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The Millstone Hill UHF radar was used as a diagnostic tool for investigating plasma waves and turbulence. During the 15-month interval covered by the first year of this award, experiments were performed using an alternating-code technique in order to assess this capability for use as a plasma-wave diagnostic. Experiments at fixed antenna position and with real-time interaction investigated phenomena near perpendicular flow angle when looking very close to perpendicular magnetic aspect angle conditions. Analysis of prior data showed that when flow angle is varied through perpendicular while holding 0° aspect angle, an abrupt change in sign of the line of sight phase velocity is observed. Preparations were continued for bistatic coherent backscatter experiments in FY '94 using the MIDAS-C data acquisition system developed at Millstone Hill for use as a bistatic receiver in Canada.					
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ANNUAL SCIENTIFIC REPORT

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**MILLSTONE HILL RADAR STUDIES
OF PLASMA WAVES AND TURBULENCE**

Principal Investigator:

**Dr. John C. Foster
Assistant Director
MIT Haystack Observatory
(617)-981-5621**

for the period
1 August 1993 - 31 October 1993

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Scientific Accomplishments: First Year

The Millstone Hill UHF radar provides a sensitive diagnostic tool for investigating plasma waves and turbulence by means of radar backscatter from waves of 34-cm wavelength. Permission was given to begin work under AFOSR Grant # F49620-93-1-0019 during a three-month pre-award period which began August 1, 1992. During the 15-month interval covered by the first year of this AFOSR-supported research program, experiments were performed (September, 1992) using an alternating-code technique in order to assess this new capability for use as a plasma-wave diagnostic. Experiments at fixed antenna position and with real-time interaction were performed in order to investigate phenomena found near perpendicular flow angle when looking very close to 0° (perpendicular) magnetic aspect angle conditions. Preparations were continued for the start of bistatic coherent backscatter experiments in FY '94 in cooperation with researchers at the University of Western Ontario and using the MIDAS-C data acquisition system developed at Millstone Hill for use as a bistatic receiver. Scientific presentations of the ongoing plasma wave research program at Millstone Hill were made in Russia and at the IAGA Symposium in Argentina.

A). September 1992 Coherent Backscatter Experiments

On September 9 and 17, 1992, coherent echoes were collected using the MIDAS data acquisition system on the Millstone Hill UHF radar. The September 9th experiment was run with a fixed antenna position directed towards the position of maximum coherent backscatter sensitivity (19 AZ, 6 EL). The event rose very quickly to maximum power level in 10 min @ 20.5 UT with some oscillation in power of 10 dB-30 dB amplitude near the start. RTI analysis shows enhancements moving N to S in field of view. After 21.0 UT, the backscatter amplitude smoothed out and decreased very slightly over time after that (@112 km). V_{ph} rose from 200 m/s to 500 m/s over the next 2-hr period and then dropped after 23.2 UT as the event started to break up. The experiment was terminated @ 23.8 UT, having given good, constant data for > 2 hours. This experiment demonstrated the utility of the alternating-code technique for coherent backscatter experiments. Analysis of the data taken is proceeding.

The September 17, 1992 experiment was run with continual real-time operator interaction in order to sample a number of parameters while investigating the perpendicular flow velocity/zero aspect angle effects seen during experiments on June 5, 1991 which were the subject of reports given at meetings during 1993. Azimuth scans at a number of elevation angles were made to provide a grid of azimuth/aspect data at several altitudes. There was little altitude difference in the characteristics of the phase velocity observed during the experiment. The complex sampling pattern used in this detailed investigation is apparent in the data of Figure 1 which presents a summary of the observations made during the two experiments.

B). Flow and Aspect Angle Studies of 440 MHz E Region Spectra Observed at Millstone Hill

Azimuth and elevation scanning experiments with the 46-m steerable antenna and the Millstone Hill 440MHz radar have been used to investigate the spectral characteristics of 34-cm coherent backscatter from the auroral E region as a function of both magnetic aspect angle and flow angle. When flow angle, the angle between the measured $E \times B$ direction and the radar k vector, is varied through perpendicular while holding 0° aspect angle, an abrupt change in sign of the line of sight phase velocity is observed, with little variation in the amplitude of the backscattered signal.

