

Cluster EFW Commissioning

Some useful data and plots

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1. Introduction

After the launch of Cluster II in July and August 2000, there was a commission period during which the instruments were switched on and made ready for routine operations. This document describes details of the commissioning of the Electric Fields and Waves (EFW) instrument, in particular the deployment of the wire booms. Dates and times are given for all relevant events, and plots are included of raw data from the EFW probe potential differences and the individual probe potentials.

2. Overall commissioning schedule

The Cluster EFW commissioning was focused on the deployment of the wire booms and the thin wire interspersed with diagnostics of the instrument. The dates for the various activities are seen in the following Table.

Activity	Boom 1+2 length	Boom 3+4 length	C1	C2	C3	C4
First EFW on (~15 rpm)			000829	000825	001009	001023
First EFW verification			000829- 000830	000825	001009	001023
Open boom covers			000907	000905	001011	001025
1 st Deployment		0-3	000907	000905	001011	001025
2 nd Deployment		3-15	000907	000905	001011	001025
3 rd Deployment	0-3		000907 *)	000905	001011	001025
4 th Deployment	3-15		000907 *)	000905	001011	001025
1 st Spin-up ~12-22 rpm (thin wire deployment)			000908	000905	001011	001026
EFW diagnostics			000908	000905	001011	001026
WEC diagnostics			000916	000909	001012- 001013	001027- 001028
5 th Deployment		15-35	000920	000912	001016	001030
6 th Deployment	15-20		000920 *)	000912	001016	001030
EFW diagnostics			000920	000912	001016	001030
WEC diagnostics			000921- 000923	000913- 000914	001017	001031- 001101
2 nd Spin-up ~13.5-17.5 rpm			000925	000918	001018	001102
7 th Deployment		35-41	000925	000918	001018	001102
EFW diagnostics			000925	000918	001018	001102
WEC diagnostics			000926- 001006	000920- 000928	001019- 001026	001104- 001114
8 th Deployment	20-41		001006	001004	001108	001116
3 rd Spin-up ~11-15 rpm			001006	001004		
EFW diagnostics			001006	001004	001108	001116
3 rd Spin-up ~11-15 rpm						001116
WEC diagnostics			001007- 001008	001005	001108	001116
3 rd Spin-up ~11-15 rpm					001111	
Full EFW tests			001009	001009	001130	001124

*) The 0-15 m deployments on C1 boom 1+2 actually deployed boom 2 to 18.5 m, due to missed clicks in the deployment monitor. This was compensated for on the next deployment, where boom 1 was deployed 15-20 m and boom 2 was deployed 18.5-20 m.

3. Wire boom deployments and spin-ups, overview

The tables below list all deployments and spin-ups during commissioning. Date is yymmdd, Time is hhmmss, Spin rate is in rpm. Mode is E-field/Density for probe 1234, Ibias is in nA, Vbias, Vguard, Vpuck are in V, these are the same for all four probes except for the 3rd deployment on C4. SAA (Solar Aspect Angle) is in degrees, of interest during the thin wire deployment.

Cover opening, booms 1+2 followed by booms 3+4:

	C1	C2	C3	C4
Date	000907	000905	001011	001025
Time	205430, 210416	172541, 174310	165359, 170559	171540, 172628
Spin rate	15.14	15.04	14.96	15.10
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-40	-40	-40	-40
Vguard	-5	-5	-5	-5
Vpuck	0	0	0	0

No EFW data available at time of cover opening since the SC pyro data are transmitted in SC telemetry data acquisition (TDA) mode 1, while science data use TDA mode 9L.

C1 EFW data gaps 20:39:54 - 20:56:49.1 and 21:01:02 - 21:06:11.1

C2 EFW data gaps 17:03:36 - 17:27:54.6 and 17:35:02 - 17:45:00.6

C3 EFW data gaps 16:53:17 - 16:56:49.2 and 17:04:21 - 17:07:43.2

C4 EFW data gaps 17:11:42 - 17:17:07.8 and 17:23:48 - 17:27:56.7

1st deployment, booms 3+4 0-3 m:

	C1	C2	C3	C4
Date	000907	000905	001011	001025
Time	212322-212833	181148-181600	173600-174105	175600-180100
Spin rate	15.14-15.04	15.04-14.95	14.96-14.86	15.10-15.00
Mode	DDDD	DDDD	EEEE	DDDD
Ibias/Vbias	0	0	-80	0
Vguard	0	0	0	0
Vpuck	0	0	0	0

2nd deployment, booms 3+4 3-15 m:

	C1	C2	C3	C4
Date	000907	000905	001011	001025
Time	214108-220111	182613-184350	175900-181945	181129-183250
Spin rate	15.04-13.43	14.95-13.35	14.86-13.24	15.00-13.36
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-40	-40	-80	-80
Vguard	-3	-3	-6	-6
Vpuck	0	0	+1	+1

3rd deployment, booms 1+2 0-3 m:

	C1 *)	C2	C3	C4
Date	000907	000905	001011	001025
Time	222140-222715	190444-190940	183752-184250	190400-190840
Spin rate	13.43-13.34	13.35-13.27	13.24-13.17	13.36-13.28
Mode	DDDD	DDDD	EEEE	DDEE
Ibias/Vbias	0	0	-80	0 0 -80 -80
Vguard	0	0	-6	0 0 -6 -6
Vpuck	0	0	+1	0 0 +1 +1

*) Boom 2 step counter missed 5 clicks, deployed 0-3.3 m

4th deployment, booms 1+2 3-15 m:

	C1 *)	C2	C3	C4
Date	000907	000905	001011	001025
Time	225535-232011	192017-194003	184900-190900	192713-194720
Spin rate	13.34-11.71	13.27-11.97	13.17-11.88	13.28-11.99
Mode	EEEE	EEEE	EEEE	EEEE

Ibias/Vbias	-40	-40	-80	-80
Vguard	-3	-3	-6	-6
Vpuck	0	0	+1	+1

*) Boom 2 step counter missed 33 clicks, deployed 3.3-18.5 m

1st spin-up at 17 m, thin wire deployment:

	C1	C2	C3	C4
Date	000908	000905	001011	001026
Time	010002-010208	210014-210208	205918-210119	134508-134710
Spin rate	11.71-21.77	11.97-21.86	11.88-21.83	11.99-21.86
SAA	97.5	97.7	97.1	95.8
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-40	-40	-80	-80
Vguard	-5	-5	-6	-6
Vpuck	0	0	+1	+1

5th deployment, booms 3+4 15-35 m:

	C1	C2	C3	C4
Date	000920	000912	001016	001030
Time	190704-193900	111400-114156	165730-172950	150600-154020
Spin rate	21.79-14.45	21.84-14.33	21.82-14.26	21.86-14.23
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-180	-120	-140	-140
Vguard	-3	-3	-6	-6
Vpuck	+1	+1	+1	+1

6th deployment, booms 1+2 15-20 m:

	C1 *)	C2	C3	C4
Date	000920	000912	001016	001030
Time	200600-201311, 202800-203017	121122-121934	175132-175930	160800-161615
Spin rate	14.45-13.94	14.33-13.58	14.26-13.53	14.23-13.50
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-180	-120	-140	-140
Vguard	-3	-3	-6	-6
Vpuck	+1	+1	+1	+1

*) Boom 1 deployed 15-20 m, boom 2 deployed 18.5-20 m, separate deployments

2nd spin-up at 20/35 m:

	C1	C2 *)	C3	C4
Date	000925	000918	001018	001102
Time	193827-193939	200000-200125	152927-153047	161447-161607
Spin rate	13.94-17.54	13.58-17.48	13.53-17.50	13.50-17.51
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-180	-180	-140	-180
Vguard	-3	-3	-6	-6
Vpuck	+1	+1	+1	+1

*) No EFW data available during spin-up, data gap 19:31-20:13

7th deployment, booms 3+4 35-41 m:

	C1	C2	C3	C4
Date	000925	000918	001018	001102
Time	201629-202557	211300-212125	161700-162636	165000-170018

Spin rate	17.54-15.03	17.48-14.96	17.50-14.97	17.51-14.95
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-180	-180	-140	-180
Vguard	-3	-3	-6	-6
Vpuck	+1	+1	+1	+1

8th deployment, booms 1+2 20-41 m:

	C1 *)	C2	C3	C4
Date	001006	001004	001108	001116
Time	150900-174540	172800-180159	143500-150817	145013-152455
Spin rate	15.02-10.84	14.95-10.81	14.96-10.84	14.94-10.83
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-160	-180	-180	-180
Vguard	-6	-3	-6	-6
Vpuck	+1	+1	-1	-1

*) Deployment done in 13 steps, alternating boom 1 and boom 2

3rd spin-up at 41 m:

	C1	C2	C3	C4
Date	001006	001004	001111	001116
Time	194510-194719	193112-193326	200010-200220	175953-180202
Spin rate	10.84-15.01	10.81-14.97	10.84-14.99	10.83-14.98
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-160	-180	-160	-180
Vguard	-6	-5	-6	-6
Vpuck	+1	+1	+1	-1

4. Wire boom deployments and spin-ups, with plots

This section again lists all the deployments and spin-ups, now with plots of the available measured quantities during each event. During deployments, only individual probes are available, since the HX telemetry is used for deployment monitoring. During spin-ups, both differential and individual probe signals are available. Black curves indicate probes in E-field mode, green indicate probes in density mode, and red curves indicate E-field data filtered at 180 Hz (otherwise 10 Hz).

4.1. Cover opening, booms 1+2 followed by booms 3+4:

	C1	C2	C3	C4
Date	000907	000905	001011	001025
Time	205430, 210416	172541, 174310	165359, 170559	171540, 172628
Spin rate	15.14	15.04	14.96	15.10
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-40	-40	-40	-40
Vguard	-5	-5	-5	-5
Vpuck	0	0	0	0

No EFW data available at time of cover opening since the SC pyro data are transmitted in SC telemetry data acquisition (TDA) mode 1, while science data use TDA mode 9L.

C1 EFW data gaps 20:39:54 - 20:56:49.1 and 21:01:02 - 21:06:11.1
C2 EFW data gaps 17:03:36 - 17:27:54.6 and 17:35:02 - 17:45:00.6
C3 EFW data gaps 16:53:17 - 16:56:49.2 and 17:04:21 - 17:07:43.2
C4 EFW data gaps 17:11:42 - 17:17:07.8 and 17:23:48 - 17:27:56.7
EFW HX data (V12 and V34) are not available since other information was transmitted in HX around the cover opening.

Plots:

C1: 2034-2035, 2058-2059, 2107-2108
C2: 1656-1657, 1729-1730, 1746-1747
C3: 1652-1653, 1657-1658, 1708-1709
C4: 1710-1711, 1718-1719, 1728-1729



C1, covers 1+2 open



C1, all covers open



C2, all covers closed



C2, covers 1+2 open



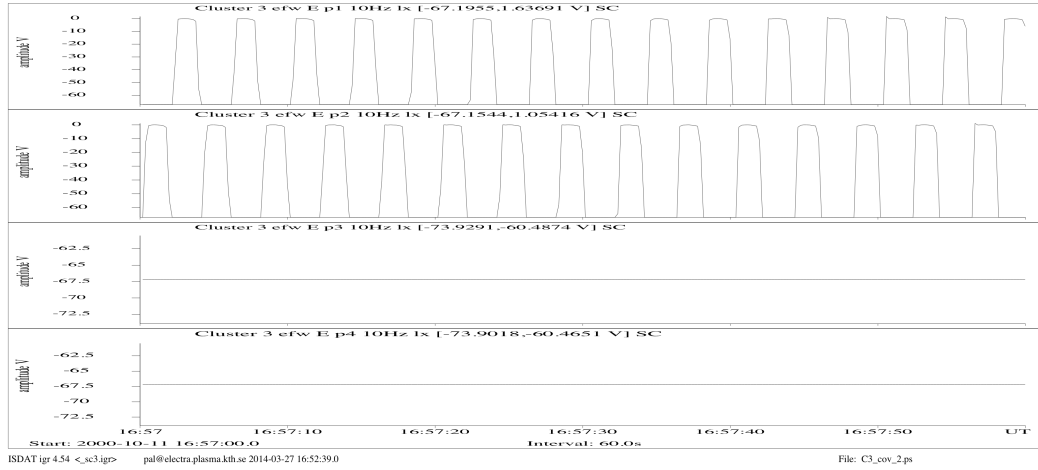
C2, all covers open



C3, all covers closed



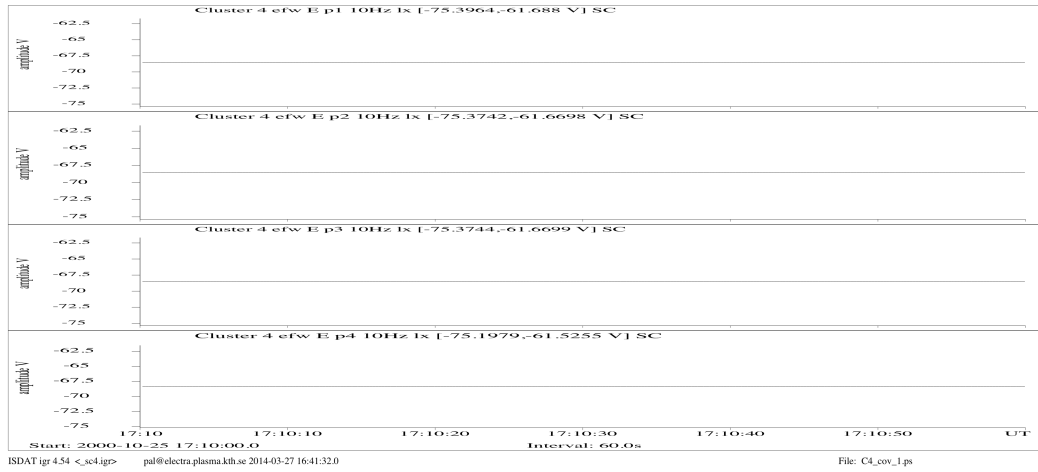
C3, covers 1+2 open



C3, all covers open



C4, all covers closed



C4, covers 1+2 open



C4, all covers open



4.2. 1st deployment, booms 3+4 0-3 m:

	C1	C2	C3	C4
Date	000907	000905	001011	001025
Time	212322-212833	181148-181600	173600-174105	175600-180100
Spin rate	15.14-15.04	15.04-14.95	14.96-14.86	15.10-15.00
Mode	DDDD	DDDD	EEEE	DDDD
Ibias/Vbias	0	0	-80	0
Vguard	0	0	0	0
Vpuck	0	0	0	0

Plots:

