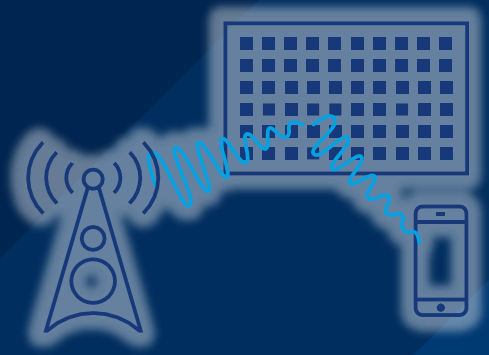
6G RIS

SHAPING THE RADIO CHANNEL FOR BEST CONNECTIVITY

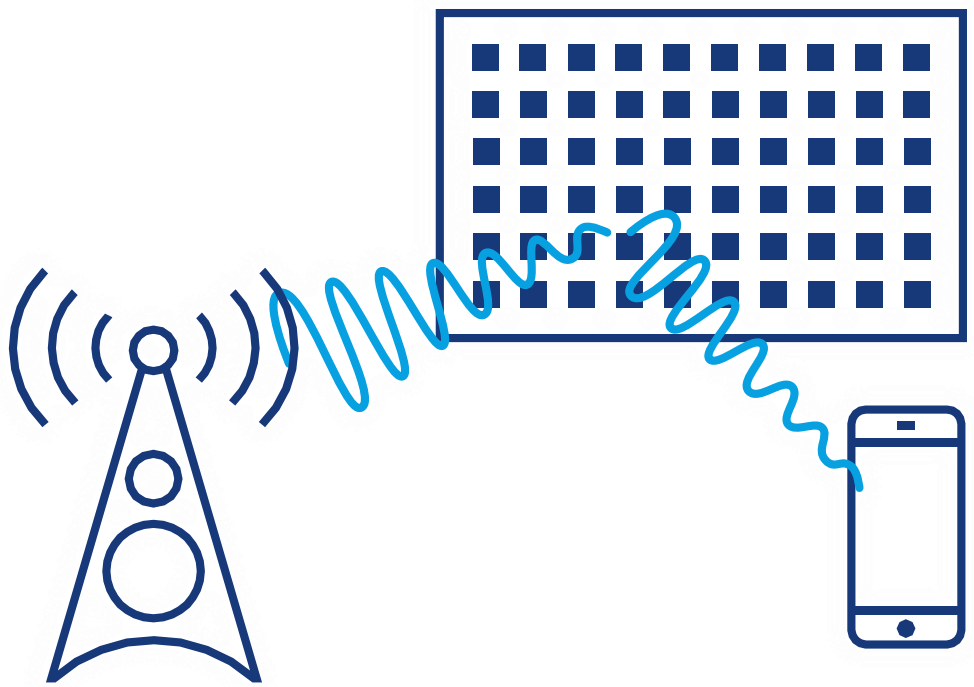


Heinz MELLEIN
Technology Manager Wireless Markets

ROHDE&SCHWARZ
Make ideas real

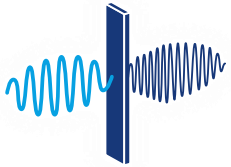
SCOPE

- 6G outlook
- Motivation for RIS
- What is RIS?
- How to measure RIS?
- Anything else about RIS?
- What does the industry think about RIS?
- R&S and RIS



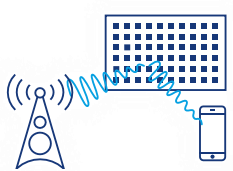
6G INNOVATION CANDIDATES

There is certain diversity on 6G technology candidates from different regions but majority seem common

