NATIONAL RADIO ASTRONOMY OBSERVATORY
GREEN BANK, WEST VIRGINIA

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Title: **ARRAY FEED RECEIVER STATUS**

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General

The Array Feed Receiver is designed to increase the effective hour angle tracking range of the 300-foot antenna and minimize the scan loss when compared with a single feed receiver. It provides frequency coverage over the 400-500 MHz band with instantaneous bandwidths of 5 to 10 MHz. A 2 x 8 array of feeds as shown in Figure 1 will be used. The antenna efficiency and sidelobe levels when fed with a 2 x 8 array are improved over those obtained with a 4 x 4 or 1 x 8 array feed configurations.

Array Power and Phase Patterns

The computed 2 x 8 array power and phase patterns for 0.0 feet offset from focus are shown in Figures 2 and 3 for two planes 90 degrees apart. Figure 2 shows the pattern (ϕ = 90) in a plane thru the long dimension of the array. The power pattern shows a null at about 62 degrees which is at the edge of the reflector. With the array offset 15 feet the computed power and phase patterns in the ϕ = 90 plane are illustrated in Figure 4.

Scanned Antenna Patterns

The antenna beam patterns for the 300-foot antenna illuminated with the 2 x 8 array feed have also been calculated. These patterns do not include effects of feed or feed support blockage. Figures 5, 6 and 7 show the beam patterns with the array feed offset 0.0, 5.0, 10.0, 15.0, 20.0, and 23.0 feet. The antenna gain, efficiency, 3 dB beamwidth, and maximum relative sidelobe levels are tabulated below.

Offset (feet)	Gmax at Theta (dB) (deg)	Efficiency	3dB BW (deg)	Sidelobe (dB) (deg)
0.0	50.7 at -0.0	.64	0.48	-22.2 at ± 0.75
5.0	50.5 at -1.90	.61	0.48	-24.4 at -3.05
10.0	49.3 at -3.80	.44	0.53	-28.2 at -3.05
15.0	47.4 at -5.75	.30	0.62	-15.3 at -3.65
20.0	46.4 at -7.80	.24	0.80	-17.2 at -6.15
23.0	45.6 at -9.15	.20	0.80	-10.5 at -7.05

The computed maximum gain decreases more rapidly than expected. It is possible that the method used to calculate the beam phase shifts does not result in the maximum obtainable gain. The procedure used is to first calculate the coordinates Yap and Xap of each of the 16 array beam centers on the aperture plane. The aperture plane, in this case, is defined as a plane located between the antenna focus and vertex and passing thru the rim of the reflector. The path length from the center of the array feed to the reflector surface and back to the aperture plane is then calculated. From this path length a constant equal to the on axis focal length plus the dish depth is subtracted leaving the path error. The beam phase shifts are then calculated using the relationship:

$$\text{Beam Phase} = (2\pi/\lambda)*((\text{patherror} - \text{Yap})*\sin\theta_b))$$

where θ_b = BDF*arctan (offset/focal length) and BDF is the Beam Deviation Factor which is fixed at .85 based on measurements made with a single feed. λ is the wavelength and Yap is the aperture Y coordinate of the particular array beam center that is being phased.

The above procedure is based on the idea that the beam centers located on the aperture plane are equivalent to elements of an array. The phasing of each element is such as to maximize the array gain in the θ_b direction.

Array Feed Receiver Block Diagram

The block diagram of one channel of the receiver is shown in Figure 8. The signals from each pair of dipoles are combined and amplified using hybrids followed by low noise amplifiers. The amplifier outputs are fed to the Butler Matrix. The Butler Matrix combines the dipole pair signals with proper phasing to produce outputs corresponding to eight orthogonal array beams. The voltage controlled phase shifters provide independent control of the array beam phases. The eight phase shifted beam signals are summed, amplified and sent to the control room. As noted on Figure 8, Array Feed Receiver Block Diagram, a duplicate set of components is needed to receive the orthogonal polarization.

Voltage Controlled Phase Shifters

A voltage controlled phase shifter has been developed that varies the phase thru 340 degrees over the 400 to 500 MHz band. The tuning voltage ranges from 0 to 25 volts with the maximum change in phase per volt of 14 degrees. An eight bit D-A converter would be needed to step the phase in less than two degree increments.

