstehen

bayern innovativ
Innovation leben.

Wi-SUN UWB ZigBee
LoRa Wi-Fi6E Sigfox
NG-UWB 4G
2G Wi-Fi5 Wi-Fi7 LoRa
Bluetooth 5 Wi-Fi8
Wi-Fi6 Thread 3G
5G NR

Jörg Köpp
Marktsegment- & Technolgie Manager
Rohde & Schwarz

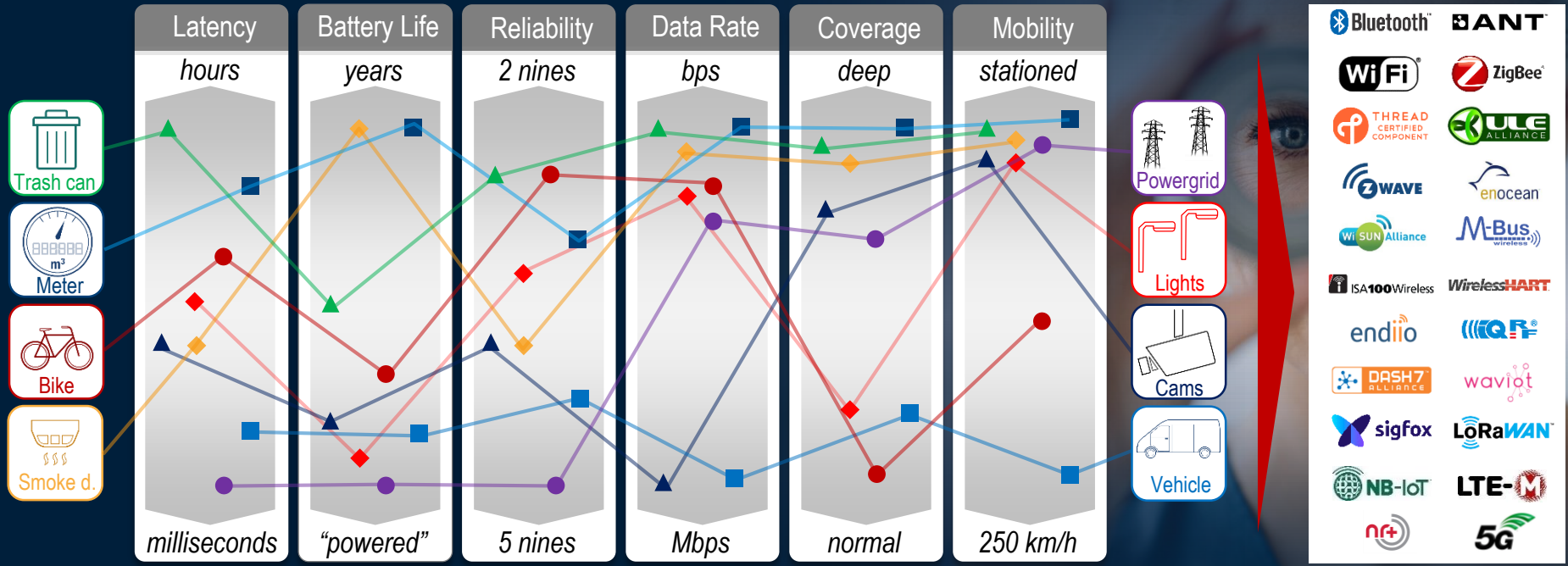
ROHDE&SCHWARZ
Make ideas real

https://www.bayern-innovativ.de/de/mechatronikakademie-uebersicht/veranstaltung/wifi-5g-oder-lieber-uwb-#!ueberblick

Drahtlose Kommunikation – überall & jederzeit

Wie findet man die ‚richtige' Technologie?

No single wireless communication technology is best, nor is any one right for every use case.

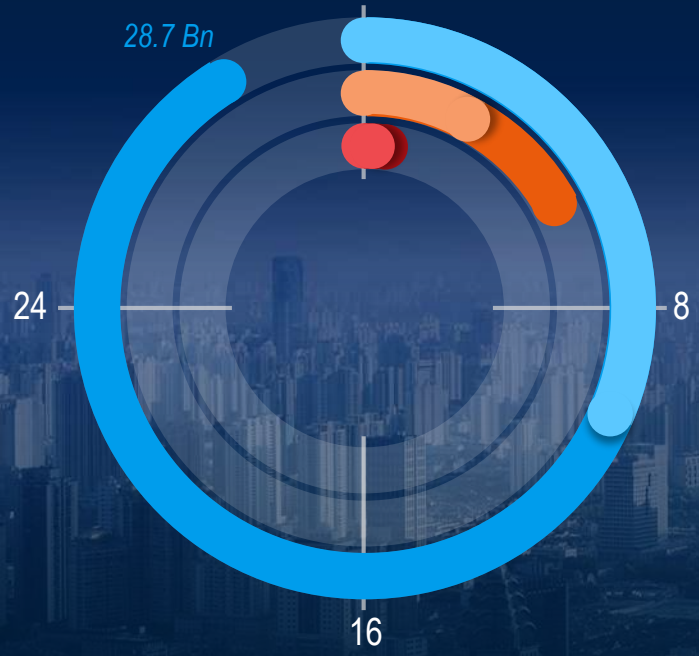


Wie findet man die ‚richtige' Technologie?

No single wireless communication technology is best, nor is any one right for every use case.

