EISCAT Experiments

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Contents

Cover art: Visualisation of the alternating code used in the manda experiment.

1 Introduction

This document is created in order to give a brief overview of the measurement capabilities of the EISCAT radar systems. It describes standard experiments, that is experiments that are used in the common programmes, and other supported experiments to aid the understanding of their differences.

2 Overview

Before making measurements with EISCAT, there are some choices that the experimenter has to make: the geographic/geomagnetic location, the time of day and year, the ionospheric region, the resolutions in time and space, the antenna scan patterns, and so on. These choices naturally depend on the scientific objectives of the measurements, but for some of the choices knowledge of the radar systems is needed.

2.1 The radar systems

EISCAT Scientific Association operates three radar systems (UHF, VHF and ESR) with transmitters on two geographical locations, working in three different radio frequency ranges.

- The UHF (Ultra High Frequency) system operates at a frequency range around 929 MHz with a transmitter and receiver on the Ramfjordmoen site near Tromsø (see Table 1). The antenna is a 32 m steerable parabolic dish.
- The VHF (very High Frequency) system operates at a frequency range around 224 MHz with a transmitter and receiver on the same site as the UHF system (Ramfjordmoen near Tromsø). The antenna consists of four 30 m $\times$ 40 m tiltable rectangular dishes, limited to point in the zenith direction or northward. The VHF system also contains two receive-only stations located in Kiruna and Sodankylä (see Table 1). The antennas on these stations are 32 m steerable dishes, and they provides possibility for tri-static measurements of plasma flow.
- The ESR (EISCAT Svalbard Radar) system operates at a frequency range around 500 MHz with a transmitter and receiver at Longyearbyen on Svalbard. The system consists of two antennas: one fully steerable 32 m parabolic dish, and one fixed 42 m parabolic dish pointing in the direction of the local magnetic field. This set-up enables simultaneous measurements in two different directions.

Table 1: Geographic location of the EISCAT radar facilities.

Location	**Country**	**Coordinates**	
Tromsø	Norway	69°35′ N	19°14′ E
Longyearbyen	Svalbard	78°9′ N	16°1′ E
Kiruna	Sweden	67°52′ N	20°26′ E
Sodankylä	Finland	67°22′ N	26°38′ E

2.2 Antenna scan patterns

EISCAT has pre-defined a set of antenna scan patterns that should be useful for most scientific measurements. They are named after the Common Programme they are used in.

2.2.1 Mainland systems

The UHF and VHF radars are often operated simultaneously during the Common Programme experiments. Such observations offer comprehensive data sets for atmospheric, ionospheric, and magnetospheric studies.

- Common Programme One, CP-1, uses a fixed transmitting antenna, pointing along the geomagnetic field direction. The three-dimensional velocity and anisotropy in other parameters are measured by means of the VHF receiving stations at Kiruna and Sodankylä. CP-1 is capable of providing results with very good time resolution and is suitable for the study of substorm phenomena, particularly auroral processes where conditions might change rapidly. Continuous electric field measurements are derived from the tri-static F-region data. On longer time scales, CP-1 measurements support studies of diurnal changes, such as atmospheric tides, as well as seasonal and solar-cycle variations.
- Common Programme Two, CP-2, is designed to make measurements from a small, rapid transmitter antenna scan. One aim is to identify wave-like phenomena with length and time scales comparable with, or larger than, the scan (a few tens of kilometers and about ten minutes). The first three positions form a triangle with vertical, south, and south-east positions, while the fourth is aligned with the geomagnetic field.
- Common Programme Three, CP-3, covers a 10° latitudinal range in the F-region with a 17-position scan up to 74°N in a 30 min cycle. The observations are made in a plane defined by the magnetic meridian through Tromsø. The principal aim of CP-3 is the mapping of ionospheric and electrodynamic parameters over a broad latitude range.
- Common Programme Four, CP-4, covers geographic latitudes up to almost 80°N (77°N invariant latitude) using a low elevation, split-beam configuration. CP-4 is particularly suitable for studies of high latitude plasma convection and polar cap phenomena. However, with the present one-beam configuration of the VHF radar, CP-4 is run with either both UHF and VHF radars or with UHF only in a two position scan.
- Common Programme Six, CP-6, is designed for low altitude studies, providing spectral measurements at mesospheric heights. Velocity and electron density are derived from the measurements and the spectra contain information on the aeronomy of the mesosphere. Vertical antenna pointing is used.
- Common Programme Seven, CP-7, probes high altitudes and is particularly aimed at polar wind studies. The present version, with only one of the VHF klystrons running, is designed to cover altitudes up to 1500 km vertically above Ramfjordmoen.

2.2.2 The EISCAT Svalbard Radar

Equivalent Common Programme modes are available for the EISCAT Svalbard Radar.

- CP-1 is directed along the geomagnetic field (81.6° inclination).
- CP-2 uses a four position scan.
- CP-3 is a 15 position elevation scan with southerly beam swinging positions.
- CP-4 combines observations in the F-region viewing area with field-aligned and vertical measurements.
- CP-6 is similar to the mainland radar CP-6.
- CP-7 is similar to the mainland radar CP-7.

The different common programmes are usually run using a specific experiment, as denoted in Table 2. See next section for a brief overview of the different experiments.

