GBT Prime Focus (Band 1-4): Focus Tracking

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Abstract

Focus tracking is empirically determined for the GBT prime focus (band 1-4). Measurements of the axial (Y) and lateral (X) focus are made as a function of elevation. A least-squares analysis yields $Y = 1203 - 263.7\,\mathrm{Cos(El)} - 84.5\,\mathrm{Sin(El)}$ and $X = 780.8 - 329.4\,\mathrm{Cos(El)} - 84.5\,\mathrm{Sin(El)}$. Measurements of the axial focus are also made as a function of frequency with $Y = -1717 + 5.97\nu - 0.00323\nu^2$ for circular polarization and $Y = -2057 + 6.89\nu - 0.00389\nu^2$ for linear polarization. These results are compared with lab measurements of the variation of the feed's phase center with frequency.

1 Introduction

The GBT prime focus (PF) receiver (band 1-4, 680–920 MHz) is optimized using astronomical observations to determine changes in the focus as a function of elevation and frequency. The GBT PF system has three degrees of freedom: an axial motion along the optical axis (Y or FOCUS), a lateral direction along the line of symmetry (X), and a rotation (POLAR). It is assumed that the POLAR direction will not be affected by either gravity or frequency and thus is fixed to zero.

2 Observations and Results

2.1 Focus Position as a Function of Elevation

2.1.1 Axial Direction (Y)

The Y focus was studied using the GBT observing interface (GO) procedure *FocusPrime* at a frequency of 800 MHz. The observations were taken on 25 July 2001 under project pnt_prime_16. The PF was driven in the Y direction from 250 mm to 1143 mm at a rate of 200 mm per minute while the telescope was tracking 3C48. The X focus was fixed at a nominal value of 508 mm. The GO procedure *Peak* was used to update the local pointing corrections before each focus measurement. It was determined that changes in the Y focus do not significantly effect the pointing. This was verified by discretely changing the Y focus and performing a *Peak* for each value. The local pointing corrections (LPCs) varied at most by $0\overset{'}{.}34$ in azimuth and $0\overset{'}{.}54$ in elevation. There was no obvious trend with the pointing as a function of Y and the variations in the LPCs correspond to only a small fraction of the $15'$ beam.

Figure 1 shows a typical focus profile at an elevation of $41°$. Plotted is the intensity as a function of Y focus position. The intensity is in units of the noise diode and the Y focus is in millimeters. At the peak of the curve there are no significant changes in the gain for variations of ~ 100 mm in the Y focus. The top panel shows a 2^{nd} order polynomial fit to the data while the bottom panel a 7^{th} order polynomial. The value of Y for the peak intensity of the fit is 997 mm and 970 mm for the top and bottom panels, respectively. The 7^{th} order polynomical fit better determines the peak and is thus used in the final analysis.

Figure 2 summarizes the results of the *FocusPrime* measurements by plotting the peak Y value versus the elevation. Each symbol corresponds to the result of a specific *FocusPrime* measurement. The solid line is a fit to the data with $Y = 1203 - 263.7\,\mathrm{Cos(El)} - 84.5\,\mathrm{Sin(El)}$. The total range requried in Y over elevations from 20–80° is about 5 inches, similar to the results of the Gregorian focus (See Figure 6 of commissioning memo 7). Although the sense is opposite. Here Y increases with elevation.

2.1.2 Lateral Direction (X)

Unlike the Y focus the telescope pointing is very sensitive to changes in the X focus. Therefore, scanning in X is not a viable option unless the pointing can be updated continuously. An alternative method is to perform a *Peak* after each discrete change in the X focus. Because changes in the X focus only effect the elevation LPC a more efficient method is to scan in elevation. Therefore the following method was adopted. Perform a *Peak* with X = 508 mm (20 in, near the middle of the range) to update the LPCs. Then run the last scan of the *CrossAzEl* procedure which scans in elevation. Because the pointing does not significantly change with azimuth the telescope will pass through the center of the source. The peak will occur at the center of the scan only when X = 508 mm where the LPCs were measured. Therefore the scan length must be increased to insure that the center of the source is observed. Telescope rates of $120'$/min were used with an elevation length of $180'$. The Y focus was held fixed at 990.6 mm (39 in). The X focus was varied from 127–889 mm (5–35 in) at increments of 127 mm. The data were taken on 24 July 2001 under project pnt_prime_15.

