ZTE Reconfigurable Intelligent MetaSurface for More Sustainable and High Performance 5G and Beyond

Challenges Facing 5G-Advanced and Beyond

With the acceleration of 5G commercialization, research on 5G-advanced and 6G communication systems is in full swing. On the path ahead, there are still challenges facing the industry.

On one hand, the conventional network deployment is insufficient for seamless coverage because the wireless environment is generally assumed uncontrollable and often an impediment to be reckoned with. For example, signal attenuation limits the network connectivity, multi-path propagation results in fading phenomena, reflections and refractions from objects are a source of uncontrollable interference. Nevertheless, network construction cost and energy consumption are high.

On the other, for 5G and beyond, some new promising services and applications that are hungry for high speed, large bandwidth, and low latency, are foreseen. such as mixed reality (XR), holographic rendering, sensing, positioning, and wireless medical services. The contradiction between huge capacity requirements and scarce spectrum resources has been markedly exacerbated.

While 5G is still grabbing all the headlines, telecom industry facing above challenges is already looking ahead to even more advances in technology after the 5G era. RIS (Reconfigurable Intelligent metaSurface) has emerged as a strong candidate technology for 5G-
Advanced and 6G mobile networks and has attracted worldwide attention from both academia and industry.

Large
capacity

High
speed

Low
latency

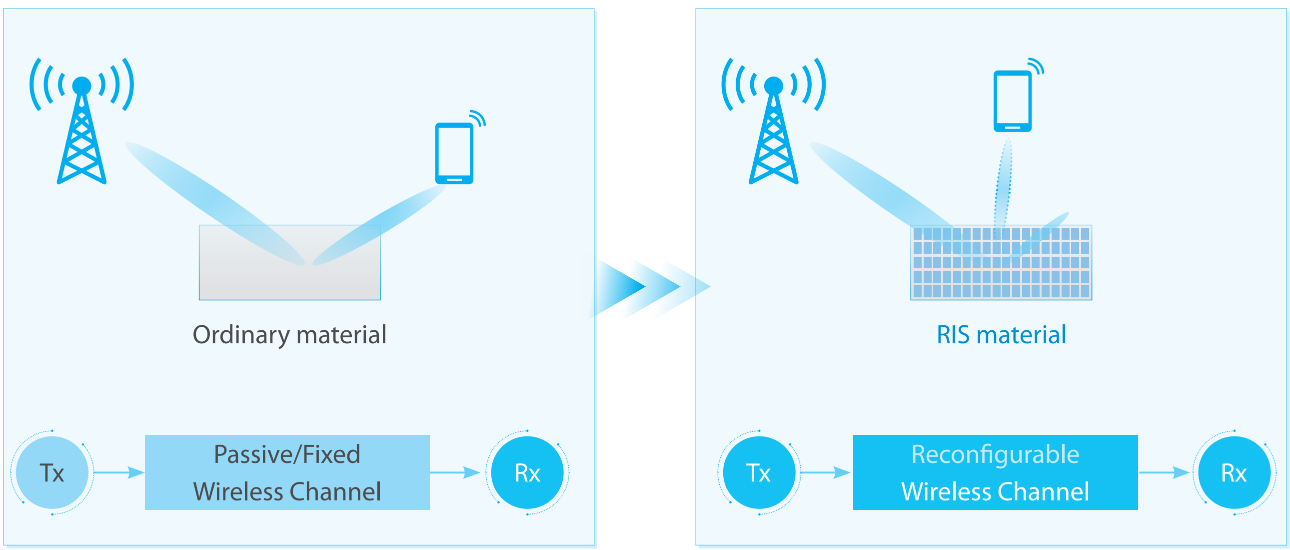
RIS, a Cutting-edge Innovation for Next Generation Networks

Reconfigurable Intelligent metaSurface (RIS) is an up-and-coming innovative technology with commercial prospects in 5G-Advanced and 6G, on enhanced performance, low cost, easy deployment, and greener, low-carbon networks. promoting the sustainable evolution of 5G and beyond.

RIS Reshapes the Wireless Environment

The basic principle of RIS is to construct an intelligent and controllable environment by manipulating the electromagnetic property of metamaterials through digital programming with tremendous flexibility.

Different from the ordinary materials which follow Snell's Law (the angles of reflection and incidence signals are equal and cannot be changed), RIS utilizes electromagnetic (EM) meta-materials to control the direction, width, and number of EM waves, then achieving accurate reflection or penetration. RIS breaks the bottleneck of conventional wireless system limited by the environment, from passive adaptation to reconfiguration of the wireless channel.



