

# Integrated Sensing and Communication – Recent advances and the **one6G association** perspective

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Panel: P2. Integrated Sensing and Communications for Industrial Applications

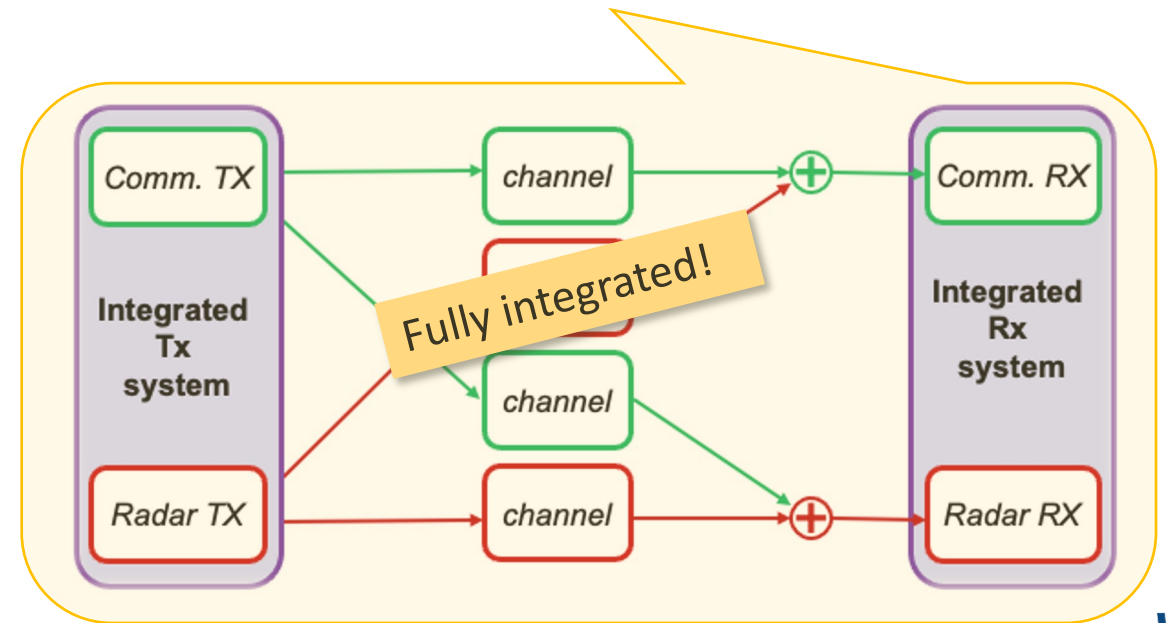
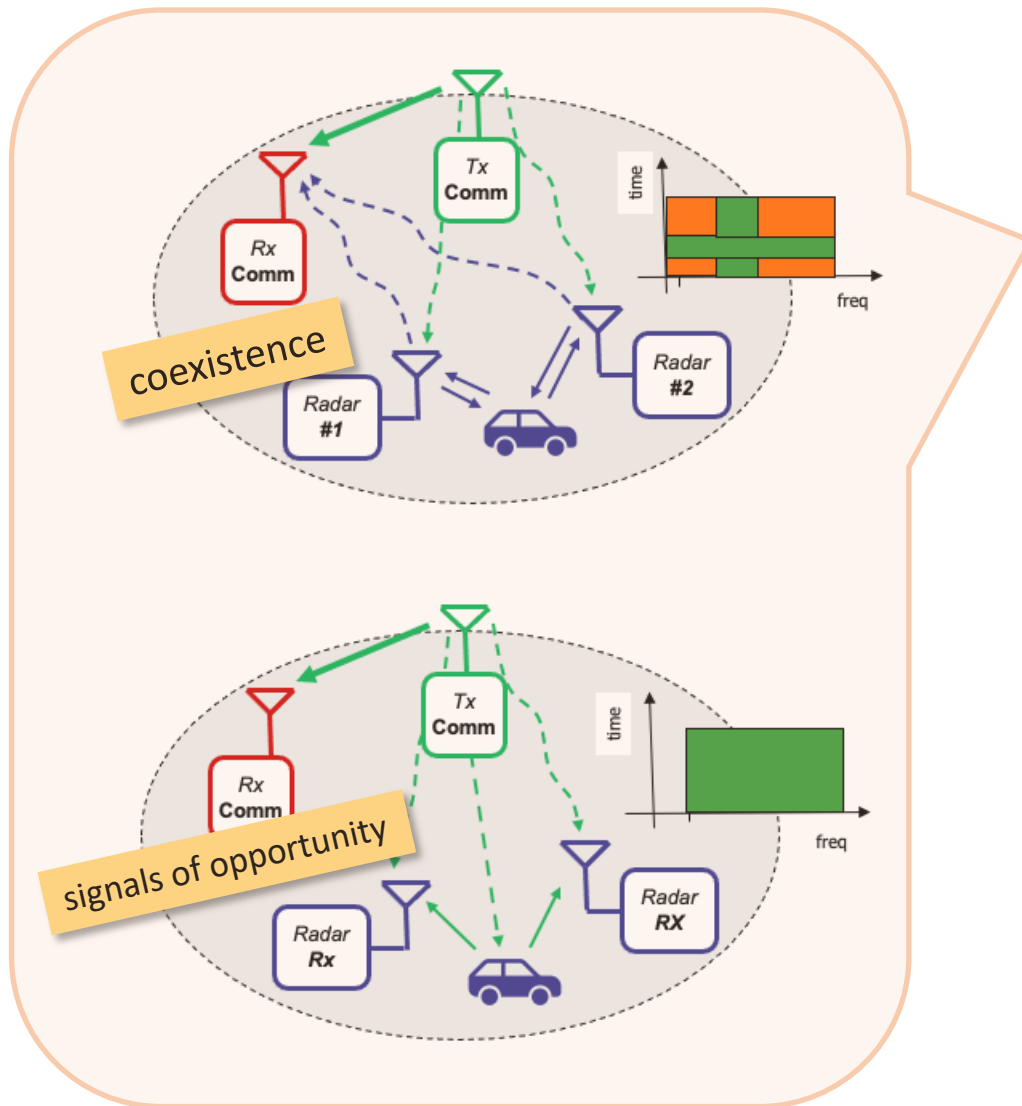
*IEEE Int. Mediterranean Conf. on Comm. and Netw. (MeditCom)*

