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RIS Designs Based on Stacked FSS Elements

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The uses of millimeter waves in mobile communication has driven the need for reconfigurable intelligent surfaces (RIS). It not only improves the base station coverage but also enriches the diversity of propagation paths, which is crucial to the operation of multiple-input multiple-output (MIMO) technology. The most essential RF component in a RIS system is the reflection phase regulating unit, which is basically a phase shifter. This work proposes an alternative approach to implement the RIS cell. By stacking several layers of reflection/transmission reconfigurable elements, desired phase delays can be assigned to individual cells.

Numerous papers about RIS have been published. Topics involved includes its required performance features as well as its impact on wireless communication systems. To one's surprise, there are very few papers focus on the implementation of adjustable reflecting cells. The most intuitive implementation approach for configuring a RIS apparatus is through reconfigurable meta-surface that alters the reflection phase of individual cells. In [1], integrated circuits are mounted among four patch elements to provide resistive and capacitive loadings. By changing R/C loading values, patch reflection phases can be adjusted. In [2], a rather completed RIS system is presented for mmWave band uses. The proposed RIS contains a 10-by-10 array of patch elements. Cell reflection phases can be toggled between 0 and 180 degrees according to the biasing states of loaded diodes. Measurements demonstrate that a ±60° beam scanning range is achievable.

This work explores the feasibility of implementing a RIS via stacked reconfigurable frequency selective surfaces (FSS). Individual FSS elements can be configured to either reflective or transmissive state. Since the elements are overlaid vertically, the phase delay produced from each cell is decided by the top reflecting elements. In other words, this spatial phase shifter can realize phase adjustment via true propagation delays. This concept has been proposed in [3]. The RIS array is made of resonant patches with adjustable height driven by micromotors.

For an inclined planar surface, the reflection direction can be found via the Snell's law by knowing the surface's normal and incident directions. Note, the slanted surface can be approximated with stepped surfaces as long as the required propagation delay can be met. For the four-step example shown in Fig. 1, if the height difference between adjacent steps is chosen as one eighth of a wavelength, a 90° phase difference can be generated. Hence, the four-layer cell design shown is equivalent to a 2-bit phase shifter. In order to provide switchable delay, elements need to be configured into either reflective or transmissive. This can be facilitated by changing biasing states of RF diodes loaded on cross elements.

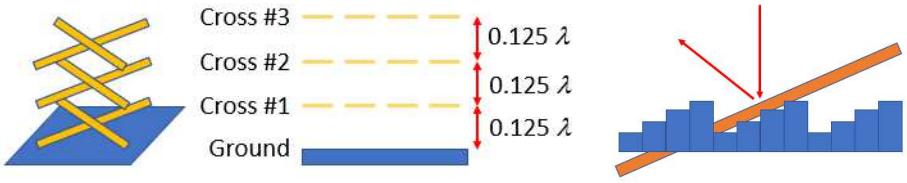


Figure 1. The scheme of a four-layer RIS cell and its approximation of an inclined surface.

References

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