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EISCAT_3D: A European three-dimensional imaging radar for atmospheric and geospace research

EISCAT_3D will be Europe's next-generation radar for the study of the high-latitude atmosphere and geospace. The facility will be located in northern Fenno-Scandinavia, with capabilities going well beyond anything currently available to the international research community. Several very large active phased-array antenna transmitter/receiver arrays, and multiple passive sites will be located across three countries. 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 envisaged. 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.

Implementation of all currently used and envisaged modulation schemes and antenna codings (such as polyphase alternating codes, array tapering, orbital angular momentum beams) is possible, as well as adaptation to any kind of future codes. In addition, it will allow advanced clutter mitigation strategies such as adaptive null steering and null shaping.

The science case of EISCAT_3D is versatile, ranging from global change related studies of the atmospheric energy budget and coupling of atmospheric regions to space plasma physics with both small-scale structures and large-scale processes, as well as planetary and meteor radar applications. Additional societal value is in opportunities for continuous geospace environment monitoring and possible service applications to users needing information on space debris and space weather.

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