*Sept. 7, 2022, Athens, Greece*

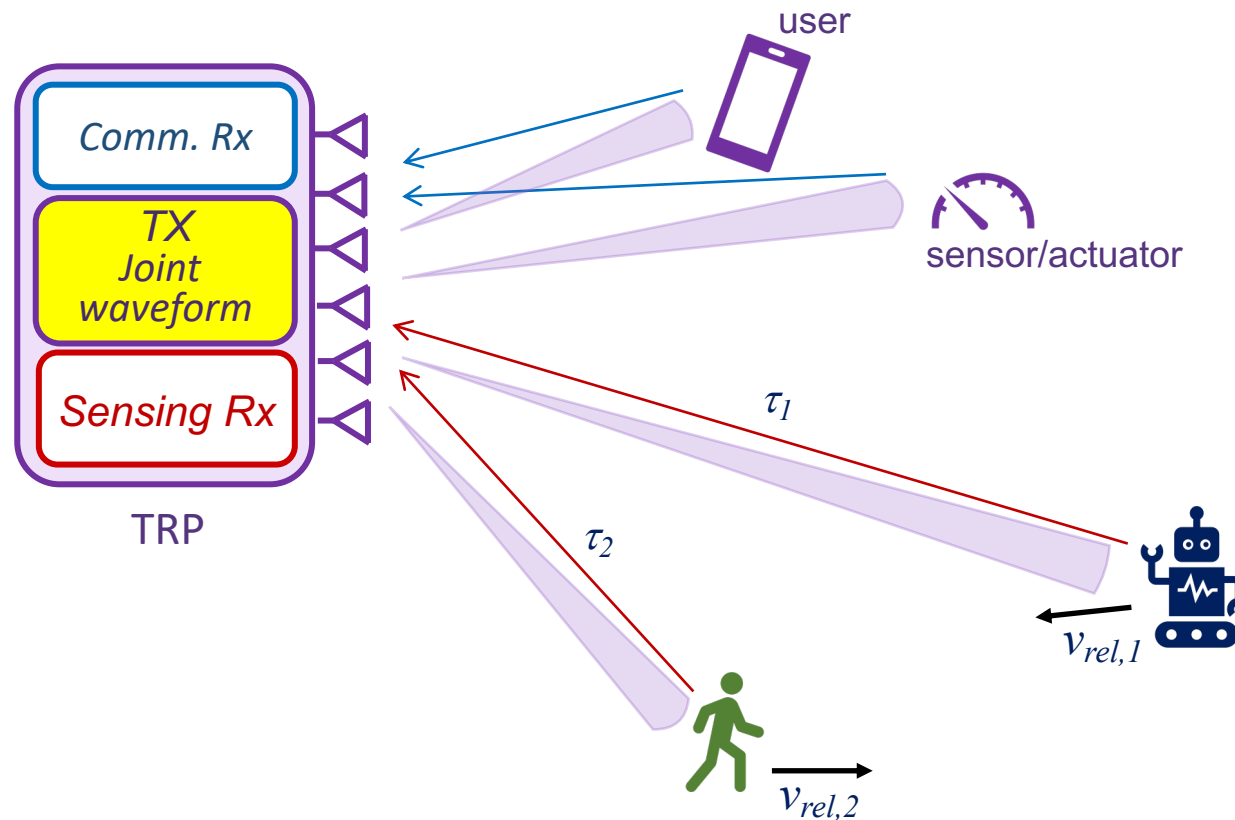


# From coexistence to joint comm and sensing (JCAS)

- ❑ **Different systems and bands** – Integration at the higher layers. Sensing and communications systems exchange information to aid operation in some way.
- ❑ **Different systems and shared bands** – E.g., integration by multiplexing in time, frequency, and space, enabling the two functions to share the spectrum.
- ❑ **Full integration (Joint Comm & Sensing)** – Same band, same waveform, shared hardware.



