EISCAT Scientific Association

Technical Specification for Sub-Array Transmitter Unit

CHANGE RECORD

Version		Date	Changed Paragraphs	Remarks
Issue	Rev			
1	0	2018-05-18	New document	

TABLE OF CONTENTS

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1 INTRODUCTION

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 goal is a new system, the EISCAT_3D, which will be a next generation incoherent scatter radar capable of providing 3D monitoring of the atmosphere and ionosphere.

1.1 Purpose

The purpose of this document is to describe the technical requirements for the Transmitter Unit, which consists of a High-Power stage (HPA), a TR-switch and power supplies.

1.2 Application

The document is used as the technical specification for the procurement of the Transmitter Unit. Note that this document describes logical interfaces and the actual system design is up to the vendor.
Both the text-based requirements *and* the activity diagrams shall be considered as requirements (with prefixes SS_TU, ...) that shall be fulfilled by the Transmitter Unit.

2 REFERENCE DOCUMENTS

2.1 Normative

ND1 [SOWFSRU] Statement of Work for Transmitter Unit

3 SYSTEM DESCRIPTION

This chapter contains the system description for the Sub-Array Transmitter Unit (SAT). The first section contains an overview of the entire system and the following sections contain the detailed description of the SAT.

3.1 Typical EISCAT_3D operational set-up

The typical mode of operation for the EISCAT_3D system is to make three-dimensional observations of the parameters of the ionosphere within its field of view. The way that this is implemented is as follows:

A list of different directions (elevation and azimuth) with respect to the core site is pre-defined. The transmitter follows this list so that each beam pulse goes in a new direction. Each receiver site also has a corresponding pre-defined list identifying sets of viewing directions designed to observe the transmitter beam simultaneously at different altitudes. See the figure for a simplified example with a list of 4 transmission directions and 4 corresponding sets of 5 simultaneous receiver viewing directions at one receiver site.

