2018-11-16

EISCAT Scientific Association

Technical Specification

for

Pulse and Steering Control Unit

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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 implementing a project called EISCAT_3D where the final product is a new, multi-static radar system, the EISCAT_3D, which will be a next generation incoherent scatter radar capable of providing 3D monitoring of the atmosphere and ionosphere.

1.2 Purpose

The purpose of this document is to describe the technical requirements for the Pulse and Steering Control Unit.

1.3 Application

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

2. REFERENCE DOCUMENTS

2.1 Normative

Reference	Title
None	

3. SYSTEM DESCRIPTION

This chapter contains the system description for Pulse and Steering Control Unit [PSCU]. The first section contains an overview of the EISCAT_3D Subarray, and the following sections contain the detailed description of the PSCU.

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, shown in figure 1.

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 at a pre-defined UTC time. 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.

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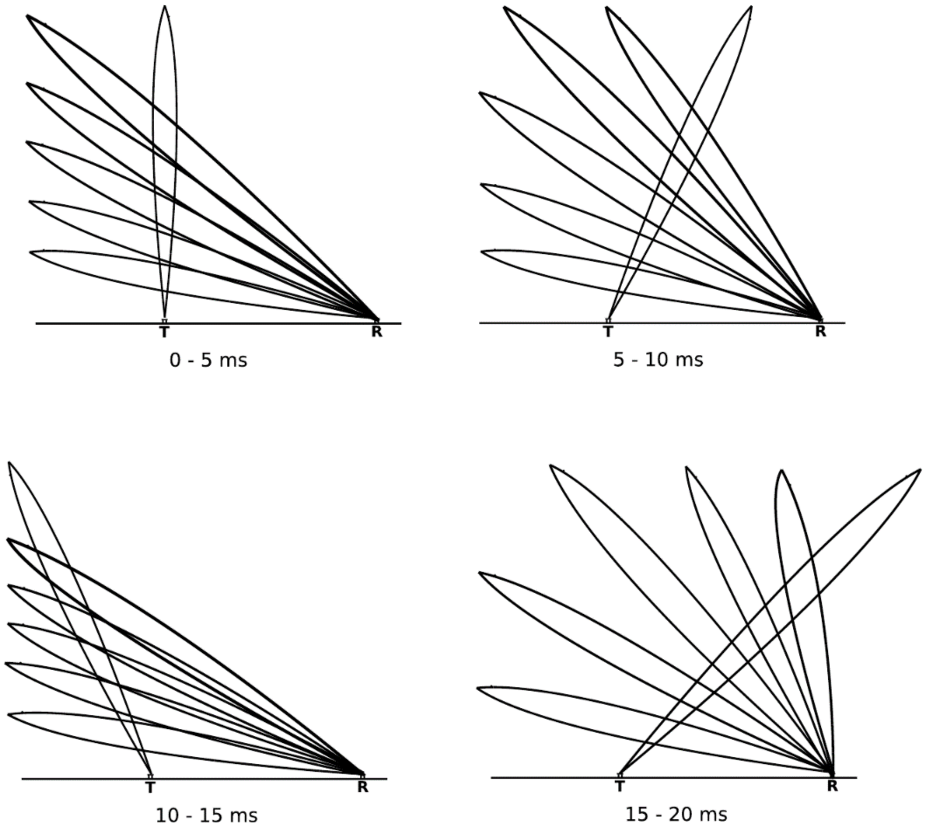

Figure1. Simplified illustration of transmitter and receiver beams.

Thus, an EISCAT_3D experiment requires a number of control parameter lists which are streamed to the hardware units from a higher level control system. Each list identifies a number of transmitter beam directions *(phases)* and waveforms and corresponding sets of simultaneous receiver viewing directions. The lists are also tagged with specific UTC times at whichthe directions should be activated.

Waveforms typically include coding (e.g. PSK) and pulse envelopes and are specified as IQ modulations to be applied to a carrier frequency.

3.2 Technical Description

Overall, the EISCAT_3D system includes around 100 Subarrays at the Skibotn, Norway, Karesuvanto, Finland and Kaiseniemi, Sweden sites. Figure 2, illustrates the different subsystems within one Subarray.

