5.5A CAPABILITIES AND LIMITATIONS OF EXISTING MST RADARS: POKER FLAT

B. B. Balsley, W. L. Ecklund and D. A. Carter

Aeronomy Laboratory
National Oceanic and Atmospheric Administration
Boulder, CO 80303

The Poker Flat MST Radar was designed as a prototype system to continuously monitor the atmosphere up to ~100 km. Initial funding was received from the National Science Foundation in September, 1978. The system began operations -- at a relatively low sensitivity -- some five months later. Since that time the system has been in almost continuous operation, and the sensitivity has increased steadily toward its ultimate design characteristics. Both the current and the final parameters are shown in Table 1. A more complete description of the system appears in BALSLEY et al. (1980). The current (fixed-position) antenna beams are shown in Figure 1, and a picture of the site is shown in Figure 2.

In addition to the parameters listed in Table 1, the Poker Flat radar embodies both a number of specific design features and an operating philosophy that are reasonably unique. These are discussed briefly below.

The modular system design incorporated in the Poker Flat radar uses 64 transmitting modules distributed throughout the 200m x 200m antenna array. Each transmitter is connected to four coaxial-collinear (COCO) dipole chains in one of two possible orthogonal polarizations. Each of these subsets (1 transmitter - 4 COCOs) is independently controlled from low-power RF pulse drivers located in the main building. Reception is accomplished by a similar process: the same four antennas feed a low-noise 50-MHz amplifier located at the output of the TR (Transmit-Receive) switch in the same transmitter. Each set of eight receiver outputs (i.e., one polarization-quarter) is combined in the field, so that eight separate inputs (i.e., eight separate polarization-quarters) are fed into the main building.

This modular design has a number of advantages relative to that for single transmitter/antenna systems. One of the most important advantages lies in the fact that the scientific observational program can begin with the completion of the first module; it is not necessary to await completion of the full system. A second advantage is that the probablity of catastrophic failure is considerably reduced. The loss of a single transmitter, power supply, or antenna module merely reduces the system sensitivity, and the observational program can continue. For example, the loss of one transmitter in the final system reduces the system sensitivity by only a fraction of 1 dB. A third advantage of modularity is the relatively simple maintenance procedures necessary to keep the system operational. Any single transmitter, for example, can be replaced in less than an hour, and repaired subsequently (a transmitter module weighs less than 20 kgm and can be changed by one person). These and other advantages to a modular design are listed in Table 2.

The operational philosophy adopted at Poker Flat is one of continuous, uninterrupted operation. This precludes all but the most crucial "campaign-type" experiments. It also precludes -- at least for the time being -- a number of desirable long-term studies using either higher temporal or spatial resolution. This latter limitation arises primarily from the amount of taped records (see Figure 3 for an example of the taped spectra) that would accumulate at the higher data rates if data were to be taken at all possible heights: currently Poker Flat uses a single standard digital tape every two days; improved resolution studies using, say, 300 m resolution instead of the standard

Table 1. Poker Flat MST radar* parameters

		CURRENT (FEBRUARY 1983)	FINAL
Transmitter	Frequency	49.920 MHz	49.920 MHz
	Peak pulse power (oblique)	1.2 MWatts/polarization	3.2 MWatts/polarization
	(vertical)	0.35 MWatts	3.2 MWatts
	Average power (oblique)	22 kW/polarization	64 kW/polarization
	(vertical)	6 kW	64 kW
	Pulsewidth	2-16 μsec	2-16 μsec (coded)
	Pulse rate	1.2 kHz	1.25 kHz
Receiver	Noise figure	≃ 3 dB	≃ 3 dB
	Bandwidth	Matched to pulse width	Matched to pulse width
	Filtering	Bessel	Bessel
Antenna	Area (oblique)	3×10^4 m^2	4×10^4 m^2
	(vertical)	1×10^4 m^2	4×10^4 m^2
	Beamwidth (two-way)	≃ 1°	≃ 1°
	Direction	Oblique/vertical	Oblique/vertical
Processing	Coherent averaging (oblique)	58 pulses	58 pulses
	(vertical)	412 pulses	412 pulses
	Spectral resolution	64 points	64 points