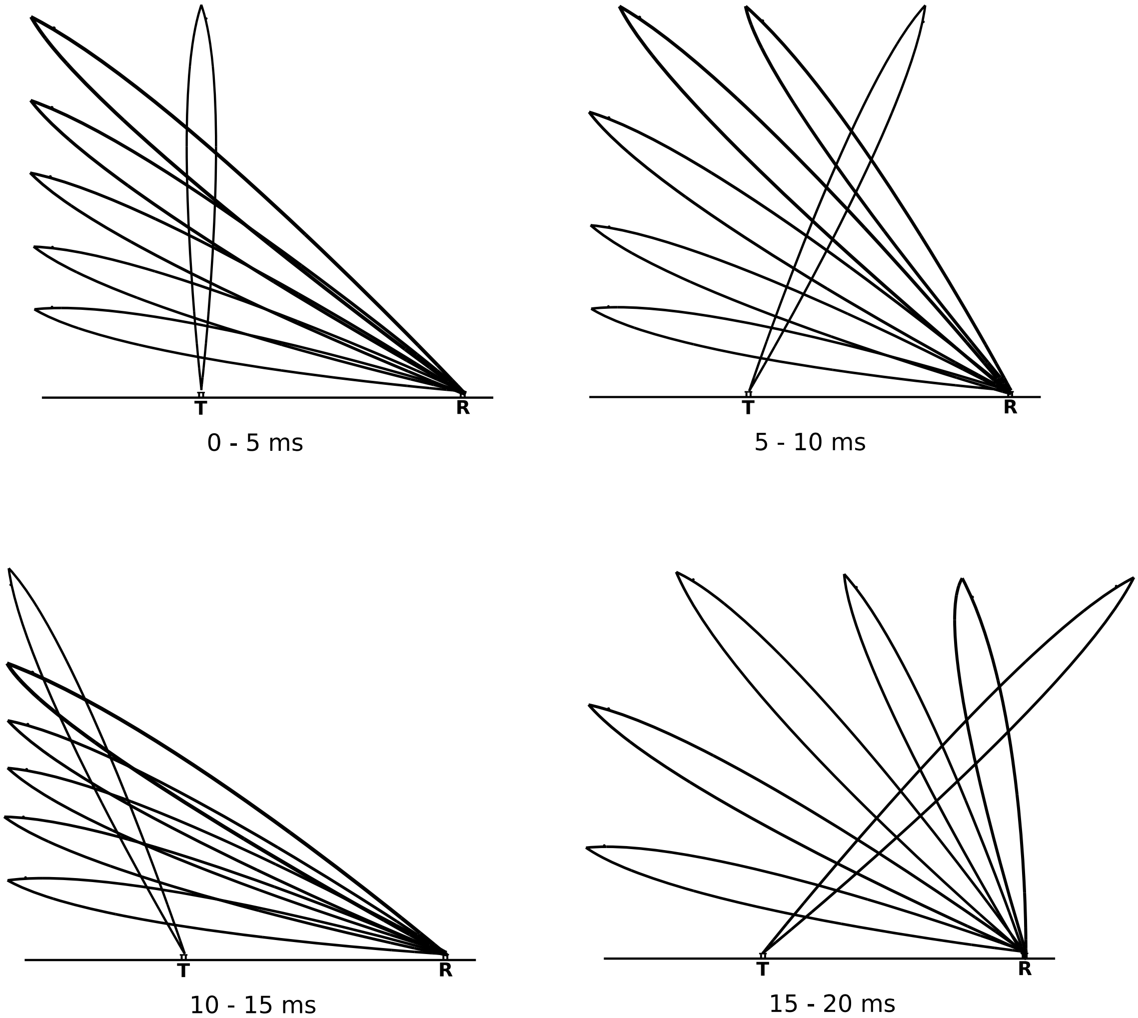

Figure 1. Simplified example of transmitter receiver beams

In case the ionospheric conditions change or there is an interesting event (meteor, auroral arc) it should be possible within a one second to change the list of transmitter directions, and at the same time change the corresponding lists of sets of simultaneous viewing directions at all receive sites.

Thus, an EISCAT_3D experiment requires a number of lists. Each list identifies a number of transmitter beam directions, each with corresponding sets of simultaneous receiver viewing directions.

List				
	Transmitter	Receiver 1	Receiver 2	...
Pulse 1	(el1, az1)T	(el1,1, az1,1)R1 (el1,2, az1,2)R1 (el1,3, az1,3)R1 ...	(el1,1, az1,1)R2 (el1,2, az1,2)R2 (el1,3, az1,3)R2 ...	...
Pulse 2	$(el_2, az_2)_T$	$(el_{2,1}, az_{2,1})_{R1}$ $(el_{2,2}, az_{2,2})_{R1}$ $(el_{2,3}, az_{2,3})_{R1}$ ...	$(el_{2,1}, az_{2,1})_{R2}$ $(el_{2,2}, az_{2,2})_{R2}$ $(el_{2,3}, az_{2,3})_{R2}$ ...	...
Pulse 3	$(el_3, az_3)_T$	$(el_{3,1}, az_{3,1})_{R1}$ $(el_{3,2}, az_{3,2})_{R1}$ $(el_{3,3}, az_{3,3})_{R1}$ ...	$(el_{3,1}, az_{3,1})_{R2}$ $(el_{3,2}, az_{3,2})_{R2}$ $(el_{3,3}, az_{3,3})_{R2}$ ...	...
...	...	...	...	...

Table 1. Example of the Main Event List

3.2 Technical description

Overall, the EISCAT_3D system includes 119 Sub-arrays at the Skibotn, Norway site and 109 Sub-arrays each at the Karesuvanto, Finland and Kaiseniemi, Sweden sites. Figure 2 displays the different subsystems within one Sub-array and also displays, where applicable, where the subsystems are located physically.

