

Transmit Waveform Weighting for Secure Wireless Communications in Distributed Phased Arrays

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Security in wireless networking often combines encryption at the data level and at the physical layer. The latter has taken many forms, however the use of security techniques leveraging the antenna aperture are of increasing interest due to the rapidly evolving capabilities of phased arrays. Beamforming yields significant gain increases to the intended receiver, resulting in higher signal-to-noise ratio (SNR), while reducing power and thus SNR in other directions, making recovery of the information more challenging to eavesdroppers. However, beamforming that effectively reduces the recoverability of the information may require significant array sizes, providing hardware constraints. Other approaches such as directional modulation use dynamics between the antenna elements to change the waveform as a function of angle, thereby providing a spatial encryption layer. This approach generally results in reduced power in the intended direction, however, as the dynamics often require a reduction in main beam gain to open additional degrees of freedom.

Recently, research on distributed phased arrays has seen increasing interest, as wireless coordination capabilities have improved dramatically in recent years, yielding the ability to support distributed beamforming amongst separated platforms. A distributed array is a collection of nodes that are wirelessly time synchronized, phase aligned, and frequency synchronized to support distributed coherent wireless operations. By being disconnected, the nodes can move in arbitrary fashion, which results in the beamforming pattern changing depending on the relative locations of the nodes, which can increase security since the locations of strong sidelobes or grating lobes are effectively random and potentially changing over the course of the wireless operation. However, the sparsity of distributed phased arrays means that appreciable grating lobes will generally be present in space, leaving areas where potential eavesdroppers may intercept information.

In this work we explore a new approach to wireless security using nonuniform transmit weighting in a coherent distributed transmit array. Rather than transmitting the same information from multiple locations, the information is separated amongst the elements in the distributed array and transmitted such that coherent and recoverable combination of the signal is directed towards the intended receiver. The information thus combines differently at separate spatial locations, reducing recoverability outside the intended direction. While grating lobes with high energy manifest regardless, the information in the mainbeam remains the most coherent while that in the grating lobes is reduced. We explore various transmit weighting schemes to reduce the recoverability of information in the grating lobes of distributed phased arrays by modeling a distributed transmit operation with realistic coordination error tolerance and evaluate the effectiveness of the physical layer security by calculating the bit error ratio (BER) as a function of space, with the goal of minimizing the BER at the intended destination and maximizing the BER elsewhere.