

## Practical Performance of Regular Sparse Array Direction of Arrival Estimation in 1-D

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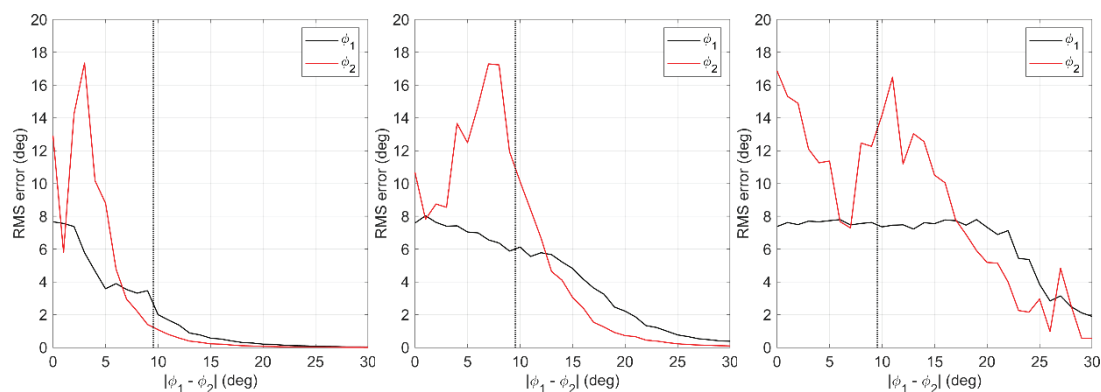
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Recently, a new algorithm for robust direction of arrival (DoA) estimation, using regular sparse array antenna systems, was described in [1]. Aliasing (grating lobes) is removed through the use of two sparse arrays – one a shifted version of the other. Minimum spacing between any two elements is not required to be smaller than a half wavelength. The method completely removes the dense Nyquist spacing requirement, allowing improved resolution for a fixed number of sensors and reduced mutual coupling between antenna elements. Because of a shared structured linear system of equations between the two arrays, as a consequence of the shift between the two, the analysis of both is automatically paired, thereby avoiding a computationally expensive matching step as is required in the use of so-called coprime arrays. Furthermore, the method provides an accurate estimate of the number of signals impinging on the system without any prior knowledge, while there is no requirement that the respective signals be uncorrelated. Distinct, fully coherent signals, such as those that occur in a multipath environment, can thus be accurately distinguished. Several examples were presented in [1], investigating both the performance in increasing noise, as well as increasing mutual coupling scenarios. In all of these, the new method performs better than standard techniques on a variety of metrics.

Here we present some results regarding the performance of the algorithm when practical radio frequency receiver system effects are considered. Specific attention is given to the effects of sampling and digitization of the incoming signals at the array elements, as well as the calibration requirements of the system for uncertainty in the complex element gains due to systematic effects and mutual coupling. As a simple first example, a dense array consisting of 12 elements at approximately half wavelength spacing is considered. The new method suggested in [1] is used to estimate the DoA of two incoming signals from directions  $\phi_1 = 10^\circ$  and  $\phi_2 \in [10^\circ, 40^\circ]$  when random errors on the positions of the array elements are constrained to spheres with radius  $\epsilon \in \{0.001\lambda, 0.01\lambda, 0.05\lambda\}$ . To isolate the effect of positional errors or, equivalently, channel phase calibration errors, an SNR of 30 dB and isolated elements are assumed here. In Fig. 1, the Rayleigh limit is shown as a vertical dashed line, and RMS errors in the estimated angles over 100 Monte Carlo runs are indicated as a function of incoming angular separation. These results indicate that a phase calibration accuracy of around  $\lambda/100$  is required to achieve an estimation accuracy of better than the Rayleigh limit.



**Figure 1.** RMS accuracy of two incoming directions for a range of angular separations. The left panel shows results for positional errors of  $\epsilon < \lambda/1000$ , the middle panel for  $\epsilon < \lambda/100$  and the right for  $\epsilon < \lambda/20$ .

A prototype system is currently under development, and the first practical measured results of a sparse regular array, employing the new algorithm in [1], will be presented at the conference, along with a wide range of performance estimates for a variety of array configurations and error situations. Comparisons with classical methods such as MUSIC and ESPRIT will be made, where these methods are only useful in arrays conforming to the spatial Nyquist constraint.

1. F. Knaepkens, A. Cuyt, W-s Lee and D.I.L. de Villiers, “Regular Sparse Array Direction of Arrival Estimation in One Dimension”, *IEEE Transactions on Antennas and Propagation*, submitted.