The instrument container houses:

- First Stage Receiver Unit (FSRU)
- Pulse & Steering Control Unit (PSCU)
- Time & Frequency Unit (TFU)
- Transmitter Unit (TU)
- Sub Array Computer (Sub Array Manager software)
- Climate Monitoring Equipment

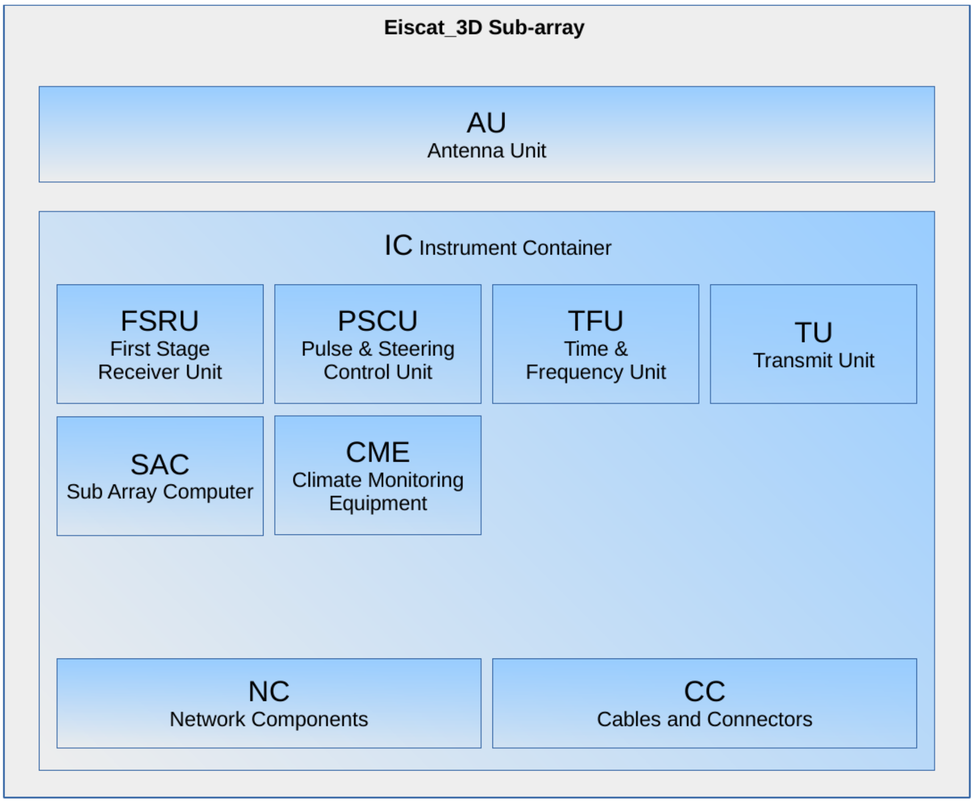

Figure 2. The Sub-array system

Also included in the Sub-array are Network Components plus Cables and Connectors to connect the different subsystems and components.
Note that Figure 2 only displays the Sub-array sub systems. External systems (e.g. Computing System which is located outside of the Instrument Container) are not displayed.

Antenna signals in the Sub-array are collected from a hexagonally shaped area and fed to the sub-array container placed underneath a steel structure ("Array Structure") which the Antenna Elements are also mounted on.

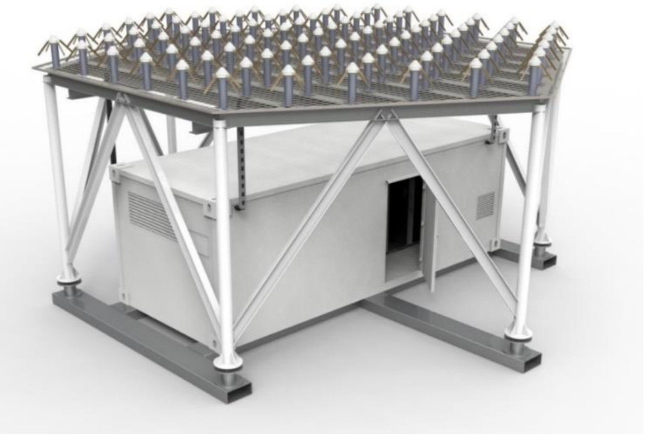

Figure 3. EISCAT_3D Sub-array

3.3 EISCAT_3D Sub-array

The Sub-array consists of 91 crossed-dipole antenna elements, a beamformer, a receiver, a transmitter and other subsystems for control, time-keeping etcetera.

