Polarization Calibration of the Central Pixel of ALFA

Hands-on Project AO-6

Outline

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Motivation

Determine the flux and % polarization of 3C286
Determine instrumental polarization of ALFA beam zero without assuming source parameters
Characterize instrumental polarization so that it can be removed in future observations
Determine instrumental parameters as a function of frequency

Observations

Source: 3C286 (polarized quasar)
Receiver: ALFA, beam 0
Back end: WAPPs
Central Frequency: 1385 MHz
Bandwidth: 100 MHz
Sampling time: 1 ms

Observations (cont'd)

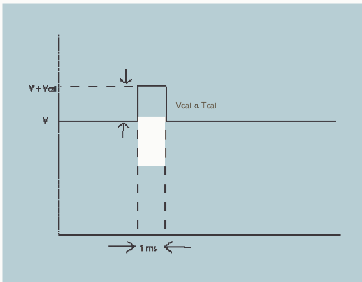
91 on-source scans:
- Integration time per scan: 20 sec
- Total rotation of feed: 180 degrees
- Rotation per scan: 2 degrees

Off-source scan:
- Integration time ~100 s, drifting

Calibration #1

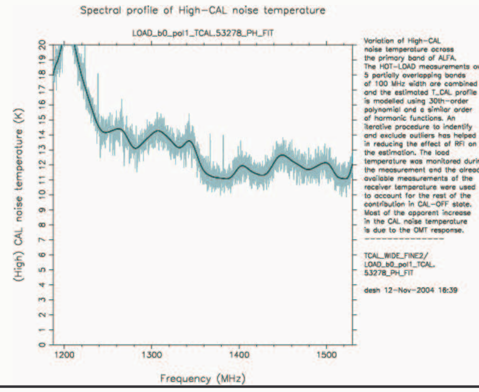
25 Hz hot winking cal during both ON and OFF source observations
Accounts for gain and phase difference between two polarization channels after noise is injected
$T_{cal}(\nu)$ is known across bandpass
Used $V_{cal}(\nu) \alpha T_{cal}(\nu)$ to put on- and off- source observations on same temperature scale

Calibration #1



$$T(\nu) = T_{cal}(\nu) \times \frac{V_{cal\ off}}{V_{cal\ on} - V_{cal\ off}}$$

T_{cal} versus Frequency



Calibration 2

$T_{on\ source}$ - $T_{off\ source}$

Removes receiver temperature (effects from before noise injection)

Otherwise, differences between the two pol. chans can lead to pseudo-polarization

Data Analysis

Observed combinations of Stokes parameters: $\begin{pmatrix} I+Q \\ I-Q \\ U+V \\ U-V \end{pmatrix}$

$$\begin{pmatrix} I_m \\ Q_m \\ U_m \\ V_m \end{pmatrix} = |G|^2 \begin{pmatrix} \frac{(1+\gamma^2)(1+\epsilon^2)}{2} & \frac{(1-\gamma^2)(1-\epsilon^2)}{2} & (1-\gamma^2)\epsilon\cos(\phi) & (1-\gamma^2)\epsilon\sin(\phi) \\ \frac{(1-\gamma^2)(1+\epsilon^2)}{2} & \frac{(1+\gamma^2)(1-\epsilon^2)}{2} & (1-\gamma^2)\epsilon\cos(\phi) & (1+\gamma^2)\epsilon\sin(\phi) \\ 2\gamma\epsilon\cos(\phi)\cos(\theta) & 2\gamma\epsilon\sin(\phi)\sin(\theta) & \gamma(1+\epsilon^2)\cos(\theta) & \gamma(1-\epsilon^2)\sin(\theta) \\ 2\gamma\epsilon\cos(\phi)\sin(\theta) & 2\gamma\epsilon\sin(\phi)\cos(\theta) & \gamma(1+\epsilon^2)\sin(\theta) & \gamma(1-\epsilon^2)\cos(\theta) \end{pmatrix} \begin{pmatrix} I_i \\ Q_i \\ U_i \\ V_i \end{pmatrix}$$

