Preparing RLAN (Wi-Fi 6/7) 6 GHz for Indonesia:
Potential Outdoor Usage and AI for Coexistence with FS, FSS, and 5G

Assoc. Prof. Dr. Eng. Khoirul Anwar, ST., M.Eng.[1,2,3]

[1]Director, The University Center of Excellence for Advanced Intelligent Communications (AICOMS), Telkom University, Bandung, Indonesia
[2]Chairman of Technical and Education Activities (TEA), Senior Member IEEE Indonesia Section, 2020, 2021, 2025
[3]Research Collaboration of Quantum Technology (PKR Kuantum 2.0)
[4]Beyond 5.5G Laboratory
E-mail: *anwarkhoirul@telkomuniversity.ac.id*

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PUIPT AICOMS 2016-2025

- AICOMS (formerly AdWiTech) established in September 2016 and received funding from national and international funding bodies.

2016

Established since Sept. 2016

2017

RP700M

- EPSRC UK
- Ristekdikti
- Internal

2018

RP2.5B

- LPDP Rispro
- Ristekdikti
- Insinas

2019

RP2.5B

- LPDP Rispro
- Ristekdikti
- Insinas

2020

RP4B

- ASEAN IVO
- LPDP Rispro
- Ristekdikti
- PUI-PT
- Kemendikbud

2021

RP4B

- ASEAN IVO
- LPDP Rispro
- Kominfo
- PUI-PT
- Kemendikbud
- BRIN

2022

RP5.4B+

- ASEAN IVO
- LPDP Rispro
- Kominfo
- PUI-PT
- BRIN

2023

RP6.5B

- Huawei
- LPDP Rispro
- Kominfo
- BRIN

2024

RP5.1B

- Huawei
- Kominfo
- BRIN
- DSA

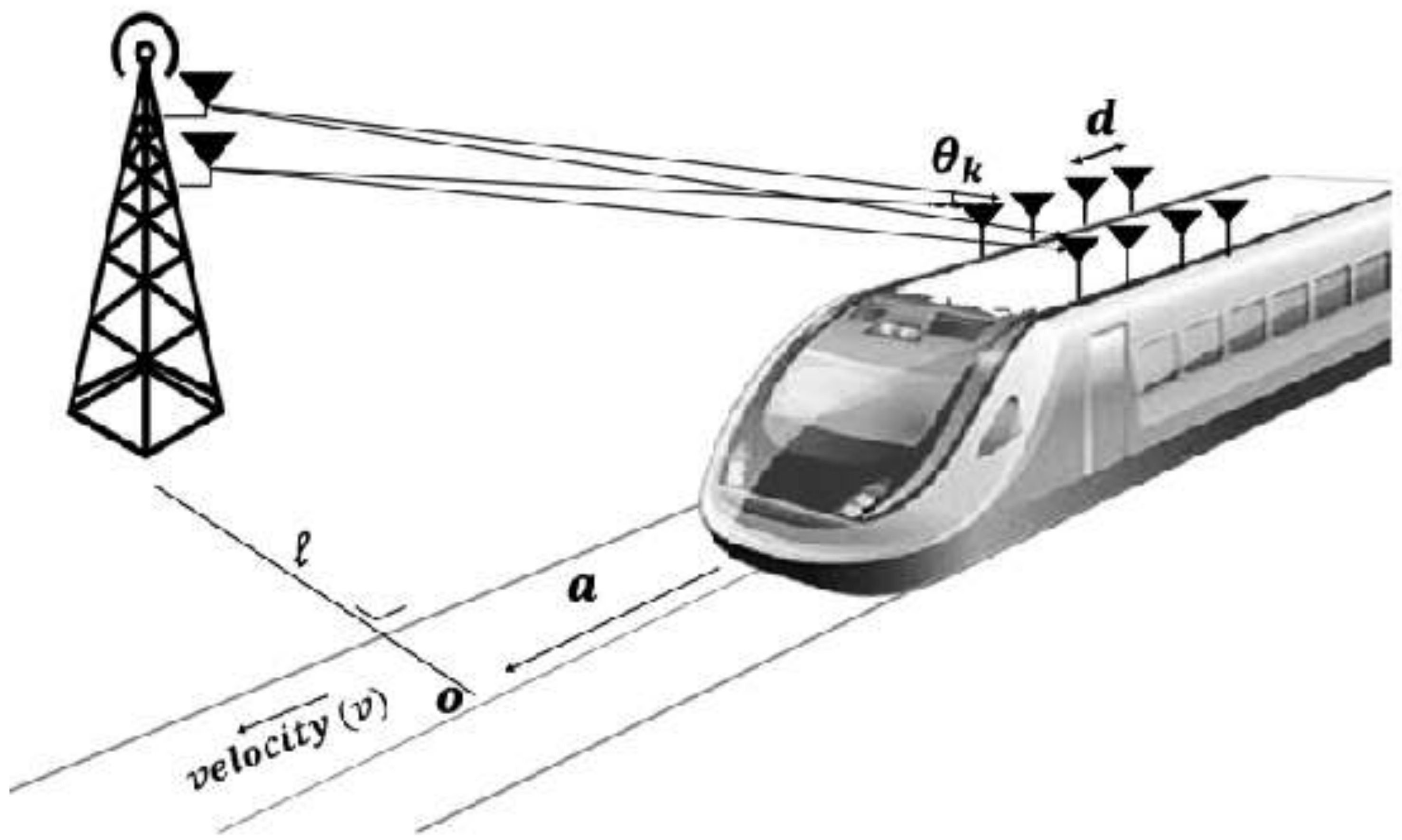
AICOMS Current 5 Top Products/Projects

(1) MCRBS & 5G-MERDEKA

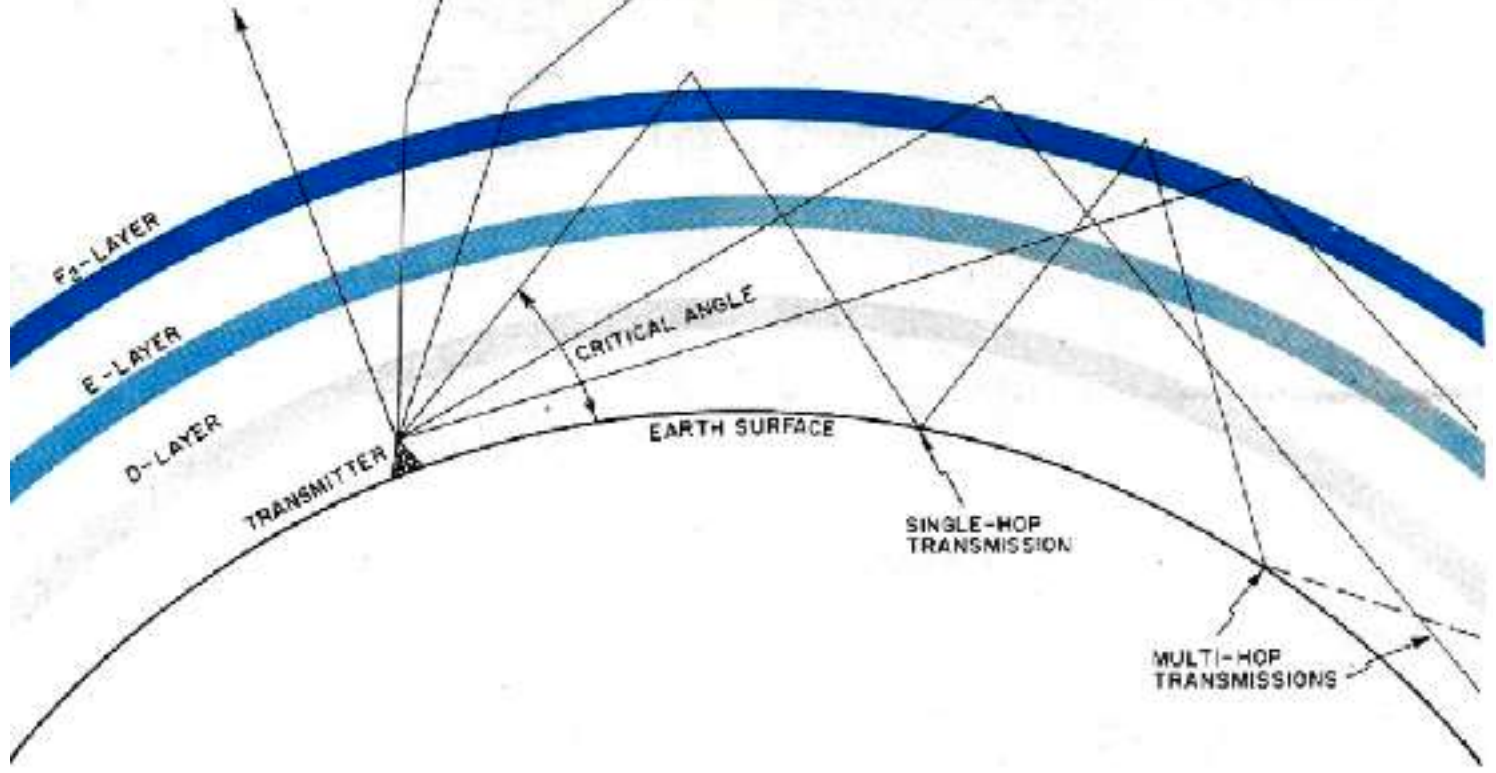
Mobile Cognitive Radio Base Station

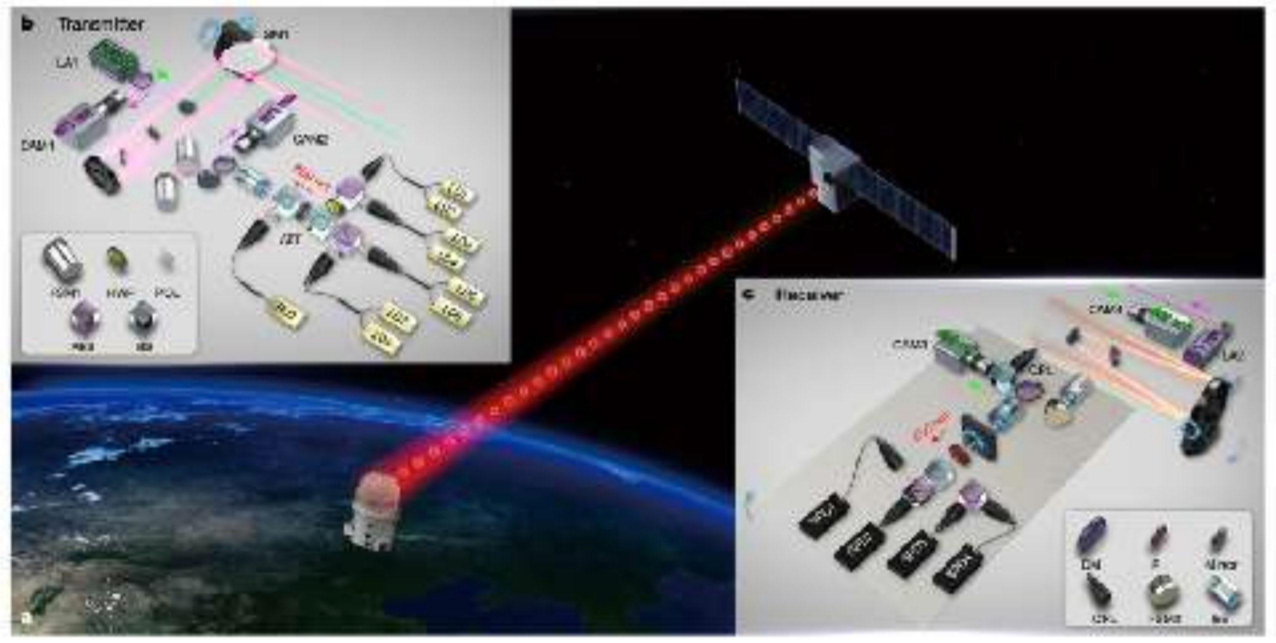
image: © K. Anwar, Telkom University, 2020.

