tsdsi India's Telecom SDO Years of developing ICT Standards celebrating 10

WIRELESS WORLD RESEARCH FORUM

TSDSI-WWRF JOINT ONLINE WORKSHOP

RECONFIGURABLE INTELLIGENT SURFACES (RIS)

17 September 2024

Supported by

IAFI ITU-APT Foundation of India ITU's Association in India

Reconfigurable Intelligent Surfaces: Sharing Some Experience

by

Arzad Alam Kherani, IIT Bhilai

A motivating case: Industrial IoT

What if we can **control the channel** and **leave the end-devices dumb**

Multiple wireless technologies working in parallel

Channel Estimation Algorithms at sender and receiver

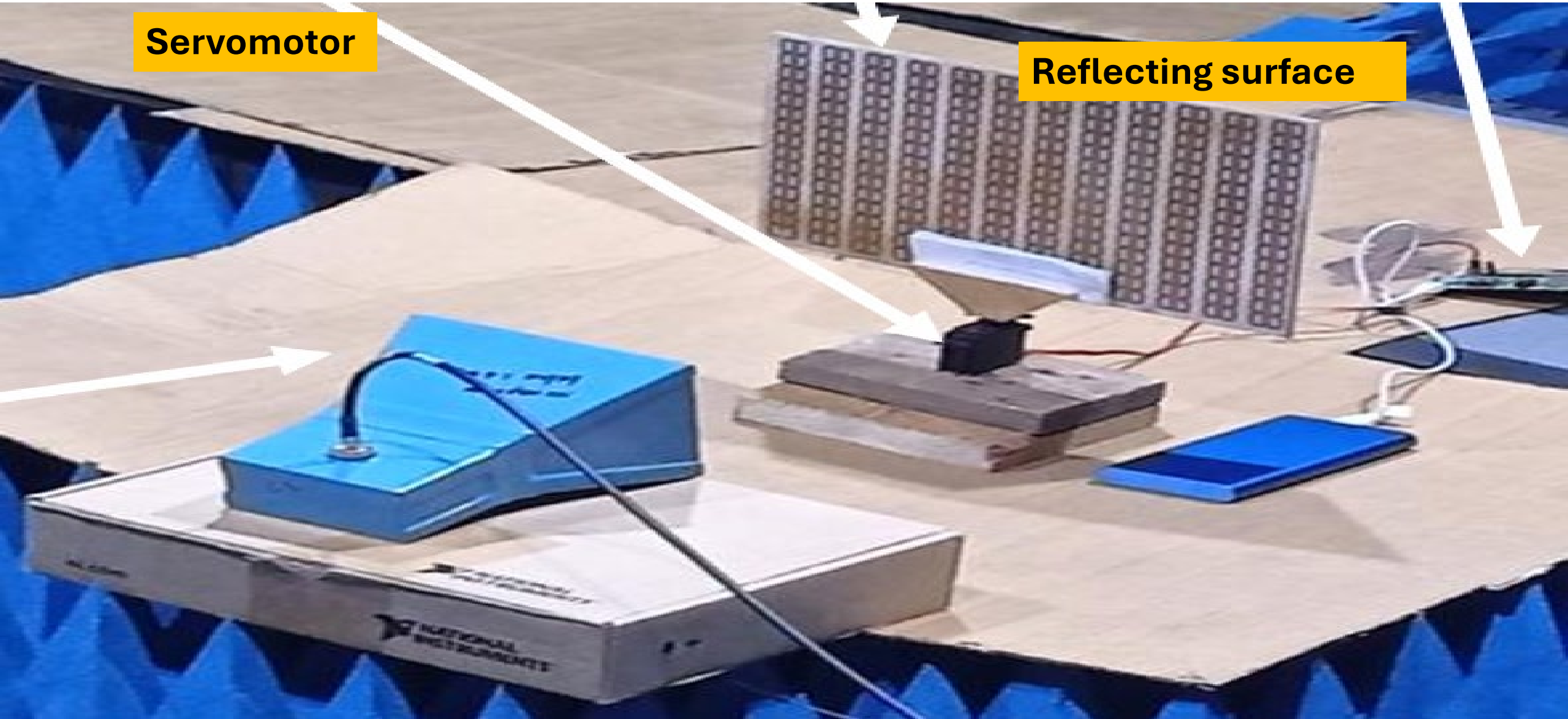
Intelligence at sender and receiver

Sensor manufacturers forced to work with, and choose the "right" wireless technology

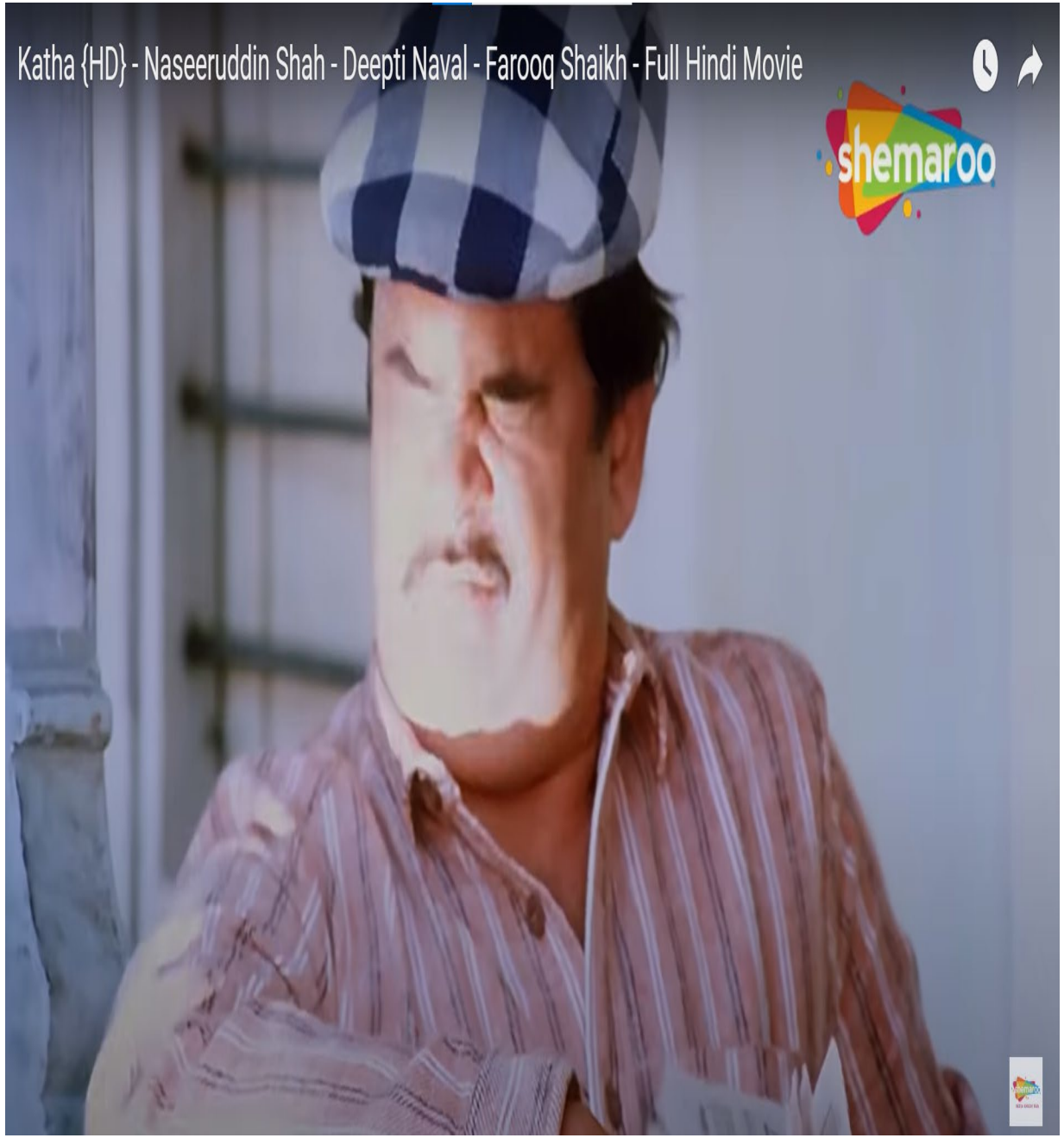
- Interoperability
- Difficult for smaller wireless technology providers
- Significantly high end-device cost

Image Source: https://iiot-world.com/industrial-iot/connected-industry/benefits-of-using-wireless-industrial-iot-sensors/

A Simple “Smart” Radio Environment (our first attempt at achieving SRE)




Katha {HD} - Naseeruddin Shah - Deepti Naval - Farooq Shaikh - Full Hindi Movie
shemaroo


Katha {HD} - Naseeruddin Shah - Deepti Naval - Farooq Shaikh - Full Hindi Movie
shemaroo

Very Promising

Smart Radio Environments and Reconfigurable Intelligent Surfaces

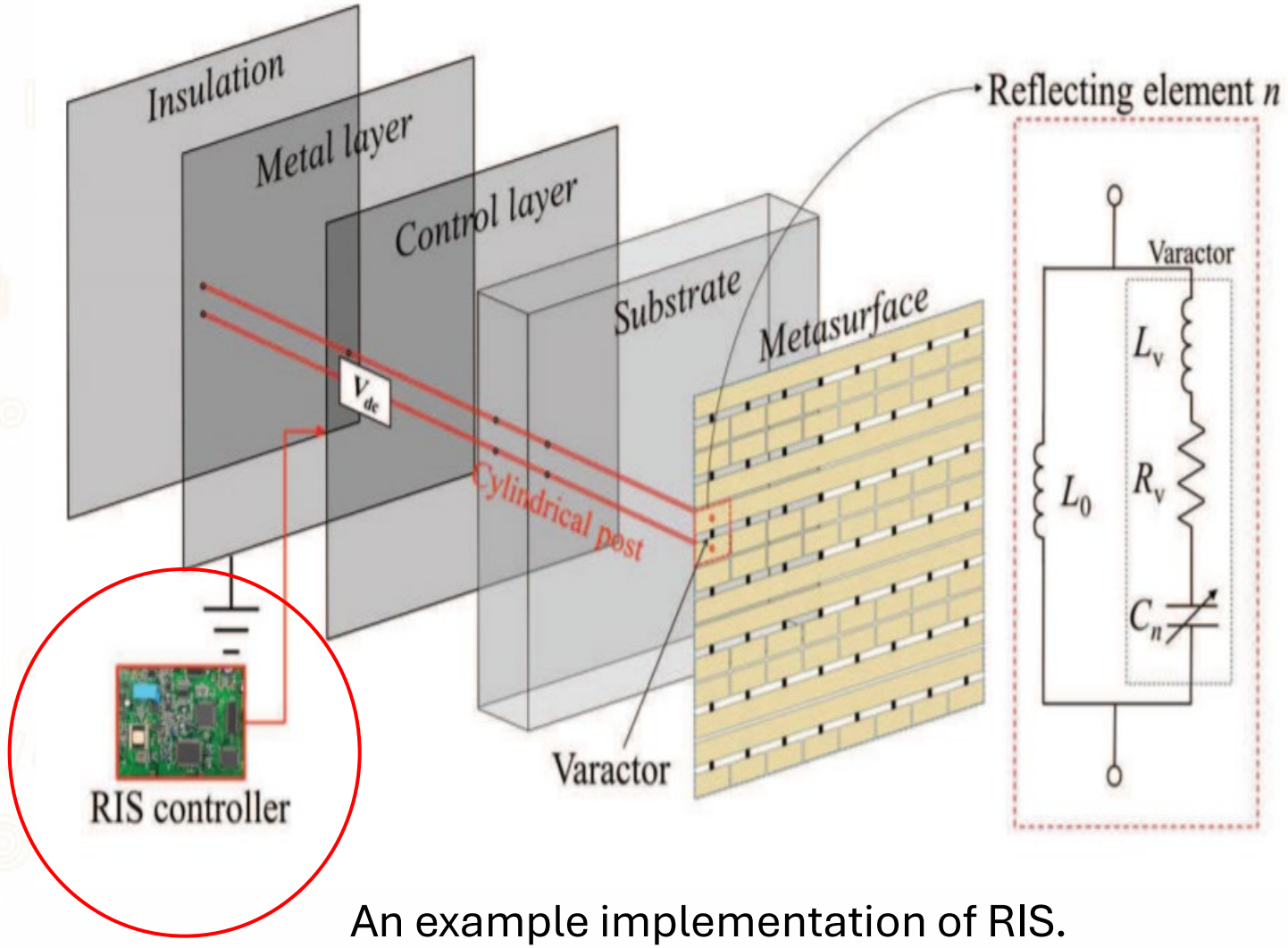
A Smart Radio Environment (SRE) is a wireless environment that is turned into a smart reconfigurable space and that plays an active role in transferring and processing information

