Enabling Smarter, Connected Industries: Exploring ISAC's Role in 6G

Webinar

NGA Participants

Amitava Ghosh, Michael Millhaem, Harish Viswanathan

Moderator: Jaydee Griffith

Agenda

- > Introduction
- > ISAC vs. JSAC
- > ISAC Use Cases and Sensing Topologies
- > Spectrum Tradeoffs, Sensing Requirements and Link Budgets
- > Sensing Waveforms
- > ISAC Proofs-of-Concept (PoC) and Summary

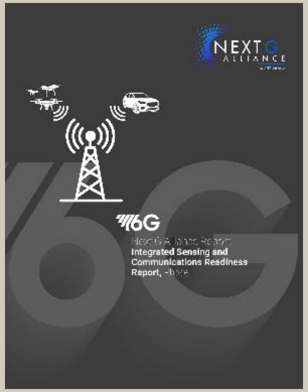
ISAC Readiness Group

- **Mission**
  - Assess readiness of ISAC technology for integration into 6G and develop use cases of particular interest to the North American market.

- **Additional information**
  - *Channel Measurements and Modeling fot Joint/Integrated Communication and Sensing, as well as 7-24 GHz Communication*
  - *Channel Measurements and Modeling for Joint/Integrated Communication and Sensing, as well as 7-24 GHz Communication Channels, Phase II*

Outcomes ISAC Readiness subgroup:

- *Integrated Sensing and Communications Readiness Report, Phase I*



- **Identify North America priority sensing use cases**
- **ITU-R WP5D contributions on sensing**
- **Response to DoD ISAC Dear Colleague Letter**

ISAC Readiness Phase Report

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Phase I report, published September 2025

> Use cases across industries,
> Spectrum needs and regulatory considerations,
> North American priorities for deployment,
> Technical parameters, including sensing requirements, waveform design, and radar cross-section (RCS) modeling,
> System-level challenges and link budget assessments,
> Proofs of concept demonstrating practical feasibility.

Access the report here:

Member institutions in NGA ISAC readiness small group launched a dedicated effort to explore the requirements and use cases of ISAC, outlined the growing maturity of ISAC technology and its transformative potential for 6G systems

Panelists

Amitava Ghosh

Nokia Fellow and
Bell Labs Leader

Harish Viswanathan

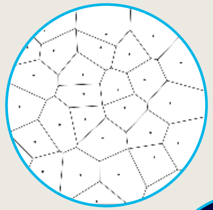
Nokia Head of Radio
Systems Research Lab

Mike Millhaem

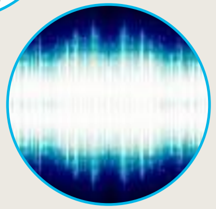
Keysight 6G Technical
Architect

Drivers of 6G Communication and Sensing Convergence

6G



Dense Network — Infrastructure / spectrum reuse



Wide Bandwidths — High-resolution sensing

AI & Signal Processing — Sensing data fusion enabled by AI-native air interface

MIMO and Beamforming — Dual-function spatial processing

Sensing Type	Range Resolution	Maximum Speed
Traffic Monitoring	1m	40 m/s
Pedestrian detection	tens of cm	3 m/s
Parked Vehicle Detection	50cm	N/A
Drone Detection	1m	30 m/s
Around the corner vehicle	1m	15 m/s
Motion sensing	< 10 cm	1 m/s

6G will enable widespread sensing by leveraging cellular infrastructure and spectrum

ISAC vs. JSAC

ISAC vs. JSAC

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Aspect	JSAC	ISAC
Primary Purpose	Communication signals repurposed for sensing	Integrated system for both sensing and communication
Signal Type	Same signals used for both communication and sensing	Different signals or carriers may be used for each function
Carrier Usage	Typically uses the same carrier for both functions	May use different carriers for sensing and communication
Resource Allocation	Limited to communication resources repurposed for sensing	Optimized resource allocation for both functions
Integration Level	Lower level of integration	Higher level of integration within the same system
System Design	Primarily designed for communication, sensing is secondary	Designed to support both functions from the outset
Examples	Using Wi-Fi signals for indoor localization	5G base station using different signals for communication and radar sensing

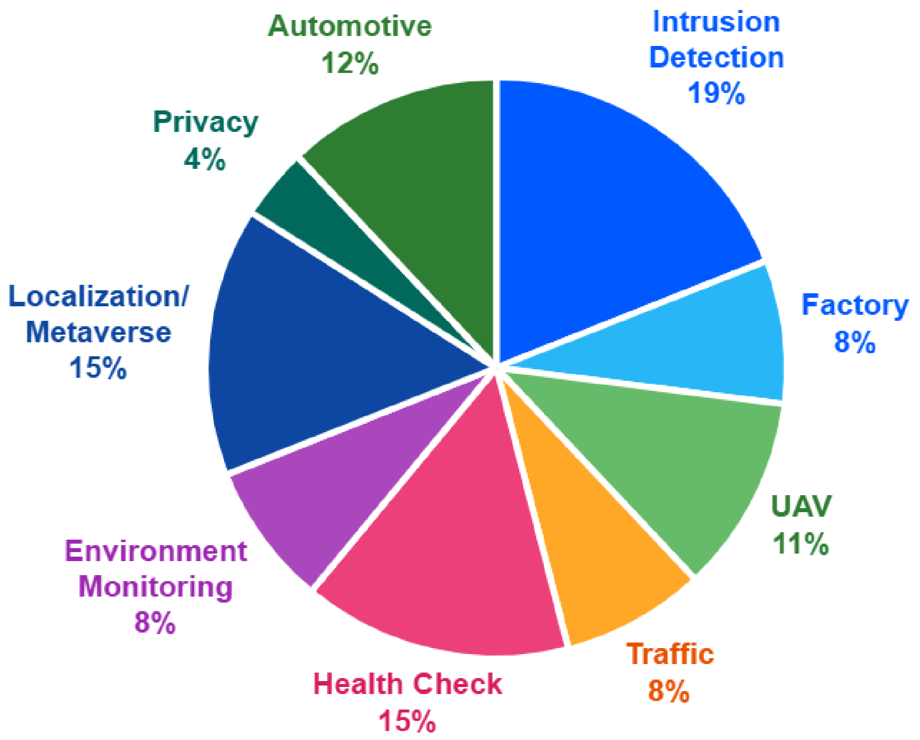
JSAC typically involves sensing using signals primarily intended for communication, whereas ISAC represents using integrated system for both sensing and communication.