*Location 65° 07' 58" N, 147° 21' 30" W

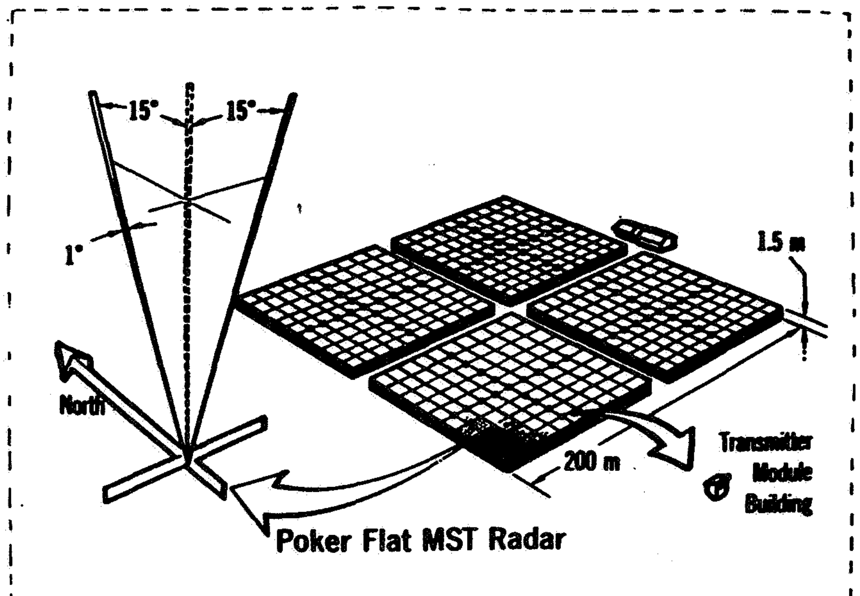

Figure 1. Showing the current three fixed-beam arrangement of the Poker Flat MST radar.

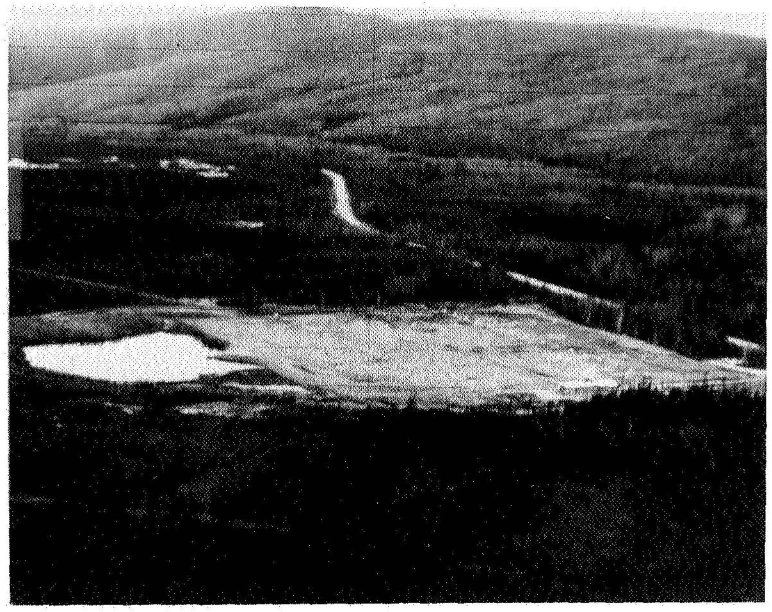

Figure 2. Aircraft view of the Poker Flat radar (foreground) and the University of Alaska Geophysical Institute's Poker Flat rocket range (upper left area). View looking approximately WNW.