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Elevation scans which vary the aspect angle, while holding perpendicular flow angle, revealed an altitude-dependent, abrupt change in sign for the observed phase velocity near 0° aspect angle. Spectral widths of 200 m/s - 500 m/s are characteristic of these studies and two such spectra, with opposite-sign Doppler, are evident at altitudes near 100 km near the phase velocity transition. Observations using a 5-pulse multipulse mode as well as a 16-baud alternating code were analyzed.

Data taken at Millstone Hill during experiments on June 5, 1991 which illustrate these effects are presented in Figure 2.

Research Papers Generated under AFOSR Support: FY '93

- 1) del Pozo, C. F., J. C. Foster, and J.-P. St. Maurice, Dual-Mode E Region Plasma Wave observations from Millstone Hill, *J. Geophys. Res.*, 98, 6013-6032, 1993.
- 2) Groves, K. M., M. C. Lee, and J. C. Foster, Nonlinear Ionospheric Propagation Effects on UHF Radio Signals, in *Physics of Space Plasmas (1991)*, pp 377-391, Sci. Pubs., Cambridge, MA, 1993.
- 3) Uspensky, M. V., A. V. Kustov, G. J. Sofko, J. A. Koehler, and J. C. Foster, An Alternative Look at the Aspect Sensitivity of Auroral Radar Backscatter: A Forward Scatter Effect, *J. Geophys. Res.*, 98, 7721-7728, 1993.

Travel Supported by AFOSR Project

August, 1993, Buenos Aires, Argentina: J. Foster to attend 1993 IAGA Symposium in order to participate in a special session devoted to ionospheric plasma-wave backscatter experiments. A research paper on flow and aspect-angle sensitivity studies was presented.

Professional Personnel

Dr. J. C. Foster - Principal Investigator
Dr. D. Tetenbaum - Research Scientist
Mr. A. D. Pailes (digital engineer - MIDAS-C)
Ms. C.-N. Lue (applications programmer))

Scientific Interactions

1. Spoken Papers:

"Ionospheric Backscatter Investigations of Plasma Waves and Processes", (J. Foster), International Summer School on Space Plasmas, Nizhny Novgorod, Russia, June 1993 (tutorial).
"Flow and Aspect Angle Studies of 440 MHz E Region Spectra Observed at Millstone Hill", (J. Foster), 1993 IAGA Symposium, Buenos Aires, Argentina, August, 1993.

2. Consultative and Advisory Functions:

- | | |
|------------------------------|--|
| a) DMSP overflight campaign. | AF/Phillips Laboratory personnel: F. Rich. |
| b) Ionospheric Tomography | AF/Phillips Laboratory personnel: J. Klobuchar |