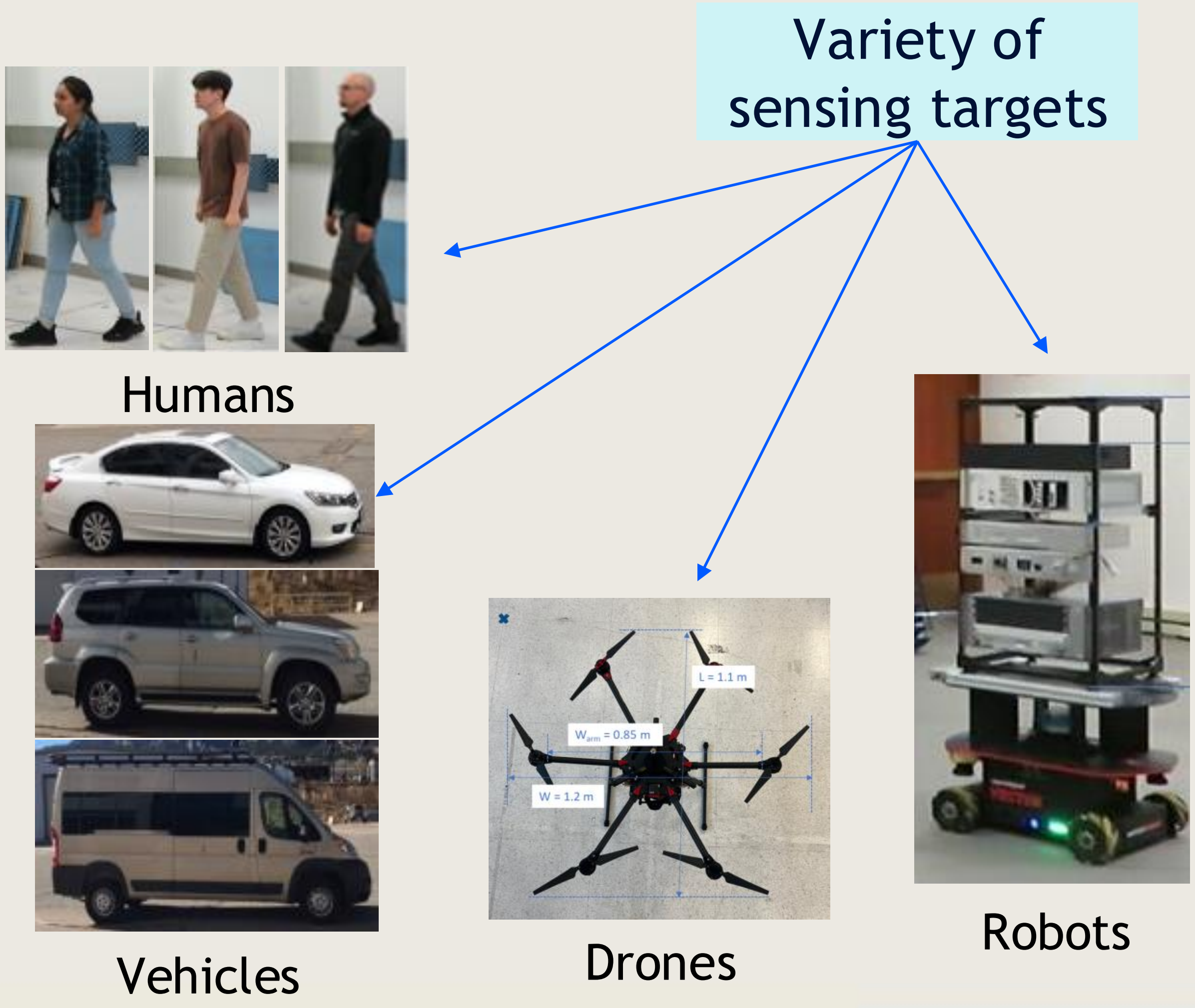
ISAC Use Cases and Sensing Topologies

ISAC Use Cases

Captured in 3GPP Technical Report 22.837 (work in progress)

SA1 USE CASES





ISAC Use Cases (2/4)

Captured in 3GPP Technical Report 22.837 (work in progress)

Factory IoT

- AGV detection and tracking

UAV (Drone)

- Flight trajectory tracking
- Collision avoidance
- Intrusion detection

Traffic Monitoring

- Tourist spot traffic management

ISAC Use Cases (3/4)

Captured in 3GPP Technical Report 22.837 (work in progress)

Automotive

- Automotive maneuvering & navigation
- Road safety at junction

Intruder Detection

- In home, private premises
- On highway, railway

Environment

- Rainfall and flood monitoring

ISAC Use Cases (4/4)

Captured in 3GPP Technical Report 22.837 (work in progress)

Health checking

- Sleep monitoring
- Health monitoring at/outside home

Localization

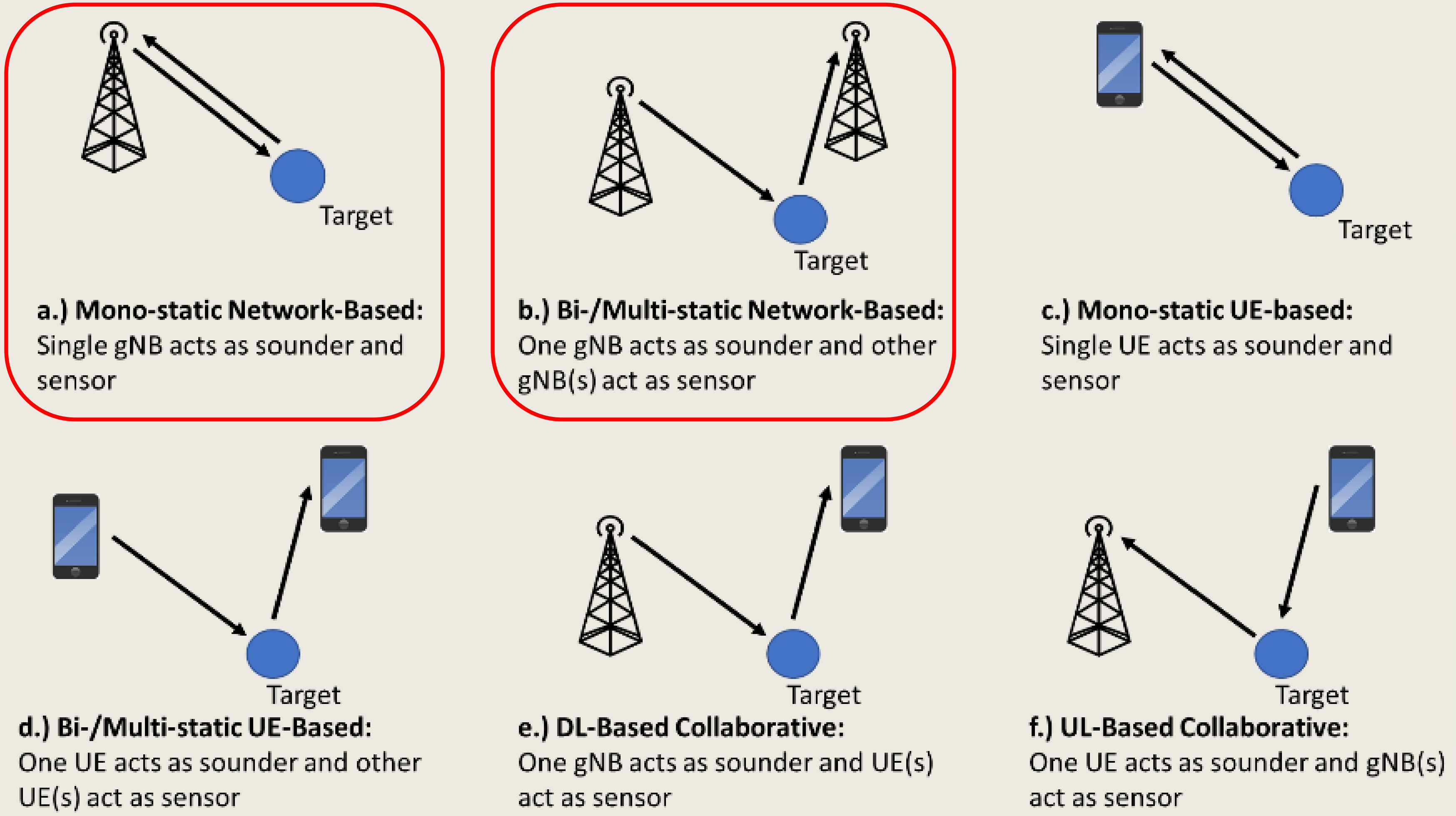
- Employing sensing results for spatial localization

Privacy protection

- Preventing unauthorized use of sensing results

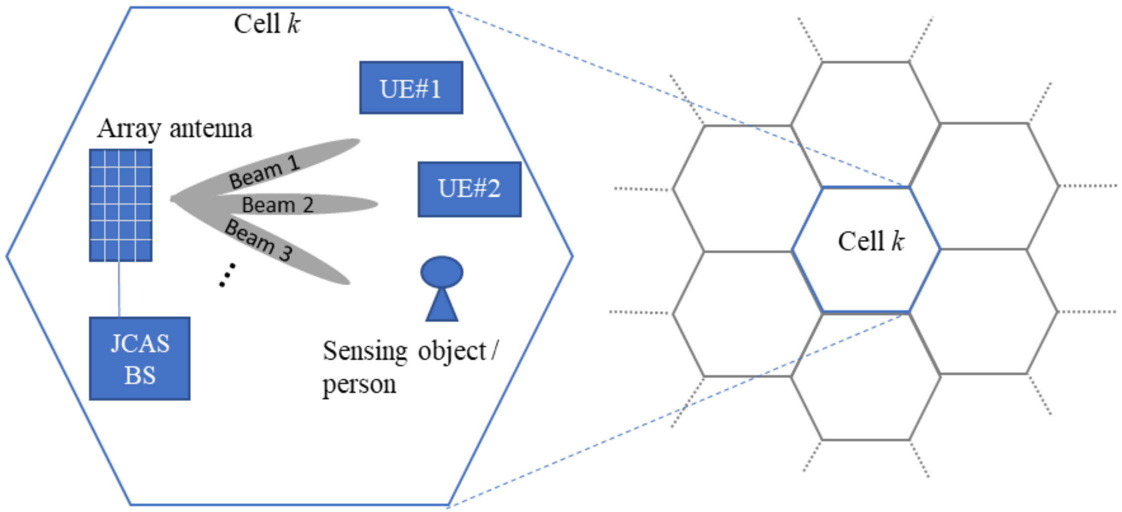
Potential Sensing Topologies Considered in 3GPP RAN