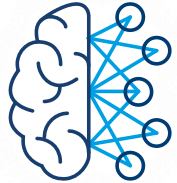


(sub)THz

JCAS

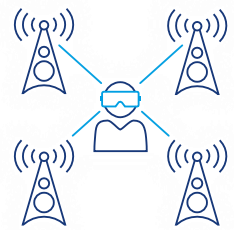


RIS

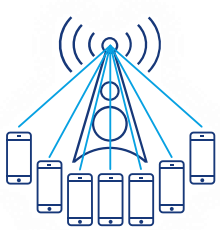


AI

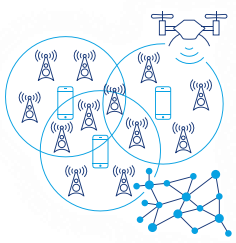
VLC



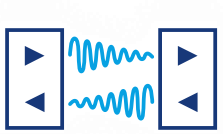
Extreme large-scale MIMO



Coding/modulation



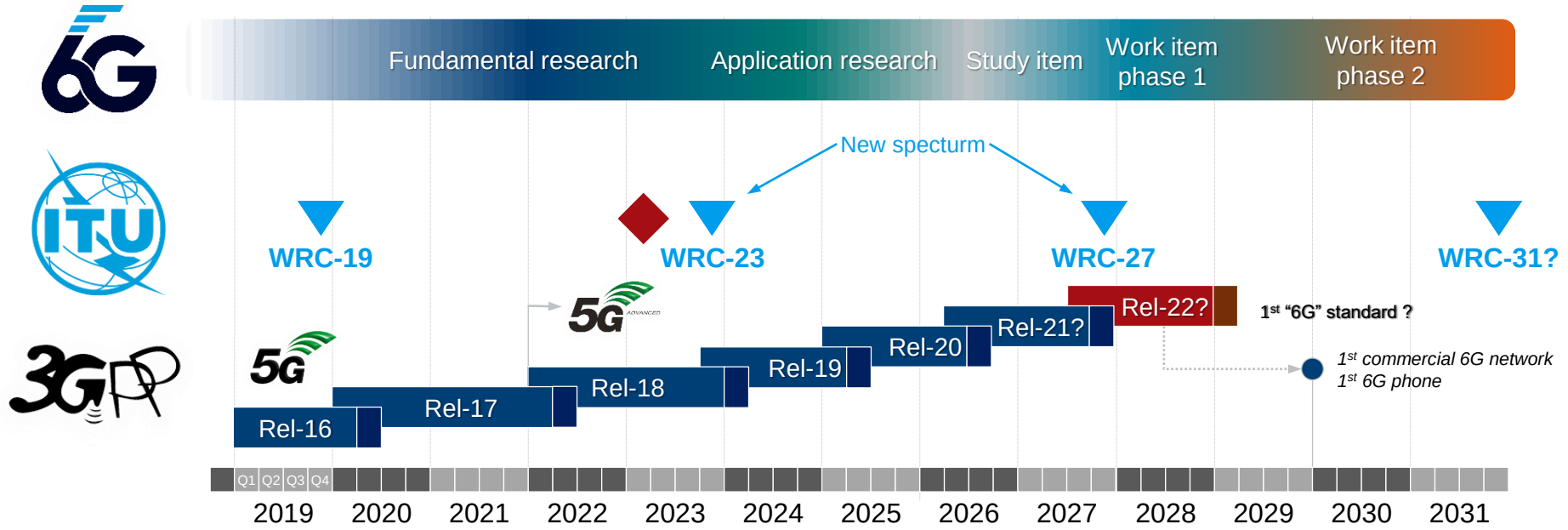
Network topology



Full duplex

Security

EXPECTED 6G ROADMAP



SCOPE

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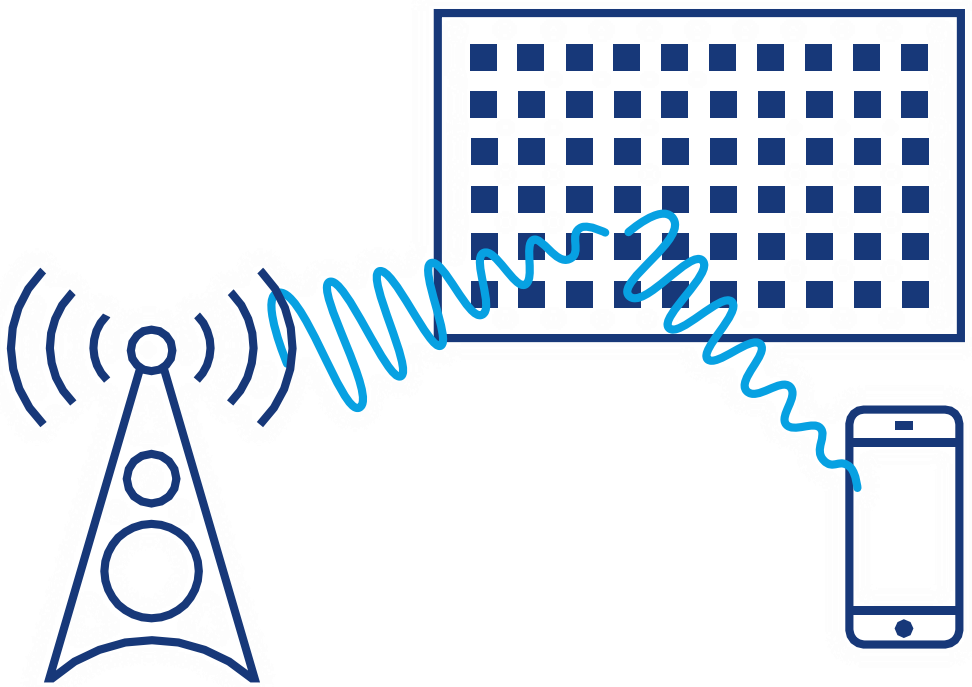


REMEMBER: IT IS ALL ABOUT CAPACITY (AND LATENCY) …

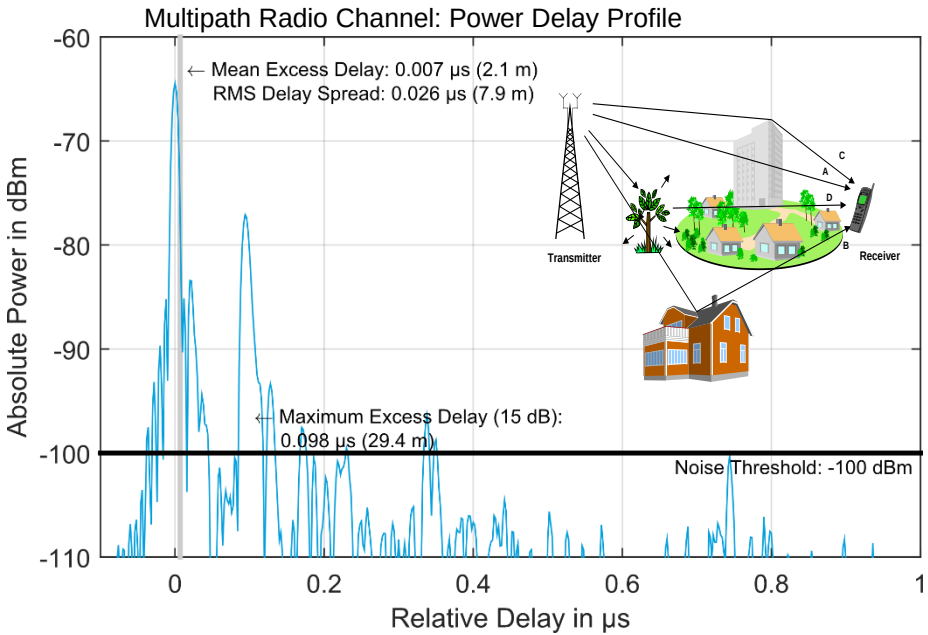
$log_2(1 + SNR)$*

$$\left[\frac{bps}{m^3}\right] = \left[\frac{bps}{Hz}\right] \cdot \left[\frac{node}{m^3}\right] \cdot \left[\frac{Hz}{node}\right]$$

Spectral efficiency	Radio node density	Bandwidth per node
• SNR optimized reception • MCS, MIMO • Interference control • … • … RIS ?	• DSS • Small cells • D2D • … • … RIS ?	• Carrier aggregation • mmWave spectrum • (sub)THz spectrum • … • … RIS ?

*Shannon-Hartley Theorem

… AND STILL THE SAME (MOBILE) RADIO CHANNEL

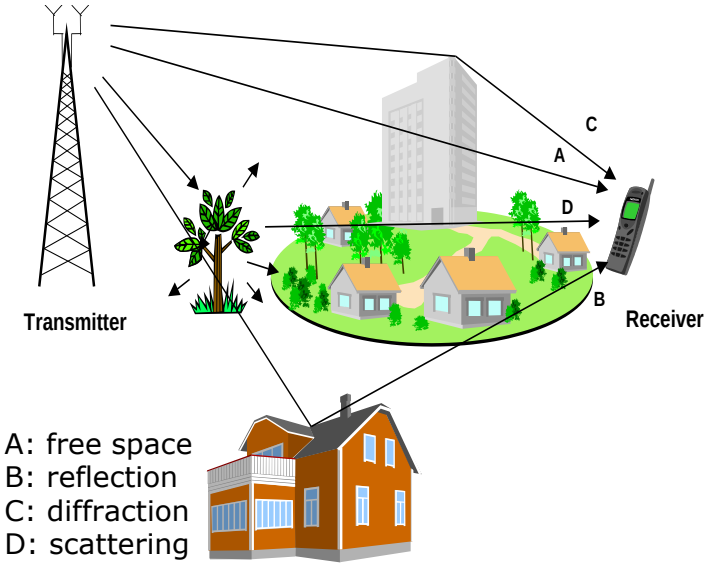


Taking advantage of multipath channels,
i.e. making use of SPACE:

RX Diversity: multipath reception
TX Diversity: spatial channel coding
MIMO schemes: spatial multiplexing
Adaptive beamforming: select the best path

However, what if there are
no suitable paths at all?

BASIC PROBLEM: SOLVE THIS EQUATION



$$\boldsymbol{r(t) = h(f,t)s(t) + n(t)}$$

What is the job of a radio communication designer, so far?

Design transmission schemes s(t) to target channel h(f,t)
e.g. CP-OFDM, MIMO, MCS etc.

Receiver‘s are optimized for the known transmission schemes, channel models and noise/interference assumptions.

In any case, so far, we take the radio channel as it is!
Now, RIS will allow to design the channel!