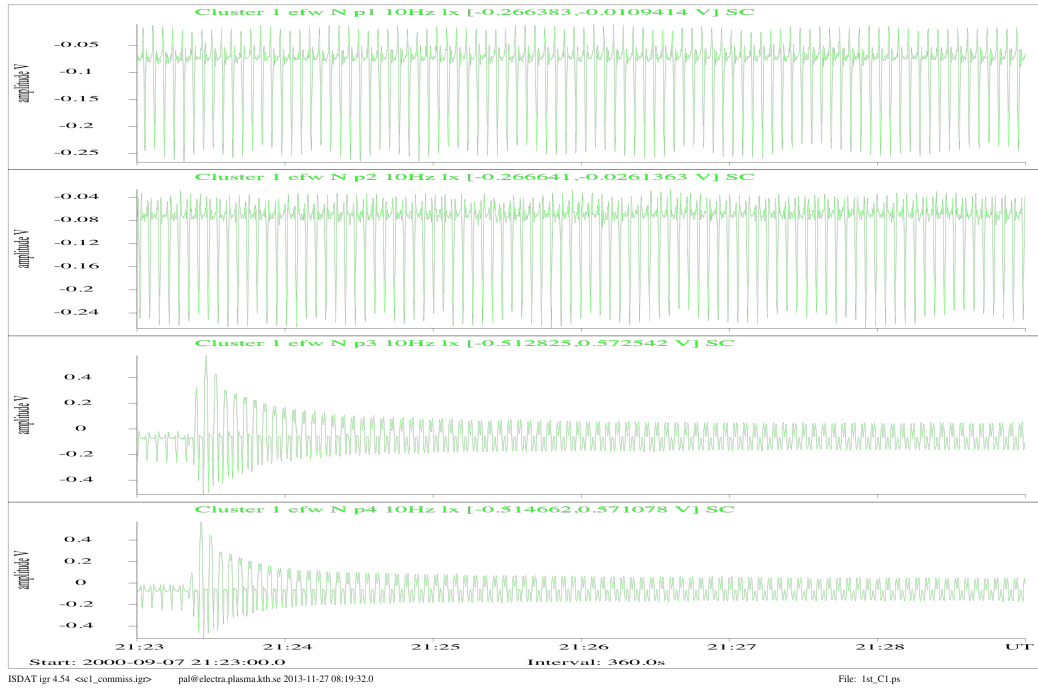
C1: 2123-2129

C2: 1811-1817

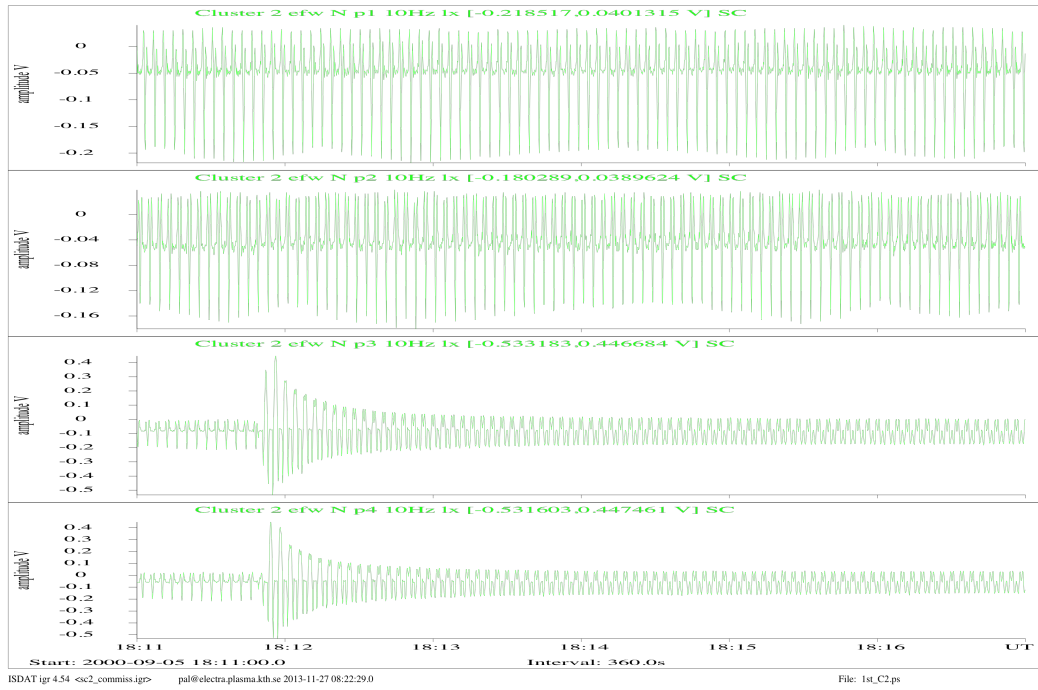
C3: 1735-1742

C4: 1755-1802

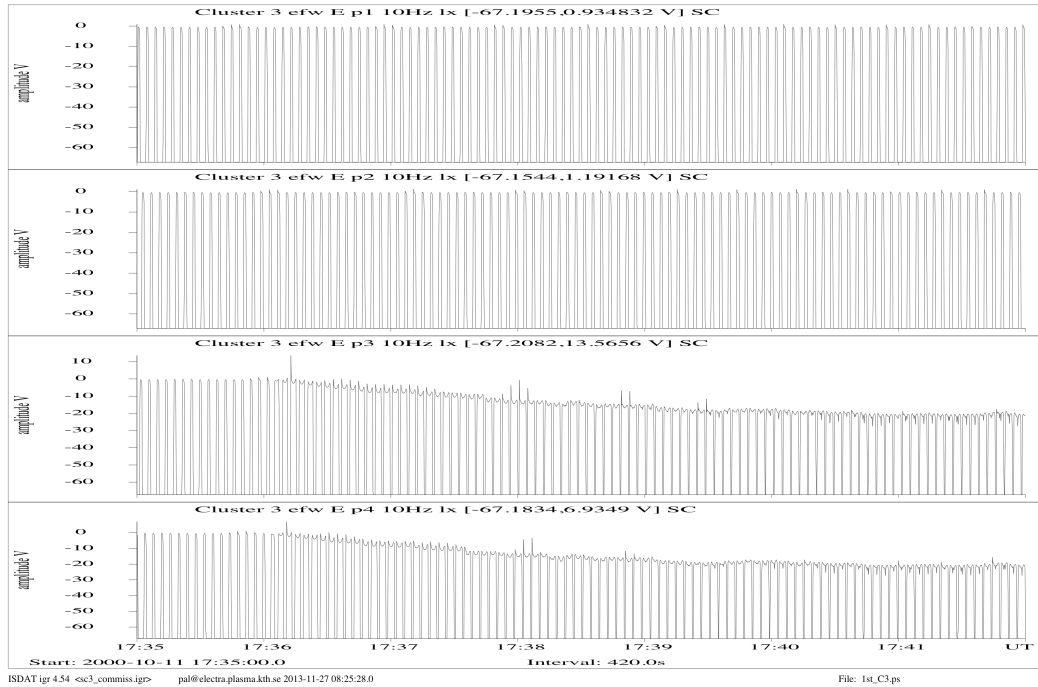
C1 1st deployment



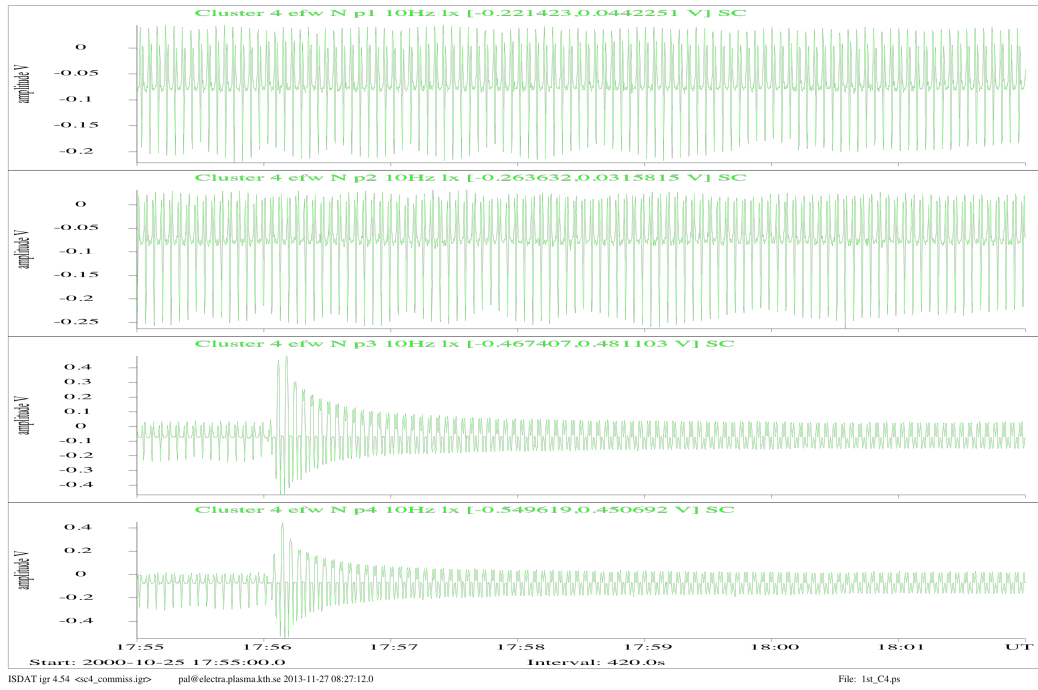
C2 1st deployment



C3 1st deployment



C4 1st deployment



4.3. 2nd deployment, booms 3+4 3-15 m:

	C1	C2	C3	C4
Date	000907	000905	001011	001025
Time	214108-220111	182613-184350	175900-181945	181129-183250
Spin rate	15.04-13.43	14.95-13.35	14.86-13.24	15.00-13.36
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-40	-40	-80	-80
Vguard	-3	-3	-6	-6
Vpuck	0	0	+1	+1

Plots:

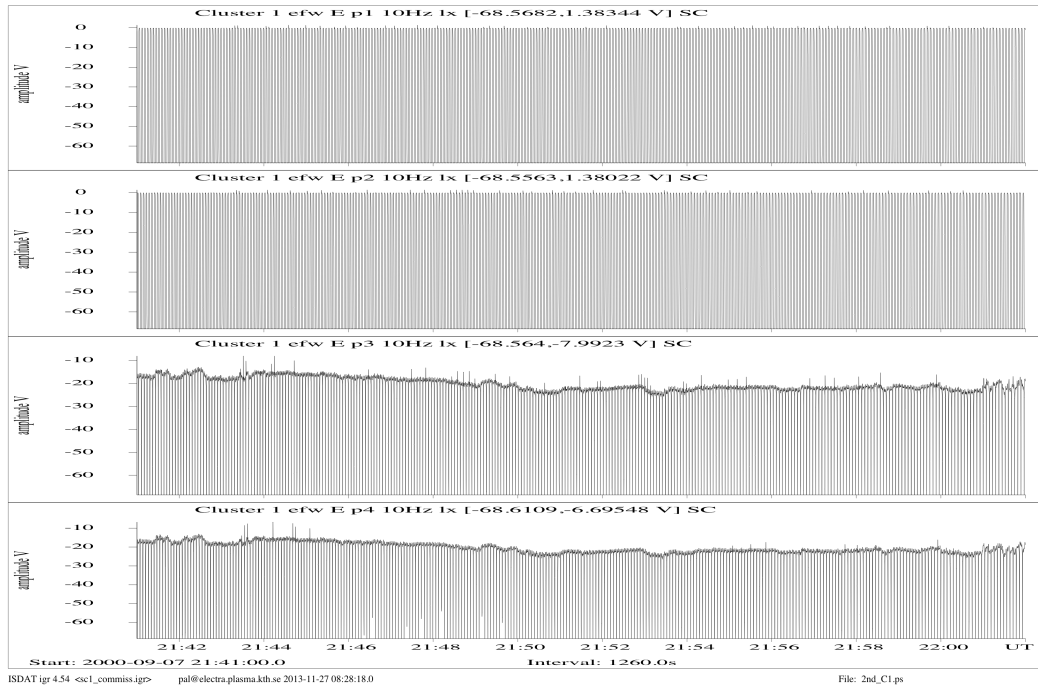
C1: 2141-2202

C2: 1826-1844

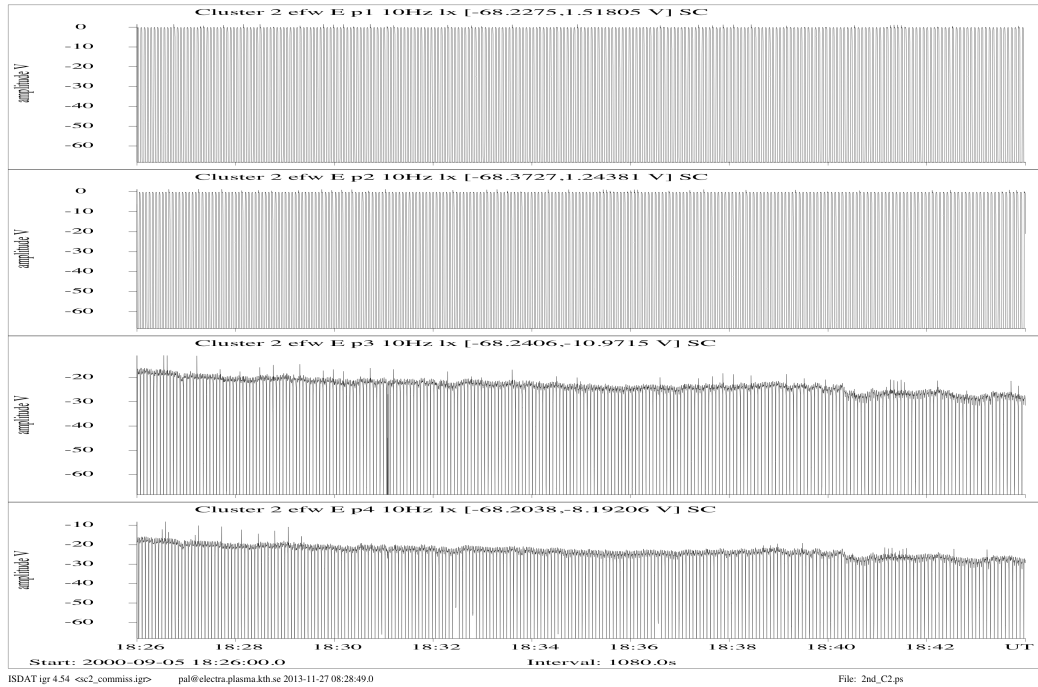
C3: 1758-1820

C4: 1811-1833

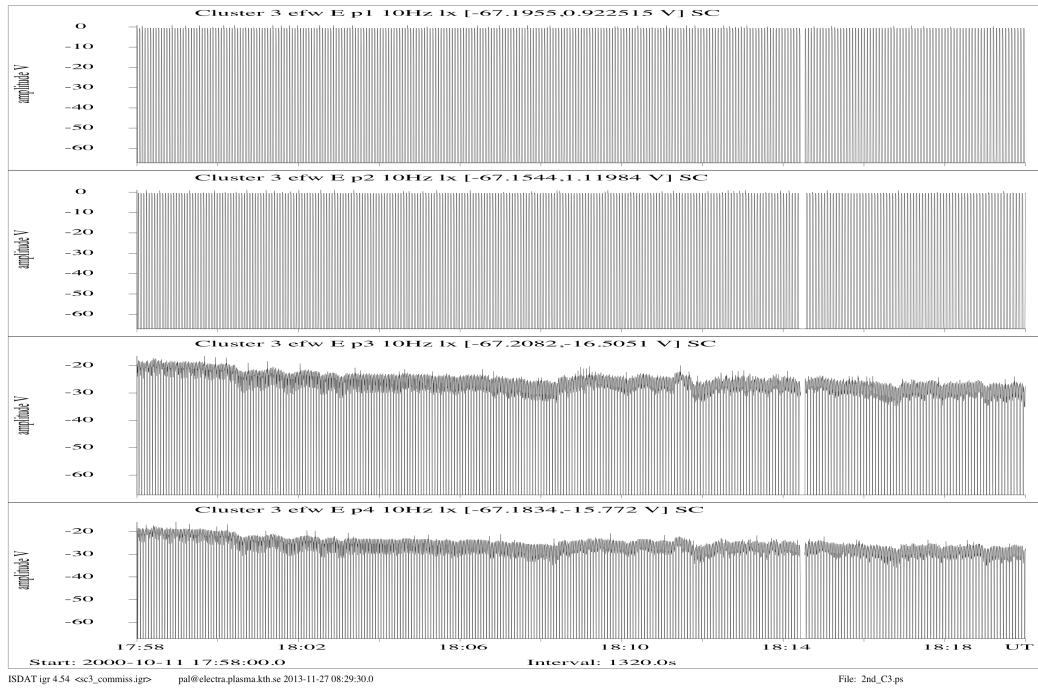
C1 2nd deployment



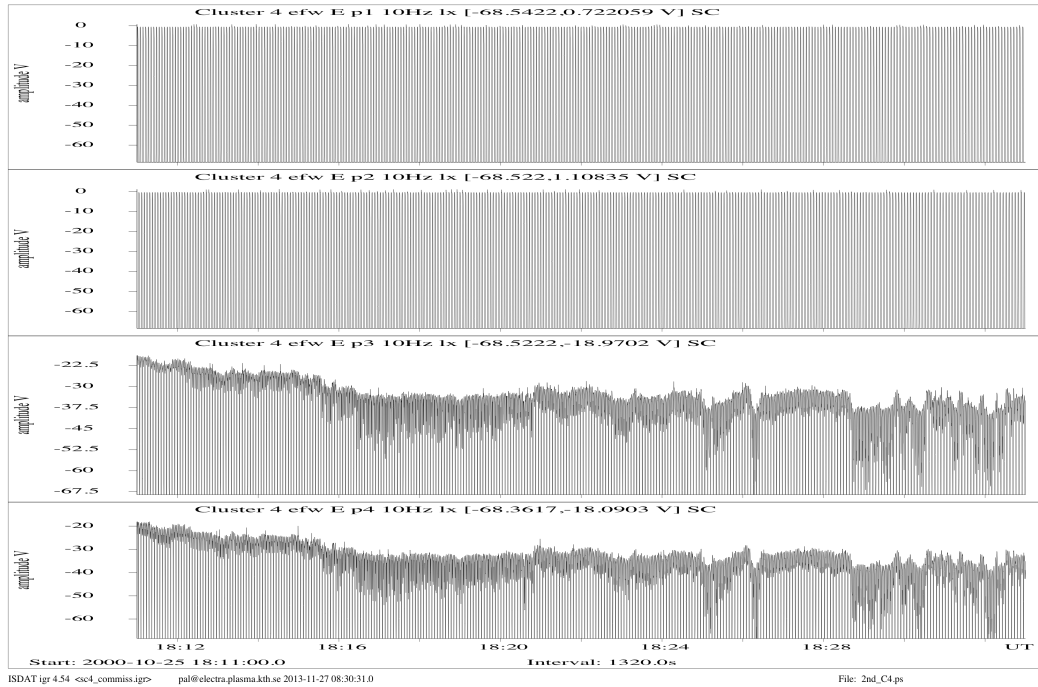
C2 2nd deployment



C3 2nd deployment



C4 2nd deployment



4.4. 3rd deployment, booms 1+2 0-3 m:

	C1 *)	C2	C3	C4
Date	000907	000905	001011	001025
Time	222140-222715	190444-190940	183752-184250	190400-190840
Spin rate	13.43-13.34	13.35-13.27	13.24-13.17	13.36-13.28
Mode	DDDD	DDDD	EEEE	DDEE
Ibias/Vbias	0	0	-80	0 0 -80 -80
Vguard	0	0	-6	0 0 -6 -6
Vpuck	0	0	+1	0 0 +1 +1

*) Boom 2 step counter missed 5 clicks, deployed 0-3.3 m

Plots:

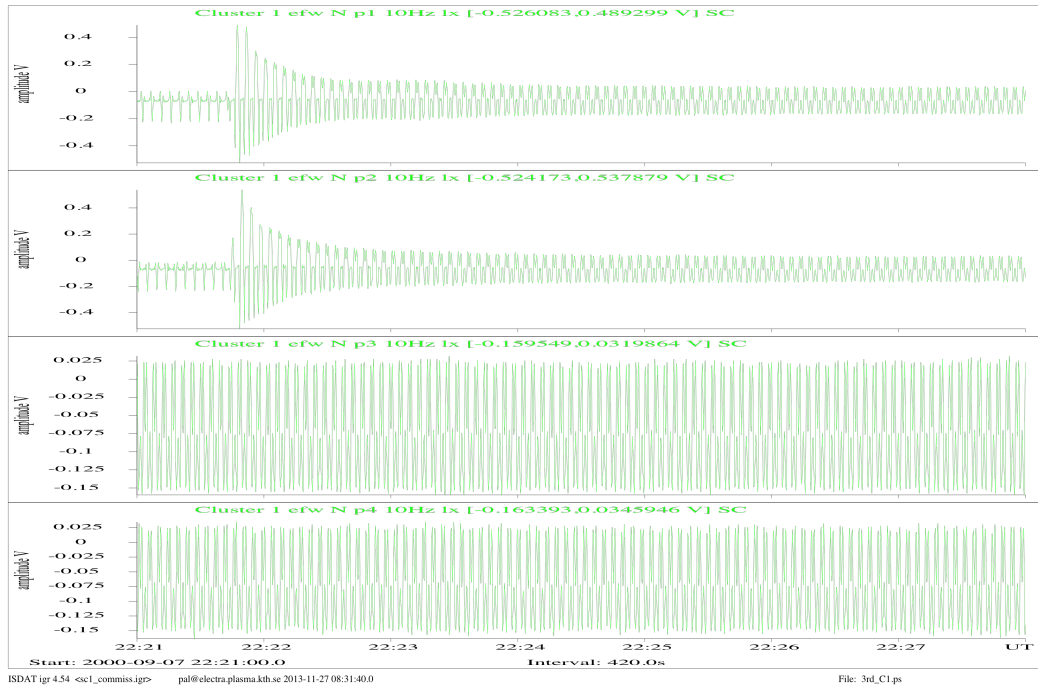
C1: 2221-2228

C2: 1904-1910

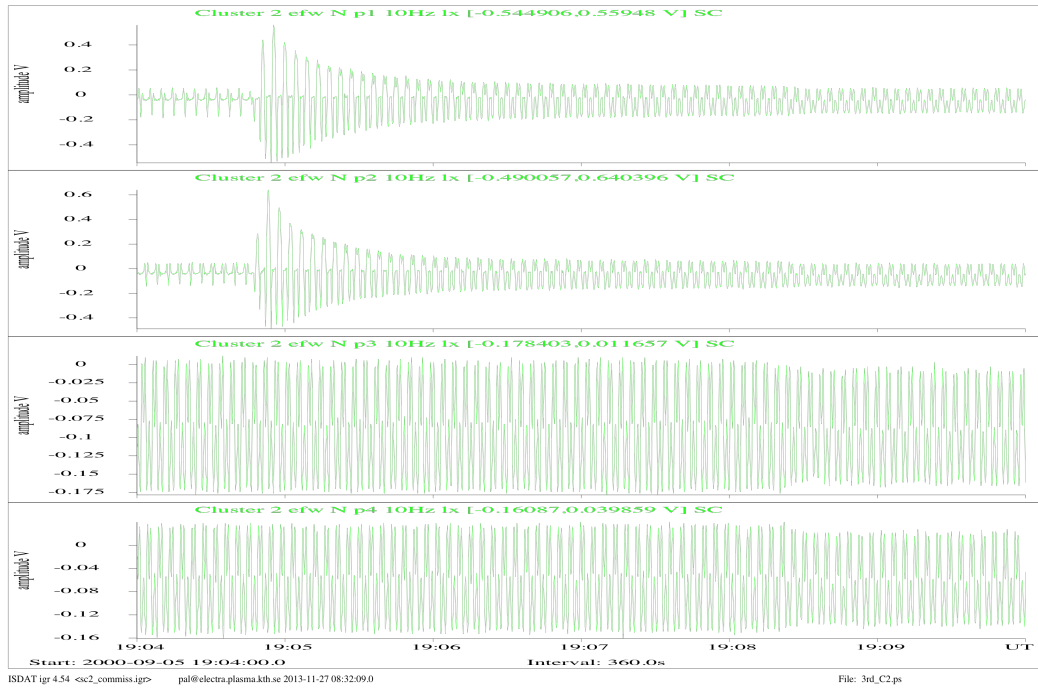
C3: 1837-1843

C4: 1903-1909

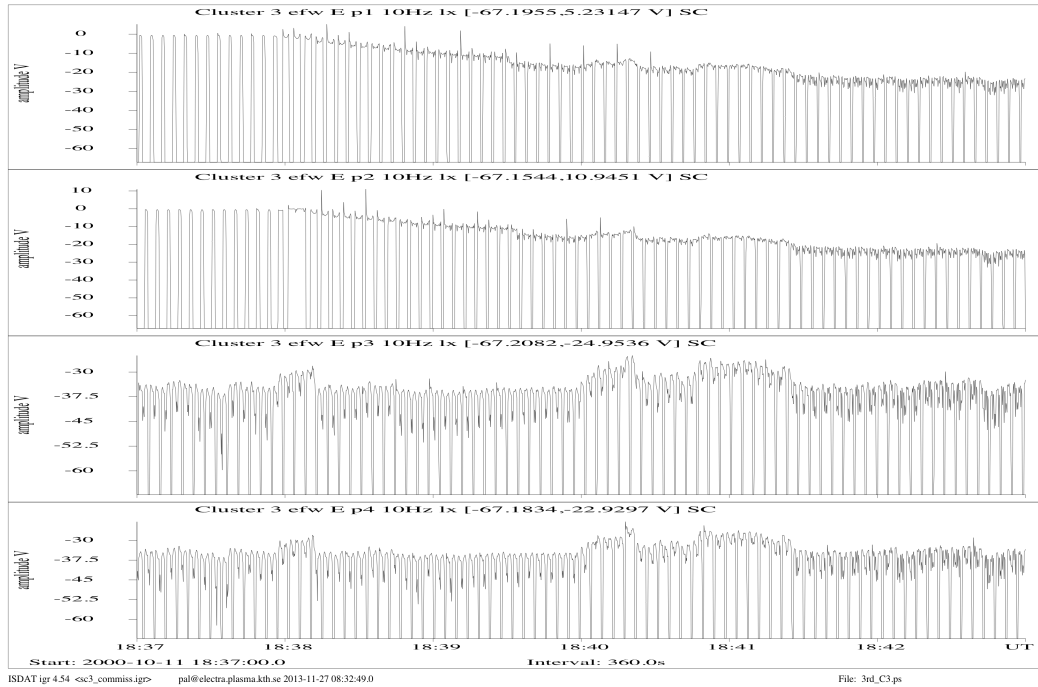
C1 3rd deployment



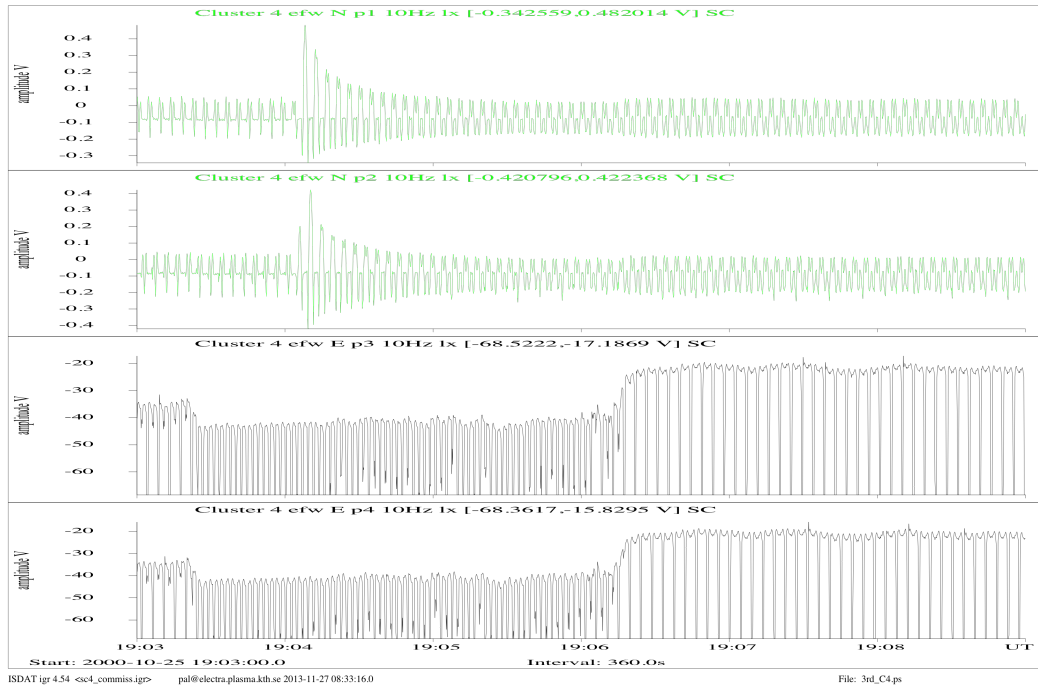
C2 3rd deployment



C3 3rd deployment



C4 3rd deployment



4.5. 4th deployment, booms 1+2 3-15 m:

	C1 *)	C2	C3	C4
Date	000907	000905	001011	001025
Time	225535-232011	192017-194003	184900-190900	192713-194720
Spin rate	13.34-11.71	13.27-11.97	13.17-11.88	13.28-11.99
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-40	-40	-80	-80
Vguard	-3	-3	-6	-6
Vpuck	0	0	+1	+1

*) Boom 2 step counter missed 33 clicks, deployed 3.3-18.5 m

Plots:

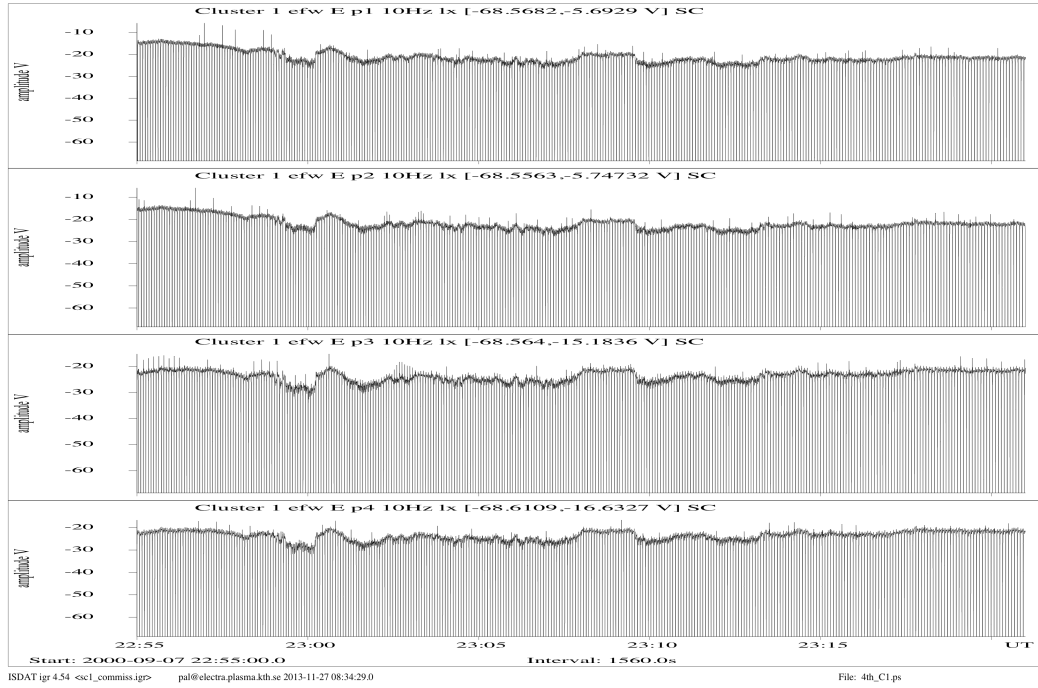
C1: 2255-2321

C2: 1920-1941

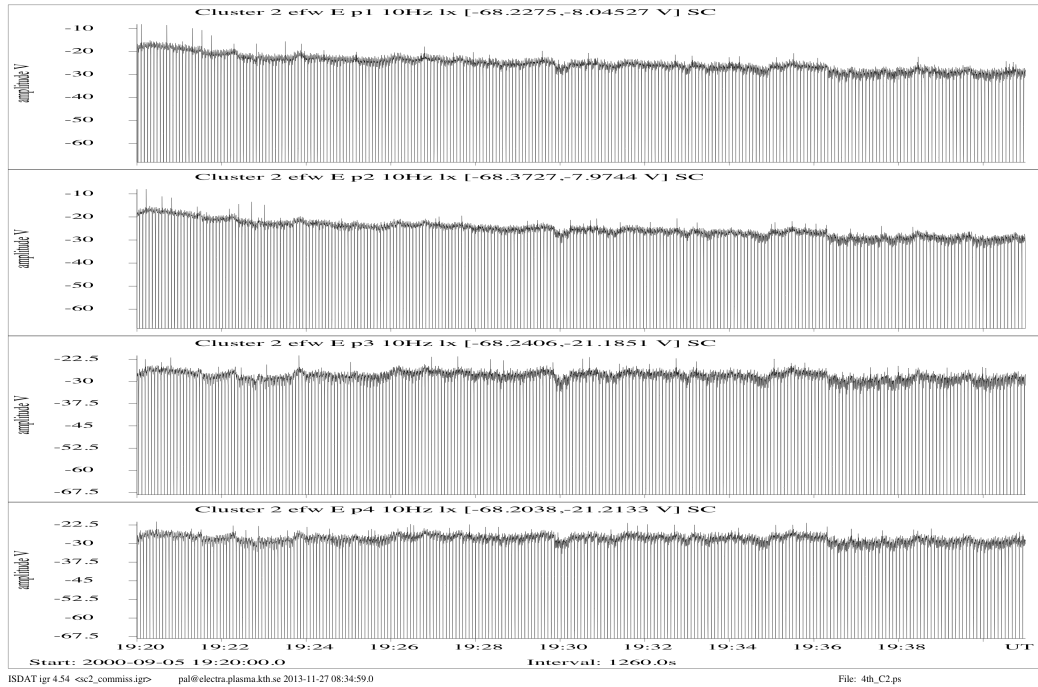
C3: 1848-1910

C4: 1927-1948

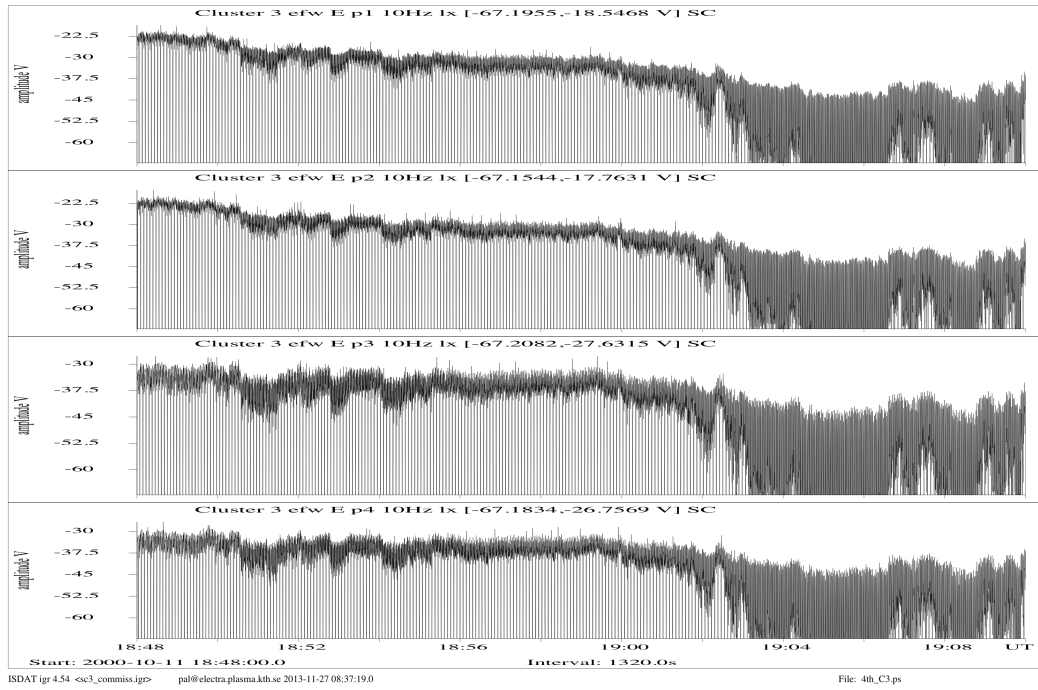
C1 4th deployment



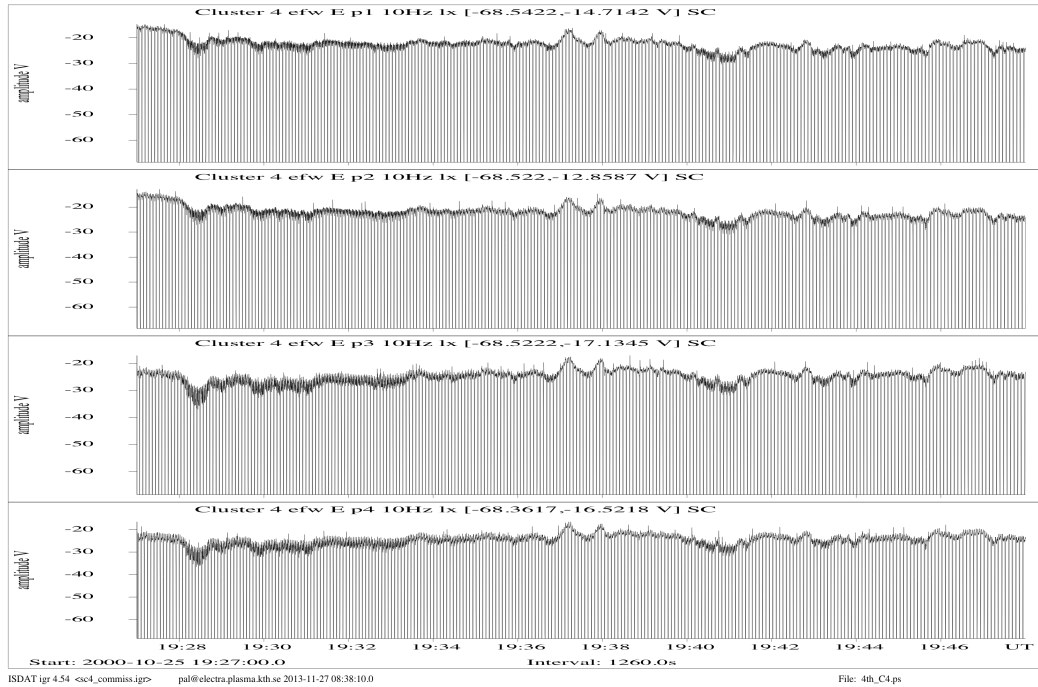
C2 4th deployment



C3 4th deployment



C4 4th deployment



4.6. 1st spin-up at 17 m, thin wire deployment:

	C1	C2	C3	C4
Date	000908	000905	001011	001026
Time	010002-010208	210014-210208	205918-210119	134508-134710
Spin rate	11.71-21.77	11.97-21.86	11.88-21.83	11.99-21.86
SAA	97.5	97.7	97.1	95.8
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-40	-40	-80	-80
Vguard	-5	-5	-6	-6
Vpuck	0	0	+1	+1

The thin wire deployment was accomplished by a spin-up when all four wire booms had been deployed to 15 m length. The spin rate was increased from about 12 rpm to about 22 rpm in 2 minutes. The centrifugal force increase due to this spin rate increase caused the yoyo inside each probe to deploy. Figures below show the behaviour of the measured signal before, during and after the thin wire deployment. Before the deployment, each probe is shadowed by the puck (the preamplifier housing) once per spin, which causes a large negative excursion of the probe voltage. As the thin wire deploys, the duration and the amplitude of the voltage spike decreases, to disappear altogether when the probe and puck are sufficiently far apart. After the deployment the instrument is ready to measure the ambient electric field, seen as a sine wave in the probe-probe differential signals (upper 2 panels in each plot). The spin-up is accomplished with thrusters, causing a plasma cloud around the spacecraft, which is seen as a reduction in the otherwise 20-40 V positive spacecraft potential (lower 4 panels in each plot). The red potential difference plots for C3 and C4 indicate 180 Hz filtered data, which are more susceptible to noise spikes (the black plots are filtered at 10 Hz). For each spacecraft, there is a 140-second overview plot covering the spin-up, and two 20-second plots just before and after the spin-up. At these spin-ups, the EFW bias current was (-40, -40, -80, -80) nA, the guard voltage was (-5, -5, -6, -6) V, and the puck voltage was (0, 0, +1, +1) V on (C1, C2, C3, C4), respectively. The Solar Aspect Angle (SAA) at the time of the spin-ups was (97.5, 97.7, 97.1, 95.8) °, for (C1, C2, C3, C4), respectively (which agrees with the fact that the C4 thin wire needs to be deployed further before the voltage spikes disappear).