# Joint Comm And monostatic Sensing with multibeam technology

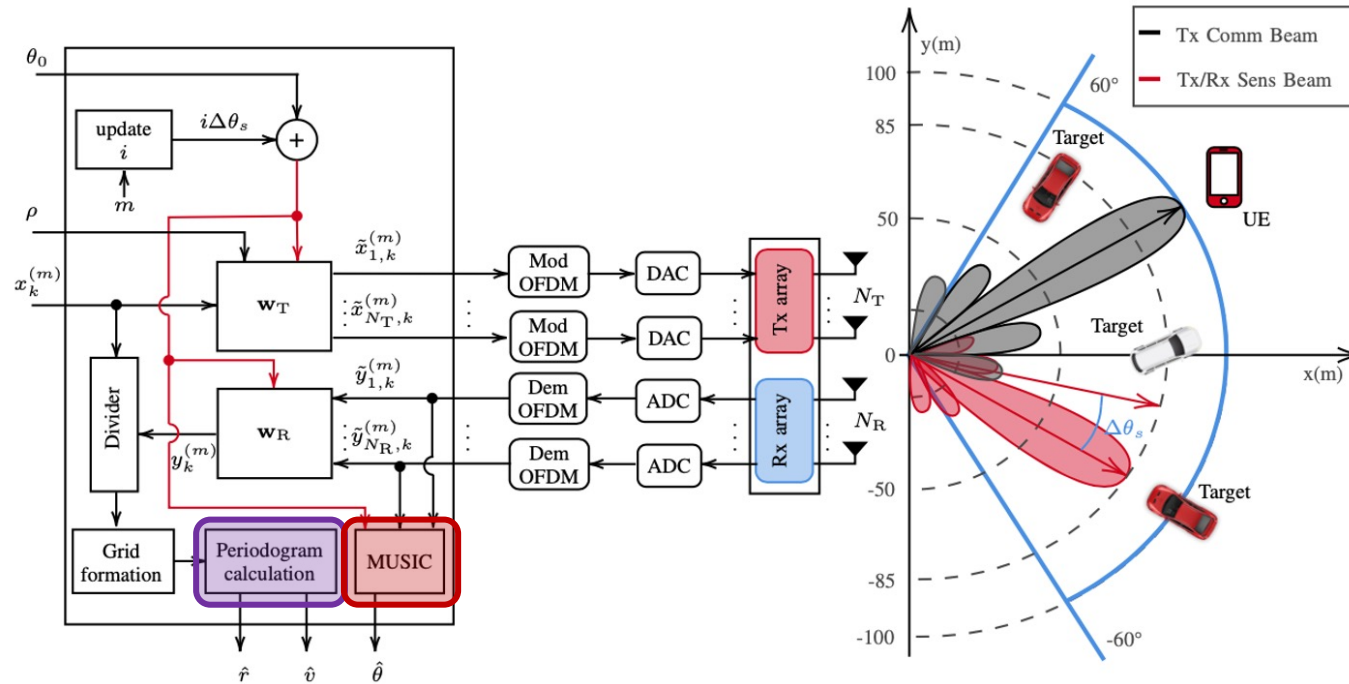


- Object detection
- AoA, range, velocity estimation
- Tracking
- Object recognition

- Stand alone solution
- Full duplex required!

L. Pucci, et. al., "System-Level Analysis of Joint Sensing and Communication based on 5G New Radio," IEEE J. on Sel. Areas in Comm. (JSAC), 2022.

# System-level analysis of JCAS system based on OFDM



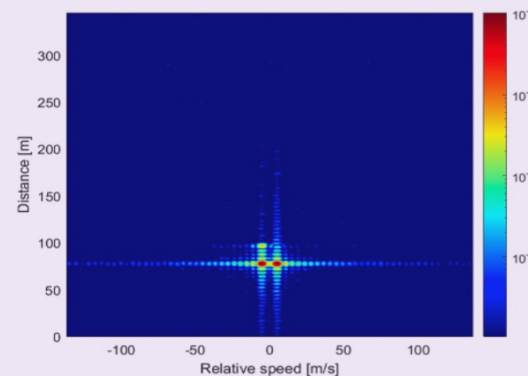
From received OFDM symbols (time-frequency matrix)

$$g_k^{(m)} = \sum_{l=1}^L \alpha_l e^{j2\pi m T_s f_{D,l}} e^{-j2\pi k \Delta f \tau_l} \Upsilon(\theta_{T,s}, \theta_{R,s}, \theta_l) + \nu_k$$

via periodogram in both directions

$$P(q, p) = \left| \sum_{k=0}^{K_p-1} \left( \sum_{m=0}^{M_p-1} g_k^{(m)} e^{-j2\pi \frac{mp}{M_p}} \right) e^{j2\pi \frac{kq}{K_p}} \right|^2$$

Range-Doppler map



From received OFDM symbols

$$\hat{\mathbf{R}} = \frac{1}{KM_s} \sum_{m=0}^{M_s-1} \sum_{k=0}^{K-1} \tilde{\mathbf{y}}_k^{(m)} \tilde{\mathbf{y}}_k^{(m)\dagger} = \mathbf{U}\mathbf{U}^\dagger$$

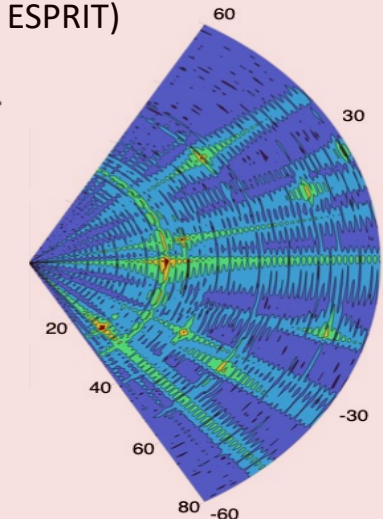
Estimation of the number of targets via MDL

$$\text{MDL}(s) = -\ln \left( \frac{\prod_{i=s+1}^{N_R} \lambda_i^{1/(N_R-s)}}{\frac{1}{N_R-s} \sum_{i=s+1}^{N_R} \lambda_i} \right)^{(N_R-s)KM_s} + \frac{1}{2}s(2N_R - s) \ln(KM_s).$$

MUSIC (root-MUSIC, ESPRIT)

$$f_m(\theta) = \frac{1}{\|\tilde{\mathbf{U}}^\dagger \mathbf{a}(\theta)\|_2^2}$$

