ETSI GR RIS 002 V1.1.1 (2023-08)

Reconfigurable Intelligent Surfaces (RIS); Technological challenges, architecture and impact on standardization

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Reference

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Foreword

This Group Report (GR) has been produced by ETSI Industry Specification Group (ISG) Reconfigurable Intelligent Surfaces (RIS).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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1 Scope

The present document identifies and includes the information on:

- The technological challenges to deploy RIS as a new network entity.
- The potential impacts on internal architecture, framework and the required interfaces of RIS.
- The potential impacts on architecture, framework and the required interfaces of RIS-integrated network.
- The potential recommendations and specification impacts to standardization to support RIS as a network entity.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI EG 203 336 (V1.2.1) (2020-05): "Guide for the selection of technical parameters for the production of Harmonised Standards covering article 3.1(b) and article 3.2 of Directive 2014/53/EU".

[i.2] 3GPP TR 22.858: "Study of enhancements for residential 5G".

[i.3] 3GPP TR 22.859: "Study on Personal Internet of Things (PIoT) networks".

[i.4] ETSI TS 122 261: "5G; Service requirements for the 5G system (3GPP TS 22.261)".

[i.5] ETSI GR RIS 001: "Reconfigurable Intelligent Surfaces (RIS); Use Cases, Deployment Scenarios and Requirements".

[i.6] ETSI GR RIS 003: "Reconfigurable Intelligent Surfaces (RIS); Communication Models, Channel Models, Channel Estimation and Evaluation Methodology".

[i.7] ETSI TS 138 401: "5G; NG-RAN; Architecture description (3GPP TS 38.401)".

[i.8] ETSI TS 138 300: "5G; NR; NR and NG-RAN Overall description; Stage-2 (3GPP TS 38.300)".

[i.9] Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC Text with EEA relevance.

[i.10] IEC 61000-4-2: "Electromagnetic compatibility (EMC) - Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test".

[i.11] IEC 61000-4-3: "Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test".

[i.12] IEC 61000-4-4: "Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test".

[i.13] IEC 61000-4-5: "Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test".

[i.14] IEC 61000-4-6: "Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test".

[i.15] IEC 61000-4-11: "Electromagnetic compatibility (EMC) - Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase".

[i.16] CISPR 32: "Electromagnetic compatibility of multimedia equipment - Emission requirements".

[i.17] Recommendation ITU-R SM.329: "Unwanted emissions in the spurious domain".

[i.18] IEC 61000-3-2: "Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤16 A per phase)".

[i.19] IEC 61000-3-12: "Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and ≤ 75 A per phase".

[i.20] IEC 61000-3-3: "Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection".

[i.21] IEC 61000-3-11: "Electromagnetic compatibility (EMC) - Part 3-11: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems - Equipment with rated current ≤ 75 A and subject to conditional connection".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

micro-controller: entity that determine the response of RIS in the electromagnetic domain according to control information from RIS controller

RIS: entity that consists of a large number of RIS Elements and micro-controller

NOTE: The incoming signal on RIS from any direction can be shaped to any direction (including absorption) in a programmable/controllable manner.

RIS controller: entity that generates/deliver the control information to RIS (see the illustration in clause 4.1).

NOTE: Depending on the considered deployment scenario and controlling type (see subsections in clause 4.2), RIS Controller can be co-located with a network node or co-located with RIS.

RIS element: entity that facilitates shaping/tuning incoming signals/reflection coefficients

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AoD	Angle of Departure
BS	Base Station
CPN	Customer Premises Networks
CSI	Channel State Information
CU	Central Unit
DU	Distributed Unit
EIRP	Effective Isotropic Radiated Power
LMF	Location Management Function
LOS	Line Of Sight
MIMO	Massive Input Massive Output
MU-MIMO	Multiple-Users Massive Input Massive Output
PIN	Personal Internet of things networks
PRAS	Premises Radio Access Station
PRS	Positioning Reference Signal
RIS	Reconfigurable Intelligent Surfaces
RSRP	Reference Signal Received Power
RSTD	Reference Signal Time Difference
SRS	Sounding Reference Signal
TCI	Transmission Configuration Indication
TDM	Time Division Multiplexing
UE	User Equipment
UL	Up Link

4 Deployment scenarios and operation modes

4.1 Deployment scenarios of RIS

The deployment of RIS refers to the integration of a new type of system node with reconfigurable surface technology, where its response can be adapted to the status of the propagation environment through control signalling.

