Radiophysical Research Institute (NIRFI)
Nizhny Novgorod, Russia

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RADIO SOUNDING OF THE MAGNETOPAUSE FROM THE GROUND
(NIRFI part)

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13. ABSTRACT (Maximum 200 words)

This report results from a contract tasking Radio Physical Research Institute (NIRFI) as follows: The contractor will investigate whether a high frequency radio pulse transmitted from a ground-based station and backscattered from the magnetopause can be observed in a large receiving antenna .

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1. Introduction

The goal of the Contract is to test an exciting possibility of ground based remote sensing of the Earth's magnetopause using HF radio sounding technique.

. The magnetopause is of particular interest to the space physics community, since it is the active boundary between the solar wind and magnetosphere. Experiments were carried out to transmit a high frequency (9 MHz range) high power radio pulse from a ground-based transmitter and determine if a backscattered off the magnetopause signal can be detected by large receiving antenna. The Radiophysical Research Institute (NIRFI, N. Novgorod, Russia) provided operation of powerful SURA transmitters (effective radiated power, ERP > 100 MW) as a transmitter part of bi-static radar while receiving was provided by the Radio Astronomical Institute of Ukrainian Academy of Sciences (Kharkov) that operated the largest in the northern hemisphere UTR-2 radio telescope

Taking into account current increasing of solar activity when the critical frequency of the ionosphere becomes higher in the day time we decided to carry out main sounding experiments prior to date of contract activation immediately after proposal approvement. The case is that growing critical frequency of the ionosphere would prevent sounding wave penetration through the ionosphere making magnetopause sounding impossible. In particular, subsolar point sounding from SURA location leads to oblique sounding wave propagation through the ionosphere when penetration condition requires less ionospheric critical frequency and can be satisfied more rear. So, main experimental campaign was carried out during Summer and Fall, 1998.

2. Description of experiments

The object for investigation is the transition region between solar wind and the Earth's magnetosphere (the region between Earth's bow shock and magnetopause). According to the model of the interaction between the solar wind and the Earth's magnetic field distances to the subsolar point of the magnetopause can vary in the range of 8–10 Re (Re is the Earth's radius) for the period of moderate solar activity. Distances to the subsolar point of the Earth's bow shock under the same conditions could be in the range of 10–14 Re (see for example Tsyganenko model from `http:\\sscweb.gefc.nasa.gov`).

The sounding was performed using pulse operation of the radar. Pulse lengths and interpulse periods are determined from the geometry of the experiments. Magnetopause echo is expected to be 0.34–0.42 s delaied for the subsolar point depending on the solar activity while bow shock echo can be delaied up to 0.6 s. Model magnetopause and bow shock shapes are used to determine expected echo delays for other sounding directions. While the MP backscattered echo should stand out, in a temporal sense, and not get lost in the backscattering from nearby objects, a possibility of sounding wave propagation around the Earth with a delay of about 0.14 s should be taken into account. Although its characteristics (Doppler shift and width) should be significantly different from ones of magnetospheric origin, they could of principal make detection of scattered signals ambiguous. Choosen parameters are indicated in the schedule of experiments.

To cover more different geophysical conditions all experiments were divided into two major sessions, Summer session (June–July) and Fall session (October). Calibration of the radar was performed in October during the Fall session using reflected from the Moon radar signal. Moon sounding permits to check all radar sistems due to the known Moon cross section and distance from the Earth.

Summer session consisted of three sets of experiments differed in the direction of sounding:

- near the 45 deg to the east from the subsolar point near ecliptic plane (along the direction of solar wind sector boundaries, morning hours)
- near the subsolar point (along the solar wind velocity, noon), and
- near the 34 deg to the north in the meridium plane (zenith for SURA, most efficiency of the antenna array).

Each direction was studied during 4–6 days, about one hour per day.

During Fall session subsolar point cannot be reached by SURA, and scattering was studied in two sets with different zenith angles (36 deg to the south and zenith directions) only in the morning hours.

Special experiments were carried out using a bi-static radar with space borne receiver, namely, RAD2 receiving system of NASA WIND spacecraft. Forward scattering of HF radio waves was studied when the WIND was in sunward direction around the local noon. Forward scattering is sensitive to plasma inhomogeneities of 100 km scale while back scattering is sensitive to much smaller scales of half wavelength of sounding wave (about 15 m in case of SURA–UTR-2 radar).

