OPERATION PLAN FOR THE ICELAND-SYOWA CONJUGATE CAMPAIGN IN 1983–1985

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***Abstract*:** Geomagnetic conjugate points of Syowa, Mizuho and Molodezhnaya Stations in Antarctica are located in the vicinity of Husafell, Isafjördur and Husavik in Iceland. This campaign aims at a further understanding of physical processes in auroras and their related phenomena from coordinated observations of magnetic field variations, magnetic ULF waves, ELF-VLF emission, cosmic noise absorption and spatial and temporal variations of auroras at these three pairs of geomagnetic conjugate stations. This paper gives an outline of the campaign schedule, the location of three observatories to be set up in Iceland and the specifications of facilities.

1. Introduction

Ground foot points of a geomagnetic field line in the northern and southern hemispheres are defined as geomagnetic conjugate points. Auroral particles precipitate along the geomagnetic field line. Therefore, similar types of auroras are generally observed at conjugate points. Pc 1 magnetic pulsations and ELF-VLF emissions also have a tendency to propagate along the geomagnetic field line. In the recent studies, however, it is reported that the characteristics of aurora such as shape, intensity and motion are not always identical in conjugate regions (STENBAEK-NIELSEN *et al.*, 1972; MAKITA *et al.*, 1981). It is also found that some types of magnetic pulsations and ELF-VLF emissions show a poor conjugacy (SATO *et al.*, 1980; TONEGAWA and FUKUNISHI, 1984).

Observations of conjugacy and non-conjugacy give us useful information on acceleration mechanisms of auroral particles and generation and propagation mechanisms of ULF, ELF and VLF waves. However, there are few conjugate-pairs of observatories in the nothern and southern polar regions. Fortunately the conjugate point of Syowa Station is located near Husafell in Iceland. The National Institute of Polar Research (NIPR) carried out the first conjugate campaign at Husafell and Syowa under the International Magnetospheric Study (IMS) program in 1977 and 1978. Nevertheless, the period of this campaign was limited only to the northern summer season from July to September. Observations of seasonal variations in conjugacy are important for understanding a role of the ionosphere in acceleration of aurora particles since the electron density of the ionosphere is greatly different between the summer and winter hemispheres. It is also important to observe auroras and associated phenomena at multi-stations around conjugate points in order to study motion of auroras and propagation of waves. Therefore, the second conjugate campaign was planned by NIPR on an enlarged scale.

The campaign takes advantage of geographical condition that the conjugate points of Syowa, Mizuho and Molodezhnaya Stations in Antarctica are located in the vicinity of Husafell, Isafjördur and Husavik in Iceland. From the data recorded at three pairs of conjugate stations Syowa-Husafell, Mizuho-Isafjördur and Molodezhnaya-Husavik, we aim at understanding of temporal and spatial variations in conjugacies of auroras and wave phenomena associated with auroral particle precipitation. Then we study auroral particle acceleration processes in the ionosphere-magnetosphere energy coupling system and also generation and propagation mechanisms of ULF, ELF and VLF plasma waves.

We expect to solve the following problems. 1) Conjugacy of fine structures in discrete auroras and acceleration processes of auroral particles in the topside ionosphere. 2) Conjugacy of fine structures in pulsating auroras and pitch angle scattering mechanisms in the magnetosphere. 3) Rapid movement of conjugate points during substorms and associated deformation of magnetic field configuration in the magnetosphere. 4) Effect of the electron content and its vertical profile in the topside ionosphere on auroral arc formation. 5) Conjugacy of Pc 1 magnetic pulsations and their generation and propagation mechanisms in the magnetosphere. 6) Conjugacy of long-period Pc and Pi magnetic pulsations and their generation and propagation mechanisms in the magnetosphere. 7) Screening effect of the ionosphere on magnetic pulsations. 8) Conjugacy of ELF-VLF emissions (ELF hiss, chorus, QP emission and auroral hiss) and their generation and propagation mechanisms. 9) Conjugacy of high-energy electron precipitation and wave-particle interaction processes in the magnetosphere. 10) Effect of electron density profile and magnetic field configuration on propagation paths of ELF-VLF waves.

