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NOAA Technical Mememorandum ERL WPL-120

DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA

RADAR WIND PROFILERS IN THE COLORADO NETWORK

R. G. Strauch
D. A. Merritt
K. P. Moran

Wave Propagation Laboratory
Boulder, Colorado
March 1985

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Malcolm Baldrige,
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NATIONAL OCEANIC AND
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Environmental Research
Laboratories

Vernon E. Derr,
Director

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Every effort has been made to assure that this document accurately reflects the Profiler systems as they were actually built. However, some errors in documentation may have been overlooked.

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Radar Wind Profilers in the Colorado Network

R.G. Strauch, D.A. Merritt, and K.P. Moran

ABSTRACT. Radar systems used to measure vertical profiles of the horizontal wind in nearly all weather conditions can use frequencies between about 40 and 1000 MHz. This report describes three radar systems that measure wind profiles continuously and automatically. They operate at different frequencies (~ 50 MHz, 405 MHz, and 915 MHz) but are designed with a common philosophy and use many identical subsystems. Descriptions of hardware, software, and data processing are included.

The Wave Propagation Laboratory (WPL) has constructed a network of six wind-profiling radars. These radars operate continuously and unattended, and they automatically measure vertical profiles of horizontal winds in nearly all weather conditions. Four of these radars operate at VHF: 49.8 MHz ("50 MHz"); two operate at UHF: 405 and 915 MHz. Much of the basic VHF radar technology used in the 50-MHz radars was developed by the Aeronomy Laboratory (AL). One of the VHF radars (located at Platteville, Colo.) was built by AL as a test site and is operated jointly by AL and WPL. Three new VHF radars were built and installed by WPL at Fleming (near Sterling, Colo.), Lay Creek (near Craig, Colo.), and Cahone (near Cortez, Colo.) in 1983.

The two UHF systems were designed and built by WPL; the 915-MHz radar is located at the National Weather Service Forecast Office at Stapleton International Airport, Denver, Colo., and the 405-MHz radar is located at Platteville, Colo.

I. 50-MHz RADAR HARDWARE

The three new 50-MHz radar systems are similar to the first. They were designed to measure vertical profiles of horizontal winds, using two fixed antenna pointing positions. The transmitters and antennas were purchased; the remaining hardware and data processing software were developed by WPL. The purpose of these three radars was to establish wind profiling capability at locations that would be useful for predicting weather in the Denver metropolitan area. Their characteristics and operating values are summarized in Table I.1.

Table I.1.--VHF radar characteristics and typical operating values

Characteristic	Value	
Radar		
Frequency	49.8 MHz	
Authorized bandwidth	0.4 MHz	
Peak power (maximum ~60 kW)	30 kW	
Average power (maximum ~1 kW)	400 W	
Pulse width	3, 9 μs	
Pulse repetition period	238.67, 672 μs	
Antenna aperture	50 m x 50 m	
Antenna pointing	15° off-zenith to north and east (two antennas)	
Antenna type	Fixed phased array of colinear-coaxial dipoles	
Two-way beamwidth	5°	
Data Processing	3-μs pulse	9-μs pulse
Time domain averaging	419 pulses	124 pulses
Spectral averages	8	16
Maximum radial velocity	±15.05 m/s	±18.06 m/s
Spectral resolution (64 points)	0.47 m/s	0.56 m/s
Height Sampling		
1st height	1.7 km	2.6 km
Height spacing	290 m	870 m
Number of heights	24	18

The radar at Fleming (Fig. I.1) is situated about 200 meters from the farm buildings. All three installations have identical hardware, equipment shelters, and equipment layout, and occupy an acre of land. The shelters are 10 ft x 24 ft transportable buildings with 8-ft ceilings, central heat, and air conditioning. They were built by Modulaire Industries in Longmont, Colo., and delivered on-site for a total cost of about $7,200 each. Figure I.2 shows the radar equipment in the shelter. The radar uses less than half the available floor space; the remaining space is reserved for microwave radiometers for measuring water vapor, liquid water, and temperature, and for surface instrumentation. A Topaz model 70308-3KVA power conditioner ($1,100) is used for regulating line power for the computer and associated equipment.

These radars measure wind profiles (typically once per hour) and transmit their data to a remote computer by telephone. Data transfer takes place automatically; the telephone interface also allows the radar to be controlled and operated with any terminal equipped with a 300-baud modem. There is no long-term data storage or recording hardware on-site; however, data are available on an RS-232 port for local or remote recording. Data can be stored on disk for special experiments and can be displayed at the site on a terminal or a printer. In normal operation there is no readout or display at the radar site because the radars are designed for unattended operation.

Figure I.3 shows a block diagram of the radar. The terminal and test oscilloscope are not used in routine operation; they are not normally left at the site. The radar is operated by telephone but can be operated locally through the terminal. All typical radar functions are controlled by keyboard; there are no local switches to control radar functions such as pulse repetition rate. The radar has these major subsystems:

(1) RF source

(2) Transmitters and power supply

(3) Receiver

(4) Antenna

(5) Radar controller and data pre-processor

(6) Computer with disk, diskette, modem, and terminal

(7) Software.

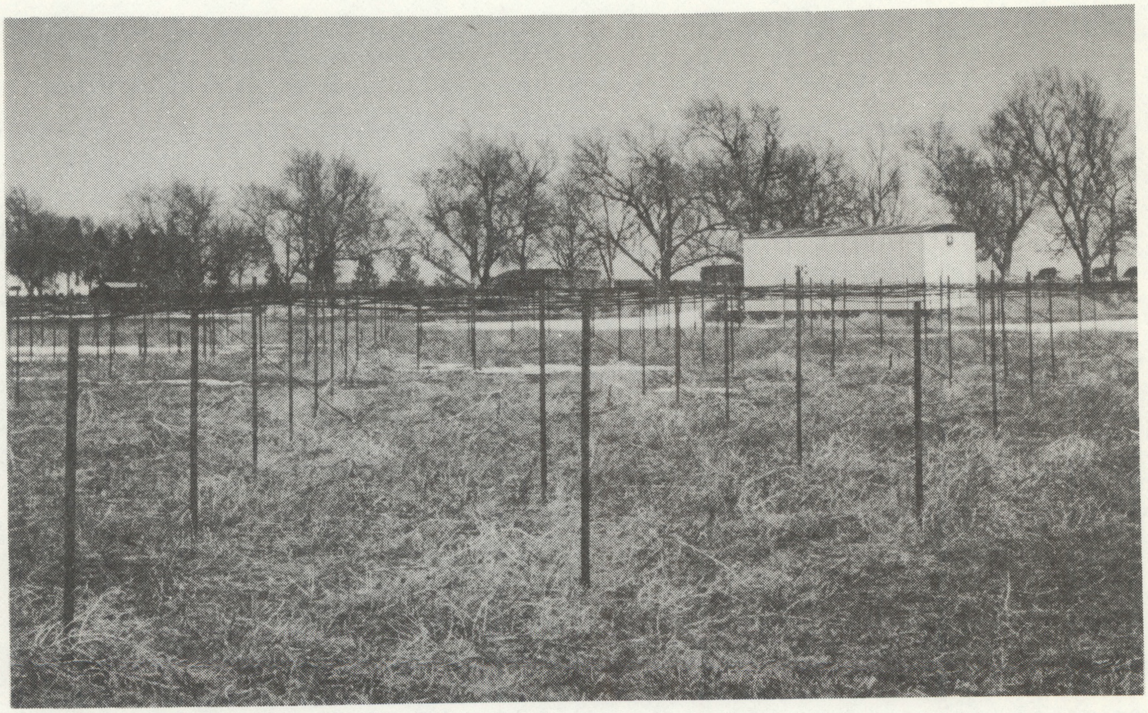


Figure I.1.--50-MHz radar: View of Fleming site toward NNE, showing equipment housing and antenna.

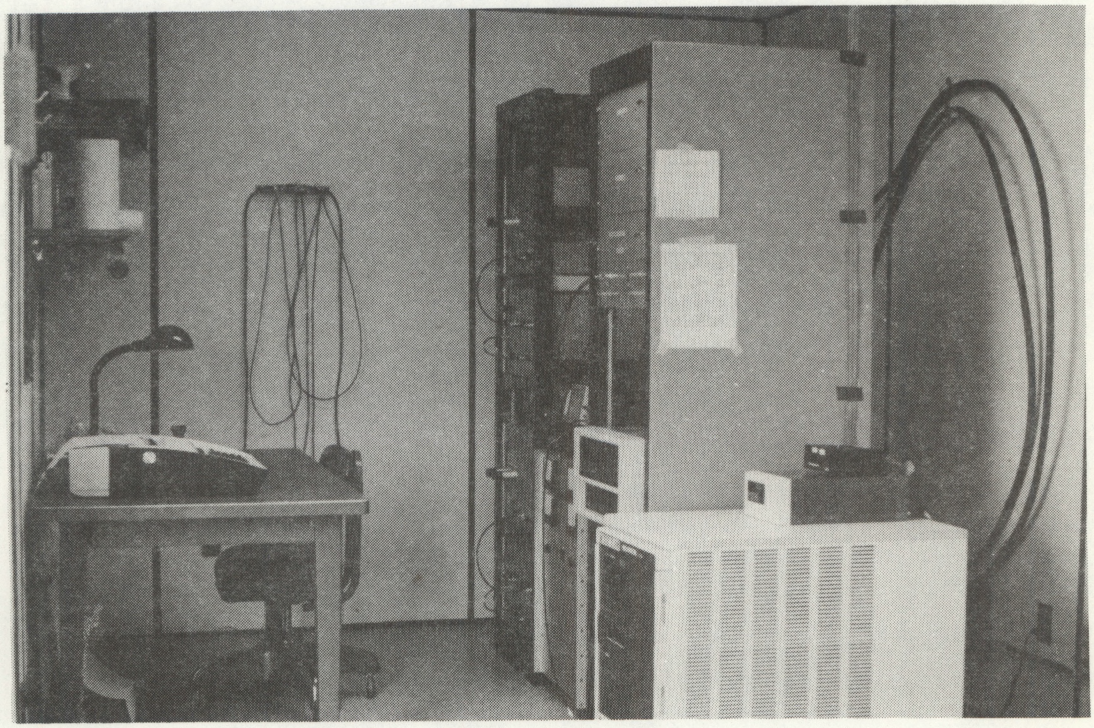
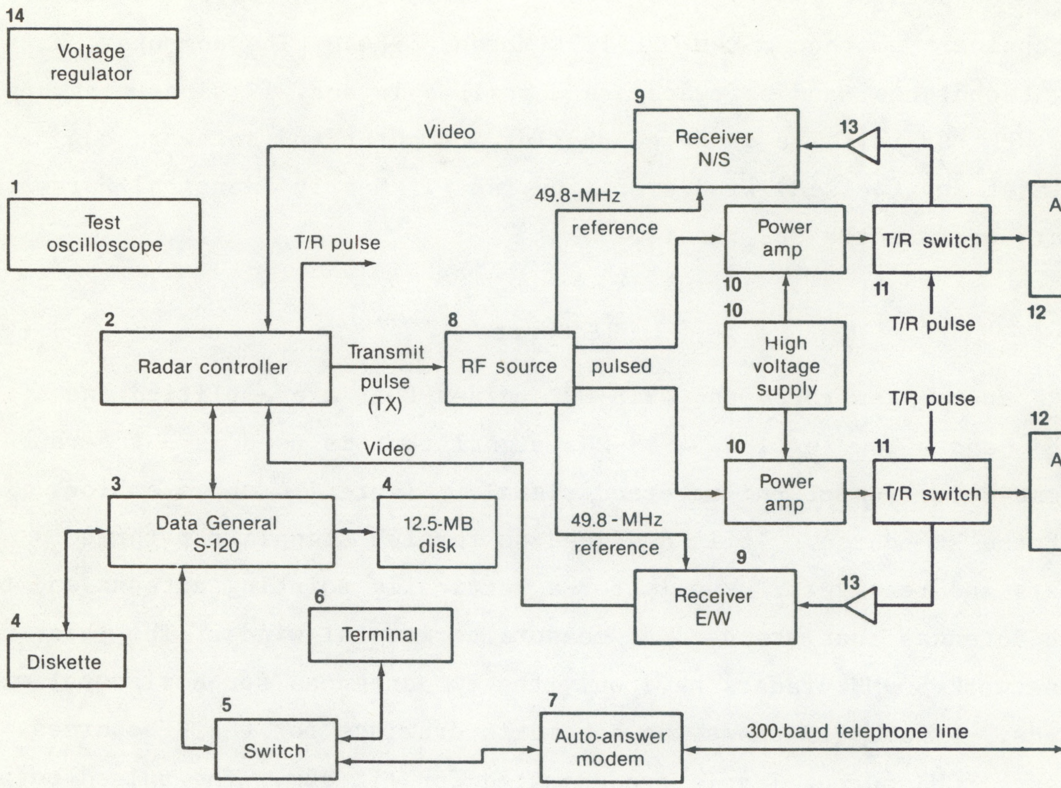


Figure I.2.--50-MHz radar: Equipment in radar housing.



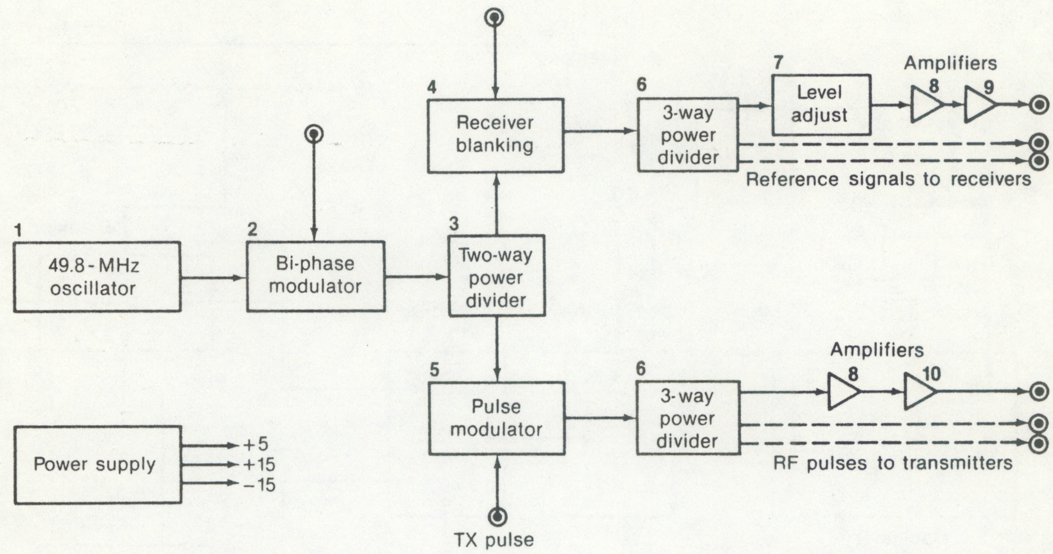
Key to Figure I.3	
1. Textronix, 2213 (or equivalent)	9. WPL-built (Fig. I.9)
2. WPL-built (Moran, 1984)	10. Tycho Technology, MST-50-ITX (Fig. I.6)
3. Data General, S-120	11. Tycho Technology (Fig. I.7)
4. Data General, 6099	12. Tycho Technology, MST-50-IANS (Figs. I.11, I.12)
5. Black Box Co., SW010	13. Tycho Technology (Fig. I.8)
6. Teletype Corp., 43 (or equivalent)	14. Topaz, 70308
7. Racalvadic, VA3451 (or equivalent)	
8. WPL-built (Figs. I.4 and I.5)	

Figure I.3.--50-MHz radar: System, block diagram.

Descriptions of subsystems (1)-(4) follow. The radar controller is described in NOAA Technical Memorandum ERL WPL-119 (Moran, 1984). The computer, data processing techniques, and software are described in sec. IV since they apply to all the WPL radars. The radar controller, computer and software can control almost any (pulsed) wind-profiling radar. Nearly identical hardware and software operate the UHF radars.

1. RF Source

The RF source generates the 49.8-MHz pulses that are amplified and transmitted, and a low-level CW 49.8-MHz signal that is used as a reference for coherent detection of the returned signal. Figure I.4 shows a block diagram of the RF source. It is designed to furnish signals for three transmitters and receivers, usually for a vertically pointing antenna and two off-zenith antennas that are used to measure horizontal winds. The three new Colorado network 50-MHz radars have only the two antennas for horizontal wind measurements. Figure I.5 shows the schematic drawings for the RF sources. The reference (CW) output levels are adjusted for +12 dBm. The pulsed output levels are about +23 dBm. The phase of the RF source (reference and pulsed signals) can be selected for each transmitted pulse (see Fig. I.5a). This feature allows range-ambiguous signals to be canceled in the data processing, but it is not used in these radars. The reference signal can be turned off by a TTL pulse that will blank the receivers to improve receiver recovery following the transmitted pulse. This function is also not implemented in the VHF radars. An additional feature that should be available is phase coding of the RF pulse; this could be implemented by inserting a mixer before or after the pulse modulator.



Key to Figure I.4	
1. Vectron, CO233T	6. Minicircuits, PSC3-1
2. VARI-L, CM1H8	7. Minicircuits, SRA1
3. Merrimac, 113C	8. Avantek, GPD-402
4. Minicircuits, SRA-1	9. Avantek, GPD-404
5. VARI-L, SS-50	10. Avantek, GPD-405

Figure I.4.--50-MHz radar: RF source, block diagram.

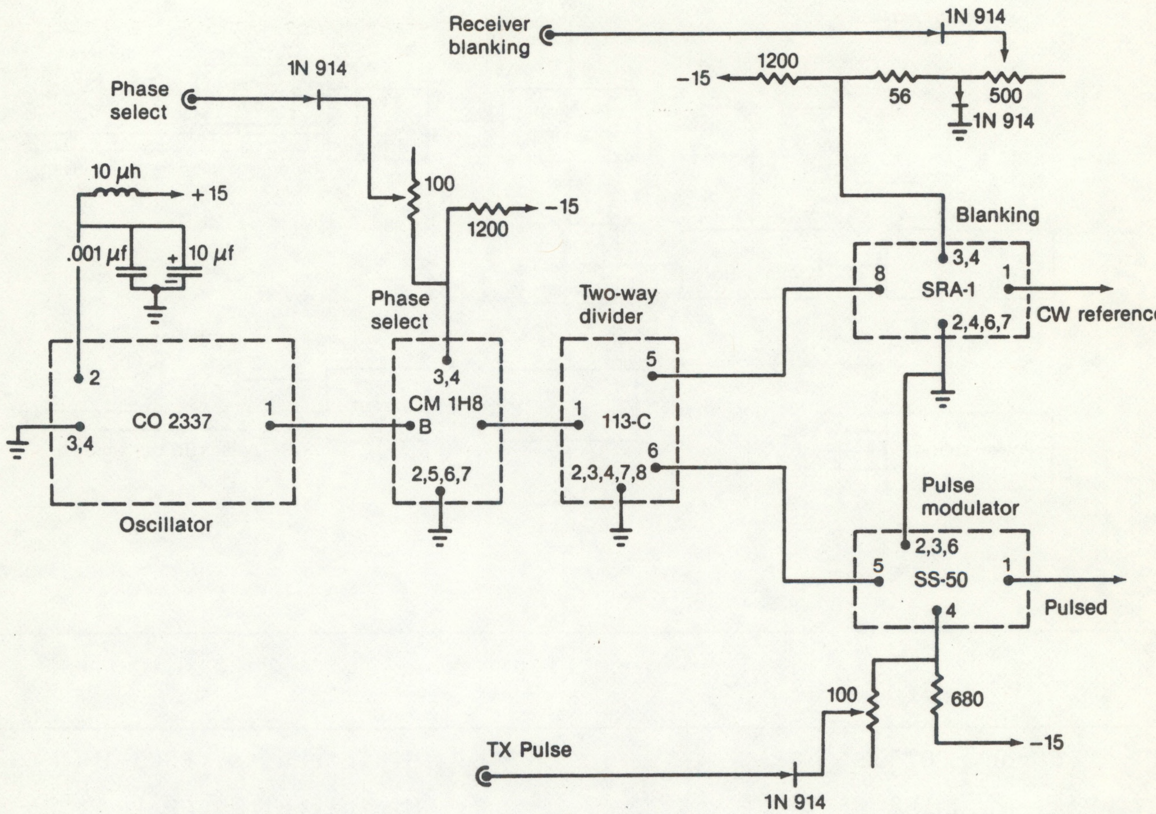


Figure I.5a.--50-MHz radar: RF oscillator and modulator.