Each radar transmitting was supplemented by the operation of ionosound at SURA that provided critical frequences of the ionosphere during experiments. Radiation frequency was above ionospheric cutoff in the direction of sounding in all sessions.

3. Schedule of experiments

The schedule of experiments with the SURA ionosound data is shown in the tables below. Here

LT is local time,
f0 — sounding frequency (in kHz),
f0F2 — critical frequency of ionosphere (in MHz),
Tp — pulse length (in seconds),
IPP — interpulse period (in seconds),
Direction — antenna beam inclination from zenith (in degrees, S — to south).

Table 1. Magnetopause sounding (SURA–UTR-2)

Summer session

Set 1

Date	LT*	f0, kHz	f0F2, MHz	Tp, s	IPP, s	Direction, deg
06/10/98	08:20–08:50	8916	6.1	0.25	1.1	36 S
06/11/98	08:20–08:50	8916	6.3	0.25	1.1	36 S
06/12/98	08:20–08:50	8916	6.8	0.25	1.1	36 S
06/13/98	08:20–08:50	8916	6.4	0.25	1.1	36 S
06/14/98	08:20–08:50	8916	6.0	0.25	1.1	36 S
06/15/98	08:20–08:50	8916	5.9	0.25	1.1	36 S

Set 2

Date	LT*	f0, kHz	f0F2, MHz	Tp, s	IPP, s	Direction, deg
06/18/98	11:20–11:50	8916	6.4	0.16	0.9	36 S
06/19/98	11:20–11:50	8916	6.2	0.16	0.9	36 S
06/20/98	11:20–11:50	8916	6.2	0.16	0.9	36 S
06/21/98	11:20–11:50	8916	5.4	0.16	0.9	36 S
06/22/98	11:20–11:50	8916	5.4	0.16	0.9	36 S

Set 3

Date	LT*	f0, kHz	f0F2, MHz	Tp, s	IPP, s	Direction, deg
06/30/98	10:20–10:50	8916	6.9	0.25	1.1	Zenith
07/01/98	10:20–10:50	8916	7.3	0.25	1.1	Zenith
07/02/98	10:20–10:50	8916	6.7	0.25	1.1	Zenith
07/03/98	10:20–10:50	8916	6.5	0.25	1.1	Zenith

Fall session

Set 1

Date	LT*	f0, kHz	f0F2, MHz	Tp, s	IPP, s	Direction, deg
10/11/98	05:40–06:20	8916	4.7	0.30	2.5	36 S
10/12/98	06:35–07:15	8916	5.3	0.30	2.5	36 S
10/13/98	05:40–06:20	8916	4.8	0.30	2.5	36 S

Set 2

Date	LT*	f0, kHz	f0F2, MHz	Tp, s	IPP, s	Direction, deg
10/14/98	06:20–07:00	8916	5.1	0.30	2.5	Zenith
10/15/98	06:20–07:00	8916	5.1	0.30	2.5	Zenith
10/16/98	06:20–07:00	8916	5.3	0.30	2.5	Zenith

Table 2. SURA–UTR-2 radar calibration (Moon sounding)

Date	LT*	f0, kHz	f0F2, MHz	Tp, s	IPP, s	Direction, deg
10/11/98	04:43–05:33	8916	4.6	1.0	5.0	36 S
10/12/98	05:39–06:29	8916	5.1	1.0	5.0	36 S

Table 3. Forward scattering (SURA–WIND) experiments****

Date	LT*	f0, kHz	f0F2, MHz	Direction, deg	R, Re
07/04/98	10:20–11:10	8925	6.3	34.6 S	35
07/05/98	11:10–12:00	8925	6.3	34.3 S	49.3
07/06/98	11:50–12:40	8925	6.3	35 S	49.4
07/07/98	12:20–13:10	8925	6.6	35.8 S	69.1
07/08/98	12:40–13:30	8925	6.8	36.6 S	76.1
07/09/98	13:00–13:40	8925	6.7	37.5 S	81.6

* Local time for SURA is LT = UT + 3h.

** Here R is the distance of WIND from the Earth in Earth's radii (Re), and direction means WIND position.

It should be mentioned, that SURA operation requires heating of transmitters before switching on and their cooling after switching off that takes about 30 minutes each cycle of operation.

The information on the SURA site conditions during experiments was transferred to Ukrainian collegues that operated receiving site of the ground based bi-static radar at UTR-2 and recorded back scattered signals.

Data obtained during additional SURA–WIND experiments are under processing at NIRFI.