

5G Testbed at IISc



सत्यमेव जयते

Department of Telecommunications
Ministry of Communications
Government of India

Chandra R. Murthy
Professor, ECE Department, IISc Bangalore

<http://ece.iisc.ac.in/~5G-Testbed/>

IISc's 5G Vision

▶ Goals/Mission:

- ▶ Build expertise in the area
- ▶ Develop niche competency
- ▶ Make key contributions
- ▶ Impact standards development and 5G use case scenarios
- ▶ Create IP, engage with startups
- ▶ Educational activities: workshops, industry outreach, etc

Vision

Gbps for everyone, get a bps from everything, in real-time



Key solution areas

- ▶ Massive MIMO (sub 6 GHz)
- ▶ mmWave (~28 GHz)
- ▶ V2X
- ▶ VLC
- ▶ System level simulation
- ▶ IoT
- ▶ Tactile internet
- ▶ Drone/UAVs

5G testbed project



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Other parallel efforts

National 5G Testbed: Responsibility chart

Subsystems	IITB	IITH	IITM	IISc	IITK	CEWiT	SAMEER	IITD
Radio Front End subsystem <6 GHz		X	X			X	X	
Radio Front End subsystem >6 GHz		X	X			X	X	X
Massive MIMO		X	X	X		X		X
Base band subsystems		X	X	X		X		X
Relays					X			
Cognitive Radio								X
Unlicensed (WiFi)	X							
High-speed Serial Links			X					
L2/L3 subsystems		X				X		
CloudRAN		X				X		
Edge Computing & SDN		X						X
Core Network & SDN	X	X	X					
Devices		X	X			X		
IoT		X				X		X
IMS & Service layer								
Security								X
LiFi				X				X
V2X				X				



5G Testbed at IISc: People

Faculty



Staff

- Principal/Senior Engineers:

- Alok Gupta
- Ganesan Thiagarajan
- Sudhakar B.
- S. V. R. Anand

- Engineers:

- Syed Sadaf
- Srushti Patil
- Ashish Meshram
- Rahul Gottipatti
- Vinay Chowdappa
- Keertipriya Sathish
- Pratik Sharma
- Amol Bhindwale
- Ishan Darwhekar
- More (not here)

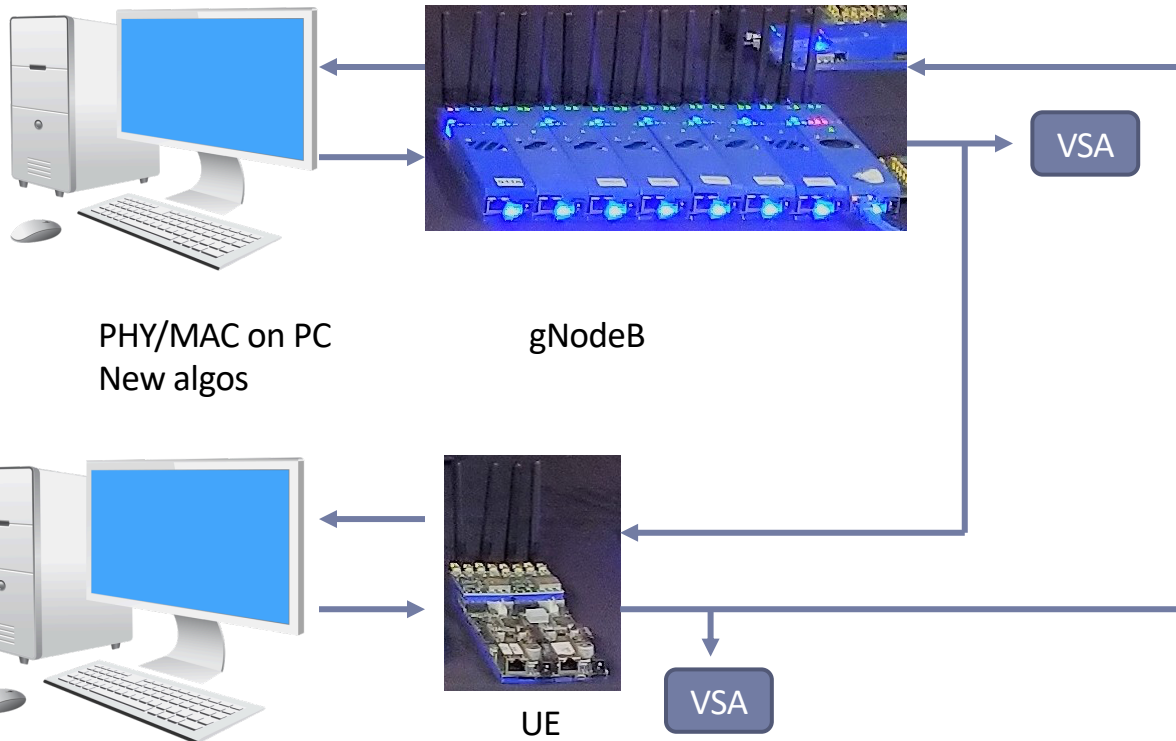
- Pratik Sharma
- Faheem Ahmed

Students:

- Sai Thoota
- Vineeth Kumar
- Rama Kiran
- Sarvendranath R.
- More (not here)

