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6G Radio Technology Project Repeater, metasurface, and RIS/IRS WG

(Short Ver.)

September 30, 2025

Construction of White Paper

- Title: Repeater, Metasurface, and RIS/IRS
  - Sec.1: Introduction
  - Sec.2: Use cases and scenarios
  - Sec.3: Technology trend survey
  - Sec.4: Standardization survey
  - Sec.5: Recent activities in Japan
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Section II
Use cases and scenarios

II. Use case and Scenario

Outline of use cases and scenarios concerning to repeater, metasurfaces, and IRS/RIS

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- Repeater
  1. Operating mode
     1. Decode and forward
     2. Amplify and forward
     3. Beamforming
  2. Use case
     1. Coverage enhancement
     2. Spectrum efficiency
        - MIMO, AMC and Beamforming
     3. Others
        - Reliability and Energy efficiency

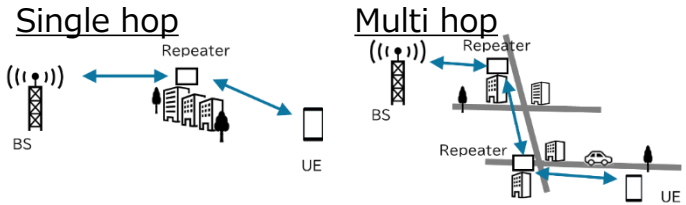
- Metasurface and IRS/RIS
  1. Operating mode
     1. Passive
        - Reflection, Refraction, etc…
     2. Active and Hybrid
        - Transmitting, Receiving, and Transceiver
  2. Use case
     1. Coverage enhancement
     2. Spectrum efficiency
        - MIMO, Beam Manipulation
     3. Others
        - Reliability, Physical layer security, Sensing capabilities, Energy efficiency, etc…

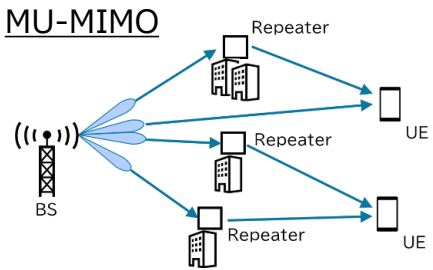
- Operating environment and deployment scenarios
  1. Operating environment
     - Indoor, Outdoor and Hybird
  2. Deployment scenarios
     - Static and nomadic

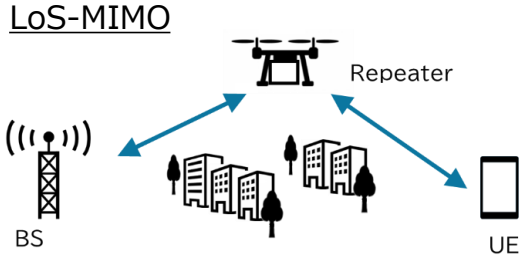
Repeater

- Operating mode
  - Decode and forward, Amplify and forward, and Beamforming
- Use case
  - Coverage enhancement
    - To mitigate signal attenuation due to obstructions such as buildings, a repeater enables coverage extension
    - Multi hop relaying is supported by incorporating multiple repeaters
  - MIMO
    - Spatial multiplexing is achieved through amplify-and-forward relaying
    - Line-of-sight MIMO (LoS-MIMO) is realized by asymmetrically arranged antenna elements.
  - Others (AMC, beam control, Reliability, and Energy efficiency)

Coverage enhancement



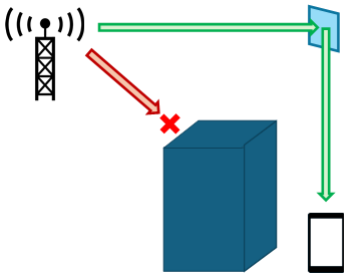




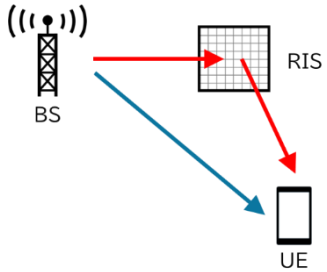
Metasurface and RIS/IRS

- Operating mode
  - Passive: Reflection mode, Refraction mode (Transmission mode), Absorption mode, and Omni Surface/STAR-RIS
  - Active and hybrid：Transmitting , Receiving, and Tranceiver
- Use case
  - Coverage enhancement
    - By placing a reflector at a position where both the transmitting and receiving antennas have LOS (Line-of-Sight), a propagation path that avoids attenuation due to the obstacle can be established.
  - MIMO
    - By introducing RIS, multipaths arriving from various angles can be added to the channel, and the number of spatial multiplexing can be increased.
  - Beam Manipulation
    - Beam manipulation is a fundamental capability of RIS technology, enabling precise control over the direction, shape, and focus of electromagnetic waves.

