Exploiting Rarely Capitalised Spectrum Future Technologies using THz and beyond THz bands

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The Scotland 5G Centre

Glasgow 5G Testbed G5G

CSI Communication, Sensing & Imaging

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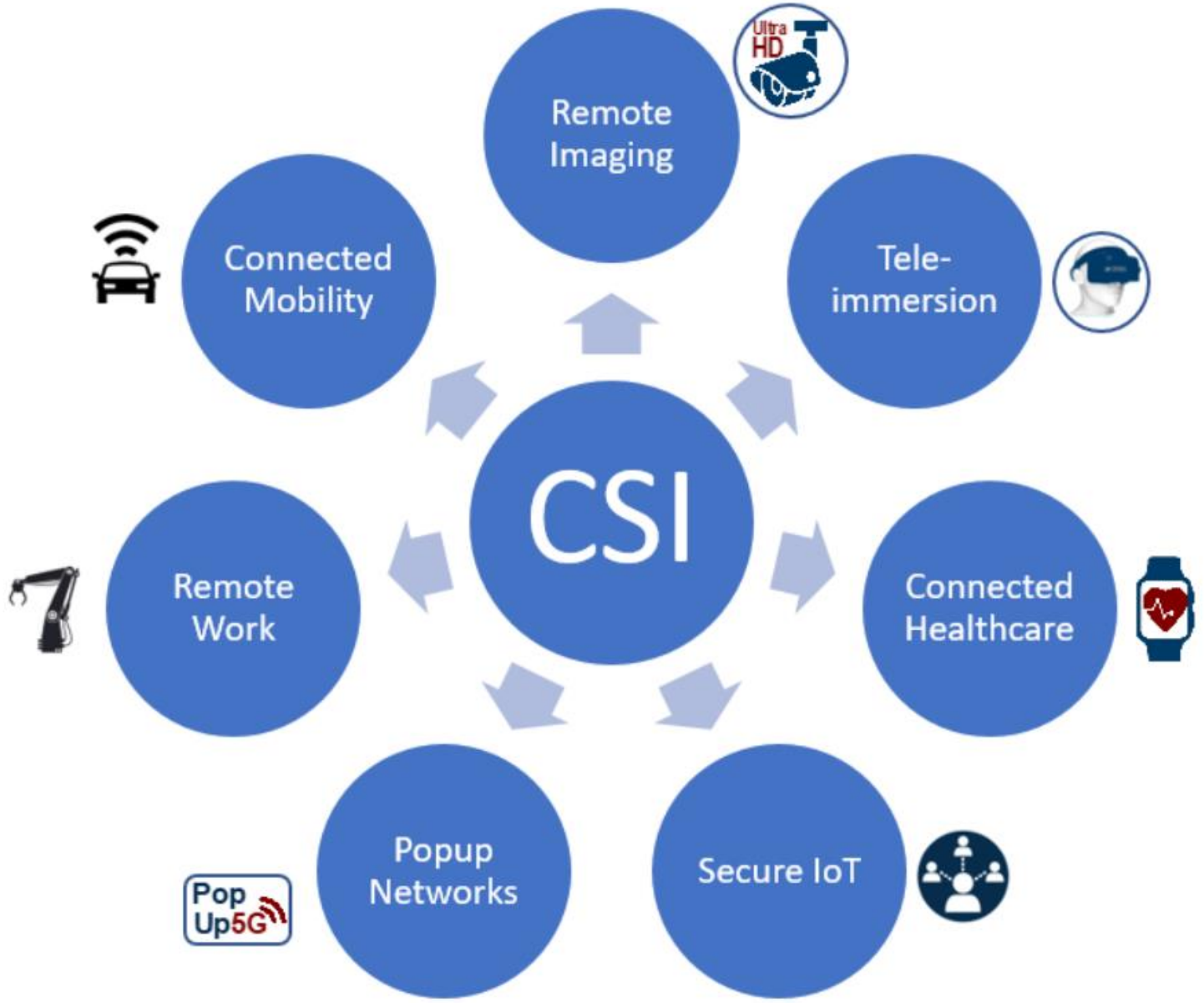
Our main applications …



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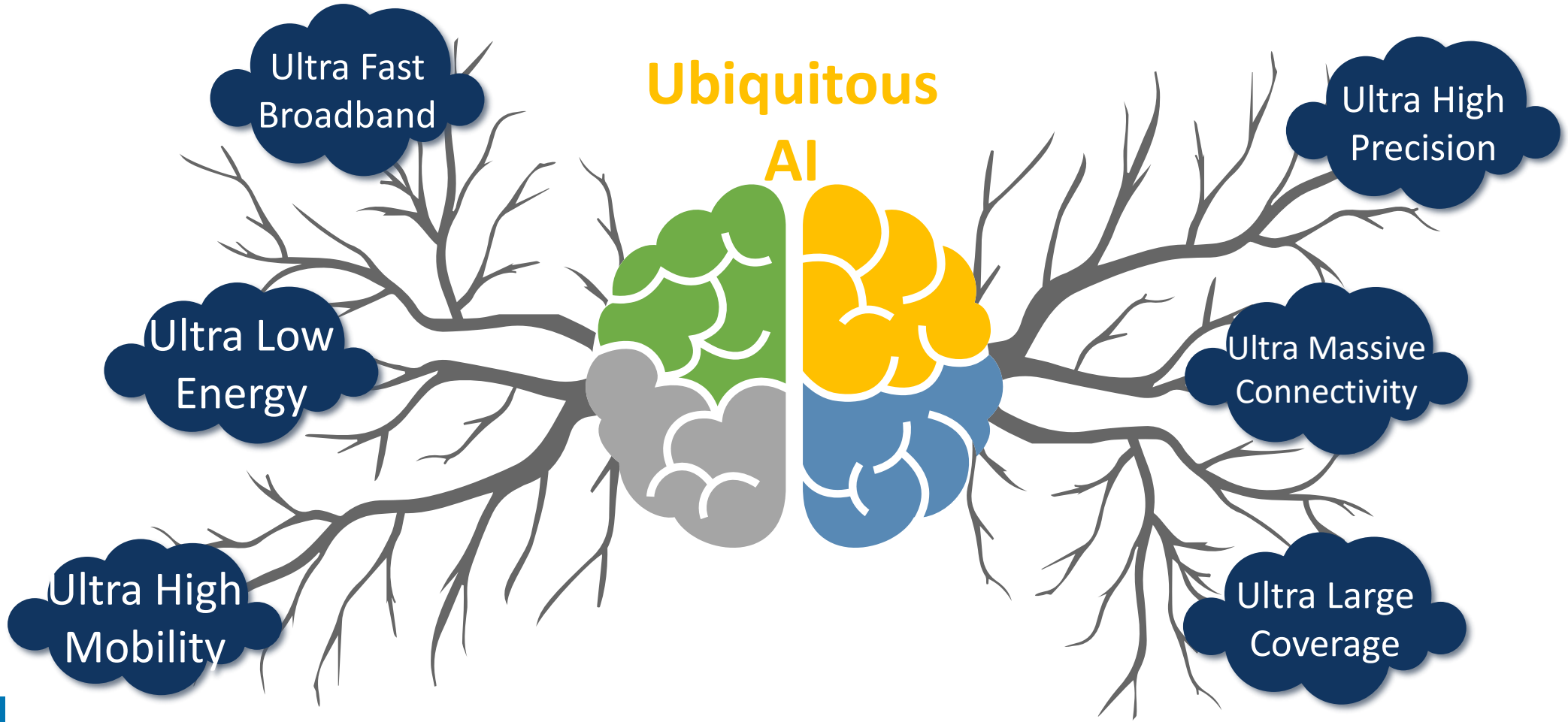
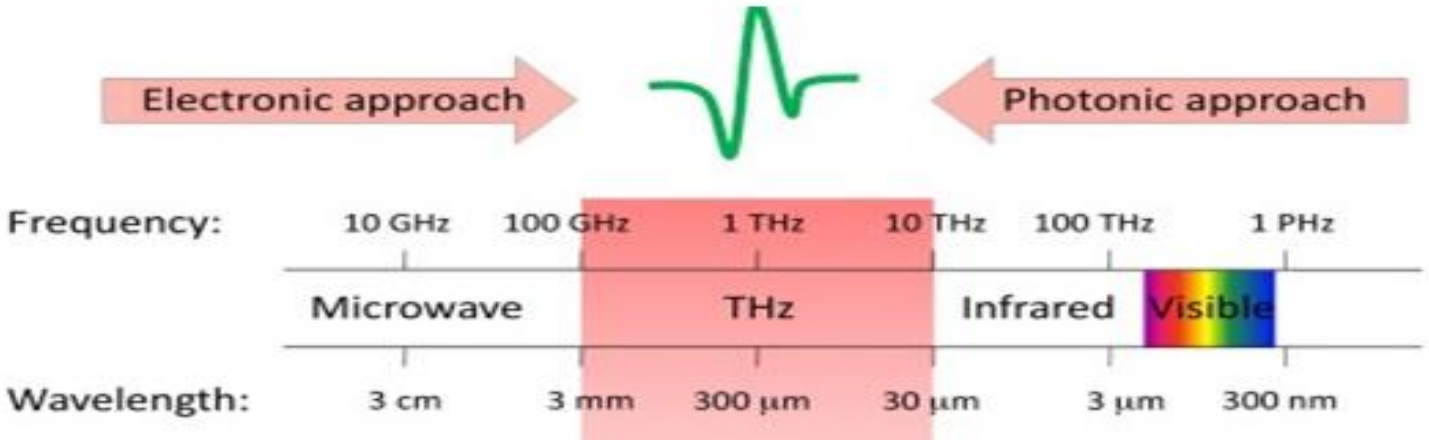
Elements of 6G