Source: https://hal.archives-ouvertes.fr/hal-02395877/document

Can be achieved using

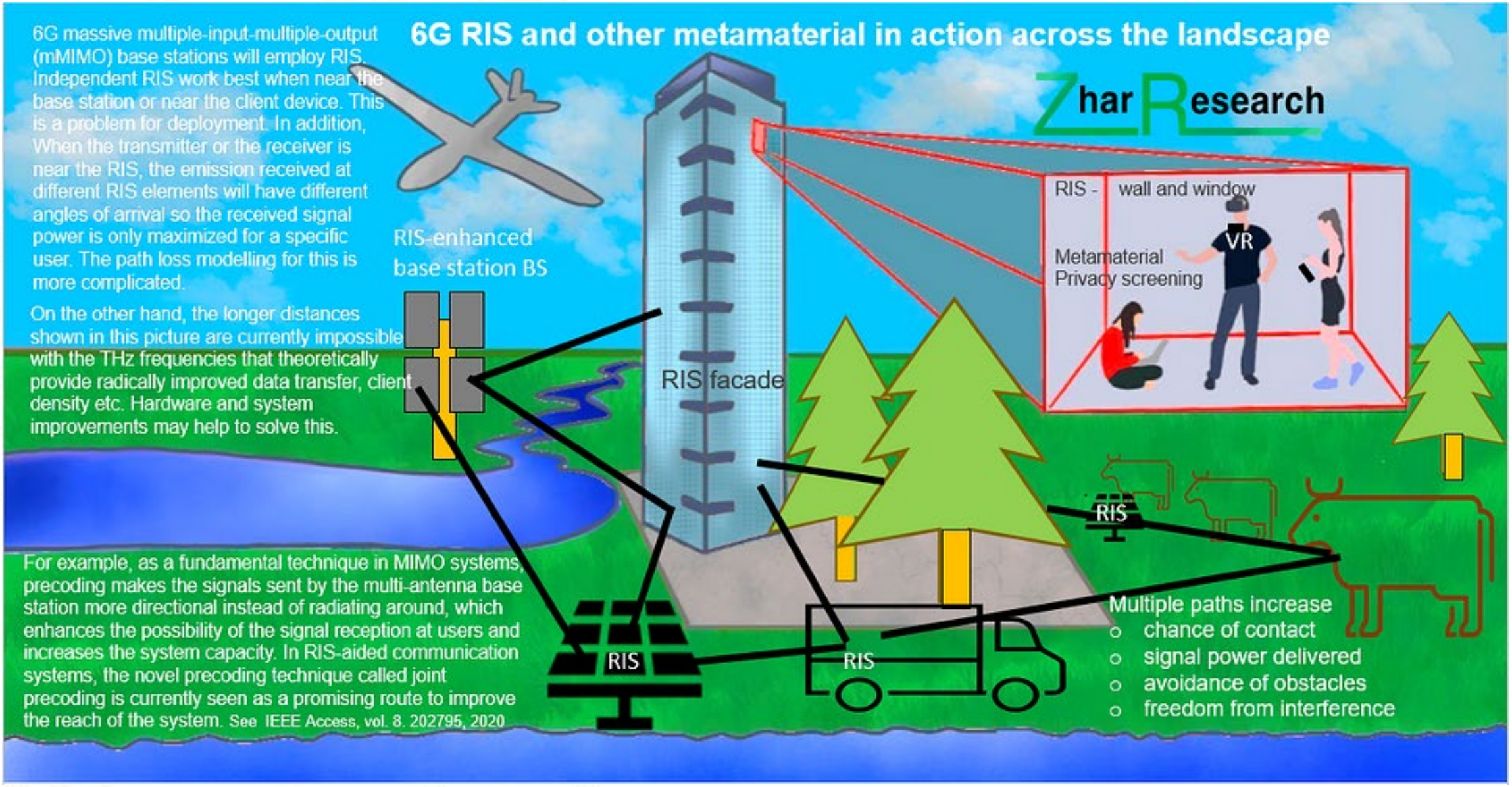
A Reconfigurable Intelligent Surfaces (RIS) is an artificial surface, made of electromagnetic material, that is capable of customizing the propagation of the radio waves impinging upon it.

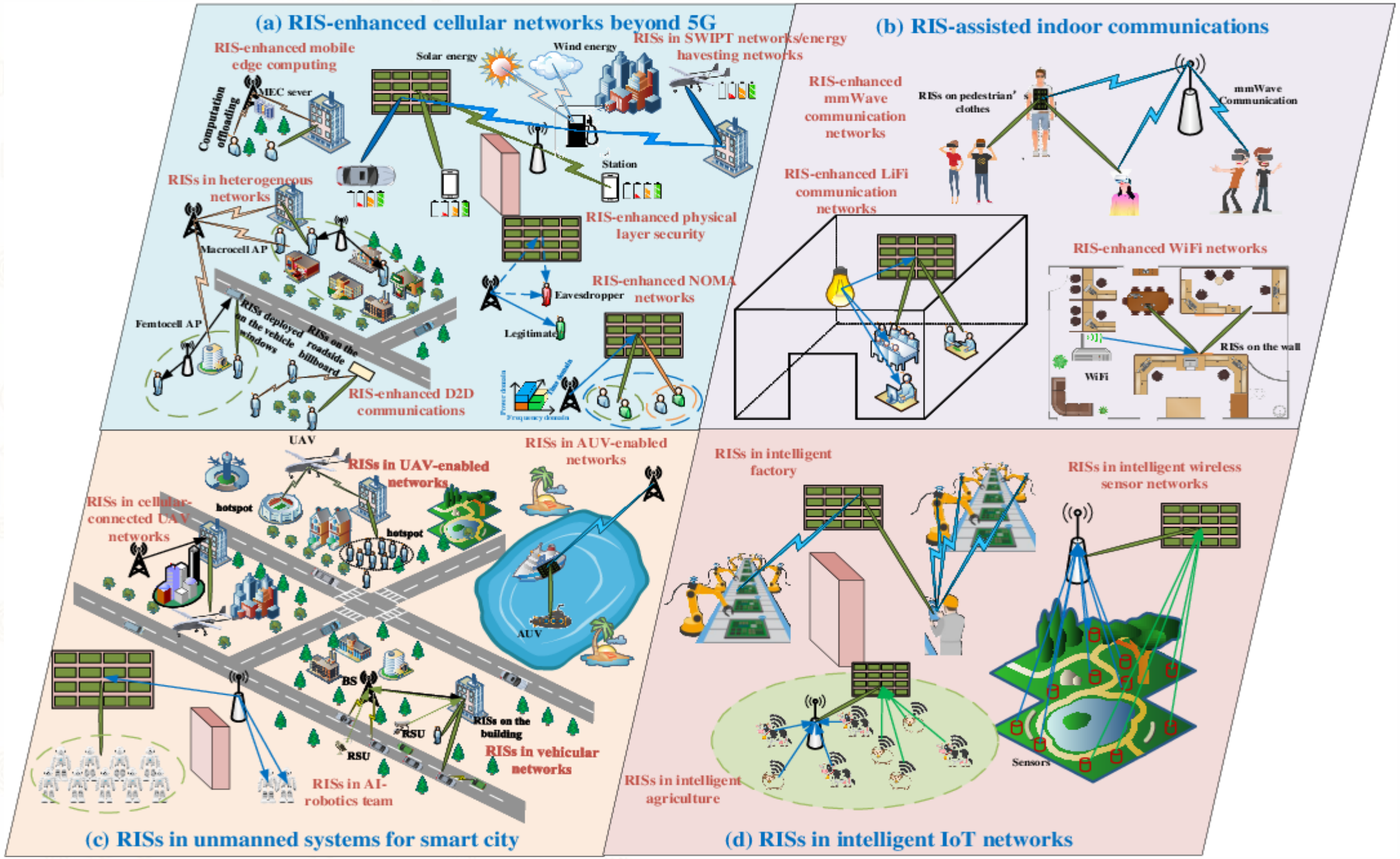
(Source: https://arxiv.org/pdf/1908.08747.pdf)



An example implementation of RIS.

Source: https://arxiv.org/pdf/1910.00968.pdf


6G RIS and other metamaterial in action across the landscape
6G massive multiple-input-multiple-output (mMIMO) base stations will employ RIS. Independent RIS work best when near the base station or near the client device. This is a problem for deployment. In addition, When the transmitter or the receiver is near the RIS, the emission received at different RIS elements will have different angles of arrival so the received signal power is only maximized for a specific user. The path loss modelling for this is more complicated.
On the other hand, the longer distances shown in this picture are currently impossible with the THz frequencies that theoretically provide radically improved data transfer, client density etc. Hardware and system improvements may help to solve this.
Zhar Research
RIS-enhanced base station BS
RIS facade
RIS - wall and window
Metamaterial Privacy screening
VR
RIS
RIS
RIS
For example, as a fundamental technique in MIMO systems, precoding makes the signals sent by the multi-antenna base station more directional instead of radiating around, which enhances the possibility of the signal reception at users and increases the system capacity. In RIS-aided communication systems, the novel precoding technique called joint precoding is currently seen as a promising route to improve the reach of the system. See IEEE Access, vol. 8. 202795, 2020
Multiple paths increase
chance of contact
signal power delivered
avoidance of obstacles
freedom from interference


(a) RIS-enhanced cellular networks beyond 5G
RIS-enhanced mobile edge computing
Computation offloading
MEC sever
Solar energy
Wind energy
RISs in SWIPT networks/energy havesting networks
Station
RISs in heterogeneous networks
Macrocell AP
Femtocell AP
RISs deployed on the vehicle windows
RISs on the roadside billboard
RIS-enhanced physical layer security
RIS-enhanced NOMA networks
Eavesdropper
Legitimate
RIS-enhanced D2D communications
(b) RIS-assisted indoor communications
RIS-enhanced mmWave communication networks
RISs on pedestrian's clothes
mmWave Communication
RIS-enhanced LiFi communication networks
RIS-enhanced WiFi networks
RISs on the wall
WiFi
(c) RISs in unmanned systems for smart city
UAV
RISs in UAV-enabled networks
RISs in AUV-enabled networks
RISs in cellular-connected UAV networks
hotspot
hotspot
AUV
BS
RSU
RSU
RISs on the building
RISs in vehicular networks
RISs in AI-robotics team
(d) RISs in intelligent IoT networks
RISs in intelligent factory
RISs in intelligent wireless sensor networks
Sensors
RISs in intelligent agriculture