2. Locations of Observatories and Campaign Schedule

2.1. *Station network*

Table 1 gives geographic and dipole coordinates, invariant latitude and longitude, magnetic local time and L value of Syowa, Mizuho and Molodezhnaya Stations in Antarctica and Leirvogur, Husafell, Isafjördur and Husavik in Iceland which are located in the vicinity of the conjugate points of the Antarctic stations (*cf.* Fig. 1).

At present the location of a station conjugate to Syowa is fixed at Husafell. The locations of stations conjugate to Mizuho and Molodezhnaya, however, are finally fixed after the survey in the summer of 1983.

2.2. *Campaign schedule*

Campaign period: August 1983–December 1985

(1) 1983 schedule

Three Japanese scientists stay in Iceland from August 13 to October 2. In the

Table 1. Geographic and geomagnetic coordinates of the stations, calculated with the IGRF model dated August 1, 1983. Magnetic local time (MLT) is given by adding universal time (UT) to the time listed in the colum.

	Station	Geographic		Magnetic dipole		Invariant			
		Latitude	Longitude	Latitude	Longitude	Latitude	Longitude	MLT (HH: MM)	*L*
Antarctica	Syowa	69.00S	39.58E	−69.97	80.18	66.12	70.81	00:06	6.10
	Mizuho	70.70S	44.33E	−72.30	81.46	67.98	70.96	00:06	7.12
	Molodezhnaya	67.67S	45.85E	−70.04	88.03	66.56	76.98	00:30	6.32
Iceland	Leirvogur	64.18N	21.73W	69.66	72.43	65.66	69.12	23:59	5.89
	Husafell	64.70N	20.90W	69.97	74.07	66.04	70.24	00:03	6.06
	Isafjördur	66.08N	23.13W	71.62	73.42	67.80	69.59	00:01	7.01
	Husavik	66.04N	17.35W	70.49	79.79	66.80	74.24	00:19	6.44

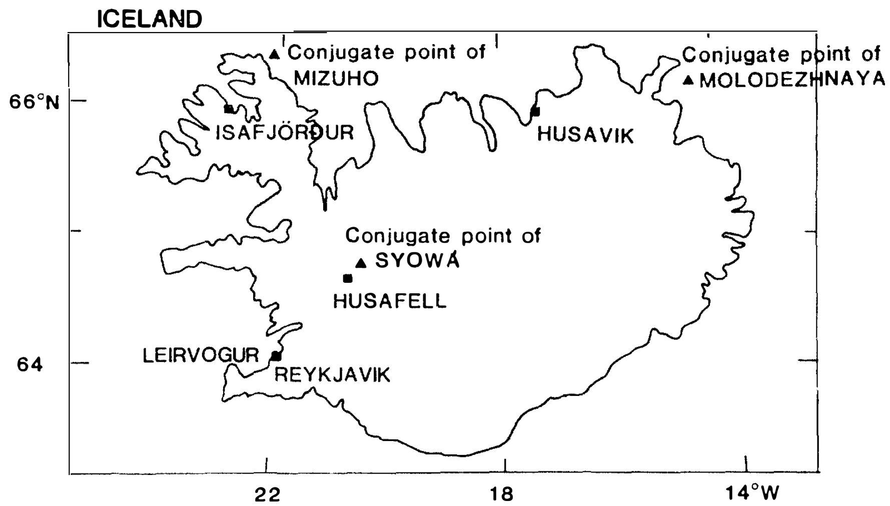

Fig. 1. Locations of Husafell, Isafjördur, Husavik, Leirvogur and Reykjavik (squares) and the geomagnetic conjugate points of Syowa, Mizuho and Molodezhnaya Stations (triangles).

first half of their stay they visit Isafjördur (66.1°N, 23.1°W) and Husavik (66.0°N, 17.4°W) to find locations suitable for observations of geomagnetic field variations, cosmic noise absorption and ULF, ELF and VLF natural waves. Then, they stay about one month at Husafell. During their stay at Husafell, they set up several kind of sensors (fluxgate magnetometer, search coil magnetometer, ELF-VLF wave receiver, riometer and all-sky camera) and recording facilities. These facilities are operated by the Icelandic research fellows until next summer.