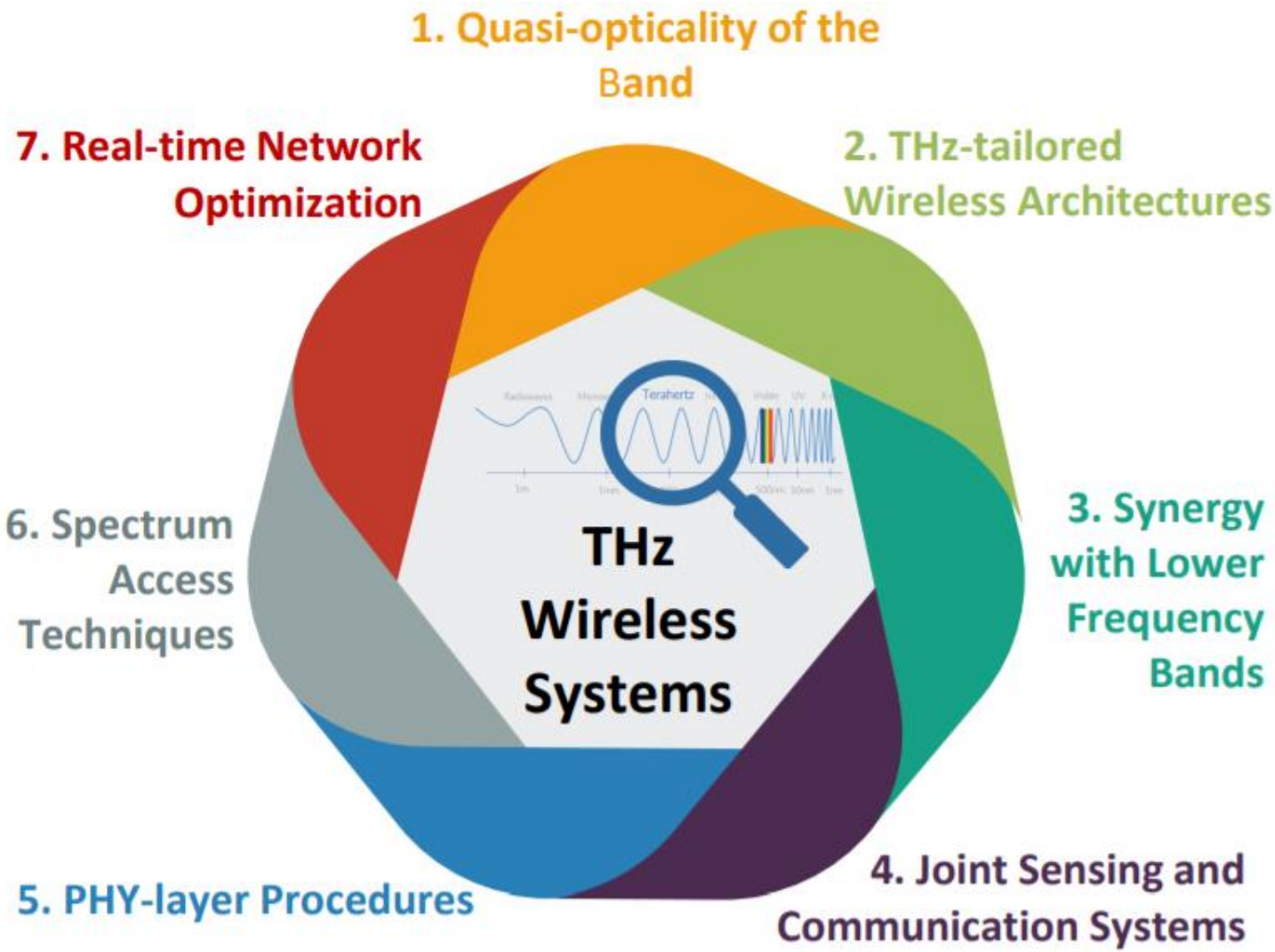


Use Cases	6G Elements					
	Ultra High Precision	Ultra Fast Broadband	Ultra Massive Connectivity	Ultra High Mobility	Ultra High Coverage	Ultra Low Energy
Smart City		☑	☑			☑
Healthcare	☑		☑			
Smart Factory	☑		☑			
Autonomous Cars	☑			☑	☑	
Urban Air Mobility	☑	☑		☑	☑	
Gbps for Bullet trains/ Hyperloop		☑		☑		
Live Concert/ Sport Broadcast	☑	☑	☑			☑
IoT Networks			☑			☑

Terahertz (THz) Band for 6G



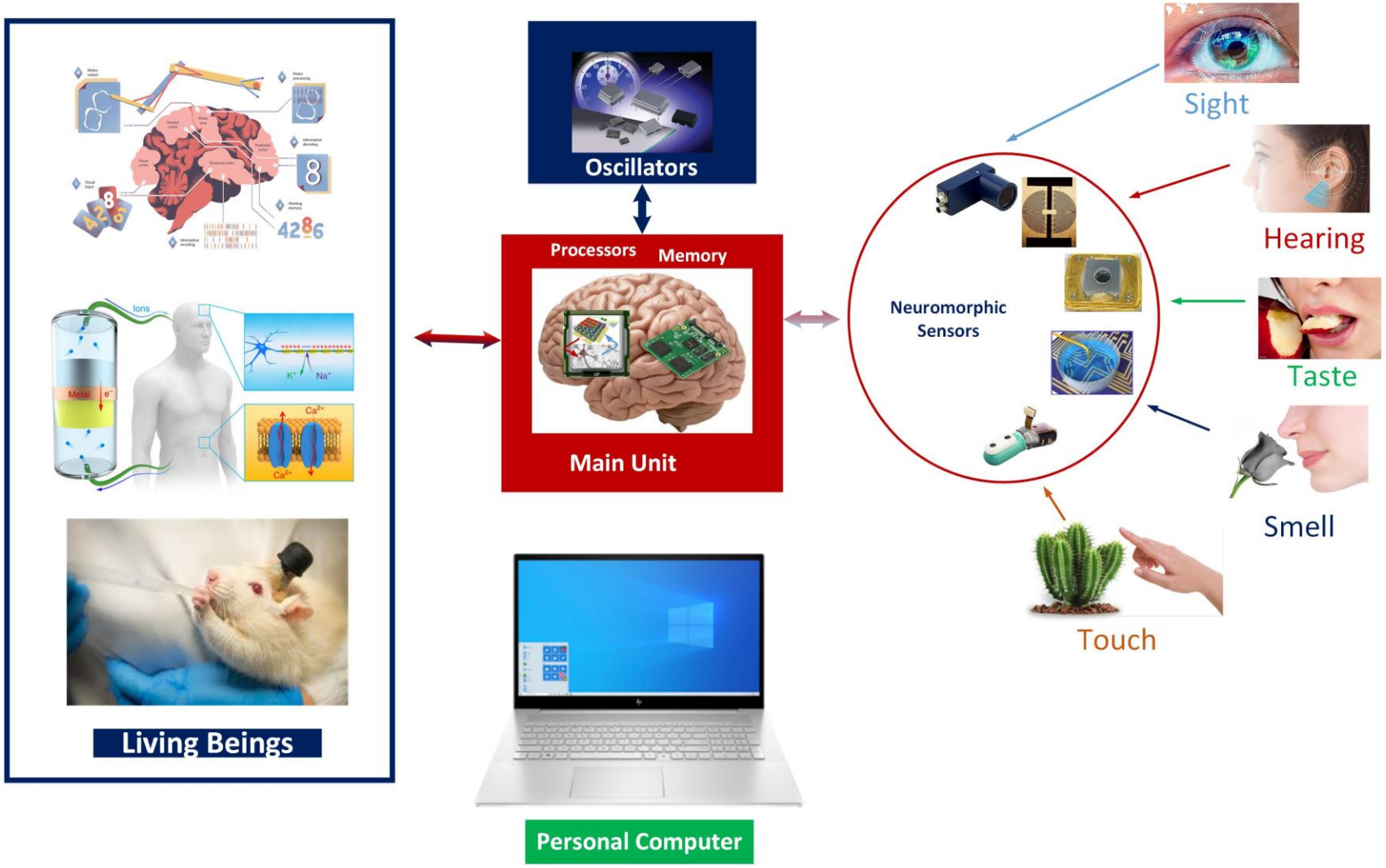
Features of THz Wireless System



Source: Chaccour, Christina, Mehdi Naderi Soorki, Walid Saad, Mehdi Bennis, Petar Popovski, and Merouane Debbah. "Seven defining features of terahertz (THz) wireless systems: A fellowship of communication and sensing." arXiv preprint arXiv:2102.07668 (2021).

Terahertz Applications

Communicating the Senses



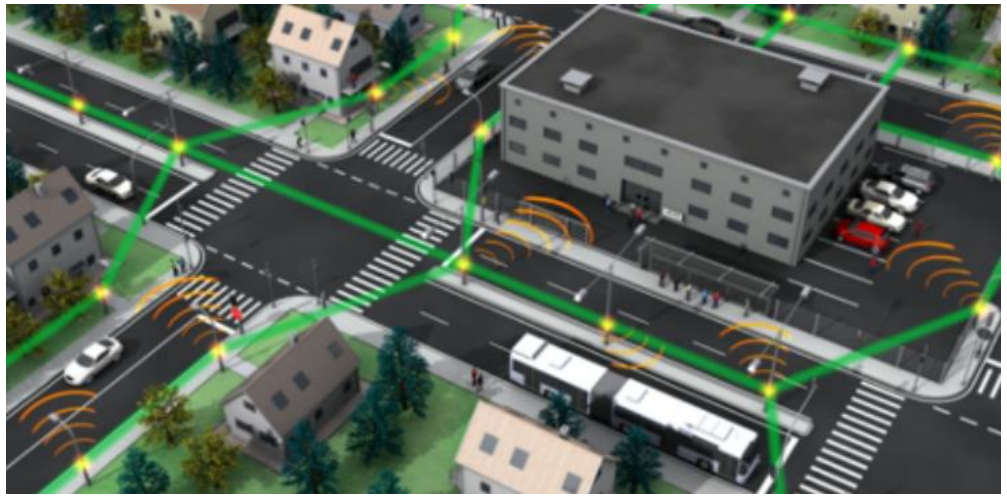
Terahertz Applications

Holographic Communication

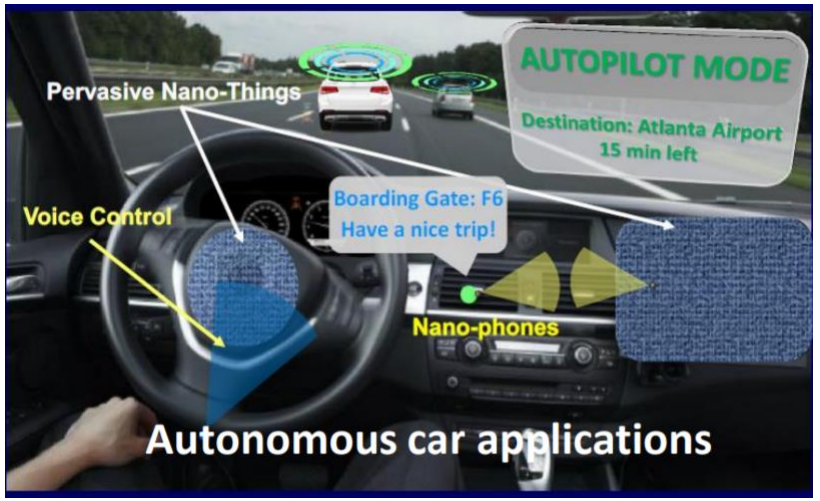
Courtesy @
euclideonholographics.com
sfumatohologram.com
vix.com

