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9.7A URBANA RADAR SYSTEMS: POSSIBILITIES AND LIMITATIONS

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INTRODUCTION

The Aeronomy Laboratory Field Station of the University of Illinois at Urbana contains three different radar systems capable of probing various regions of the atmosphere below about 100 km. These are an MST radar, a VHF meteor radar and an MF partial-reflection radar. All three radars can measure winds and waves in the ionospheric D region. The MST radar is, in addition, capable of probing the lower stratosphere and upper troposphere. A sodium (Na) LIDAR is also located at the Field Station and provides an additional way of studying winds and waves in the mesosphere by observing temporal variations in the sodium density profile.

The MST radar and the meteor radar use the same powerful 41-MHz transmitter, but separate antennas and receivers. No provisions have been made to split the power between the MST and the meteor-radar antennas, so the two systems cannot be run simultaneously. However, interlaced runs can be made in order to compare winds observed by the two systems.

The partial-reflection radar uses a separate transmitter, antennas and receiving system and can be run simultaneously with any of the other experiments.

Recently, data collection and analysis have been shifted from a single PDP-15 minicomputer to a series of 8-bit microcomputers allowing much flexibility on simultaneous runs. It should be noted, however, that the LIDAR cannot run simultaneously with the 41-MHz radars because of strong electromagnetic interference.

The three radars will be described separately, and the emphasis will be placed on recent upgrading of the different systems. A summary of the radar parameters is given in Table 1.

MST RADAR

The capabilities and limitations of the Urbana MST radar have been described by ROYRVIK and GOSS (1983) and only a short review of the general design will be given here. The radar operates at 40.92 MHz in a bistatic mode with an antenna array consisting of 1008 phased dipoles. The radar presently uses a pulse repetition frequency of 400 Hz. Coherent integration of the received signal is performed giving one coherent sample every 1/8 sec. Autocorrelation functions are calculated on line, and incoherently integrated for one minute and stored for later processing. Twenty range gates are sampled with a range separation of 1.5 km, spanning an altitude range of 30 km. By using two separate data-collecting microcomputers it is possible to obtaine data from both the stratosphere/troposphere and the mesosphere regions simultaneously.

The antenna is located on ground that slopes to the southeast by 1.5°, and the on-axis antenna beam direction is off-vertical by the same amount.

Line-of-sight Doppler velocities are calculated from the autocorrelation function, along with estimates of the signal correlation time and the scattered power. Because of the known relation between horizontal and vertical oscilla-

Table 1. Parameters of the Urbana radar systems.

	MST	Meteor Radar	Partial Reflection
Radar frequency	40.92 MHz	40.92 MHz	2.66 MHz
Peak power	1 (3) MW	1 (3) MW	50 kW
Pulse width	20 μs	20 μs	23 μs
Pulse repetition frequency	400 Hz	400 Hz	200 Hz
Receiver system bandwidth	100 kHz	100 kHz	40 kHz
Antenna			
transmitting	1008 dipoles	24 dipoles	60 dipoles
receiving	1008 dipoles	13 element yagis (4)	9 dipoles (4)

tions in internal gravity waves, we can interpret short- and long-period oscillations in the line-of-sight velocity as resulting from vertical and horizontal wind velocities, respectively (ROYRVIK and GOSS, 1983).

During the last year several upgrading projects of the MST radar have been undertaken; these will be described in the rest of this section.

(a) Transmitter

A continuous refurbishing and upgrading of the 41-MHz transmitter has resulted in a substantial improvement in peak transmitted power from a previous value of 0.7 MW to 3 MW at the present time.

A frequency-hopping technique is being investigated to increase the range resolution of the radar. A series of pulses will be transmitted, each pulse with a different radio frequency which is under the control of an Apple II microcomputer. By comparing phase differences between the different pulses in the sequence, it is possible to obtain an estimate of the location of the scatterer within the volume determined by the pulse length. This approach is similar in nature to the linear FM technique, but does not require the extensive hardware modifications necessary to implement a chirp-radar or a more conventional pulse-coding technique.

(b) Antenna

The transmit/receive antenna consists of six separately fed groups of dipoles (Figure 1). Because of the sloping ground and the orientation of the antenna, it is possible to phase the individual groups so that the antenna beam is pointing 2.5° off-vertical in the south and east directions. At the present this steering is done by manually inserting different lengths of cable in the feed lines to the different groups. This operation takes about 5 minutes and is impractical for day-to-day operation. Effort is underway, however, to implement an electromechanical switching arrangement so that the antenna beam can be switched in about one second between the four positions 2.5° to the east, 1.5° to the southeast, 2.5° to the south, and vertical. With the use of this