2.3 Experiment overview

An EISCAT experiment is a set of instructions telling the transmitters, receivers and digital signal processing units what to do at what time. In order to considerably simplify for the users of the radar systems a set of standard experiments have been created. They differ in range coverage, range resolution, time resolution and spectral resolution so that they are fitted for studies of different regions of the ionosphere. Some experiments are usable when the antenna is scanning while others are best used at fixed antenna positions. Some experiments provide plasma line data in addition to the standard ion line data, and some experiments in addition collect raw voltage level data to be analysed by the more experienced user. Expert users can modify the standard experiments, or even create their own ones.

All supported EISCAT experiments are based on alternating codes, but the codes are of different lengths in different experiments.

Some parameters describing the standard experiments used by the EISCAT UHF radar are collected in Table 3. The experiments used when running Common Programmes are beata, bella and manda. The main difference between

Table 2: Common programmes and their connected experiments. Experiment names in italic indicates common programmes not normally run.

	UHF	**VHF**	**ESR**
CP-1	beata	*beata*	ipy
CP-2	beata	-	tyko
CP-3	bella	-	folke
CP-4	*bella*	bella	folke
CP-6	*manda*	manda	manda
CP-7	-	tau7	tau7

these experiments lies in the range coverage, as is illustrated in Figure 1. More details about these experiments are found in Section 3.1. Other supported experiments on the UHF radar are arc_dlayer (optimised for D-region measurements), arc1 (good time resolution, for auroral studies) and tau1 (older experiment comparable to bella). More details on these specialised experiments are found in section Section 4.1.

Parameters describing the standard experiments used by the EISCAT VHF radar are collected in Table 4. The experiments used when running Common Programmes are beata, bella, manda and tau7. Similar to the UHF experiments, the main difference between these experiments is in the range coverage, as is illustrated in Figure 2. More details about these experiments are found in Section 3.2. Other supported experiments on the VHF radar are arc_dlayer (optimised for D-region measurements), tau1 (older experiment with similar range span as tau7) and tau8 (older experiment with similar range span as bella). More details on these specialised experiments are found in section Section 4.2. There are three experiments with supported tri-static capabiliy: beata, bella and manda.

Parameters describing the standard experiments used by the EISCAT ESR radar are collected in Table 5. The experiments used when running Common Programmes are ipy, tyko, folke, manda and tau7. Differences include range coverage, as well as power consumption, and is illustrated in Figure 3. The folke experiment is using both the 32 m and the 42 m antennas, and can thus by default make observations in two directions at the same time. More details about these experiments are found in Section 3.3. Other supported experiments on the ESR radar are arc_slice (good time resolution, for auroral studies), beata (an alternative to ipy or tyko), steffe (different range resolution for different range intervals), tau0 (older experiment with similar range span as tau7), hilde (two antennas, three different range resolutions) and taro (both antennas are used over a large range interval, but with different duty cycles). More details on these specialised experiments are found in section Section 4.3. The experiments using both antennas in coordination are thus folke, hilde and taro. In addition, ipy, tyko, tau7, arc_slice, beata, steffe and taro can switch between the antennas.

When reading the following tables, we can also get quick estimates of range resolution (from baud length), spectral resolution (from the inversion of the multiplication of code length and baud length) and spectral range (inverse of sampling rate). However, the actual numbers may differ from these estimates depending on what is done during the digital signal processing.

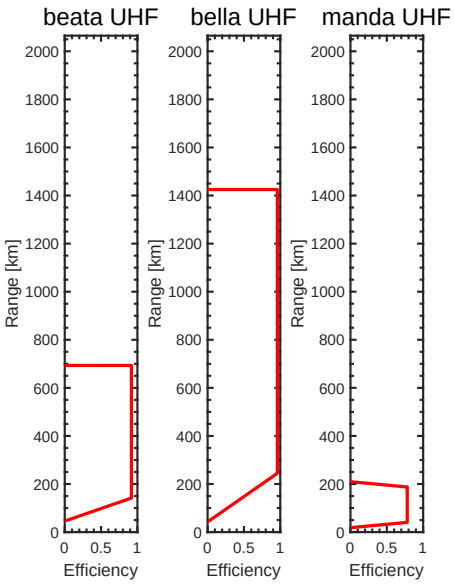

Figure 1: Overview of the ranges covered at the EISCAT UHF radar by the experiments used in the common programmes.

Table 3: EISCAT UHF radar standard experiments.

Name	**Code length** [bit]	**Baud length** [µs]	**Sampling rate** [µs]	**Range span** [km]	**Time resolution** [s]	**Plasma line**	**Raw data**
beata	32	20	10	49–693	5.0	Yes	-
bella	30	45	15	47–1425	3.6	Yes	-
manda	61	2.4	1.2	19–209	4.8	-	Yes
arc_dlayer	64	2	2	60–139	5.0	-	-
arc1	64	6	6	95–420	0.44	-	-
tau1	16	60	12	48–1353	5.0	-	Yes

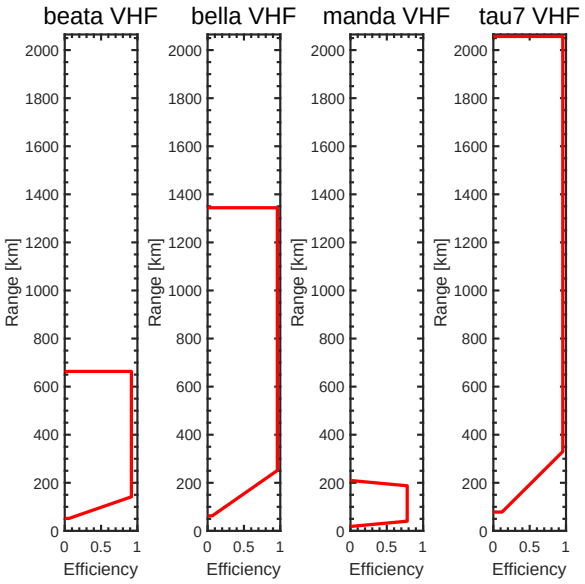

Figure 2: Overview of the ranges covered at the EISCAT VHF radar by the experiments used in the common programmes.