Figure 3 shows a typical result. The circles are the data points while the solid line is a 2^{nd} order polynomial fit to the data. This procedure was performed while tracking 3C48 from low to high elevations. As with the Y focus there are no significant changes in the gain over 100 mm of the X focus position. Figure 4 summarizes the results for all elevations where the value of X at the peak intensity of the fit is plotted versus elevation. The solid line is a fit to the data with $X = 780.8 - 329.4\,\mathrm{Cos(El)} - 84.5\,\mathrm{Sin(El)}$.

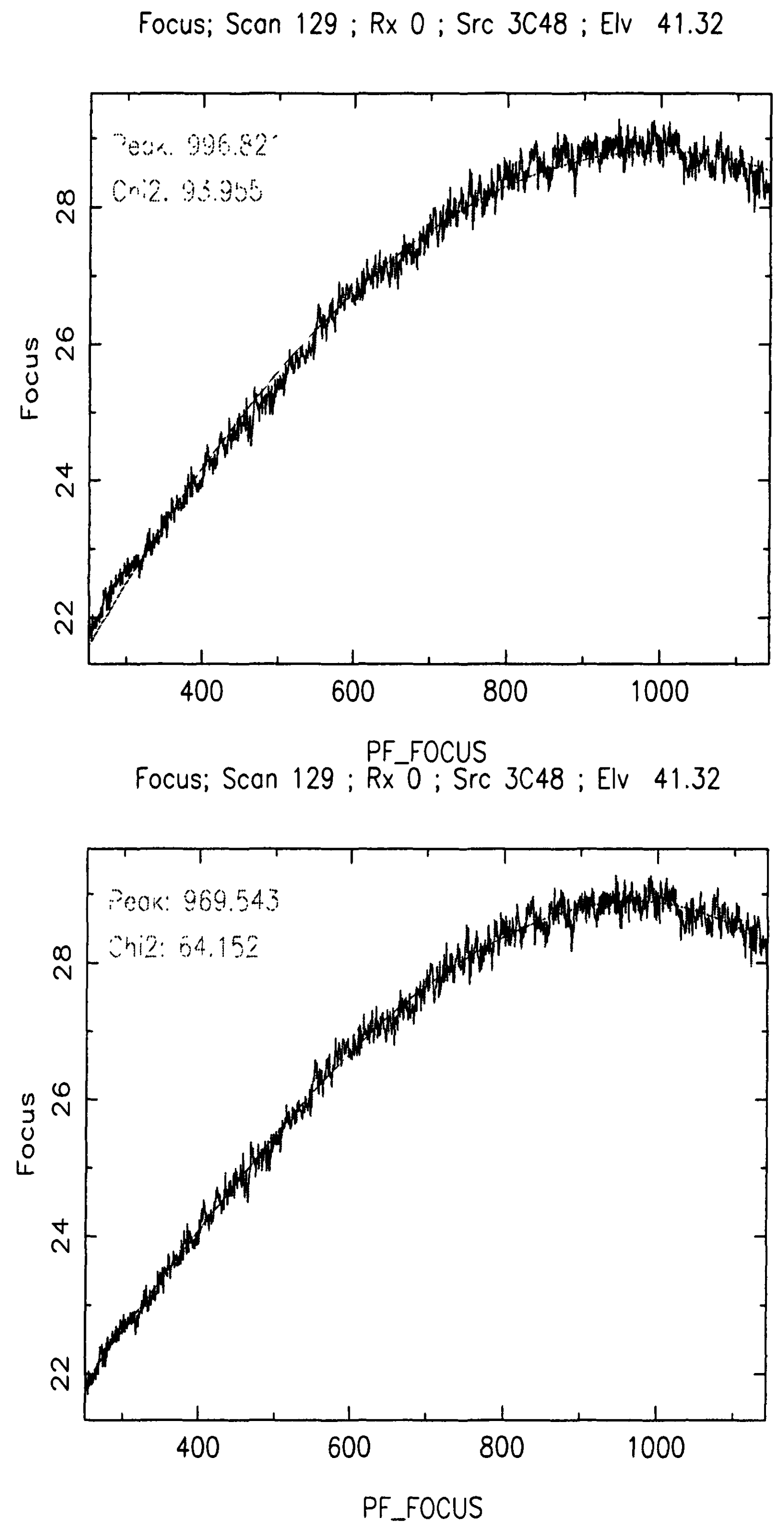

Figure 1: Result of *FocusPrime* observation where the Y focus is moved while tracking a source (3C48). Intensity, in units of the noise cal, is plotted as a function of the Y position, in units of millimeters. The top panel fits a 2^{nd} order polynomial to the data while the bottom panel uses a 7^{th} order polynomial. The value of Y at the fitted peak is 997 mm and 970 mm for the top and bottom panels, respectively.