Some Caution

WIRELESS SENSOR NETWORKS

THESIS TOPICS

- *Energy-Efficient Routing Protocols in WSNs*
- *Security Mechanisms for WSNs*
- *Application of Machine Learning in WSNs*
- *Integration of WSNs with IoT for Smart Cities*
- *Underwater Wireless Sensor Networks (UWSNs)*
- *WSNs for Precision Agriculture*
- *Health Monitoring Using WSNs*
- *Cross-Layer Optimization Techniques for WSNs*
- *Blockchain for Data Integrity in WSNs*

phdprojects.org

What “we” did (and, are doing) …

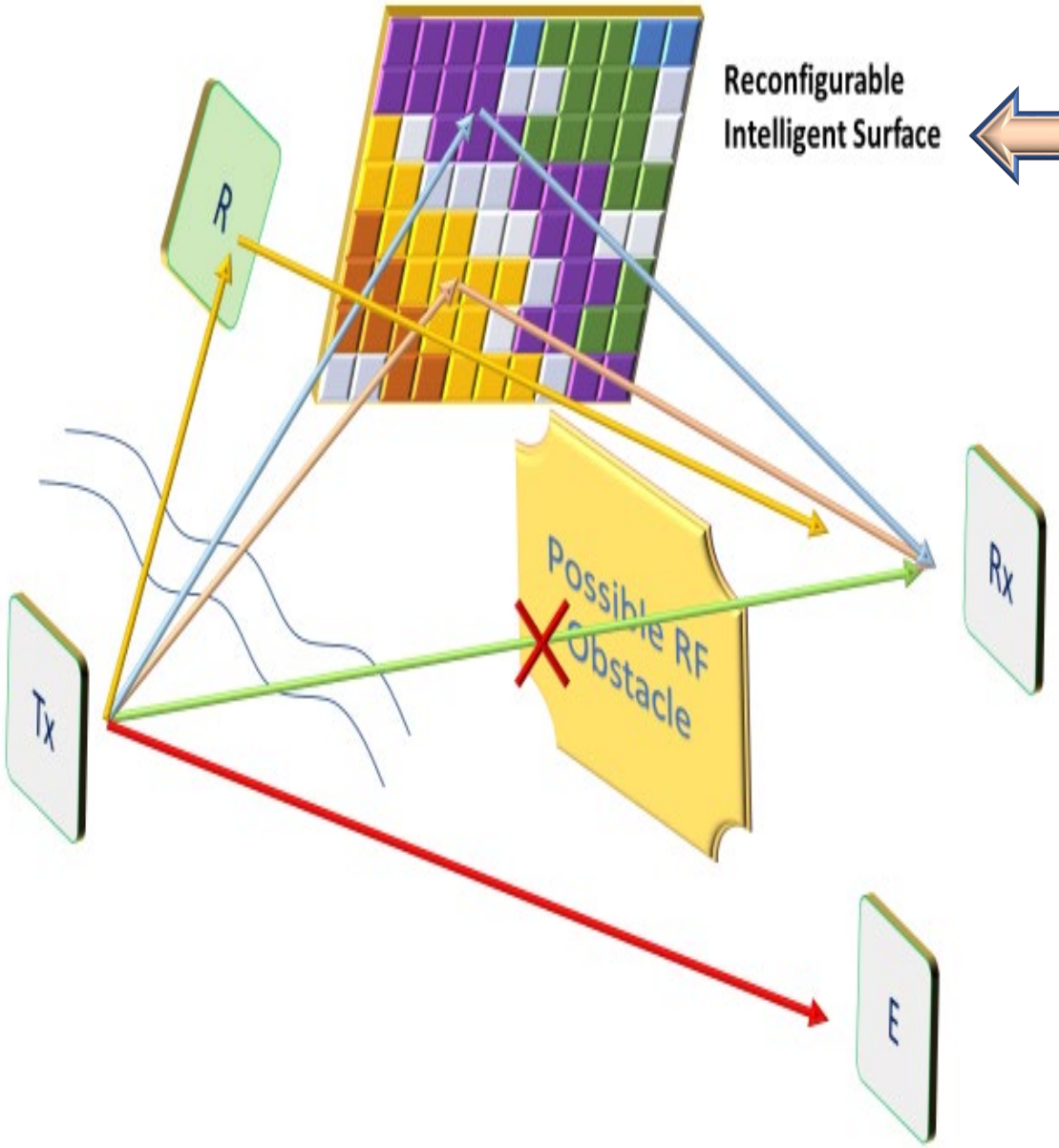
Students/Staff: Saksham, Kaushik, Ashutosh, Sai, Shubhika, Smriti, Vishwajeet, Amit, Khushboo, Bhavesh

and, with **COMET Foundation (IIIT Bangalore)**
Brejesh Lall (IIT Delhi), Vimal Bhatia (IIT Indore), Rajarshi Mohapatra (IIIT Naya Raipur), Sanjeev Sharma (IIT BHU), Samrat Mukhopadhyay (IIT Dhanbad), Ravi Panwar (IIT BHU), Soumava Mukherjee (IIT Jodhpur), Priyanka Das (IIIT Bangalore),

and, Jishnu, Gautam from Tejas Networks.

and, the impressive pool of TSDSI members and Secretariat (for the standardization aspect)
Ably supported by Prof. Debabrata Das, Milind Gandhe, Sridhar P., Amudeeshan
(Apologies if I missed someone)

Views presented are my own and based on publicly available information.



One controller for the overall radio environment configuration

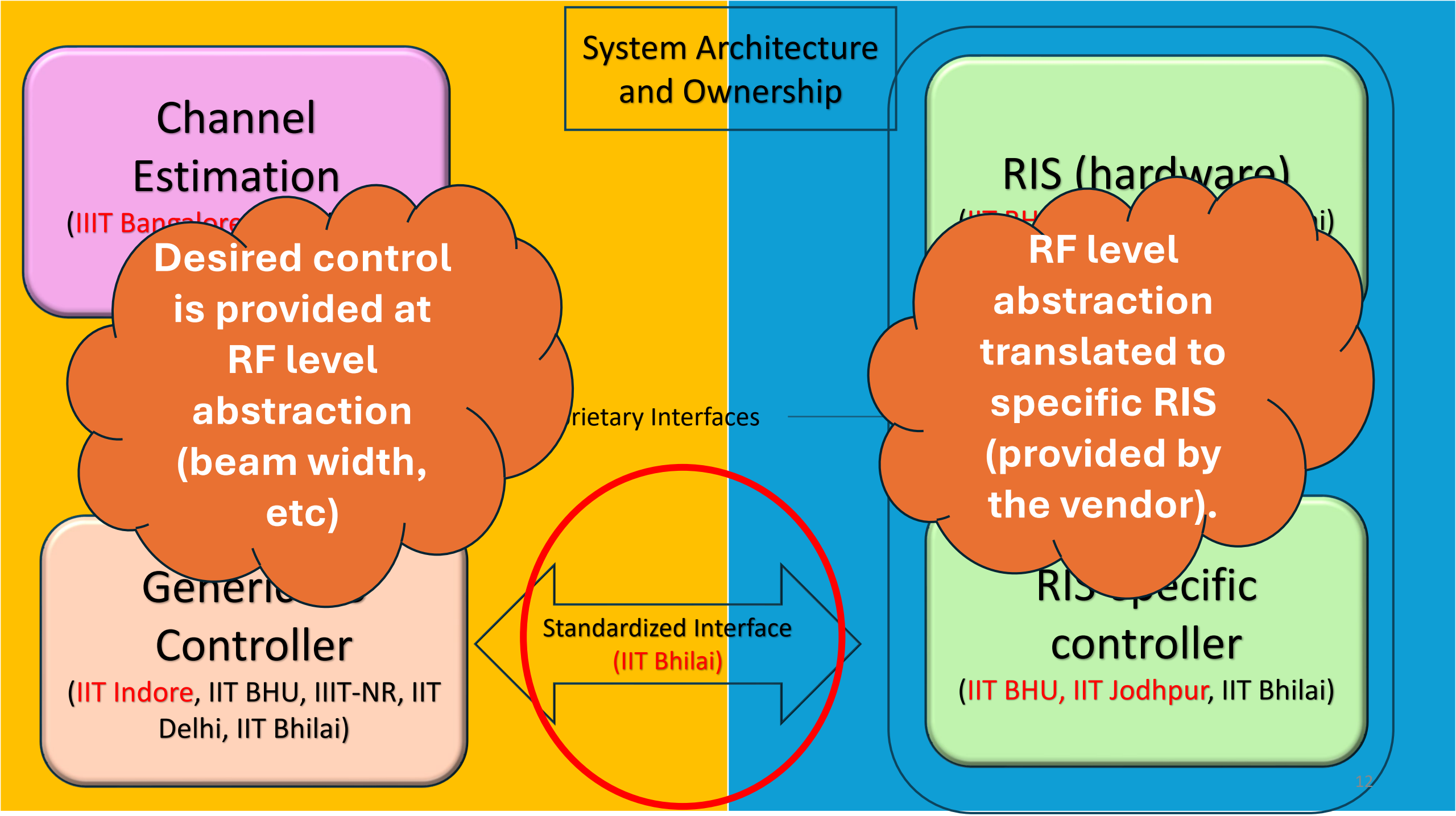
Challenges:

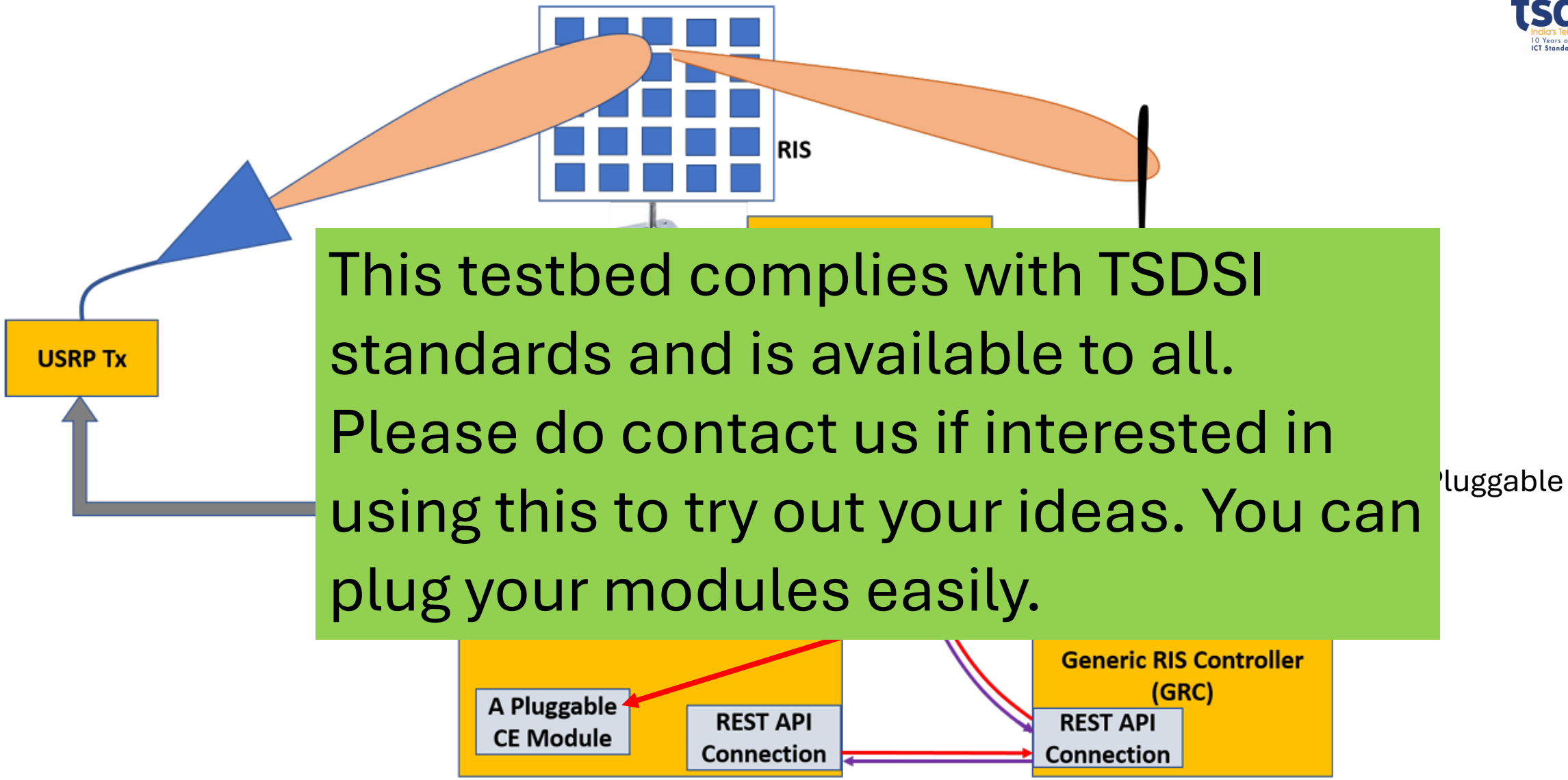
Fabrication

Control and Communication capability over RIS systems

Estimation of ongoing performance to help control

Does standardization even make sense?
- Exactly what should be standardized?