Range-Angle map

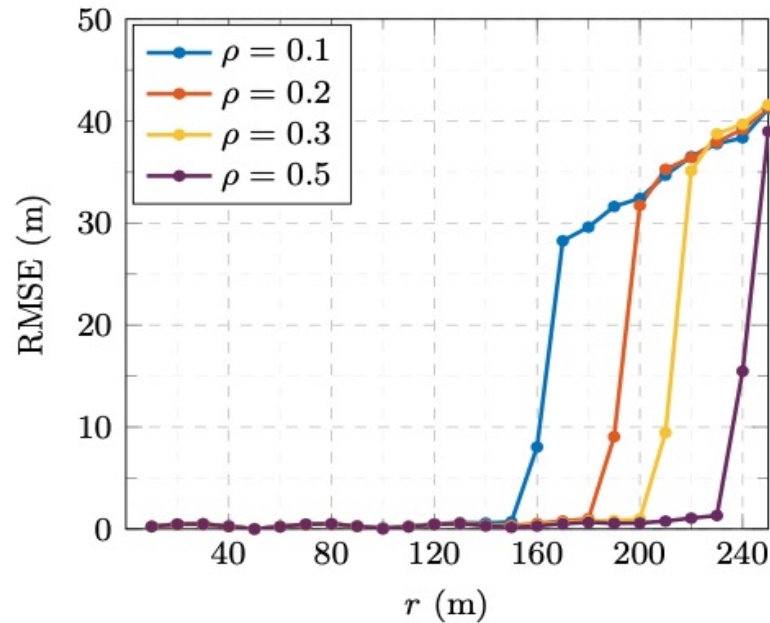


# Sub-6GHz vs mmWave

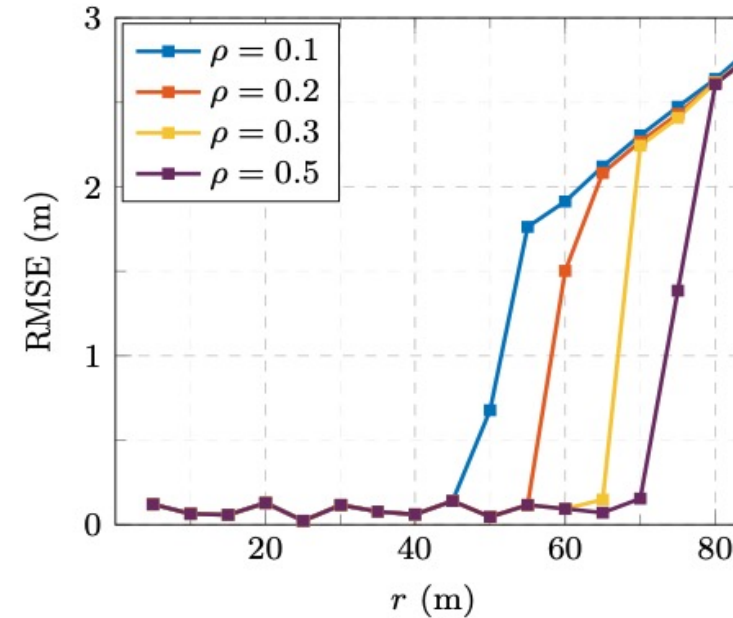
- Position RMSE as a function of comm/sensing **power ratio**
- **Sub-6GHz vs mmWave**

TABLE I: JSC system parameters

5G specification →	NR 100	NR 400	
$f_c$ [GHz]	3.5	28	
$\Delta f$ [kHz]	30	120	
Active subcarriers $K$	3276	3168	
OFDM symbols per frame $M$	280	1120	
OFDM symbols per direction $M_s$	112	112	
Number of antennas $N_T = N_R$	10	10	100
Array beamwidth $\Delta\Theta$ [°]	27	27	5.3 2.6



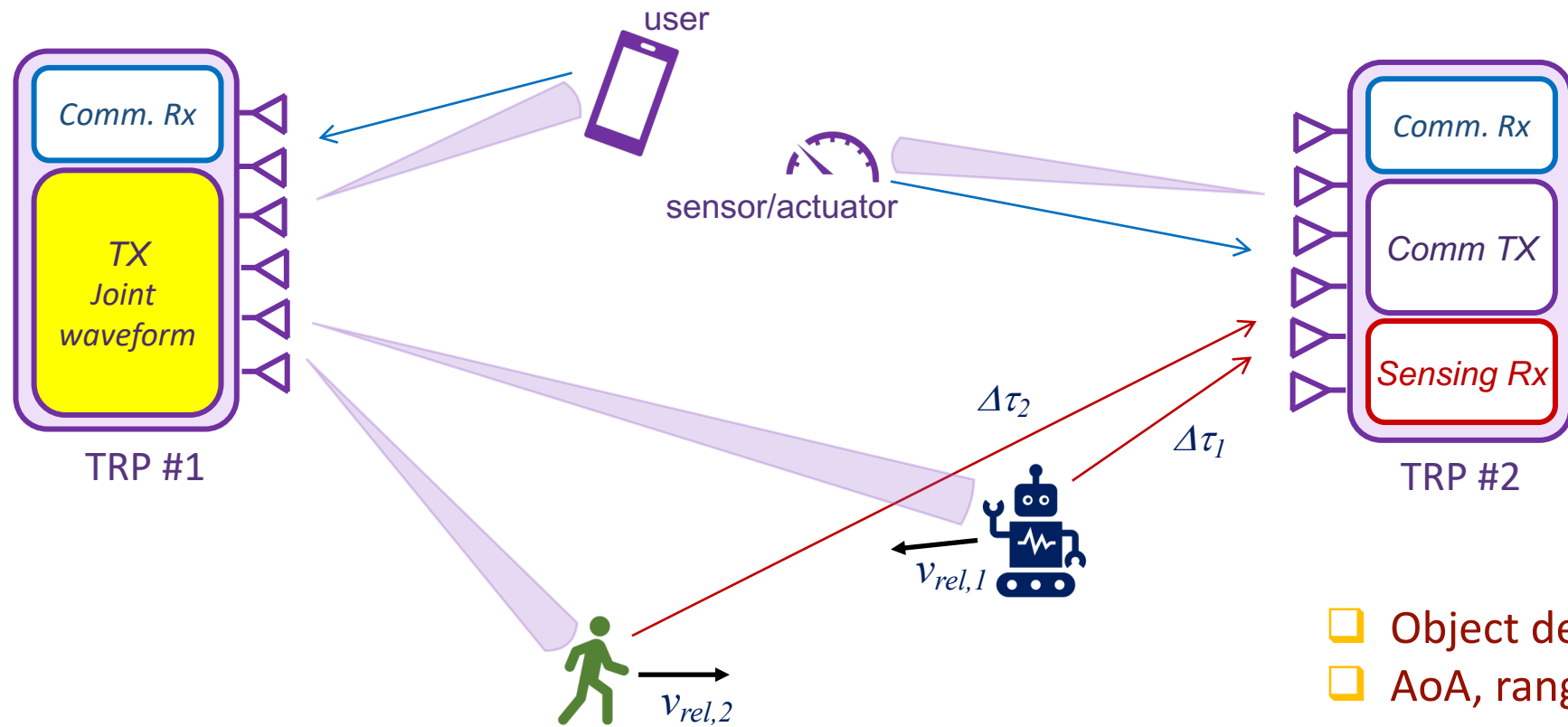
(a) Position RMSE at  $f_c = 3.5$  GHz,  $N_R = 10$