Terahertz Applications

Autonomous Vehicles

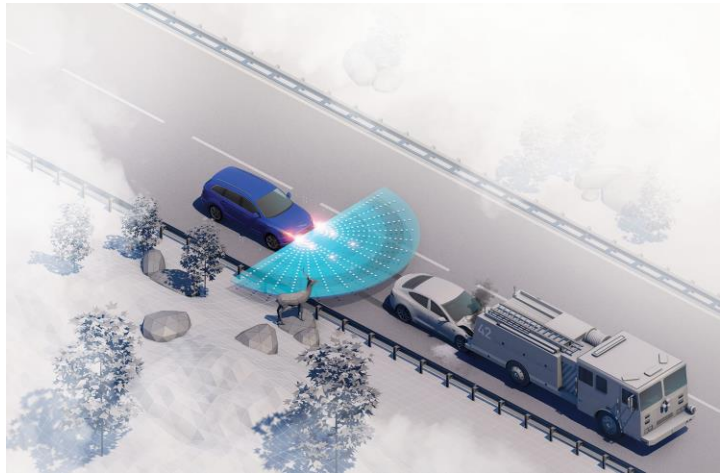


Providing **high data rate connectivity** to vehicles at THz band. Orange links are small base station to vehicle and green are high data rate THz links



THz can provide **high quality infotainment services** inside autonomous vehicles

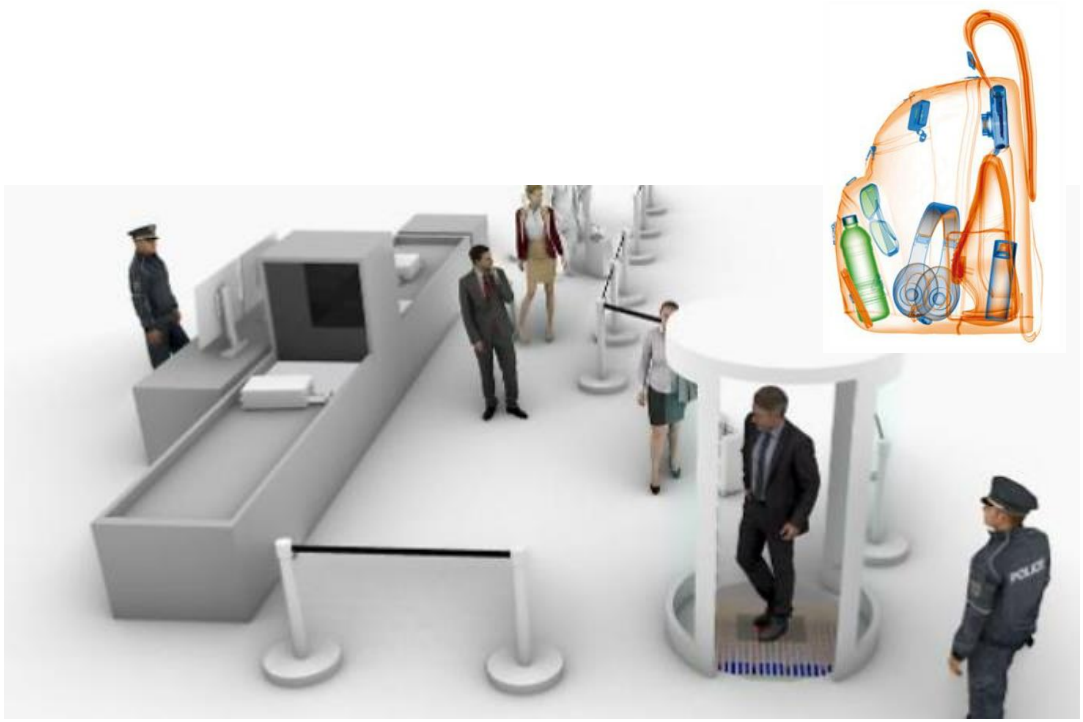
Terahertz system gives autonomous vehicles **keener eyesight** (better than LiDAR) in fog and dust.



Courtesy @
6gworld.com
MBCI
therobotreport.com

Terahertz Applications

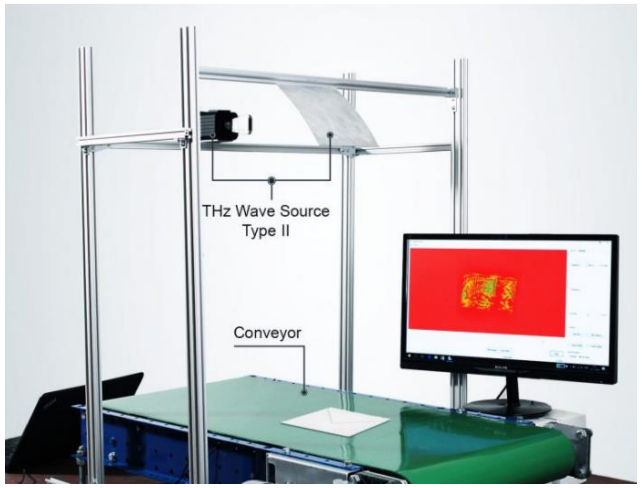
Terahertz Enabled Security and Fingerprints



Airport security

E-commerce warehouses

Man hiding knife in public



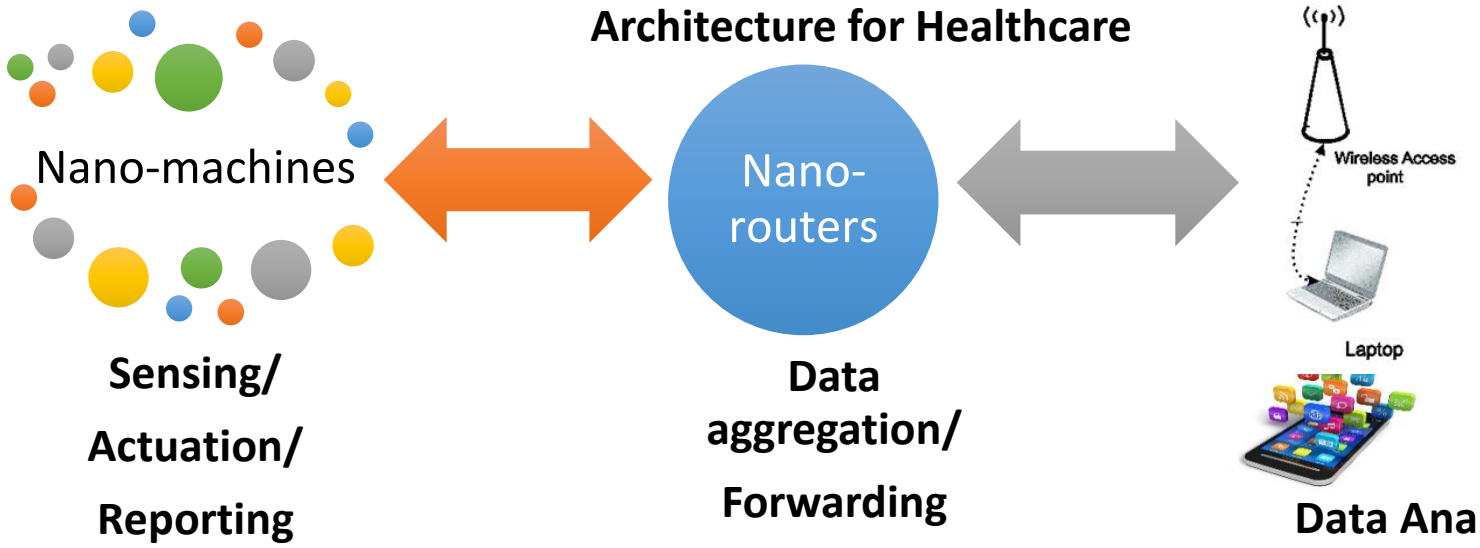
Identify biological material in parcels

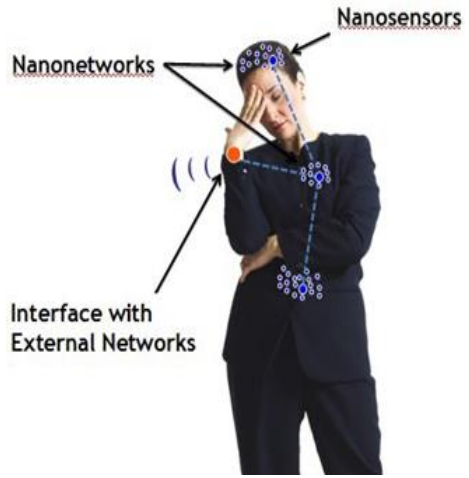
Locate hidden explosives

Courtesy @
Electroopics
Terasense
Smithsonianmag
MBCI
ETRI
ESA

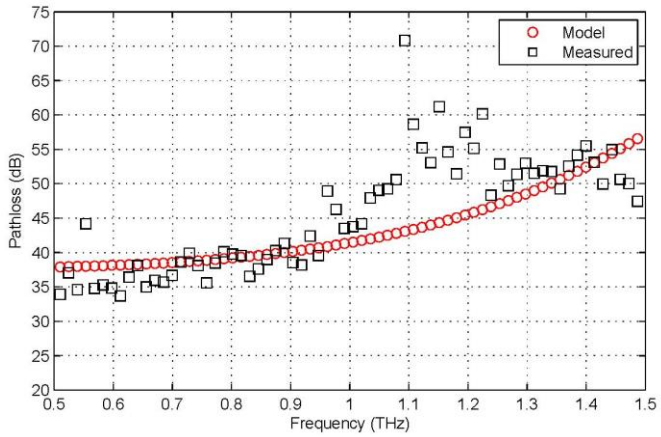
Terahertz Applications

Terahertz Enabled Nano-Scale Healthcare





$$PL(d, f, N) = -0.2 * N + 3.98 + (0.44 * N + 98.48)d^{(0.65)} + (0.068 * N + 2.4)f^{(4.07)}$$



