TESTING 6G SUB-THZ COMMUNICATION

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ROHDE&SCHWARZ

Make ideas real

FROM 5G TO 6G
FIRST, SOME OBSERVATIONS…

- ► Odd numbered G's were almost exclusively for business, even-numbered G's for consumers
  - 1G: Connection for business people
  - 2G: Commercialization of cellular communication
  - 3G: Internet access/email for business customers
  - 4G: Internet, video streaming, social media for everyone
  - 5G: eMBB, yes, but the focus is on market verticals (automotive, IIoT)
  - 6G: Metaverse, digital twin, holographic communication, etc.

- ► Another observable trend: we tend to change the physical layer from an odd to an even G
  - 1G to 2G: analog → digital (CDMA/TDMA/FDMA)
  - 3G to 4G: CDMA/TDMA/FDMA → OFDM
  - 5G to 6G: OFDMA → ??? (e.g. AI-native air interface)

IF 6G IS FOR THE CONSUMER, WHAT DO WE NEED?
A NEW TYPE OF DEVICE!?

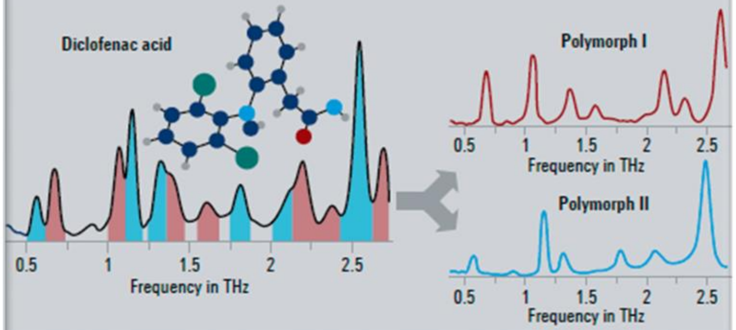
“A hologram display over a mobile device (one micrometer pixel size on a 6.7-inch display, i.e., 11.1 Gigapixel) form-factor requires at least 0.58 Tbps.”

Source: [Samsung 6G White Paper]

6G USE CASES SPAN A PLETHORA OF APPLICATIONS
COMMUNICATIONS, SPECTROSCOPY, IMAGING AND…

Spectroscopy

- Material analysis
- Analysis of the terahertz spectra from diclofenac acid can distinguish between the two chief forms of the drug



Imaging

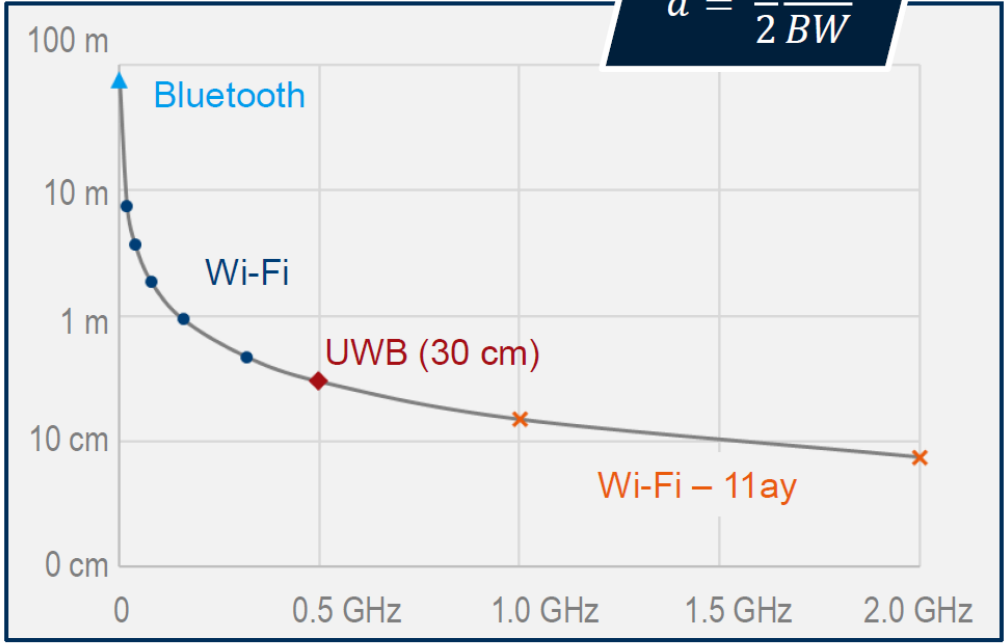
- Nondestructive imaging (with R&S®QPS100 security scanner)
- Production line (final assembly test)

White Paper: Fundamentals of THz technology for 6G

JOINT COMMUNICATION AND SENSING
ONE USE CASE BENEFITING FROM HIGH BANDWIDTH

- Design communication signal that can be used for objection detection, tracking, recognition, localization and imaging
- Sensing-assisted communication by utilizing sensed information to aid beam management/alignment, CSI acquisition, medium-aware links, interference mitigation etc.
- Research challenges
  - Channel sounding/modeling?
  - What frequency/bandwidth?
  - Waveform design (e.g. PAPR)?
  - Full duplex transceivers?
  - Interference? Distributed sensing?

THE DEPENDENCY OF BANDWIDTH AND RESOLUTION



$$d = \frac{1}{2}\frac{c}{BW}$$

BW [MHz]	Resolution [m]
100	1.5
500	0.30
1000	0.15
5000	0.030
10000	0.015

- Note that there are many techniques to improve resolution accuracy, e.g. averaging