(2) Kereta Cepat (5G-FRMCS)



(3) Over-The-Horizon Comm. /Roket.





(4) Next Generation IoT

Contention-based Access	IoT Technologies	Throughput
Pure ALOHA	SigFox, LoRa	0.18 pck/slot
Slotted ALOHA	RFID, RACH of LTE, NB-IoT (CIoT), Weightless	0.37 pck/slot
Non-slotted CSMA/CA	Zigbee, WiFi	0.5–0.8 pck/slot
Slotted CSMA/CA	Zigbee	0.8 pck/slot
Coded Random Access	AICOMS, Telkom Univ.	0.9-3.7 pck/slot

(5) AI, Quantum Coding & Security

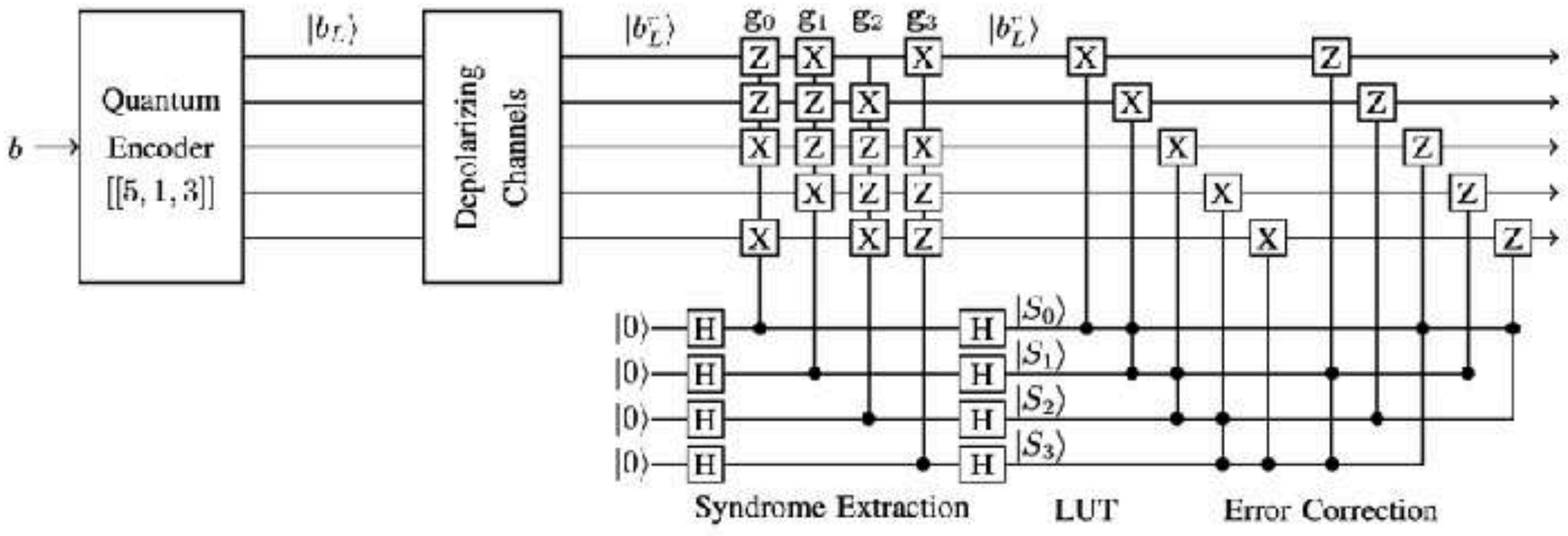


Fig. 3. The quantum circuit of the proposed perfect [[5, 1, 3]] quantum accumulate codes.

image: © K. Anwar, IEEE APCC2021.

International Collaboration: Vientiane, Laos, 15-16 November 2023 and Bangkok, August 2025

The Philosophy of Telecommunications for Future RLAN and IMT

Bandwidth

Error correction

Energy

Business

EM or quantum

Channels

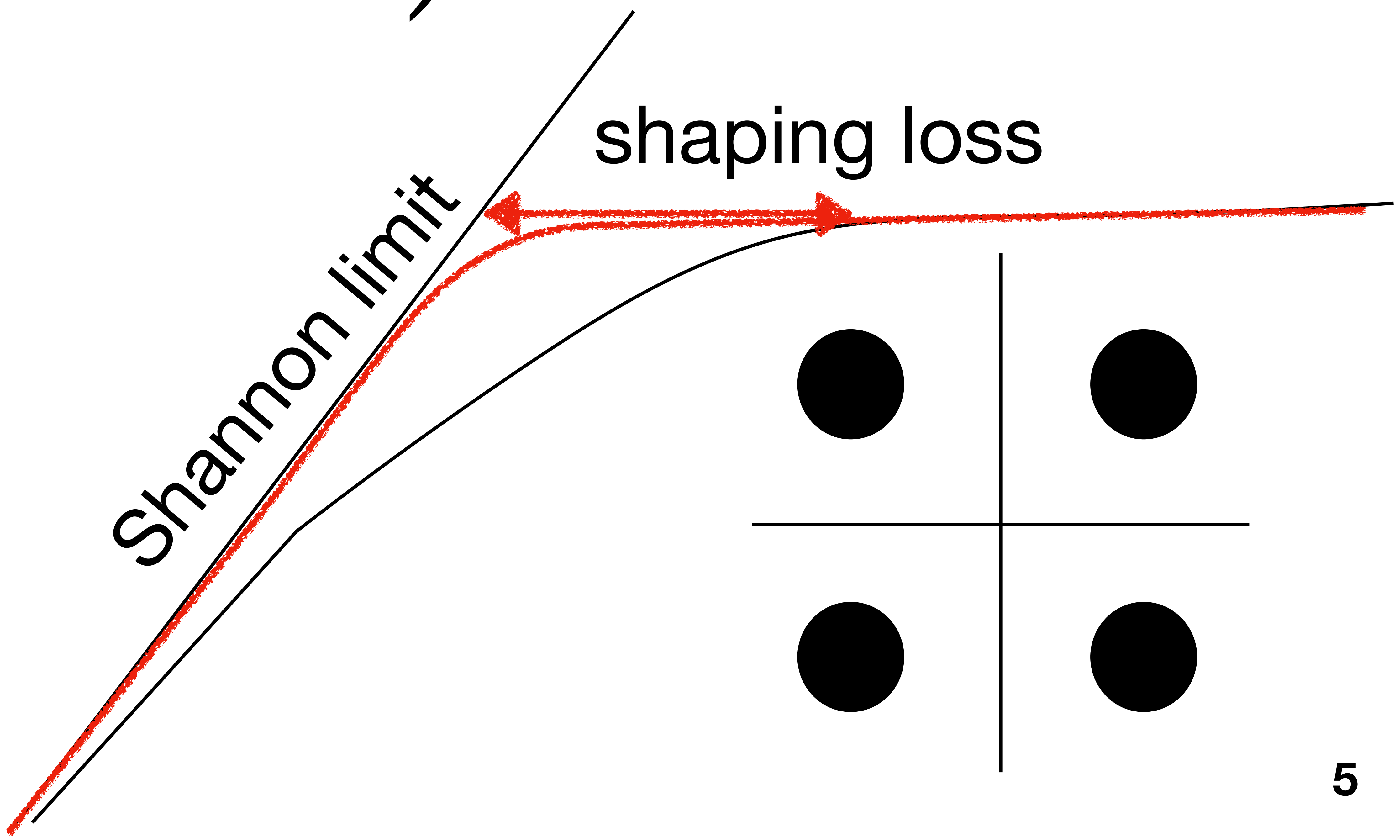
$$C \approx K \cdot n \cdot B \log_2 \left(1 + m \cdot R \cdot |h|^2 \frac{E_b}{N_0} \right) \text{ bit/s/Hz/}m^2\text{/Joule/Rp}$$