Modeled Pathloss at Terahertz for in-vivo

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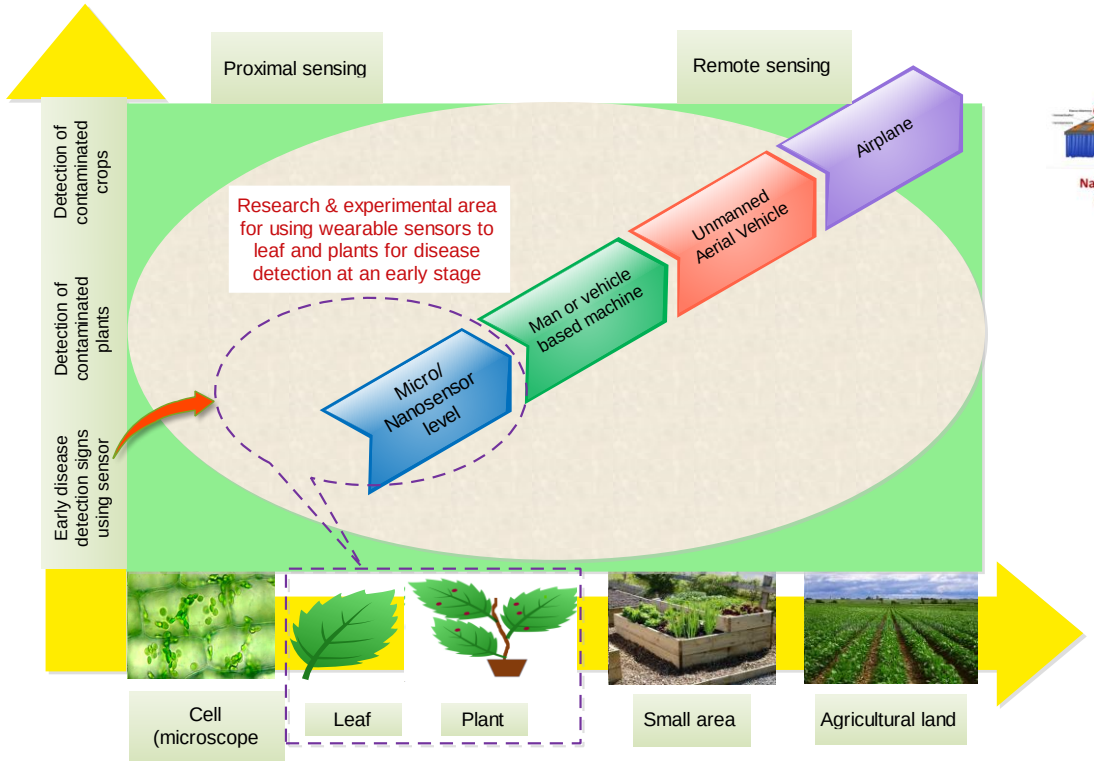
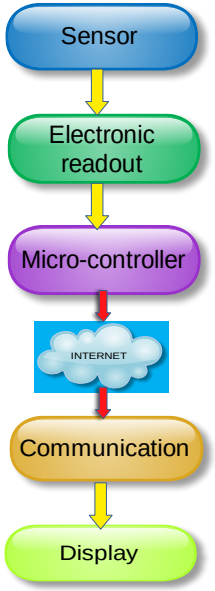
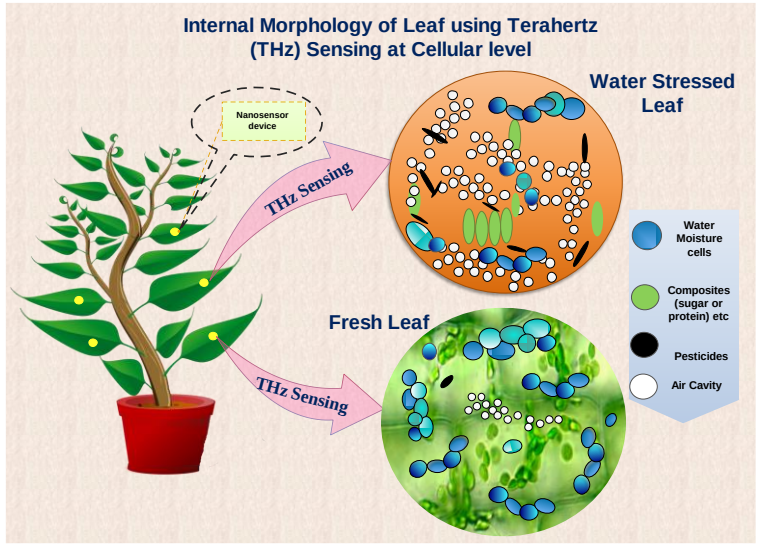
Terahertz Applications

Terahertz Enabled Nanoscale Plant Health







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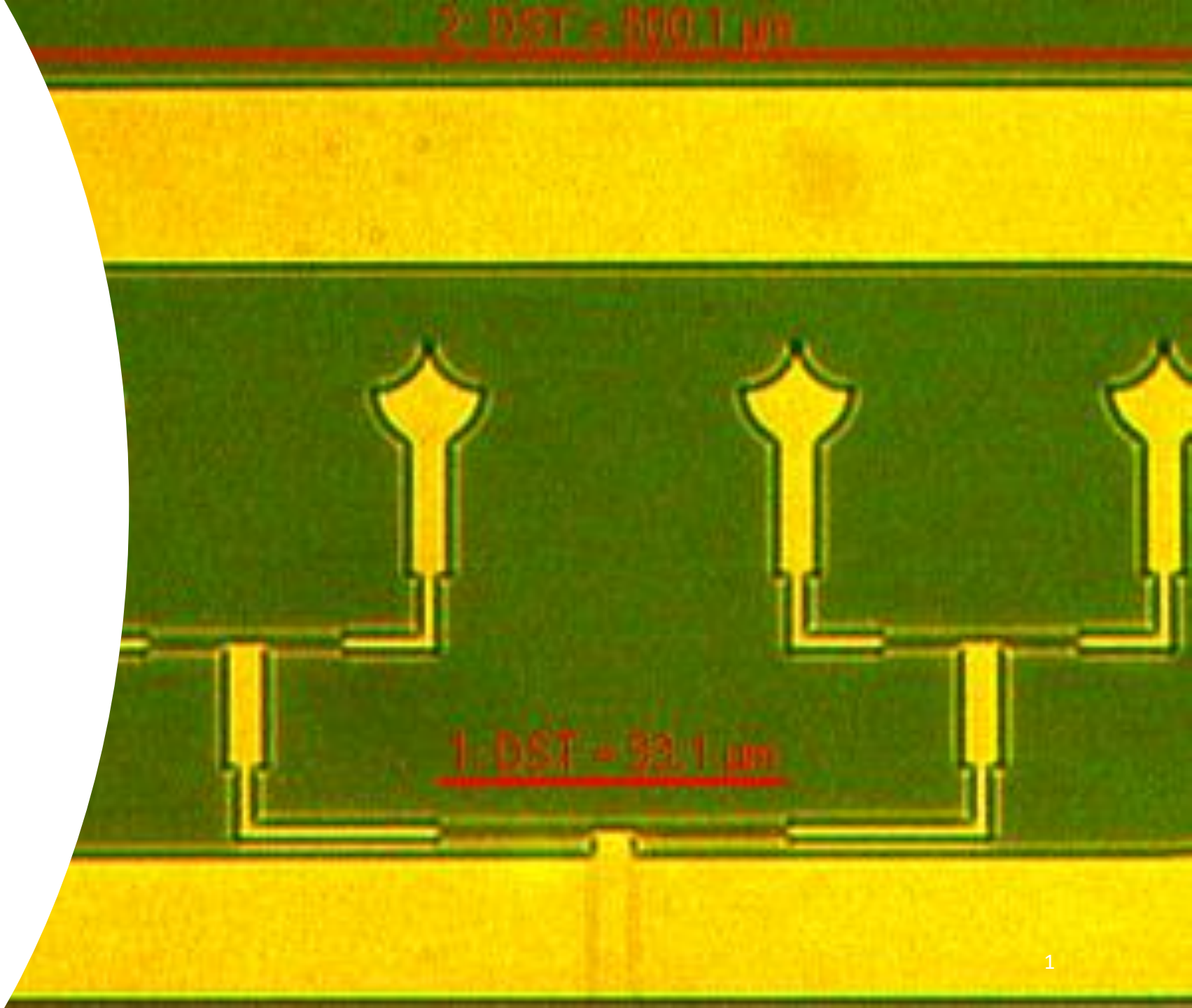
Antennas for 6G

THz Antennas



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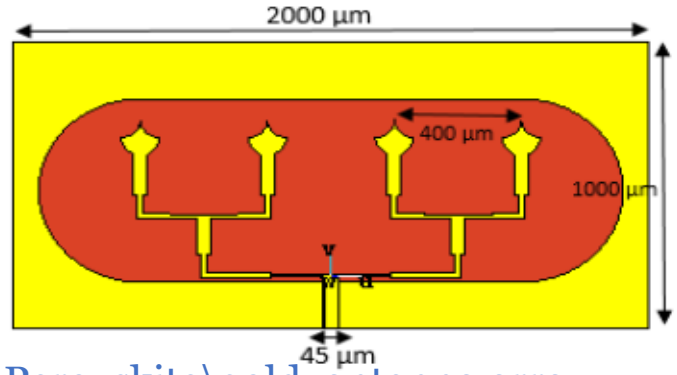
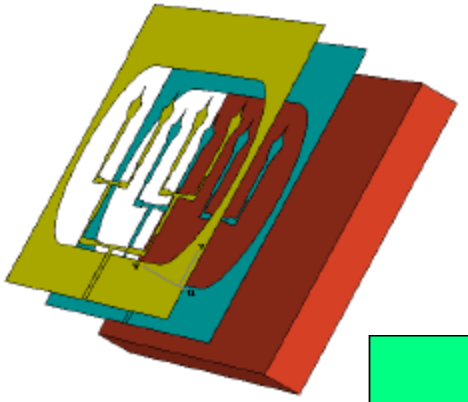
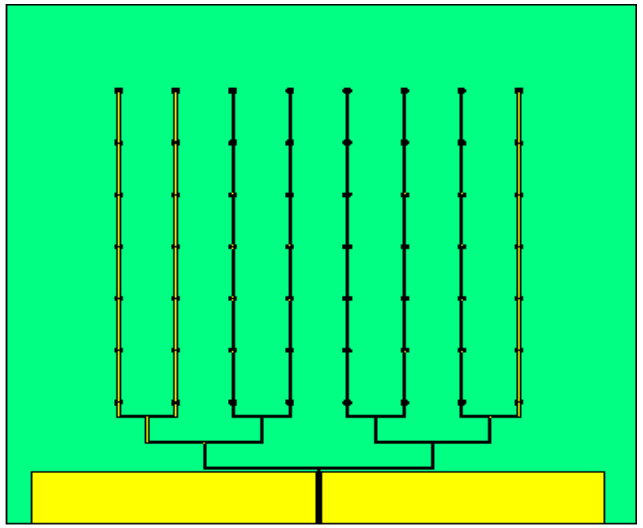
THz Antenna Designs

