

A Heuristic Study of the Impacts of Manufacturing and Assembly Techniques on the Performance of High-Power-Capable, Polarization-Rotating Phase Shifters

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In recent years, phased-array antennas with high-power-handling capabilities have become a keystone of research and development activities in high-power radar, electronic warfare, satellite communications, directed energy systems, and other application areas requiring precise and/or rapid beam scanning at high continuous wave (CW) or pulsed power levels. Currently, our group at the University of Wisconsin-Madison (UW-Madison) is researching a novel, high-power-capable, electromagnetic lens consisting of a periodic surface of polarization-rotating unit cells (PRUCs) for use in hybrid phased-array architectures offering rapid, electronic beam steering. Our previous research resulted in the design and fabrication of a 1-bit electronically-reconfigurable PRUC phase shifter (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) with a maximum CW and peak power handling capability of $>23 \text{ W/cm}^2$ and 347 W/cm^2 , respectively, over an octave bandwidth from 6-12 GHz. Our current research, which we will present at this conference, focuses on investigating the impacts of manufacturing and assembly techniques on the CW power-handling capability of this PRUC phase shifter.

We designed and tested the original version of the PRUC using custom aluminum double-ridge waveguides (DRWGs). We fabricated the electronically-switchable component of this PRUC on an aluminum nitride substrate. Experimental and simulation results indicated that the surface roughness and conductivity of the aluminum waveguides could negatively affect the insertion loss of the unit cell through ohmic losses, particularly at high frequencies. This, in turn, could lower the CW power-handling capability of the structure, due to ohmic losses and associated heat generation. We therefore designed a study of whether different post-manufacturing methods such as polishing or electroplating with a higher conductivity metal such as copper could reduce these effects. We fabricated six different waveguide setups for low- and high-power measurements using different manufacturing processes – CNC machining, EDM, and metal 3D printing – and surface finishes – unfinished, polished, and copper-electroplated. Additionally, we fabricated five different switchable element lots to explore differences in substrate permittivity, geometry, and AlN manufacturing. This work will present the low-power experimental measurements of these 30 variations of PRUCs to identify which unit cell and waveguide material is most suitable for high CW power levels. We will also present high-power experimental results of the chosen waveguide/PRUC combination and we will experimentally investigate the limit of the CW power-handling capability quantified over the 6-12 GHz range. Details of the design of these unit cells as well as their low- and high-power experimental characterizations will be presented at the symposium.

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