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The technological challenges for the EISCAT-3D radar system

The radar system will be built in several stages as funding is provided. For the first stage, it will consist of three radar sites, each with 9919 crossed dipoles divided into 109 sub-arrays. On one of the sites, about half of the antenna will be equipped with transmitter units, giving about 5MW of total transmitter power. All of the sites will receive the scattered signal from the transmitted radio pulses, and at each of the antenna elements the signal will be digitised. This is done to be able to point the whole collective antenna into about 100 different directions simultaneously. This puts a large challenge onto the hardware and software.

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The data will go through several steps before it's ready as a scientific product, each of them demanding large resources: two stages of beam forming, a 1D profiling with first analysis results, a 3D profiling with a full analysis, and a selection process of what will be finally stored in the data archives. As with all environmental data, all data is unique, and the with the richness of the EISCAT data there will be a continuously reanalysis done by the users for studies of different aspects.

The first beam former is taking the digitised signal from each antenna element at about 100MHz speeds, delaying the signal at 10 ps resolutions to steer the beam (look direction), mixing the signal down to base band, and filter it and re-sample it. The delays are individual for each antenna and ten simultaneous look directions are formed. This process is done using FPGA technique and needs very accurate timing given by the White Rabbit protocol. This is done separately for each of the 109 subarrays, and the data is going with high speed network into a central site server. Here is the 2nd beam forming unit, based on a CPU cluster, where each of the 10 beams are divided into further 10 narrow ones, making a total of 100 look directions. After the beams are formed a first analysis of the data is done via decoding of the signals and computing spectral components.

The data from the radar sites will be processed online at the Operations Centre, estimated for 500 Tflop/s processing and 20PB buffer storage, and used to simultaneously direct the radar and search directions. The challenge for this Operations Centre computing is to combine the data online from multiple sources into three-dimensional data products using tightly-coupled high-throughput computing. These data products must then be used to control the radar direction and the search directions of the receive sites.

The EISCAT_3D scientific programme encompasses many areas of study, one of the key areas being the Geospace Environment, ranging from troposphere out to the topside ionosphere some at 2000 km altitude, along with Climate change, Near-Earth object studies, Radio astronomy and Micrometeors. The Operations Centre computing must be able to react and adapt between the science cases in real-time as natural phenomena occur randomly and are not repeatable.

Summary

The EISCAT Scientific Association will establish a system of distributed phased array radars, EISCAT_3D, which is an environmental research infrastructure on the ESFRI (European Strategy Forum on Research Infrastructures) roadmap. Once assembled, it will be a world-leading international research infrastructure to study the atmosphere in the Fenno-Scandinavian Arctic and to investigate how the Earth's atmosphere is coupled to space. The use of new radar technology, combined with the latest digital signal processing, will achieve many times higher temporal and spatial resolution over larger volumes than obtained by present radars while offering continuous measurement capabilities.

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