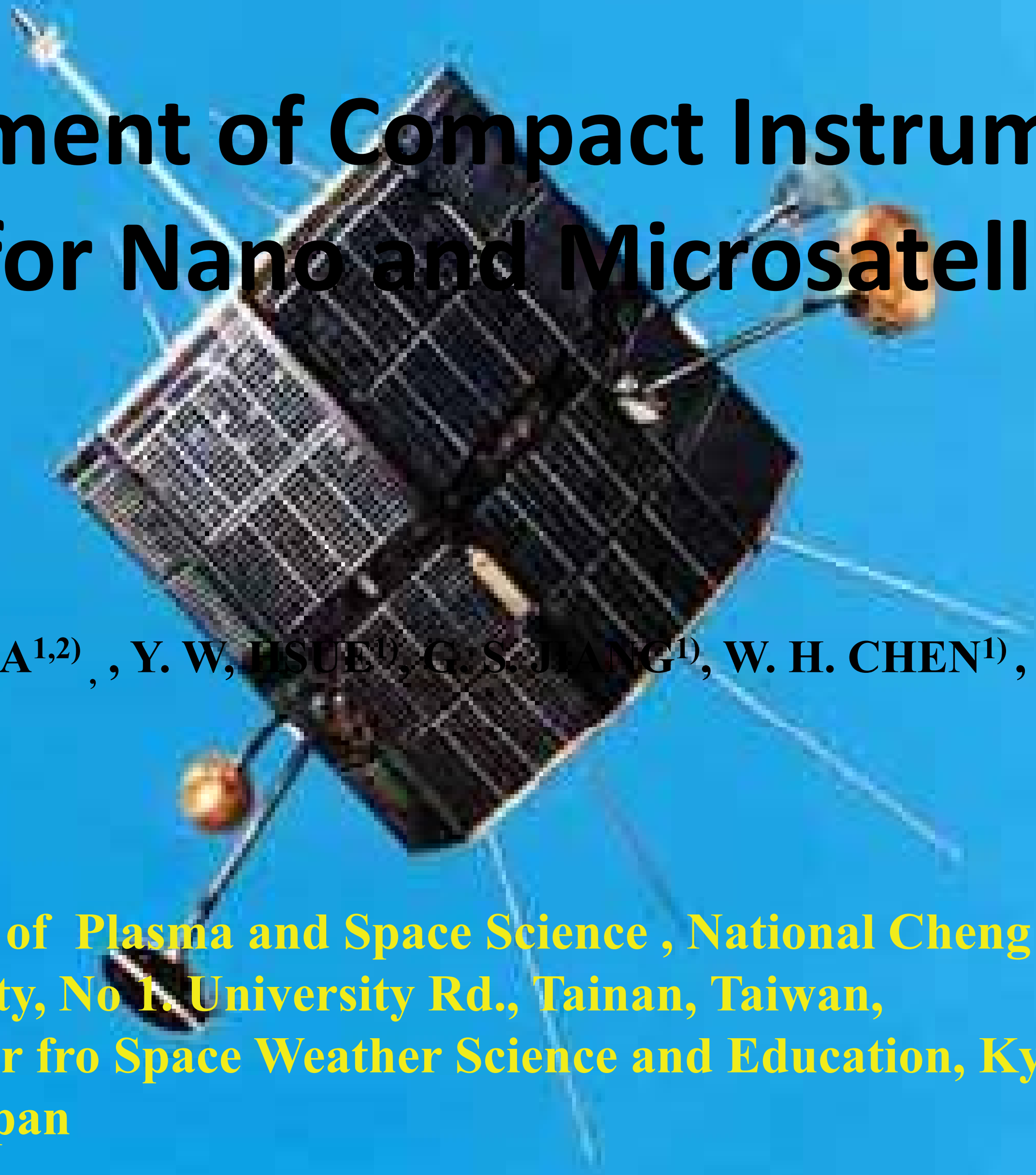
5th Nanosatellite Symposium 21 Nov. 14:30-15:50 Takeda Hall, Univ. of Tokyo, Japan

Development of Compact Instrument (TeNeP) for Nano and Microsatellite



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Abstract

Electron Temperature Probe (ETP) which has been widely used until recently since it was developed in the beginning of 1970’ s has been modified to measure electron density as well (TeNeP). We developed TeNeP in a strong motivation to install it even in picosatellite. The instrument can be easily completed by technical college, and university students. The TeNeP is small in size, and requires low power consumption , and low data bit rate, but still provides scientifically useful basic ionosphere parameter, especially for tiny satellite constellaltion mission.

The instrument does not need large conductive area as a counter electrode(Satellite), and is free from electrode /satellite contamination.

CONTENT

1. **ETP (Electron temperature measurement) in low frequency region,**

2. TeNeP (Density measurement in high frequency region/ Electron temperature measurement in low frequency region)

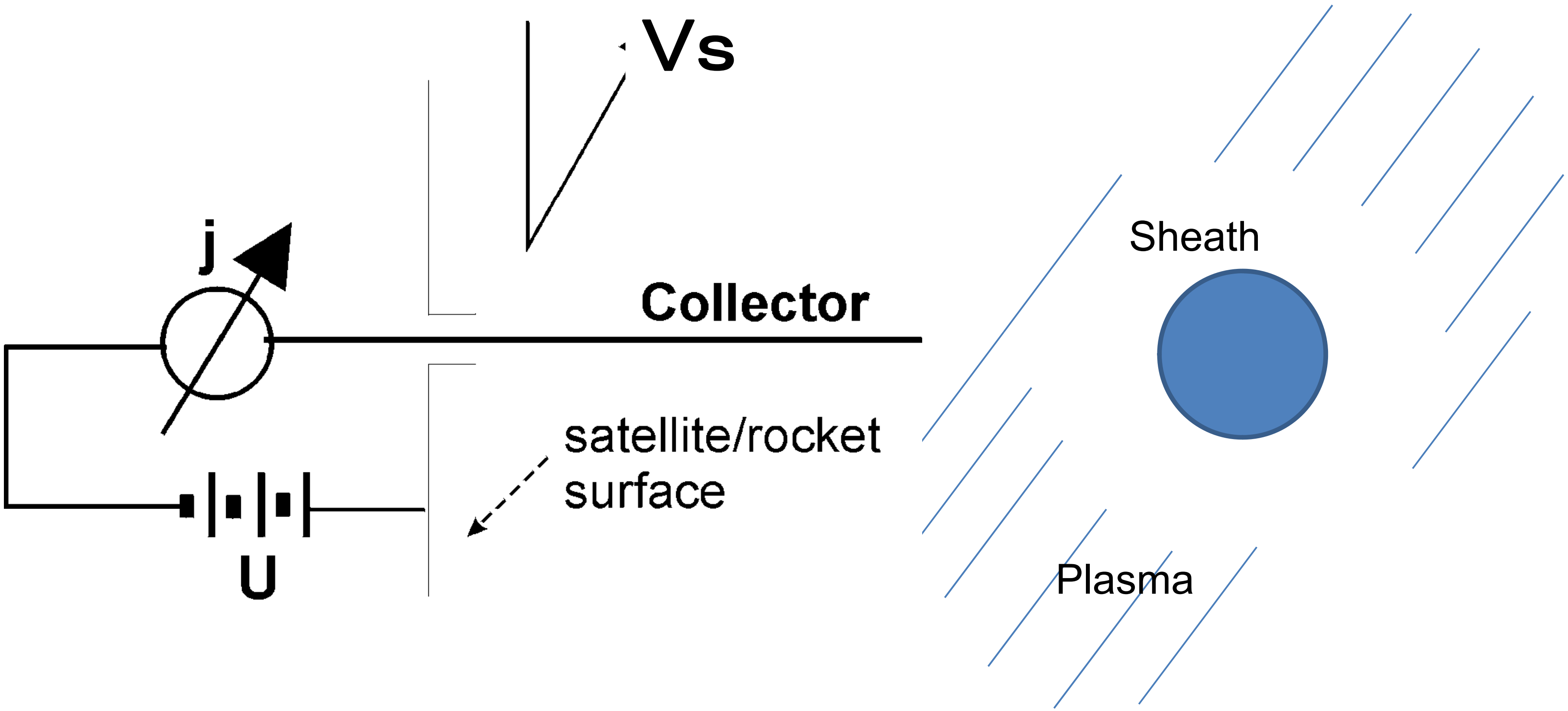
3. **Summary on TeNeP**

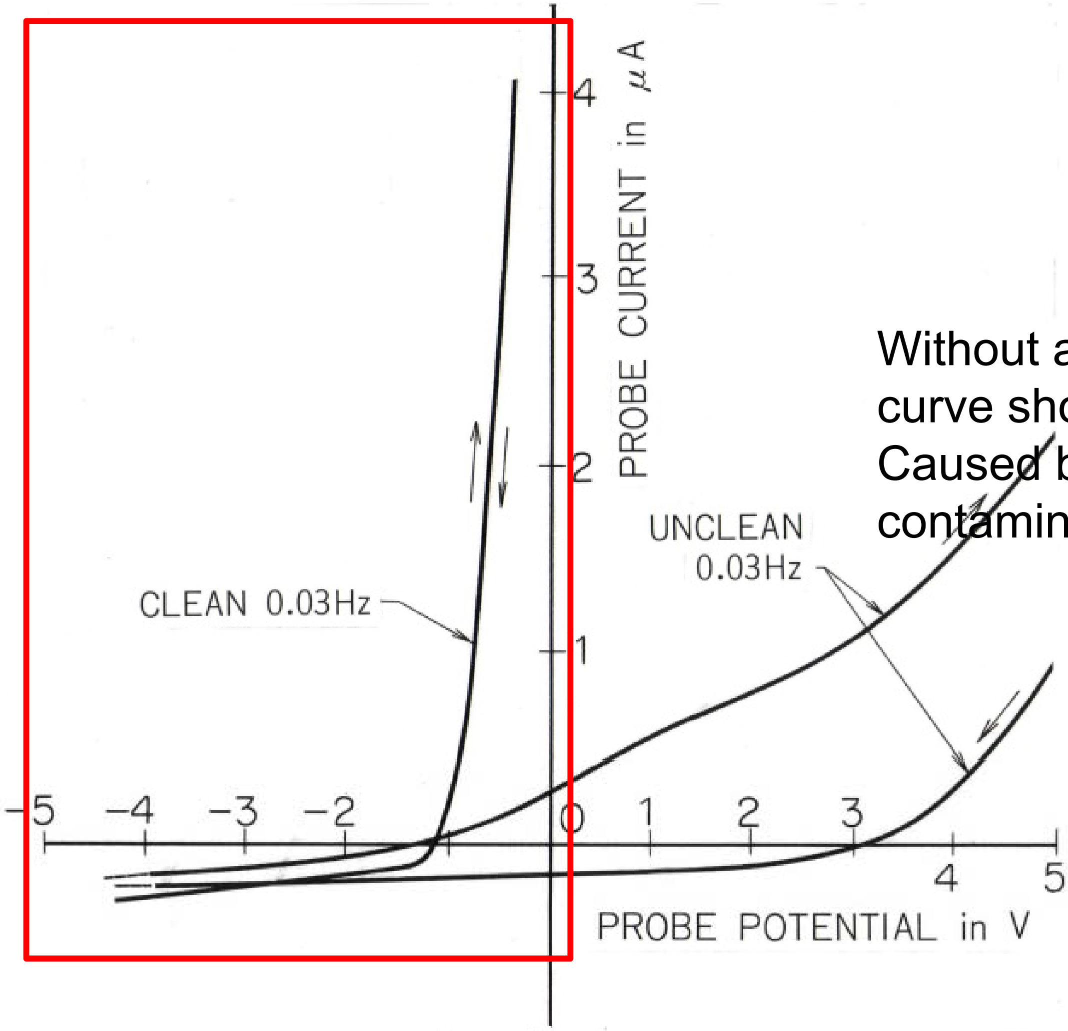
4. Toward satellite mission (Introduction on Tiny satellite task Group)

Electron Temperature probe was first invented by Hirao and Miyazaki., and improved by Oyama and Hirao in 1970’s . It has been used until now, because of the high performance in spite of the light weight (200g), low power consumption (5mA, +/-12V), and low bit rate (minimum, 32 bits/s).

The probe has been flown in 5 earth orbiting satellites in Japan, and Korea, Brazil and Russia. The probe was accommodated in more than 50 Japanese sounding rockets including Antarctic Showa base , West Germany, Brazil, India, USA, and Canada.

