Royal Norwegian Council
for Scientific and Industrial Research
(NTNF)

NORSAR

NORSAR Scientific Report No. 1-92/93

Semiannual Technical Summary

1 April — 30 September 1992

Kjeller, November 1992

7 Summary of Technical Reports / Papers Published

7.1 Extensions of the Northern Europe Regional Array Network -- New small-aperture arrays at Apatity, Russia, and on the Arctic island of Spitsbergen

As of the summer of 1992, the Northern Europe Regional Array Network contributing real-time data to the NORSAR Data Processing Center comprised the high-frequency arrays NORESS and ARCESS in Norway, FINESA in Finland and GERESS in Germany, as well as the two three-component stations KSP and SFP in Poland. In addition, data were available in an off-line mode from a three-component station installed in Apatity on the Kola Peninsula of Russia in June 1991 (see Mykkeltveit et al, 1991). The transmission of continuous data to NORSAR via satellite from the two stations in Poland was discontinued on September 30, 1992.

In September and October 1992, two new small-aperture arrays were added to the network. These are located near Apatity, Russia, and on the Arctic island of Spitsbergen. This contribution offers technical descriptions of these two new arrays and their integration into the network. Fig. 7.1.1 shows the network as of 1 November 1992. From approximately 1 January 1993, all data from the six arrays of this network will be processed jointly in the Intelligent Monitoring System (IMS).

A new small-aperture array near Apatity, Russia

As described in Mykkeltveit et al. (1991), a digital, high-quality three-component station was installed in Apatity on the Kola Peninsula of Russia in June 1991, as part of an agreement of scientific cooperation between NORSAR and the Kola Science Centre of the Russian Academy of Sciences. During June 1991 - June 1992 data from this station were recorded locally in Apatity and copied to cartridge tapes that were sent to NORSAR.

During the summer and autumn of 1992, several significant extensions and changes were made to the installations in Apatity. In June, a dedicated satellite link, based on Norwegian Telecom's NORSAT B system, was installed between NORSAR and the Kola Regional Seismological Centre (KRSC) in Apatity. A computer-to-computer Ethernet connection was established over this link. This enables NORSAR to retrieve continuous data from the system in Apatity. At the same time, several SUN workstations for data analysis were installed, and a NORAC array controller (Paulsen, 1992) replaced the PC system installed in June 1991 with respect to the data acquisition function. The configuration of the three-component station was otherwise unchanged. From June 1992, continuous data from the Apatity three-component station are thus stored on Exabyte cassettes at NORSAR.

In late September, a small-aperture array was installed approximately 17 km to the west of KRSC in Apatity, at the location indicated in Fig. 7.1.2. The geometry of the array is shown in Fig. 7.1.3. The instruments are placed on two concentric rings plus one in the center, and the aperture is approximately 1 km. All sites are equipped by a short period vertical seismometer of type Geotech S-500, and the site at the center of the array has in addition two horizontal seismometers of the same type.

The field work in preparation for the array installation work was organized and conducted by the KRSC and sponsored by the Kola Nuclear Power Plant (Kola NPP). The Kola NPP is located approximately 30 km southwest of the array (see Fig. 7.1.2). An assessment of the local seismicity is a topic of interest to the Kola NPP.

At each of the seismometer sites on the A- and B-rings, the soil overburden was removed, and an iron tube with a bottom plate was placed in wet concrete on top of competent rock. Iron rods attached to the underside of the bottom plate ensure the coupling of the tube to the concrete and underlying bedrock. The vertical seismometers were then placed inside the tube, resting on the bottom iron plate. Power (commercial power is available at the central housing of the array) is provided to the seismometers via trenched cables, and the same cables are used to transmit analog signals from each seismometer to a centrally located housing in the array. The three-component station at the central site A0 is placed in a shallow vault.

Fig. 7.1.4 shows in detail how the data from the new array are acquired at the seismometer sites, digitized at the central array site and then transmitted via three radio channels to Apatity where the NORAC array controller collects and timetags the data. The digitizers used are of types Nanometrics three-channel RD-3 and six-channel RD-6, which are both 16-bit converters with gain ranging. Short-period data from the nine vertical sensors of the array are sampled at 40 Hz. The amplitude (displacement) response function of the short-period channels is given in Fig. 7.1.5. Data from the three seismometers at site A0 are sampled at 80 Hz, thus providing a high-frequency three-component station integrated with the array. The seismic data from the vertical sensor at site A0 are thus sampled both at 40 Hz (and used in the processing together with the vertical sensors of the A- and B-rings) and at 80 Hz (and used as part of the high-frequency three-component station). As shown in Fig. 7.1.4, there is a certain redundancy in the data acquisition, with data from sensors B2 and B3 being represented twice in the data stream. This ensures that data from a useful array geometry are received even in case of failure of one of the digitizers or one of the radio channels. Also note that timing signals in the form of second marks are recorded as a separate time series, using one of the available channels. Fig. 7.1.4 also shows the three-component broad-band seismometer installed on the pier of the basement of the building of the KRSC in Apatity. The seismometer is of type Guralp CMG-3T, and the data are digitized using a Nanometrics RD-3 digitizer. Timing is provided throughout the system on the basis of reception of GPS signals, as shown in the figure.

Fig. 7.1.6 shows the current configuration of the data acquisition and analysis system at the KRSC. The figure shows the local Ethernet established, the NORAC array controller that receives data from the four digitizers, three SUN Sparcstations (kan, imandra and umb) and a SUN X-terminal, and the Cisco router that provides the gateway connection to NORSAR via the dedicated satellite link. Also shown schematically is the multiplexing equipment used for a phone/fax connection via the same satellite channel. IDU is the satellite indoor unit containing the modem and other communications equipment. The system described in Fig. 7.1.6 allows the staff at the KRSC to perform on-line processing as well as interactive analysis of the data recorded at Apatity. Using the satellite link, all data recorded at NORSAR from the other arrays of the network can also be retrieved by the KRSC personnel.