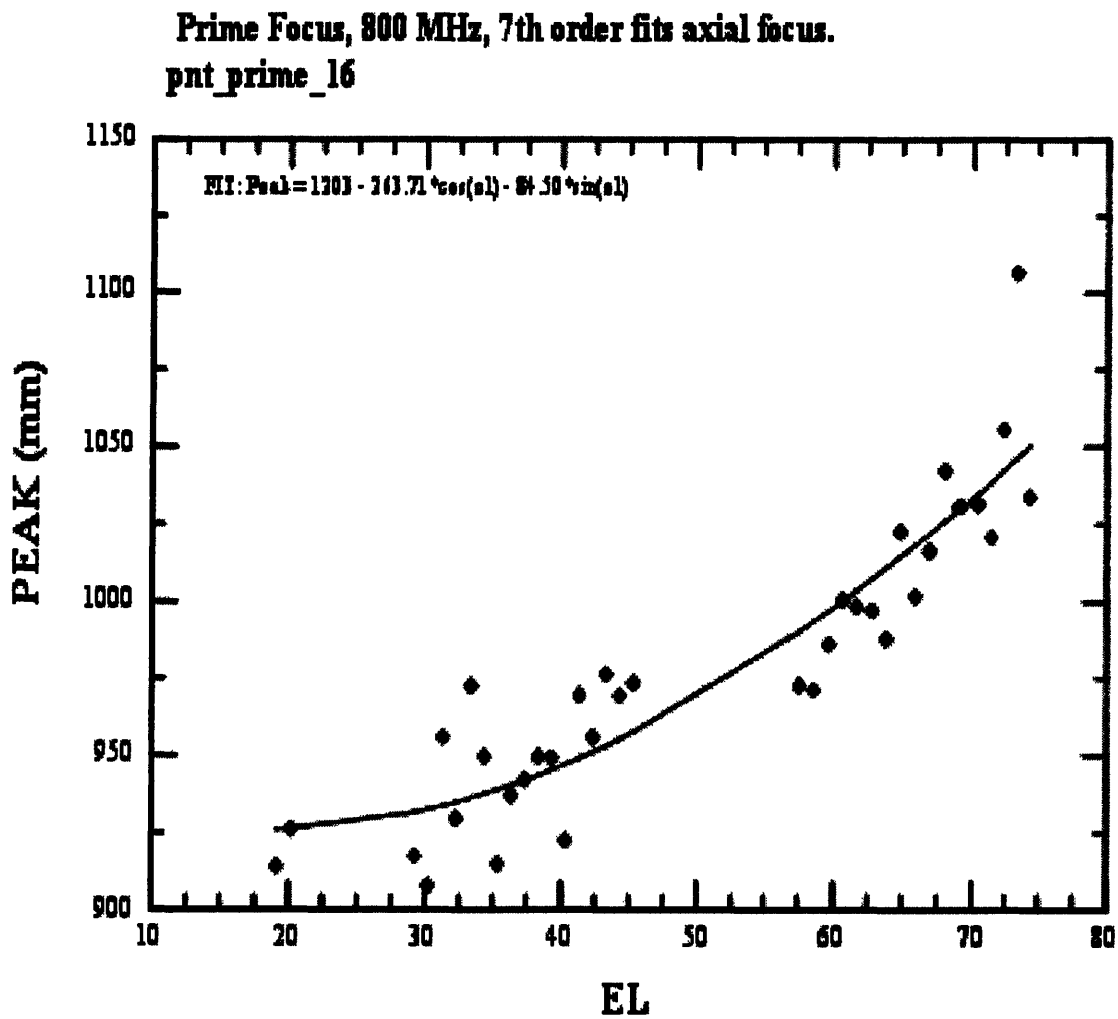

Figure 2: Axial focus (Y) versus elevation. The results of polynomial fits to the *FocusPrime* data are used and displayed as solid points. The solid line is a fit to the data with $Y = 1203 - 263.7\,\mathrm{Cos(El)} - 84.5\,\mathrm{Sin(El)}$.