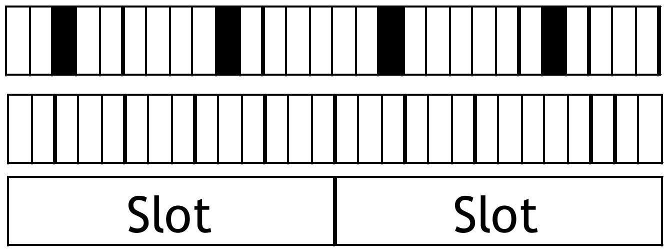
- Several architectures could be supported by existing network infrastructure and UE deployments
- Flexible support for all relevant architectures is needed for reliable evaluation
- Channel modeling for sensing is being actively discussed in 3GPP



Spectrum Tradeoffs, Sensing Requirements and Link Budgets

Major Design Considerations for ISAC





Sensing burst alloc
for direction w/o comm service

→ Symbols

→ NR slots

System Resource		System Service	
		Sensing	Communi-cations
Space	Beam shape & directions	Volume coverage, angle resolution	Throughput & coverage
Time	Burst frequency	Coverage rate & max. velocity	Latency
Time	Burst duration	Range, velocity resolution	Throughput
Frequency	Bandwidth	Range resolution	Throughput & reliability
Power/ EIRP	PA power constraints & linearization	Volume coverage	Throughput & coverage

Time-multiplexing of sensing symbols is preferred (better range resolution, no guard bands)

Spectrum: Tradeoffs

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Sensing Resolution

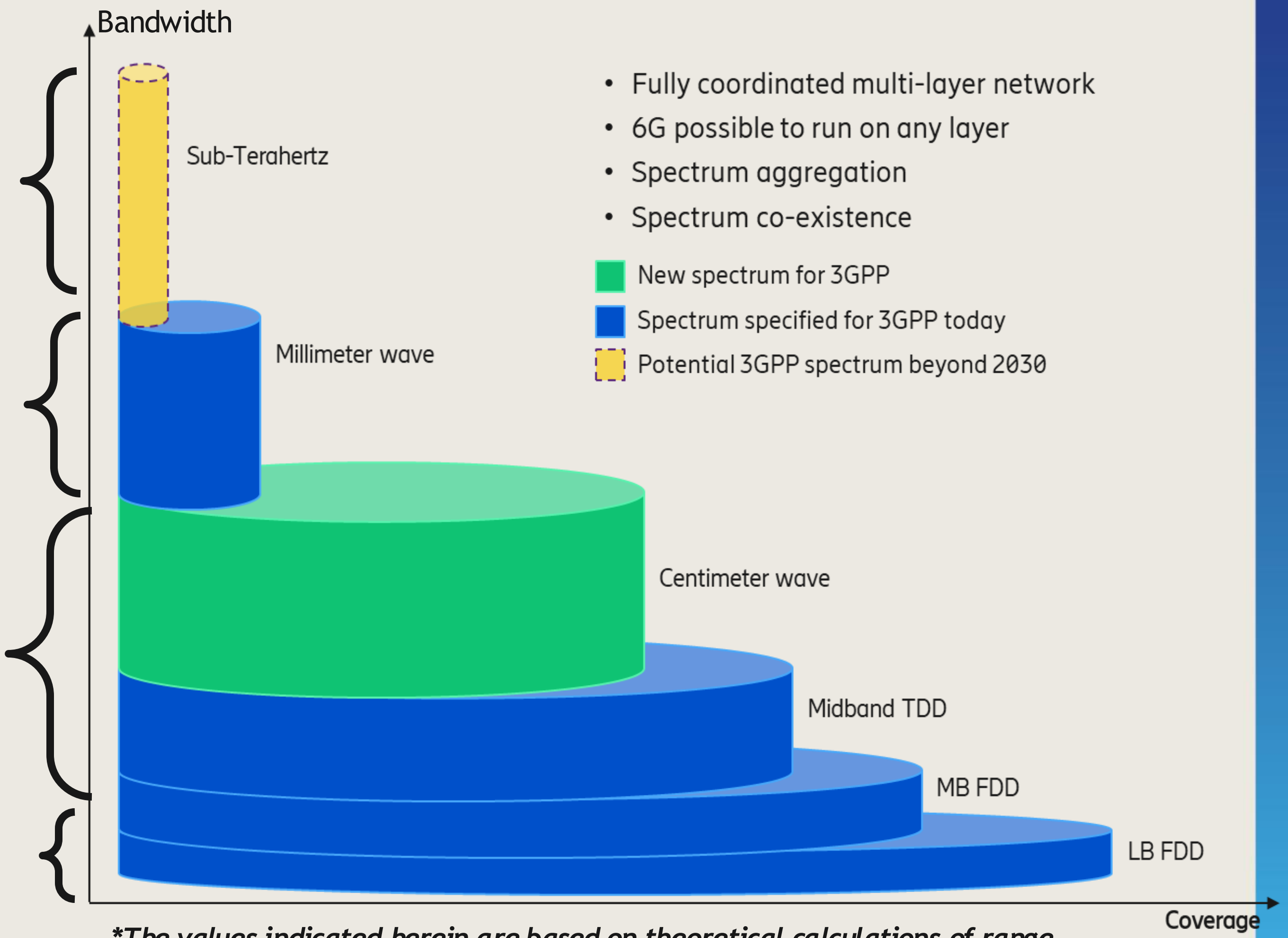
Sub-Terahertz (90-300 GHz):
Sensing Resolution of ***15 mm*** for a bandwidth of 10 GHz*

mmWave (24-47 GHz):
Sensing Resolution of ***15 cm*** for a bandwidth of 1 GHz*

Midband (2.3-7 GHz) and Centimetric (7-13 GHz): Sensing Resolution of ***1.5 m*** for a bandwidth of 100 MHz*

Lowband (<2.6 GHz) :
Sensing Resolution of ***7.5 m*** for a bandwidth of 20 MHz*

Sensing Coverage



***The values indicated herein are based on theoretical calculations of range resolutions in a mono-static setting using an OFDM waveform.**

Sensing Requirements

Requirement		Test Environment (TE)	
		Indoor - ISAC (Ground level)	Outdoor - ISAC (Aerial Vehicles)
Detectability	$P_{False\ Alarm}$	[3%]	[2%]
	$P_{Detection}$	[99%]	[98%]
Localization accuracy	Horizontal	[0.5 m]	[1-2 m]
	Vertical	[0.5 m]	[1-2 m]
Velocity accuracy		[1 m/s]	[1-2 m/s]

Preliminary Sensing requirements (Need SLS to verify)

Sensing Link Budgets for Various Environments

Table 11: Sensing Coverage Analysis at 7 GHz for UMi-AV and InF-AGV Scenarios.

Coverage Analysis	Units	UMi-AV High SNR	UMi-AV Low SNR	InF-DH High SNR	InF-DH Low SNR
Channel model		UMi LOS	UMi LOS	InF-DH	InF-DH
Size or ISD	m	200.0	200.0	120 X 60	120 X 60
Radar Cross Section (RCS σ)	dBsm	-20.0	-20.0	3.0	3.0
Smallest detectable received power	dBm	-115.9	-139.9	-115.9	-139.9
γ: d^(4) in dB	dB	122.8	146.8	109.7	133.7
Estimated sensing distance (with Margin)	**m**	**1176.1**	**4682.1**	**553.0**	**2201.4**
Estimated sensing distance (without Margin)	**m**	**2954.2**	**11760.8**	**1389.0**	**5529.6**

UAV

AGV

16 dB margin (e.g., beampointing error, scan loss, and reflection loss)

These distances considerably surpass the Inter-Site Distances (ISDs) of the respective scenarios, indicating that the sensing coverage is sufficient and does not present a challenge for ISAC systems.