- Technical requirements
- Deployment model
- Operation model
- Lifetime availability
- Solution scalability
- Security
- Ecosystem support
- Total Cost of Ownership
- and more

Was sagt uns der Markt …



- Short-Range (10.3 ⇨ 28.7 Bn ; CAGR: +19%)
- Cellular WAN (2.7 ⇨ 5.5 Bn; CAGR: +12%)

  Globally, 124 service providers have deployed or commercially launched NB-IoT networks and 57 have launched Cat-M, while 56 have deployed both technologies

  By the end of 2028, almost 60 percent of cellular IoT connections are forecast to be broadband IoT, with 4G connecting the majority.
- Non-cellular LPWAN (0.2 ⇨ 0.5 Bn)

Sources: Ericsson Mobility Report (Nov 2022)

Nur ein paar Beispiele: drahtlose Anwendungen in der Fabrik

Bluetooth
UWB

locks

NB-IoT
LoRaWAN

sensors

Wi-Fi
4G/5G

body worn

Wi-Fi
4G/5G

robots

Bluetooth
UWB

tools

RFID
UWB

assets

Wi-Fi
Thread

headlights

Wi-Fi
4G/5G

handhelds

Wi-Fi
4G/5G

vehicle

Bluetooth® Entwicklung über die letzten Jahre

Speed

100% data rate improvement for low latency

Range

4x range to cover smart home or office

Broadcast

Extended advertising capabilities

Mesh

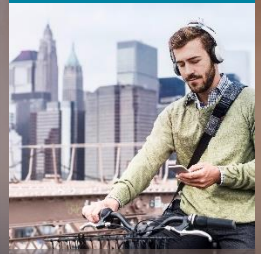
Meshed networking

Direction

Angle of Arrival and Angle of Departure

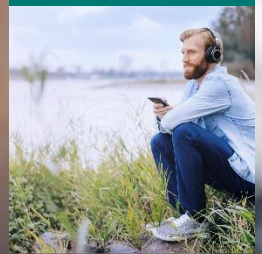
Power ctrl

Dynamic optimization of TX power



LE audio

Isochronous physical channels



Bluetooth 5.0 | Bluetooth 5.1 | Bluetooth 5.2

WiFi, 5G, oder lieber UWB?

The HISTORY and FUTURE of Wi-Fi

HOME AND OFFICE NETWORKS

M2M AND IoT NETWORKS

ROOM AND DESK AREA NETWORKS

VEHICLE NETWORKS

WaveLAN, the starting point for Wi-Fi development, was used for wirelessly connecting cashing machines.

802.11 b

Higher speed physical layer extension in the 2.4 GHz band

Spatial streams: 1x1 SISO	Modulation type: CCK
Channel bandwidth: 22 MHz	Bands: 2.4 GHz
Transmission/access method: CSMA/DSSS	

Need for faster speed and better distance coverage.

802.11 a

High speed physical layer in the 5 GHz band

Spatial streams: 1x1 SISO	Modulation type: 64QAM
Channel bandwidth: 20 MHz	Bands: 5 GHz
Transmission/access method: CSMA/OFDM	

802.11 g

Further higher data rate extension

Spatial streams: 1x1 SISO	Modulation type: 64QAM
Channel bandwidth: 20 MHz	Bands: 2.4 GHz
Transmission/access method: CSMA/OFDM	

The ability to connect to the internet via mobile devices and the rising number of smart-phones on the market required the introduction of features

5

Very High Throughput

802.11ac

eople wanted Wi-Fi ork. High speed re required in the o relieve the over- spectrum.

Designed for in-room/desk network applications requiring very high data rates such as for HD video streaming.

HD.

802.11 ad

Directional m... in the 60 GHz ...

Spatial streams: 1x1 SISO	
Channel bandwidth: 2.16 MHz	

6

Achieves up to 20 Gbit/s throughput and enables extended distances for enlarged application space.

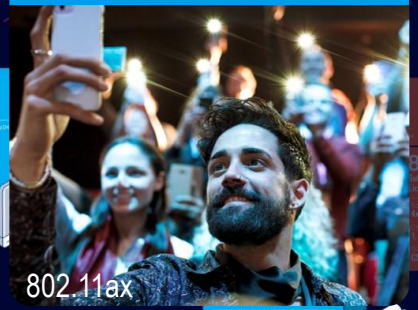
802.11 ay

Enhanced DMG (EDMG) in bands above 45 GHz

Spatial streams: 8x8 MU-MIMO	Modulation type: 64QAM
Channel bandwidth: 8.64 MHz	Bands: >45 GHz
Transmission/access method: CSMA/OFDM	

7

High Efficiency



802.11ax

802.11 bd

Enhancements for next generation vehicular (NGV)

Spatial streams: 2x2 SU-MIMO	Modulation type: 256QAM
Channel bandwidth: 10, 20 MHz	Bands: 5.9, 60 GHz
Transmission/access method: CSMA/OFDM	

Spatial streams: 8x8 MU-MIMO	Modulation type: 1024QAM
Channel bandwidth: 160 MHz	Bands: 2.4, 5, 6 GHz
Transmission/access method: CSMA/OFDM/OFDMA	

The advent of home office and schooling as well as industrial applications require improved data throughput, reduced latency and efficiency.