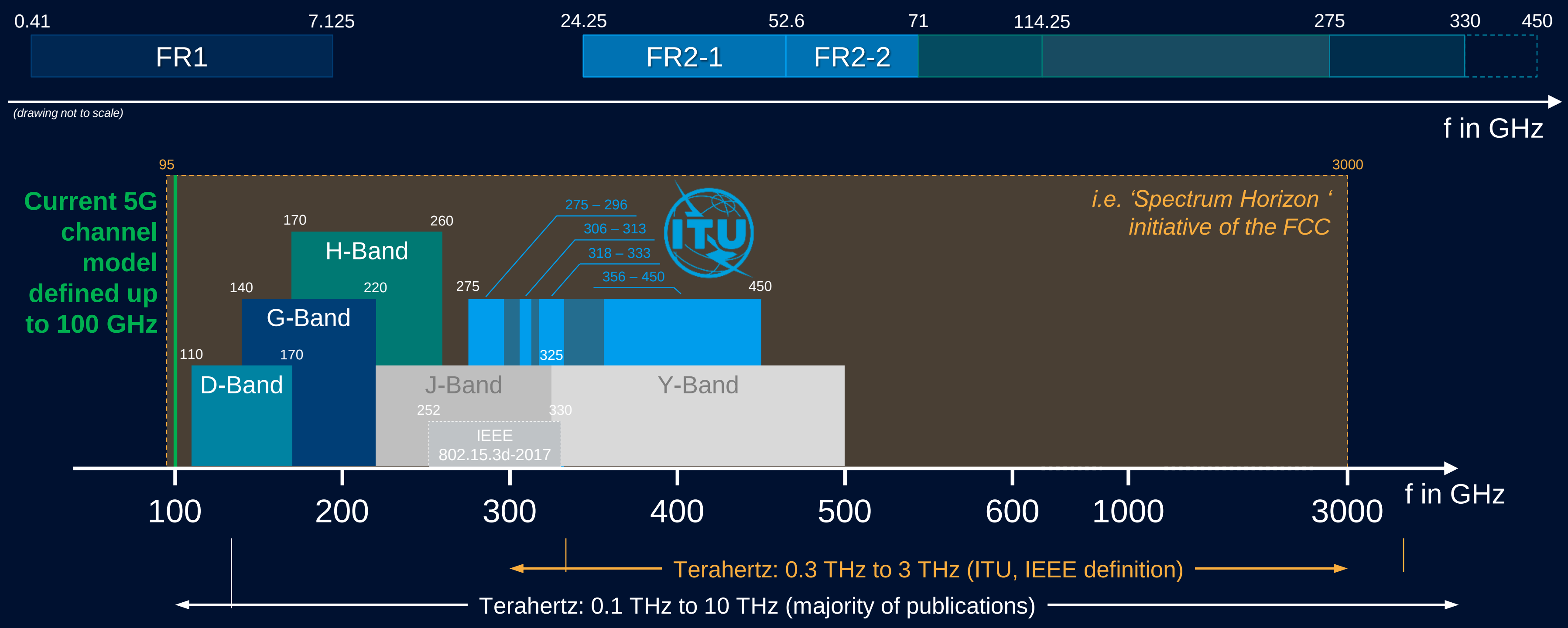
HOW DO WE ENABLE ALL OF THIS?

WITH AN ORCHESTRA OF 6G TECHNOLOGY COMPONENTS

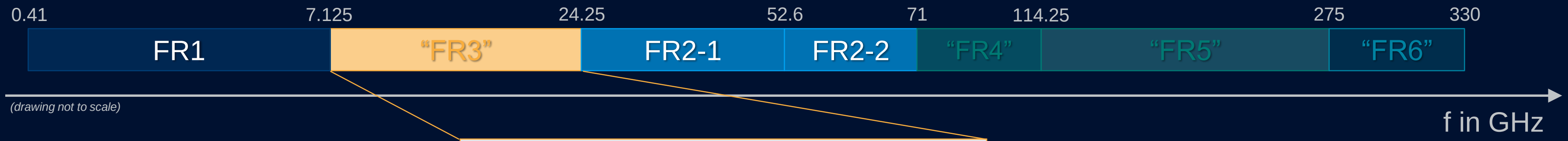
- THz communication & "FR3"
- Joint communication & sensing
- Artificial Intelligence and Machine Learning
- Reconfigurable Intelligent Surfaces
- Photonics, Visible Light Communication
- Multiple access, new waveforms, channel coding
- Ultra-massive MIMO
- New network topologies, distributed computing
- Full-duplex communication
- Security & Trustworthiness

A high-level overview on all these research areas is provided in one of our #THINKSIX video. Don't miss it!

6G WILL TAKE ADVANTAGE OF FR1 AND FR2
THz WILL BE ANOTHER FREQUENCY LAYER



BUT AGAIN, 6G SPECTRUM IS MORE THAN THz
A LOT OF INDUSTRY PLAYERS DISCUSS “FR3” SPECTRUM



- 6.1.6 Potential Spectrum bands for study
  - 6.1.6.1 UHF Band
    - 6.1.6.1.1 1300-1350 MHz
    - 6.1.6.1.2 1780-1850 MHz
  - 6.1.6.2 Lower-cmW spectrum
    - 6.1.6.2.1 3100-3450 MHz
    - 6.1.6.2.2 3980-4180 MHz (TBD)
    - 6.1.6.2.3 4400-4940 MHz
    - 6.1.6.2.4 7125-8500 MHz
  - 6.1.6.3 Upper-cmW spectrum
    - 6.1.6.3.1 10-10.5 GHz
    - 6.1.6.3.2 10.7-12.2
    - 6.1.6.3.3 12.2 – 12.7 GHz
    - 6.1.6.3.4 12.7-13.75 GHz
    - 6.1.6.3.5 13.75-15 GHz
    - 6.1.6.3.6 25.25-27.5 (TBD)
  - 6.1.6.4 EHF Band
    - 6.1.6.4.1 37.0-37.6 GHz
    - 6.1.6.4.2 42-43.5 (TBD)
    - 6.1.6.4.3 92-114.25 GHz (W-band) and 122.25-174.8 GHz (D-band):

Source:
Spectrum Working Group

(SUB)-THZ RESEARCH EXAMPLES

The 6G SENTINEL (Six-G Enablers: Flexible Networks, THz Technology and Integration, Non-Terrestrial Networks, SidElink and Localization) project

ARIADNE

Artificial Intelligence aided D-band network for 5G long term evolution

6G-TERAKOM:
Key components for THz communication for intelligent 6G networks

FCC GRANTS QUALCOMM AND SAMSUNG D-BAND FREQUENCY LICENSES IN THE US

Samsung

The South Korean company's license started in December 2021 and will last until January 2024. Samsung will test a 6G wireless communication system prototype comprising a phased array transmitter and receiver to emulate a cellular base station and mobile device.

