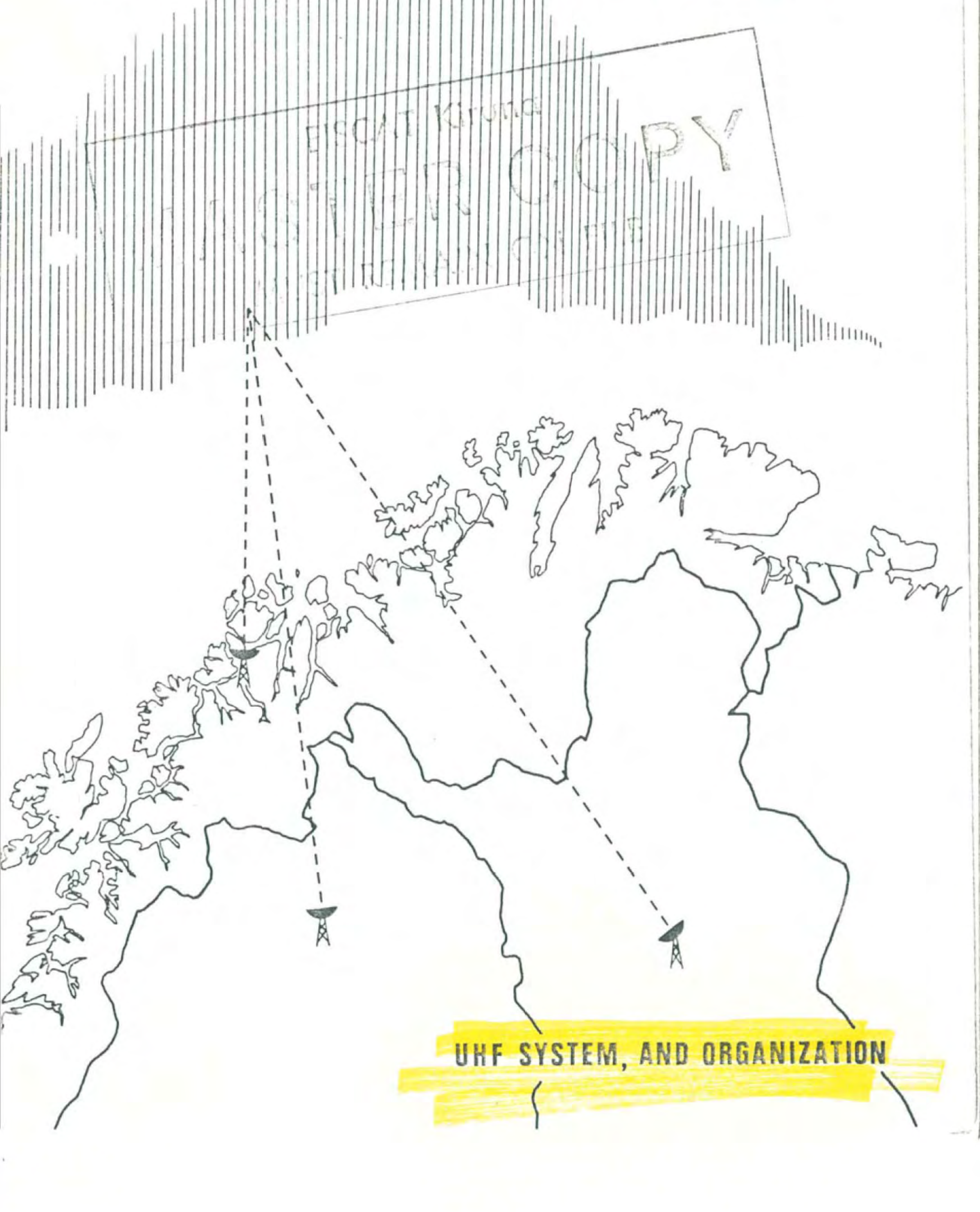
# A European incoherent scatter facility in the auroral zone





## UHF SYSTEM, AND ORGANIZATION

# A European Incoherent Scatter Facility

# in the Auroral Zone,

## Organization and Operation, Implementation of the UHF Part of the System

Presented by the

EISCAT Steering Committee

June 1974

TABLE OF CONTENTS


| | | |
|---|---|---|
| | Abbreviations | 4 |
| | FOREWORD | 5 |
| 1 | INTRODUCTION | 7 |
| 1.1 | THE SCIENTIFIC IMPORTANCE OF EISCAT | 8 |
| 1.2 | OTHER INCOHERENT SCATTER DEVELOPMENTS | 11 |
| 1.3 | SCOPE OF THE PRESENT REPORT | 15 |
| 2 | SYSTEM DESCRIPTION AND CAPITAL COSTS | 15 |
| 2.1 | THE UHF TRANSMITTER | 16 |
| 2.2 | THE UHF RADAR ANTENNA | 19 |
| 2.3.1 | The UHF Receivers at Kiruna and Sodankyla | 22 |
| 2.3.2 | The UHF Receiver at Radar Site (Tromsø) | 23 |
| 2.4 | THE UHF RECEIVING ANTENNAS | 24 |
| 2.5 | FREQUENCY AND TIME SYSTEM | 27 |
| 2.6 | COMPUTER, DATA RECORDING AND CONTROL SYSTEM | 28 |
| 2.7 | BUILDINGS, SITE DEVELOPMENT, POWER | 32 |
| 2.7.1 | Receiving Site near Kiruna | 32 |
| 2.7.2 | Receiving Site near Sodankylä | 33 |
| 2.7.3 | Radar Site near Tromsø | 33 |
| 2.8 | SUMMARY OF CAPITAL COSTS | 35 |
| 3 | OPERATION OF THE OBSERVATORY, OPERATING COSTS | 35 |
| 3.1 | STRUCTURE OF THE EISCAT EXECUTIVE ORGANIZATION | 36 |
| 3.2 | SUBCONTRACTORS | 38 |
| 3.2.1 | Kiruna Geophysical Institute | 38 |
| 3.2.2 | Sodankylä Geophysical Observatory | 38 |
| 3.2.3 | The University of Tromsø | 38 |
| 3.3 | SALARY EXPENSES FOR THE OPERATION | 39 |
| 3.4 | OPERATING EXPENSES | 40 |
| 3.5 | SUMMARY OF THE OPERATING COSTS | 42 |
| 4 | THE CONSTRUCTION PHASE | 43 |
| | References | 44 |
| | Illustrations | 45 |

## FOREWORD

The original proposal for the EISCAT facility was completed during June of 1971. The proposal was presented to the funding agencies in the various participating countries and was well received by the scientific communities. However, it soon evolved that no national funding agency was about to make a firm commitment on its own before other agencies were committed and no further progress could be made.

A meeting of interested European scientists was convened by Professor Beynon in London during October, 1973 in order to bring about further progress with EISCAT. At that meeting it was decided that a steering committee be formed and that the membership include an administrator and a scientist from each country. Dr. F. Schneider (Germany) was elected chairman of the committee and Professor T. Hagfors (Norway) secretary. The membership of the committee is:

| | |
|---|---|
| Finland | Dr. J. Oksman<br>Dr. O. Ranta |
| France | M. J. Delhaye<br>Dr. A. Giraud |
| Germany | Dr. H. Kohl<br>Dr. F. Schneider |
| Norway | Dr. T. Hagfors<br>M. A. Sandbo |
| Sweden | Dr. H. Wilhelmson<br>Dr. J. Gustafson |
| U. K. | Dr. W.J.G. Beynon<br>Dr. F. Horner |

The charge of the committee was stated to be the drafting of an international agreement to be entered into by the various funding agencies. The committee was also charged with the updating of the technical and administrative parts of the original proposal in order to provide a firm estimate of the investment and operating costs. It was required to provide a convincing organizational structure as well as an account of the organization during the construction phase.

A draft of the international agreement is now available. The present report represents an updated version of the original proposal, but, unfortunately, deals primarily with the UHF part of the system. As soon as the planning and cost estimates for the VHF part is available an additional report will be produced.