Extreme High Throughput

802.11be

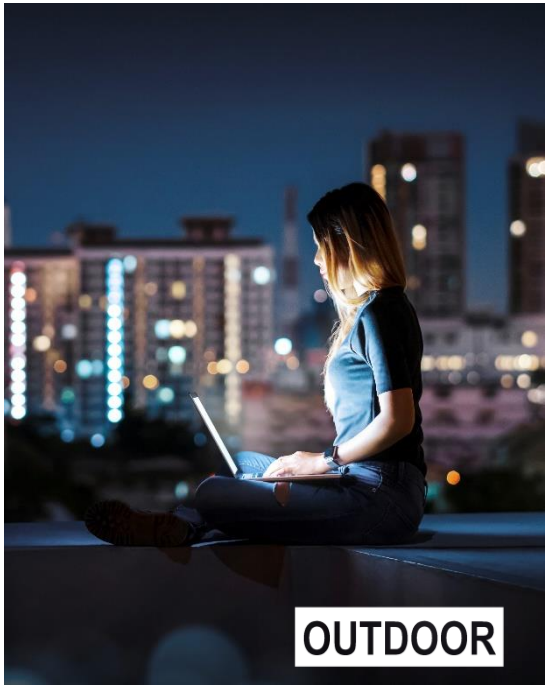
Spatial streams: 16x16 MU-MIMO	Modulation type: 4096QAM
Channel bandwidth: 320 MHz	Bands: 2.4, 5, 6 GHz
Transmission/access method: CSMA/OFDM/OFDMA	

Provide Wi-Fi based car-to-car communications to enable emerging intelligent traffic services.

Meet today's and tomorrow's rising demands on V2X communications on the way to fully autonomous vehicles.

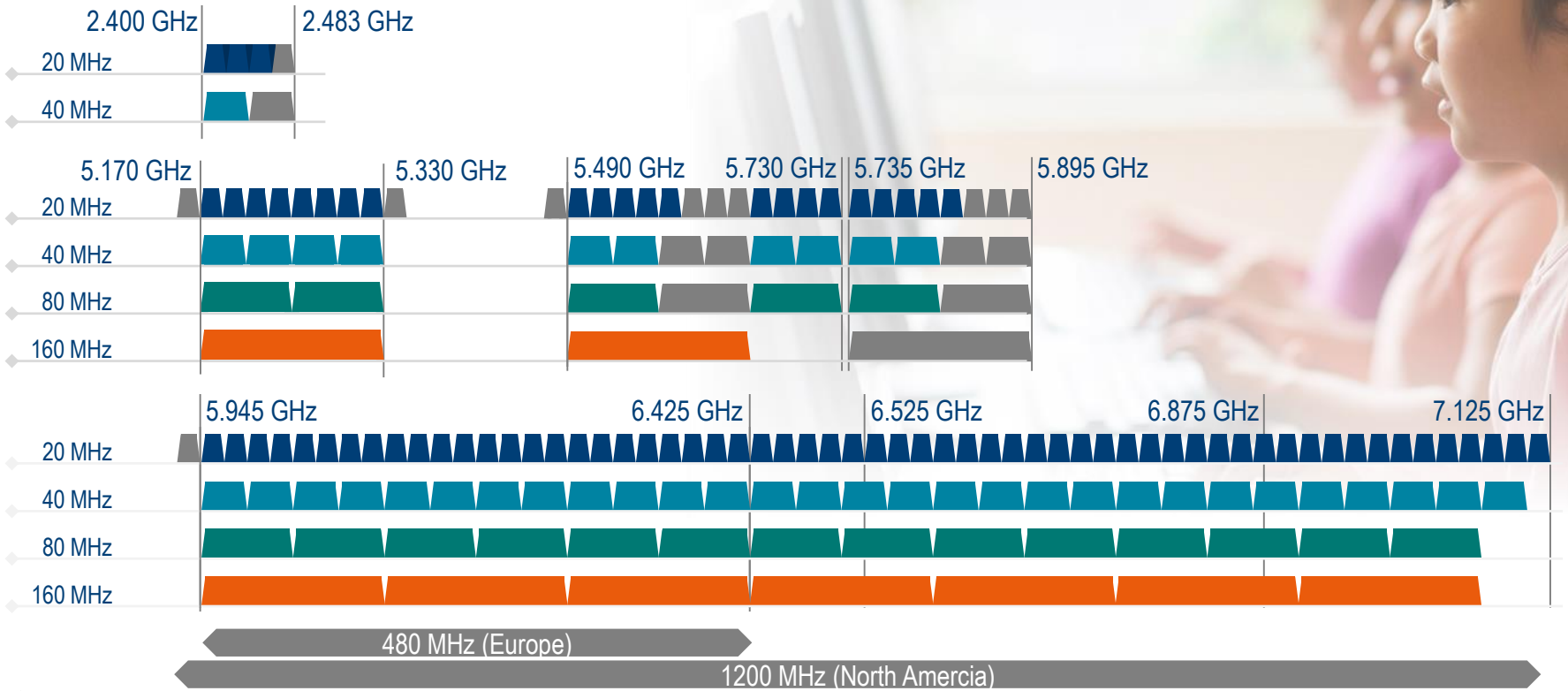
Poster available at rohde-schwarz.com

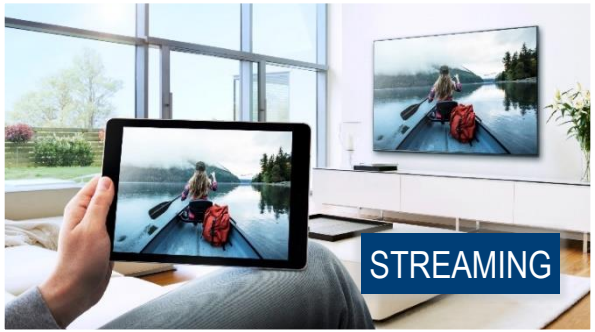
Rohde & Schwarz



Wi-Fi6 – die erste Wi-Fi Revolution
IEEE802.11ax – High Efficiency (HE)

