FAA TECHNICAL CENTER LETTER REPORT

WAKE VORTEX DETECTION WITH PULSED-DOPPLER RADAR ASR-8 FEASIBILITY TESTS

by

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PURPOSE.

The purpose of this project was to examine the feasibility of detecting aircraft wake vortices with the Technical Center's Airport Surveillance Radar (ASR)-8 weather system.

BACKGROUND.

The trailing wake vortices produced by large jet aircraft have long been identified as a problem confronting the Air Traffic Control (ATC) system. The problem arises primarily from small aircraft encounters with these vortices when following too closely behind large jets in terminal area operations. A number of damaging and/or fatal accidents have occurred under such circumstances.

Although much effort has been expended, no effective solution has yet been developed in terms of reliable detection and quantification. Rather, the solution implemented by the Federal Aviation Administration (FAA), i.e., an increase in aircraft separation standards, has served to worsen the existing problems of operations delay and airport capacity. The increasing emphasis on fuel conservation makes a decrease in separation standards desirable; hence, the search for solutions to the wake vortex problem has once again become acute.

Work performed by the Wave Propagation Laboratory (WPL) indicates that sensitive, continuous wave (CW) radars can detect wake vortices. Further, WPL has proposed that a pulsed radar, such as the Technical Center's ASR-8 equipped with Doppler processing and a conical-beam antenna, be used to detect and measure the vortices. As a result, ARD-231 requested a short-term effort to establish feasibility. If promising, a longer-term effort would follow.

A parallel short term feasibility effort, sponsored by the FAA office of Systems Engineering Management (OSEM) is also underway at WPL. In their tests, a frequency modulated (FM), CW radar is being used at Denver's Stapleton Airport to see if aircraft wake vortices can be detected by radar.

Their techniques and methods of approach are similar to those described in this report. Close coordination and cooperation was maintained with WPL to assure a timely information exchange which could be mutually beneficial.

A complete description of the Technical Center system, and an analysis of the factors involved in wake vortex detection by radar is presented in the Project Plan (Reference 1).

TEST PROGRAM

Because this was a short-term feasibility effort, tests were performed without any modification to the existing system. Data were collected just prior to (for comparison purposes) and following the passage of a heavy jet aircraft through the systems sampling window. The early testing was to have been conducted using targets of opportunity to avoid high costs associated with large jet operation. The Technical Center airport is normally used extensively by New York based air carriers to conduct routine training flights, but because of the air traffic controller strike, routine training flights were severely cut back, thus limiting the data collection in this mode.

TARGETS OF OPPORTUNITY TESTS.

The system was configured to obtain data along the 13-31 instrumented runway as shown in figure 1. The antenna was oriented at an azimuth and elevation such that the landing aircraft intercepted the radar beam. All data were obtained with the aircraft on approach since the wake vortices problem has been reported to be more severe with aircraft in this configuration. Because of the radar's offset location with respect to the 13/31 runway, the antenna beam sampling volume was located at the 800-foot level above ground to gain higher signal-to-clutter (ground) ratios.

Data were recorded in several range gates straddling the glidepath center line. The system was on continuously, but data were recorded only during those times just prior to and for several minutes following the flight of any large jet along the glidepath. Flight operations were monitored via standard radar and PPI presentations and air-ground voice communications.

The data were recorded in real-time using a Tektronix graphics display and associated hard copy unit, and were examined for presence or absence of spectral signatures for the "before and after" cases of aircraft passage through the data collection window.

There were a number of limitations inherent with these tests which must be considered. First, since the ASR-8 location is offset from the runway, the antenna elevation angle setting was lower than in a standard 3^{o} glide slope mode resulting in stronger ground clutter returns which masked the wake vortices signals. Second, the aspect angle between the radar antenna and extended vortex system was acute, so that the vortex cross-sectional areas viewed were smaller than would be obtained parallel to the glide slope. These factors coupled with the previously mentioned lack of targets-of-opportunity resulted in no detection of wake vortices in this mode.