A number of individuals not members of the steering committee have contributed during phases of the writing of the present report. Particularly valuable contributions have been made by:

| | |
|---|---|
| Dr. H. Atkinson | Dr. B. G. Hooghout |
| Dr. Audé | Dr. B. Hultquist |
| Dr. Creyssel | M. D. Leiulfsrud |
| Dr. F. Du Castel | Dr. N. Taylor |
| Dr. G. Haerendel | Dr. S. Westerlund |
| Dr. O. Holt | Dr. P.J.S. Williams |

Our sincerest thanks are due all contributors.

On behalf of the Steering Committee

Trondheim, June 20th,1974.

T. Hagfors.
Secretary.

# 1 INTRODUCTION

A proposal for the construction of a European incoherent scatter facility (EISCAT) to be located in Northern Scandinavia was completed during the summer of 1971. Scientists from Finland, France, Germany, Norway, Sweden and the United Kingdom participated in the preparation of this proposal. Since then, representatives of the various proposed funding agencies have met at a number of informal meetings to discuss the proposal and ways of implementing the facility. At the same time more detailed engineering and cost studies have been carried out by participating laboratories and by manufacturers of major components.

At the present time there is available a draft for an international agreement between the various funding agencies to form an EISCAT organization, charged with the construction and operation of the facility. The agencies which plan to enter into this agreement are:

Science Academy of Finland (S.A.)

Centre National de la Recherche
Scientifique de France (C.N.R.S.)

Max Planck Gesellschaft (Germany) (M.P.G.)

Research Council for Science and the Humanities
(Norway) (N.A.V.F)

National Research Council (Sweden) (N.F.R.)

The British Science Research Council plans to join the organization at a future date and contribute toward the VHF part of the system. The planning of the VHF system is not as advanced as that of the planned UHF system and will, therefore, be described separately in a forthcoming addendum to the present report.

The purpose of the present extension to the original proposal is to summarize the ideas about the structure of the organization which have crystallized as a result of discussions between representatives of the agencies listed above. It is also the purpose to define in greater detail the cost of the major hardware items of the UHF system and to spell out the cost and mode of operating the facility when completed. The details of the sharing of costs between the member agencies will not be given here, but will be defined in the international agreement to be signed.

## 1.1 THE SCIENTIFIC IMPORTANCE OF EISCAT

It is now widely recognised that the establishment of a major European incoherent scatter facility at high latitudes would constitute an important landmark in the development of atmospheric and magnetospheric physics.

Incoherent scatter radar has already proved to be the most powerful and comprehensive ground-based method for studying the upper atmosphere. The technique makes use of the scattering of VHF or UHF radio waves by thermally-induced irregularities in the plasma. The theory of the scattering process is well understood and analysis of the total intensity and frequency spectrum of the scattered signals allows several parameters to be measured. These include: (1) electron density, (2) electron temperature, (3) positive ion temperature, (4) positive ion composition, (5) ion-neutral collision frequency, (6) line-of-sight plasma velocity, (7) the flux of suprathermal precipitating electrons and in favourable cases, (8) the electric current density. From these direct measurements other parameters can be reliably derived, including: (9) electric field strength, (10) neutral-air temperature, (11) neutral composition, (12) neutral-air wind speed, (13) electron-neutral collision frequency and (14) downward flux of heat energy.

Very good precision, with errors of a few per cent in the best cases, can generally be achieved, and since the technique does not significantly perturb the medium, the results are free of systematic error. Incoherent scatter gives continuous measurements and the height range covered extends from about 80 km up to 2000 km or more, although not all parameters can be measured together over the whole height range with a single mode of operation. No other ground-based technique produces so much information and certain parameters, such as the electron and ion temperatures, cannot be measured from the ground in any other way.

Incoherent scatter is complementary to satellite and rocket measurements. Satellites give good global coverage for a limited range of altitudes, but observations at any one location are only repeated after long intervals. Rockets can cover a wide altitude range - including heights less than 80 km where the radar measurements are often seriously contaminated by ground clutter. Rockets are also best suited to determining certain parameters such as the energy spectrum of precipitated particles or the positive ion composition. Rockets are very expensive, so continuous measurements over a long period are out of the question.

Incoherent scatter measures a comprehensive list of parameters with good height and time resolution over an altitude range from about 80 km to 2000 km or more.

Moreover, once an incoherent scatter facility is in operation it will provide such parameters continuously for a decade or more at very little extra cost.

Until 1971, all incoherent scatter systems were operating near the equator or in mid-latitudes. The proposed European facility offers exciting possibilities because it will be situated at a high latitude where the lower atmosphere and the ionosphere, being connected by magnetic field lines to the magnetosphere, serve as detectors for magnetospheric processes. The field lines along which the system aims will at times be connected to interplanetary space, at other times, when the auroral oval passes overhead they will be connected to the tail and other active regions of the magnetosphere. This means that EISCAT will be very well placed to examine various magnetic storm phenomena which constitute major problems in present-day aeronomy.

The technique will give detailed information about neutral atmospheric and ionospheric parameters which are very poorly known at high latitudes. It can be argued that many of the major scientific problems relating to the mid-latitude ionosphere have been solved and that the most challenging problems are now those of the high latitude regions. For example, we have no idea of the relative magnitude of the energy inputs to the atmosphere from particles precipitation, joule heating, solar radiation, viscous dissipation of waves and so on. We do not know the localised heat inputs into the auroral regions during disturbed conditions - and these are major uncertainties in thermospheric - upper atmospheric models. Also, we have predicted tremendous motions at these heights but the morphology of these motions has never been established experimentally. Finally, nobody knows how effective wind - and wave - motions are in transferring energy and momentum over long distances and to other altitudes.

All these problems concern thermal balance and dynamical phenomena in the upper atmosphere but there is now evidence that they affect the lower atmosphere, though the connection is not understood. Incoherent scatter can play a large part in solving these problems and EISCAT will be at exactly the right latitude to play a key role in this.

Among the specific scientific problems that EISCAT will be able to investigate are the following:-

1. By looking directly along field lines in the topside ionosphere, the system will measure the velocity of the polar wind, i.e. the outflow of plasma along magnetic field lines. No other technique enables this

important geophysical phenomenon to be studied in such a direct and continuous manner.

2. Measurements of the ionospheric drift velocity along magnetic field lines at lower altitudes will give practical information about thermospheric winds which have a major influence on the behaviour of the ionosphere.

3. The velocity of the plasma perpendicular to the magnetic field lines will also be measured and from this the electric field may be determined. Because the ionosphere and magnetosphere are magnetically linked at these latitudes, the distribution of electric fields will give us information about the large-scale circulation of plasma in the magnetosphere. The ESRO GEOS satellite will also lie on almost the same magnetic field line so that if the satellite is still active when EISCAT comes into operation then a comparison of the electric field measurements and other data will lead to a better understanding of the various forms of coupling between the ionosphere and the magnetosphere.

4. The electric fields in the ionosphere can also produce currents, particularly at auroral latitudes and these currents can also be measured directly. These currents, in turn, contribute to the magnetic variations observed at ground level - even at mid-latitudes - and any information on the auroral currents is of value to geomagnetism.

5. The neutral winds and electric fields together produce ionospheric drifts and currents which have a very strong influence on the overall structure of the ionosphere. Other techniques of measuring these drifts and currents are difficult to use and their results are often hard to interpret. The accurate measurements which EISCAT will make will solve several outstanding problems.

6. The input of energy by particles and electric currents at high latitudes is a major heat source for the themosphere, rivalling that due to solar ionizing radiation. The EISCAT temperature measurements will provide information which is vital to studies of the energy balance of the thermosphere - comparison with data obtained by means of the radars in France and the U.K. (if still available) will particulary be interesting.

7. The plasma line phenomenon observed in incoherent scatter is intensified by the precipitation of energetic particles and it is, therefore, a good indicator of particle activity. The EISCAT facility will thus provide information about particle precipitation which will be useful to many other experimenters.

8. Electron density profiles through the auroral D and E layers, using short time resolution, will also indicate the varying flux and spectrum of precipitating particles. These measurements will also indicate the effective recombination coefficients at these heights.