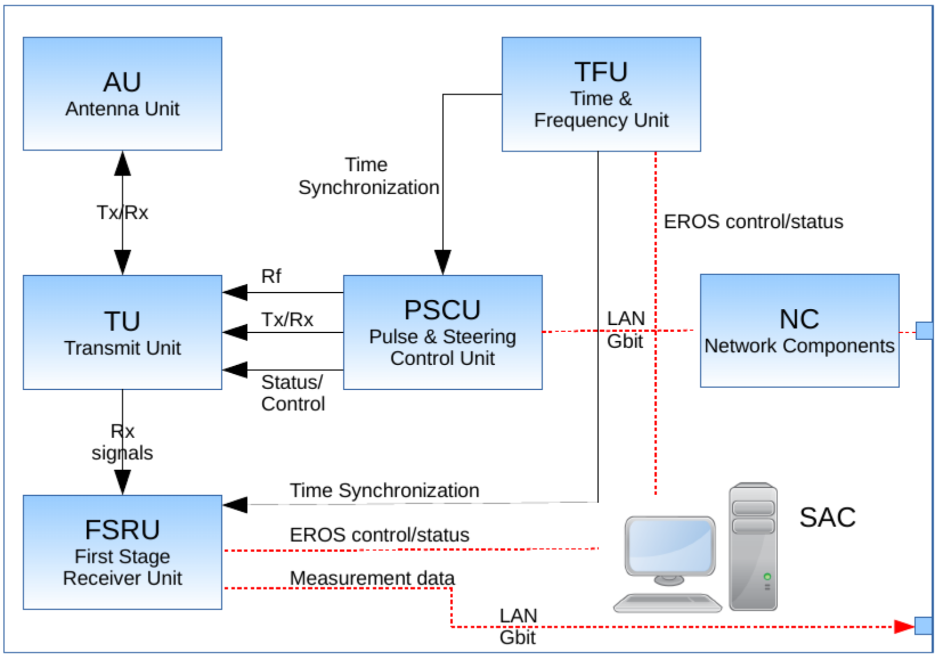

Figure 4. Sub-array Technical systems High level Overview

Figure 4 above displays a high-level overview of the technical subsystems of the Test Sub-array. It conveys not only which components interact with each other, but also the kind of information that is exchanged between the components.
In the Sub-array container there are 6 full racks and one half-rack space for the 182 channel Transmitter Unit. Examples of possible configurations are shown in Figure 5.

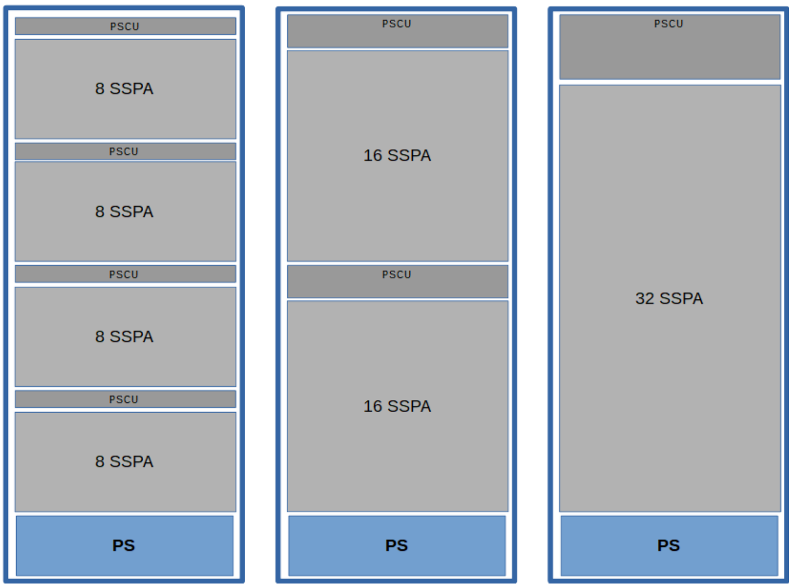

Figure 5. Possible rack configurations

3.4 Sub-Array Transmitter Unit

Sub-Array Transmitter Unit consists of following blocks:

- Solid State Power Amplifiers
- Power supplies

3.4.1 Solid State Power Amplifier (SSPA)

The Solid-State Power Amplifier Unit is part of TU and consists of the following main parts:

- High Power Amplifier (HPA)
- TR-switch (TR)
- Isolator
- Interface (IF)

Figure 6 show the functions of one SSPA. Functions can be organized in to different physical units.