Sensing Waveforms

Sensing Waveform Design (alternatives to OFDM)

From communications world:

> DFT-spread OFDM or SC-FDE can be processed like OFDM radar

> Orthogonal Time Frequency Space (OTFS) can be overlaid on OFDM grid

From radar world:

> Frequency Modulated Continuous Wave (FMCW)

> Pulse Doppler Radar

ISAC Waveform Candidates

KPI	FMCW	OFDM	Single Carrier	FMCW + OFDM	FMCW + SC
PAPR	++	--	+	++/--	++/+
Full duplex effort	+	-	-	+	+
Cost BB	+	-	-	-	-
Carry data	--	++	++	+	+
Commun. proc. flexibility	--	++	+	+	+
User MUX	-	++	+	++	+
Radar proc. accuracy	+	+	-	+	+
Full CSI available for sensing	-	++	+	-	-

OFDM offers best flexibility & easiest integration capability (plus cross-usage of communication data symbols for sensing)

T. Wild, V. Braun, H. Viswanathan, “Joint Design of Communication and Sensing for Beyond5G and 6G Systems”, IEEE Access, Feb 2021

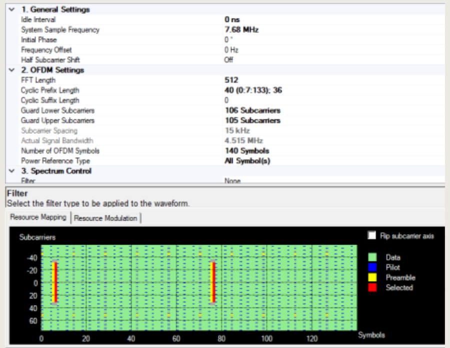
ISAC Waveforms: Tradeoffs (*Approximate*)

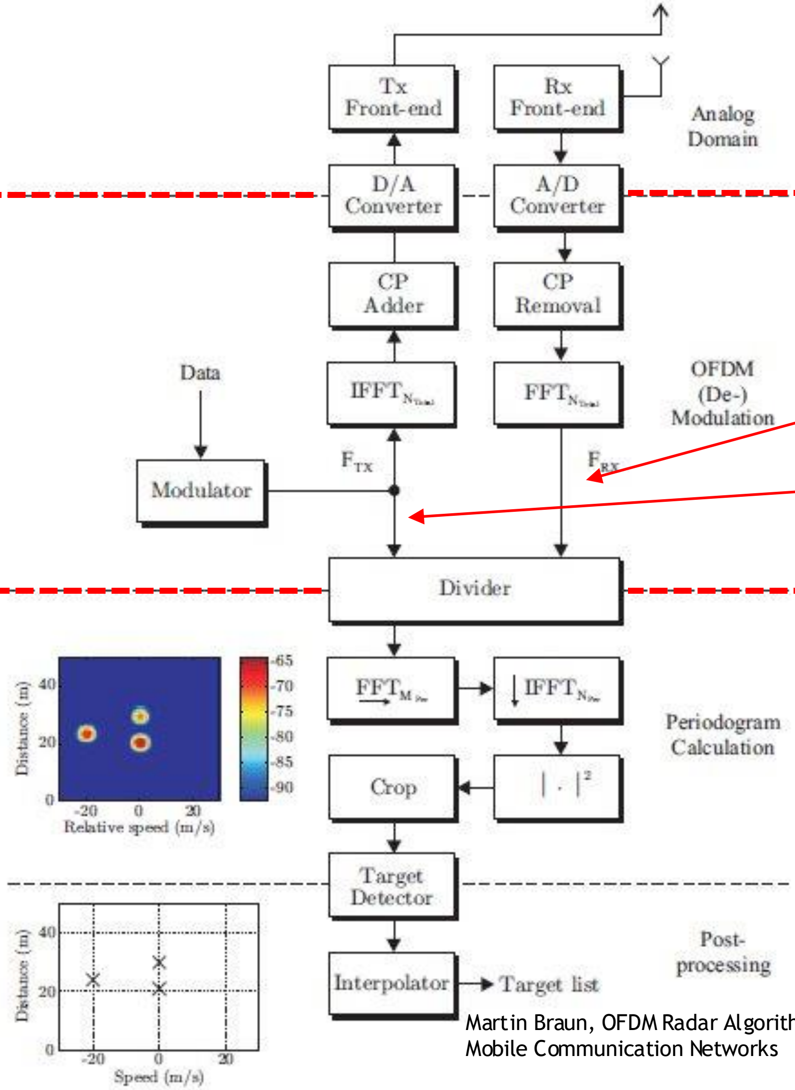
KPI	FMCW	OFDM	Single Carrier	FMCW + OFDM	FMCW + SC
PAPR	🟢 Low	🔴 High	🟢 Low	🟡 Mixed	🟡 Mixed
Full Duplex Effort	🟢 Low	🟡 Moderate	🟡 Moderate	🟢 Flexible	🟢 Flexible
Baseband Cost / Complexity	🟢 Low	🟡 Medium	🟡 Medium	🟡 Medium	🟡 Medium
Data Carrying Capability	🔴 Poor	🟢 Strong	🟢 Strong	🟢 Strong	🟢 Strong
Comm Flexibility	🔴 Limited	🟢 Strong	🟢 Flexible	🟢 Flexible	🟢 Flexible
User Multiplexing	🟡 Moderate	🟢 Strong	🟢 Flexible	🟢 Strong	🟢 Flexible
Radar Accuracy	🟢 High	🟢 High	🟡 Medium	🟢 Flexible	🟢 Flexible
CSI Availability for Sensing	🟡 Partial	🟢 Full	🟢 Partial	🟡 Medium	🟡 Medium

🟢 Green = Strong/Advantage 🟡 Yellow = Moderate/Trade-off 🔴 Red = Weak/Limitation

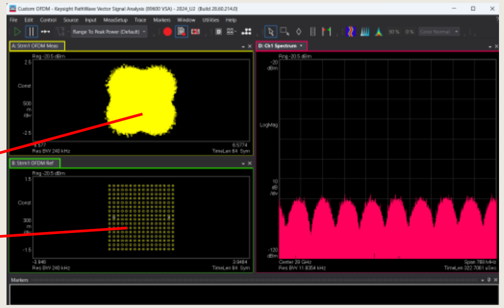
ISAC Proofs-of-Concept (PoC) and Summary

OFDM Radar

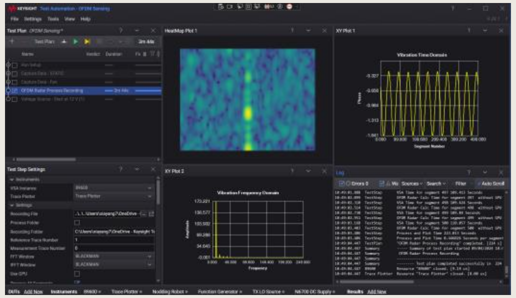




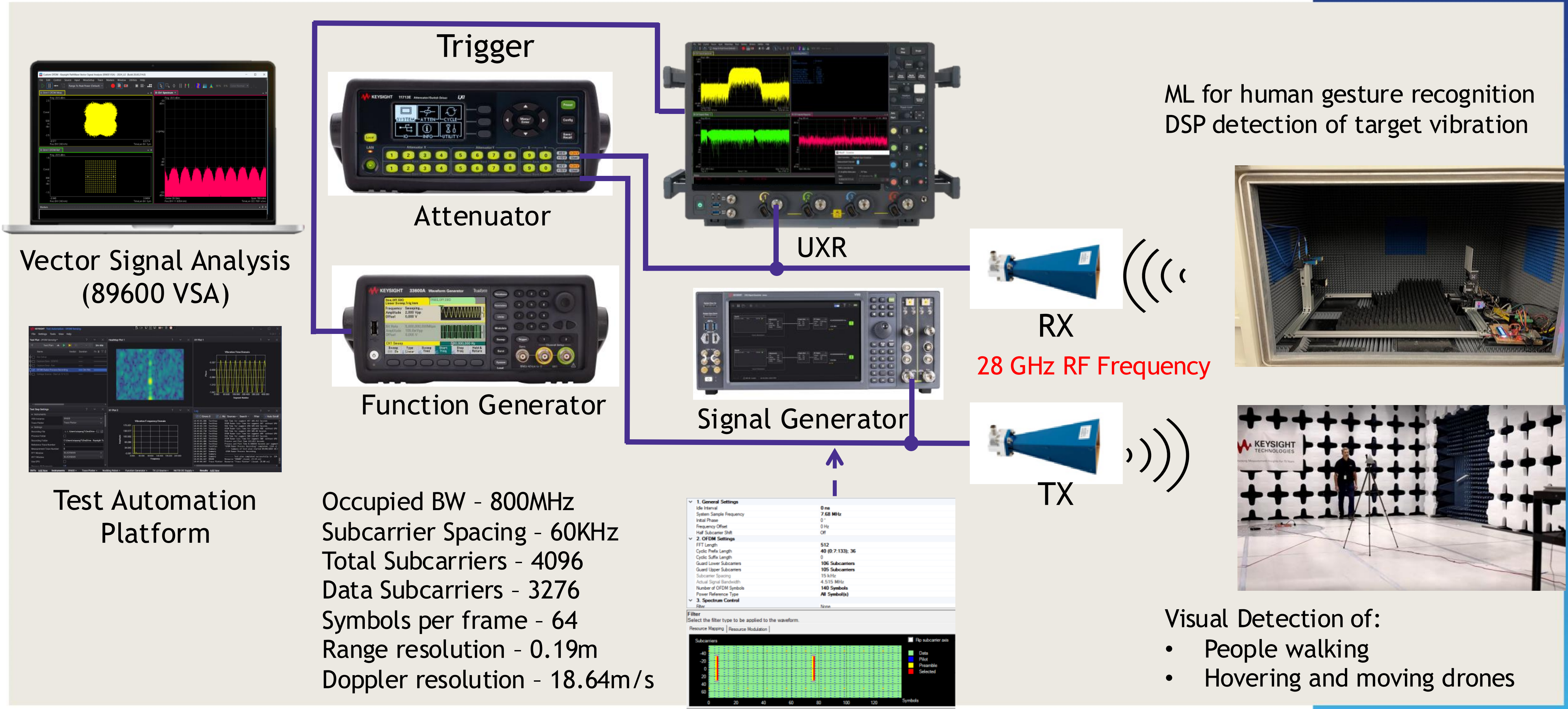
Martin Braun, OFDM Radar Algorithms in Mobile Communication Networks