9. Measurements at the lowest height ranges which can be studied will provide information about the effects of stratospheric warmings on the D region and similar lower ionosphere phenomena. Many of these originate at high latitudes.

10. F-region storm phenomena and seasonal variations are largely the result of composition changes in the thermosphere, which are in turn caused by variations in the air circulation pattern. High latitude studies are very important for a proper understanding of these phenomena.

11. The EISCAT system will enable gravity waves and travelling ionospheric disturbances, many of which originate in auroral regions during storms, to be studied near their source.

## 1.2. OTHER INCOHERENT SCATTER DEVELOPMENTS

Since the completion of the original EISCAT proposal two similar projects have been in progress on the North-American continent. The first project involved the transfer of an existing radar from Stanford, California to Chatanika near Fairbanks, Alaska, which lies in the auroral zone. This radar has been in operation since the end of 1971. In the other project it is proposed to build an Upper Atmosphere Observatory (UAO) near the U.S.-Canadian border in upper New York State. This observatory is to be funded and operated as a cooperative venture between the two countries. According to our latest information a commitment to fund the UAO is unlikely to be forthcoming in the near future.

The Chatanika radar is operated at 1290 MHz into a 27 m fully steerable parabolic dish. The parameters of the system are listed in Table 1.1. The radar which is only operating in a monostatic mode is situated at a latitude corresponding to L-shell value 5.6 (c.f. L-value of 6.3 for EISCAT). Although the Chatanika facility was originally meant to be a pilot project to investigate the feasibility of conducting auroral zone incoherent scatter studies, a large amount of interesting data has been obtained in spite of the limited sensitivity. Observational results from Chatanika have played an important part in recent international meetings concerned with the arctic ionosphere and magnetospheric phenomena. Specifically the Chatanika radar is capable of supplying data on:

Table 1.1 Chatanika Radar Parameters

| | |
|---|---|
| Frequency: | 1290 MHz |
| Transmitter peak power: | 5 MW maximum |
| Transmitter average power: | 150 kW maximum |
| Beamwidth: | 0.6 degrees |
| Antenna diameter: | 26.8 m |
| Antenna gain | 41.1 db |
| Transmit polarization: | Circular, right |
| Receive sum chanel: | Circular, left |
| Noise temperature: | 120 $^{o}$K |
| PRF: | Adjustable in steps of 30, 75, 150, 300 Hz |
| Pulse length: | 10- to 500- $\mu$s CW pulse continuously adjustable |

a) Electron density profiles
b) Plasma velocity
c) E-region neutral wind
d) Electric fields normal to $\underline{B}$
e) Hall and Pedersen conductivities
f) Electric currents normal to $\underline{B}$
g) Atmospheric Joule heating rates.

A major advantage to the Chatanika system are the other geophysical institutions located nearby at College, Sheep Creek, Ester Dome, Gilmore and Poker Flat. Within 30 km of Chatanika there is a wide variety of supporting instrumentation, including a C-3 ionosonde, 30 MHz riometer, 3-axis magnetometer, all-sky camera, zenith-narrowfield camera, TV sky coverage, multichannel photometer, earth-potential recorder, satellite tracking system and rocket range. Moreover, the multi-frequency auroral radar at Homer can obtain coherent auroral clutter echos from above Chatanika. Similar advantages will be enjoyed at Tromsø and cooperative experiments will undoubtedly form an important part of the programme.

Some of the basic limitations of the Chatanika system are: The sensitivity of the system is low so that the height resolution which can be achieved under normal electron density conditions is rather poor. The limitation to monostatic operation makes it possible to derive three-dimensional plasma motion only by scanning the antenna beam over a large area and assuming the motion to be the same over that area and over the necessary integration time. This assumption is probably good at middle and low latitudes but is suspect in the auroral zone where the motion changes rapidly in space and time. The fully steerable antenna, however, does give the Chatanika radar an advantage over the proposed EISCAT facility in that the auroral phenomena may be tracked in space. We shall return to a comparison in tabular form of the characteristics of the Chatanika radar and the proposed EISCAT system presently.

Although Chatanika is a relatively modest system, the following list of headings indicate the range of research topics already studied: Auroral E-layer. Electric fields and ionospheric current systems. Morphology of auroral ionosphere and plasma trough. Conjugate photo electron flux. Solar eclipse. Storm effects. Spread F. Cooperative experiments include: D-region absorption. Optical emission. Particle precipitation. X-ray radiation. Magnetic activity. Auroral clutter.

The proposed UAO would be operating at a frequency of 430 MHz in a tristatic mode. The transmitting antenna would be steerable in the north-south direction to $\pm 85^{\circ}$ from zenith and have a diameter of 100 m. The two receiving antennas would be 25 m fully steerable dishes. The average transmitter power would be 300-600 kW.

The proposed UAO would be operating at a frequency of 430 MHz in a tristatic mode. The transmitting antenna would be steerable in the north-south direction to $\pm 85^{\circ}$ from zenith and have a diameter of 100 m. The two receiving antennas would be 25 m fully steerable dishes. The average transmitter would be 300-600 kW.

A comparison of some of the characteristics of the three planned or existing auroral incoherent scatter radars is shown in Table 1.2. As can be seen the EISCAT VHF system

Table 1.2 <u>Characteristics of present or planned high latitude incoherent scatter observatories (Evans), 1974).</u>

| Observatory | Frequency (MHz) | Observatory mode | Volume explored | Sensitivity rel. Chatanika (db) | Typical altitude range (km) |
|---|---|---|---|---|---|
| EISCAT | 933 | Tristatic | Cylinder along magnetic field | + 5 | 100-1000 |
| | 224 | Partly steerable monostatic | Slice, magn. meridian | +12 | 80-2000 |
| UAO | 430 | Partly steerable tristatic | Slice, magn. meridian | +10 | 80-1500 |
| Chatanika | 1290 | Fully steerable monostatic | Any volume above horizon | 0 | 100- 400 |

has a sensitivity 2 db above that of the planned UAO and the UHF system 5 db below that of UAO. Both the planned new systems have a sensitivity well above that of Chatanika.

## 1.3 SCOPE OF THE PRESENT REPORT

In the following sections we shall first define the overall system and identify the major components. These major components will be described in some greater detail and their aquisition cost will be determined in the greatest possible detail, item by item. This is done in order to find the capital expenditure necessary to construct a workable system. It must be emphasized that some of the major components will be subject to further engineering studies and alternative solutions may be chosen if they are more cost-effective and can be acquited without exceeding the cost limits defined in the present report.

The following section deals with the organization and the mode of operation of the facility once it has been completed and details of the personnel requirement at each observing site.

The fourth section deals with the organization and supervision of the project during the construction phase and lists the personnel required for this task.

## 2 SYSTEM DESCRIPTION AND CAPITAL COSTS

As explained in the original proposal the complete EISCAT system is to include three stations. One near Sodankylä, Finland, one near Kiruna, Sweden and one near Tromsø, Norway. In order to locate the scattering volume as far north as possible with this configuration Tromsø was chosen as the site for both transmitters. A detailed discussion of the justification for the choice of frequencies and the configuration will be found in the original proposal. At Tromsø, therefore, there will be two complete monostatic pulsed radar systems. One operating at 224 MHz (VHF) and the other at 933.5 MHz (UHF). At Kiruna and Sodankylä there will be receiving stations for the UHF transmissions. Each site will have special pupose computers designed to average the raw data. The three sites will be connected by telephone lines to allow the averaged data to be transferred between sites and be stored in a single storage element for further analysis. All pertinent experimental parameters will be transferred over the same lines. Frequency and time will be kept at each observatory by accurate caesium standards kept in synchronism by means of a travelling standard clock. A conceptual sketch of the complete system is shown in Figure 1.

In the following sections only the UHF system will be discussed. A separate report will be prepared for the VHF system when the design studies are sufficiently advanced.