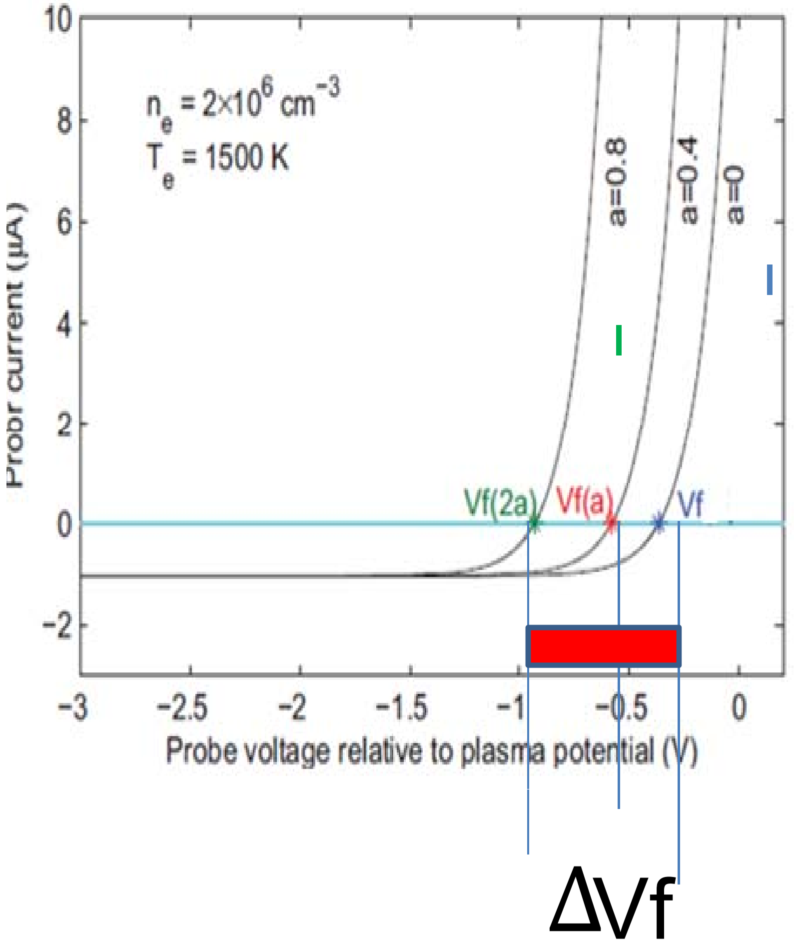
Principle of Electron Temperature probe





Without any exception, I-V curve shows hysteresis. Caused by the surface contamination

When sinusoidal signal is applied to an electrode, the floating potential (potential where probe current is zero, $V_f(0)=\frac{kT_e}{e}\ln\left(\frac{I_{es}}{I_i}\right)$) shifts .



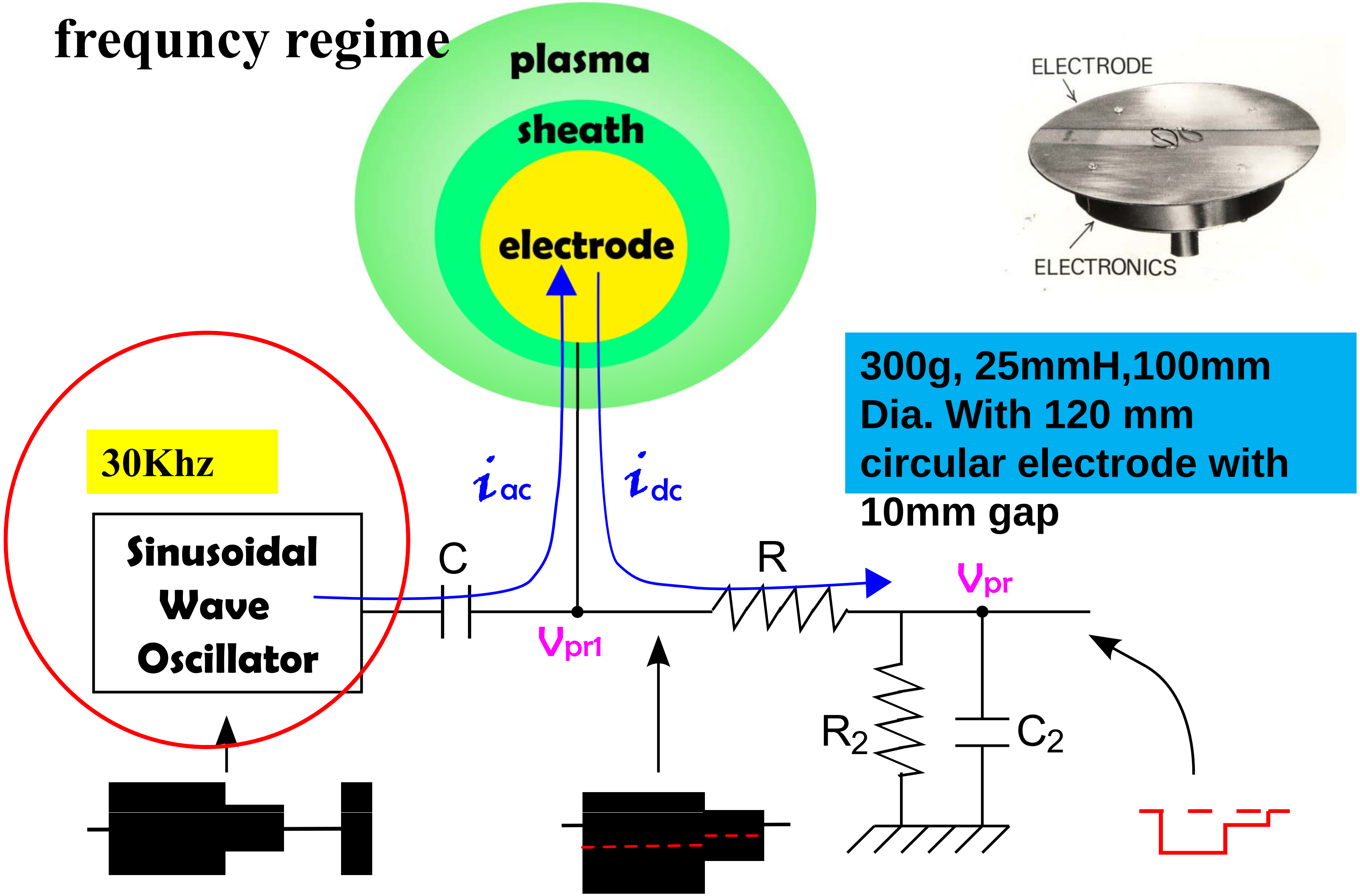
$$\Delta V_f(a)=V_f(a)-V_f(0)=\frac{kT_e}{e}\ln\left[I_0\left(\frac{ea}{kT_e}\right)\right]$$

$$\Delta V_f(2a)=V_f(2a)-V_f(0)=\frac{kT_e}{e}\ln\left[I_0\left(\frac{2ea}{kT_e}\right)\right]$$

$$\Rightarrow T_{e1}\,\&\,T_{e2}$$

$$R=\frac{\Delta V_f(2a)}{\Delta V_f(a)}=\frac{\ln\left[I_0\frac{2ea}{kT_e}\right]}{\ln\left[I_0\frac{ea}{kT_e}\right]}\Rightarrow T_{e3}$$