Accordingly, an additional limited number of tests were performed with the Technical Center's B-727 to obtain data under optimized conditions.

CONTROLLED AIRCRAFT TESTS.

In the first series of controlled flight tests the antenna was oriented along an azimuth advantageous to existing conditions (i.e., prevailing low level winds, ground clutter, angel clutter, etc.) at a +3° elevation angle. The point at which data collection commenced was free of ground clutter contamination. The aircraft flew with flaps and landing gear deployed as in actual landings, and was directed (by local control) toward the radar. Data were recorded just prior to and for several minutes following the flight. Radar and voice communications were employed to monitor test flights, and low level wind information (from a site-located anemometer) was noted. Results for these flights, were negative, with no indication of vortices detection in any of the data samples.

In the second series of controlled flight tests, with the antenna at an elevation angle of 90° and the aircraft flying over the radar site, there were indications of clear air signals in the data on a number of flights, but not in all cases. The exact nature of these signals, and their relationship to aircraft wake vortices was not determined for these feasibility tests. A sample of the observed signals is shown in figure 2. In this case, the aircraft was flying at 1600 feet, on a path which was not directly over the site, but displaced about 1500 feet upwind (perpendicular to the wind direction) so that the vortices would drift over the site. The wind velocity as measured by the aircraft was approximately 15 knots at that altitude. Thus, the vortices would be expected to be in the antenna beam sampling volume approximately 1 minute after passage of the aircraft.

The system was configured to obtain data at one fixed point in altitude (range) at about 1575 feet, and recording was continuous. The resulting clear air signals associated with the aircraft's wake can be seen in the 8th, 9th, and 10th data samples, alternating from -20 to +20 knots radial velocity as the vortices drifted across the radar antenna beam from 42 to 54 seconds after the aircraft's passage. Since the aircraft was traveling at a speed of 120 knots, it was approximately 2 nmi from the radar site when the signals shown in figure 2 were detected. Therefore, they were not due to reflections from the aircraft. This is further verified by the change from negative to positive doppler velocities associated with the signals as a function of time.

For the test configuration used, there was very little radial velocity (vertical movement) associated with the aircraft wake signals being detected. The spectral signals centered about zero doppler in all the data samples are due to side-lobe detected ground clutter, and ambient clear air returns. The low amplitude signals at ±35 knots are caused by ground clutter signal saturation in the receiver.

It is of interest to note that the ±20 knot radial velocities in this data correspond closely with the ±9 m/s velocity in vortex data obtained by WPL personnel in a previous experiment (Reference 2). They indicated that the change in velocity they observed was due to the vortex being considerably larger in diameter than the antenna beams diameter, thus preventing the entire vortex from being detected at one time. The ASR-8 weather test bed antenna beam diameter (3dB) at the data collection range was 40 feet. Based on the analyses in Reference 3, the vortex would be expected to be greater than 80 feet in diameter when detected. The velocities also correspond to predicted values of vortex tangential velocities based on models, as reported in Reference 3.

SUMMARY OF RESULTS

The analysis showed that the system may be capable of detecting vortices. Targets-of-opportunity tests were limited in number, and did not produce any positive data.

no space

Controlled aircraft tests produced indications of clear-air signals associated with the aircraft flying over the radar site.

CONCLUSIONS AND RECOMMENDATIONS

It is concluded that wake vortex detection with the ASR-8 may be feasible. It is recommended that further testing be conducted following the upgrading of the Technical Center's radar capabilities. The upgrading should be based on results of a system analysis, and similar work performed at the Wave Propagation Laboratory.

REFERENCES

1. Offi, D.L., Wake Vortex Detection with Pulsed Doppler Radar-Project Plan, DOT/FAA/CT-81/187.

2. Campbell, W.C., Chadwick, R.B., Earnshaw, K.B., and Moran, K.P., Low Elevation Angle Wind Measurements by FM-CW Radar, Proceedings of the 19th Conference on Radar Meteorology, American Meteorological Society, Boston, MA. PP 722-726, April, 1980.

