NATIONAL RADIO ASTRONOMY OBSERVATORY

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WAVEGUIDE SIGNAL TRANSMISSION SYSTEM

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Introduction

The VLA requires transmission of IF, local oscillator, and control signals between a central control room and each of 27 antennas located along the 21 km long arms of a Wye. The antennas are transportable and four configurations of antennas are planned to allow different angular resolutions and fields of view. The present plan of observing stations is shown in Table 1 and Figure 1. In summary, as a worst case on one arm we must allow for up to 43 observing stations, occupied by up to 11 antannas (12 if sub-array operation is desired), with the furthermost antenna 21 km from the control building.

The signals which must be communicated to each antenna are summarized as follows:

1. IF - the front-end at each antenna produces two channels (from two polarizations or two RF frequencies) of IF signals. These IF signals are broadband Gaussian noise comprised of receiver noise plus a noise-like signal from an astronomical source. All of the IF signals will be correlated in the control room and after appropriate processing a radio brightness map of the astronomical object is produced. The sensitivity of the array improves as the bandwidth, B, is increased (proportional to $\sqrt{B}$). The front-ends

and delay lines in the system will limit B to 500 MHz or less and an IF transmission system capable of B = 500 MHz is highly desirable. This band can be centered at whatever frequency, fo, that is desired in the transmission system. Other requirements of the IF transmission system are as follows:

a. The noise power and cross-talk contributed by IF transmission system shall be less than 1% of the signal. Correlated cross-talk must be much lower but the correlation can be eliminated by a proper system design.

b. The phase response, $\zeta(f)$, of each channel must be identical to within 0.2 radians. The constant phase and first derivative ($d\zeta/df \equiv$ group delay) will be corrected by pilot tones and calibration methods. However the variation in group delay must be equalized. Equalization to within 0.12 ns over a 500 MHz band is required.

c. The amplitude response of each channel shall be constant within $\pm$ 1 dB over the 500 MHz bandwidth.

2. Local Oscillator - The LO frequency at each antenna must be variable in steps no larger than 100 MHz over the range of 0.1 to 25 GHz. The path length stability must be better than 1 mm. These requirements can be met by synthesizing the LO at each antenna from lower frequency (i.e., .1 to 1 GHz) signals which are transmitted to each antenna and used to lock an oscillator whose output is then transmitted back to the main control room. The round trip phase change is then twice the one way phase change and appropriate corrections or feedback can be used

to correct for actual path length changes of up to several meters. Any phase correction scheme requires a reciprocal path (i.e., the same phase variations going to and from an antenna) and thus no repeaters are allowed.

3. Control and Monitor Data - Information to point the antenna and monitor the antenna and receiver must be communicated. The required bandwidth is under 1 MHz and the transmission problem is fairly straightforward.

These communication problems were investigated in 1965-1967. Free-space transmission, laser links, TE_{01} waveguide, and various sizes of coaxial cable were studied and are discussed in the ITT VLA Electronics Report and VLA Electronics Memoranda #2, 5, 6, 7, 9, 10 and 11. A system utilizing one 1-5/8" cable for LO and two 1-5/8" cables for IF transmission was chosen and prototyped. The IF transmission bandwidth was limited to 30 MHz and 26 repeaters were required on each arm of the Wye.

The TE_{01} mode waveguide system was rejected in 1967 because the waveguide and various necessary accessories were not being manufactured, there was insufficient experience in its use, and solid-state millimeter-wave terminal equipment was not available. The situation was re-examined in 1972. It was evident that a large amount of development had occurred at the Bell Telephone Laboratories and in Japan and its use in the VLA was feasible and desirable. The system is estimated to cost no more than the coaxial cable system and has the following advantages:

a. The IF transmission bandwidth can be increased by a factor of 16 and thus the potential of increasing sensitivity by a factor of 4 is realized.

b. The waveguide loss is so low that no repeaters are required. The elimination of 78 repeaters should increase the array reliability.

c. The low loss transmission medium will simplify the problem of LO distribution and allow more flexibility in the choice of RF operating frequency of the array.

Table 1

LOCATIONS OF OBSERVING STATIONS FOR THE VLA

(All distances are in meters from the center of the Wye)