Controlling the Phase Shifters

As the array feed receiver is moved along the traveling feed track, the phase of the 16 phase shifters, eight for each polarization, must be changed to maximize the antenna gain. To determine the control data rate, the rapidity and range of the phase changes needs to be considered. Calculations of the phase difference for offsets of 15.0 and 15.1 feet and 22.9 and 23.0 feet show the greatest change is near the end of the tracking range with the maximum being 2.3 degrees phase difference for 0.1 feet offset change. This offset moves the antenna beam thru 2.3 minutes of angle and corresponds to 9.2 seconds of tracking time. Thus to track a source, the maximum rate at which the phase shifters must be set is once every 5 seconds or whenever the required phase is 1 bit different from the previous commanded phase. The data rates needed to control the phase shifters while tracking a source are slow, but the rates required to determine the phase shifter settings initially are much faster. One method which may be used to determine the optimum phase shifter setting for each 0.1 foot incremental position along the traveling feed track is to observe a strong source and rapidly step each of the eight phase shifters to obtain maximum gain for each of the two polarization channels. If we can use 0.1 second integration time to measure the antenna gain and can determine the required phase shifter setting from five different points, then optimizing each phase shifter would require 0.5 seconds. The whole array would take four seconds assuming both polarization channels could be done simultaneously. If the first 10 milliseconds of each 0.1 second integration is used to transmit one of the phase shifter positions the bit rate would be 8 bits * 2 polarizations / .01 seconds = 1600 bits per second. Actually several more bits would have to be sent to identify the phase shifter and perhaps check parity or provide synchronization.

Remaining Tasks

1. Increase the bandwidth of the low noise amplifier input matching network - construct and test amplifiers.

2. Layout Butler Matrix printed circuit board and fabricate.

3. Construct and test array feed elements.

4. Design receiver box in two sections to minimize transport and installation difficulties.

5. Construct and test phase shifters.

6. Define,design, and construct control computer - phase shifter interface and data link.

Schedule

Task 6 will have to be done by the digital group. Task 4 will require a mechanical designer for three or four weeks. The machine shop will be constructing most of the parts of the receiver. Their workload and the priority of various projects will control when the parts can be finished. The receiver should be completed during the first quarter of 1988 if the required people are available.

