Differential Instrumental Polarization Calibration

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***Abstract*—The standard instrumental polarization calibration procedures for radio interferometers like the EVLA assume that both the instrumental and calibrator source polarizations are constant during the observations and among sources and use the different effect of parallactic angle to separate the two. At the upper frequency range of an instrument, the assumption of constant instrumental polarization may be invalidated due to flexure in the mechanical structure. This memo describes a technique which can correct for residual instrumental polarization that is common to all antennas. An example is given from observations at low elevation at the top of the VLA frequency range showing strong time variations in instrumental polarization. These results show a strong correlation with source elevation and are suggestive of a gravity induced effect and the possibility that standard corrections as a function of elevation and frequency may correct the bulk of the observed variations.**

***Index Terms*—interferometry, calibration, polarimetry**

I. Introduction

THE polarization state of incoming signals can be readily measured by radio interferometers. One of the real world complications is that, due to imperfections in design and construction, an instrument will give a false polarized response to an unpolarized signal; this is referred to as instrumental polarization. A standard part of data calibration is to characterize and remove the spurious polarized response. In general, neither the polarization state of the calibrator nor instrument is known in advance but the difference of the instrumental response with the parallactic angle of the observation can be used to separate them. Thus, if both the calibrator and instrumental polarizations are constant, observations over a range of parallactic angles can be used to separate them. Under some circumstances, the assumption of constant instrumental polarization breaks down and the standard technique becomes inadequate. This memo describes an approximate correction for the residual instrumental polarization implemented in the Obit package [1] [1].

II. Standard Instrumental Polarization

Detailed discussions of instrumental polarization is given in [2] and [3]. The standard instrumental calibration assumes that both instrumental and calibrator contributions to the observed polarized signal are constant over the course of the observations. In the general case that neither the calibrator nor instrumental polarizations are known, the difference in response of these effects to the antenna parallactic angle for antennas with alt-az mounts and observations over a range of parallactic angle can be used to separate instrumental from source polarization. Application of instrumental polarization corrections also generally assume that the correction is constant with tiime and observing geometry. This procedure breaks down if there are time and/or observing geometry variations in the antenna polarization response.

III. Differential Calibration

For a homogeneous array such as the EVLA, we assume that the standard instrumental polarization calibration removes the bulk of the antenna specific effects but allows time and/or observing geometry variations common to all antennas due to such effects as gravity, wind loading, differential solar heating of the structure, etc.

Under the assumption that antenna specific corrections have been made, there may be a variable deviation of the array polarization response which can be expressed as a residual fractional polarization; that is there are additive Q and U components to the measured signal that are proportional to Stokes I. Any such effects will be visible as temporal variations in the array average polarized response.

Differential corrections can be applied after standard instrumental polarization calibration. If a calibration source of known polarization close on the sky to a target source is observed with scans interspersed with the target, it can be used to estimate the residual instrumental polarization as a function of time and/or frequency. These residuals expressed as a fractional Q and U can be used to correct the target source.

IV. Implementation

Differential instrumental polarization calibration is implemented in the Obit Task DPCal. DPCal can be used to calibrate a source using a nearby calibrator of known polarization which is assumed to suffer the same residual instrumental polarization effects as the target. Data are assumed to have standard polarization calibration applied. The calibrator polarization model is used with the calibrator data to estimate a time and frequency dependent series of array residual fractional Q and U (ratio to Stokes I). These estimates are the used with the observed target Stokes I to estimate and remove the residual instrumental Q and U and a corrected dataset is written.

V. Example

The following gives results on a unresolved, weakly polarized target and nearby calibrator pair observed by the EVLA in Q band at low elevations. The data covered the frequency range 40.6 to 48.7 GHz or the highest frequency range for which the VLA antennas are usable. These data should be sensitive to any gravity induced changes in the antenna polarization properties.