The FCC has granted authorization for works in the range between 133-148 GHz, and the experiments will take place in Plano, Texas, within a 500 metres radius. "The end-to-end test is to verify the feasibility of long-range cellular communication in the sub-Terahertz spectrum, in terms of coverage, throughput, latency, beam steering capability," the company said in its application.

According to Samsung's filing, the key innovations in this test would be the high-performance phased array using Indium Phosphide (InP), a compound inorganic semiconductor; adaptive beamforming at Terahertz carrier frequencies; and full digital beamforming to support multi-beam communication systems.

Qualcomm

Qualcomm's license started in January 2022 and will expire in February 2024. The company explained to the FCC that "the experimental license would allow Qualcomm to develop new wireless communications systems technologies for the operating range of 132.5-147.5 GHz in SanDiego, California."

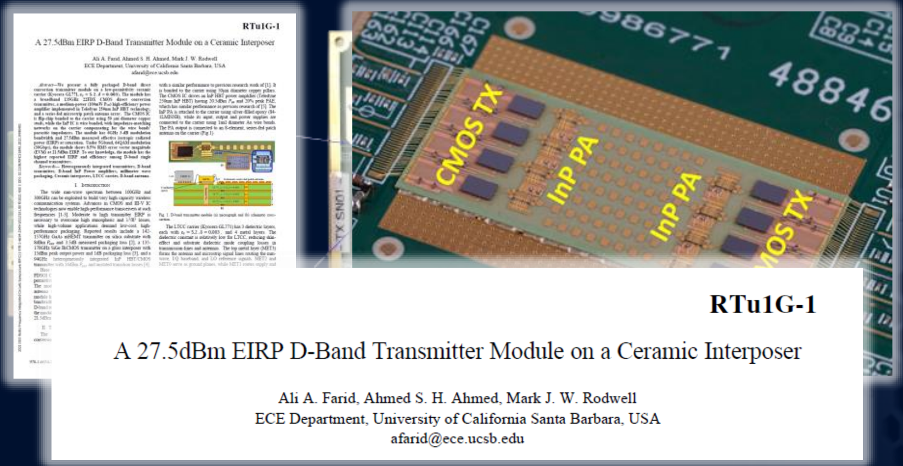
According to the company, the experiments will include prototype transmitters and receivers. "Higher power transmitters will be fixed and located indoors and outdoors. Mobile devices will operate within the coverage range of the transmitter. Transmission BW [bandwidth] is comprised of four subcarriers at 2.5 GHz each using OFDM [Orthogonal Frequency-Division Multiplexing] modulation. Fixed site transmitters will use beam-steering antenna arrays," Qualcomm details in one document supporting its application.

Source: https://www.6gworld.com/exclusives/qualcomm-samsung-and-the-us-battle-for-beyond-5g/ (March 2022)

THE INDUSTRY IS ACTIVELY WORKING ON THz, SO DO WE!

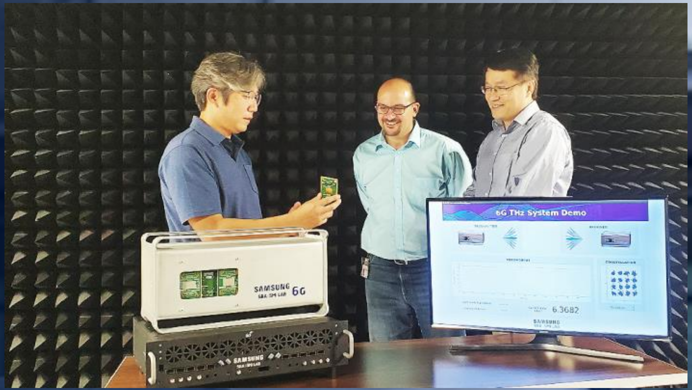
Samsung Electronics and University of California Santa Barbara Demonstrate 6G Terahertz Wireless Communication Prototype

Korea on June 16, 2021 Audio Share


RTu1G-1

A 27.5dBm EIRP D-Band Transmitter Module on a Ceramic Interposer

Ali A. Farid, Ahmed S. H. Ahmed, Mark J. W. Rodwell
ECE Department, University of California Santa Barbara, USA
afarid@ece.ucsb.edu



- CMOS-based D-Band (110 to 170 GHz) RFIC with 128 antenna element array
- 2 GHz signal bandwidth with MIMO 2x2
- 12 Gbps @ 30 m, 2.3 Gbps @ 120 m

https://news.samsung.com/global/samsung-electronics-and-university-of-california-santa-barbara-demonstrate-6g-terahertz-wireless-communication-prototype [June 2021]

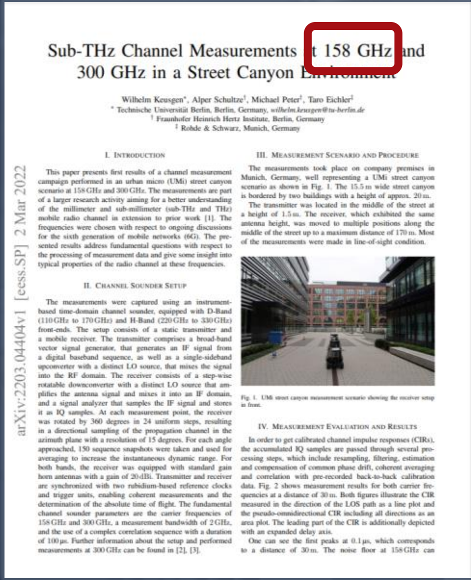
R&S SUPPORTS CHANNEL SOUNDING MEASUREMENTS

- Fraunhofer IAF InGaAs mHEMT technology: extremely low-noise and broadband applications at room temperature
- Signal generation TX and analysis RX at 275 to 325 GHz operating frequency
- Signals can be arbitrary modulated for transmission experiments with beyond 5G candidate waveforms for THz communication or for channel propagation measurements

„THz Channel Sounding: Design and Validation of a High Performance Channel Sounder at 300 GHz" (IEEE WCNC2020) https://ieeexplore.ieee.org/document/9124887