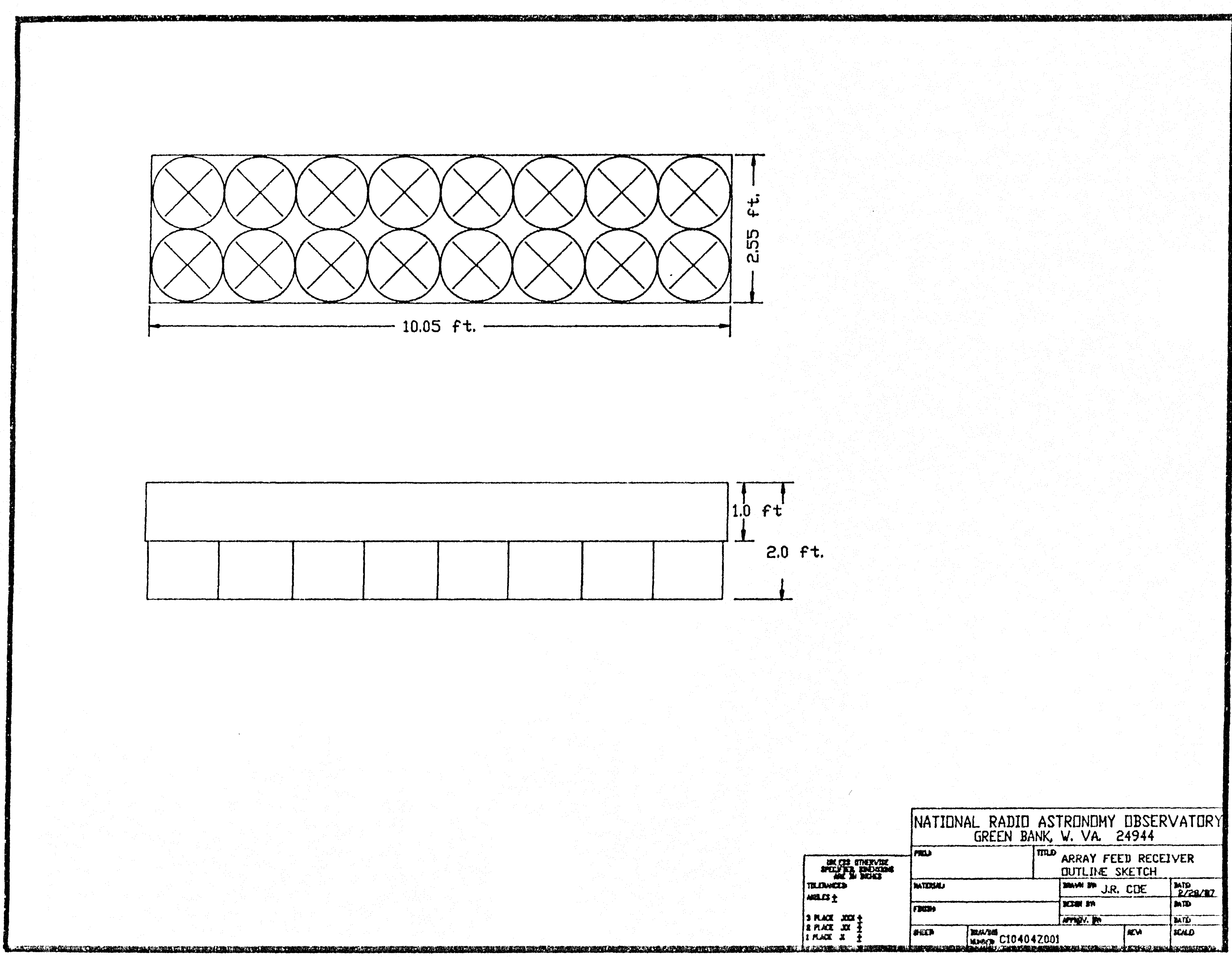


FIGURE 1. ARRAY FEED RECEIVER OUTLINE

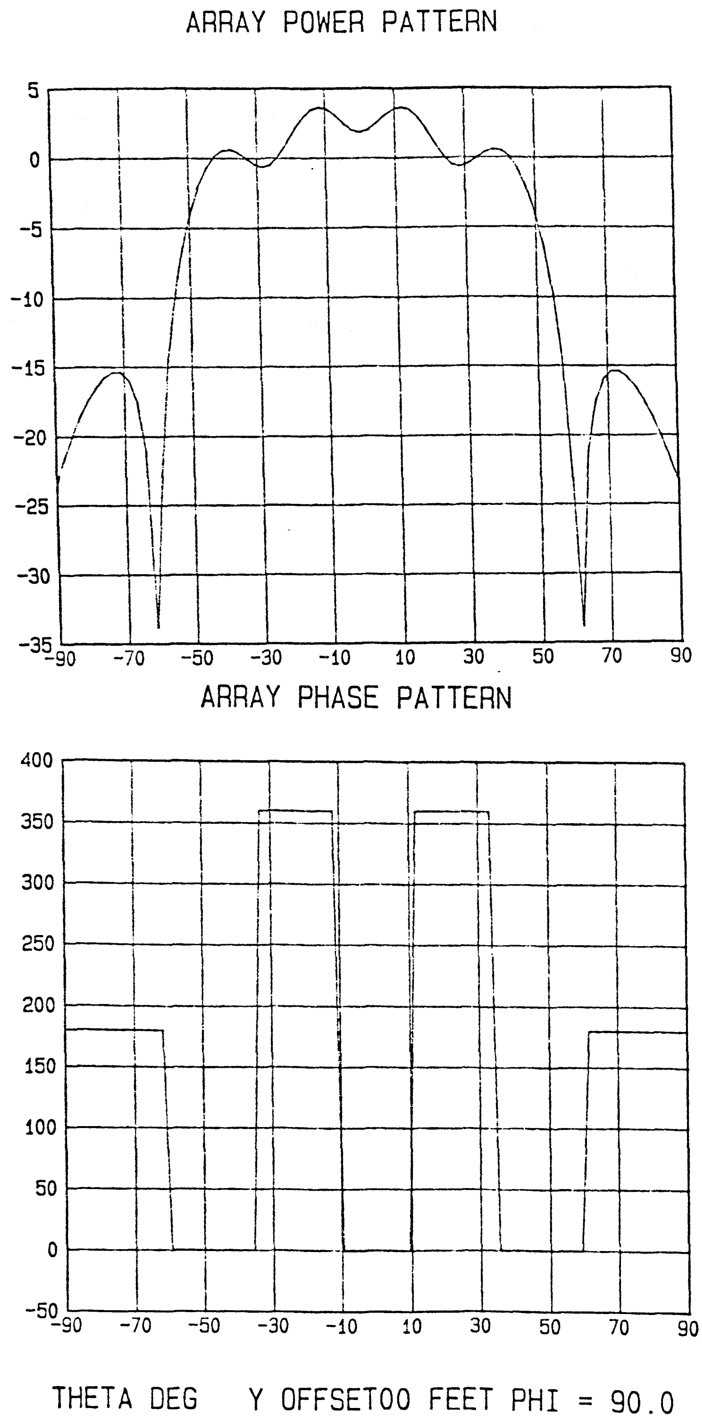


FIGURE 2. ARRAY POWER AND PHASE IN PLANE ALONG ARRAY.