Fundamental circuit for Te measurement - Low frequncy regime

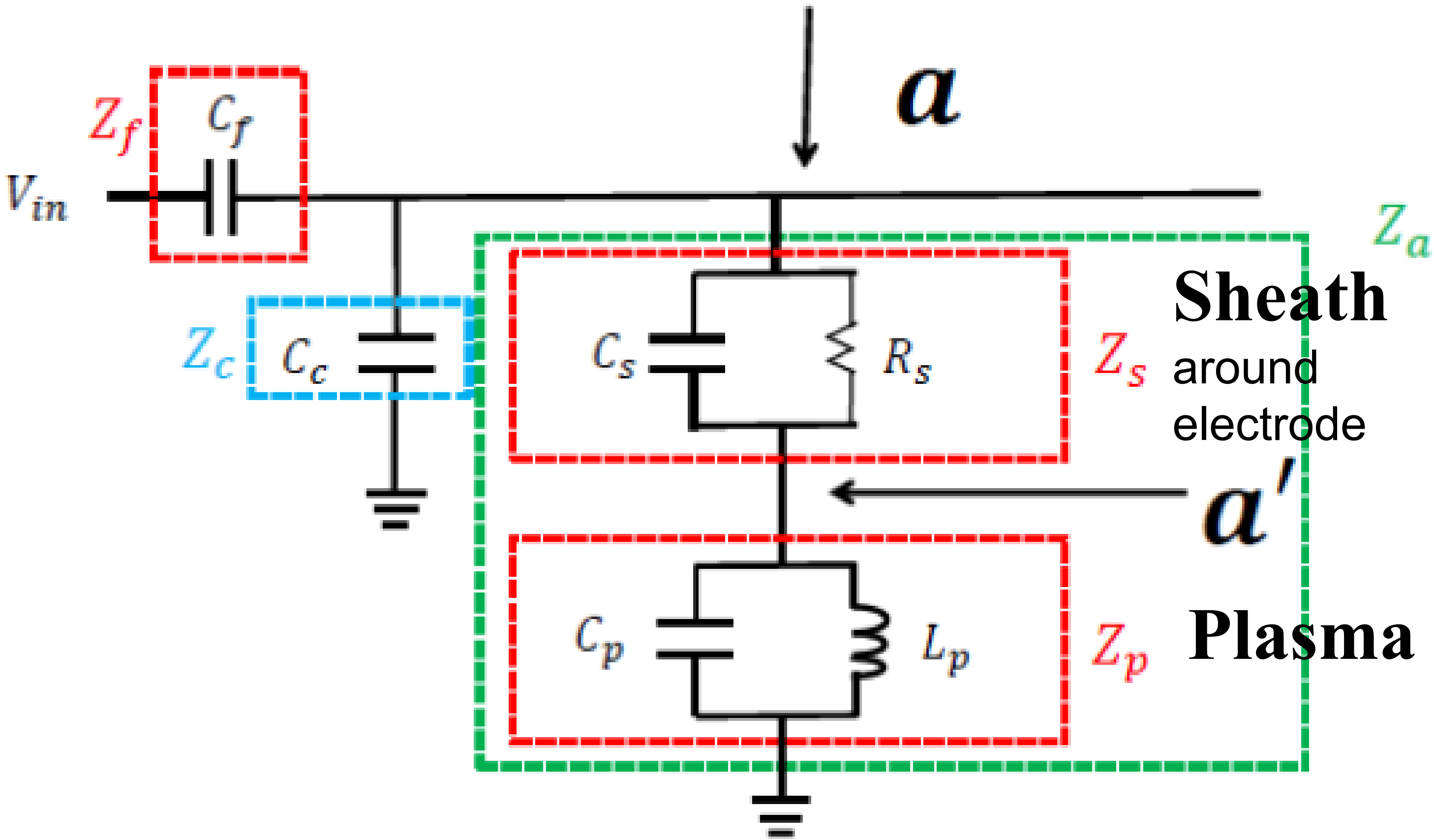


300g, 25mmH,100mm Dia. With 120 mm circular electrode with 10mm gap

Principle of TeNeP

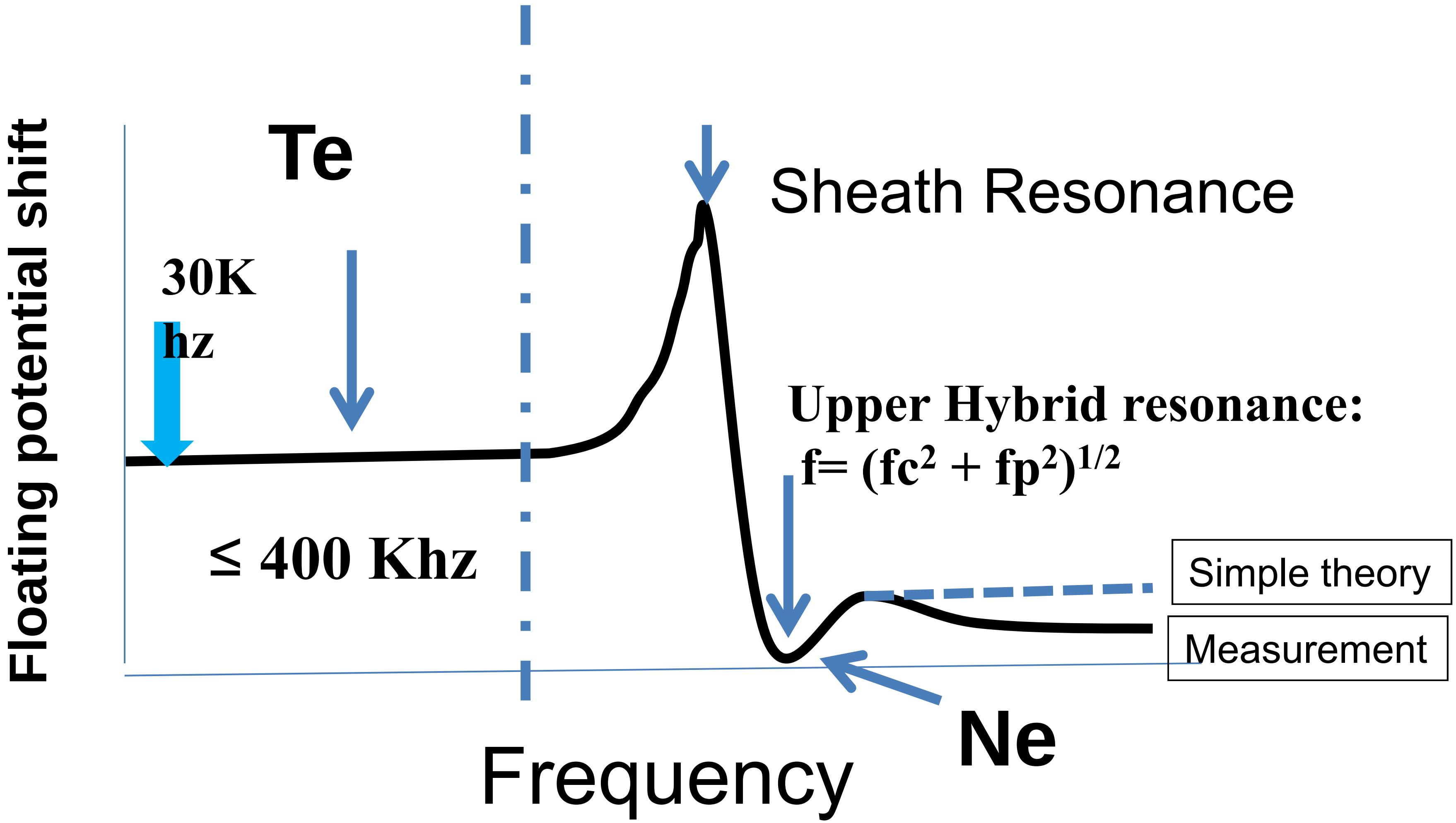
When sinusoidal wave of high frequency is superposed to the probe bias, plasma capacitance and reactance, and sheath capacitance need to be taken into account.

Sinusc
signal

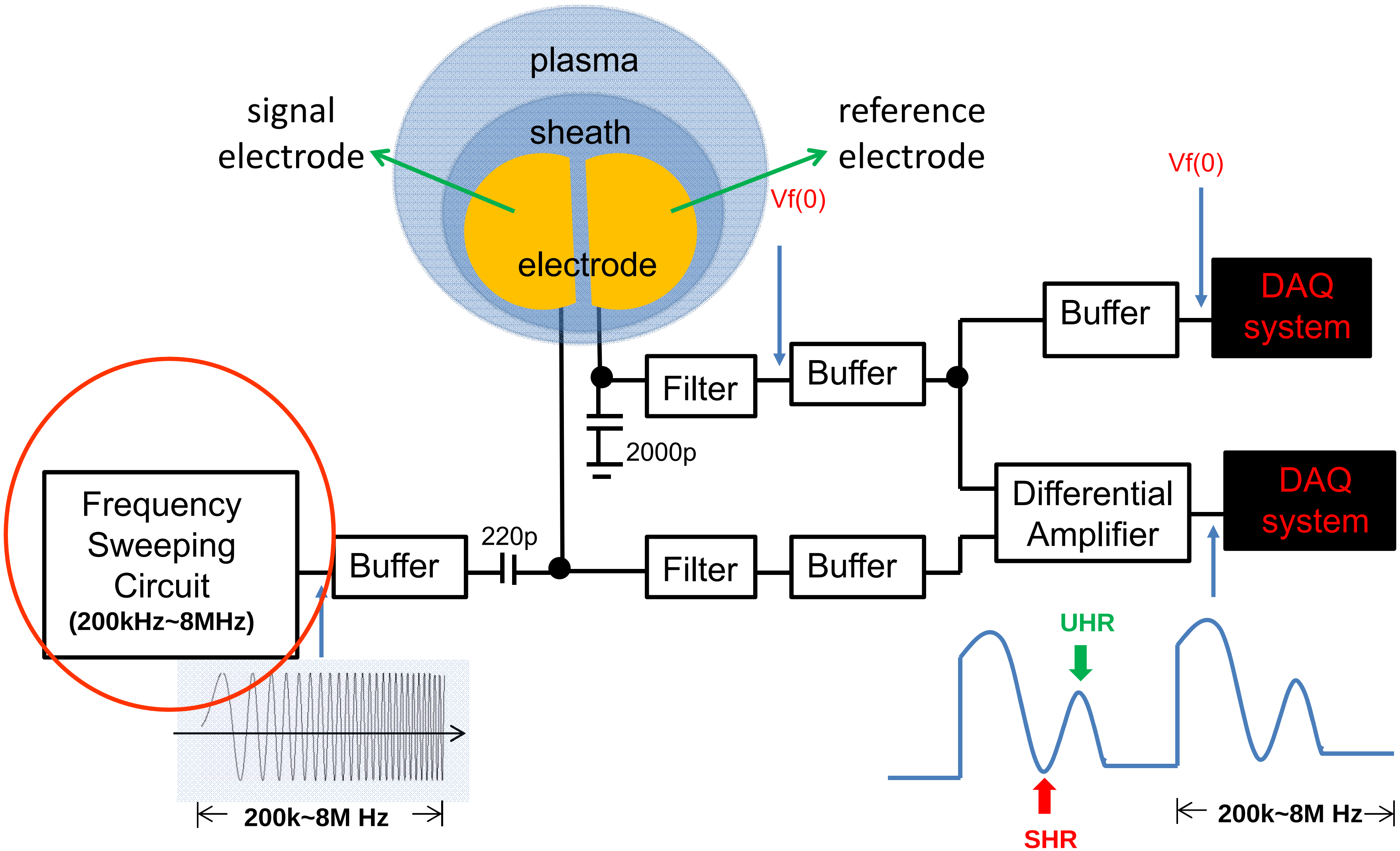


Amplitude of sinusoidal signal which is applied to the sheath depending on frequency

$\Delta Vf = (KT_e/ea)\ ln[(I_0(ea_s/KT_e)];$ a is amplitude of sinusoidal signal which is applied bewtnn electrode and sheath edge. a_s changes depending on the frequency of the signal. a_s= a- a ‘



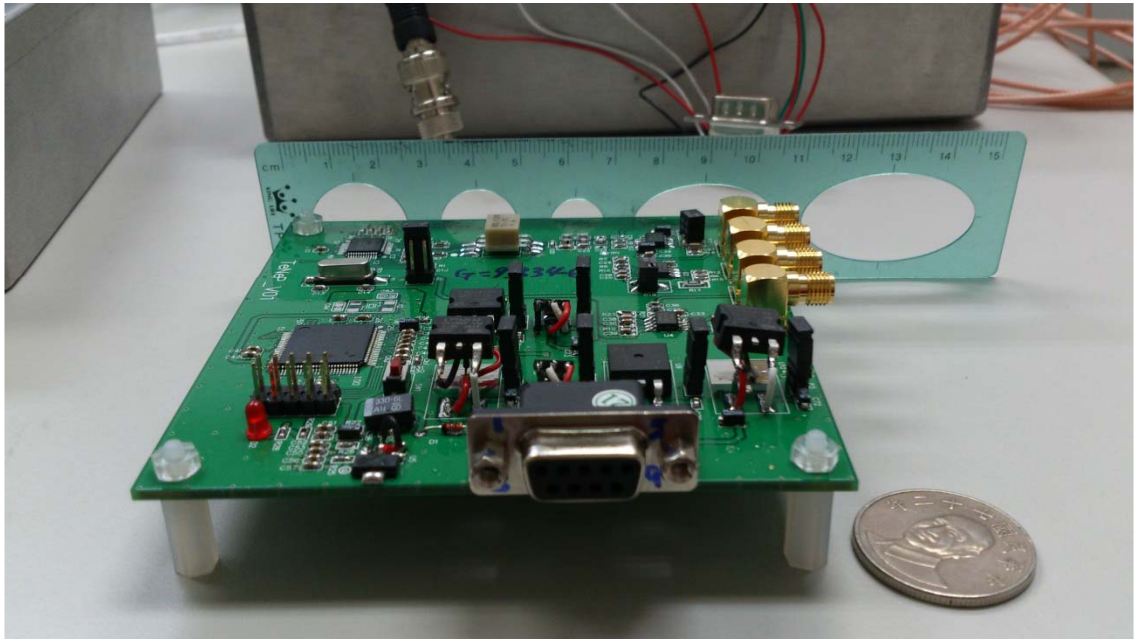
System configuration of TeNeP



IP consists of frequency sweeping oscillator, 4 DC buffer amplifiers, two filters, one DC differential amplifier, and with 10 cm diameter circular electrode.

Size:100X100 mm
Height:
30mm(including plastic column)
,18 mm(without plastic column)
Sensor;100mm circular

Weight::
76 g(include plastic column)
74 g(without plastic colum)
Sensor 20 g

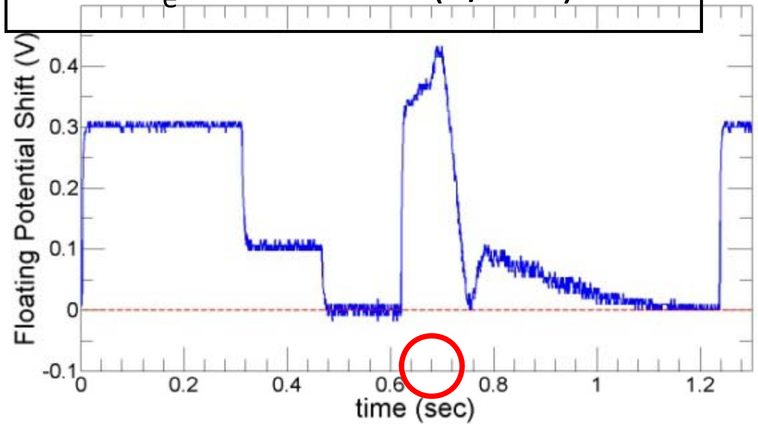


Total : 415+207.2 +74(does minus voltage power in calculation ?) = 696 mW

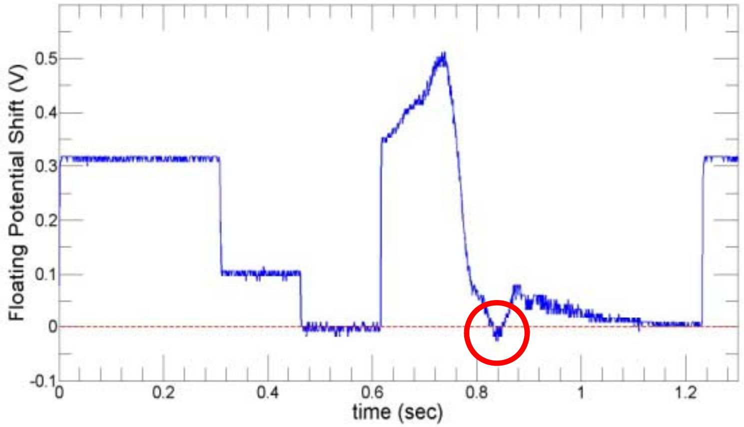
MCU:5V , 18mA   MCU+DDS: 5V , 80~83mA   V*I= 400~415 mW
TeNeP Circuits(including amplifier without DDS and MCU):
14.8V, 14mA   V*I=   207.2 mW
-14.8V, 5mA   V*I= 74 mW