The overall picture related to the Apatity developments is given in Fig. 7.1.7. It shows that the data acquired in Apatity and retrieved via the NORSAT B satellite link are made available to the IMS at NORSAR.

A new small-aperture array on the Arctic island of Spitsbergen

A small-aperture array very similar to the Apatity array described above was installed on the island of Spitsbergen (see Fig. 7.1.1) during late October/early November 1992. The implementation of this array was supported financially by Oljeindustriens Landsforening (OLF), which is an association of oil companies taking part in oil exploration and production on the Norwegian Continental Shelf. The establishment and operation of the communications channels needed in order to integrate the Spitsbergen array data into IMS is being supported by DARPA in the follow-on contract to the one reported on here.

A suitable location for the Spitsbergen array was found during a site-selection survey in August 1991. The site is located on Janssonhaugen in Adventdalen approximately 15 km east-southeast of Longyearbyen (see Fig. 7.1.8), which is the largest Norwegian settlement and also administrative center on the island. Longyearbyen has direct airline connections to mainland Norway. Janssonhaugen is a hill in the middle of a valley (Adventdalen), and the array is deployed on the plateau of this hill. The rocks at the site are of Cretaceous age, covered by thin moraine of variable depth. The sensors are placed at the bottom of 6 m deep cased boreholes. The bottom of the boreholes are either in Cretaceous rock or in moraine material in stable permafrost conditions (temperature approximately -5°C all year round at a depth of 6 m), such that there is no melting/freezing taking place at this depth.

Fig. 7.1.9 shows the geometry of the Spitsbergen array. All nine seismometer sites are equipped with short-period vertical seismometers of type Geotech S-500. Cables on the ground connect each of the sites with a housing located approximately 40 m south of site B4. The entire system with seismometers, digitizers, radio links and array controller is shown schematically in Fig. 7.1.10. The system design is very similar to that of the Apatity array described above. Power at the Spitsbergen array site is provided through the use of a windmill which delivers 12V DC through a battery bank. Data from the two Nanometrics RD-6 digitizers located at the housing close to site B4 are transmitted over two radio links to Longyearbyen, where the data are entered into a NORAC array controller located at a Norwegian Telecom facility. As can be seen from the figure, there is a certain data redundancy, as data from channels B2 and B3 are transmitted on both radio links. As of November 1992, the seismometers at sites A1, A2 and B3 are not yet connected. They will be connected in the spring of 1993, as soon as permitted by the prevailing Arctic conditions.

From Longyearbyen, the Spitsbergen array data are transmitted via a terrestrial link to Norwegian Telecom's satellite hub station at Isfjord Radio, from where a simplex 64 kbits/s satellite link (Norwegian Telecom's NORSAT B system) is used for transmission of the continuous data to Norway. The NORAC array controller in Longyearbyen is also connected to NORSAR via a dial-up line, thus providing a back-link for control and command purposes.

The data from the new Spitsbergen array provides another data source for the IMS. As this array is located in an area of much younger geology than the other five arrays, its integration into IMS is expected to present interesting seismological challenges.

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Mykkeltveit, S., A. Dahle, J. Fyen, T. Kværna, P.W. Larsen, R. Paulsen, F. Ringdal and E.O. Kremenetskaya (1991): Extensions of the Northern Europe Regional Array Network -- a new three-component station at Apatity, USSR, and a planned array at Spitsbergen, Semiann. Tech. Summ. 1 April - 30 September 1991, NORSAR Sci. Rep. No. 1-91/92, Kjeller, Norway

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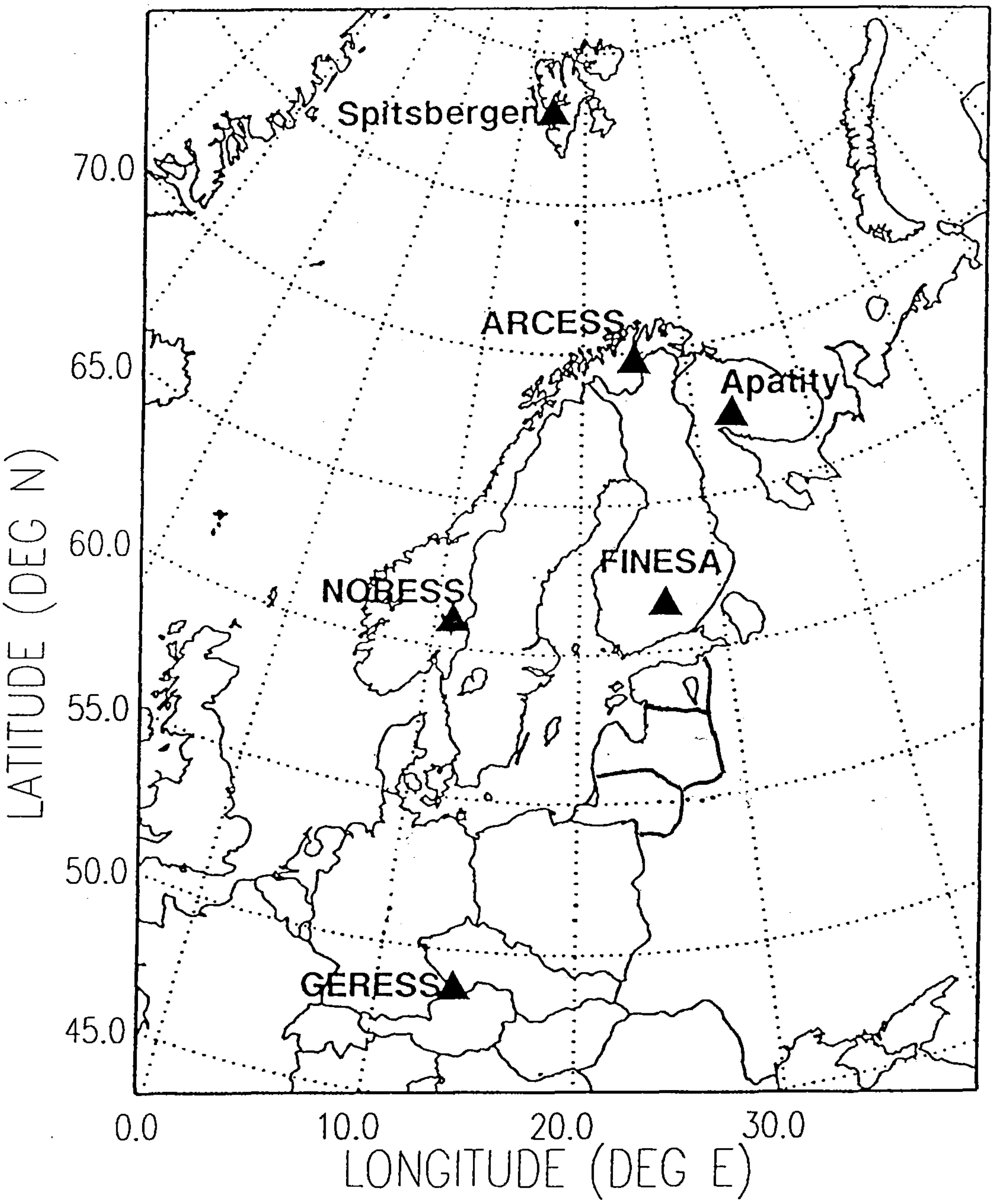