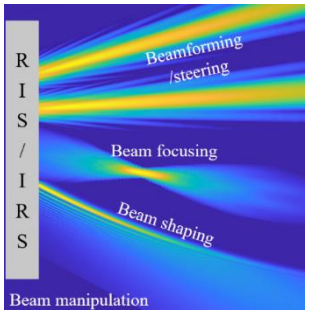
Coverage enhancement



MIMO



Beam Manipulation



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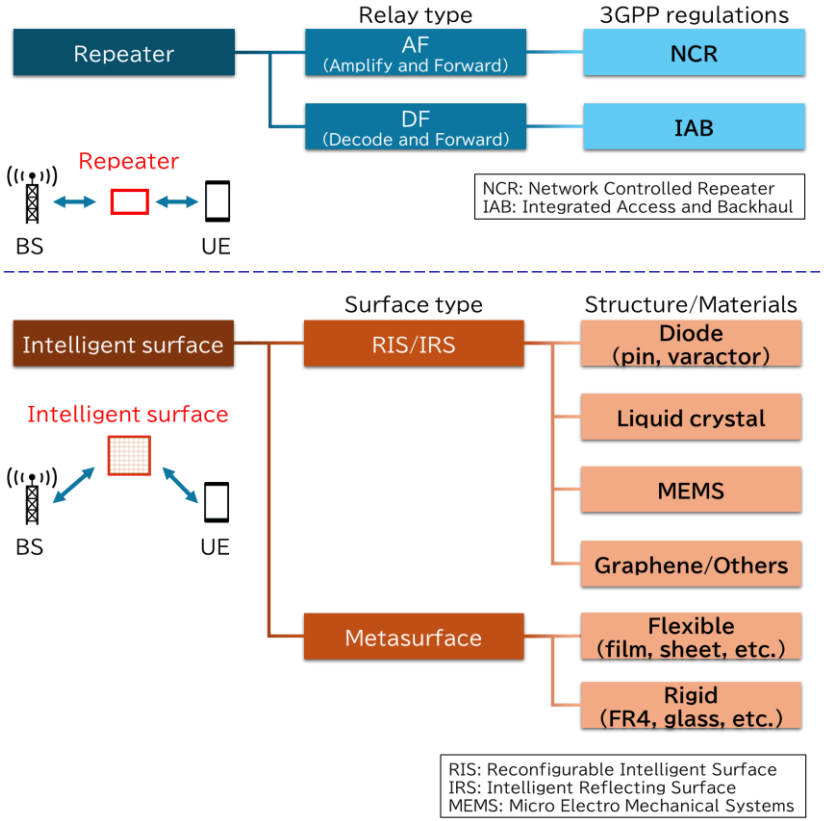
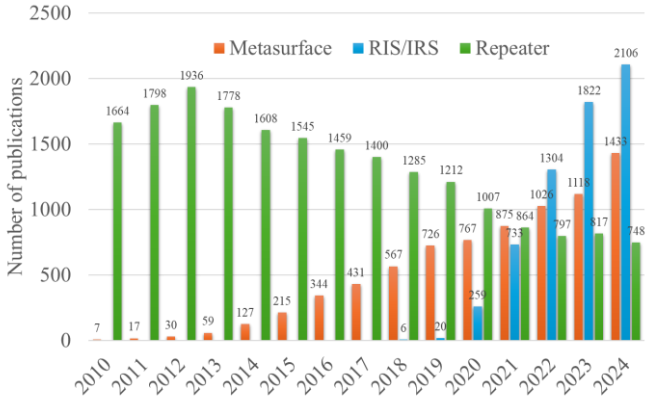
Section III
Technology trend survey

