11.7 SOLID STATE FRACTIONAL PHASED ARRAY ADDITION TO NWRT

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1. INTRODUCTION

The National Weather Radar Testbed (NWRT) (Forsyth, et.al., 2005) serves as a tool for radar meteorological research and for investigation of techniques for utilizing phased array radars for weather sensing. Using a SPY-1A phased array antenna, loaned to NOAA by the U. S. Navy, the testbed is capable of performing scans over user-defined sectors considerably faster than conventional weather radars using rotating reflector antennas.

Lockheed Martin and NSSL are planning an addition to the NWRT in the form of a solid state transmit/receive (T/R) module fractional array. This array will provide a proof of concept capability for advanced phased array applications to meteorological sensing and multifunction applications. In particular, implementation will support validation of concepts such as dual polarization control and calibration over all scan angles, application of digital beamforming, beam multiplexing, site specific nulling of point clutter, split array processing for wind direction estimation and real time dwell scheduling to support adaptive scan algorithms. Other capabilities could include real time dedicated point target tracking to support future combined weather surveillance and target surveillance and track requirements for both enroute aircraft and in the airport terminal area. Thus the fractional array provides a practical first step towards a phased array radar capable of simultaneously satisfying the weather surveillance requirements of the NWS and the air traffic surveillance requirements of the FAA.

In this paper we provide an overview of the proposed fractional array capabilities, integration with NWRT and some of the radar design tradeoffs that may be required as the project proceeds.

2. PHYSICAL CHARACTERISTICS

Solid state active phased array antennas employ transmit/receive modules instead of the centralized transmitter common to passive phased array radars. As such they offer the advantages of reduced transmit and receive losses, increased performance, higher reliability and lower weight. Figure 1 shows a notional active array configuration in which there is one radiating element per T/R module, each of which has its own power amplifier (PA) in the transmit path and low noise amplifier (LNA) in the receive path. Standard array tradeoffs exist between aperture size, beamwidth, scan volume, number of T/R modules and T/R module transmit power.

Fitting the fractional array within the current NWRT structure provides significant cost advantages, since the existing building, housing a SPY-1 array and pedestal approximately 40 feet above ground level, can be used. In addition, several other components of NWRT such as the Environmental Processor, Real Time Controller and Radar Scheduler could also support the fractional array.

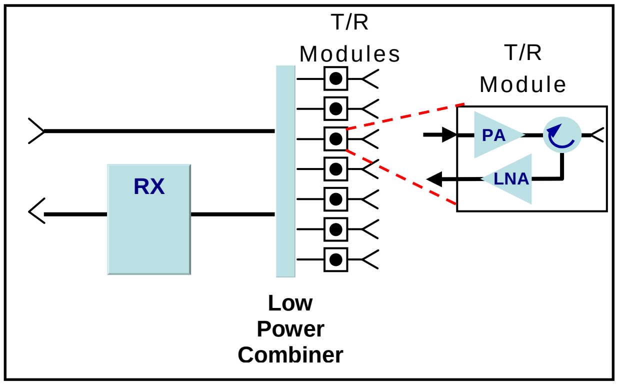

Figure 1 – Active Phased Array Configuration

To fit within the current structure of the NWRT, the fractional array will be subject to weight and size constraints. Initial tradeoff studies point to an array diameter of between 1 and 2 meters containing between 200 and 500 S-band dual polarization T/R modules of readily achievable transmit power corresponding to a beamwidth between 4 and 6 degrees. The array module spacing will support an azimuth scan of ±30° and elevation scan from 0° - 60° with a 15° array tiltback. The primary candidate array architecture applies overlapping subarrays for sidelobe control. Sensitivity will provide an SNR = 0 dB on a 20 dBZ reflectivity at 50 km with a pulse compressed waveform.

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This is sufficient to support the concept validation goals. Figure 2 is an artist's conception of a circular aperture fractional array installed on the NWRT array shelter. The SPY array is on the opposite side of the shelter (not shown).

3. CONCEPT VALIDATION REQUIREMENTS

3.1 *Dual Polarization*

Dual polarization is a critical requirement for any phased array weather radar. However, it is well known that the polarization vector of a beam with horizontal polarization at boresite will rotate as the beam is scanned. Thus a beam with orthogonal vertical and horizontal polarizations transmitted at boresite will not have the same orthogonal polarizations when scanned off boresite. A method for correcting for this off-boresite effect on receive is presented elsewhere in this session (Urkowitz, 2006).

The polarization correction method invented by Urkowitz (2006) places requirements on the T/R module for phase and amplitude control on receive. A significant objective for the fractional array is the incorporation of these requirements into the T/R module and array design and implementation and testing of this polarization correction scheme.

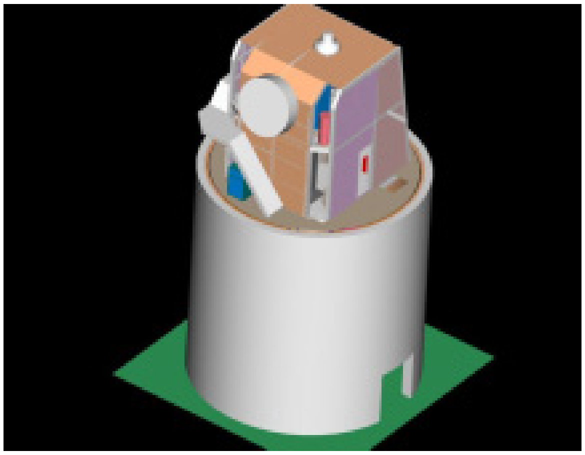

Figure 2 – Fractional array installed on rear of NWRT array shelter.