RIS is an Integration of Meta-materials and Mobile Communications Technology

By definition, a meta-material is any material engineered to possess a property that cannot be found in existing materials in the universe. However, the designed meta-material needs to be digitally controlled to obtain the desired functionalities.

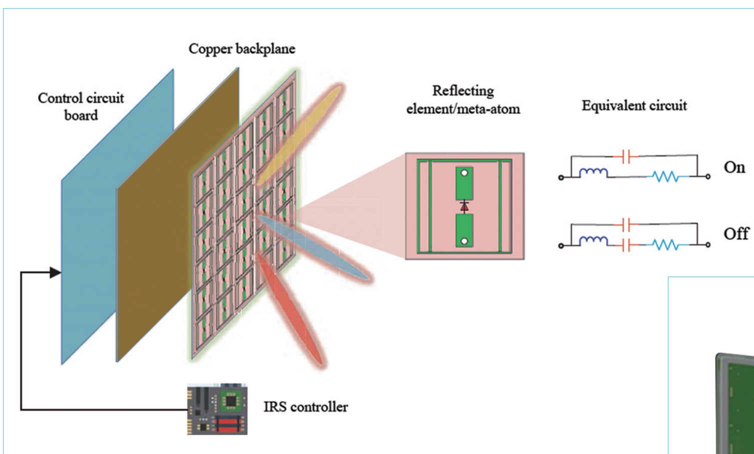
RIS is a 2D planar structure surface consisting of an array of passive scattering elements based on meta-material, each of which can independently impose the required phase shift, and possibly an amplitude gain, on the incident EM waves. By carefully adjusting the phase shifts and the amplitudes of all the scattering elements, the reradiated electromagnetic waves can be shaped to propagate towards specified directions, with the help of an attached RIS controller. In this way, it can establish so-called alternative links within a cell using RIS and allow communication in non-line-of-sight (NLOS) scenario.

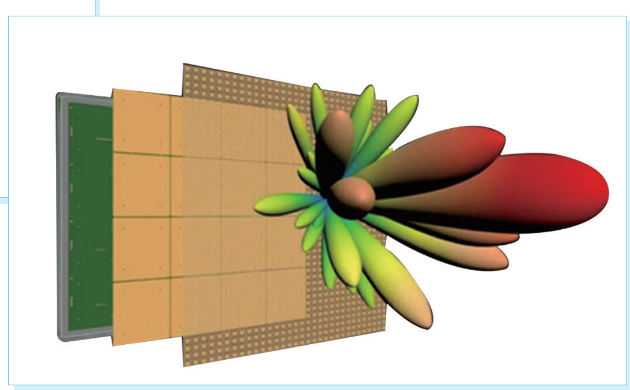
As specific coding sequences of the meta-material create the ability to manipulate EM waves, the RIS starts with an array composed of multiple antenna elements to which the opposite phase concept is added through a 2-bit coding approach. This design provides phase control to each antenna element independently and various codebooks are available to address multiple beamforming options. Put another way, the coding manipulates EM waves through different sequences of 0 and 1 that affect the phase and therefore the direction of the beam, which can be adjusted in 3 distinct modes:

- **Static:** the initial adjustment remains constant
- **Semi-static:** the beam can be adjusted but not in real time
- **Dynamic:** real-time beam adjustment

It's also worth noting that power consumption is zero in static mode and remains low in semi-static and dynamic modes.

The typical structure of RIS consists of three layers. The outer layer is the metaSurface composed of a large number of passive reflecting elements to directly reflect the incident signals. The middle layer is a copper plate that is used to avoid the leakage of signal energy to enhance the reflecting efficiency. Last, the inner layer is a control circuit board that is responsible for adjusting the reflection amplitude / phase of each element.