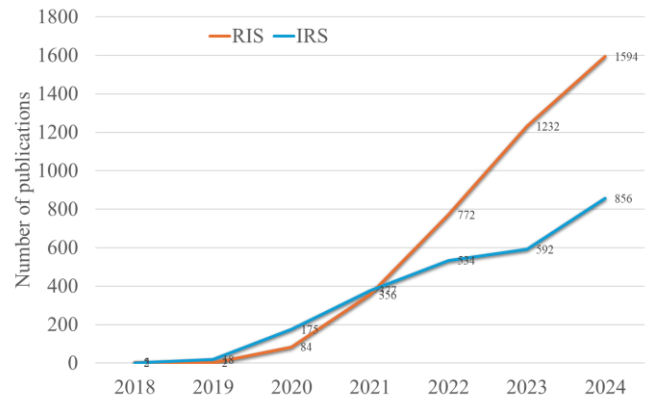
Technology Trend

Categories



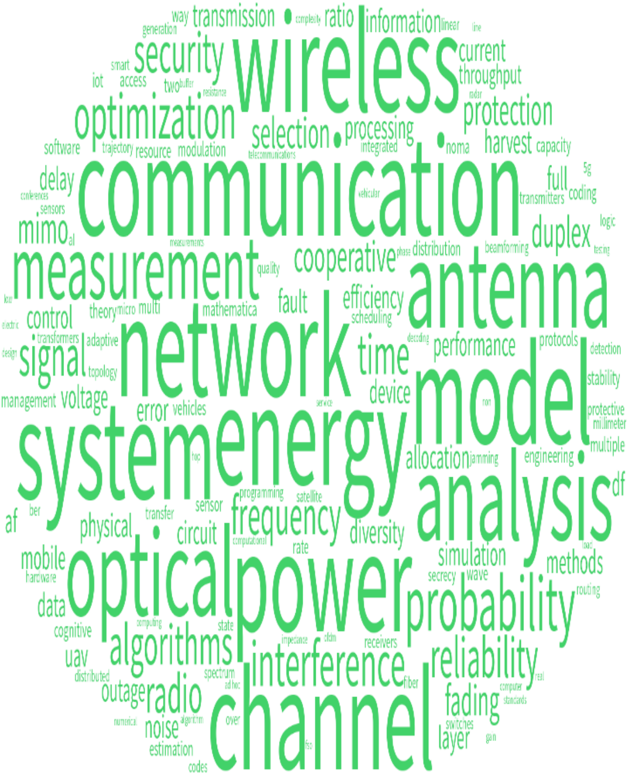
Publication Trends



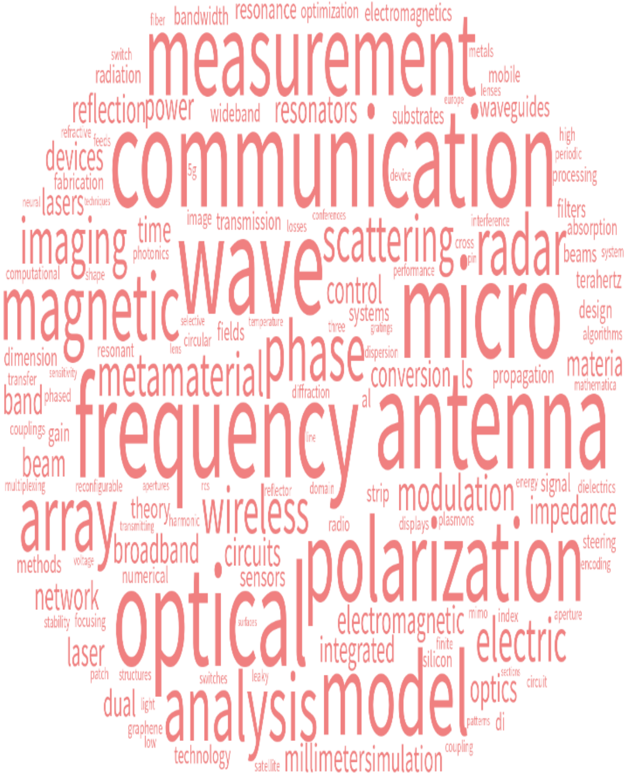


Related technical terms for relay technology

Repeater



Metasuface



RIS/IRS

Services Employed: https://textmining.userlocal.jp/

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Section IV
Standardization survey