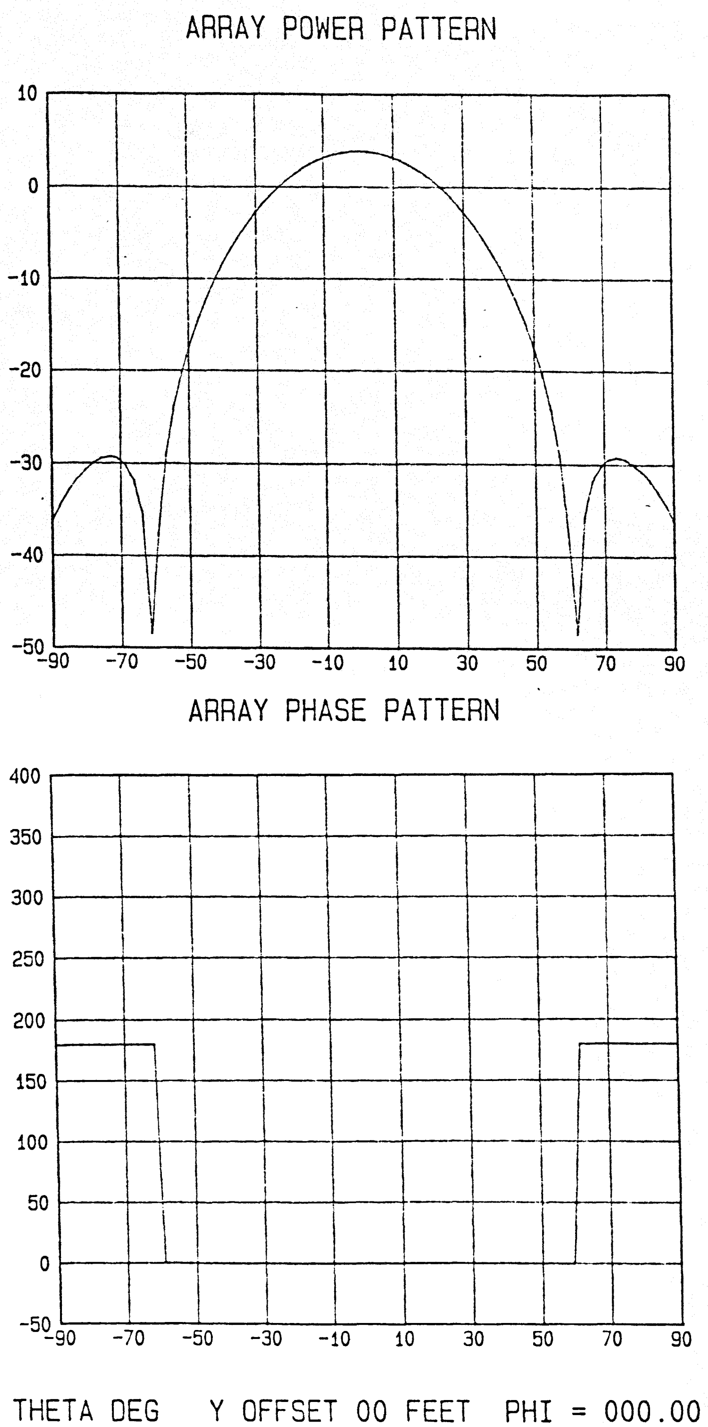


FIGURE 3. ARRAY POWER AND PHASE ACROSS ARRAY.