Nutzen von Wi-Fi6 (z.B. 160 MHz) bleibt eingeschränkt in den vorhandenen Bändern





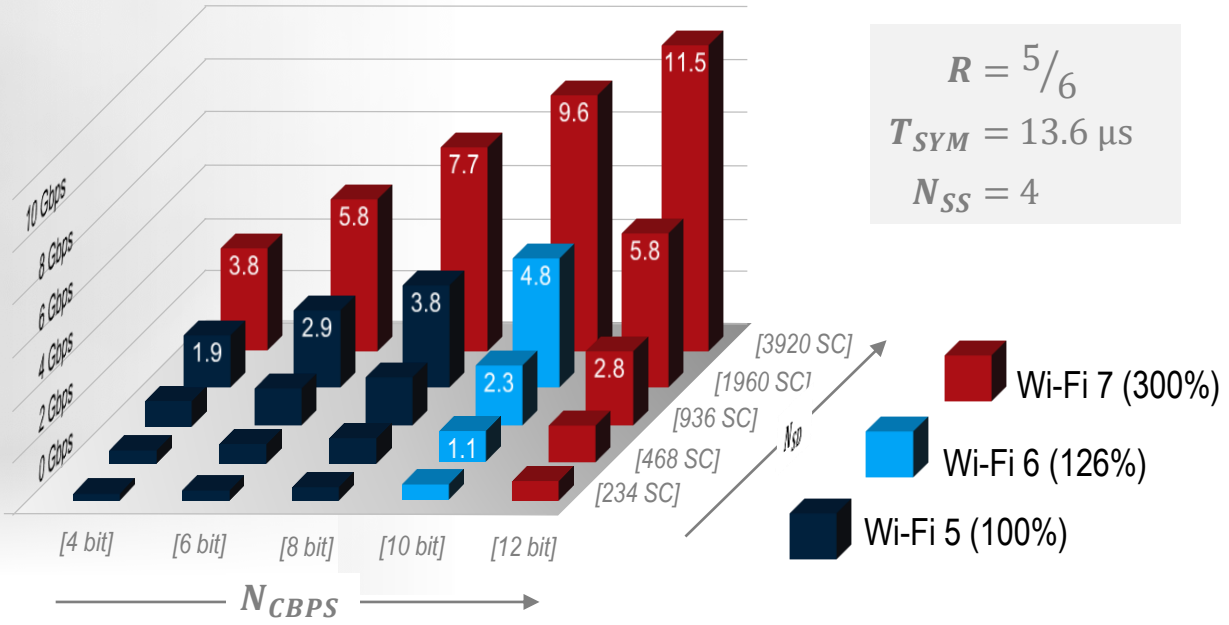
Wi-Fi7 für die ultimative Kundenzufriedenheit
IEEE802.11be – Extreme High Throughput (EHT)

Wie kann man extrem hohen Datendurchsatz erreichen?

$$\textit{Max physical data rate per link} = N_{SD} \frac{N_{CBPS} \cdot R}{T_{SYM}} N_{SS}$$

# of data carriers; # modulated bits; code rate; symbol time; #spatial streams

$$R = {}^{5}/_{6}$$
$$T_{SYM} = 13.6\ \mu s$$
$$N_{SS} = 4$$



Wi-Fi PHY Layer im Vergleich

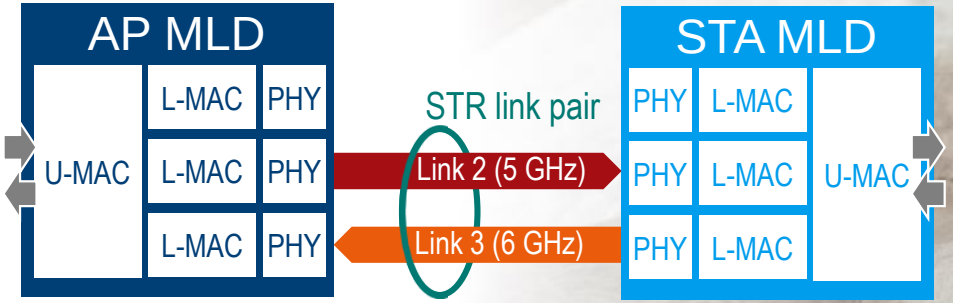
	Wi-Fi 5 (802.11ac) *Very High Throughput (VHT)*	Wi-Fi 6E (802.11ax) *High Efficiency (HE)*	Wi-Fi 7 (802.11be) *Extreme High Throughput (EHT)*
Supported bands	5 GHz	2 GHz, 5 GHz, **6 GHz**	2 GHz, 5 GHz, 6 GHz
Channel bandwidth (MHz)	20, 40, 80, 80+80, 160	20, 40, 80, 80+80, 160	20, 40, 80, 160, **320**
Transmission scheme	OFDM	OFDM, OFDMA	OFDM, OFDMA
Subcarrier spacing	312.5 kHz	78.125 kHz	78.125 kHz
Guard interval	0.4 µs, 0.8 µs	0.8 µs, 1.6 µs, 3.2 µs	0.8 µs, 1.6 µs, 3.2 µs
Spatial streams	8x8 (incl. DL-MU-MIMO)	8x8 (incl. MU-MIMO)	**16x16** (incl. MU-MIMO)
Modulation (highest)	256QAM (8 bit)	1024QAM (10 bit)	**4096QAM (12 bit)**

