Reflector-Based Phased Array for High Power G-band radars

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***Abstract*—We will present the ongoing development of a reflector-based phased array for high power G-band radars and beyond to address the need for global measurements of water vapor content within clouds, and the detection of small-size particles in clouds. The array will use a limited number of medium-gain antennas and state-of-the-art low-power-density solid-state power modules with high DC efficiency. Our concept is applicable to high-power 155-165 GHz Differential Absorption Radar (DAR) for probing the planetary boundary layer (PBL), a targeted observable for incubation in the 2017 Decadal Survey [1], with high vertical resolution. The technology is also applicable to 240 GHz radars which, when combined with observations at more traditional lower frequencies, can better characterize particle size distributions within clouds.**

As emphasized in the NASA PBL Incubation Study Team Report [2], 100 W of emitted power at G-band is the necessary characteristic of any spaceborne DAR system dedicated to PBL remote sensing. As a complementary remote sensing technique to passive radiometer counterparts, a high-power and widely tunable G-band DAR can achieve high resolution and high precision profiling of the water vapor content inside PBL clouds and precipitation, as well as total-column water vapor estimates, both over ocean and terrain [3].

We will present a two-element phased array, as a unit cell of an envisioned 2-meter aperture modular array with 100 W of transmit power, able to steer the beam by +/- 25 beamwidths with sub-second speed. When upgraded with tilt-able secondary reflector, the array architecture will enable fast electromechanical beam-steering to improve global coverage of humidity profiles inside of clouds and precipitation, compared to a fixed-beam radar which lacks the agility to target a cloud-track path within the PBL. The phased array will use closely packed low-profile parabolic antennas of 15-20cm, each featuring fully solid-state, high DC-efficiency electronics that can work under pulsed DC condition. For each array element, the input signal will be up-converted at G-band using JPL-built GaAs Schottky-diode-based frequency multipliers and commercially available W-band and G-band amplifiers, resulting in an emitted power of about 0.5W per element. The relative phase of the emitted signal is electronically tuned to the desired value without any additional phase-shifter, reducing complexity and RF power losses. The transmit and receiver modules are isolated via a custom circular-polarization orthomode transducer. The received signal is down-converted using an LNA and a mixer designed at JPL, before being digitally equalized, phase-shifted, and combined.

The array elements, when tiled over a flat hexagonal surface, will result in a thinner antenna than a classic single solid-dish approach. In addition, the array can be dynamically subdivided for multi-beam forming, pointing simultaneously at different directions. Our concept departs from the focal plane array approach that requires large, high power density MMICs at G-band with both high DC-efficiency for the integrated emitters and low noise for the integrated receivers. Instead, our approach is based on a combination of existing commercial state-of-the-art components, along with some JPL-built strategic ones. It also offers key advantages over the legacy technology of high-power vacuum electronic sources. Among them are active components with long lifespan and wide RF bandwidth, failure mitigation with “graceful degradation” in case of component failure, scalability to large apertures, low power-generation density for easy thermal management, low DC bias voltages, and much less challenging transmit/receive isolation requirements. Our concept takes full advantage of the rapid evolution of analog and digital electronics owing to the continuing consumer electronics revolution, including the breakthroughs in component availability due to the emerging 5G market. These advantages make our approach well suited for space-based missions for future earth science missions.

The paper will present the radar architecture and field test results on a calibration target situated in the far-field, at a distance of about 250m.

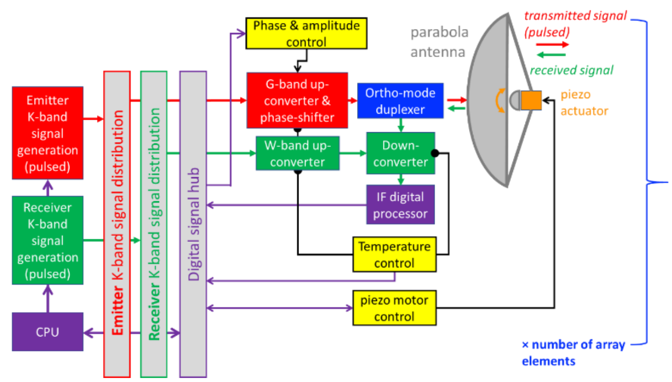

Fig. 1. schematic of our reflector-based phased array concept for G-band DAR operations. For simplicity, the DC power distribution is not represented.

References

[1] National Academies of Sciences, Engineering, and Medicine 2018. Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space. Washington, DC: The National Academies Press. https://doi.org/10.17226/24938 - This is the final product of the 2017-2027 decadal survey for Earth science and applications from space (“ESAE 2017”).

[2] João Teixeira et al., The NASA PBL Incubation Study Team Report

[3] K. B. Cooper et al., "G-Band Radar for Humidity and Cloud Remote Sensing," in IEEE Transactions on Geoscience and Remote Sensing, vol. 59, no. 2, pp. 1106-1117, Feb. 2021, doi: 10.1109/TGRS.2020.2995325.