OAM, qudit

Massive MIMO

Modulation

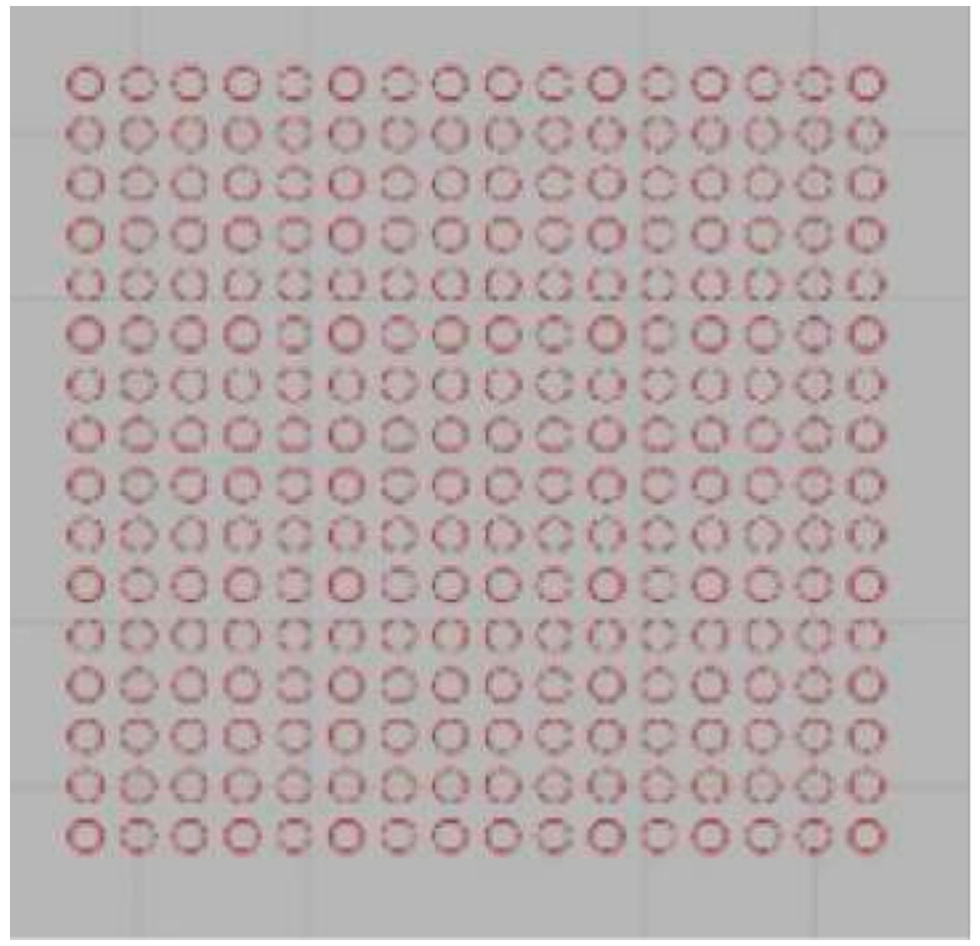
> 1Tbps



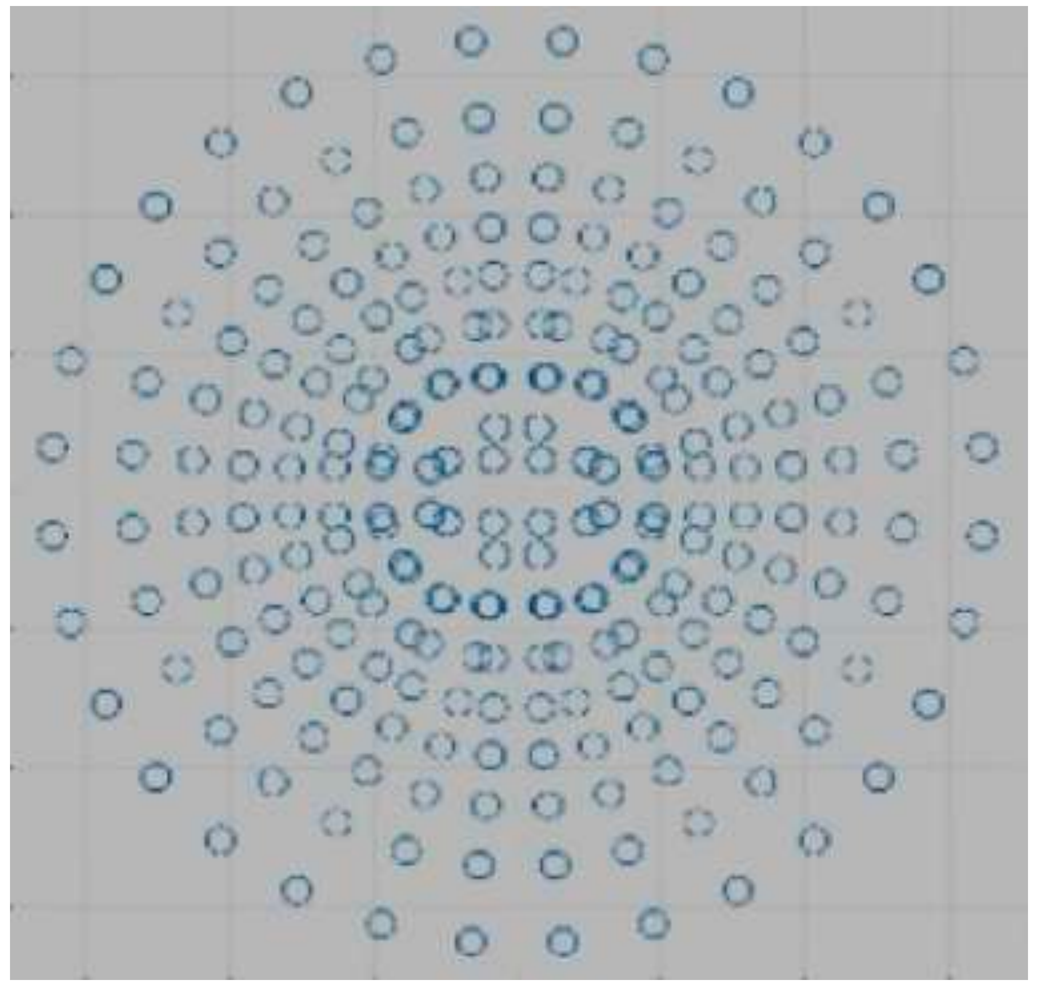
- Understanding philosophy for being better in research and teaching

Future Modulations

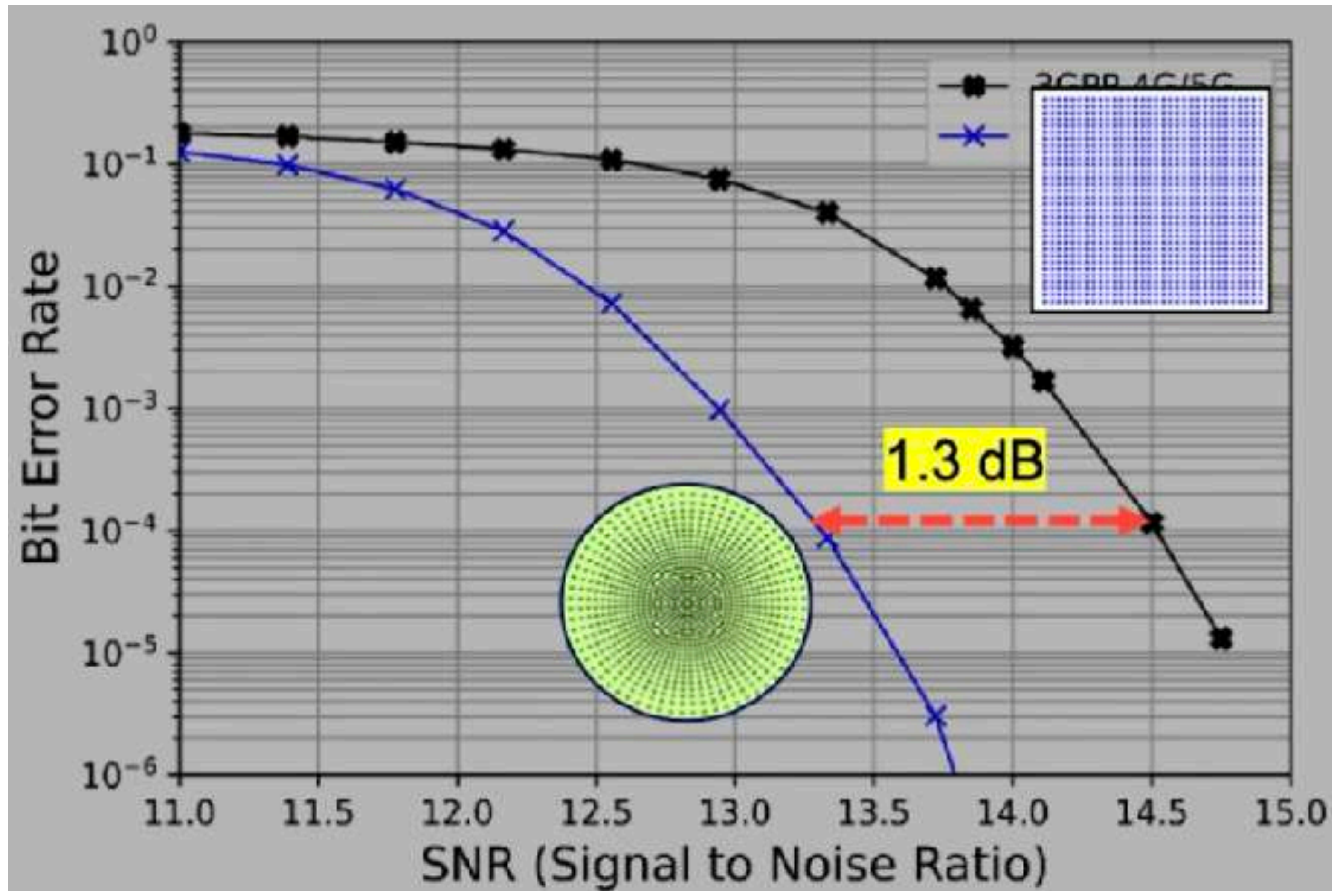
- Square QAM (has equidistant and equprobable distribution) suffers a shaping loss of up to 1.53 dB in a spectral efficiency compared to the Shannon capacity bound.



Uniform (square)