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[1] http://www.cv.nrao.edu/∼bcotton/Obit.html

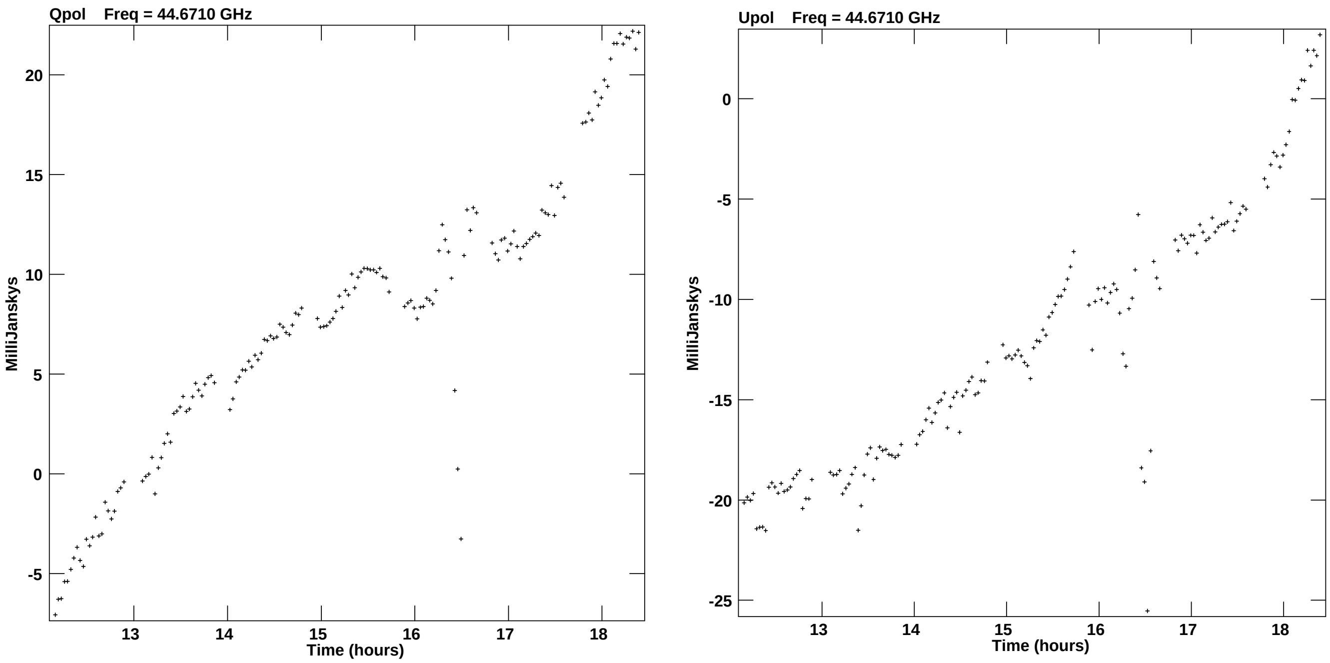

Fig. 1. Target source at 45 GHz with standard calibration. On right is average Stokes Q as a function of time; on left is Stokes U.