Fraunhofer IAF

Fraunhofer HHI



Sub-THz Channel Measurements at 158 GHz and 300 GHz in a Street Canyon Environment

Wilhelm Keusgen*, Alper Schultze†, Michael Peter†, Taro Eichler‡

* Technische Universität Berlin, Berlin, Germany

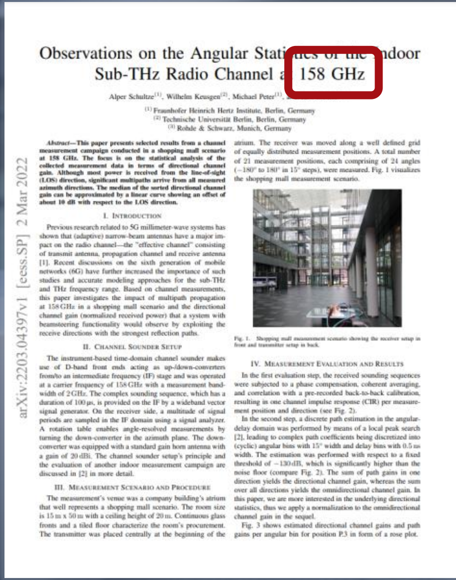
† Fraunhofer Heinrich Hertz Institute, Berlin, Germany

‡ Rohde & Schwarz, Munich, Germany

arXiv:2203.04404v1 [eess.SP] 2 Mar 2022

https://arxiv.org/abs/2203.04404

(March 2022)



Observations on the Angular Statistics of the Indoor Sub-THz Radio Channel at 158 GHz

Alper Schultze(1), Wilhelm Keusgen(2), Michael Peter(1)

(1) Fraunhofer Heinrich Hertz Institute, Berlin, Germany

(2) Technische Universität Berlin, Berlin, Germany

(3) Rohde & Schwarz, Munich, Germany

arXiv:2203.04397v1 [eess.SP] 2 Mar 2022

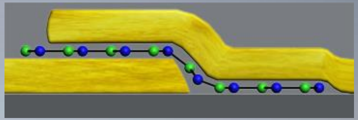
https://arxiv.org/pdf/2203.04397.pdf

(March 2022)

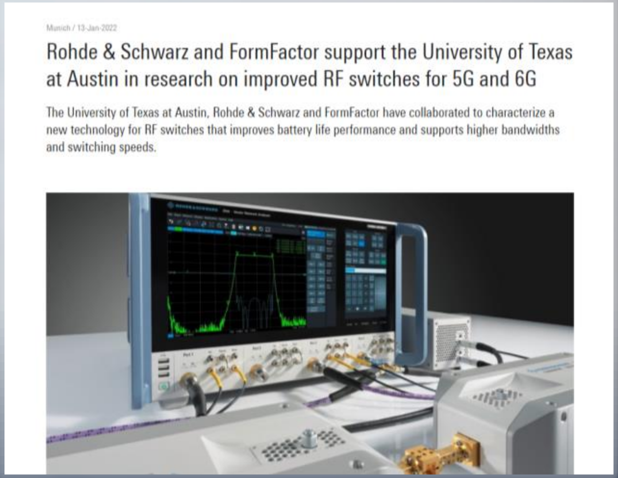
COLLABORATION WITH ACADEMIA ON mmWAVE AND THz

TESTING RF SWITCHES @ D-BAND W/ R&S®ZNA43 & R&S®ZC170

Non-volatile memristor-like switch from 2D hexagonal boron nitride



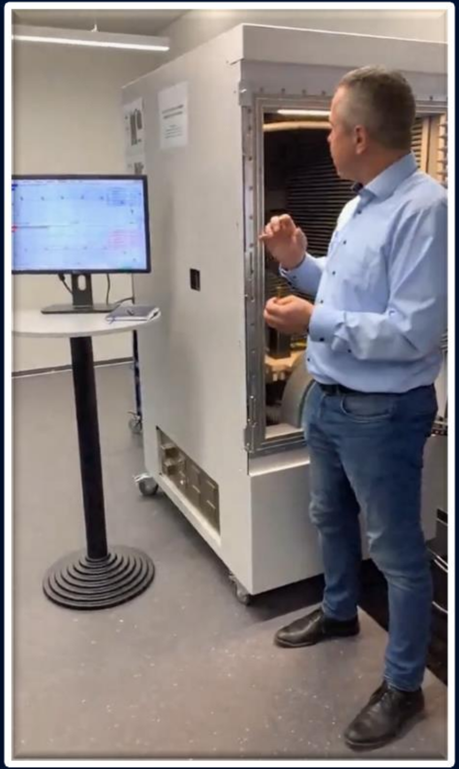
An atom-thin layer of hexagonal boron nitride sandwiched between gold electrodes acts as a switch to route 5G and possibly higher frequencies
https://spectrum.ieee.org/atomthin-switches-5g-6g-radio-signals


Munich / 13-Jan-2022

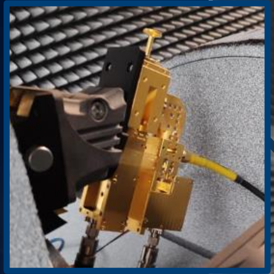
Rohde & Schwarz and FormFactor support the University of Texas at Austin in research on improved RF switches for 5G and 6G

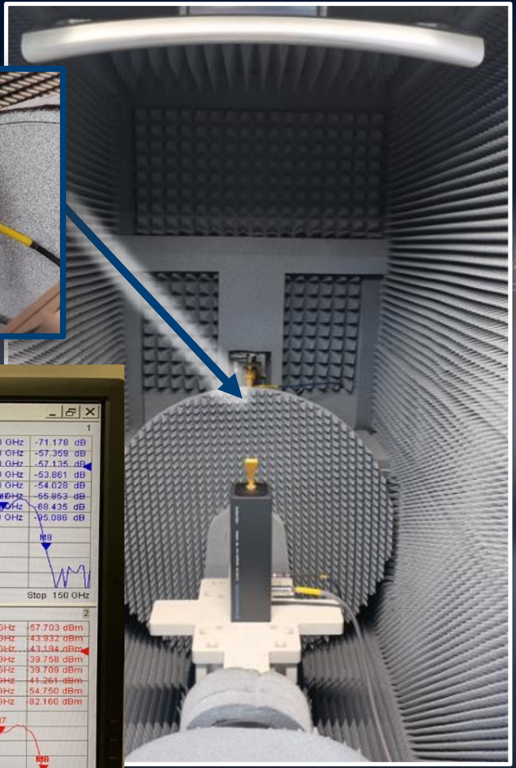
The University of Texas at Austin, Rohde & Schwarz and FormFactor have collaborated to characterize a new technology for RF switches that improves battery life performance and supports higher bandwidths and switching speeds.