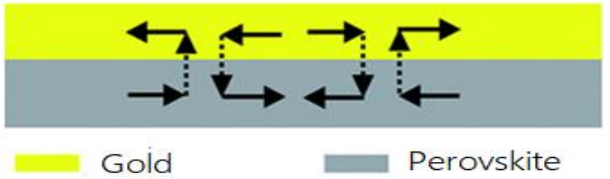


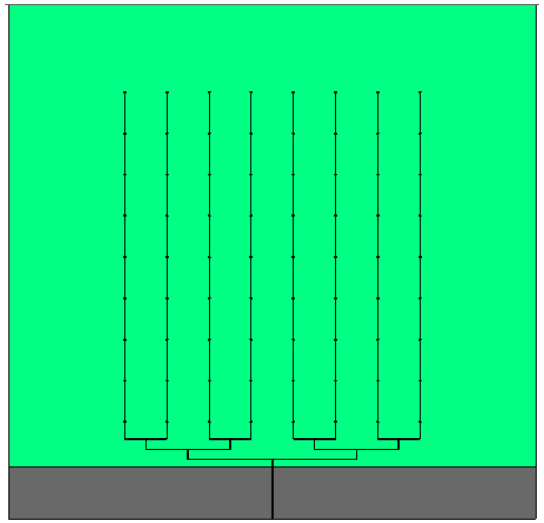


Perovskite\gold antenna array



Gold & Graphene

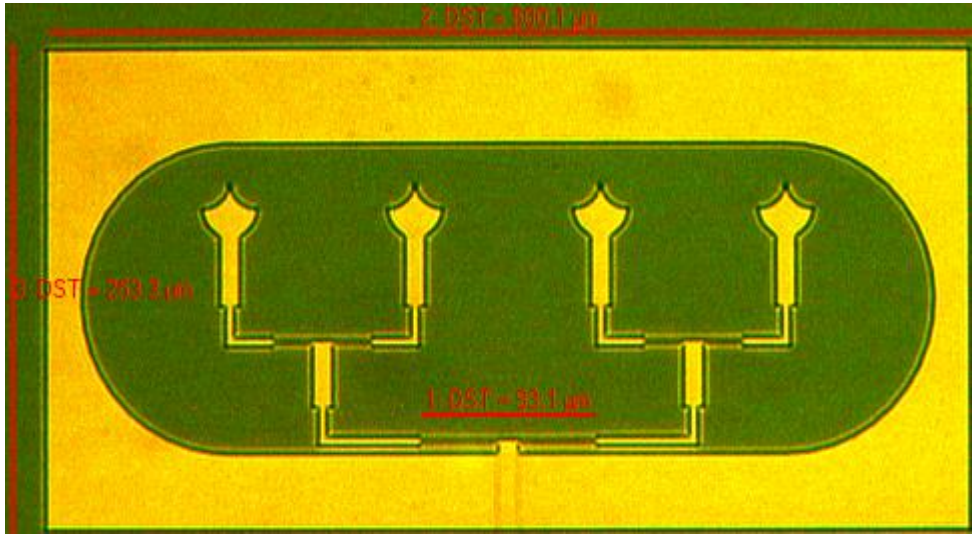




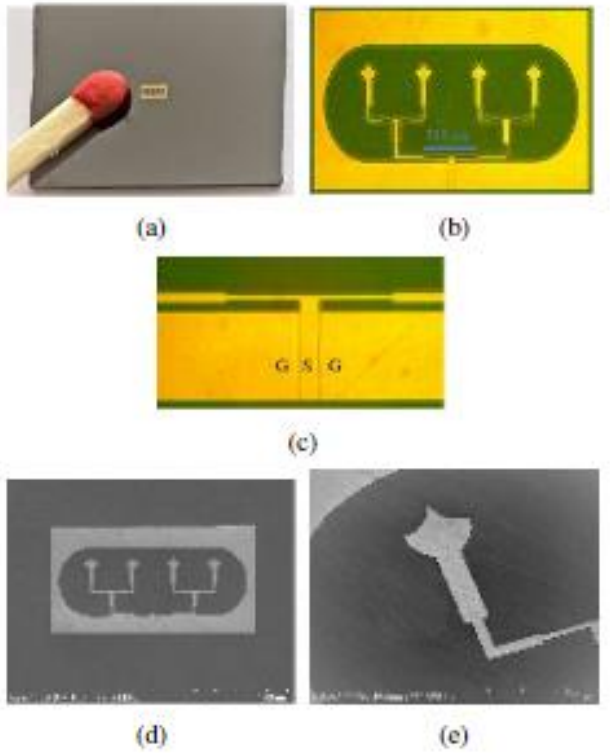
Graphene antenna array

Terahertz PICA Antenna

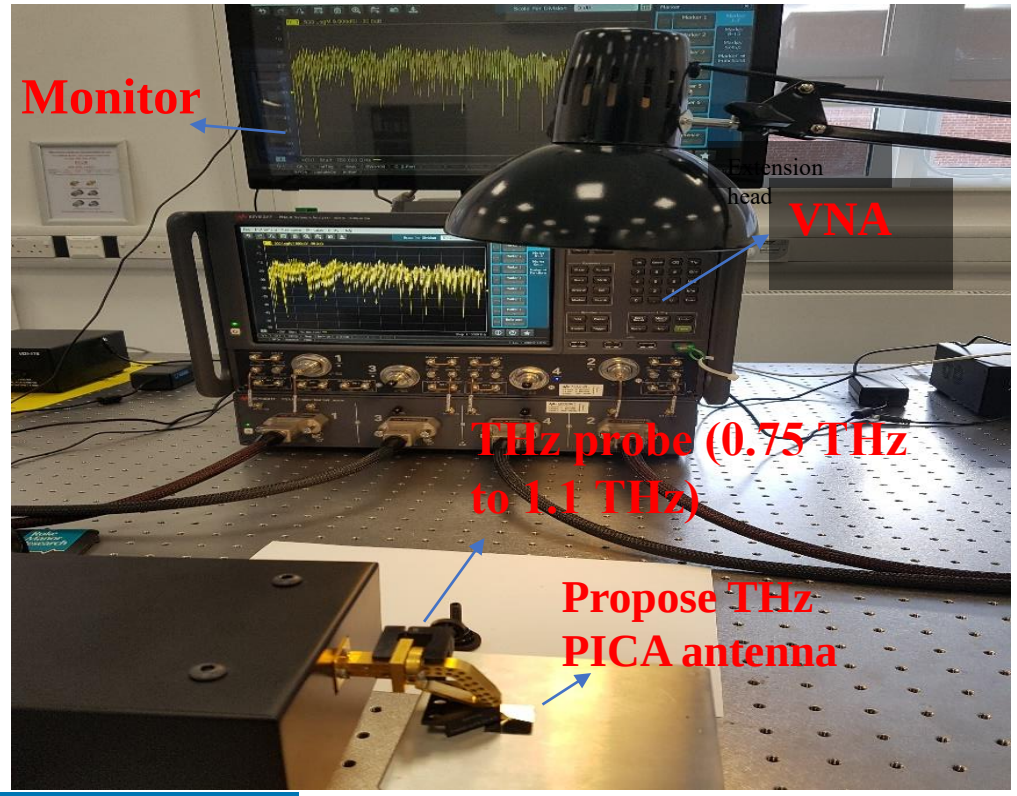
- Ultra-wideband Hybrid PICA Terahertz Antenna for high-speed THz communications
- PICA antenna with wide range from 0.5 THz to 2.4 THZ fabricated based on gold.