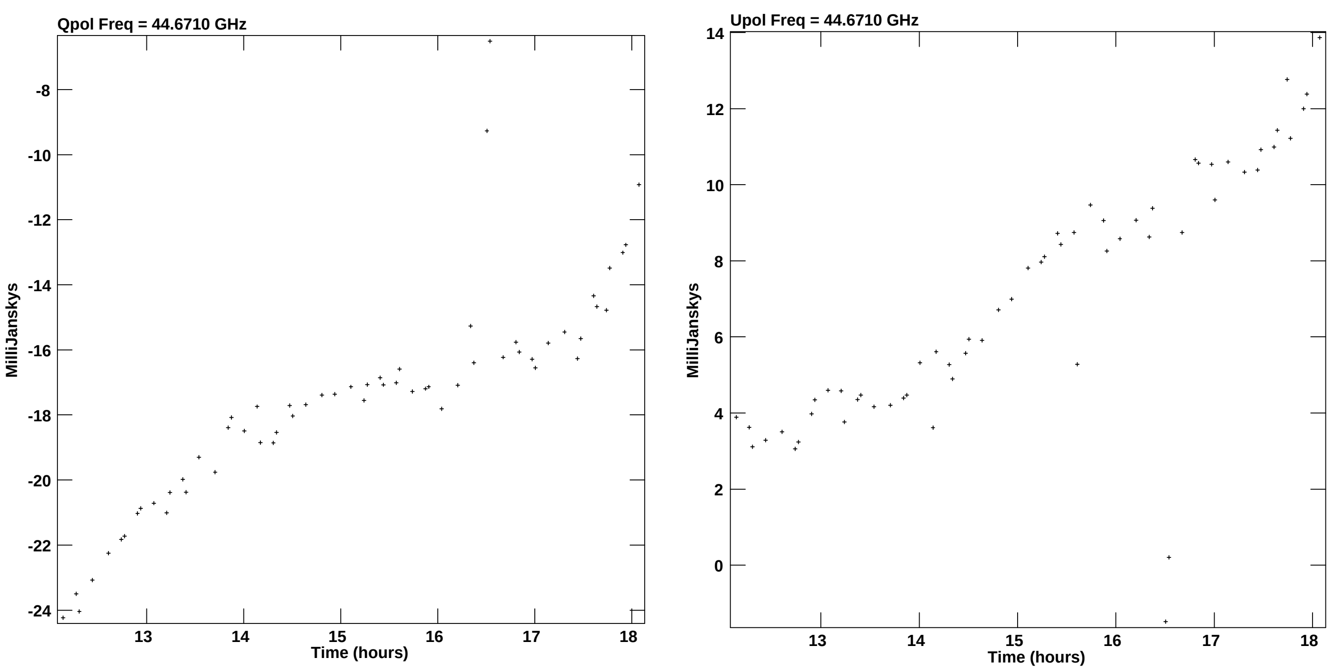

Fig. 2. Like Fig 1 but a nearby calibrator.