Table 4: EISCAT VHF radar standard experiments. The top three experiments have tri-static support.

Name	**Code length** [bit]	**Baud length** [µs]	**Sampling rate** [µs]	**Range span** [km]	**Time resolution** [s]	**Plasma line**	**Raw data**
beata	32	20	20	52–663	5.0	Yes	-
bella	30	45	45	63–1344	3.6	Yes	-
manda	61	2.4	1.2	19–209	4.8	-	Yes
tau7	16	120	15	78–2057	3.6	Yes	-
arc_dlayer	64	2	2	60–139	5.0	-	-
tau1	16	72	24	104–2061	5.0	-	-
tau8	16	84	14	52–1307	5.0	Yes	-

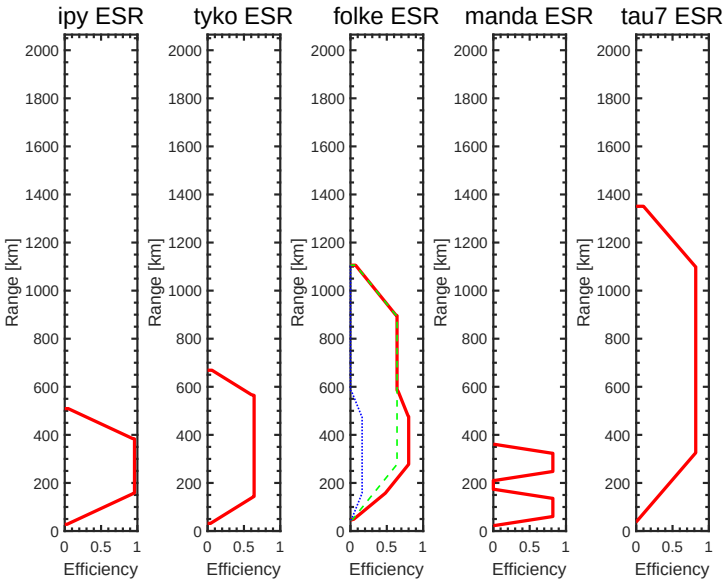

Figure 3: Overview of the ranges covered at the EISCAT ESR radar by the experiments used in the common programmes.

Table 5: EISCAT ESR radar standard experiments.

Name	**Code length** [bit]	**Baud length** [µs]	**Sampling rate** [µs]	**Range span** [km]	**Time resolution** [s]	**Plasma line**	**Raw data**
ipy	30	30	15	28–509	6.0	Yes	Yes
tyko	16	50	25	32–564	4.0	Yes	Yes
folke	16	100	25	45–1106	6.4	Yes	-
(dual)	16	50	25	45–581	6.4	Yes	-
manda	64	4	2	23–361	4.0	-	Yes
tau7	16	120	5	39–1351	6.0	Yes	-
arc_slice	64	6	6	85–481	0.5	-	-
beata	30	50	25	45–645	6.0	Yes	Yes
steffe	16	105	15	34–1021	6.4	Yes	-
	16	30	15	214–1033	6.4	-	-
tau0	16	60	20	53–1297	6.4	-	-
hilde	16	96	16	34–917	5.1	-	-
(dual)	16	32	16	34–963	5.1	-	-
	16	60	20	35–1288	5.1	-	Yes
taro	16	50	25	47–830	6.4	-	-
(dual)	16	50	25	47–830	6.4	-	-

3 Experiments used in common programmes

3.1 UHF

3.1.1 beata

Version	2.1
Raw data available	No
Plasma line	Yes
Transmitter frequency	928.4 MHz
Integration time	5.0 s
Code	Alternating, 32 bit, 64 subcycles
Baud length	20 µs
Sampling rate	10 µs (0.4 µs plasma line)
Subcycle length	5.58 ms
Duty cycle	0.115

Ion line Normal

Time resolution	5 s
Range span	49 km to 693 km
Range gate size	1.5 km
Spectral range	±50 kHz
Spectral resolution	1.22 kHz
Lag step	10 µs
Maximum lag	41 (410 µs)

Ion line Short slices

Time resolution	0.357 s
Range span	49 km to 693 km
Range gate size	1.5 km
Spectral range	±50 kHz
Spectral resolution	50.0 kHz
Lag step	10 µs
Maximum lag	1 (10 µs)

Plasma line One up-shifted and two down-shifted frequency ranges

Time resolution	5 s
Range span	107 km to 374 km
Range gate size	3.0 km
Spectral range	±1.25 MHz
Spectral resolution	1.56 kHz
Lag step	0.4 µs
Maximum lag	800 (320 µs)

3.1.2 bella

Version	1.0
Raw data available	No
Plasma line	Yes
Transmitter frequency	929.9 MHz
Integration time	3.6 s
Code	Alternating, 30 bit, 64 subcycles
Baud length	45 µs
Sampling rate	15 µs (0.6 µs plasma line)
Subcycle length	11.25 ms
Duty cycle	0.120

Ion line Normal

Time resolution	3.6 s
Range span	47 km to 1425 km
Range gate size	2.2 km
Spectral range	±33 kHz
Spectral resolution	1.04 kHz
Lag step	15 µs
Maximum lag	32 (480 µs)