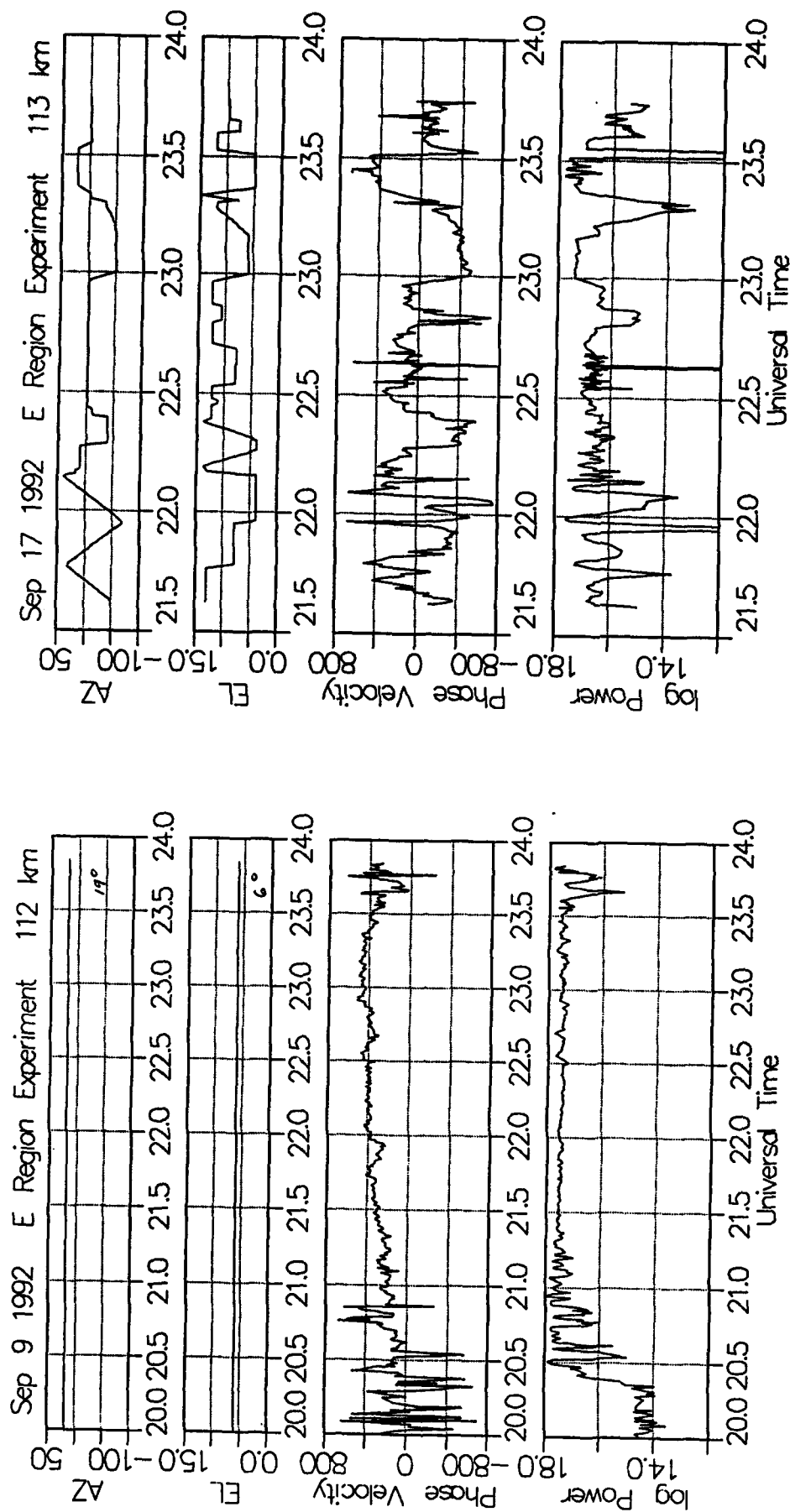


Figure 1. Summary plots of radar backscatter data taken during alternating-code experiments in September, 1992. Fixed azimuth (AZ) and elevation angles (EL) were used on September 9th during which a long-duration coherent backscatter event was observed. Backscatter amplitude increased rapidly by 40 dB at the beginning of the two-hour event and was steady and decreasing slowly through the body of the event. Line of sight phase velocity increased from 200 ms^{-1} to 500 ms^{-1} through the event. The September 17th experiment consisted of many individual experimental operating modes designed to probe various aspects of the backscatter mechanism. Azimuth and elevation angles of the transmitting antenna were varied and the resultant variations in signal power and phase velocity recorded for analysis and interpretation.

