Optimization of Phased Array Antenna Systems for 3D Surfaces

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Current phased-array (PA) antenna systems utilize beamforming techniques that are optimized for 2D surfaces. Therefore, the implementation of these systems is limited to flat surfaces. To solve for a growing need for 3D antenna arrays, this project rederives fundamental beamforming equations in 3D space to optimize the transceivers' phase shifts in 3D antenna systems. The project contains three parts: mathematically reformulating beamforming equations with a third dimension, simulating efficacious arrangements of antenna arrays in MATLAB, and building a physical 3D PA with hardware to validate the new equations and simulations. Original MATLAB programs were written to compute array selectivity based on Half-Power-Beamwidth (HPBW) angles and antenna gain. Original schematics and printed circuit-boards were created to build a physical PA antenna system with surface mount RF components. By rederiving the beamforming equations in 3D space, the HPBW decreases and correspondingly increases antenna gain. The HPBW of a 64-receiver cone, planar, hemisphere, and plane-wing array decreased by 24.0, 13.71, 4.47, and 4.50 degrees respectively from 2D model to 3D model. The PA built in this project beamsteered signals that were 13.56 and 12.84 dB (or 20 times) greater than the surrounding emitted power when directing the signal at elevation angles of 90 and 45 degrees respectively. This decrease in HPBW and increase in power within 10 degrees increases the directivity of the beampower, essential for 5G communications and distance detection. The new beamforming equations derived and modeled in this project allow for implementation of PA onto 3D-surfaces such as planes, drones, and satellites.

Awards Won:
Second Award of $2,000
Air Force Research Laboratory on behalf of the United States Air Force: First Award of $750 in each Regeneron ISEF Category
Raytheon Technologies Corporation: Each winning project will receive $1,000.