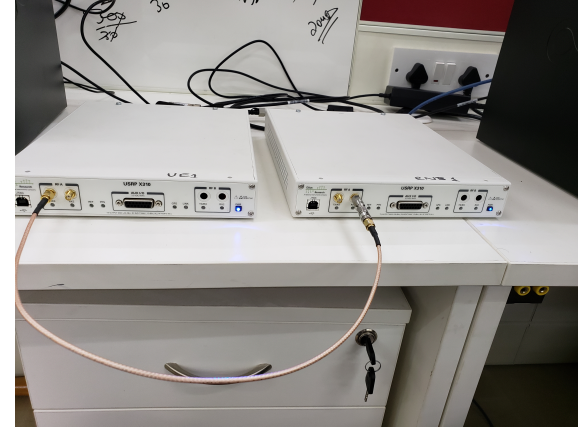
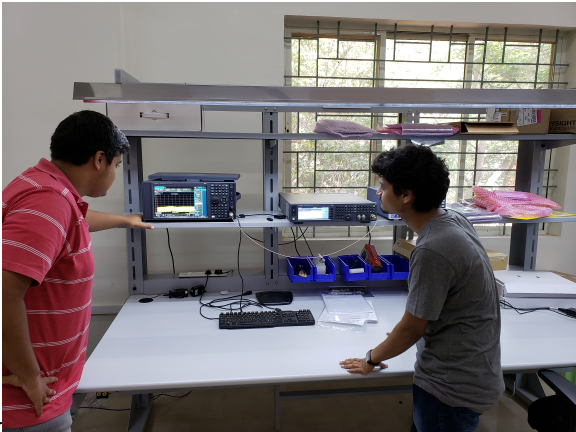
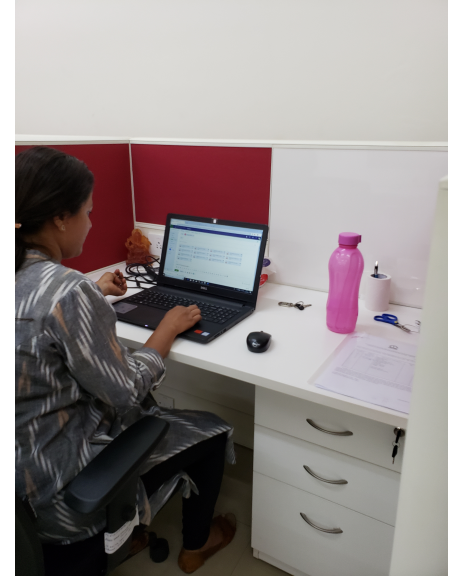
Administrative Assistant: Rajani B.

Ver 1: Dec. 2019



- Link testing in lab environment
- 80 MHz BW
- Separate testbeds for high BW and large MIMO demos

In Pictures – 5G Lab



Current Status of Sub 6 GHz

- ▶ DL PHY channels implemented & verified on hw
 - ▶ 80 MHz BW
 - ▶ Test equipment based validation done
- ▶ UL PHY channels: OAI code **incomplete**
 - ▶ Working with them to implement the channels
- ▶ Link level simulator
 - ▶ 5G NR OAI code (gNB and UE RAN implementation)
 - ▶ Demo: [Link](#)
- ▶ Index modulation demo: [Link](#)
 - ▶ Skylark boards: auto-synchronized when daisy chained

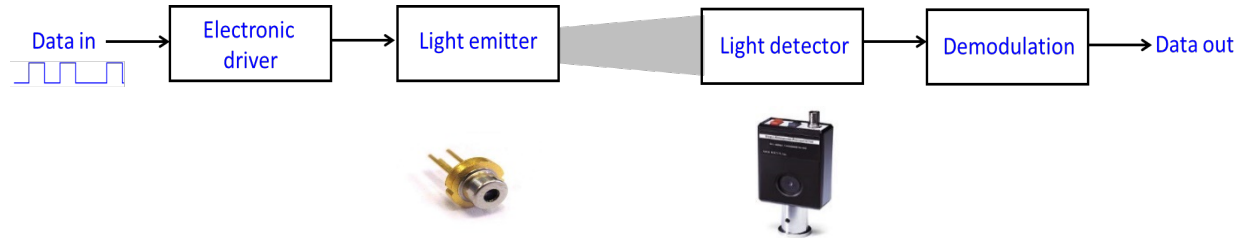
Current Status of Sub 6 GHz

- ▶ LTE end-to-end link demo: [Link](#)
 - ▶ USRP B210
 - ▶ 10 Mbps over 5 MHz BW
- ▶ 5G NR downlink demo: [Link](#)
 - ▶ gNB tx @ 40MHz and UE operating @ 40MHz, USRP x310
 - ▶ PBCH, PDCCH and PDSCH
 - ▶ Can view LLR, constellation, and CIR in the PHY-scope

IISc VLC Project: Implementation Plans

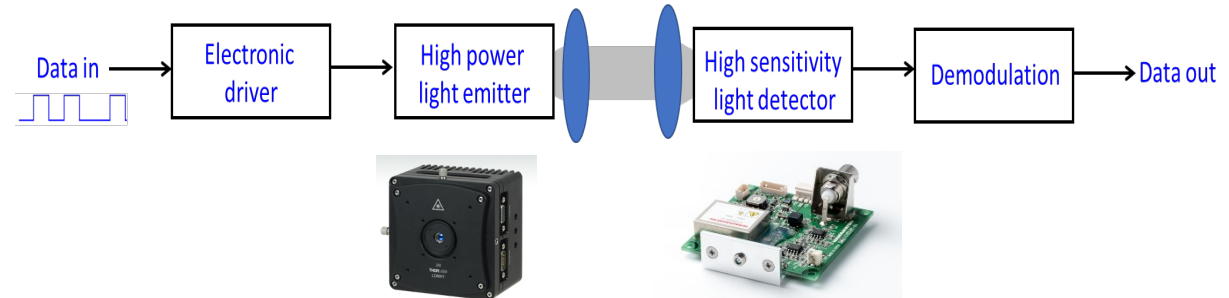
Version 0 (03-2019):

