7.1.2 BEAM STEERING SYSTEM

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This paper describes a simple technique for steering the beam of a multimodule phased-array MST radar antenna. The Urbana radar antenna consists of six modules, each having 14 elements in the northwest direction and 12 elements in the northeast direction. The antenna is constructed on a ground plane tilted 1.61 deg from horizontal in the southeasterly direction. This has made it possible to measure horizontal velocity in the southeasterly direction by averaging the line-of-sight velocity over a 1-hr period to minimize gravity-wave contamination.

It is clearly desirable to be able to point the antenna in multiple directions, so as to derive all components of the horizontal velocity. This has been done on an experimental basis by adding parallel-wire line to the feed for the southwest module pair, and subtracting it from the northeast pair, thereby achieving a southward tilt of the antenna, and conversely to achieve a northeast tilt.

The calculated E-plane (i.e., northwest) patterns of Figure 1 show the extent of beam degradation for slewing angles of up to 4 deg. The beam can be steered 2 deg or perhaps 3 deg without serious degradation of the pattern (remembering that the sidelobes are reduced by an equal factor during transmitting and receiving). The scheme shown in Figure 2 was therefore devised. The incoming power is connected to a rotor with two silver-plated copper brushes in contact with a stator consisting of two semicircular silver-plated copper strips, spaced so as to match the antenna impedance. The northeast and southwest module pairs are connected to the ends of the stator, while the center module pair is connected to the rotor.

With the rotor in the central position, all three module pairs are fed in phase. If the rotor is turned to one side, the phase of the energy for one end module pair is increased, and for the other is decreased, thereby steering the antenna beam away from the broadside direction. The rotor is motor-driven, and the stopping points are located by microswitches running on a cam.

It is proved possible to steer the beam through most of the available range without adversely affecting the VSWR seen from the transmitter. No problems have arisen from burning of the contacts. The entire assembly is surrounded by a water-proof plastic enclosure.

Calibrating the antenna direction can be accomplished by observing radio sources, though there are an inadequate number to cover all directions. An easier way is to measure the direction and magnitude of stratospheric winds with the radar, and compare the results with radiosonde observations. When this was done for the broadside direction of the Urbana antenna, a zenith angle of 1.13 deg was found rather than the theoretical value of 1.61 deg based on land surveys and phase measurements. We believe that the discrepancy arises from aspect sensitivity of the stratospheric echoes.

For various assumed values of the aspect sensitivity in dB/deg, and the calculated antenna pattern, it is possible to calculate the effective pointing angle of the antenna, defined as that angle which would give an identical location for the centroid of the power spectrum if aspect sensitivity were absent. The results for the Urbana antenna are shown in Table 1. The apparent

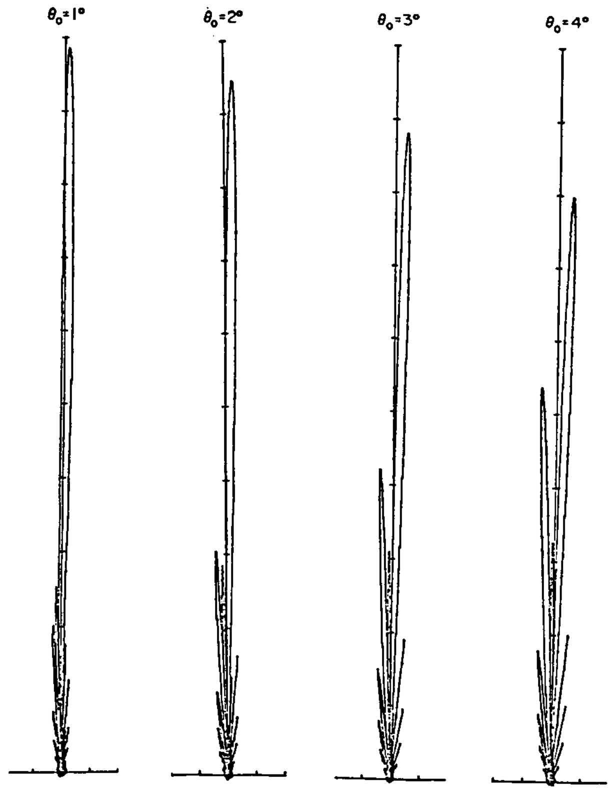

Figure 1. E-plane field strength plots for various pointing directions of the antenna.