Gx, Gy are complex voltage gains in each polarization channel

$\epsilon e^{i\phi}$ is the complex mutual coupling factor

$$G_y/G_x = \gamma e^{i\theta}$$

Data Analysis

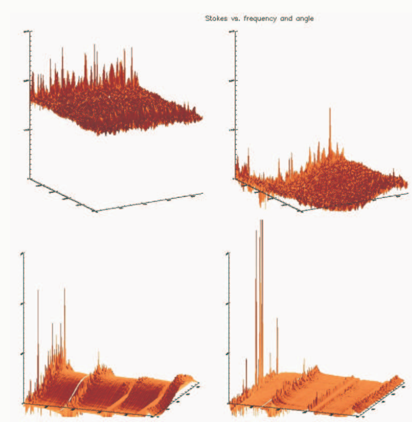
$$invariant = 2\frac{\epsilon}{1+\epsilon^2}\cos\phi$$

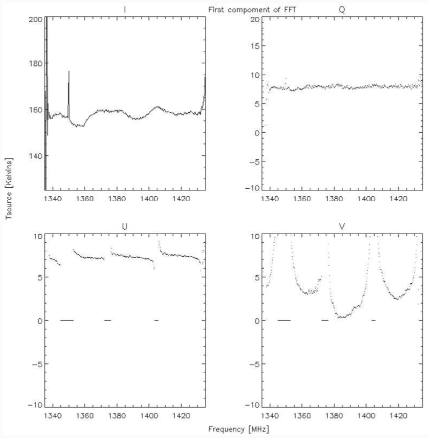
$$\theta_i = tan^{-1}\left(-\frac{V_m}{U_m}\right) \qquad \gamma_i = \sqrt{\frac{I_m - Q_m}{I_m + Q_m}}$$

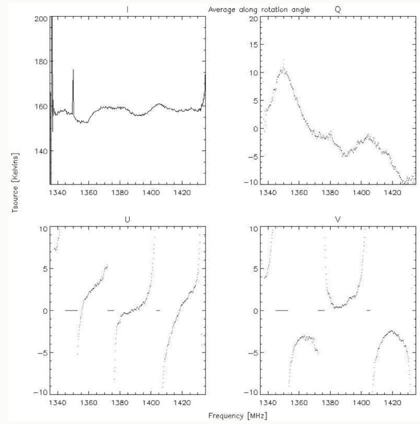
$$\phi = cos^{-1}\left[invariant \times \frac{1+\epsilon^2}{2\epsilon}\right]$$

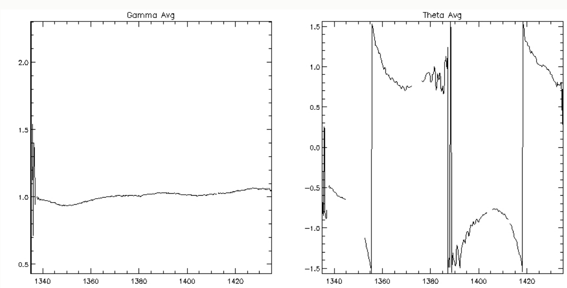
$$temp = \sqrt{\left(1 - cos^2(\phi)\left(\frac{2\epsilon}{1+\epsilon^2}\right)^2\right) \times \frac{invariant+1}{invariant-1}}$$

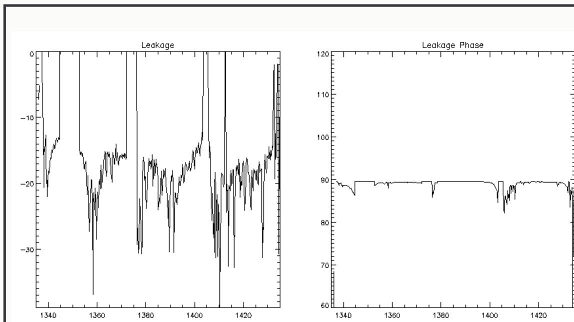
$$\epsilon = \frac{1-\sqrt{\frac{1-temp}{1+temp}}}{1+\sqrt{\frac{1-temp}{1+temp}}}$$











Future Work

Expand calibration of central pixel to the whole bandpass
Calibrate the other ALFA pixels