Table 2. Poker Flat MST radar

Advantages

Modular Design

- Allows operation using only a portion of the system
- No catastrophic failures (distributed elements)
- Easy maintenance
- Beam switching using very low power phase switching
- Air-cooled (not water cooled) transmitting tubes
- Heat exchangers not required
- Small spare parts reserve (∿ 10%) relative to single unit system
- Lower feedline costs (not major)
- No moving parts (i.e., dishes, mechanical switches)

Continuous, uninterrupted operation (> 4 years)

- Virtually unattended (except for maintenance)
- Reliability (> 90%): no start-up problems
- Cost effective
- Operates well in climate extremes (+ 30°C to - 56°C)
- Power supply "bleeder" resistors heat main building

Miscellaneous

- Remote site: less man-made interference (RF, aircraft, etc.)
- Proximity to University of Alaska rocket range (Met rockets and balloons and experiments)

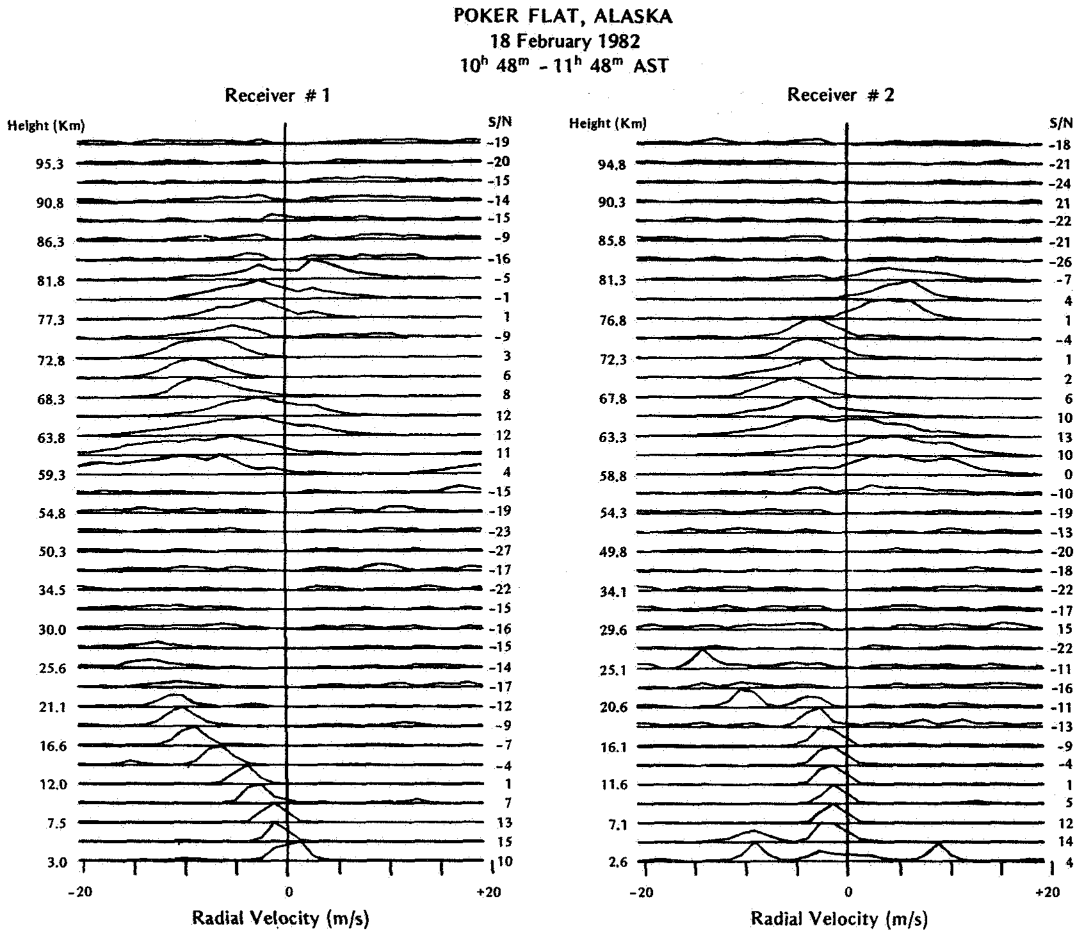

Figure 3. Example of the spectral information obtained from Poker Flat taped data. Shown are one-hour averaged values of normalized Doppler power spectra for "EAST" receiver (#1) and "NORTH" receiver (#2). S/N values are printed on right of each spectrum.