(2) 1984 schedule

Four Japanese scientists stay in Iceland for two months in August and September. In the first half of their stay in Iceland they set up stations in the neighborhood of Isafjördur and Husavik. These stations are maintained by the Icelandic research fellows thereafter. Then, the Japanese scientists visit Husafell to check up the instruments installed last summer, and to set up new equipment (fixed-direction photometer, scanning photometer and auroral TV camera). They operate all the instruments during their stay at Husafell. After their departure from Husafell, fluxgate and search coil magnetometers, ELF-VLF receiver and riometer are operated by the Icelandic research fellows until next summer.

(3) 1985 schedule

Three Japanese scientists stay in Iceland for two months in summer, and one scientist stays also for two months in winter. They check up the instruments installed at Isafjördur, Husavik and Husafell Stations, and operate these instruments during their stay.

2.3. Participating organizations

The following organizations participate in the campaign.

(1) National Institute of Polar Research
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3. Specifications of Facilities

3.1. Observation items and facilities

(1) Husafell Station

Table 2 gives the observation items and facilities installed at Husafell Station.

In addition to the digital and analogue data recorders listed in Table 2, an 8-channel pen recorder is used for monitoring the recording condition. The chart speed is 0.2 cm/min, and the recording items are the H and D components of geomagnetic variation, the H component of geomagnetic ULF wave, intensity of ELF-VLF wave at 0.75, 2, 8 and 35 kHz, and cosmic noise absorption.

The time code is recorded on digital and analogue magnetic tapes and also on paper charts. The absolute accuracy of the time code to the universal time is within 3 ms.

A block diagram of the observation system installed at Husafell Station is given in Fig. 2. A layout of the observation system is schematically illustrated in Fig. 3.

(2) Isafjördur and Husavik Stations

Table 3 gives the observation items and facilities installed at Isafjördur and Husavik

Table 2. Observation items and facilities installed at Husafell Station.

Observation item	Observation equipment	Recording equipment
Geomagnetic field variation (H, D, Z; DC-2 Hz)	Ring-core type fluxgate magnetometer	Digital data recorder (A) (sampling time, 2 s)
Geomagnetic ULF wave (H, D, Z; 0.001–3 Hz)	Search coil magnetometer	Digital data recorder (A) (sampling time, 2 s) Low-speed (0.03 ips) analogue data recorder
ELF-VLF wave (100 Hz–100 kHz)	ELF-VLF receiver (N-S direction loop antenna)	Audio tape recorder (tape speed, 3.75 ips; wide-band signal) Digital data recorder (A) (sampling time, 2 s; filter bank signals at 350, 750 Hz, 1.2, 2, 4, 8, 35, 60 kHz) Low-speed (0.03 ips) analogue data recorder (filter bank signal at 1.2 kHz)
Cosmic noise absorption (30 MHz)	Riometer	Digital data recorder (sampling time, 2 s) Low-speed (0.03 ips) analogue data redorder
Auroral image	All-sky camera	Film (400 feet)
	All-sky TV	Video tape recorder
Auroral emission intensity	Fixed-direction photometer (4278 Å)	Digital data recorder (B) (sampling time, 1 s) Low-speed (0.03 ips) analogue data recorder
	Scanning photometer (5577 Å, Hβ)	Digital data recorder (B) (sampling time, 1 s)

Stations.

In addition to the digital and analogue data recorders listed in Table 3, a 6-channel pen recorder is used for monitoring the recording condition. The chart speed is 0.2 cm/min, and the recording items are the H and D components of geomagnetic variation, the H component of geomagnetic ULF wave, intensity of ELF-VLF wave at 1.2 and 8 kHz, and cosmic noise absorption.