3. Huffaker, R.M., et al. Development of a Laser Doppler System for the Detection, Tracking and Measurement of Aircraft Wake Vortices, FAA/RD-74-213 March, 1975.

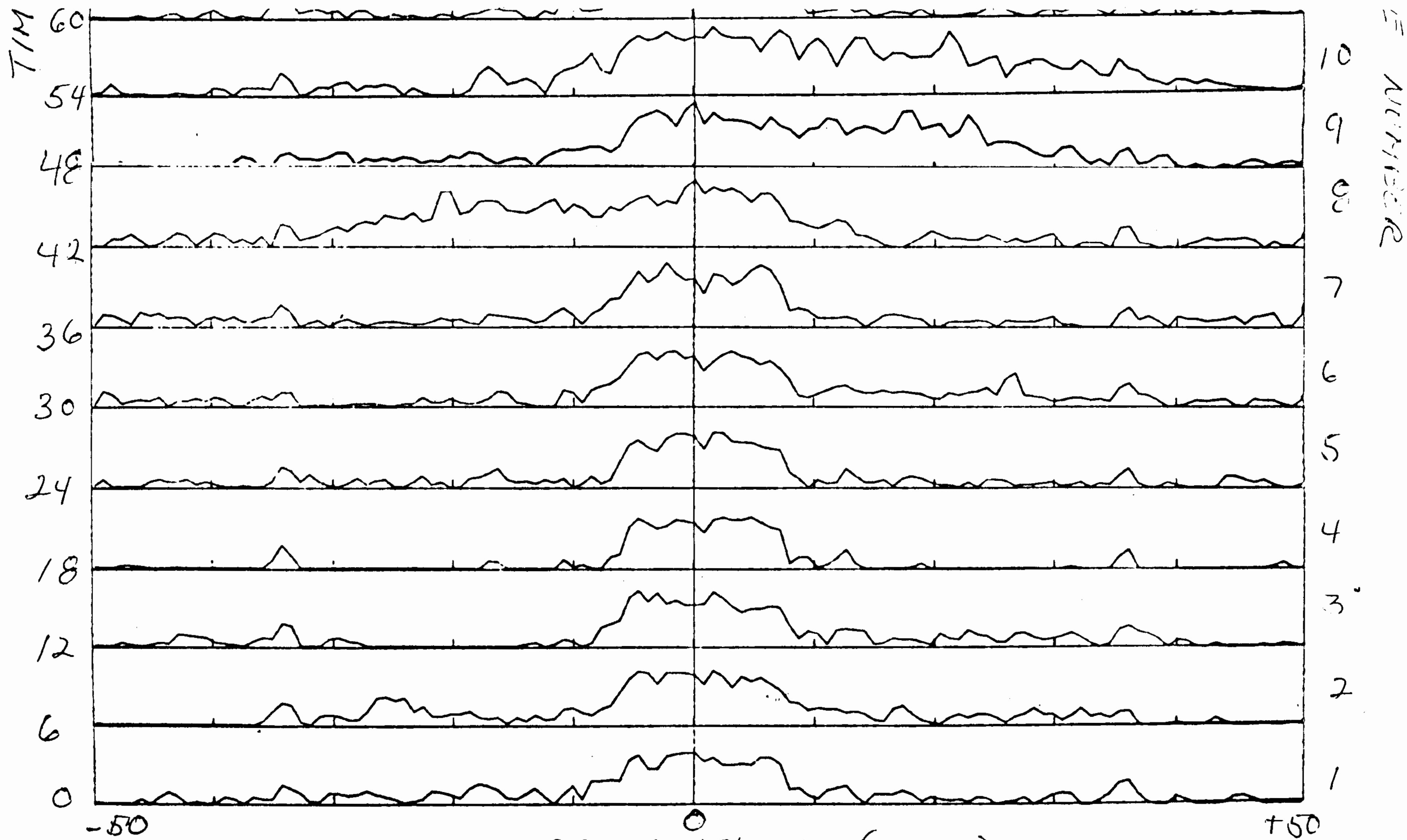

FIG. 2. WAKE ASSOCIATED SPECTRAL SIGNALS

18A

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PRPR    0.0        DLAY    3.0        SPAC   0.0