Plasma line Four down-shifted frequency ranges

Time resolution	3.6 s
Range span	44 km to 735 km
Range gate size	138 km
Spectral range	±833 kHz
Spectral resolution	11.3 kHz
Lag step	0.6 µs
Maximum lag	74 (44.4 µs)

3.1.3 manda

Version	4.0
Raw data available	Yes
Plasma line	No
Transmitter frequency	929.6 MHz
Integration time	4.8 s
Code	Alternating, 61 bit, 128 subcycles
Baud length	2.4 µs
Sampling rate	1.2 µs
Subcycle length	1.5 ms
Duty cycle	0.098

Ion line Normal

Time resolution	4.8 s
Range span	19 km to 209 km
Range gate size	0.36 km
Spectral range	$\pm$417 kHz
Spectral resolution	3.47 kHz
Lag step	1.2 µs
Maximum lag	120 (144 µs)

Ion line D region

Time resolution	4.8 s
Range span	19 km to 109 km
Range gate size	0.36 km
Spectral range	$\pm$333 Hz
Spectral resolution	2.62 Hz
Lag step	1.5 ms
Maximum lag	127 (190.5 ms)

Ion line D region, long lags

Time resolution	4.8 s
Range span	19 km to 109 km
Range gate size	0.36 km
Spectral range	$\pm$2.6 Hz
Spectral resolution	0.174 Hz
Lag step	192 ms
Maximum lag	15 (2.88 s)

3.2 VHF

3.2.1 beata

Version	2.1
Raw data available	No
Plasma line	Yes
Transmitter frequency	223.6 MHz
Integration time	5.0 s
Code	Alternating, 32 bit, 64 subcycles
Baud length	20 µs
Sampling rate	10 µs (0.8 µs plasma line)
Subcycle length	5.58 ms
Duty cycle	0.115

Ion line Normal

Time resolution	5.0 s
Range span	52 km to 663 km
Range gate size	3.0 km
Spectral range	±25 kHz
Spectral resolution	0.781 kHz
Lag step	20 µs
Maximum lag	32 (640 µs)

Plasma line Two down-shifted frequency ranges

Time resolution	5 s
Range span	109 km to 375 km
Range gate size	3.0 km
Spectral range	±1.25 MHz
Spectral resolution	1.56 kHz
Lag step	0.4 µs
Maximum lag	800 (320 µs)

Ion line Remote sites, two polarisations

Time resolution	5.0 s
Timing interval	0 µs to 800 µs
Time step	20 µs
Spectral range	±25 kHz
Spectral resolution	0.781 kHz
Lag step	20 µs
Maximum lag	31 (620 µs)

3.2.2 bella

Version	1.0 (2.1 on remote sites)
Raw data available	No
Plasma line	Yes
Transmitter frequency	223.6 MHz
Integration time	3.6 s
Code	Alternating, 30 bit, 64 subcycles
Baud length	45 µs
Sampling rate	45 µs (0.6 µs plasma line)
Subcycle length	11.25 ms
Duty cycle	0.120

Ion line Normal, two signals (one per antenna half)

Time resolution	3.6 s
Range span	63 km to 1344 km
Range gate size	6.7 km
Spectral range	$\pm$11 kHz
Spectral resolution	0.370 kHz
Lag step	45 µs
Maximum lag	30 (1350 µs)

Plasma line Two down-shifted frequency ranges, two signals (one per antenna half)

Time resolution	3.6 s
Range span	56 km to 746 km
Range gate size	138 km
Spectral range	$\pm$833 kHz
Spectral resolution	11.3 kHz
Lag step	0.6 µs
Maximum lag	74 (44.4 µs)

Ion line Remote sites, two polarisations

Time resolution	3.6 s
Timing interval	0 µs to 6570 µs
Time step	45 µs
Spectral range	$\pm$11 kHz
Spectral resolution	0.383 kHz
Lag step	45 µs
Maximum lag	29 (1305 µs)

3.2.3 manda

Version	4.0
Raw data available	Yes
Plasma line	No
Transmitter frequency	223.4 MHz
Integration time	4.8 s
Code	Alternating, 61 bit, 128 subcycles
Baud length	2.4 µs
Sampling rate	1.2 µs
Subcycle length	1.5 ms
Duty cycle	0.098

Ion line Normal, two signals (one per antenna half)

Time resolution	4.8 s
Range span	19 km to 209 km
Range gate size	0.36 km
Spectral range	±417 kHz
Spectral resolution	3.47 kHz
Lag step	1.2 µs
Maximum lag	120 (144 µs)

Ion line D region, two signals (one per antenna half)

Time resolution	4.8 s
Range span	19 km to 109 km
Range gate size	0.36 km
Spectral range	±333 Hz
Spectral resolution	2.62 Hz
Lag step	1.5 ms
Maximum lag	127 (190.5 ms)

Ion line D region, long lags, two signals (one per antenna half)

Time resolution	4.8 s
Range span	19 km to 109 km
Range gate size	0.36 km
Spectral range	±2.6 Hz
Spectral resolution	0.174 Hz
Lag step	192 ms
Maximum lag	15 (2.88 s)

Ion line Normal, remote sites, two polarisations

Time resolution	4.8 s
Timing interval	0 µs to 124.8 µs
Time step	2.4 µs
Spectral range	±11 kHz
Spectral resolution	3.47 kHz
Lag step	2.4 µs
Maximum lag	60 (144 µs)

