Short Wavelength Technology and the Potential for Distributed Networks of Short-Range Radar Systems

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Today's weather observing radar networks are designed for long-range coverage of the atmosphere using with single-beam antennas designed to comprehensively map winds, precipitation, and other phenomena over large volumes of the mid- to upper-regions of the troposphere. Data collected by these sensors serve as critical inputs to weather-related decision making in many public and private sector functions (such as hazardous weather warning, transportation, agriculture, energy, among others). Although the coverage of these radars is adequate for many situations, coverage at low altitudes far away from the radars is insufficient for many applications due to Earth's curvature and terrain-induced blockage. For example, the WSR-88D (NEXRAD) system is unable to view ~ 80% of the troposphere's volume below 3 km altitude. This prevents the system from detecting the full vertical rotation of most tornadoes and limits the accuracy of radar-derived precipitation estimates near the surface. Long-range radars operate at wavelengths in the 5-10 cm range in order to minimize attenuation due to precipitation, and this necessitates their use of physically large antennas to achieve high spatial resolution. Despite the use of large antennas, spatial broadening of the radar beam with increasing range prevents these systems from resolving structures on the sub-km scale over most of the coverage volume.

Distributed Collaborative Adaptive Sensing (DCAS) is a new approach to comprehensive radar sensing of the atmosphere being investigated to overcome the coverage limitations inherent in the use of long-range radar networks. *Distributed* refers to the use of large numbers of small solid-state radars, spaced appropriately to overcome blockage due to the Earth's curvature and improve resolution degradation caused by beam spreading. In addition to providing the potential for high-resolution sampling throughout the entire troposphere, this distributed concept lends itself to the efficient utilization of low-power solid-state radars. These radars (once they are developed) are highly reliable, inexpensive, adaptive, and can operate *collaboratively*, via rapid coordinated targeting of multiple radar beams, based on atmospheric and hydrologic analysis tools (detection, tracking, and predicting algorithms) that diagnose weather conditions in real-time and re-steer radar beams onto atmospheric regions where threats exist. *Collaborative* operation is envisioned as a means to achieve greater sensitivity, precision, and resolution than is possible with a single beam by coordinating the beam-positions of multiple radars and by processing echoes from multiple beams viewing the same scattering region. *Adaptive* refers to the ability of these radars and their associated computing and communications infrastructure to rapidly reconfigure in response to changing conditions in a manner that optimizes the systems' ability to respond to competing end-user demands. For example, a DCAS radar network might pinpoint tornado locations with extremely high spatial resolution to meet the need for public warning while simultaneously mapping the horizontal wind field associated with the parent thunderstorm to support a storm forecaster while simultaneously providing quantitative precipitation estimates for input to distributed hydrological models for a user concerned with flood warning. The system accomplishes this by rapidly adjusting both radar parameters (such as scan rate and coverage sector, pulse-repetition frequency and radiated bandwidth) and computational and communications functions (such as calculating Doppler spectral moments versus calculating full Doppler spectra and then conveying this information at different data rates to an appropriate computing facility). This adjustment is made optimally "on the fly" during the volume scans of multiple coordinated radars, all in response to changing weather – and the changing needs of the multiple users of the system.

The U.S. National Science Foundation recently established an Engineering Research Center titled the Center for Collaborative Adaptive Sensing of the Atmosphere (CASA), formed by a consortium of four universities, namely (listed alphabetically), Colorado State University, University of Massachusetts (lead University), University of Oklahoma, and University of Puerto Rico at Mayaguez, and a partnership with industry and government labs to create the underlying knowledge, technology, and systems-engineering trade-off space for realizing future DCAS systems and to conduct proof-of-concept experiments that demonstrate how these systems can improve our ability to detect, track, and predict localized hazardous weather for improved response to atmospheric hazards. This paper summarizes key geometric and physical principles governing design trade-offs for DCAS radar networks, summarizes CASA's 10-year strategy for realizing test-bed demonstrations of this concept, and presents the architecture and initial test results for the center's first deployed end-to-end DCAS system.