EISCAT Scientific Association
Technical Specification and Requirements
for
Antenna Unit
V 2.0

---

1. Technical Specification for Antenna Unit

The EISCAT Scientific Association, also called "EISCAT" throughout this document, conducts research on the lower, middle and upper atmosphere, and ionosphere using the incoherent scatter radar technique. EISCAT is conducting a project called EISCAT_3D where the final product is a new system which will be a next generation incoherent scatter radar capable of providing 3D vector monitoring of the atmosphere and ionosphere.

Purpose

The purpose of this document is to describe the technical requirements for the Antenna Unit, which consist of an antenna array with supporting structures, cables and temperature-controlled containers for electronics.

Application

The document is used as the technical specification for the procurement of the Antenna Unit. Note that this document describes logical interfaces and the actual system design is up to the vendor. If an interface does not have requirements allocated to it, the interface design and implementation is up to the vendor.

Revision History

Version 2.0, 2018-01-25 / Harri Hellgren

Items changed	
SS_AU_01_04,05	Removed
SS_AU_02_06	Complement
SS_AU_02_11	Complement
SS_AU_02_12	Complement
SS_AU_03_01	Complement
SS_AU_03_12	Rephrased with SS_AU_03_13
SS_AU_03_14	Rephrased
SS_AU_04_01	Completed
SS_AU_04_02	Rephrased

Items changed	
SS_AU_04_03	Rephrased
SS_AU_04_04	Completed
SS_AU_04_05	Rephrased
SS_AU_04_06	Rephrased
SS_AU_04_07	Rephrased
SS_AU_04_09	New requirement
SS_AU_04_10	New requirement
SS_AU_05_01	Rephrased
SS_AU_05_02	Rephrased
SS_AU_05_03	Rephrased
SS_AU_05_06	Rephrased
SS_AU_05_01	Completed
SS_AU_06_02	Completed

1.1. System Description

This chapter contains a short system description for the EISCAT_3D system. More information is available in separated documents.

Stage 1 of the EISCAT_3D implementation shall comprise three sites in northern Norway, Finland, and Sweden. Each site has a core antenna array with 9919 dual-polarization antenna elements organized into 109 subarrays of 91 elements each. The Norway site will also have an additional 10 subarrays, located separate from the core array.

In addition to the antenna elements, the sites will also have support structures, beamformers, receivers, transmitters and other subsystems for control, time-keeping et cetera. Active RF components are placed into Subarray Containers which are placed under the Array Structure. For each site, there shall be 109 Containers with electrical installation and racks pre-installed.

Active electronics including transmitters, receiver and computer systems will be installed after Antenna Unit is in place. Figure 1 shows the different subsystems of EISCAT_3D and also where the subsystems are located physically.