Ion line D region, remote sites, two polarisations

Time resolution	4.8 s
Timing interval	0 µs to 124.8 µs
Time step	2.4 µs
Spectral range	±333 Hz
Spectral resolution	2.62 Hz
Lag step	1.5 ms
Maximum lag	127 (190.5 ms)

Ion line D region, long lags, remote sites, two polarisations

Time resolution	4.8 s
Timing interval	0 µs to 124.8 µs
Time step	2.4 µs
Spectral range	±2.6 Hz
Spectral resolution	0.174 Hz
Lag step	192 ms
Maximum lag	15 (2.88 s)

3.2.4 tau7

Version	2.0
Raw data available	No
Plasma line	Yes
Transmitter frequency	223.6 MHz
Integration time	3.6 s
Code	Alternating, 16 bit, 32 subcycles
Baud length	120 µs
Sampling rate	15 µs (0.6 µs plasma line)
Subcycle length	16.065 ms
Duty cycle	0.120

Ion line Normal

Time resolution	3.6 s
Range span	78 km to 2057 km
Range gate size	18 km
Spectral range	±33 kHz
Spectral resolution	0.260 kHz
Lag step	15 µs
Maximum lag	128 (1920 µs)

Plasma line Two down-shifted frequency ranges

Time resolution	3.6 s
Range span	44 km to 735 km
Range gate size	138 km
Spectral range	±833 kHz
Spectral resolution	4.19 kHz
Lag step	0.6 µs
Maximum lag	199 (119.4 µs)

3.3 ESR

3.3.1 folke

Version	2.0
Antenna	Dual, four parts 32 m, one part 42 m
Raw data available	No
Plasma line	Yes
Transmitter frequency	499.9 MHz and 500.1 MHz
Integration time	6.4 s
Code	Alternating, 16 bit, 32 subcycles
Baud length	100 µs (32 m) and 50 µs (42 m)
Sampling rate	25 µs (0.4 µs plasma line)
Subcycle length	7.950 ms (32 m) + 7.975 ms (32 m) +4.075 ms (42 m) = 20.000 ms
Duty cycle	0.160 (32 m) + 0.040 (42 m) = 0.200

Ion line Normal, 32 m

Time resolution	6.4 s
Range span	45 km to 896 km
Range gate size	3.7 km
Spectral range	±20 kHz
Spectral resolution	0.645 kHz
Lag step	25 µs
Maximum lag	31 (775 µs)

Ion line Top end, 32 m

Time resolution	6.4 s
Range span	911 km to 1106 km
Range gate size	15.0 km
Spectral range	±20 kHz
Spectral resolution	0.625 kHz
Lag step	25 µs
Maximum lag	32 (800 µs)

Ion line Normal, 42 m

Time resolution	6.4 s
Range span	45 km to 476 km
Range gate size	3.7 km
Spectral range	±20 kHz
Spectral resolution	0.645 kHz
Lag step	25 µs
Maximum lag	31 (775 µs)

Ion line Top end, 42 m

Time resolution	6.4 s
Range span	484 km to 581 km
Range gate size	7.5 km
Spectral range	±20 kHz
Spectral resolution	1.25 kHz
Lag step	25 µs
Maximum lag	16 (400 µs)

Plasma line Two down-shifted and two up-shifted frequency ranges, 32 m

Time resolution	6.4 s
Range span	41 km to 655 km
Range gate size	123 km
Spectral range	±1.25 MHz
Spectral resolution	5.02 kHz
Lag step	0.4 µs
Maximum lag	249 (99.6 µs)

Plasma line Two down-shifted and two up-shifted frequency ranges, 42 m

Time resolution	6.4 s
Range span	41 km to 348 km
Range gate size	61 km
Spectral range	±1.25 MHz
Spectral resolution	10.1 kHz
Lag step	0.4 µs
Maximum lag	124 (49.6 µs)

3.3.2 ipy

Version	4.2
Antenna	Single, switchable
Raw data available	Yes, on fixed 42p scan
Plasma line	Yes
Transmitter frequency	499.85 MHz
Integration time	6.0 s
Code	Alternating, 30 bit, 64 subcycles
Baud length	30 µs
Sampling rate	15 µs (0.2 µs plasma line)
Subcycle length	3.75 ms
Duty cycle	0.240

Ion line Normal

Time resolution	6.0 s
Range span	28 km to 383 km
Range gate size	2.2 km
Spectral range	±33 kHz
Spectral resolution	0.813 kHz
Lag step	15 µs
Maximum lag	41 (615 µs)

Ion line Top end

Time resolution	6.0 s
Range span	388 km to 509 km
Range gate size	4.5 km
Spectral range	±33 kHz
Spectral resolution	0.556 kHz
Lag step	15 µs
Maximum lag	60 (900 µs)

Plasma line One up-shifted and one down-shifted frequency range

Time resolution	6.0 s
Range span	93 km to 455 km
Range gate size	4.5 km
Spectral range	±2.5 MHz
Spectral resolution	1.09 kHz
Lag step	0.2 µs
Maximum lag	2304 (460.8 µs)

3.3.3 manda

Version	4.0
Antenna	Single
Raw data available	Yes
Plasma line	No
Transmitter frequency	500.3 MHz
Integration time	4.0 s
Code	Alternating, 64 bit, 128 subcycles
Baud length	4 µs
Sampling rate	2 µs
Subcycle length	1.25 ms
Duty cycle	0.205

Ion line E region

Time resolution	4.0 s
Range span	23 km to 173 km
Range gate size	0.6 km
Spectral range	±250 kHz
Spectral resolution	1.95 kHz
Lag step	2 µs
Maximum lag	128 (256 µs)

