VLB ARRAY MEMO No. 463

To: VLBA Site Group
From: Craig Walker
Subject: Effect of wind on pointing.

Wind is a significant factor in the choice of specific sites for VLBA antennas. This is especially true for the site on or near Kitt Peak. Winds in excess of 15 mph, the maximum for precision operating conditions, occur a large fraction of the time (see VLBA Memos 447 and 448) on Kitt Peak. However the frequency of occurance is a very strong function of wind velocity in the 10-25 mph range. Winds greater than about 25 mph are relatively rare. Therefore the question arises - how do the pointing errors scale with wind velocity? If 25 mph winds are not especially harmful, the task of finding an acceptable site is much easier.

In order to explore the effect of wind velocity, I have used error budget numbers from a memo by Bill Horne dated May 2, 1984 for pointing and from the antenna contract (VLBA 100) for surface. These numbers predate the final design but should be sufficiently accurate for the purposes of this memo.

I have separated the error budgets into wind dependent and wind independent factors and then scaled the wind dependent factors by the square of the wind speed and recalculated the RSS's. The pointing error budget used does not include thermal effects which can dominate the pointing errors at low wind velocities. However thermal effects are reduced in high winds because of more effective heat transfer to the air. The table attached gives the results. I have assumed wind independent terms of 0.274mm for the surface error and 3.56" for the pointing. The wind dependent terms are 0.068 mm for surface error and 2.77" for pointing at 15.7 mph. The spec for the antenna is that the pointing be within 8" in precision operating conditions. It appears from Bill Horne's memo that this spec should be exceeded significantly when thermal gradients are small and the conclusions of this memo depend somewhat on that conclusion.

The pointing error due to wind is a function of both the wind speed and the orientation of the antenna relative to the wind direction. The errors given are not an rms in the usual sense but rather are half of the peak error that can occur at the optimum antenna-wind angle. The value of half is used by Bill Horne in the error budgets to take into account the relatively low probability that the optimum angle will occur. However when the optimum angle does occur, it will remain in effect for significant periods of time because neither the wind direction nor the pointing change rapidly. Note that a pointing error of 8" at 43 GHz causes a 5 percent loss of amplitude for a source at the pointing center. Twice that offset (16") reduces the amplitude by 18 percent.

The site wind measurements can be either mean or peak velocities. It they are mean velocities, the effects of gusts must be considered. The ratio of gust velocities to the mean velocity will be terrain dependent with higher ratios likely to occur in mountains than in open, flat areas. The peak velocity measurements are probably the best to use in site evaluation since frequent amplitude dips due to gusts will make calibration difficult. Memo 447 on Kitt Peak wind measurements discusses both peak and mean winds. The numbers mentioned in the first paragraph above apply to the peak velocities.

Recall that 1/16 wavelength is 0.44 mm at 43 GHz and 0.22 mm at 86 GHz. The FWHM of the primary beams are about 60" and 30" at 43 and 86 GHz respectively (scaled from VLA).

The table shows that the surface error is dominated by wind independent factors below wind speeds of about 25 mph. The surface error remains below 1/16 wavelength for 43 GHz in winds below 35 mph and for 22 GHz in winds below about 53 mph.

The effect on pointing is more significant. In the absence of thermal effects, it appears that the precision pointing spec should be met in wind speeds up to 25 mph. This performance is expected based on analysis of the antenna design but, since it exceeds the specifications, cannot be guaranteed. The attached figure (modified from a figure in the VLA 'Green Book') shows the primary beam pattern for several frequencies and, along with the table, helps give an impression of the effects of pointing offsets. By scaling by the beam size, the table indicates that performance equivalent to that obtained with an 8" pointing error at 43 GHz can be obtained, in the absence of significant thermal gradients, in peak winds up to about 12 mph at 86 GHz, 25 mph at 43 GHz, 37 mph at 22 GHz, 45 mph at 15 GHz, and above 55 mph (maximum before stow) at all lower frequencies.

Assuming the final design meets or exceeds the error budgets used for this memo (ie. exceeds the specification by the expected amount - Bill Horne makes no promises in this regard), a site such as Kitt Peak should be acceptable. Useful observations at 43 GHz should be possible most of the time since winds above 25 mph are relatively rare. Operation at 86 GHz will be restricted but that frequency, while very important, probably will not represent a major fraction of the use of the array. With dynamic scheduling, it should be possible to obtain good conditions. The antenna should perform well at 22 GHz and lower frequencies most of the time at most sites that we might consider.