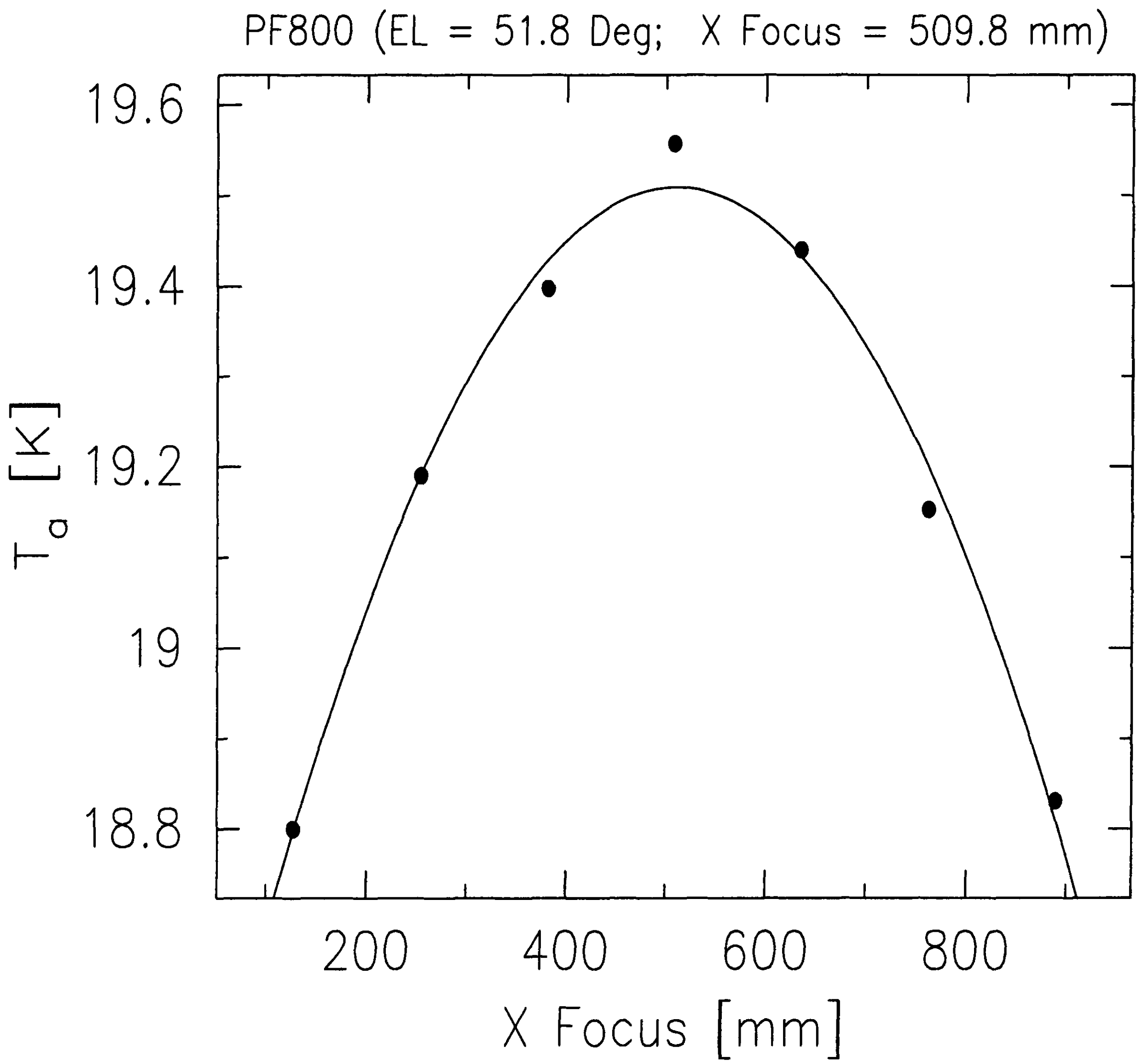

Figure 3: A typical plot of antenna temperature (assuming $T_{\rm cal} = 1$) as a function of X. The data are denoted with filled circles while the solid line is a 2$^{\rm nd}$ order polynomial fit to the data.