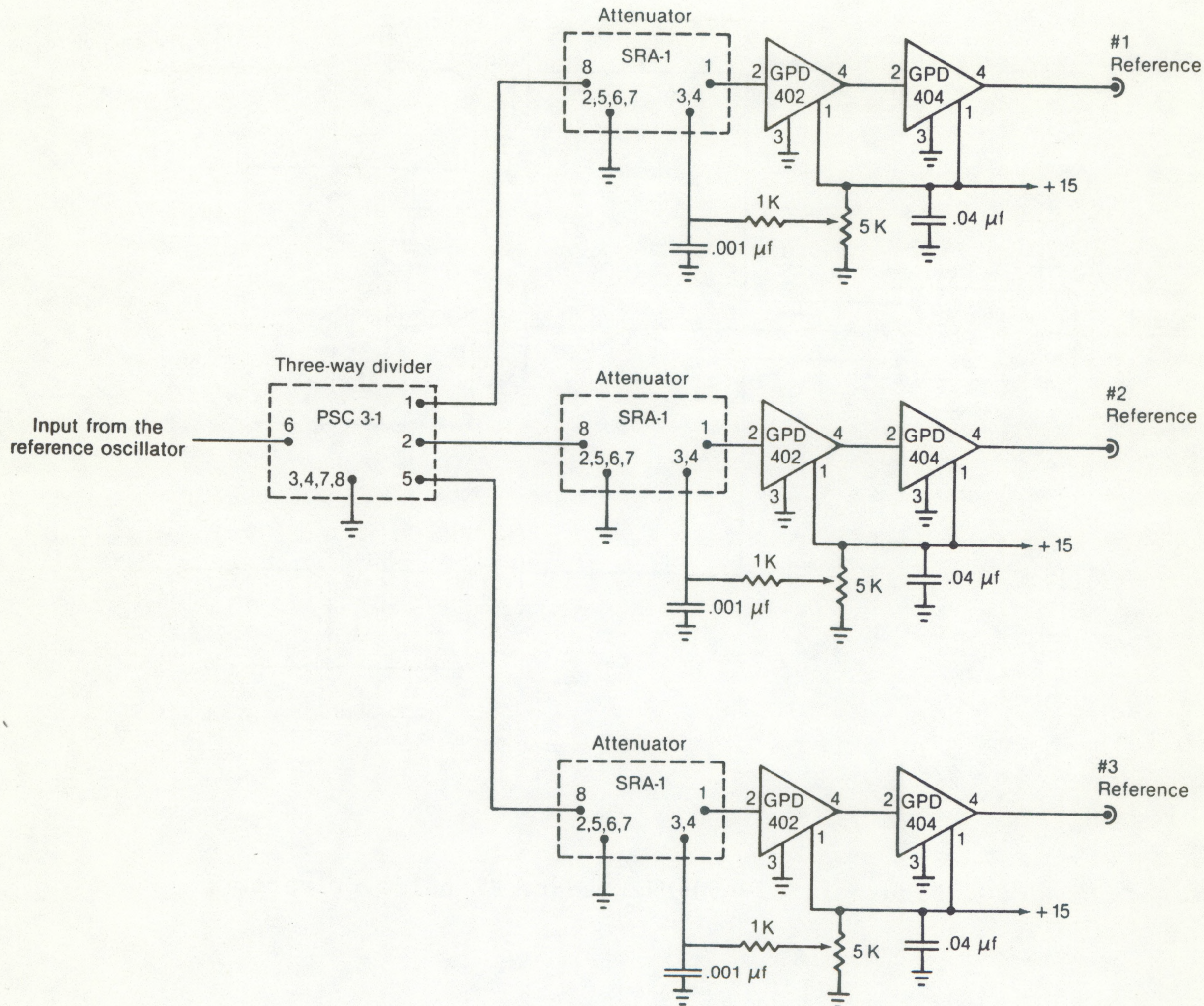


Figure I.5b.--50-MHz radar: RF reference drivers.

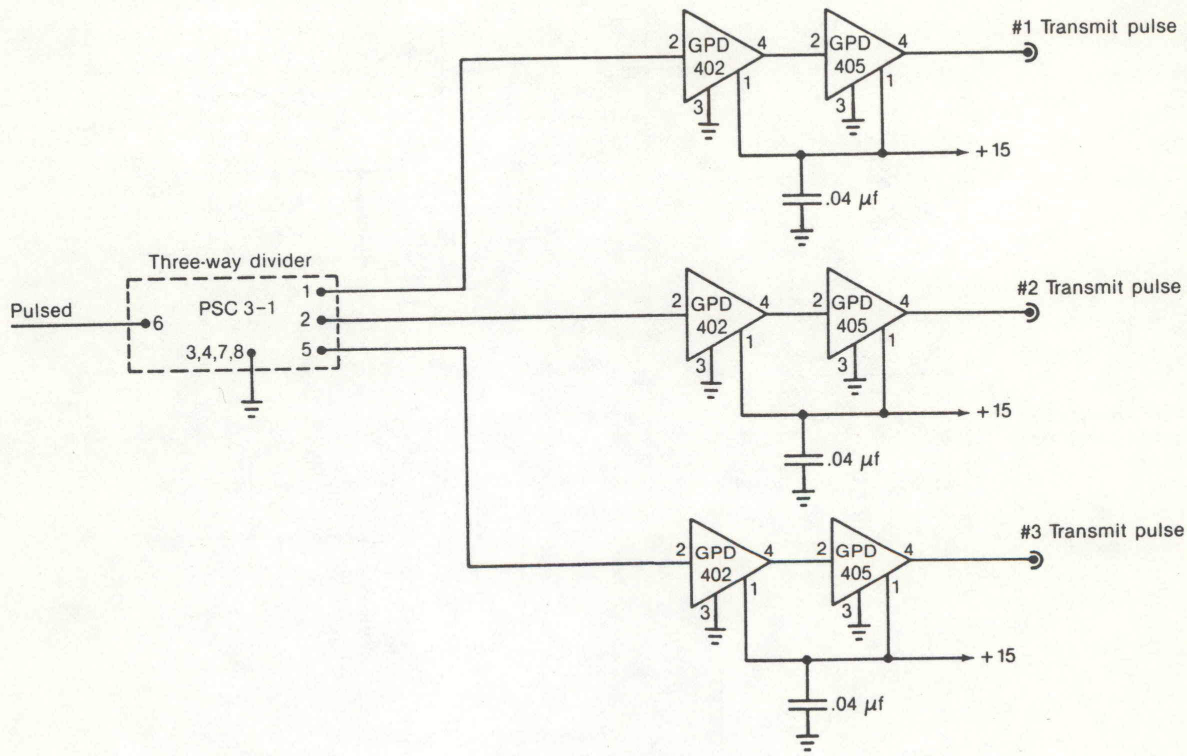


Figure I.5c.--50-MHz radar: RF pulse drivers.

2. Transmitters

The power amplifiers, transmit/receive (T/R) switches, RF preamplifiers, and associated power supplies were purchased from Tycho Technology, Inc., Longmont, Colo. (Model MST-50-1). A block diagram of the transmitter is shown in Fig. I.6. The T/R switch and its drive circuitry (TTL input) are mounted in the final power amplifier chassis. The first three gain stages are in a separate chassis. Protection circuits monitor temperature and air pressure and remove RF drive in the event of power supply failure, over-temperature, or lack of air flow. A directional coupler monitors forward and reflected output power. Plate supply voltages for the third and fourth stages are furnished by a separate power supply; other power supplies are built into the amplifier chassis. In normal operation the final stage supply input is 600 W average (each transmitter); RF output (average) is 400 W. Duty cycle is 1.33% or 30 kW peak power output. The final stage operates with 6-kV plate supply. The transmitter is capable of higher output but is operated conservatively for greater reliability. Pulsing is interrupted without removing the plate voltages; both high voltage supplies are very well regulated. The transmitters cycle on automatically after a power failure. The only problems that have occurred during the first months of operation are occasional arcing in the third- and fourth-stage tubes that require replacement of a protective fuse.

The T/R switch uses TR and ATR diodes that are biased on 1 μs before the start of the transmitted pulse and are held on for about 2 μs after the transmitted pulse ends. The T/R switch (Fig. I.7) is described by Ecklund (1983). An RF preamplifier (Fig. I.8) is part of the commercial transmitter. A low-noise preamplifier (Advanced Receiver Research P50VDG) has also been used; low-noise receivers are not usually required for VHF radars because cosmic background noise usually governs system noise.

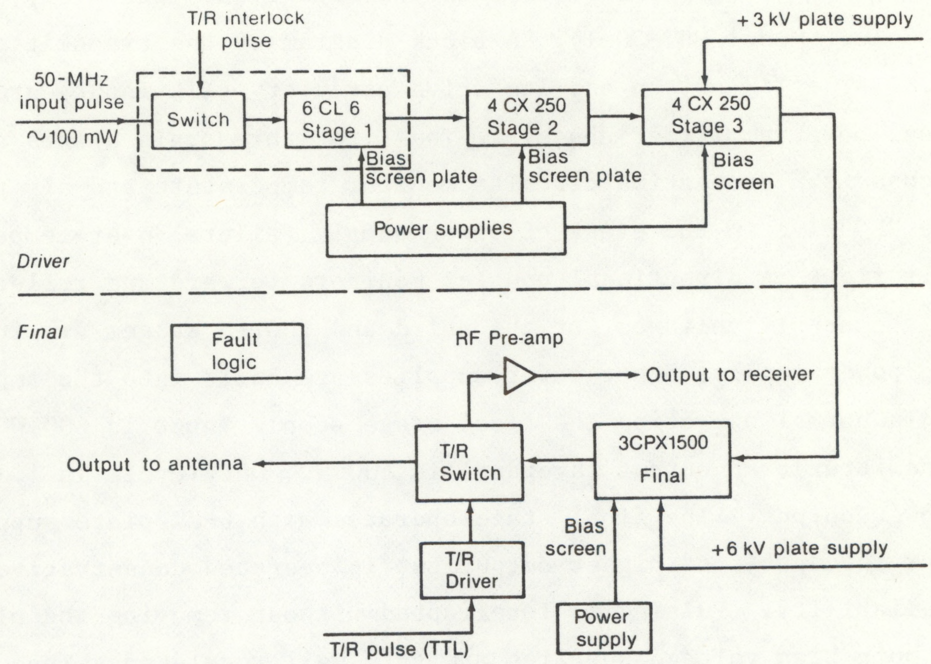


Figure I.6.--50-MHz radar: RF transmitters, block diagram.

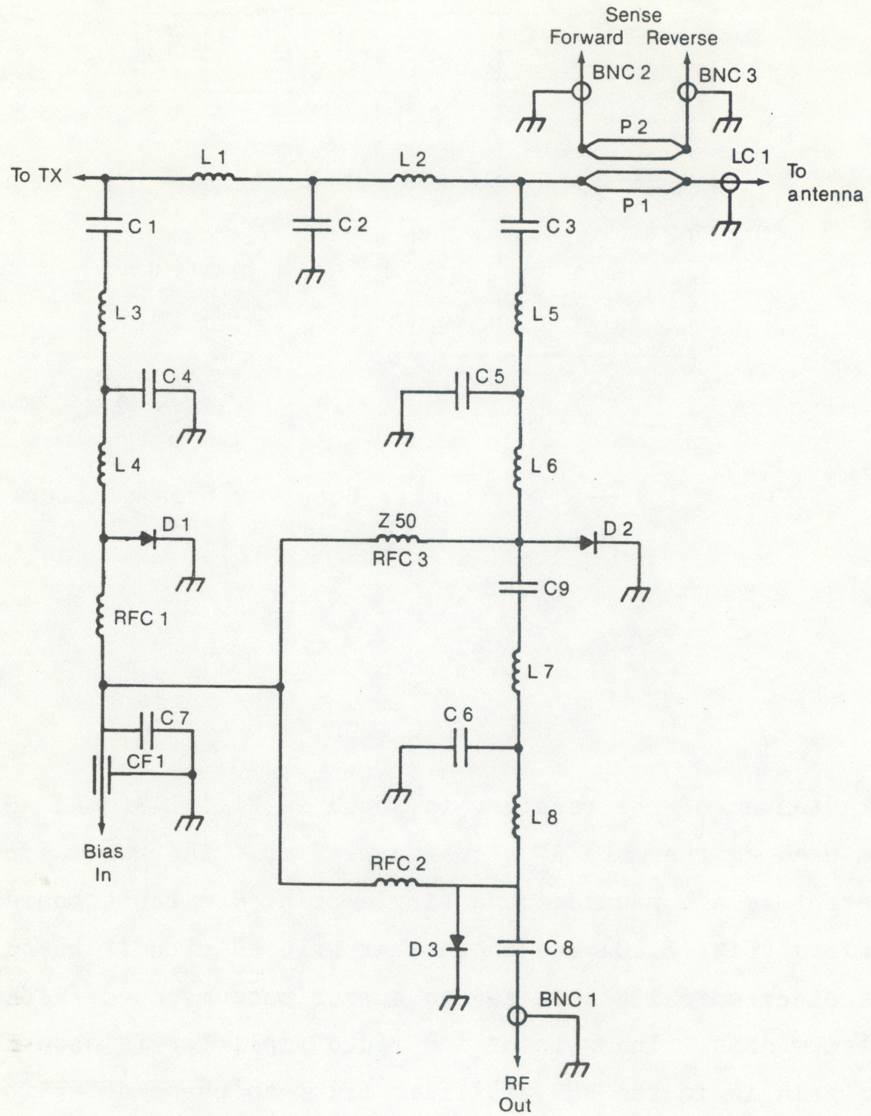


Figure I.7.--50-MHz radar: TR switch.

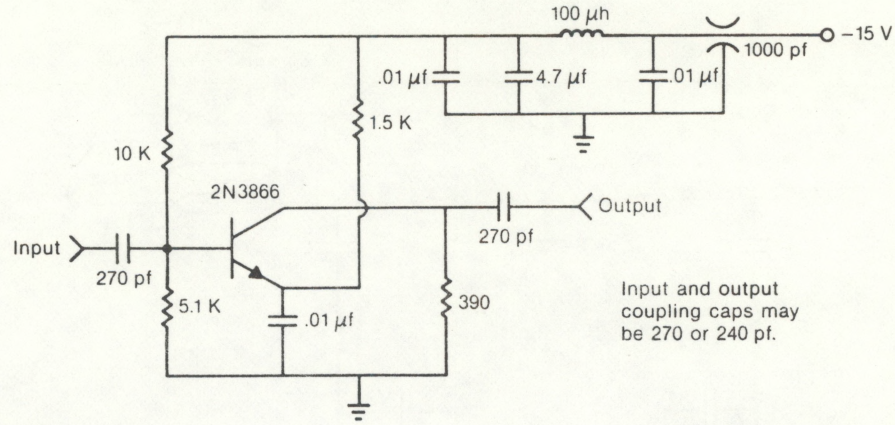


Figure I.8.--50-MHz radar: Receiver preamplifier.

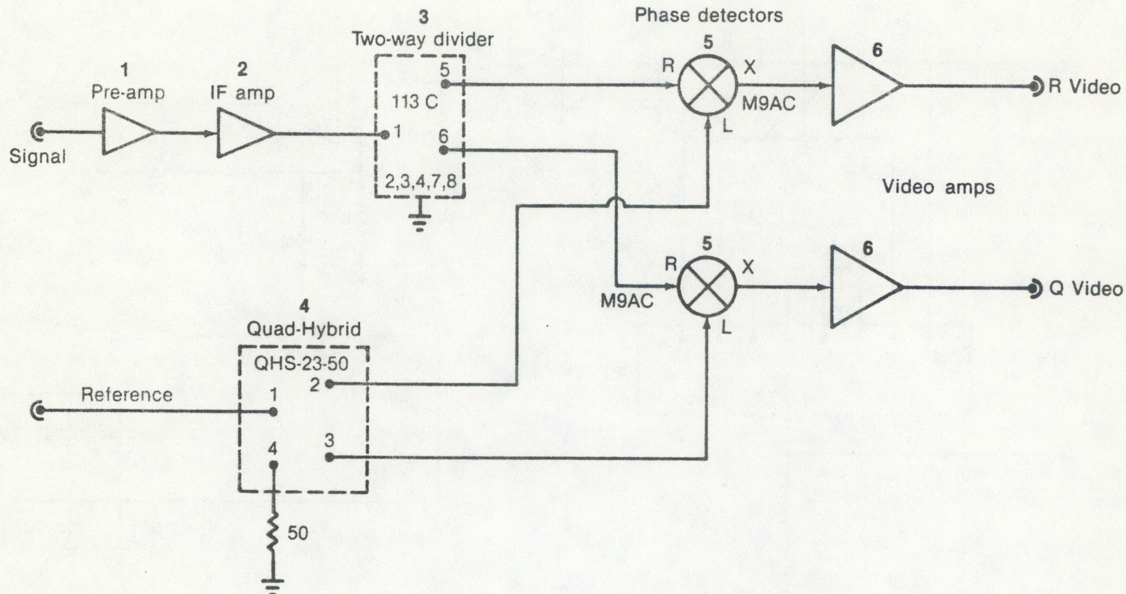
3. Receiver

A block diagram of the receiver is shown in Fig. I.9. An RHG IF amplifier is used as the main RF signal amplifier. The two-way power dividers and phase detectors are mounted on a single printed circuit board. The two video amplifiers (Fig. I.10) are on another printed circuit board. The video bandwidth is electronically selected to approximate matched filter operation with two pulse widths. The gain of the video amplifier is about 3; most of the receiver gain is in the RHG amplifier prior to phase detection. The system gains are adjusted to achieve the following:

(a) An input signal at 49.8 MHz that saturates the RHG amplifier will produce at ±5 volts video output signal. The analog-to-digital converters in the signal pre-processor (located in the radar controller) will therefore not saturate.

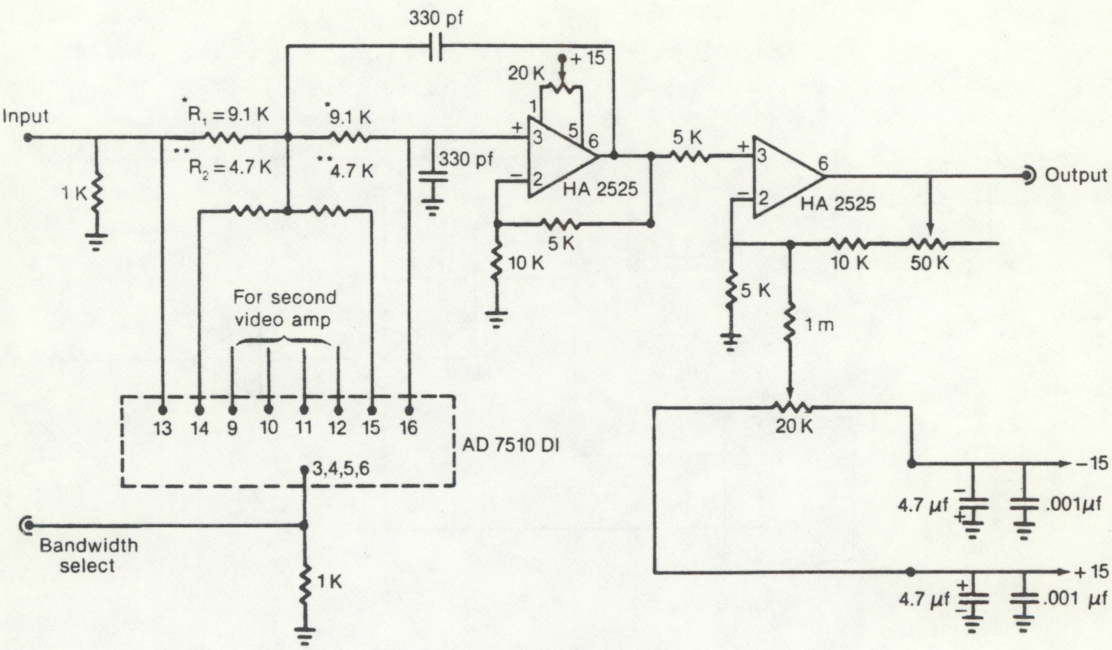
(b) The output noise level is about ±0.5 volts when the system bandwidth is selected for the lower of the two positions.