(b) Position RMSE at  $f_c = 28$  GHz,  $N_R = 50$

Fig. 3: Target localization performance as a function of the sensor-target distance varying the fraction of power  $\rho$  reserved for sensing.

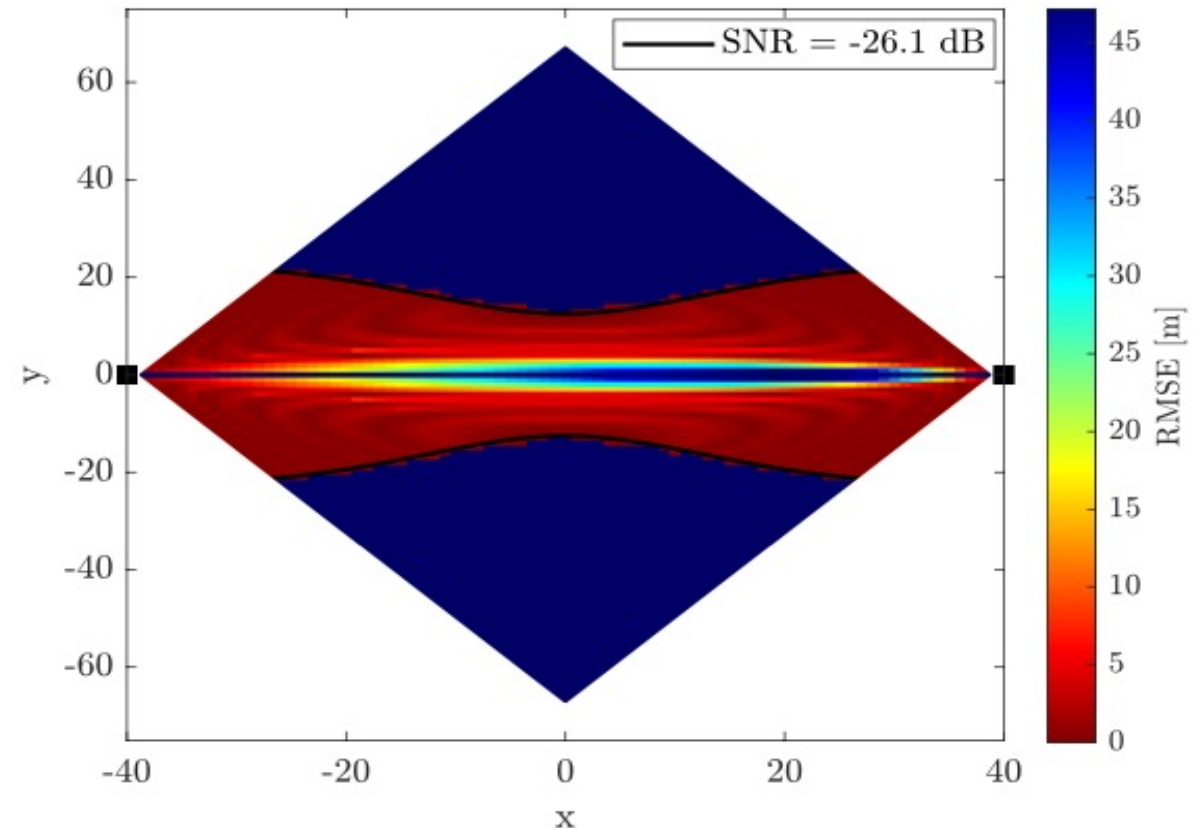
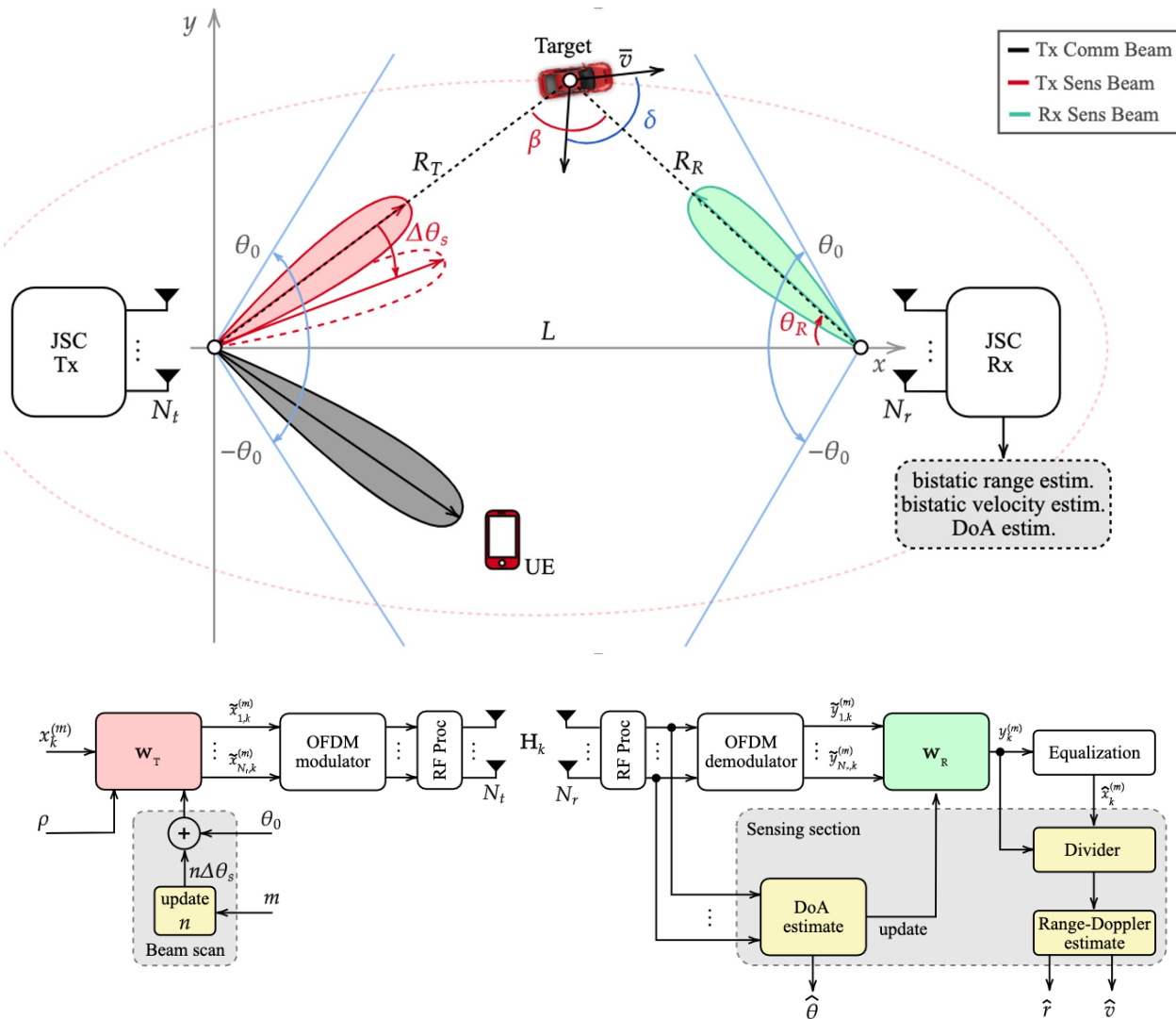
# Joint Comm And bistatic Sensing with multibeam technology



