

Design of an Electronically Tunable Microwave Lens for High-Power Phased-Array Applications

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Recent advances in critical application areas such as high-power radar, electronic warfare, directed-energy weapons, and satellite communications have created a significant demand for antenna arrays capable of rapid and accurate beam steering at high continuous wave (CW) and pulsed power levels. Traditionally, radar and electronic warfare applications have used active electronically scanned array (AESA) antennas for beam scanning. AESAs are effective but expensive, as each element of the array requires a transmit/receive (T/R) electronics module, significantly increasing the cost and leading to high power consumption by the array. Furthermore, the peak power levels achievable from AESAs generally fall significantly short of what is needed for directed energy or high-power-microwave (HPM) applications.

At the University of Wisconsin-Madison, we are advancing the state-of-the-art in high-power-capable phased-array antenna technology by developing an electronically tunable electromagnetic lens with high power-handling capability over an ultrawide bandwidth. An electromagnetic lens used in a passive phased-array architecture offers advantages of lower cost and higher power-handling capability over state-of-the-art AESAs. The lens under development in this project consists of a planar array of 1-bit polarization rotating unit cells (PRUCs), which rotate the polarization of an incident linearly polarized plane wave by ± 90 degrees using an electronic switch (Z. Zhang, M. Gao, M. M. Honari, J. Wu, J. H. Booske, and N. Behdad, "A Wideband, 1-bit, Electronically Reconfigurable Phase Shifter for High-Power Microwave Phased-Array Applications," *IEEE Trans. Plasma Sci.*, vol. 51, issue 7, July 2023). Experimental studies of previously developed PRUCs have demonstrated a maximum CW power handling capability of 500 W (corresponding to a power density of over 22 W/cm²) with an octave bandwidth from 6-12 GHz. The lens we will present at this conference employs a modified version of the previously published PRUC integrated with two, small-aperture double ridge waveguide (DRWG) horn antennas with a total of 49 elements arranged in a 7x7 grid. It also builds upon our prior success at integrating this type of PRUC into a manually reconfigurable lens consisting of a 20x20 array of PRUCs and DRWG horn antennas (Y. Youn, J. Wu, H. Topözlü, S. Hajitabarmarznaki, J.H. Booske, and N. Behdad, "Recent Advancements on Wideband Phased Array Antennas for High Power Microwave Applications," in 2024 IEEE International Symposium on Phased Array Systems and Technology, 15-18 October 2024). Modifying the lens to be electronically reconfigurable will allow for real time switching of each unit cell's state and thus control of the radiation pattern. The research presented at this conference will focus on the design of the new electronically reconfigurable lens, accounting for the introduction of electronic components as well as DC bias wires and the RF/DC isolation mechanisms. We also plan to present experimental results obtained from the fabrication of a prototype of this lens. Ultimately, we plan for the lens to be used in hybrid passive/active phased array architectures where multiple feed antennas are used with the lens to generate multiple beams and facilitate beam or null steering. Details of the design process, power handling capability analysis, thermal management solution development, and preliminary experimental results of the lens will be presented and discussed at the symposium.

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