** dependent on configuration (GI) and incl. signaling overhead*

Multi-link operation (MLO)

Non-simultaneous transmit & receive (NSTR) operation

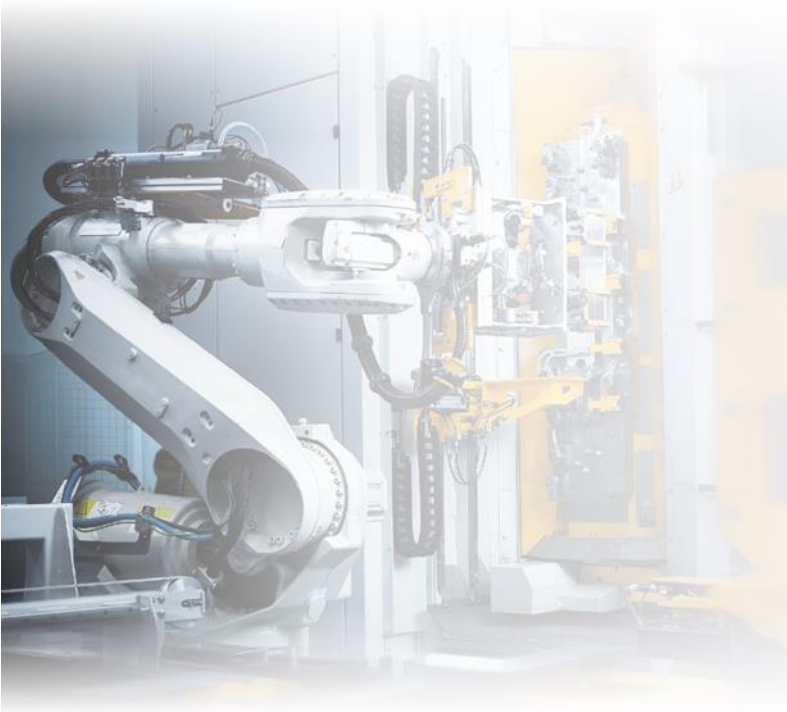
Simultaneous transmit & receive (STR) operation

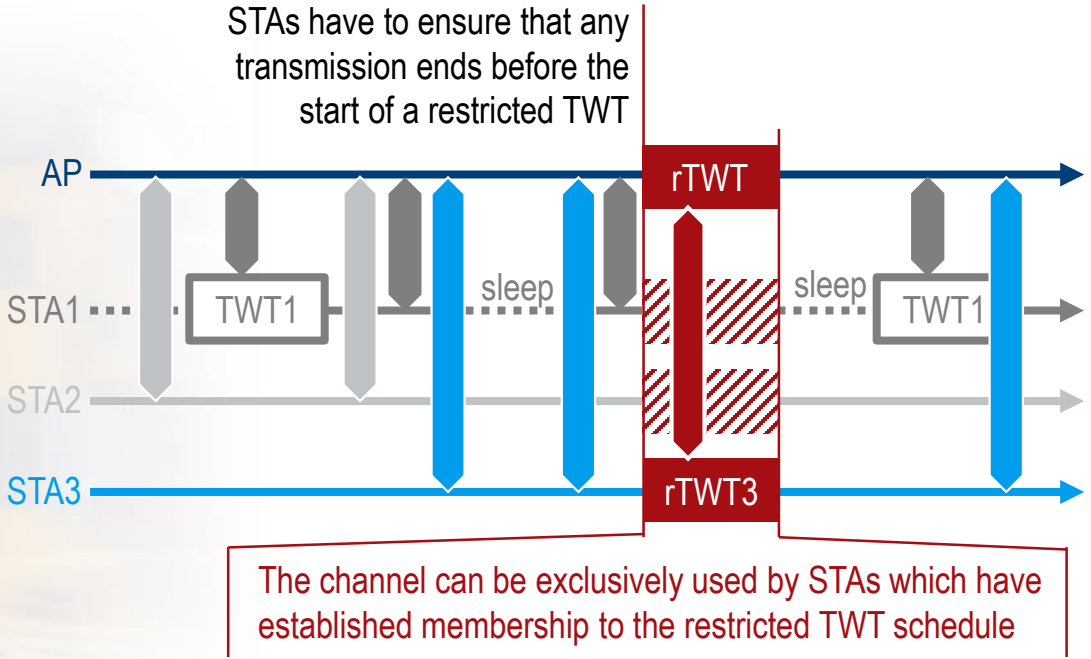


WiFi, 5G, oder lieber UWB?