The first condition is met by limiting the phase detector output to about ±1.5 V by adjusting the level of the reference drive to about +12 dBm with a saturated input signal. The video amplifier gain is then set for ±5 V output. The second condition is met by adjusting the gain of the RHG amplifier.



Key to Figure I.9	
1. Tycho Technology, Inc. (Fig. I.8) or Advanced Receiver Research, P50VDG	3. Merrimac, 113-C
2. RHG, EST-50-D-22EM. (Uses ±12-V power supply: can be purchased with ±15-V supply.)	4. Merrimac, QHS-23-50 or Minicircuits, PSCQ2-70
	5. Watkins Johnson, M9AC
	6. Figure I.10

Figure I.9.--50-MHz radar: Receiver.



*Resistance (K)=pulse width (μs) of wide-pulse mode
**Parallel combination of R_1R_2(K)=pulse width (μs) of narrow-pulse mode

Figure I.10.--50-MHz radar: Video amplifiers.

Figure I.11.--50-MHz radar: View of Fleming antenna toward WSW.

4. Antennas

Each radar has two antennas so that orthogonal wind components can be measured simultaneously. The two antennas are phased arrays with fixed orthogonal pointing directions. The pointing directions are 15 deg off-zenith toward north or south and 15 deg off-zenith toward east or west. Each antenna consists of 16 rows of colinear-coaxial dipoles. Each row has 24 dipoles and is centerfed. The elevation pointing angle is determined by the phase of the feed points on the rows (line length of the feed cables). The azimuth pointing angles are determined by the mechanical alignment of the rows of dipoles. The two antenna azimuth angles are orthogonal; their exact pointing angles relative to north are measured in reference to the sun. The measured azimuth pointing angle is used in the calculation of wind direction.

The elevation angles are assumed to be the theoretical values determined by feed cable lengths. Figure I.11 shows the Fleming antenna. All 16 rows are fed with equal power. Quarter-wavelength cable sections are used to match the impedance. Figure I.12 shows the power splitting, impedance matching, and phasing of the antenna. The antennas were built and installed by Tycho Technology, Inc., Longmont, Colo. The two antenna arrays share the same 50 m x 50 m area.

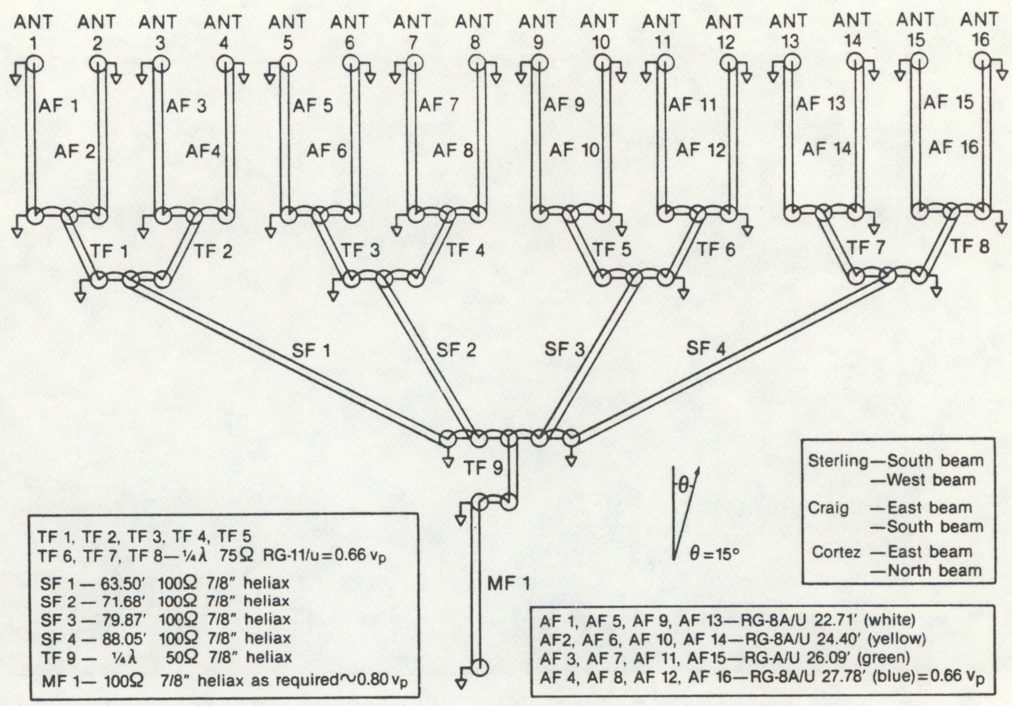


Figure I.12.--50-MHz radar: Antenna power splitting and feeds.

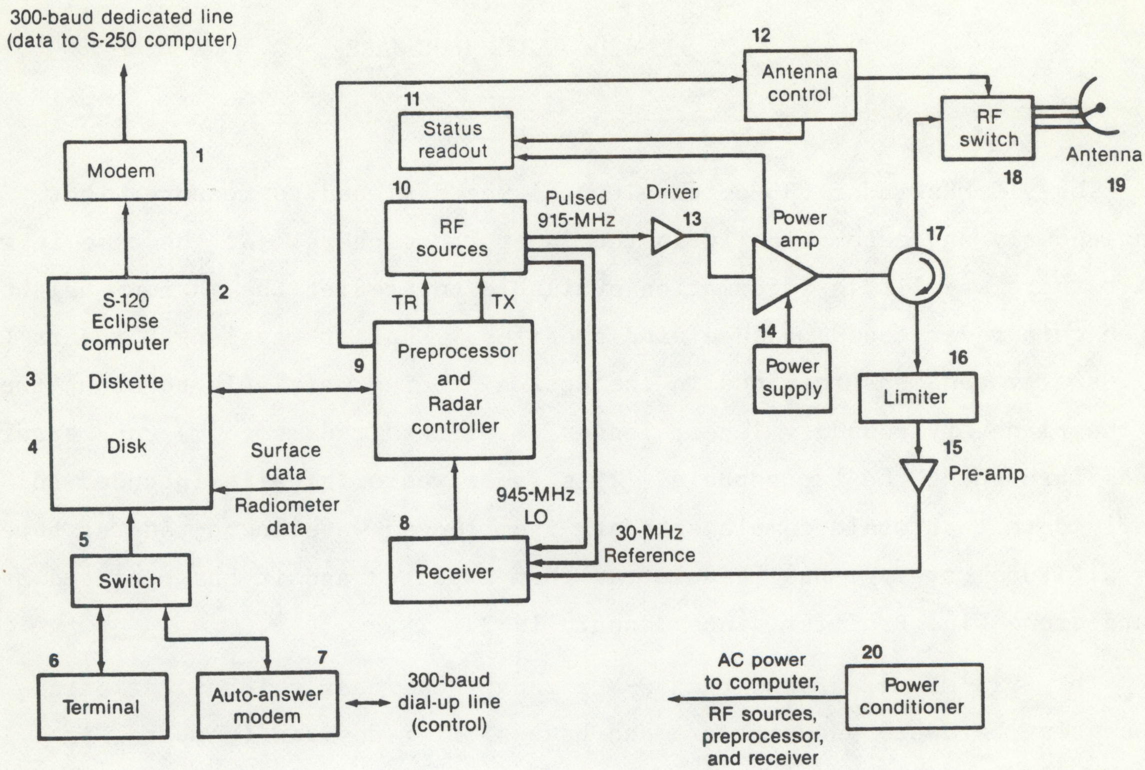
II. 915-MHz RADAR HARDWARE

The 915-MHz radar (33-cm wavelength) was designed to measure winds continuously and automatically in the lower troposphere. At the time it was built there was little information available to predict the maximum height at which this radar could measure wind profiles. Shorter wavelength radars (10 cm) usually can measure winds in the optically clear air only to about the top of the planetary boundary layer; longer wavelength radars (6 m) can measure winds throughout the troposphere. This radar was originally intended to supply data that would complement data from longer wavelength radars; however, its altitude coverage has been better than expected and it has operated as a stand-alone wind Profiler since January 1983.

This 915-MHz radar and the 50-MHz radars use nearly identical data processing hardware and software and have similar designs (compare Figs. I.3 and II.1). The 915-MHz radar uses three antenna pointing positions and a single transmitter to observe the radial velocity sequentially in the three pointing directions (i.e., toward zenith and 15 degrees off-zenith toward east and north). Figure II.2 is a photograph of the antenna; the antenna is described by Earnshaw et al. (1982). The transmitter is a solid-state amplifier procured under contract from the Raytheon Corporation. It uses 2 modules to drive 24 modules, and the outputs of the 24 modules are combined to yield 5.6 kW peak power with up to 25% duty cycle. The radar would have to use pulse compression to utilize the available average power; the maximum duty cycle used with unmodulated pulses is about 8.2% (see Table II.1 for typical operating values). The system was designed so that pulse compression with complementary binary phase coding could be added.

The rf excitation and receiver (Figs. II.3 and II.4) are of conventional (one-of-a-kind) design. The IF and following stages of the receiver are the same as those of the 50-MHz radar receivers (the IF is 30-MHz). Receiver bandwidth is selected in the video amplifiers.

The only radar hardware failures that have occurred with the 915-MHz radar in two years of operation have been failures in the coaxial switches



Key to Figure II.1	
1. Racalvadic, VA-355G (or equiv.)	13. Minicircuits, ZHL-2-H
2. Data General, S-120	14. Raytheon Corp. special design to WPL specs; complete drawings available
3. Data General, 6099	
4. Data General, 6099	15. Trontech, Inc., L900A
5. Black Box CO., SW010	16. American Electronic Laboratory, MIC-3152
6. Teletype Corp., 43 (or equiv.)	
7. Racalvadic, VA3451 (or equiv.)	17. TRAK Microwave Corp., 12A011
8. WPL-built (Fig. II.4)	18. Dynatech, D2-115B10P
9. WPL-built (Moran, 1984)	19. TIW construction to WPL design (Earnshaw et al., 1982)
10. WPL-built (Fig. II.3)	
11. WPL-built (Fig. II.5)	20. Topaz, 70308-3KVA
12. WPL-built (Fig. II.5)	

Figure II.1.--915-MHz radar: System, block diagram.

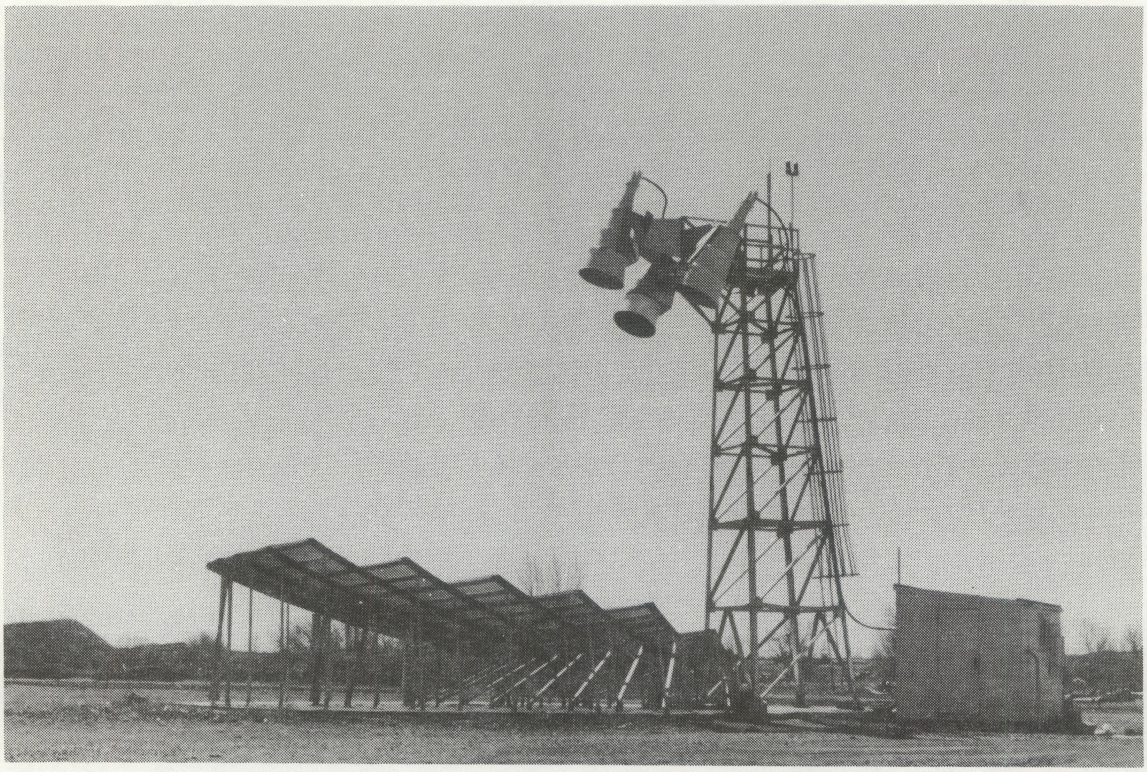


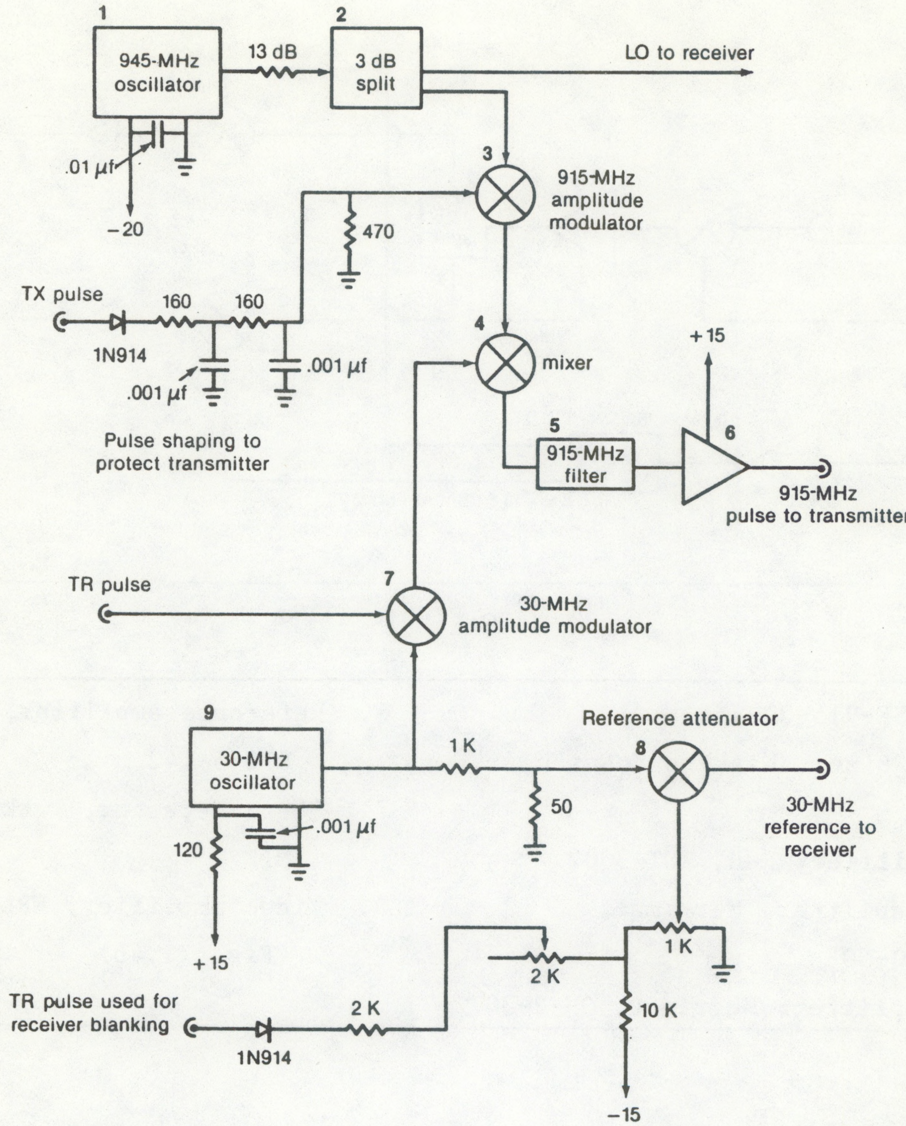
Figure II.2.--915-MHz radar: View of antenna installation.

used to select the antenna pointing position. These switches were replaced in 1984 with new switches and new control circuitry (Fig. II.5).

Minimum height of observation is about 350 m above ground. Maximum height varies from 8 to 15 km depending on the particular air mass. There are two telephone lines to the radar; one controls the radar and the other, a dedicated line, transmits data to a central computer that collects data from all Profiler stations.

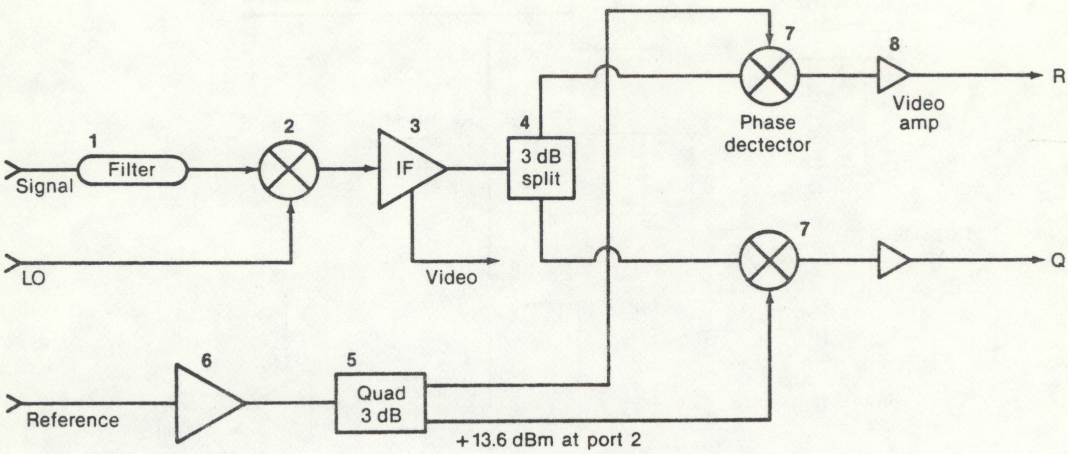
Table II.1. UHF (915-MHz) radar characteristics and typical operating values

Characteristic	Value		
Radar			
Frequency	915 MHz		
Maximum bandwidth	2 MHz		
Peak power	5.6 kW		
Duty cycle	≤25%		
Antenna aperture	~10 m x 10 m		
Antenna pointing	Zenith, 15° off-zenith to north and east		
Antenna type	Offset paraboloidal reflector with offset horn feeds		
Two-way beamwidth	1.7°		
System noise temperature	240 K		
Data Processing	1	2	3
Pulse width	1 μs	3 μs	9 μs
Pulse repetition period	50 μs	64 μs	110 μs
Average power	110 W	260 W	450 W
Time domain averaging	136 pulses	80 pulses	46 pulses
Spectral averaging	8 spectra	32 spectra	32 spectra
Maximum radial velocity	±12.02 m/s	±15.97 m/s	±16.2 m/s
Spectral resolution (64 points)	0.19 m/s	0.25 m/s	0.25 m/s
Height sampling			
1st height	0.35 km	1.64 km	2.7 km
Height spacing	100 m	290 m	870 m
Number of heights	24	24	18



Key to Figure II.3	
1. Frequency West, MO-100XA-43	6. Avantek, UTC-12-104
2. Merrimac, PDM-22-.75G	7. Hewlett-Packard, 10514A
3. Merrimac, DBm-8-500	8. VARI-L, DBm-100
4. Watkins Johnson, MIJ	9. Accutronics/GRRC, KL10-11M
5. Lark, SF-915-33-4AB	

Figure II.3.--915-MHz radar: RF sources.



