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Practical Aspects of Optimal Coherent Illumination for Information Extraction: Application to Wireless Backscatter Communication in MIMO RFID

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Given the rapid proliferation of source arrays and detector arrays across all wave engineering disciplines, the question of how to optimally use coherent illumination of a scattering system for imaging and communication purposes arises. It is by now well understood that ideal illumination highlights salient features for the specific sensing or communication task at hand [1], as opposed to aiming at an indiscriminate acquisition of all information. But how can one identify the ideal illumination? The recently introduced "learned sensing" paradigm consists in integrating the tuning knobs of programmable measurement hardware as trainable *physical* weights into an end-to-end pipeline together with the trainable *digital* post-processing layer [1]. Thereby, coherent illumination and post-processing can be jointly optimized such that the coherent illumination is endowed with "task awareness" and pre-selects relevant information. Through modern deep-learning approaches, this technique can be applied to extremely complicated problems provided that training data is available. However, as in most inverse-design problems, there is no guarantee that the optimized coherent illumination is globally optimal.

Nonetheless, for a few special scenarios, provably optimal coherent illumination patterns have recently been identified. Indeed, for binary decision problems, it is clear from linear algebra that the optimal wavefront to discriminate between two system configurations is the first eigenstate of $(\Delta T)^{\dagger}(\Delta T)$, where ΔT is the difference between the transmission matrices for the two configurations to be distinguished and † denotes the conjugate transpose [2]. Interestingly, this approach is globally optimal irrespective of the complexity of the scattering system. However, neither its performance under non-ideal conditions (noisy measurements of ΔT) nor the influence of the nature of the change in the scattering system (point-like vs extended vs spatially distributed perturbation) is clearly understood to date. Moreover, it is unclear to what extent this operator-based approach can be scaled up to beyond-binary problems.

In this presentation, we explore these open questions in the context of wireless backscatter communication inside complex scattering enclosures such as vessels, trains, planes, or rooms inside buildings. Given a transmit array and a receive array, our goal is to probe the system in order to determine the impedance state of one or multiple antennas at unknown locations. Each antenna can modulate its impedance and be either in an open-circuit or matched-load state. This is precisely the operating principle of wireless backscatter communication, dating back to the Great Seal bug [3] and nowadays routinely used in RFID. In fact, we also perform our experiment using a commercial RFID tag manufactured by Alien Technology.

Our results further the fundamental understanding of the wave problem underlying optimal coherent illumination for information extraction, and simultaneously explore a new approach for MIMO readers in RFID technology.

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