Surface Wave Technique Enabled RIS Applications

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(Invited Paper)

Abstract: Increasing demands on high-performance platforms in the sixth generation (6G) of mobile communications raise research focus on new transducers. Recently, reconfigurable Intelligent Surfaces (RIS) have been proposed to address both the coverage and power issues. However, it may not be sufficient to solely rely on the manipulated reflections on RIS in the cases of high free-space path loss and blind spots in urban areas. To bridge such a gap, we propose a novel surface wave technique to enable a new communication surface to tackle the coverage and power concerns.

I. INTRODUCTION

Reconfigurable Intelligent Surfaces (RIS) has gained significant attention in the field of wireless communications due to its potential to address the challenges posed by the increasing demand for higher data rates, improved coverage, and more efficient spectrum utilization [1 – 4]. It holds promise for applications in 5G and beyond, as well as various Internet of Things (IoT) scenarios.

RIS employs an extensive array of meta-cells to manage and direct reflected radio waves with precision, amplifying signal coverage and information capacity for intended recipients. However, the potency of these reflected waves from RIS diminishes rapidly over communication distances. For instance, at 30 GHz and a communication range of 100 meters, the attenuation reaches approximately 102 dB. Furthermore, due to the linear propagation nature of the reflected waves, users positioned in blind spots may remain unreached. On the other front, surface wave travels along specially engineered surfaces, benefiting from a confined propagation mode that yields low path loss [5]. Under the same conditions of free space propagation, surface wave experiences only around 50 dB attenuation. Notably, as the signal primarily follows specific pathways, it significantly curtails mutual interference among users, streamlining interference management. Recent research has already extended the application of surface waves in wearable devices for body area networks [6] and even on-chip network systems [7]. Importantly, as shown in Fig. 1, the nature of surface wave propagation enables it to navigate corners, eliminating the non-line-of-sight connectivity issues typical of traditional RIS setups.

Recent studies highlight the strategic deployment of surface wave communication not solely for amplifying power amplitudes at designated loci but also for surmounting a pivotal quandary in cellular communication: the shadowing phenomenon. Through adept channelling of signals along surfaces encompassing edifices and towers via surface technology, the potential to furnish user access to wireless networks crystallizes [8, 9]. Although sparse investigations have endeavoured to explore RIS applicability in surface wave communication [10, 11], the pursuit of achievably adaptive characteristics remains an axial pursuit. In this paper, we present our recent work on the surface geometry which can reduce the propagation loss of the surface wave and launch the wave to the users from the surface to the free space to complete the whole communication path.

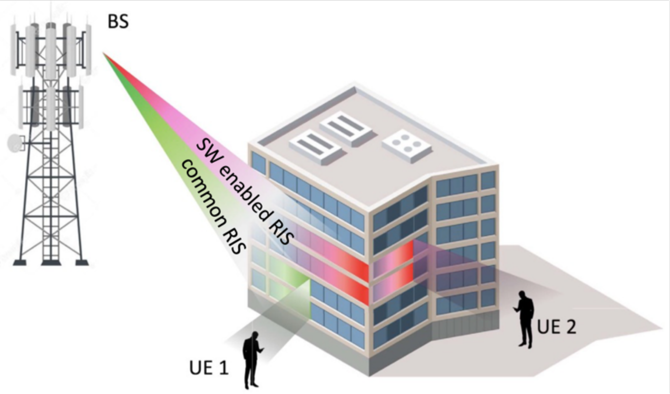


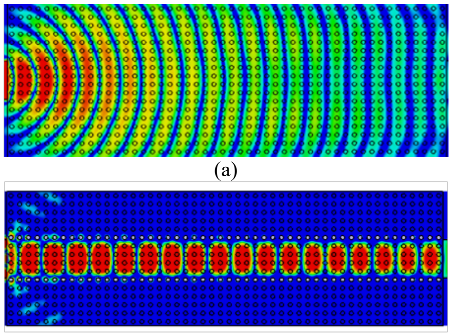
Figure 1. Illustration of surface wave enabled reconfigurable intelligent surface.

II. FROM SURFACE WAVE BACK TO SPACE WAVE

This paper introduces a pioneering methodology that champions a compact, solitary stratum reconfigurable meta cell as the cornerstone for an innovative reconfigurable surface wave guided structure. The chosen substrate material materializes as a low-loss PTFE Teflon sheet (ε_r = 2.1, tan δ = 0.00005@10GHz, thickness = 2.0 mm). Cylindrical cavities of 0.5 mm radius and centre-to-centre spaced 2 mm are evenly distributed on the dielectric to create a porous surface. Metallic pin are inserted in the cavities for creating a guided pathways [12, 13] to diverting the surface wave to the desirable positions for re-radiation on the surface. To realize ON/OFF states of the meta-cell involves the deployment of a high-frequency PIN-diode connecting between the pins and ground plane. Employing the diode's touchstone model, numerical simulations was performed through commercial CST software lay bare the dispersion diagram of the cell across discrete ON/OFF modalities. Subsequently, predicated on these numerical extrapolations, a repertoire of waveguide architectures is formulated and subject to analysis.

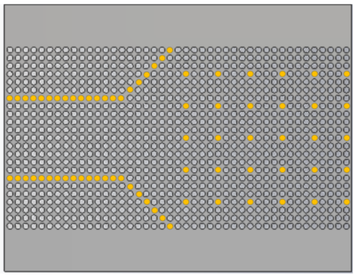
Fig. 2 shows the synthesized simulation findings, comparing the OFF and ON states of a reconfigurable surface-wave waveguide operational at 25 GHz [12, 13]. The figure distinctly showcases the propensity of the surface wave to diffuse along the dielectric interface while in the OFF state. In stark contrast, upon effectuating activation of the PIN diodes (ON state), the signal experiences judicious guidance, adhering to its intended trajectory. These simulated outcomes unveil a noteworthy 3-dB S21 bandwidth from 23.5 GHz to 26.5 GHz. Different frequency coverage can be obtained by changing the width of the channel [13].

Fig. 3 shows one of the possible activated pin distributions on the user end of the guided surface wave for launching focused radiation at 25 GHz for the demonstrating the last stage completing the communication.


(a)

(b)

Figure 2 (a) non-guided surface wave when the pins are in OFF state, (b) guided surface wave when the pins are in ON state.


(a)

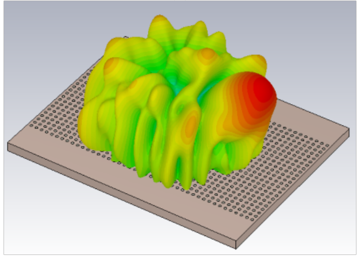

(b)

Figure 3 Demonstration example for launching the surface wave to the space with a focused beam (a) the active pin distribution, (b) the corresponding radiation pattern at 25 GHz.

III. CONCLUSION

In this paper, we show a new concept utilising the low loss on surface propagation feature of surface wave to step up the performance of common RIS covering the potential blind spots in urban areas. The surface wave can be launched to space wave by special distributed metallic pins on the surface near the users to complete the whole communication path.

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