System Architecture and Ownership
Channel Estimation
(IIIT Bangalore
Desired control is provided at RF level abstraction (beam width, etc)
RIS (hardware)
RF level abstraction translated to specific RIS (provided by the vendor).
rietary Interfaces
Standardized Interface
(IIT Bhilai)
Controller
(IIT Indore, IIT BHU, IIIT-NR, IIT Delhi, IIT Bhilai)
controller
(IIT BHU, IIT Jodhpur, IIT Bhilai)

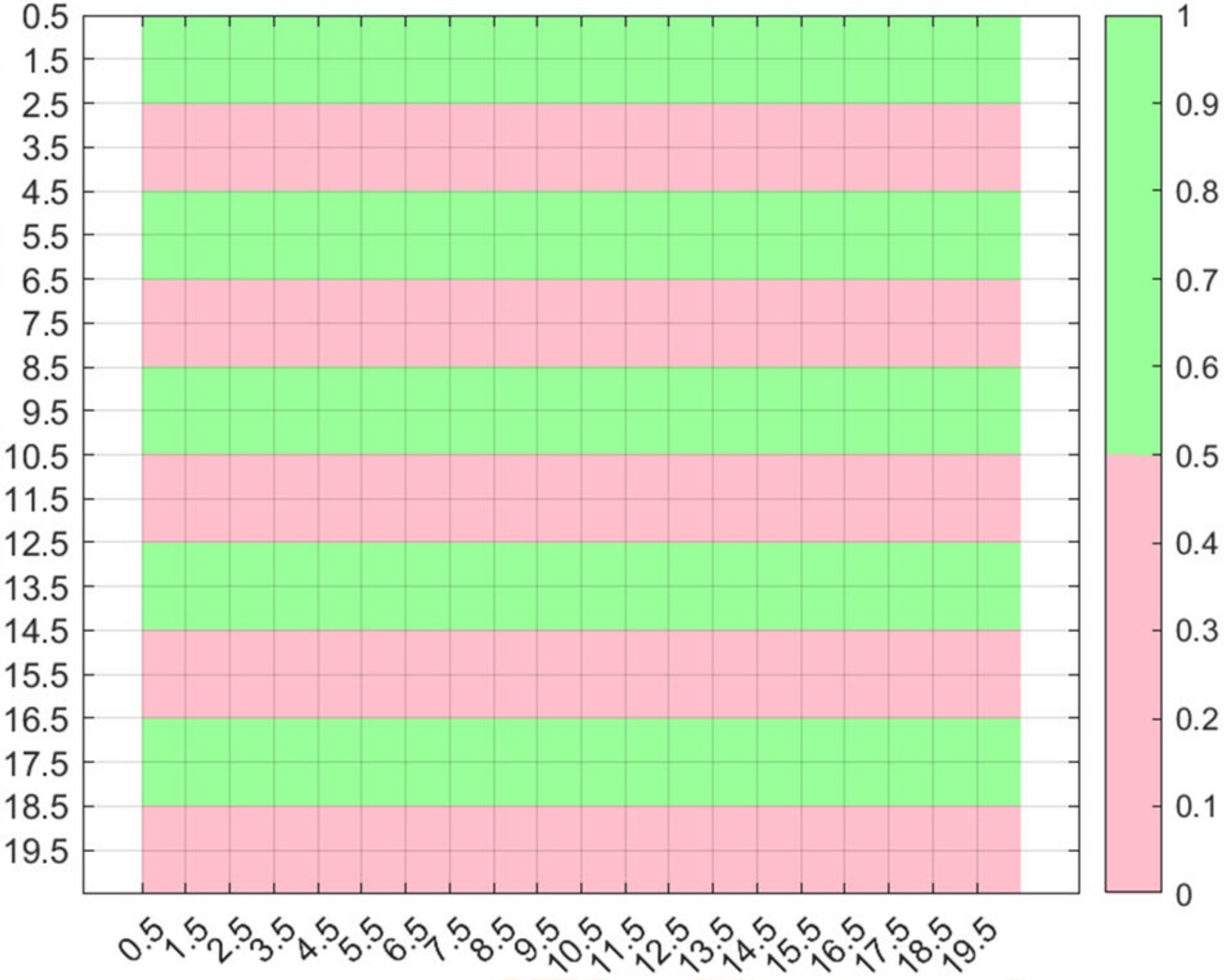


This testbed complies with TSDSI standards and is available to all. Please do contact us if interested in using this to try out your ideas. You can plug your modules easily.

luggable

Fig. 1: System model for RIS assisted communication.

RIS-Specific Controller: A Lookup Table Approach



The pattern in theta plane

```
[1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0]
```

Matrix generated for **30-degree** reflection

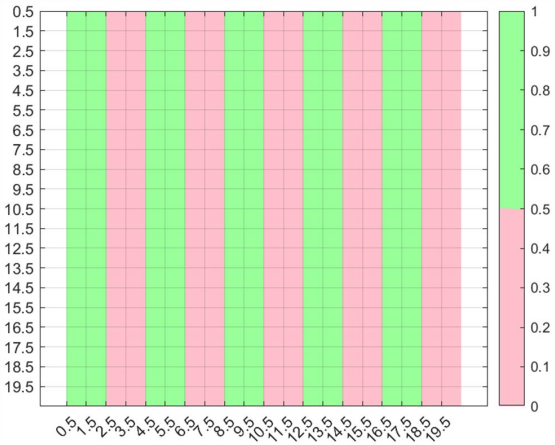
Acknowledgement: Soumava and Anjana, IIT Jodhpur

Reflection Patterns for Various Angles in Theta and Phi Planes

Θ=20º

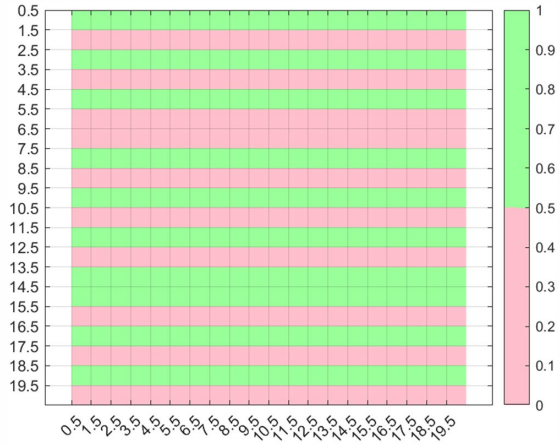
ϕ=20º

Θ=45º



ϕ=30º

Θ=10º



Θ=60º

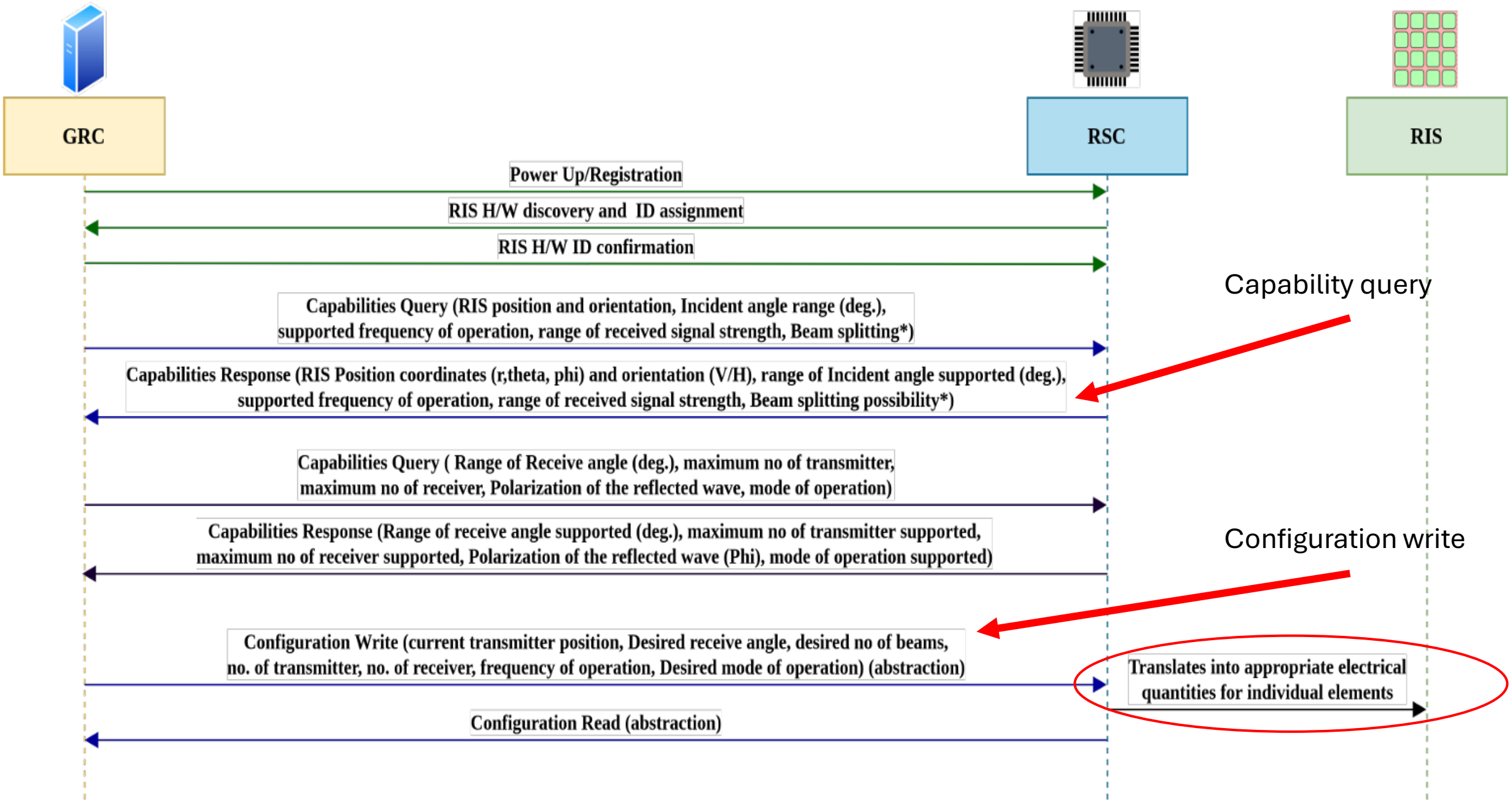
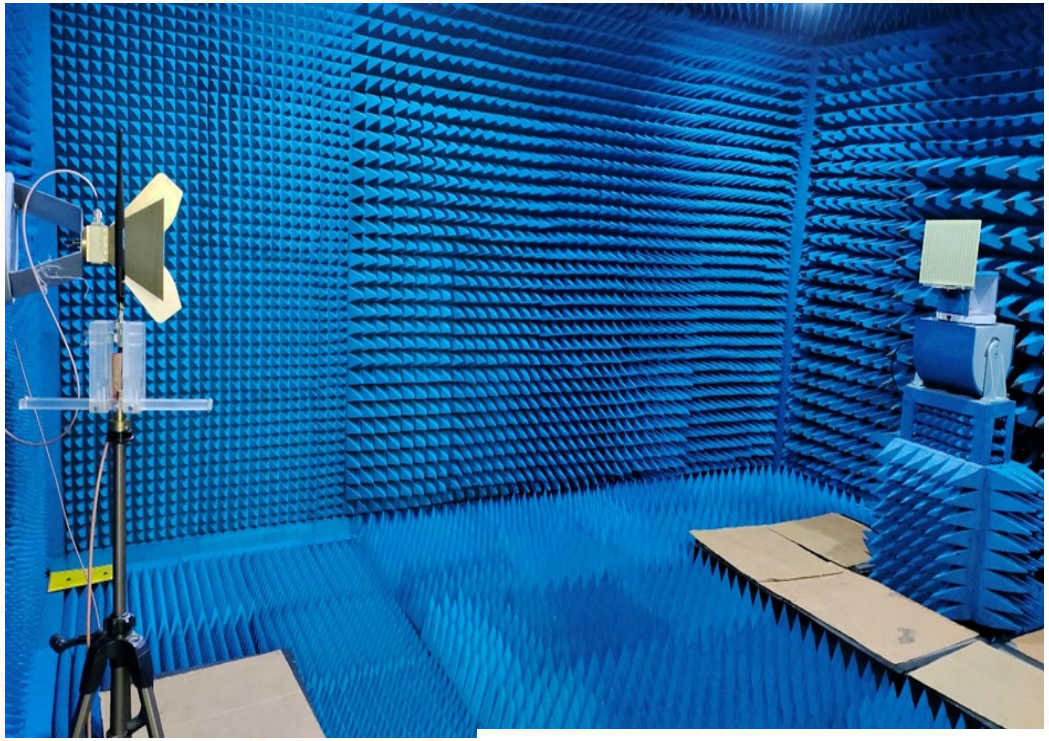
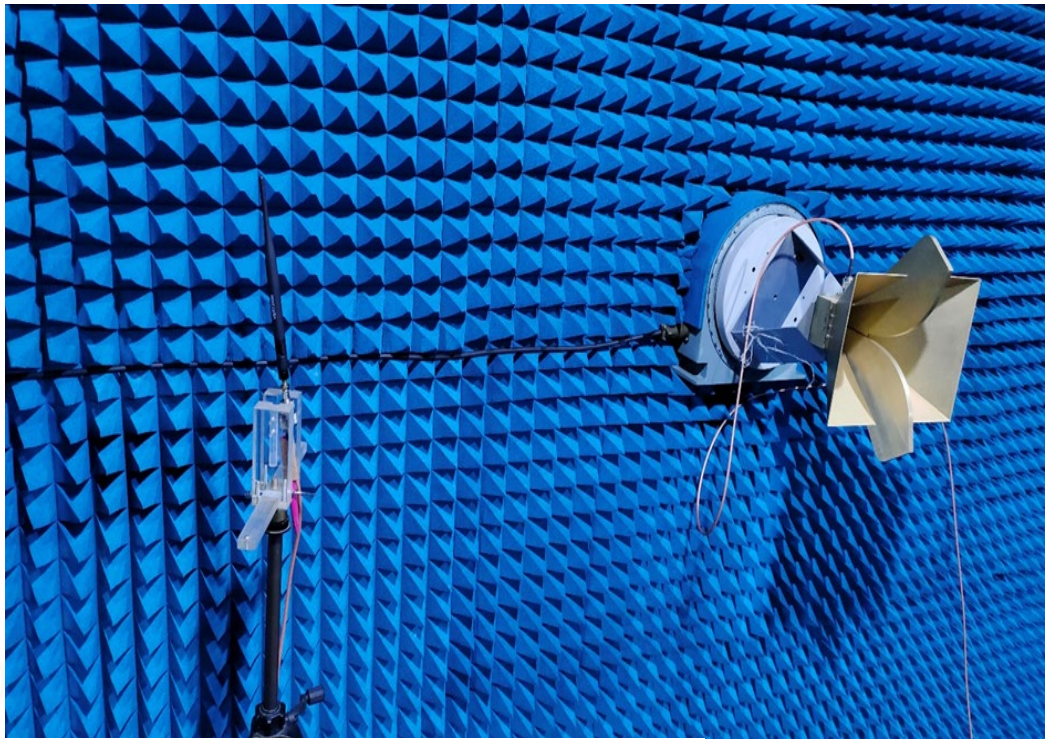