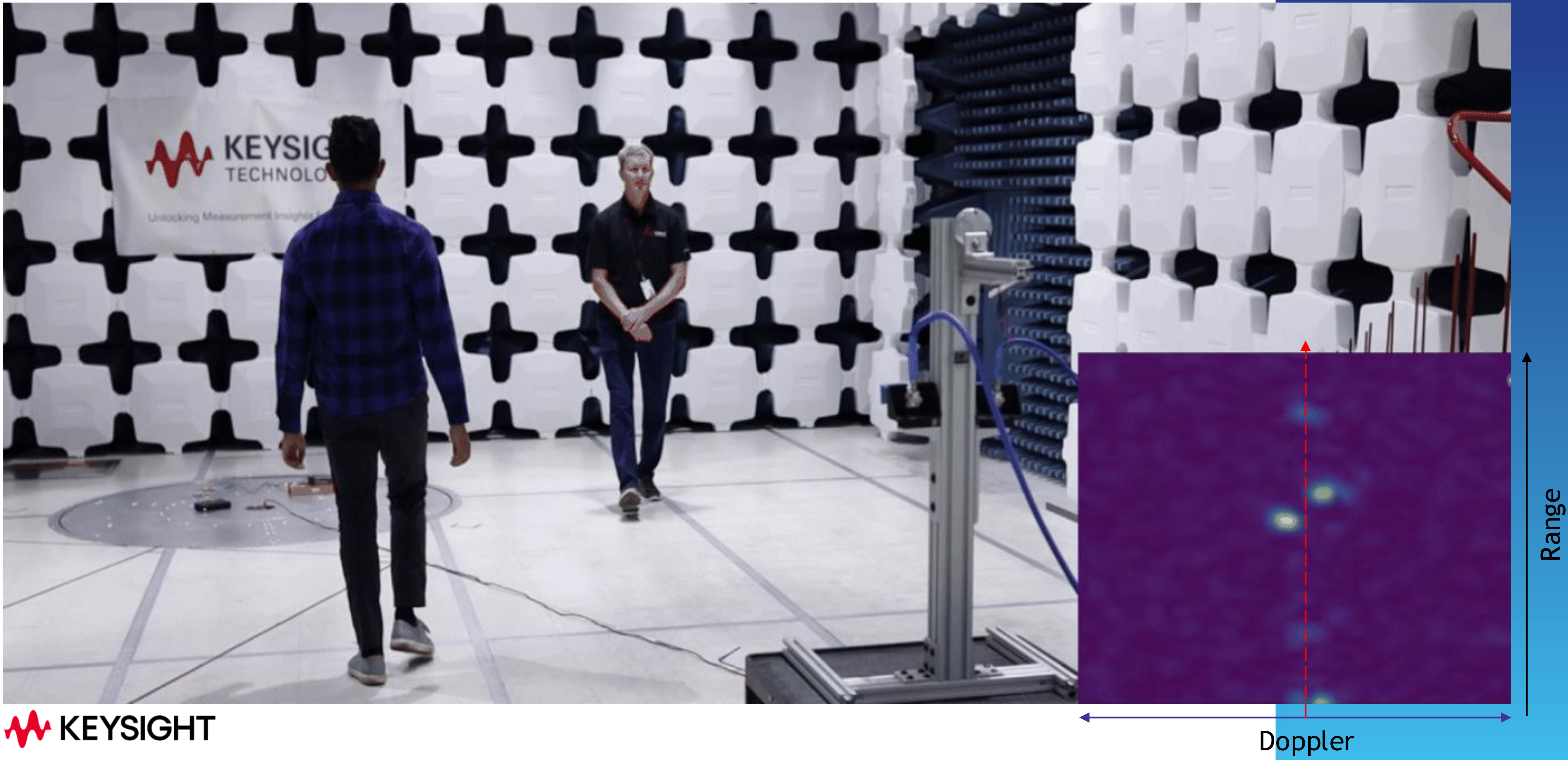
OFDM Radar
Signal Processing



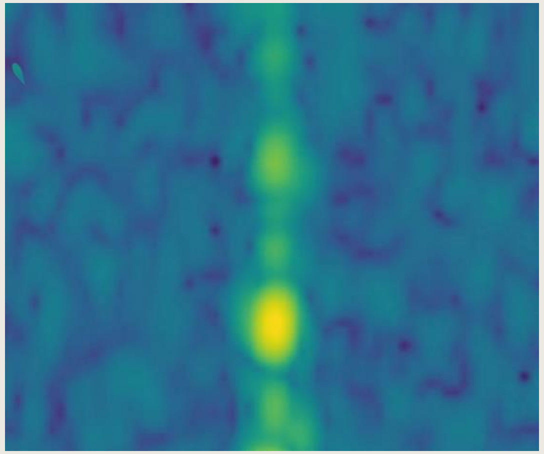
Testbed Setup



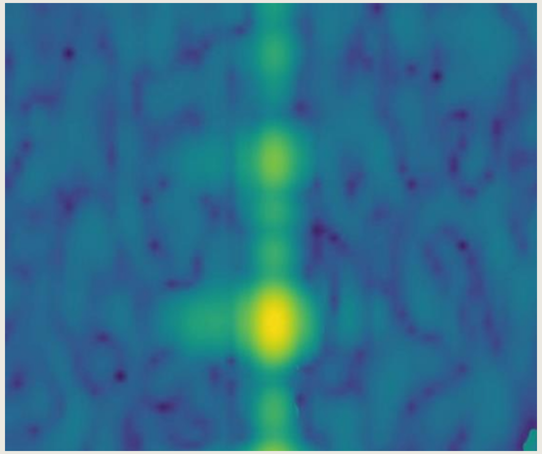
People Walking



Measuring Micro Doppler



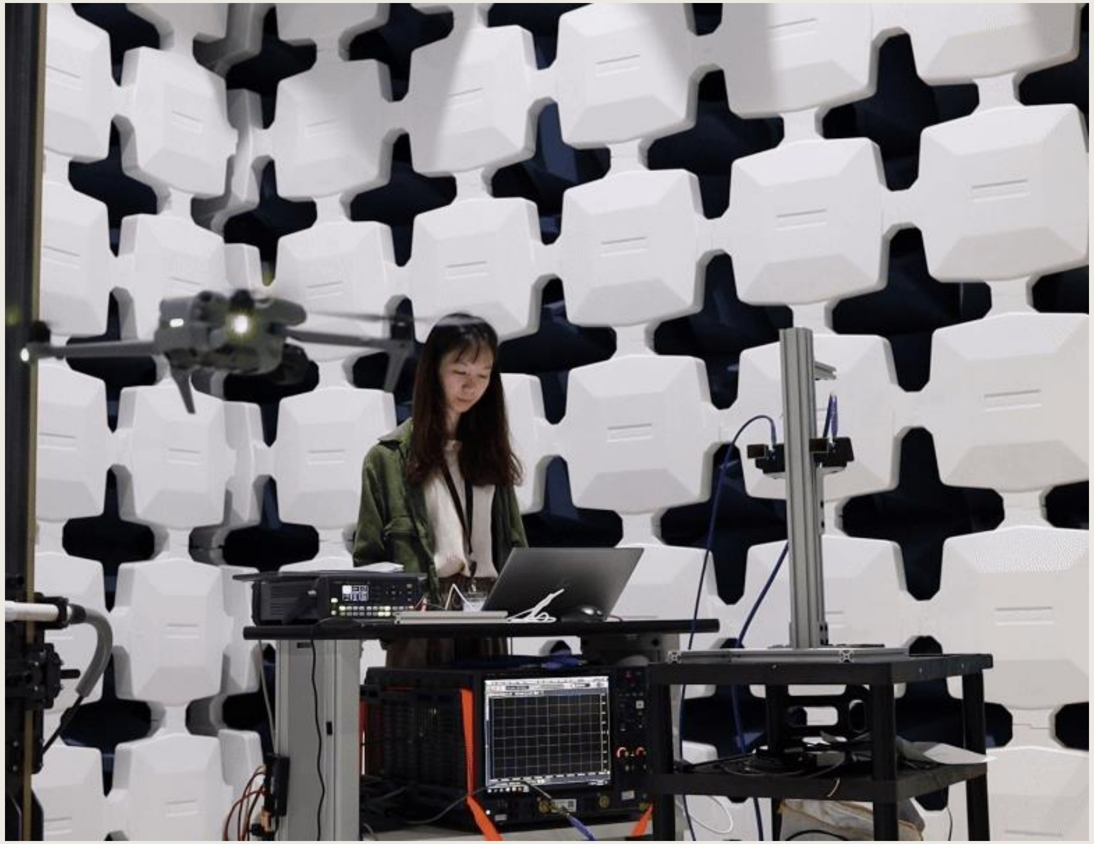
Static Fan

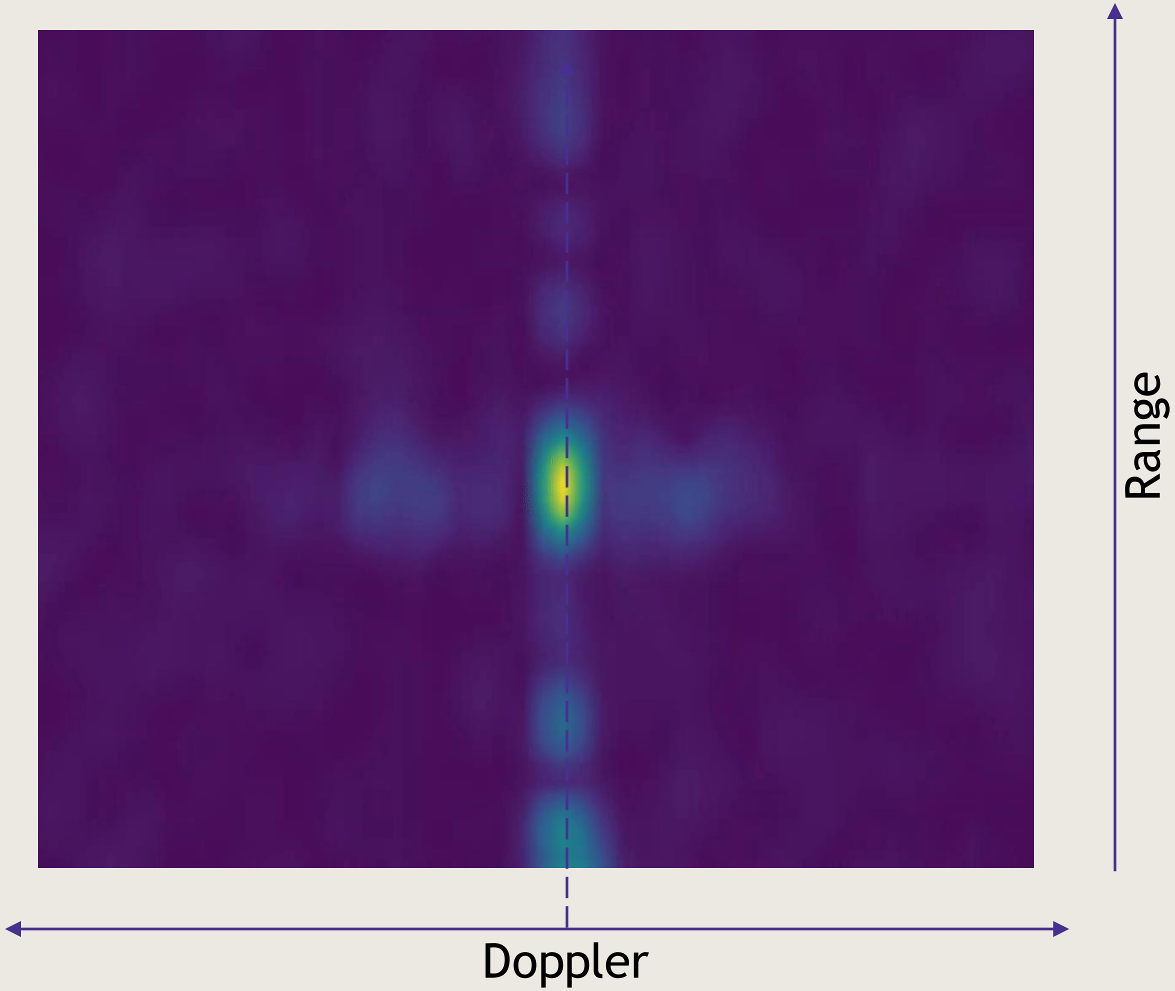


Fan Spinning

KEYSIGHT

Hovering Drone





Vibration Sensing