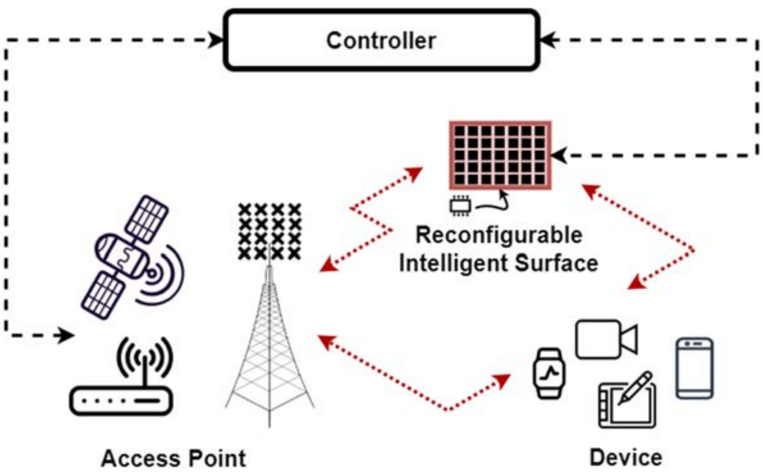

Figure 4.1-1: Illustration of deployment scenario of RIS

Deployment scenarios are determined by the user application trends and business models, as well as the maturity of RIS technologies. In ETSI GR RIS 001 [i.5], several key deployment scenarios are summarized, including indoors, outdoors, and hybrid scenarios. RISs can be deployed in a static manner, as well as a nomadic manner, serving different use cases such as vehicular communications.

4.2 Controlling type of RIS

4.2.1 Network-controlled RIS

In the network-controlled mode, the network determines the control information, which is used to control and configure RIS, based on the collected information from UE and/or RIS. The "RIS controller" may also collect data from UE and/or RIS itself and provide the collected data to the network. The "RIS controller" is deployed and owned by the network.

4.2.2 Network-assisted RIS

In the network-assisted mode, the network provides certain feedback or assistance information to the "RIS controller". The "RIS controller" can be either deployed and owned by the network or separately deployed as an authorized 3rd party component. The "RIS controller" collects information from UE and/or RIS itself. The "RIS controller" then utilizes the assistance information provided by the network and configures the RIS based on the collected information from UE and/or RIS itself.

4.2.3 Standalone RIS

In the standalone RIS controller, the "RIS controller" determine the control information, which is used to control and configure RIS, based on the collected information from UE and/or RIS itself. The "RIS controller" can be either deployed and owned by the network and can be pre-configured by the network or separately deployed as an authorized 3rd party component.

4.2.4 UE-controlled RIS

In the UE-controlled RIS, the UE determine the control information, which is used to control and configure RIS via the "RIS controller". The "RIS controller" can be either deployed and owned by the network operator or separately deployed as an authorized 3rd party component. The network authorizes the UE to configure the RIS for a specific operating frequency range including licensed and unlicensed spectrum. The UE either pre-configures the RIS or (re)configures via the "RIS controller.

4.2.5 Hybrid-Controlled RIS

In the hybrid-controlled RIS, the "RIS controller" could be split into "remote RIS controller" and "local RIS controller". The "remote RIS controller" is deployed at a part of network or the controlling UE(s) or at an authorized 3rd party entity, while the "local RIS controller" is supposed to be deployed at the RIS microcontroller (as defined in clause 5.1). The owner of the RIS control functionality can decide to split it between the remote and local entities in order to reduce the latency and communication overheads of the dynamic RIS control. The owner of the RIS control function can decide which information from the UE (s) and RIS side will be collected by the "local RIS controller" or by the "remote RIS controller". Optionally, the "remote RIS controller" can instruct the served UEs to provide assisting information to the "local RIS controller".