## 2.1 THE UHF TRANSMITTER

A preliminary study of a transmitter satisfying the requirements of the UHF system (RR 3) showed that the only suitable power amplifier tube would be a Varian klystron derived from the existing VA 862. The study also showed that pulses with rise times less than µsec would require a floating deck modulator with two power triodes of type ML-2PT. Amplitude and phase stability for maximum pulse length of 10 msec was found to require a storage capacitance to exceed 0.4 mF.

To reduce cost the capacitor bank was reduced to 100 µF by relaxing the amplitude stability requirement to 0.4 db per pulse and by retaining frequency stability to within 5 Hz by designing a feedback loop round the final amplifier. A further 5% reduction in cost which could be achieved by sacrificing the quasi-CW-capability (i.e. the 10 msec pulse width) was considered undesirable in view of the advantages of such operation for the two remote stations (Kiruna and Sodankylä).

A decrease in operating cost which would ensue from the replacement of the high power triode in the modulator by several smaller and less expensive ones in parallel was ruled out because of an undesirable increase in pulse rise-time.

Inquiries were also made regarding a change of frequency from 933 to 1300 MHz. Klystrons with a higher peak power are available near the latter frequency. However, at this frequency the height range that could be accurately studied would have been reduced by the Debye-length limitation. Also the transmitter costs would increase by 10% because of the higher voltage required and the maximum pulse-length would have been reduced to 150 µsec, hence, excluding the quasi-CW mode. The higher frequency was, therefore, abandoned.

A firm price proposal, dated July 5th, 1973 was received from "Radars de surface" Division of Thomson-CSF, Bagneux, France for a transmitter with the following characteristics:

| | |
|---|---|
| Frequency: | 933.5 MHz |
| Bandwidth: | 20 MHz at -3db, 10 MHz at -1 db |
| Peak power: | 2 MW |
| Average power: | 250 kW |
| Pulse lengths: | 20 μsec - 10 msec |
| Max p.r.f.: | 4 kHz |

A block diagram of the proposed transmitter is shown in Figure 2. It includes:

- driver and preamplifier rack
- set of racks for distributing and protecting the main power supply
- a set of regulated high voltage (120 kV, 6A) power supplies
- a 100 μF capacitor bank
- a crow bar with trigger for discharging the capacitor bank
- a 28 kΩ resistor tank
- a 50 kΩ resistor tank
- a tank containing the anode modulator of the klystron
- a tank containing the klystron filament supply and the housing for the klystron
- regulated power supply for klystron focusing
- power supply for the klystron getter pump
- lead shield for personnel protection
- a console for manual control of transmitter
- a set of high voltage connections
- water-water and water-oil cooling system.

One should specifically note that the price quoted does not include the klystrons and the modulator tubes. Also excluded is the transmit-receive switch. A separate price quotation is given at the end of this section.

The price includes design, construction, testing, packaging, insurance, transportation, assembling the transmitter at the final location and starting of the transmitter operating according to specifications. Also included is documentation, status reports every three months and a detailed report at the outset of the final testing stage. Break-down of price estimates in French Francs, excluding tax, is as follows:

| | |
|---|---|
| engineering studies: | 5,350,167.6 |
| construction/test at plant: | 12,084,414.0 |
| transportation, assembly, site tests: | 1,285,418.4 |
| (3,370,428.-) | 18,720,000.0 |

The set of tubes which was excluded is to be bought in the US at the following price, in French Francs:

| | |
|---|---|
| 2 klystrons, Varian VA 862 C | 1,272,800.- (229,160.-) |
| 4 triodes, Machlett ML 8548 | 1,453,300.- (261,658.-) |

Total price for transmitter, including tubes but excluding receiver protective circuitry becomes:

22. MFF (3,953,772.-)

Interfaces which must be available on site are:

buildings, $400m^2$ floor area, about half with 7 m ceiling and handling equipment - 5 tons overhead travelling crane

electric power: 380 V $\pm$ 10%, 50 Hz, 3 phase at 1000 kVA

cooling water, filtered, input pressure $\geq$ 10 bars, input temperature $5^o < T < 15^o$ C, rate 150 $m^3h^{-1}$

computer interface, standard frequency, timing at modulation, logic signals to identify frequency and phase

output RF flange to be connected to protective duplexing device.

An informal quotation for a transmit-receive switching device has been obtained from Westinghouse Electric Corporation, Baltimore, Md 21203, dated April 11th, 1974. Price for one complete unit involving three pin diodes in corrugated waveguide preceded by a plasma limiter and for control and fail-safe circuitry is quoted at:

US \$ 78,500.- (65,417.-)

## 2.2 THE UHF RADAR ANTENNA

The gain of the transmitter antenna was specified to 52 db in accordance with RRc. The cost of the required 2000 $m^2$ aperture reflector can be limited by keeping the curvature of the reflector as low as possible. In the design to be specified below the fixed reflector surface can be maintained nearly horizontally and the individual reflector panels can be supported by prefabricated, light-weight galvanized steel columns and trusses. A heating system will have to be included to prevent snow accumulation on the panels. The application of wire-mesh reflector panels with electric heating of the wires themselves will allow the passage of snowflakes through the open areas without total melting. A heating capacity of 100 W per $m^2$ should then be sufficient. This amount of power is readily available from the transmitter power supply.

The configuration of the transmitting antenna is such that the antenna beam points about $10^o$ south of zenith, approximately along the geomagnetic field at F-region heights.

A long focus, asymmetric paraboloid with limited curvature is placed near the ground level. A feedhorn in Cassegrain configuration illuminates the subreflector which is suspended from a 40 m high tripod arrangement as shown in Figure 3. The feedhorn can be placed in the immediate vicinity of the transmitter building, thus avoiding losses in long waveguides.

The electrical specifications of the antenna are given in Table 2.1.

Table 2.1 Electrical characteristics of transmitting antenna.

| | |
|---|---|
| Effective aperture: | 47 m diameter |
| Main reflector diameter: | 50 m |
| Frequency: | 960 $\pm$ 10 MHz |
| Gain: | 52 db |
| Aperture efficiency: | 65% |
| Peak power: | 5 MW |
| Mean power: | 500 kW |
| Main beam (3 db) | $0.4^{\circ}$ |
| Sidelobes - coma: | - 20 db |
| - northern horizon: | - 50 db |
| Pointing direction: | $10^{\circ}$ S. from zenith |
| Adjustment - all directions: | $0.5^{\circ}$ |
| Surface accuracy: | 3 mm r.m.s. |
| Polarization - Transmitting: | L or R circular linear |
| - Receiving: | R or L circular linear, adjustable |

The diameter of the reflector will be 50 m and the f/D ratio = 0.7. The expected surface r.m.s. error is 3 mm with a gain loss of only 1 db. The shadowing caused by tripod and subreflector in this symmetric configuration will be small, amounting to only 0.3 db.

The cost of the transmitter antenna has been estimated by Dr. Hooghoudt, consultant to M.P.G. as follows:-

| | | Unit price | Total |
|---|---|---|---|
| 2,2000 $m^2$ | wiremesh reflector panels | DM 350.- per $m^2$ | 770,000.- |
| | transport and mounting | | 30,000.- |
| 50 tons | lightweight steel structure beams, girders, columns | 3.- per kg. | 150,000.- |
| 250 kW | electrical heating 5 transformers 50 kW | 15,000.- | 75,000.- |
| | cabling | | 25,000.- |
| | tripod with 3 masts | 5,000.- | 15,000.- |
| | subreflector 4-5 m Ø | 2,500.- per $m^2$ | 50,000.- |
| | remote positioning controls | | 20,000.- |
| | feedhorn, polarizers, diplexers, etc. | | 300,000.- |
| | antenna model testing | | 100,000.- |
| | construction, design and supervising 15% | | 200,000.- |
| | | Total costs | DM 1,735,000.- |

Not included:

site preparation - drainage
columns foundation blocks (100)
tripod foundation
transmitter building (see 2.7.3)
main power supply (see 2.7.3)
testpanels
taxes, custom duties

Consultations with a possible industrial vendor, M.A.N. has indicated that the price should be increased by possibly as much as 20%. This should place the price of the transmitter antenna, with the exclusions indicated, at :

DM 2,082,000.- (727,641.-)

An additional cost for the concrete foundations was estimated by Dr. Hooghoudt to be:

DM 100,000.- ( 34,949.-)

2.3.1 The UHF receivers at Kiruna and Sodankylä

The UHF receivers are to operate on two separate antennas at each site each with dual feeds. At each site this will require low noise preamplifiers, one for each feed system. At times pairs of receivers from either antenna must work in parallel for maximum gain, at other times all four channels must work independently. Frequency hopping of the transmitter is contemplated. The frequency of the receivers at these two sites must, therefore, be capable of rapid retuning under computer control. The frequency hopping will occur within a narrow band compared to the bandwidth of the preamplifiers since these must be wide enough to also accommodate the plasma lines which may be displaced by $\pm$ 10 MHz from the transmitter frequency.