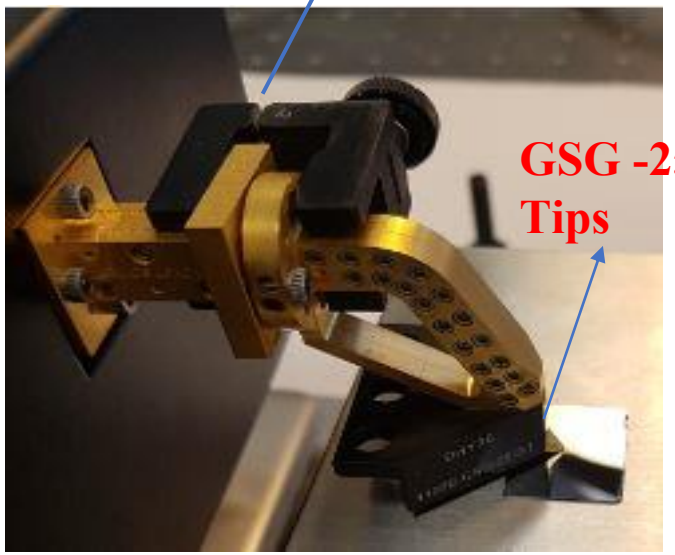


Fabricated PICA antenna under the Optical microscope

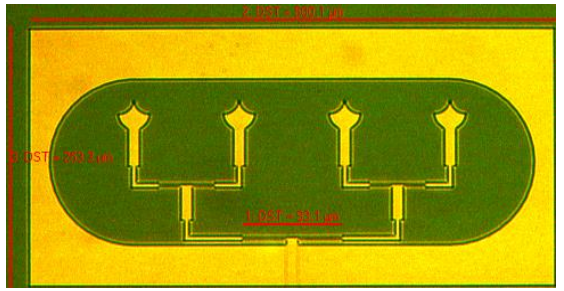


Terahertz Measurement Setup

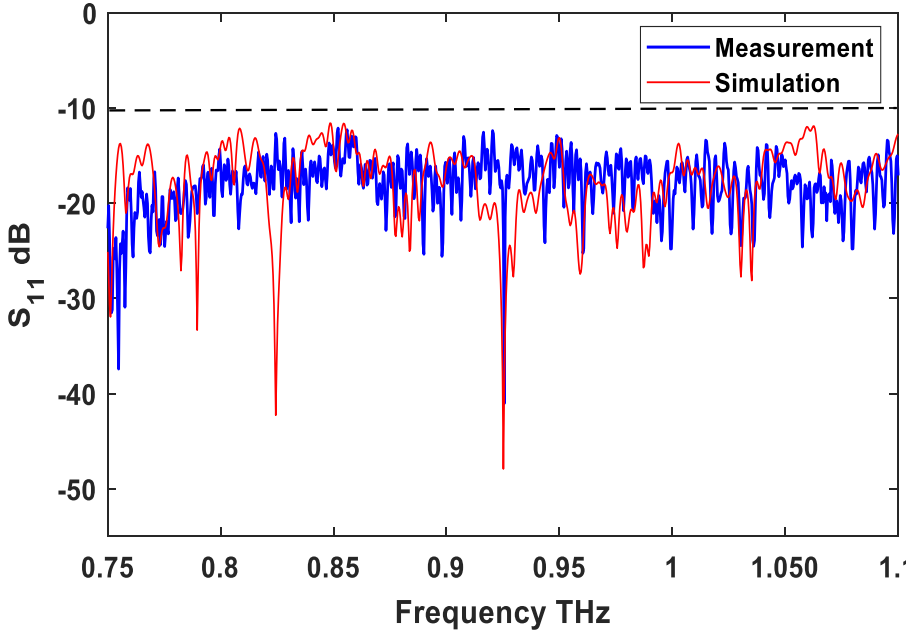


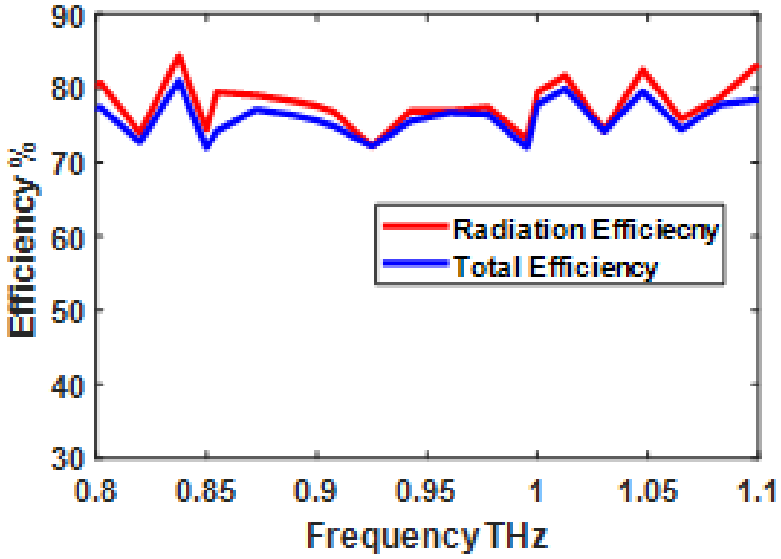


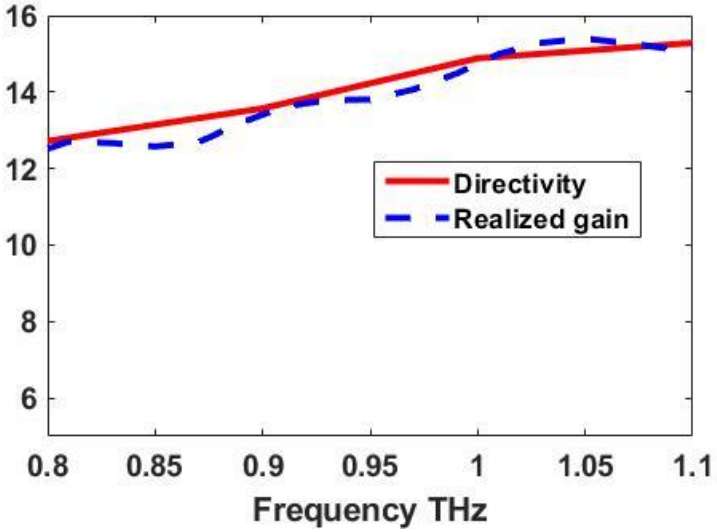
Results and Analysis



A. Return Loss, Gain and Radiation Efficiency







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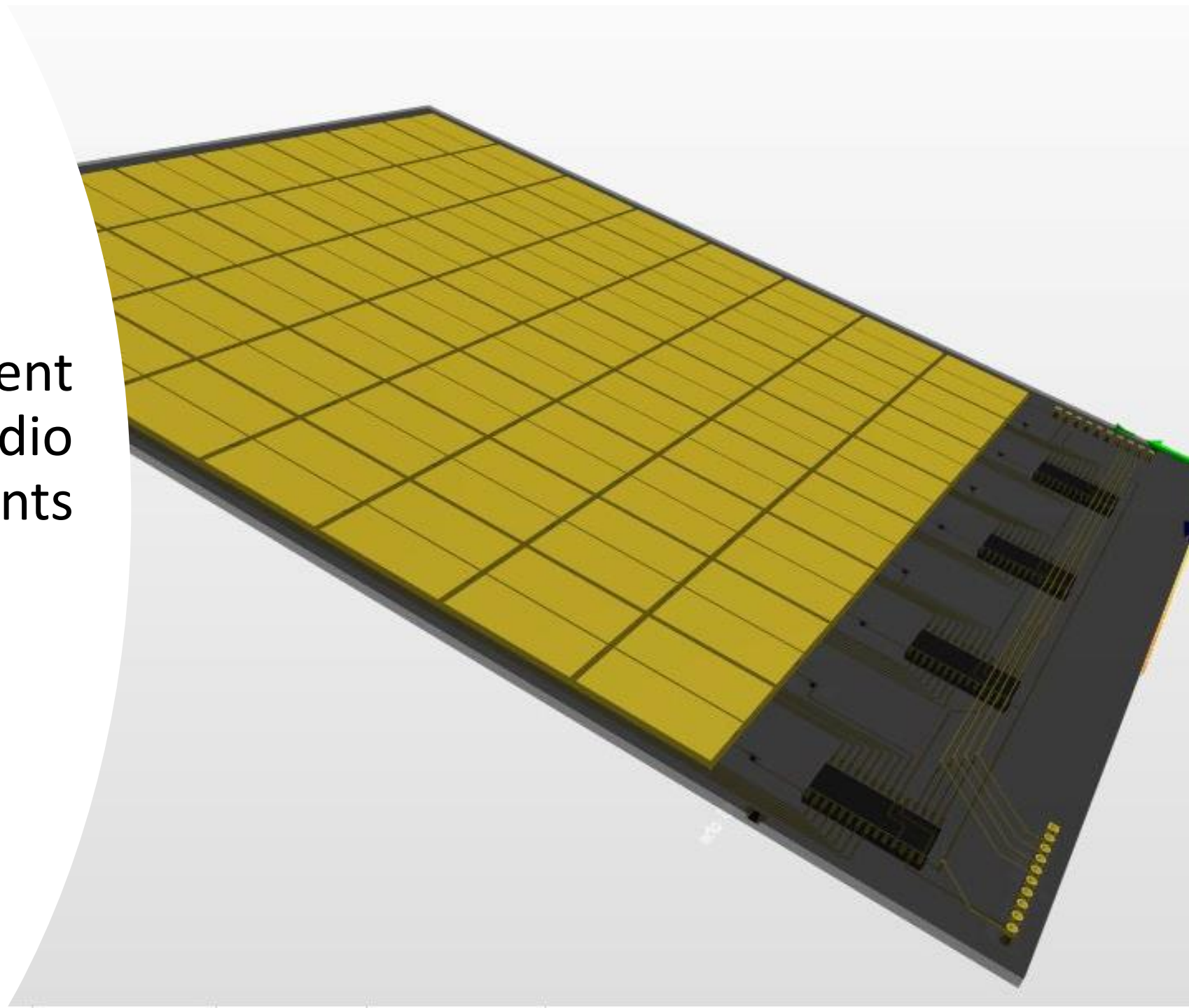
Reconfigurable Intelligent Surfaces for Smart Radio Environments



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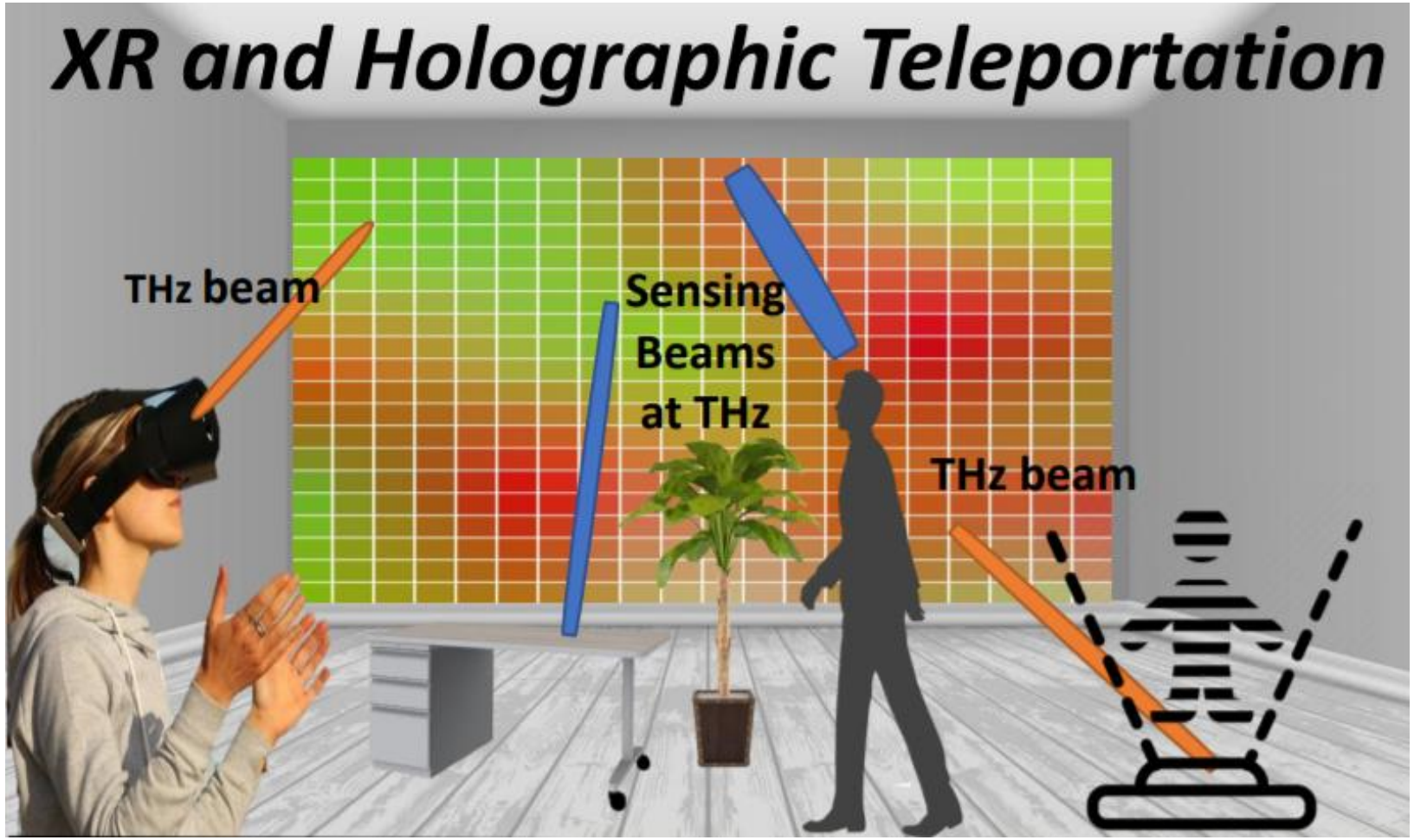
RIS-Enabled THz Communication