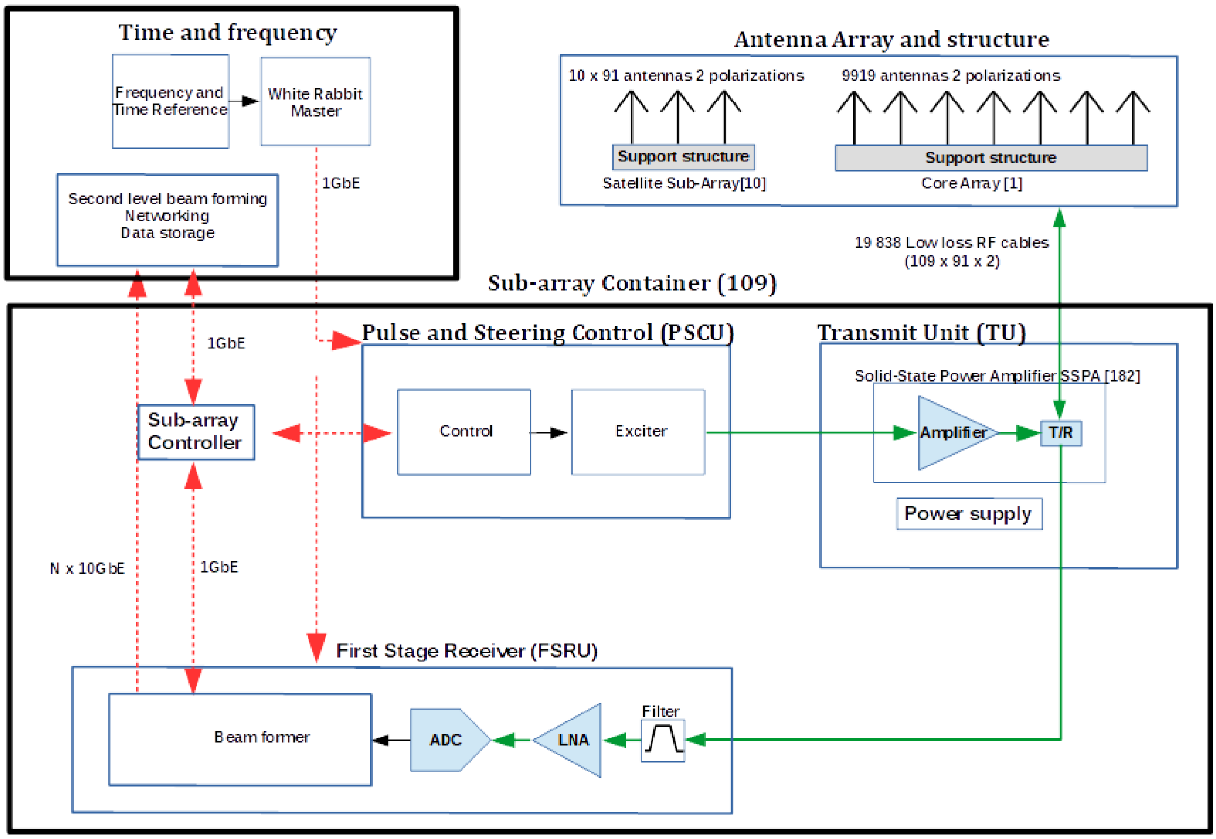

Figure 1. Parts of the EISCAT_3D system.

1.1.1. Ground preparations

EISCAT will prepare the Site so that flat gravel bed with sufficient drainage system installed. Also pipes for electricity and network cables will be prepared in advance. EISCAT will ensure that the access road is made for heavy transport and at the antenna site has space for easy unloading of the antenna system.

1.1.2. Antenna Array

The Array is an approximately 80-meter-diameter roughly circular shaped structure with 9 919 Antenna Elements mounted. Array shall be elevated a sufficient distance above the ground level to allow room for the Subarray Containers and for personnel access to those containers using an Array Structure. The Antenna Element is an inverted V cross dipole or similar. Antenna Array has also RF cables connecting antenna dipoles to the active electronics.

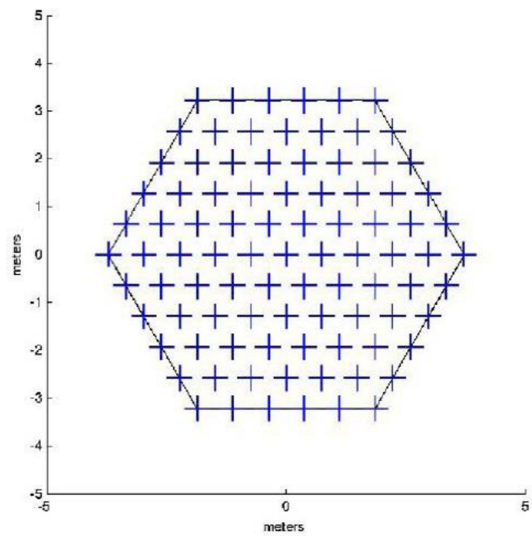

Figure 2. Antenna elements in the Sub-array.

The above pictures show a prototype of the antenna (the units are in mm). Note that the pictures are provided as information and not as requirements.

1.1.3. Subarray Container

Under the antenna array there are Sub-Array Containers for active electronics. Containers house:

- Time and Frequency Unit
- First Stage Receiver Unit
- Pulse and Steering Control Units
- Transmit Units
- Sub-Array Controller
- The Subarray Containers shall also include electrical installations (circuit breakers, wiring, etc.) and both heating and ventilation equipment sufficient to maintain a stable environment for the electronics.