ZTE is Leading Applying RIS into the 5G Networks and the RIS Ecosystem

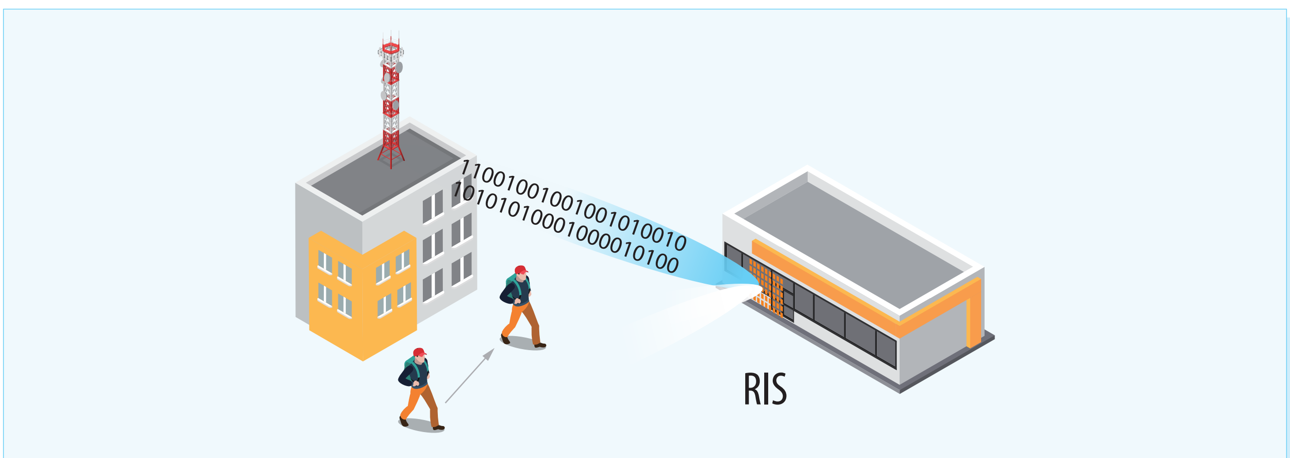
ZTE is the first vendor with RIS prototype test and the first company in the industry to apply RIS technology to expand the spatial freedom of 5G base station signals. ZTE is leading the RIS ecosystem with advanced algorithm, diverse portfolio, comprehensive partnership, and standardization.

Advanced Algorithm

The basic principle of RIS is to construct an intelligent and controllable environment by manipulating the electromagnetic property of metamaterials through digital programming with tremendous flexibility.

ZTE has conducted in-depth research on core algorithms like precoding design, dynamic beam tracking, automatic codebook optimization, etc. Especially, ZTE has innovatively launched coordinated beamforming technology between 5G base stations and dynamic RIS. 5G base station transmits beam ID and other information to RIS through the 5G air interface, instructing RIS to select and switch beams automatically, and realize dynamic beam scanning and user tracking, which significantly improves the coverage of base stations and ensures that the users always have seamless connectivity even during movement.

The core of this technology is that the base station delivers information such as beam IDs to the dynamic RIS through the air interface to guide it to dynamically select and switch beams to achieve dynamic beam scanning and beam tracking.



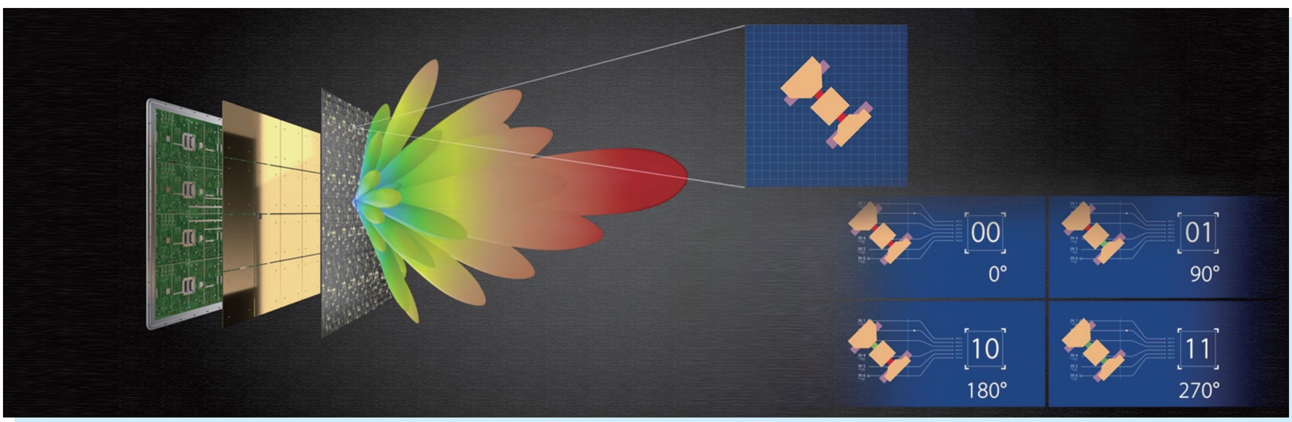
Diverse Portfolio

Depending on the use case and its environment as well as the beam adjustment mode, ZTE has launched diverse RIS product portfolio by exploring a variety of materials, mainly including 3 types of RIS prototypes: PIN diode RIS, liquid crystal RIS, transparent RIS. ZTE RIS prototype products cover Sub-6GHz to mmWave frequency bands (supporting 2.6G, 3.5G, 4.9G, 26G and 28G).