2.2 km resolution would require three tape changes per day. While this is not an unreasonable rate for a few days, it becomes prohibitive for long-term studies. In the final operational mode at Poker Flat, however, such data will be obtained using a separate recording system with minimal interruption.

Continuous operation has a number of advantages. For example, continuous operation combined with every-two-day tape changes enables an essentially unattended operation (except for maintenance tasks and special experiments). It also results in a cost effective operation and an enhanced reliability (owing in part to the lack of normally expected "turn on" problems). As an example, during 1982, the system was operational ~92% of the time, with much of the off-time arising from tape changing discontinuities. Figure 4 shows an example of the percentage of echoes received at Poker Flat versus height and time. Also, although the ambient temperature during this period ranged between about +30°C and -56°C, the system operation was not affected. This can be attributed in part to the continuity of data taking. These advantages, along with other less-important ones, are listed in Table 2.

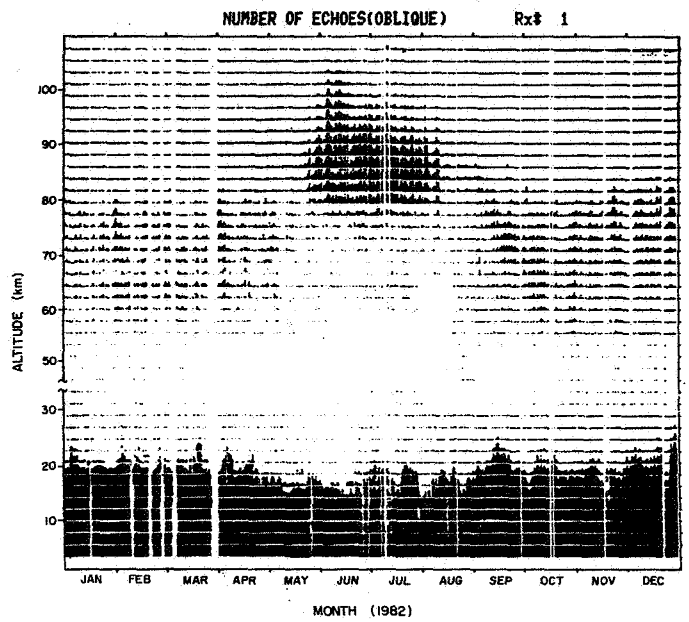

Figure 4. Example of the continuity of the Poker Flat observations (R. Garello, private communication). For each height, the percentage of possible echoes for each hourly averaged period is scaled in terms of the full height range at that time and height (e.g., the full-height lines for all seasons below ∿ 12.5 km indicate 100% echo rate; half-height lines at 23.3 km in mid September indicate 50% echo/no-echo rate). Note the seasonal change in the mesospheric echo heights and occurrence rates. The relatively darkened lines that maximize at ≃ 92 km arise from meteor echoes.

Table 3. Poker Flat MST radar

Disadvantages

Not-Yet-Finished Problems

- Not yet steerable (3 fixed beams)
- Three-quarters of antenna only on oblique beam
- One-quarter of antenna only on vertical beam
- Continuous observations with < 2.2 km resolution requires separate tape unit
- Preprocessor unit (for maximum sensistivity) under construction
- Current reliable peak Tx power $\leq$ 60 kW
- No ancillary measurements on-line yet
- Full sensitivity on vertical to "see through" still in the future

General Problems

- Reasonably expensive operation (power bill ∿ $\$10^5$/year)
- Remote site (cold in winter, muddy in spring, mosquitoes in summer)
- Continuous operation mode precludes some special studies
- Not portable
- Mountain echoes added to atmospheric echoes below ≃ 7 km
- Moose in the (fenced-in) antenna array