SIMULTANEOUSLY WE TAKE THE NEXT STEP TOWARDS FULL OTA TEST SOLUTIONS FOR D-BAND



Initial realization:
90 to 140 GHz
– full D-band support under development

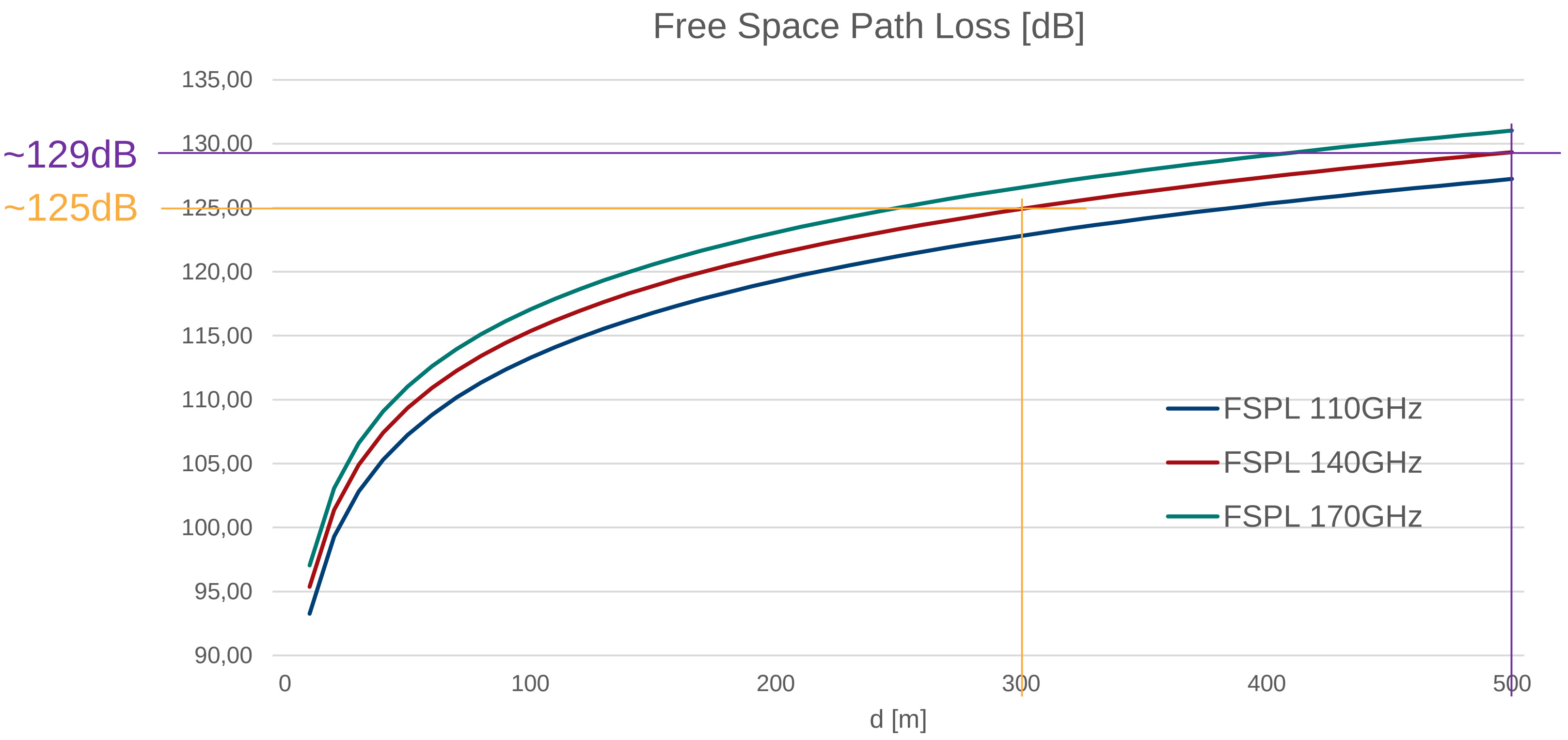




ONE OF THE OFTEN RAISED QUESTION

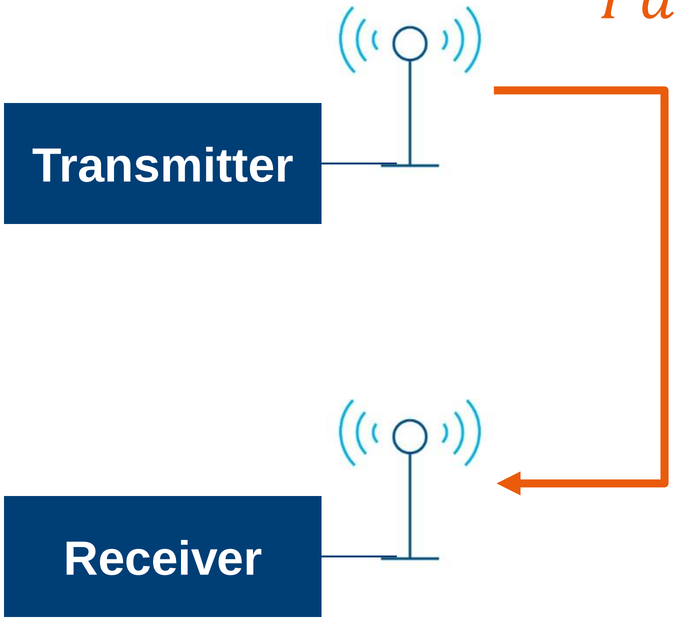
Can we ever realize significant cell sizes at D-Band frequencies?