Fig. 4: Message flow sequence between GRC, RSC and RIS.





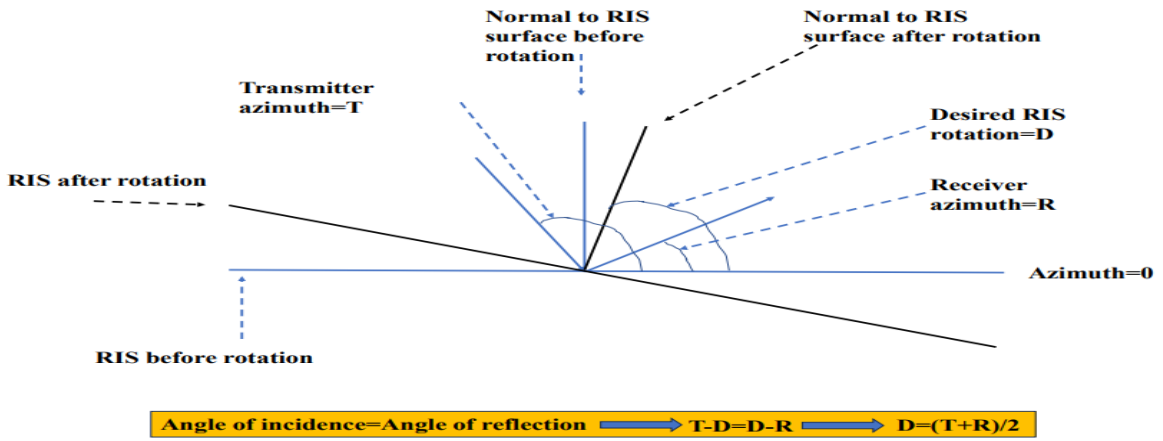


Fig. 6: Rotation of RIS required for beamforming at the desired location.

How to use these interfaces?

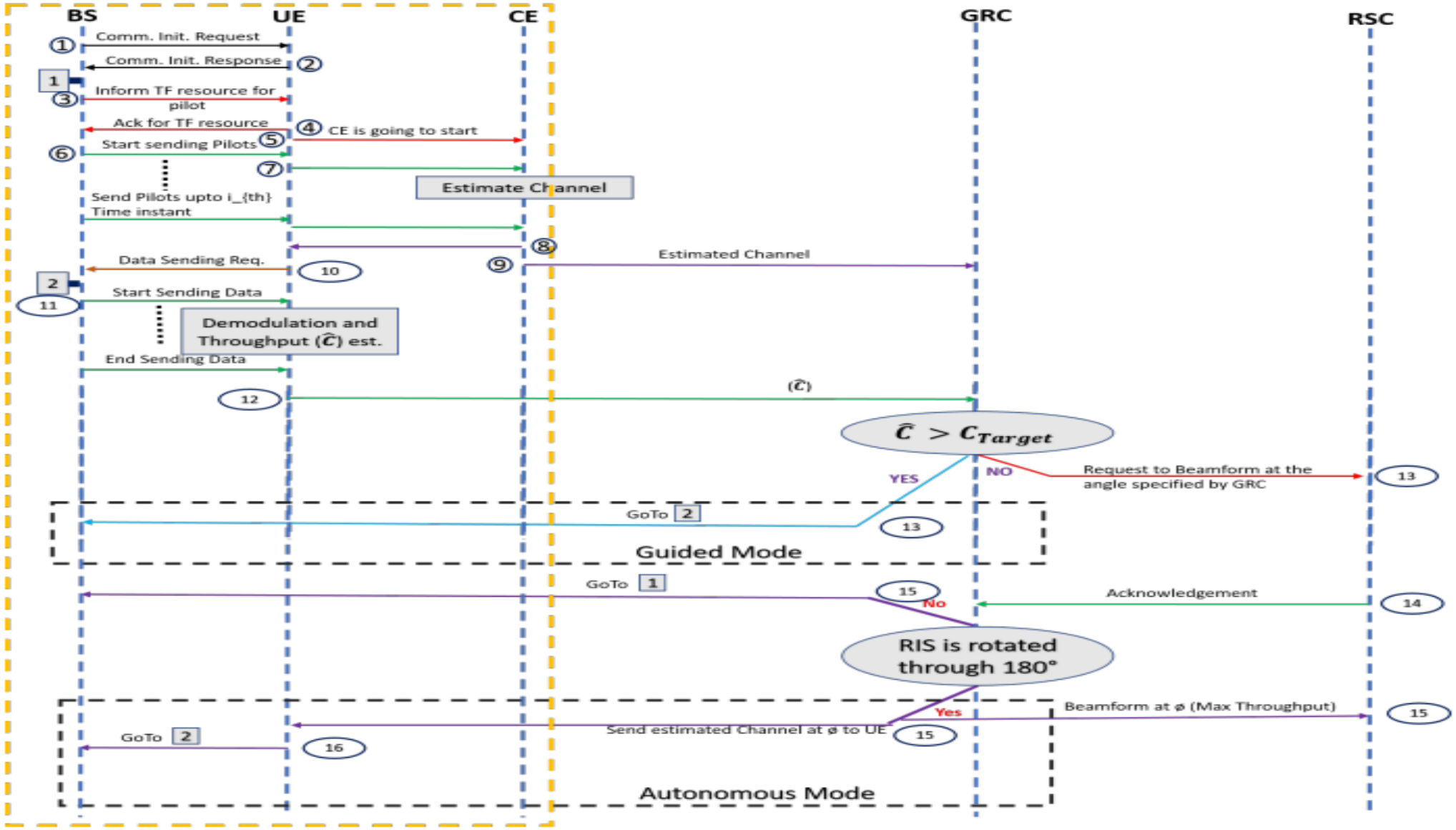


Fig. 3: Message flow between CE and GRC.