Fig. 7.1.1. The figure shows the stations of the Northern Europe Regional Array Network as of November 1992. All stations of the network are small-aperture arrays.

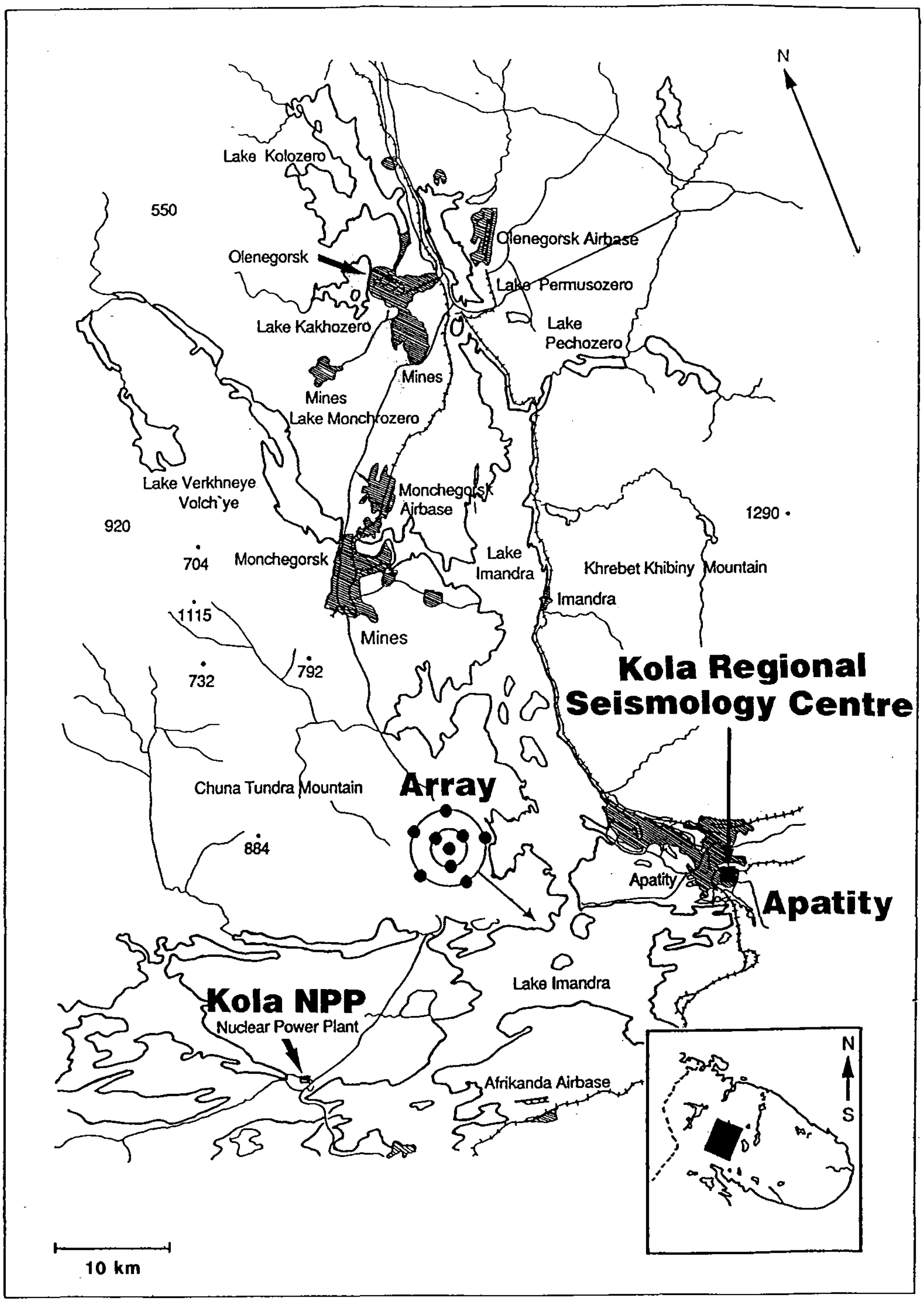

Fig. 7.1.2. Map of the Apatity region on the Kola Peninsula of Russia, showing the location of the Kola Regional Seismology Centre and the location of the new small-aperture array (not drawn to scale; the array aperture is 1 km). Also shown are the mining areas in Monchegorsk and Olenegorsk to the north of the array. The seismicity in the area, and in particular the seismicity associated with the mining activity in the Khibiny Mountain area to the northeast of Apatity, is described in Kremenetskaya (1991).