It should suffice to have four complete receivers at each receiving site. Figure 4 shows a diagram of a single receiver. When pairs of receivers are used in parallel the combination into a pair would occur manually at the input of the first filter in the main building. The adjustment of frequency to account for the frequency hopping would take place in the mixer bringing the signal frequency from 100 MHz to 5 MHz. The appropriate local oscillator frequencies would be available from frequency synthesizers and the switching between them would occur under the control of the radar controller, see section 2.5 for frequency and time control system and section 2.6 for radar controller. It should be observed that all the frequencies used in the four receivers at each site would be identical so that only one set of frequency synthesizers need be included at each site.

Temperature monitoring is necessary at a number of points in the receiving system, such as at the paramp klystrons, the local oscillators, the encoders, the frequency standard etc.

The following price estimates are quoted without customs duty and VAT as of March 1974. Prices in Swedish kr. :

| | |
|---|---|
| Uncooled paramps AIL 35° (Alternative I) | |
| 8 for both sites together, each 60,000.- | 480,000.- |
| per site | 240,000.- |
| Cooled paramps AIL 20° (Alternative II) | |
| for both sites, 4 pr. ca. 240,000.- | 960,000.- |
| per site | 480,000.- |
| Receiver channel to second mixer excluding paramps, each 40,000.- per site | 160,000.- |
| Receiver from second mixer to A/D, each 10,000.- 4 per receiver site | 40,000.- |
| Temperature monitoring | 20,000.- |
| Spare parts | 25,000.- |
| Spectrum monitor AIL 707 | 75,000.- |
| Laboratory instrumentation, including tools | 260,000.- |

Total cost of receivers including spare parts and test instrumentation, but excluding time and frequency generation equipment, (see section 2.6)

| Alternative I | Alternative II |
|---|---|
| per site | per site |
| 820,000.- (149,066.-) | 1,060,000.- (192,695.-) |

2.3.2 The UHF receiver at radar site (Tromsø)

The receiver at the transmitting site will be basically the same as at the receiving sites. It will, however, only be possible to make use of a single receiver channel up to the power divider (see Figure 4). Here all the different frequencies in a frequency hopping experiment will be simultaneously present and the second mixer and everything following must be present eight-fold. Temperature monitoring for receiver purposes will be reduced in complexity, but spare parts and laboratory instrumentation will be the same as at Kiruna and Sodankylä. Prices in Sw. kr. as in the previous section:

| | |
|---|---|
| Uncooled paramp AIL 35$^o$ (Alternative I) | |
| 2 (one spare), each 60,000.- | 120,000.- |
| | |
| Cooled paramp AIL 20$^o$ (Alternative II) | |
| one pair (one channel spare) | 240,000.- |
| Receiver channel to second mixer | |
| excluding paramps, each 40,000.- | 40,000.- |
| Temperature monitoring | 12,000.- |
| Receivers from second mixer to A/D | |
| 10 channels, each 10,000.- | 100,000.- |
| Spare parts | 25,000.- |
| Spectrum monitor AIL 707 | 75,000.- |
| Laboratory instrumentation | 260,000.- |

Total cost of receiver at transmitter site including spare parts and test instruments, but excluding time and frequency generation instrumentation, (see 2.5).

| Alternative I | | Alternative II | |
|---|---|---|---|
| 632,000.- | (114,909.-) | 752,000.- | (136,727) |

## 2.4 THE UHF RECEIVING ANTENNAS

For each receiving station 2 identical 25 m paraboloid reflectors, steerable in one scanning direction, have been planned. A twin Cassegrain feedhorn, either a diverting or a refocussing type, will produce 2 beams, each 1$^o$ off-set from the paraboloid axis, therefore, giving a 2$^o$ height separation.

The following observational combinations may be realized at each section:

1. Height correlation - simultaneous observation with double beams at 2 different heights.
2. Height detailing - simultaneous observations with 4 beams at 1-2$^o$ intervals at adjacent heights.
3. Enlarged sensitivity - combining the corresponding beams of the 2 antennas at the same height an improvement of $\sqrt{2}$ in sensitivity is obtained (i.e. equivalent aperture 35 m).

If the feedhorns are equipped with both left and right hand circular polarizers, it will be possible to receive all linear polarization angles at 2 different heights.

The antenna specifications are summarized in Table 2.2. Figure 5 shows the basic antenna design. This antenna design is a replica of the type built for the Netherlands Synthesis Radio Telescope at Westerbork. The twelve radiotelescopes there have been in satisfactory operation at 1420 MHz for 7 years. Two more are presently being added.

Table 2.2. Characteristics of the UHF receiving antennas

| | | |
|---|---|---|
| Main reflector diameter - aperture: | 25 m | |
| Frequency: | 933 $\pm$ 10 MHz | |
| Gain | 46 db | |
| Aperture efficiency: | 70% | |
| Power: | mW | |
| Main beams (3 db): | double - 0.8$^\circ$each | |
| Beam separation: | 2$^\circ$ in height | |
| Sidelobes: | -15 db | |
| Polarization: | L and R circular | |
| | linear, adjustable | |
| Sites | Kiruna | Sodankylä |
| Scanning range | | |
| Height: | 10-75$^\circ$min. | 24-84$^\circ$ min. |
| Adjustment: | 0.5$^\circ$ | 0.5$^\circ$ |
| Temperature range: | -40 to + 30$^\circ$ C | |
| Wind velocity - operational: | 20 m/sec (72 km/h) | |
| survival: | 33 m/sec (120 km/h) | |
| Snow accumulation: | max. 100 cm. at ground level. | |

The cost of constructing these antennas has been estimated by the designer, Dr. Hooghoudt, consultant to M.P.G. as follows:-

| | | Unit price | Total |
|---|---|---|---|
| 550 $m^2$ | wiremesh reflector panels | DM 500.- per $m^2$ | 275,000.- |
| 10 tons | reflector support structure | 15.- per kg | 150,000.- |
| 50 tons | tower structure | 10.- per kg | 500,000.- |
| | quadripod and subreflector | | 35,000.- |
| | bearings and drive system | | 90,000.- |
| | serve control - scanning angle resolver | | 40,000.- |
| | LNA cabin, 2 $m^3$ | | 20,000.- |
| | transport, erection, measuring | | 190,000.- |
| | painting | | 30,000.- |
| 2 | feedhorns, polarizers | 60,000.- | 120,000.- |
| | antenna model testing | 1/4 part | 20,000.- |
| | construction, design and supervision 7.5% | 1/4 part | 110,000.- |
| | | 1 antenna: | 1,580,000,- |
| | Total cost | 4 antennas: DM | 6,320,000.- |

Not included:

site preparation
concrete foundation
low noise amplifiers (LNA) (see 2.3.1)
heating of reflector panels
receiver building (see 2.7)
main power supply
taxes, custom duties

Consultations with M.A.N., a possible manufacturer, indicate that 20% should be added to these prices. The estimated cost for the four receiving antennas, therefore, amounts to:

DM 7,584,000.- (2,650,543.-)

In addition Dr. Hooghoudt estimates that the concrete foundations of the two receiver sites will amount to:

DM 200,000.- (69,898.-)

## 2.5 FREQUENCY AND TIME SYSTEM

In order to measure velocities accurately a relative frequency uncertainty of $10^{-8}$ is sufficient. In order to synchronize the transmitters and the receivers time must be measured to an accuracy of 1 µsec. Three alternative time-keeping systems have been considered. Alternative I involves a highly stable crystal oscillator synchronized at the three sites by means of Loran-C. However, the distance from the closest Loran-C slave at Bø in Vesterålen is too great for reliable reception at Sodankylä. The work involved in keeping such systems in synchronism to within 1 µsec is also excessive. Alternative II involves an Rb-oscillator synchronized by Loran-C and by TV signals. Again there is a lack of good Loran-C signals at Sodankylä which makes this alternative not attractive. TV channel synch pulses will jump as a result of rerouting and cannot be blindly relied upon. Alternative III which was chosen, involves a Cs-standard at each site plus a travelling standard. In addition TV synch pulses will be monitored. This system should keep time with adequate accuracy and it should only be necessary to perform calibrations with a travelling clock once every two or three months.