Blue laser diode with remote phosphor (Phos.)
40 Mbps, On-off keying
100-200 Lux, 100-200 cm



Version 1 (12-2019):

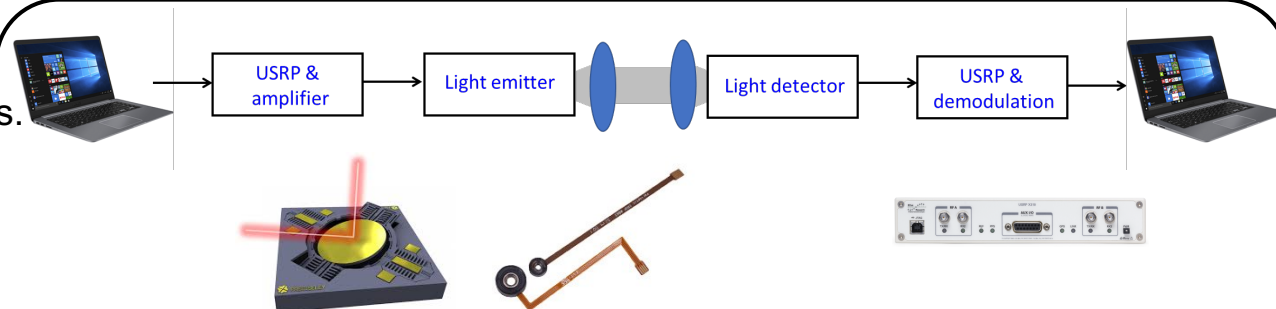
Blue laser diode with Phos.
100 Mbps,
On-off keying/ QAM
> 200 Lux, 100-200 cm



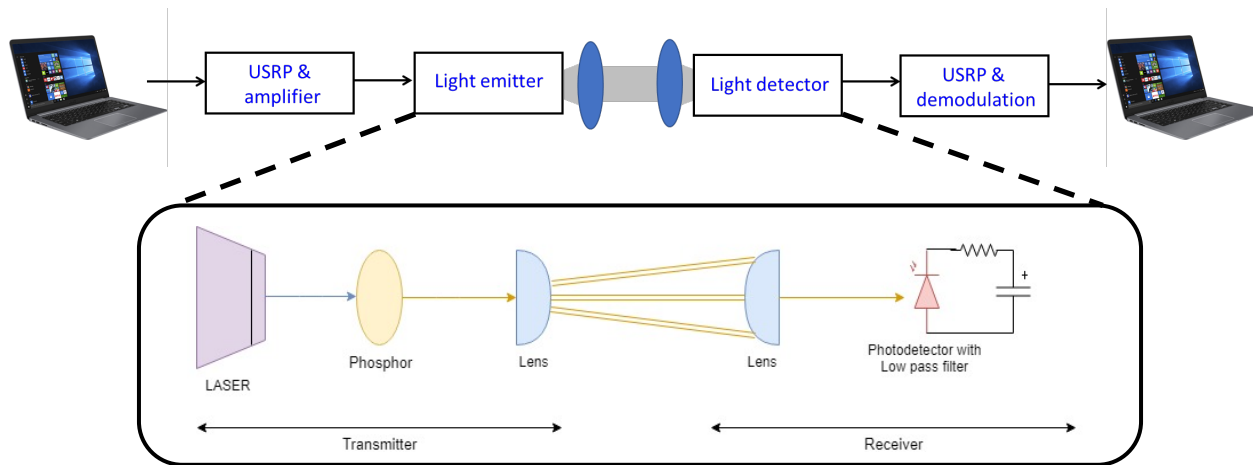
Version 2-3

(06-2020 / 03-2021):

Blue laser diodes with Phos.
300-1000 Mbps,
M-QAM OFDM
400 Lux, 200 cm
Beam steering/ focusing
USRP based smart-light
prototype

