Passive Microwave Remote Sensing of Atmospheric Water Vapor, Cloud Liquid, and Temperature

Steven J. Walter
Ground Based Microwave Application Group
Jet Propulsion Laboratory, California Institute of Technology
Mail Stop T-1182/3, 4800 Oak Grove Dr., Pasadena, CA 91109

Passive microwave techniques for sensing the earth's atmosphere provide powerful tools for understanding and monitoring its dynamics. These techniques exploit the microwave and millimeter-wave emissions of atmospheric constituents. Tuning a sensitive radio receiver, termed a radiometer, to these emissions allows the atmosphere to be probed remotely from satellites, airplanes, and the earth's surface. Microwave radiometers are able to sense water vapor, atmospheric temperature profile, cloud liquid, and concentrations of various upper atmospheric constituents.

Microwave radiometers have applications in many areas: weather prediction, pollution forecasting, aviation, climatology, spacecraft tracking, geodesy, and atmospheric chemistry. Four specific applications for low-cost radiometer systems have been identified. Microwave temperature profilers (MTPs) can provide real-time detection of temperature inversions which trap automobile emissions and industrial pollution near the ground. Timely, accurate prediction of weather conditions which are conducive to creating high pollution levels have significant value in mitigating pollution hazards. Water vapor radiometers (WVRs) could significantly enhance weather radar measurement. Concurrent WVR measurements can relate liquid content of clouds to the radar returns. Third, DOE has initated the Atmospheric Radiation Measurement (ARM) program to validate and improve the performance of global climate models. ARM scientists have identified critical measurement needs including measurement of horizontal distribution of total-column cloud liquid and water vapor, and cloud mapping/imaging capability. Additionally, ARM is interested in airborne and ground based temperature profiles. Finally aircraft icing poses a serious winter hazard at many U.S. airports. In freezing conditions, clouds can form which contain appreciable amounts of supercooled liquid water. Ground-based radiometers are able to sense both the atmospheric temperature profile and amount of cloud liquid remotely. Combining radiometric measurements with ceilometer or radar determinations of cloud height would allow clouds bearing supercooled liquid to be identified.

Widespread application of radiometric remote sensing systems have been restricted by costs. Plumbed-waveguide radiometer system for monitoring water vapor, cloud liquid, or temperature profiles cost between $120,000 to $500,000 depending on antenna beamwidth and pointing requirements, and number of measurement frequencies. Recent advances in monolithic and hybrid microwave integrated circuit (MMIC and MIC) technologies promise to reduce production costs by allowing radiometers to be etched on an integrated circuit. In addition to cost savings, conversion to MIC will reduce radiometer size and power requirements, thereby lowering costs of the associated power, antenna pointing, and temperature regulation subsystems. It is also anticipated that the compact size and reduced power consumption will translate into

improved temperature control which will increase radiometer stability. Preliminary studies indicate that system cost reductions of a factor of 3 to 8 appear feasible with minimal development costs. These cost reduction will foster commercialization of radiometric atmospheric remote sensing. JPL's expertise in radiometry teamed with an industrial partner's MIC and MMIC capability would create a powerful partnership with which to transfer this technology to the industrial team member or members.