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New Simulation Software for VLBI Observations

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Abstract. This is a report on simulation software for VLBI observations. The software is part of the `ASL for Windows` project. It implements a new class of mathematical algorithms that allow a user to completely simulate any VLBI observation on the MS Windows platform. In particular, these are simulations of the interferometer structure, simulations of a radio source structure, and simulations of the noises. The possibility to introduce any new radio telescopes including space radio telescopes is also explored and presented in this software. The software is extremely user friendly.

1. Introduction

Investigation of astronomical radio sources with VLBI method often requires to create the simulated VLBI-data. At least three problems could be solved with VLBI-data simulator:

1. The creation of schedule for any future VLBI observation
2. The evaluation of results of future VLBI observation in advance
3. The evaluation of Space VLBI data processing results.

Thus, it is necessary to create some algorithms of VLBI data synthesis. The initial data of these algorithms are the geocentrical coordinates of antennae, and also `Right Ascension` and `Declination` of sources observed. If the source structure is known in advance, it is not a problem to estimate the values of visibility function for any time, any frequency, and any baseline. The main principle of such calculation is that any interferometer is, in fact, a 3-dimensional Fourier transformer.

Hence, the `Astro Space Locator` (Chuprikov 2002) VLBI-data simulator consists of 3 parts:

1. The simulation of (u, v)-plane (VLBI Configuration Modeling)
2. The simulation of structure of the source to be observed (Source Modeling)
3. The simulation of visibility amplitude and phase noises (Error Modeling).

2. The simulation of the (u, v)-plane

As mentioned above, we use some a priori data to simulate the baseline motion. The VSOP continuum source list (Fomalont et al. 2000) has been included into

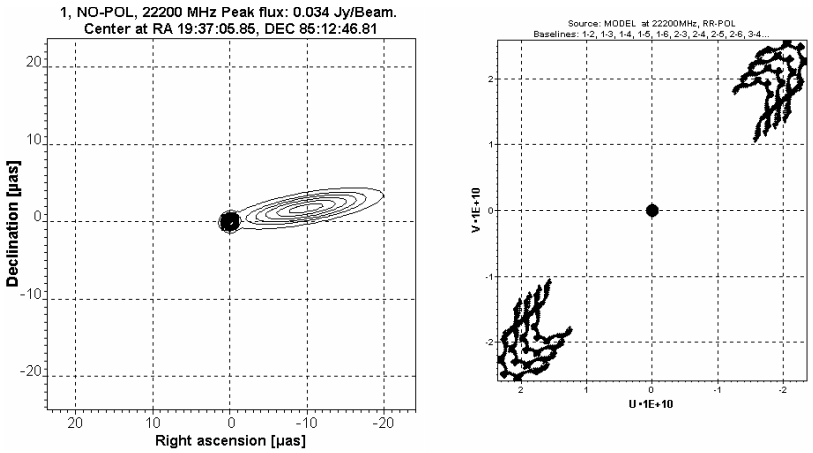

Figure 1. Model of Source (left) and model of (u, v)-plane coverage (right).

our simulator. Moreover, the user could simply insert the source coordinates manually if necessary.

We use the extended NRAO list of antennae with their coordinates, effective area values and noise parameters. The user could insert any new ground as well as new space antenna into this listing manually if necessary. List of antennae contains data for 126 scopes for today.

There is a possibiltty to install manually any `time structure` and `frequency structure`, and any `polarization type` of data simulated. The current version of `ASL Simulator` is able to synthesize the VLBI data for any of 12 radio astronomical frequency ranges (`3 mm, 7 mm, 1.35 cm, 2 cm, 2.4 cm, 4 cm, 6 cm, 13 cm, 18 cm, 21 cm, 50 cm, 92 cm`), and for any of 12 polarizations (`RR, RL, LL, LR, XX, XY, YY, YX, I, Q, U, V`)

3. The simulation of the astronomical radio source

The radio structure of source simulated is determined by user. The user has to choose the number of components and properties for each of them. These properties are : the `Flux Density` value (in `Jy`), the `Large Axis` value (in `Arcsecond`), the `Axes ratio` value, the component `Inclination` value (in `Degrees`). Location of component in the image plan depends on the `Position Angle` (in `Degrees`), and the `Distance` from the centrum (in `Arcsecond`). Another important parameter is a type of component. There are the following component types :

