LOFAR Simulator and Array Development

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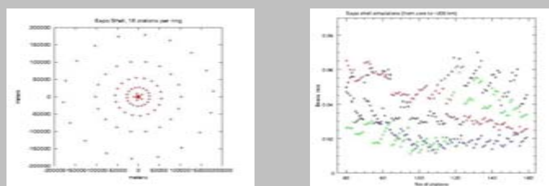
The Low Frequency Array (LOFAR), still in development, is an example of a next-generation radio interferometer array. The new design is intended to expand the lower range of radio frequencies available for observation and to provide scientists with a highly flexible, sensitive and robust observational tool. Since the array differs substantially from the design of current radio telescopes, effects that can be ignored with current instruments become critically important to the performance of the new array. The Haystack group has developed a software simulator to model the roles these effects play in the telescopes' performance. Recently, tests were conducted on a variety of LOFAR array designs, including layouts tailored specifically to the terrain of potential LOFAR sites. In addition, phase errors due to ionospheric effects are being introduced into the simulations.

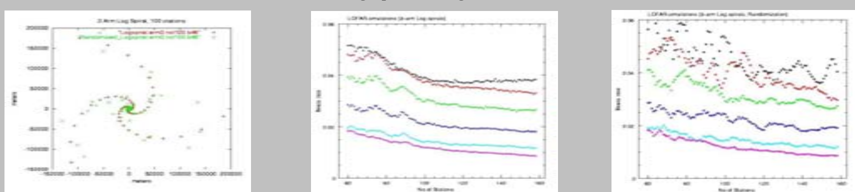
Potential Configurations

The two basic configurations under consideration are the logspiral and the exposhell. Both layouts are largely scale-free and conform to LOFAR design specifications that 25% of the stations lie within 2 km of the center of the array, 50% lie within 12km, and 75% lie with 75 km. Randomization of logspiral station locations was based on stations' distances from the center of the array and from other stations in adjacent spiral arms. While a logspiral randomized in this manner may not strictly conform to the LOFAR station distribution requirements, it does provide more extensive uv-plane coverage.

Expo Shell Configuration



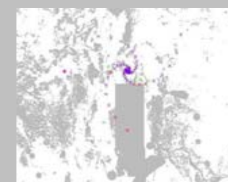
Log Spiral Configuration



Testing Candidate Sites

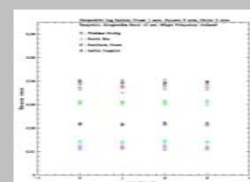
There are several potential LOFAR sites in the Netherlands, western Australia and the southwestern United States. ASCII maps of each region have been generated that highlight areas with high levels of man-made radio interference, vertical inclines of greater than 2%, and natural obstacles presented by oceans and seasonal floods. The Haystack configuration editor superimposes a given antenna configuration on a specified LOFAR location. The entire array can be rotated and transposed to avoid obstacles; in addition, it is possible to manually relocate individual stations. Symmetric and asymmetric 1-, 3- and 5-arm logspirals were tailored to each candidate site using this technique. As illustrated by the rms plots below, the western Australian sites performed best overall.