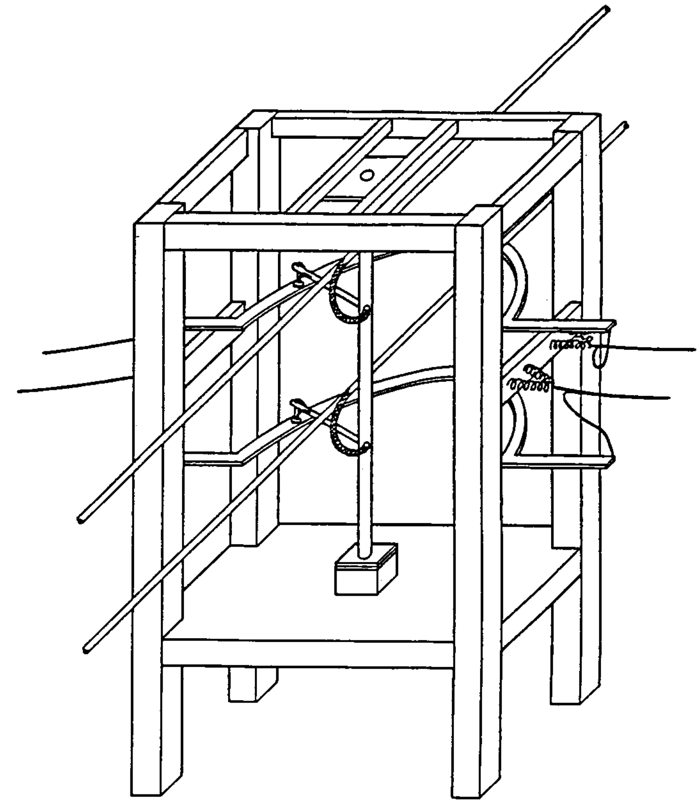

Figure 2. Sketch of the phasing device for the Urbana MST radar antenna.

Table 1

Aspect Sensitivity dB/deg	Apparent zenith angle deg
0	1.610
0.2	1.534
0.4	1.461
0.6	1.391
0.8	1.323
1.0	1.258
1.2	1.196
1.4	1.137
1.6	1.081
1.8	1.027
2.0	0.976
2.2	0.928
2.4	0.882
2.6	0.838
2.8	0.797
3.0	0.758

pointing angle of 1.13 deg corresponds to an aspect sensitivity of about 1.4 dB/deg, in agreement with measurements using steerable antennas. This calibration procedure was repeated for 2 off-axis pointing directions, and the results are shown in Figure 3. The spread of the points is primarily due to geographic separation of the radiosonde station, Peoria, from the Urbana radar.

Using averaged apparent steering directions, eastward and northward winds were calculated for special radar runs simultaneous with 14 balloon launches at Peoria and results are presented in Table 2. Overall, agreement is quite good, with the differences perhaps due to spatial separation between the sites.

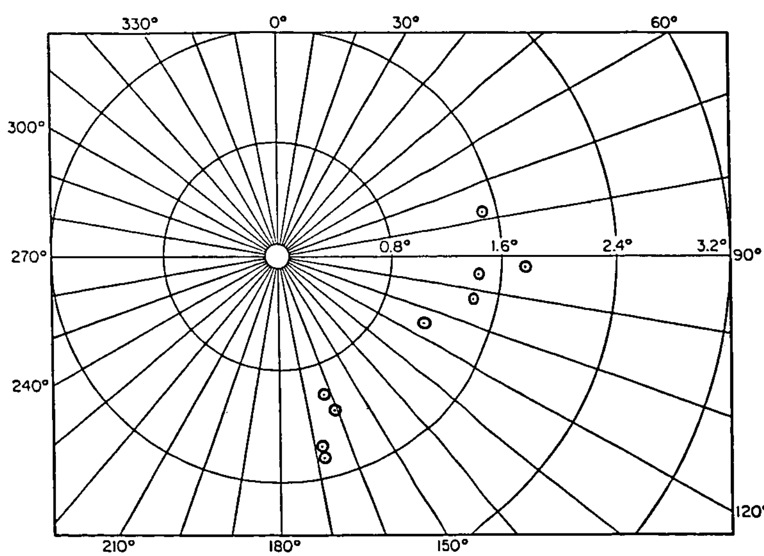

Figure 3. Derived pointing directions for the Urbana array.