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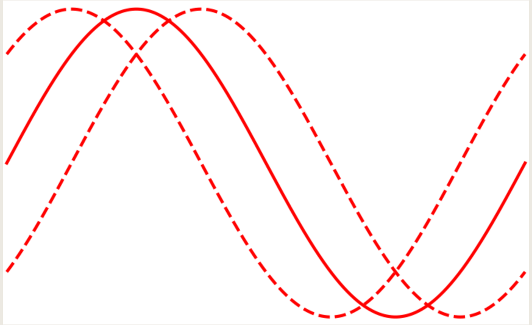
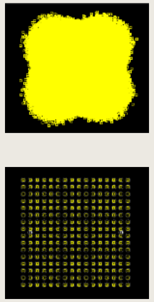
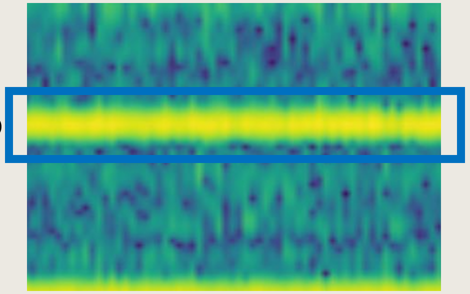
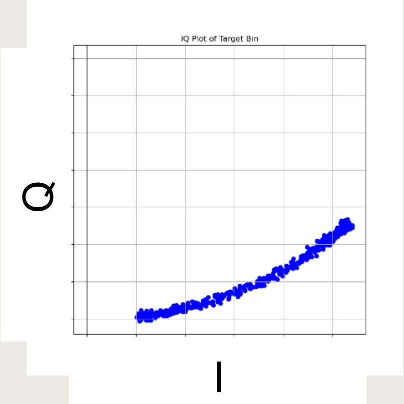
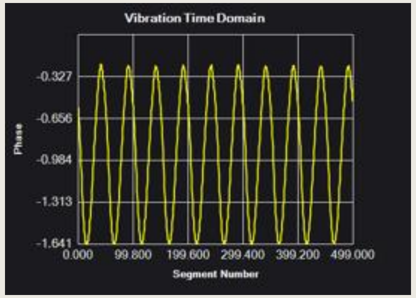


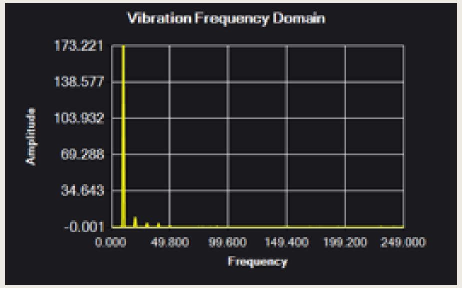
$\frac{(F_{RX})_{n,m}}{(F_{TX})_{n,m}}$ → IFFT → Target Bin Detection → Phase on Target Bin → FFT











