VSRT MEMO #003

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To: VSRT Group
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Subject: Sign ambiguity in the closure phase

The "closure" phase is given by

$$\phi_c = \phi_{01} - \phi_{02} + \phi_{12}$$

where ϕ_{01}, ϕ_{02}, ϕ_{12} are the interferometer phases on baselines 01, 02, 12 formed by a triangle of station 012.

The key property of the closure phase is that it is independent of the station atmosphere and local oscillator phases. This was first realized by Jennison (1958). It was further independently developed by Rogers et al (1974) for VLBI and given the name "closure" phase. While the closure phase is extensively used in VLBI it is now being used at optical wavelengths where atmospheric and instrumental phase errors are much more severe. There is a strong connection between closure phase and "self-cal" (see Cornwell 1987) of instrumental phases in aperture synthesis. Since the closure phase is largely free of instrumental errors it can be used to model source structure and remove the ambiguity in structure modeled with visibility amplitudes alone.

Properties of closure phase

1] Symmetric source

Any source which has point symmetry has closure phase of zero or 180˚. [Any figure with point symmetry is unchanged when rotated by 180˚]

2] Triangle rotation

Rotation the triangle by 180˚ reverses the sign of the closure phase.

3] Station identification exchange

Reordering the stations can only result in the same closure phase or a change in sign.

If 3 antennas are connected to the VSRT power combiner the 3 baselines show as 3 spectral lines in the spectrum of the detector output. If the antennas are not identified we can still calculate a closure phase as follows

$$\phi_c = \theta_0 + \theta_1 - \theta_2$$

where ϕ_0, ϕ_1, ϕ_2 are the phases of the spectral lines which are ordered in increasing frequency. For example, if the L.O. offsets are 10, 100, 300 kHz for stations 0,1,2

$$\theta_0 = \phi_{01}$$
$$\theta_1 = \phi_{12}$$
$$\theta_2 = \phi_{02}$$

so that

$$\phi_c = \phi_{01} + \phi_{12} - \phi_{02}$$

Even if we haven't identified the L.O. offset of each LNB we can calculate a closure phase with only an ambiguity in sign. If we identify the L.O. offset for each LNB we will still need to know the sign of the offset to avoid having a sign ambiguity in the closure phase.

Figure 1 shows the spectrum of 3 LNBs about 3 feet from a compact fluorescent lamp (CF20/s/41K). The signals from the 3 baselines are at 210, 453 and 663 kHz. The signal at 95 kHz is from the modulation produced by the electronics in the lamp. These frequencies have to close that is

$$f_0 + f_1 - f_2 = 0$$

where f_0, f_1 and f_2 are the frequencies in increasing order. The closure phase was measured and found to be zero within the noise. At this time the only method I have found to determine the correct sign of the closure phase is to measure the L.O. frequencies with a spectrum analyzer to determine the sign of the L.O. offsets. Clearly this is not practical outside of a well equipped lab so that other methods will need to be investigated.

Candidates are:

1] Using the LNB "turn on" drift

2] Using an artificial double source with 2 compact fluorescent lamps.

3] Examining 3 baseline data on the Sun to find a sign of the closure phase consistent with the solar image from the web.

References:

Jennison, R.C., 1958, MNRAS, 188, 276

Rogers, A.E.E. et. Al., 1974, Ap.J., 193, 293

Conwell, T.J., 1987, A&Ap., 180, 269.

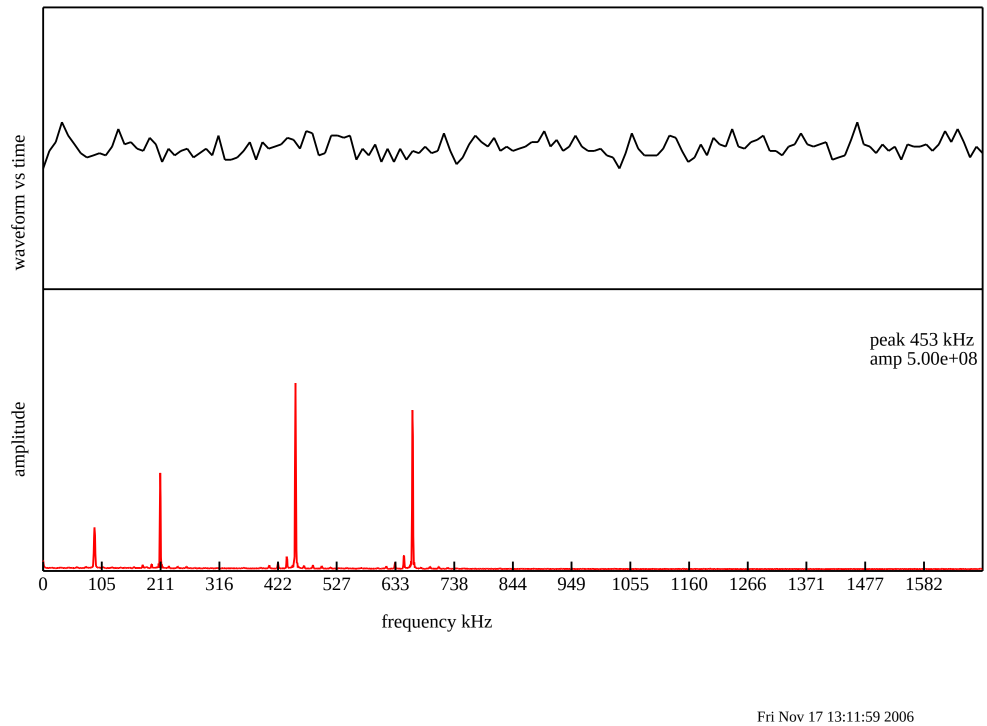

Figure 1. Fringes from 3-LNBs using fluorescent lamp as a source of radio emission.