An Algorithm for the Optimization of a Dual-Beam Steerable Phased Array System with Real-Time Reconfigurable Element-wise Power Amplifier Load Impedance Tuners

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Dual-beam phased-array systems can suffer degradation to the array pattern caused by variation in antenna impedance from beam steering and spurious beams created by spatial intermodulation from power-amplifier nonlinearities. The amplifier intermodulation results in additional unwanted spurious "beat" beams that can compromise the ability of the system to operate without interference, and can also cause security challenges. In previous work we have shown that element-wise impedance tuning can be used to compensate for these effects, maximizing element gain while significantly reducing the unwanted beat beams. In this work we present an algorithm that can be used to control these impedance tuners to optimize in real time for both minimal array-pattern distortion and maximal output power. This approach will maximize dual-beam performance for frequency-sharing applications, allowing better utilization of the spectrum.

The search algorithm for real-time tuner optimization in the array elements is a modified multi-dimensional, multi-objective gradient optimization adapted to account for the high dimensionality of the search space. We demonstrate experimental results from using this algorithm, using an impedance tuner of each element of the phased array. For the impedance tuners, a model of a 90 W mechanical evanescent-mode cavity impedance tuner previously developed by Purdue University (Semnani, *IET Microwaves, Antennas & Propagation*, 2019) is used. The tuner has two cavities whose resonant frequencies can be adjusted by changing the positions of movable discs atop the cavities. This means that when optimizing an N element array, there are $2N$ dimensions to tune across. A 16-element array is used in the initial experiments, resulting in a 32-dimensinal search. In an attempt to overcome the curse of dimensionality, the algorithm works by performing 16 two-dimensional searches in parallel instead of one 32-dimensinal search. These searches are coordinated by an overarching engine that tracks all tuner positions and each element's performance, and assigns subsequent measurement points to each search.

The element-wise search uses two objectives: (1) maximize the current gain in each element, and (2) maintain the array pattern by equivalent amplifier adjustment of the current phasors in all elements. A simulation platform using a combination of the Advanced Design System circuit simulator with the Momentum electromagnetic simulator, both from Keysight Technologies, is controlled by a co-simulation with MATLAB. The simulation results demonstrate effectiveness of the search algorithm in maximizing output power for the two beams, maximizing amplifier gain in the elements, and maintaining good dual-beam performance, with desirable minimization of the unwanted beat beams. Upcoming steps toward implementation of these real-time optimizations in arrays for measurement-based assessment are discussed.