KEYSIGHT

Measurement Results

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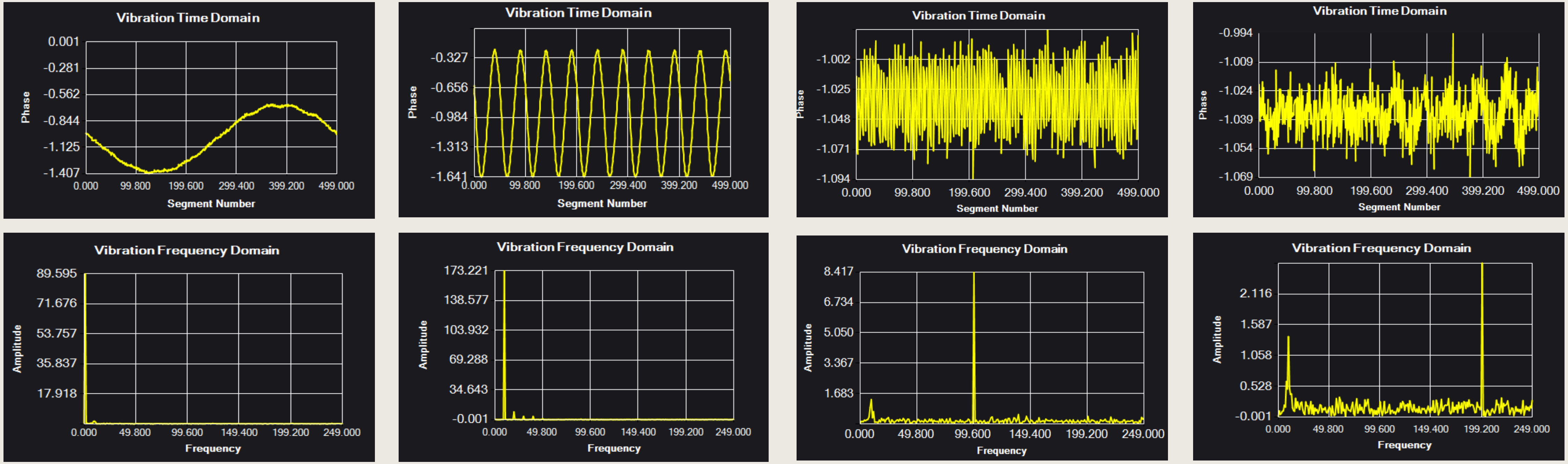

1Hz 10Hz 100Hz 200Hz

6G Sensing @ Arena 2036

FR2 @ 28 GHz

ARENA2036

https://arena2036.de/en/

- **Installed at Nokia truss towards cargo exit + in rack**
- **RU height: 5.12m, Sniffer height: 4.14m**
- **Vertical Tilt: 10 deg**
- **Distance to gate: 23m**

view from gNB RU

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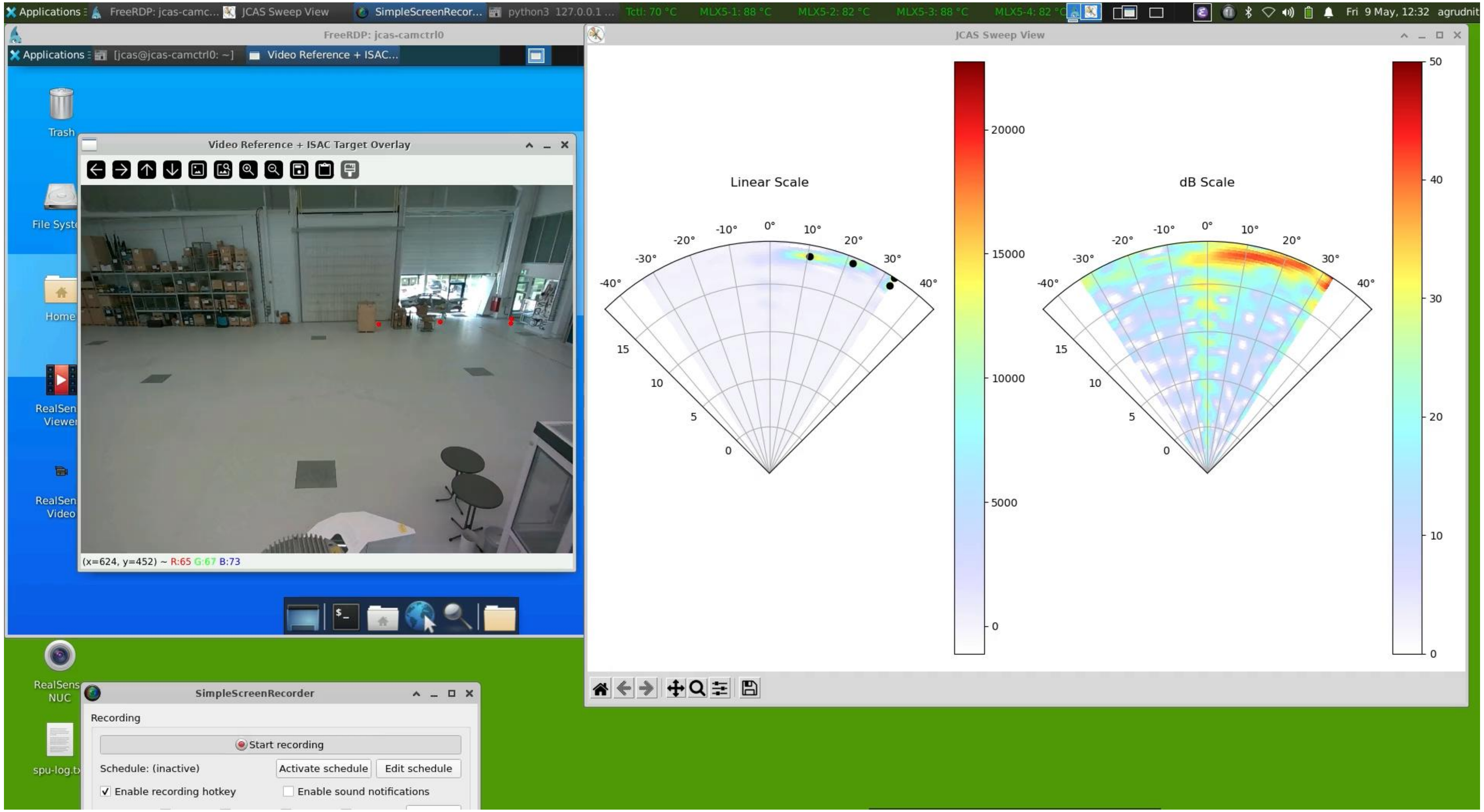
Indoor Pedestrian Monitoring in Factories



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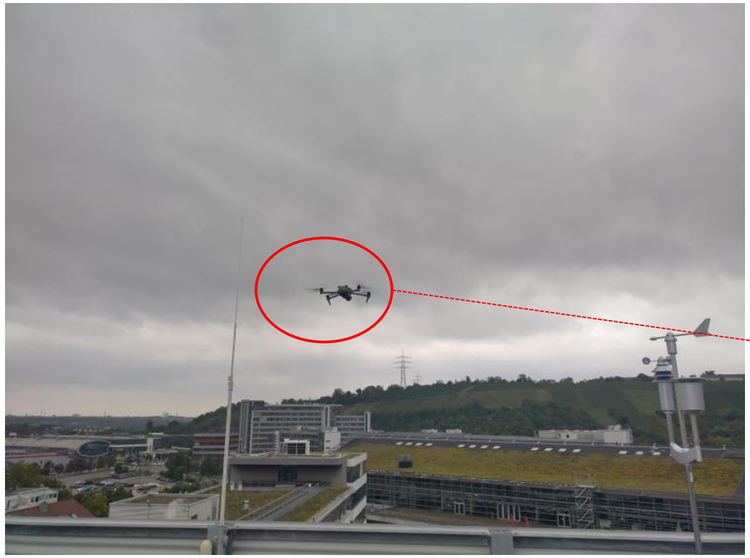
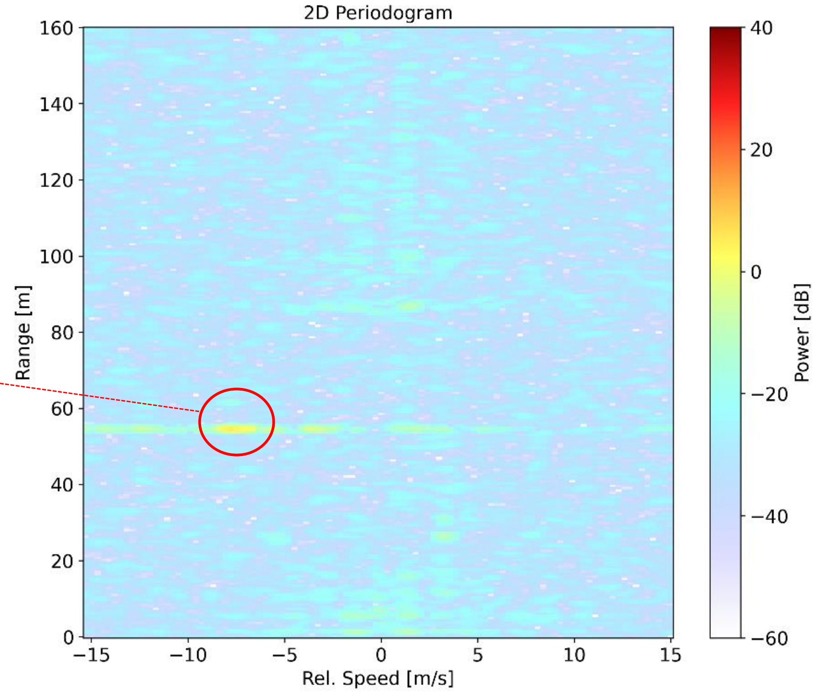
Drone Detection: Initial Measurements