The time code is recorded on digital and analogue magnetic tapes and also on paper charts. The absolute accuracy of the time code to the universal time is within 3 ms.

A block diagram of the observation system installed at Isafjördur and Husavik is given in Fig. 4. A layout of the system is shown in Fig. 5.

3.2. *Specifications of observation system*

(1) ELF-VLF receiving system and telemeter link

The receiving site of natural ELF-VLF waves should be located far from a power line. Therefore, we use a telemeter link between the receiving and recording sites. The specifications of the telemeter are given in Table 4. The UHF telemeter is used

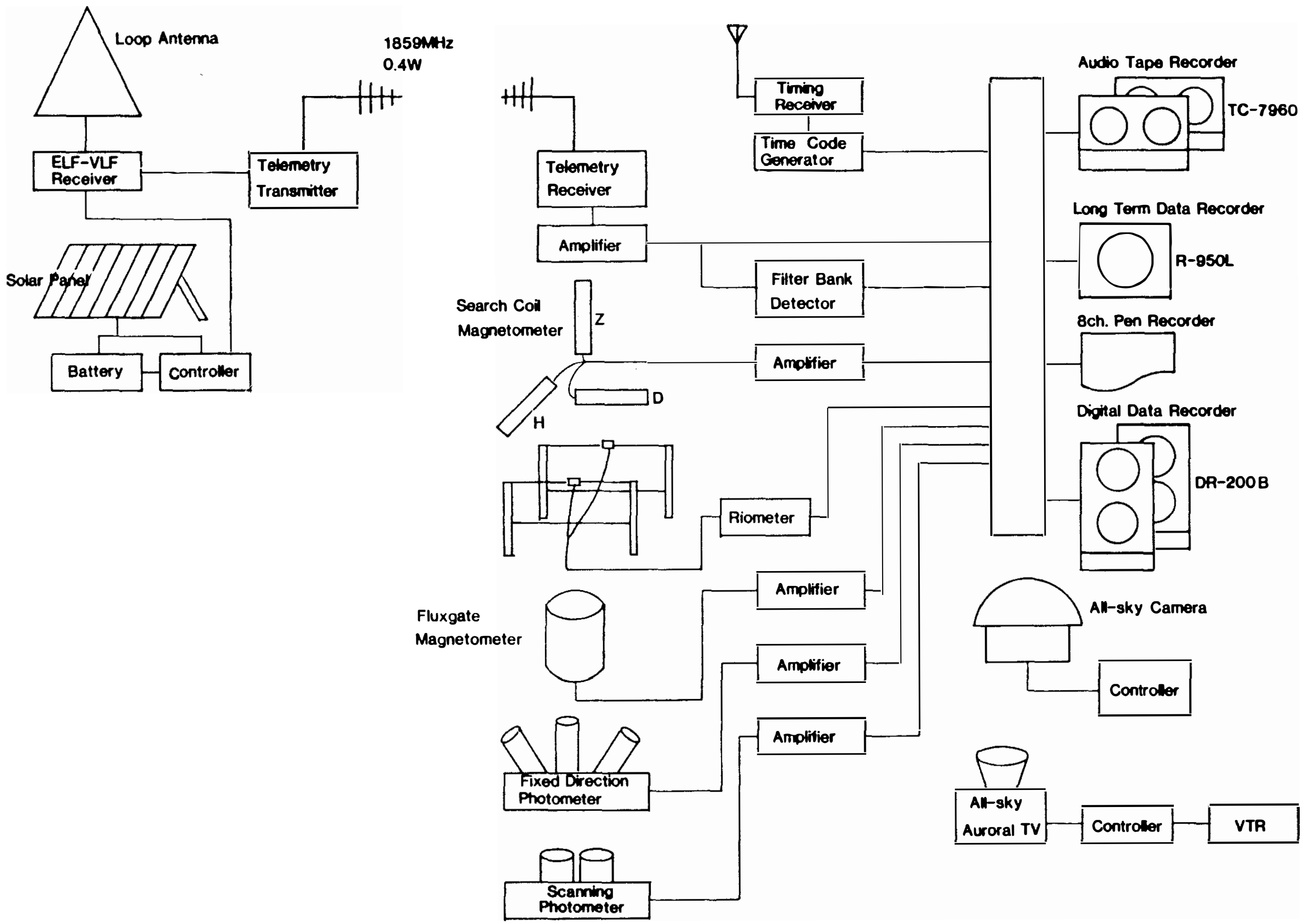

Fig. 2. Block diagram of the observation system at Husafell.

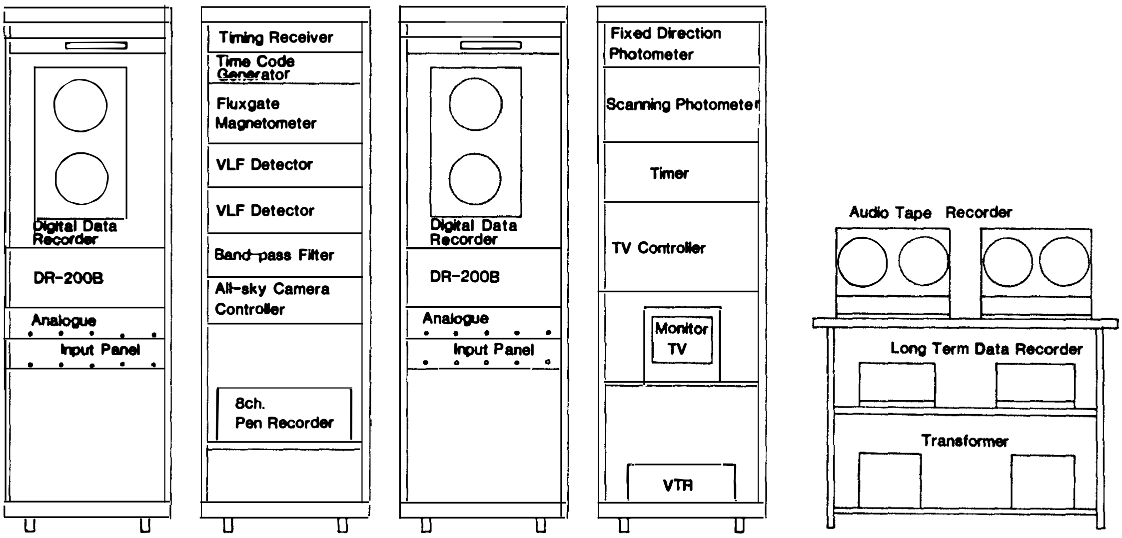

Fig. 3. A layout of the observation system at Husafell.

Table 3. Observation items and facilites installed at Isafjördur and Husavik Stations.

Observation item	Observation equipment	Recording equipment
Geomagnetic field variation (H, D, Z; DC-2 Hz)	Ring-core type fluxgate magnetometer	Digital data recorder (sampling time, 2 s; H, D, Z) Low-speed (0.03 ips) analogue data recorder (H, D)
Geomagnetic ULF wave (H, D, Z; 0.001–3 Hz)	Search coil magnetometer	Digital data recorder (sampling time, 2 s; H, D, Z) Low-speed (0.03 ips) analogue data recorder (H, D)
ELF-VLF wave (100 Hz–100 kHz)	ELF-VLF receiver	Audio tape recorder (tape speed, 3.75 ips; wide-band signal) Digital data recorder (sampling time, 2 s; filter bank signals at 350, 750 Hz, 1.2, 2, 4, 8, 35, 60 kHz) Low-speed (0.03 ips) analogue data recorder (filter bank signal at 1.2 kHz)
Cosmic noise absorption (30 MHz)	Riometer	Digital data recorder (sampling time, 2 s) Low-speed (0.03 ips) analogue data recorder
Auroral emission intensity	Zenith photometer (4278 Å)	Digital data recorder (sampling time, 2 s) Low-speed (0.03 ips) analogue data recorder

at Husafell, while the VHF telemeter is used at Isafjördur and Husavik.