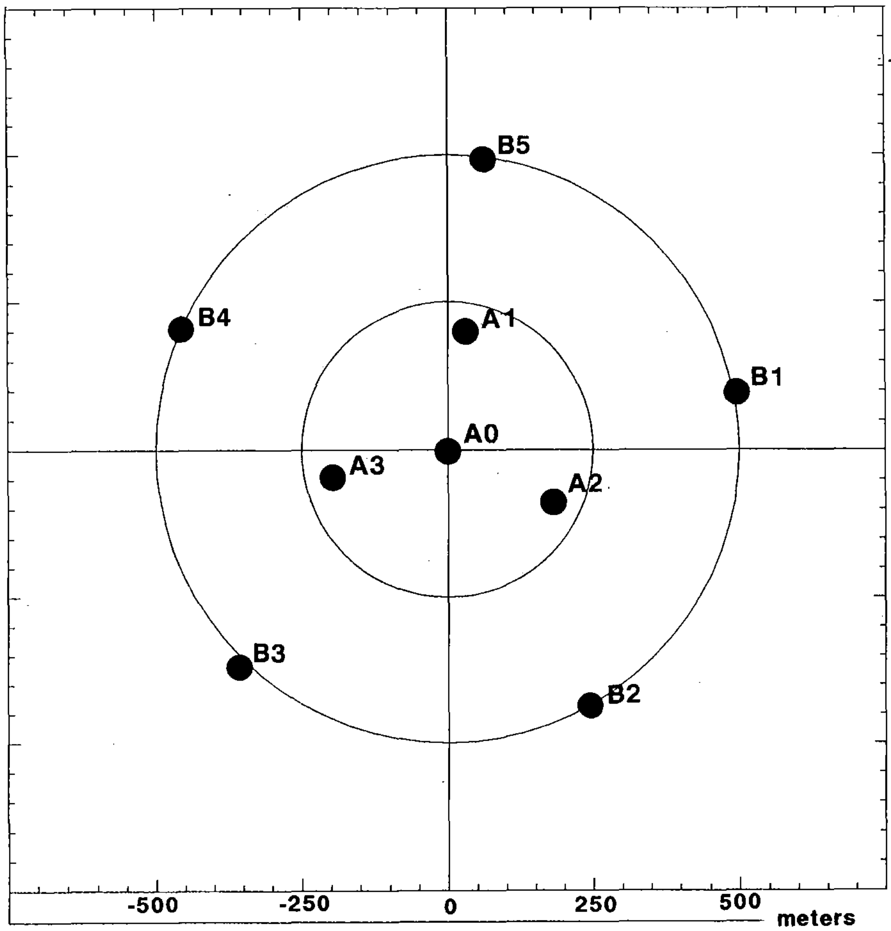

Fig. 7.1.3. Configuration of the new Apatity small-aperture array.