Rooftop installation

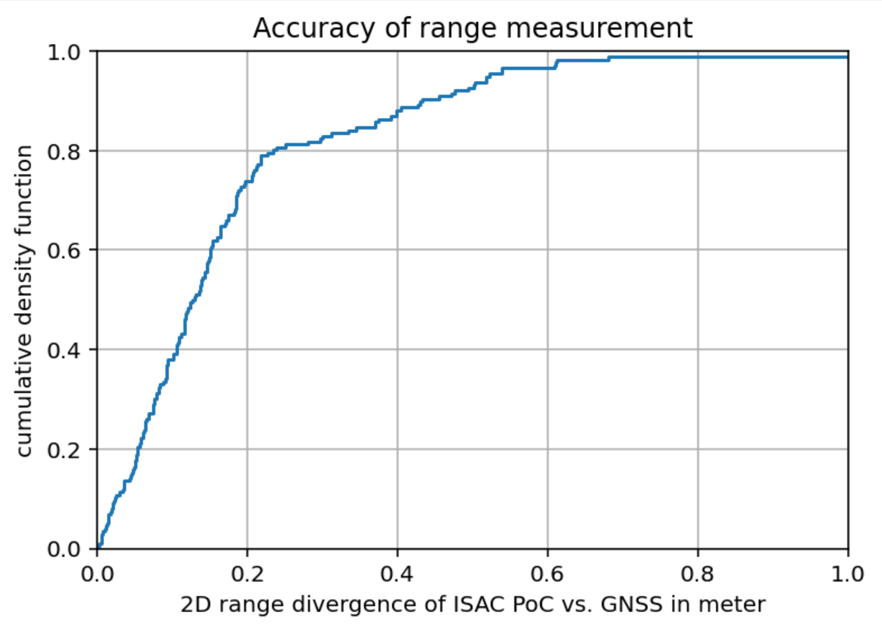


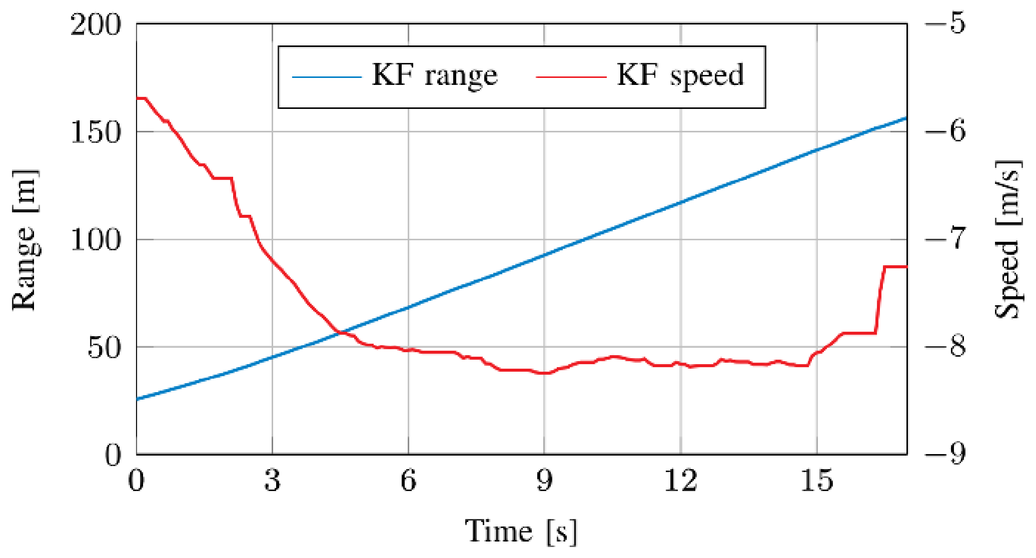


Drone Detection

Drone: DJI Air3,
920g, C2 class,
259 × 326 × 106 mm
(L×W×H)

Accuracy of Range Measurements

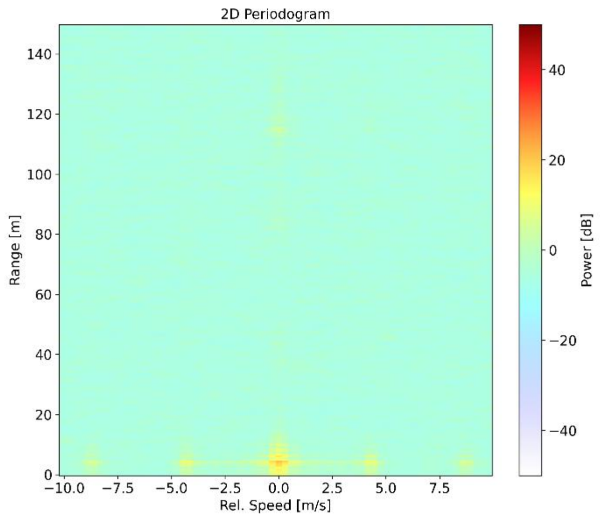


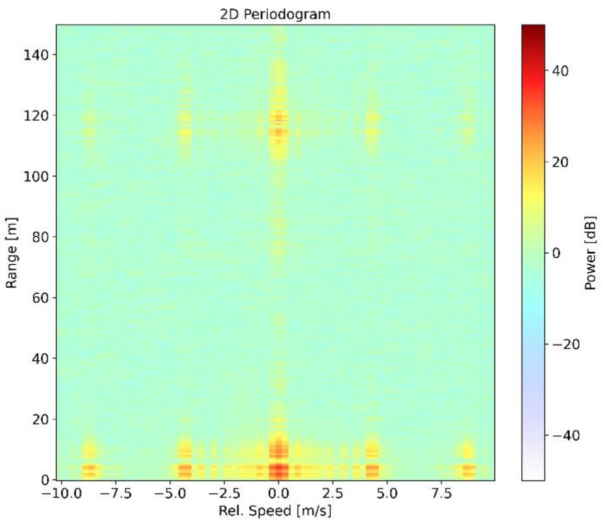


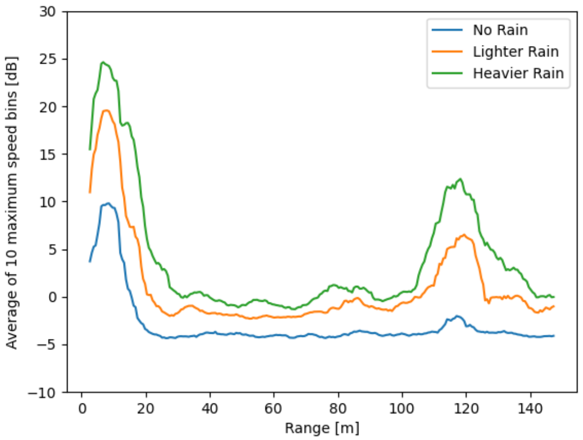
Weather Sensing

No rain

Heavier rain







Weather radar for ground truth

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Summary

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Integrated sensing and communication (ISAC) **expands cellular network capabilities** by sensing objects not connected to the network

ISAC has **many promising use cases** in various verticals within the **enterprise domain**

NGA will continue to investigate and study ISAC for use cases important to NAM, have additional channel measurements studies and various/novel technology options

NGA will continue to drive ISAC requirements for IMT-2030

3GPP is actively studying ISAC use cases and channel models

Q&A Session

How to Participate

- Please post your questions in the Q&A Function
- Our experts will address as many as possible

Discussion Topics

- Current Status and timelines
- Use case prioritization
- Spectrum Considerations
- ISAC vs. JSAC and Waveform Design
- Coverage and Capacity

Panelists

Amitava Ghosh

Nokia Fellow and
Bell Labs Leader

Harish Viswanathan

Nokia Head of Radio
Systems Research
Lab

Mike Millhaem

Keysight 6G Technical
Architect

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Building the foundation for North American leadership in 6G and beyond