EISCAT_3D: Preparation for Production

EISCAT3D_PfP

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Test plan for the Test Sub-array

Work Package 2 – Coordination and Outreach

Leading Beneficiary: EISCAT Scientific Association

Authors

Mr. Harri Hellgren, Mr. Robert Juhlin, Mr. Lennart Lövqvist, Mr. Peter Bergqvist and Dr. Sathyaveer Prasad

Reviewed by: Dr. Craig Heinselman and Dr. Assar Westman

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Abstract

This report discusses the test plan for each of the subsystems and for the overall sub-array, which is planned to be constructed at Ramfjordmoen site in Norway. Further, this report will serve as guideline for the testing of test sub-array and also, to assess the interoperability of the various subsystems.

Introduction

The EISCAT_3D system is in implementation phase and it is initiated through EISCAT_3D preparation for production (EISCAT3D_PfP) project. EISCAT3D_PfP project will enable smooth transition from preparatory phase to implementation by moving from individual prototype subsystems to manufacture ready designs for immediate implementation in an industrial production environment. Further, this project also focusses on the operation of these subsystems as a single system by assessing the interoperability of the various subsystems. The above challenges will be addressed (via industrial outreach) by implementing and testing a demonstrator sub-array, at EISCAT's Ramfjordmoen site, near Tromsø in Norway, by using subsystems that are as close as possible to a final configuration. This report discusses the test plan for each of the sub-systems and also, for the overall sub-array. Thus, enabling the testing of various subsystems and overall sub-array by the end of this project. Further, this report also discusses the test plan for sub-system manager interface to assess the interoperability of various subsystems.

During EISCAT3D_PfP project, an EISCAT_3D test sub-array system will be produced and tested at EISCAT's Ramfjordmoen facility in Norway. This hardware will be similar to the final sub-array configuration that will be deployed at the EISCAT_3D core site in the future. The total size of this test sub-array will be approximately 7m in diameter with an additional buffer for safety reasons. This test sub-array will transmit a maximum peak output power of 91 kW (500W per polarisation per antenna) in the frequency band around 233 MHz and with a maximum bandwidth of 5 MHz. Currently, Ramfjordmoen facility has transmit license in the band of 230.016-236.544 MHz with a peak transmit power of 2 MW. The receiver frequency band is 218-248 MHz. A top-level block diagram of the different procurement objects/subsystems in the test sub-array is shown in Figure 1.

The test sub-array system consists of following sub-systems:

- **Antenna Unit (AU)**, made up of 91 inverted v-shaped crossed dipole antenna elements together with its meshed ground plane, mounted approximately 3.0m above the ground level. This unit also includes array structure and other supporting structure such as the mounting poles.

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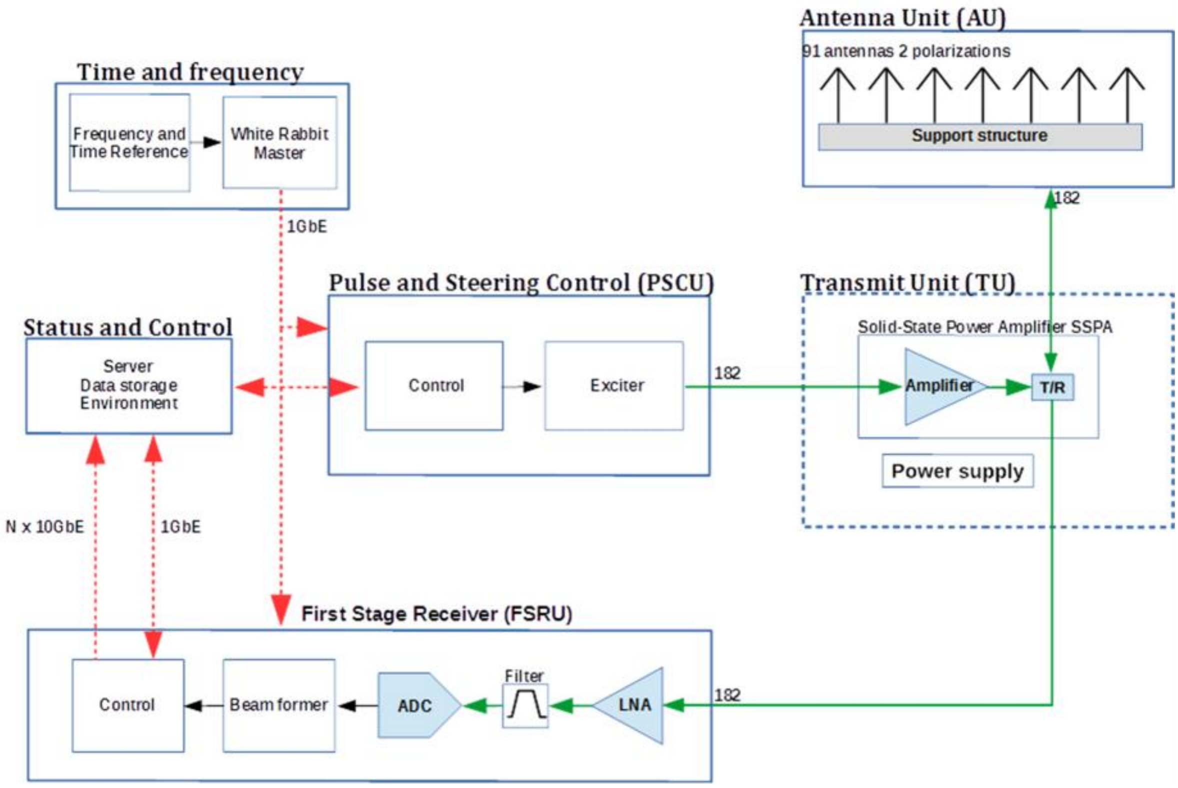