Plots:

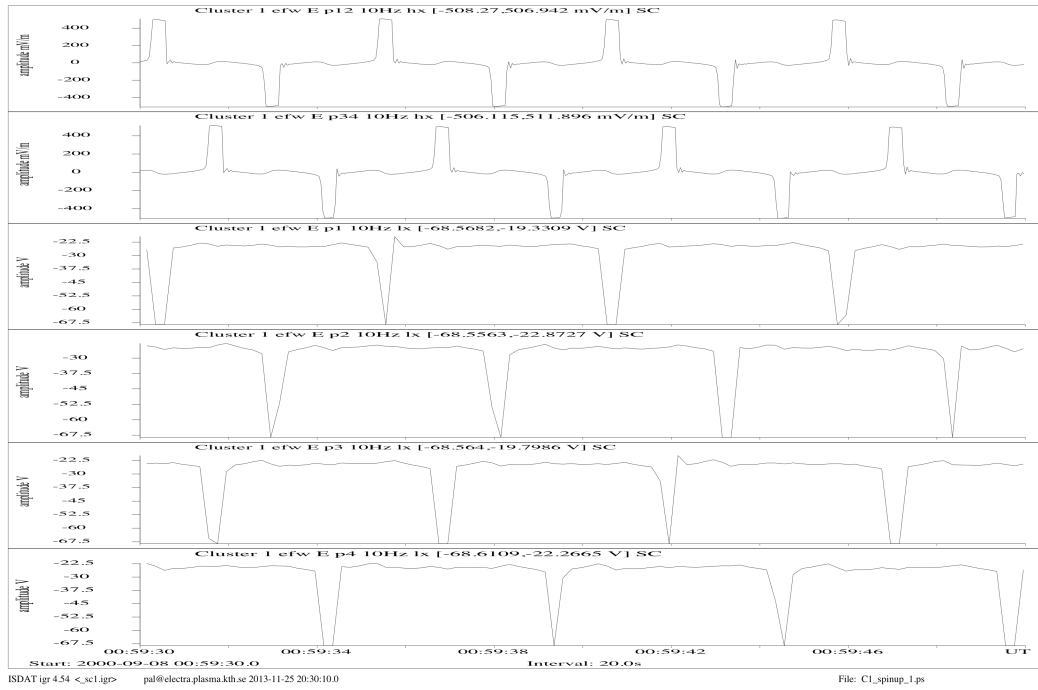
C1: 005930-005950, 005950-010210, 010210-010230

C2: 205940-210000, 210000-210220, 210220-210240

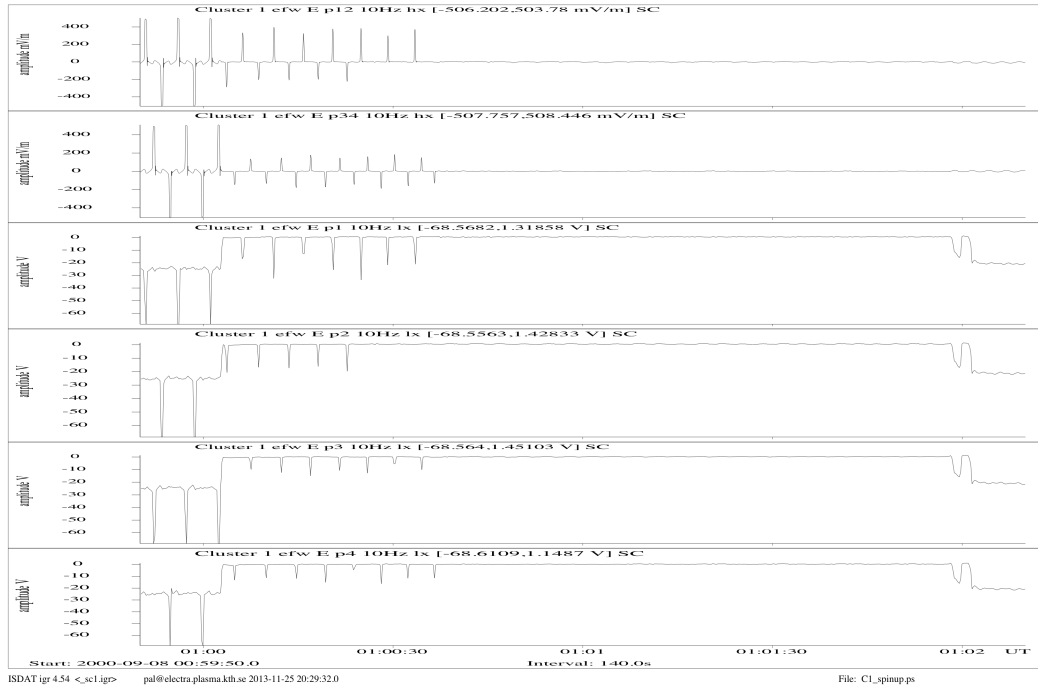
C3: 205850-205910, 205910-210130, 210130-210150