Restricted Target Wake Time für zeitkritische Anwendungen

TWT introduced in 802.11ah to support low power IoT applications and allow the AP to minimize contention





Die Entwicklung des Mobilfunks wurde in der Vergangenheit weitgehend durch die Wünsche der Konsumenten bestimmt

5G *eMBB, mMTC, URLLC, RedCap*

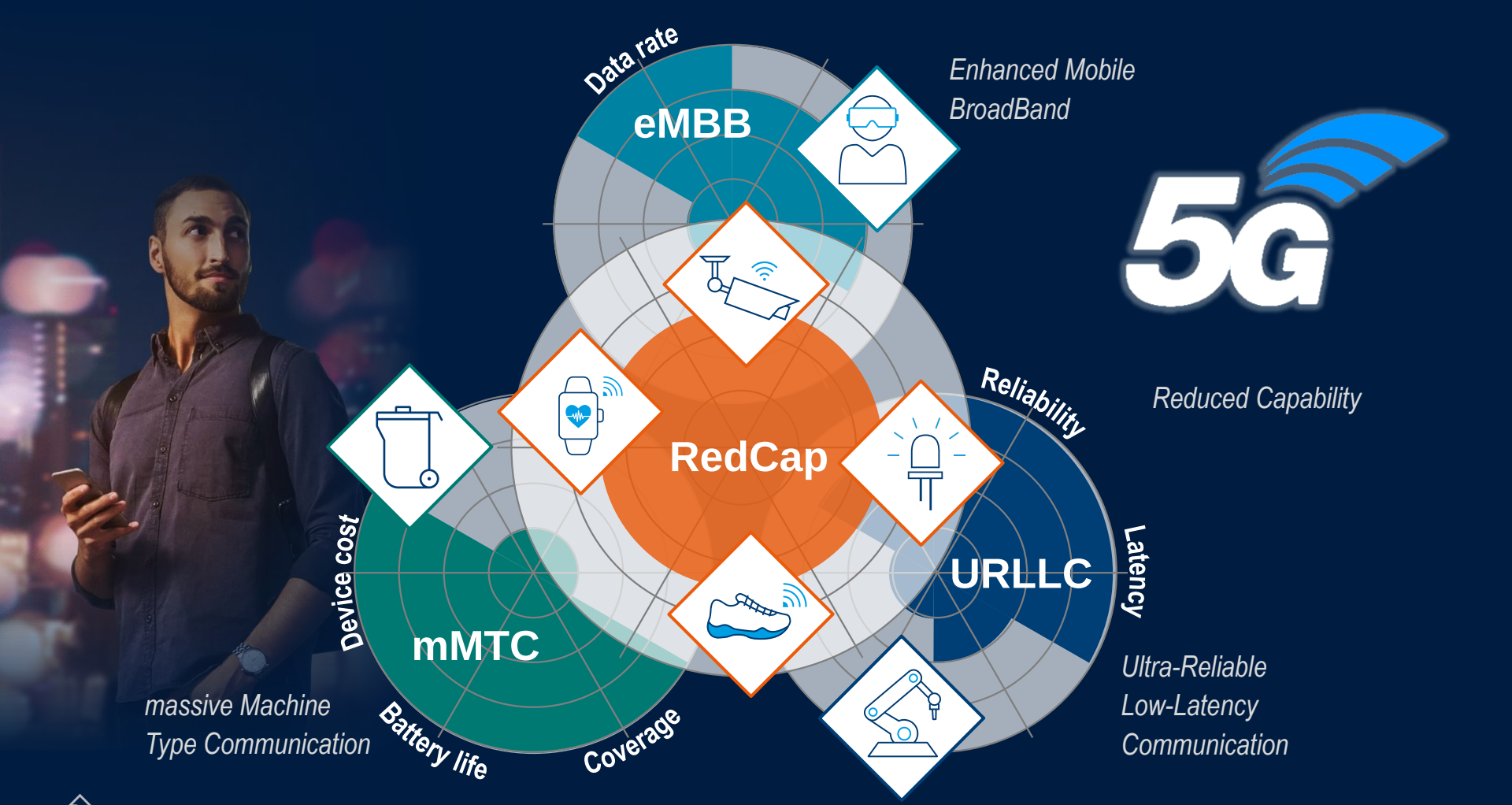
4G *Voice, Audio, Video, Apps , …*

3G *Phone, SMS, Web*

2G *Phone,SMS*

1G *Phone*

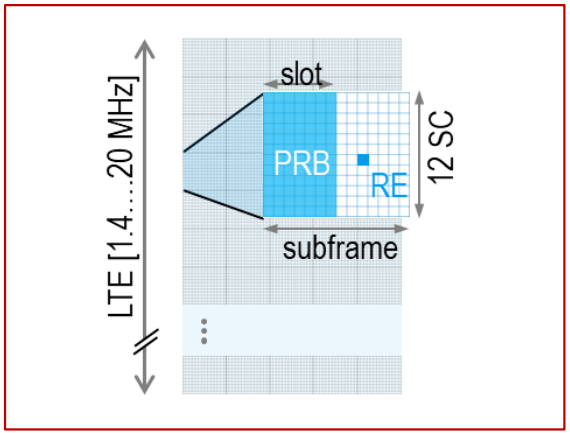
1990 2000 2010 2020 2030



WiFi, 5G, oder lieber UWB?