Subarray instrument container houses:

- First Stage Receiver Unit [FSRU]
- Pulse and Steering Control Unit [PSCU]
- Subarray Transmitter [SAT] consists of several Transmit Units [TU]
- Climate Monitoring Equipment [CME]

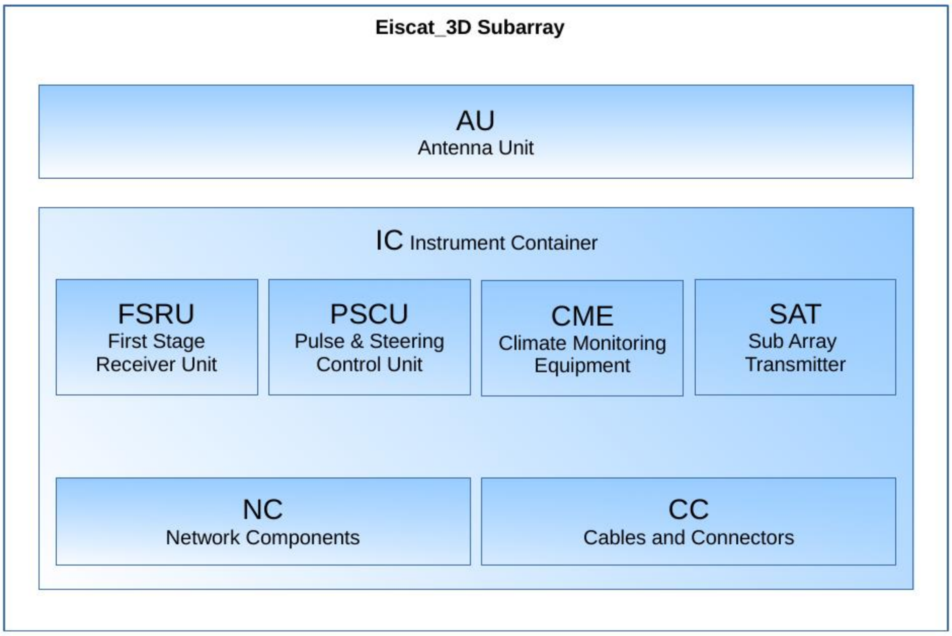

Fig 2. The Subarray system

Figure 2 displays the different subsystems comprising one Subarray. Note that figure 2 only displays the Subarray sub-systems. External systems *(e.g. a Computing System which is located outside of the Instrument Container)* are not displayed.

Antenna signals in each subarray are collected from a hexagonally spaced array of antennas and fed to a subarray container which is placed underneath a steel structure *("Array Structure")* which the antenna elements are also mounted on, figure 3.