For the transmitting site (Norway Skibotn) the container will have 182 amplifiers distributed in 26 subracks. The subracks will be install in 19” racks or a similar shelf system, this will give 6,5 racks for the amplifiers, power supply and control electronics.
For receiving only sites (Finland, Karesuvanto and Sweden Kiruna) we estimate that the electronics need space for 1 rack.

182 Cables from 91 Antenna elements are lead to the Subarray Container. Three phase electrical connections and fiber-optic cables are lead through the floor into the container. EISCAT will prepare cable ducts to each container under the gravel before Passive Element installation.

2. Requirements

The following chapter and subchapters contain requirements on the Antennal Unit and its subsystems. Each chapter contains general requirements and interface requirements.

2.1. Simulations and 3D models

This section has requirements for work to be done during the design phase.

Requirement	
SS_AU_01_01	RF field simulations of the Antenna Element including at least 3D directivity pattern and return loss.
SS_AU_01_02	Simulation of sufficient amount of Antenna Elements in the array showing directivity and mutual coupling.
SS_AU_01_03	3D model of antenna structures and containers.
SS_AU_01_04	Estimations of signal losses from antenna to the end of the cable including connectors.

2.2. Antenna Element

This section has requirements for the Antenna Element.

Requirement	
SS_AU_02_01	The Antenna Element shall allow independent orthogonal polarization.
SS_AU_02_02	The Antenna Element shall meet the IEC norms for outdoor antennas.
SS_AU_02_03	The Antenna Element shall have an expected lifetime of more than 15 years.
SS_AU_02_04	The Antenna Element shall be designed to operate in the 218-248 MHz frequency band for receiving (3 dB points), in the array environment.
SS_AU_02_05	The Antenna Element shall be designed to operate in the 230-236 MHz frequency band for transmitting, in the array environment.

Requirement	
SS_AU_02_06	The Antenna Element elevation scan pattern shall be optimized to have flat response down to 60 degrees from zenith and reduced response for angles > 60 degrees.
SS_AU_02_07	The azimuth scan pattern of the Antenna Array shall be 360 degrees.
SS_AU_02_08	The Antenna Element shall be able to deliver max power of 500 Watt per polarization, with 25% duty cycle.
SS_AU_02_09	The nominal impedance of the Antenna Element shall be 50 ohms (in the array environment).
SS_AU_02_10	The Antenna Element shall be constructed of material that can handle temperatures that ranges between -40 and 40 degrees Celsius.
SS_AU_02_11	The Antenna Element return loss in the Tx band shall be better than 15 dB for all scan directions.
SS_AU_02_12	The Antenna Element shall have a return loss better than 10 dB in the Rx band (excluding the Tx band).
SS_AU_02_13	Top point of the antenna element shall be reflective (not black) to allow easy laser distance measurement.

2.3. Antenna Array and supporting structures

This section has requirements for the Antenna Array and supporting structures.

Requirement	
SS_AU_03_01	The Antenna Unit shall be designed for operation in an arctic environment (-40 to +35 degrees Celsius) with rain, snow, and ice and should allow snow to pass through.
SS_AU_03_02	The Antenna Unit shall include the cables and connectors connecting it to its interfacing subsystems.
SS_AU_03_03	The Antenna Unit shall be fully operational in winds up to 30m/s.
SS_AU_03_04	The Antenna Unit shall not be subject to permanent deformation by winds up to 50m/s.
SS_AU_03_05	The Antenna Unit shall include supports for organized cable routing below the Array Structure.
SS_AU_03_06	The Ground Plane shall form an RF ground.
SS_AU_03_07	The Ground Plane shall be constructed using sufficiently thin wires to allow snow to pass through.
SS_AU_03_08	The Array Structure shall be sufficiently elevated to allow access to the Antenna Containers (approximately 3 meters high).

