URSI-B EMTS 2025, Bologna, 23–27 June

On Peak Sidelobe Level Reduction Using Octomino-Based Subarrays

B. L. G. Jonsson*[(1)], Harald Hultin[(1)(2)], and Lucas Åkerstedt[(1)]
(1) KTH Royal Institute of technology, Stockholm, Sweden, e-mail: ljonsson@kth.se
(2) Surveillance, Saab AB, Stockholm, Sweden

Digital control of each element in a large array offers desirable far-field configurability useful for both communication and sensing applications. However, at higher frequencies, particularly in the upper-band 6G and sensing applications, heat dissipation, tight element spacing, and the costs of the transmit/receive modules (TRMs) constrain the number of actively controlled ports. Irregular subarrays [1] can be used to efficiently reduce the number of actively controlled ports while preserving some of the desired far-field properties. Furthermore, power efficiency is a key constraint for the desired array solution. Equal amplitude excitation, also known as isophoric excitation, is one method to limit the solution space to power-efficient configurations.

This work considers a set of far-field scenarios for a 28×30 array with BOR-elements [2], where a single pencil beam is steered within a radiation window $(\pm\theta, \pm 10^\circ)$, with $\theta = 50^\circ$ or 60°, using phase-only excitation. The array elements can be exactly covered (without holes) by subarrays in the form of tall octomino tiles. Each tile is associated with a TRM that feeds the corresponding elements through a passive network. Such configurations limit the achievable far-field performance, and a key question is the minimum achievable sidelobe level (SLL) for each steering direction. Although exact-covering with octominos is NP-hard, a large number of solutions have been identified. This work focuses on the efficient evaluation of SLL, a key step in our optimization algorithm for finding the optimized subarray configurations. This is particularly important given that there are over 10^{38} exact coverings within this set.

A method for determining the (SLL) of a pencil-beam configuration is to evaluate the far field over the forward hemisphere and identify the maximum sidelobe outside the main beam region. Because irregular (octomino-based) subarrays inherently have irregularly positioned side and grating lobes, efficiently finding the maximum sidelobe is challenging. Furthermore, certain sparse realizations of the far field can lead to suboptimal subarray solutions when used in a greedy optimization algorithm. In a thoroughly examined case, such an approach degraded the peak SLL (pSLL) by up to 0.6 dB, as the subarray configuration optimization algorithm converged to a suboptimal exact-covering solution.

Given that SLL determination for a particular subarray configuration is a significant computational bottleneck, algorithms for efficient SLL estimation are investigated. The properties of two distinct SLL estimation algorithms are considered, focusing on both memory requirements and computational time. Notably, implementing the more efficient of these two algorithms in both Julia and C (compiled with -march=native) revealed a performance advantage for Julia.

To further improve the optimization algorithm, the selection of the set of scan directions to be evaluated for each exact-covering solution must be addressed. The goal is to efficiently rank subarray configurations. The minimum number of SLL evaluations per configuration required to estimate the pSLL for a given radiation window is examined. Examples and results will be presented in detail.

Acknowledgments: This work was supported by the Swedish Foundation for Strategic Research (ID20-0004), the Strategic Innovation Program Smarter Electronics System (2022-00833), by Vinnova, Formas, and the Swedish Energy Agency, and the Swedish Research Council's Research Environment grant (SEE-6GIA 2024-06482) for research on sixth-generation wireless systems (6G).

References

[1] R. J. Mailloux, S. G. Santarelli, and T. M. Roberts, "Wideband arrays using irregular (polyomino) shaped subarrays," *Electronic Letters*, **42**, 18, August 2006, pp. 1019–1020.

[2] H. Holter, "Dual-Polarized Broadband Array Antenna With BOR-Elements, Mechanical Design and Measurements," *IEEE Trans. Antennas Propagat.*, **55**, 2, February 2007, pp. 305-312.