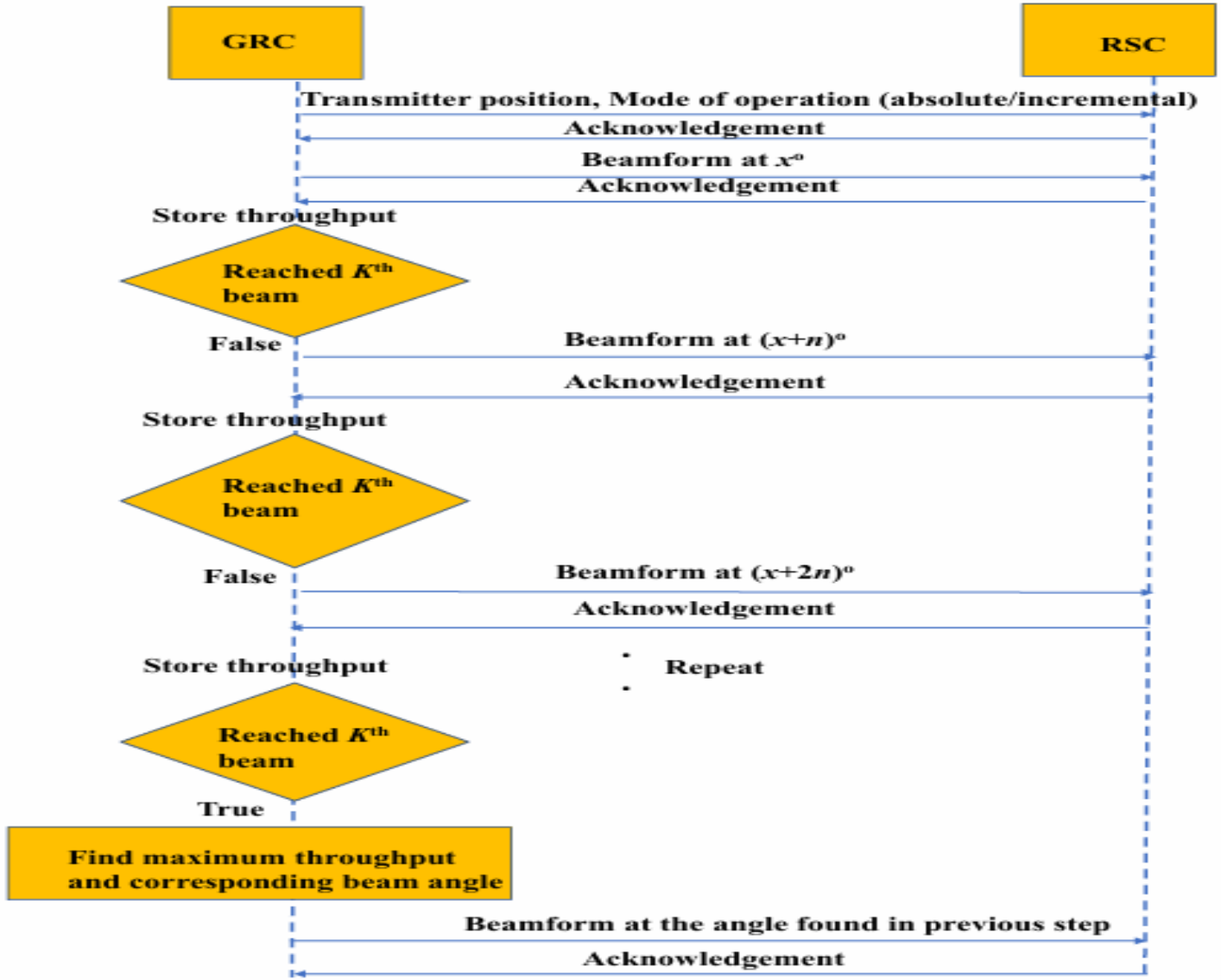


Fig. 5: GRC algorithm to find maximum power and corr sponding beamforming angle.

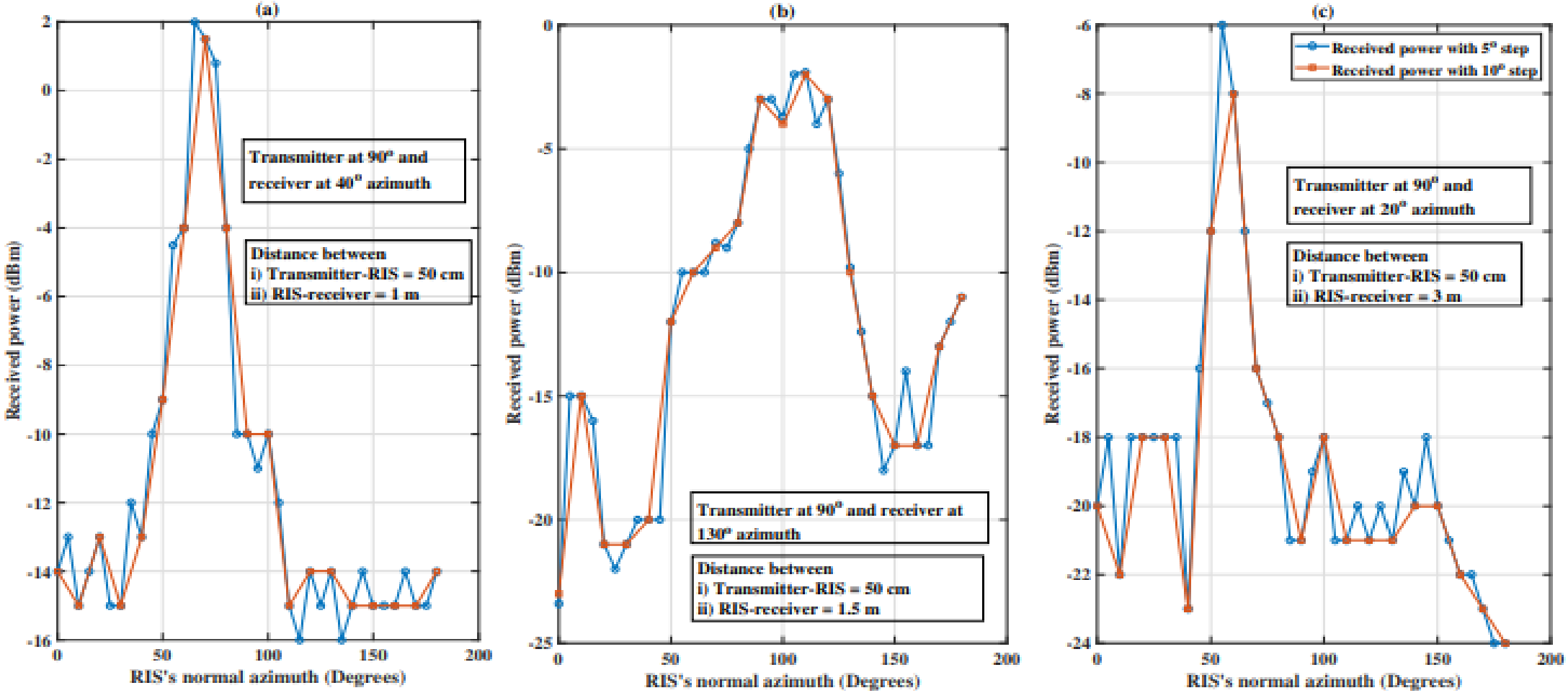


Fig. 7: Received power variation versus RIS's normal azimuth varying at 5° and 10° stepsize with transmitter at 90° azimuth and receiver at (a) 40° azimuth (b) 130° azimuth (c) 20° azimuth.

TSDSI STD 5003 V1.0.0

Great support from TSDSI members and Secretariat.

Also covers RIS with Localized Control Unit (tighter integration between BS and RIS)

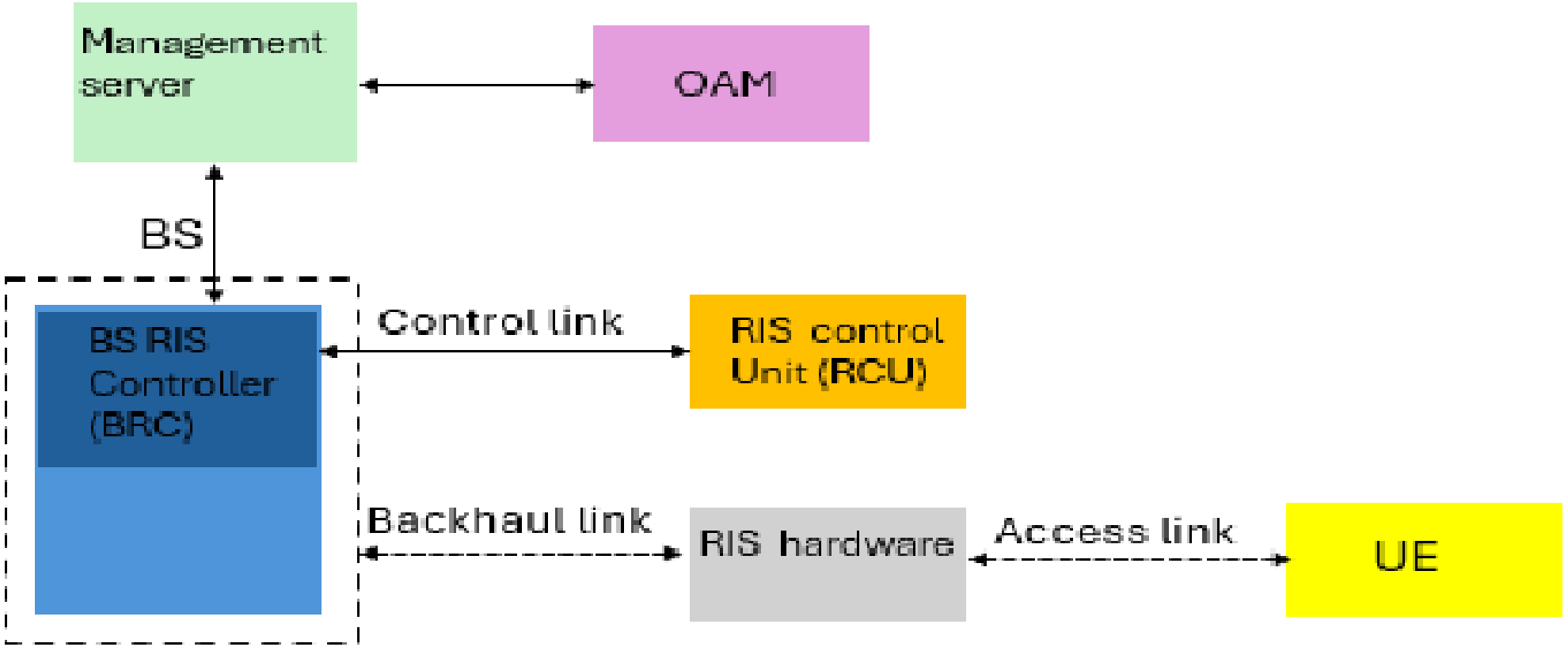


Figure 3 Architecture of RIS with localized control unit

ETSI:

- Three whitepapers published by RIS ISG.
- Ongoing activities on
  - System/link performance, spectrum, co-existence, and security.
  - Technological challenges in terms of deploying RIS as a new network node.
  - impacts to network architecture, protocol architecture, and framework of RIS controlling
  - requirements and potential impact to specifications to support RIS

RISTech Alliance(RISTA):