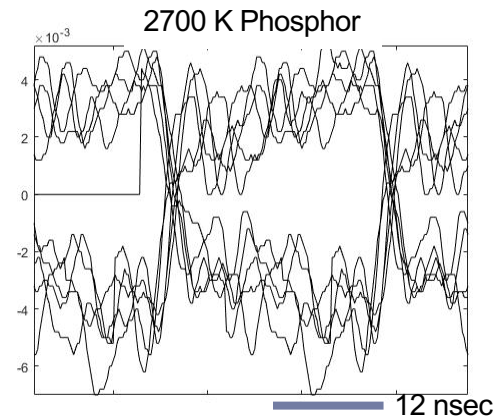
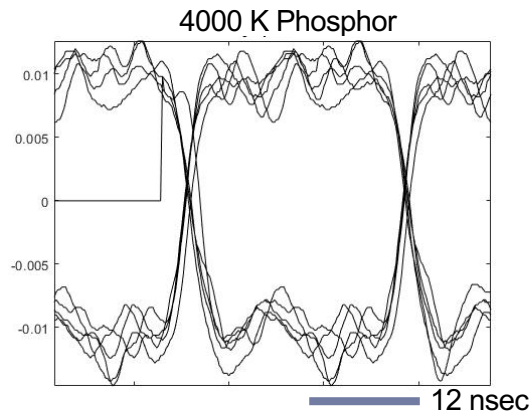
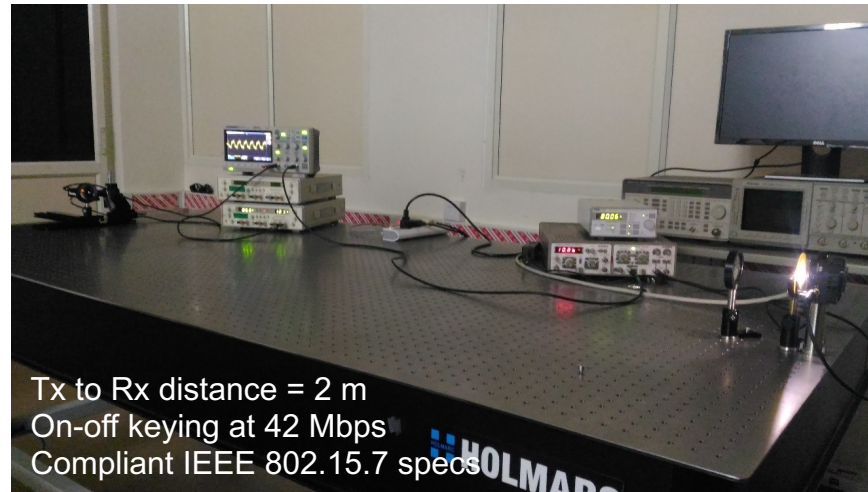


Block diagram of laser based VLC



- ▶ VLC system comprising of USRP hardware with built-in FPGA for data processing
- ▶ Use case: Smart light-pole for seamless transfer from wireless to VLC
- ▶ Direct modulated light source and intensity detected with silicon detectors

Communication link demonstration



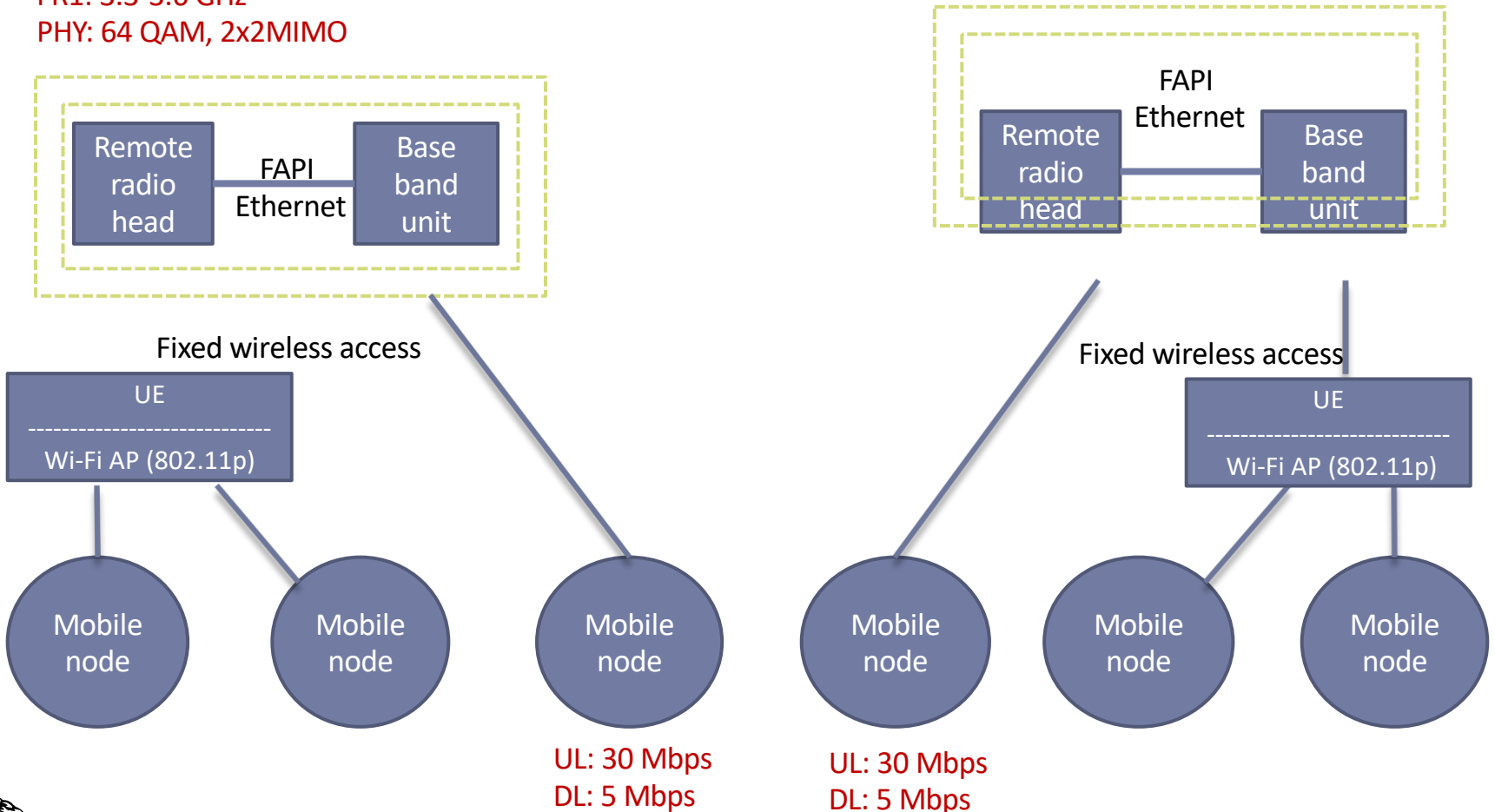
F. Ahmad et. al. "Laser-based indoor VLC systems: Comparison of different remote phosphors," Photonics 2018, Delhi