Figure 1: A top level block diagram of the different subsystems in the EISCAT_3D test sub-array.

- **Transmit Unit (TU)** consists of a power amplifier, transmit/receive switch and a power supply unit. This unit will be supplied as in-kind contribution from National Institute of Polar Research (NIPR), Japan.
- **First Stage Receiver Unit (FSRU)** is made up of low noise amplifier (LNA), anti-aliasing filter, analog to digital converters (ADC) and a digital beamformer along with a control circuitry and application programming interface (API).
- **Pulse and Steering Control Unit (PSCU)** consists of a radar controller unit, an exciter, and an interface to the other sub-systems.
- **Status and Control Unit** is a standard Linux server with number of 10 GbE and 1 GbE Ethernet connections.
- **Time and Frequency Unit** consists of a Time and Frequency standard and White Rabbit (WR) master and network node units.

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1 Instruments

Following instruments are needed for the tests:

- Antenna analyser
- Vector Network Analyzer (VNA)
- Signal generator (SG)
- Frequency counter
- Spectrum analyser

2 Test programs

The test programs are made to record as well as analyse FSRU output data and further, control signal generator. Programs can be written during the development phase of FSRU and PSCU by using languages such as LabVIEW, MATLAB or Python.

Test programs include at least:

2.1 Signal measurements

During FSRU and PSCU development phase the test programs which analyse the following test parameters are developed:

2.1.1 Signal level

Calculates signal level in given frequency.

2.1.2 Noise level

Calculates noise level and system temperature using given noise bandwidth and frequency range.

2.1.3 Amplitude and phase difference

Measures amplitude and phase difference between two channels.

Beamforming test program is used to test full band delay. Wide band signal (Sinc or noise) is used to generate 30 MHz signal in the input of FSRU. Having one channel as a reference and the other as a measurement we can check the variation in signal delay.

2.2 Waveform generation

Generate digital signals in to a file. Files are used as waveforms for PSCU unit and can be downloaded to the signal generator. All needed waveforms are included to LabVIEW and can be used directly from there.

2.2.1 Sine wave

Single sine wave with adjustable frequency and amplitude is used for testing.

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2.2.2 Frequency Sweep

A program to produce frequency sweep with adjustable amplitude, sweep time and start/stop frequency.

2.2.3 Sinc and Chirp

One waveform which includes many frequencies. Adjustable frequency range, amplitude and duration.

2.2.4 Wideband noise

Generate noise signal with adjustable bandwidth and amplitude.

2.3 Complete test sets

Following test programs for more complicated test tasks are made.

- Frequency Response
- Crosstalk
- Linearity

3 First Stage Receiver Unit

3.1 Mechanics and connectors

Mechanical connections are verified first in the supplier documentation and then visually during the Factory Acceptance Tests.

3.1.1 Mechanical connections

Verify that unit can be rack mounted.

3.1.2 Electrical connections

Verify that:

- 230V 1 phase connections with standard plug in
- RF in connectors MMCX or similar coaxial connector
- Ethernet connectors RJ-45

3.2 Front-End

Analogue properties of the Front-End is measured using VNA and signal generator. FSRU will be in test mode so that raw signal from ADC is feed directly to data out and measured using PC.