D-BAND BASICS
FREE SPACE PATH LOSS



D-BAND LINK BUDGET
A VERY BASIC EXAMPLE

$$Path\ loss = TX\ power\ - RX\ sensitivity$$

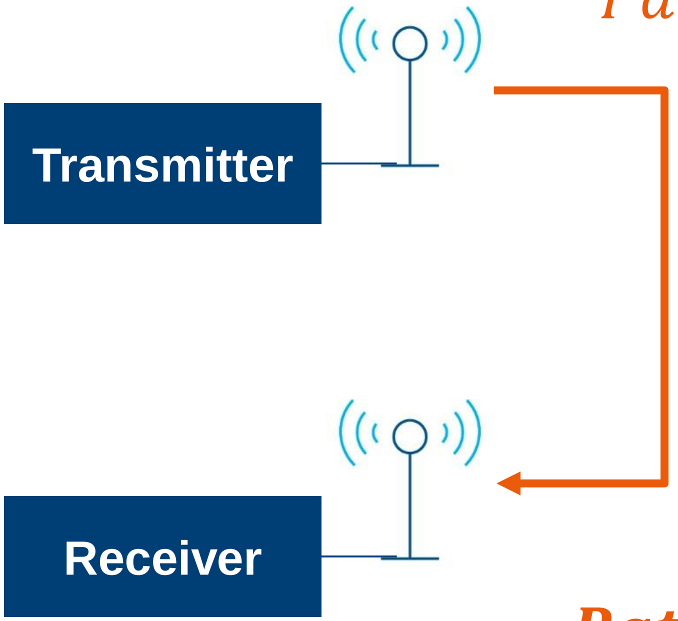


TX power
Device power
+ TX ant gain

RX sensitivity
Noise (BW)
+ Noise figure
+ Required SNR
- RX ant gain

D-BAND LINK BUDGET
A VERY BASIC EXAMPLE

$$Path\ loss = TX\ power\ - RX\ sensitivity$$



TX power
10dBm
+ 25dB
+35dBm

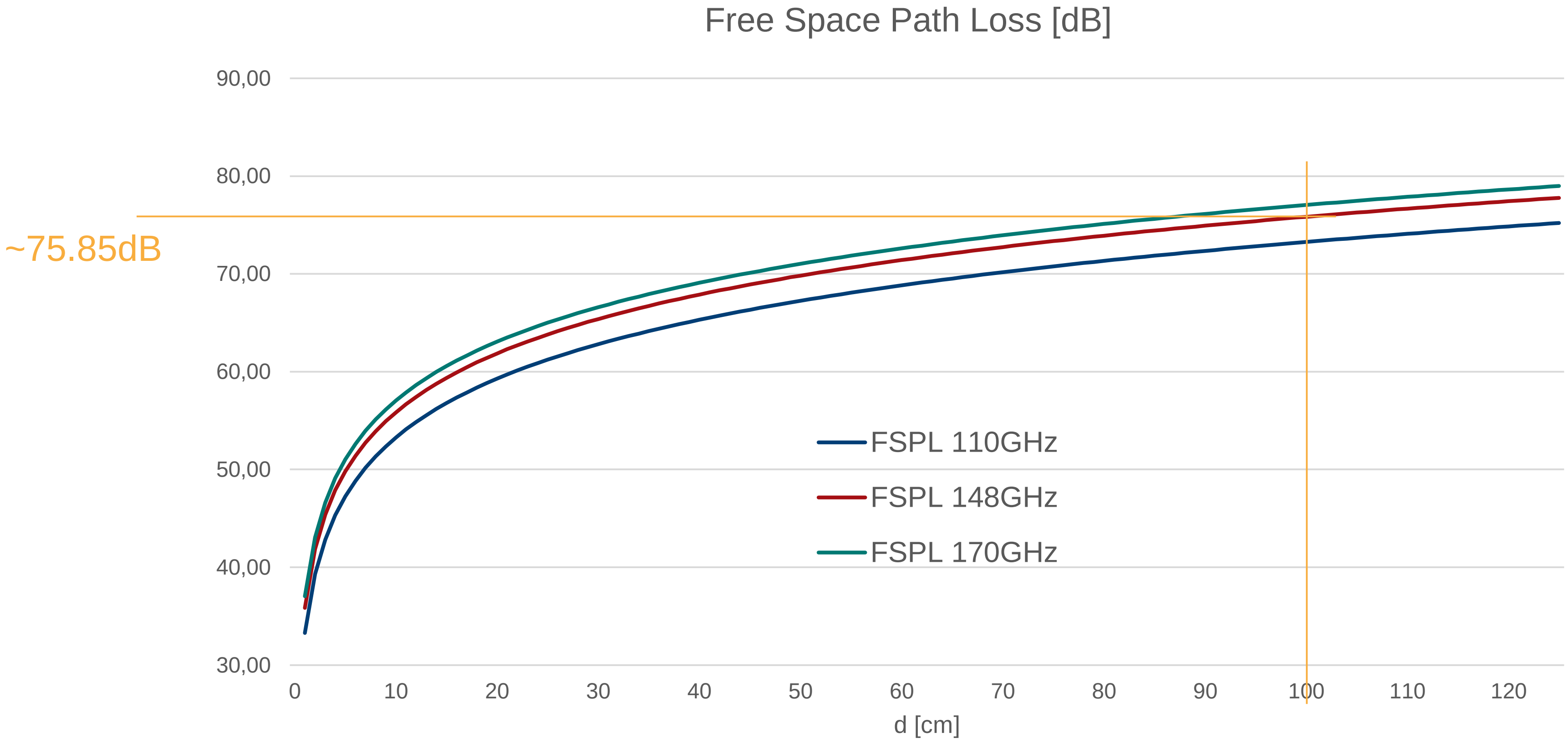
RX sensitivity
-87dBm (500MHz)
+ 8dB
+ 10dB
- 25dB
- 94dBm