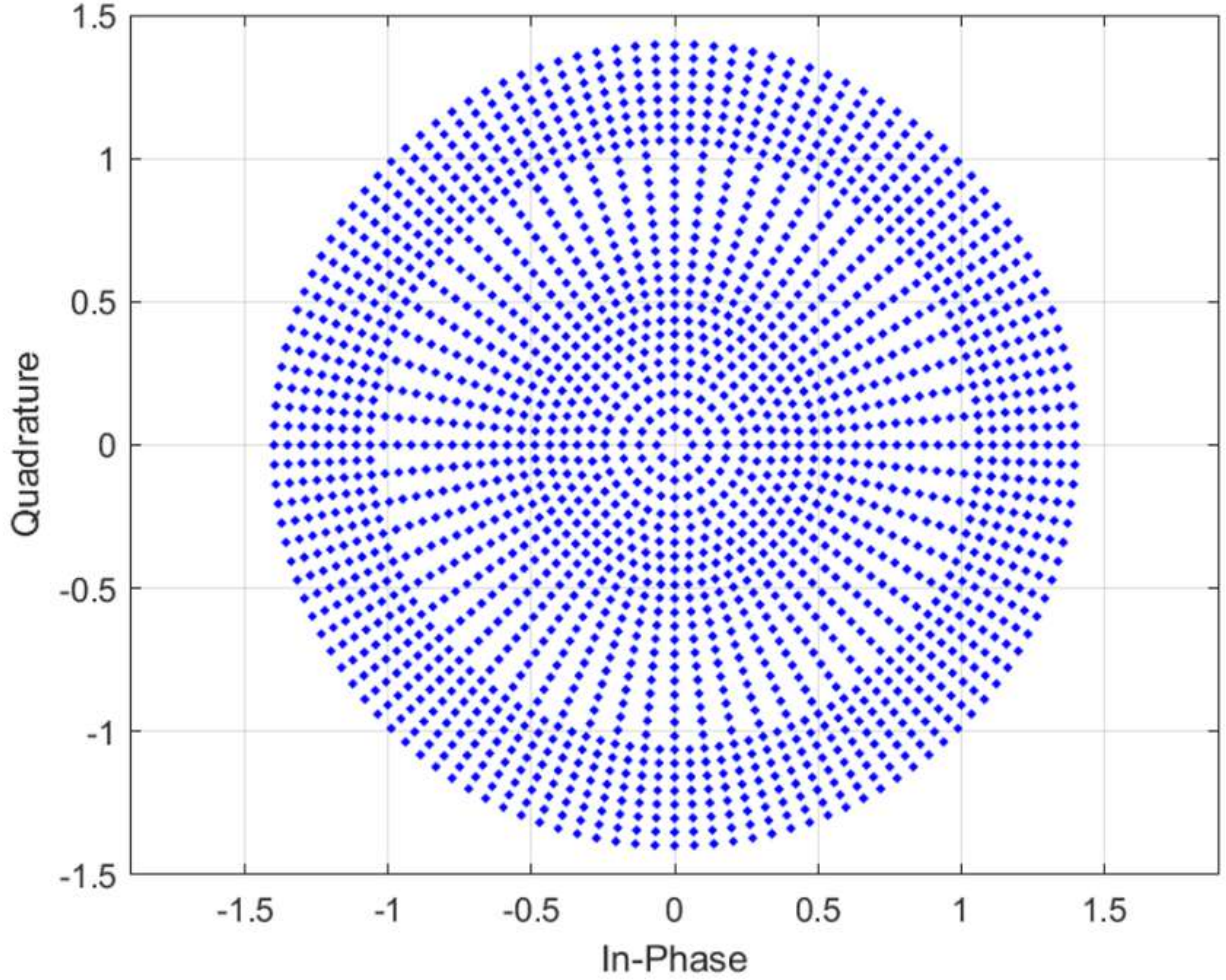


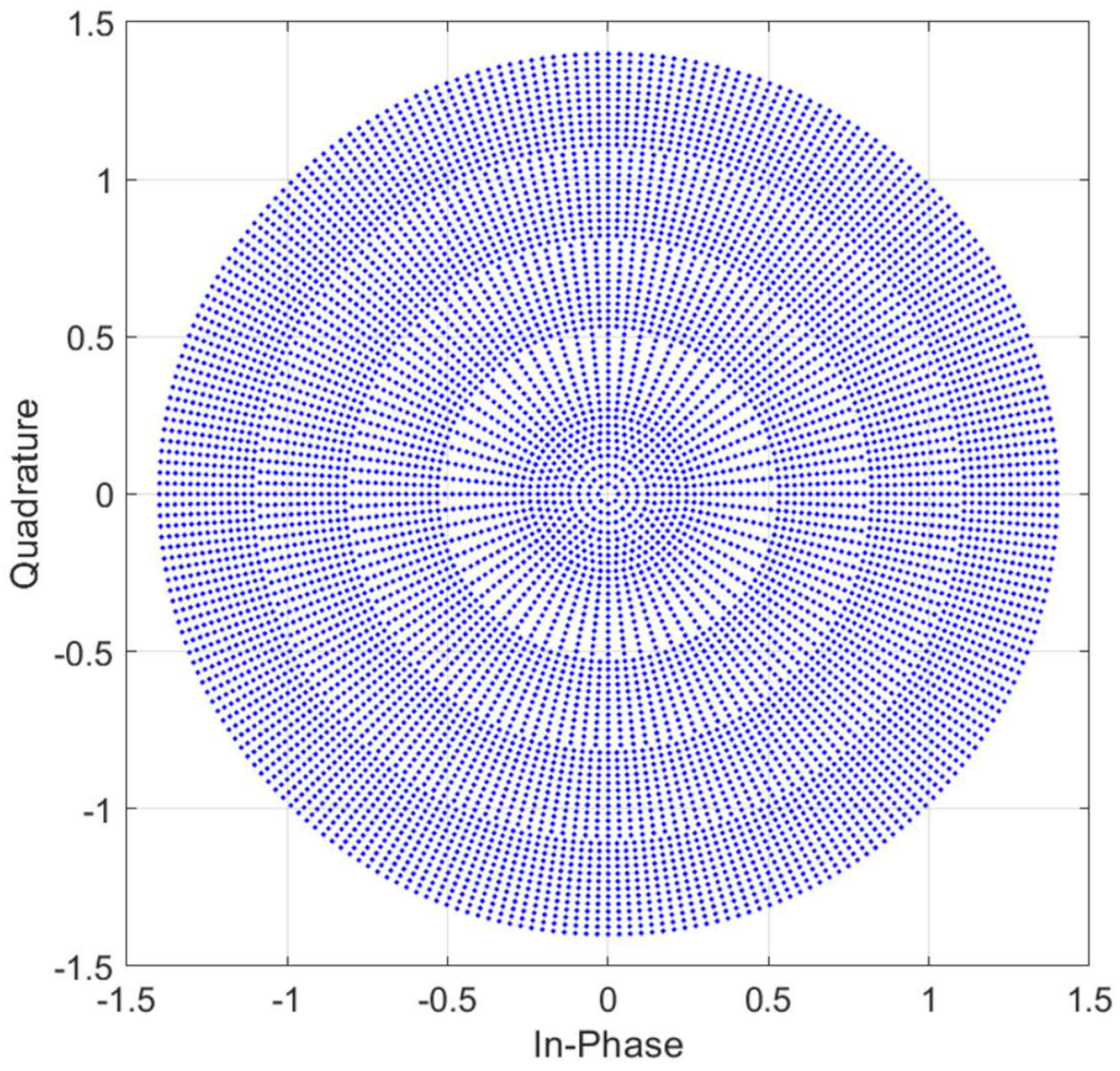
Circular



Source: 3GPP Workshop on 6G 6GWS-250036, Incheon, Korea, March 10-11, 2025

Our Developed Quantum Machine Learning for Future WiFi and 6G





- QML still works well for random non-QAM: 4096-QAM (left) and 8192-QAM (right).[7]

[7] Wahidin, "Quantum Machine Learning for Demapping of Irregular Circular QAM Modulations", A Master's Thesis, Telkom University, 2025.

This work is with Wahidin in his Maste's Thesis, 2025.

Recent Updates on Advanced SPEKTRAn Project

- AICOMS, Telkom University, in collaboration with The Ministry of Communication and Digital Affairs of the Republic of Indonesia (KOMDIGI), is currently conducting a study on:
  - the potential regulatory frameworks for outdoor RLAN (Wi-Fi 6/7) operation in the 6 GHz band (5 925–6 425 MHz) and
  - coexistence between RLAN (Wi-Fi 6/7) and IMT in the 5 925–7 125 MHz,
  - the potential use of guard band between RLAN (Wi-Fi 6/7) indoor in 5 925–6 425 MHz and IMT outdoor in 6 425–7 125 MHz.
- Currently we found that countries permitting outdoor Access Point (AP) implementation for RLAN mandate the use of an Automated Frequency Coordination (AFC) system to minimize interference impact on incumbent services.
- Several scientific studies on the impact of 6 GHz RLAN operation on FSS uplinks conclude that interference from RLAN in the 6 GHz band does occur for FSS uplinks. However, based on our assessment, this interference can be considered negligible because the RLAN signal cannot effectively reach the FSS satellite receiver.
- Note: Indonesia is still assessing the potential regulatory options and the most suitable implementation approach.

KOMDIGI
Kementerian Komunikasi dan Digital Republik Indonesia

ADVANCED SPEKTRAN

Outdoor RLAN (Wi-Fi 6/7) in 6 GHz Band and Its Coexistence with IMT – Outdoor Definition

- We are defining the outdoor e.g. a case of stadium → Indoor or Outdoor?
  - Dilemma: How should we define indoor versus outdoor?
- Proposed Definitions:
  - Outdoor: A system that can be used as part of a backbone network.
  - Indoor: A system that cannot be used as part of a backbone network.
- Rationale:
  - Backbone connectivity is critical because it may generate interference to surrounding systems.
  - Indoor RLAN (Wi-Fi 6/7) has no such backbone objective, reducing interference concerns.
- VLP Consideration:
  - Very Low Power (VLP): No outdoor access point allowed.
- Findings: (after intensive review) In the 6 GHz band without Standard Power and AFC, the majority of use cases fall under indoor usage. Outdoor operation requires the use of AFC.

Outdoor RLAN (Wi-Fi 6/7) in 6 GHz Band and Its Coexistence with IMT – Regulation in Indonesia

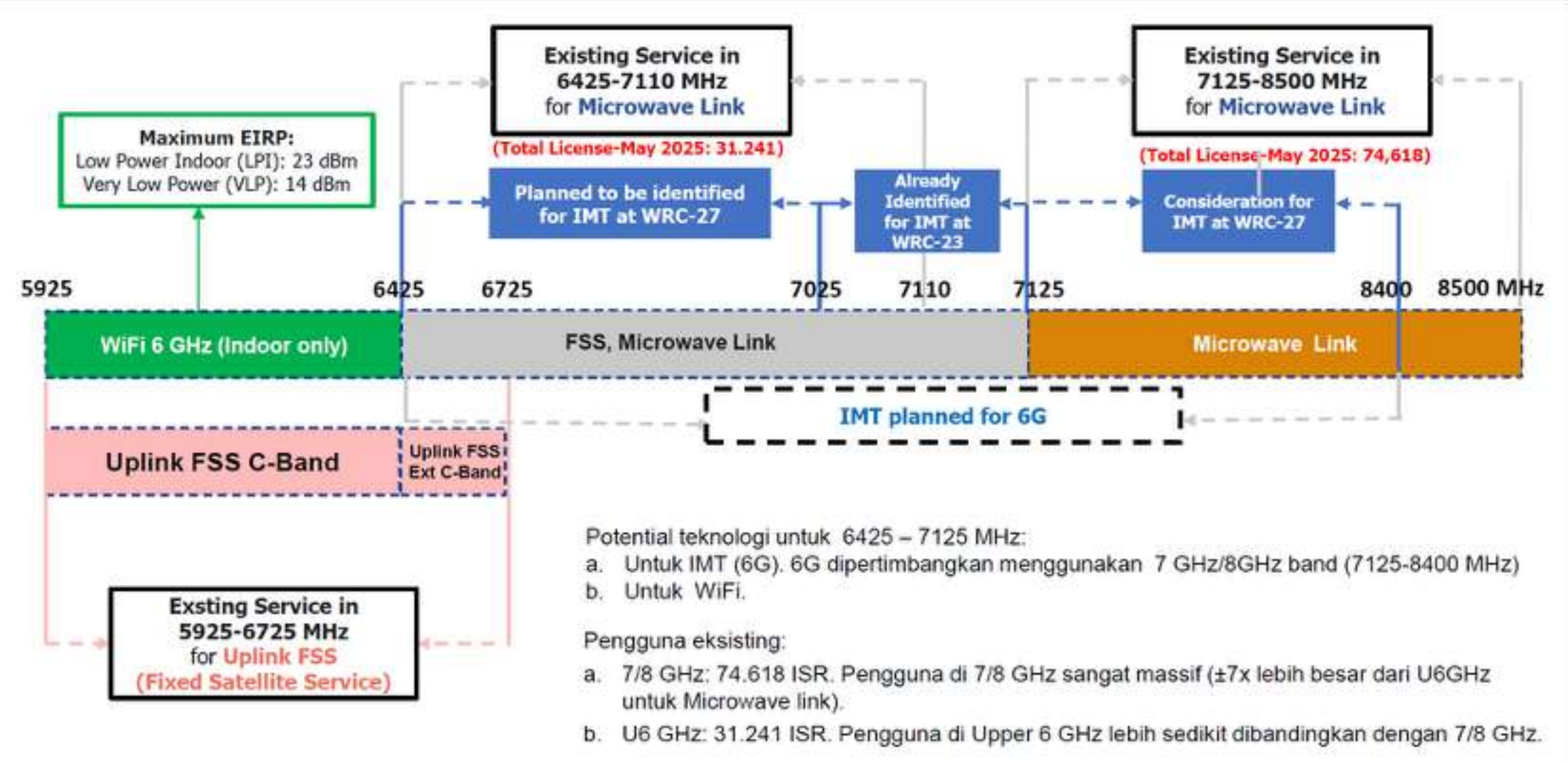
No.	Spektrum Frekuensi Radio	Penggunaan Daya Pancar Maksimum *Effective Isotropic Radiated Power* (EIRP)	Bandwidth Maksimum per Kanal Frekuensi Radio	Penempatan Perangkat
1	2 400–2 483.5 MHz	Akses tipe 1: 500 mW (27 dBm)	40 MHz	Indoor
		Akses tipe 2: 4 Watt (36 dBm)	20 MHz	Outdoor
		Backhaul: 4 Watt (36 dBm)		
2	5 150–5 250 MHz	Akses tipe 1: 200 mW (23 dBm)	80 MHz	Indoor
3	5 250–5 350 MHz	Akses tipe 1: 200 mW (23 dBm)	80 MHz	Indoor
4	5 150–5 350 MHz	Akses tipe 1: 200 mW (23 dBm)	160 MHz	Indoor
5	5 725–5 825 MHz	Akses tipe 1: 200 mW (23 dBm)	80 MHz	Outdoor
		Akses tipe 2: 4 Watt (36 dBm)	20 MHz	Outdoor
		Backhaul: 4 Watt (36 dBm)		
6	5 925–6 425 MHz	Akses tipe 1: Low Power Indoor (LPI): 200 mW (23 dBm)	320 MHz	Indoor
		Akses tipe 1: Very Low Power (VLP): 25 mW (14 dBm)		Indoor dan Outdoor
7	57–64 GHz	10 Watt (40 dBm)	2.16 GHz	Indoor

Based on Ministry of Communication and Digital Regulation (Permenkomdigi) No. 2 of 2025

*) For outdoor RLAN use, the maximum Effective Isotropic Radiated Power (EIRP) refers to the maximum transmit power allowed for RLAN devices, whether the antenna is integrated with the device or externally connected.

- Under Permenkomdigi No. 2/2025, the 5 925–6 425 MHz band is limited to Type-1 access (Wi-Fi devices providing direct access to end users).
- Outdoor use is restricted to Very Low Power (VLP) devices only.
- Maximum allowed EIRP: 25 mW (14 dBm).