Ongoing Work

- ▶ Experimental characterization of optoelectronic devices, modulation of VLC system.
- ▶ VLC system performance characterization, performance improvement
- ▶ USRP integration with VLC, single Tx-Rx, targeted data rate: 100 Mbps, QPSK/ M-QAM modulations. Breadboard demo.
- ▶ Identify use cases relevant in 5G context
- ▶ Demonstration of data streaming from Tx to Rx: [Link](#)

V2X Testbed

UL: 300 Mbps, DL: 50 Mbps (10 UEs/ BS)
Roundtrip latency: 10 ms, Coverage: 1 Km/BS
FR1: 3.3-3.6 GHz
PHY: 64 QAM, 2x2MIMO



Setup for the WiFi Experiment

Goal: Remote driving using video feedback over WiFi

WiFi Setup

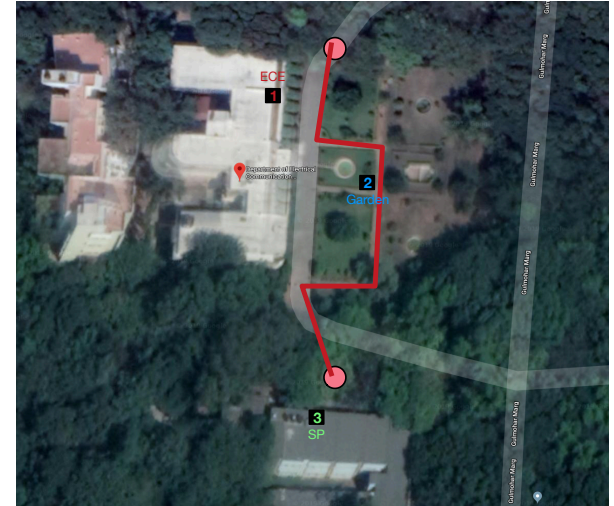
- Station running Raspbian
- APs running OpenWRT

UGV Platforms

- UGV controlled over PIXHAWK
- PIXHAWK interfaced with R-Pi
- Handover is a major source of latency in WiFi
- Video stream has high-delays during handover

Our Approach

Preemptively do handover based on location estimation

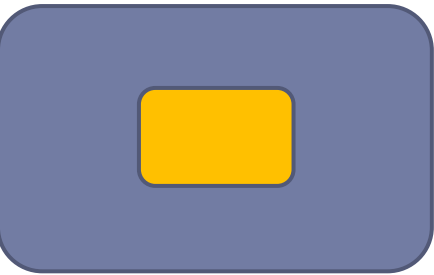


What next in V2X?

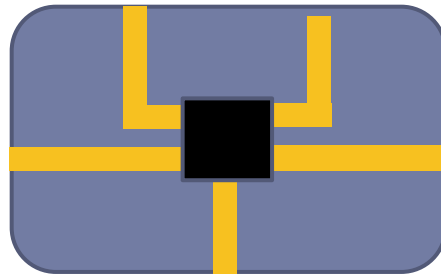
- Deploy a multimodal network across campus with WiFi (11n, 11r, 11p) and LTE coverage
 - UAV intrusion detection demo: [Link](#)
- Do a thorough latency profiling of the network and identify the main bottlenecks
- Experimental setup for remote driving using video feedback and autonomous control over the network
- *Develop appropriate PCRF, RRM, Scheduler modifications to admit profiles for low-latency control*



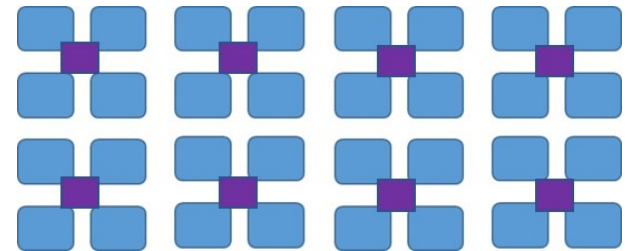
mmWave Testbed



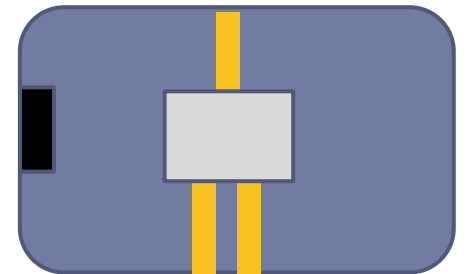
28GHz Patch Antenna Elements: Design, fabrication & Characterization



