Acoustic astrometry with a VLBI-like interferometer

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Abstract

We show how loud speakers, home digital recorders, and common personal computers can be used to emulate VLBI observations at a small scale. These audio-VLBI observations allow for single-field astrometry (sources within the same interferometric field), differenced group-delay astrometry, etc. These experiments can be set up very easily and in many possible configurations. Students may find these experiments very useful to learn about the innermost details of the interferometric technique.

Experimental setup

We performed VLBI-like observations using, as signal, sound waves generated by two stereo loud speakers separated by a distance d (left side of Fig. 1). We used home digital audio recorders, located at a distance D from the speakers, as receiving antennas (right side of Fig. 1). Our interferometer consisted of 10 identical antennas, ordered by us in the East-West direction at random distances. The recorded audio signals were treated following all the usual steps of real VLBI data (down-conversion from the observing frequency, Nyquist sampling, amplitude digitization, phase rotation, correlation, Van Vleck correction, amplitude calibration, and fringe fitting).

1. SINGLE-FIELD ASTROMETRY

When the signal bandwidth is narrow enough (10 Hz, with the central frequency at 3 KHz, in our case), for an appropriate geometry (d = 0.5m and D = 2m, see Fig. 1) the signals from both speakers will fall within the same fringe. Thus, the resulting visibilities will correspond to the Fourier transform of a double source. In Fig. 2, we show spectral plots of visibility amplitudes and phases for some example baselines, resulting from an FX correlation. In Fig. 3, we show the fringe, in delay space, resulting from an XF correlation of the data coming from antennas 1 and 2. The plot of correlated amplitudes vs. baseline length (Fig. 4) shows a clear modulation produced by the double source.

Due to the relatively high central frequency (3 KHz) and our low visual precision of the alignment of the signals in delay space, we need to fringe-fit the visibility phases prior to Fourier inverting into the “sky” plane.

As shown in Fig. 5, after performing Global Fringe Fitting and one Hybrid Mapping iteration to the data, we recover a “sky” map with a clear double source, (note that we have also synthesized resolution in the North-South direction). Given that we know the true angular separation of the speakers, we can use the measured source separation in the map for fitting the free parameters of the geometric model of our interferometer.

In our case, the only free parameter is the speed of sound (the fit results in an estimate of ~350 m/s).

2. GROUP-DELAY ASTROMETRY

For a wide signal bandwidth (22KHz centered on 11KHz, in our case) the signal from each speaker generates its own fringe (i.e. the interferometer sees two single sources, instead of one single double source). Each speaker produces its own set of visibility phases. We can separately perform Global Fringe Fitting to the signals coming from each speaker and compute, for each baseline, the difference (group) delays. The latter are the time separations between the fringe peaks generated by both signals.

Conclusions:

We have shown that it is possible to perform realistic VLBI emulations using sound waves as signal, home digital recorders as antennas, and a common personal computer as correlator. The observations can be carried out under a large number of different configurations: using the same or different clocks for the recorders, changing the sound pitch, adding spectral lines (i.e. tones) to the continuum, moving the sources during the data acquisition, etc. The educational capabilities of these hands-on experiences appear promising.