$$\mathbf{Path\ loss = 129\ dB}$$

ANOTHER OFTEN RAISED QUESTION

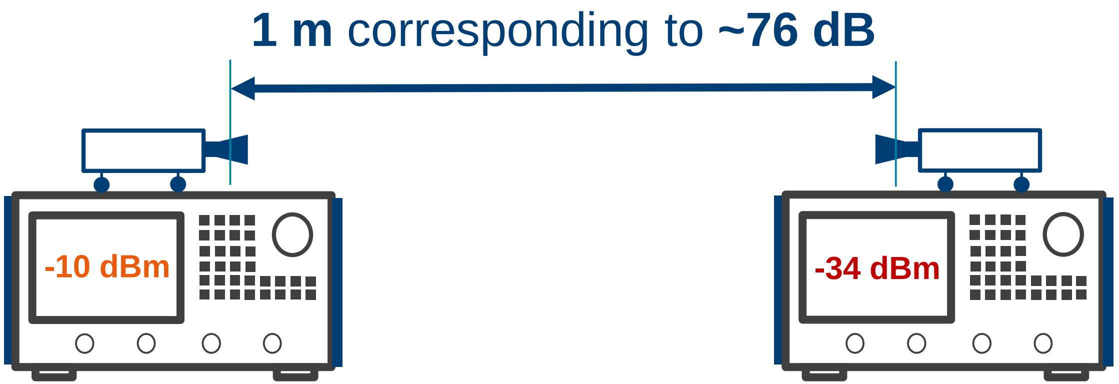
Can we at all transmit through material?

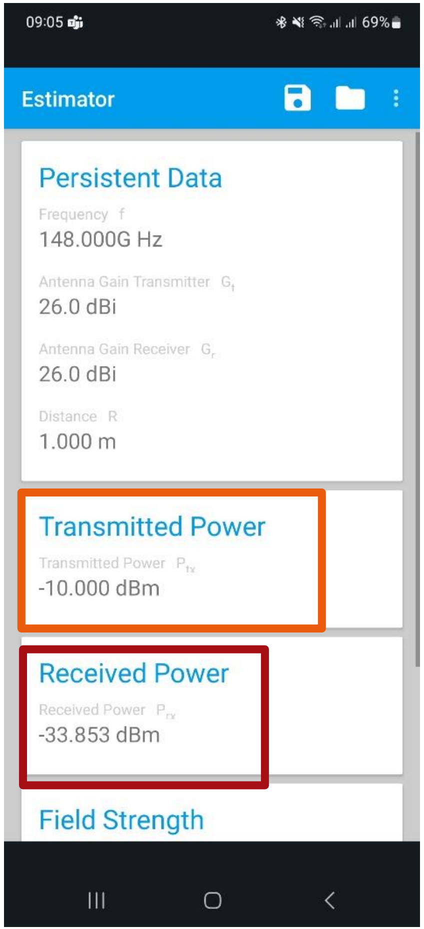
D-BAND BASICS
FREE SPACE PATH LOSS



CALCULATIONS
TODAYS DEMO SETUP

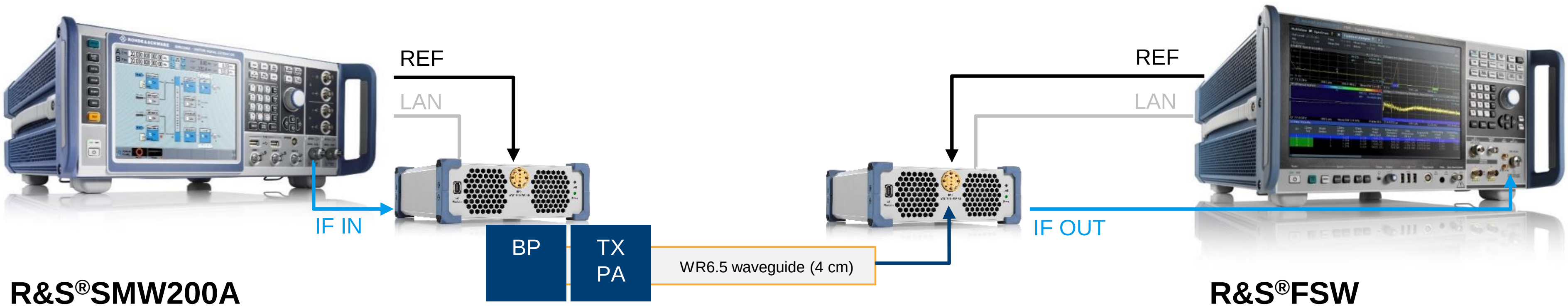
- Part 1: simple LOS case
- Part 2: impact from various materials
- Part 3: reflection NLOS case