RIS PROMISE: PROGRAMMING THE ENVIRONMENT

- Current network design assumptions on the wireless environment
  - Set by the environment and cannot be „controlled“.
  - Wireless channel to be addressed by sophisticated transmission and reception schemes
  - Select BS locations accordingly (e.g. based on radio propagation measurements/simulations)
- Emerging paradigm towards next generation of wireless communication
  - Breaking free from the postulate that regards the wireless environment as “uncontrollable”
  - Introduce means to allow „programming“ the wireless environment
  - Simple model of the RF multipath environment: Assembly of reflecting/diffracting objects
  - First choice: Reconfigurable Intelligent Surfaces (RIS)
  - Enabling technology: Metamaterial

- **Smart Radio Environment (SRE), SW Defined Environment (SDE) ?**

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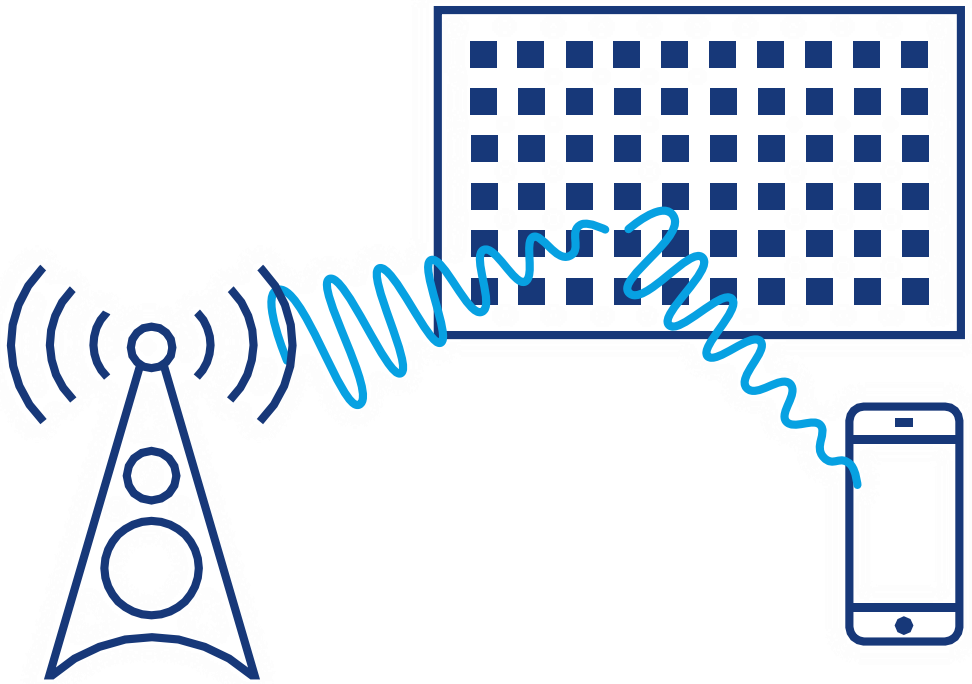
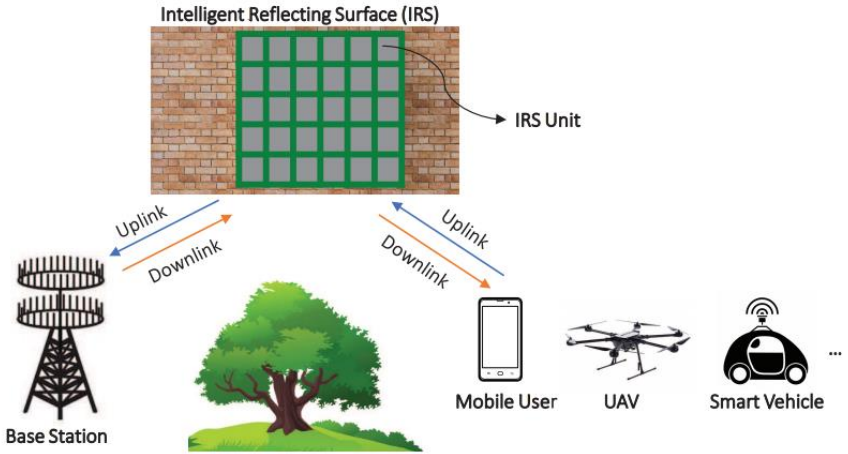


RECONFIGURABLE INTELLIGENT SURFACES

PROMISING TECHNOLOGY FOR FUTURE WIRELESS COMMUNICATIONS

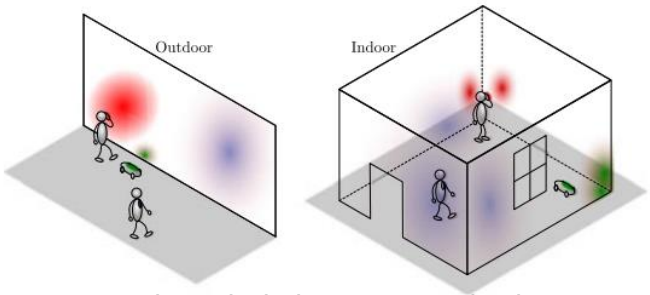
- RIS or intelligent reflecting surface (IRS) tune wireless environments to increase spectrum and energy efficiencies
  - Reconfigurable reflect arrays
  - Liquid crystal meta-surfaces
  - Programmable meta-materials



RIS-aided wireless communications

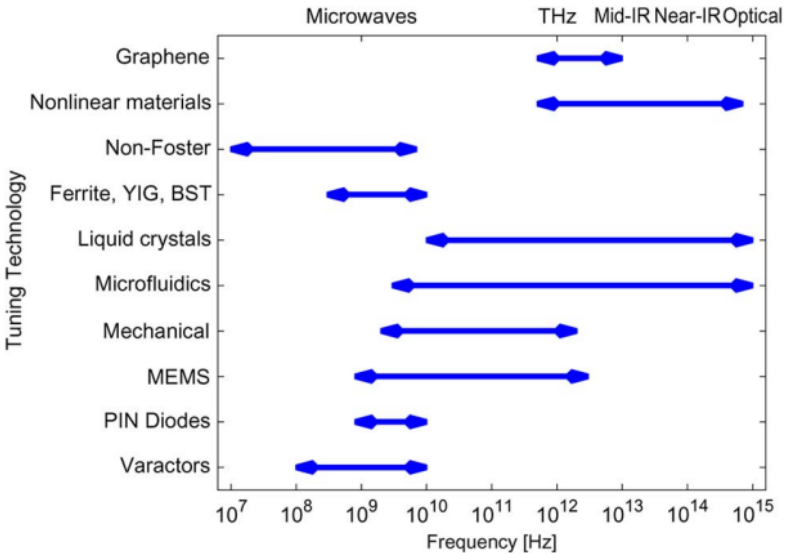
"man-made structures become more and more electronically active, with integrated electronics and wireless communication making the entire environment intelligent"