Wave shape of floating potential shifts

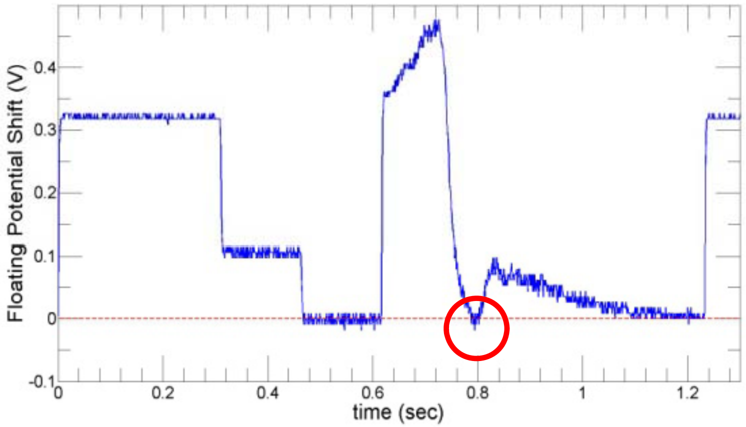
$N_e1=4.32\text{x}10^4$ $(1/cm^3)$



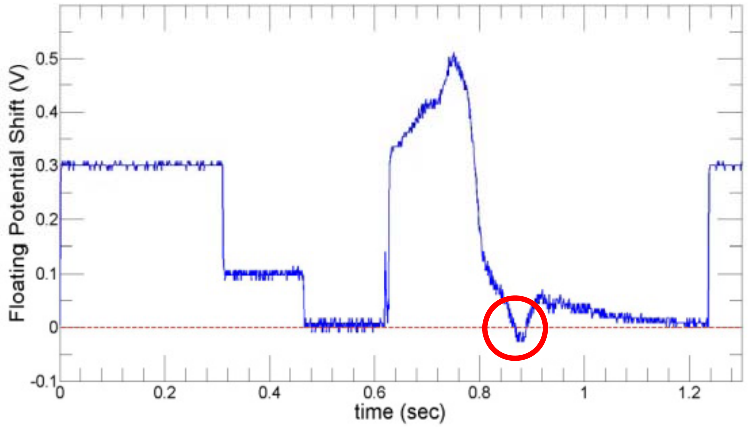
$N_e3=1.18\text{x}10^5$ $(1/cm^3)$



$N_e2=7.51\text{x}10^4$ $(1/cm^3)$



$N_e4=1.44\text{x}10^5$ $(1/cm^3)$



TeNeP for Earthquake Study

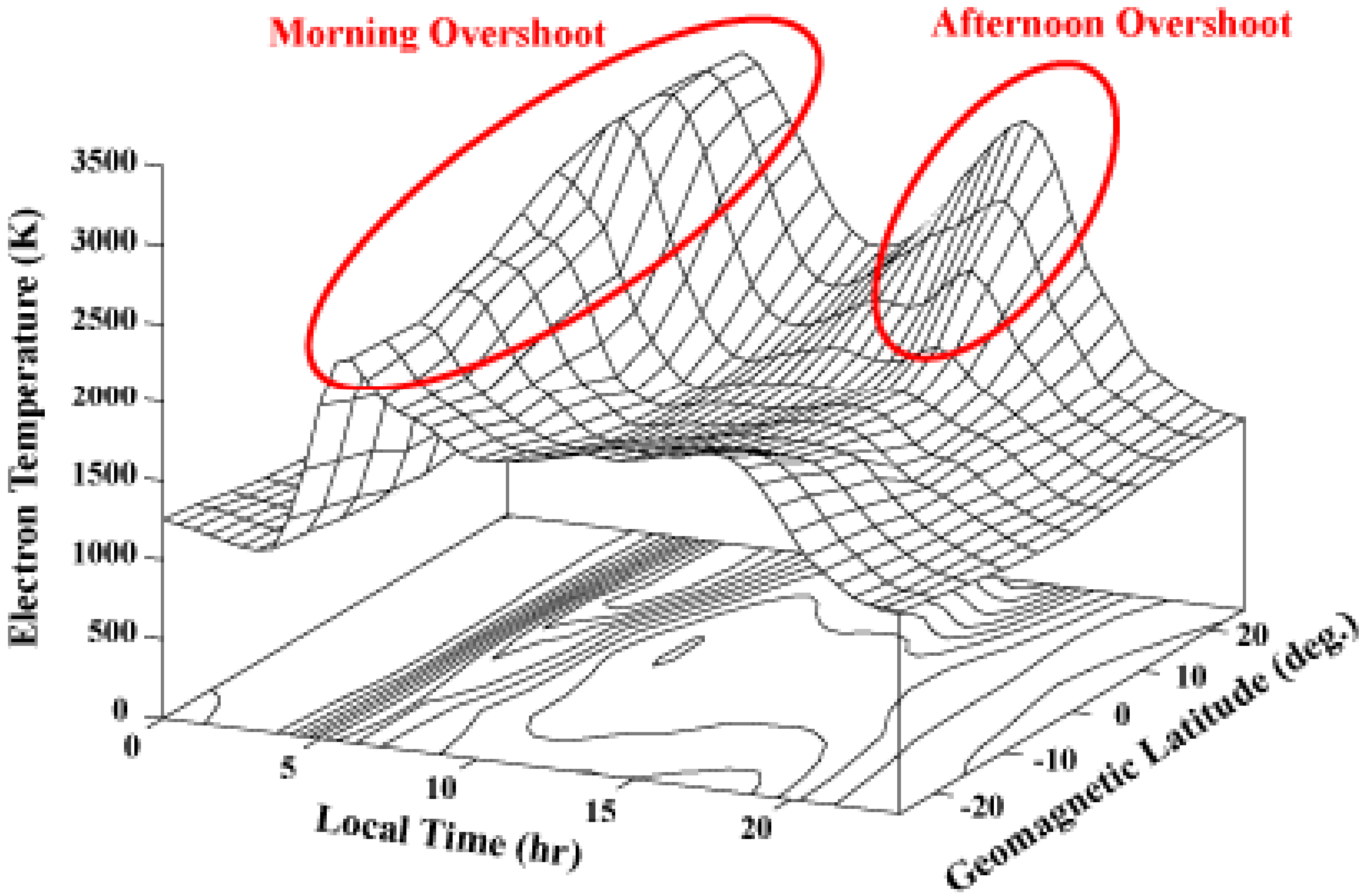
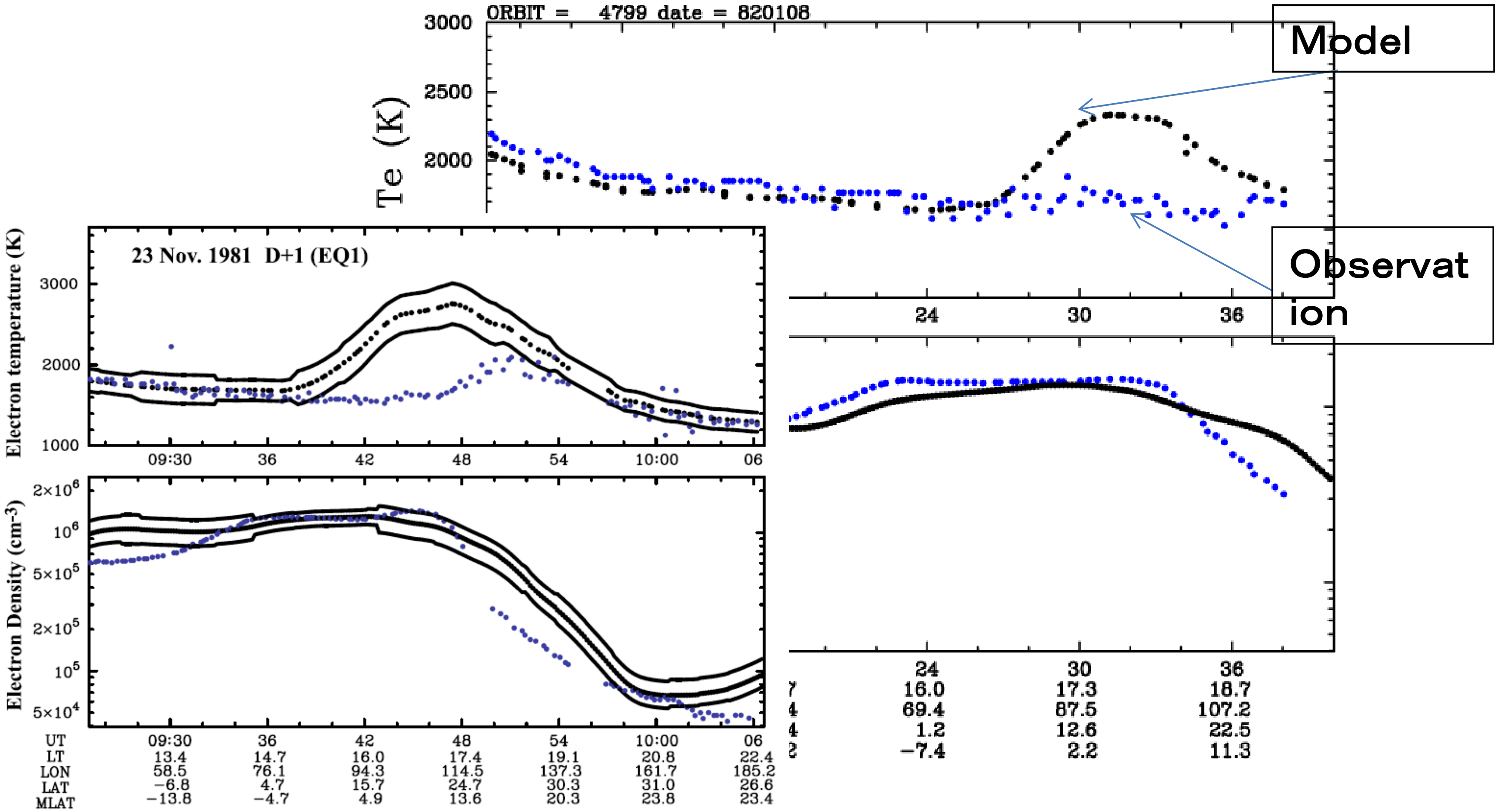
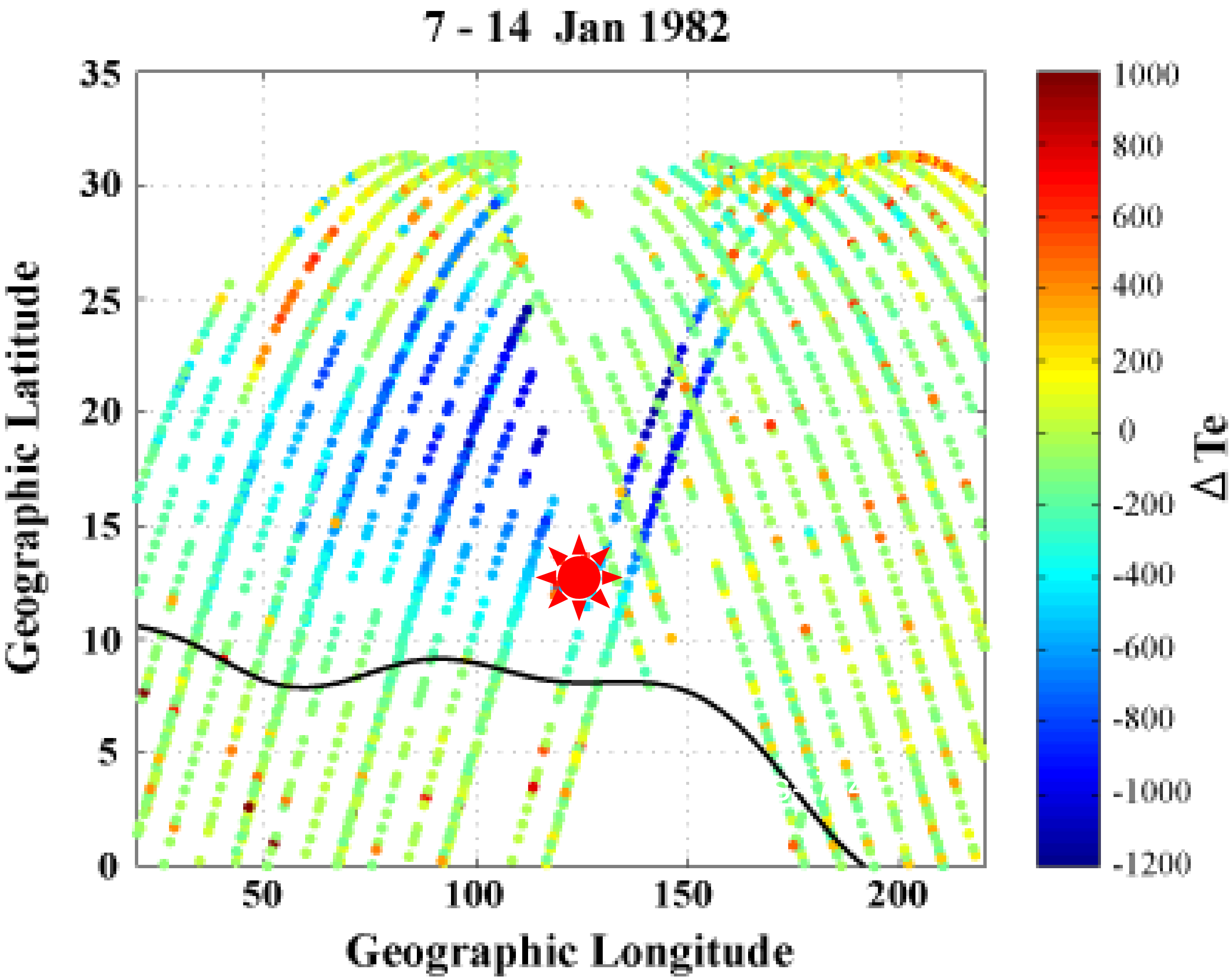