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RIS Hardware Testbeds @ UofG

Multi-Bit Column-Controlled Metasurface Design

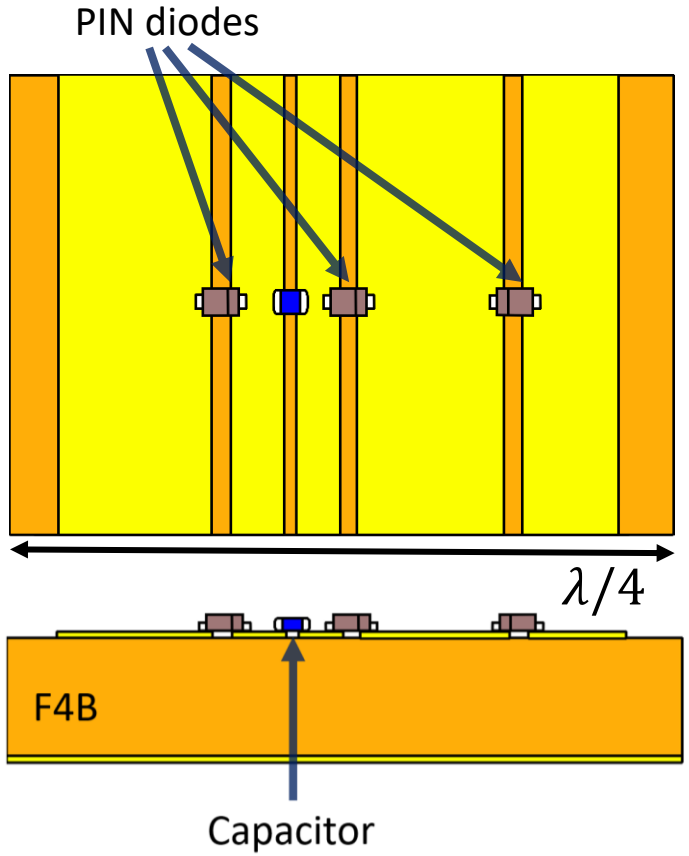
Planar design with high resolution azimuthal control at 3.75 GHz

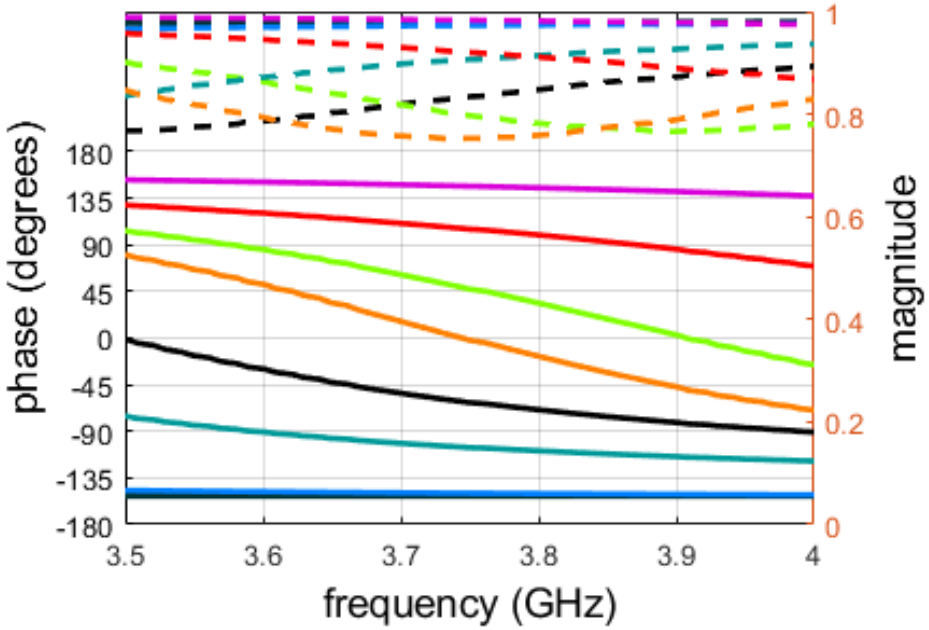
3 PIN diodes per unit cell

Patch spacing and widths optimized for 7 discrete phase shifts spaced approx. 50°

Average 1 dB reflection loss

Columns of unit cells controlled with a common set of digital values





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Rains et al., *Reflecting Metasurface Unit Cell Design with Multi-Bit Azimuthal Control (submitted),* 1st International Conference on Microwave, Antennas & Circuits (ICMAC 2021) Dec 2021

RIS Hardware Testbeds @ UofG

Multi-Bit Column-Controlled Metasurface Design

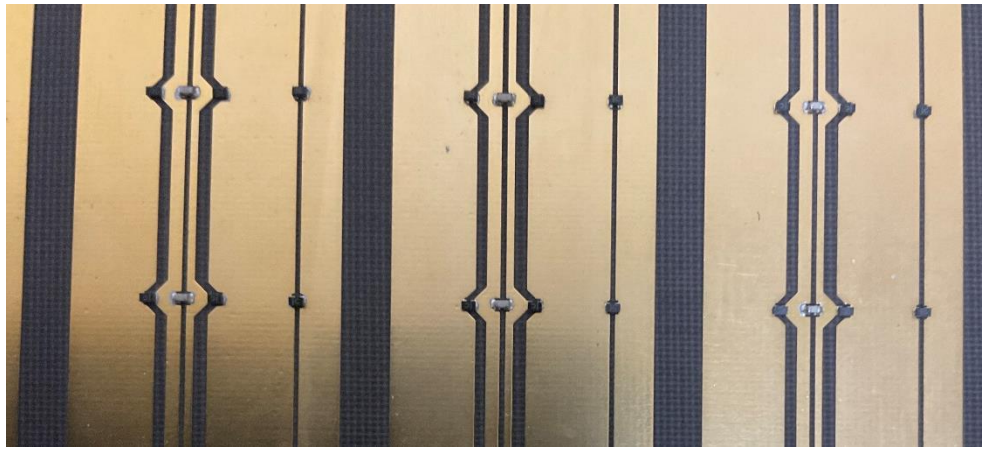
2304 unit cells (48 x 48)