Key to Figure II.4a	
1. Lark, SF-915-33-4AB	6. Reference amplifier, Avantek, UTC-5-142
2. Signal mixer, Watkins Johnson, MIJ	7. Phase detector, Watkins Johnson, MIE
3. IF amplifier, RGH, EST-3002	8. Video amplifier, WPL-built (Fig. II.4b)
4. Power splitter, Merrimac, PD-20-50	
5. Quad splitter, Merrimac, QH-2-30	

Figure II.4a.--915-MHz radar: Receiver, block diagram.

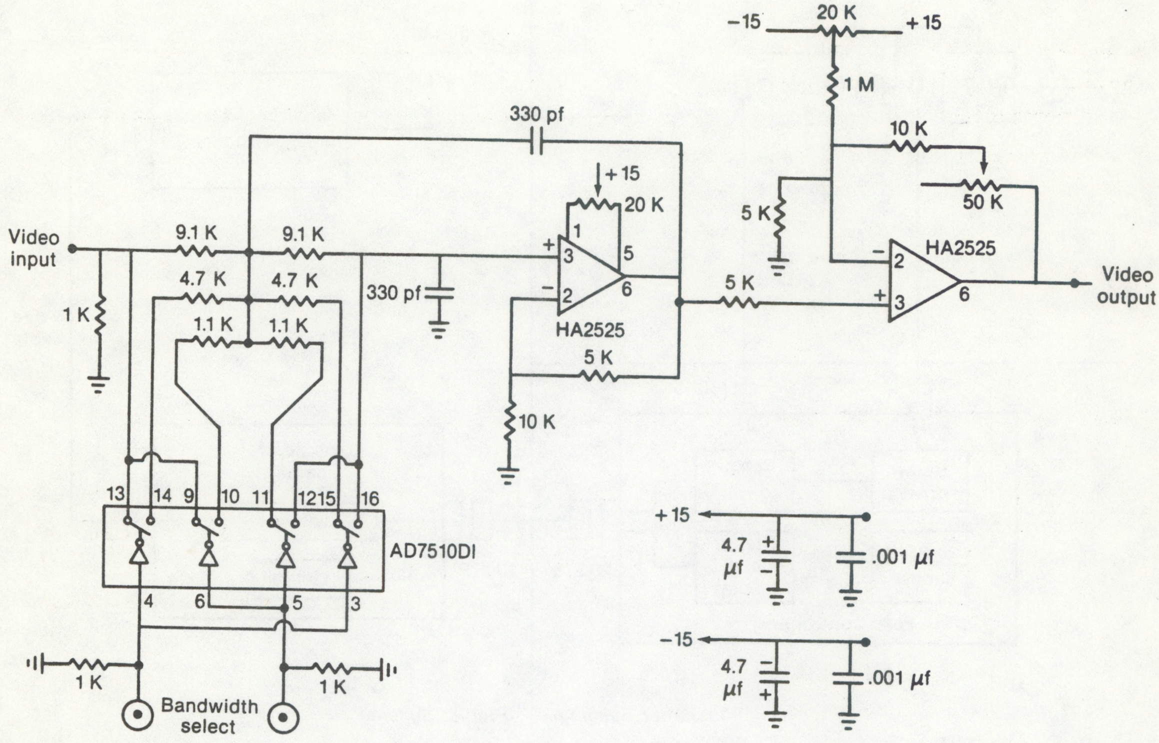


Figure II.4b.--915-MHz radar: Video amplifiers.

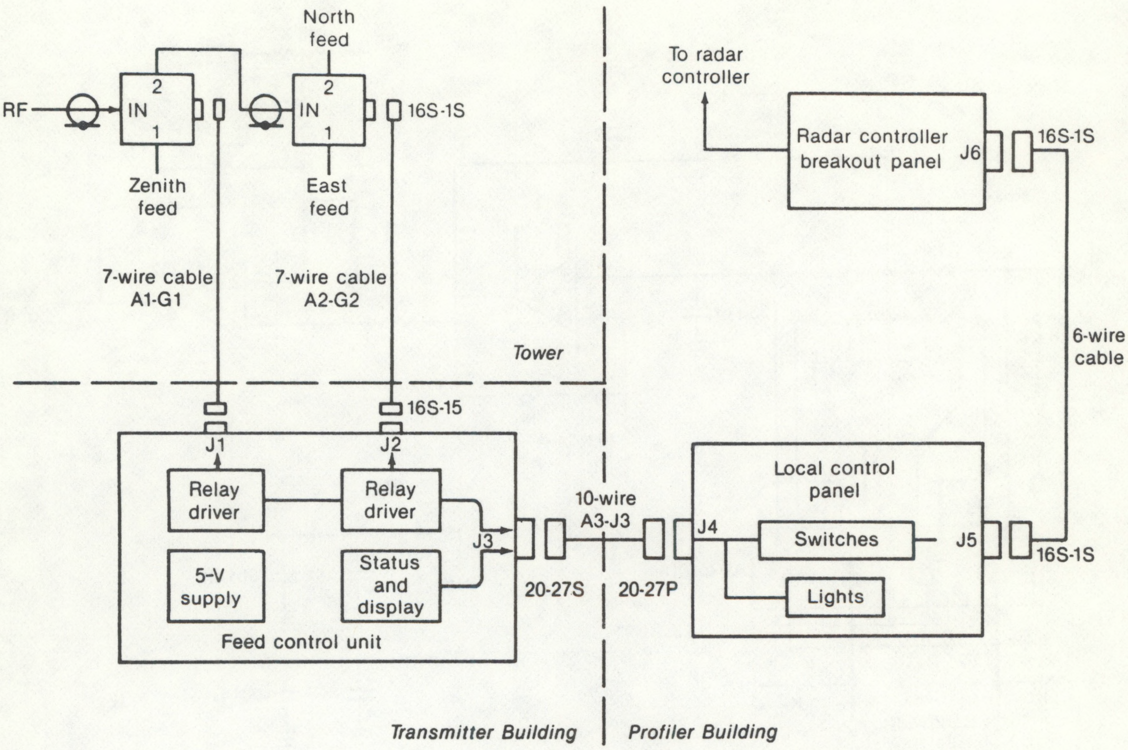


Figure II.5a.--915-MHz radar: Antenna control, block diagram.

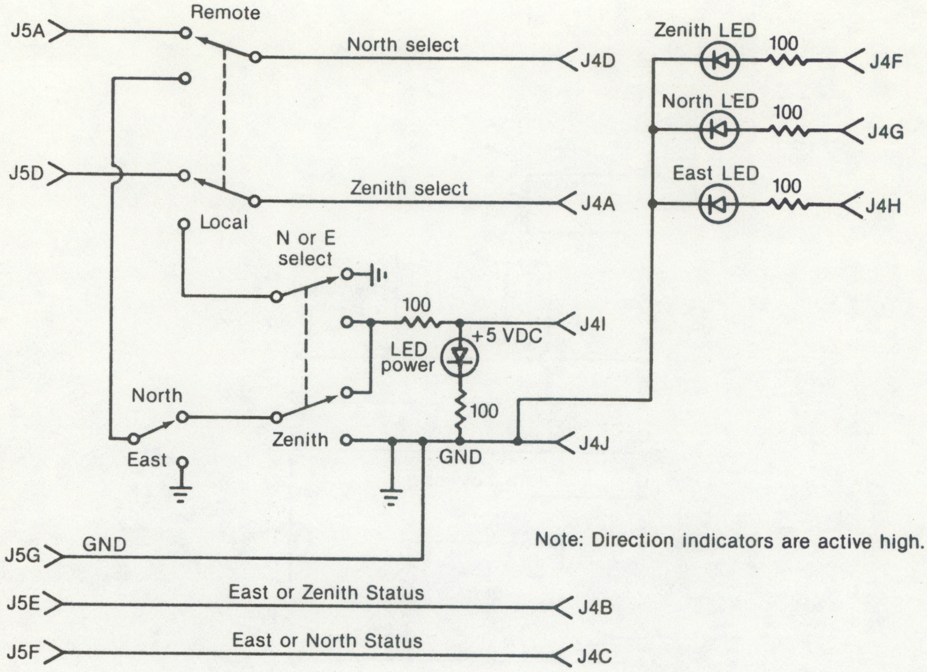


Figure II.5b.--915-MHz radar: Local/remote control.

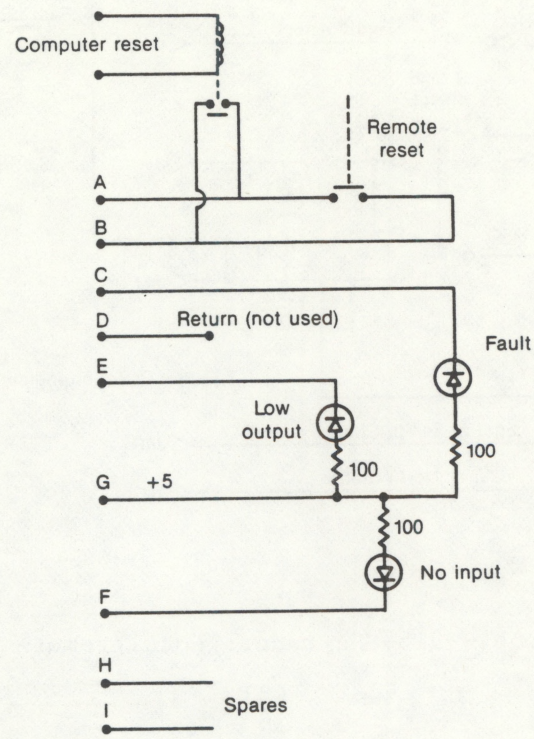
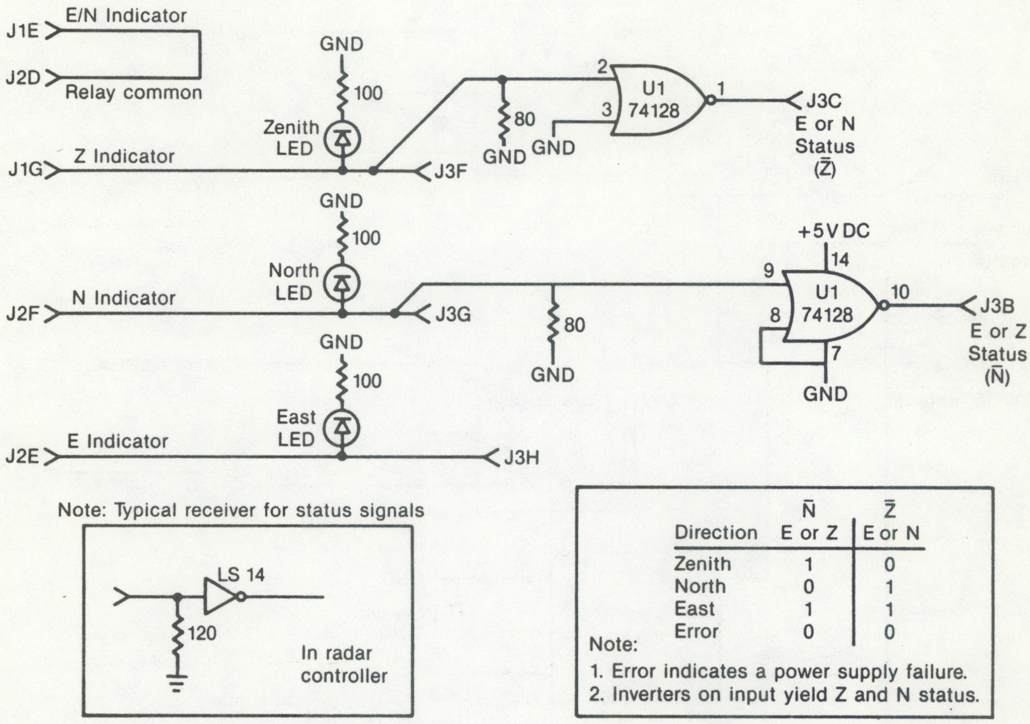


Figure II.5c.--915-MHz radar: Remote readout for power amplifier.



Direction	$\bar{N}$ E or Z	$\bar{Z}$ E or N
Zenith	1	0
North	0	1
East	1	1
Error	0	0

Note:

1. Error indicates a power supply failure.
2. Inverters on input yield Z and N status.

Figure II.5d.--915-MHz radar: Display and status indicators.

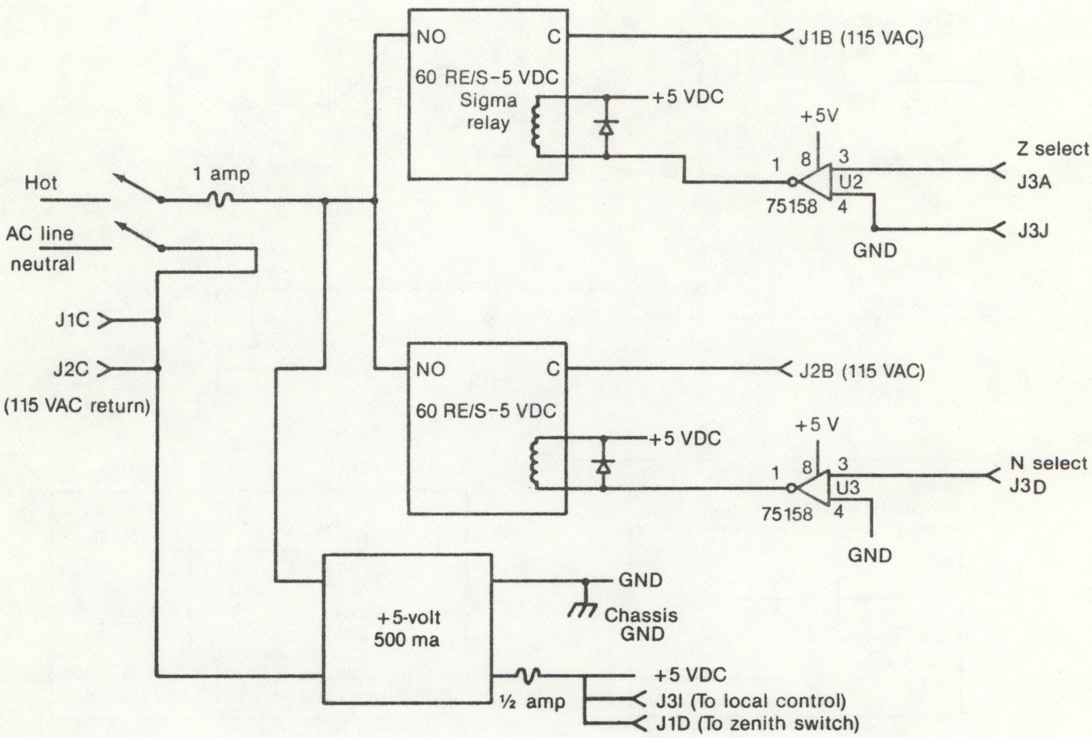


Figure II.5e.--915-MHz radar: Switch drivers.

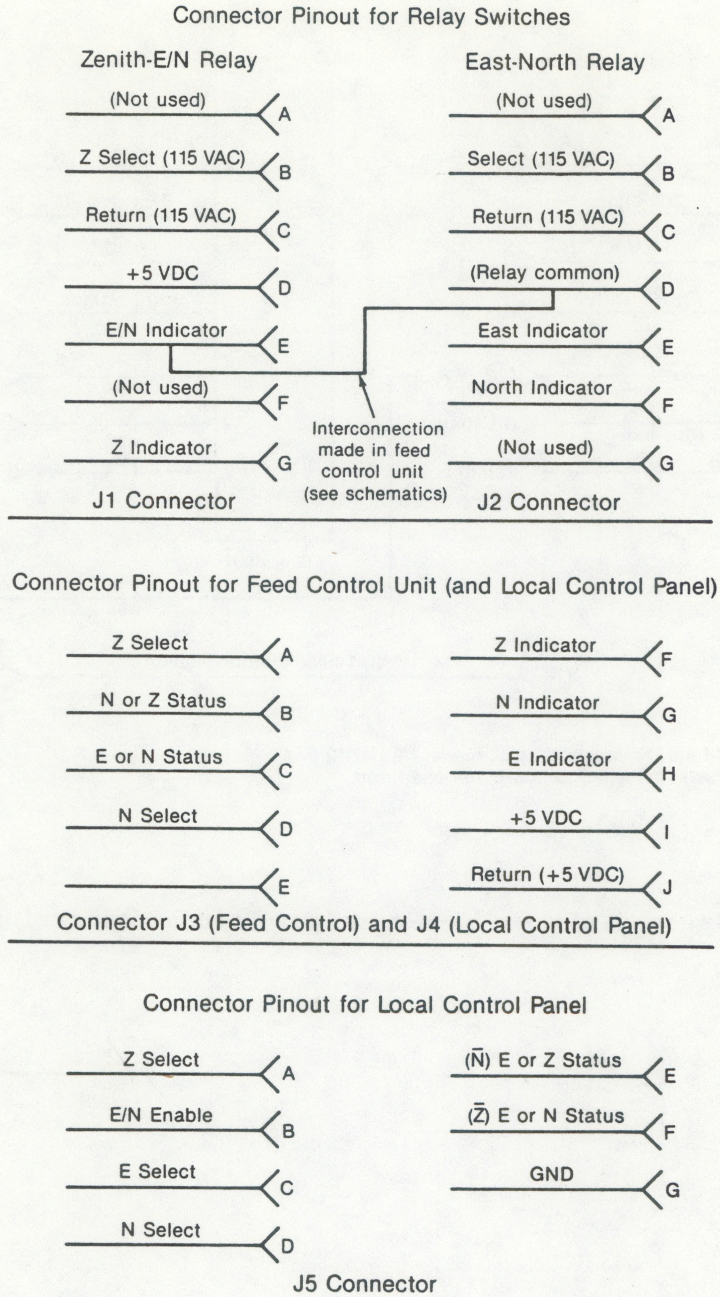
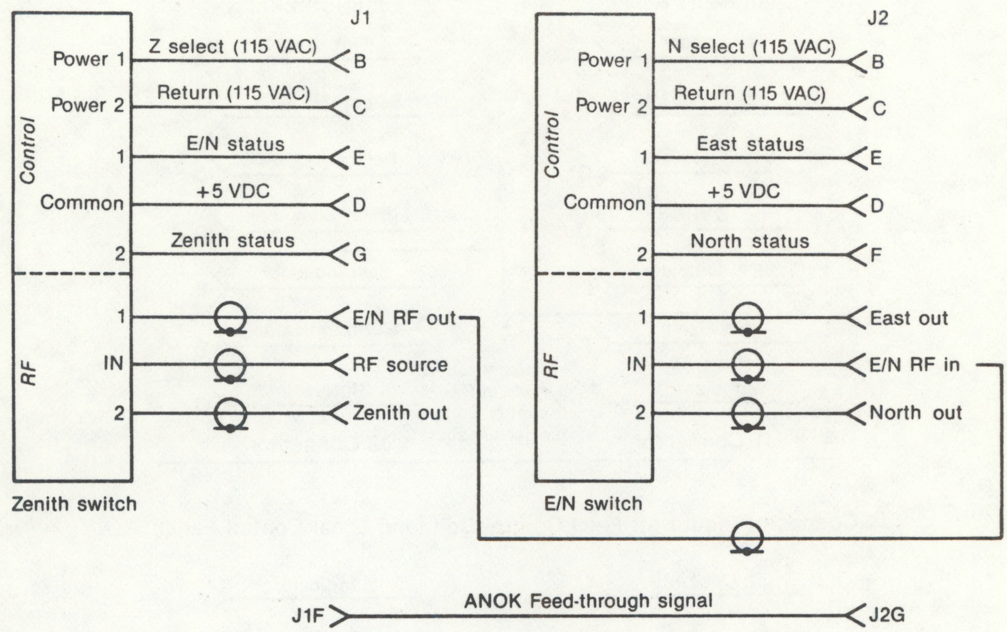


Figure II.5f.--915-MHz radar: Cabling connections.



Note:
1. Switches used are Dynatech/V-Z, Inc., model D2-115B10 P.
2. Position 1 is selected when switch is *not* energized.

Figure II.5g.--915-MHz radar: Switch connections.

