full-Stokes polarimetry with circularly polarized feeds
Linear and circular polarization standard sources in the GHz regime

High-precision linear and circular polarimetry with the 100-m telescope

We present a polarimetric data analysis pipeline which can be used to recover the linear and circular polarization properties of point-like sources in the radio window. The methodology presented here was developed using data obtained with the 4.85-GHz and 8.35-GHz receivers of the 100-m Effelsberg telescope, equipped with two circularly polarized feeds and it is then immediately applicable to this type of receivers. Our methodology eliminates a number of systematics bringing the uncertainty to levels as low as 0.1% for linear polarization degree, 0.5° for polarization angle and 0.2% for circular polarization degree measurements.

New features

Instrumental linear polarization correction

The observing system introduces spurious signals in the receiver channels responsible for the Stokes \(I\) and \(V\) measurements. These signals are the manifestation of the instrumental linear polarization and they can either (a) create fake polarization measurements for unpolarized sources, (b) obscure weak polarization signals present or (c) modify the polarization signal of polarized sources.

We use the Stokes \(I\) and \(V\) datasets obtained from linearly unpolarized sources to create an instrument model for every observing session (Fig. 3). This model is then used to compute the expected shape and amplitude of the instrumental polarization signals for each measurement. Finally, the modeled signals are subtracted from the observed ones at the first step of our pipeline (Fig. 1).

Extracting the observables

The observables, i.e. the amplitude, the full width at half maximum and the peak offset of the telescope’s response for each measurement are extracted by a fitting operation. We investigated different beam pattern models in order to optimize this procedure. Our results show that the Airy disk pattern, i.e. the diffraction pattern of a circular aperture:

\[ I = I_0 \left( \frac{2 \pi a}{\lambda} \right)^2 \]

describes the whole area of the dataset with high accuracy (Fig. 3). This approach is essential for our Stokes \(I\) measurements, i.e. the difference between the LCP and RCP channel amplitudes, due to the low intrinsic circular polarization degree of the sources (~0.5%).

Instrumental circular polarization correction

The instrumental circular polarization is manifested by a systematic offset of the Stokes \(I\) measurements as well as the significant correlation at time lag 0 between the Stokes \(I\) light curves of sources which are expected to be stable (Fig. 4).

Under the assumption that the instrumental circular polarization is caused by an imbalance between the LCP and RCP receiver channel gains, we use the Stokes \(I\) measurements of sources which are expected to be stable to restore the gain balance.

Linear and circular polarization standard sources

The consistency of our polarimetric methodology is tested with the study of the linear and circular polarization of the most stable sources in our sample. In Fig. 5 we show the boxplots of their linear and circular polarization parameter distributions. The corresponding expectation values can be used for further calibrating polarization measurements performed with other telescopes at similar radio frequencies. Here, we report both circularly polarized and unpolarized sources since both are needed for polarization data reduction. Usually, the former are used to subtract instrumental effects and the latter to calibrate the datasets and quantify their variability.