Outdoor RLAN (Wi-Fi 6/7) in 6 GHz Band and Its Coexistence with IMT – Potential Interference to The Existing Technologies (FS and FSS)



Lower 6 GHz:

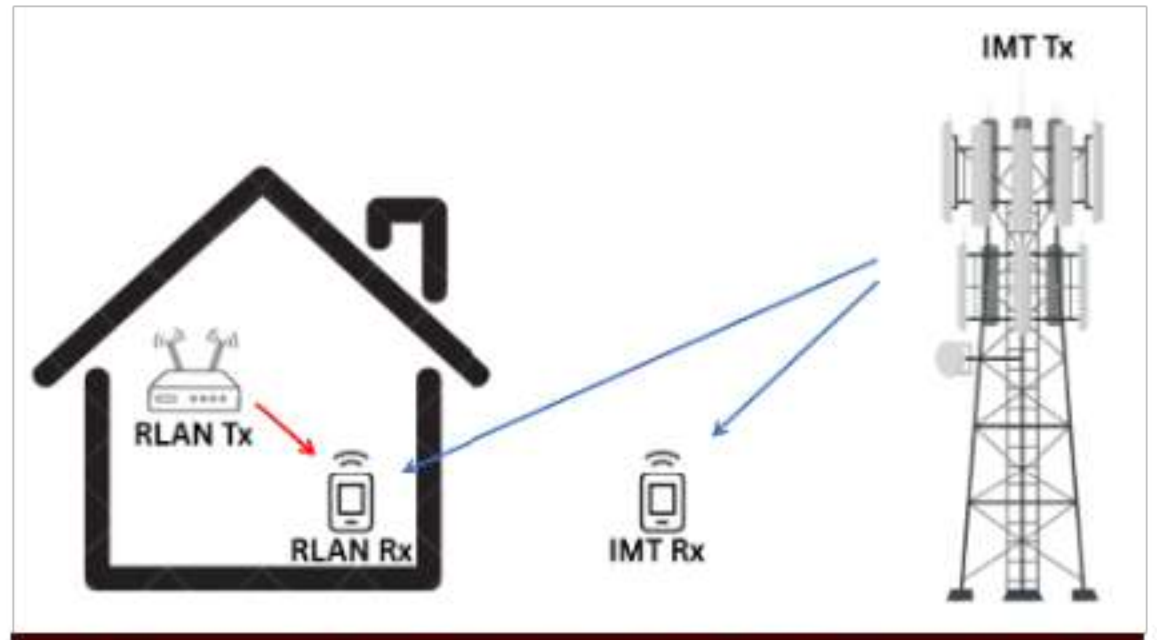
- 5 925–6 425 MHz: sesuai Permenkomdigi No. 2 Tahun 2025 dialokasikan untuk RLAN

Upper 6 GHz:

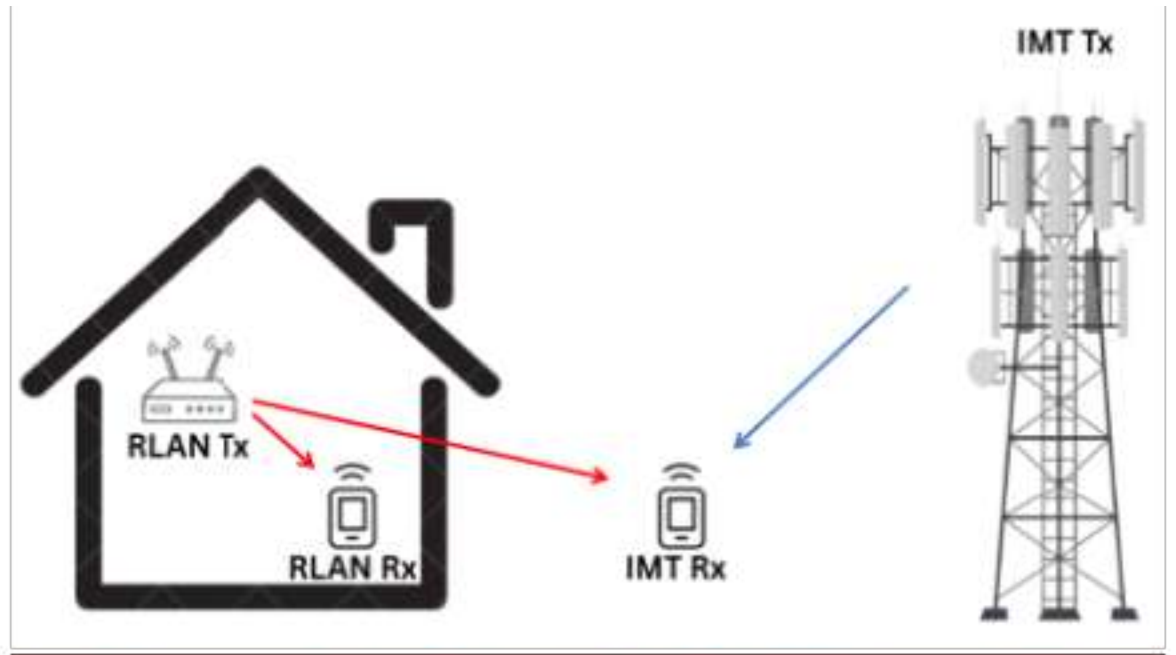
- 6 425–7 125 MHz: saat ini dialokasikan untuk FSS dan Microwave Link
- 7 125-8 500 MHz: saat ini dialokasikan untuk Microwave Link
- 6 425–8 400 MHz: dipertimbangkan akan dialokasikan untuk IMT

- Our current results indicates:
- Interference from RLAN (Wi-Fi 6/7) to FSS in 5 925-6 725 MHz may be ignored, since the FSS is in uplink direction.
- Interference from RLAN (Wi-Fi 6/7) to FS in 6 425-7 110 MHz may also be ignored, because the FS is in different band.

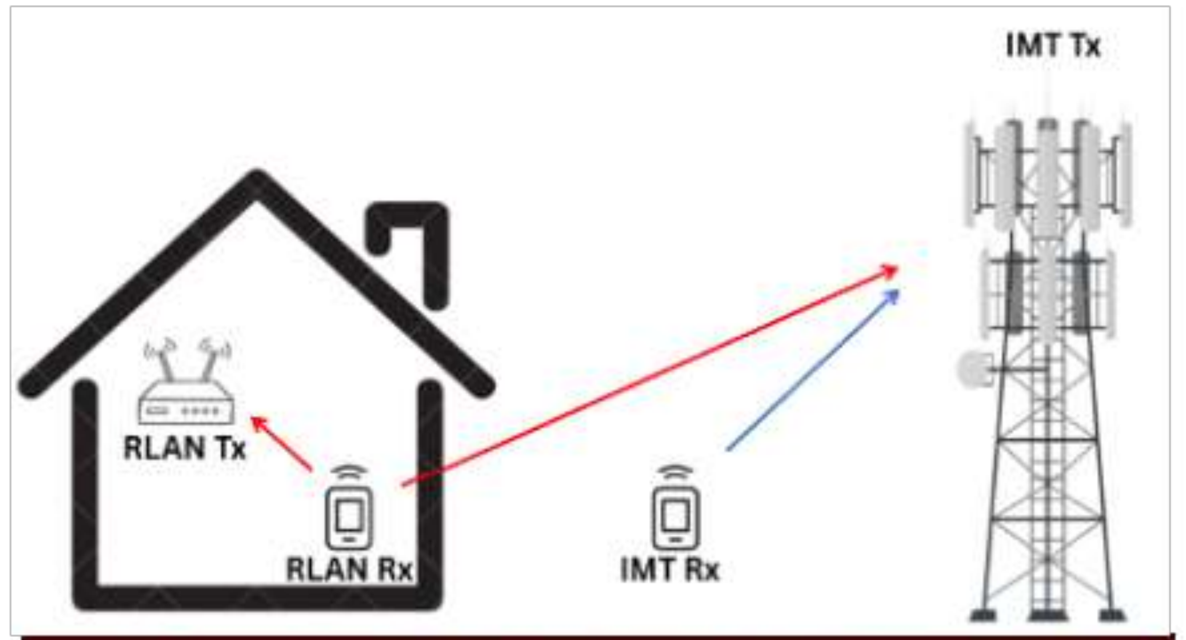
Potential Intereference between RLAN (Wi-Fi 6/7) and IMT: Investigating All Possible Scenarios



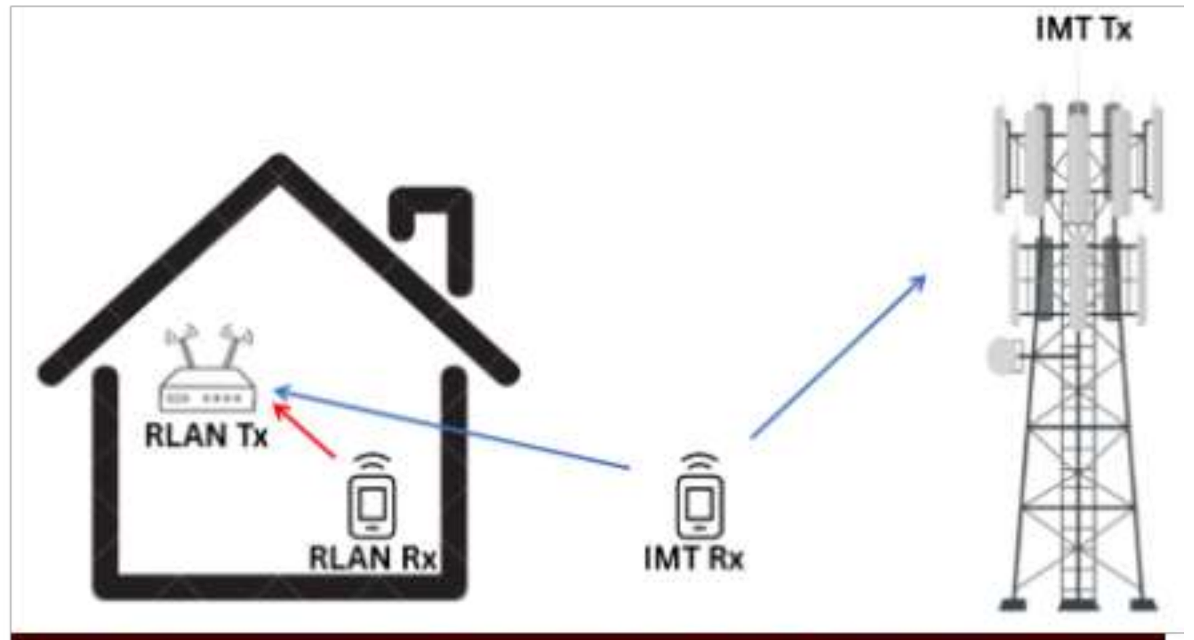
Skenario 1: RLAN (Wi-Fi 6/7) dan IMT sama-sama dalam kondisi *downlink*, diukur pada perangkat pengguna RLAN (Wi-Fi 6/7)