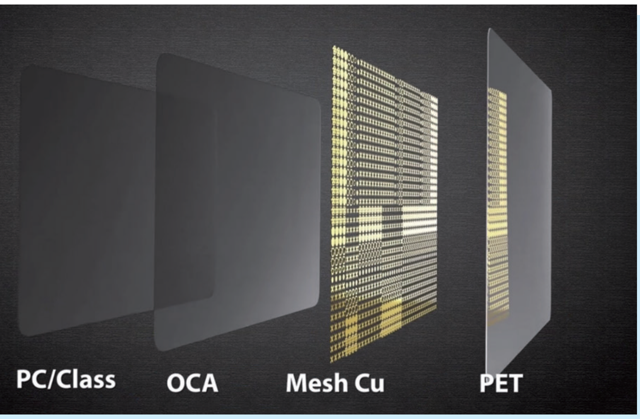
PIN Diode RIS:

the material is widely used as RF switches, attenuators, photodetectors and phase shifters, the PIN diode is the most mature component to build a reconfigurable intelligent meta-surface; it features nanosecond switching speeds, which make it suitable for the dynamic mode.

The principle is that on each reflecting element or unit cell, there will be one or two PIN diodes to control the phase of each cell. With and without a voltage, PIN diode has two statuses On and Off, which can be represented by binary digits 0 and 1. These two statuses can be corresponding to 0° and 180° phase shifts respectively. Similarly, Two PIN diodes can represent 4 phase shifts. Then the combination of the phase shifts of all unit cell will eventually form a beam with a specific direction and width. The digital sequence of all diodes is called the codebook, which can be used to control the RIS beam.

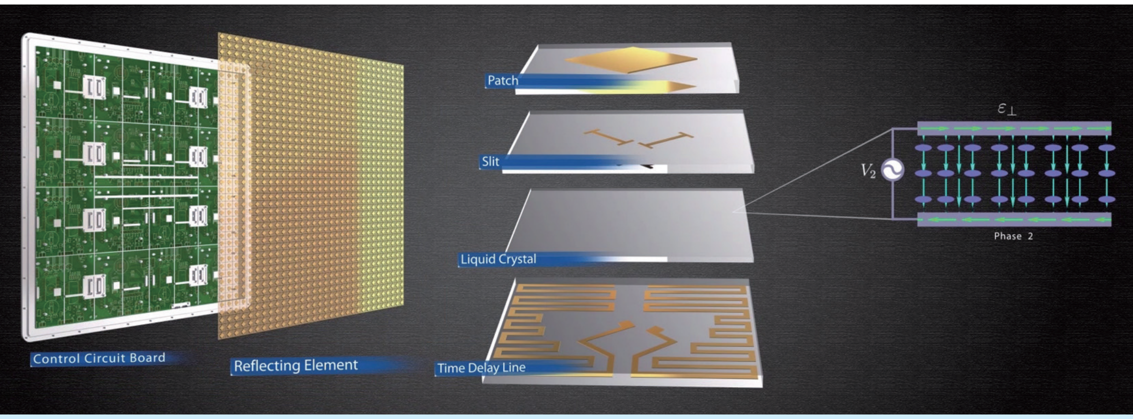


Transparent RIS:
Metals are usually opaque, but when the metal is thin enough, light transmission can be achieved. In transparent RIS, we etch copper mesh on a transparent substrate (glass or PC) to achieve the transmission of electromagnetic waves and visible light.



Liquid Crystal RIS:
liquid crystal is a low-cost low-power element widely used for TV screens, boasts a millisecond switching speed that makes it suitable for semi-static RIS applications.

Like PIN diode, in the liquid crystal RIS, we also control the state of the liquid crystal by application of different voltages. When there is no voltage, the liquid crystal molecules are parallel to the substrate. When a small voltage is applied to the liquid crystal, the liquid crystal molecules begin to turn, and finally can be perpendicular to the substrate. Liquid crystal molecules in different orientations can achieve different signal delays, thereby realizing phase shift.



Standard Contributor

Enterprises, scientific research institutions, colleges and universities, and organizations have carried out research, standardization, and industrialization of RIS-related technologies, to jointly build the RIS ecosystem and promote the development of the RIS industry.