Purchase prices are:

| | |
|---|---|
| Cs standard HP 5061 A | Sw. kr. 110,000.- |
| Clock option 001 | 10,400.- |
| Standby power 002 | 4,200.- |
| One third of portable standard | 41,400.- |
| TV synch receiver | 4,000.- |

Total price for clock and timing system for each site

Sw. kr. 170,000.- (30,904.-)

The various local oscillator frequencies are generated from the standard by synthesizers, multiplers and locked oscillators as shown in Figure 6. Prices in Sw. kr., excluding taxes:

| | |
|---|---|
| Distribution amplifier HP 5087A (2) | 19,000.- |
| Frequency synthesizers HP 3320A (12) | 140,000.- |
| Phase locked oscillators 1033 and 833 MHz | 19,000.- |
| Frequency multipliers | 22,000.- |

Total price for frequency synthesis system at each site:

Sw. kr. 200,000.- (36,357.-)

In all the frequency and time keeping system for each site will amount to:

Sw. kr. 370,000.- (67,261.-)

## 2.6 COMPUTER, DATA RECORDING AND CONTROL SYSTEM

In order to extract the available data from the system it is necessary to perform special types of data handling operations at extremely high speeds. In addition a computer system is required to control the radar system and to monitor its performance. Real time data analyses of similar type must take place at all the observing sites. The data handling and control problem at the transmitter site is more severe than at the receiver sites. The following general ground rules serve as guide-lines for the design of a computer facility for the radar system.

1. The system must be of modular construction so that advantage may be taken of future hardware improvements by replacing modules.

2. The pre-processing and partial integration of the data must proceed in real time.

3. It is to be preferred that all pertinent radar data, time information and integrated data be recorded on a single magnetic tape at one of the observing stations. This requires that the receiving stations are connected to the transmitting station by means of telephone lines.

4. The final extraction of physical parametres from the integrated data tapes should occur at general purpose computing facilitites, now in existence at either of the three observatories. Tape compatibility is, therefore, important.

The basic philosophy which should govern the real time data handling is that the incoming signals be decoded in analog fashion where coded pulses are used, then digitized and passed to a modular memory capable of accepting data into one half whilst a correlator device can operate on the other half, simultaneously and asynchronously, at a complex sample rate of 250 kHz. The correlator should have a distributed memory system with a number of multipliers permitting operating in parallel and the transfer of data to different memory modules in parallel.

At the end of an integration interval the contents of the memory modules are passed to a data processing computer which also accepts similar inputs from the remote receiving sites. In this computer the data is rearranged, combined, weighted and properly formatted. Radar information, timing etc. is also accepted by this computer and written on magnetic tape together with the pre-processed data from the three sites. It is assumed that pre-processed data is exchanged between stations by telephone lines, see Figure 1

A price estimate for a data handling and control system has been obtained from Norsk Data Industri, dated February 22nd, 1974.

The block diagram for the proposed system is shown in Figure 7. The main components are as follows:

Master control
Radar controller
Correlator unit
Data handling and editing computer unit
Communication buffer and control
Memory

Micro computer units of standard type are utilized for data handling, editing, communication and control. The correlator unit is of special design. For the standard micro computer units the INTELLEC 8 modules will be used enabling the programming to be carried out in the high level language PL/M. The data transmission between the units is either in series asynchronous transmission with a speed of 9600 baud or in parallel fashion. The data handling and editing computer will, however, have direct access to the correlator memory as well as to the communication buffer/control disc file under the administration of the master control computer unit.

The data path may be described as follows:-

The digitized data will be temporarily stored in the input memory half of which can be filled at the same time as the correlator operates on the other half.

The correlator module will under control of the master control computer unit deliver its results to a 4 kbyte buffer memory from where the data handling and editing computer unit will pick up data, buffering the data in a 16 kbyte memory and on a disc file of a 1/4 mbyte for ultimately storing the data on a magnetic tape unit. The data is further transmitted to the communication buffer and control computer unit where the external direct on-line communication of the data is controlled.

The master control computer unit sets up all the output data paths and does a total supervision over the experiment. Under the experiment the units are working asynchronously and in parallel and it is possible on-line to change the parametres or the type of experiment performed based on the information on the oscilloscope or a graphical monitor. This interactivity during the experimental phase will enable one very quickly to adjust the data processing according to the information received. The system as shown in Figure 7 is modular and can be implemented gradually by starting with the correlator unit, continuing with the communication buffer and control unit, finally adding the master control unit to complete a fully interactive system.

The price estimate, given in N. kr. with VAT included is as follows:

Correlator unit

| | | |
|---|---|---|
| Input interface | 10,000.- | |
| Eight multiplexing multiplication units | 160,000.- | |
| 4 k 32 bits memory | 40,000.- | |
| Control output interface | 16,000.- | |
| Power supply, rack and cabling | 10,000.- | |
| Development costs (1/3 for each site) | 200,000.- | |
| Sum for correlator unit | 436,000.- | (63,451.-) |

Data handling editing computing unit

| | | |
|---|---|---|
| CPU I/O 16 kbytes memory | 60,000.- | |
| Disc file 1/4 mbytes | 40,000.- | |
| Magnetic tape recorder with interface | 300,000.- | |
| Monitor display unit with interface | 60,000.- | |
| Sum for data handling editing computing unit | 460,000.- | (66,944.-) |

Communication control and buffer unit

| | | |
|---|---|---|
| CPU I/O 8 kbyte memory | 34,000.- | |
| Disc file 1/4 mbyte | 40,000.- | |
| Modem interface | 20,000.- | |
| Sum for communication control and buffer unit | 94,000.- | (13,680.-) |

Master control computer unit

| | | |
|---|---|---|
| CPU I/O 8 kbyte memory | 34,000.- | |
| Teletype tape reader with interface | 40,000.- | |
| Disc file 1/4 mbyte | 40,000.- | |
| Power supply, wiring and racks | 10,000.- | |
| Sum for master control computer unit | 124,000.- | (18,047.-) |

| | | |
|---|---|---|
| Radar controller | 100,000.- | (14,553.-) |
| Total price | N.kr 1,214,000.- | (176,673.-) |

The price for the magnetic tape recorder and the radar controller are both uncertain due to uncertainty in specifications. Some of these can only be arrived at after the design of other items such as receivers and transmitters have become firmer. The price for modem installation, to allow communication between sites is:

Modem installation (4800 bits/sec) = 37,000.-(5,385.-)

Rental of telephone lines for data transfer is included under operating costs, see below.

The delivery time for the data processing equipment will not be a controlling factor in the installation. The systems will be nearly identical at the three sites.

Total price for data handling and control system investment per site:

N. kr. 1,251,000.- (182,058.-)

## 2.7 BUILDINGS, SITE DEVELOPMENT, POWER

At the transmitter site near Tromsø the cost of the building for the receivers, the data processing equipment and the scientists quarters appears to be well defined. The building which must house the UHF and the VHF transmitters can only be approximately defined due to some lack of technical specifications. Only the buildings required for the UHF transmitter is included in the following estimates.

### 2.7.1 Receiving site near Kiruna

A preliminary design for a building with an area of 175 $m^2$ is available. This building will be placed near Aptasvaara in order to make use of some natural shielding to the north. This increases cost for road and electric power, but provides an extra margin of safety against clutter problems.