Table 2

Derived wind components at Urbana
using two antenna pointing directions.
Theta1 = 18.63 Phi1= 1.3580
Theta2 = 72.96 Phi2= 1.2084

12 KM		13.5 KM		15 KM		16.5 KM		18 KM	
URBANA	RAWIN	URBANA	RAWIN	URBANA	RAWIN	URBANA	RAWIN	URBANA	RAWIN
-.5873	-1.446	1.5808	1.0404	2.8033	1.4338	2.3258	3.3039	2.3131	.15253
11.125	17.339	13.539	19.462	14.356	14.519	12.766	12.593	10.103	8.7386
5.5465	2.5889	3.5606	.53753	2.8057	-.5222	2.1243	-.2309	3.8776	3.9760
24.164	22.038	21.892	21.383	18.765	17.092	14.875	12.847	9.9010	6.6173
-2.198	2.8252	-2.257	-.1694	.08998	-3.100	-.9411	-.3125	-1.154	-2.915
19.799	17.837	18.216	16.459	14.176	13.231	9.5989	9.2747	5.4083	4.8515
5.7387	5.4837	4.2904	-.4858	3.9420	-.2071	3.8307	-1.925	1.4106	-1.619
31.344	37.774	27.477	15.632	22.764	10.407	17.886	10.199	11.754	7.0154
15.674	17.164	12.025	2.0885	8.2250	2.1394	3.4321	1.7042	1.4943	-.1256
15.383	18.790	15.417	14.126	13.891	10.065	7.9296	8.5212	7.4322	3.5978
4.2922	4.3600	1.9227	-2.027	-.1922	-.4517	-1.961	-.0696	-2.951	-3.140
19.845	17.474	17.599	14.317	13.369	9.7595	9.4240	9.7397	7.3270	7.0525
-2.397	-.0249	-1.770	.99704	-2.905	-2.734	-4.350	-2.185	-3.555	-2.491
6.8860	8.4099	9.1101	11.948	9.6625	11.365	7.8260	8.9984	5.2935	4.4955
-3.817	-6.986	-4.930	-7.927	-6.513	-4.134	-4.205	-3.159	-2.846	-4.901
1.3133	1.3707	2.2294	5.4140	2.4217	6.1854	3.2352	4.6962	2.5401	2.83
-8.342	-11.82	-7.964	-11.41	-5.263	-6.792	-3.824	-5.471	-2.110	-2.613
1.0480	2.1902	1.9593	5.6119	4.3792	5.5951	4.7528	5.9317	5.7361	6.1581
-12.10	-11.10	-12.09	-9.506	-9.781	-7.917	-7.884	-6.163	-4.251	-3.703
-1.076	-2.895	.45044	7.2896	3.7955	7.4039	4.8583	6.6538	3.2644	1.8060
-11.49	-12.62	-11.89	-8.592	-10.02	-5.854	-7.837	-2.884	-4.609	-6.105
4.8336	9.0953	4.7323	10.229	5.1024	9.8518	4.2017	7.1716	5.3166	3.8154
-7.397	-14.67	-9.865	-8.368	-10.04	-5.991	-4.389	-6.240	-5.249	-4.971
7.4801	4.2345	8.1176	11.085	6.2928	10.673	5.2882	4.3031	3.4041	4.4764
-22.60	-15.88	-20.50	-10.44	-8.912	-1.524	-.5903	-1.152	-3.218	-5.137
28.369	23.326	24.408	19.578	20.483	14.168	16.244	14.714	9.1429	7.0708
-2.867	2.0799	-1.886	-4.536	.16551	-.9604	-1.210	-6.753	-1.443	-.3137
27.989	39.555	32.225	24.645	26.251	26.192	20.176	16.631	13.200	3.5863