Error Budget vs. Wind Speed
(excluding thermal effects)

Wind Speed mph	Pointing Error arc-sec RSS	Surface Error mm RSS
0.0	3.6	0.274
5.0	3.6	0.274
10.0	3.7	0.275
15.0	4.4	0.281
20.0	5.7	0.295
25.0	7.9	0.323
30.0	10.7	0.370
35.0	14.2	0.435
40.0	18.3	0.519
45.0	23.0	0.622
50.0	28.3	0.742
55.0	34.2	0.878

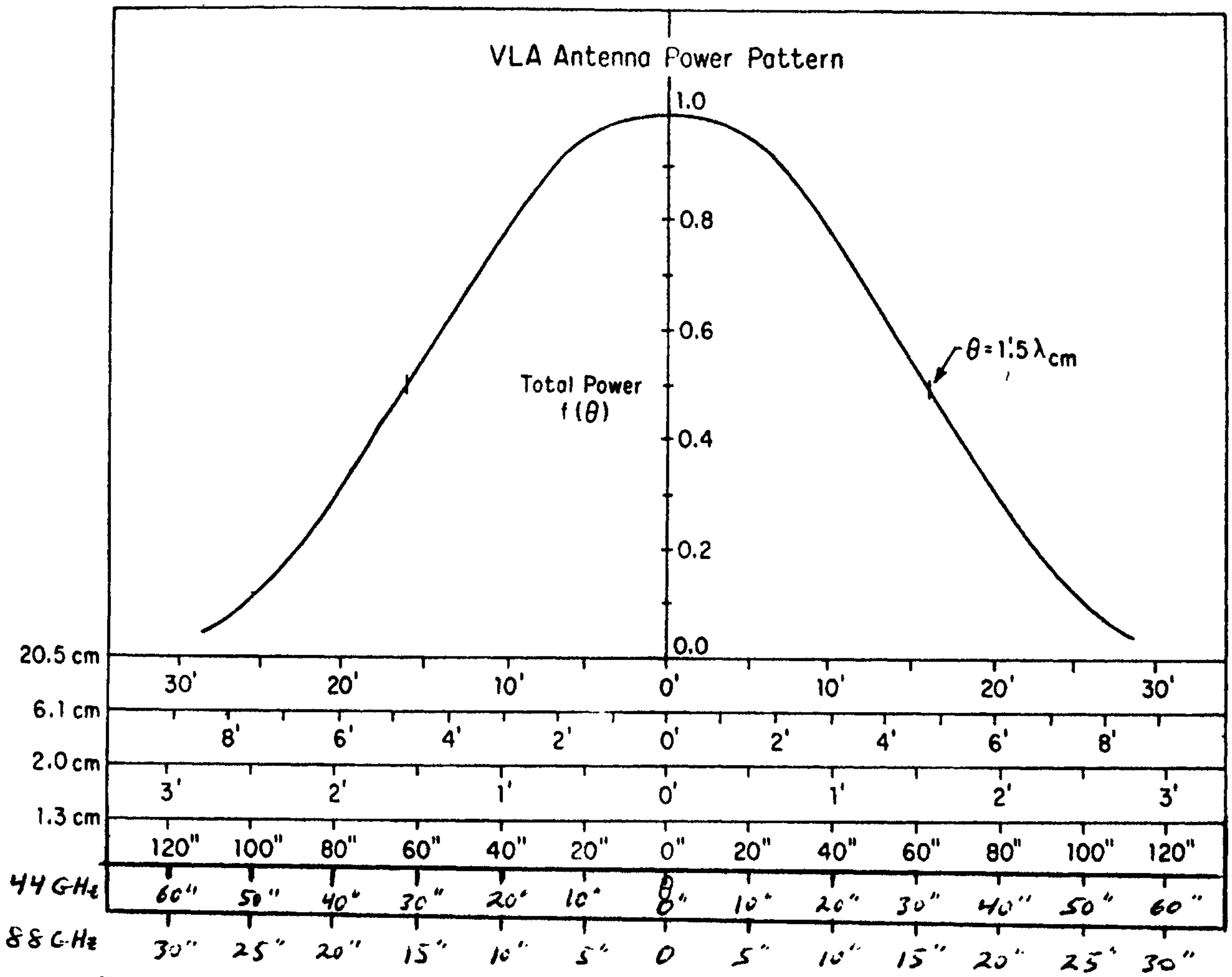

Figure 5-5. Antenna power pattern for all four VLA oberving bands.

Same size antenna as for VLBA