RIS Unit Cell with Continuous Amplitude and Phase Control for Millimeter-Wave OTA Measurement Platforms

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Summary

This paper proposes the design of a unit cell (UC) as the enabling element of the reconfigurable intelligent surface (RIS) for the application of future millimeter-wave over-the-air (OTA) measurement methods and platforms. By integrating two electronic components within the UC, both the reflection amplitude and phase of the incident wave can be controlled in a real-time continuous manner. The developed RIS configuration and the simulation performance of wave manipulation are presented.

1. Introduction

The rapid development of 5G wireless systems requires advanced millimeter-wave over-the-air (OTA) measurement platforms in the millimeter-wave frequency band. Among them, cost-effective candidates are of particular interest. However, current solutions such as anechoic, reverberation, and hybrid chambers still suffer from certain cost drawbacks, especially for diverse testing scenarios where large-scale electronically controlled active antenna arrays are needed [1].

The concept of the reconfigurable intelligent surface (RIS) has attracted increasing attention due to its powerful ability to control or improve electromagnetic wave propagation. With its assistance, the hardware complexity and cost can also be dramatically reduced compared to previous phased array systems. Conventionally, most RIS architectures only focus on the tunability of the reflection phase while ignoring the response of the reflection amplitude [2]. Although several RISs or metasurfaces with amplitude control have been proposed recently, their tunability is still limited, and fewer studies are extending to the millimeter-wave bands [3], [4].

Considering its application in OTA testing, the RIS provides a promising low-cost implementation scheme towards a reconfigurable electromagnetic environment, which is capable of satisfying specific testing requirements such as multiple line-of-sight, MIMO, etc. In this context, simultaneous amplitude and phase control are desired to generate a qualified test zone. Besides that, a higher number of bits in amplitude and phase quantization with a sufficient dynamic range is beneficial to further enhance its quality. Aiming at this objective, the implementation of a millimeter-wave RIS unit cell (UC) with continuous amplitude and phase control ability is investigated in this research contribution.

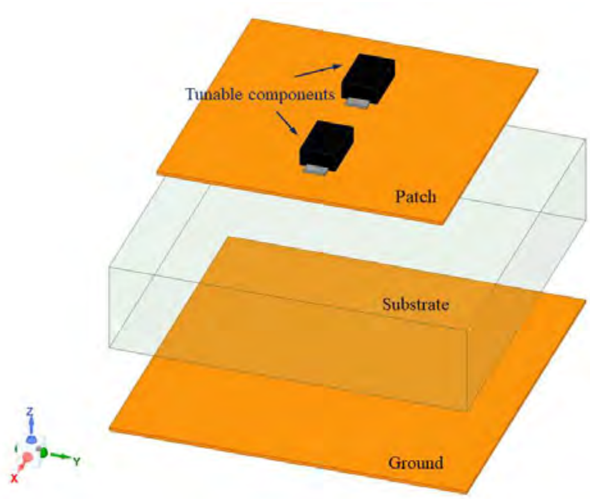

Figure 1. Configuration of the RIS UC.

2. RIS UC with Continuous Amplitude and Phase Control

The contemplated structure of the RIS UC is shown in Figure 1. It consists of a resonant radiator with integrated electronically tunable components and a full metallic back shield (control and biasing lines are not shown). The tunable components can be the PIN diode and the varactor diode to change the response of the reflection amplitude and phase, thus enabling real-time continuous manipulation. The RIS has a square lattice with a period at the subwavelength scale.

To evaluate the RIS performance, the UC can be simulated in an infinite periodic environment with various states of the tunable components. Herein, an incident linearly polarized plane wave is used for the UC illumination. And the components can be simplified as tunable resistors and capacitors. The idea is to obtain a mapping relationship between the amplitude and phase of the wave reflection coefficient on the complex plane, where the resistance and capacitance should adjust the amplitude and phase independently. An entire phase range of 2π with a certain dynamic range of amplitude can be identified by investigation of the UC reflection coefficient on the complex plane. Such a demonstration of the amplitude-phase coverage can indicate the potential of the RIS UC for the full complex field control and makes it a suitable candidate for future OTA testing platforms. More details will be presented at the conference.

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