- Whitepaper available

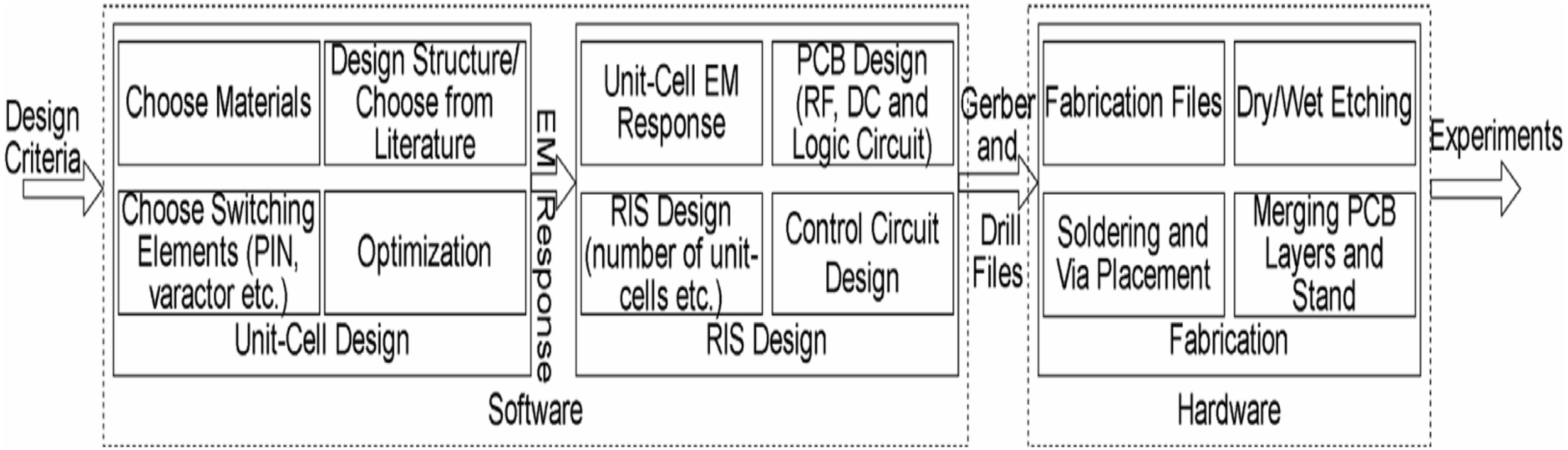
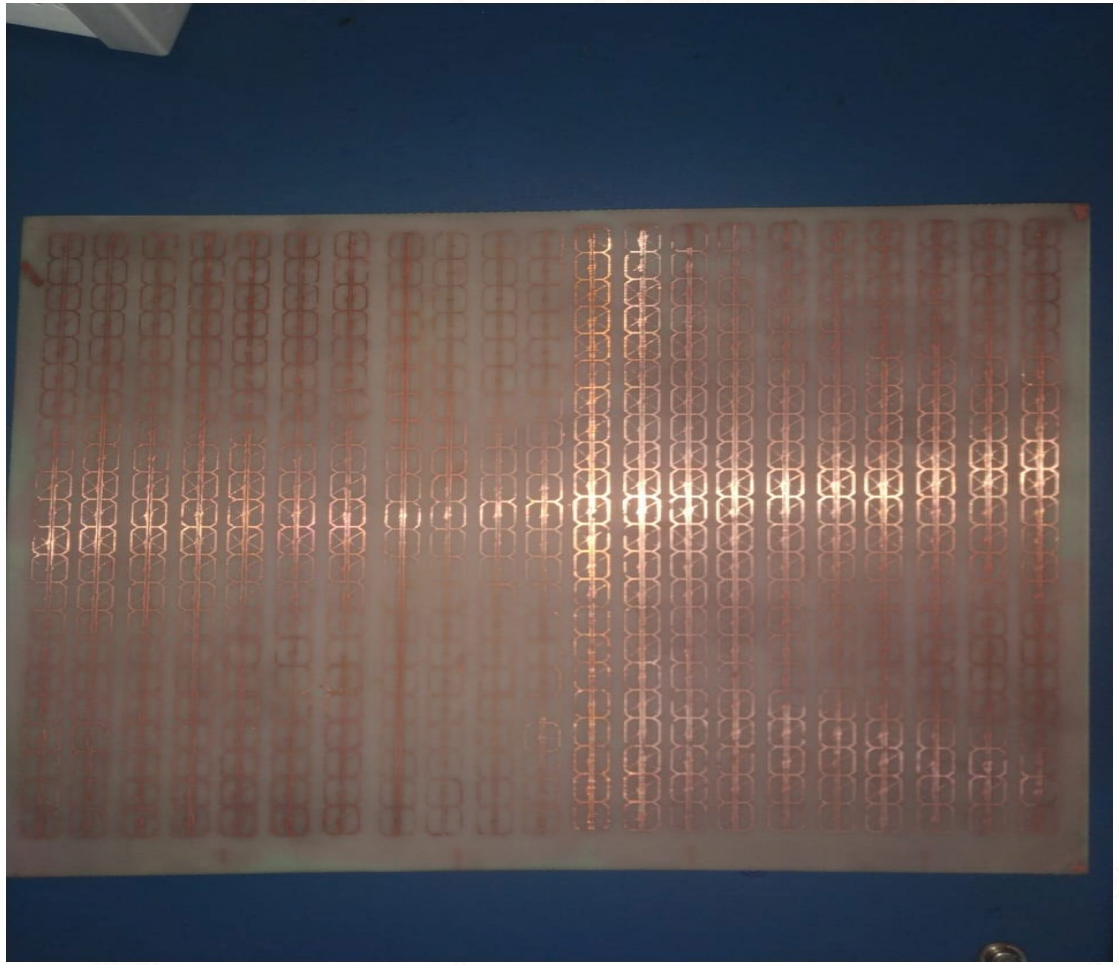


Fig. 1: Design to Fabrication, complete workflow summary.

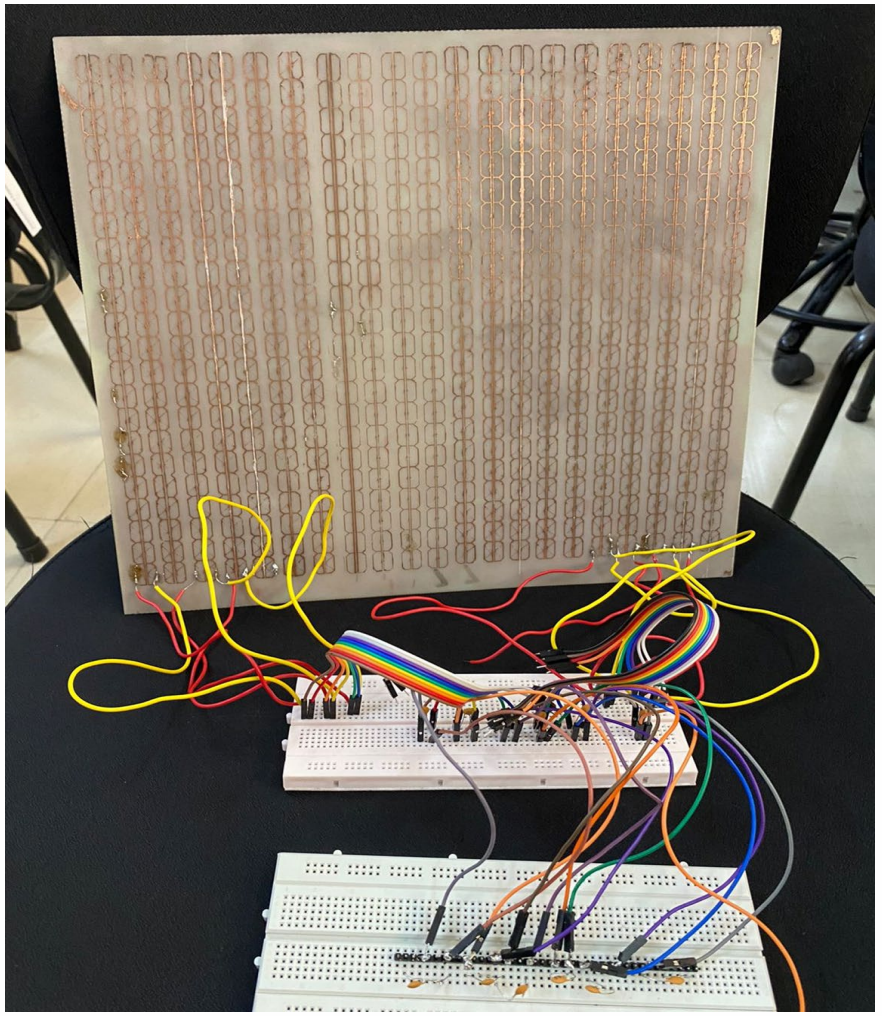
Source: A Guide for RIS Fabrication for Quick Prototyping in Lab Settings Using Low Cost Fabrication Techniques

