

Full RIS-domain Standing Waves for Elements' Biasing

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An innovative method has developed recently for biasing the varactors of a reconfigurable intelligent surface (RIS) by utilizing resonant standing waves on the “biasing transmission line (TL)” [E. Ayanoglu, F. Capolino, and A. L. Swindlehurst, “Wave-controlled metasurface-based reconfigurable intelligent surfaces,” *IEEE Wireless Communications*, vol. 29, no. 4, pp. 86–92, 2022] located beneath the reflective surface. Using this approach, each RIS element does not require separate external biasing. For estimating the RIS reflection properties controlled by varactors, we analyze a planar array with phase gradient in one direction, of side length L , of reconfigurable elements. We employ the analytical model for predicting the reflection coefficients of the unit cells presented in [D. Hanna, M. Saavedra-Melo, F. Shan, and F. Capolino, “A versatile polynomial model for reflection by a reflective intelligent surface with varactors,” *IEEE AP-S/URSI*, 2022] and investigate how the standing wave biasing approach compares with the traditional way to generate field patterns of the reflected wave.

As described in [M. Saavedra-Melo, K. Rouhi and F. Capolino, “Wave-Controlled RIS: A Novel Method for Reconfigurable Elements Biasing,” Int Conf. IEEE AP-S/URSI, Portland, OR, 2023], the TL under the RIS does not interfere with the incident or reflected RF waves and supports a number P of resonant standing waves that correspond to the degrees of freedom to control the reflection scattering pattern. Each varactor can then be connected to a specific location, x , on the biasing TL, positioned after the pre-designed rectifier, to receive biasing DC voltage according to its location, which is represented as the sum of standing waves which consists of the summation of a DC bias V_0 and P standing waves of amplitude V_p . The standing waves are excited by using *a single port* where a time-domain periodic signal with a prescribed waveform is injected into the biasing TL. As an illustration, Figure 1 displays both the voltage distribution (on the left) and the reflection scattering pattern (on the right) of an array comprising 30 rectangular patches in the x direction, connected to grounded varactors, directing a reflected beam at $\theta_{max} = -20^\circ$. The smoothed biasing voltage distribution, in dashed green, mitigates abrupt voltage changes between adjacent elements while maintaining the beam direction. The reconstructed biasing voltage distributions using the standing wave summation is shown in magenta, and the inset shows the weight of each standing wave. F_i denotes the ideal reflected pattern with linear phasing and no attenuation, F_{vs} accounts for varactors effects (losses and parasitics) with a smoothed voltage distribution, and F_{vp} is derived by using the biasing voltage standing waves with only 15 harmonics. Details will be given at the presentation.

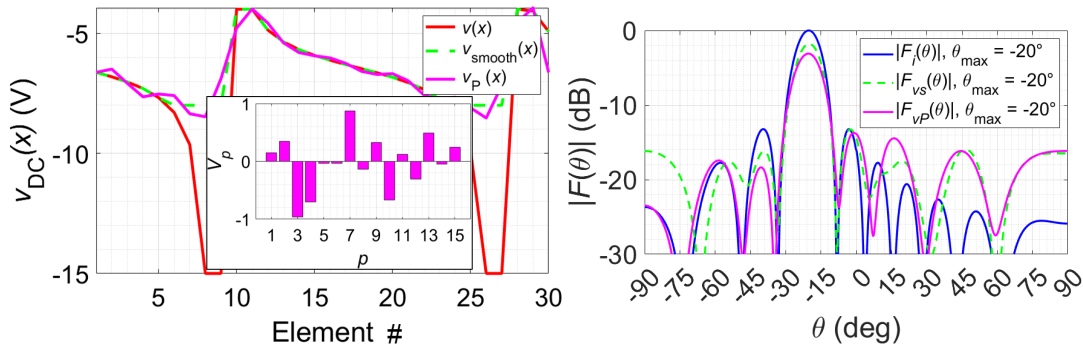


Figure 1. Voltage distribution (left) and reflection scattering pattern (right) of a RIS made of 30 elements in one direction to obtain a reflected beam pointing to $\theta_{max} = -20^\circ$.