Requirement	
SS_AU_03_09	The antenna elements shall be evenly distributed in the Antenna Array in a hexagonal arrangement with equal distance between nearest antennas.
SS_AU_03_10	The Antenna Arrays shall be circular having diameter about 80 m.
SS_AU_03_11	The subarray inter-element antenna distance shall be optimized so that no grating lobes exists within 60 degrees of zenith over the transmitter operating band and also to minimize mutual coupling.
SS_AU_03_12	For antenna array design the goal is to have a gain better than 45 dBi in the zenith and greater than 42 dBi on all scan directions down to 60 degreen zenith angle. At the same time, we wish to have very little gain near the horizon where terrestrial interference sources are located.
SS_AU_03_13	Allowed tolerance in antenna spacing must correspond to maximum 5% reduction in the on-axis gain of the array, without correction.
SS_AU_03_14	Active reflection loss shall be better than 10 dB for all scan angles. Active reflection loss is reflection from the antenna and power coupled from other antennas.

2.4. Sub-Array Container

This section has requirements for the Subarray Container and items related to it.

Requirement	
SS_AU_04_01	Containers for transmitters and electronics shall be constructed under the array and shall be designed for operation in an arctic environment (-40 to +35 degrees Celsius) with rain, snow and ice
SS_AU_04_02	Containers shall include seven (7) 19_inch equipment racks.
SS_AU_04_03	Internal height shall be high enough to have place for 2_meter_tall racks.
SS_AU_04_04	Containers shall have remotely controlled temperature regulation equipment (insulation, heaters, and forced air cooling) sufficient for the operational temperature range of +15 to +40 degree C and for equipment heat dissipation of 0 to 20 kW. Passive cooling using filtered cold air from outside.
SS_AU_04_05	Containers shall have access for RF cables from the antennas and for power and fiber optics from below.
SS_AU_04_06	Number of Containers shall be one per 91 antennas.

Requirement	
SS_AU_04_07	Containers shall be placed to allow access for maintenance.
SS_AU_04_08	Containers shall be designed so that racks can be accessed from both side either inside or outside.
SS_AU_04_09	A good electromagnetic isolation between the radiating antennas and the electronics in the container is required. This can be provided via a combination of shielding of the container together with the effect of the ground plane. Attenuation from inside container to the antenna elements over the receiving band (233 +- 15 MHz) should be more than 100 dB.
SS_AU_04_10	6 racks for amplifiers shall be designed to accommodate 200 Kg. One rack for instruments shall be designed for 100 Kg.

2.5. Electrical installations

This section has requirements for electrical installations inside the Subarray Container

Requirement	
SS_AU_05_01	Container shall include an electrical power distribution box.
SS_AU_05_02	The electrical power distribution box shall have 3 phase 400V circuit breakers for incoming current, 3 x 100A.
SS_AU_05_03	The electrical power distribution box shall have 3 phase circuit breakers for 7 racks, 3 x 20A.
SS_AU_05_04	Container shall have inside lighting installed.
SS_AU_05_05	Electrical installation shall include also residual_current circuit breaker (RCCB).
SS_AU_05_06	Installations shall include single phase 230 V sockets for miscellaneous equipment.
SS_AU_05_07	Container shall include backup thermostat controlled heater sufficient to keep air above 5 degrees C.

2.6. RF Cables and Connectors

This section has requirements for RF cables and connectors between antenna element and active elements in the container.

Requirement	
SS_AU_06_01	The connectors used shall be of type N or 4.3-10.
SS_AU_06_02	The length of the antenna cables shall be minimized and have equal electrical length with in 0.1 ns.

Requirement	
SS_AU_06_03	The component shall meet the IEC norms for outdoor antennas
SS_AU_06_04	The losses from antenna to receiver electronics shall be minimized but smaller than 0.5 dB.
SS_AU_06_05	The lifetime for cables shall be 15 years.
SS_AU_06_06	RF cable loss should be in order of 0.05 dB/m at 233 MHz

3. Definitions used within the AU Technical Specification

Definition	Description
dBi	dB isotropic. The forward gain of an antenna compared with the hypothetical isotropic antenna, which uniformly distributes energy in all directions. Linear polarization of the EM field is assumed unless noted otherwise.(Wikipedia)
dBm	**dBm** (sometimes **dB**$_{mW}$ or decibel-milliwatts) is an abbreviation for the power ratio in decibels (dB) of the measured power referenced to one milliwatt (mW).(Wikipedia)
IEC	International Electrotechnical Commission
PfP	Preparation for Production
RF	Radio Frequency
SSDD	System and Subsystem Design Description