Source: IEEE TRANSACTIONS ON SIGNAL PROCESSING, VOL. 66, NO. 10, MAY 15, 2018



RIS-based wireless communications

META-MATERIALS REVIEW



Tuning Technologies for reconfigurable meta-materials vs. operation frequency

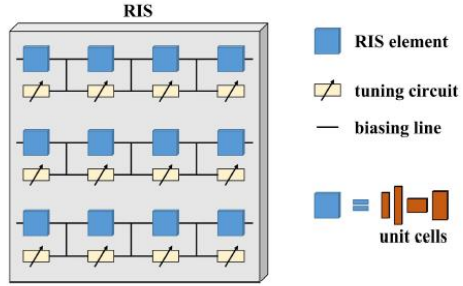


Fig. 2. *Conceptual architecture of an RIS.*

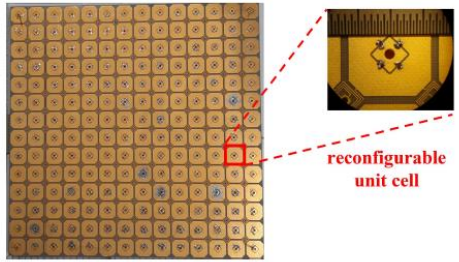
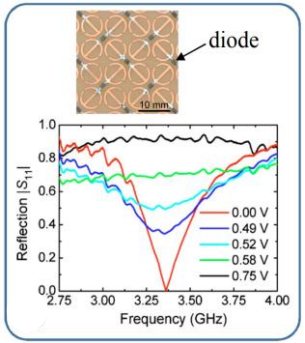
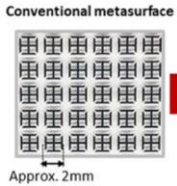
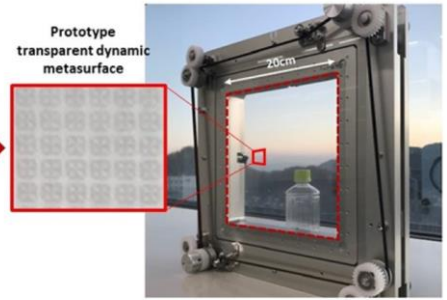


Fig. 3. *Example of manufactured RIS made of 196 identical elements (unit cells) and four voltage-controlled varactors for each cell [30].*



Reflection control with varactors





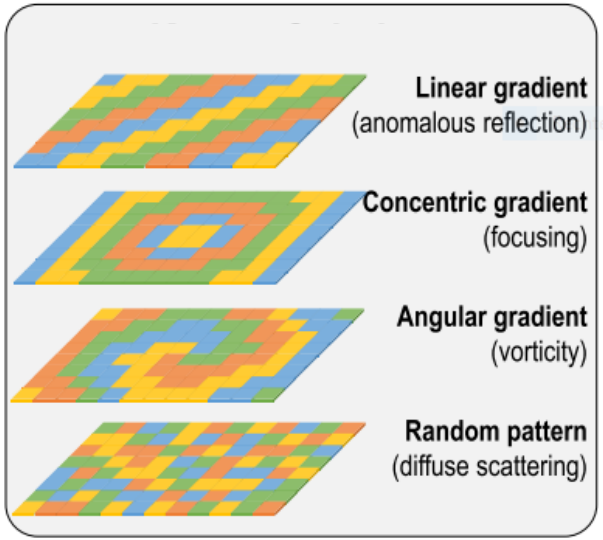
Prototype of transparent dynamic metasurface

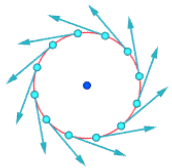
- VARACTORs (variable capacitors, e.g. used in VCOs or frequency multipliers)
- microelectromechanical systems (MEMS)

Source:Oliveri et al.: Reconfigurable Electromagnetics Through Metamaterials VA Review, Proceedings of the IEEE | Vol. 103, No. 7, July 2015

METAMATERIAL EM WAVE MANIPULATION CAPABILITIES

- Wavefront shaping
- Focusing
- Anomalous reflection
- Asymmetric transmission
- Polarization control
- Vorticity
- Absorption
- Diffuse scattering
- Frequency shifting
- Non-reciprocity





Source: ABADAL et al.: PROGRAMMABLE METAMATERIALS FOR SOFTWARE-DEFINED ELECTROMAGNETIC CONTROL; IEEE JOURNAL ON EMERGING AND SELECTED TOPICS IN CIRCUITS AND SYSTEMS, VOL. 10, NO. 1, MARCH 2020

KPI COMPARISON OF DIFFERENT RIS IMPLEMENTATIONS

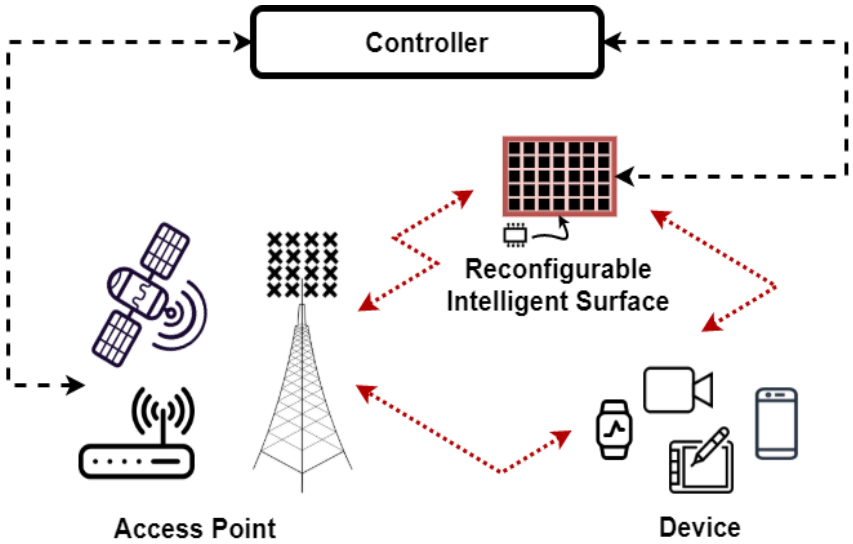
	RF-MEMS	PIN diodes	Varactor diodes	MOSFET	Photo-conductive	Ferro-electric	Liquid crystal
Working frequency (GHz)	<40	<110	<20	<200	/	/	>20
Working voltage	High	Medium	High	High	Low	Very high	High
Power consumption	Low	Medium	High	Low	Medium	Low	Low
Time to change codebook	µs	ns	ns	ns	µs	ms	ms
Insertion loss	Low	Medium	High	Medium	Medium	/	High
Digital/analog control	D	D	A	D	D	A	A
Cost	Medium	Low	High	Medium	/	High	/

Source: ETSI ISG RIS GR002

RIS IN STANDARDS

- **3GPP pre-R18-Workshop** ZTE Corporation, “Support of Reconfigurable Intelligent Surface for 5G Advanced,” RP-210618
- **IEEE** VESTEL Electronics Corp., “EHT via Reconfigurable Surfaces” IEEE 802.11-17/1720r1
- **3GPP** RIS was considered as part of 3GPP Rel-18 proposals discussions for 5G-Adv
- **3GPP** *Rel-18 Network controlled Repeater* ***SID: RP-213700 – TR 38.867, WID: RP-222673*** – *considered a steppingstone for RIS*
- **ITU-R IMT-2030** Future Technology Trends report https://www.itu.int/md/R19- WP5D.AR-C/
- **ETSI ISG RIS** a recently established ISG to review and establish global standardization for RIS technology
- **RISTA white paper on RIS** http://www.risalliance.com/RISTA-Reconfigurable%20Intelligent%20Surface%20Technology%20White%20Paper(2023).pdf
- **SIG** on RECONFIGURABLE INTELLIGENT SURFACES FOR SMART RADIO ENVIRONMENTS (**RISE**)
  - https://sites.google.com/view/ieee-comsoc-wtc-sig-rise
- **SIG** on REconFigurabLE Intelligent Surfaces for Signal Processing and CommunicatIONS (**REFLECTIONS**)
  - https://spcc.committees.comsoc.org/special-interest-groups/sig-reflections/
- **Emerging Technology Initiative** on Reconfigurable Intelligent Surfaces (**ETI-RIS**): https://riseti.committees.comsoc.org/
- **Best Readings** in RISs: https://www.comsoc.org/publications/best-readings/reconfigurable-intelligent-surfaces
- **IEEE Proceedings Special Issue** on RIS: https://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=5

ETSI ISG RIS DEFINITION OF RIS

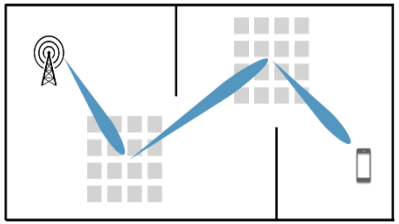


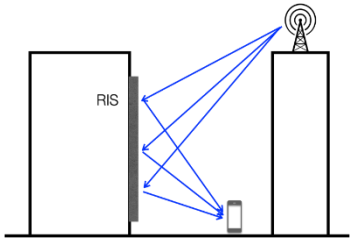
RIS is a new type of **network node** leveraging **smart radio surfaces**, whose **response** can be adapted to the status of the *propagation environment* through **control signalling**.