4.3 Capability aspect of RIS

In this clause, the general capability aspect of RIS and RIS controller according to the different controlling types in clause 4.2 is shown as following:

- Network-controlled RIS:
  - In the network-controlled mode, the control information is fully determined by the network, the RIS only needs to be capable of tuning the coefficients and properties of RIS elements according to the control information. As for the RIS controller, it needs to receive the control information from the network and may need to feedback to the network. The RIS controller should be capable of:
    - receiving control signals from the network;
    - (optionally) transmitting signals to the network;

        - reconfiguring the coefficients of RIS elements.

- Network-assisted RIS:
    - In the network-assisted mode, the capability of RIS panel is same as the above. While for the RIS controller, in addition to receiving the control information from the network, the RIS controller can collect data and perform calculations to configure the RIS. In this case, the capability of RIS controller includes the following:
        - receiving control signals from the network;
        - reconfiguring the coefficients of RIS elements;
        - limited processing and calculating capability;
        - collecting data from UEs/RISs.
- The standalone RIS:
    - In the standalone mode, higher capabilities are needed since the control information is determined by the RIS controller. In this case, the capabilities of RIS may include the following aspects:
        - tuning the coefficients and properties of RIS elements;
        - (optionally) sensing capability (e.g. power sensing, location sensing);
    - As for the RIS controller in this mode, the RIS controller may be capable of:
        - reconfiguring the coefficients of RIS elements;
        - collecting data from UEs/RISs;
        - basic data processing and calculation.
- UE-controlled RIS:
    - In the UE-controlled mode, the control information is determined by UE. In this case, the capability of RIS can consider the following aspects:
        - tuning the coefficients and properties of each RIS elements.
    - As for the RIS controller, following capabilities aspects should be considered:
        - receiving signals from the network (e.g. initial configuration information or information of authorized UEs);
        - reconfiguring the coefficients of RIS elements;
        - receiving control signals from authorized UEs.

In addition to the RIS capability aspects for specific RIS types, as described above, additional capability aspect of RIS related to mode of operation can be considered. Depending on the RIS elements and its hardware capabilities, RIS can further report to the controlling node on whether it supports multi-functional mode of operation or not. If RIS supports multi-functional mode of operation, then it can further report specific modes, for example:

- Reflection mode.
- Refraction mode.
- Absorption mode.

Based on the reported capability for operating modes, the related control information described in clause 7.2.1 can be impacted. In case if multi-functional mode is not supported by RIS, then no additional control information signalling would be needed for operating mode indication.

4.4 Complexity aspect of RIS

The complexity aspect of RIS is related to the capability of RIS, the structure architecture, etc. As analysed in the above clause, the capability of RIS panel for the network-controlled type, network-assisted type and UE-controlled type is mainly to tune the coefficients and properties of RIS elements according to the configuration from the RIS controller, thus the complexity of these three type of RIS mainly depends on the structure architecture, hardware implementation and other aspects. While for the standalone RIS, the control information is determined by the RIS controller itself, which may require the RIS element to be configured with the sensing capability, thus to increase the complexity of RIS itself.

As for the complexity aspect of RIS controller, for network-controlled RIS and UE-controlled RIS, the RIS controller only needs to receive the control information from the network or UE and configure the RIS element according to the control information, while the RIS controller of network-assisted and standalone RIS may need additional processing and calculating capability, which causes higher complexity.

Table 4.4-1 below illustrates the complexity aspect of the four different controlled type of RIS.

Table 4.4-1: Complexity aspect of different controlled type of RIS

RIS Controlling Type	Complexity aspects of RIS	Complexity aspects of RIS Controller
Network-controlled RIS	Depends on the structure and implementation of RIS panel	Low
Network-assisted RIS	Depends on the structure and implementation of RIS panel	Medium
Standalone RIS	High, and also depends on the structure and implementation of RIS panel	High
UE-controlled RIS	Depends on the structure and implementation of RIS panel	Low

4.5 Regulation aspects of RIS

4.5.1 Regulatory aspects of RIS according to EU Directive 2014/53/EU

As RIS are specified as radio components of radio communication networks, they will be regarded as radio equipment to which the European Directive 2014/53/EU [i.9] (known as Radio Equipment Directive, RED) applies.