The price summary for the receiver site estimated in Sw. kr. may be broken down as follows:

| | | | |
|---|---|---|---|
| Building (175 $m^2$) | | 35,000.- | (350,000 |
| Power line | | 120,000.- | |
| Signal cable to Kiruna Geophys. Inst. | | 100,000.- | |
| Road | | 250,000.- | |
| Consultants cost 12.5% | | 103,000.- | |
| Internal fittings and misc. | | | |
| Furniture in offices, kitchen and labs. | 10,000.- | | |
| Equipment racks | 8,000.- | | |
| Signal and manoeuvering cables | 30,000.- | | |
| Intercom telephone system | 9,000.- | 75,000.- | |
| (178,152.-) | Sw. kr. | 980,000.- | |

Building during the winter increases the cost by about 80,000.- (14,543.-)

It will be assumed that the signal cable to Kiruna Geophysical Institute can also carry telephone traffic so that the cost connecting the telephone will be minimal.

2.7.2 Receiving site near Sodankylä

The rooms needed for EISCAT equipment will be found in the existing ionospheric station. The total floor area of the house is 180 $m^2$ and practically all can be made available for EISCAT equipment. Investment cost in receiver building is estimated as follows:-

| | | |
|---|---|---|
| Building | Sw. kr. | 350,000.- |
| Power line | | 50,000.- |
| Road | | 50,000.- |
| Furniture | | 10,000.- |
| Intercom telephone | | 5,000.- |
| Racks/cables | | 38,000.- |
| | | 503,000.- |

In addition a building must be constructed to house EISCAT personnel since it would be impractical for them to live in Sodankylä proper. The cost of this building would be:

Sw. kr. 580,000.-

Total capital costs for buildings, room, roads etc. at Sodankylä:

Sw. kr. 1,080,000.- (196,364.-)

2.7.3 Radar site near Tromsø

The building for the receivers, data processing, offices, sleeping accommodation is planned to contain an operations room (70 $m^2$), laboratory (30 $m^2$), six small offices, stock room, lecture room (30 $m^2$), kitchen and lounge (35 $m^2$) and four bedrooms (40 $m^2$). The total floor space will amount to 400 $m^2$.

Cost of receiver building N. kr. 680,000.- (98,960.-). Included is electrical installation, heating and plumbing.

For the transmitter building a price estimate is available for a building with a floor space of 250 $m^2$ with 5 m ceiling height over an area of 150 $m^2$. The requirement of Thomson - CSF for the UHF transmitter amounts to 315 $m^2$ of which 180 $m^2$ should be with a ceiling of 7 m. The originally planned building was estimated at N.kr.850,000.- If the price is increased in proportion to the increased floor space the transmitter building will cost N. kr. 1,071,000.- (155,862.-). Included in this price is heavy electrical installation and cranes in the operations room.

Additional site expenses (N. kr.):

| | |
|---|---|
| Road (660 m. including drainage) | 120,000.- |
| Parking space (400 $m^2$) | 16,000.- |
| Water supply (650 l/h) | 50,600.- |
| Drainage and sewage system | 32,400.- |
| Fencing | 23,000.- |

| | | |
|---|---|---|
| Total for civil work excluding tax and fees | | 2,058,000.- |
| Consultants fees 8% | | 164,640.- |
| | | 2,222,640.- |
| 20% VAT | | 444,528.- |
| Total for buildings, roads, water supplies | N. kr. | 2,667,168.-(388,152.-) |

Recent discussions with the power company show that we shall have to build a new transformer station to tap the 132 kV line in the area. Power company estimates place the price of such a transformer station at N.kr.2,500,000.- which is prohibitively expensive. As an alternative we have considered a system involving diesel generators in order to cut capital costs. Running costs, however, will then be increased by 30%. Installation expenses will amount to:

| | | |
|---|---|---|
| 3 diesel generators 242 kVA each including controls for starting and phasing | N. kr. | 465,000.- |
| Building | | 90,000.- |
| Transformer to tap 22 kV + lines | | 48,000.- |
| | N. kr. | 603,000.-(87,754.-) |

Miscellaneous:

| | | |
|---|---|---|
| Vehicles, car and pickup truck | | 80,000.- |
| Telephone connecting cable | | 15,000.- |
| Total | N. kr. | 95,000.-(13,825.-) |

Summary of capital site expenditure at radar location - excluding antenna work and space for the VHF transmitter:

| | |
|---|---|
| Buildings, roads, water | N. kr. 2,667,168.- |
| Power supplies | 603,000.- |
| Miscellaneous | 95,000.- |
| Total site costs | N. kr. 3,365,168.- |
| | (489,732.-) |

## 2.8 SUMMARY OF CAPITAL COSTS

| | |
|---|---|
| Transmitter | 3,953,772.- |
| TR device | 65,417.- |
| Transmitter antenna + foundation | 762,590.- |
| Receivers at two receiving sites | 385,390.- |
| Receiver at transm. site | 136,727.- |
| Receiving antennas + foundation | 2,720,441.- |
| Frequency and time, three sites | 201,783.- |
| Computer system | 546,174.- |
| Kiruna site | 192,695.- |
| Sodankylä site | 196,364.- |
| Tromsø | 489,732.- |
| Total capital cost UHF (EAU) | 9,651,085.- |

## 3. OPERATION OF THE OBSERVATORY, OPERATING COSTS

The mode of operation of the EISCAT organization is described in the Draft Agreement between C.N.R.S., M.P.G., N.A.V.F., N.F.R. and S.A.. An administrative council of 12 is to act as a legislative body which is to meet at least twice annually to consider technical and administrative tasks. The distribution of the membership of the council is defined in the Draft Agreement. A scientific advisory committee is to consider scientific and technical questions concerning the operation of the observatory and is to advise the council on such matters.

The administrative council is to appoint a director charged with the day to day operation of the observatory. The council also appoints two assistant directors. One in charge of scientific affairs to reside preferably at the headquarters in Kiruna - the other in charge of technical matters, to reside by preference in Tromsø.

It is considered that the most practical way of operating the facility is to create a small executive organization in Kiruna. This executive organization which includes the director and the two assistant directors is to be responsible to the administrative council only. The executive organization will operate EISCAT through a system of subcontractors: these being the University of Tromsø, The Geophysical Institute in Kiruna and The Geophysical Institute in Sodankylä, or in the latter two cases, the parent organization of these institutes.

## 3.1. STRUCTURE OF THE EISCAT EXECUTIVE ORGANIZATION

The executive organization is to be responsible for the execution of the policy defined by the administrative council. The executive organization should prepare budgetary proposals and make the councillors aware of new developments which might require special action. The executives of the organization should report on observatory activity during council meetings. The executive organization should also oversee the activity of the sub-contractors but should in no way enter into direct interaction with employees of the subcontractor unless this occurs with the specific approval of the subcontractor.

The EISCAT executive organization should preferably be established as a national Swedish organization, or if necessary as an international one. The larger items supplied to the organization might remain the property of EISCAT whereas smaller items purchased by the sub-contractors may remain the property of the subcontractor.

The EISCAT executive organization should include the following staff:

Director
Assistant director for technical matters
Assistant director for scientific matters
Business manager
Clerical staff
Programming staff

The responsibility of these staff members should be:

Director

Is directly responsible to the council for the operation. He should work out the annual budgets for presentation to the council and conduct research in accordance with guidelines established by the council. Included in the budget should be the subcontracts for the operation by the member observatories in Tromsø, Kiruna and Sodankylä. He should supervise the accounting and cost sharing between the various member organizations. He should also deal with fellowships, proposals and general policy matters. (position in Kiruna).

Assistant director for technical matters

Is responsible for the technical operation of the whole facility. He should be hired early to take part in transmitter, receiver and antenna construction in order to be completely familiar with the whole technical operation once the observatory starts regular operation. (mainly Tromsø).