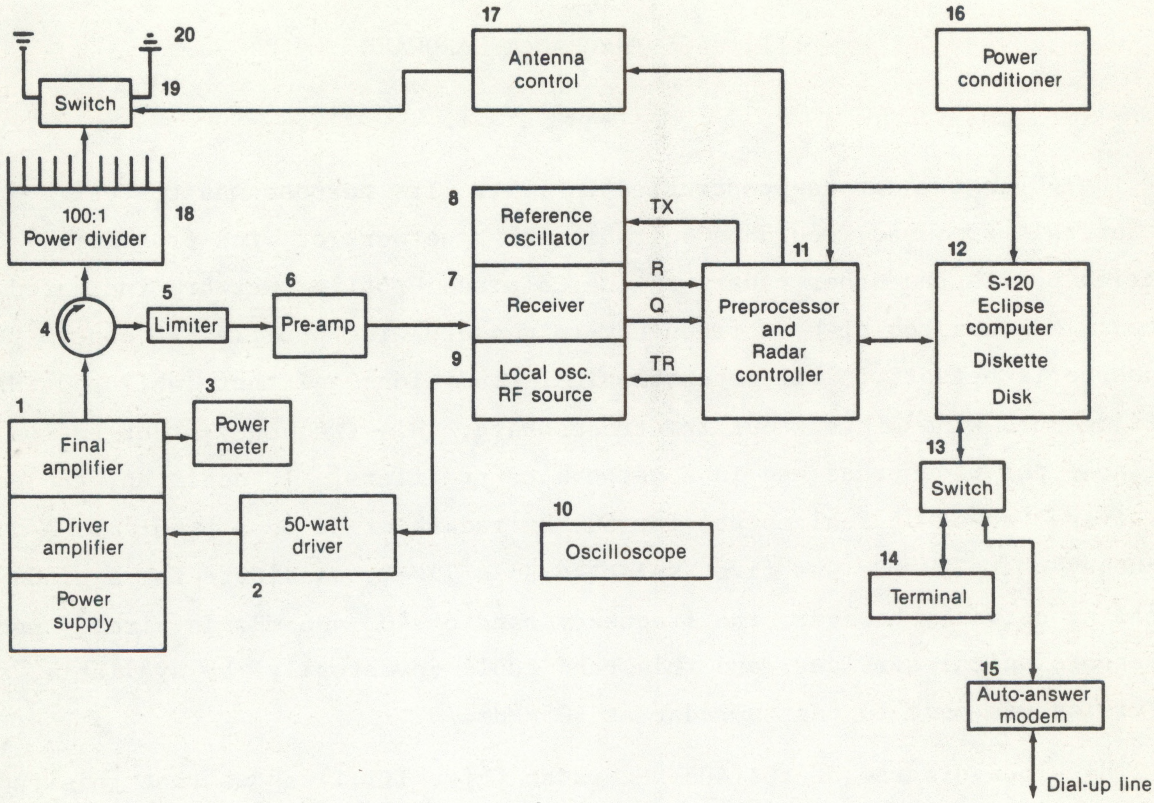
III. 405-MHz RADAR HARDWARE

The 405-MHz radar was contructed in 1984. Its purpose was to test whether this frequency would be suitable for a network of wind profilers. Experience with the other radars in the Colorado Profiler Network indicated that 915 MHz was too high in frequency to measure wind profiles at upper tropospheric heights in all meteorological conditions and that, while 50 MHz could measure winds throughout the troposphere, this frequency might not be available for widespread use in a network of profilers. In addition, the need for several acres of real estate for 50-MHz radars might be a problem. A frequency near 220 MHz was first selected as a likely candidate for a wind-profiling network; however, the frequency band of 403-406 MHz is already used by meteorological services, and this band could (eventually) be available, so a decision was made to test a radar at 405 MHz.

The block diagram of the 405-MHz radar (Fig. III.1) shows that this radar was designed with the same philosophy as the 915- and 50-MHz radars. It is similar to the 915-MHz radar in that one transmitter is sequentially switched to different pointing directions. The first version of the antenna (Fig. III.2) has just two pointing directions, 15 degrees off-zenith toward east and north. It is a phased array of 100 five-element Yagi-Uda antennas. Other antennas with three or five pointing positions are being designed. Antenna control is shown in Figs. III.3a-III.3d.

The transmitter was procured from Microwave Control Company. It uses parallel output tubes to deliver about 30 kW peak power and 1.3 kW (maximum) average power. Typical operating modes are listed in Table III.1. The transmitter has not been operated at full power for extended periods as of January 1, 1985.

The 405-MHz and 30-MHz sources (Fig. III.4 and Fig. III.5) and the receiver (Fig. III.6) are similar to those used with the 915-MHz radar. This radar was originally constructed in Boulder, Colo., but because of interference from local radiosonde research work the system was moved to Platteville, Colo., in October 1984. Testing began in November 1984.



Key to Figure III.1	
1. Microwave Control Co., QTDHR	12. Data General, S-120 computer Data General, 6099 disks
2. Microwave Control Co., 51037	
3. Hewlett-Packard, 431C	13. Black Box Co., S-010
4. Microwave Control Co., 463	14. Teletype Corp., 43 (or equivalent)
5. AEL, 3152	15. Racalvadic, 3451 (or equivalent)
6. MITEQ, AV-2A-1045	16. Topaz, 70308-3KVA
7. WPL-built	17. WPL-built (Fig. III.3)
8. WPL-built	18. Microwave Control Co., 578
9. WPL-built	19. SAGE, SBN 490E
10. Textronix, 1122	20. Tycho Technology, Inc., built to WPL specifications
11. WPL-built (Moran, 1984)	

Figure III.1.--405-MHz radar: System, block diagram.

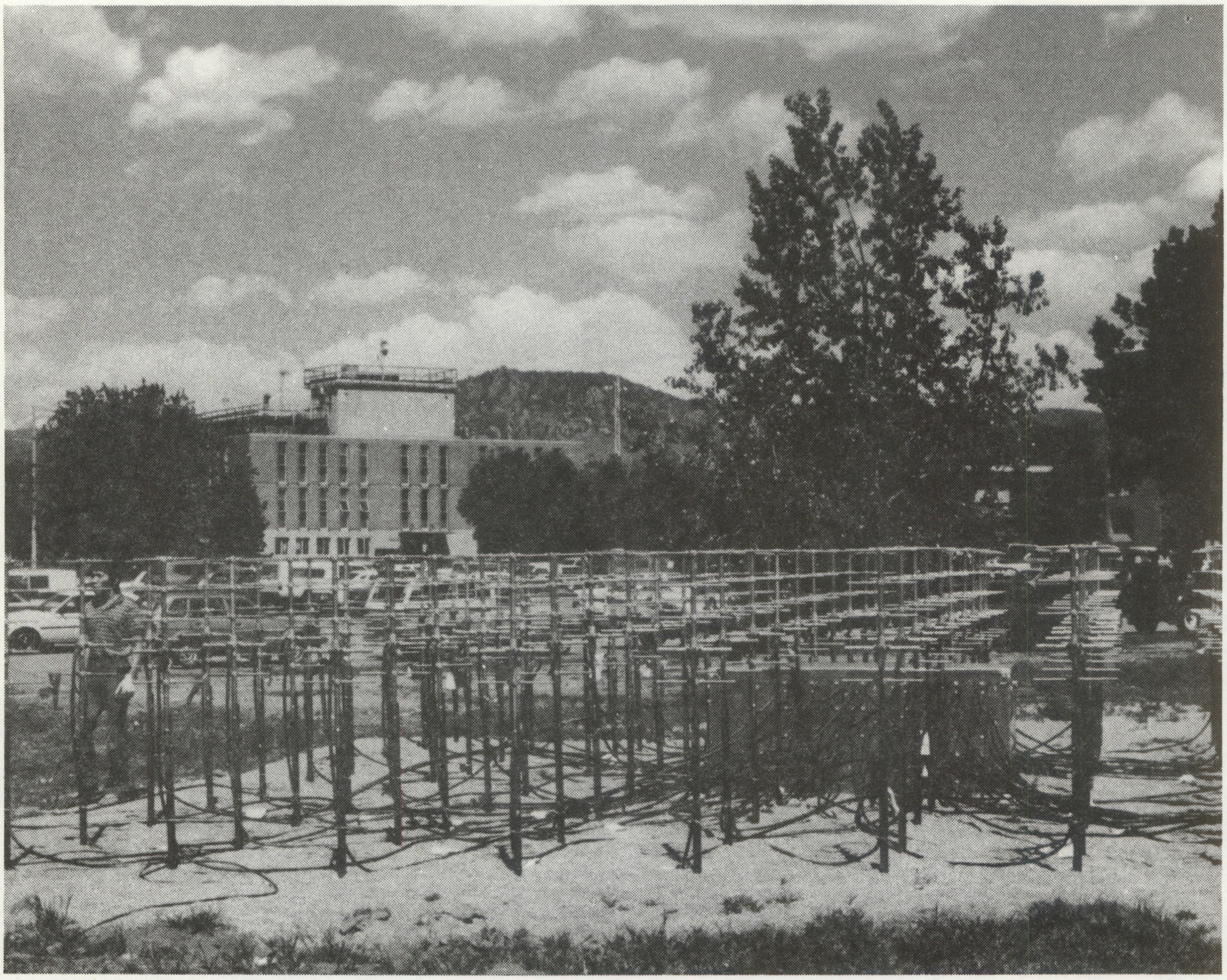


Figure III.2.--405-MHz radar: View of antenna installation.

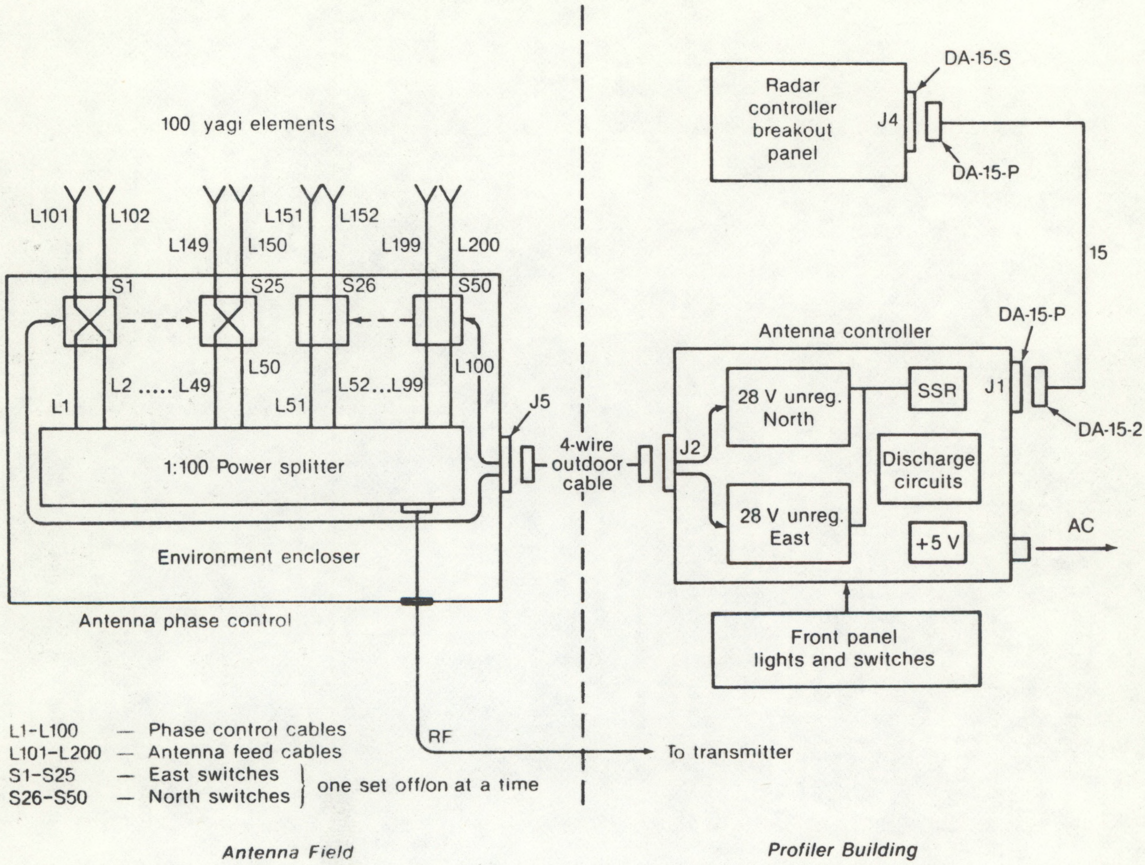


Figure III.3a.--405-MHz radar: Antenna control, block diagram.

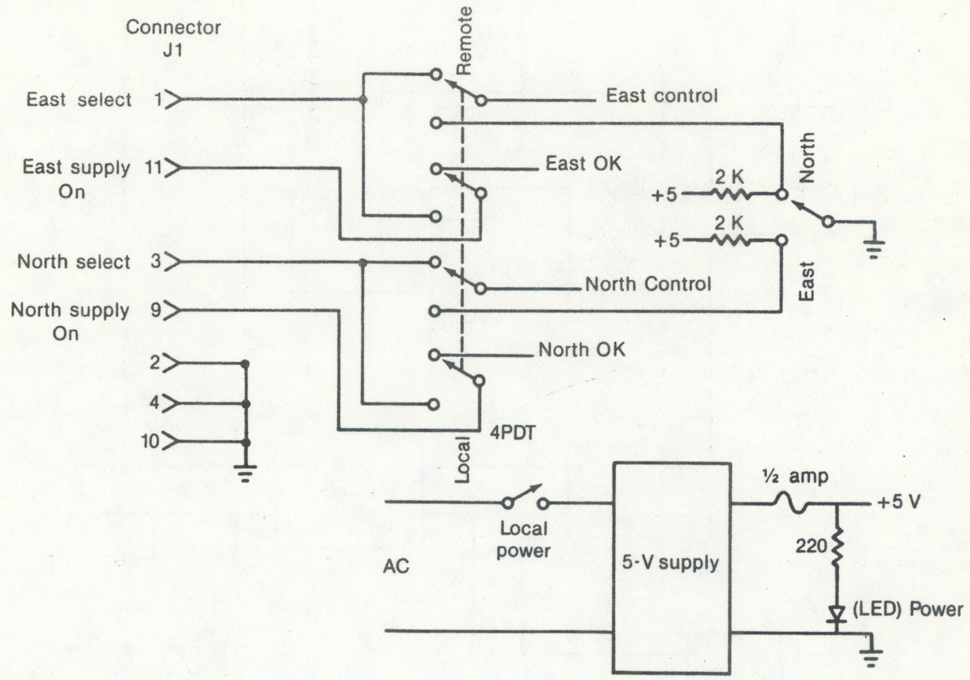


Figure III.3b.--405-MHz radar: Remote/local control.

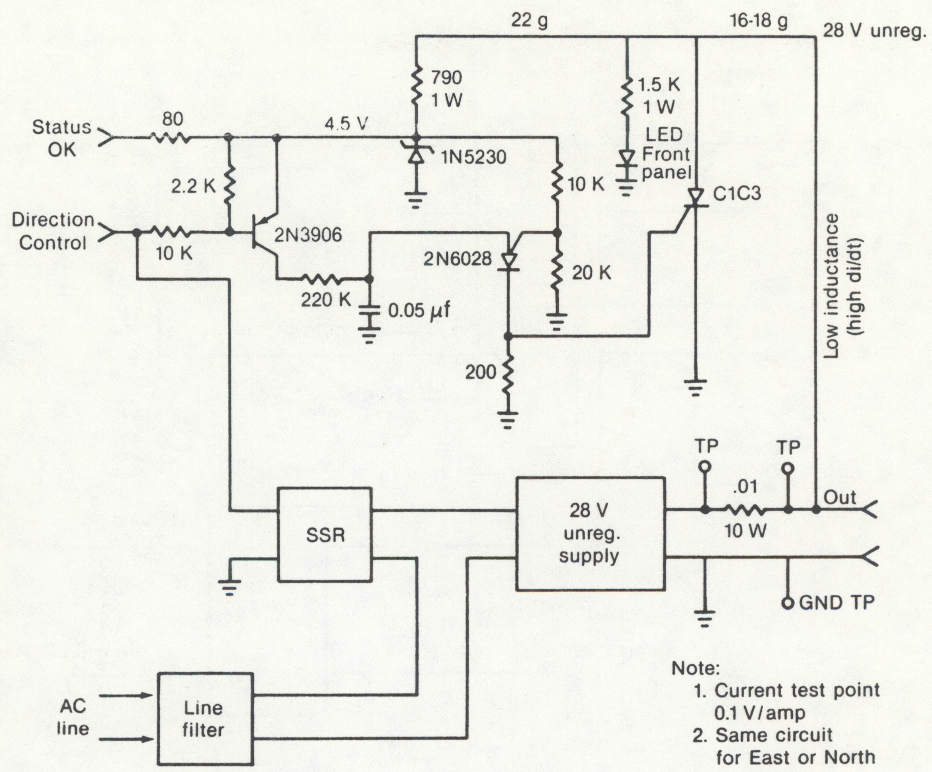


Figure III.3c.--405-MHz radar: Switching circuit.

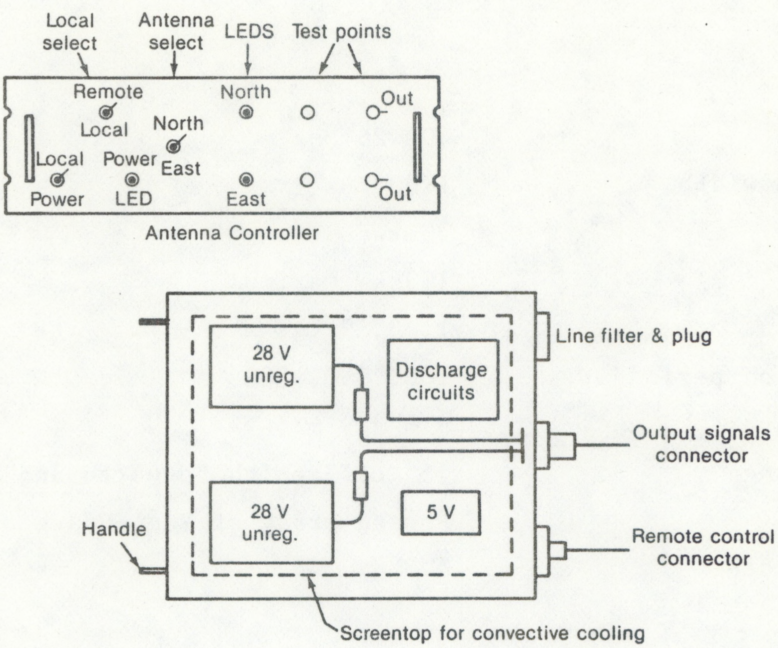
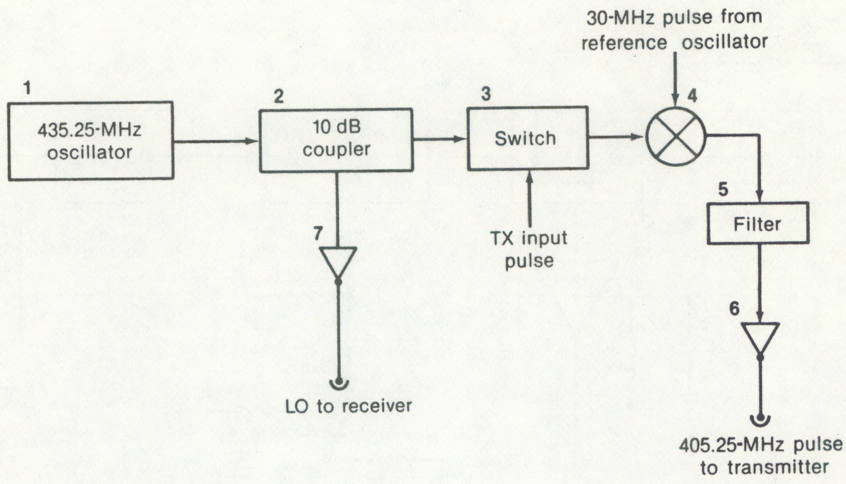


Figure III.3d.--405-MHz radar: Component layout.