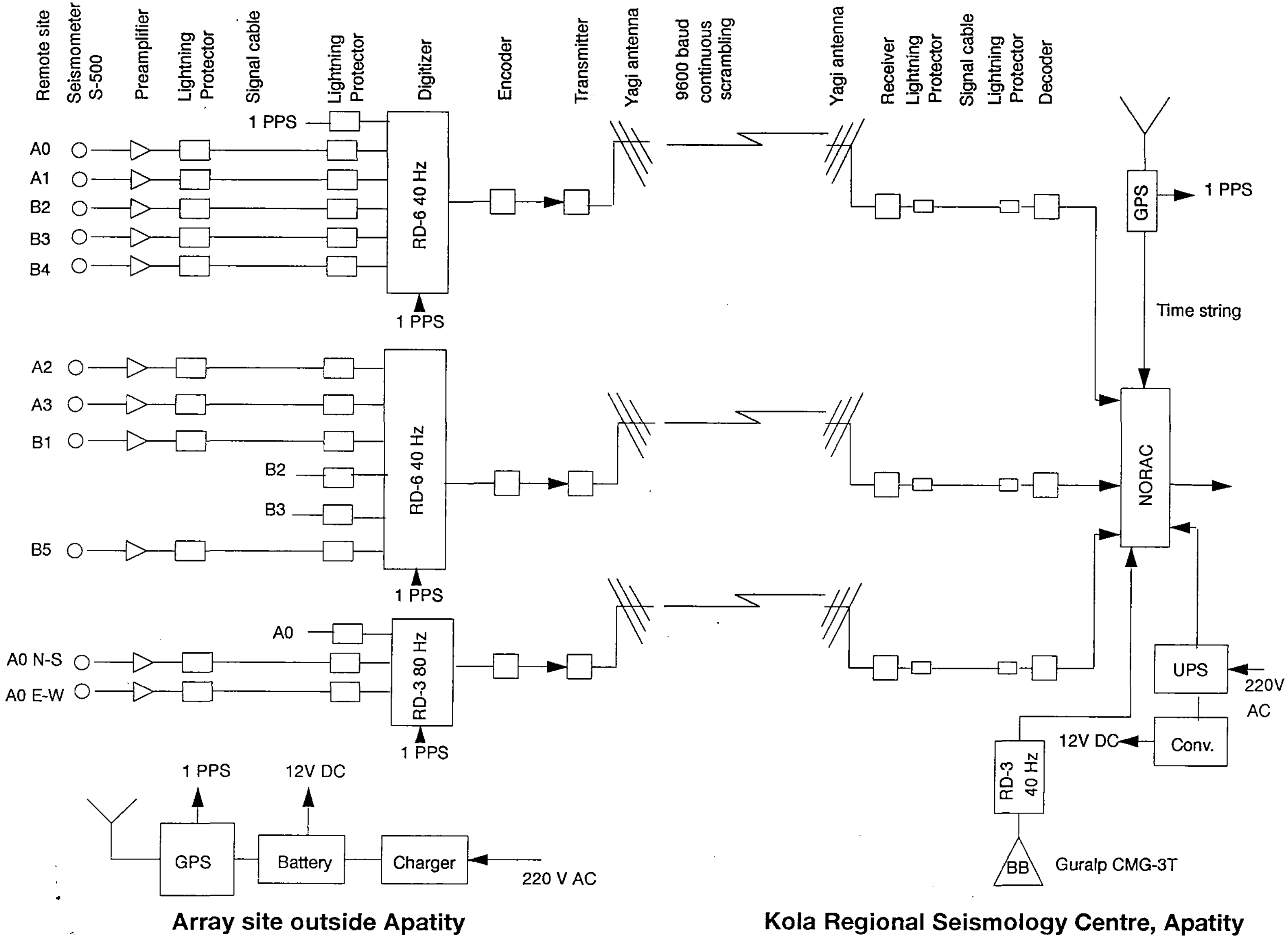

Fig. 7.1.4. Data flow chart for the array and the broadband station in Apatity. 1 PPS ("one pulse per second") denotes timing signals.

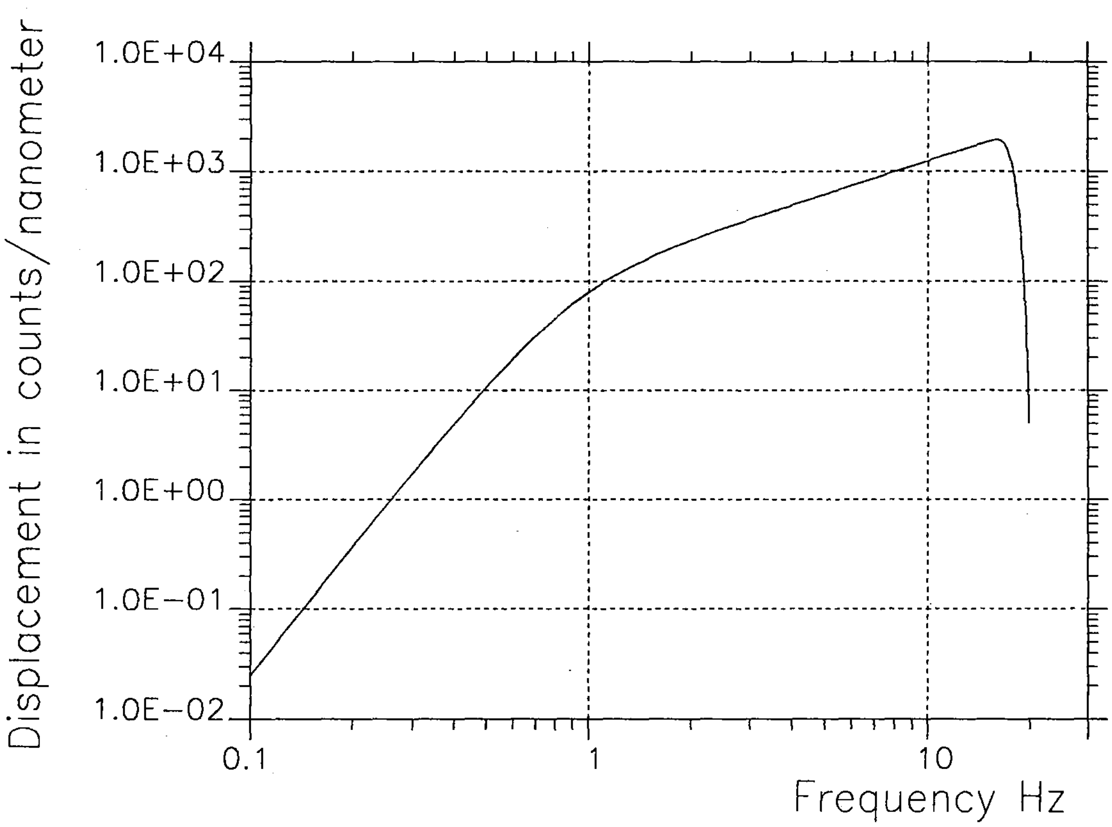

Fig. 7.1.5. Amplitude (displacement) response function for the nine short-period channels of the small-aperture array installed in Apatity in September 1992.