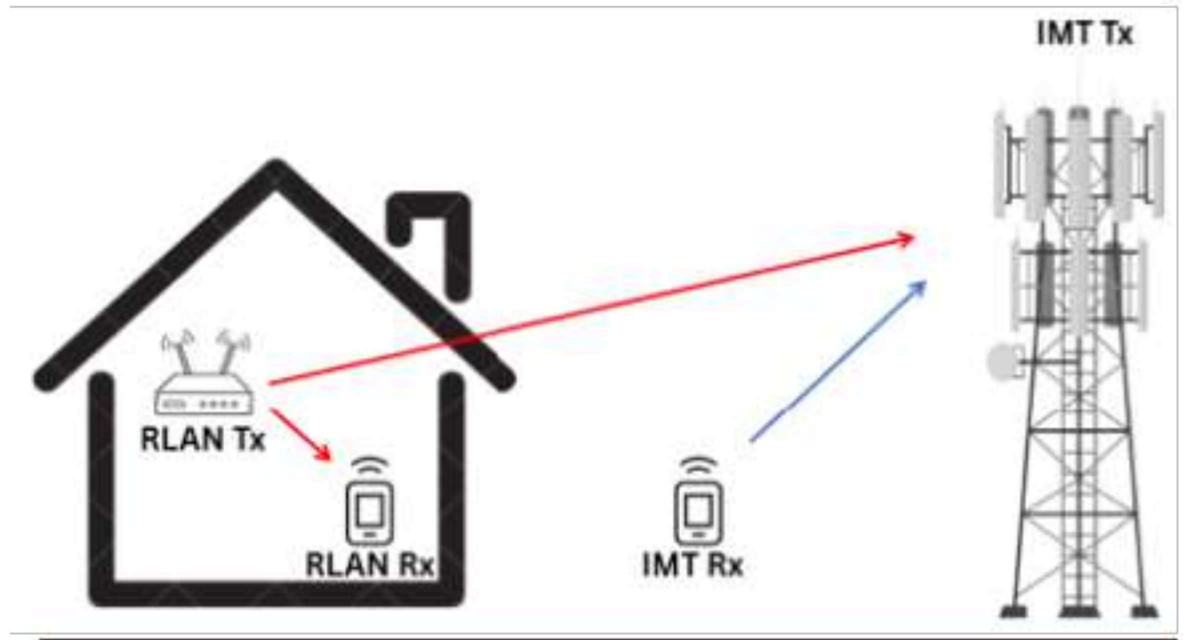
Skenario 2: RLAN (Wi-Fi 6/7) dan IMT sama-sama dalam kondisi *downlink*, diukur pada perangkat pengguna IMT



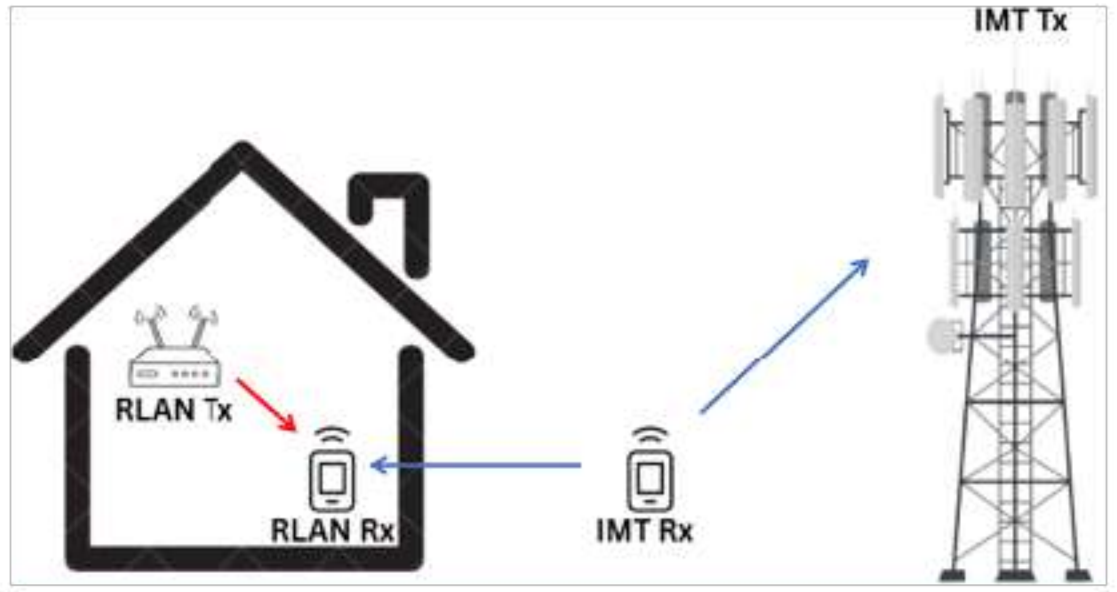
Skenario 3: RLAN (Wi-Fi 6/7) dan IMT sama-sama dalam kondisi *uplink*, diukur pada *base station* (BS) IMT



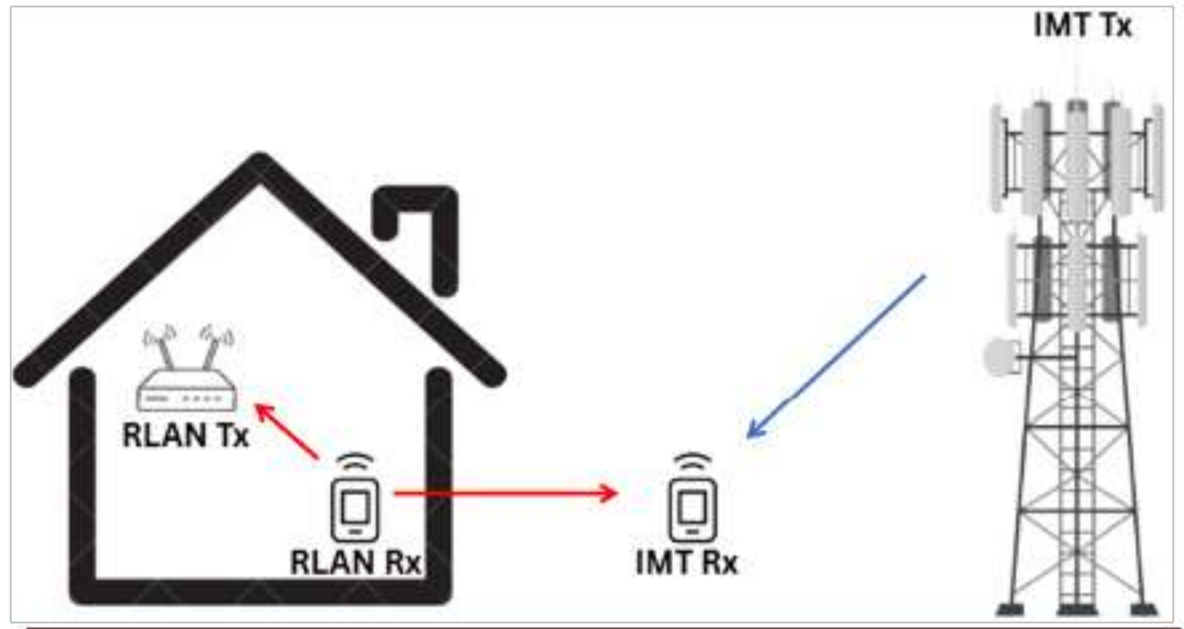
Skenario 4: RLAN (Wi-Fi 6/7) dan IMT sama-sama dalam kondisi *uplink*, diukur pada *access point* RLAN (Wi-Fi 6/7)



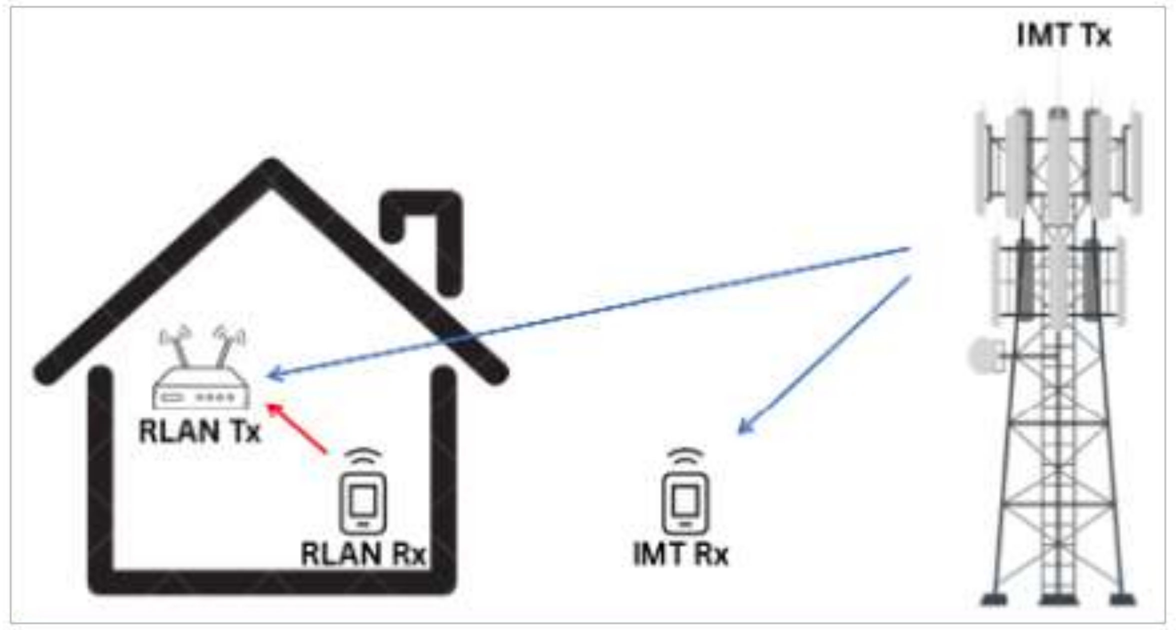
Skenario 5: RLAN (Wi-Fi 6/7) *downlink* dan IMT *uplink*, diukur pada *base station* (BS) IMT



Skenario 6: RLAN (Wi-Fi 6/7) *downlink* dan IMT *uplink*, diukur pada perangkat pengguna RLAN (Wi-Fi 6/7)



Skenario 7: RLAN (Wi-Fi 6/7) *uplink* dan IMT *downlink*, diukur pada perangkat pengguna IMT



Skenario 8: RLAN (Wi-Fi 6/7) *uplink* dan IMT *downlink*, diukur pada *access point* RLAN (Wi-Fi 6/7)