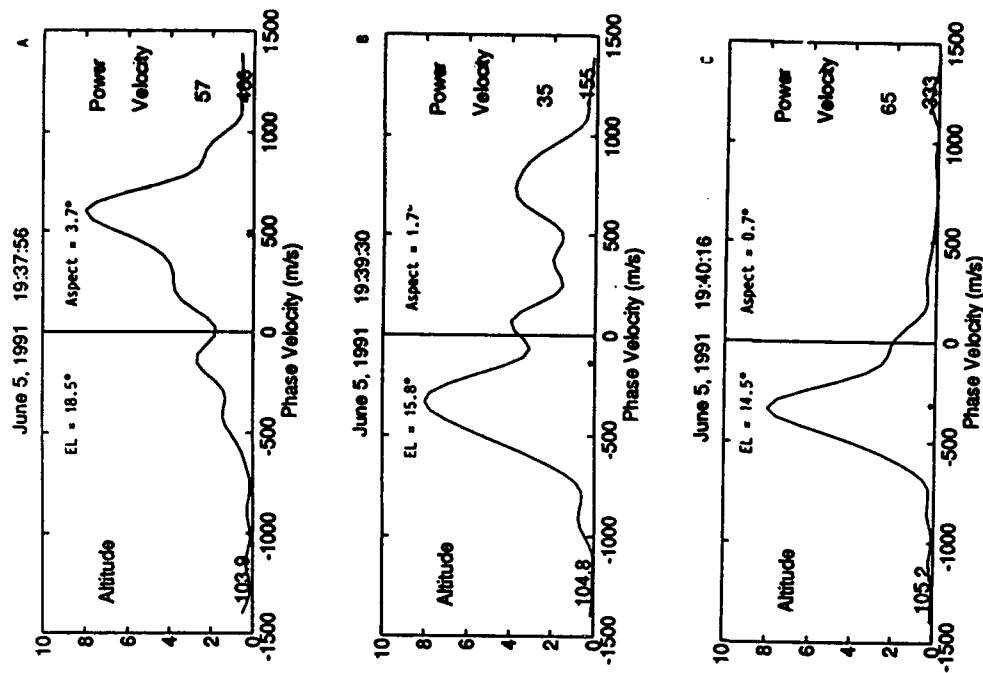
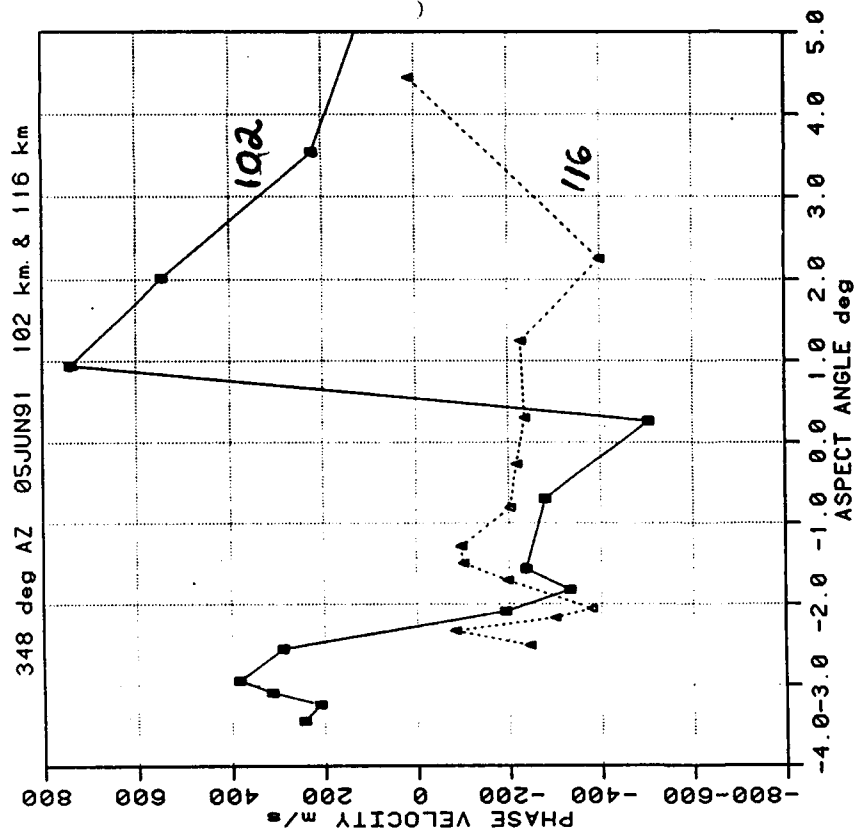


Figure 2. During experiments at Millstone Hill on June 5, 1991, elevation scans which varied the aspect angle, while holding perpendicular flow angle, revealed an altitude-dependent, abrupt change in sign for the observed phase velocity near 0° aspect angle. Phase velocity data taken at two distinct altitudes, as a function of magnetic aspect angle, are shown in the panel on the left. The low-altitude observations show positive phase velocity for aspect angles away from 0° while the data at 116 km altitude yield negative phase velocities throughout the scan. This effect is unexpected and currently unexplained by theory. Low-altitude coherent backscatter spectra, taken with a multipulse technique, for aspect angles near the transition point, are shown on the right. Two spectral components are seen near the transition, suggesting that two plasma modes might exist for waves near zero aspect angle.