Summary of Standardization

- **NCR**
  - ✓ Discussions have been started from 3GPP Rel-17, and TS began in 3GPP Rel-19 38.806
  - ✓ Support FR1/FR2 and split function C/U-Plane. Especially, enhance the function of C-Plane
- **IAB**
  - ✓ Rel-16: basic architecture of IAB is proposed, including core network management
  - ✓ Rel-17: functionalities of multi-hop and QoS management have been enhanced
  - ✓ Rel-18: integration of AI and automation technologies makes NW more efficient
- **RIS/IRS**
  - ✓ 3GPP: Some companies proposed including RIS as a SI in 3GPP for Rel-18 in 3GPP Rel.-18 workshop that was held in June 2021. However, the proposal was not approved
  - ✓ ETSI: Industry Specification Group (ISG) on Reconfigurable Intelligent Surfaces (RIS) was launched in September 2021. This group published three Group Reports (GRs)
  - ✓ ITU-R: ITU-R published Report ITU-R M.2516-0 (11/2022) and Recommendation ITU-R M.2160-0 (11/2023). RIS is introduced as one of technologies to enhance radio interface and performance of IMT systems

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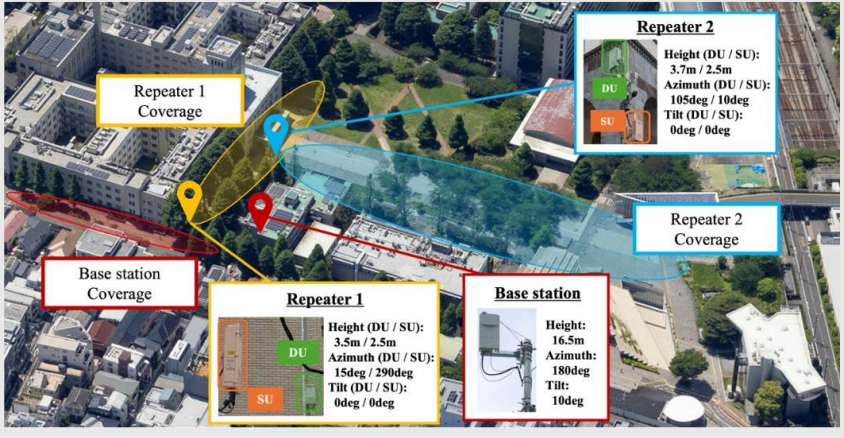
Section IV
Recent activities in Japan

Repeater, metasurface, and RIS/IRS Working Group

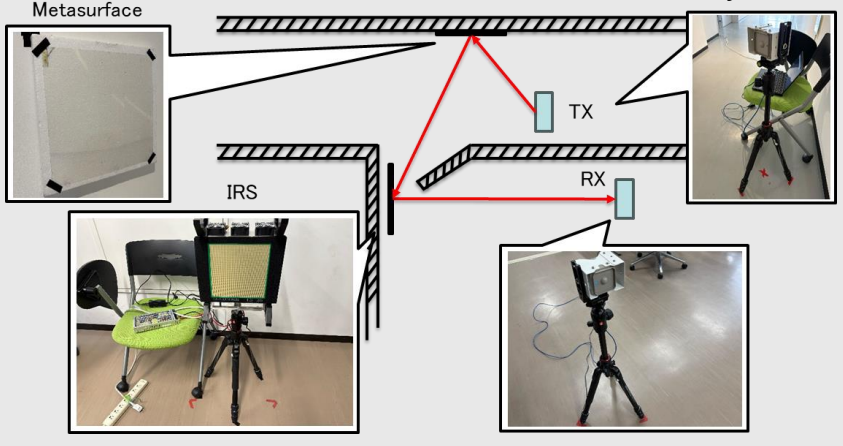
- **Organization of WG**
  - Chair: K. Sakaguchi (Science Tokyo), Vice chair: Yuichi Kawamoto (Tohoku Univ.)
  - 40 Members
- **Objectives of WG**
  - Engage in discussions regarding domestic and international technological trends, standardization activities related to repeater, metasurface, and RIS/IRS as well as use cases and scenarios of practical application.
  - Propose directions for repeater, metasurface, and RIS/IRS technologies toward 6G.