Ion line D region

Time resolution	4.0 s
Range span	23 km to 114 km
Range gate size	0.6 km
Spectral range	±400 Hz
Spectral resolution	3.15 Hz
Lag step	1.25 ms
Maximum lag	127 (158.75 ms)

Ion line D region, long lags

Time resolution	4.0 s
Range span	23 km to 114 km
Range gate size	0.6 km
Spectral range	±3.1 Hz
Spectral resolution	0.208 Hz
Lag step	160 ms
Maximum lag	15 (2.4 s)

Ion line F region

Time resolution	4.0 s
Range span	211 km to 361 km
Range gate size	0.6 km
Spectral range	±250 kHz
Spectral resolution	1.95 kHz
Lag step	2 µs
Maximum lag	128 (256 µs)

3.3.4 tau7

Version	1.0
Antenna	Single, switchable
Raw data available	No
Plasma line	Yes
Transmitter frequency	499.7 MHz
Integration time	6.0 s
Code	Alternating, 16 bit, 32 subcycles
Baud length	120 µs
Sampling rate	5 µs (0.4 µs plasma line)
Subcycle length	9.375 ms
Duty cycle	0.205

Ion line Normal

Time resolution	6.0 s
Range span	39 km to 1099 km
Range gate size	0.7 km
Spectral range	±100 kHz
Spectral resolution	0.840 kHz
Lag step	5 µs
Maximum lag	119 (595 µs)

Ion line Top end

Time resolution	6.0 s
Range span	1117 km to 1351 km
Range gate size	18 km
Spectral range	±100 kHz
Spectral resolution	0.521 kHz
Lag step	5 µs
Maximum lag	192 (960 µs)

Plasma line One down-shifted and one up-shifted frequency range, power spectrum only

Time resolution	6.0 s
Range span	98 km to 402 km
Spectral range	±1250 kHz
Spectral resolution	9.77 kHz

3.3.5 tyko

Version	1.0
Antenna	Single, switchable
Raw data available	Yes, on fixed 42p scan
Plasma line	Yes
Transmitter frequency	499.9 MHz
Integration time	4.0 s
Code	Alternating, 16 bit, 32 subcycles
Baud length	50 µs
Sampling rate	25 µs (0.4 µs plasma line)
Subcycle length	5.0 ms
Duty cycle	0.160

Ion line Normal

Time resolution	4.0 s
Range span	32 km to 564 km
Range gate size	3.7 km
Spectral range	±20 kHz
Spectral resolution	0.645 kHz
Lag step	25 µs
Maximum lag	31 (775 µs)

Ion line Top end

Time resolution	4.0 s
Range span	571 km to 669 km
Range gate size	7.5 km
Spectral range	±20 kHz
Spectral resolution	1.25 kHz
Lag step	25 µs
Maximum lag	16 (400 µs)

Plasma line Two down-shifted and two up-shifted frequency ranges

Time resolution	4.0 s
Range span	28 km to 450 km
Range gate size	61.4 km
Spectral range	±1.25 MHz
Spectral resolution	10.1 kHz
Lag step	0.4 µs
Maximum lag	124 (49.6 µs)

4 Other supported experiments

4.1 UHF

4.1.1 arc_dlayer

Version	1.11
Raw data available	No
Plasma line	No
Transmitter frequency	929.6 MHz
Integration time	5.0 s
Code	Alternating, 64 bit, 128 subcycles
Baud length	2 µs
Sampling rate	2 µs
Subcycle length	1.346 ms
Duty cycle	0.095

Ion line D-region

Time resolution	5.0 s
Range span	60 km to 139 km
Range gate size	0.3 km
Spectral range	±371 Hz
Spectral resolution	2.92 Hz
Lag step	1.346 ms
Maximum lag	127 (170.942 ms)

Ion line E-region

Time resolution	5.0 s
Range span	60 km to 139 km
Range gate size	0.3 km
Spectral range	±16 kHz
Spectral resolution	5.21 kHz
Lag step	32 µs
Maximum lag	3 (96 µs)

4.1.2 arc1

Version	1.0
Raw data available	No
Plasma line	No
Transmitter frequency	929.6 MHz
Integration time	4.0 s
Code	Alternating, 64 bit, 128 subcycles
Baud length	6 µs
Sampling rate	6 µs
Subcycle length	3.468 ms
Duty cycle	0.111

Ion line Normal

Time resolution	0.443 904 s
Range span	95 km to 420 km
Range gate size	0.9 km
Spectral range	$\pm$21 kHz
Spectral resolution	1.39 kHz
Lag step	24 µs
Maximum lag	15 (360 µs)

4.1.3 tau1

Version	1.3
Raw data available	Yes
Plasma line	No
Transmitter frequency	929.3 MHz and 929.6 MHz
Integration time	5.0 s
Code	Alternating, 16 bit, 32 subcycles
Baud length	60 µs
Sampling rate	12 µs
Subcycle length	11.16 ms
Duty cycle	0.086

Ion line Normal

Time resolution	5.0 s
Range span	48 km to 1353 km
Range gate size	1.8 km
Spectral range	$\pm$42 kHz
Spectral resolution	1.44 kHz
Lag step	12 µs
Maximum lag	29 (348 µs)

4.2 VHF

4.2.1 arc_dlayer

Version	1.11
Raw data available	No
Plasma line	No
Transmitter frequency	224.2 MHz
Integration time	5.0 s
Code	Alternating, 64 bit, 128 subcycles
Baud length	2 µs
Sampling rate	2 µs
Subcycle length	1.346 ms
Duty cycle	0.095