North Arm				South-East Arm				South-West Arm			
1"	3"	9"	27"	1"	3"	9"	27"	1"	3"	9"	27"
3500.00	1166.67	388.89	129.63	1500.00	500.00	166.67	55.56	2000.00	666.67	222.22	74.07
4500.00	1500.00	500.00	166.67	6000.00	2000.00	666.67	222.22	4000.00	1333.33	444.44	148.15
8500.00	2833.33	944.44	314.81	8000.00	2666.67	888.89	296.30	7500.00	2500.00	833.33	277.78
9000.00	3000.00	1000.00	388.89	9500.00	3166.67	1055.56	340.00	12000.00	4000.00	1333.33	444.44
10500.00	3500.00	1166.67	500.00	10000.00	3333.33	1111.11	370.37	13500.00	4500.00	1500.00	500.00
17500.00	5833.33	1944.44	648.15	14500.00	4833.33	1611.11	537.04	15000.00	5000.00	1666.67	555.56
19000.00	6333.33	2111.11	703.70	16000.00	5333.33	1777.78	592.59	16000.00	5333.33	1777.78	592.59
				17000.00	5666.67	1888.89	629.63	19500.00	6500.00	2166.67	722.22
				17500.00	5833.33	1944.44	666.67	21000.00	7000.00	2333.33	777.78
				20000.00	6666.67	2222.22	740.74				
				21000.00	7000.00	2333.33	777.78				

Total number of observing stations = 100

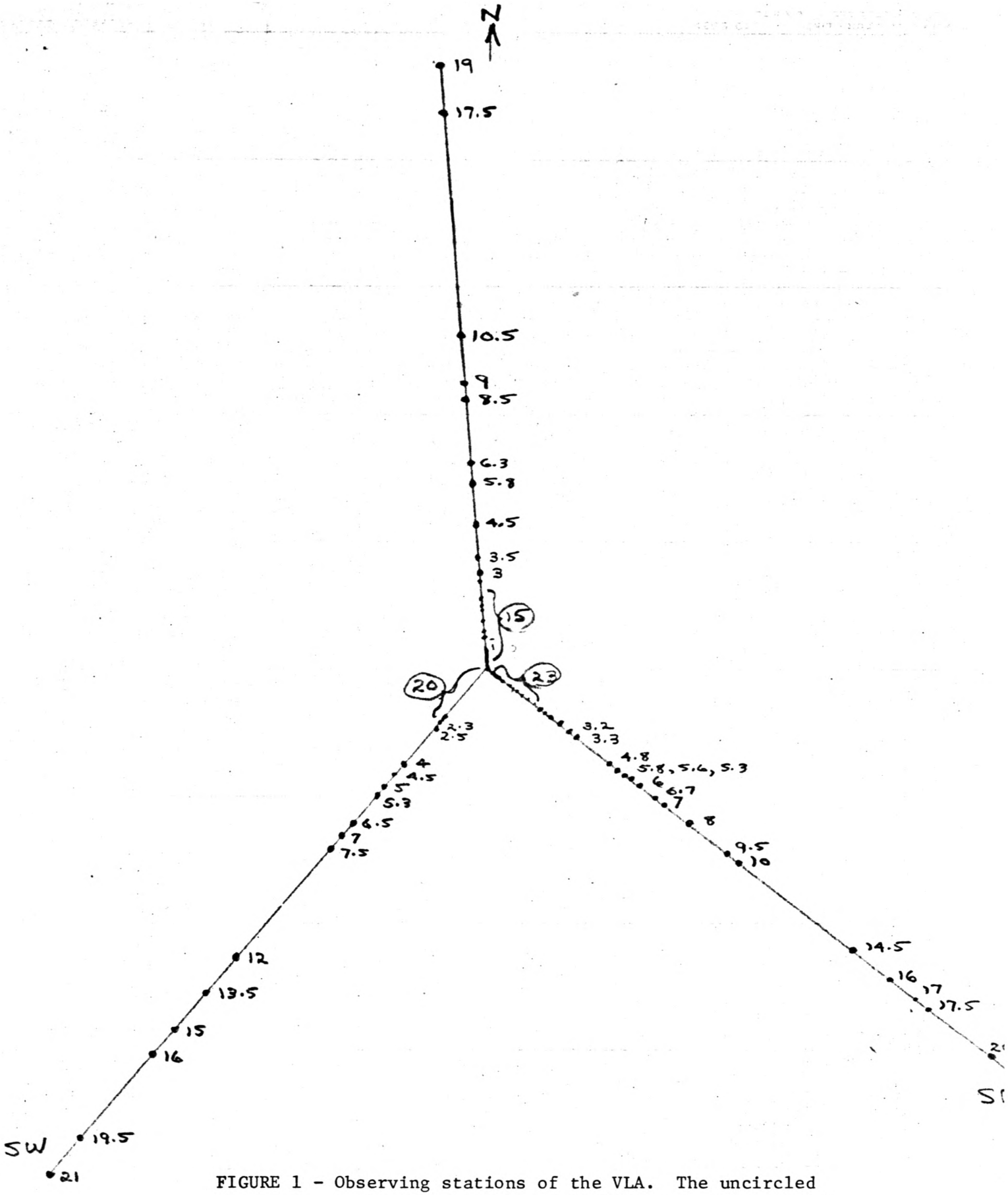

FIGURE 1 - Observing stations of the VLA. The uncircled numbers are distances in km from the Wye center. The circled numbers are the total number of stations in the first 2 km of each arm. No more than 12 observing stations on an arm will be occupied at one time.