The disadvantages of the Poker Flat system are shown in Table 3. Many of the current disadvantages stem from the fact that the system is not yet completed. For example, maximum sensitivity in the vertical will not be realized until the full system is steered between vertical and oblique positions (this will allow us to examine the region of weak echoes near 45 km with full system sensitivity). Also, higher resolution studies not currently possible will be enabled with the advent of an additional recording system and a digital "preprocessing" system currently under construction. We also lack a series of ancillary measurements (surface wind, temperature, all-sky camera, riometer, airglow, etc.) at the site, which will be eventually included on the standard data format. Finally, the system in some 5-1/2 dB below the final sensitivity. This is due in part to transmitter tube HV arc-over problems, to the (current) lack of a fast preprocessor, and to the fact that only three-quarters of the full antenna is currently used for oblique operation. Additional disadvantages along with those mentioned above, are included in Table 3.

(The reference in this paper is included in the Publications listed below.)

PUBLICATIONS RELATING TO THE POKER FLAT RADAR

Balsley, B. B., W. L. Ecklund, D. A. Carter and P. E. Johnston (1979), The Poker Flat MST radar: First results, Geophys. Res. Lett., 6, 921-924.

Balsley, B. B. and K. S. Gage (1980), The MST radar technique: Potential for middle atmospheric studies, Pure Appl. Geophys., 188, 452-493.

Balsley, B. B., W. L. Ecklund, D. A. Carter and P. E. Johnston (1980), The MST radar at Poker Flat, Alaska, Radio Sci., 15, 213-223.

Ecklund, W. L., B. B. Balsley and D. A. Carter (1980), The Poker Flat MST radar: Preliminary results between 3-20 km, Preprints, AMS 19th Conf. on Radar Meteorol., April 15-18, Miami Beach, FL, 557-562.

Balsley, B. B., W. L. Ecklund and D. A. Carter (1980), The Poker Flat MST radar: An outline of the primary echoing mechanisms and a description of the facility Preprints, AMS 19th Cong. on Radar Meteorol., April 15-18, Miami Beach, FL, 557-562.

Carter, D. A., B. B. Balsley and W. L. Ecklund (1980), The Poker Flat MST radar: Signal analysis and data processing technique with examples, Preprints 19th Conf. on Radar Meteorol., April 15-18, Miami Beach, FL, 563-567.

Gage, K. S. and B. B. Balsley (1981), Recent advance in Doppler radar probing of the clear atmosphere, Atmos. Tech., 13, 3-21.

Nastrom, G. D., K. S. Gage and B. B. Balsley (1981), The variability of C_n^2 at Poker Flat, Alaska from MST Doppler radar observations, SPIE, 227, 10-15.

Ecklund, W. L. and B. B. Balsley (1981), Long term observations of the Arctic mesosphere with the MST radar at Poker Flat, Alaska, J. Geophys. Res., 86, 7775-7780.

Balsley, B. B. and K. S. Gage (1981), On the vertical-incidence VHF backscattered power profile from the stratosphere, Geophys. Res. Lett., 8, 1173-1175.

Balsley, B. B., W. L. Ecklund, D. A. Carter, P. E. Johnston and A. C. Riddle (1981), The Poker Flat MST radar system: current status and capabilities, Preprint, Vol., 20th Conf. on Radar Meteorol., Boston, MA, Nov 30 - Dec 3, AMS, 1-6.

Gage, K. S., D. A. Carter and W. L. Ecklund (1981), The effect of gravity waves on specular echoes observed by the Pcker Flat MST radar, Geophys. Res. Lett., 8, 599-602.

Nastrom, G. D., B. B. Balsley and K. S. Gage (1981), Changes with season of C_n^2 at Poker Flat, AK, from MST Doppler radar observations, Preprint, Vol., 20th Conf. on Radar Meteorol., Boston, MA, Nov 30 - Dec 3, AMS.

Nastrom, G. D., B. B. Balsley and D. A. Carter (1982), Mean meridional winds in the mid- and high-latitude summer mesosphere, Geophys. Res. Lett., 9, 139-142.