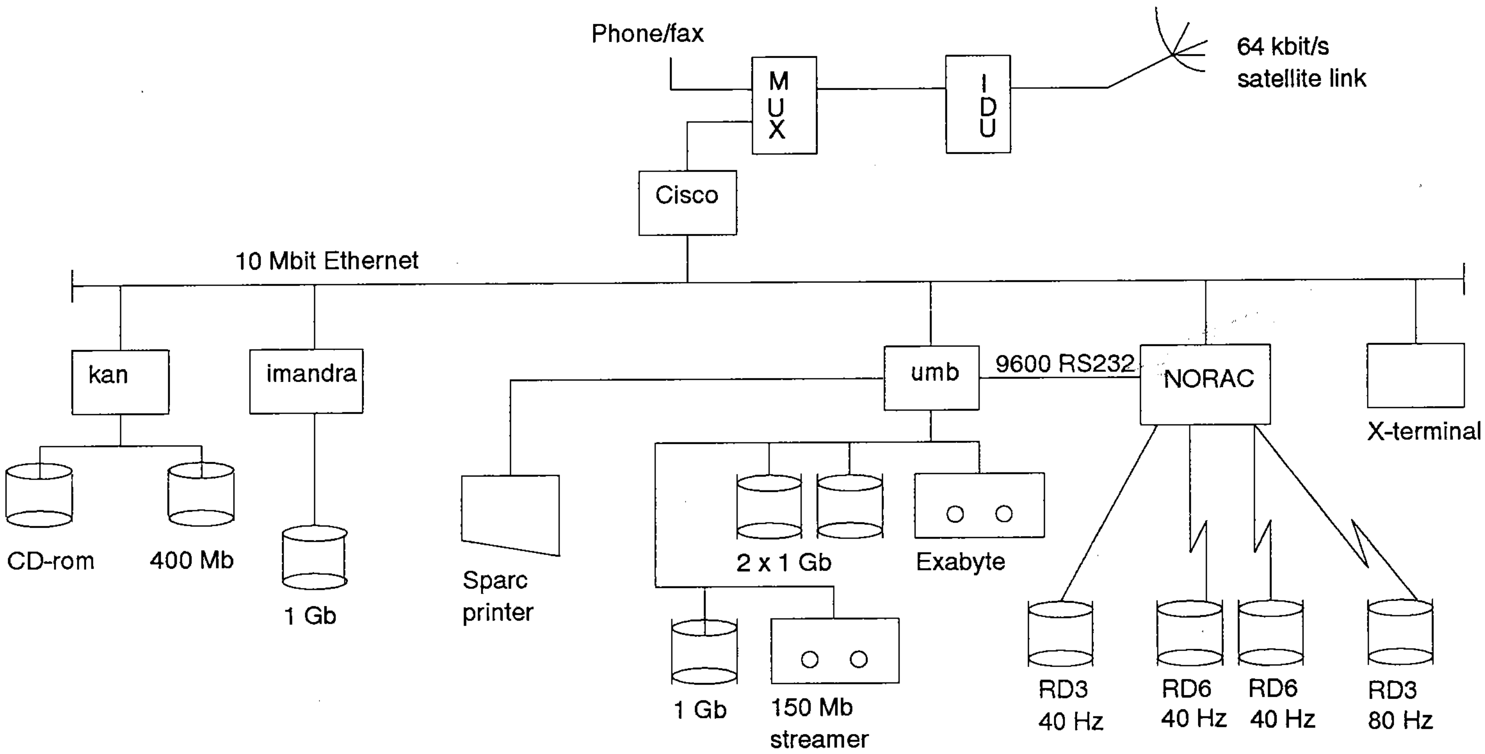

Fig 7.1.6. The figure shows the configuration of the computer systrem installed at the Kola Regional Seismology Centre in Apatity. Also shown is the network connection to NORSAR via the dedicated 64 kbits/s satellite link.