Fig 5. Local time variation of Te

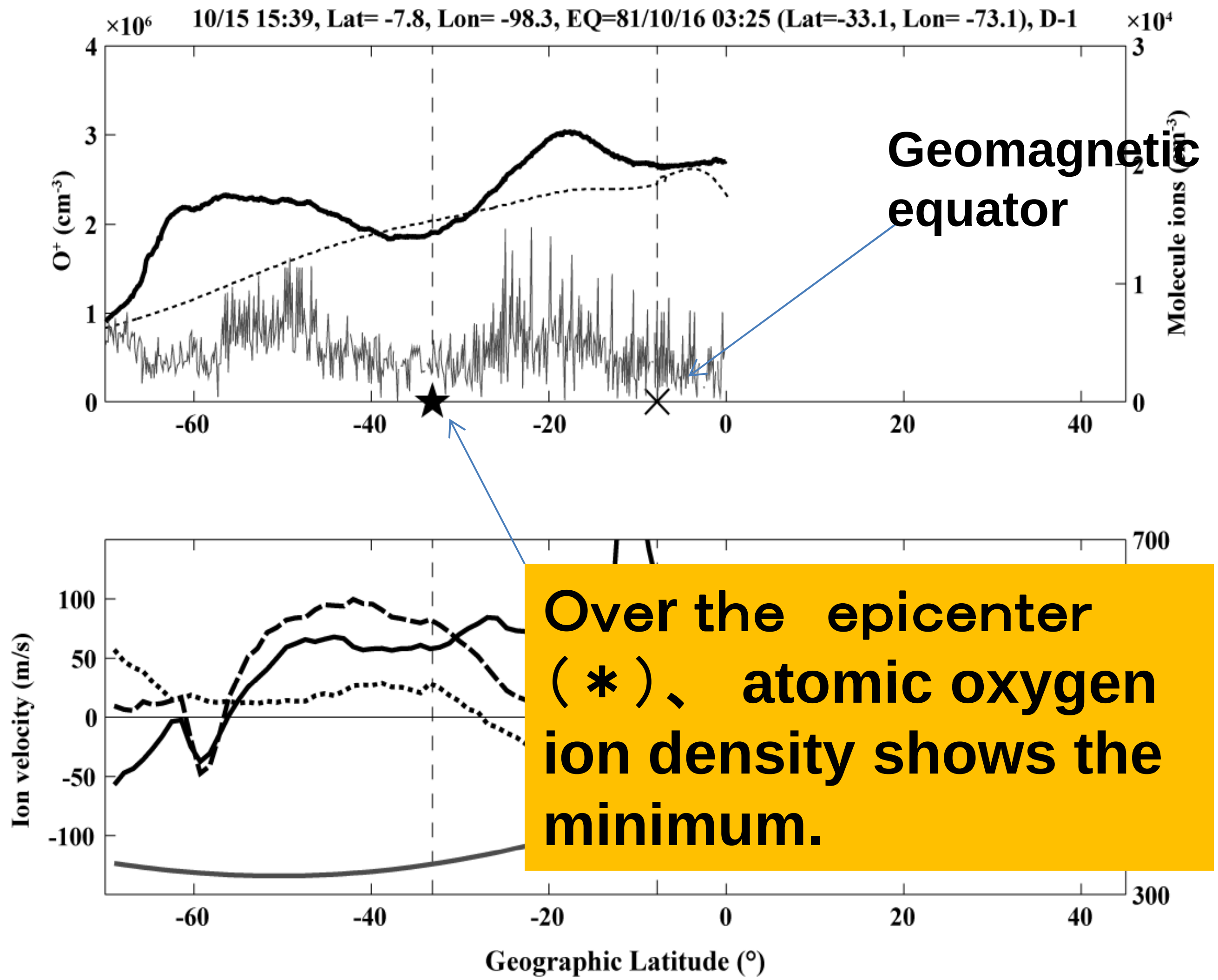


Example of total disappearance of Afternoon overshoot(Upper panels), and electron density(lower panel) **Black dotted line is the average value of Te. Blue line is data along one orbit** Oyama et al., JGR 2008

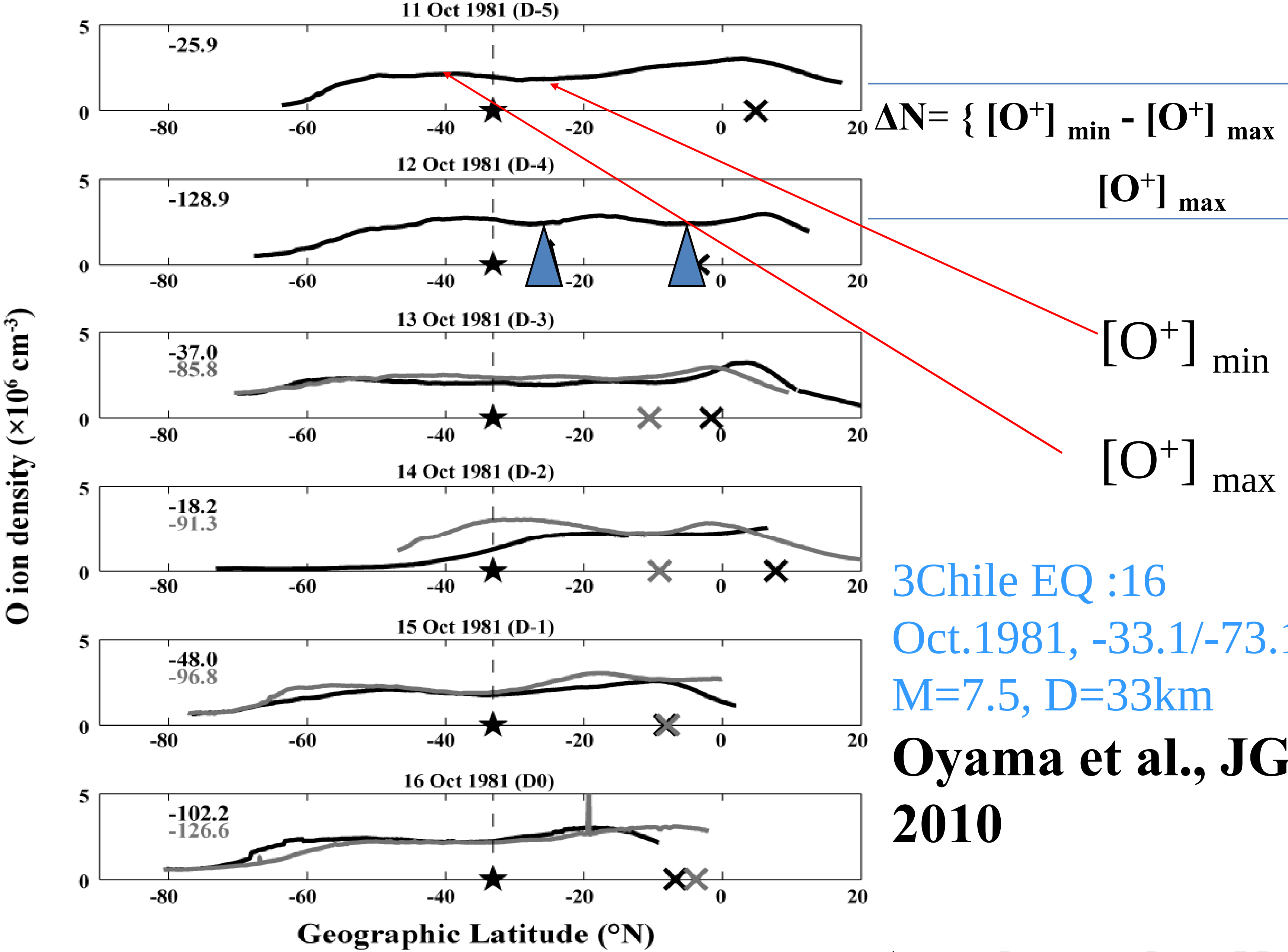


Reduction of Te , 7 days accumulation for 11 Jan 1982 earthquake. Red star shows the epicenter

Atomic Oxygen Ion density measured by Dynamics Explorer Satellite(DE-2) I day before Oct 16 1981 EQ



Over the epicenter（＊）、 atomic oxygen ion density shows the minimum.



$\Delta N = \{ [O^+]_{min} - [O^+]_{max} \} / [O^+]_{max}$

3Chile EQ :16 Oct.1981, -33.1/-73.1, M=7.5, D=33km

Oyama et al., JGR 2010

Abnormal behavior of Atomic Oxygen ions (nearly equal to Ne)
Dynamic Explorer -2(1981) over Epicenter . PIA

When is the Day of EQ？ Earthquake occurred on 16 Oct,1981

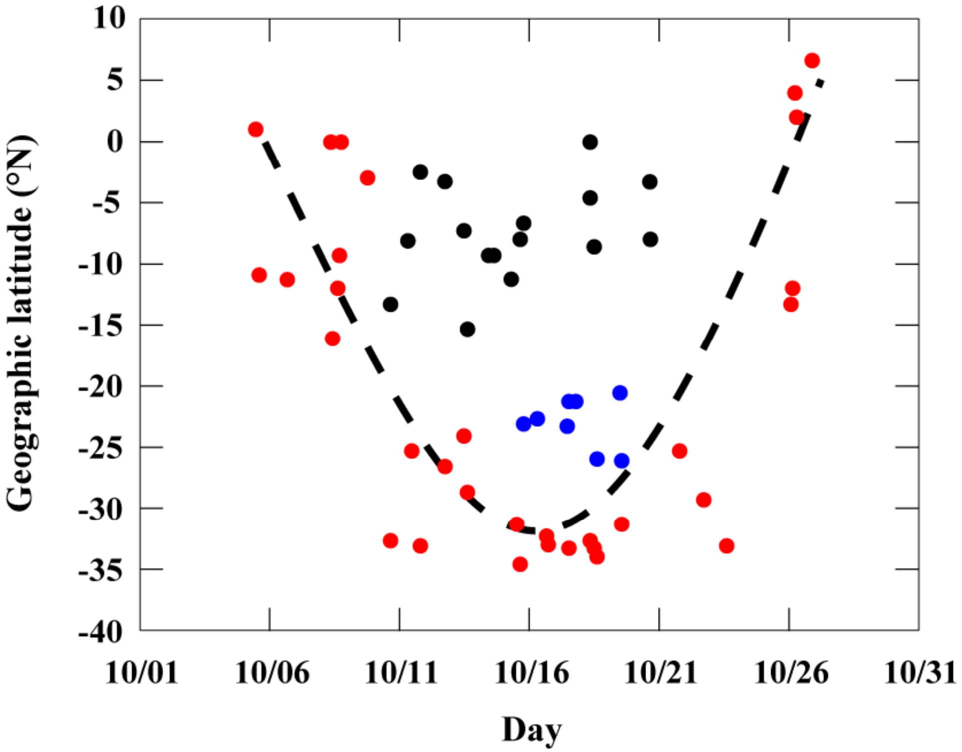


Fig.11b Molecular ion shows more clear future(see below)

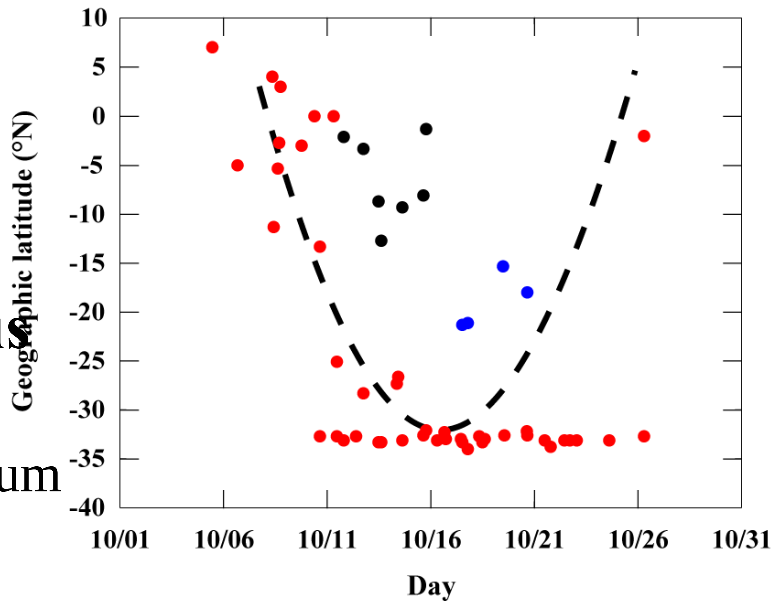


Fig.11a Latitude of minimum O^{+} versus day.