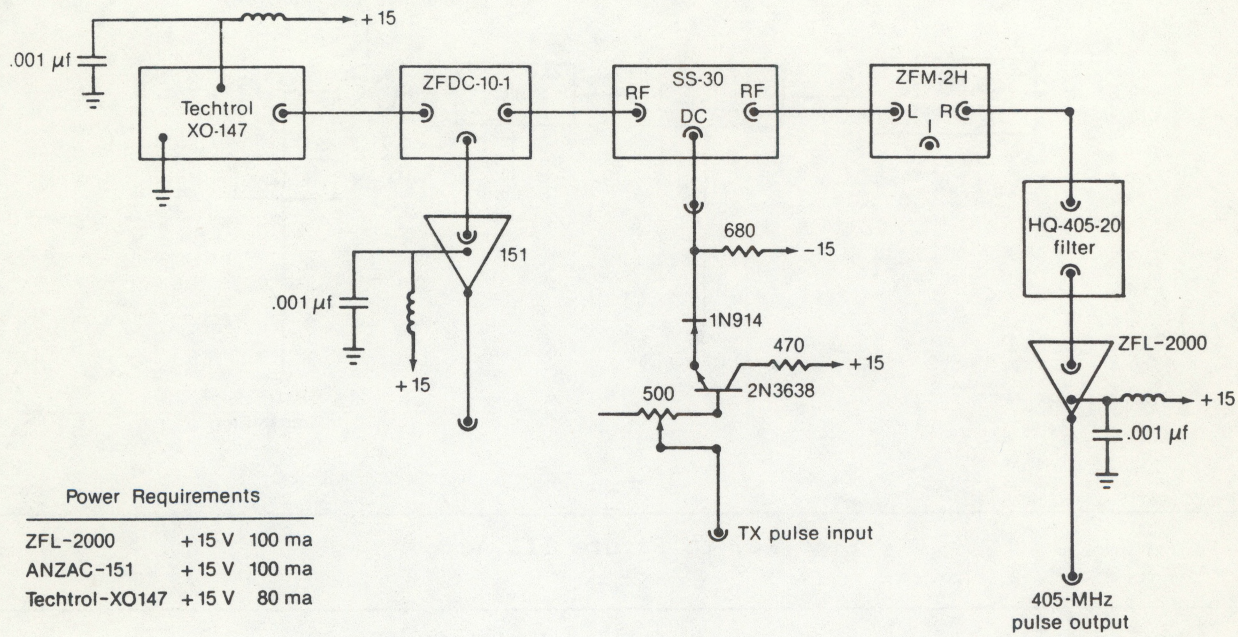
Table III.1.--UHF (405-MHz) radar characteristics and typical operating values

Characteristic	Value		
Radar			
Frequency	405.25 MHz		
Authorized bandwidth	1.00 MHz		
Peak power	30 kW		
Average power	1.3 kW maximum		
Pulse width	1, 3, 9 μs		
Pulse repetition period	100, 150, 300 μs		
Antenna aperture	9 m x 9 m		
Antenna pointing	15° off-zenith to north and east		
Antenna type	Phased array of Yagi-Uda elements		
Two-way beamwidth	4.3°		
Data Processing	1-μs pulse	3-μs pulse	9-μs pulse
Time domain averaging	120 pulses	75 pulses	35 pulses
Spectral averages	8	16	24
Maximum radial velocity	±15.41 m/s	±16.44 m/s	±17.62 m/s
Spectral resolution (64 points)	0.48 m/s	0.51 m/s	0.55 m/s
Height Sampling			
First height	0.4 km	2.4 km	4.0 km
Height spacing	100 m	290 m	870 m
Number of heights	24	24	14



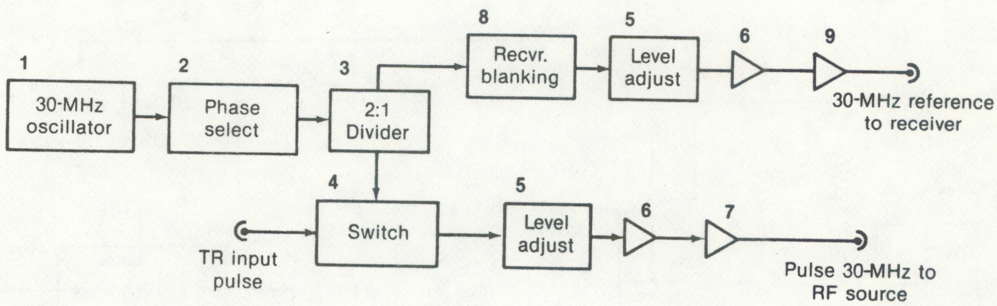
Key to Figure III.4a	
1. Techtrol, XO-147	5. Lark, HQ-405-20
2. Minicircuits, ZFDC-10-1	6. Amplifier, Minicircuits, ZFL-2000
3. VARI-L, SS-30	7. Amplifier, ANZAC, 151
4. Minicircuits, ZFM-2H	

Figure III.4a.--405-MHz radar: RF sources, block diagram.



Power Requirements		
ZFL-2000	+15 V	100 ma
ANZAC-151	+15 V	100 ma
Techtrol-XO147	+15 V	80 ma

Figure III.4b.--405-MHz radar: RF sources, circuit diagram.



Key to Figure III.5a	
1. Vectron, CO 233T	6. Avantek, GPD-402
2. VARI-L, CM1H	7. Avantek, GPD-405
3. Merrimac, 113C	8. Minicircuits, SRA-1
4. VARI-L, SS-50	9. Avantek, GPD-404
5. Minicircuits, SRI-A	

Figure III.5a.--405-MHz radar: Reference oscillator, block diagram.

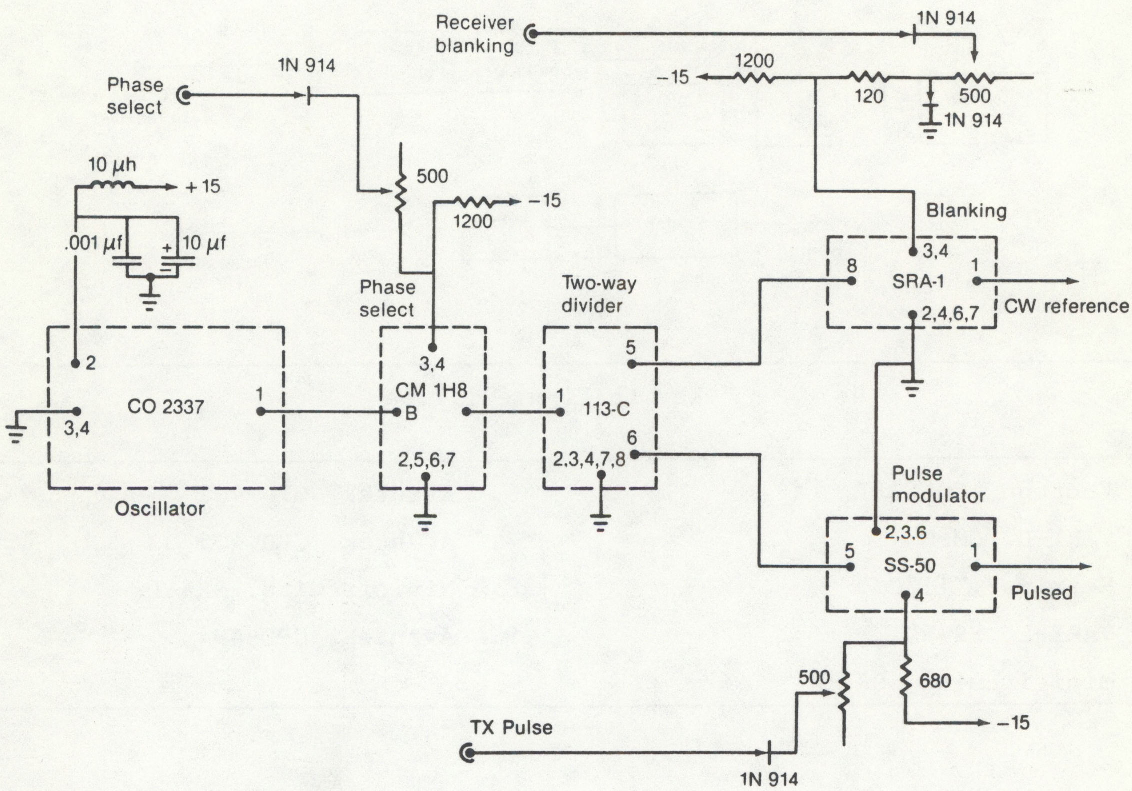


Figure III.5b.--405-MHz radar: Oscillator and pulse modulator.

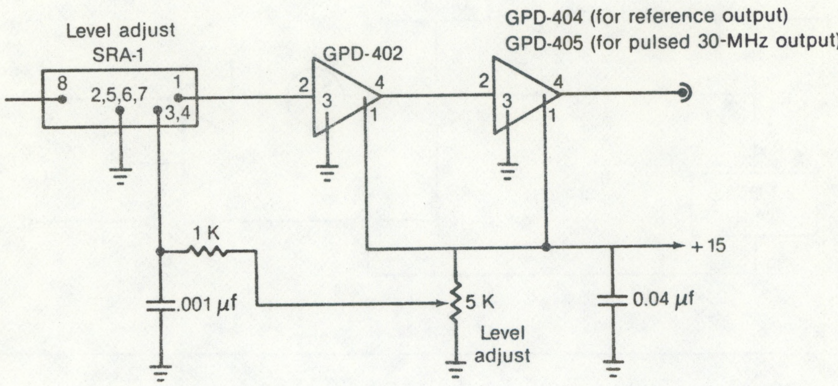
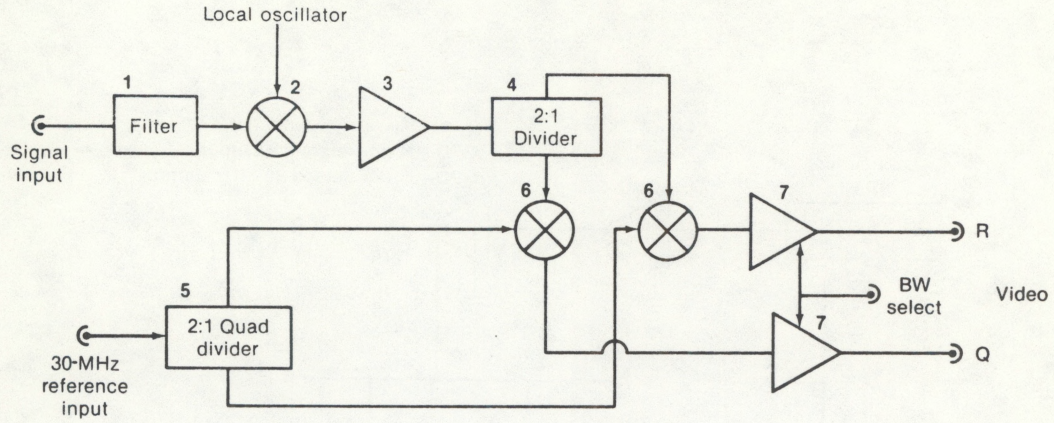


Figure III.5c.--405-MHz radar: Reference and pulse driver.



Key to Figure III.6a	
1. Lark, HQ-405-20-5EF	5. Minicircuits, PSCQ-2-40
2. VARI-L, DBM 100B	6. Mixers, Watkins Johnson, M9AC
3. Amplifier, RHG, EST-3002	7. Video amplifiers, WPL-built (Fig. III.6b)
4. Merrimac, 113-C	

Figure III.6a.--405-MHz radar: Receiver, block diagram.

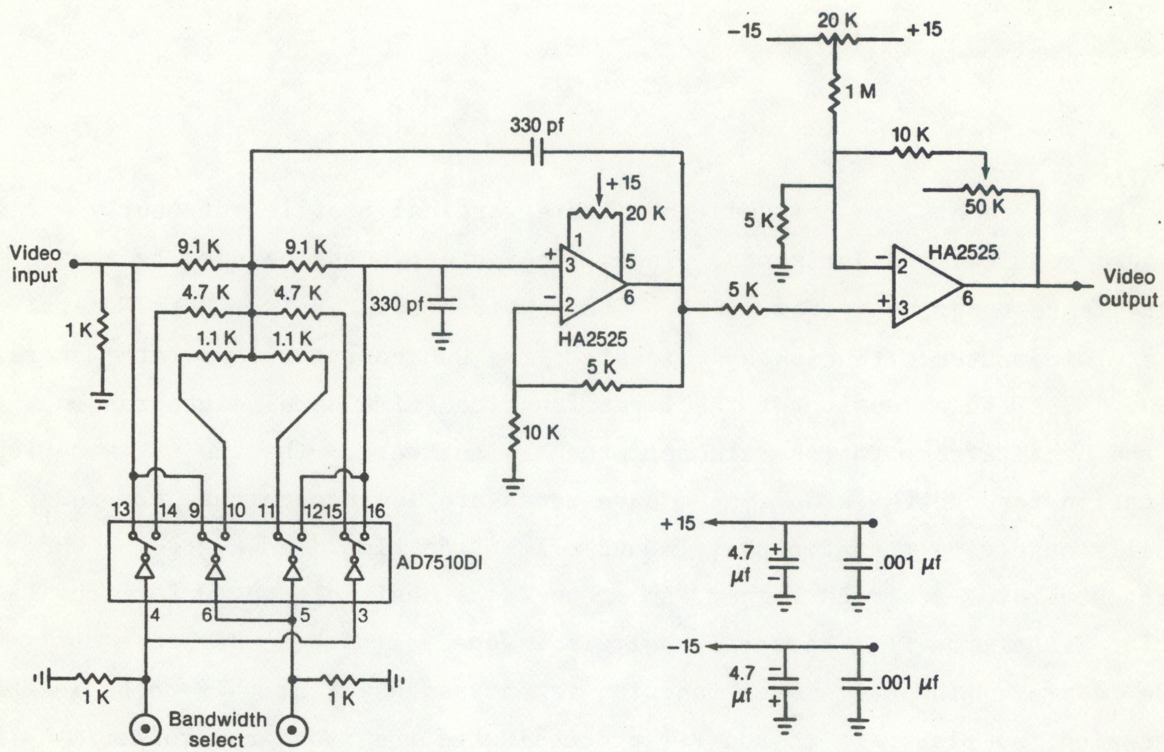


Figure III.6b.--405-MHz radar: Video amplifiers, circuit diagram (duplicate of video amplifiers for 915-MHz radar, Fig. II.4b).

IV. SOFTWARE

1. Data Processing

The WPL radars are designed to measure vertical profiles of hourly-averaged vertical and horizontal winds. The data processing used by these radars is represented in Fig. IV.1. The on-site computer is a Data General S-120 minicomputer with disk and diskette; the Hub computer is a Data General S-250. With the exception of the first function (time domain integration), all the on-site computations are performed in software. This is not a serious limitation for the VHF radars; the data rates are low enough that the radar is actually observing the atmosphere about 67% of the time. However, the UHF radar data rates are much higher, so it would be desirable to perform the Fast Fourier Transform (FFT) spectral analysis in special-purpose hardware for these radars. (The DC removal function is not essential at this point in the processing, so plans are to add FFT processing to the radar controller/preprocessor [Moran, 1984] and then do the remaining functions in software.)

The various data processing steps have the following functions:

A. Time Domain Integration

The Doppler velocity spectrum of a pulsed Doppler radar is a discrete sample of the actual velocity spectrum that spans the velocity interval $-\lambda/2T$ to $\lambda/2T$ in velocity intervals of $\lambda/2NT$, where λ is the radar wavelength, T is the pulse repetition interval, and N is the number of radar pulses used in the FFT spectral analysis. Since the velocity interval of interest is typically one-tenth to one-thousandth of $\lambda/2T$, and since the spectral width is about 1 m/s, in order to resolve the Doppler spectrum of atmospheric targets it is necessary to use 10^3 to 10^5 radar pulses in the Fourier analysis. A brute-force approach using FFT analysis of lengthy time series would be burdensome. To avoid this computing load, the radar pulses are effectively resampled so that T is increased to MT by averaging M radar samples. This yields an M-fold decrease in the data rate with a small sacrifice in performance as the velocity approaches $\pm \frac{\lambda}{2MT}$. The averaging process is

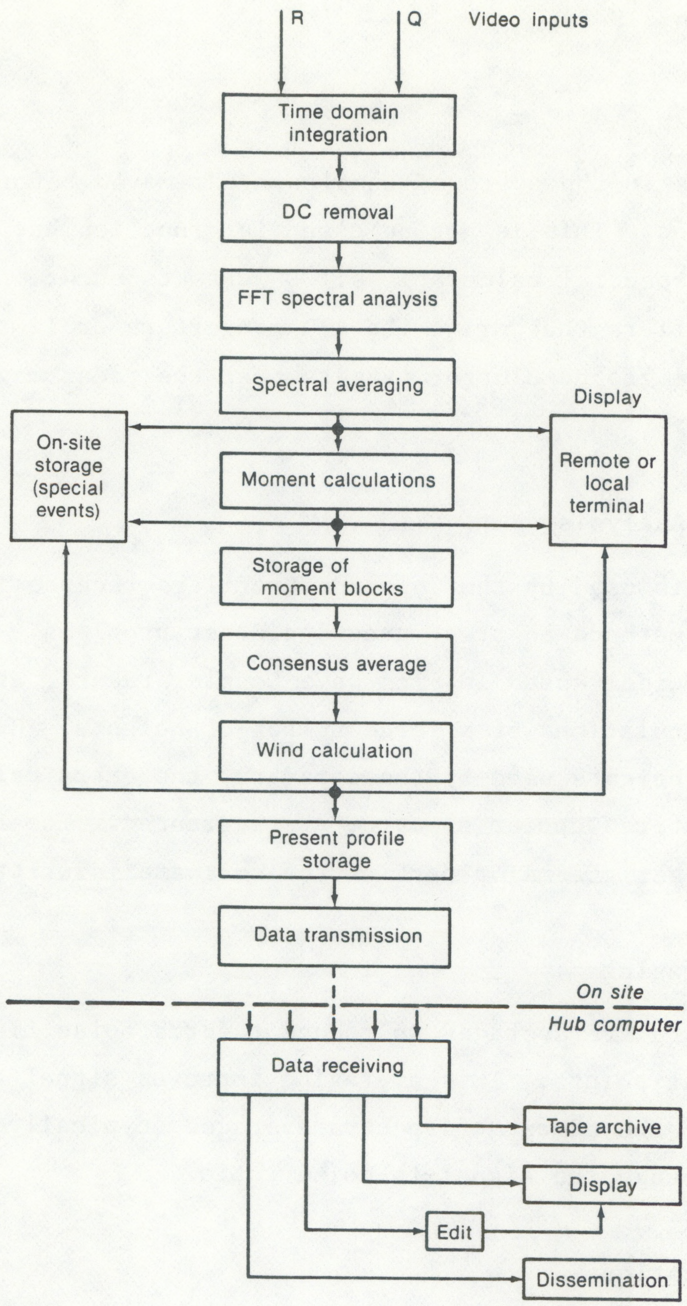


Figure IV.1.--Data processing flow diagram described by Schmidt et al. (1979). The averaging is performed in the preprocessor (Moran, 1984).

B. DC Removal

Any DC offsets in the averaged samples are removed before the power spectrum is computed. This is not an essential function but is performed as a subroutine in the spectral calculations. DC offsets occur in the hardware (drift in DC amplifiers that drive the A/D converters or in the A/D converters) or from ground clutter targets that the radar may detect through antenna sidelobes.

C. FFT Spectral Analysis

FFT analysis is used by the Colorado Profilers because it allows flexible and more complete methods to treat ground clutter problems. Covariance analysis methods, widely used in microwave Doppler radars, are better suited for high speed calculations of a large number of heights. However, with the limited number of heights used by these radars, the extra calculations needed to estimate the entire Doppler spectrum are warranted. The FFT routines are in assembly language; the major part of the software is written in Fortran.

D. Spectral Averaging

Doppler spectra are averaged to reduce the rms noise fluctuations of the individual spectral points. This averaging improves signal detectibility by the square root of the number of spectra averaged (typically between 2 and 40) but it does not change the signal-to-noise ratio.