1. Gaussian
2. Disk
3. Thin Ring
4. Thin Sphere
5. Rectangle

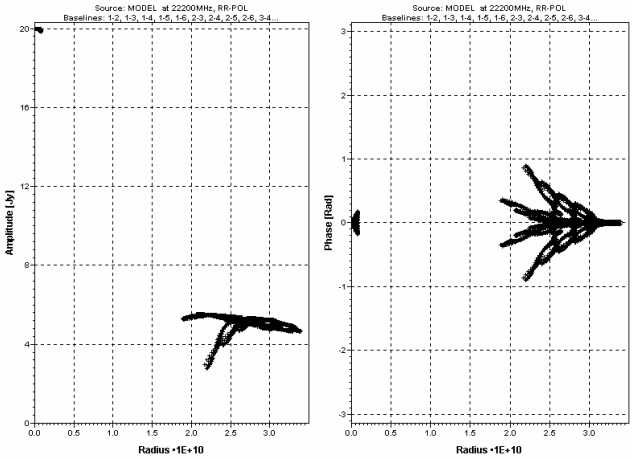

Figure 2. The visibility simulated amplitude (left) and phase (right).

We use the stadard Fourier transformation equations to make all necessary estimations for each type pointed above. The source structure could be directly laid on the :

1. (u, v)-plane has already been simulated (see `paragraph 2`)
2. (u, v)-plane has been read from `any available UVX-file`

The transformation between `FITS` and `UVX` format is very quick and easy. Thus, our software allows the user to lay any created source structure on any real (u, v)-plane. The comparison of real visibility with synthesized one should be very useful.

4. The simulation of the noise

The user has to install :

1. the `Input UVX-file` containing the visibility has already been simulated
2. the `Output UVX-file` will contain the same visibility with noises
3. the level of `Phase Noises` in `Degrees` for each antenna
4. the level of `Amplitude Noises` in `dB` for each antenna

This simulation allows to evaluate the influence of noise and to develop some methods to decrease it.

5. An example of VLBI data simulation

Figure 1 shows the simulated radio source consisting of two Gaussian functions. This is a good model for the "core-jet" source. The (u, v)-plane for the `"Radioastron"` Space VLBI observation is shown in the right picture. We supposed to use 5 VLBA antennae (HN, MK, OV, PT, SC) in this experiment. Wavelength range is 1.35 cm. Source is close to the perpendicular to the current orbit plane direction. Coordinates of source are :

Right Ascension 10 h 37 m 06 s

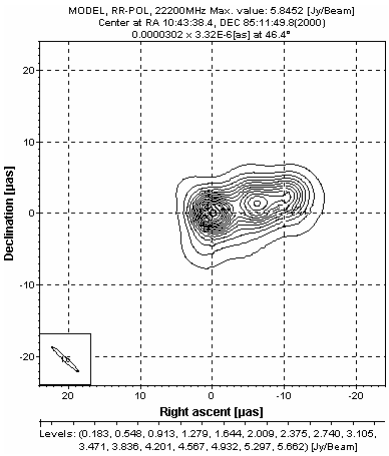

Figure 3. The reconstructed source image (`CLEAN MAP`).

Declination +85:12:46

The orbit has high apogee (approximately 360000 km). Perigee is about 19000 km, and the orbit period is about 11 days.

VLBI observation is between 3-d and 8-th day after perigee and the Integration Time value is supposed to be equal to 1 hour.

Figure 2 shows the simulated amplitude and phase of visibility. Figure 3 shows the reconstructed image of source simulated.

6. Conclusions

The VLBI-data simulator presented above is a part of the software titled `Astro Space Locator (ASL for Windows)`. Our main goal is to give another possibility for any VLBI-data processing to astronomers who prefer to deal with PC-computers. The ASL software is free and could be easily installed. It is availabe in the Internet (see `http://platon.asc.rssi.ru/DPD/ASL/asl.html`).

Development of the `Astro Space Locator` software is continuing.

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