- Object detection
- AoA, range, velocity estimation
- Tracking
- Object recognition

- Evolving towards network-based sensing
- No full duplex!

# JCAS with bistatic setup: system-level analysis



(b) Baseline  $BL = 80$

L. Pucci et.al. "Performance Analysis of a Bistatic Joint Sensing and Communication System," IEEE Int. Conf. on Comm. (ICC), May 2022.

## DRIVE 6G RESEARCH AND INNOVATION EFFORTS

Launched in March 2021, one6G is a non-profit and membership fee free association offering an open collaborative framework to explore how to move beyond current communication networks technologies and business.

### EMPOWERING SMART CONNECTIVITY FOR A BETTER FUTURE

- ✓ Help unlock the full potential of both public and private organizations in the digital decade, empowering international co-creation.
- ✓ Foster participation of visionary researchers from academia and industry, global operators, major market players in selected verticals, regulatory agencies, market analysts, as well as innovative SMEs.
- ✓ On-board major players from several vertical industries to be engaged from the beginning.
- ✓ Promote cutting-edge technologies through joint initiatives, working groups, pre-standardization efforts, testbeds, user engagement, trials, demonstrations, dedicated liaisons and other activities.





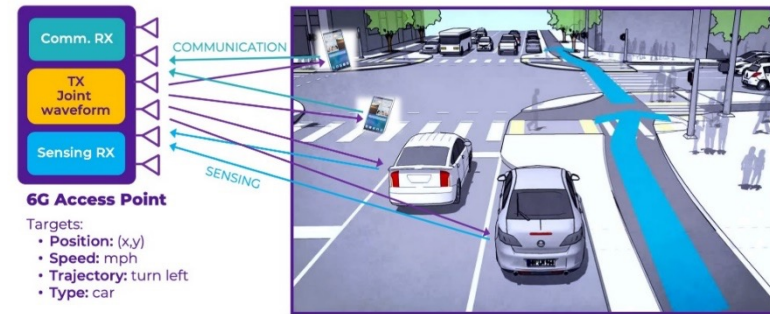
# MEMBERS

As of July, 2022 (80)



