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7.0 PHASED-ARRAY DESIGN FOR MST AND ST RADARS

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INTRODUCTION

All of the existing radar systems fully dedicated to clear-air radar studies use some type of phased-array antenna. The aim of this session is to communicate developments in array design and application. The suggested subtopics for this session are listed below along with a brief discussion of each subject.

BEAM-STEERING TECHNIQUES INCLUDING FEED NETWORKS AND PHASE SHIFTERS

Clear-air radars built to date have varying degrees of beam-steering flexibility, depending on the planned research goals (and the available funding). The simplest clear-air radar arrays use fixed beams (hard wired), and the most complex use computer-controlled phase shifters that can steer the beam to any position within 20 to 30 degrees of the zenith in a few micro-seconds. In general, increased beam-steering flexibility requires more complicated feed networks with additional phase-shifting hardware and associated control and testing circuitry.

SIDELOBE CONTROL, GROUND-CLUTTER SUPPRESSION AND LOW ALTITUDE COVERAGE

Sidelobe reduction in clear-air radar arrays is important for two major reasons. First, if the atmospheric reflectivity is very nonuniform horizontally, unwanted echoes from regions of high reflectivity in the sidelobes may override the wanted echoes from the main lobe of the array. Specular reflections from stable layers and scattering from isolated rainclouds are examples of regions with high reflectivity that may cause problems. The second reason that sidelobe reduction is important involves clutter from nonatmospheric targets. Echoes from airplanes, cars and the sea surface may override the atmospheric echo. In addition, the Doppler shifts from these objects may be nearly the same as the Doppler shifts from the wanted atmospheric targets making it difficult to filter out the unwanted clutter. Ground clutter may also be so strong that it overdrives the receiver at fixed ranges. The above problems suggest that at least under some circumstances it may be important to reduce the antenna array sidelobes.

The goal of most of the clear-air radars built to date has been to get useful data from the highest possible altitudes. However, for some applications (particularly wind profiling) continuous measurements from the ground upward are desired. Most clear-air radars operating in the lower VHF band do not obtain data below several km. It would be very useful if this lower altitude coverage could be extended downward. Reasons why these radars do not work at lower altitudes are not very well established at this time but may include the following problems: leakage of frequency-coherent energy from the transmitter after the pulse (turn-off problem); reflection of energy within the array with an intensity that overdrives the receiver for a finite time; reflection of energy from the nearby ground (ground clutter) that overdrives the receiver.

ARRAYS WITH INTEGRATED RADIATING ELEMENTS AND FEED NETWORKS

Most clear-air radar antenna arrays use a large number of radiating elements. This means that the feed network is generally complex, consisting of at least one feed cable per element. This approach makes it possible to steer the beam to a large number of positions, since the phase of each element can be controlled separately. However, if only limited or no beam steering is required, the antenna system can be simplified by using designs that physically integrate the radiating elements and the feed network. These designs are generally either traveling wave or resonant structures. The traveling wave structures have the property that beam position is controlled by the operating frequency. Beam steering by frequency scanning or stepping might be attractive for some clear-air radar applications. However, since most radars operate at a single, fixed frequency, the resonant structures seem to be most applicable for clear-air radar use. The Franklin and coaxial-collinear arrays are examples of structures that drive a number of radiating elements end-to-end from a single feed point. The grid or chain array is a structure that allows a large square array to be driven from a single feed point.

ANALYSIS OF THE COAXIAL-COLLINEAR ANTENNA

The earliest clear-air radar experiments were conducted at the Jicamarca Radar Observatory in Peru. This radar uses coaxial-collinear elements made of rigid metal tubes and rods with the inner and outer conductors interchanged at half-wavelength intervals. Antennas using the same design but made of ordinary flexible coaxial cable have been widely used in clear-air radar arrays for the past 10 years. In spite of their widespread use (and usefulness), a number of questions still remain about how these antennas work and whether or not the design could be further optimized. Several studies of the coaxial-collinear antenna are currently in progress and the results from these studies may lead to improved designs in the future.

USE OF ARRAYS WITH MULTIPLE BEAMS

The usual way to form multiple beams with an array antenna is to use phase shifters in the feed network to form one beam at a time. There is currently some debate about how many beams are required to adequately describe the wind and wave fields in the atmosphere. A practical problem of using too many beams is that for dwell times of a minute or more (required to get adequate sensitivity) the cycle time around a large number of positions is so long that short period wave activity cannot be measured. One way to overcome this problem is to use an interferometer array to form a number of beams simultaneously. If the wind field is fairly uniform over the beams, the Doppler shifted echoes from each beam are separated in frequency and can be uniquely identified. This approach can be used for special studies when the reduced sensitivity is not a problem and when simultaneous measurements of velocity and signal to noise are required on a number of separate beams.

ARRAY MEASUREMENT AND TESTING

It is difficult to measure the antenna patterns of large area array antennas because the near field often extends to altitudes that cannot be reached by airplanes. Even in those cases when airplanes can be used to map the patterns, it is difficult to know or control the position of the airplane with sufficient accuracy. Most array patterns have been measured by using satellite beacons or cosmic radio sources. Radiating elements in the array can also be probed for relative phase and amplitude, and the resulting measurements can be used to compute the antenna patterns. The important pattern parameters are beam position, beam width and sidelobe levels. It is desirable to know the sidelobe levels over the entire hemisphere, since in some antenna designs unwanted high level sidelobes can occur far from the main beam.