VLA ELECTRONICS MEMO #115

BANDWIDTHS FOR THE VLA RECEIVING SYSTEM

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The VLA receiving system will incorporate a variable bandwidth capability using a series of filters in the final IF section any one of which can be selected by the computer. The principal objective of this variability is to control the width of the delay beam in the continuum mode to allow mapping over the full primary beamwidth of the individual antennas. A maximum of six different bandwidths is suggested for reasons of cost and convenience in mechanical layout of the IF system. One will be the full system response which extends from 1 or 2 MHz to 50 MHz, the upper frequency limit being set by the 100 MHz sampling capability of the digital delay and correlator system. The other responses will be controlled by filters centered on 25 MHz so that the IF center frequency will be the same for any bandwidth. The purpose of this memorandum is to discuss the choice of bandwidths to be used.

As a first criterion for choice of bandwidth the values that are required to make the delay beamwidth at the longest antenna spacing equal to the primary beamwidth will be calculated. For a pair of antennas with spacing ℓ the width of the delay beam between the half-amplitude responses , θ_d, for a direction normal to the baseline is given by

$$\frac{\sin\ (\pi b\ell\ \theta_d/2c)}{\pi b\ell\ \theta_d/2c} = 0.5$$

or

$$\pi b\ell\ \theta_d/2c = 1.895$$

where b is the bandwidth, for simplicity assumed to be rectangular, and c is the velocity of light. Then if ℓ is measured in km and b in megahertz the delay beamwidth in arc minutes is $1.24 \times 10^3\ b^{-1}\ell^{-1}$.

The maximum spacing between any two antennas in the VLA is taken to be that between the ends of the SE and SW arms which is 36.4 km. This is used in configuration A. In configuration B the spacings are decreased by a factor 1400/5000 = 0.28 relative to A. In configuration C the spacings are decreased by a factor 1400/1500 = 0.0933 relative to A. In configuration D the spacings are decreased by a factor 0.25 relative to C. These data on configurations were supplied by D. E. Hogg. Values of the delay beamwidth as a function of bandwidth based on the above spacing values are given in Table 1.

The primary beamwidth of a single antenna at the half power level, θ_p, in radians, is given by

$$\theta_p = 1.08\ \lambda/d$$

where λ is the wavelength and d is the antenna diameter of 25m. Note that the numerical constant would be 1.02 for uniform illumination; the value 1.08 was supplied by P. J. Napier and takes account of the design illumination.* The resulting beamwidth values are believed to be correct to $\pm$ 5%. Values of primary beamwidth for the four principal wavelengths are given in Table 2.

The bandwidth for which the delay beamwidth is equal to the primary beamwidth is given in Table 3 for each of the four wavelengths at each configuration. Rounding off the values in Table 3 suggests the following choice of bandwidths: 1, 4, 12, 18, 40 & 49 MHz. However, a more even distribution of values with multiplicative increments between 2 and 3 would probably be more generally useful, especially as other observing wavelengths may eventually be implemented. B. G. Clark also suggests that a bandwidth less than 1 MHz would be useful for making maps which contain mainly line radiation by tuning to a line frequency when operating in the continuum mode. The present best suggestion for choice of bandwidths is therefore 0.5, 1.5, 4, 12, 24 & 49 MHz.

Final choice of the bandwidth values will be made in October 1973 when filters for the systems of the first two antennas are ordered. Since the present choice is made on a rather arbitrary basis, any other suggestions would be appreciated if received before the above date.

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*Beamwidth values given in a memo by C M. Wade dated February 1973 are based on a value of approximately 1.24 for this constant.

Configuration	Maximum Spacing (km)	Delay Beamwidth at the Max Spac (arc min)
A	36.4	34.1/b
B	10.2	122/b
C	3.4	365/b
D	0.85	1460/b

Table 1. Delay Beamwidth for the Maximum Spacing of each Configuration expressed as a Function of b, the Bandwidth in MHz

Wavelength (cm.)	Half-power Beamwidth (arc min)
20	30
6.3	9.4
2.0	3.0
1.3	1.9

Table 2. Primary Beamwidth of the VLA Antennas

Wavelength (cm)	Configuration			
	A	B	C	D
20	1.14	4.1	12	49
6.3	3.6	13	39	>50
2.0	11.4	41	>50	"
1.3	18	>50	"	"

Table 3. Values of Bandwidth in MHz for which the Delay Beamwidth is equal to the Primary Beamwidth