Latest info please refer to: <https://one6g.org/members/>


# CURRENT WORK ITEMS



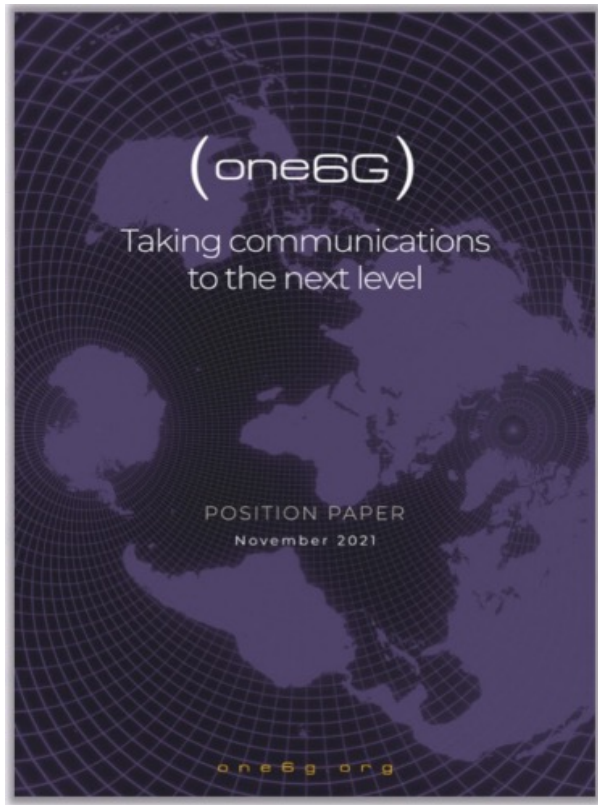
(one6G)

	Work Items	Scope of the WGs
<b>WG1</b> Use cases, KPIs, and Future Market and Business Scenarios	WI 101 - Collection of 6G-related Use Cases and Related Scenarios (completed and in the maintenance mode)	<ul style="list-style-type: none"> <li>Consolidate vision</li> <li>Use case and requirements analysis</li> <li>Streamline terminology, etc.</li> </ul>
<b>WG2</b> Enabling Technologies and System Architecture	WI 204 - Higher Frequencies WI 205 - 6G Radio Access WI 207 - Intelligent User Plane, In-Network Computing WI 208 - Distributed/Federated AI WI 209 - Next-generation MIMO WI 210 - Integrated Sensing and Communication WI 211 - Flexible Programmable Infrastructures	<ul style="list-style-type: none"> <li>Research of key enabling technologies, concepts, etc.</li> <li>Evaluation and selection of most promising ones</li> <li>Integration thereof into a coherent architecture</li> </ul>
<b>WG3</b> Communication & Dissemination	WI 301 - 6G position paper (completed) WI 302 - Dissemination: web page, social media, newsletter, one6G internal and external events, webinars	<ul style="list-style-type: none"> <li>Liaisons and partnership management</li> <li>Marketing and promotional activities</li> <li>Preparation of workshops, conferences, etc.</li> </ul>
<b>WG4</b> Evaluation, Testbeds, and Pilots	WI 210 - (cross WG2/WG4) Integrated Sensing and Communication WI 402 – Definition of the evaluation guidelines for simulation/emulation	<ul style="list-style-type: none"> <li>Aspects of testing and evaluation</li> <li>Test procedures and verification</li> <li>Testbeds, prove of concepts and trials, etc.</li> </ul>

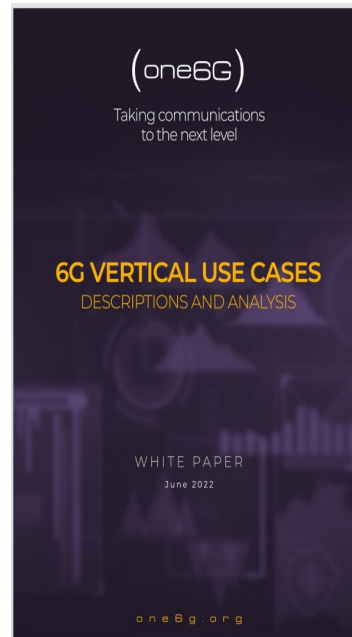
# ONE6G POSITION PAPER



one6G organization published the **1<sup>st</sup>** position paper to lay out its vision and work plan in Nov 2021.



one6G published 2 white papers during EuCNC2022 and ITU-R June meeting time period.



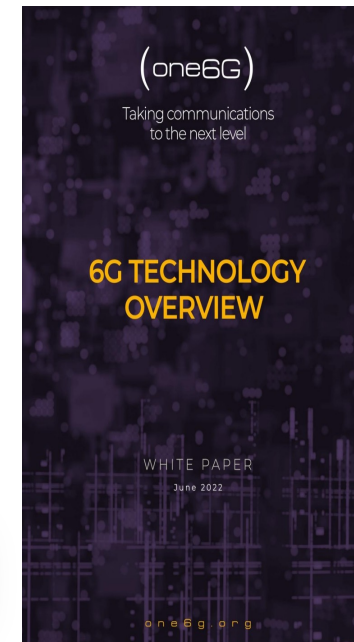
## 6 Use cases families with 25 use cases analyzed:

- Manufacture: 7
- Automotive: 5
- Health: 5
- Telecom (MBB/Resiliency): 4
- Agriculture: 3
- Transportation (railway):

### Use case#22

AI-as-a-service for industrial robots: Learning to be collaborative

...



## 7 technologies identified:

- THz Frequencies
- 6G Radio Access (6GRA)
- Next Generation MIMO
- Integrated Sensing and Communication (ISAC)
- Distributed Federated AI
- Intelligent User Plane, In-Network Computing
- Flexible programmable infrastructures

# ONE6G OPEN LECTURE



one6G establishes 5 open lectures in 2022, and aims to provide an open 6G knowledge sharing forum

(one6G) OPEN LECTURES  
Lecture 1/5  
**6G Network AI**

In an effort to share the progress and results of the work performed within the one6G Association with the extended one6G community, one6G launches a series of open lectures. The 2-hour online presentations will be open to anyone interested in the world's journey toward 6G.

The first open lecture will take place on-line on the 5<sup>th</sup> of May 2022 at 14:00 CEST. It features presentations delivered by high-level speakers and interactive Q&A sessions on the subject "6G Network AI".