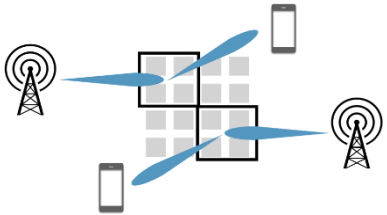
Source: ETSI ISG RIS GR001

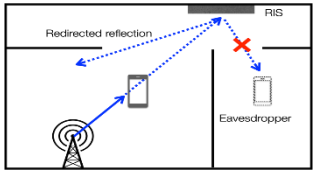
RIS USE CASES

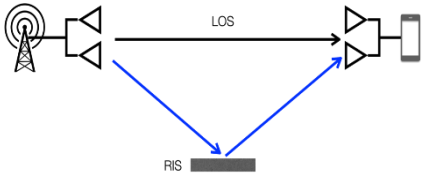
- Coverage enhancement
- Spectral efficiency improvement
- Beam management
- Secure communication
- Localization accuracy
- Sensing capabilities
- Energy efficiency











Source: ETSI ISG RIS GR001, GR002

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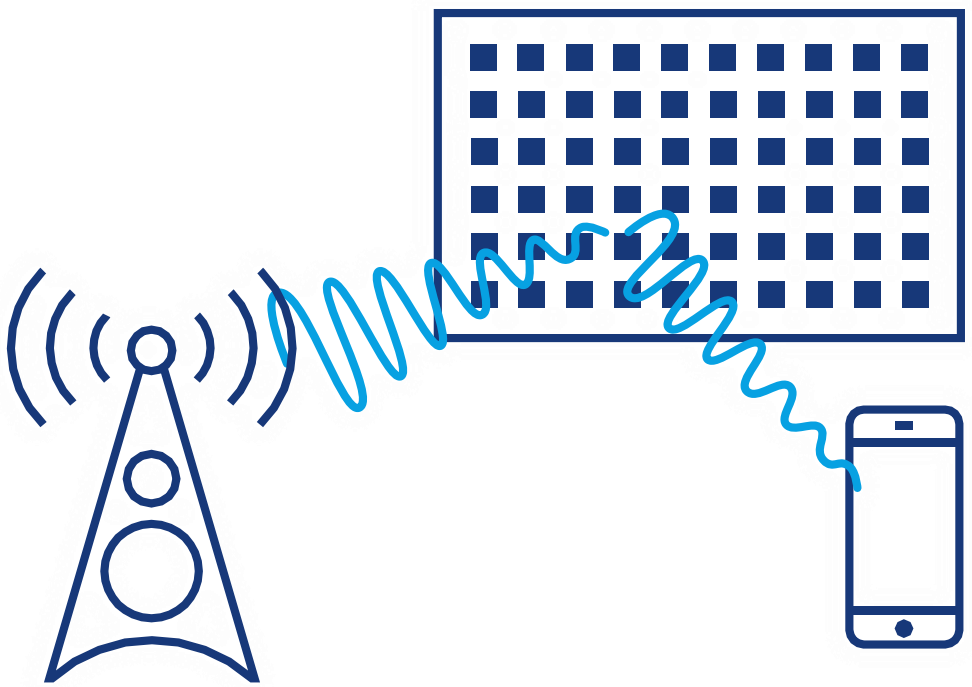
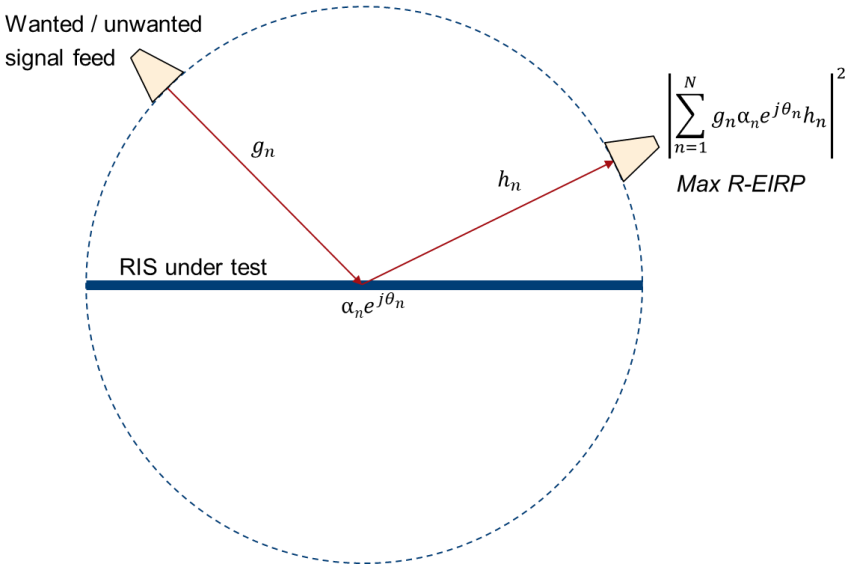


RIS TESTING MEANS OVER-THE-AIR TESTING



ETSI ISG RIS GR002: Principle RIS OTA assessment setup

Source: ETSI ISG RIS GR002

Relevant RF testing areas:

Regulatory testing
e.g. according to RED

EMC testing
e.g. according to CISPR32

Conformance testing ???
e.g. according to 3GPP?

3D RIS ASSESSMENT IN ANECHOIC CHAMBER

„Regarding RIS as an intelligent antenna“

Feed signal generation
e.g. R&S®SMW200A
vector signal generator

Feed path

SGH
e.g. R&S TC-SGH40

e.g. R&S TC-TA85CP
Probe

Measurements
e.g. R&S®FSW signal
and spectrum analyzer

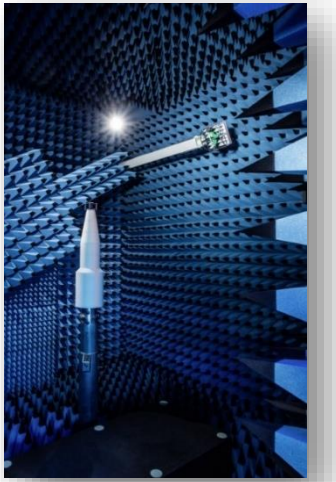
Elevation measurement range
according to RIS configuration

