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7.5.2 USE OF THE SUN TO DETERMINE POINTING OF ST RADAR BEAMS

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Verification of the beam-pointing direction for ST radars is a technically difficult problem. Consequently it is not usually done. For measurement of horizontal winds, the lack of precise knowledge of the beam-pointing direction is usually of little consequence as any errors cause only a small uncertainty in the measured velocity. However, instantaneous vertical velocities are typically more than an order of magnitude less than horizontal velocities and average vertical velocities are more than two orders of magnitude less than average horizontal velocities. Hence even small pointing errors ($< 10^{-2}$ radian) for vertical beams can result in large errors due to contamination by horizontal winds. Experimental confirmation of pointing accuracy using the measured winds is difficult but has been achieved where horizontal and vertical winds are measured at the same site (BALSLEY and RIDDLE, 1984; RIDDLE and BALSLEY, 1985).

Sited at Ponape, Federated States of Micronesia, is a ST radar with only a vertical beam. However, because of the equatorial location (+ 7°N) the sun passes through the beam for a few days twice a year. The passage of the sun through the beam in April 1985 was used to determine the pointing of the beam. The analysis below suggests that the beam is within 11 arc min (.003 radian) of vertical. Already this is a useful confirmation of verticality. Improvement of the measurement by a factor of 3 or 4 should be easily achieved and will be very useful for equatorial ST radars. It should be noted that this measurement refers only to the receive beam. For radar operation the effective beam is a combination of the transmit and receive beam.

The ST radar at Ponape operates at 50 MHz and collects spectral data about every 80 seconds. From each set of spectra an estimate of the background noise can be obtained. For the days of solar passage through the beam, 2 hrs of noise values were computed. The 40 minutes of data at each end of the computed interval were used to remove any linear trend in the noise values. The center 40 minutes contained the solar transit which caused a maximum of 3-dB enhancement. The noise fluctuations were about 0.5 dB.

By fitting a Gaussian enhancement to each of 13 days of noise data, 13 estimates of the effective beam longitude were obtained (Figure 1a). The difference between the effective longitude and the site longitude is an estimate of the off-vertical pointing angle. The average estimate was 7 arc min with a formal error from the dispersion of individual values of 5 arc min. The whole data set was also fitted by a two-dimensional Gaussian (Figure 1b) to produce both effective longitude and effective latitude estimates. For this fit, the longitude error was 5 arc min and latitude error 11 arc min. A formal value for the error of the pointing-angle estimate was obtained by repeating the fitting process after adding more noise to the data and amounted to 2 arc min.

The actual determinations of the effective longitude and latitude of the beam are given in Table 1. The formal errors in determining the off-vertical pointing angle are only a lower bound to the errors because no account has been taken of systematic errors. Consequently, we prefer to use the actual estimated off-vertical angles as an estimate of the accuracy of our beam pointing. The largest of these estimates was 11 arc min.