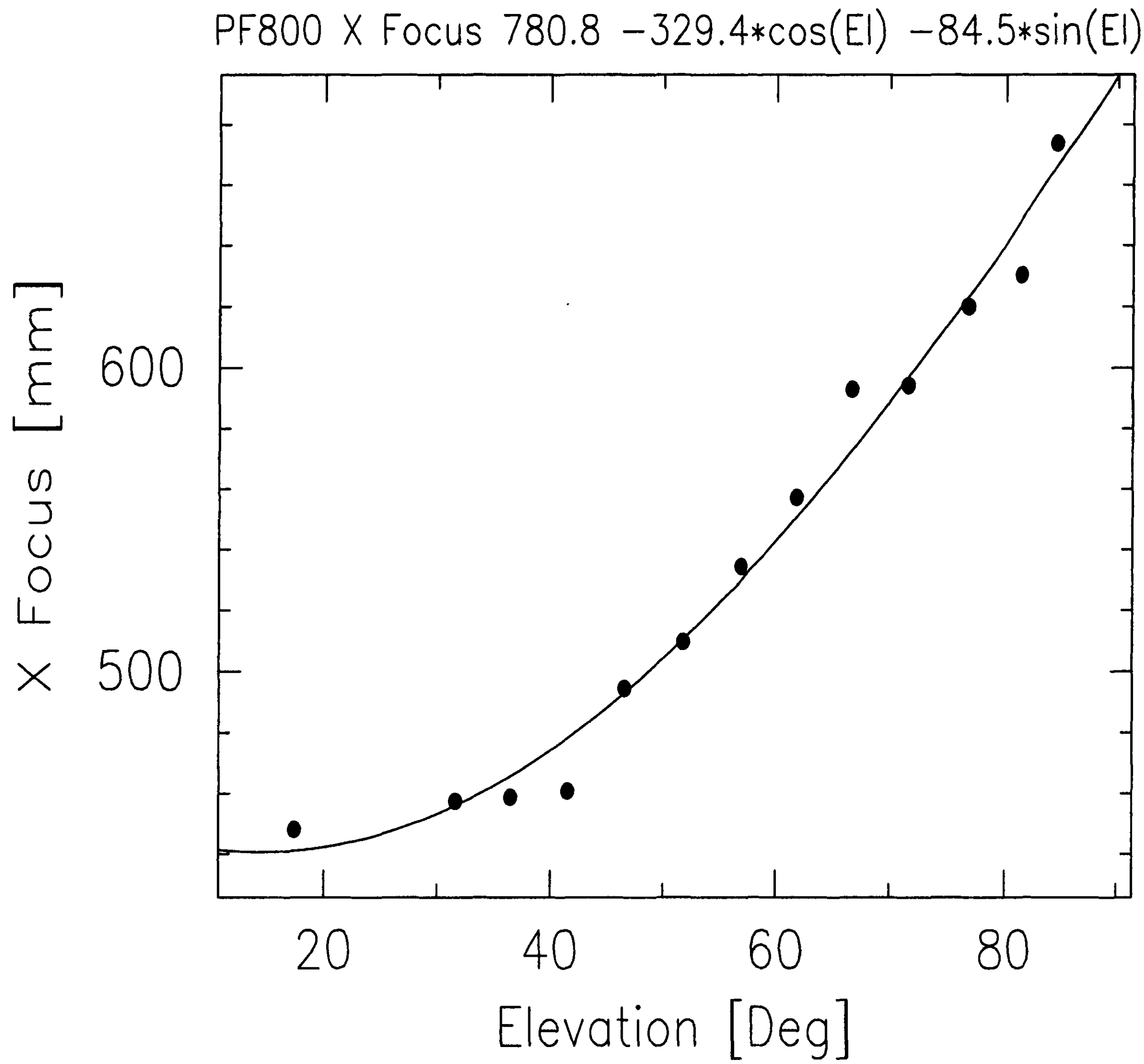

Figure 4: Lateral focus (X) versus elevation. The polynomial fits of the optimum X values are used and shown as solid points. The solid line is a fit to the data with $X = 780.8 - 329.4\,\mathrm{Cos(El)} - 84.5\,\mathrm{Sin(El)}$.

2.2 Focus Position as a Function of Frequency

2.2.1 Axial Direction (Y)

The empirically determined focus tracking measurements discussed in §2.1 are determined at a frequency of 800 MHz. Because the phase center of the PF receiver is a function of frequency the optimal focus values will change for the axial direction for different frequencies. The *FocusPrime* procedure was used to measure this effect where the procedure was run for frequencies between 660-940 MHz. This was performed for both circular and linear polarization for both channels. The Y focus was varied from 200 mm to 1143 mm at a rate of 400 mm per minute. Therfore each scan took 2.4 min. The elevations changed less than 5° to scan the focus for all the frequencies for a given polarization. The data were taken on 30 July 2001 under project pnt_prime_17.

The results are summarized in Figures 5 and 6 for circular and linear polarization, respectively. Second order polynomial fits to the results are displayed. The fit for the circular and linear polarizations are typically within 50 mm. In Figure 6, lab data measuring the phase center for the PF is also plotted. The lab measurements are not consistent with the astronomical data. Even if the E and H plane data are averaged the profile is different.