The earthquake days is the days when two minimum of atomic ion density merge. Three minima (red, black , and blue) sometimes appears

Conclusion

Electron temperature probe(ETP) has been modified to measure both electron temperature (Te) and electron density (Ne) , so that the instrument (TeNeP) can be installed in tiny satellite of even several kg.

The probe is light weight (small size), low power consumption, low data bit rate , and low cost, but still provide excellent performances; high accuracy, electronically stable performance. The instrument performance is not influenced by electrode contamination/satellite potential, does not need large surface area as a counter electrode.

Thank you for your attention

July 15 2013 CAUSES-II 12:00-14:00

Tiny satellite Task Group has been formed under the umbrella of Asia Oceania Geosciences Society(AOGS)

1.Tiny satellite Task Group; 1st Kick off meeting , room P7, 27 June 12:30- 14:00 ,lunch will be served
2. Session”ST12 Geoscience using Nano/pico satellite Constellation, Room P7,16:00-18:00

Aim of Task group, and role of task group

We expect that task oriented constellation of Nano/Micro satellites would provide the community of space sciences with opportunities which have not been possible with large scale missions. One good example is the QB50 project which is currently under development for the study of the lower thermosphere. With a network of about 50 double CubeSats, QB50 is to make multi-point, in-situ measurements of the key ionospheric/thermospheric parameters to understand the temporal and spatial variations of the least explored layer of the atmosphere. On the other hand, such constellation missions require participation from many institutions and countries for cost reduction as well as good coordination for efficient management of the program. The task group is expected to provide an opportunity to discuss all aspects of the mission, from scientific goals that attract common interest such as earthquake predictions to candidate instruments as well as satellite systems, and to mission scenarios and data acquisition schemes including ground facilities.

Specific activities of task group/ member

1.International; Organize one session in AOGS every year , and other workshop/meeting

Domestic; interact with university/college

2. To set goal for the near future mission

Discussion on the mission , aim of science mission (including engineering mission which might be useful for future science mission , and possible outcome from the mission,

The instruments to full fill the mission objectives, number of the satellite ¥ needed

System ;Transmitter frequency, command, interface between system and science payload, data stream format, common program for orbit analysis, attitude/data analysis

Requirements for orbit maneuver ; height of the satellite , how to distribute satellites in roughly equal distance,

3. Negotiation with Space related agency in individual countries

Which country is responsible for multiple satellites ? Cost share ?

Pave the road to the satellite launch!!

………………………………………………………………………………………

4. Education Encouragement of young generation to join space science/engineering communities

Satellite design contest(www.satcon.jp), and mission idea contest(www.unisec.jp)

Task Group members as of June 2013

(at least 2 representatives from each countries one is from space related agency, one scientists. In the near future the group will be divided into two group, Advisory and working groups)

K.-I. Oyama	oyama@plasma.pssc.ncku.edu.tw	Japan/Taiwan
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V. Korepanov	vakor@isr.lviv.ua	Ukraine
S. Ismail	sholehah@angkasa.gov.my	Malaysia
J.Y.Sumantyo	jtetukoss@faculty.chiba-u.jp	Indonesia
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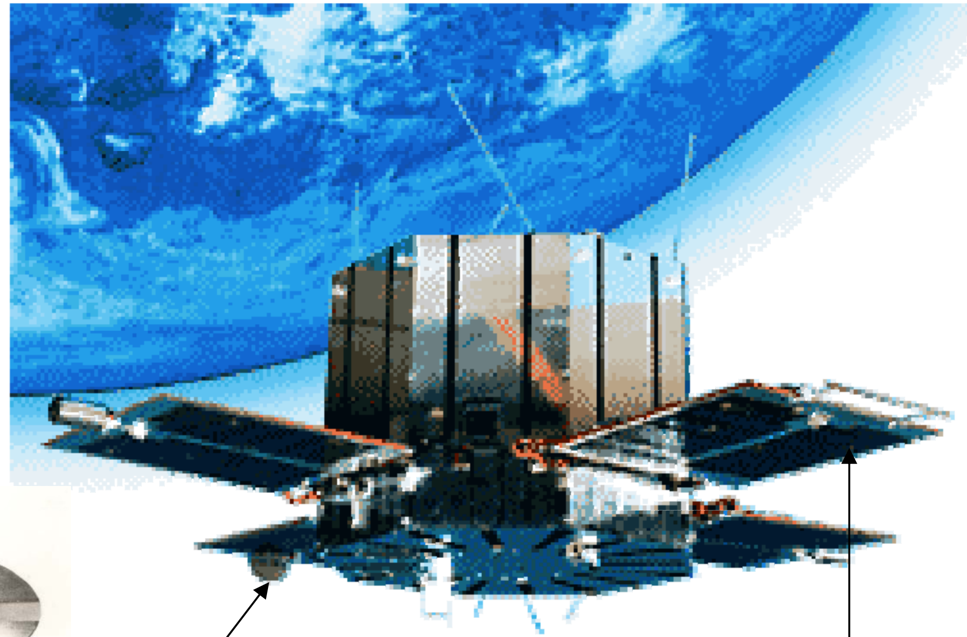
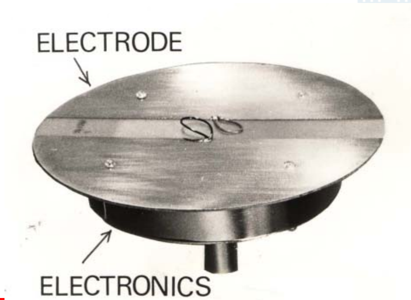
S.-I. Nakasuka	nakasuka@space.t.u-tokyo.ac.jp	Japan
J.H. Juang	juang@mail.ncku.edu.tw	Taiwan
D.Kataria	ucasdka@live.ucl.ac.uk	UK
M. Devi	md555@sify.com	India
I. Cairns	cairns@physics.usyd.edu.au	Australia
L.Arban		Phillipine
D. Bilitza	dieter.bilitza-1@nasa.gov	USA

Secretary of Task group; T. Kodama, kodama.tetsuya@jaxa.jp

Representatives from other countries are under communication ,

HINOTORI Sun Observer
(Launched ;1981 Feb
Mission Termination ;June
1982

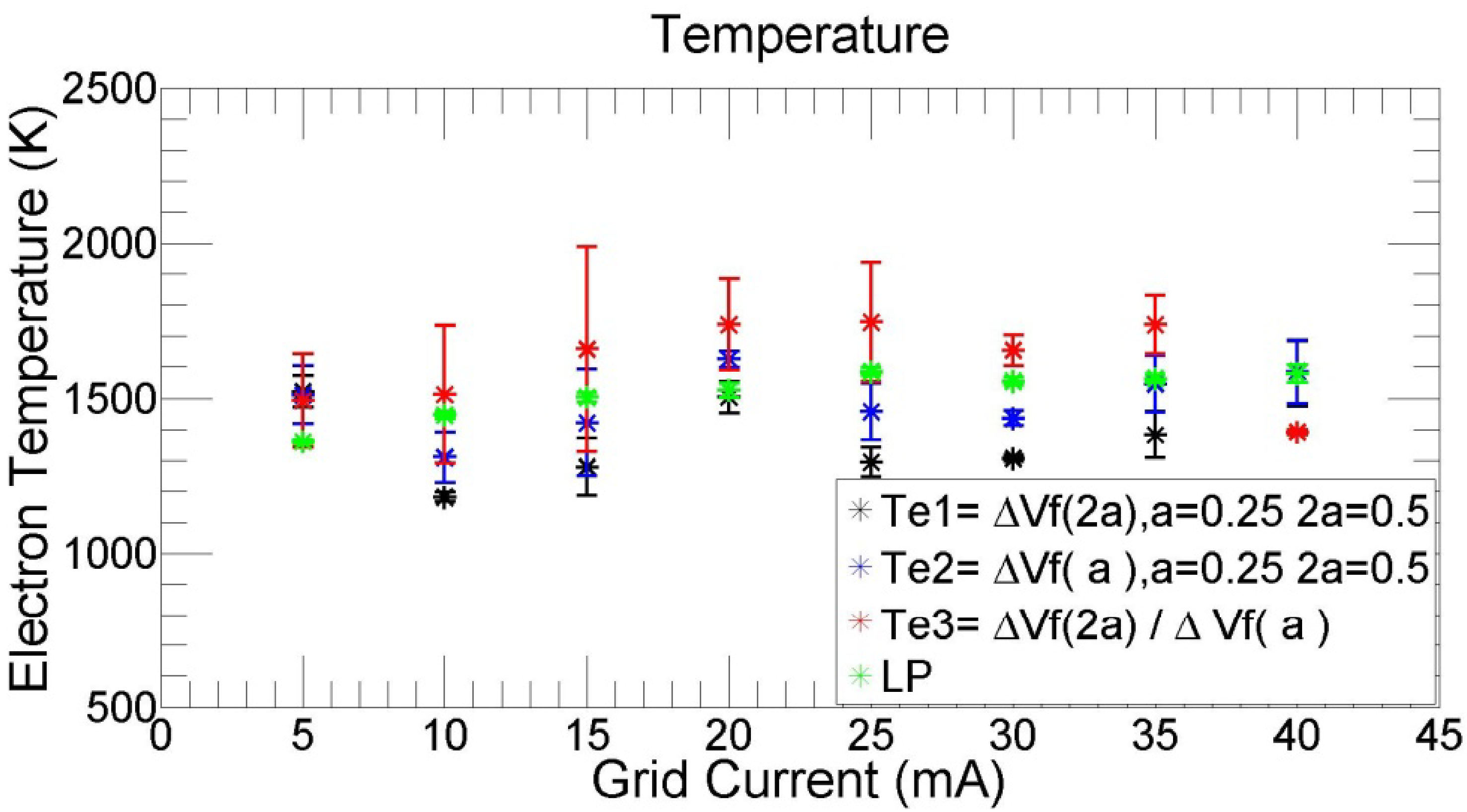




Electron Temperature Probe(Te)
Hirao, K. and K.- I.Oyama,
J.Geomag Geoelectr . ,**22**,239-402,1970.

300g, 25mmH,100mm Dia. With 120 mm circular electrode with 10mm gap

Impedance Probe (Ne)
Oya,H.,T.Takahashi,and S.Watanabe,,
J.Geomag.Geoelectr.,38,111-124,1986.