E. Moment Calculations

The zeroth, first, and second moments of the averaged Doppler spectra are calculated by the following methods:

(1) Ground clutter near 0 velocity is removed for those ranges (heights) where the radar observes signals from fixed targets. Three options are available to do this:

(a) A selectable number of points on both sides of 0 velocity can be set to 0. (This method has never been used in normal operation.)

(b) The spectral value of a selectable number of points on each side of 0 velocity can be set equal to the mean value of the next points on either side of 0 ("zero suppression").

(c) Each spectral point is subtracted from its image point. If that value is 0 or <0, the point is set to 0. If that value is >0, the subtracted value is retained ("half-plane subtraction"). This is the method used for the Colorado wind profilers (Passarelli et al., 1981).

[A slight modification of (b) is perhaps a good compromise for clutter suppression: Replace the spectral value of a selectable number of points on either side of 0 velocity with a linear interpolation of the signal between the points at the edge of the clutter.]

(2) The noise level ($\overline{N}$, see Fig. IV.2) is found by an objective method described by Hildebrand and Sekhon (1974).

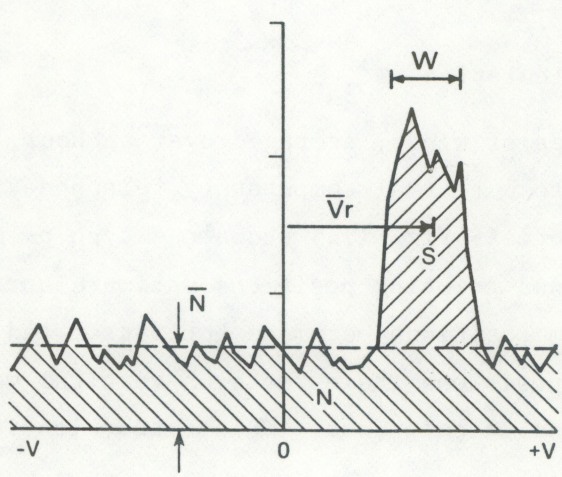


Figure IV.2.--Moment calculations.

(3) The signal spectrum is isolated from the signal-plus-noise spectrum by selecting the signal spectrum to consist of the spectral point with the highest value and all contiguous points on either side that are above the noise level (or above zero when half plane subtraction is used).

(4) Power, mean velocity, and spectrum width are computed by applying the classical definitions for these moments to the signal spectrum.

(5) SNR is computed by $S/[\overline{N}*FFTL]$ where FFTL equals number of spectral points. Note that this is an approximation; SNR should be found by $S/[(S + N) - S]$ where S + N is the sum of the power in all spectral points.

F. Storage of Moment Blocks

Tables of moment values are stored for the number of profiles used in the wind calculation. Figure IV.3 shows an example of the data in each moment table, as well as the averaged Doppler spectrum that was used to derive the data in the moment table.

G. Data Averaging

After all the profiles are stored for the desired averaging time, the data are averaged to generate a single profile for the averaging period. The averaging method is described in Strauch et al. (1984).

H. Wind Profile Calculation

Vertical profiles of winds, averaged over an hour, are calculated, and the data are output to a central computer by telephone. Figure IV.4 shows a sample of the data format; Fig. IV.5 shows one type of Hub computer display. Radars with two antenna pointing positions estimate horizontal wind profiles; those with three beam positions estimate horizontal and vertical winds. With these beam-pointing positions the effects of vertical winds can be corrected in the horizontal wind calculations. This correction is optional.

HT	DOPPLER M/S	POWER DB	NOISE DB	SIG/NOISE DB	WIDTH M/S
1	1.4213	54.8859	20.9754	15.8488	4.8935
2	-.5516	49.2716	22.3789	8.8309	1.4730
3	-2.3693	40.3853	17.3375	4.9861	1.8151
4	-5.8489	45.8041	15.9824	11.7599	1.3977
5	-6.0156	50.7871	14.8849	17.8405	1.0275
6	-5.6346	47.1127	15.9015	13.1493	1.2472
7	-5.2704	47.6960	15.6406	13.9936	1.2321
8	-4.9424	46.6131	16.1308	12.4206	1.1627
9	-5.6409	39.9613	14.1256	7.7739	1.3944
10	-6.0717	37.2356	14.3251	4.8487	1.4548
11	-8.6202	39.4990	14.0272	7.4100	1.0775
12	-9.4143	38.9730	14.6850	6.2263	.9605
13	-7.8168	38.1478	15.1027	4.9834	1.1116
14	-6.5963	43.0716	14.8413	10.1685	1.1112
15	-7.3267	40.2745	14.4995	7.7132	1.1567
16	-6.0222	33.1189	14.8800	.1770	1.5202
17	-6.0960	36.8180	14.4863	4.2699	.7055
18	-6.6704	40.0887	14.2663	7.7605	1.1852
19	-7.3745	34.5731	14.1467	2.3646	1.7162
20	-10.4946	30.0539	14.1623	-2.1702	1.5289
21	-11.5843	28.9619	13.3643	-2.4641	1.1757
22	-12.7501	24.8886	14.3075	-7.4807	1.2767

```
HT# RECEIVER: 1 RANGE: LOW THRESH: 16.0 RESOL: 1.00

 1 IHDEEFIMOQRSRNJIIH<FIJLIIIKUYWZZZZWRMPLNMORSQMLJGKSRJJMQSPNLMLLK>
 2 KJGIEEFIKKJLLIGGFDCFHJLLIG<PUPWZVZUKKK>IJLNONLKJHHRRKGHLNLKLMNNMK
 3 CCCCB..BAA..BBACBBCC<CECDCCIQQOUPRJCEE>.BCCCFDEEB.DD.AABBA.CEFFEC
 4 .CD....B.......<ACEDDFEACCERZZUMIIHIGGBB>.CADC.BA.B.BA.ABB...CCB.
 5 ..B..................A..<BIWZZYOLKJKLH..A>..B......B...........A.
 6 B.....A.......CC.CBAB...<ACRZZWPNJWJJCBDCB>...BB.BC.ADB...ACCACBB
 7 .BB.B..........AA.A..ABD.<FUZZZTNMJIID>.CCA...B....BB..A.....CB..
 8 .BCABB.B.B.AA....AB....A<ADPXZYSLMIKGDB>CB........BBBAAABAA.A.B..
 9 .............B..........<.DOTTPLEHEDC....>......A.........A......
10 .............BB.....CB...<FLRRKEBDBDE.>A..A....BA..........A...A.
11 D...................C..<.IRUSNEE.B..>.......A.....CCB..........AD
12 ........B........A.....<DMSTQJCC>...BB........AB........AB.......
13 ...B......A...B..BC.A.<.BHNRRQJC>.ABDDB.....A.......A..AB....A...
14 ...ABA.............B.BA.<CMTXWQFBBCDDC..>.............A...AB.....
15 ......................<BDELTURMDAD.BC>......A...........B...A.B..
16 B..A........A...AA......<BFINLJDAEBB>.CB.........A.........AB..AB
17 .........................<.IRSKE>DBBB.......A..............BB....
18 .....................<...AHQUTLFCD.BDA>..........................
19 .......................<.EJNOKFBAF..B.>B..........................
20 .....................<BBEHJIHB.A>...AB...........................
21 ................B....<..FIIG....>..............................A.
22 ....A.......BA.......<.CEEEC...>..BAAA......A......A.............
   !--------------------------------!--------------------------------!
  -32                               0                               32
```

Figure IV.3.--Sample moment table (above) and coded spectral display.

```
SITE: FLEMING
DATE:  5  7 83
TIME: 12  0  0
NPRO:  11  NTDA:  419  NOSP:   8  PULW:   3.67  PRPR:  238.67
VMAXH:  58.147
FIRST HEIGHT (KM,AGL):   1.40
# OF HEIGHTS:  22
DELTA HEIGHT (KM):  .29
RFLC ANT:   1
HT#    WS     WD      HT     #E     #N    RFLC
 1     1.1  255.7    2.7     11     11    56.4
 2     1.2  232.0    3.0     11     11    49.7
 3     2.8  261.5    3.3     11     11    52.3
 4     2.8  285.0    3.6     11     11    53.6
 5     5.0  330.1    3.9     11     10    53.1
 6     9.7  347.3    4.2     11     11    54.0
 7    10.5  355.1    4.5     11     11    52.2
 8    10.7    4.2    4.8     11     11    50.2
 9    10.5    5.4    5.1     11     11    49.8
10    10.1  358.1    5.3     11     11    50.3
11     9.8  347.0    5.6     11     11    47.7
12     8.8  335.3    5.9     11     11    46.2
13     9.2  331.4    6.2     11     11    41.2
14     6.7  313.7    6.5     11     11    30.8
15     7.5  330.9    6.8     11     11    32.1
16     6.0  329.4    7.1     11     11    31.5
17     3.3  340.4    7.4     10     11    28.4
18     2.3   30.6    7.7      9     11    27.2
19     2.4     .8    8.0      8     10    21.8
20     4.0  315.5    8.2     11     11    32.2
21     6.6  321.4    8.5     11     11    34.9
22     7.0  319.6    8.8     11     11    31.9

SITE: FLEMING
DATE:  5  7 83
TIME: 12  1 33
NPRO:  11  NTDA:  124  NOSP:  16  PULW:   9.67  PRPR:  672.00
VMAXH:  69.782
FIRST HEIGHT (KM,AGL):   2.90
# OF HEIGHTS:   18
DELTA HEIGHT (KM):  .87
RFLC ANT:   1
HT#    WS     WD      HT     #E     #N    RFLC
 1    10.1  351.7    4.2     11     11    54.7
 2    10.2  357.9    5.1     11     11    53.5
 3     9.3  344.3    6.0     11     11    49.3
 4     7.5  333.6    6.8     11     11    39.3
 5     4.2  332.5    7.7     11     11    34.5
 6     6.9  324.6    8.6     11     11    38.2
 7    13.4  324.9    9.4     11     11    37.2
 8    20.6  320.7   10.3     11     10    35.8
 9    23.5  314.5   11.2     10      9    33.6
10    25.1  298.0   12.1     10      9    29.1
11    23.9  289.7   12.9      9     10    27.6
12    21.8  288.7   13.8     10     10    25.6
13    20.9  283.2   14.7     10      9    25.4
14    20.9  283.4   15.5      8     10    24.8
15    14.0  239.5   16.4      8      6    24.8
16    14.4  244.2   17.3      7      5    22.9
17  -999.0 -999.0   18.1      1      4  -999.0
18     8.9  227.7   19.0      5      5    19.4
```

Figure IV.4.--Wind profile.

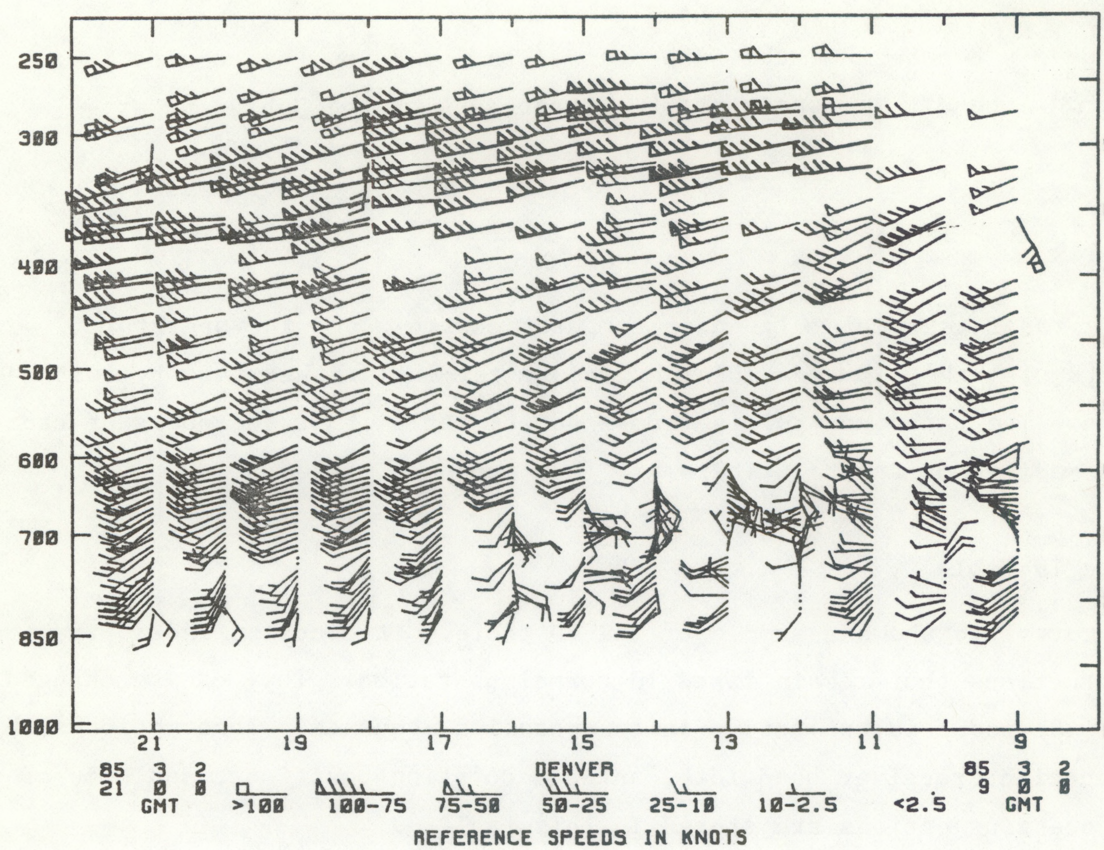


Figure IV.5.--Hub display of wind profiles. (Original is multicolor.)

I. Computer Subprocesses

Appendix B describes the subprocesses performed by the on-site computer. Appendix C describes the subprocesses of the Hub computer.

2. Radar Control

The radar is completely under computer control, and the operator interacts with the radar by local or remote terminal rather than by switches or dials. The radar control is from a set of tables that the operator can select, modify, or create. There are four types of tables:

A. The ID Table

Figure IV.6 shows a sample of the ID table. It contains radar parameters or instructions that remain fixed in normal operation. They can be changed only if the radar is not active in an operating sequence. Information such as site location, receiver bandwidth, antenna pointing positions, and some of the data processing options are stored in this table.

B. The Scan Tables

Figure IV.7 shows a Scan table. The Scan table sets the particular parameters desired for radar operation. They include radar pulse repetition period (PRPR), pulse width (PULW), delay to the first sample (DLAY), spacing between samples (SPAC), the number of time domain averages (NTDA), the number of spectra averaged (NOSP), the number of ranges sampled (NSMP), the antenna pointing position, receiver bandwidth, and a number of test or special commands. These tables (as many as 10) are called from disk files or are created in the radar control program. They can be changed whenever they are not actually being used to control the radar.

```
PRG REV:   1.43  LOC: DENVER         FREQ: 915.0 MHZ  ANT BMWT:  2.3 DEG
INT REV:   1.00  LAT: 39.77 DEG-N    WVLN:   .327 M   ANT EFCY: 53.0 %
FFT VER: PVILL   LNG:104.88 DEG-W    PKPW:    5.6 KW  ANT AREA:   100. M*M
FFT MOM: PVILL   ELV:1611.0 M-MSL    RCON:   3.14     REJ MTHD: RSC

RCVR MODE/BNDWTH(MHZ): 1/1.000  2/ .333  3/ .111

(1) OP: DAM                        (2) STARTED: 12 18 84
(3) # OF ANT POS: 3                (4) # OF RCVRS: 1

#1 AZ:    .0, EL: 90.0
#2 AZ:  90.0, EL: 75.0
#3 AZ:    .0, EL: 75.0

(5) DC FILTERED:   Y (6) DATA WINDOWED:  Y  (7) # Z-SUP PNTS:+/-  0
(8) CORRECT W/ZEN: Y (9) REJECT SPECTRA: N (10) PWR REJ THRS:     .0

(11) # PNTS AT Z-FREQ TO ZERO:+/-  0       (12) # PNTS FOR FFT:     64
(13) RSC MIN SUBSET HORIZONTAL:    4       (14) RSC MAX DIF(H):    2.0
(15) RSC MIN SUBSET ZENITH:        5       (16) RSC MAX DIF(Z):    2.0
(17) RSC MIN SUBSET ZEN IF COR:    6       (18) RSC MAX DIF(ZC):   2.0

(19) ANTENNA FOR POWER: EW

>
```

Figure IV.6.--Example of ID table.

```
(1) IN: 2-CHAN A/D  (2) AVRGD  (3) LCU DISABL (4) OUT: BOTH  (5) PHAS: OFF
(6) STANDARD PULSE  (7) RF ON  (8) ANT EAST   (9) RCVR LOW

PRPR:   50.00   PULW:    1.00   DLAY:    5.00   SPAC:     .67   (MICRO-SECS)
NTDA:  124      NOSP:   10      NSMP(NORG):   24
```

Figure IV.7.--Example of Scan table.

```
SEQUENCE: STAP

  1: HPS L    1  8
  2: SCAN (TBL)  1
  3: SCAN (TBL)  2
  4: SCAN (TBL)  3
  5: LOOP (TO)  2  4 TIMES
  6: SCAN (TBL)  4
  7: SCAN (TBL)  5
  8: SCAN (TBL)  6
  9: LOOP (TO)  6  4 TIMES
 10: SCAN (TBL)  7
 11: SCAN (TBL)  8
 12: SCAN (TBL)  9
 13: LOOP (TO) 10  4 TIMES
 14: LOOP (TO)  2  3 TIMES
 15: CALC WINDS
 16: START STAP   NEXT 60
```

Figure IV.8.--Example of Sequence table.

```
RADAR:          ACTIVE
SEQUENCE:       STAP
INSTRUCTION:      3
SCAN TBL #:       2
FFT  LNTH:       64
NOSP LOOP:       12
NPRO LOOP:        4
HPS MODES:        L
    GATES:      1  8
DISPLAY REQ:    NONE
ARCHIVE REQ:    NONE
ERROR LOGGING: YES

>
```

Figure IV.9.--Example of Status table.

C. The Sequence Table

This table (Fig. IV.8) is the program the operator creates (or calls from disk) that controls the sequence of operations that the radar performs. The radar starts on the hour (in normal operation) and observes the radial wind from a series of antenna pointing positions (SCANs). After a specified number of profiles (LOOP), the winds are calculated and the sequence starts on the next hour. In the example, the first instruction specifies that half-plane subtraction is to be used in the data processing for the first eight heights when the radar is using a receiver bandwidth for the "LOW" mode, or 1-μs pulse width mode. Scan tables 1-9 are used 12 times before the winds are calculated.

D. The Status Table

Because the radar sequence takes nearly an hour before the winds are calculated, there is a Status table (Fig. IV.9) that enables the operator to monitor what the radar is doing at any given time. The Status table also allows the operator to ask for certain displays, save data on disk, and examine errors that may have occurred (power fails, antenna switch fail, etc.) during operation.

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Appendix A: Bibliography of Publications Relating to WPL Wind Profilers, 1980-1984, in Chronological Order

Wave Propagation Laboratory Publications

1. Hogg, D.C., F.O. Guiraud, C.G. Little, R.G. Strauch, M.T. Decker and E.R. Westwater (1980): Design of a ground-based remote sensing system using radio wavelengths to profile lower atmospheric winds, temperature, and humidity. In Remote Sensing of Atmospheres and Oceans, Academic Press, 313-364.

2. Strauch, R.G., M.T. Decker, D.C. Hogg, C.G. Little and R.F. Bunting (1981): The ERL Profiler and aviation meteorology. Proc., 1st International Conf. on Aviation Weather Systems, Montreal, P.Q., Canada, May 4-6, 1981. American Meteorological Society, 153-156.

3. Strauch, R.G. (1981): Radar measurement of tropospheric wind profiles. Prepr., 20th Conf. on Radar Meteorology, November 30 - December 3, 1981, Boston, Mass. American Meteorological Society, 430-434.

4. Decker, M.T., R.G. Strauch and E.R. Westwater (1982): Ground-based remote sensing of atmospheric temperature, water vapor, and wind. Proc., 1982 International Geoscience and Remote Sensing Symp., (IGARSS '82) Munich, FRG., June 1-4, 1982. IEEE (Catalog No. 82CH14723-6), sec. WA-6, 1.1-1.5.