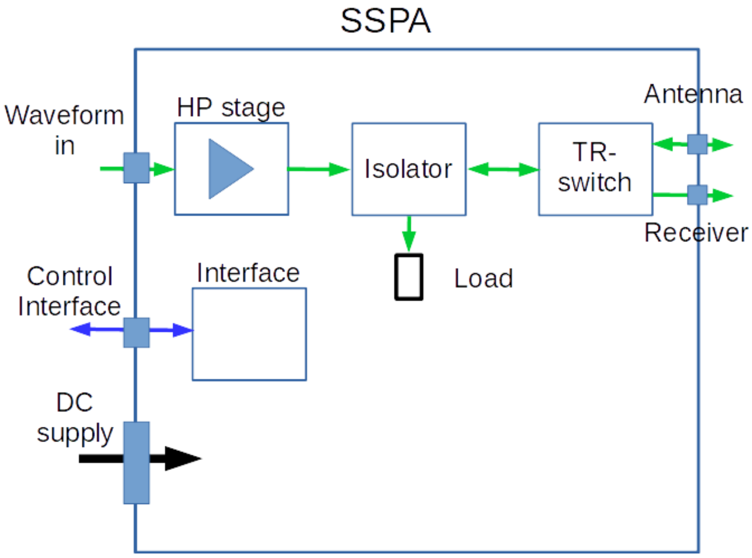

Figure 6. SSPA connections and functions

3.4.1.1 High Power Amplifier Stage (HPA)

High Power Amplifier shall amplify input signal 42 dB so that maximum power available is 500W peak during the maximum pulse length of 3 ms. During idle time HPA should be switched off by a control signal.

3.4.1.2 TR-switch

TR-switch connects either the HPA or the receiver port to the antenna. TR-switch is controlled through external signal.

3.4.1.3 Isolator

Function of the isolator is to protect HPA from high reflections and incoming power from mutual couplings. Isolator is not required if protection for reverse power can be made otherwise. Due to mutual coupling between antennas in the array, reverse power can be up to 47 dBm peak.

3.4.2 Power Supply (PS)

All necessary power supplies shall be included to the delivery. There can be one or more PS for one rack but vertical space of 38 unit shall not be exceed. PS can have mains connection to 3 phases 380V or one phase 230V system. PS can be placed freely in to the available rack space.

3.5 Interfaces

Interfaces of the system are described in Table 2.

Name	*Type*	*Information*
Antenna	Analog 50 ohm	Interface to antenna. Female N connector or similar.
Receiver	Analog 50 ohm	Interface to receiver. BNC or similar.
Waveform in	Analog 50 ohm	Analog waveform. BNC or similar.
Control	Data	Interface for receiving control signals and sending status signals out to the Control Board. RJ-45, SFP, sub-D or similar.
TR-switch	Control	Interface to operate TR-switch. Can be part of the Control Interface or separated coaxial or differential connector.
Mains	380V 3 Phase or 230V 1 Phase	Interface with the Mains Power. Standard connector or terminal block.

Table 2. SSPA sub-system interfaces

4 REQUIREMENTS

The following chapter and subchapters contain requirements on the Sub-Array Transmitter Unit (SAT).

4.1 General requirements

Requirement	
SS_TU_01_01	Amplifiers shall be mountable to the standard 19-inch racks having 80 cm depth
SS_TU_01_02	In to the one19-inch rack it should be possible to install 32 SSPA units. Racks can be accessed from both sides.
SS_TU_01_03	Vertical available rack space is 38 units
SS_TU_01_04	Amplifiers shall be operated through control interface
SS_TU_01_05	Each SSPA shall have interface for antenna
SS_TU_01_06	Each SSPA shall have interface for receiver
SS_TU_01_07	SAT shall have control interface for controlling one or more SSPA units
SS_TU_01_08	Input signal level of 15 dBm shall correspond to 57 dBm output power.
SS_TU_01_09	Input impedance shall be 50 ohm
SS_TU_01_10	Maximum pulse length is 3000 µs