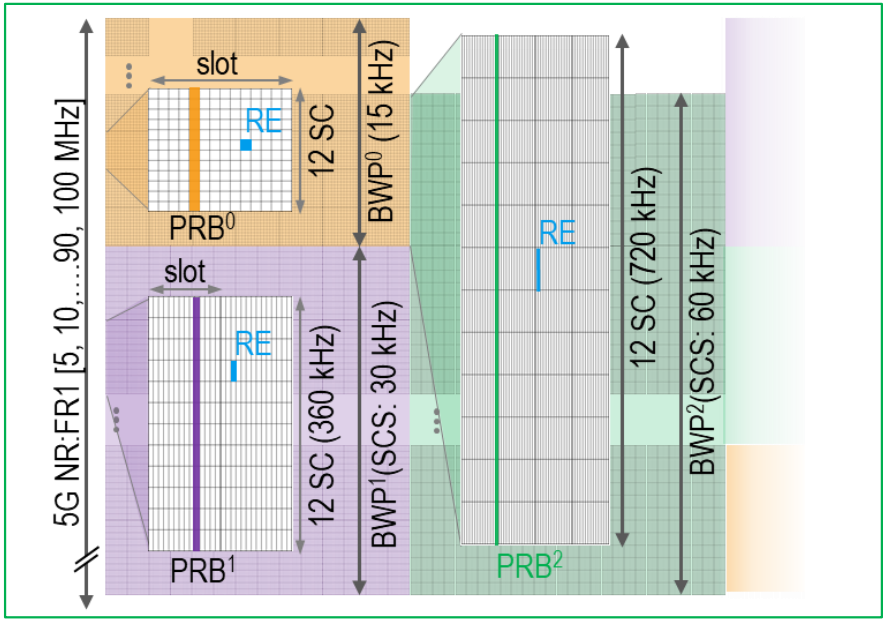
PHY Layer Flexibilität und Komplexität

Fixed numerology based on 15 kHz subcarrier spacing

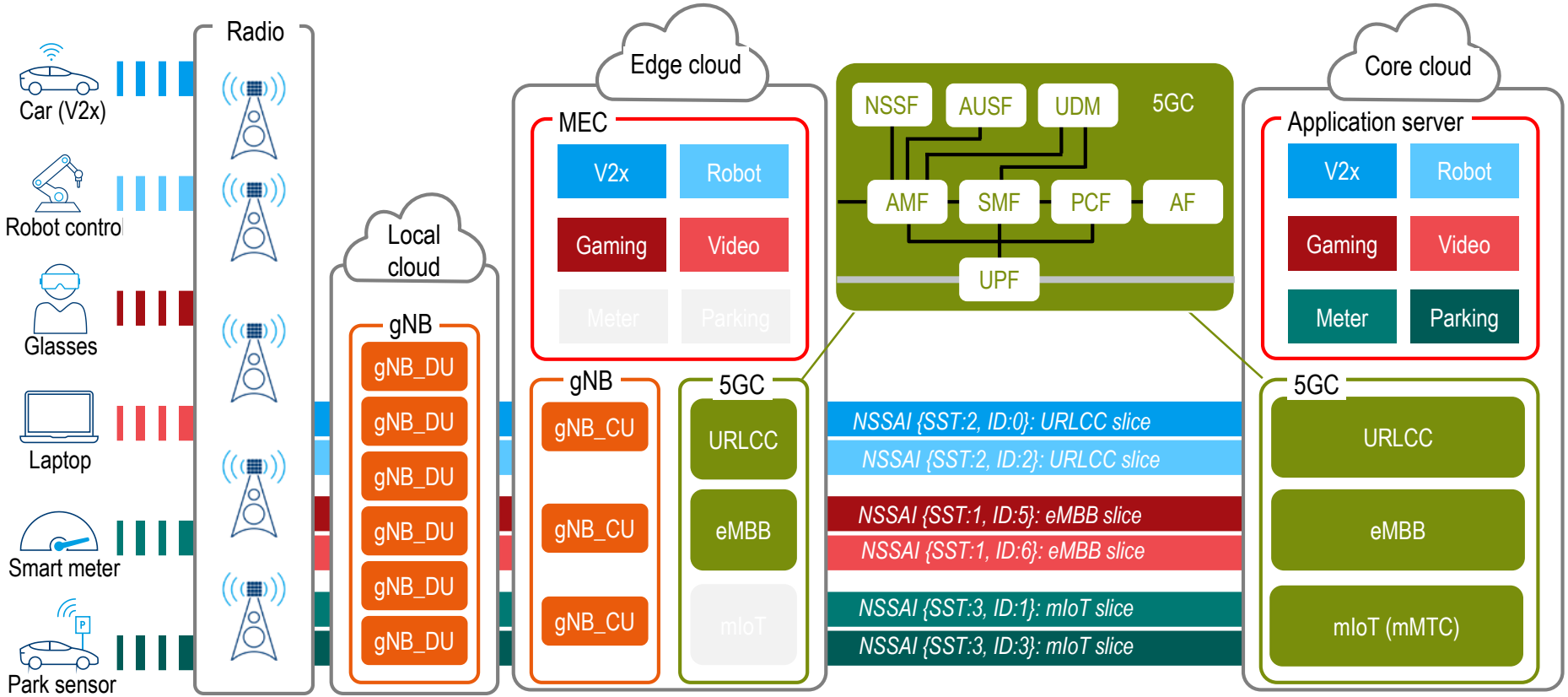


Additional uses cases besides mobile broadband especially in the IoT space: URLLC & mMTC

Flexible numerology e.g. 15 kHz, 30 kHz or 60 kHz in FR1. Dynamic assignment of different BWPs



Eine virtualisierte Netzwerk Infrastruktur – Ende-zu-Ende



Continuous evolution of 5G NR to make the 5G vision real

2020 2025 2030

5G NR Phase 1 | 5G NR Phase 2 | 5G NR Phase 2+ | 5G NR **Advanced**

3GPP **Rel.15**	3GPP **Rel.16**	3GPP **Rel.17**	3GPP **Rel.18**
eMBB	uRLLC	NTN	XR
	5GAA Automotive Association	RedCap	AI
	5G ACIA		Energy
FR1/2		FR2-2	
04.2019	06.2020	06.2022	03.2024