Feed Circuit using Anokiwave AWMF 0108/0158 for Beam Steering Board
Design, fabrication, characterization



28GHz Patch Antenna Array
Design, fabrication & Characterization
Integrated with beam steering circuits



Up-/Down converters: Design, fabrication, characterization

Plans for 2019

Antenna Design

- ▶ Both 26/28GHz
 - ▶ Fabrication, preliminary testing of small array
 - ▶ Control algorithms development, tests for beam steering: current work
- ▶ New Studies on Antenna element
 - ▶ Bandwidth enhancement of antenna element to cover different international standards
 - ▶ Feed schemes to beat multilayering constraints
 - ▶ Modified element design developed and fabricated
 - ▶ Slot antenna, modified patch, SIW feed scheme or other modifications

System Level Studies

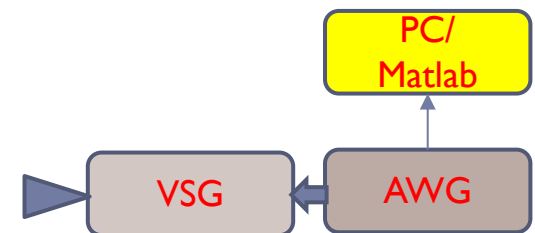
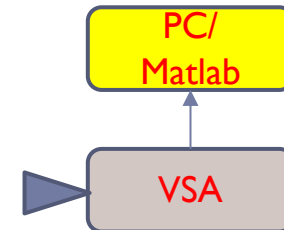
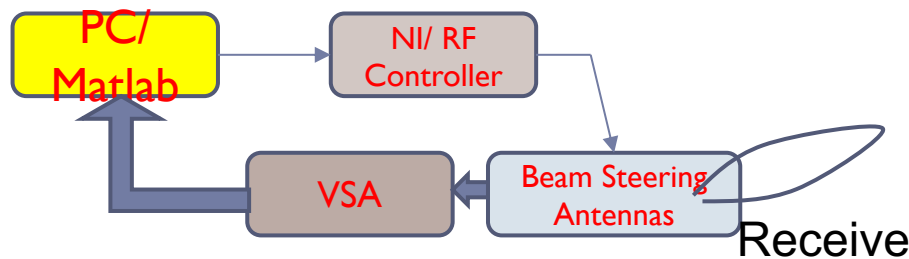
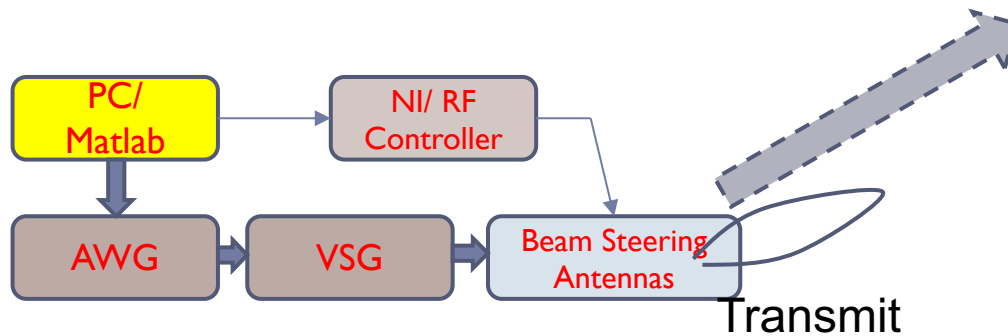
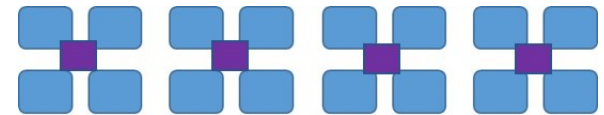
- ▶ Anokiwave IC based system simulations done
- ▶ Concept design & verification simulations of full array done
- ▶ Up/down converter (using CW input): Ongoing
- ▶ Moderate array (eg **16x4**) at 28GHz: Design, fabrication & testing by Dec. 2019