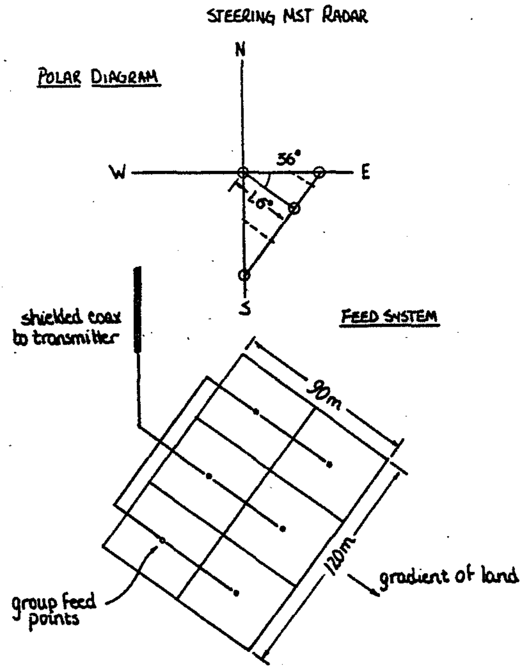

Figure 1. Schematic diagram of the MST radar antenna.

antenna beam-switching capability, it will be possible to obtain estimates of both the zonal and meridional long-period wind oscillations. The effective loss of power due to time sharing between the antenna positions will be more than made up for by the increase in transmitted power from 750 kW to 3 MW peak.

(c) Computer

Apple II microcomputers have replaced the PDP-15 as the major data-collection instrument. The two channels of the complex signal (sin, cos) is presently sampled on alternate transmitted pulses. A fast processor card is being incorporated into the microcomputer so that both channels of the complex signal can be sampled simultaneously. This improvement effectively increases the power of the radar by a factor of two.

A project is also underway to interface a fast coherent-integrator with 1 μs sample rate to the Apple allowing for better height resolution. With the transmitter capable of 2 μs pulses, the effective height resolution will be about 300 m.

(d) Transmit/Receive switch

A new T/R switch has been designed for the MST radar to allow probing of the troposphere at lower altitudes. Tests performed with one of the four gas tubes presently used, replaced by a PIN diode switch, have shown an improvement, indicating that with all four tubes replaced the radar will be able to obtain echoes as low as 4 km.

METEOR RADAR

The Urbana meteor radar (HESS and GELLER, 1976) is a very sensitive tool for studying winds and waves in the region of meteor precipitation from about 80- to 110-km altitude; it uses the powerful 41-MHz transmitter also used for the MST radar. Separate transmitting and receiving antennas are used. The transmitting antenna consists of two rows of center-fed full-wavelength dipoles. Each row contains twelve elements giving an elliptic antenna pattern. The elements are phased so that the antenna beam direction is at an elevation of 45° in the geographic north direction (HESS and GELLER, 1976). The effective east-west beam width in the meteor region is approximately 15°. The receiving antennas used in an interferometer mode to determine the azimuth and elevation angle of the reflected radar signal (Figure 2). Doppler shift, range, and phase differences between the receiving antennas give line-of-sight velocity as well as the location in space of the scattering meteor trail.

Meridional and zonal winds can be calculated from multiple meteor echoes if it is assumed that the wind is the same everywhere within the radar volumes which are limited by the antenna beam width and the effective altitude range gates. A recent test of the meteor-radar system has shown that the line-of-sight velocity and range can be measured with an accuracy of about 0.2 m/s and 500 k, respectively. However, the accuracy with which the elevation angle can be measured is quite poor, making the altitude calibration of the wind profile somewhat unreliable. Two independent phenomena appear to contribute to the problem. First, mutual coupling between the receiving antennas appears to distort the relationship between the measured phase difference and the direction of arrival of the meteor echo. Meteor echoes at greater distances from the radar appear to occur at lower altitudes. Second, due to unknown phase differences in the receiving channels, the absolute calibration of the wind profile is presently done by fitting the peak of the meteor number profile to 92 km. This procedure is suspect since it is known that the mean altitude of the ionized trail depends on the meteor velocity that changes as a function of season. For instance, the high-velocity Perseids meteors burn up before they reach an altitude of 100 km.

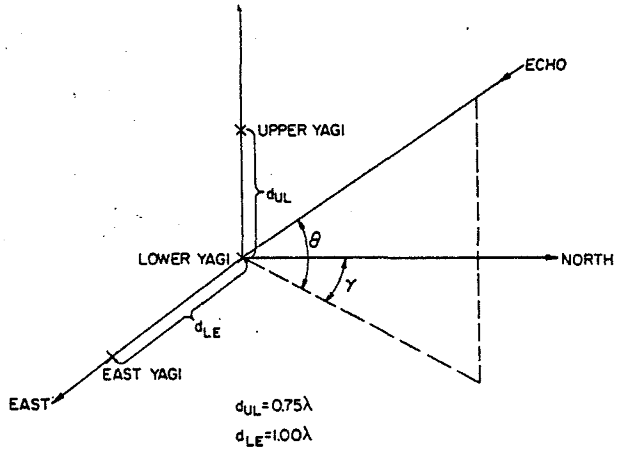

Figure 2. Meteor radar receiving antenna positioning.