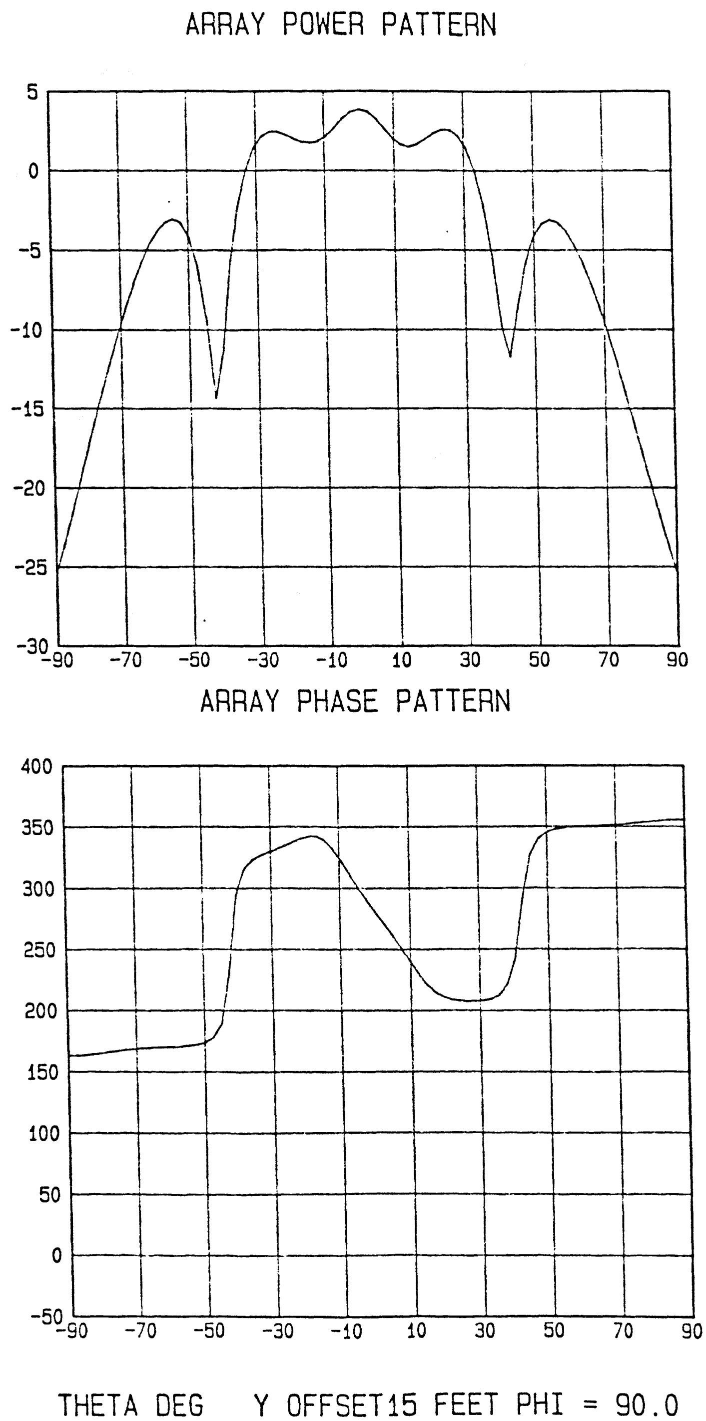
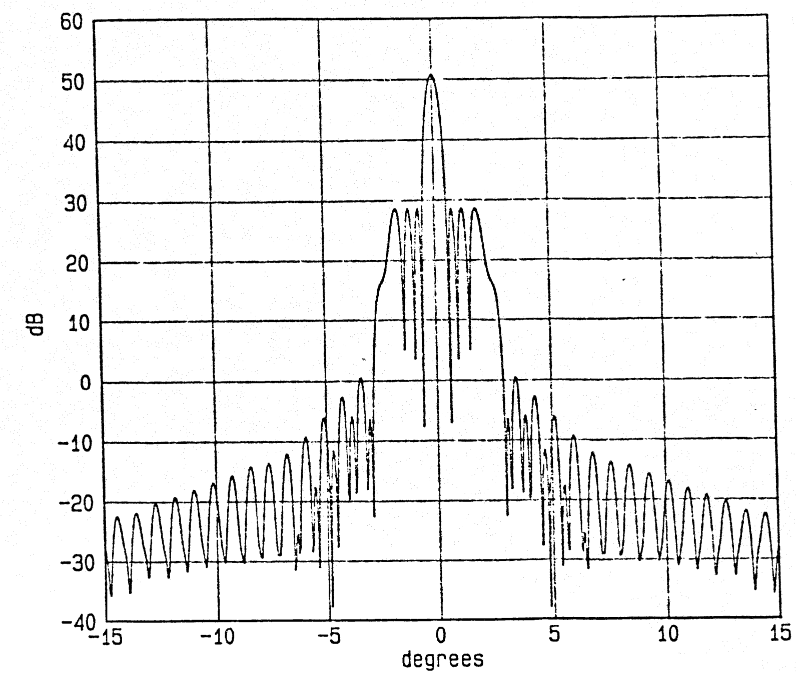


FIGURE 4. ARRAY POWER AND PHASE ALONG ARRAY WITH 15 FEET OFFSET.