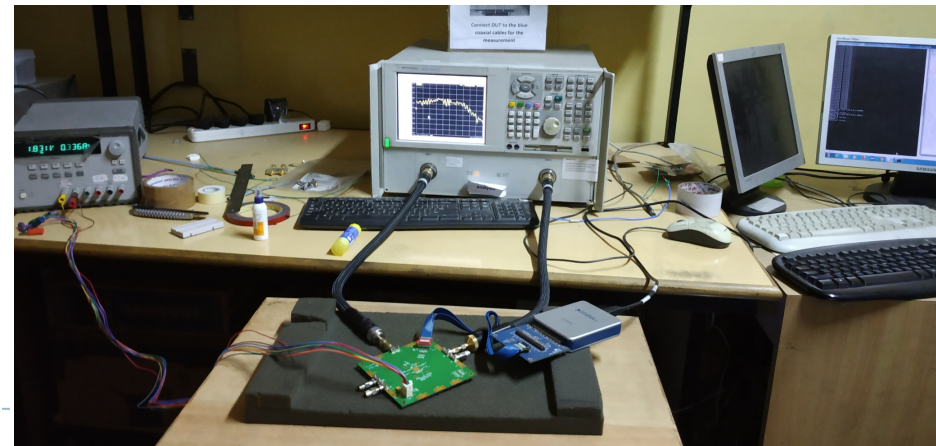
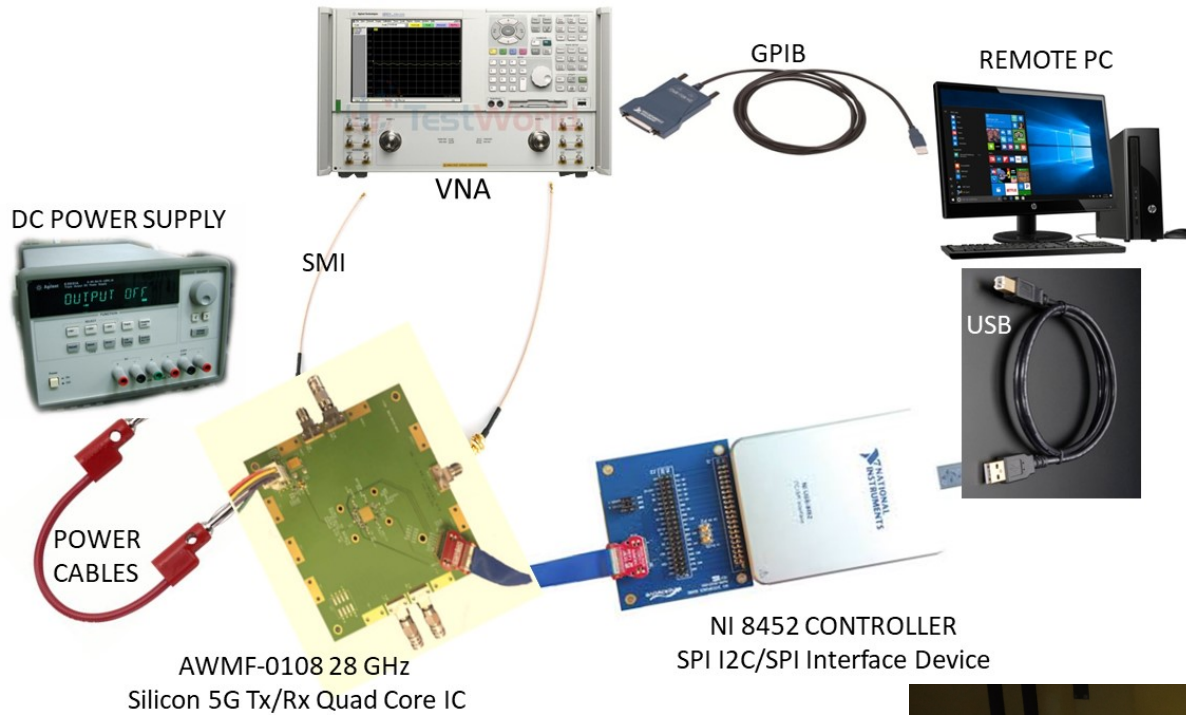
Ver 1: Small Arrays

- ▶ Sub array design 8 element (4x2) array

Dec 2019



Evaluation of Anokiwave ICs



Evaluation of Anokiwave ICs

- ▶ **Established capability to automate measurements**
 - ▶ Shows some non-linearity in phase (within specified limits)
 - ▶ Alternate phase jumps are 7° and 14° (instead of 11.25° uniform)
 - ▶ Shows some variation in amplitude when phase is varied (and vice versa)
- ▶ **Evaluated statistics of variations**
 - ▶ absolute max error, RMS error etc (between intended ampl/phase to realized)
- ▶ **2 x 2 mmWave antenna design demo: [Link](#)**





Other 5G R&D at IISc



IoT, mmWave VLSI

▶ IoT and LPWAN

- ▶ Interference management from massive number of devices
- ▶ Access techniques to enable long sleep cycles
- ▶ Seamless switching between guaranteed time-slot and random access
- ▶ Algorithms for large-scale deployment
- ▶ Tactile CPS: extremely low latency control & feedback

▶ mmWave VLSI

- ▶ Design key RF blocks such as LNA, PA, synthesizer
- ▶ Explore advanced techniques including phased arrays and dual band RF transceiver design



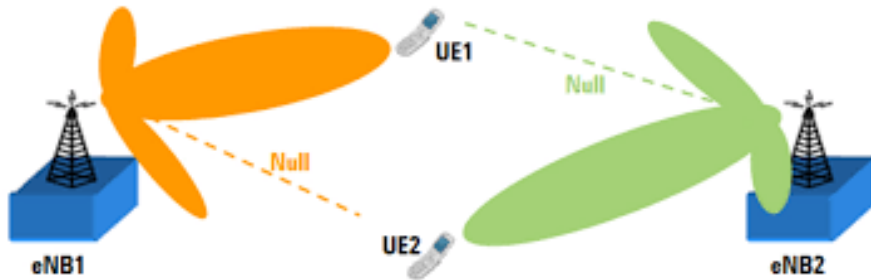
Edge Computing, massive MIMO, etc

- ▶ **Edge computing**
 - ▶ Coded caching, coded computation, streaming codes
- ▶ **Massive MIMO algorithms & baseband platforms**
 - ▶ Beamforming, beam selection and tracking
 - ▶ Frame structure: design and optimization
 - ▶ Channel measurements and characterization
 - ▶ AI/ML for wireless
- ▶ **System-level simulation**
 - ▶ Ability to simulate large-scale 5G networks
 - ▶ Hardware-in-the-loop co-simulation
 - ▶ Feeds into the IMT-2020 evaluation
- ▶ **Greater participation in 3GPP standardization meetings**