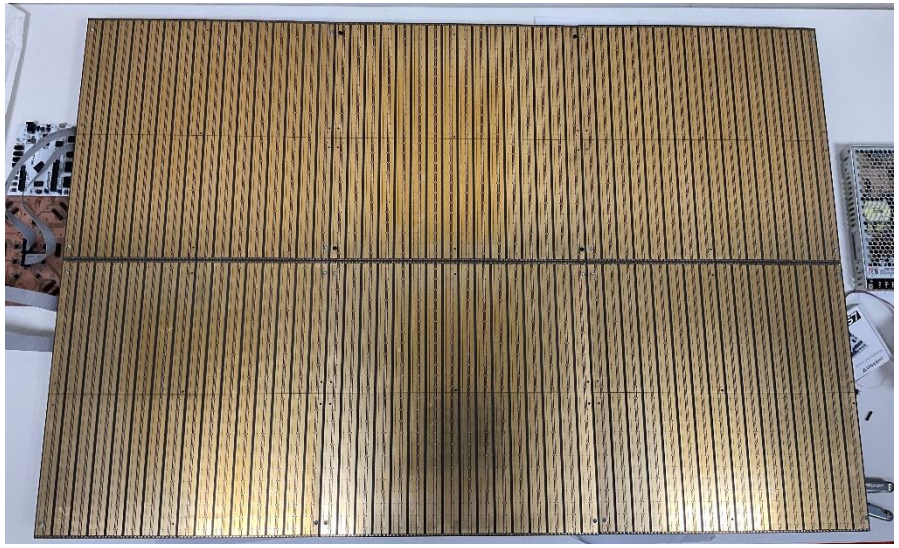
Total size 1 m x 0.7 m

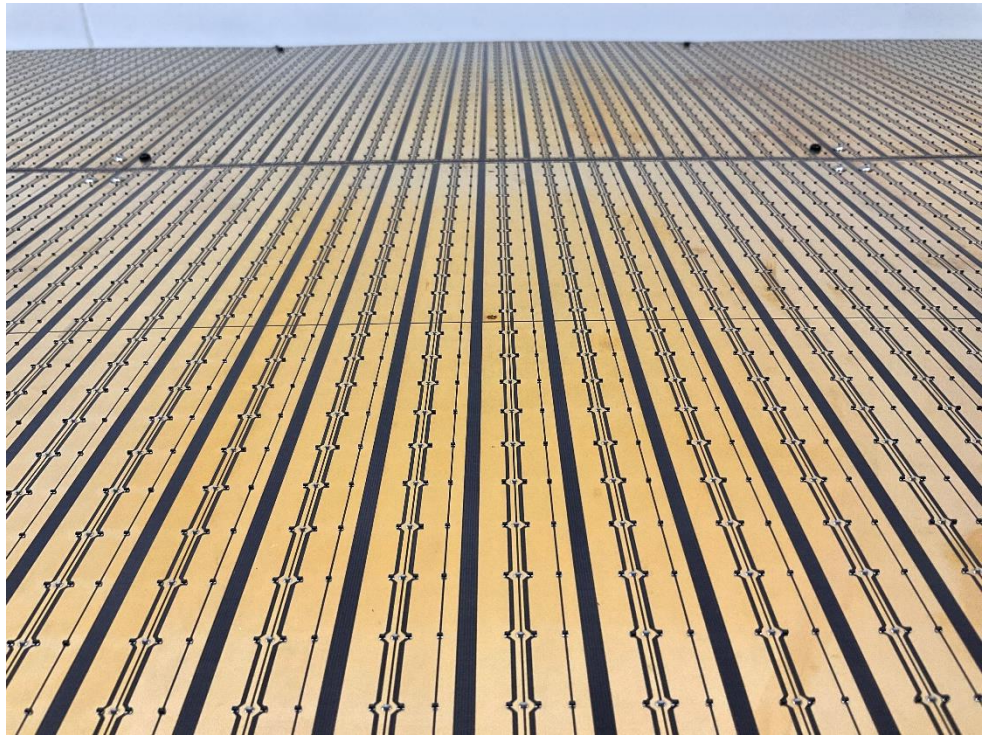
6 tiles of 16 x 24

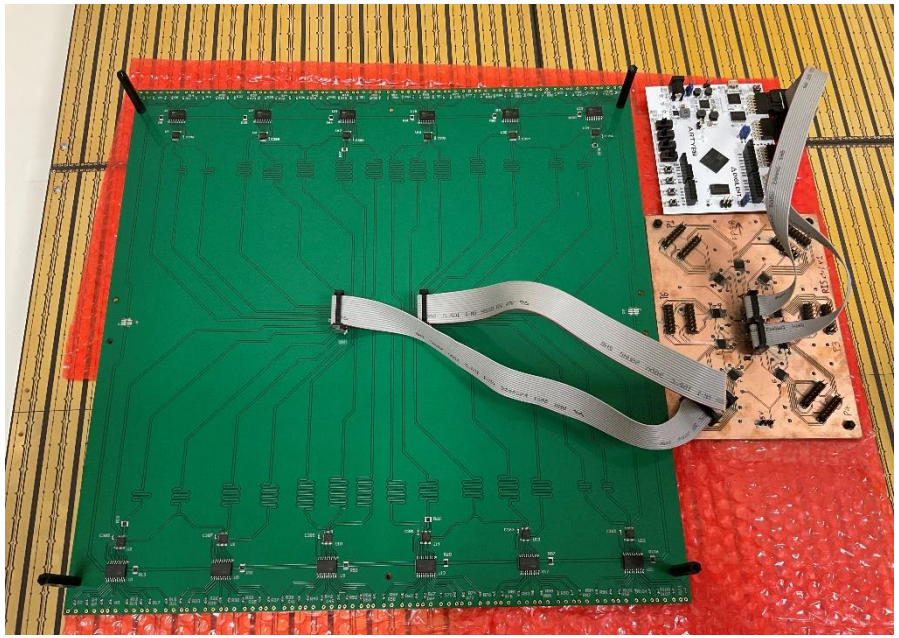
Each column split into groups of 12 unit cells controlled with similar biasing voltages

FPGA interfacing with 81 shift registers

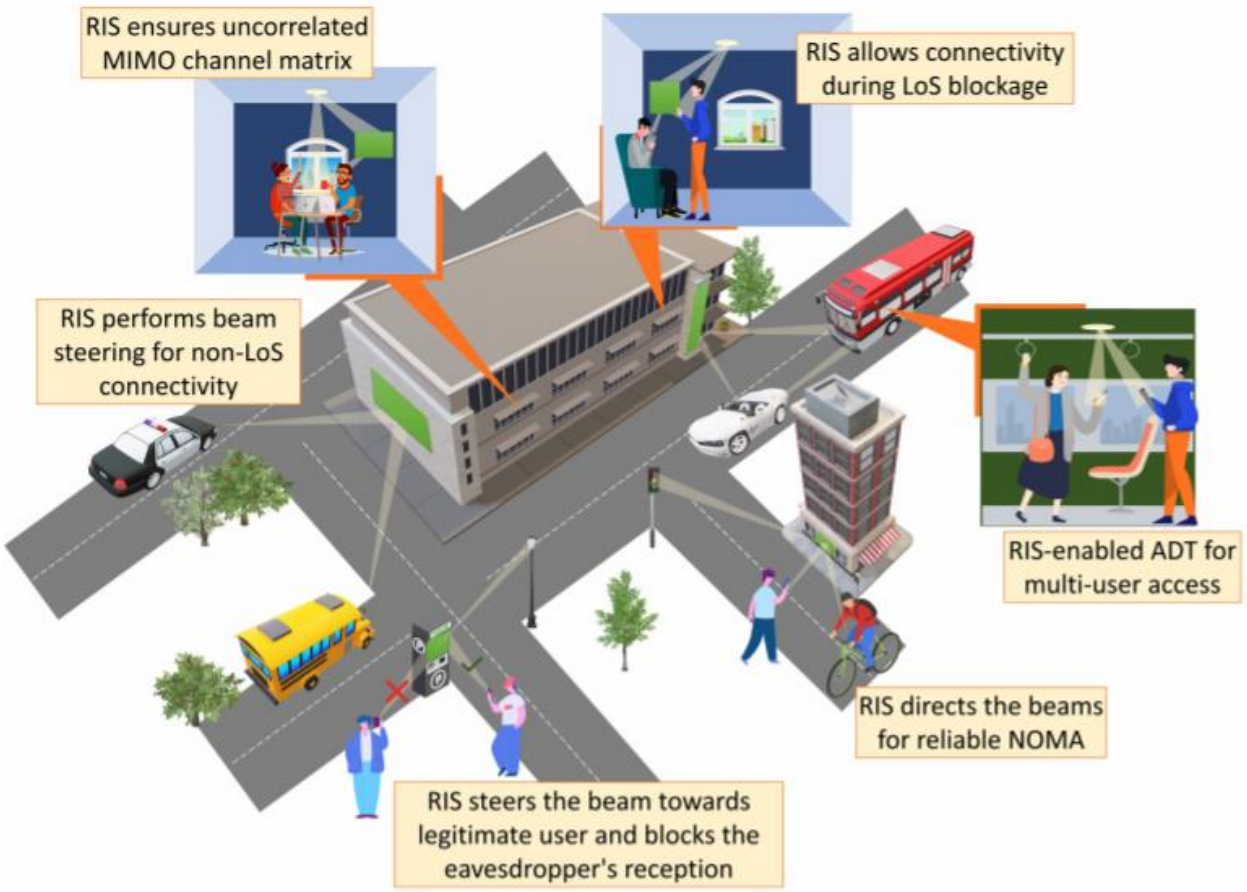








Beyond THz? LiFi?



LiFi meets RIS

LiFi meets THz

Sources:
Abumarshoud, Hanaa, Lina Mohjazi, Octavia A. Dobre, Marco Di Renzo, Muhammad Ali Imran, and Harald Haas. "LiFi Through Reconfigurable Intelligent Surfaces: A New Frontier for 6G?." arXiv preprint arXiv:2104.02390 (2021).
https://spie.org/news/photonics-focus/marapr-2021/autonomous-cars-drive-terahertz-research?SSO=1

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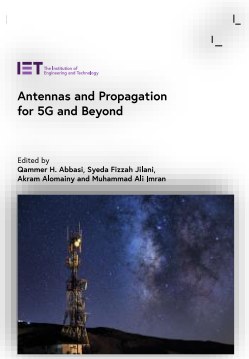
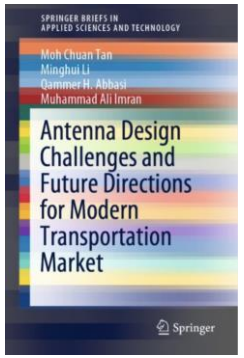
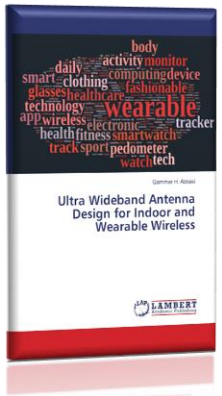
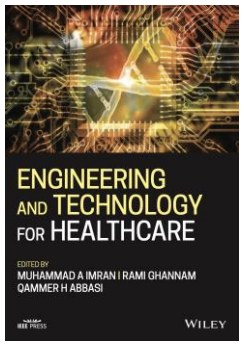
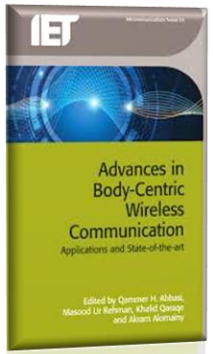
Reaching all …

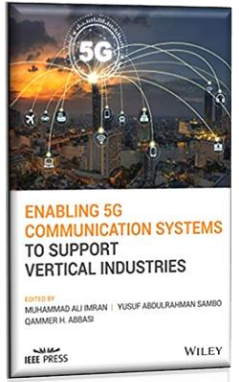


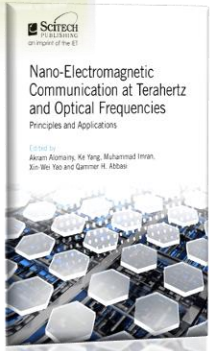


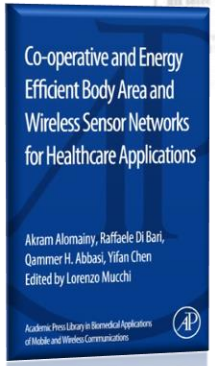


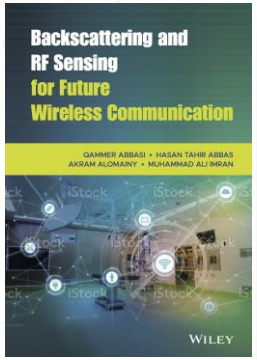


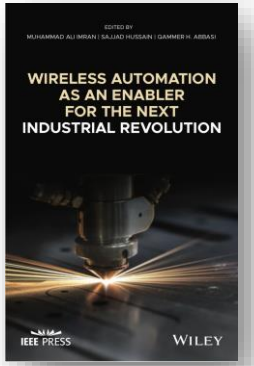












Scotland's First Minister
5G Demonstrations

UCET 2019

CSI Away Day 2020

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Success is a group achievement …

Sincerely appreciate contributions from colleagues, students and external supporters!

Thank you

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