300 FOOT BEAM PATTERN WITH 2X8 ARRAY FEED OFFSET 0 FEET



300 FOOT BEAM PATTERN WITH 2X8 ARRAY FEED OFFSET 5 FEET

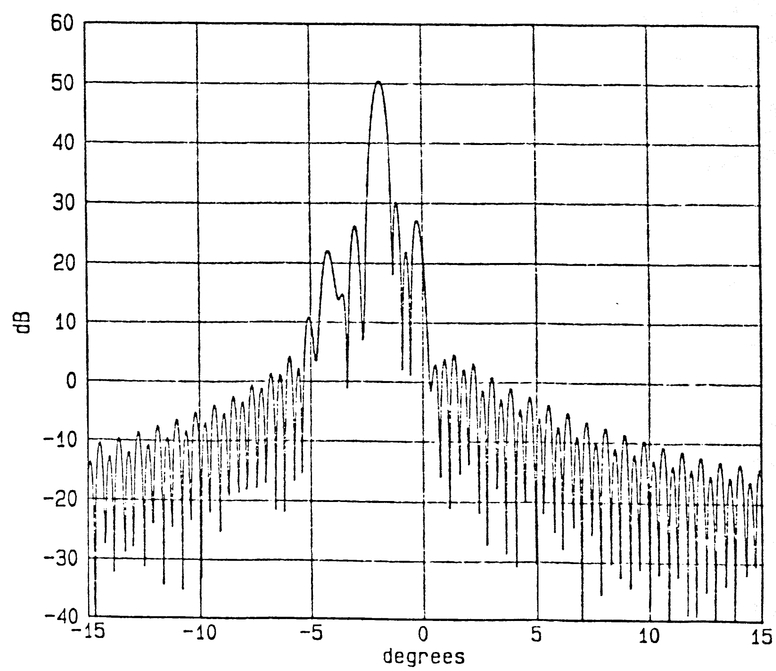
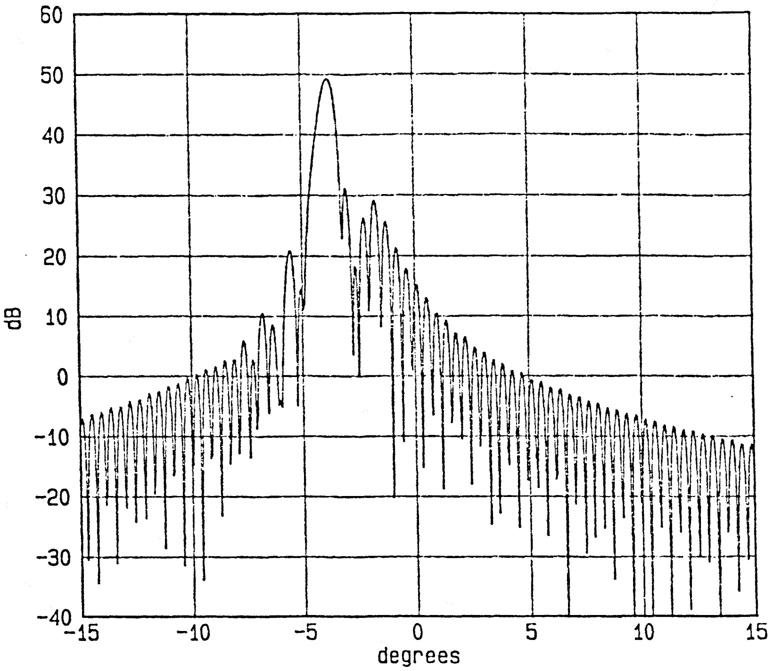