The subsystem at the receiving site comprises 1) triangle-shaped one-turn loop antenna (10 m in height, 20 m across at the base), 2) preamplifier, 3) telemetry transmitter and 4) solar batteries for power supply. The subsystem at the recording site

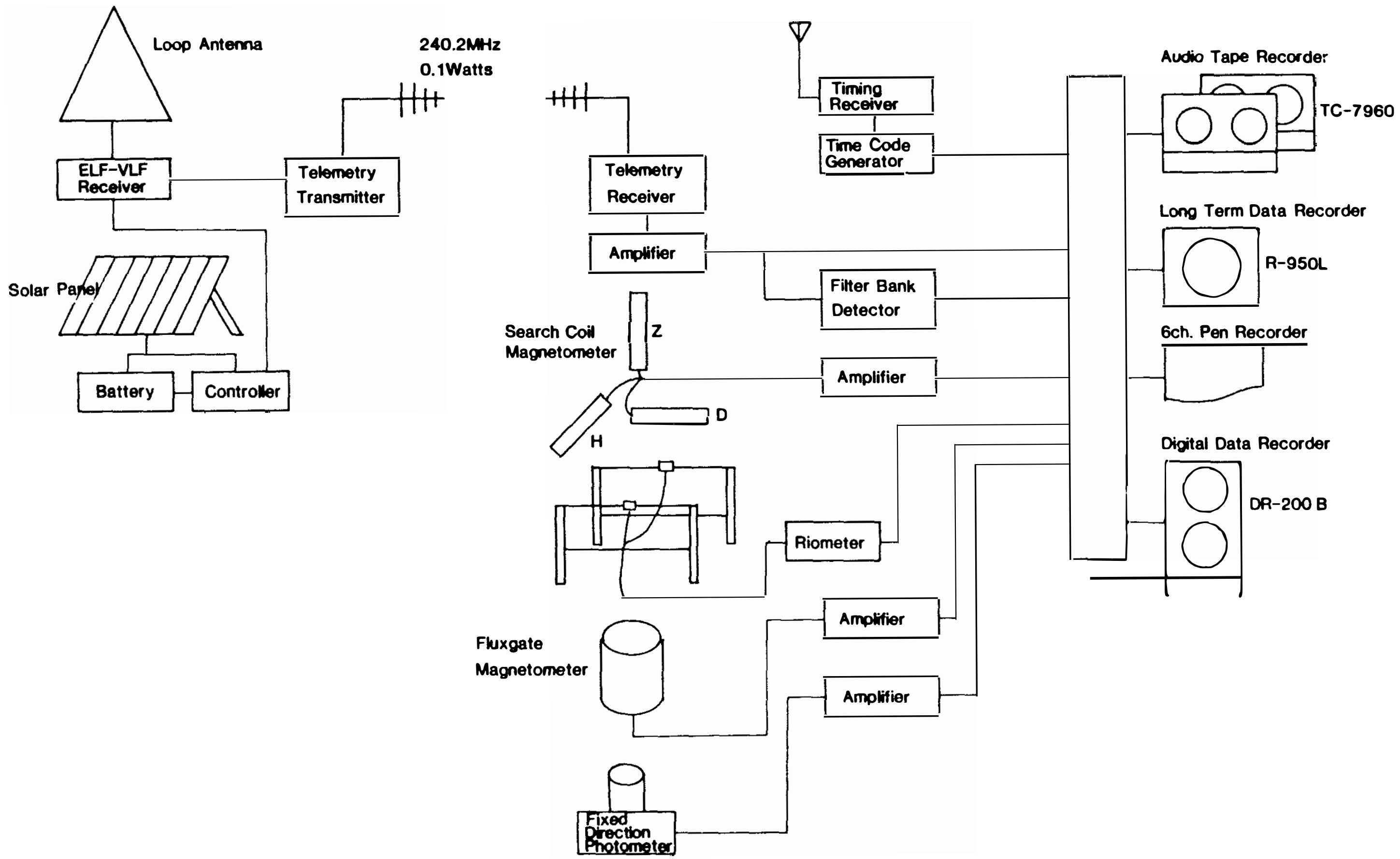

Fig. 4. Block diagram of the observation system installed at Isafjördur and Husavik.