3.2 *Digital Beamforming*

Digital beamforming can be used when the analog outputs of antenna subarrays or individual T/R modules are converted to a digital data stream prior to beam formation. The receive beams are then formed by applying weights to the digitized subarray or T/R module outputs by the digital beamformer. In the fractional array, digital beamforming will support several capabilities. Figure 3 provides an overview of digital beamforming configuration with two subarrays.

A phased array radar capable of simultaneously satisfying both NWS requirements for weather surveillance and FAA requirements for air traffic surveillance must satisfy complex radar resource demands. By transmitting a broad beam and using digital beamforming to form multiple simultaneous receive beams, demands on radar resources are reduced. The gain in time occupancy comes at the cost of spreading of energy over a wider angle on transmit. An architecture exploiting digital beamforming for this multifunction array application has been proposed by Weber, et. al. (2006).

At a given radar site, buildings, towers and other forms of fixed clutter interfere with data collection at certain azimuths and ranges. For rotating reflector antennas, the region containing the obstacles may be blanked. However, for a phased array antenna with digital beamforming, a null can be inserted in the antenna pattern in the region with point obstacles, reducing the interference.

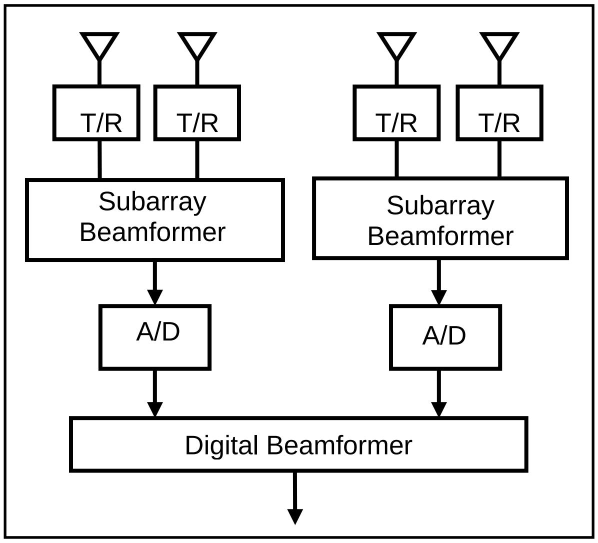

Figure 3 – Overview of Digital Beamforming Process

Radar provides direct measurement of only radial velocity. R. Doviak, et. al. (2004) have proposed use of Angular Interferometry (AI) and Spaced Angular Interferometry (SAI) to measure crossbeam winds. AI requires formation of two overlapping radar beams sequentially using the entire antenna aperture whereas SAI requires formation of simultaneous overlapping beams each formed from half the radar aperture. Although both of these techniques can be implemented and tested in the fractional array via digital beamforming, the small aperture of the fractional array may make it more suitable for testing of the SAI technique.

3.3 *Beam Multiplexing*

Beam multiplexing capability will provide the fractional array with the ability to reduce the time occupancy requirements of hazardous weather surveillance while maintaining the interpulse separation required for spectral moment measurement. It is most advantageous in situations simultaneously requiring a long PRI and short processed range, such as for hazardous weather detection in the air terminal area or in higher elevation beams. For example, a 1.0 ms PRI is nominally used for weather spectral moment estimation. However, for a 20 km altitude ceiling, beams above approximately 25 degrees in elevation require less than 50 km instrumented range. With a 2:1 beam multiplexing, data can be collected in two beams with an instrumented range in each beam of 50 km, while maintaining the 1 ms pulse to pulse separation in each beam required for spectral moment estimation. This saves 50% of the radar resources that would be required to collect data at a 1 ms PRI in each beam sequentially.

Although beam multiplexing can offer advantages, performance can be degraded by beam interference caused by multiple time around echoes. Several techniques have been proposed to mitigate this interference including use of orthogonal pulse codes (Urkowitz, 1997), frequency diversity and polarization diversity. As already stated, the fractional array will incorporate polarization diversity. Pulse compression will be required to attain the desired system sensitivity and at least two frequencies will be required to support frequency diversity. Thus the fractional array provides the opportunity to evaluate the various proposed interference mitigation techniques.

3.4 *Target Detection and Track*

To demonstrate multifunction capability, the fractional array will also incorporate aircraft surveillance, track while scan and dedicated track capability. Aircraft surveillance and track while scan can be implemented by scheduling radar dwells on a schedule defined by a fixed template. However, incorporation of dedicated track requires dynamic allocation of radar resources between competing scan functions. In general this requires implementation of a dynamic dwell scheduling capability that is not currently incorporated in NWRT. Thus revisions to the radar scheduler will be required. However, once the dynamic dwell scheduling capability is implemented, this capability can also be used to support incorporation of an adaptive weather scan capability in NWRT.

3.5 *Summary and Conclusions*

A solid state fractional array to provide proof of concepts supporting a future multifunction phased array is in the early design stages. The array will support validation of dual polarization control and calibration, use of digital beamforming for cross-beam wind measurements, beam multiplexing investigations and general multifunction applications. Table 1 summarizes some of the system constraints, functional requirements and their accompanying design impacts. Several Lockheed Martin proprietary array architectures are currently being considered as fractional array candidates.

Functional Req./ System Constraint	**Design Impact**
Fit within NWRT structure	Low size, weight => low module count
Low T/R module count	High avg. power, pulse compression
Simultaneous Wx and Aircraft Surveillance	Simultaneous beams on receive, beam multiplexing, multiple frequency channels
Cross beam wind measurements	Digital beamforming
Beam multiplexing	Polarization, frequency and waveform diversity
Dedicated Track	Dynamic dwell scheduling

Table 1 – Fractional Array Functions and Design Impacts

4. REFERENCES

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