NORG   8           NAVG   6           NSMP 128
SCLE  30           BASE   7           DNUM      0
INTR      0        RTRN      0
DATE  0/ 0/ 0    TIME  0. 0  0
AZMT  110 0        ELEV   90.0
ID#      0         ENAM WAKEVORTEX
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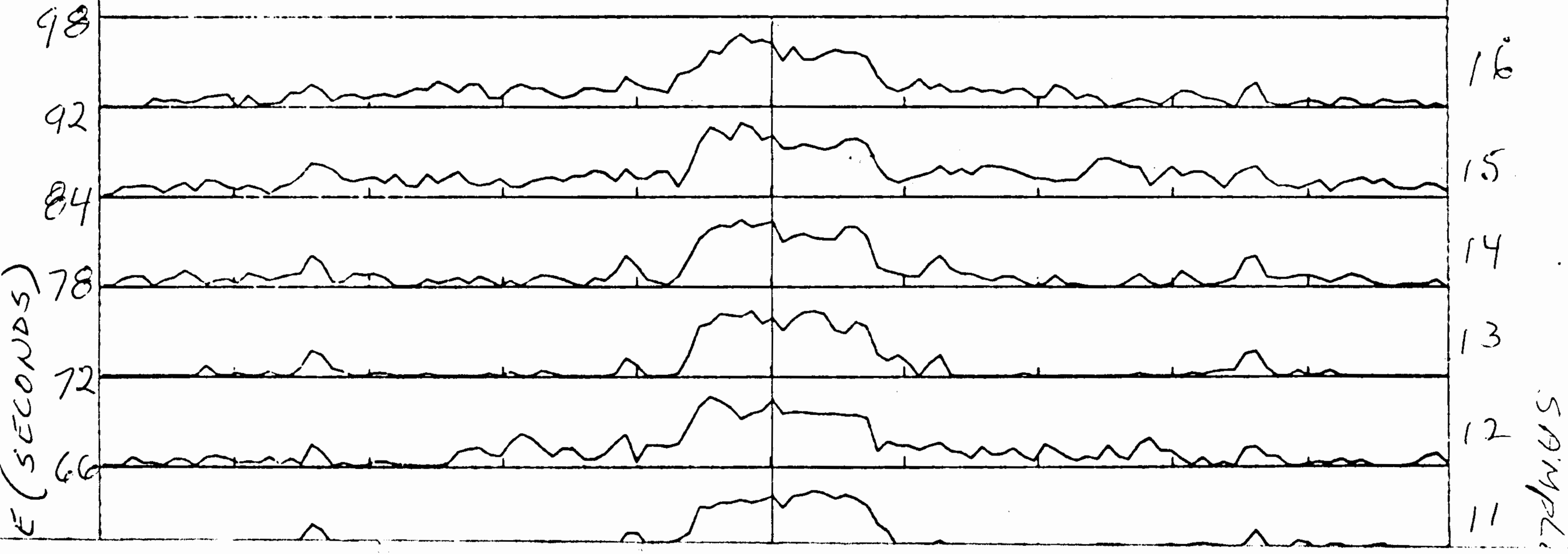