Ion line D-region

Time resolution	5.0 s
Range span	60 km to 139 km
Range gate size	0.3 km
Spectral range	±371 Hz
Spectral resolution	2.92 Hz
Lag step	1.346 ms
Maximum lag	127 (170.942 ms)

Ion line E-region

Time resolution	5.0 s
Range span	60 km to 139 km
Range gate size	0.3 km
Spectral range	±16 kHz
Spectral resolution	5.21 kHz
Lag step	32 µs
Maximum lag	3 (96 µs)

4.2.2 tau1

Version	1.30
Raw data available	No
Plasma line	No
Transmitter frequency	223.6 MHz and 224.2 MHz
Integration time	5.0 s
Code	Alternating, 16 bit, 32 subcycles
Baud length	72 µs
Sampling rate	24 µs
Subcycle length	15.6 ms
Duty cycle	0.074

Ion line Normal (two signals (one per antenna half) possible)

Time resolution	5.0 s
Range span	104 km to 2061 km
Range gate size	3.6 km
Spectral range	$\pm$21 kHz
Spectral resolution	0.718 kHz
Lag step	24 µs
Maximum lag	29 (696 µs)

4.2.3 tau8

Version	1.11
Raw data available	No
Plasma line	Yes
Transmitter frequency	223.6 MHz and 223.4 MHz
Integration time	5.0 s
Code	Alternating, 16 bit, 32 subcycles
Baud length	84 µs
Sampling rate	14 µs (0.6 µs plasma line)
Subcycle length	11.158 ms
Duty cycle	0.120

Ion line Normal, two signals (one per antenna half)

Time resolution	5.0 s
Range span	52 km to 1307 km
Range gate size	2.1 km
Spectral range	$\pm$36 kHz
Spectral resolution	0.760 kHz
Lag step	14 µs
Maximum lag	47 (658 µs)

Plasma line Up-shifted frequency range, two signals (one per antenna half), spectral domain only

Time resolution	5.0 s
Range span	53 km to 686 km
Range gate size	4 $\times$ 213 km
Spectral range	$\pm$833 kHz
Spectral resolution	13.0 kHz

4.3 ESR

4.3.1 arc_slice

Version	1.10
Antenna	Single, switchable
Raw data available	No
Plasma line	No
Transmitter frequency	500.95 MHz
Integration time	5.0 s
Code	Alternating, 64 bit, 128 subcycles
Baud length	6 µs
Sampling rate	6 µs
Subcycle length	3.906 ms
Duty cycle	0.098

Ion line Slices

Time resolution	0.5 s
Range span	85 km to 481 km
Range gate size	0.9 km
Spectral range	$\pm$21 kHz
Spectral resolution	1.39 kHz
Lag step	24 µs
Maximum lag	15 (360 µs)

4.3.2 beata

Version	1.0
Antenna	Single, switchable
Raw data available	Yes, on fixed 42p scan
Plasma line	Yes
Transmitter frequency	500.3 MHz
Integration time	6.0 s
Code	Alternating, 30 bit, 64 subcycles
Baud length	50 µs
Sampling rate	25 µs (0.4 µs plasma line)
Subcycle length	6.25 ms
Duty cycle	0.240

Ion line Normal

Time resolution	6.0 s
Range span	45 km to 625 km
Range gate size	3.7 km
Spectral range	$\pm$20 kHz
Spectral resolution	0.488 kHz
Lag step	25 µs
Maximum lag	41 (1025 µs)

Ion line Short slices

Time resolution	0.4 s
Range span	45 km to 625 km
Range gate size	3.7 km
Spectral range	$\pm$20 kHz
Spectral resolution	20.0 kHz
Lag step	25 µs
Maximum lag	1 (25 µs)

Plasma line One down-shifted and one up-shifted frequency range

Time resolution	6.0 s
Range span	154 km to 281 km
Range gate size	7.5 km
Spectral range	$\pm$1250 kHz
Spectral resolution	0.610 kHz
Lag step	0.4 µs
Maximum lag	2048 (819.2 µs)

4.3.3 hilde

Version	1.01
Antenna	Dual, one part 32 m, one part 42 m
Raw data available	Yes, from 32 m if chosen
Plasma line	No
Transmitter frequency	500.4 MHz, 499.8 MHz, 500.1 MHz and 499.5 MHz
Integration time	5.1 s
Code	Alternating, 16 bit, 32 subcycles
Baud length	32 µs, 96 µs and 60 µs
Sampling rate	16 µs (42 m), 20 µs (32 m)
Subcycle length	10.000 ms (42 m) + 9.920 ms (32 m) = 19.92 ms
Duty cycle	0.103 (42 m) + 0.096 (32 m) = 0.199

Ion line Long pulse, 42 m

Time resolution	5.1 s
Range span	34 km to 917 km
Range gate size	2.4 km
Spectral range	±31 kHz
Spectral resolution	0.893 kHz
Lag step	16 µs
Maximum lag	35 (560 µs)

Ion line Short pulse, lower ranges, 42 m

Time resolution	5.1 s
Range span	34 km to 217 km
Range gate size	2.4 km
Spectral range	±31 kHz
Spectral resolution	1.01 kHz
Lag step	16 µs
Maximum lag	31 (496 µs)

Ion line Short pulse, upper ranges, 42 m

Time resolution	5.1 s
Range span	488 km to 963 km
Range gate size	2.4 km
Spectral range	±31 kHz
Spectral resolution	1.84 kHz
Lag step	16 µs
Maximum lag	17 (272 µs)