DEMO

TEST SETUP



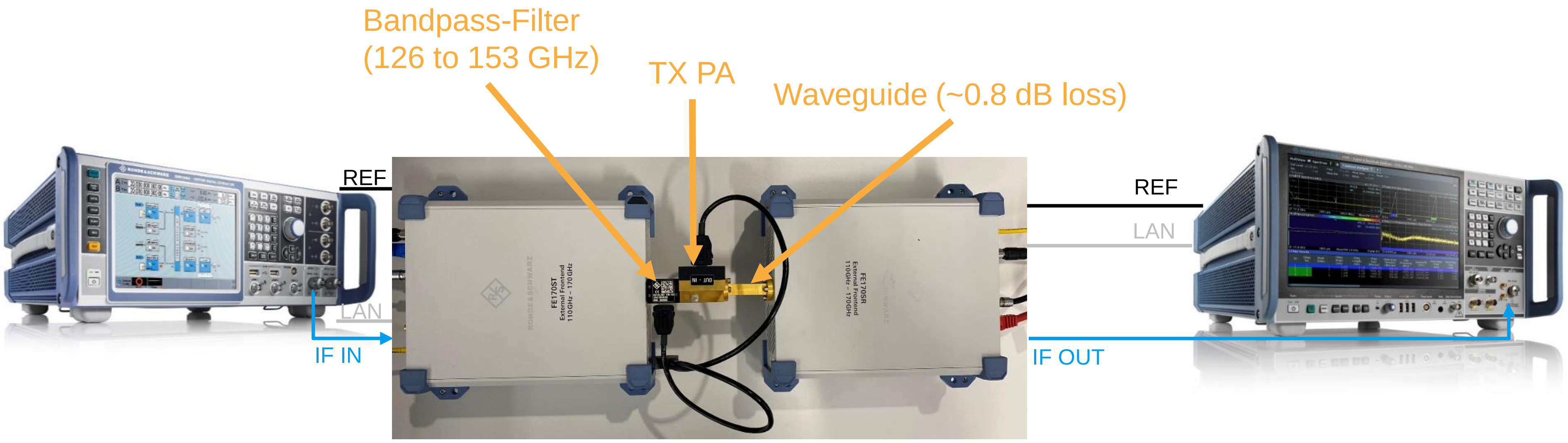
R&S®SMW200A
vector signal generator

R&S®FE170ST
frontend

R&S®FE170SR
frontend

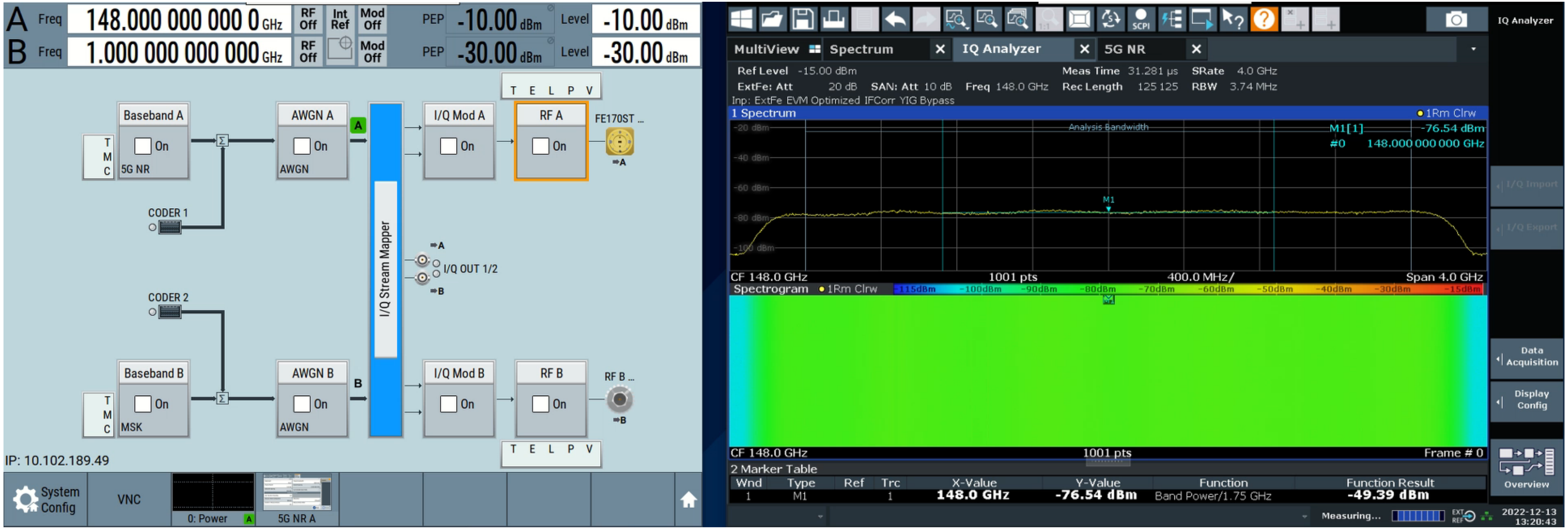
R&S®FSW
signal and spectrum analyzer

SETUP



Bandpass-Filter
(126 to 153 GHz)
TX PA
Waveguide (~0.8 dB loss)
REF
LAN
IF IN
REF
LAN
IF OUT
FE170ST
External Frontend
110GHz - 170GHz
FE170SR
External Frontend
110GHz - 170GHz

SETUP


A Freq 148.000 000 000 0 GHz
RF Off
Int Ref
Mod Off
PEP -10.00 dBm
Level -10.00 dBm
B Freq 1.000 000 000 000 GHz
RF Off
Mod Off
PEP -30.00 dBm
Level -30.00 dBm
Baseband A
On
5G NR
AWGN A
On
AWGN
I/Q Mod A
On
RF A
On
FE170ST ...
CODER 1
CODER 2
I/Q Stream Mapper
I/Q OUT 1/2
Baseband B
On
MSK
AWGN B
On
AWGN
I/Q Mod B
On
RF B
On
RF B ...
T E L P V
IP: 10.102.189.49
System Config
VNC
0: Power
5G NR A
IQ Analyzer
MultiView
Spectrum
IQ Analyzer
5G NR
Ref Level -15.00 dBm
Meas Time 31.281 µs
SRate 4.0 GHz
ExtFe: Att 20 dB
SAN: Att 10 dB
Freq 148.0 GHz
Rec Length 125 125
RBW 3.74 MHz
Inp: ExtFe EVM Optimized IFCorr YIG Bypass
1 Spectrum
1Rm Clrw
Analysis Bandwidth
M1[1] -76.54 dBm
#0 148.000 000 000 GHz
CF 148.0 GHz
1001 pts
400.0 MHz/
Span 4.0 GHz
Spectrogram
CF 148.0 GHz
1001 pts
Frame # 0
2 Marker Table
Wnd Type Ref Trc X-Value Y-Value Function Function Result
1 M1 1 148.0 GHz -76.54 dBm Band Power/1.75 GHz -49.39 dBm
Data Acquisition
Display Config
Overview
Measuring...
2022-12-13 13:20:43

CONCLUSION

- Academia and key industry players are exploring the boundaries and many research projects started looking into the next generation of wireless communication, aka 6G.
- One – out of multiple – research items investigate D-band spectrum as potential band offering wider bandwidth and therefore enabling new or enhanced use cases.
- Testing D-band components requires easy to use instruments, which provide stable and accurate measurement results as calibration is key in the sub-THz frequency range.

Find out more

www.rohde-schwarz.com/wireless/6G

ROHDE&SCHWARZ

Make ideas real