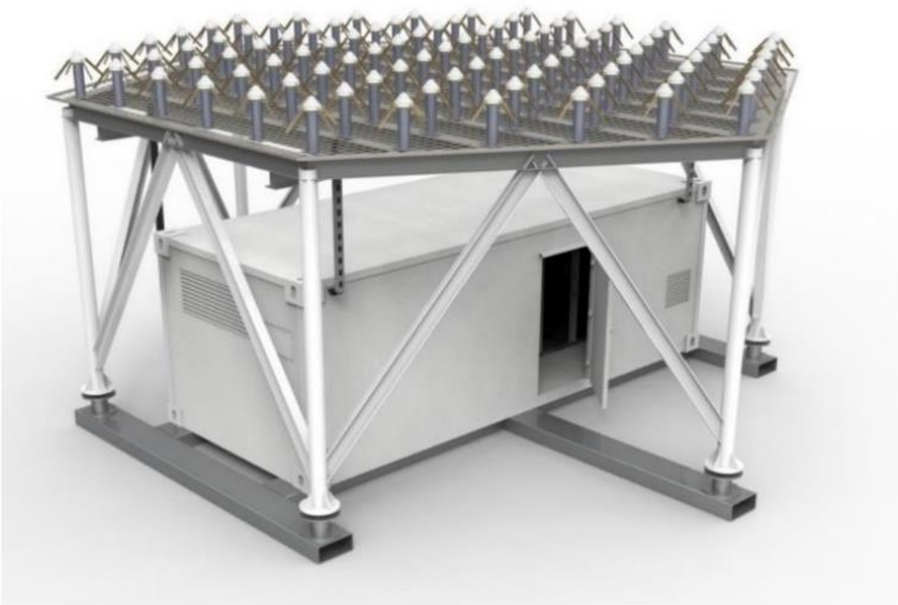

Fig 3. EISCAT 3D Subarray

3.3 EISCAT 3D Subarray

The Subarray consists of 91 crossed-dipole antennas, receivers, transmitters, pulse and steering control and other subsystems.

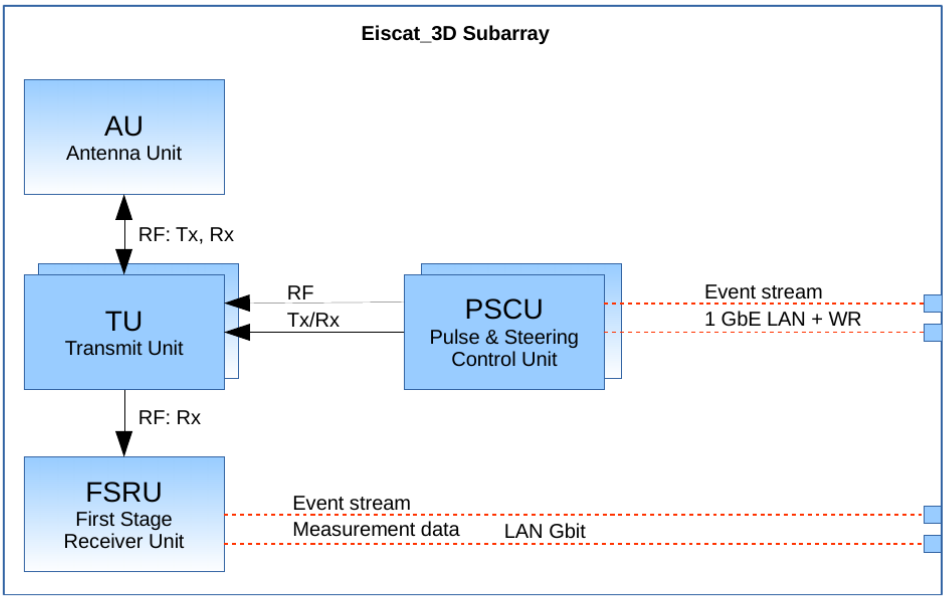

Fig 4. Subarray Technical systems High level Overview

Figure 4 displays a high-level overview of the technical subsystems of the subarray.

In the instrument container, which houses Transmit Units and PSCUs, are placed 6 standard 19" racks for the 182-channels. The transmitters are divided into groups of 8 transmit channels and up to four such groups, along with their power supplies, are placed in each rack. The PSCU is likewise to be divided into groups of 16 channels, with each group supplying signals to two groups of Solid State Power Amplifiers (SSPAs) as shown in figure 5. Each PSCU shall be 2U in height, support 16 channels to serve 16 SSPAs, and include its own power supply.