C4: 134440-134500, 134500-134720, 134720-134740

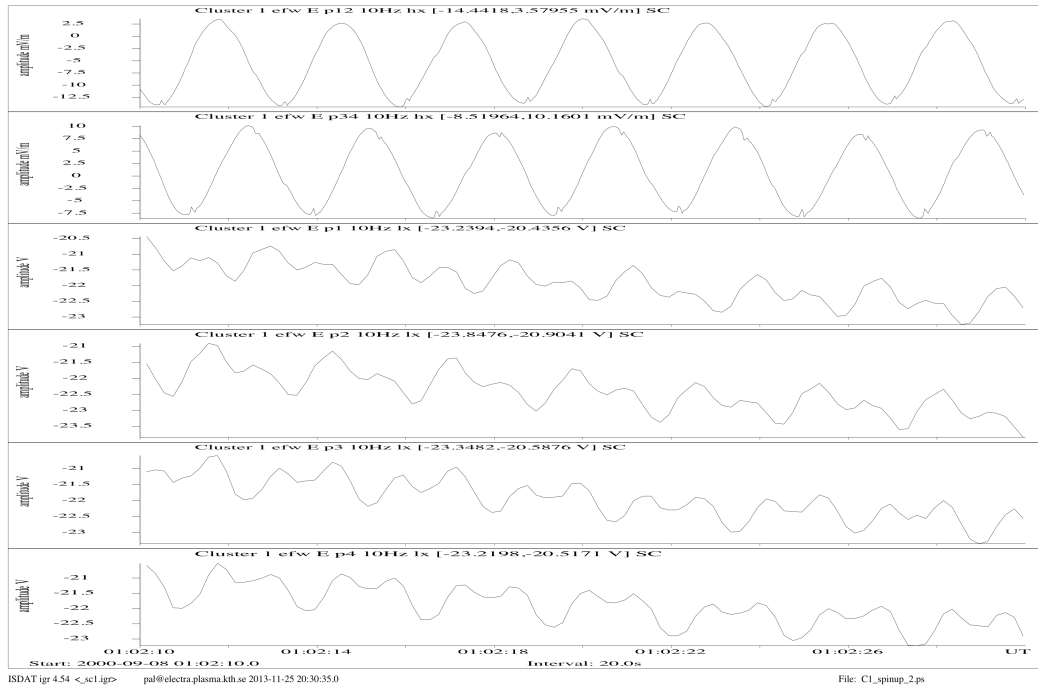
Cluster 1 pre-spinup 11.71-21.77 rpm



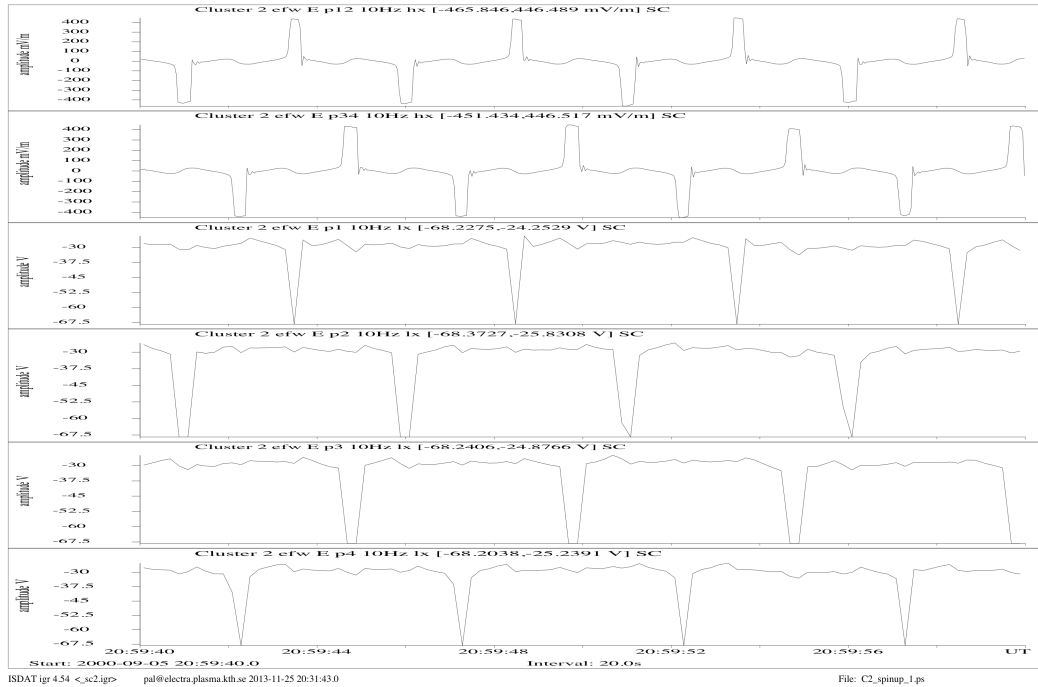
Cluster 1 spinup 11.71-21.77 rpm



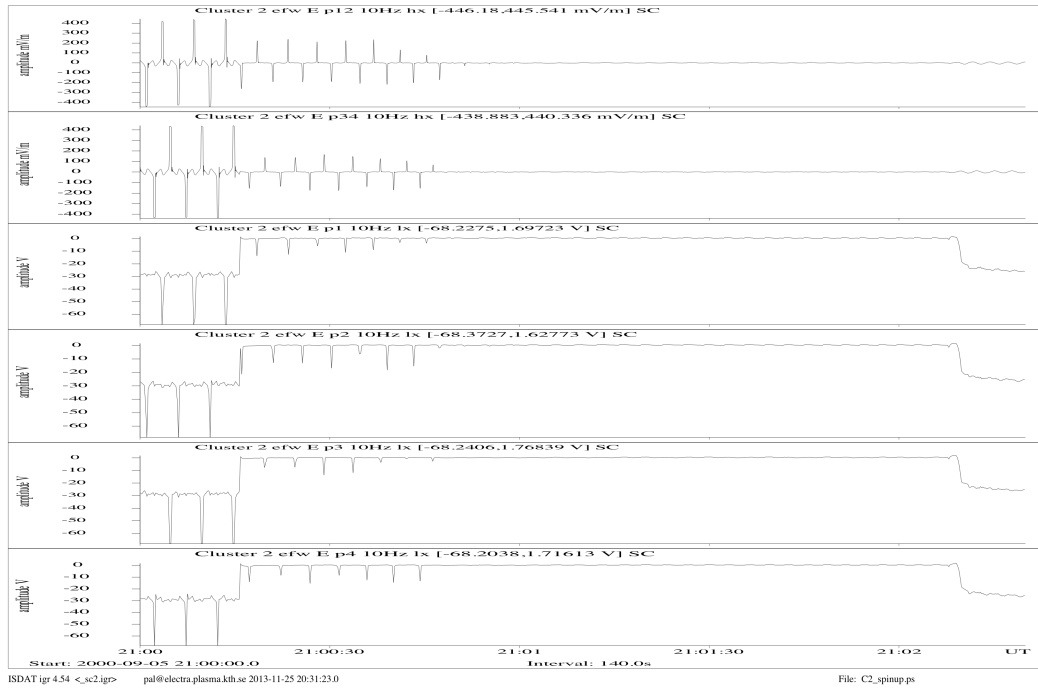
Cluster 1 post-spinup 11.71-21.77 rpm



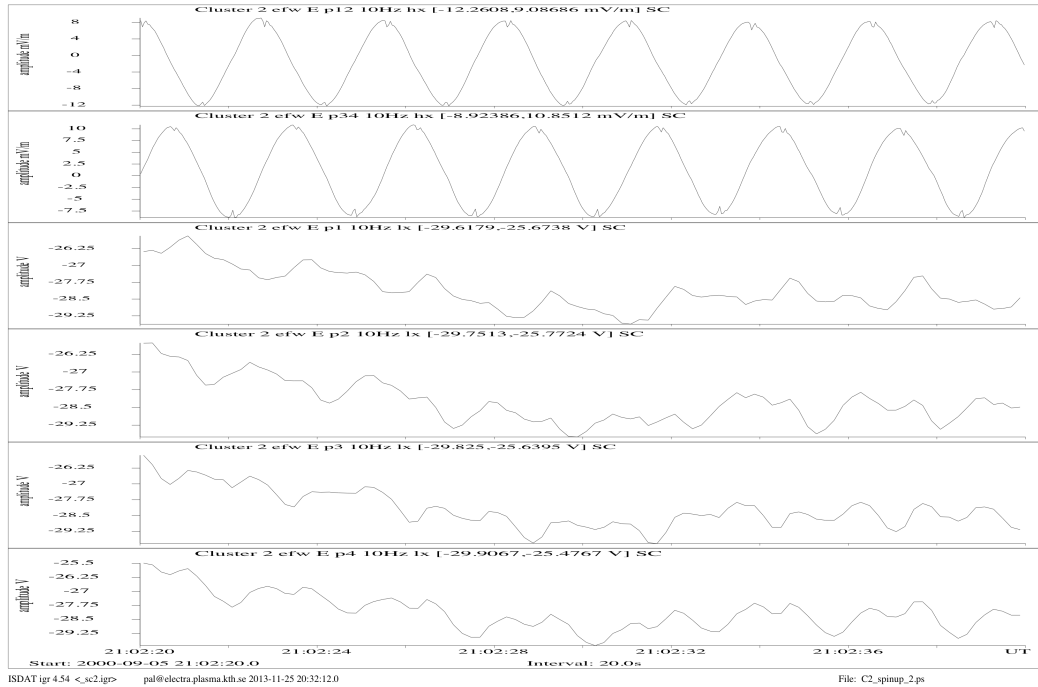
Cluster 2 pre-spinup 11.97-21.86 rpm



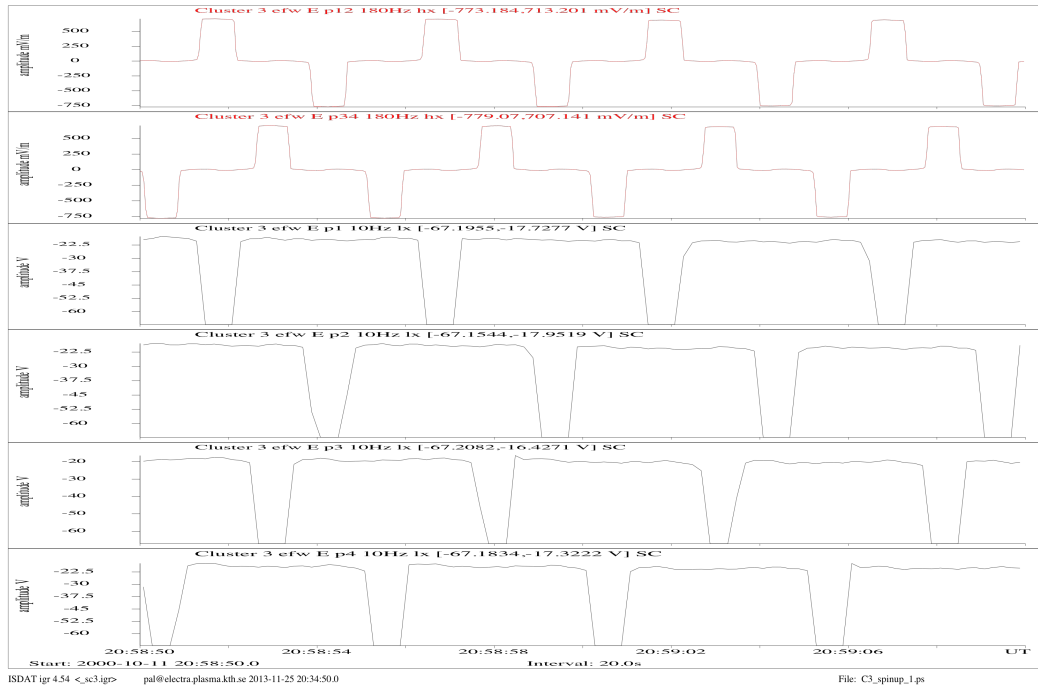
Cluster 2 spinup 11.97-21.86 rpm



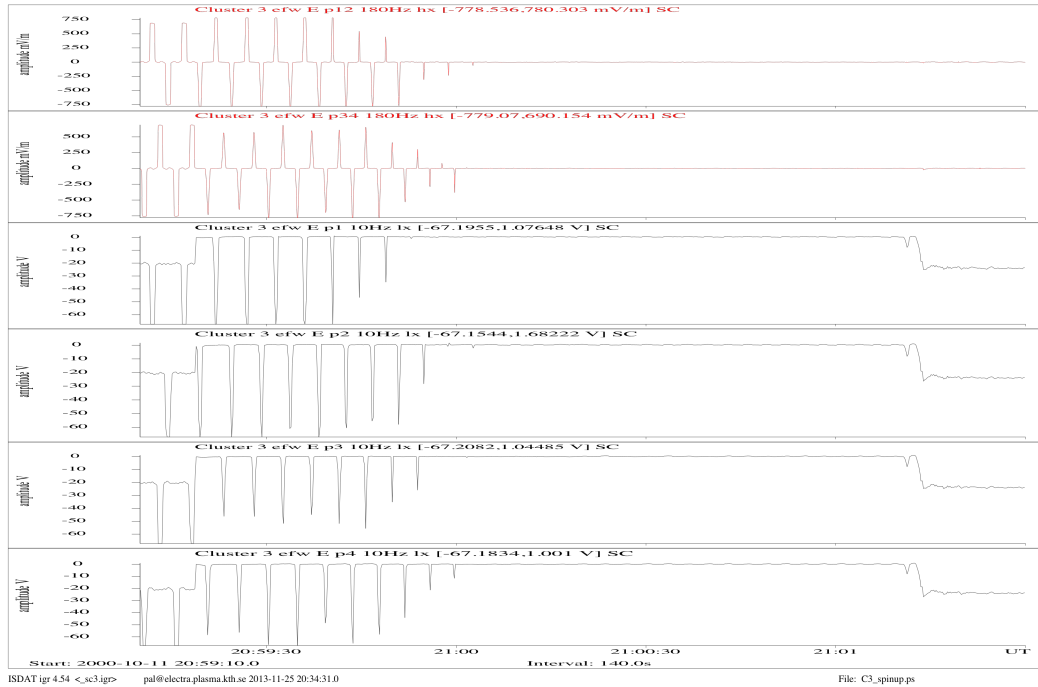
Cluster 2 post-spinup 11.97-21.86 rpm



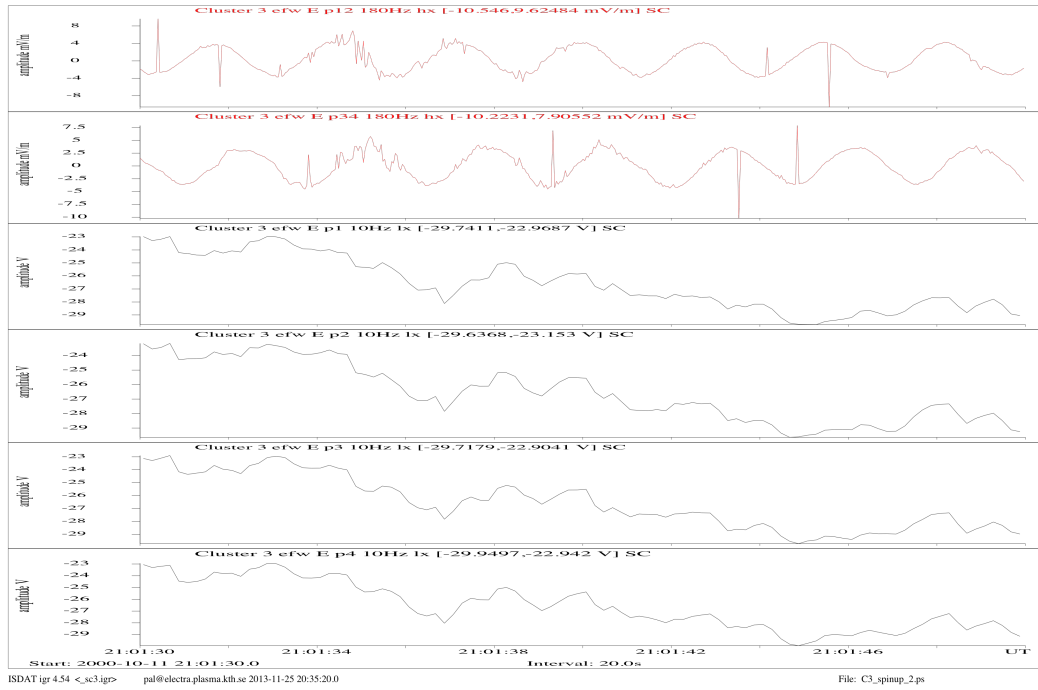
Cluster 3 pre-spinup 11.88-21.83 rpm



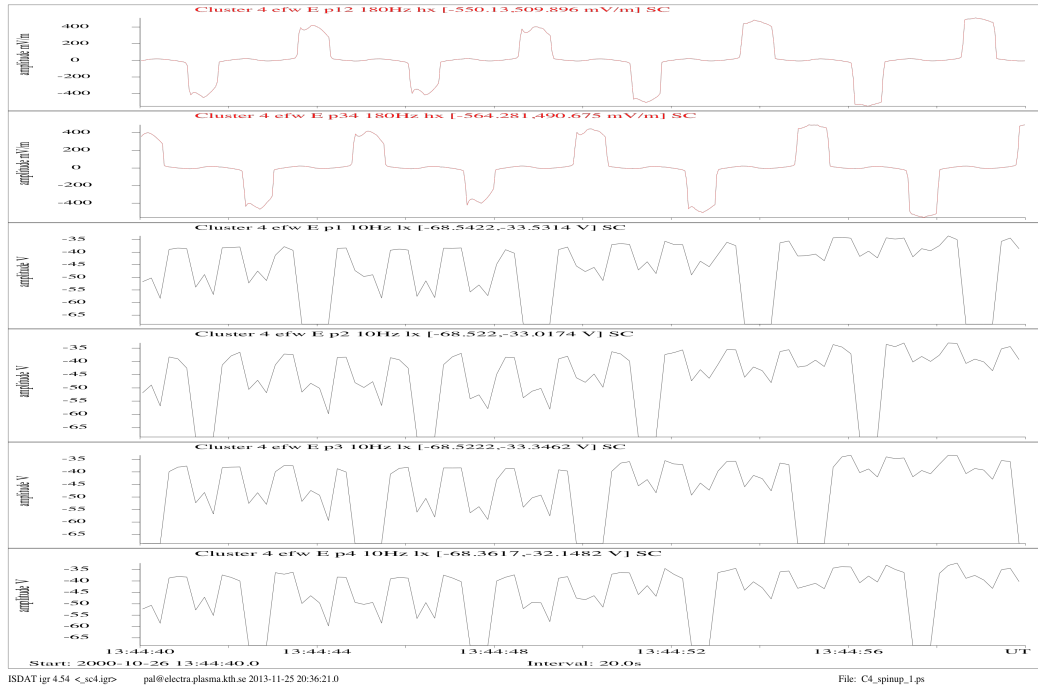
Cluster 3 spinup 11.88-21.83 rpm



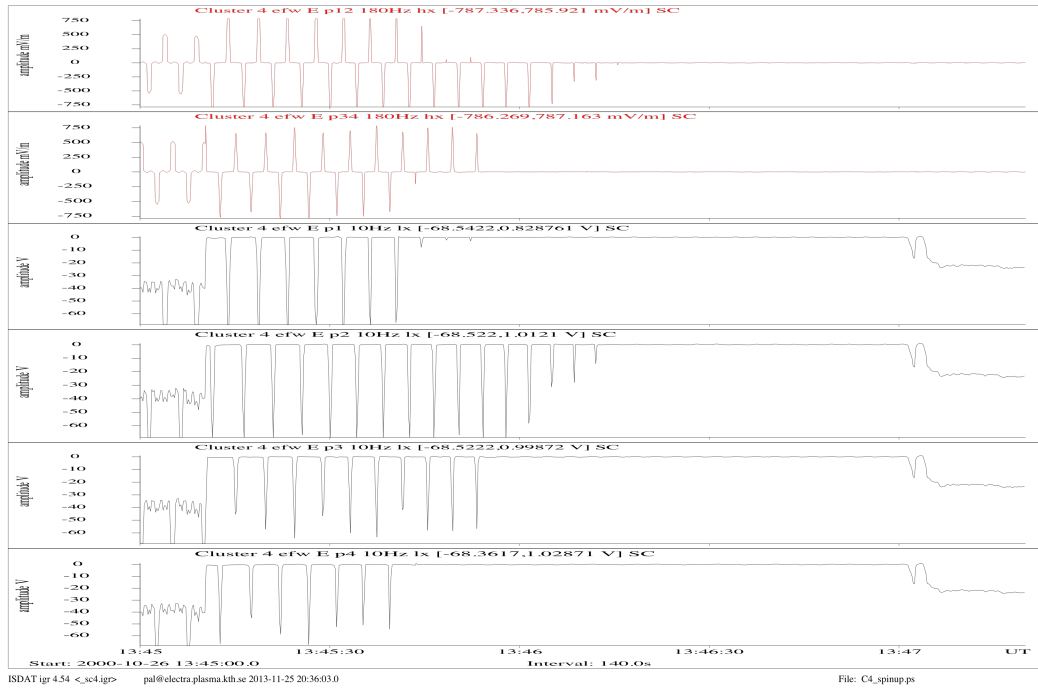
Cluster 3 post-spinup 11.88-21.83 rpm



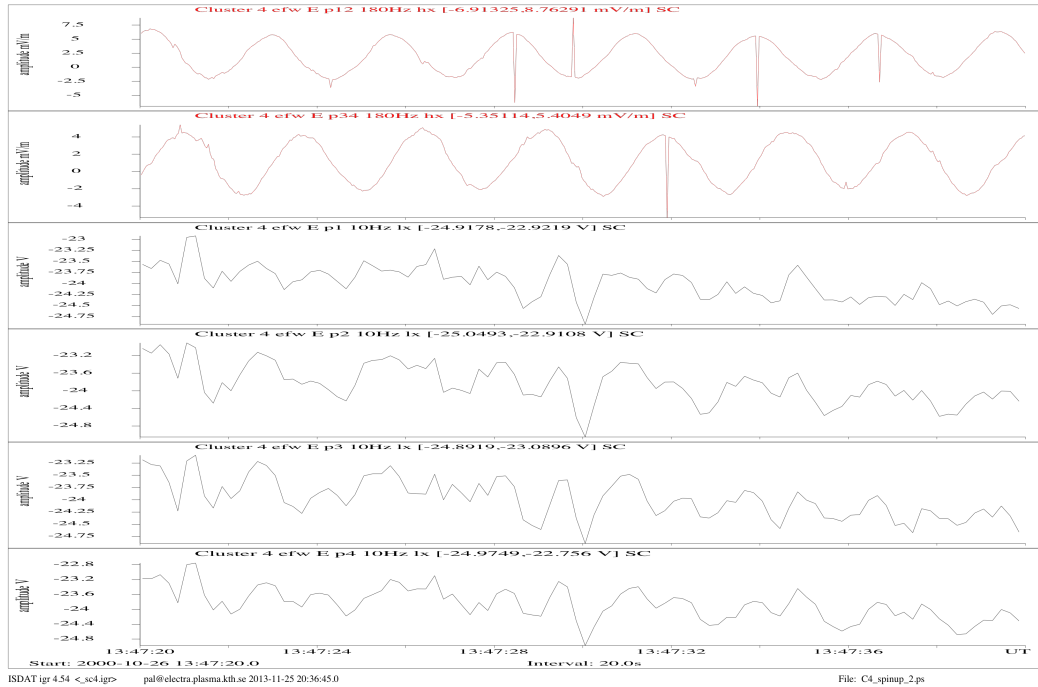
Cluster 4 pre-spinup 11.99-21.86 rpm



Cluster 4 spinup 11.99-21.86 rpm



Cluster 4 post-spinup 11.99-21.86 rpm



4.7. 5th deployment, booms 3+4 15-35 m:

	C1	C2	C3	C4
Date	000920	000912	001016	001030
Time	190704-193900	111400-114156	165730-172950	150600-154020
Spin rate	21.79-14.45	21.84-14.33	21.82-14.26	21.86-14.23
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-180	-120	-140	-140
Vguard	-3	-3	-6	-6
Vpuck	+1	+1	+1	+1

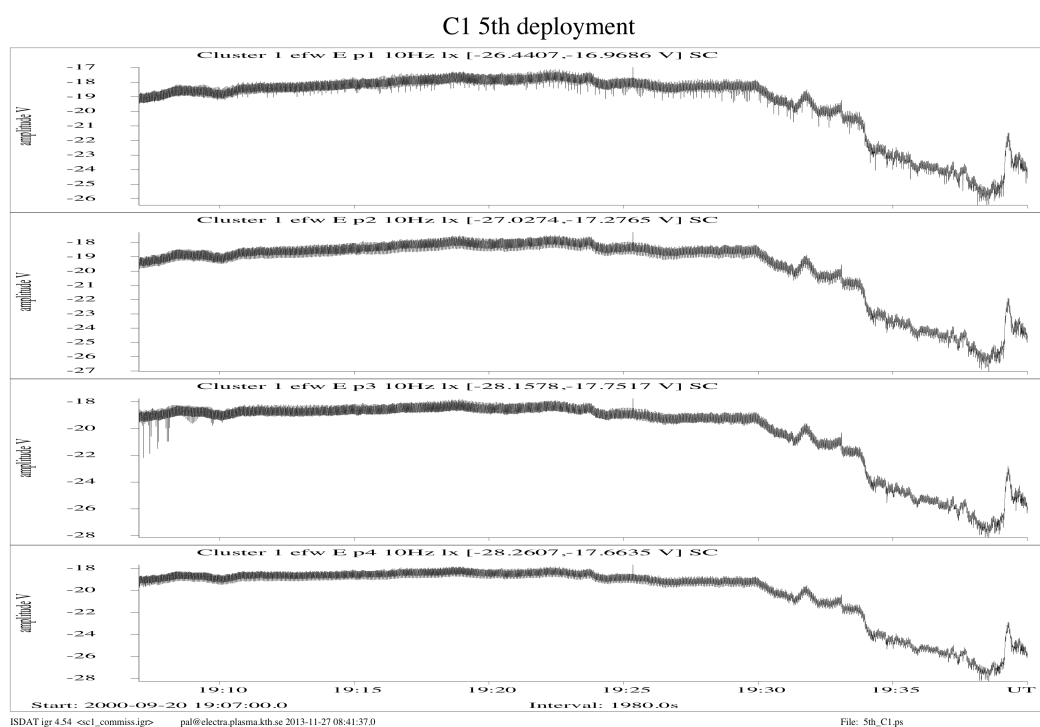
Plots:

