

Combined Transmit and Receive Null-Space Beamforming for Aperture Level In-Band Full Duplex Antenna Arrays

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Antenna systems that can simultaneously transmit and receive at the same frequency are of tremendous interest for emerging technologies. Successful implementation of such a system could lead to the development of higher channel capacity and spectral efficiency in communication systems, or multifunctional systems that can perform several tasks, like radar and communication, in parallel. The primary concern in such systems is that the transmitter power that couples to the receivers will saturate or damage the receiver circuitry or will overpower the received signal of interest (SOI). To overcome this challenge, some method of self-interference cancellation (SIC) is typically employed. This typically includes analog or digital cancellation with copies of the transmitted signal. Antenna arrays or multiple input multiple output (MIMO) systems with many elements offer a unique opportunity for aperture-level SIC. The vector of beamforming weights at the transmitter elements can be judiciously set such that it is in the null-space of the matrix describing the coupling between transmitter and receiver elements. With such an excitation, the contributions from each transmitted component to each receiver sum to zero. This approach hypothetically offers perfect nulling at each receiver elements but sacrifices $N_{tx} - N_{rx}$ degrees-of-freedom in the transmitter beamforming space, where $N_{tx} > N_{rx}$. This can lead to certain beamforming patterns being unrealizable, negating the versatility inherent to phased antenna array systems.

Combined transmit and receive null-space beamforming has received significantly less attention in the literature. The zero-forcing conditions can be relaxed such that the received interference signal at individual elements is not nulled, but the combined signal from all receivers is, after receive beamforming. In this case, only one transmit degree of freedom is sacrificed. Given a desired vector of receiver beamforming weights $\mathbf{w}_r(\theta_1, \phi_1)$ and a fully characterized coupling matrix $\mathbf{C}$, the appropriate transmitter weights $\mathbf{w}_t'(\theta_1, \phi_1, \theta_2, \phi_2)$ can be found by projecting the desired transmitter beamforming weights $\mathbf{w}_t(\theta_2, \phi_2)$ absent of SIC onto the null-space of the receiver vector and coupling matrix product $\mathbf{w}_r^T(\theta_1, \phi_1)\mathbf{C}$. This solution allows for arbitrary scanning of the receiver beam, with minimal effect on the realizable transmitter beams. There is also no restriction on the number of transmit and receive elements. Alternatively, the transmit beam weights can be set first, then receiver beam weights for SIC can be determined similarly.

We consider the application of this approach to antenna arrays, with dedicated half-duplex transmit and receive elements. We show that transmit and receive null-space beamforming can be used to achieve high isolation at the receiver while allowing for beamforming of the transmitter and receiver separately.

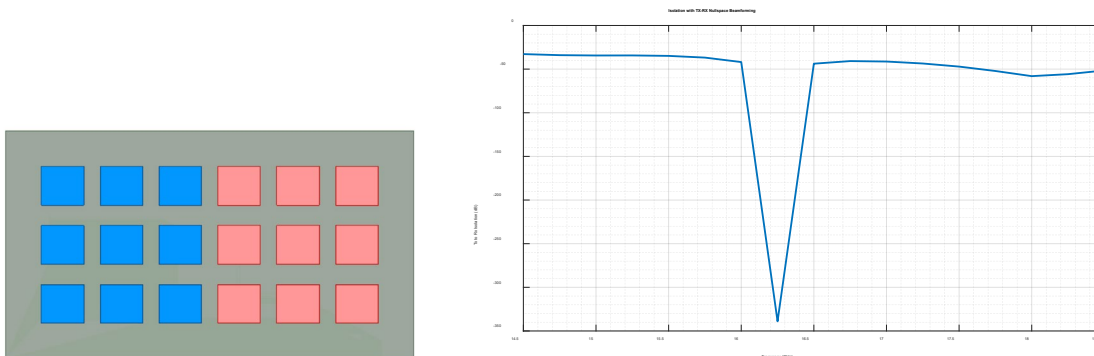


Figure 1. TX-RX Array (left) and receiver isolation (right)