FAA TECHNICAL CENTER LETTER REPORT

NEXRAD ANTENNA SCAN RATE - WIND SHEAR DETECTION INVESTIGATION

PROJECT PLAN

by

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1. INTRODUCTION.

1.1 PURPOSE.

The purpose of this project is to determine if wind shear phenomena can be reliably detected and measured with the ASR-8 pulse Doppler system employing a continuous antenna scan.

1.2 BACKGROUND.

The measurement of hazardous terminal area weather phenomena has been, and continues to be, a major goal of the FAA. Wind shear (abrupt change in wind direction and/or speed), for example, has been the cause of at least nine terminal area accidents since 1972.

As a result, a series of tests was conducted at the Technical Center to evaluate the wind shear detection capability of the Terminal Facility for Automated System Testing ASR-8 pulse Doppler, modified by the Wave Propagation Laboratory (WPL), using a special purpose parabolic antenna. In these tests (reference 1), with the antenna in a fixed position, and using the fast fourier transform (FFT) algorithm for data processing, the system was shown to be capable of measuring wind phenomena under a varity of conditions.

The need to detect and measure winds using a continuous antenna scan has arisen because of tentative FAA requirements pursuant to development of the Next Generation Weather Radar (NEXRAD). This system is being developed jointly by the Departments of Commerce (DOC), Defense (DOD), and Transportation (DOT) as a single radar designed to serve the purposes of all three organizations. Reference 2 provides an overview of NEXRAD.

Accordingly, under the sponsorship of the Program Engineering and Maintenance Service APM-310, the Technical Center's TFAST ASR-8 Wind shear Detection system will be modified as required, and tests performed to evaluate the scanning technique. This project plan provides a brief description of the system and the general tests to be performed.

1.3 SYSTEM DESCRIPTION.

The Technical Center's TFAST ASR-8 was previously modified to detect and measure winds in the terminal area under all weather conditions, including optically clear air. The radar returns occur because of scattering from refractive index fluctuations in the atmosphere. Doppler processing enables the returns to be separated by spectral analysis into radial velocity components. A more detailed system description is provided in reference 1.

As previously discussed, wind measurements were made with a fixed antenna and FFT type processing. The proposed scanning technique may require pulse pair processing and the use of a TFAST system designed for thunderstorm turbulence measurements. This system, developed by the Massachusetts Institute of Technology, Lincoln Lab (MIT/LL) records data on a grid of range-azimuth cells in a window controllable in range and azimuth dimensions. As the antenna sweeps the window, a 262K buffer memory is filled with 21-bit digital words of in-phase and quadrature (I&Q) information from each pulse volume. The data are then read out on tape through a minicomputer which also computes the three principal spectral moments (i.e. zeroth, or reflectivity; first, or Doppler mean velocity; and second, or Doppler spectral width).

The I&Q components for each radar pulse volume are recorded range sequentially. They are then reordered in azimuth and a maximum entropy estimation is used to compute the Doppler moments.

2.0 PROPOSED TEST PROGRAM.

Final system requirements for the NEXRAD are still in the formative stage. Such key parameters as siting, data update rates, coverage volume and information output have yet to be completely resolved to the satisfaction of all the joint users. Thus, this scan rate investigation will attempt to accommodate as wide a range of variables as possible. The program will be conducted in a series of distinct phases as described in the ensuing paragraphs.

2.1 ANALYSIS OF TENTATIVE REQUIREMENTS.

The FAA NEXRAD system requirements as they are presently described are presented in some detail in references 3-5. The information in these documents will form the basis for this analysis, the purpose of which is to develop a meaningful test program.

Reference 3 outlines considerations for optimum siting purposes. It shows that the detection of low level wind shear without precipitation imposes the most severe constraints on NEXRAD siting. Three general siting areas are considered in the report: 1. within the airport area, 2. within the terminal area, and 3. outside the terminal area.

Reference 4 is a draft of a system requirement statement prepared internally by FAA which provides details relating to coverage volume, information output and data update rate. Reference 5 describes certain technical characteristics.

Additional information will be obtained as it becomes available. The results of this phase of the study will be used to determine optimum system configuration for the data collection phase.

2.2 SYSTEM RECONFIGURATION.

It may be possible that reconfiguration can be accomplished with a minimum of hardware and/or software modification. The extent of such modifications will be determined during the study phase, and acqusition of necessary material, if required, will be initiated as soon as practical.

Hardware changes, if any, will be dictated primarily by need to increase processing capacity; software will be designed to provide flexibility in order to perform comparative tests.

2.3 DATA COLLECTION.

2.3.1 Comparative Tests.

Data will be obtained to provide a comparison between the "standard" or fixed antenna mode and the scanning antenna mode of operation. The system will be operated on a daily basis using a wide range of parameter settings, while observing and recording data from a variety of meteorological conditions.