Temperature
Electron Temperature (K)
2500
2000
1500
1000
500
0
5
10
15
20
25
30
35
40
45
Grid Current (mA)
Te1= ΔVf(2a),a=0.25 2a=0.5
Te2= ΔVf(a),a=0.25 2a=0.5
Te3= ΔVf(2a) / Δ Vf(a)
LP

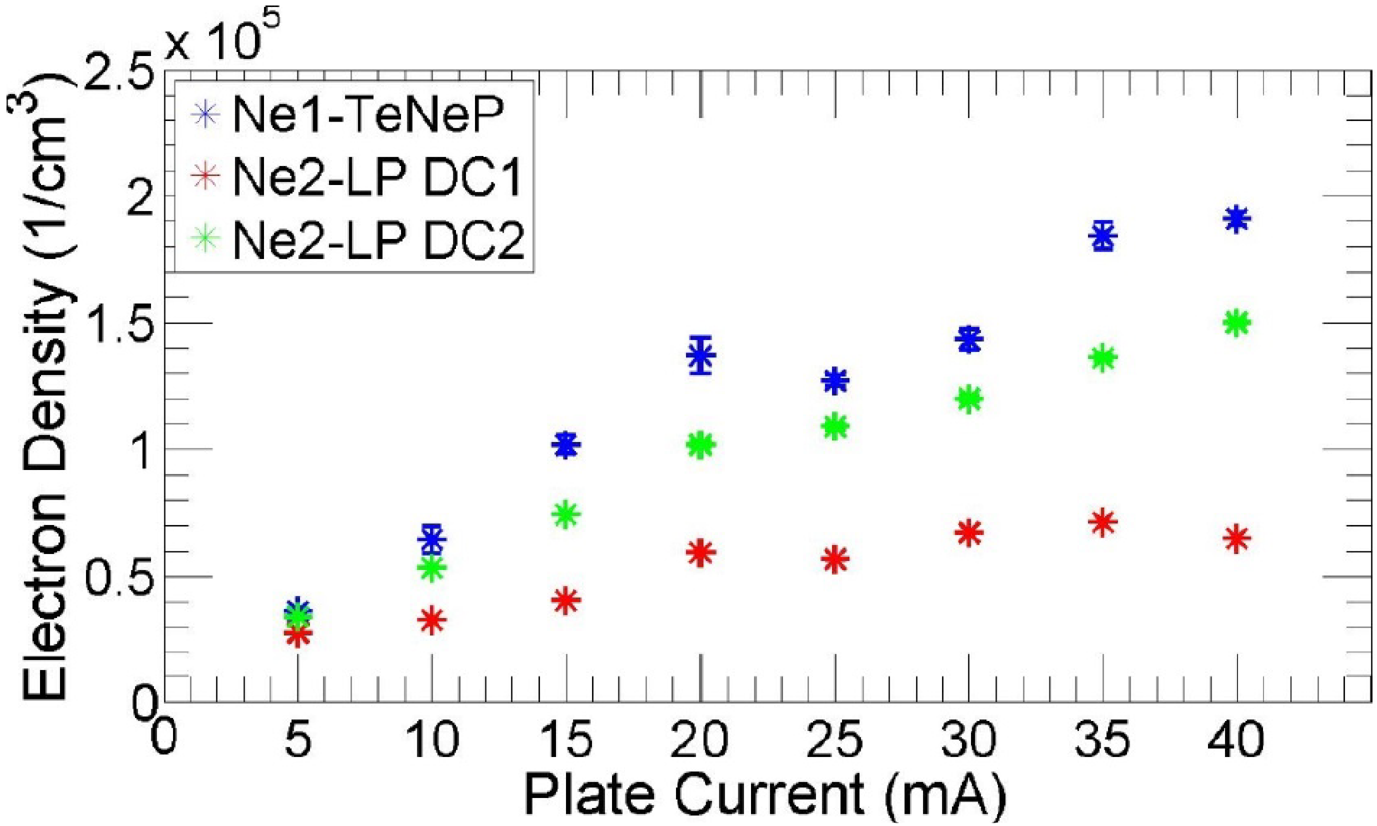
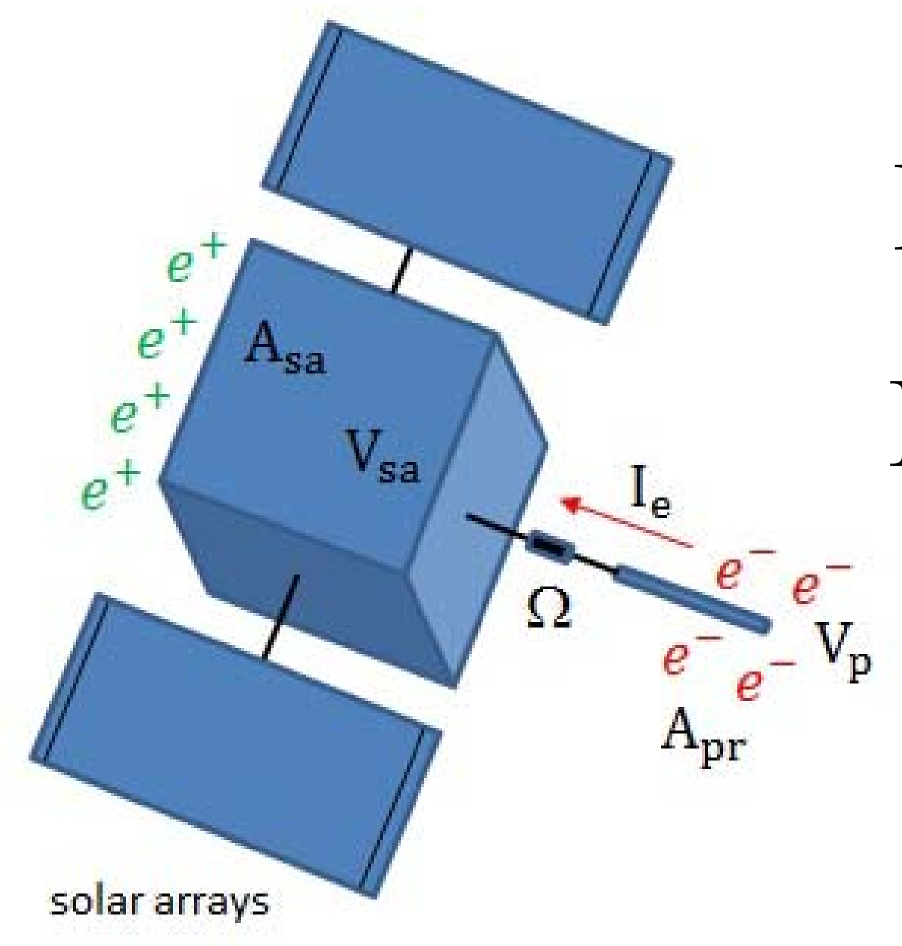
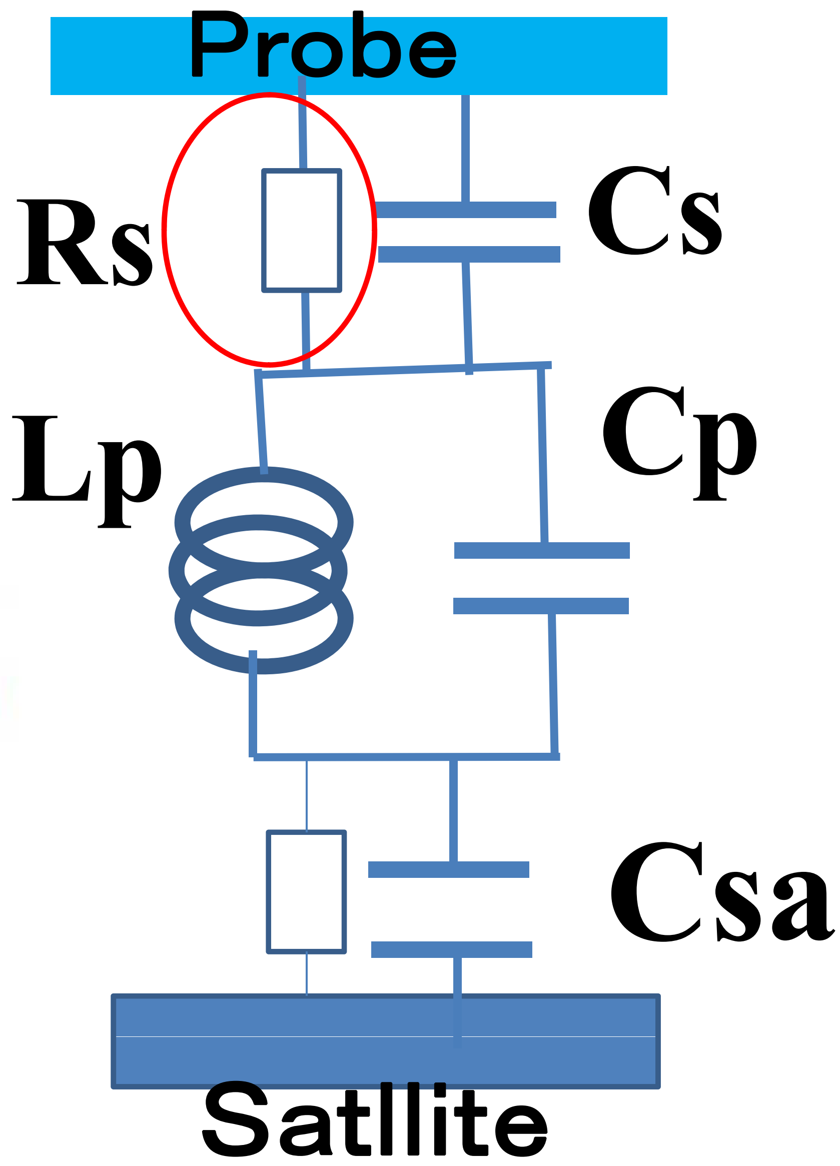


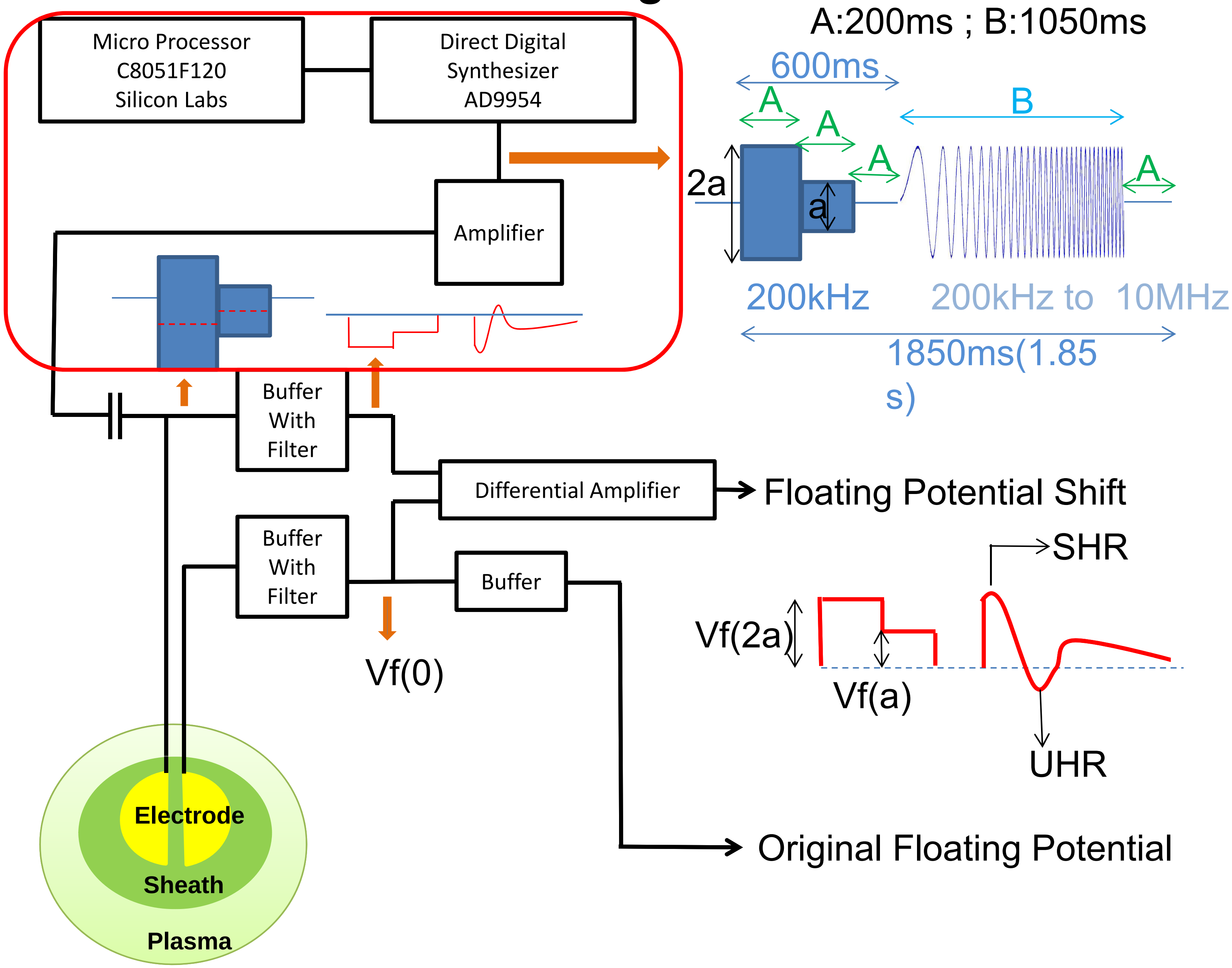
Fig.9 Comparison of measurements between DC Langmuir probe and TeNeP