FIGURE 5

300 FOOT BEAM PATTERN WITH 2X8 ARRAY FEED OFFSET 10 FEET

8DF = .85



300 FOOT BEAM PATTERN WITH 2X8 ARRAY FEED OFFSET 15 FEET

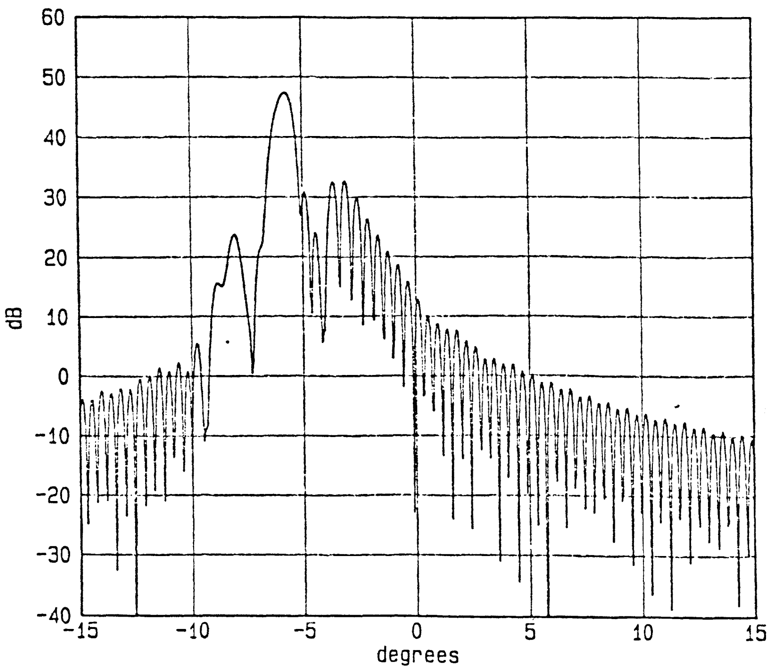
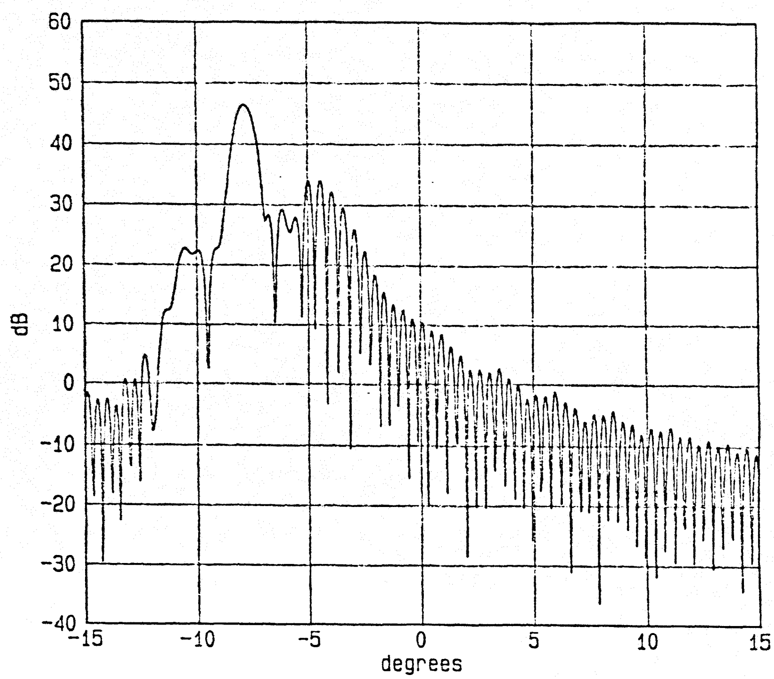