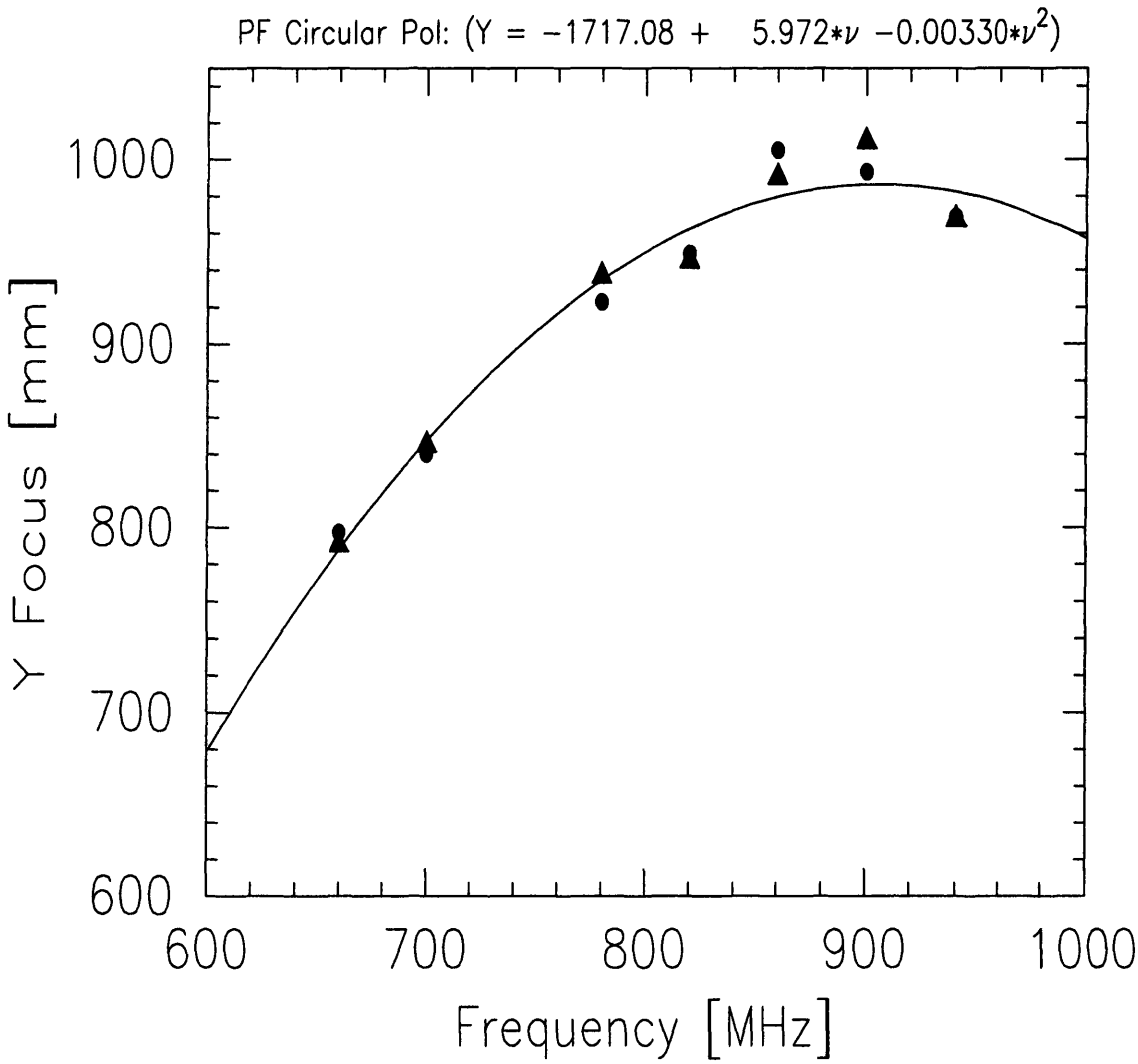

Figure 5: Axial focus (Y) as a function of frequency for circular polarization. The symbols are the data where circles correspond to channel 0 and triangles to channel 1. The solid line is a second order polynomial fit to the data ($Y = -1717 + 5.97\nu - 0.00323\nu^2$).