Reminder:

NOTE 1: Article 3.1(b) of Directive 2014/53/EU [i.9] states:

"Radio equipment shall be constructed so as to ensure….an adequate level of electromagnetic compatibility as set out in Directive 2014/30/EU."

NOTE 2: Article 3.2 of Directive 2014/53/EU [i.9] states:

"Radio equipment shall be so constructed that it both effectively uses and supports the efficient use of radio spectrum in order to avoid harmful interference."

As the basic RIS promise is to manipulate electromagnetic attributes in a wanted way, there is a need to consider RED essential requirements in particular. Thus, the following radio parameters are of interest according to ETSI EG 203 336 [i.1].

Table 4.5.1-1: RIS related essential requirements

[i.1]	Essential RF parameter of interest	RIS correspondence
5.2.2	Transmitter power limits	Reflected/penetrated (see note 2) signal power limits
5.2.3	Transmitter power accuracy	To Be Defined if RIS offers power control capabilities
5.2.4	Transmitter spectrum mask	Reflected/penetrated signal spectrum mask
5.2.5	Transmitter frequency stability	To Be Defined if RIS offers carrier frequency manipulation capabilities
5.2.6	Transmitter intermodulation attenuation	Reflected/penetrated signal quality
5.2.7	Transmitter unwanted emissions	Reflected/penetrated unwanted emissions (incl. out of band and spurious domain emissions)
5.2.8	Transmitter time domain characteristics	NA
5.2.9	Transmitter transients	NA
5.3	Receiver parameters	NA (see note 1)
NOTE 1: Receiver parameters are not to be considered, as RIS does not offer dedicated reception performance, however, if so, its performance is sufficiently determined by above listed reflected (or repeated) signal performance, as the sole goal of it is the reconfigurable reflection (or repetition) of the impinging radio signal. NOTE 2: Depending on the deployment scenario the RIS is either configured to reflect the wanted impinging signal or to penetrate to its back when applied as transparent surface.		

4.5.2 Functional test approach consideration

In table 4.5.1-1 listed essential requirements can be assessed (i.e. tested) in default RIS operation mode, i.e. while illuminated by a wanted signal of interest and optional co-channel, adjacent channel or out of band interference.

By default, measurements are done over the air, i.e. in an appropriate anechoic environment using dedicated feeds and measurement probes in terms of frequency range, bandwidth and measurement sensitivity and quality.

Figure 4.5.2-1 depicts the principle RIS performance assessment setup. The impinging wave, provided by a wanted signal feed over the air, will be reflected by the RIS under test in a wanted way. The essential requirement parameters are evaluated at the maximum of the reflected wave in terms of EIRP. This is called maximum reflected EIPR (Max R-EIRP). The maximum reflected EIRP is composed of all N components (e.g. RIS unit cells) involved, determined by the impinging wave path g_n, the reflection coefficient $\alpha_n e^{j\theta_n}$ and the reflecting wave path h_n.

The feed of wanted and interfering signal is for further study and depends on the RIS use cases to be considered for regulatory performance assessment. Furthermore, unwanted emission assessment can not be limited to the wanted reflecting angle only.

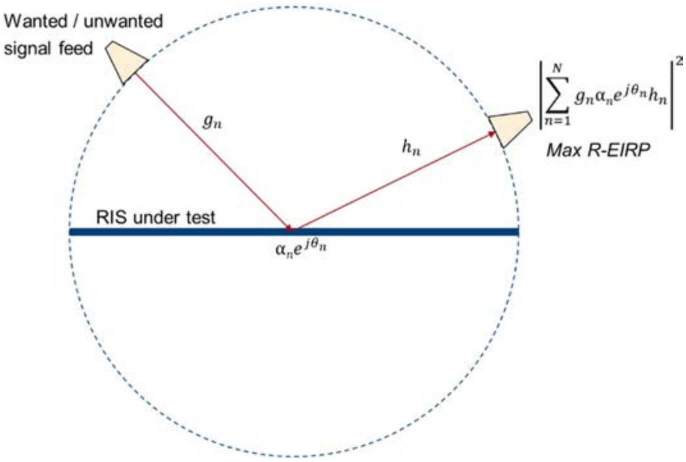

Figure 4.5.2-1: Principle RIS OTA assessment setup