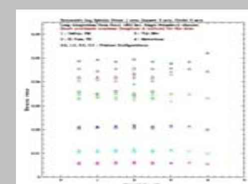
Western Australia

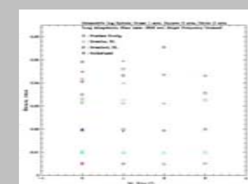


Southwestern United States

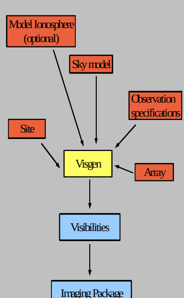
Netherlands





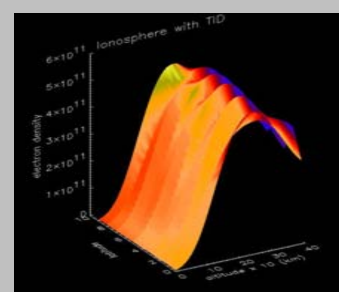


Simulator Flow Chart



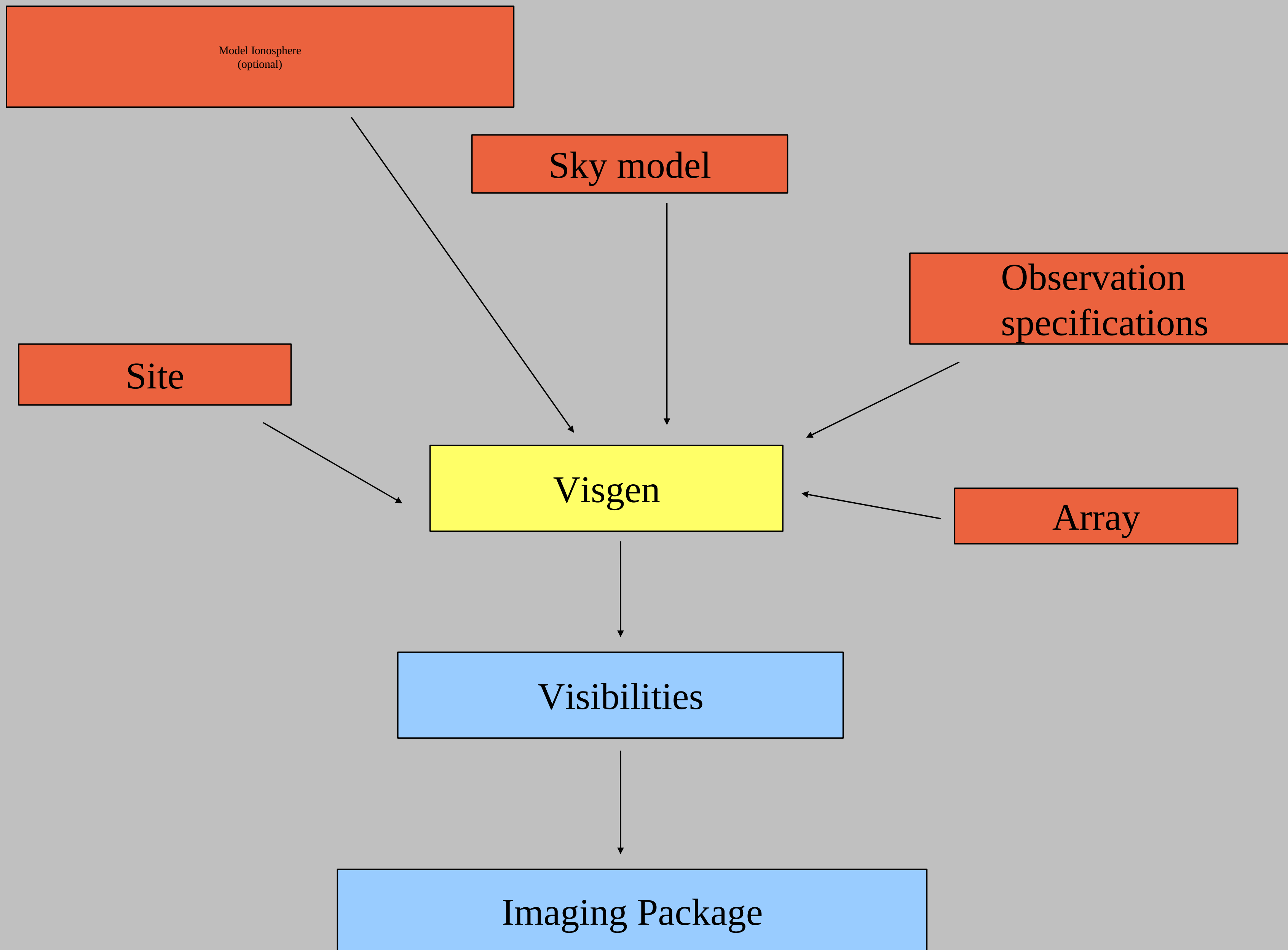
The current LOFAR simulator takes a sky model, observation specifications, an array configuration and an array site, which it uses to calculate the visibilities that the array would record. The most recent version of the simulator, which is still in development, also takes a 3D time-varying ionospheric model. From the visibilities generated by the simulator a measurement set is created, which is subsequently reduced to a FITS file by AIPS++. The code has been parallelized to run on a twenty node beowulf cluster, but it is also capable of running on a single machine.

Incorporating Ionospheric Effects



TID snapshot at a fixed latitude

The refractive index of the ionosphere is inversely proportional to wavelength. While traditional radio telescopes operate at sufficiently large frequencies to render the amount of refraction insignificant, LOFAR will encounter non-trivial signal delays and phase shifts. In addition to complications introduced by the stationary ionosphere, transient travelling ionospheric disturbances (TIDs) introduce sinusoidal variations in the ionospheric electron density.


Model Ionosphere
(optional)
Sky model
Observation
specifications
Site
Visgen
Array
Visibilities
Imaging Package