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A Performance Analysis of Partial LIS for 6G Systems

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Abstract: Large Intelligent Surfaces (LIS) emerges as a pivotal technology, acting as near-field beamformers, facilitating the new requirements of 6G. We analyze the impact of utilizing the entire LIS array versus a subset of its antennas, and we explore different receiver types, with varying complexities.

6G communications are expected to reach the requirements of a peak data rate of, at least, 1 Tbps in nomadic access (100 times higher than 5G) and 1 Gbps in a mobile environment (10 times higher than 5G), while the energy efficiency is expected to be 10 to 100 times better than 5G, with a spectral efficiency 5 to 10 times better than 5G. These requirements are expected to be achieved with LIS systems associated with terahertz bands and block transmission techniques [1]. Note that the higher the carrier frequency is, the greater the channel coherence bandwidth.

To meet these demands, 6G will employ advanced techniques such as block transmission, error correction codes, and Large Intelligence Surfaces (LIS). The LIS system, akin to a beyond-massive MIMO, boasts an even greater number of antenna elements, enabling unprecedented capacities and data rates. Interestingly, while wireless communications typically operate in the far-field beyond the Fraunhofer distance [2,3], the LIS system functions in the near-field. This near-field beamforming, distinct from traditional beamforming, allows precise directionality not only in bearing and elevation but also in distance. Consequently, it minimizes interference between users who share alignment in bearing and elevation but are located at varying distances. LIS surfaces act as near-field beamformers, facilitating exceptionally high symbol rates and enabling robust interference avoidance. In this article, we delve into the intricacies of LIS systems, specifically examining the impact of utilizing the entire LIS array versus a subset of its antennas. Our analysis centres around an LIS system coupled with Single Carrier with Frequency Domain Equalization (SC-FDE). Additionally, we explore different receiver types, each varying in complexity. Notably, when we opt for antenna elements situated closer to the user equipment—rather than the entire LIS—the computational complexity diminishes. This reduction arises from the direct relationship between computational load and the number of antennas employed. In other words, adopting a partial LIS configuration yields several advantages: (1) Energy Efficiency: by focusing on specific antenna elements, that is, partial LIS, we achieve a reduction in energy consumption that comes from the lower computational requirements; (2) Interference Mitigation: the partial LIS setup effectively curtails interference levels, resulting in performance that tends to overcome that of the complete LIS system.

We consider Monte Carlo simulations, as defined in [1]. Figure 1 shows the performance results with 4X225 LIS system, with 2 users, without LDPC codes, with and without Partial LIS. 4X225 LIS system means that 4 panels of 225 antennas each are utilized (15 antennas on each side of the panel), making a total of 900 antennas as part of the LIS. Like the previous graphic, the number of users is 2, which means that there is a reference user and one interfering user. The “Full-LIS” corresponds to using the total 900 antennas, while the "Partial LIS One Panel” corresponds to using the panel (with 225 antennas) that is closer to each user, mitigating the interferences. As can be seen, like the results of the previous figure, results obtained with "Partial LIS One Panel” overcome the performance obtained with “Full LIS”, for the different receiver types. This happens because the number of antennas per panel is still sufficiently high (225 antennas), allowing a good gain in terms of diversity, while mitigating the interference over the interfering user due to the use of a single panel, instead of the whole LIS. In terms of receiver types, it is viewed that ZF and MMSE receivers achieve the same performance, leading to the best results. This is followed by the low complexity MRC receiver, whose performance is always between those obtained with ZF/MMSE and EGC receiver. It is worth noting that, in the case of the “Full LIS”, the performance obtained with the MRC receiver is almost superimposed of those obtained with the ZF/MMSE receivers, while in the case of the “Partial LIS One Panel” the MRC shows a small degradation compared with the ZF/MMSE. Note that the receiver types are defined in [1].

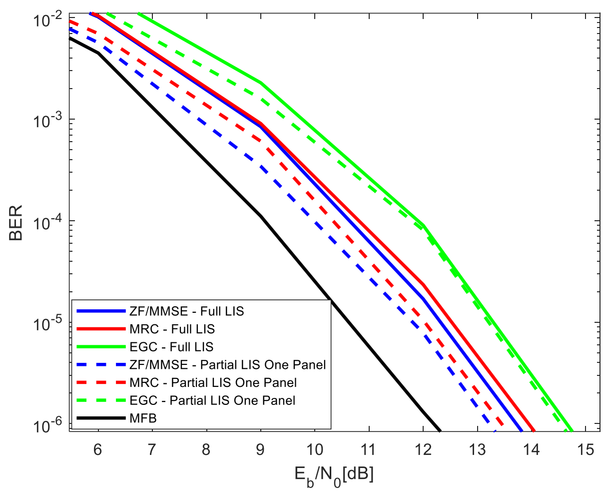

Figure 1. Performance results for 4X225 LIS System, with 2 users, without LDPC codes, with and without Partial LIS.

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