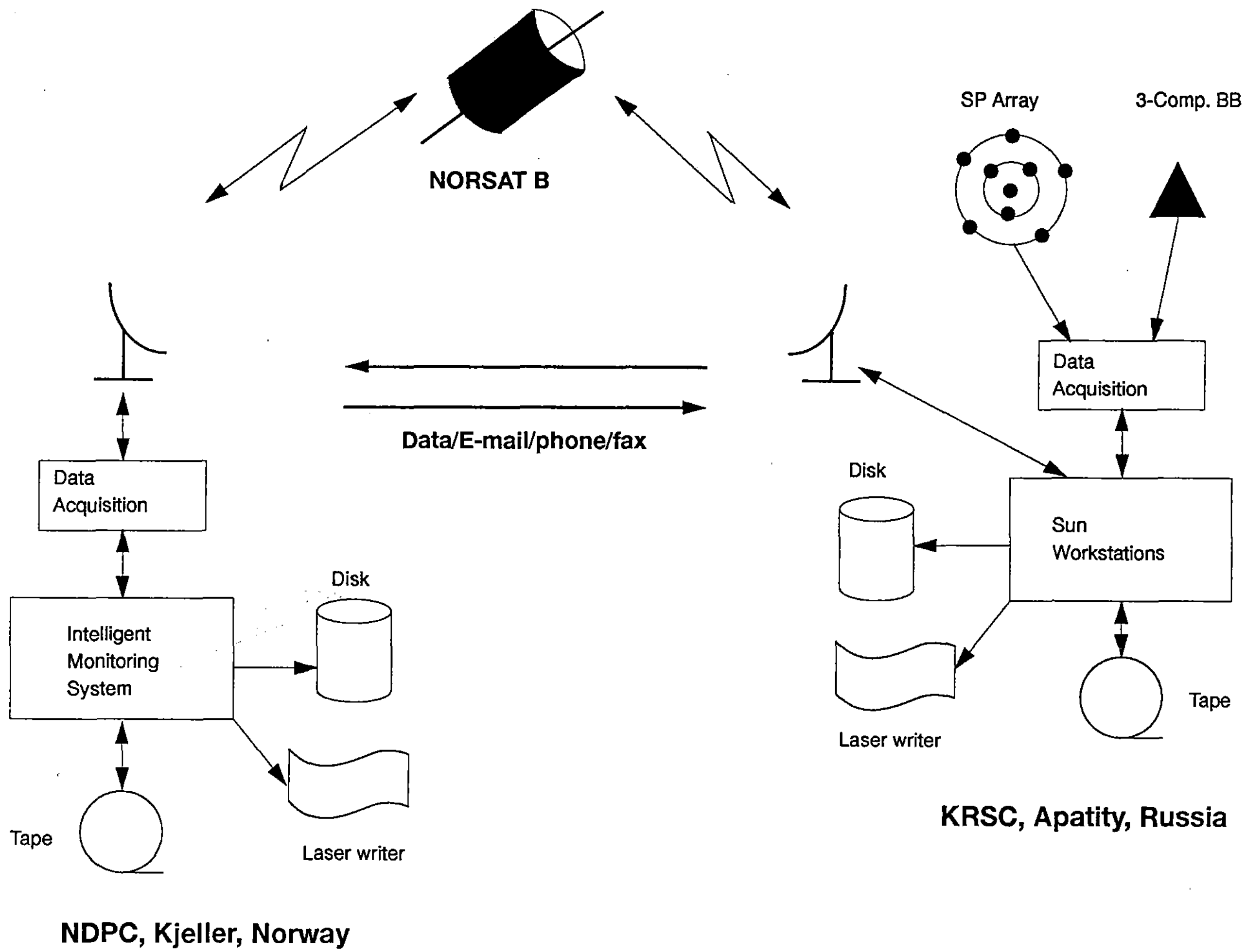

Fig. 7.1.7. Schematic overview of the field installations and computer system in Apatity and the interfacing with the NORSAR Data Processing Center (NDPC) in Norway via the NORSAT B satellite link.

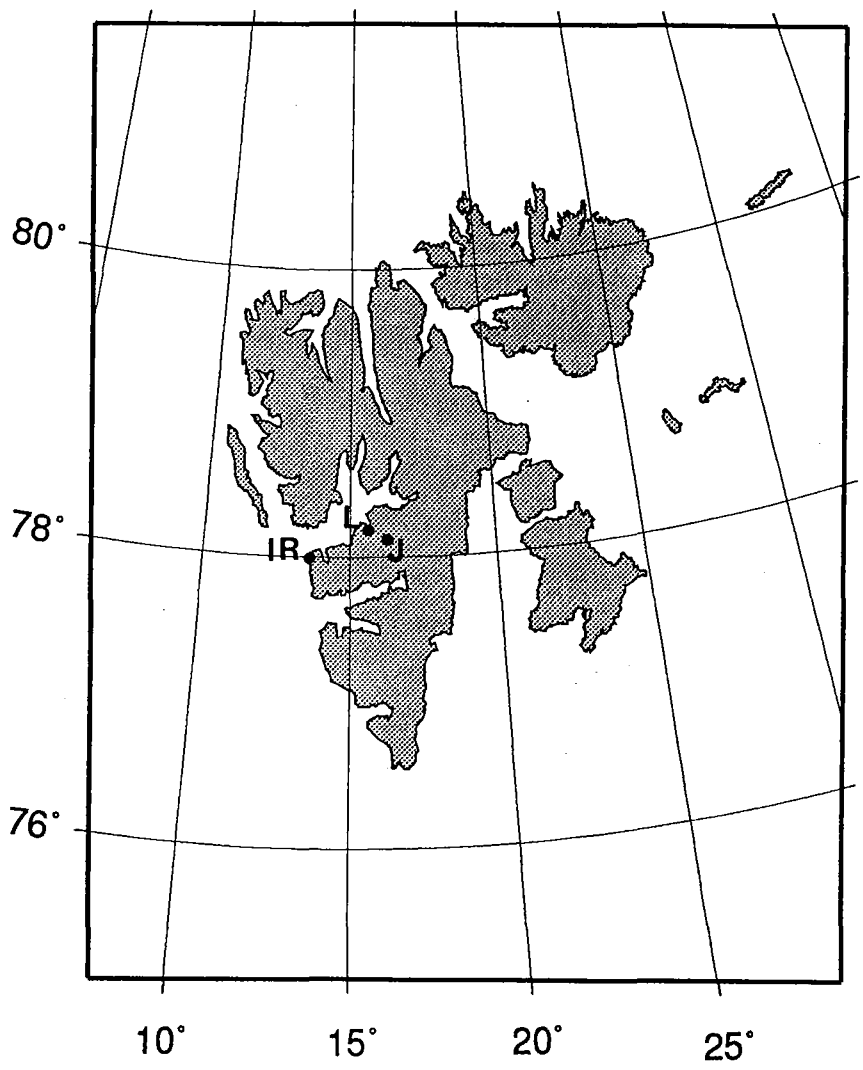

Fig. 7.1.8. This map of the Svalbard archipelago with its main island Spitsbergen shows the location of the array site at Janssonhaugen (J), the location of the array controller at Norwegian Telecom's facility at Longyearbyen (L), and the location of the NORSAT B earth station at Isfjord Radio (IR).

