Performance Analysis of Uniform Circular Arrays with Mutual Coupling in MIMO Channels

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Recently, there have been significant efforts to include the effects of mutual coupling among antennas in Multiple Input Multiple Output (MIMO) systems. In these studies, antenna structures are usually considered as linear arrays. However in practice, circular array structures are more attractive due to their symmetric construction and space utilization opportunities. In this study, the MIMO channel is treated as a geometrical model in which $L = 100$ scatterers are uniformly distributed in a disc of radius $R = 200\lambda$ around the transmitter array, where λ denotes the wavelength. The mutual coupling matrices are incorporated via electromagnetic integral equations for both transmit ($\mathbf{C}_T$) and receive ($\mathbf{C}_R$) arrays and the channel matrix ($\mathbf{H}'$) is obtained by $\mathbf{H}' = \mathbf{C}_R\mathbf{H}\mathbf{C}_T$, where $\mathbf{H}$ denotes the channel matrix ignoring mutual coupling. The details about the model and the entries of $\mathbf{C}_R$ and $\mathbf{C}_T$ can be found in (T. Svantesson and A. Ranheim, Proc. IEEE Int. Conf. Acoustics, Speech, and Signal Processing, vol. 4, 2001, pp. 2485-2488).

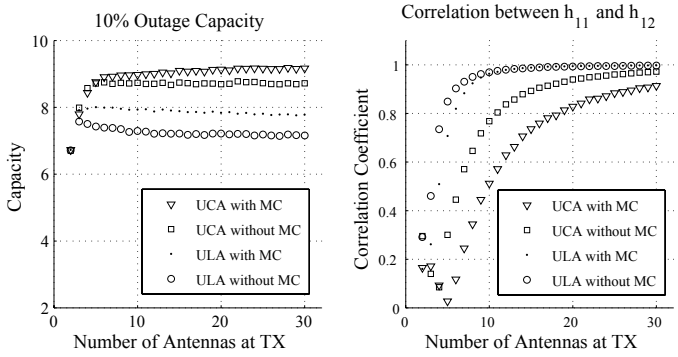

Figure 1: MIMO performance vs. number of antenna elements at the transmitter.

In order to compare channel performances of uniform linear array (ULA) and uniform circular array (UCA), we have examined two scenarios in which the Shannon capacity and the channel correlation are calculated. In both scenarios the receiver is assumed to be a ULA of $n_R = 4$ elements. In the first scenario, the transmitter is taken as a ULA broadside to the receiver and the number of the array elements is changed between $n_T = 2$ and $n_T = 30$, while the array length is kept constant at 0.5λ. Then in the second scenario, the transmitter is taken as a UCA, whose elements are placed on a circle of diameter 0.5λ; and the number of them is varied as $n_T = 2, 3, ..., 30$. In Fig. 1, the channel capacity and correlation properties of ULA and UCA are shown with and without mutual coupling (MC) effects. The results show that, UCA is advantageous over ULA in terms of both higher capacity and lower correlation. Optimum number of antennas are observed as $n_T = 4$ for ULA and $6 \leq n_T \leq 13$ for UCA. Results indicate the importance of including mutual coupling effects in MIMO system design.