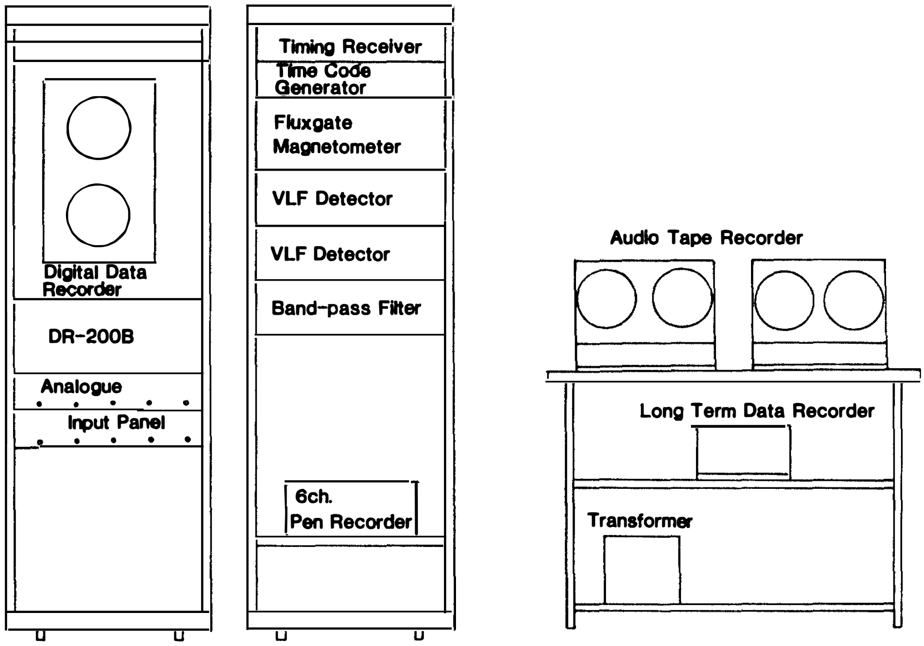

Fig. 5. A layout of the observation system at Isafjördur and Husavik.

Table 4. Specifications of telemeters which link a receiving site and a recording site.

	UHF telemeter	VHF telemeter
Modulation	FM	FM
Carrier frequency	1859 MHz	240.4 MHz
Transmitter power	0.4 W	0.1 W
Antenna	Yagi (5 elements)	Yagi (7 elements)
Max frequency deviation	200 kHz	125 kHz
VCO stability	better than 1%	better than 1%
VCO lineality	better than 1%	better than 1%
Carrier spurious	less than −30 dB	less than −30 dB

are 1) telemetry receiver, 2) main amplifier and 3) 8-channel filter units with center frequencies at 0.35, 0.75, 1.2, 2, 4, 8, 35 and 60 kHz. The measurable intensity range is 10^{-17}–10^{-13} W/m^2 Hz, and the frequency range is 0.1–100 kHz.

(2) Search coil magnetometer

The H, D and Z components of ULF magnetic pulsations are detected by three search coils with permalloy strip cores (core dimensions, 7 mm×7 mm×100 cm; coil, 0.3 mmϕ copper wire, 40000 turns). The length of the cable between the sensor and the amplifier is 200 m. The measurable intensity range is 0.001–10 nT/s, and the frequency range is 0.001–3 Hz.

(3) Fluxgate magnetometer

The magnetometer uses three ring-core sensors with a diameter of one inch. The measurable intensity range is ±64000 nT, and the frequency response is DC-2 Hz. The noise level is less than 0.1 nT. Both the analogue and digital output signals link to recorders. The quantization of digital output signal is 0.03 nT/bit.