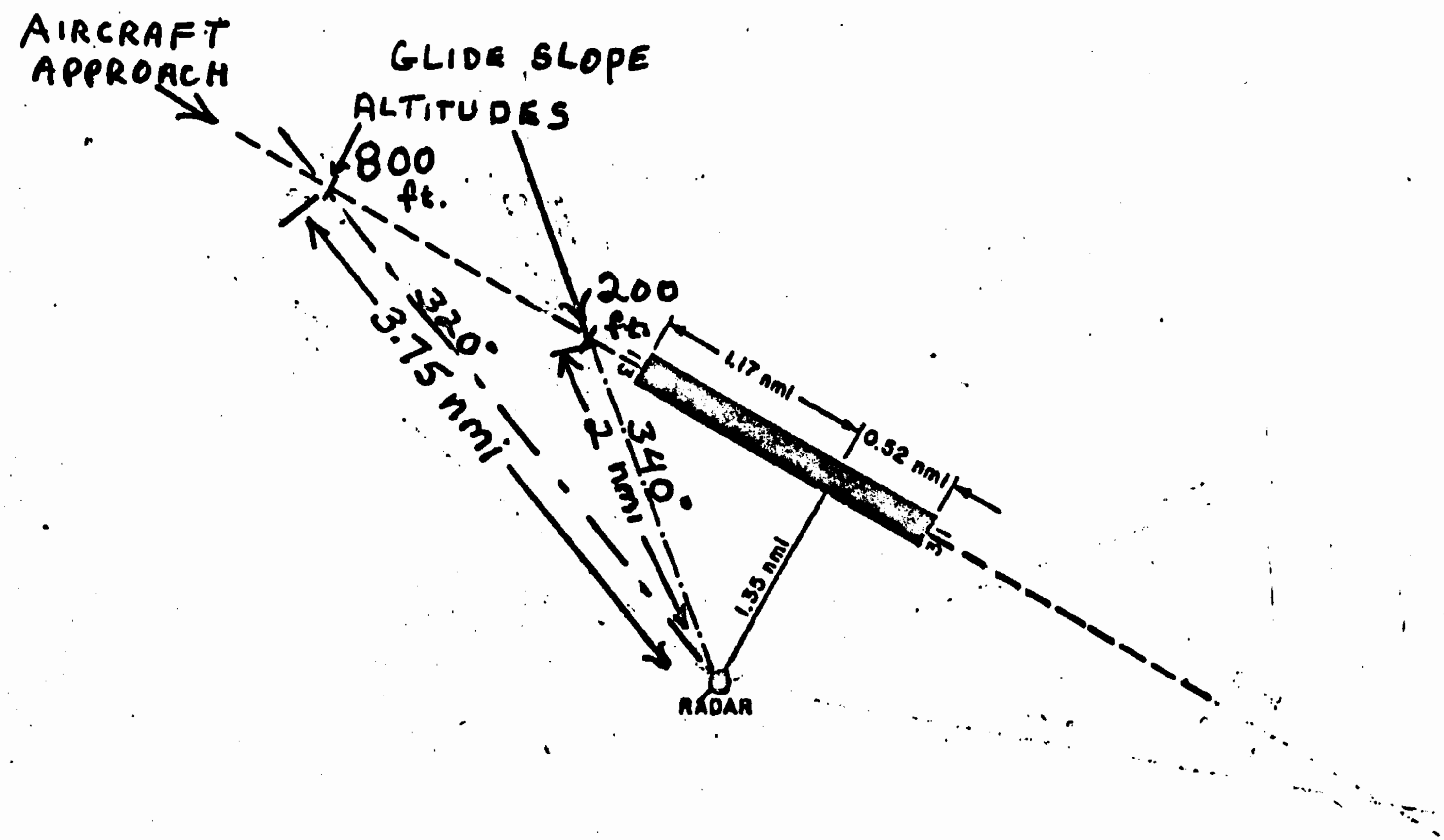

FIGURE 8 RUNWAY 13-31, RADAR LOCATION AND DATA AZIMUTHS FOR VORTEX DETECTION TESTS.