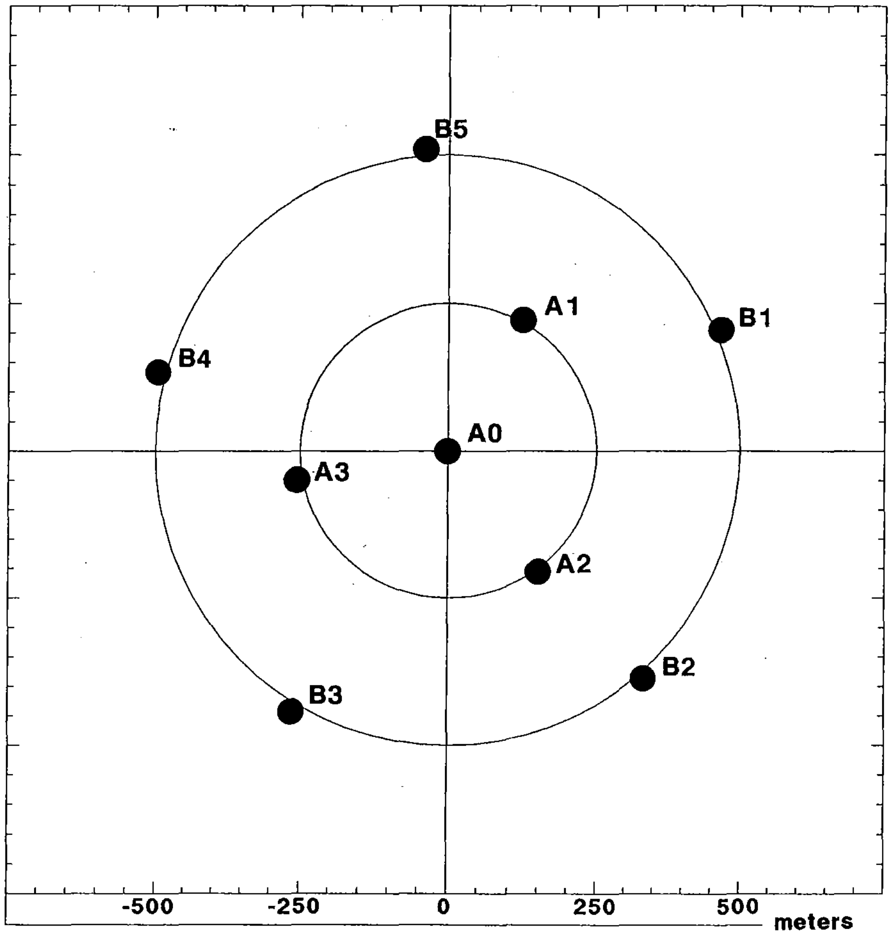

Fig. 7.1.9. Configuration of the new Spitsbergen small-aperture array.

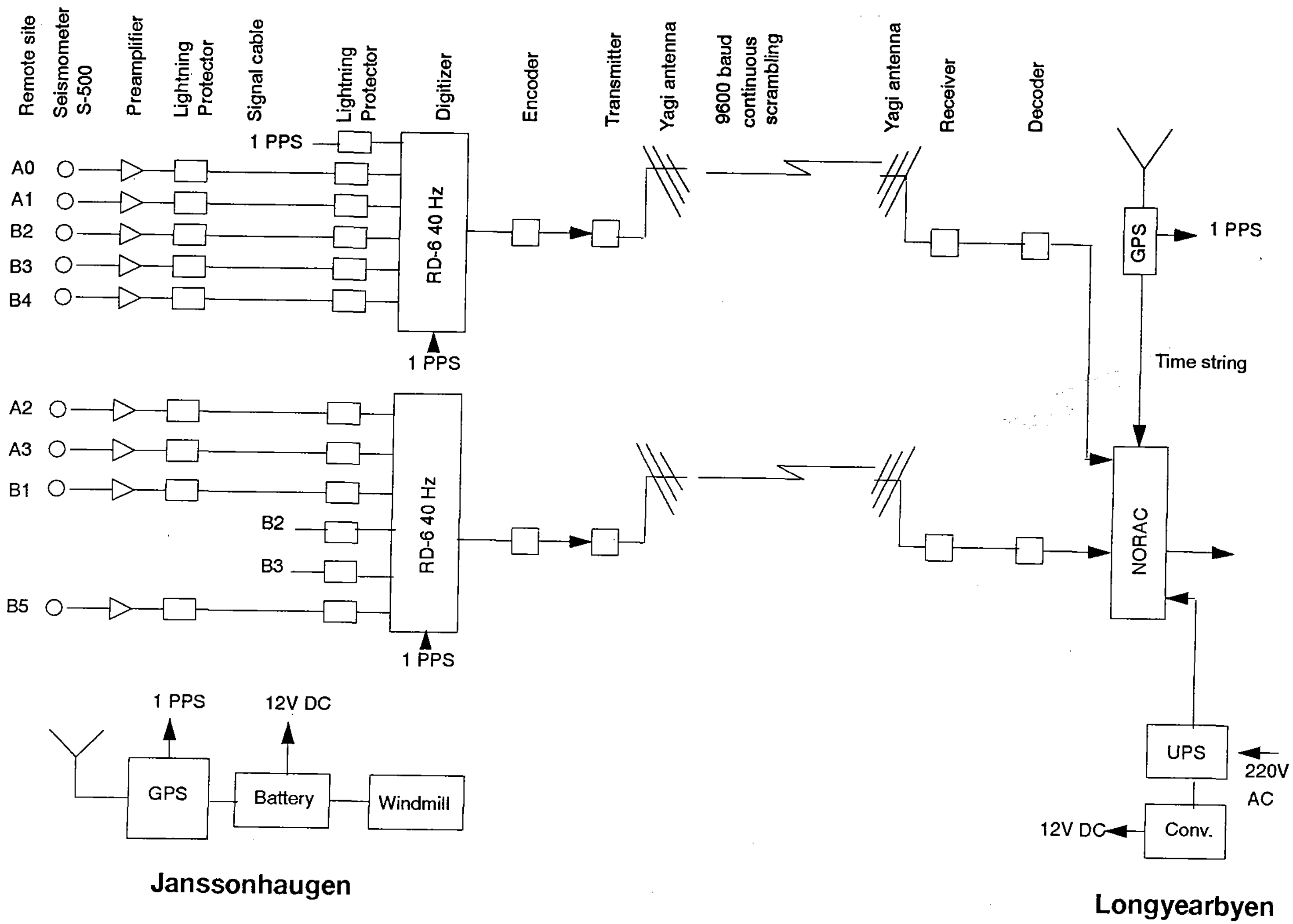

Fig. 7.1.10. Data flow chart for the Spitsbergen array. 1 PPS ("one pulse per second") denotes timing signals.