Measurement SW: e.g. R&S®AMS32

Incident angle

RIS under test

Turn table



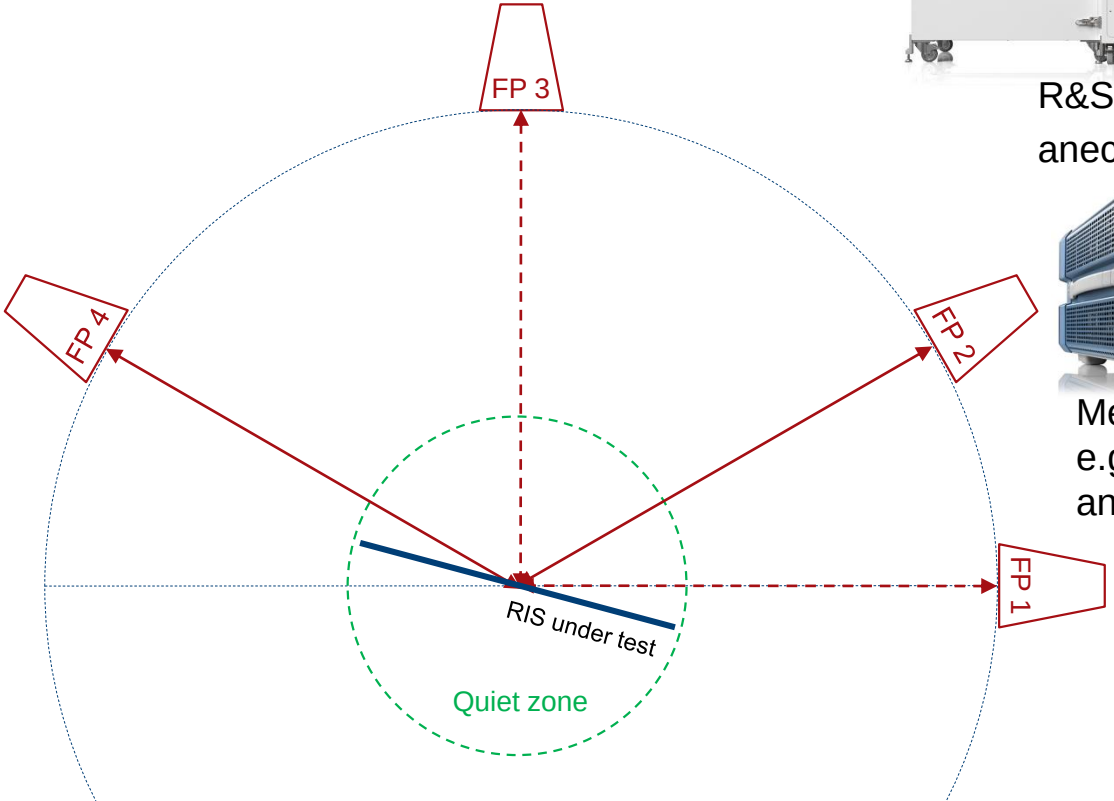
MULTI-ANGLE RIS ASSESSMENT SETUP

„Regarding RIS as an intelligent reflector“

R&S®ATS1800M
anechoic chamber

Feed signal generation
e.g. R&S®SMW200A
vector signal generator

Measurements
e.g. R&S®FSW signal
and spectrum analyzer



Turning of RIS allows
any impinging wave angle

FP = Feed or Probe

RIS PERFORMANCE TEST

„Regarding RIS as a network node“

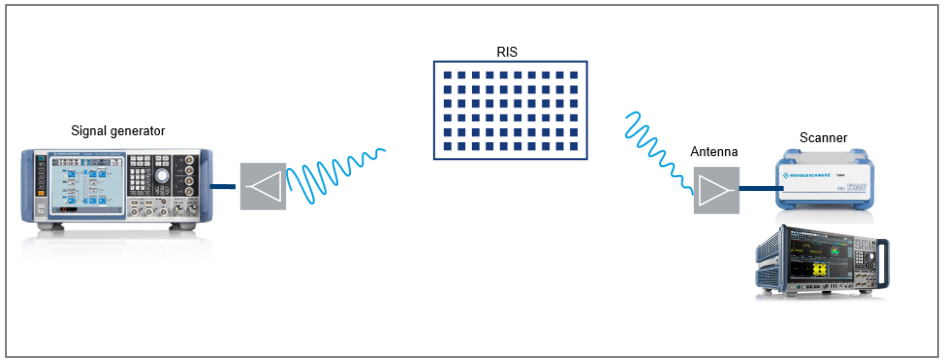
Signal quality measurements based e.g. on 3GPP or IEEE WLAN signals:

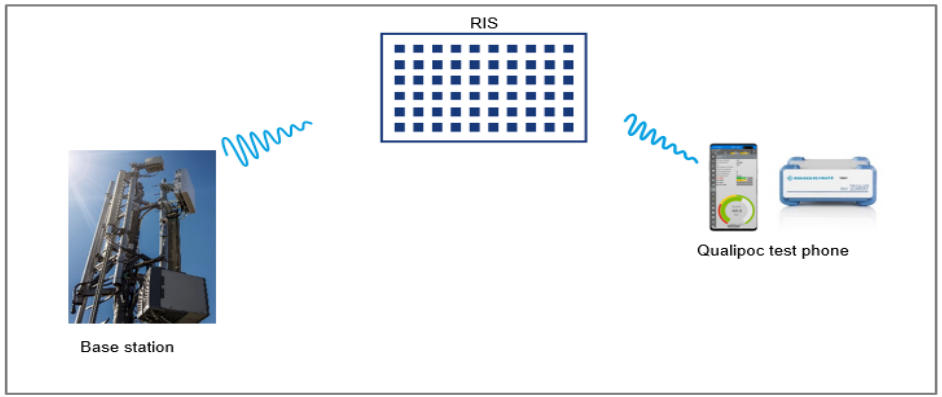
- EVM
- BER/BLER
- etc.

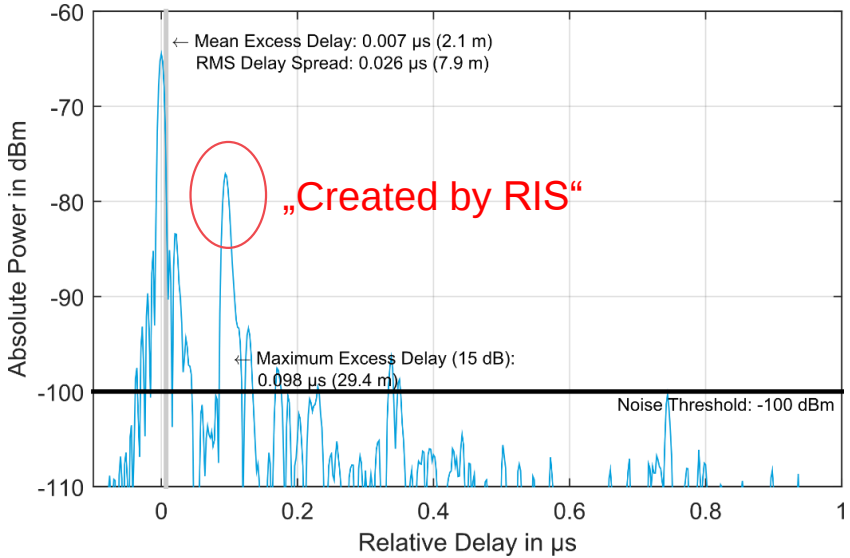
To assess possible (unwanted) signal quality degradation by RIS!

CHANNEL SOUNDING AND COVERAGE MEASUREMENTS

„Regarding RIS as a radio channel component“







Channel sounding with dedicated sounding signals or in live network !