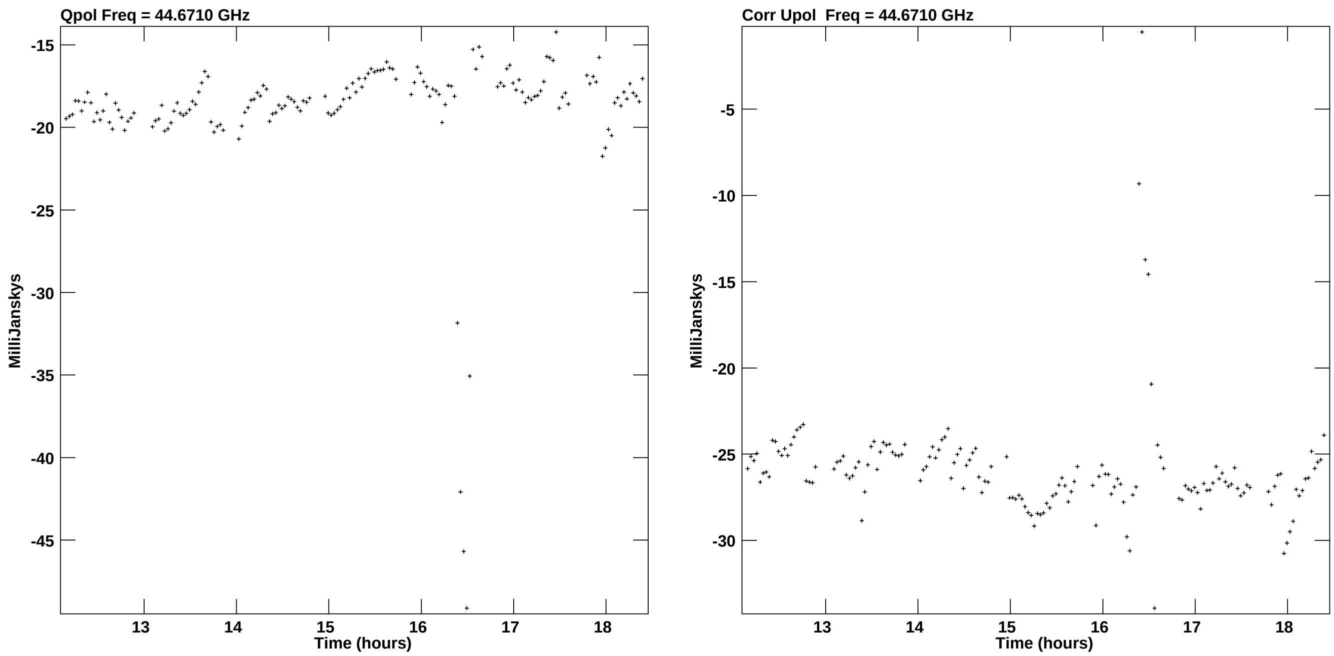

Fig. 3. Target source after differential calibration.

A. Residual polarization as a function of Time

Figures 1 and 2 show the average Stokes Q and U following normal polarization calibration as a function of time. Both sources show strong variations in time with the curves having the same shape. Differential instrumental polarization calibration was performed assuming the true calibrator Stokes Q was -16.8 mJy and Stokes U was 6.0 mJy. After differential calibration, the same data are shown in Figures 3 and 4. The values for both sources are basically flat in time indicating the removal of time variable residual instrumental polartization.

B. Residual polarization as a function of Elevation

The frequency averaged residual instrumental fractional polarization used for the corrections shown in Figures 3 and 4 are plotted in Figure 5 as a function of elevation. The fractional Q+iU was rotated to remove the effects on instrumental polarization of the calibration process to return the values to the antenna frame. These plots show a strong, nearly linear relation between the residual fractional polarization and the elevation suggesting the effect is largely caused by the flexure of the antenna due to gravity.

VI. Discussion

The strong correlation of residual fractional Stokes Q and U with elevation seen in Figure 5, and the largest residuals being at lowest elevation, strongly suggest gravity induced variations in EVLA instrumental polarization at low elevations and the highest frequencies. If this effect is shown to be a constant function of elevation and frequency then standard elevation/frequency dependent corrections may be possible.

References

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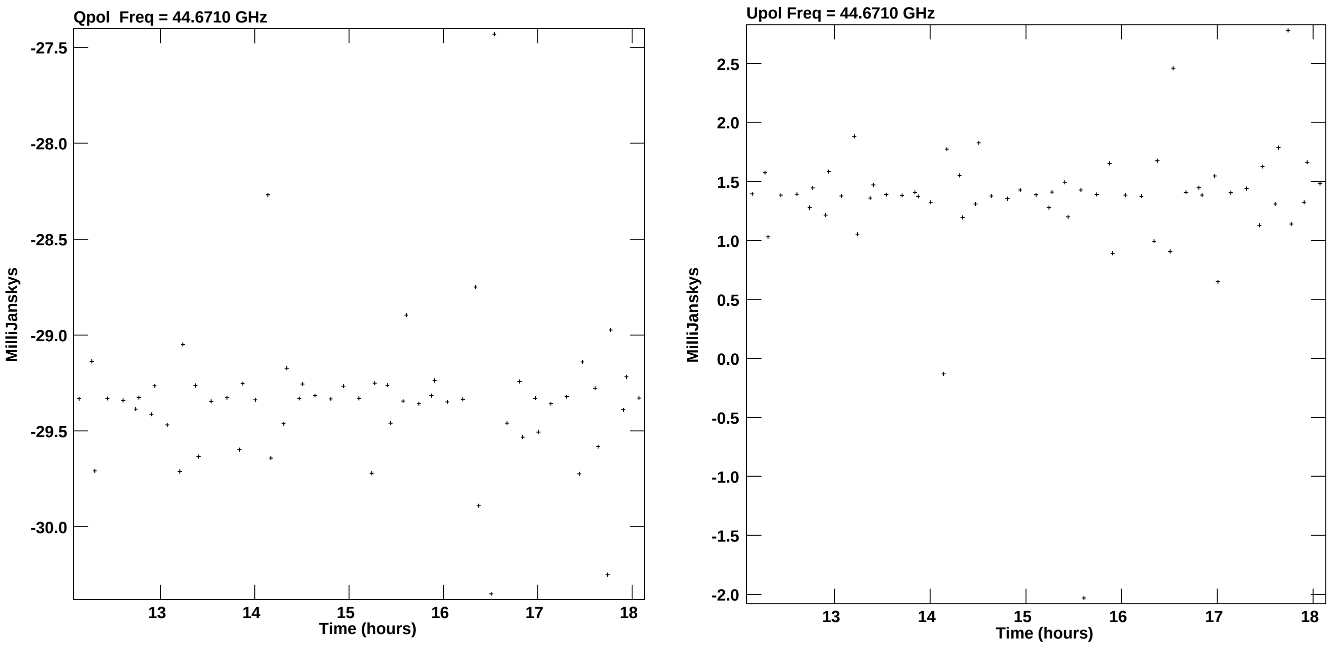