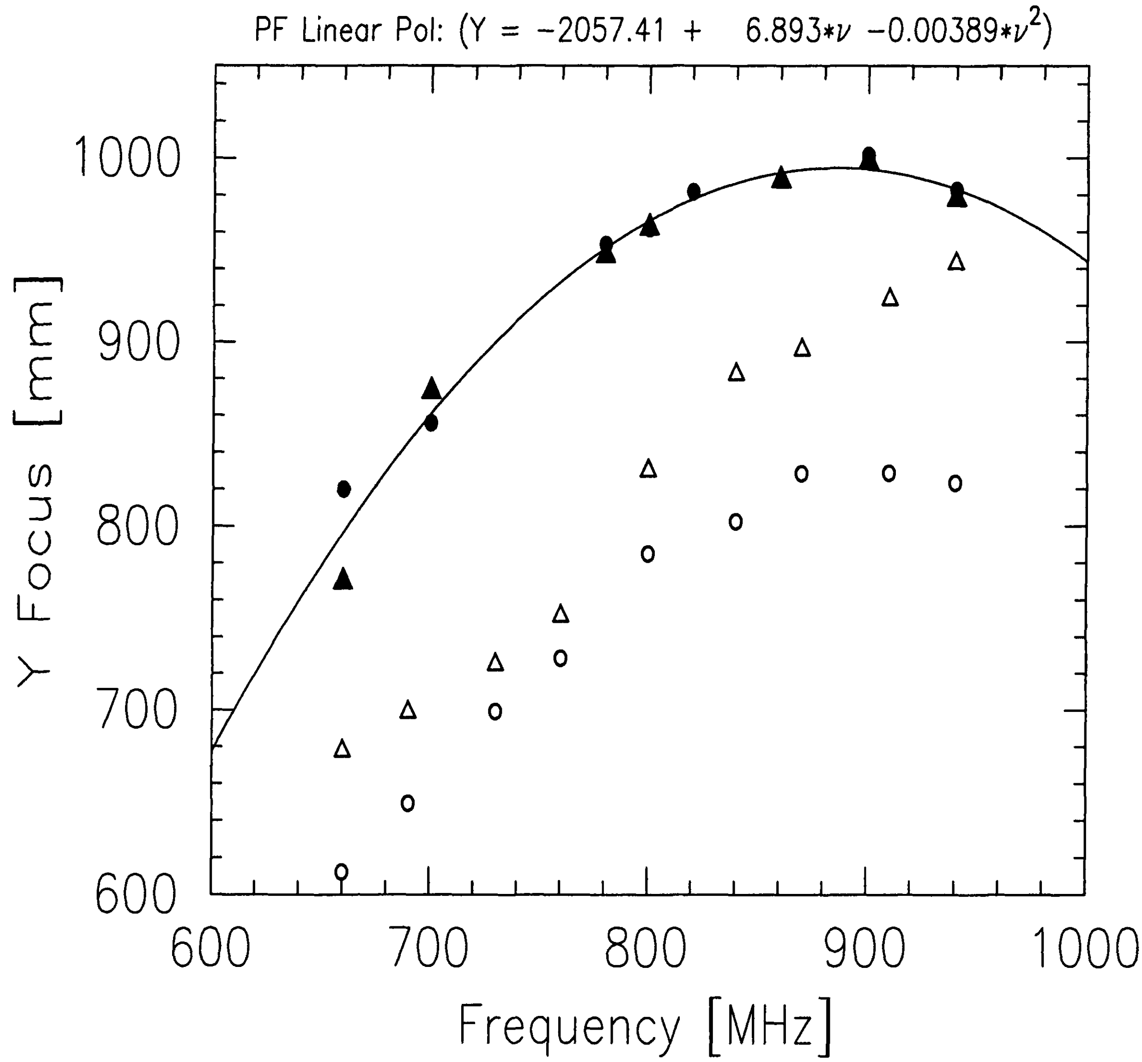

Figure 6: Axial focus (Y) as a function of frequency for linear polarization. The filled symbols are the data where circles correspond to channel 0 and triangles to channel 1. The solid line is a second order polynomial fit to the data ($Y = -2057 + 6.89\nu - 0.00389\nu^2$). The open symbols corresond to differences in the PF feed phase center as a function of frequency measured in the lab. The actual numbers are scaled to fit on the plot using $Y' = (1 - 25.4Y) + 925$. The units are converted from inches to millimeters. The scale is inverted since the phase center was measured positive from the flange towards the main reflector, opposite the sense of the Y focus. The open circles correspond to the E-plane while the open triangles correspond to the H-plane.