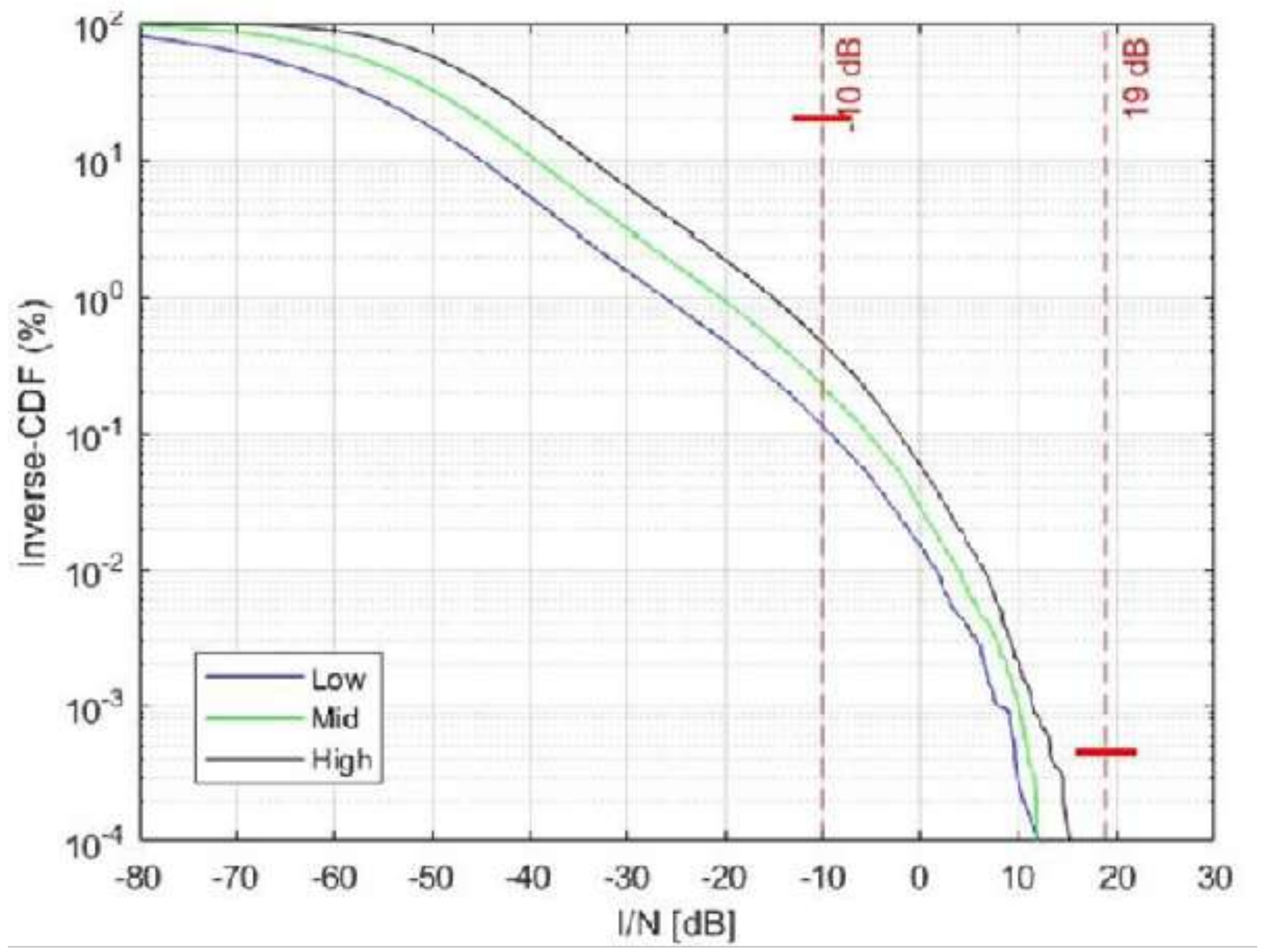
Long-term:
I/N = −10 dB not exceeded for more than 20% oftime
(Recommendation ITU-R F.758: Table 4)

Short-term:
I/N = +19 dB not exceeded for 4.5 x10−4 %
(Recommendation ITU-R SF.1650-1)

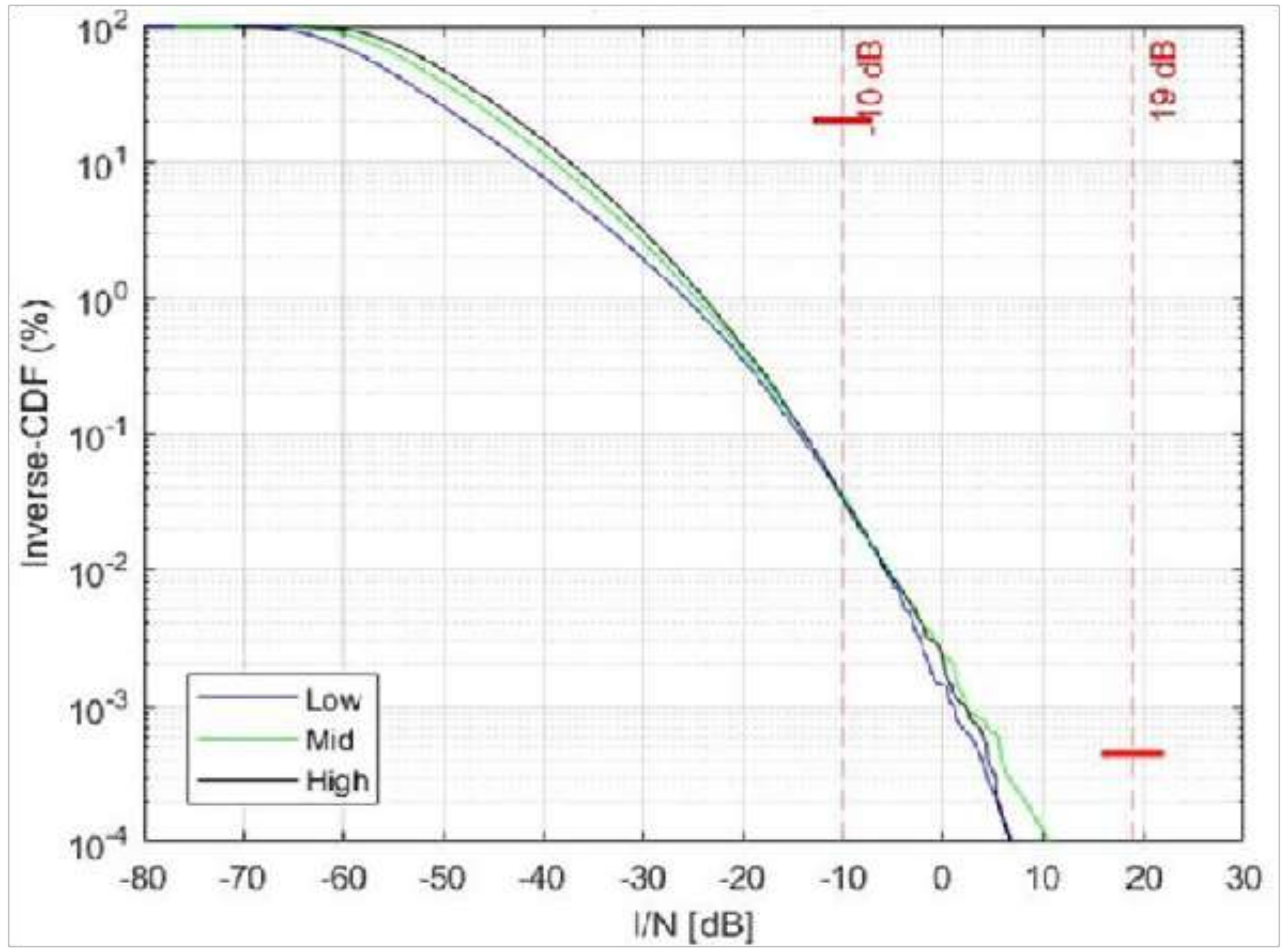
Investing WiFi for Possible Use in Upper 6 GHz: RLAN vs FS

Parameter	Value
Centre frequency (MHz)	6 445 MHz (6 425+20 (half BW)) MHz
Channel spacing Bandwidth (MHz)	40 MHz
Feeder/multiplexer loss (dB)	1.3 dB
Antenna peak gain (dBi)	39 – 43 dB
Antenna diameter	1.8 m and 2.4 m
Antenna pattern	*Recommendation* ITU-R F.1245
Antenna height (m) Rx	70 m, 65 m, 90 m
Receiver noise figure (NF) typical (dB)	5 dB
Receiver Noise Floor (dBm)	-94 dBm
Protection Requirement (dB)	• *Short term criteria limit*: I/N = +19 dB *not exceeded* 4.5%×10^{-4} • *Long-term criteria limit*: I/N = -10 dB *not exceeded* 20%