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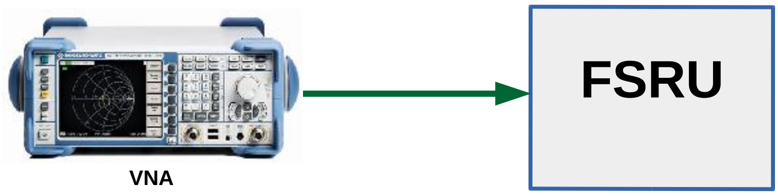
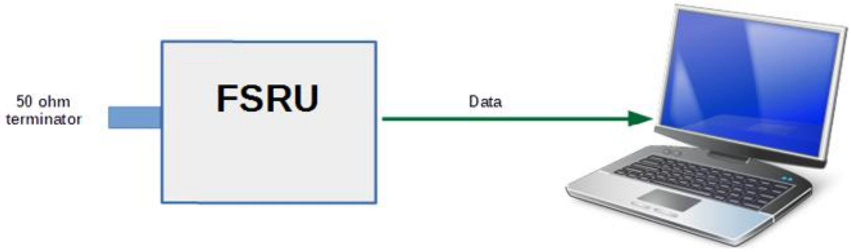
3.2.1 Input

Measure return loss of the input using VNA. Verify that requirement is met for full band and each 182 input channels.



3.2.2 Noise I

Connect 50-Ohm termination to input and record raw data from all channels to hard disc. Verify using program that requirement of maximum noise level is met for all channels.

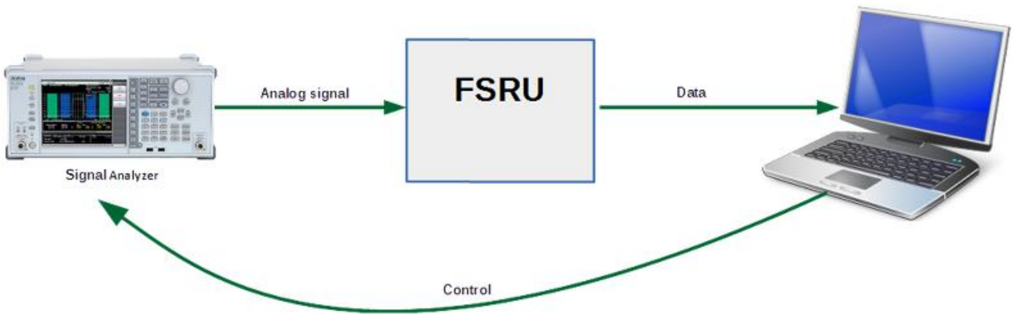


3.2.3 Signal level

Connect signal generator having CW 233 MHz and -30 dBm to input and record raw data from all channels to hard disc. Using test program verify that all channels receive signal.

3.2.4 Linearity

Connect signal analyzer to laptop and run non-linearity test program for linearity checks.



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3.2.5 Crosstalk

Send signal to one channel and measure from next and using signal level program check that level doesn't exceed -20 dB.

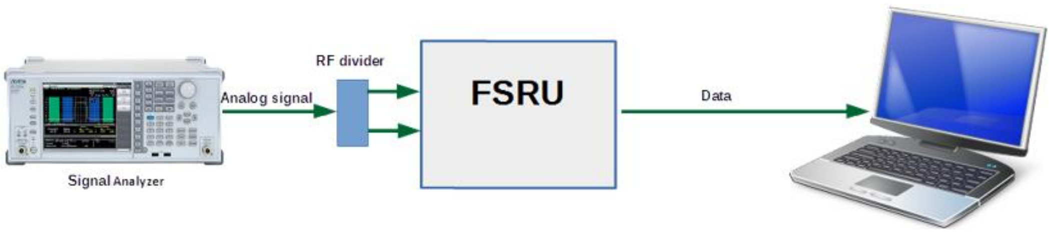
3.3 Control commands

Connect FSRU to LAN network and start commands test program. Check that following tasks can be made:

- Start acquiring data
- Stop acquiring data
- Set delays
- Set filter taps
- Set decimation

3.4 Beamforming

Connect signal analyzer as shown in figure below. One channel is used as a reference and other for measurement.



Run test program and verify that delay variation in all channels is correct.

4 Pulse and Steering Control Unit

4.1 Mechanics and connectors

Mechanical connections are verified first in the supplier documentation and then visually during the Factory Acceptance Tests.

4.1.1 Mechanical connections

Verify that unit can be rack mounted.