Typical procedures will include a series of fixed antenna glide slope observations, with elevation angle increments of +3°, +6° and +9° (or higher, depending on conditions), followed by a repeat of elevation cuts with the antenna scanning at 2, 3 and 4 rotations per minute (RPM), also as dictated by conditions. The data will be recorded in each case for later playback and analysis. The tests will be made while observing radar returns from signals which may vary from noise level (for optically clear air with low values of C_n^2) to greater than 60 dB for heavy rain showers. Returns from "angels" (ground traffic, birds, and/or other anomalous moving targets), which are detected under certain conditons will be examined, as well as the effects of ground clutter.

When potentially dangerous thunderstorms are in the area, the system parameters will be varied to record "before" and "after" data resulting from such signal returns. Low-level winds from thunderstorm gust fronts as well as upper level winds associated with the storms will be examined for comparison.

Data will also be recorded with system parameters set to simulate the various siting locations, update rates and coverage volumns being considered for NEXRAD, as previously discussed. Other important parameter changes which may be determined by new NEXRAD system requirements will be exercised during the course of this evaluation.

2.3.2 Controlled Flight Tests.

A limited number of tests will be made to compare the two radar modes while simultaneous data is obtained from an inertial navigation system (INS) - equipped Technical Center aircraft. Two operating procedures will be used; first, with a fixed radar antenna mode the aircraft will fly simulated 3° glide slope approaches directed toward the radar site (assumed to be at the touchdown point) on a heading approximately aligned with the winds. The radar will be configured to measure the radial wind components for discrete altitude levels just ahead of the aircraft as it descends. This same procedure will then be repeated with the antenna scanning mode.

Secondly, the aircraft will be directed to fly a more complex, curved pattern towards the radar site to simulate a Microwave Landing System (MLS) approach. In this case, radar data will be recorded first with the antenna incrementally fixed at several points along the expected flight path in the fixed antenna operational mode, then the flights will be repeated with the radar in the antenna scanning mode. As in the previous case, the radar will record wind information for discrete altitude levels just ahead of the aircraft as it descends.

3. DATA ANALYSIS AND REQUIRED RESULTS.

The data recorded during the daily tests will be examined to compare the three principal spectral moments resulting from the fixed antenna, FFT radar system, and the scanning antenna, (or variations thereof) radar system. Similar data comparisons of the various parameter changes will also be examined and noted. The data will be presented in a form similar to data shown in reference 1.

The aircraft data will be statistically summarized in tabular form and compared to simultaneously recorded radar data, and will also be graphically plotted to show a direct comparison of computed wind profiles for each case.

4. PROPOSED CONCLUSIONS AND RECOMMENDATIONS.

It will be concluded that radar performance with the various antenna scan rates (and other optional parameter variations) does or does not compare favorably with the fixed antenna radar performance. It may also be concluded that only certain siting locations can be employed for a terminal NEXRAD system.

Based on those conclusions it will be recommended that either a scanning antenna or fixed antenna system be employed by the FAA. Recommendations will also address the various parameter options examined during these tests.

5. RESOURCES.

Manpower

Project accomplishment	3.0 MY

Facilities

TFAST	260	Hours
(INS Aircraft)	10	Hours
Flight Operations	30	Hours

Contract Dollars 10.0K

6. SCHEDULE.

Project Plan	11/82
Analysis	2/83
System Reconfiguration	4/83
Data Collection	10/83
Data Analysis	11/83
Report	1/84

7. ORGANIZATIONAL RESPONSIBILITY.

The entire test effort will be accomplished by the Systems Test and Evaluation Division, ACT-100.

8. REFERENCES.

Offi, D.L., Lewis, W., Lee, T. and Delamarche, A., Test and Evaluation of the Airport Radar Windshear Detection System, DOT/FAA/RD-81/85, DOT/FAA/CT-81/63, Final Report; Washington, D.C.; February 1982.

Bonewitz, J.D., The NEXRAD Program - An Overview, Pre-prints, 20th Conference on Radar Meteorology, PP757-761, American Meteorological Society, Boston, MA; December 1981.

Mahapatra, P.R., ZRINC', D.S., and Doviak, R.J., Considerations for Optimum Siting of NEXRAD to Detect Convective Phenomena Hazardous to Terminal Air Navigation (Part 1); DOT/FAA/RD-82/56 SRDS, Final Report; Washington, D.C., May, 1982.

System Requirements Statement for Next Generation Weather Radar (NEXRAD); DOT/FAA Order (1812.) (Draft), undated.

Sirmans, D., NEXRAD Radar Subsystem Evaluation Study, Interim Report (un-numbered), Joint Systems Project Office, National Weather Service, NOAA, Department of Commerce, Silver Spring, MD; July, 1980.