Fig. 4. Like Fig 3 but nearby calibrator.

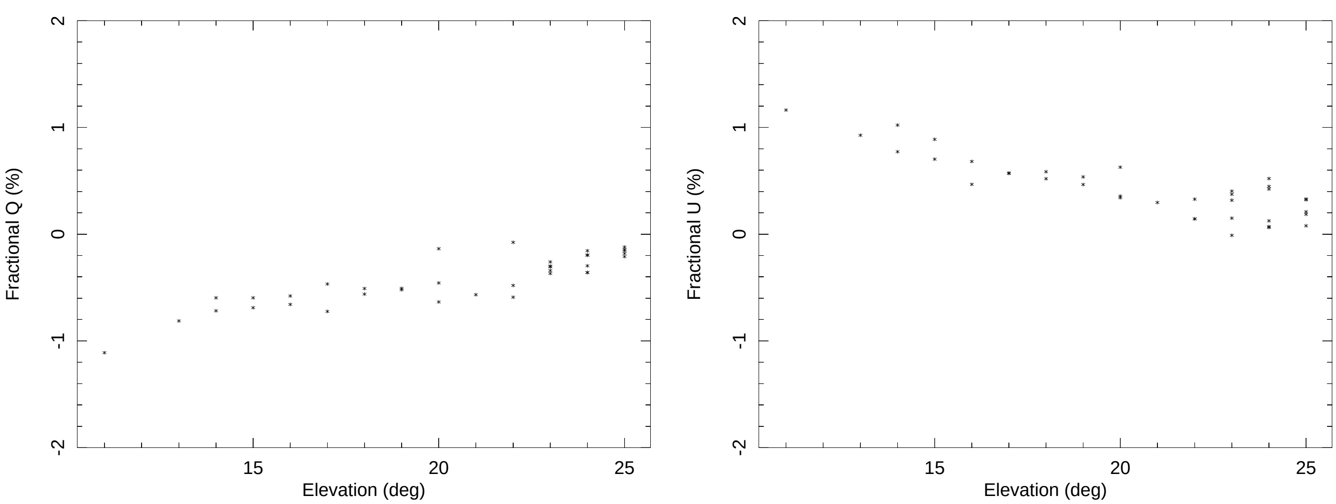

Fig. 5. Frequency and antenna average residual fractional polarization as a function of elevation. Stokes Q on left, U on right. The calibrator rises and sets during the observations. Q+iU rotated by 2*parallactic angle.