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Revolutionising incoherent scatter science with EISCAT_3D: A European three-dimensional imaging radar for atmospheric and geospace research

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EISCAT_3D will be Europe's next-generation radar for the study of the high-latitude atmosphere and geospace, located in northern Fenno-Scandinavia, with capabilities going well beyond anything currently available to the international research community. The facility will consist of several very large active phased-array antenna transmitters/receivers, and multiple passive sites located in three countries. Depending on the available funding, EISCAT_3D will be comprised of tens of thousands, up to more than 100 000, individual antenna elements.

EISCAT_3D combines several key attributes which have never before been available together in a single radar, such as volumetric imaging and tracking, aperture synthesis imaging, multistatic configuration, improved sensitivity and transmitter flexibility. The use of advanced beam-forming technology allows the beam direction to be switched in milliseconds, rather than the minutes which it can take to re-position dish-based radars. This allows very wide spatial coverage to be obtained, by interleaving multiple beam directions to carry out quasi-simultaneous volumetric imaging. It also allows objects such as satellites and space debris to be tracked across the sky. At the passive sites, the design allows for at least five simultaneous beams at full bandwidth, rising to over twenty beams if the bandwidth is limited to the ion line, allowing the whole range of the transmitted beam to be imaged from each passive site, using holographic radar techniques. EISCAT_3D has a modular configuration, which allows an active array to be split into smaller elements to be used for aperture synthesis imaging. The result will be an entirely new data product, consisting of range-dependent images of small sub-beamwidth scale structures, with sizes down to 20 m.

EISCAT_3D will be the first phased array incoherent scatter radar to use a multistatic configuration. A minimum of five radar sites, consisting of two pairs located around 120 km and 250 km from the active site respectively, on baselines running East and South from the active core, is enivisaged. This provides an optimal geometry for calculation of vector velocities in the middle and upper atmosphere. The gain of the EISCAT_3D antennas and the large size of the active site arrays will deliver an enormous increase in the figure-of-merit relative to any of EISCAT's existing radars. An active site of 5,000 elements would already exceed the performance of the current EISCAT VHF system, while an active site comprising 16,000 elements, as suggested in the Design Study carried out from 2005 to 2009, will exceed the sensitivity of the present VHF radar by an order of magnitude.

Each transmitter unit will have its own signal generator, allowing the generation and transmission of arbitrary waveforms, limited only by the available transmission bandwidth and spectrum allocation by the frequency management authorities. This unique innovation allows the implementation of all currently used and envisaged modulation schemes and antenna codings (such as polyphase alternating codes, array tapering, orbital angular momentum beams) and also provides the possibility to adopt any kind of future code. In addition, it will allow advanced clutter mitigation strategies such as adaptive null steering and null shaping.

In this talk the upper atmosphere and geospace science case for EISCAT_3D is reviewed. Studies of the atmospheric energy budget, space plasma physics with both small-scale structures and large-scale processes, as well as geospace environment monitoring and possible service applications are reviewed, showing recent highlights from the current EISCAT incoherent scatter radars for comparison.