Rural

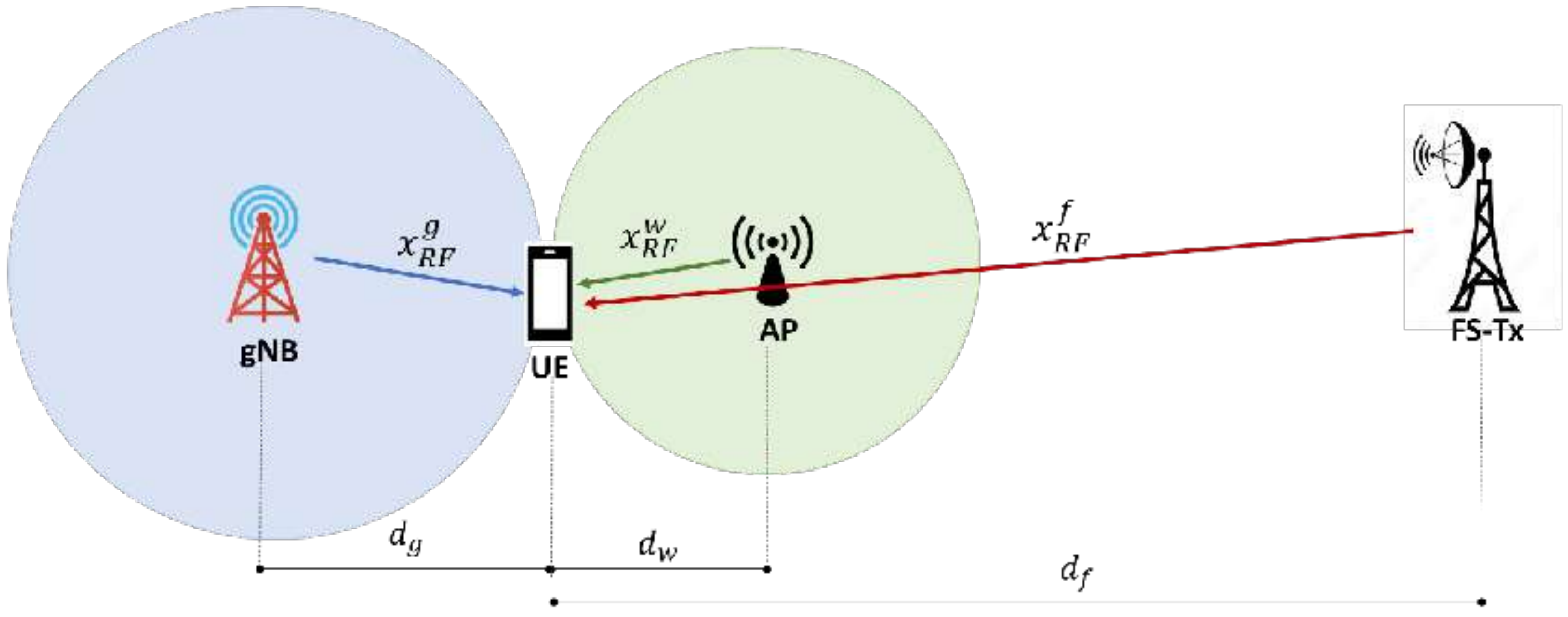


Sub-urban



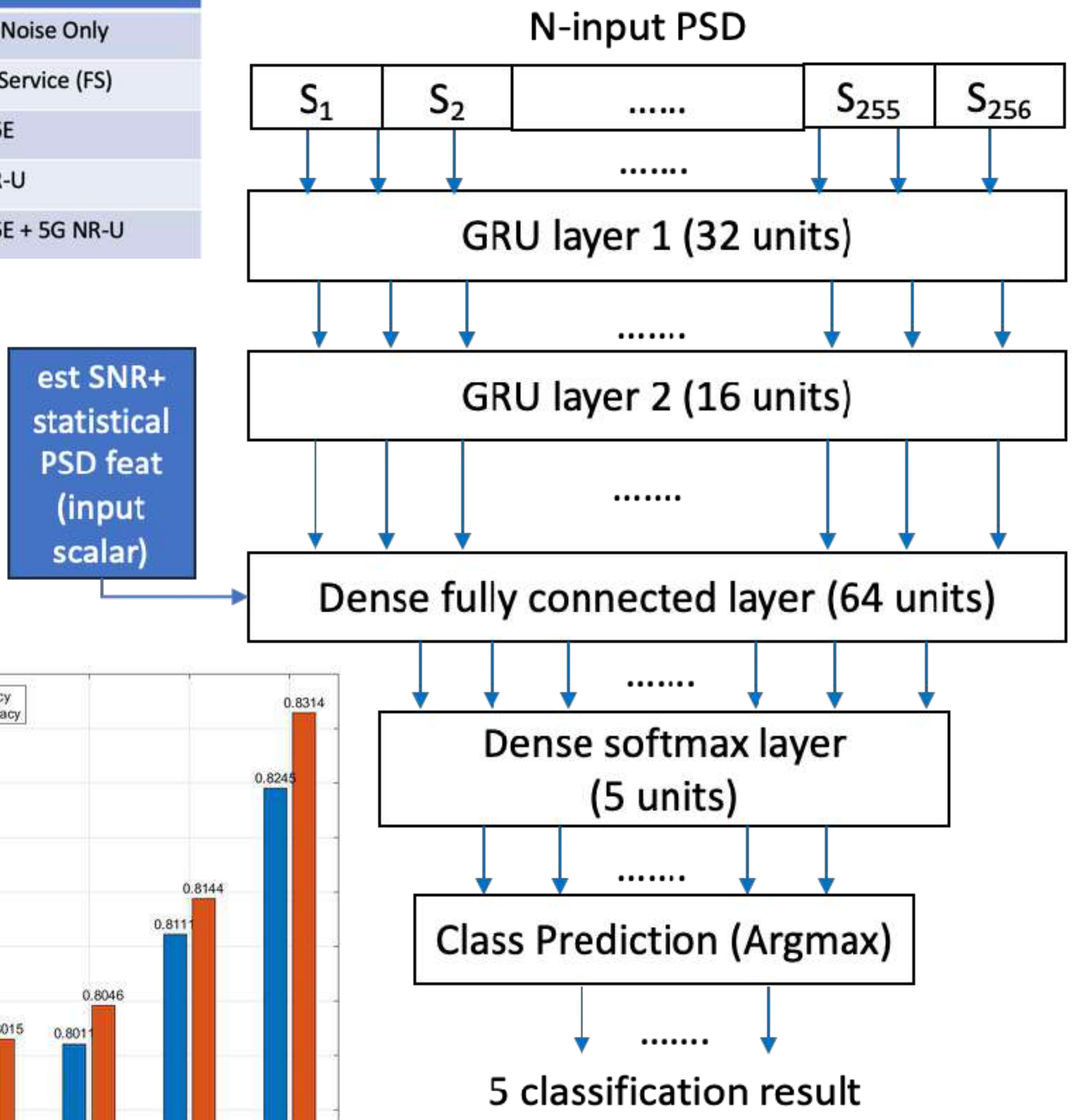
- Rural:
  - All criterions of short term are satisfied, while long term is only when low deployment.
- Suburban:
  - All criterion of both sort and long terms are satisfied.

The Help of AI for Interference Mitigation

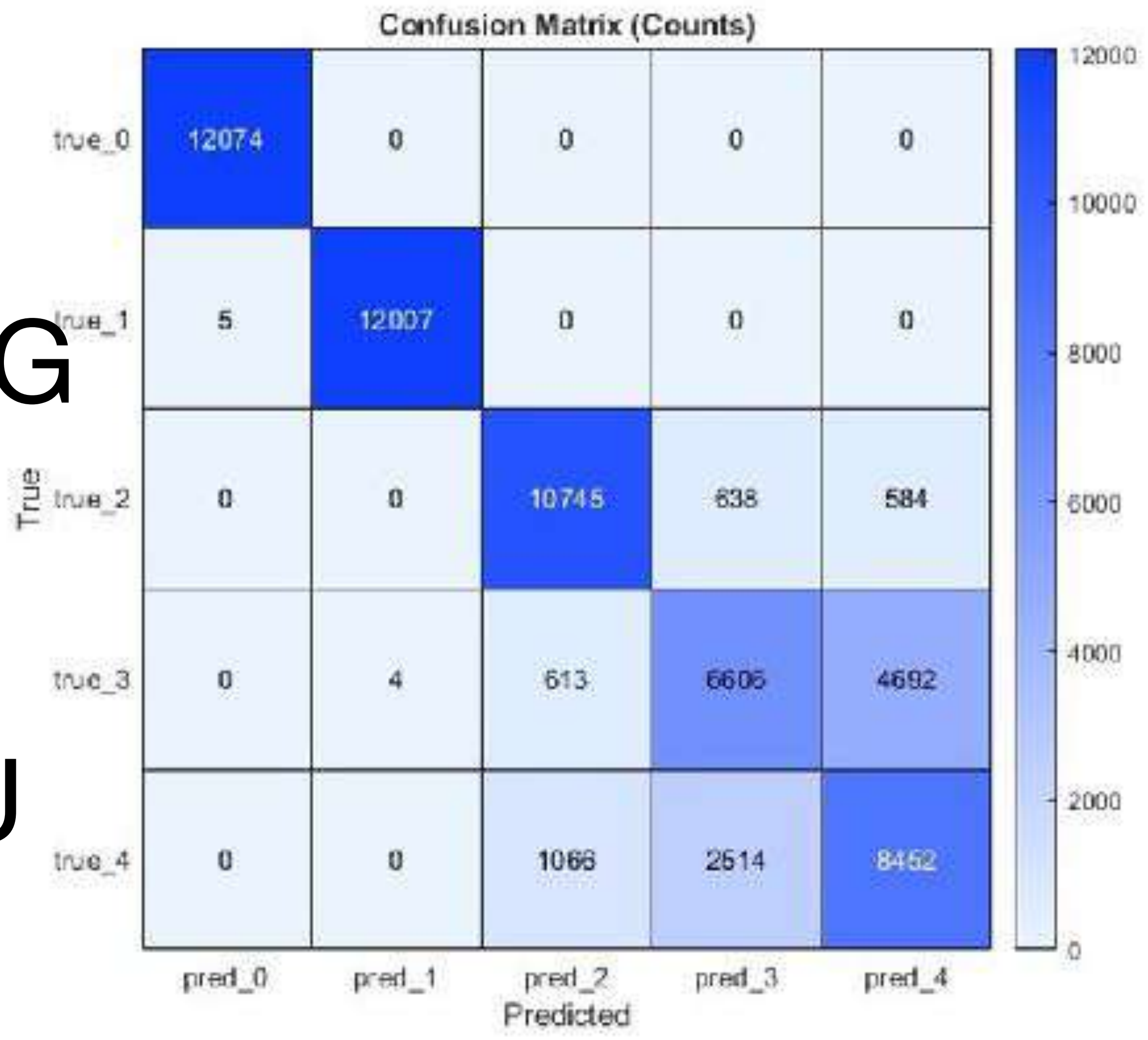


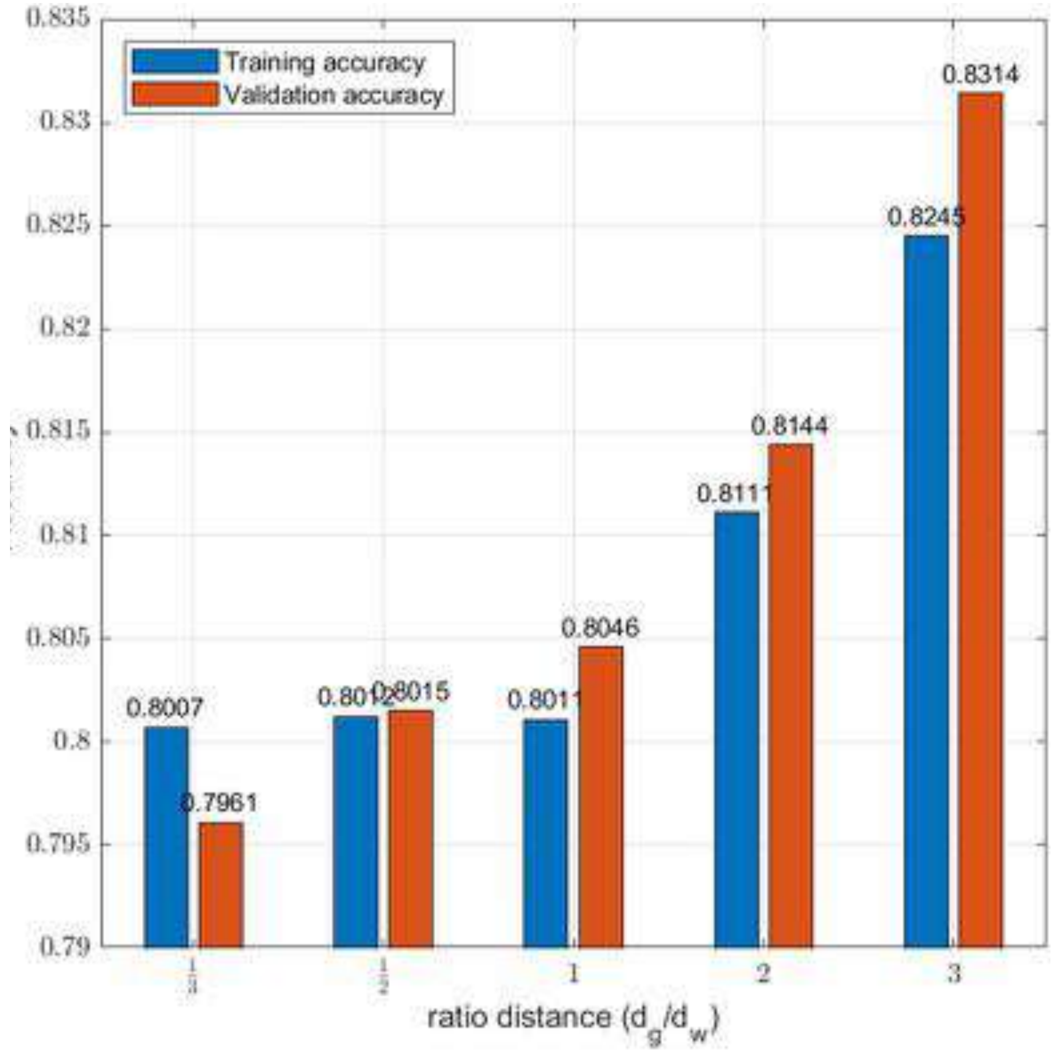
Class	Channel Occupation
0	Idle – Noise Only
1	Fixed Service (FS)
2	WiFi 6E
3	5G NR-U
4	WiFi 6E + 5G NR-U

Skenario: df = 10 km	1	2	3	4	5
(A) dw = 100 m	dg = (1/3)*dw	dg = (1/2)*dw	dg = dw	dg = 2*dw	dg = 3*dw



- The Algorithm struggles to differentiate class 3 (5G NR-U) and class 4 (WiFi+5G NR-U).
- PSD of WiFi+5G NR-U resembles 5G





Conclusions

- The future trend of modulations is on the use of more than 4K-QAM to increase the target of higher throughput (beside bandwidth and antennas)
- There will be some good technology candidates in the future to demap/decode very high constellation of more than 8K-QAM, e.g. Quantum machine learning.
- Indonesia has decided to use lower 6 GHz for RLAN (WiFi 6E/7) based on Ministry of Communication and Digital Regulation (Permenkomdigi) No. 2 of 2025 for Indoor and Indoor (LPI) +Outdoor (VLP) applications.
- We are further studyng on the possible use of WiFi 6E/7 in the upper 6 GHz, where FSS, and Microwave Links are currently is the incumbent, with possible IMT2020 as the new technology in the same band using:
    - Artificial Intelligence for envelope detection
    - Guard Band as used in Australia