Requirement	
SS_TU_01_11	Minimum pulse length is 0.3 µs
SS_TU_01_12	Phase stability shall be better than 10 degrees over the operational temperature range
SS_TU_01_13	Overall efficiency, excluding power supplies, shall be better than 50% and preferably better than 60%
SS_TU_01_14	SAT shall be air cooled. Vendor is responsible for any necessary air flow management.
SS_TU_01_15	Ambient operational temperature range inside the sub-array container is from 15 to 40 degrees
SS_TU_01_16	SSPA shall have an interlock for excessive internal temperature.
SS_TU_01_17	Maximum reverse power SSPA shall be able to accept is 50 Wpeak and 12,5 W average
SS_TU_01_18	SSPA unit shall survive any load at the antenna input
SS_TU_01_19	SSPA units shall be field replaceable individually
SS_TU_01_20	Slide-in SSPA modules are preferable

4.2 HPA requirements

Requirement	
SS_TU_02_01	Nominal operational frequency band is 233 MHz ± 3 MHz (3db).
SS_TU_02_02	1 dB bandwidth shall be better than 233 MHz ± 2.5 MHz
SS_TU_02_03	
SS_TU_02_04	Maximum peak output power shall be more than 500 W
SS_TU_02_05	Maximum average output power shall be more than 125 W (25% duty cycle)
SS_TU_02_06	Gain shall be equal or greater than 42 dB
SS_TU_02_07	Gain variation over operational temperature range shall be less than 1 dB
SS_TU_02_08	Gain variation between devices shall be less than 1 dB
SS_TU_02_09	Amplitude droop over maximum pulse length shall be less than 5%
SS_TU_02_10	Phase stability shall be better than 20 degrees over the operational temperature range
SS_TU_02_11	Phase stability over the maximum pulse length shall be better than 20 degrees
SS_TU_02_12	Phase variation between units shall be better than 20 degrees
SS_TU_02_13	Group delay shall be better than 500 ps over the 1 dB frequency bandwidth
SS_TU_02_14	Harmonics shall be better than -50 dBc

Requirement	
SS_TU_02_15	Leakage to the receiver port when SSPA in receive mode shall be less than -170 dBm/Hz over the 233 +/- 15 MHz receiver bandwidth
SS_TU_02_16	Maximum pulse length shall be more than 3000 µs
SS_TU_02_17	Minimum pulse length shall be less than 0.3 µs
SS_TU_02_18	Minimum period between pulses is 300 µs
SS_TU_02_19	Rise and fall time shall be better than 0.1 µs (10%/90%)
SS_TU_02_20	It shall be possible to switch HPA section off

4.3 Requirements for TR-switch

Requirement	
SS_TU_03_01	TR switch shall be operated through separated control interface
SS_TU_03_02	Insertion loss from antenna port to receive port shall be better than 0.8 dB, preferably better than 0.6 dB
SS_TU_03_03	Switching time shall be faster than 2 µs
SS_TU_03_04	Switching delay from TR control signal to receive or transmit state shall be less than 10 µs
SS_TU_03_05	Switching delay variation between devices shall be better than 1 µs
SS_TU_03_06	Isolation to receive port during transmission shall be better than 55 dB, preferably better than 60 dB
SS_TU_03_07	TR switch control connection shall be either coaxial or differential line
SS_TU_03_08	TR switch control can be common for multiple devices

4.4 Control interface and operational requirements

Requirement	
SS_TU_04_01	SAT shall be operated through one or more control interfaces, which can be either ▪ LAN, electrical or optical ▪ Differential serial data connection
SS_TU_04_02	Control interface can be for each SSPA unit or common for multiple devices

5 DEFINITIONS

Definition	*Description*
API	Application Programming Interface
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)
EROS	EISCAT Realtime Operating System
M&C	Monitoring and Control
ns	Nano second
PSCU	Pulse and Steering Control Unit, Device to form required wave forms and TR switch signal
RC	Radar Controller
RF	Radio Frequency
SAT	Sub-Array Transmitter
SFDR	Spurious Free Dynamic Range
SNR	Signal to Noise Ratio
SSDD	System and Subsystem Design Description
SSPA	Solid State Power Amplifier
VSWR	Voltage Standing Wave Ratio