Gage, K. S., W. L. Ecklund and B. B. Balsley (1982), Comparison of Poker Flat MST radar observations with the Fresnel scattering model, submitted to Radio Science.

Balsley, B. B. and D. A. Carter (1982), The spectrum of atmospheric velocity fluctuations at 8 km and 86 km, Geophys. Res. Lett., 9, 465-468.

D. A. Carter and B. B. Balsley (1982), The summer wind between 80 km-93 km observed by the MST radar at Poker Flat, Alaska (65°N), J. Atmos. Sci., 39, 2905-2915.

Nastrom, G. D., K. S. Gage and B. B. Balsley (1982), Variability of C_n^2 at Poker Flat, Alaska, from mesosphere, stratosphere, troposphere (MST) Doppler radar observations, Optical Engineering, 21, #2, 347.

Fritts, D. C., B. B. Balsley and W. L. Ecklund (1982), Evidence of tidal breakdown at the summer mesopause, submitted to Radio Science.

Balsley, B. B., D. A. Carter and W. L. Ecklund (1982), On the potential of radar observations for studying coupling processes between the ionosphere and middle atmosphere, Proc. Second International Symp. on Solar-Terrestrial Influences on Weather and Climate, submitted 11/3/82.

Larsen, M. F., Kelley, M. C. and K. S. Gage (1982), Turbulence spectra in the upper troposphere and lower stratosphere at periods between 2 hours and 40 days, J. Atmos. Sci., 39, 1035-1041.

Gage, K. S. and W. L. Ecklund (1982), Objective tropoapuse height determination using a low resolution VHF radar, Radio Science.

Avery, S. K., A. C. Riddle and B. B. Balsley (1983), The Poker Flat, Alaska MST radar as a meteor radar, Radio Sci., 18, 1021-1027.

Balsley, B. B., W. L. Ecklund and D. C. Fritts (1983), Mesospheric radar echoes at Poker Flat, Alaska: Evidence for seasonally-dependent generation mechanisms, Radio Sci., 18, 1053-1058.

Balsley, Ben B. (1983), Poker Flat MST radar measurement of winds and wind variability in the mesosphere, stratosphere and troposphere, Radio Sci., 18, 1011-1020.

Balsley, B. B., W. L. Ecklund and K. S. Gage (1983), On the use of clear-air ST radars to observe winds, waves and turbulence in the troposphere and lower stratosphere, Preprint Vol., Fifth AMS Symp. on Meteorol. Observations and Instrumentation, April 11-15, Toronto, Ontario, Canada.

Ecklund, W. L. and K. S. Gage, Vertical wind observations using UHF clear-air radars, Preprint Vol, Fifth AMS Symp. on Meteorol., Observations and Instrumentation, April 11-15, 1983, Ontario, Canada.

Luhmann, J. G., R. M. Johnson, M. J. Baron, B. B. Balsley and A. C. Riddle (1983), Observations of the high latitude ionosphere with the Poker Flat MST radar: Analyses using simultaneous Chatanika radar measurements, submitted to Geophys. Res. Lett.

Balsley, B. B., W. L. Ecklund and D. C. Fritts (1983), VHF echoes from the artic mesosphere and lower thermosphere, Part I: Observations, 1983 Proc. of U.S.-Japan Seminar.

Fritts, D. C., B. B. Balsley and W. L. Ecklund (1983), VHF echoes from the artic mesosphere and lower thermosphere, Part II: Interpretations, Proc. of U.S.-Japan Seminar.

Balsley, B. B. and A. C. Riddle (1983), Monthly mean values of the mesospheric wind field over Poker Flat, Alaska, and a proposed polar circulation cell, submitted to J. Atmos. Sci.

Balsley, B. B., W. L. Ecklund and D. C. Fritts (1983), VHF echoes from the high-latitude mesosphere and lower thermosphere: Observations and interpretations, J. Atmos. Sci., 40, 2451-2466.