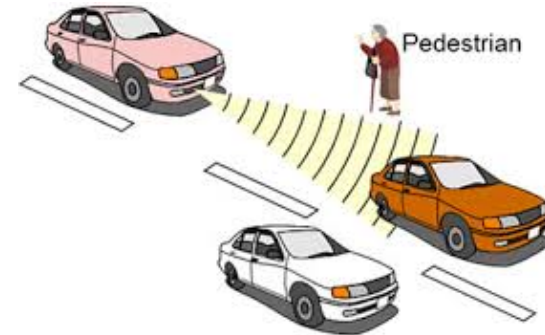


Other 5G Research Areas

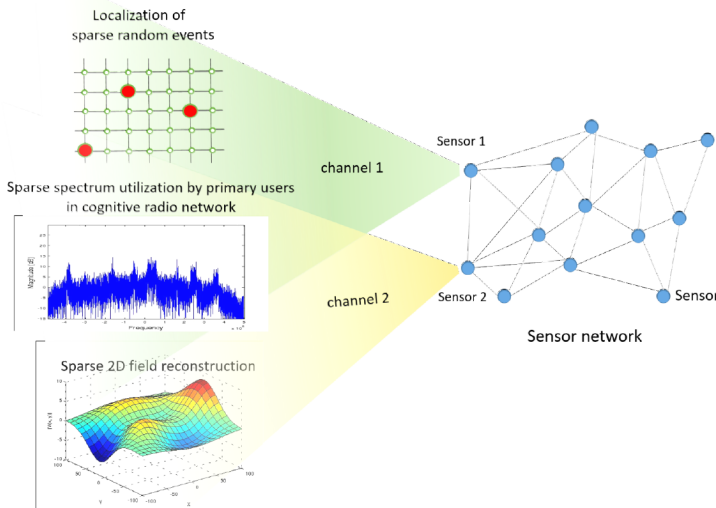
Multi-user beamforming for interference alignment



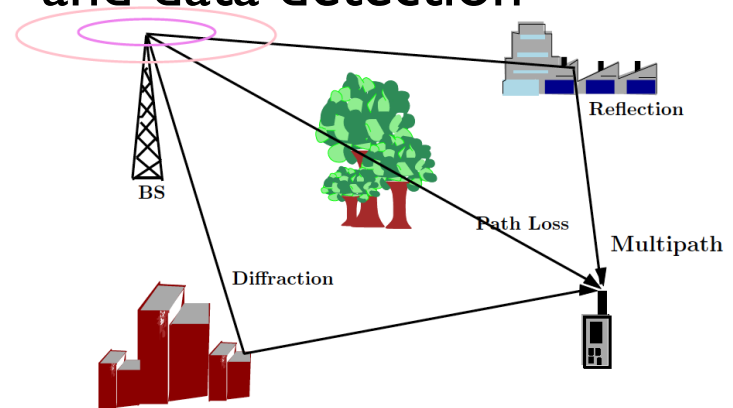
Self-driving cars



Sensor networks Energy harvesting communications



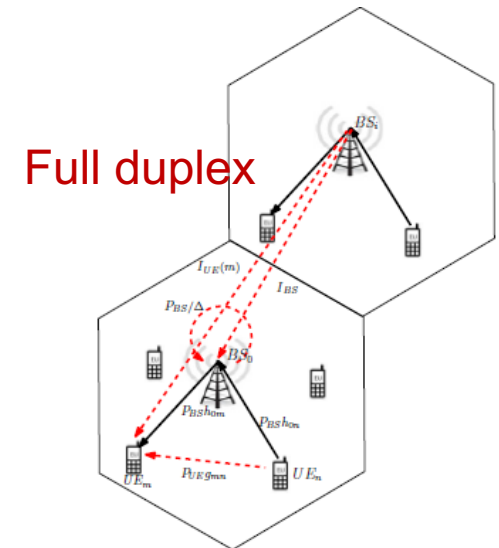
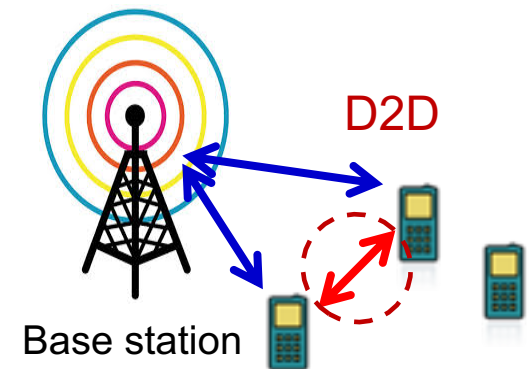
Sparse channel estimation and data detection



Summary: Gbps for everyone, g-bps from everything

▶ 5G focus areas

- ▶ Millimeter wave communications
 - ▶ Beamforming & switching, new modulation techniques
- ▶ Massive MIMO
 - ▶ D2D, full duplex, relaying
- ▶ V2X
 - ▶ Routing and scheduling for low latency
- ▶ VLC
 - ▶ Very high data rate, short range links
- ▶ Actively involve in Indian 5G ecosystem
 - ▶ IMT-2020 evaluation
 - ▶ TSDSI meetings
 - ▶ Startups, industry
 - ▶ Education, outreach



<http://ece.iisc.ac.in/~5G-Testbed/>

Thank You