Milestones in RIS industry are as follows:

- 2020.6 In IMT-2030 (6G) Promotion Group of China, the RIS task force was established.
- 2020.7 In IEEE, the emerging technology initiative (ETI) of RIS was formed.
- 2021.9 In ETSI, the industry specifications group (ISG) was kicked off.
- 2022.4 The RIS Technology Alliance (RISTA) was established.

ZTE is an active standard contributor and industry promoter in RIS. ZTE has taken the lead in initiating RIS projects in CCSA WG6, IMT-2030, ETSI RIS ISG, 3GPP and so forth. In addition, ZTE is a founder member of the RIS TECH Alliance (RISTA) established in April 2022. The RISTA is a cross-industry, open, and non-profit social organization that is formed by enterprises, public institutions, associations, colleges and universities, and scientific research institutes related to RIS.

ZTE is Leading the Verification of Both Static and Dynamic RIS Prototypes

It started in 2021 when ZTE and three mobile operators in China successfully completed the first stage of static RIS technology prototype verification, and initially explored the feasibility of RIS technology to improve fixed-point coverage in 5G blind spots and other weak areas.

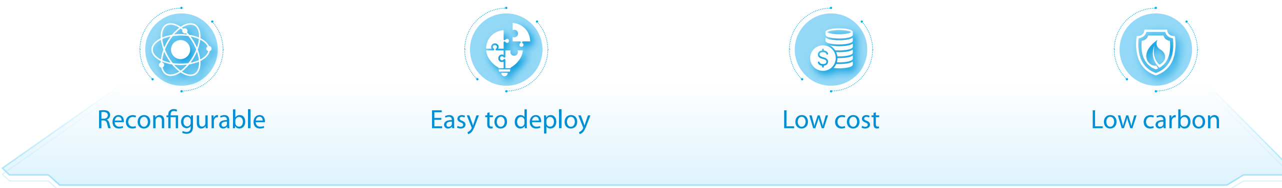
Then in 2022, ZTE and the China Mobile Research Institute conducted the test of a dynamic RIS prototype equipped with collaborative beamforming capabilities and achieved the industry's first technical verification both in the laboratory and in the field.

In both lab and field testing, it was verified that the beam of the RIS could accurately follow the user in real time, and that the signal strength and rate remained stable. Compared with verification results from the first-stage static RIS technology prototype verification, which can only improve fixed-point coverage, the dynamic RIS collaborative beamforming technology greatly improved the BTS coverage and supported seamless user connections in mobile scenarios.

- 2022.10 Europe’s First 5G Base Station and Dynamic RIS Collaborative Beamforming Verification @Italy
- 2022.8 Industry’s First 5G Base Station and Dynamic RIS Collaborative Beamforming Verification with China Mobile @Shanghai
- 2021.9 Industry’s First 4.9GHz RIS Verification with China Mobile @Beijing
- 2021.9 Industry’s First 2.6GHz RIS Cascade Verification with China Mobile @Beijing
- 2021.6 Industry's First 3.5GHz RIS Verification with China Unicom @shanghai
- 2021.6 Industry's First 5G mmWave RIS Verification with China Telecom @shanghai

The main advantages of ZTE RIS usage are:

- **Reconfigurable:** reshape the wireless environment and reconfigure the wireless channel to improve network performance without change 5G protocols and 5G terminals
- **East to deploy:** high adaptability to deployment environment; easy to expand or combine
- **Low cost:** no mixers, AD/DA, PA; reduce site density and network construction costs
- **Low Carbon:** low power consumption, reducing carbon emission; no noise, little electromagnetic radiation



Taking a macrocell BTS as a benchmarking baseline, ZTE's active RIS performance testing produced a 30% reduction in capex and power savings, and the deployment time was shortened by 50%.

RIS Will Be A Game Changer

RIS not only adds a new low-cost tool to the millimeter wave toolbox such that the promise of 5G can be truly realized. But also, RIS can do more than that: ZTE also demonstrated that it can deliver the same level of performance in the mid-band spectrum. And this is very good news since the pace of 5G rollouts continue to exceed that of 4G, both the demand for bandwidth and the users' expectations remains high.

There is a good reason to believe that every communications service provider (CSP) in the world should embrace the RIS to sustain high-capacity performance in as many venues as possible, both outdoor and indoor. Imagine yourself enjoying a video session over a 1Gbps pipe from a millimeter wave outdoor BTS, then moving inside without noticing any change, that's the real power of the RIS.

Moving forward, ZTE will work further with global industries, universities, and research institutes to build an open and innovative ecosystem for RIS and make more contributions to future wireless technologies that are applied in 5G-Advanced and 6G.

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