FIGURE 6

300 FOOT BEAM PATTERN WITH 2X8 ARRAY FEED OFFSET 20 FEET



300 FOOT BEAM PATTERN WITH 2X8 ARRAY FEED OFFSET 23 FEET

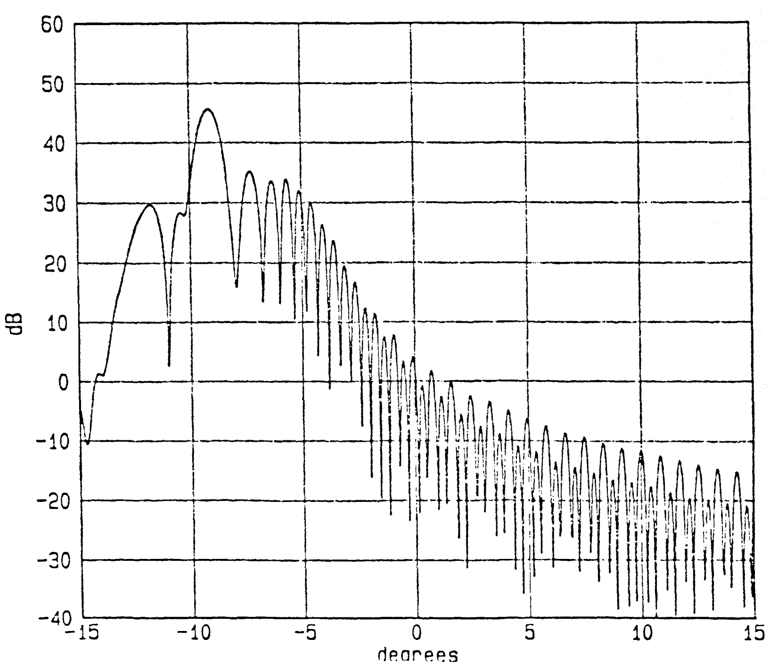


FIGURE 7

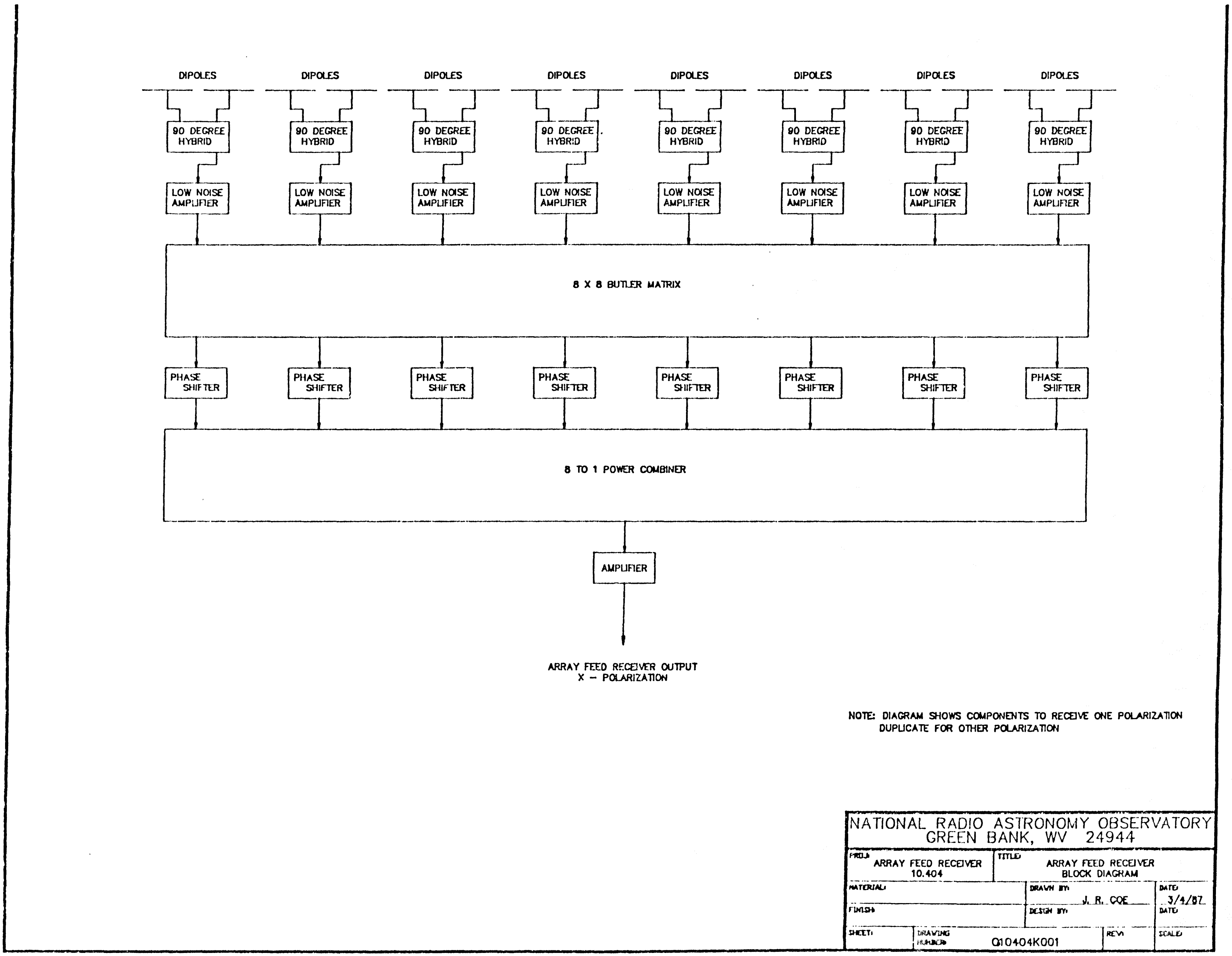


FIGURE 8. ARRAY FEED RECEIVER BLOCK DIAGRAM