### AGENDA

14:00 Welcome & opening



14:05 "The road from 5G to 6G: approaches from the perspective of 6G-RIIC"

**Slawomir Stanczak**  
Head of Wireless Communications



14:30 "Robot-Augmented data for 6G networks"

**David Gesbert**  
Professor and Director of EURECOM



14:55 "Learning PHY Layer Fun"

**Wolfgang Utschick**  
Professor at Technical University of



15:20 "Artificial Intelligence for mobile networks"

**Albert Banachs**  
Professor at the University Carlos III  
Networks research institute

15:45 Q&A session and closing

Website : <https://one6g.org/events/open-lecture-1-6g-network-ai>

(one6G) REGISTER NOW FOR FREE

(one6G) OPEN LECTURES  
Lecture 2/5  
**Integrated Sensing and Communication**  
7 July 2022 - 14h00 CEST

In an effort to share the progress and results of the work performed within the one6G Association with the extended one6G community, one6G launches a series of open lectures. The 2-hour online presentations will be open to anyone interested in the world's journey toward 6G.

The second open lecture will take place on-line on the 7<sup>th</sup> of July 2022 at 14h00 CEST. It features presentations delivered by high-level speakers and interactive Q&A sessions on the subject "Integrated Sensing and Communication".

### AGENDA

14:00 Welcome & opening



**Monique Calisti**  
CEO Martel Innovate



14:05 "Beam-Space MIMO Radar for Sensing-aided mmWave Communication"

**Giuseppe Caire**  
Chair of Communications and Information Theory, TU Berlin



14:30 "Integrated Sensing and Communication – The Killer Feature of 6G?"

**Andreas Müller**  
Head of Communication and Network Technology, Bosch Corporate Research Department



14:55 "Integrated Sensing and Communication - Some System and Access Issues"

**Reiner Thomä**  
Professor, TU Ilmenau Electrical Engineering and Information Technology Faculty



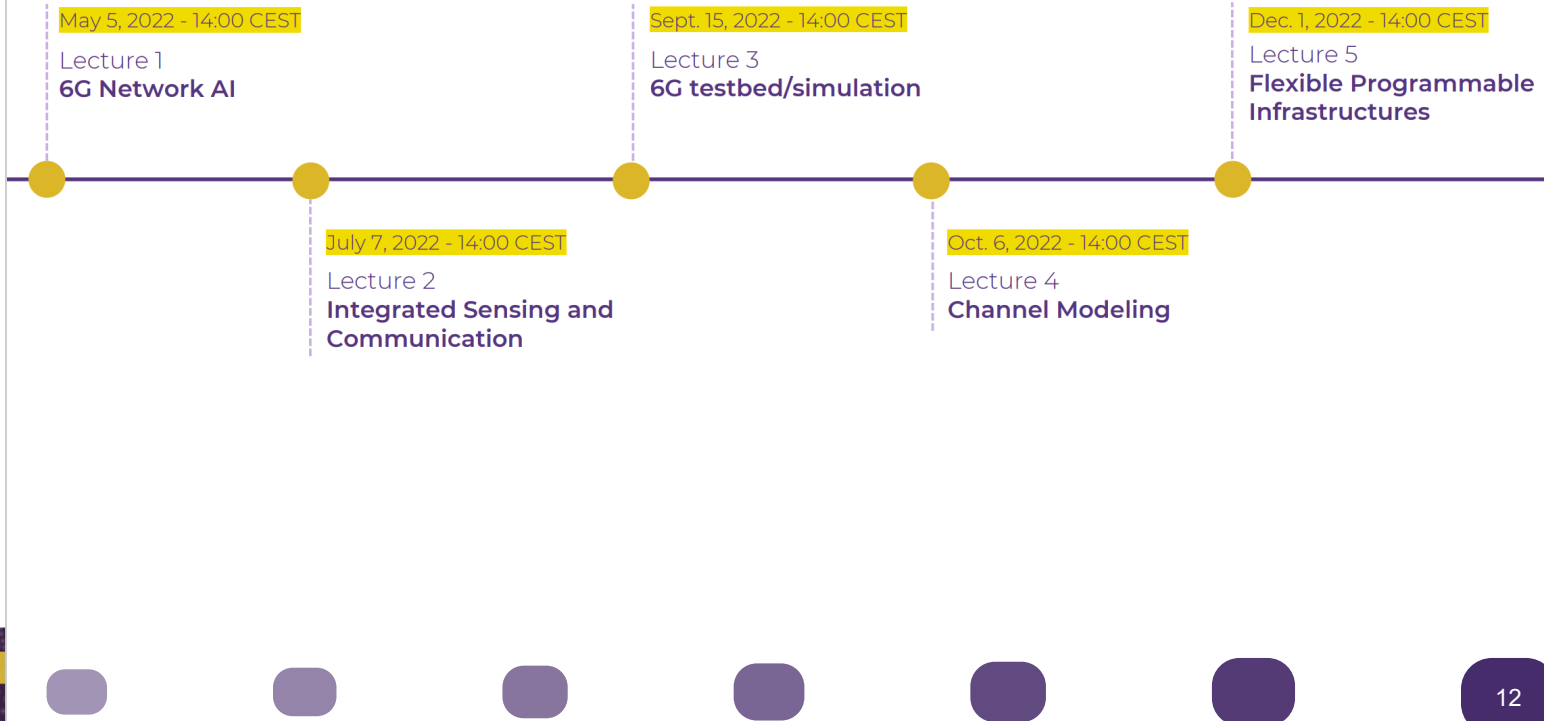
15:20 "ISAC from a telecom operator's point of view"

**Ole Grøndalen**  
Senior Research Scientist, Telenor

15:45 Q&A session and closing

[www.one6g.org/events/open-lecture-2-integrated-sensing-and-communication](https://www.one6g.org/events/open-lecture-2-integrated-sensing-and-communication)

(one6G) REGISTER NOW FOR FREE  
one6g.org





# CONTACT US TO LEARN MORE

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