Ion line Upper ranges, 32 m

Time resolution	5.1 s
Range span	181 km to 1288 km
Range gate size	3.0 km
Spectral range	±25 kHz
Spectral resolution	0.862 kHz
Lag step	20 µs
Maximum lag	29 (580 µs)

Ion line Lower ranges, 32 m

Time resolution	5.1 s
Range span	35 km to 1141 km
Range gate size	3.0 km
Spectral range	±25 kHz
Spectral resolution	0.862 kHz
Lag step	20 µs
Maximum lag	29 (580 µs)

Ion line Undecoded long pulse, interval 1, 42 m

Time resolution	5.1 s
Range span	111 km to 917 km
Range gate size	2.4 km
Spectral range	±31 kHz
Spectral resolution	5.21 kHz
Lag step	16 µs
Maximum lag	6 (96 µs)

Ion line Undecoded long pulse, interval 2, 42 m

Time resolution	5.1 s
Range span	1334 km to 2405 km
Range gate size	2.4 km
Spectral range	±31 kHz
Spectral resolution	5.21 kHz
Lag step	16 µs
Maximum lag	6 (96 µs)

4.3.4 steffe

Version	2.00
Antenna	Single, switchable
Raw data available	No
Plasma line	Yes
Transmitter frequency	499.7 MHz and 500.1 MHz
Integration time	6.4 s
Code	Alternating, 16 bit, 32 subcycles
Baud length	30 µs and 105 µs
Sampling rate	15 µs (0.6 µs plasma line)
Subcycle length	9.375 ms
Duty cycle	0.230

Ion line Long pulse

Time resolution	6.4 s
Range span	34 km to 800 km
Range gate size	2.2 km
Spectral range	±33 kHz
Spectral resolution	0.813 kHz
Lag step	15 µs
Maximum lag	41 (615 µs)

Ion line Long pulse, top end

Time resolution	6.4 s
Range span	816 km to 1021 km
Range gate size	15.7 km
Spectral range	±33 kHz
Spectral resolution	0.521 kHz
Lag step	15 µs
Maximum lag	64 (960 µs)

Ion line Lower range

Time resolution	6.4 s
Range span	34 km to 221 km
Range gate size	2.2 km
Spectral range	±33 kHz
Spectral resolution	1.08 kHz
Lag step	15 µs
Maximum lag	31 (465 µs)

Ion line Lower range, top end

Time resolution	6.4 s
Range span	226 km to 284 km
Range gate size	4.5 km
Spectral range	±33 kHz
Spectral resolution	1.04 kHz
Lag step	15 µs
Maximum lag	32 (480 µs)

Ion line Upper range

Time resolution	6.4 s
Range span	513 km to 1033 km
Range gate size	2.2 km
Spectral range	±33 kHz
Spectral resolution	1.96 kHz
Lag step	15 µs
Maximum lag	17 (255 µs)

Plasma line Two down-shifted and two up-shifted frequency ranges

Time resolution	6.4 s
Range span	235 km to 361 km
Range gate size	9.0 km
Spectral range	±833 kHz
Spectral resolution	0.543 kHz
Lag step	0.6 µs
Maximum lag	1536 (921.6 µs)

4.3.5 taro

Version	1.0
Antenna	Dual, two parts 32 m, one part 42 m
Raw data available	No
Plasma line	No
Transmitter frequency	500.1 MHz, 499.5 MHz, 500.4 MHz and 499.8 MHz
Integration time	6.4 s
Code	Alternating, 16 bit, 32 subcycles
Baud length	50 µs
Sampling rate	25 µs
Subcycle length	6.425 ms and 6.775 ms (32 m) + 6.800 ms (42 m) = 20.0 ms
Duty cycle	0.160 (32 m) + 0.080 (42 m) = 0.240

Ion line Upper ranges

Time resolution	6.4 s
Range span	170 km to 830 km
Range gate size	3.7 km
Spectral range	±20 kHz
Spectral resolution	0.645 kHz
Lag step	25 µs
Maximum lag	31 (775 µs)

Ion line Lower ranges

Time resolution	6.4 s
Range span	47 km to 706 km
Range gate size	3.7 km
Spectral range	±20 kHz
Spectral resolution	0.645 kHz
Lag step	25 µs
Maximum lag	31 (775 µs)

Ion line Lower ranges, top end

Time resolution	6.4 s
Range span	714 km to 811 km
Range gate size	7.5 km
Spectral range	±20 kHz
Spectral resolution	1.25 kHz
Lag step	25 µs
Maximum lag	16 (400 µs)

4.3.6 tau0

Version	5.10
Antenna	Single, switchable
Raw data available	No
Plasma line	No
Transmitter frequency	500.125 MHz and 499.875 MHz
Integration time	6.4 s
Code	Alternating, 16 bit, 32 subcycles
Baud length	60 µs
Sampling rate	20 µs
Subcycle length	10.00 ms and 9.98 ms (alternating)
Duty cycle	0.192

Ion line Upper ranges

Time resolution	0.5 s
Range span	206 km to 1297 km
Range gate size	3.0 km
Spectral range	$\pm$25 kHz
Spectral resolution	0.962 kHz
Lag step	20 µs
Maximum lag	26 (520 µs)

Ion line Lower ranges

Time resolution	0.5 s
Range span	53 km to 1144 km
Range gate size	3.0 km
Spectral range	$\pm$25 kHz
Spectral resolution	0.962 kHz
Lag step	20 µs
Maximum lag	26 (520 µs)