The Design of Miniaturized Water Vapor Profilers for Three-Dimensional Measurement of Atmospheric Water Vapor

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Knowledge of the temporal and spatial distribution of water vapor is fundamental for short-range prediction of precipitation and severe weather. The paucity of current observations of wind, temperature and humidity in pre-storm environments limits the improvement of forecast skill for these events. Currently, measurements of precipitable water vapor in the troposphere are limited to twice-daily radiosonde launches, costly and limited clear weather lidar techniques and networks of GPS receivers measuring wet delay. Measurements of the water vapor field at higher spatial and temporal resolutions, as well as 3-D variational assimilation into numerical weather prediction models, are needed to improve short-range weather forecasting. Networks of water vapor profiling radiometers and associated analysis techniques are needed to address these shortcomings.

A large fraction of today's ground-based and airborne microwave remote sensing instrumentation was built using waveguide-based and discrete microwave components, aging technology that is still economical in this niche market, based on quantities of one or a few copies of an instrument. In contrast, analog microwave circuits in the wireless communications and some defense sectors are based increasingly on microwave monolithic integrated circuits (MMIC), yielding a higher level of integration and lower production costs, and often higher reliabilty. The demand for components in selected wireless communication frequency allocation bands has driven down the price of commercial off-the-shelf components, such as low noise amplifiers, to the $10 range. As a result, producing a unique, "one-off" design based on commercially available MMIC components is expected to be lower than that of waveguide-based systems. MMIC-based radiometer designs enable a reduction in total volume of one-to-two orders of magnitude and a reduction in total weight and power consumption of at least one order of magnitude, as compared with waveguide-based systems.

This paper describes the design and calibration of the Miniaturized Water Vapor Profiler (MWVP) at the University of Massachusetts (UMass) Amherst. The MWVP has the advantages of low cost and power consumption, as well as high reliability for long-term operation in the field. The MWVP design permits two-point radiometric calibration using both internal and external techniques. In this design, water vapor profiles are retrieved from brightness temperature measurements at a set of frequencies near the 22.235 GHz water vapor resonance chosen to optimize the vertical resolution of the profiler. The complete RF section of the MWVP occupies less than 50 cm^3 (3.1 in^3). The entire radiometer system has a volume smaller than 1800 cm^3 (110 in^3). This substantial reduction in size, weight, cost and power consumption of the MWVP, relative to existing ground-based water vapor profiling radiometers, is expected to allow flexible deployment in ground-based networks and aboard unpiloted aerospace vehicles (UAVs).