Sparse Array Architectures for Wireless Communication and Radar Applications

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Abstract

This thesis focuses on sparse array architectures for the next generation of wireless communication, known as fifth-generation (5G), and automotive radar direction-of-arrival (DOA) estimation. For both applications, array spatial resolution plays a critical role to better distinguish multiple users/sources. Two novel base station antenna (BSA) configurations and a new sparse MIMO radar, which both outperform their conventional counterparts, are proposed.

We first develop a multi-user (MU) multiple-input multiple-output (MIMO) simulation platform which incorporates both antenna and channel effects based on standard network theory. The combined transmitter-channel-receiver is modeled by cascading $\mathbf{Z}$-matrices to interrelate the port voltages/currents to one another in the linear network model. The herein formulated channel matrix includes physical antenna and channel effects and thus enables us to compute the actual port powers. This is in contrast with the assumptions of isotropic radiators without mutual coupling effects which are commonly being used in the *Wireless Community*.

Since it is observed in our model that the sum-rate of a MU-MIMO system can be adversely affected by antenna gain pattern variations, a novel BSA configuration is proposed by combining field-of-view (FOV) sectorization, array panelization and array sparsification. A multi-panel BSA, equipped with sparse arrays in each panel, is presented with the aim of reducing the implementation complexities and maintaining or even improving the sum-rate.

We also propose a capacity-driven array synthesis in the presence of mutual coupling for a MU-MIMO system. We show that the appearance of grating lobes is degrading the system capacity and cannot be disregarded in a MU communication, where space division multiple access (SDMA) is applied. With the aid of sparsity and aperiodicity, the adverse effects of grating lobes and mutual coupling are suppressed and capacity is enhanced. This is performed by proposing a two-phase optimization. In Phase I, the problem is relaxed to a convex optimization by ignoring the mutual coupling and weakening the constraints. The solution of Phase I is used as the initial guess for the genetic algorithm (GA) in phase II, where the mutual coupling is taken into account. The proposed hybrid algorithm outperforms the conventional GA with random initialization.

A novel sparse MIMO radar is presented for high-resolution single snapshot DOA estimation. Both transmit and receive arrays are divided into two uniform arrays with increased inter-element spacings to generate two uniform sparse virtual arrays. Since virtual arrays are uniform, conventional spatial smoothing can be applied for temporal correlation suppression among sources. Afterwards, the spatially smoothed virtual arrays satisfy the co-primality concept to avoid DOA ambiguities. Physical antenna effects are incorporated in the received signal model and their effects on the DOA estimation performance are investigated.

Keywords: 5G, base station antenna (BSA), direction-of-arrival (DOA) estimation, grating lobe, MIMO radar, multi-user (MU) MIMO, multipath channel, mutual coupling, network theory, sparse array.