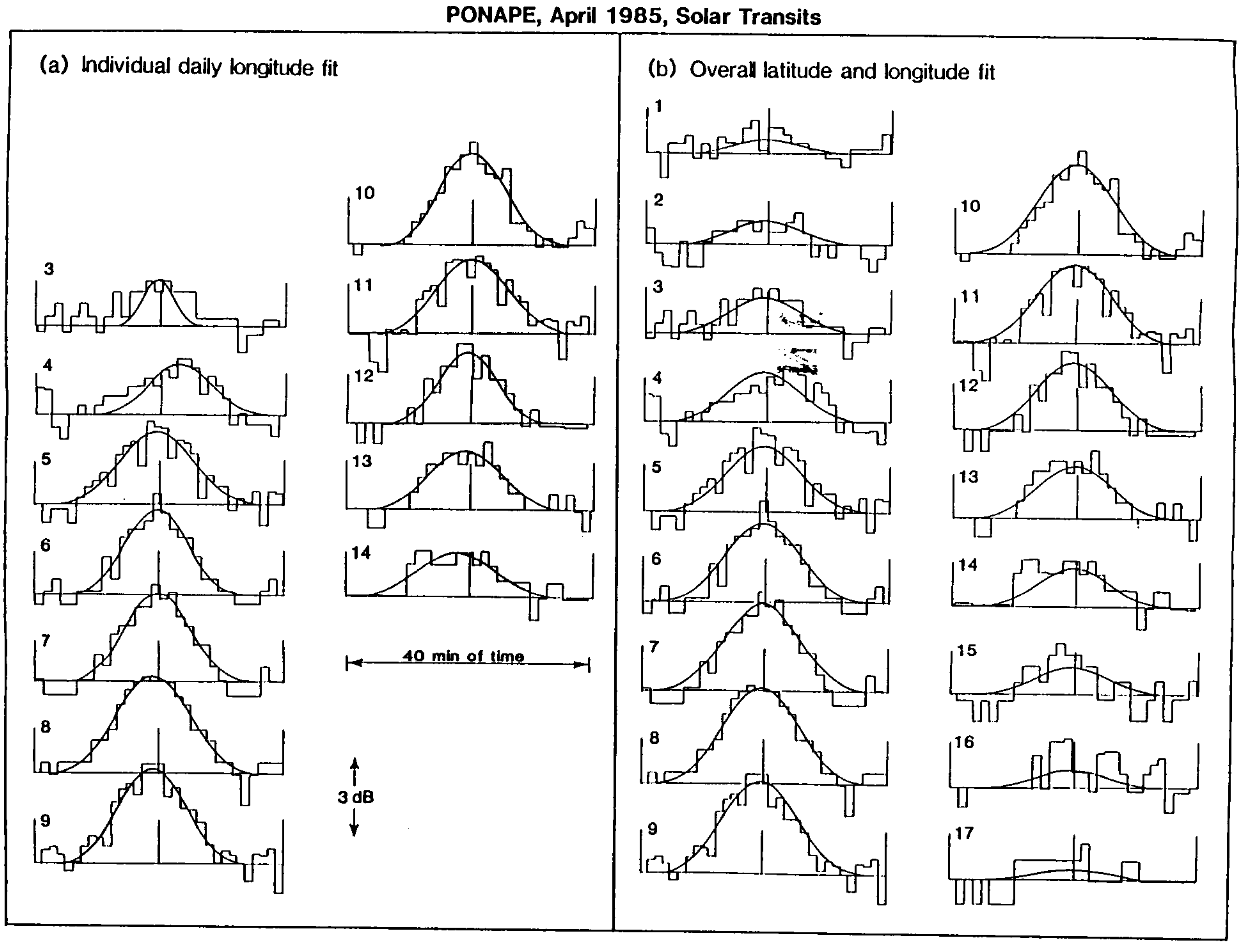

Figure 1. Noise values observed with the Ponape ST radar during solar transits of April 1985. a) The data are fitted each day to a separate 1-dimensional Gaussian model. b) The data as a whole are fitted by a 2-dimensional Gaussian model. The number on each plot is the observing date.

TABLE 1

April 1985 positions determinations

	Longitude	Latitude
Ponape site	158° 11.5'	6° 57.4'
Individual fit	158° 4.2 ± 5'	--
Overall fit	158° 6.8 ± 2'	7° 8.9 + 2'

In passing, it should be noted that the fitting process also determined a half power width for the beam of 3.2°. The expected width for a uniform aperture is 3.1°, so the fitting process also confirms that a fairly uniform aperture illumination has been achieved.

The main source of error in this pointing-angle estimation procedure is currently the high level of fluctuation of the noise values compared to the enhancement of noise due to the sun. In addition to its direct contribution the fluctuations also mask other effects described below. It is a very simple matter to reprogram our observations at Ponape to more closely emulate a radio astronomy receiver rather than a radar receiver. By reprogramming, we expect to be able to reduce noise fluctuation to well below 0.1 dB while enhancing the time resolution. We should then see clearly several other potential sources of error.

The noise level in the data is almost entirely due to the radio sky and varies during 24 hours by about 3 dB. The linear trend removal described above removes some of this variation. With lower noise fluctuations a better removal of the variation would be possible. The noise level also fluctuates from day to day due to varying atmospheric attenuation (mainly in the ionosphere) and receiver gain variations. These variations would also be easier to recognize and remove with lower noise fluctuations. Another potential error source is the inherent assumption that the 50-MHz sun is symmetric about the solar center. However, during this observing period there were no substantial active regions on the sun and no major flares. Hence we do not anticipate any problems from this cause, even at the arc minute level. Even in more active phases of the solar cycle there is not likely to be a major problem. GRAF et al. (1971) have analyzed the radio centroid at 9.1-cm wavelength over several years. They suggest rms centroid displacements of several arc minutes. However, at 50 MHz the quiet sun (the stable symmetric component) is much hotter (5×10^5 K vs 2×10^4 K) and the slowly varying component (associated with the moving active regions) less intense (2×10^6 K vs 10^7 K). Hence the centroid variations should be reduced to negligible values. Errors due to solar meter wavelength radio bursts should also be easier to detect with lower noise fluctuations.

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Addendum

Data from the September 1985 transit have been received. The sun was discernable on 15 days of data. Those days were subject to the same analysis as for April 1985, and the mean of the individual fits for longitude was 158° 11.3'. An overall fit gave 158° 7.6'.

The September 1985 analysis revealed a timing error in the April 1985 longitude fits. To correct that error 5.4' must be added to the fitted longitudes in Table 1, making those fits even better.

The final 4 days of the September 1985 transmit were obtained using the radio astronomy mode of observation described in the text. The expected reduction of noise to better than 0.1 dB was achieved.