Rohde & Schwarz

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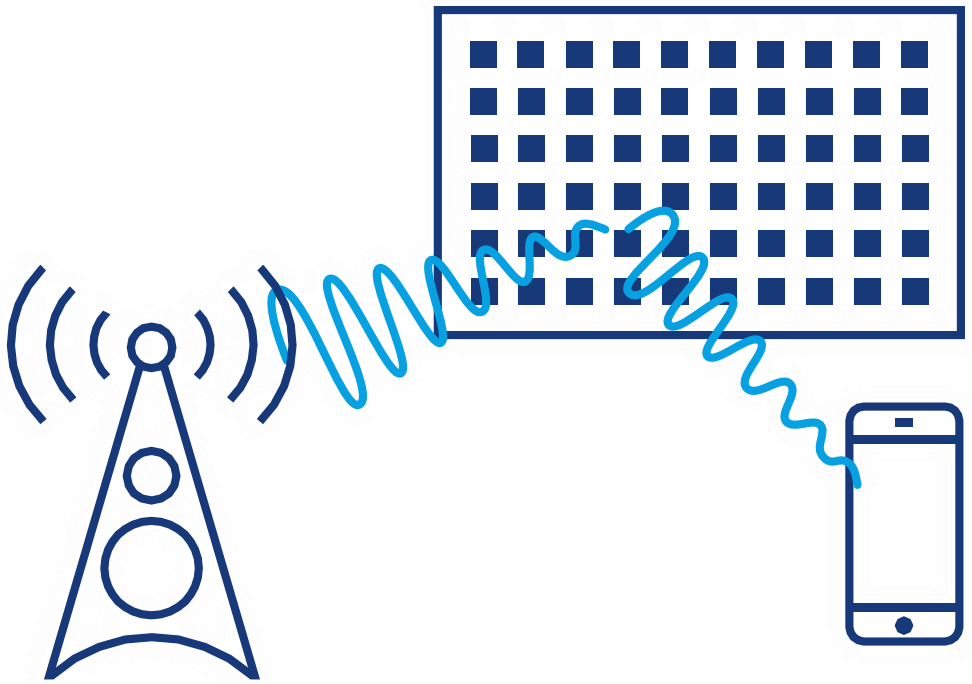
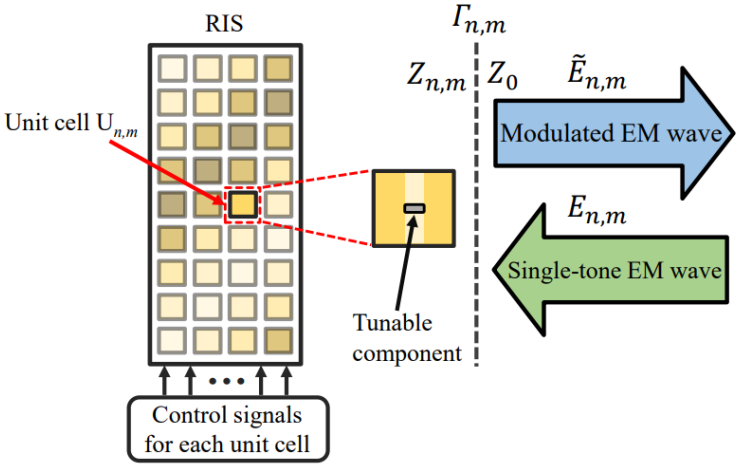
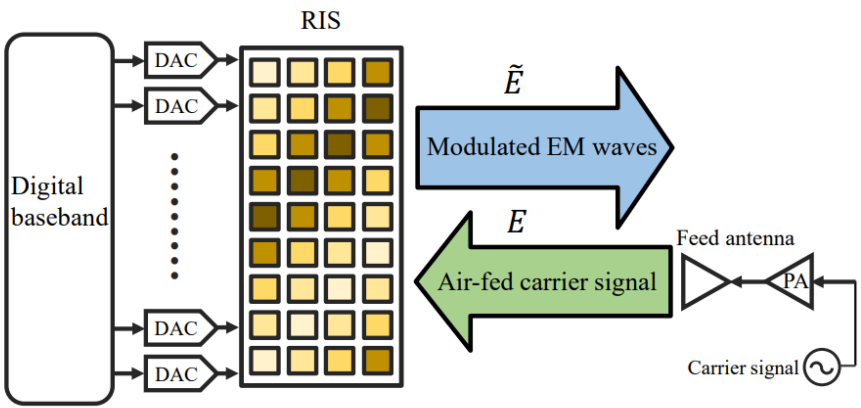


RIS BASED MODULATION AND MIMO



amplitude and phase modulation on the air-fed carrier signal

→ RIS-based modulation



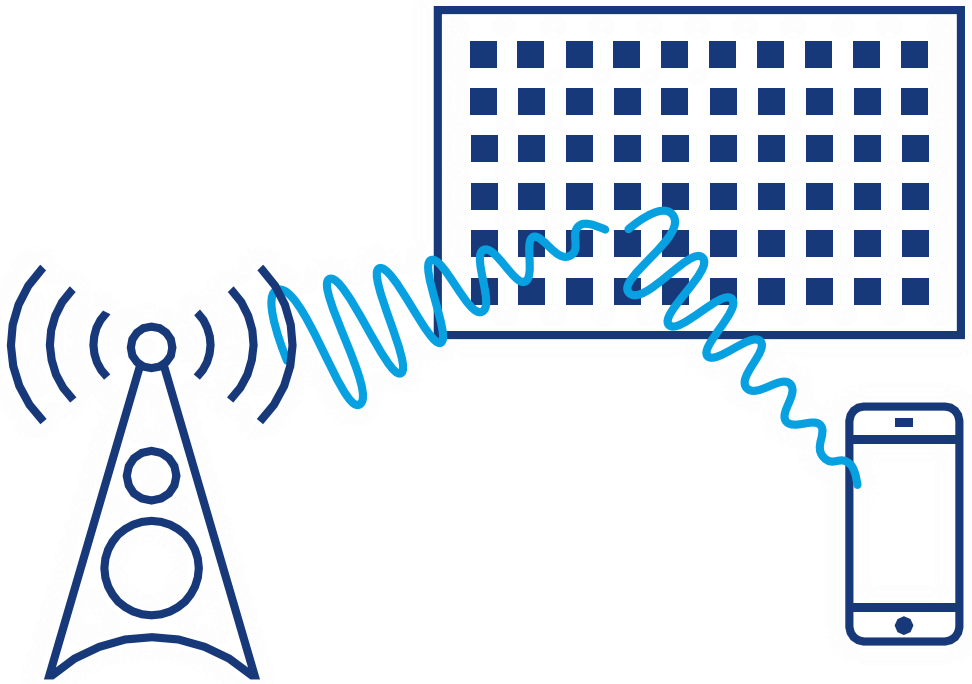
each unit cell can be controlled independently

→ RIS-based MIMO

Source: MIMO Transmission through Reconfigurable Intelligent Surface: System Design, Analysis, and Implementation; Wankai Tang, Jun Yan Dai, Ming Zheng Chen, Kai-Kit Wong, Xiao Li, Xinsheng Zhao, Shi Jin, Qiang Cheng, and Tie Jun Cui; ResearchGate

SCOPE

- 6G outlook
- Motivation for RIS
- What is RIS?
- How to measure RIS?
- Anything else about RIS?
- **What does the industry think about RIS?**
- R&S and RIS