5. Earnshaw, K.B., D.C. Hogg and R.G. Strauch (1982): A triple-beam antenna for wind profiling radar. NOAA Tech. Memo. ERL WPL-108, 23 pp.

6. Strauch, R.G., M.T. Decker and D.C. Hogg (1983): Automated profiling of the troposphere. J. Aircraft, 20(4): 359-362.

7. Hogg, D.C., M.T. Decker, F.O. Guiraud, K.B. Earnshaw, D.A. Merritt, K.P. Moran, W.B. Sweezy, R.G. Strauch, E.R. Westwater and C.G. Little (1983): An automatic profiler of the temperature, wind and humidity in the troposphere. J. Appl. Meteorol., 22(5): 807-831.

8. Strauch, R.G. (1983): Techniques for measurement of horizontal and vertical velocities: optimum pointing angle. URSI/SCOSTEP Workshop on Technical Aspects of MST Radars, May 23-27, 1983, Urbana, Ill.,* 232-234.

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* Middle Atmosphere Program; Handbook for MAP, vol. 9. Available from SCOSTEP Secretariat, University of Illinois, 1406 W. Green St., Urbana, IL 61801.

9. Strauch, R.G. (1983): Capabilities and limitations of existing MST radars: Colorado wind profilers. URSI/SCOSTEP Workshop on Technical Aspects of MST Radars, May 23-27, 1983, Urbana, Ill.,* 325-329.

10 Strauch, R.G. (1983): Data analysis techniques: spectral processing. URSI/SCOSTEP Workshop on Technical Aspects of MST Radars, May 23-27, 1983, Urbana, Ill.,* 528-531.

11. Strauch, R.G., D.A. Merritt, K.P. Moran, K.B. Earnshaw and D.W. van de Kamp (1983): Tropospheric wind profiling with Doppler radar. Prepr., 21st Conf. on Radar Meteorology, September 19-23, 1983, Edmonton, Alberta, Canada. American Meteorological Society, 118-125.

12. Strauch, R.G., D.A. Merritt, K.P. Moran, K.B. Earnshaw and D.W. van de Kamp (1984): The Colorado wind-profiling network. J. Atmos. and Oceanic Tech., 1(1): 37-49.

13. Strauch, R.G. (1984): Progress and plans for the Colorado Wind Profiler Network. 2nd URSI/SCOSTEP Workshop on Technical Aspects of MST Radars, May 21-25, 1984, Urbana, Ill. (in press).

14. Strauch, R.G. (1984): Elimination of range-aliased echoes in VHF radars. 2nd URSI/SCOSTEP Workshop on Technical Aspects of MST Radars, May 21-25, 1984, Urbana, Ill. (in press).

15. Strauch, R.G., K.B. Earnshaw, D.A. Merritt, K.P. Moran and D.W. van de Kamp (1984): Performance of the Colorado wind-profiling network. 2nd URSI/SCOSTEP Workshop on Technical Aspects of MST Radars, May 21-25, 1984, Urbana, Ill. (in press).

16. Merritt, D.A. (1984): Data base for the Colorado profiling network. 2nd URSI/SCOSTEP Workshop on Technical Aspects of MST Radars, May 21-25, 1984, Urbana, Ill. (in press).

17. Strauch, R.G., K.B. Earnshaw, D.A Merritt, K.P. Moran and D.W. van de Kamp (1984): The Colorado wind-profiling network: a summary of performance. Prepr., 22nd Conf. on Radar Meteorology, September 10-13, 1984, Zurich, Switzerland. American Meteorological Society, 439-444.

18. Moran, K.P. (1984): A digital controller for the Wave Propagation Laboratory's VHF and UHF wind-profiling radars. NOAA Tech. Memo. ERL WPL-119, 110 pp.

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* Middle Atmosphere Program: Handbook for MAP, vol. 9. Available from SCOSTEP Secretariat, University of Illinois, 1406 W. Green St., Urbana, IL 61801.

19. Chadwich [sic], R.B., A.S. Frisch and R.G. Strauch (1984): A feasibility study on the use of wind profilers to support space shuttle launches. NASA Contractor Report 3861, 109 pp.

20. Gossard, E.E., W.D. Neff, R.J. Zamora and J.E. Gaynor (1984): Finestructure of atmospheric refractive layers and implications for over-the-horizon propagation and radar sounding systems. Prepr., 22nd Conf. on Radar Meteorology, September 10-13, Zurich, Switzerland. American Meteorological Society, 461-469.

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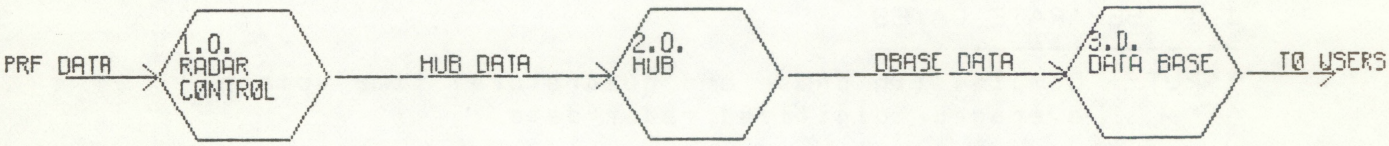
1. Fischler, M.A., and R.C. Bolles (1981): Random sample consensus: A paradigm for model fitting with applications to image analysis and automated cartography. Commun. Assoc. Comput. Mach., 24(6): 381-395.

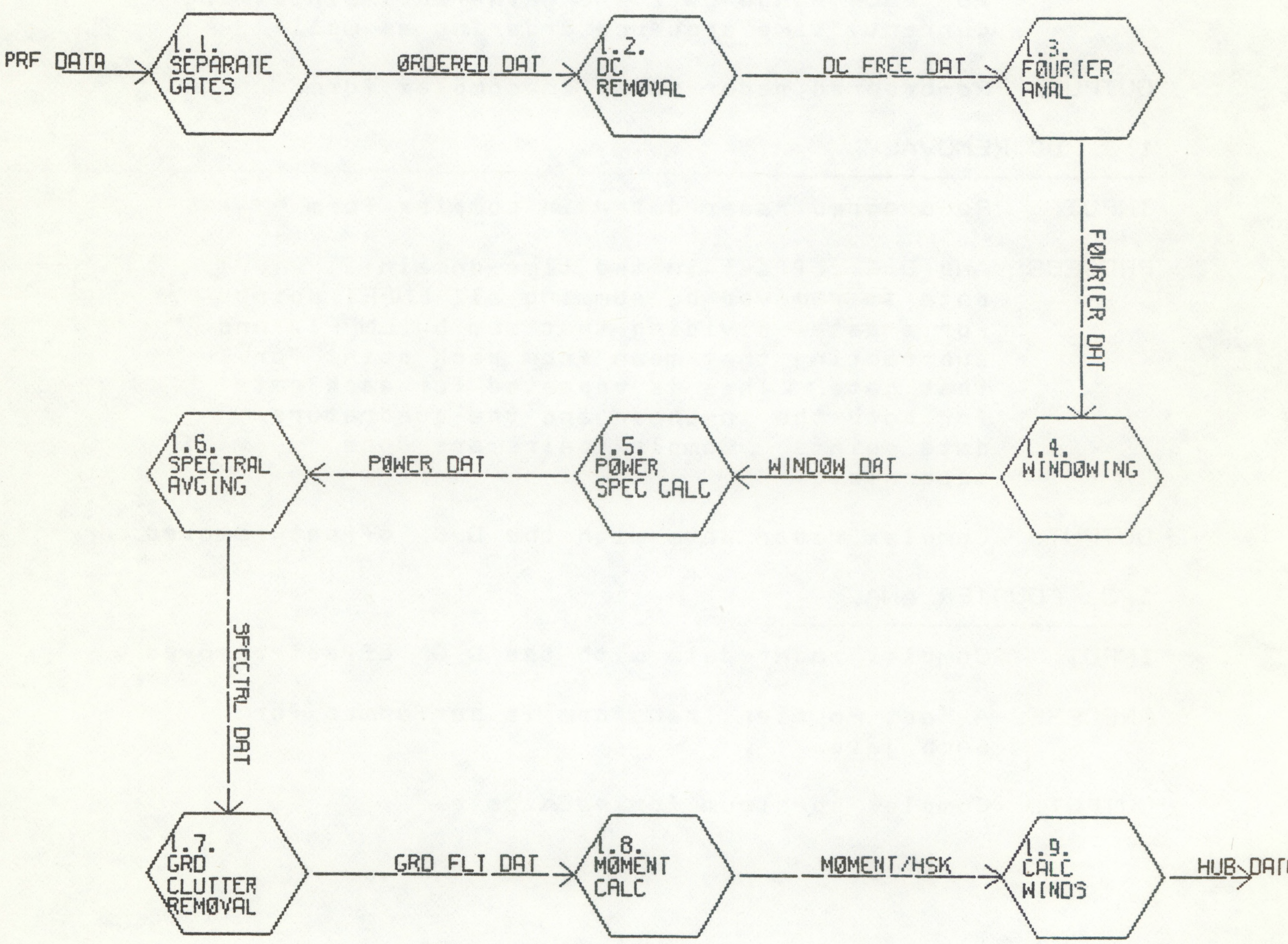
2. Ecklund, W.L. (1984): TR switch design. Middle Atmosphere Program; Handbook for MAP, URSI/SCOSTEP Workshop on Technical Aspects of MST radars, May 23-27, 1983, Urbana, Ill. (Available from SCOSTEP Secretariat, U. of Illinois, 1406 W. Green St., Urbana, Ill. 61801) 431-432.

Appendix B: Subprocesses of the On-Site Computer

S-120 SUBPRØCESSES



RADAR CØNTRØL



1.0. RADAR CONTROL

INPUT: Time domain averaged, digitized radar data.

.

PROCESS: Calculate moments: 0, 1, 2; and winds.

.

OUTPUT: Wind and supporting data.

1.1. SEPARATE GATES

INPUT: Complex (in phase and quadrature) time domain averaged, digitized radar data.

.

PROCESS: When the data points are recieved from the radar controller/preprocessor, they are in an order which is convenient to the sampling and time-domain integration sequence. This is not an appropriate order for subsequent processing. Re-ordering indices results in a gate-by-gate, FFT-point by FFT-point order. That is, all "length-of FFT" (LNFFT) points for each range gate are gathered (maintaining current "time"sequence ordering as well).

.

OUTPUT: Re-ordered radar data, in complex form.

1.2. DC REMOVAL

INPUT: Re-ordered radar data, in complex form.

.

PROCESS: Any D.C. offset in the time-domain data is removed by summing all LNFFT points for a gate, dividing that sum by LNFFT, and subtracting that mean from each point for that gate. This is repeated for each gate for both the in-phase and the quadrature data points. Complex pairs are done seperately.

.

OUTPUT: Complex radar data with the D.C. offset removed.

1.3. FOURIER ANAL

INPUT: Complex radar data with the D.C. offset removed.

.

PROCESS: A Fast Fourier Transform is performed for each gate.

.

OUTPUT: Complex spectrum for each gate.

1.4. WINDOWING

INPUT: Complex spectrum for each gate.

PROCESS: A Hann (cosine squared) window function in the frequency domain is performed for each gate. The windowed value of the kth Fourier transform point is given by: 1/2 [F (k) - 1/2 [F (k - 1) + F (k + 1)]] where F (k) is the unwindowed value at point k. This function basically reduces side lobes in the velocity spectrum. Complex pairs done seperately.

OUTPUT: Windowed data with side lobe reduction, complex pairs.

1.5. POWER SPEC CALC

INPUT: Windowed data with side lobe reduction, complex pairs.

PROCESS: The power spectrum is the sum of the squares of the in-phase and quadrature FFT values for each point. The resulting array is also "rotated" so that zero frequency is at the center of the array of LNFFT points instead of at the first element of the array. This is done for each gate.

OUTPUT: Power spectra, real.

1.6. SPECTRAL AVGING

INPUT: Power spectra, real.

PROCESS: The nodes 1.1 through 1.5 are cycled sequentially for "number of spectra" (NSPCT) times. These NSPCT spectra (for each gate) are averaged. At this point we have a single, average spectrum for each gate.

OUTPUT: Averaged power spectra.

1.7. GRD CLUTTER REMOVAL

INPUT: Averaged power spectra.

.

PROCESS: Removes the zero frequency ground clutter.
The three methods available are:

1. half-plane subtraction
2. zero frequency supression
3. zeroing out points centered about zero frequency

Used is methods 1, 2 or 3 or method 1 with method 2 or 3.

.

OUTPUT: Averaged power spectra with ground clutter removed.

1.8. MOMENT CALC

INPUT: Averaged power spectra after ground clutter removed.

.

PROCESS:

```
                                       W
                                   !-------!
                         !          /\
                         !         /  \/\
                         !         !     \/!
                         ! mean Vr !       !
                         !---------!-->!   !
         ^               !         !   S   !
  /\    / \             ^!         !       \    ^
-/ -\ -/ - \- -    /\ -/ \- /\  - / -  -  - \- /-\ -  - /- mean
/    \/     \/\   / \/   !\/  \  /           \/   \/\  /   noise
               \/        !     \/                    \/
                         !            N
---------------------------------------------------------
- v                      O                            + v
```

.

where:
S is the signal power
mean Vr is the mean radial velocity
W is the spectral width
S/N is the signal-to-noise ratio

.

We use the Hildebrand and Sekhon method described in the paper "Objective Determination of the Noise Level in Doppler Spectra", published in the Journal of Applied Meteorology, Oct, 1974 to find the mean noise level. Next we locate the peak of the Doppler spectrum and include as the "signal" all those contiguous points that exceed the mean noise. The 0, 1 and 2 moments are calculated on this signal. The signal-to-noise ratio is found by:

S - mean noise - 10 log LNFFT

where S and mean noise are in dB. Note: that this is actually a redundant quantity, as it uses mean noise instead of a calculated true noise power, N.

OUTPUT: 0, 1 and 2 moments. In other words, signal power, velocity and spectral width.

1.9. CALC WINDS

INPUT: 0, 1 and 2 moments.

PROCESS: With the appropriate number of moment data in time, calculate winds from the appropriate vector components that have been through the random sample consensus averaging.

OUTPUT: Wind and supporting data.

2.0. HUB

INPUT: Profiler data.

PROCESS: Gather data from all Profiler sites.

OUTPUT: Profiler data to be stored in the data base.

3.0. DATA BASE

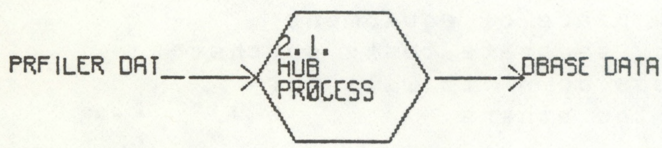
INPUT: Profiler data to be stored in the data base.

PROCESS: Store the Profiler data.

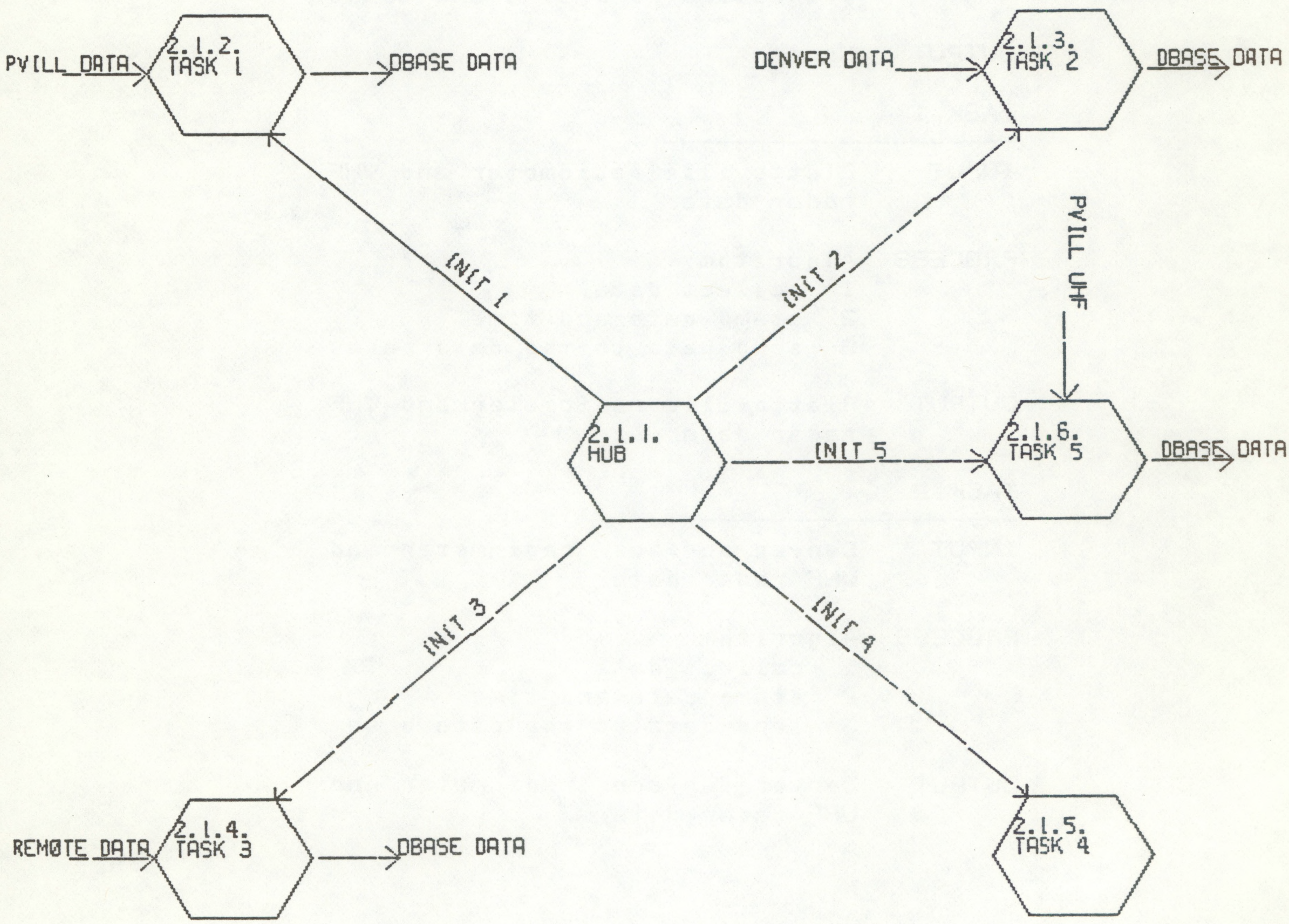
OUTPUT: Profiler data to the users.

Appendix C: Subprocesses of the Hub Computer

S-250 HUB PRØCESS



HUB PRØCESS



HUB PROCESS

INPUT Profiler data.

PROCESS Gathers data (wind speed, direction, height, etc.) from all Profiler data system equipment and sends them to the data base via an I.P.C. (interprocess communication). The data from each piece of equipment are gathered by separate tasks so that if any unit goes down, it will not affect any of the others.

OUTPUT Profiler data.

HUB

INPUT None.

PROCESS Initialzes the process identification, priorities, I.P.C.'s and tasks.

OUTPUT None.

TASK 1

INPUT Platteville radiometer and VHF radar data.

PROCESS Algorithm:
1. collect data
2. stamp date and time
3. send data to the data base

OUTPUT Platteville radiometer and VHF radar data.

TASK 2

INPUT Denver surface, radiometer and UHF radar data.

PROCESS Algorithm:
1. collect data
2. stamp date and time
3. send data to the data base

OUTPUT Denver surface, radiometer and UHF radar data.

TASK 3

INPUT Remote radiometer and VHF radar data.

PROCESS Algorithm:
1. dial site
2. collect data
3. stamp date and time
4. send data to the data base

OUTPUT Remote radiometer and VHF radar data.

TASK 4

INPUT IPC message.

PROCESS This is the SERVER process. Attempts to execute the request and LOOPS.

OUTPUT None.

TASK 5

INPUT Platteville UHF radar data.

PROCESS Algorithm:
1. dial Platteville UHF radar site
2. collect data
3. stamp date and time
4. send data to the data base

OUTPUT Platteville UHF radar data.