C1: 1907-1940

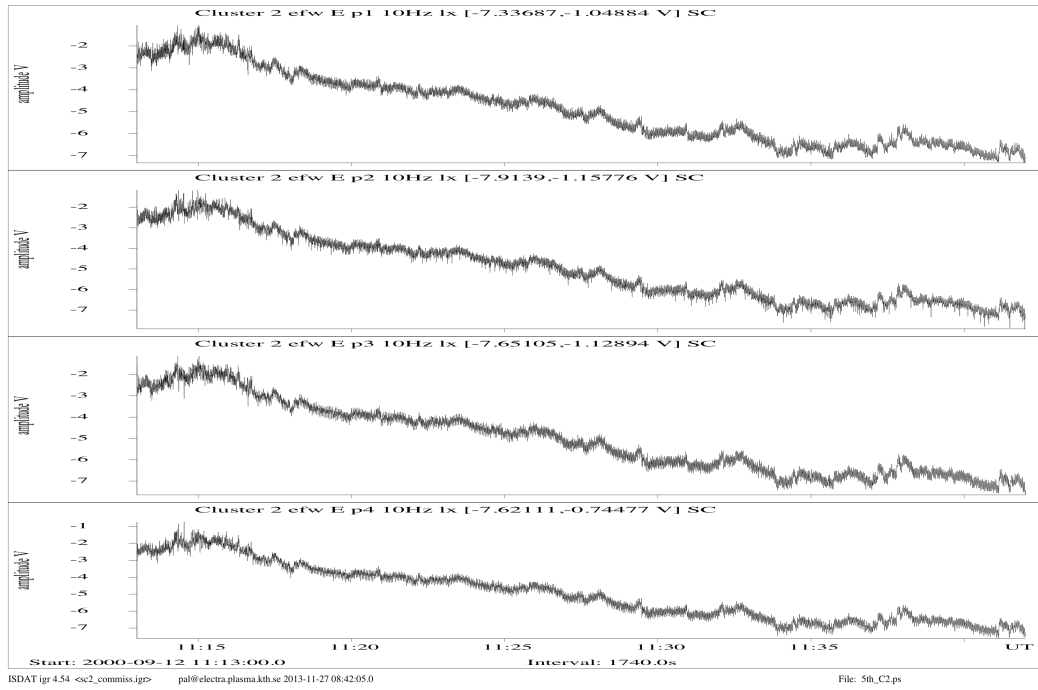
C2: 1113-1142

C3: 1657-1730

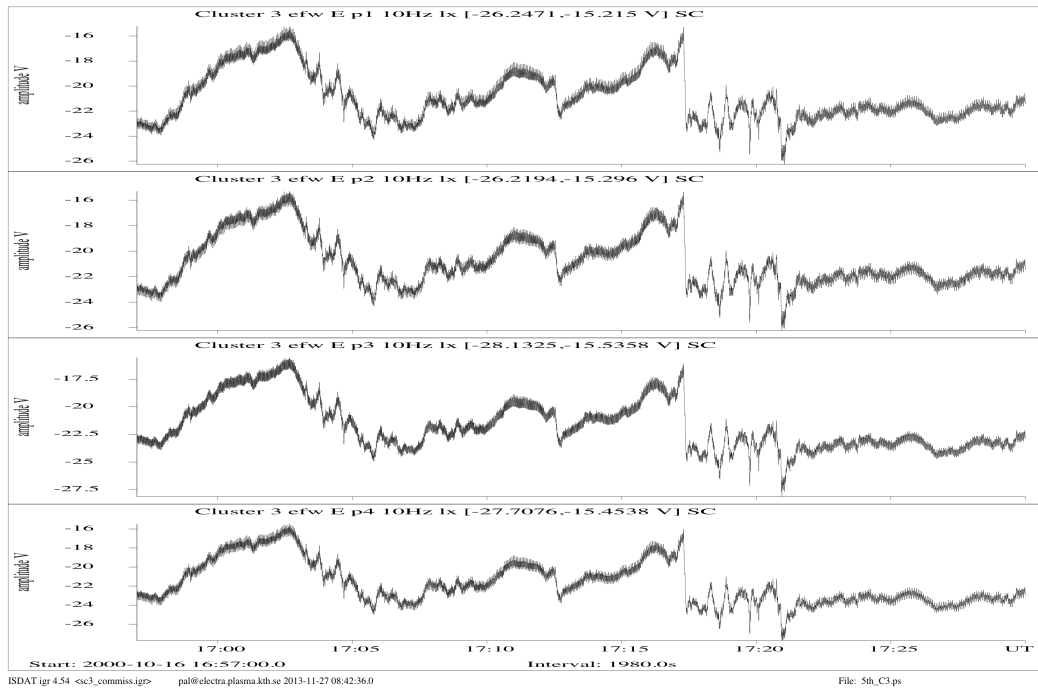
C4: 1505-1541



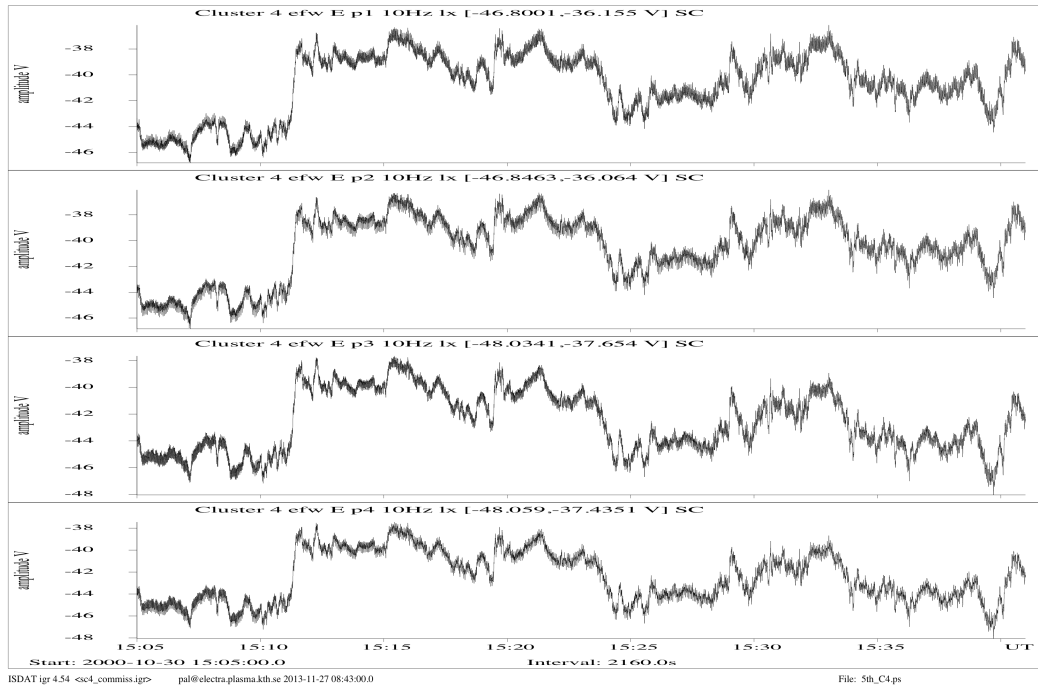
C2 5th deployment



C3 5th deployment



C4 5th deployment



4.8. 6th deployment, booms 1+2 15-20 m:

	C1 *)	C2	C3	C4
Date	000920	000912	001016	001030
Time	200600-201311, 202800-203017	121122-121934	175132-175930	160800-161615
Spin rate	14.45-13.94	14.33-13.58	14.26-13.53	14.23-13.50
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-180	-120	-140	-140
Vguard	-3	-3	-6	-6
Vpuck	+1	+1	+1	+1

*) Boom 1 deployed 15-20 m, boom 2 deployed 18.5-20 m, separate deployments

Plots:

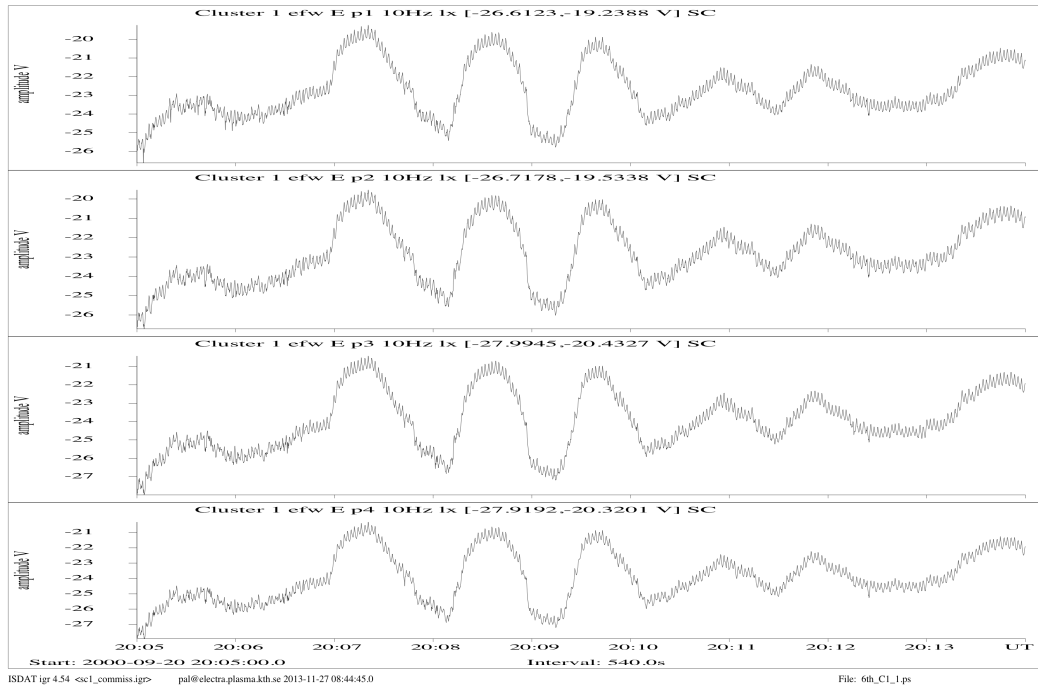
C1: 2005-2014, 2027-2031

C2: 1211-1220

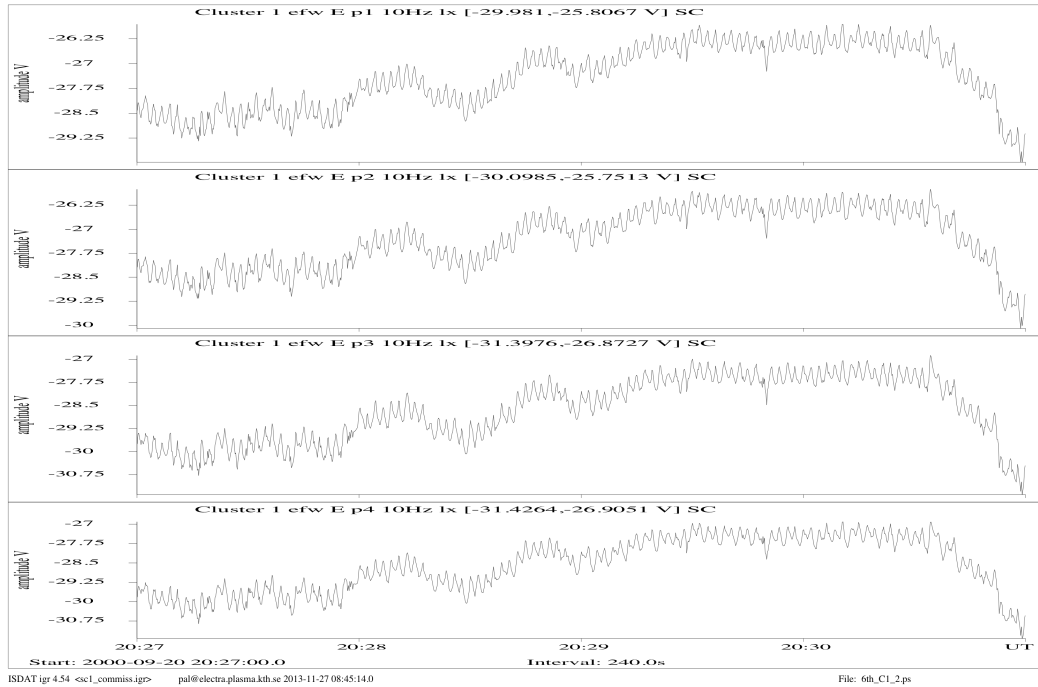
C3: 1751-1800

C4: 1607-1617

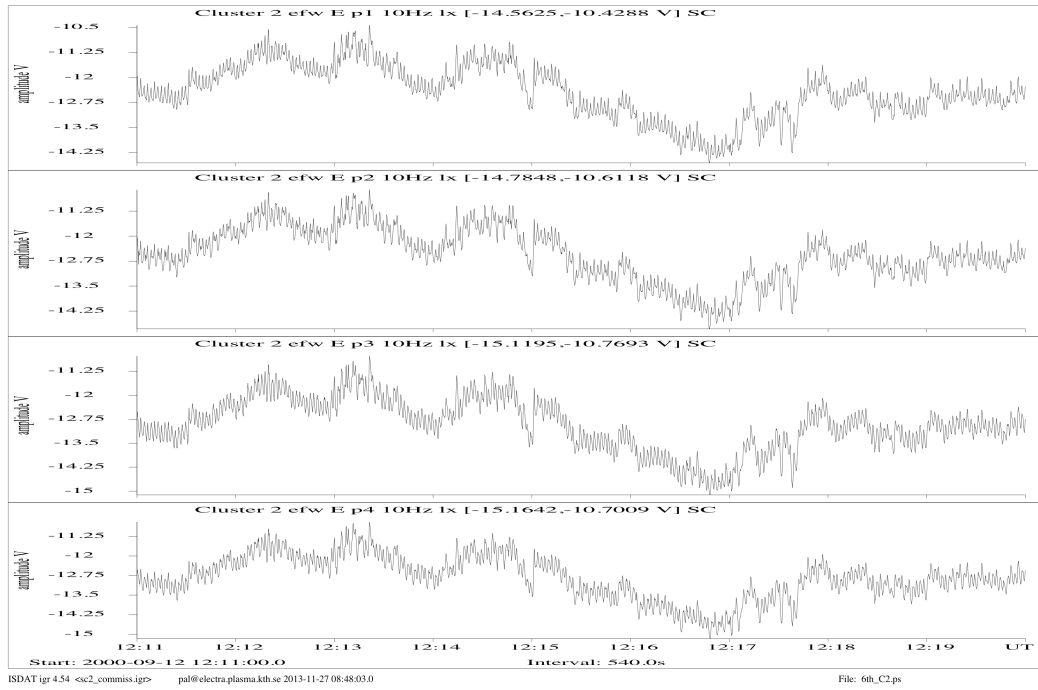
C1 6th deployment, boom 1



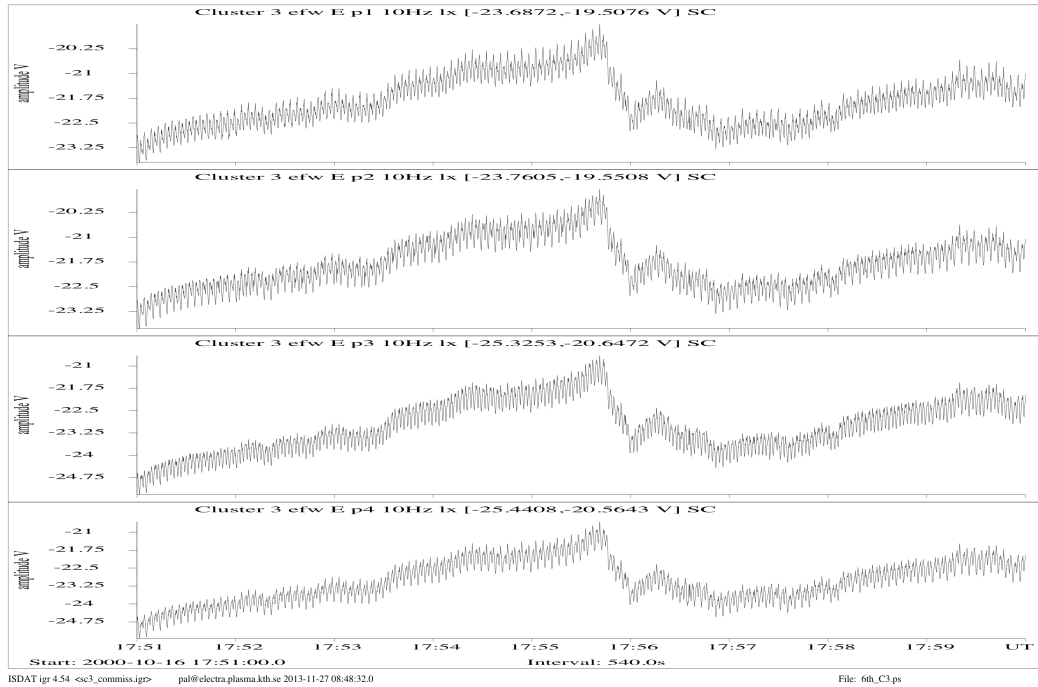
C1 6th deployment, boom 2



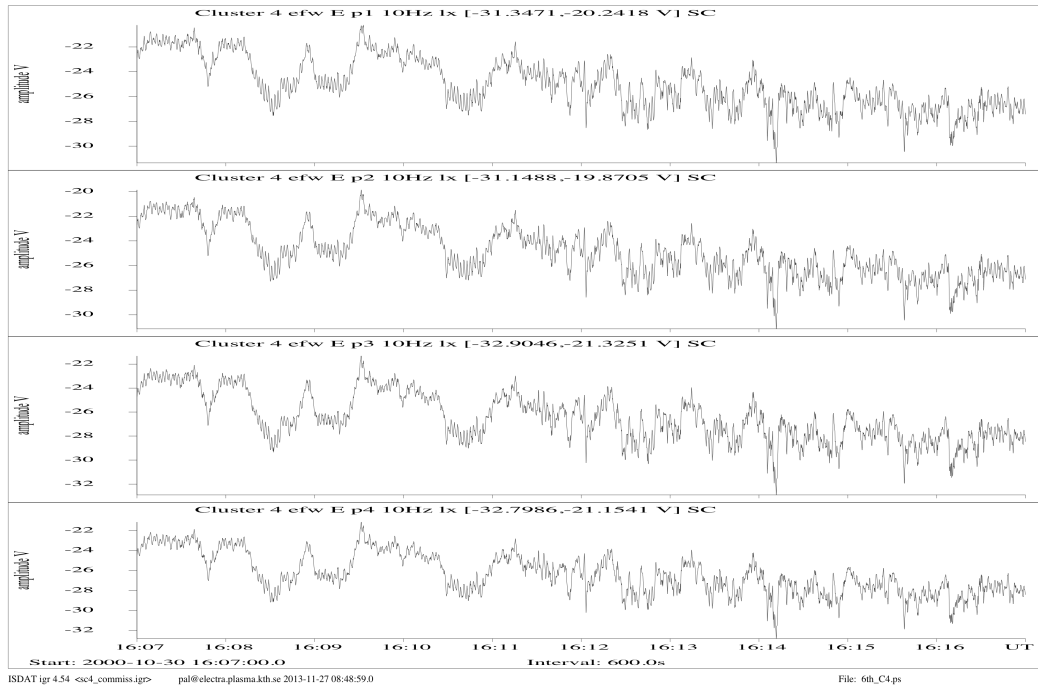
C2 6th deployment



C3 6th deployment



C4 6th deployment



4.9. 2nd spin-up at 20/35 m:

	C1	C2 *)	C3	C4
Date	000925	000918	001018	001102
Time	193827-193939	200000-200125	152927-153047	161447-161607
Spin rate	13.94-17.54	13.58-17.48	13.53-17.50	13.50-17.51
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-180	-180	-140	-180
Vguard	-3	-3	-6	-6
Vpuck	+1	+1	+1	+1

*) No EFW data available during spin-up, data gap 19:31-20:13

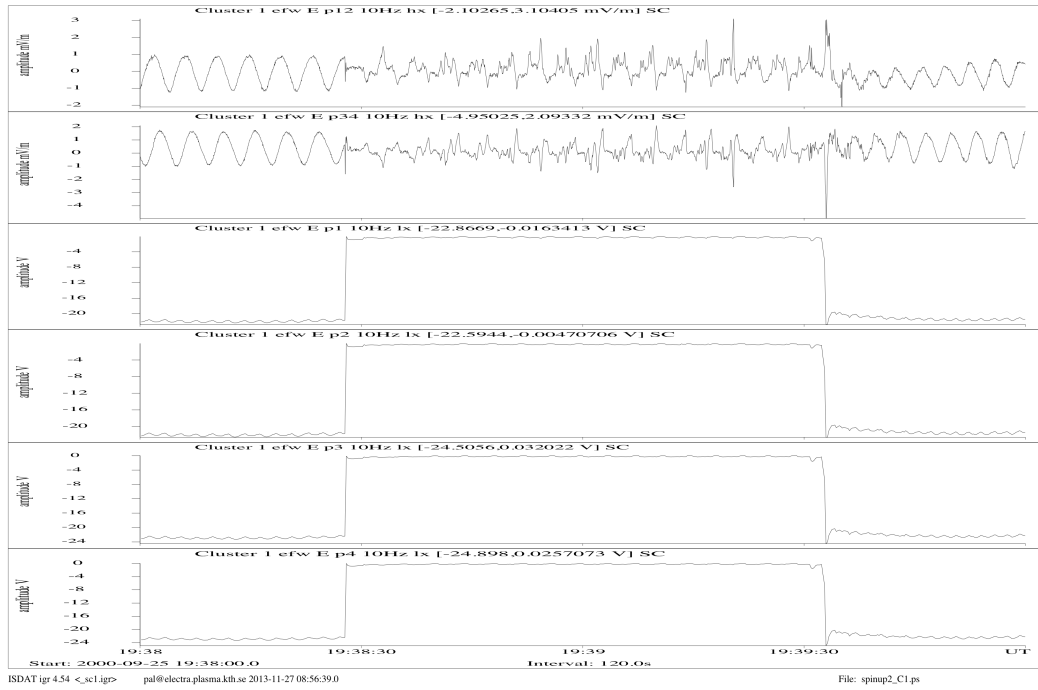
Plots:

C1: 1938-1940

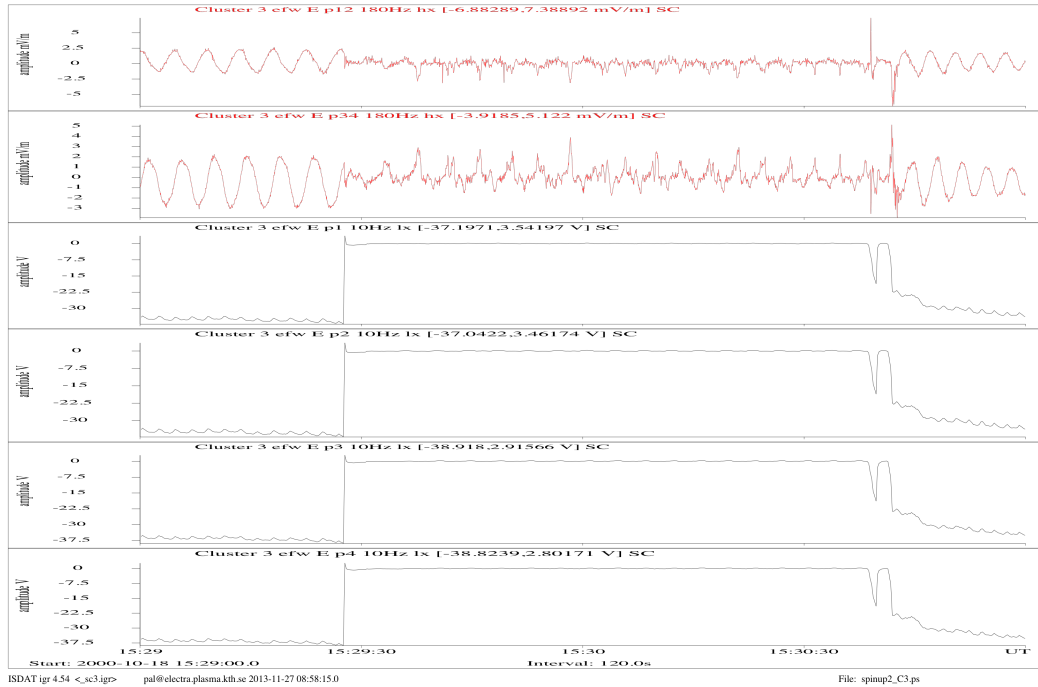
C3: 1529-1531

C4: 1614-1617

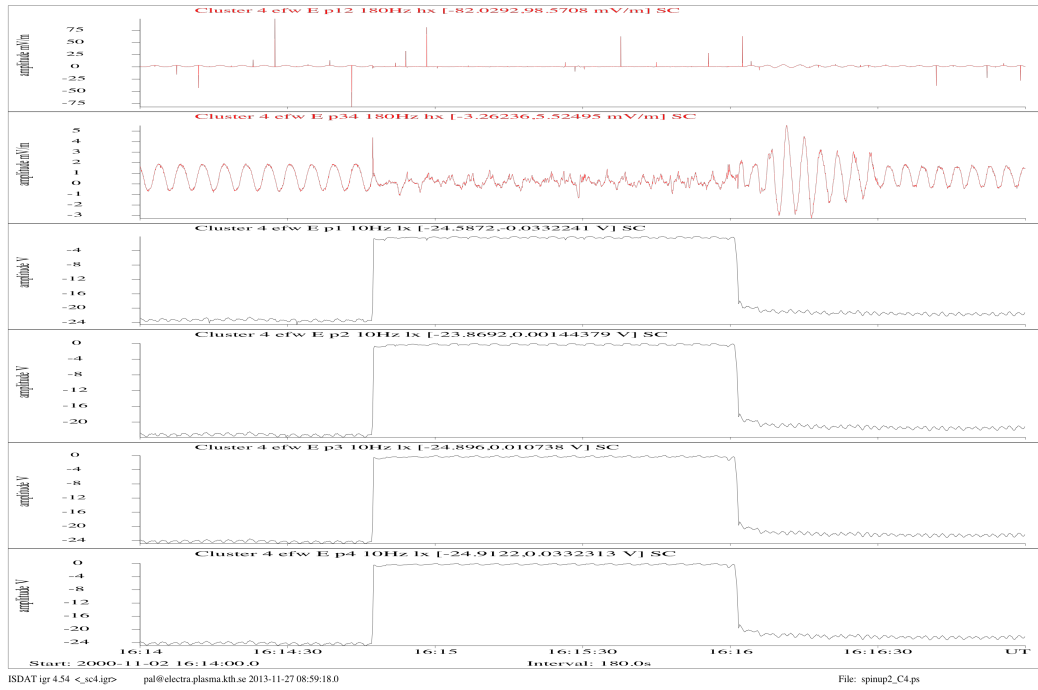
C1 2nd spinup 13.94-17.54 rpm



C3 2nd spinup 13.53-17.50 rpm



C4 2nd spinup 13.50-17.51 rpm



4.10. 7th deployment, booms 3+4 35-41 m:

	C1	C2	C3	C4
Date	000925	000918	001018	001102
Time	201629-202557	211300-212125	161700-162636	165000-170018
Spin rate	17.54-15.03	17.48-14.96	17.50-14.97	17.51-14.95
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-180	-180	-140	-180
Vguard	-3	-3	-6	-6
Vpuck	+1	+1	+1	+1

Plots:

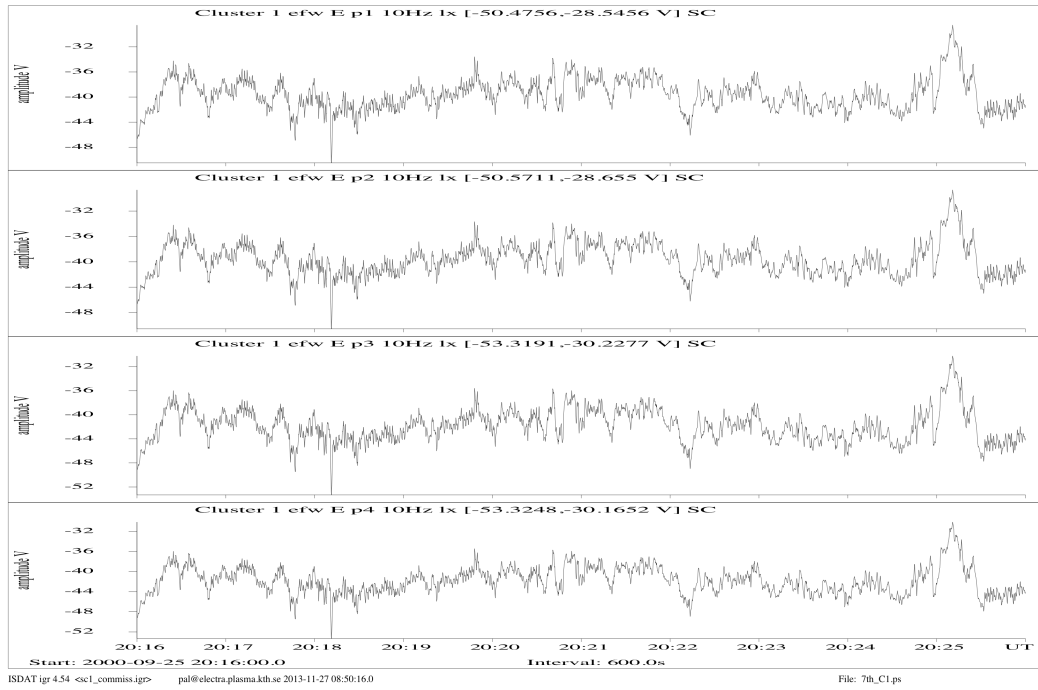
C1: 2016-2026

C2: 2112-2122

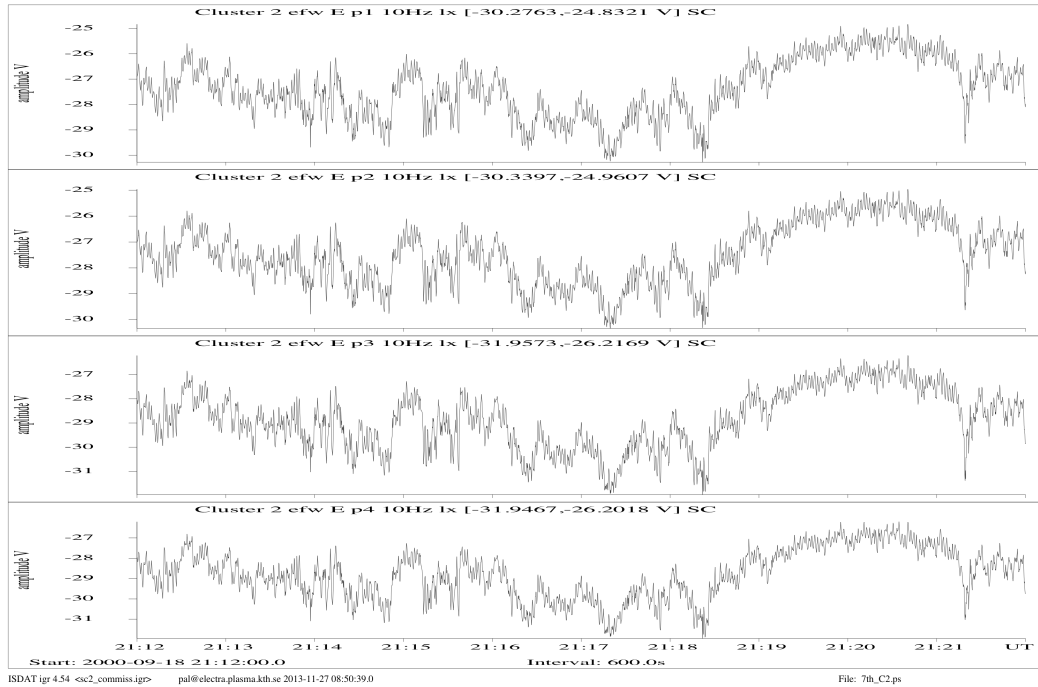
C3: 1616-1627

C4: 1649-1701

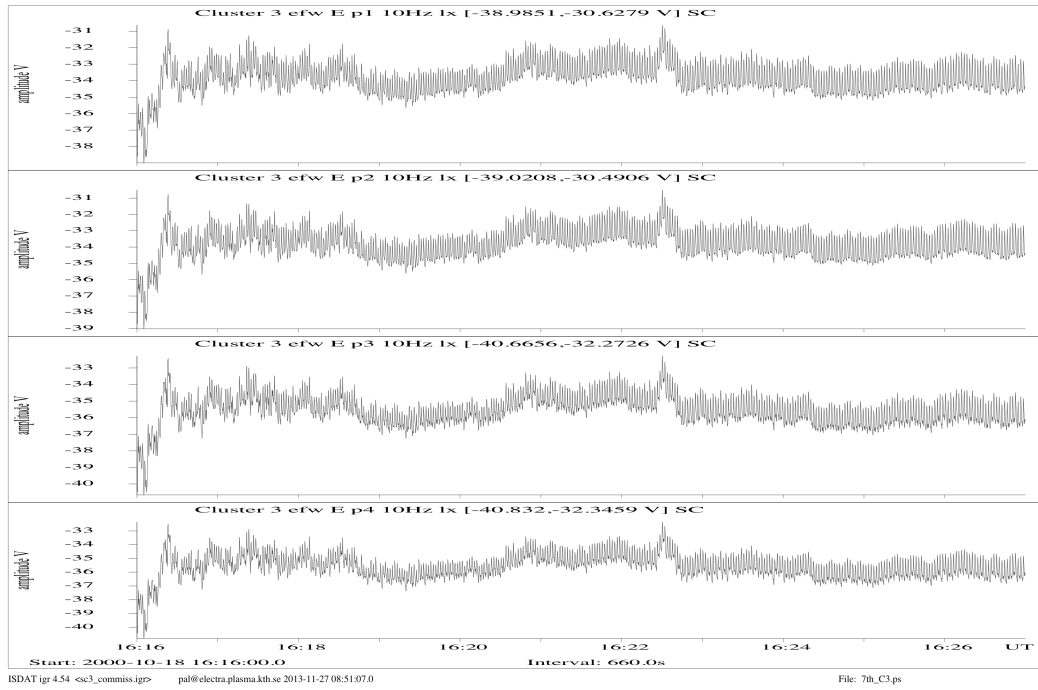
C1 7th deployment



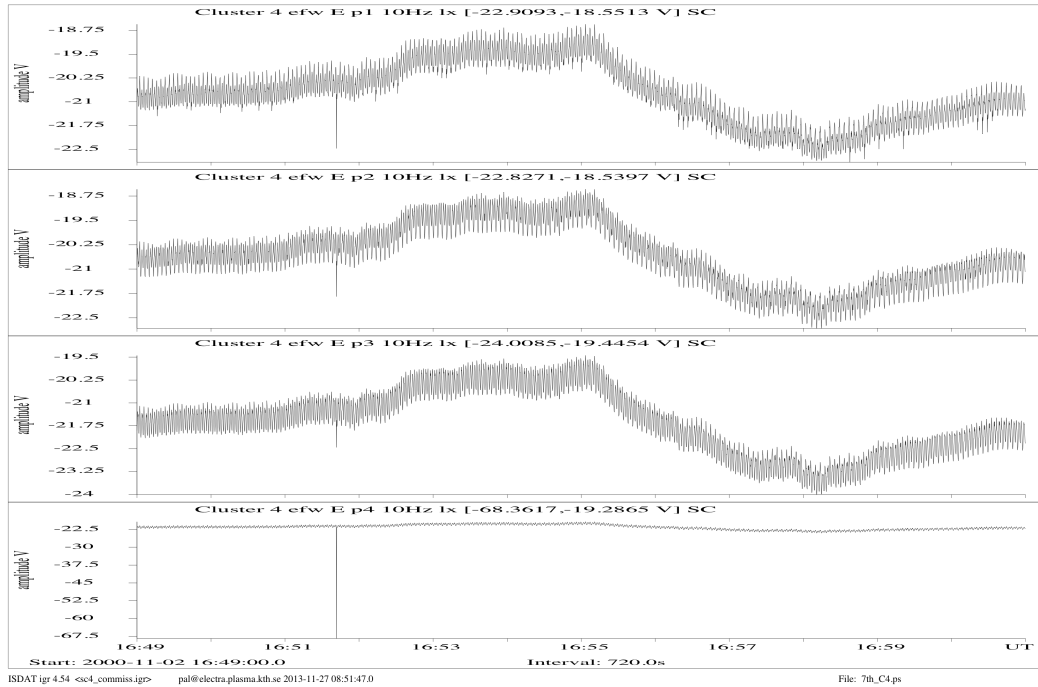
C2 7th deployment



C3 7th deployment



C4 7th deployment



4.11. 8th deployment, booms 1+2 20-41 m:

	C1 *)	C2	C3	C4
Date	001006	001004	001108	001116
Time	150900-174540	172800-180159	143500-150817	145013-152455
Spin rate	15.02-10.84	14.95-10.81	14.96-10.84	14.94-10.83
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-160	-180	-180	-180
Vguard	-6	-3	-6	-6
Vpuck	+1	+1	-1	-1

*) Deployment done in 13 steps, alternating boom 1 and boom 2

Plots:

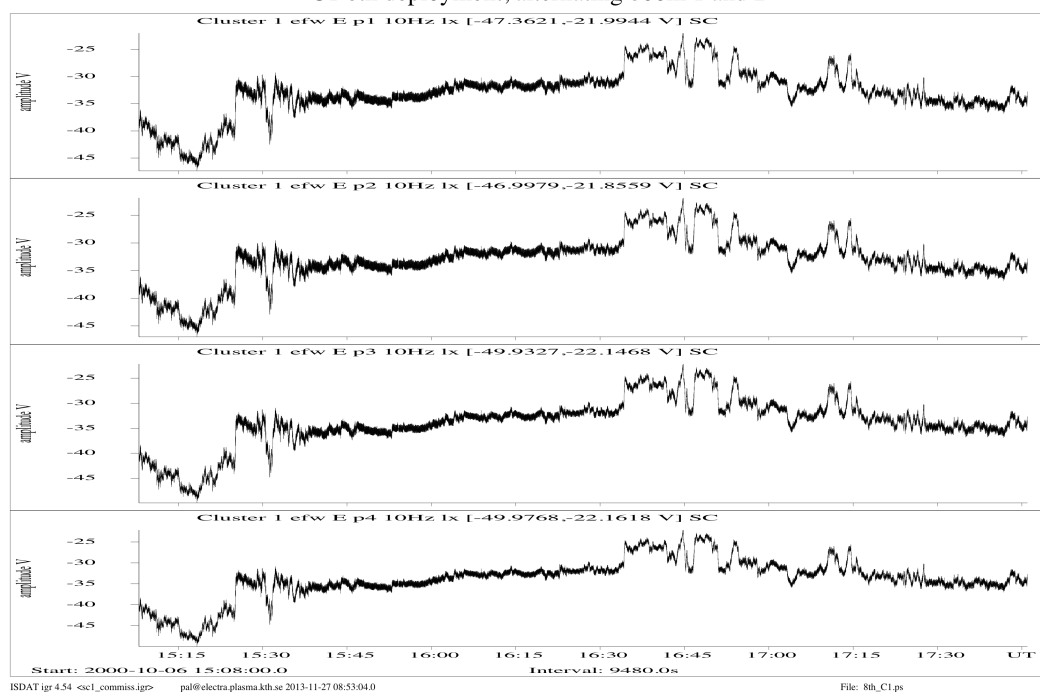
C1: 1508-1746

C2: 1727-1802

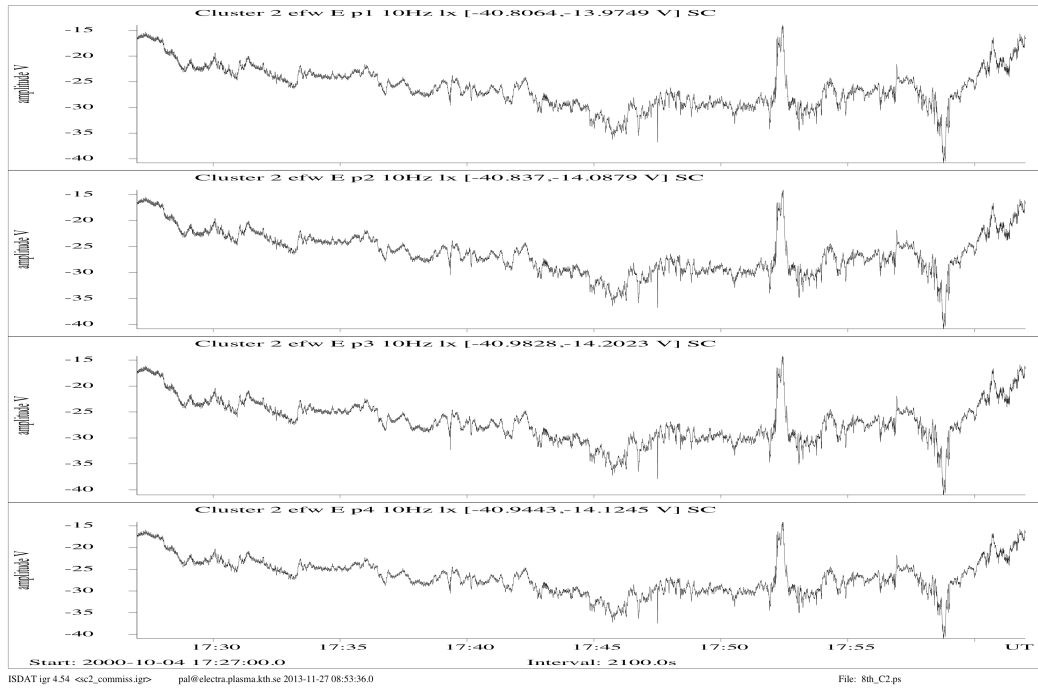
C3: 1434-1509

C4: 1450-1525

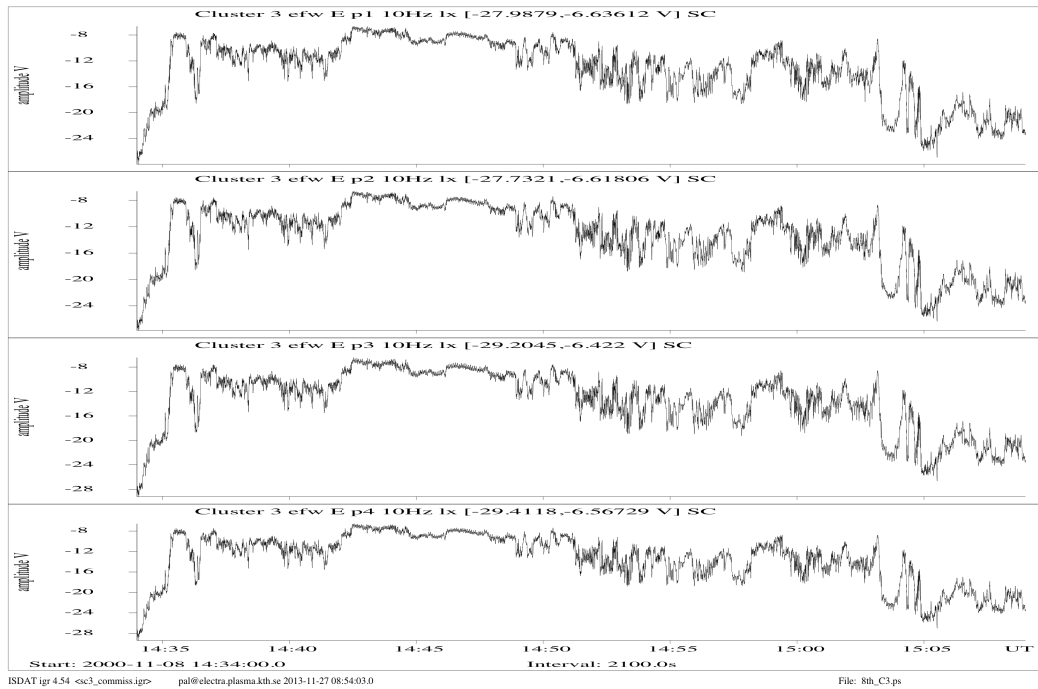
C1 8th deployment, alternating boom 1 and 2



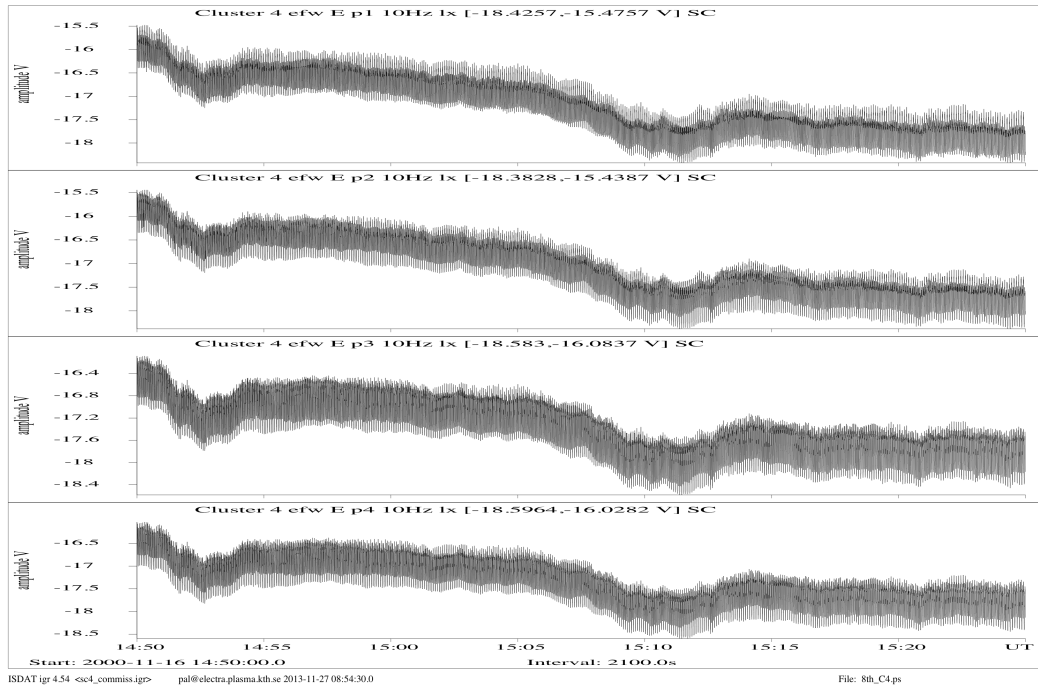
C2 8th deployment



C3 8th deployment



C4 8th deployment



4.12. 3rd spin-up at 41 m:

	C1	C2	C3	C4
Date	001006	001004	001111	001116
Time	194510-194719	193112-193326	200010-200220	175953-180202
Spin rate	10.84-15.01	10.81-14.97	10.84-14.99	10.83-14.98
Mode	EEEE	EEEE	EEEE	EEEE
Ibias/Vbias	-160	-180	-160	-180
Vguard	-6	-5	-6	-6
Vpuck	+1	+1	+1	-1

Plots:

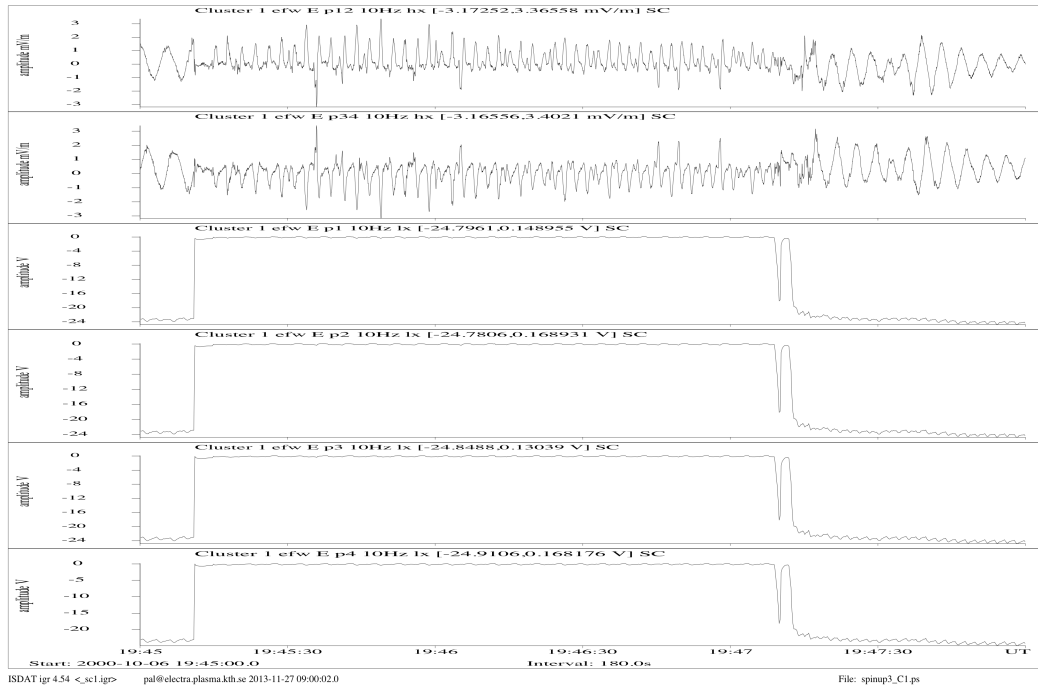
C1: 1945-1948

C2: 1931-1934

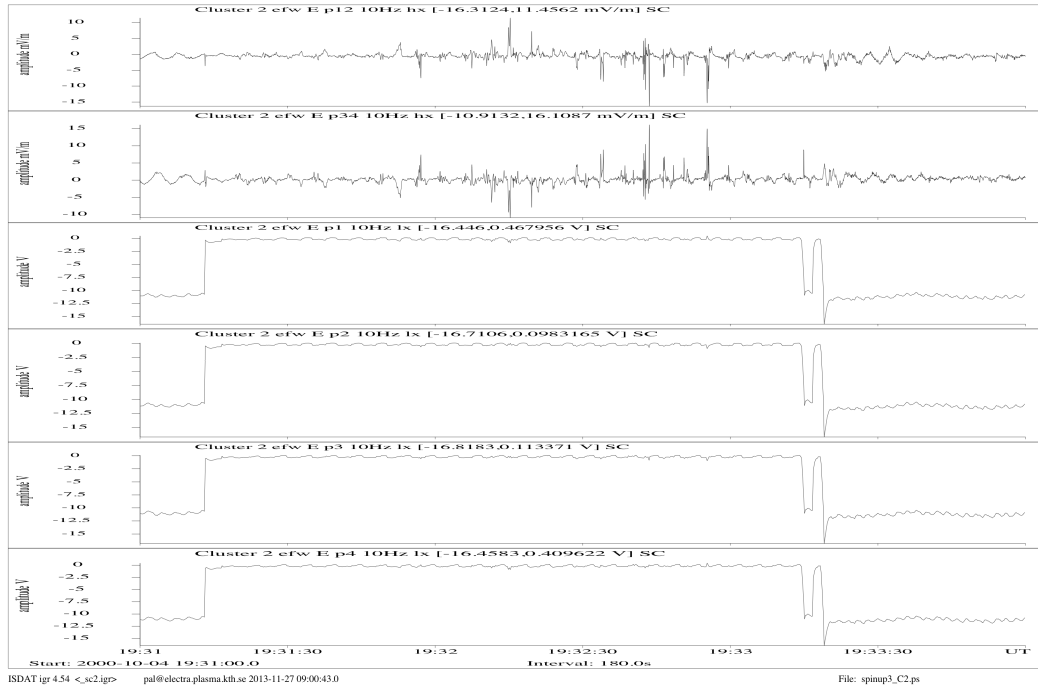
C3: 2000-2003

C4: 1759-1803

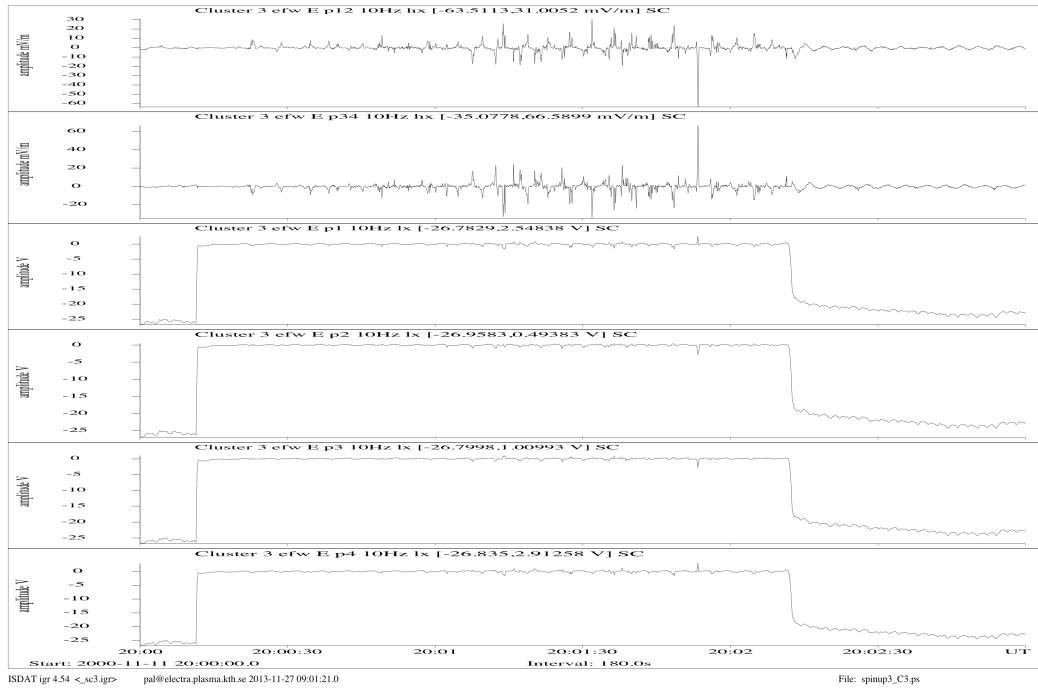
C1 3rd spinup 10.84-15.01 rpm



C2 3rd spinup 10.81-14.97 rpm



C3 3rd spinup 10.84-14.99 rpm



C4 3rd spinup 10.83-14.98 rpm