Various field experiments using repeater, metasaurface, and RIS/IRS are studied.

Network Deployment of 5G mmWave Base Station and Repeater at Ookayama Campus of Science Tokyo



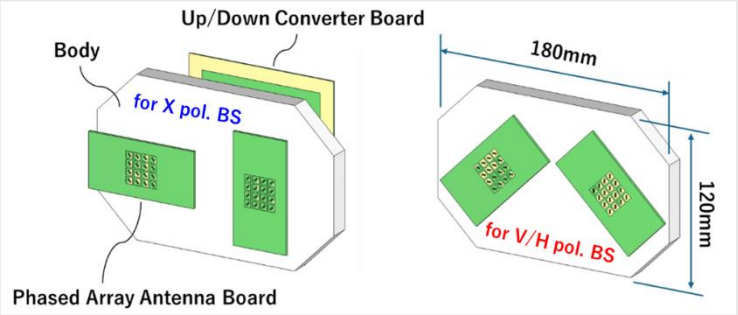
Field Experiments using 60GHz mmWave with IRS and Metasurface at Tohoku Uinversity.



Repeater, metasurface, and RIS/IRS Working Group

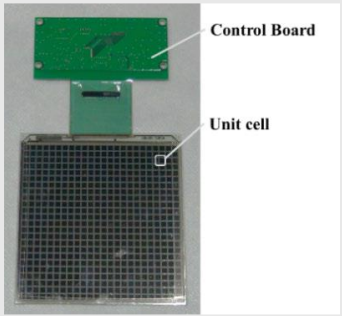
Recent activities regarding Repeater, metasurface, and RIS/IRS in Japan.

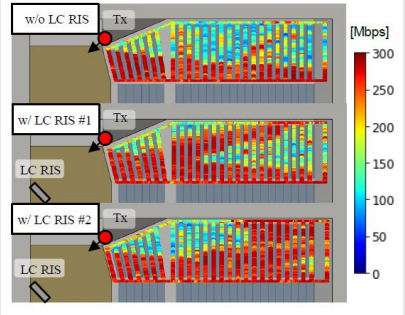
Phased array antenna system for proposed repeater system.



DKK Co., Ltd.

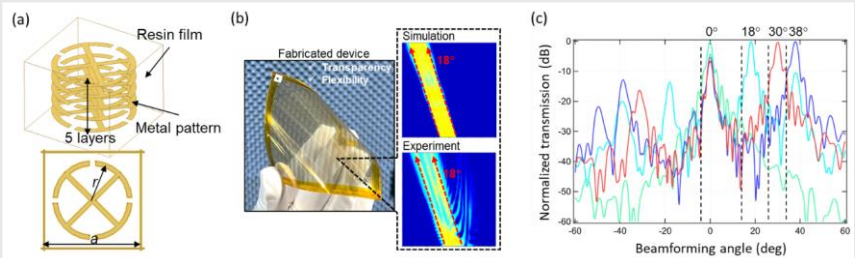
Liquid Crystal Reconfigurable Intelligent Surface.





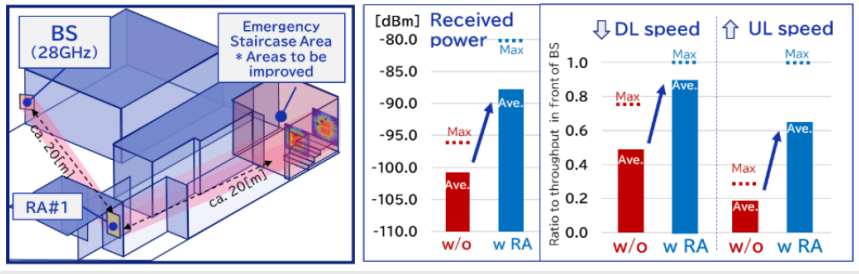
KDDI Research Inc.

(a) Multilayer metamaterial cell for 2π controllability.
(b) Fabricated gradient metasurface and beamforming results.
(c) Far-field results for gradient metasurfaces.



NTT Corporation

Verification of Reflectarray for millimeter waves in the Local 5G Open Lab.



Dai Nippon Printing Co., Ltd.