(4) Riometer

The type is La Jolla Sciences riometer. The riometer measures cosmic radio noise intensity at 30 MHz with a pair of dipole antennas. The bandwidth and time constant of the receiver are 150 kHz and 0.25 s, respectively.

(5) Meridian scanning photometer

The interference filters select OI 5577 Å and Hβ 4861 Å emissions which are typical emission lines in electron and proton auroras. The tilting filter with 0.5 s period is used for measurement of doppler-shifted Hβ emission. The field of view is 3° for 5577 Å and 5° for Hβ. The scanning period from the poleward horizon to the equatorward horizon is 30 s. The measurable intensity range is 20 R–200 kR for 5577 Å and 1–1000 R for Hβ. The instrument has digital output.

(6) Fixed direction photometer

This photometer detects 4278 Å emission at three zenith angles (zenith, 45° poleward and 45° equatorward). The measurable intensity range is 20 R–200 kR.

(7) All-sky camera

The camera uses a fish-eye lens and 35 mm black and white film. The diameter, brightness and field of view of the fish-eye lens are 236 mm, F2.8 and 220°, respectively. The length of the film is 400 feet and 3 frames are taken every 1 min.

(8) All-sky TV camera

The TV camera uses a highly sensitive SIT (silicon intensifier tube) and a fish-eye lens with field of view of 180° and brightness of F2.8. The maximum sensitivity of the camera is about 100 R. The output signal is recorded on a video tape recorder.

(9) Clock/Frequency standard

The clock system comprises a timing receiver, a 1 MHz frequency standard and a time code generator. The timing receiver detects standard time signals transmitted at 10 and 15 MHz from WWV (USA) and MSF (UK). The frequency standard with a crystal oscillator is synchronized with the radio wave signals. The stability of the frequency standard is higher than 5×10^{-10} s/day. The time code generator has analogue code output (IRIG A, B, E and slow code) and BCD digital code output.

3.3. *Specifications of recording system*

The specifications of analogue and digital recorders are as follows.

(1) Audio tape recorder (SONY TC-7960)

Recording method	DR
Channel number	4
Tape speed	3+3/4 or 7+1/2 ips
Frequency response	20 Hz–20 kHz at 3+3/4 ips
S/N	60 dB
Tape	1/4 inch wide, 10 inch reel, 3600 feet long
Recording time	6 hours/volume at 3+3/4 ips
Power consumption	60 W

(2) Thermal pen recorder (SANEI 8K13-LM)

Recording method	linear galvanometer with thermal pen
Channel number	6 or 8
Paper speed	100 mm/s–1 mm/min (variable)

Frequency response	DC-50 Hz at full scale
Linearity error	less than 0.5%
Sensitivity	0.5 mV/cm
Paper length	200 m
Recording time	67 days/volume at 0.2 cm/min
Power consumption	100 W

(3) Digital data recorder (TEAC DR-200B)

Recording format	IBM compatible
Track number	9
Recording density	1600 BPI
Block size	4096 byte
Sampling frequency	0.1–500 Hz (variable)
Analogue input channel	16
A/D converter	12-bit A/D
Digital input	8-bit parallel or 16-orbit parallel
Monitor display	12-bit D/A converter
Tape	1/2 inch wide, 10 inch reel computer tape, 2400 feet long
Recording time	20 days for 24-ch input data with 2-s sampling time
Power consumption	550 W

(4) Long-term analogue data recorder (TEAC R-950L)

Recording method	FM
Channel number	7
Tape speed	0.0075–0.06 ips (variable)
Frequency response	DC-10 Hz at 0.03 ips
S/N	45 dB rms
Tape	1/2 inch wide, 10 inch reel, 3600 feet long
Linearity error	less than 1.5%
Recording time	400 hours (16.6 days) at 0.03 ips
Power consumption	70 W

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