4.1.2 Electrical connections

Verify that:

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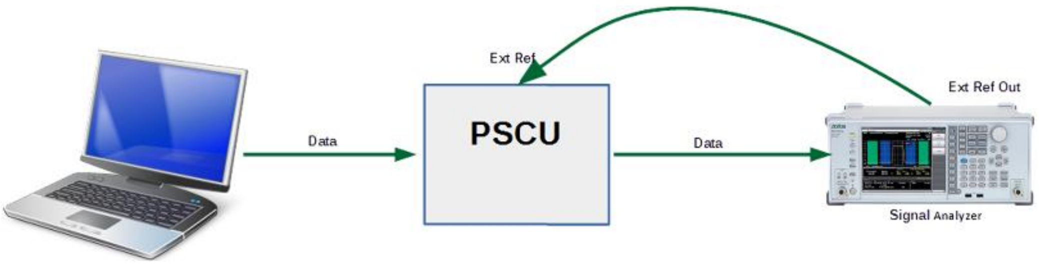
- 230V 1 phase connections with standard plug in
- RF out connectors are MMCX or similar coaxial connector
- GPIO out connectors are MMCX or similar coaxial connector
- Ethernet connectors are RJ-45

4.2 Analog signal

Analogue properties of the PSCU output are measured using test programs and signal analyser. Test Program is used to generate waveforms from PSCU and these waveforms are sent to signal analyzer.

Measurement setup is shown in figure below:



4.2.1 Signal level

Set signal to 233 MHz full scale and verify that RF signal out is 233 MHz and 0 dBm.

4.2.2 Crosstalk

Send signal to one channel and measure from next and using signal analyzer that level doesn’t exceed -20 dB.

4.2.3 Frequency response

Run frequency response test program and verify that response is correct. Repeat for all channels.

4.2.4 Linearity

Using linearity test program generate amplitude sweeps with different frequencies in the transmitting band. Measure and record signal using signal analyser verify that non-linearity does not exceed requirement. Repeat for all channels.

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4.2.5 Noise

Set PSCU to send empty waveform and verify that output signal is less than -50 dBm. Repeat for all channels.

5 Antenna Unit

5.1 Mechanical

5.1.1 Connections

Each antenna has two polarizations, check that each polarization is properly connected to a RF-cable. Check also that an N-connector is mounted on the opposite end of each cable.

5.1.2 Structure

1. Measure the height of the structure and check that the minimum height is 3.0m.
2. Check that the antennas are properly attached to the ground structure.
3. Measure that parts are electrically connected
4. Check distance between antennas
5. Check all directions for proper antenna alignment

5.1.3 Antenna elements

Check visually that each antenna element is without any mechanical defects and have a 90-degree angle between each other.

5.2 Electrical

5.2.1 Return loss

Measure full band return loss for each antenna and polarization using the VNA. Check that return loss is below the requirements for the transmit- and receive-bands.

6 Transmit Unit

Transmit Units are tested by NIPR before delivery and a basic functionality test will be performed at the site before integrating it with other sub-systems.

7 Time and Frequency Unit

These measurements are repeated to all equipment in the network:

- White Rabbit (WR) Master
- WR Slave

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7.1 10 MHz reference out put

7.1.1 Output amplitude

Check that output is at least 0 dBm.

7.1.2 Frequency Accuracy

Measure using frequency counter that frequency accuracy is better than 10^{-10}.

7.1.3 Harmonics

Check that all harmonics are below -40 dB.

7.1.4 Phase Noise

Measure that phase noise is better than -100 dBc/Hz @1 kHz out of centre frequency.

7.2 1PPS out

7.2.1 Output amplitude

Check that output is at least 0 dBm.

7.2.2 Frequency Accuracy

Measure using frequency counter that frequency error to site reference is better than 10^{-10}.

7.3 Synchronisation test

Using oscilloscope and histogram display check that 1 sigma time variation is less than 100 ps between the reference clock and any WR slave device in the network.

8 System performance tests

System test are performed using known source in the sky and reflector located either in a mast, drone or balloon.

8.1 Receiver tests

Using known radio wave source, like sun, receiver beamforming performance can be evaluated. Beam is scanned over the sun and from measured amplitude data the size of the beam can be calculated.

8.2 Transmitter tests

Reference receiver located in mast, drone or balloon is used to measure transmitter signals from array. Transmit beam is scanned over the test receiver antenna and signal

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strength is measured. Transmit beam size can be calculated from pointing directions and signal amplitude.

8.3 Radar test

Know radio wave reflector is located to the drone, balloon or mast. Radar transmitter beam and receiver beams are directed to the reflector.

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