Passive RIS Fabricated



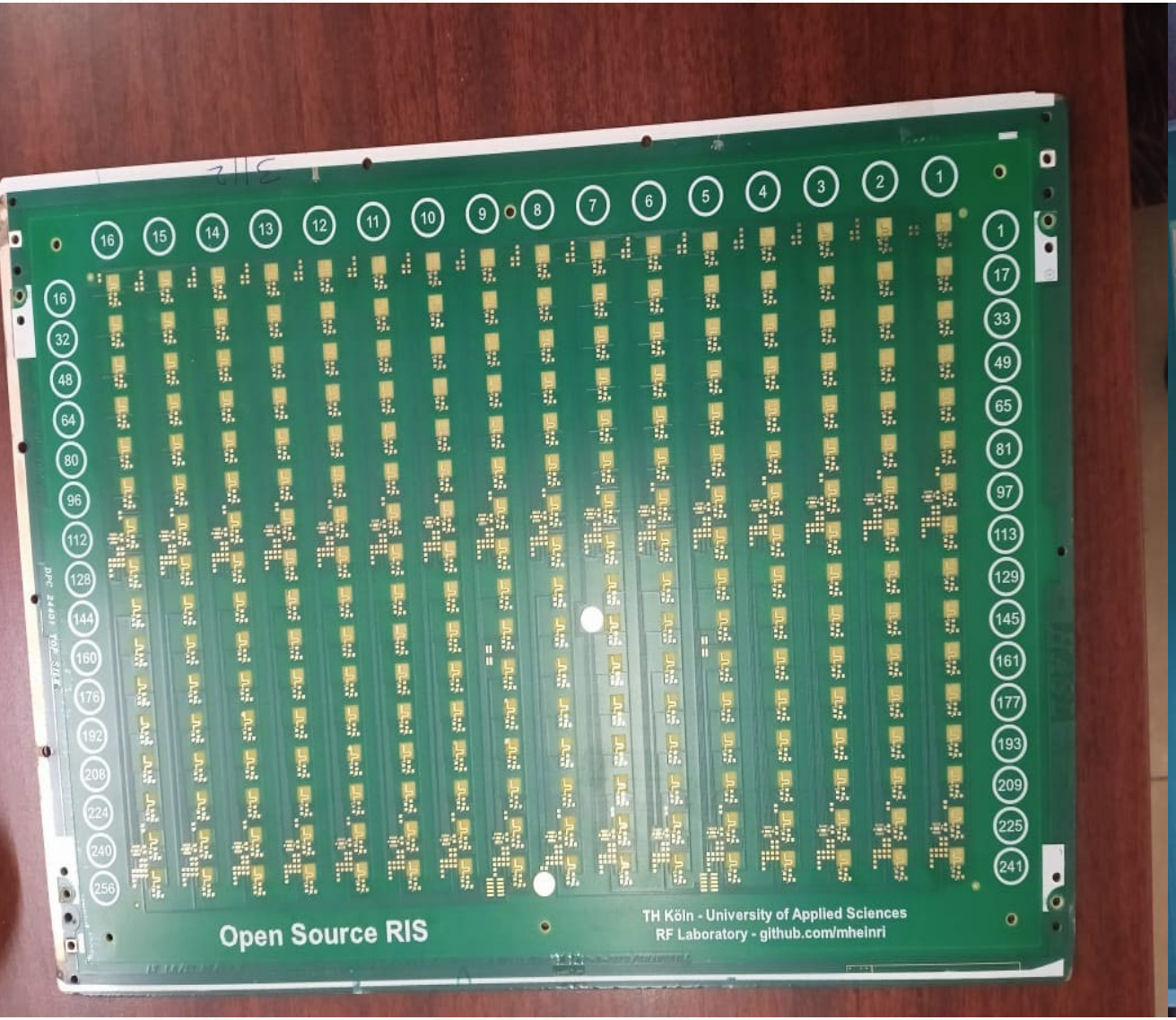
Fabricated RIS

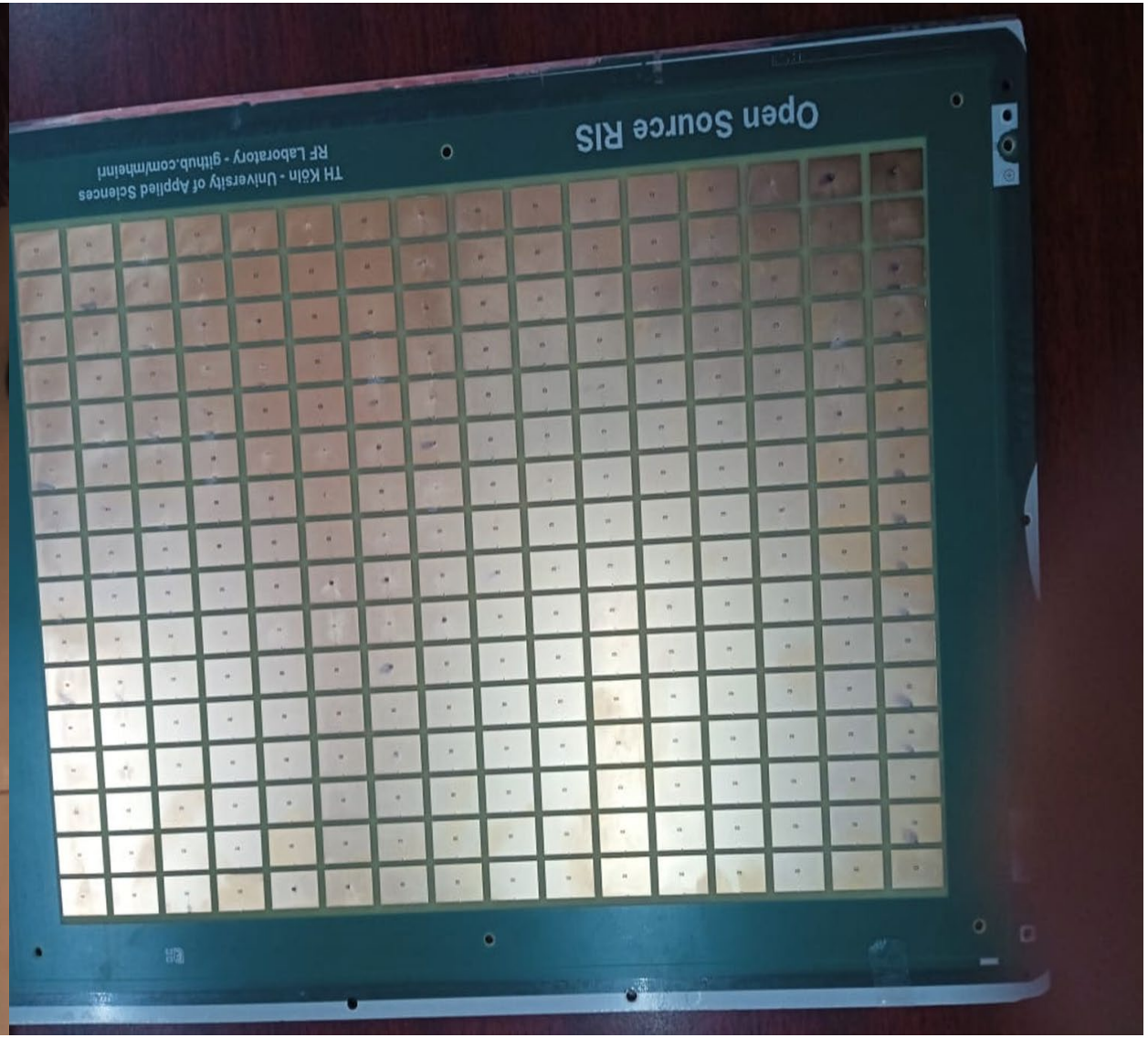
Based on University of Surrey design.
https://openresearch.surrey.ac.uk/esploro/outputs/99623165302346?skipUsageReporting=true



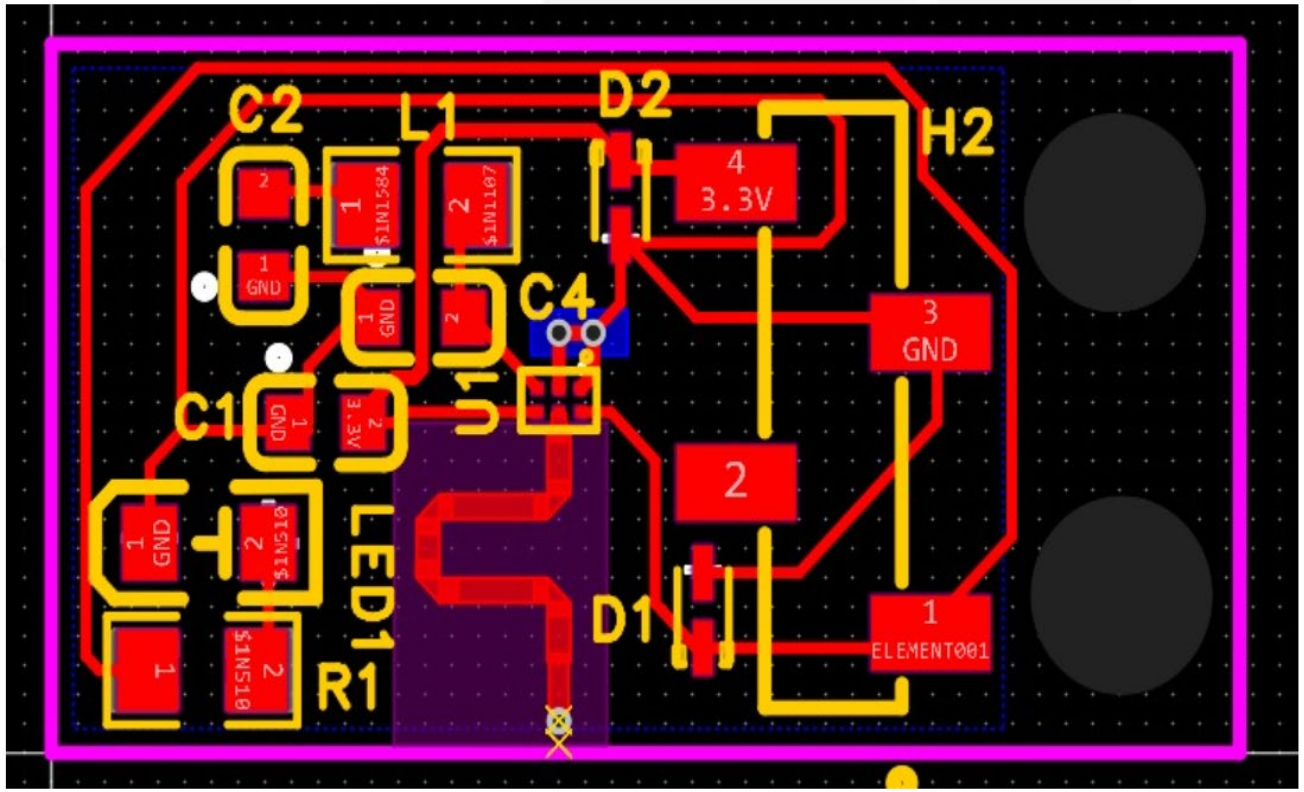
RIS with parallel capacitive setup (manual switching, to mimic varactor diodes)

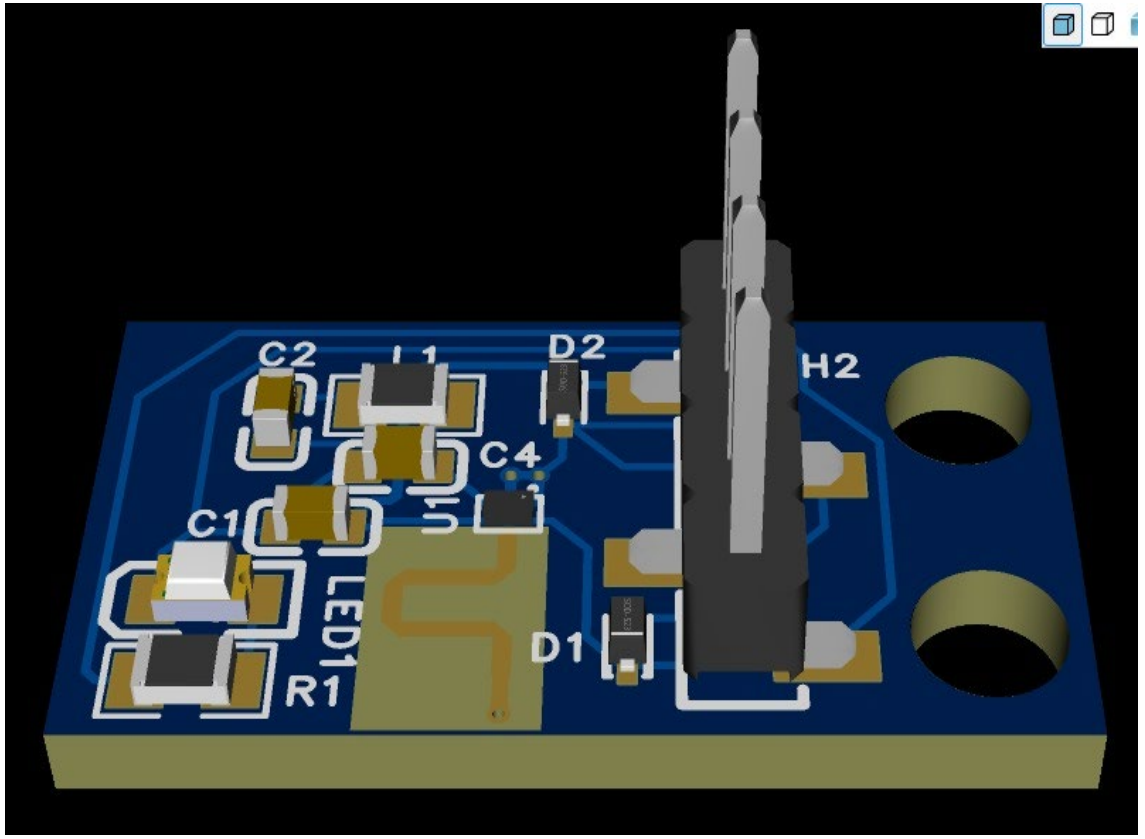
Active RIS Fabricated and Control Circuitry Designed





Designing individual elements (for flexibility)





Designator	Device
U1	BGS12PL6E6327XTSA1_C2939943 **(18-20 Rs)**
LED1	17-21SURC/S530-A3/4T **(2.5 Rs)**
R1/L1	RC0805JR-071KL **(8 Rs.)**
D1/D2	ESD5Z3V3_C502545 **(5 Rs)**
C1/C2/C4	CC0603KRX7R7BB104 **(1.5 rs)**

Extensions that we are working on

1. Static behaviour of RIS elements with random deployment
2. ISAC-capable RIS Element Design (patent process ongoing)
3. …

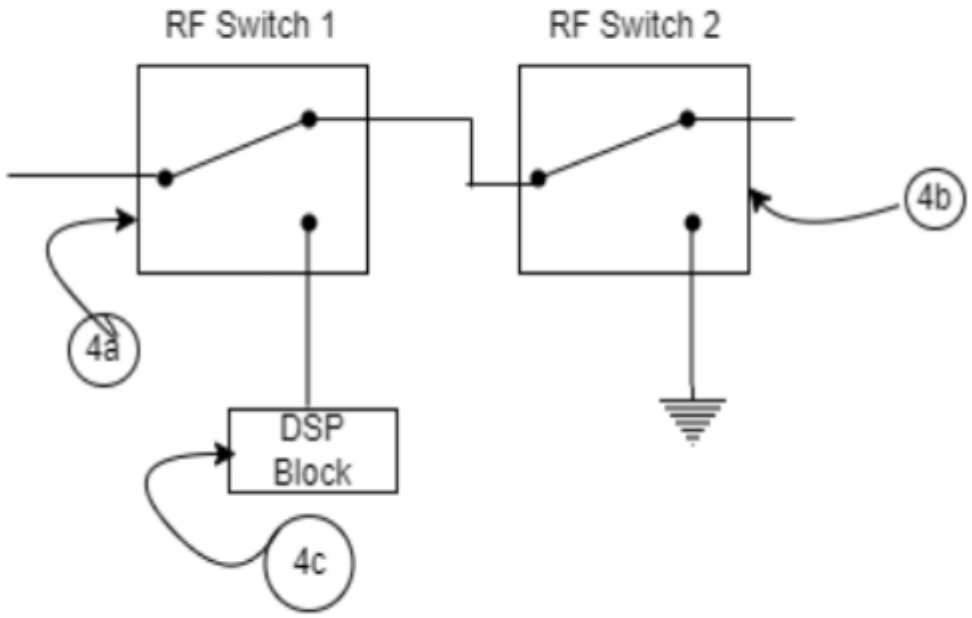


Figure 3: Switching element schematic

Thank You

arzad.alam@iitbhilai.ac.in