OSKAR station simulator: Modes of operation

This document describes the proposed modes of operation of the OSKAR beamformer simulator. A mode of operation defines the type of functionality the user is expecting from the simulator, and as a result, specifies the setup options, input parameters, outputs and post processing available.

At the first level, the mode of operation can be split into two distinct categories: diagnostic and full simulation (beamforming) mode. While these provide a clear distinction in functionality, in order to simplify the simulator and avoid presenting the user with a multitude of redundant options, a second level of operational mode is defined (see figure 1 below).

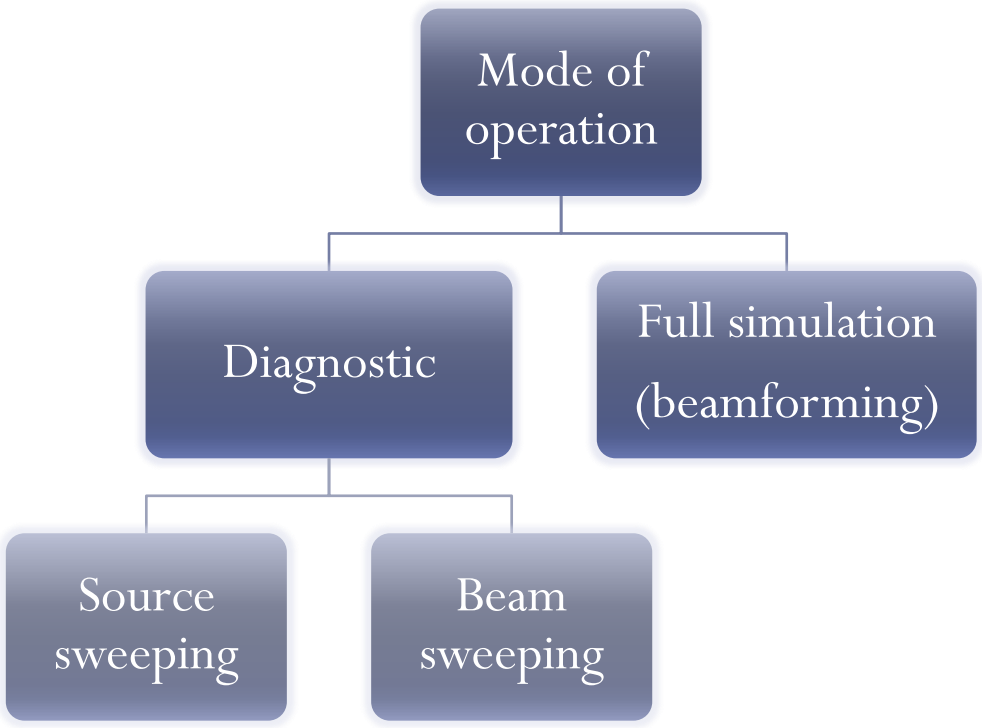

Figure 1 - Modes of operation

1 Diagnostic mode

The diagnostic mode of operation provides the user with the ability to investigate the properties of the beamformer setup, beamforming algorithm and configuration of the station. The simulator consists of two types of diagnostic operation: source sweeping and beam sweeping.

In Diagnostic mode:

- The simulator is run to gain maximum information on the beamforming operation.
- The sky will be restricted to a simple, limited set of point sources.
- The user will have additional diagnostic and post processing information available (compared to running in full simulation mode) giving for example, beam width and maximum and average side lobe level.

1.1 Sweep source

Source sweeping mode allows the user to generate the single beam direction response as a test source is moved around the sky. This is, in many ways, analogous to finding the array factor.

- Source sweeping allows the user to generate the beam pattern as a function of direction in the sky and channel frequency, given a set of beamforming weights generated by a beamforming algorithm.
- The user must specify the station and/or tile configurations and beamforming algorithm to use.
- The user must specify a direction in which to generate the beam pattern and one or more frequency channels for which it is generated.

Output from this mode will be a beam response pattern; the contribution to a beam in a specified direction from a grid of test source locations placed evenly over the entire sky. The response pattern may both be visualised and used to generate diagnostic information on the beam quality as a function of beam direction, frequency of observation, beamforming algorithm and station configuration.

1.2 Sweep beams

Sweep beams mode allows the user to generate the beam pattern from a collection of sources by generating a large number of beams on a regular grid for a specific frequency channel. While in many ways this is similar to what can be done in the full simulator mode of operation, selecting to form a set of beams from diagnostic mode allows additional information about the beam pattern to be generated at the cost of restricting various input options and longer processing time.

This mode will be used for visualizing the snapshot multisource beam patterns along with full diagnostic information (and also could, for example, be used to generate movies of how beams might track around the sky)

- A simplified sky model is used, consisting of a small collection of point sources
- A very large number of beam directions are generated on a regular grid

Output from this mode will be a beam pattern and associated diagnostic information on the beam quality.

2 Full simulation (beamforming) mode

The full simulation mode allows the user to generate collections of complex beam amplitudes and/or images from the station.

In full simulation mode:

- The simulator attempts to simulate, as closely as possible, the operation of beamforming for an SKA station.
- The user specifies the station configuration, the sky model and a collection of beam directions and frequency channels to observe.
- The user specifies the method by which beams are formed.
    - The levels of hierarchy used in the computation.
    - The beamforming algorithms to be applied at each level.
- The user specifies any corruptions that should be introduced and accounted for.
- This mode will be optimized for throughput performance rather than generating auxiliary information on the quality of the beams.
- Additional diagnostic information on the beam patterns is not available in this mode.
- The choice of beam-channel product will likely have to be limited (although, as this is a function of processing power, at this stage we can only estimate this limit)
- This mode allows the possibility of some forms of post beam processing; for example, using a single station as an interferometer by correlating between sub-stations.

This mode of operation leaves open the possibility of extending the simulator to perform direction dependent sky corrections in the beamforming weights.

By generating images at the station at some suitable interval between beamforming operations, and comparing the sky image to a local sky model, a parameterization of the direction dependent, time varying, sky corruptions could be computed and then used for beam corrections in successive processing stages. This, in principle, could provide a method of ionospheric distortion correction and adaptive nulling of unexpected transient interferers during the beamforming, processes normally in the domain of imaging corrections.