4G 4G 4G subscription 5G 5G 5G subscription

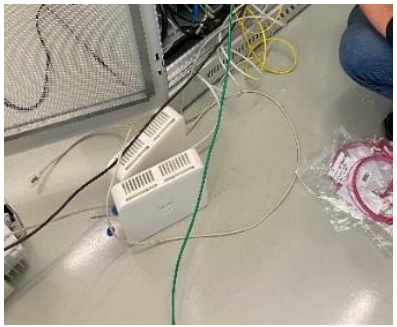
6G Research | 6G Standardization

Die 5G Toolbox für zuverlässige, zeitsensible Kommunikation

- **Flexible timing**
  Short symbol time, mini slots and flexible TDD UL/DL symbol assignment
- **Flexible scheduling**
  Flexible & fast HARQ, semi-persistant scheduling and pre-emption
- **End-to-end optimization**
  Local processing, virtualization and traffic prioritization (QoS)
- **Reliable transmission**
  Robust coding, repetition, diversity, redundant communication ways

Rohde & Schwarz 5G NR private network Testbed zur Verifikation von Zuverlässigkeit, Qualität and Verfügbarkeit



Instructions on tablets for mobile work force

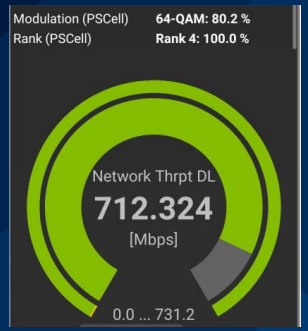
Use 5G wireless links to control stationary robots

Integration of wireless links into existing automation processes

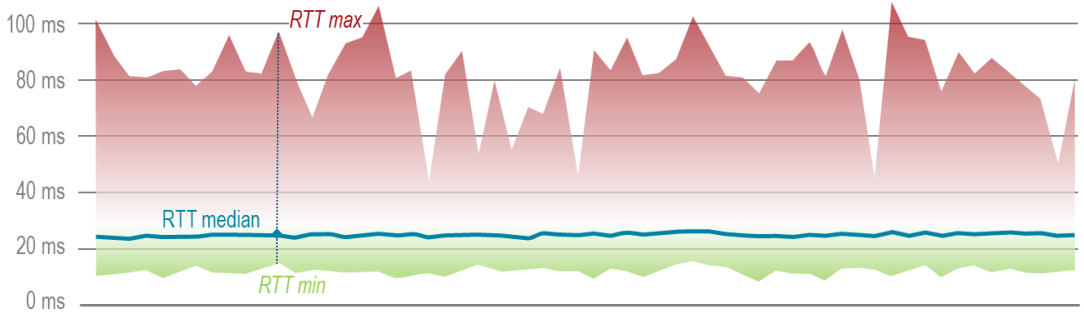
Connecting autonomous transporting systems / mobile robots

Setup

- Started with a 5G NSA installation
- Upgraded in 2022 to 5G SA with 80 MHz bandwidth in private spectrum 3.72-3.8 GHz
- Testing different scenarios with focus on throughput, round trip time and one-way latency

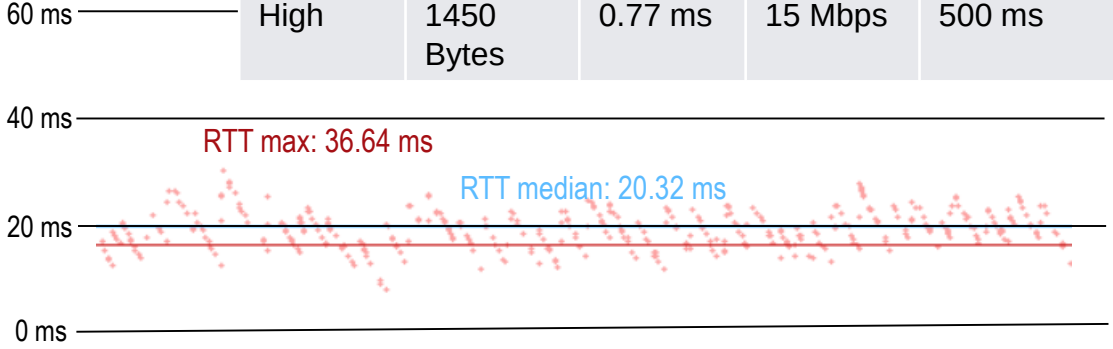


RTT for 15 Mbps data rate service while walking through the factory hall



RTT Test

Data profile characteristics				
Profile	Packet size	Packet rate	Data rate	Delay Budget
High	1450 Bytes	0.77 ms	15 Mbps	500 ms



Drahtlose Technologien für weitergehende Anwendungen

Fine Ranging

Life Sensing

Secure proximity

Technologien für die Abschätzung von Abstand und Position

	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
Time of flight		802.11mc: FTM 802.11az: NGP	802.15.4z: One way ranging Two way ranging	RTT NR Multi-RTT	Time of flight
Phase shift	(Channel sounding)				

UWB für sichere Abstandsberechnung

- Erlaubt accurate und sichere Abstands-messungen mittels Time of Flight Messungen
- Entwickelte sich in den letzten Jahren von der Nischentechnologie zum Mainstream

Populäre UWB Anwendungen

thank YOU

ROHDE&SCHWARZ

Make ideas real