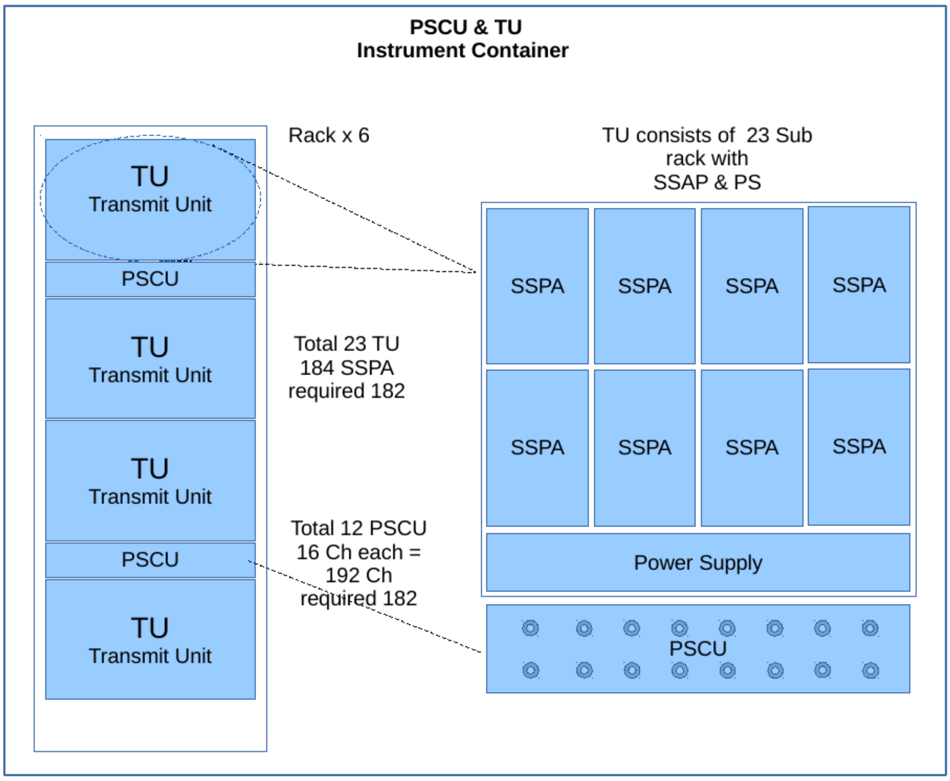

Fig 5. Instrument container rack housing arrangement of PSCU and TU.

3.4 Pulse and Steering Control Unit (PSCU)

The PSCU is a device to convert digital baseband signals to 233.28 +/- 3 MHz RF so that it can drive a set of 16 power amplifiers *(SSPA)*. Waveform details are calculated external to the PSCUs, transferred to each PSCU in advance, and shall be saved to the memory of the PSCU. A single waveform is sent to all 16 channels in a given PSCU *(we call this a waveform execution)* but different channels should have different phases *(for beam steering)*.

Time critical commands transfer channel-specific beam direction-related information to each PSCU. Beam direction is determined by a coarse time delay and a phase adjustment. A delay is implemented by shifting waveform execution time by integer numbers of sampling intervals (*which is same for all channels in a PSCU*).

Phase adjustment of the resulting RF signal for each channel is added to either the IQ signal phase or to the carrier. Polarization phase and calibration correction is included in the commanded phase

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value. Amplitude variations are handled by a combination of the gain calibration value and the vector amplitude of the IQ signal. Figure 6 shows an example of a modulated waveform and the commanded phases for three channels.