Satellite –Plasma-electrode system from DC to high Frequency region



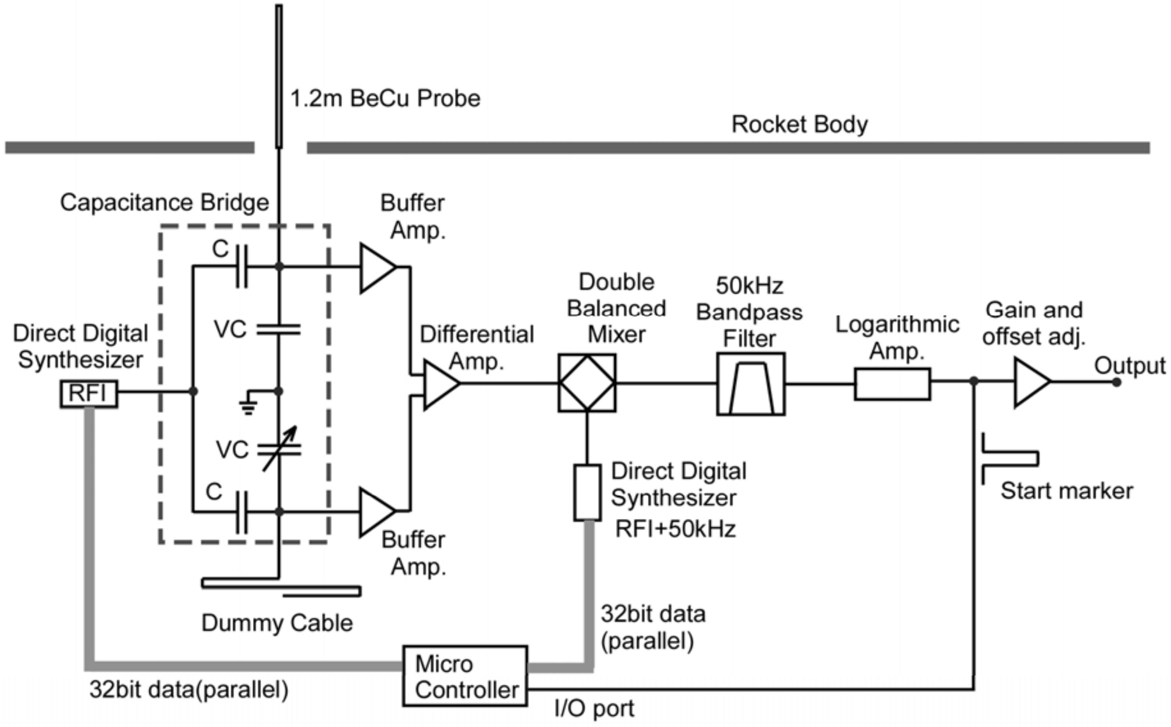


Diagram



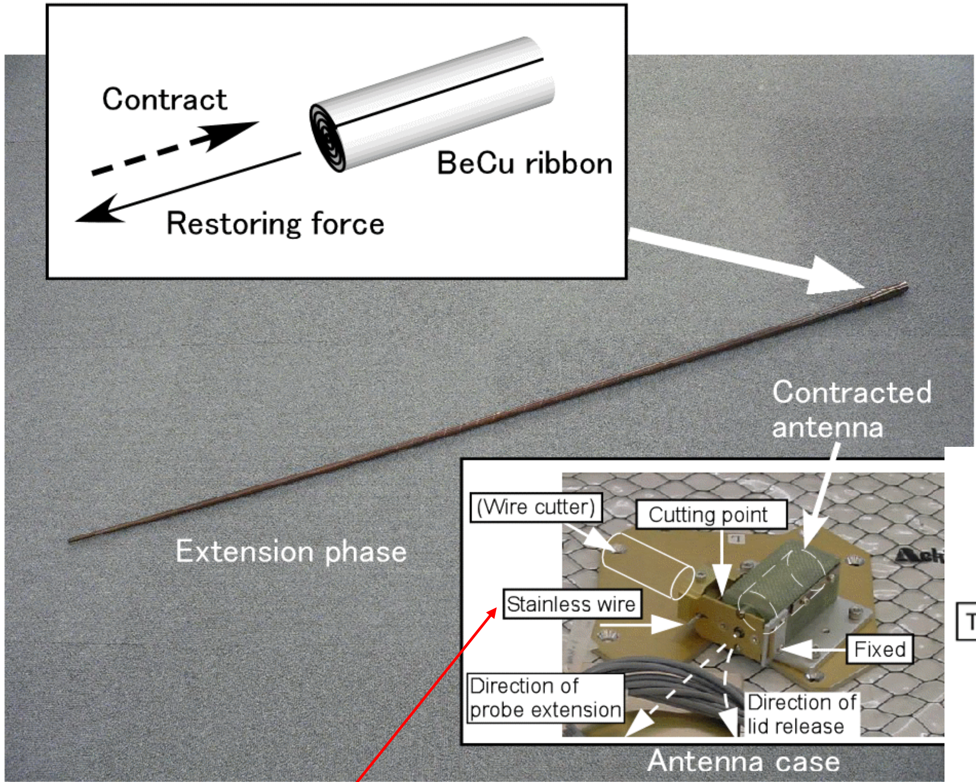
Micro Processor
C8051F120
Silicon Labs
Direct Digital
Synthesizer
AD9954
Amplifier
A:200ms ; B:1050ms
600ms
A
A
A
B
A
2a
a
200kHz
200kHz to 10MHz
1850ms(1.85 s)
Buffer With Filter
Differential Amplifier
Floating Potential Shift
Buffer With Filter
Buffer
SHR
Vf(2a)
Vf(a)
UHR
Vf(0)
Original Floating Potential
Electrode
Sheath
Plasma

How to pick up resonances ; to get accurate value in the limit of size and power allocated. What about the sensor ?

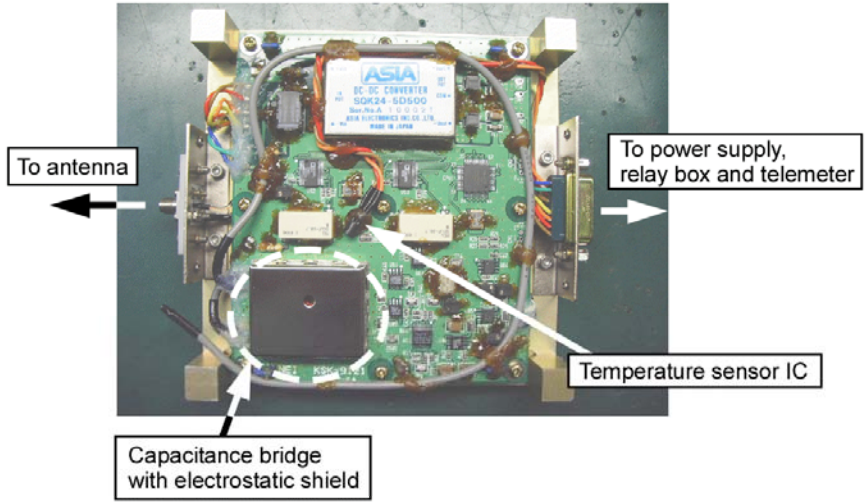


Standard configuration of impedance probe in recent years. DDSs and logarithmic amplifier are applied for SEEK-2 and DELTA campaigns, respectively.

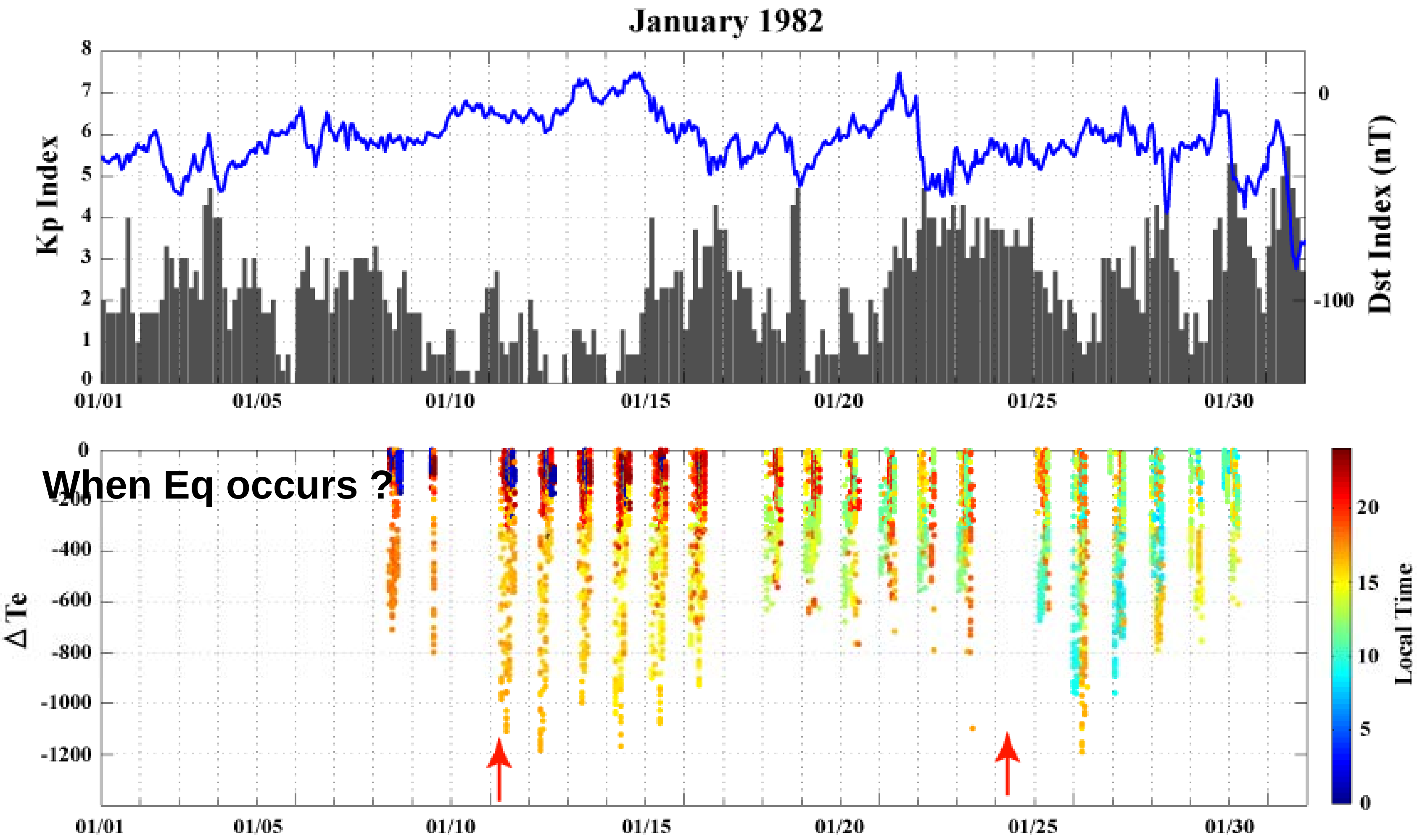
Photograph of 1.2 m BeCu ribbon antenna (extension phase) and antenna case.



Wire cutter



. *Printed board of Impedance probe circuit prepared for environmental tests before DELTA campaign in 2004. Some electric parts are fixed by thermoplastic materials or silicon bonds. The temperature sensor IC was represented in the center of this panel. This IC is only for environmental tests (non-flight item).*



M=7.4 45km M=6.6 37km

Fig. 8 (Te reduction for two earthquakes, which occurred on 11 Jan, and 24 Jan, 1982) . Te deviation becomes the largest on EQ days