Spatial Power Combining Amplifier (SPCA) for W-Band Radar in Earth and Planetary Science

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Abstract—We are developing a high efficiency, compact W-Band (94 GHz) spatial power combining amplifier (SPCA) in an effort to demonstrate a new type of millimeter-wave high-power amplifier for use in earth science cloud radar and planetary landing radar. The SPCA concept utilizes multiple monolithic millimeter-wave integrated circuit (MMIC) amplifiers, which are combined spatially within a resonant microwave cavity. In the SPCA device, an input signal enters the input cavity where it sets up a resonant cavity mode; in this case the TM_{110} cavity mode. The signal power is then equally split between multiple MMIC amplifiers, and, after amplification, is spatially recombined within a second output cavity. The cavity is then coupled to WR10 waveguide by means of an iris for suitable mode conversion and matching. This combining scheme is scalable, allowing for additional MMICs to be added in parallel to increase power without compromising gain or efficiency. Additionally, this method of combining provides a factor of 2-5 times smaller footprint as compared to standard waveguide-based power-combining packages.

This effort builds upon previous work in which we developed and tested the SPCA concept at S-band (2.4 GHz) and X-band (8.5 GHz) frequencies [1]. In this paper we present the design and results of a W-band (94 GHz) version first prototype demonstration utilizing state-of-the-art GaN HEMT MMIC amplifiers, each capable of 1 Watt saturated output power at W-band, targeting a combined power output of ~1.5 Watts. This new SPCA design was scaled by a factor of ~40 from the previous S-band version. For the next phase of development, we plan to implement a 6 MMIC combiner targeting 5 Watts of output power.

The first stage of the design involved EM simulations to determine cavity dimensions and optimize the microstrip antenna coupling, center frequency, thru-power, and bandwidth. The structure of the cavity-mode power combiner was then designed using CAD software to accommodate the EM and tolerance criteria established through EM simulations. Testing of the two-way combiner block using thru-lines indicates bandwidth and matching compare well with the simulated results. The power combiner operates between 93-107 GHz (a 3dB bandwidth of 14 GHz) as measured using microstrip thru-lines in place of the MMICs, with greater than 10 dB return loss. Our latest power-combined results will be presented at the conference.

[1] Jose Velazco, Mark Taylor, “Spatial Power Combining Amplifier for Ground and Flight Applications,” *Interplanetary Network Progress Reports* 42-207, Nov. 2016. https://ipnpr.jpl.nasa.gov/progress_report/42-207/207B.pdf