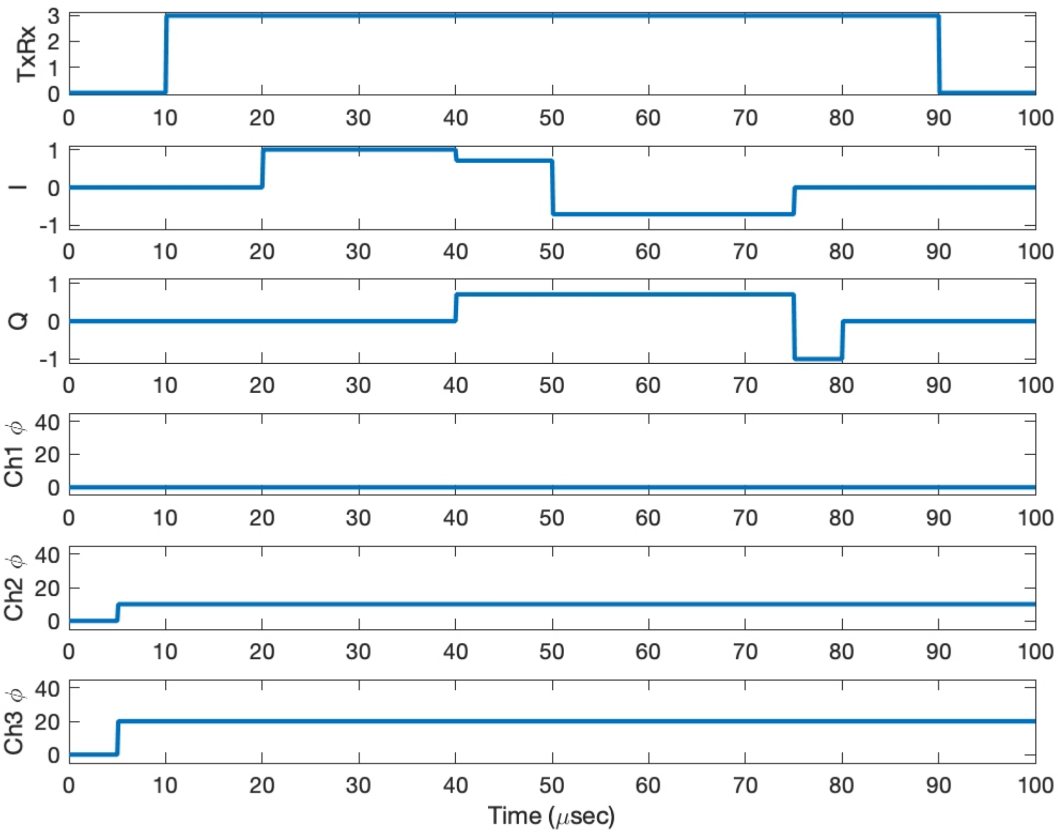

Figure 6. Example timing for a modulated waveform and beam steering phases for three of the 16 channels.

For each of the 16 channels, the PSCU shall upconvert the digitally-defined baseband waveform to an adjustable frequency around 233 MHz and this signal should be Digital-to-Analogue converted to an analogue RF signal. All analogue signals must be phase locked within a PSCU and (using White Rabbit) between PSCUs.

A PSCU consists of following logical components:

- Exciter
- Power supplies
- PSCU System Controller
- White Rabbit slave

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3.4.1 PSCU System Controller

System Controller receives waveform IQ-data and commands and controls Exciters.

- System Controller acts as a socket server connected to a site LAN network.
- System Controller also sends notifications to the external control system.
- System Controller is time synchronized through the WR system.

3.4.2 White Rabbit (WR) Slave

The WR Slave extracts the time and synchronization from the 1 GbE network and provides synchronized clock signals to System Controller and Exciters.

3.5 External Interface

Interface with External sources and Units

Name	*Type*	*Information*
RF out	16 x BNC	The radio frequency signals from PSCU to the Transmit Unit are sent over this interface.
LAN	Control interface 1 GbE SFP slot	The communication with external controls system is sent over this interface. The WR timing network also uses this interface.
Tx/Rx	2 x BNC 50Ω 3V	The Tx/Rx signal is used to place the transmitters into transmit mode prior to the start of the PSCU waveform signal and back to receive mode after the waveform is completed.

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4. REQUIREMENTS

4.1 PSCU System Controller requirements

Requirement	
SS_PSCU_01	Operational temperature range shall be from 15 to 40 degrees C.
SS_PSCU_02	PSCU shall boot up automatically after power on into a low power mode.
SS_PSCU_03	Status messages from the System Controller shall be time stamped.
SS_PSCU_04	The System Controller shall be able to issue autonomous notifications.
SS_PSCU_05	The Subsystem Controller shall have an 1GbE interface.
SS_PSCU_06	The System Controller shall provide a UDP socket server to be able to receive a command stream.
SS_PSCU_07	Configuration commands shall include at least: • Change PSCU id number • Write waveforms • Write channel gain calibration values • Clear command FIFO • Reset • Status request • Low power mode • Default centre frequency for up-conversion
SS_PSCU_08	Configuration commands shall be implemented immediately
SS_PSCU_09	Each waveform shall be uploaded in advance (e.g. at experiment start) and include at least: • Waveform index • Waveform length • Vector of 16 + 16 bit integer IQ data
SS_PSCU_10	It shall be possible to update waveform memory for a future pulse during the waveform execution.
SS_PSCU_11	Complex baseband sample rates should be 52 MSPS 16 +16 bit IQ samples.
SS_PSCU_12	PSCU shall be able to receive event stream. Events are: • Tx/Rx switch state change • Waveform execution

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SS_PSCU_13	Event stream commands include a time stamp for command execution.
SS_PSCU_14	The event stream shall be buffered into a command FIFO.
SS_PSCU_15	Start times for the commands in the FIFO will be separated by at least 100 microseconds and they will come in sequential order.
SS_PSCU_16	The command FIFO shall be able to buffer at least 10 000 events.