Press Releases

November 12, 2021

NTT and NTT DOCOMO Trial First Use of User-tracking Metasurface Reflector for Extreme Mobile Coverage in Current 5G and Coming 6G Era

— Will enable high-speed millimeter-wave communications indoors —

Metamaterials Could Solve One of 6G's Big Problems

By MARIOS POULAKIS
Huawei Technologies Sweden AB, 164 40 Kista, Sweden

ResearchAndMarkets.com

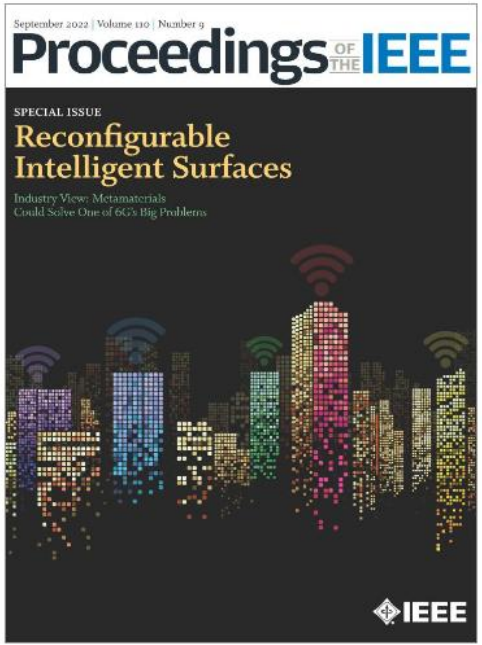
July 26, 2022 07:22 AM Eastern Daylight Time

DUBLIN--(BUSINESS WIRE)--The "6G Communications: Reconfigurable Intelligent Surface Materials and Hardware Markets: GHz, THz, Optical 2023-2043" report has been added to **ResearchAndMarkets.com's** offering.

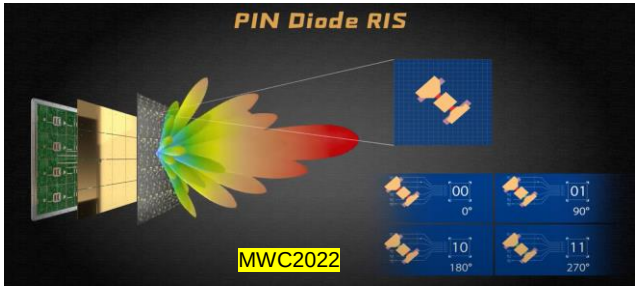
"6G Communications: Reconfigurable Intelligent Surface Materials and Hardware Markets: GHz, THz, Optical 2023-2043"

Huge emerging market for 6G reprogrammable intelligent surfaces

6G wireless communication coming in around 2030 needs new materials and devices not least "reprogrammable intelligent surfaces RIS" everywhere.



ZTE builds efficient way to 5G-Advanced and 6G with RIS solution



Source:https://www.youtube.com/watch?v=TBaUQ3YrPxc

QUALCOMM: PASSIVE MIMO

Source: Qualcomm Fierce Wireless webinar, November 2022

Air interface innovations

Evolution of duplexing schemes, Giga-MIMO, mmWave evolution, reconfigurable intelligent surfaces, non-terrestrial communications, waveform/coding for MHz to THz, system energy efficiency

Rohde & Schwarz

SELECTION OF RIS PROTOTYPING

- **NTT DOCOMO** demonstrated metasurface reflective array-aided 5G mmWave system
  Press Releases: DOCOMO Conducts World's First Successful Trial of Transparent Dynamic Metasurface
- **MIT's RFocus** a software-controlled "smart surface"
  MIT News: A smart surface for smart devices
- **6GIC**'s metasurface prototype video demonstration at University of Surrey
  University of Surrey: Reconfigurable Reflecting Surfaces for 5G/6G
- **Orange Labs** reported RIS with continuous-type phase shifting capabilities
  https://ieeexplore.ieee.org/document/9473842
- **ZTE** launch of RIS solution at MWC 2022
  ZTE builds efficient way to 5G-Advanced and 6G with RIS solution
- **NEC Laboratories Europe** working prototype of fully passive smart surface
  Smart surface technology for 5G and beyond wireless connectivity

Source: ETSI ISG RIS

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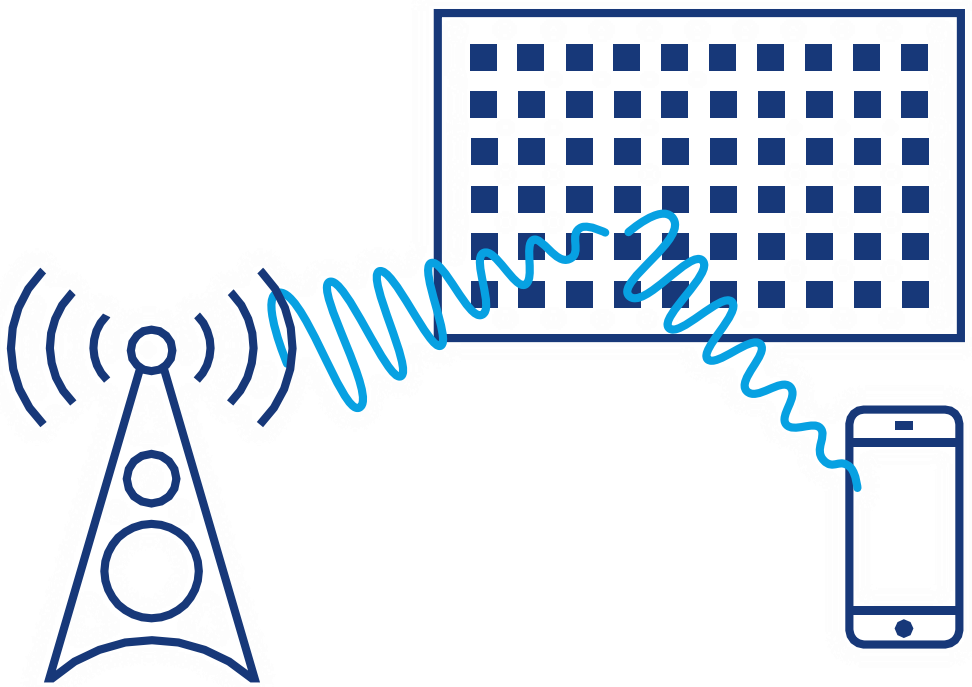

R&S AND RIS

- Our portfolio includes all ingredients to test RIS today:
  - RF signal generators
  - RF signal and network analysis
  - Anechoic chambers, feed antennas, antenna measurement systems etc.
  - Channel sounding solutions
  - Coverage measurement systems
- We are engaged in a number of research projects related to RIS, e.g. 6G-LICRIS
- We are active member in standadization of RIS related topics, e.g. ETSI ISG RIS, 3GPP, IEEE, RISTA

- Check out at www.rohde-schwarz.com/wireless/6G

TAKE AWAY

- Academia and key industry players are exploring the boundaries and started looking into next generation of wireless communication aka 6G.
- Reconfigurable intelligent surfaces, enabled by metamaterials, are judged one important out of several key technology components to enhance radio coverage, spectral efficiency, reduce power consumption and tackle radio propagation challenges.
- Rohde & Schwarz is actively engaged in this research topic, contributing our expertise in test and measurement for all aspects related to this promising technology.

Find out more

www.rohde-schwarz.com/wireless/6G

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Make ideas real