SS_PSCU_17	Waveform execution command will specify:
	• Start time
	• Waveform start index
	• Waveform length
	• Phase table
	  ○ PSCU index
	  ○ Vector of 16 channel phase values
	  ○ Time shall be UTC integer microseconds plus baseband sample clock count

SS_PSCU_18	Waveform execution with change center frequency command
	• Start time
	• Centre frequency
	• Waveform start index
	• Waveform length
	• Phase table
	  ○ PSCU index
	  ○ Vector of 16 channel phase values
	  ○ Time shall be UTC integer microseconds plus baseband sample clock count

SS_PSCU_19	The Exciter is time synchronized through the WR system.
SS_PSCU_20	Phase error between channels within a PCSU shall be better than 5 degrees standard deviation over the operational temperature range.
SS_PSCU_21	Phase error between different PSCU units shall be better than 10 degrees standard deviation over the operational temperature range.

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SS_PSCU_22	Following a power off command, System Controller shall perform the necessary shutdown procedures on the PSCU system hardware.

4.2 Exciter Requirements

Requirement	
SS_PSCU_23	Group delay over the operation band 233.28 +/- 3 MHz shall be smaller than 100 ps.
SS_PSCU_24	The residual phase noise shall be better than -100 dBc/Hz at 1K offset.
SS_PSCU_25	The Noise Spectral Density *(NSD)* better than -120 dBm/Hz.
SS_PSCU_26	The SFDR Single tone shall be about -60 dBc.
SS_PSCU_27	The maximum output amplitude shall be more than 15 dBm.
SS_PSCU_28	The PSCU exciter function shall have 16 RF output interfaces having BNC connectors.
SS_PSCU_29	Each PSCU shall have two Tx/Rx switch output connectors delivering same signal.
SS_PSCU_30	The Tx/Rx switch output interface shall be two coaxial BNC connectors.
SS_PSCU_31	The interface of the output Tx/Rx control signal shall have a characteristic impedance of 50 ohms.
SS_PSCU_32	The Tx/Rx control signal shall have a rise time of <100 ns.
SS_PSCU_33	The exciter function shall implement an RF digital to analog converter.
SS_PSCU_34	The exciter function implements a digital up converter to adjustable center frequency in the range of 233.28 +/- 3 MHz.
SS_PSCU_35	The exciter function shall send out waveforms at requested UTC times.
SS_PSCU_36	Remote software update shall be implemented to the PSCU.

4.3 Power Supply Requirements

Requirement	
SS_PSCU_37	The Power Supply inside PSCU shall have a supply voltage of 230 V *(AC)*.

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SS_PSCU_38	The Power Supply inside PSCU shall have overcurrent protection.
SS_PSCU_39	Power indicator on front panel *(LED)*.
SS_PSCU_40	PSCU shall be 2U in height and maximum depth shall be 500 mm.

5. DEFINITIONS

Definition	Description
dBc	If the dBc figure is positive, then the relative signal strength is greater than the carrier signal strength. If the dBc figure is negative, then the relative signal strength is less than carrier signal strength.
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)
IQ	In-phase and Quadrature components of the modulation.
MSPS	Mega samples per second
PSCU	Pulse and Steering Control Unit
PS	Power Supply
SAT	Sub Array Transmitters is composed of several Transmit Units
SFDR	Spurious Free Dynamic Range (in operation frequency band)
SSPA	Solid State Power Amplifier
TU	Transmitter Unit
WR	White Rabbit timing transmission protocol

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