Assistant director for scientific matters

Is responsible for the supervision of the scientific programs conducted by visitors and for routine observations. He should also receive scientific proposals and give comments on these to the scientific advisory committee. He must remain in close contact with the director for technical matters to ensure that scientific programmes can be realized with available equipment and software (Kiruna).

Business manager

Is responsible for personnel, contracting, purchasing, visitors and other business matters. (Kiruna).

Clerical staff

Must include 1 typist, a draftsman and possibly a clerk responsible for the filing of data and for responding to data requests from the outside. Both the draftsman and the data clerk may be hired by the subcontractor and "lent" to the organization. (Kiruna).

Programming staff

Should include three members initially but may be reduced to two after observatory operates normally. The head of the programming staff should be an EISCAT employee. The other two could be hired by subcontractor. (Kiruna).

## 3.2 SUBCONTRACTORS

### 3.2.1 Kiruna Geophysical Institute

As part of the subcontract with Kiruna Geophysical Institute the following staff should be supplied in addition to the personnel which is directly employed by the EISCAT organization:

| | |
|---|---|
| Programmers | (2) |
| Technicians (engineers) | (3) |

Service personnel for maintainance, cleaning, road clearing etc. must be supplied from the Institute staff on a part time basis.

### 3.2.2 Sodankylä Geophysical Observatory

Technical personnel should be the same as at Kiruna. However, since there will be no EISCAT personnel at Sodankylä a scientist must be attached to the contracting staff. No permanent programmers should be required.

### 3.2.3 University of Tromsø

As part of the subcontract with EISCAT the University of Tromsø should maintain the following staff in order to operate the UHF/VHF facility:

| | |
|---|---|
| Scientist | |
| Technicians, UHF/VHF radars | (6) |
| Computer maintainance | (1) |
| Caretaker | (1) |
| Secretary (part time) | |
| Mechanic (part time) | |

In addition the assistant director for technical matters will normally reside in Tromsø. One of the computer programmers might also spend part of his time in Tromsø, particularly during the construction phase of the observatory.

The responsibility of some of the staff in Tromsø might be:

Scientist

Is to be responsible for the quality of the data taken. It is often very difficult to sense a malfunction of the equipment unless one understands the physical situation which gives rise to the observational results. A person with scientific background should, therefore, be chosen to supervise data taking.

Technicians

The responsibility of the six technicians might be divided as follows:

1. Chief technician, responsible for the assignment of work
2. VHF transmitter/transmission lines/antenna
3. UHF transmitter/transmission lines/antenna
4. Time and frequency keeping
5. Receiver systems
6. Digital systems

In addition to these responsibilities the technicians must be prepared to attend the radar station as shift operators during the observing periods. All technicians, therefore, must know how to operate the complete radar system.

## 3.3 SALARY EXPENSES FOR THE OPERATION OF THE ORGANIZATION

For the EISCAT executive organization the salaries assumed to be in agreement with Swedish government pay scales. Salary expenses including 29% overhead will then amount to:

| | | | |
|---|---|---|---|
| Directors (3) | Sw. kr. | 220,400.- | |
| Business manager | | 62,880,- | |
| Programmer, senior | | 71,625.- | |
| Secretary | | 50,020.- | |
| Data clerk | | 54,080.- | |
| Total annual salaries EISCAT | Sw. kr. | 459,005.- | (83,441.-) |

7

The Kiruna subcontracting unit:

| | | |
|---|---|---|
| Programmer | 71,625.- | |
| Programmer, junior | 62,880.- | |
| Engineer | 78,570.- | |
| Technicians | 123,600.- | |
| Direct salaries, Kiruna subcontractor | 336,675.- | (61,203.-) |

5

There is a certain amount of part time labour required for maintenance, clerical help, drafting etc. which has not been specified by the subcontractor.

For the Sodankylä subcontracting unit:

| | | | |
|---|---|---|---|
| | Scientist | Sw. kr. | 62,280.- |
| | Scientific assistant | | 50,700.- |
| | Engineer | | 62,280.- |
| 6 1/2 | Technicians (2) | | 88,700.- |
| | Mechanic (part time) | | 28,150.- |
| | Secretary (part time) | | 15,150.- |
| | Caretaker (part time) | | 11,650.- |
| | Total direct salaries, Sodankylä | Sw.kr. | 318,910.- (57,984.-) |

For the Tromsø University subcontractor. Salaries are in N. kr. with the standard 33% overhead included.

| | | | |
|---|---|---|---|
| 1 | Scientist | | 99,750.- |
| 6 | Technicians/engineer (6) | | 383,040.- |
| 1 | Computer maintainance | | 59,850.- |
| 10 1 | Caretaker | | 53,200.- |
| 1/2 | Secretary (part time) | | 26,600.- |
| 1/2 | Mechanic (part time) | | 29,260.- |
| | Total direct salaries, Tromsø | N. kr. | 651,700.- (94,842.-) |

### 3.4 OPERATING EXPENSES

Whereas the salary expenses can be estimated relatively firmly other operating expenses are subject to large uncertainties. The following estimates are currently available.

Tromsø:

| | | |
|---|---|---|
| Tromsø, electricity, 4000 h | N. kr. | 200,000.- |
| Land lease | | 13,000.- |
| Road maintenance | | 6,500.- |
| Snow removal | | 30,000.- |
| Cleaning | | 32,000.- |
| Telephone | | 8,000.- |
| Line lease to Kiruna | | 75,000.- |
| Transportation, local | | 25,000.- |
| Building maintenance | | 15,000.- |
| Office equipment, stationary | | 20,000.- |
| Total Tromsø | N. kr. | 424,500.- (61,777.-) |

Kiruna subcontractor:

| | | |
|---|---|---|
| Electricity and heating | Sw. kr. | 10,000.- |
| Telephone | | 10,000.- |
| Data analysis 500 h at rate of 1000.- per h | | 500,000.- |
| Cleaning, snow removal, transportation | | 30,000.- |
| Land lease | | 5,000.- |
| Data link fee | | 60,000.- |
| Total Kiruna | Sw. kr. | 615,000.- (111,983.-) |

Sodankylä:

| | | |
|---|---|---|
| Spare parts | Sw. kr. | 10,000.- |
| Electricity | | 10,000.- |
| Telephone | | 10,000.- |
| Rent of offices | | 3,600.- |
| Heating of laboratory | | 6,000.- |
| Building maintenance | | 6,000.- |
| Cleaning | | 6,000.- |
| Line lease to Kiruna | | 75,000.- |
| Transportation and travel | | 60,000.- |
| Total Sodankylä, | Sw. kr. | 186,600.- (33,927.-) |

EISCAT executive organization:

| | | | |
|---|---|---|---|
| Rent | Sw. kr. | 50,000.- | |
| Telephone | | 30,000.- | |
| Office supplies, books etc. | | 40,000.- | |
| Cleaning, transportation | | 10,000.- | |
| Travel for councillors, advisors and employees | | 150,000.- | |
| Mag tapes, 150 per year | | 40,000.- | |
| UHF transm. tubes 1 per three years | | 212,000.- | |
| Modulators tubes 1 per year | | 320,000.- | |
| Purchase of components, spare parts and replacements | | 100,000.- | |
| Total EISCAT executive organization | | 952,000.- | (173,246.-) |

3.5 SUMMARY OF OPERATING COSTS

Annual operating costs:

| | | | |
|---|---|---|---|
| EISCAT, salaries | 83,441.- | | |
| Kiruna, salaries | 61,203.- | | |
| Sodankylä, salaries | 57,984.- | | |
| Tromsø, salaries | 94,842.- | 297470 [illegible] 44% | |
| EISCAT, running | 173,246.- | | |
| Kiruna | 111,983.- | | |
| Sodankylä | 33,927.- | | |
| Tromsø | 61,777.- | 380933 | 56% |
| Total operating costs (EAU) | 678,403.- | 3730 | |

## 4.0 THE CONSTRUCTION PHASE

The detailed planning of the construction phase of the observatory is made difficult by the lack of detailed time tables for most of the major hardware items. It is fortunate that the single major item which almost certainly has the longest delivery time - the transmitter - has been the subject of a detailed study by Thomson-CSF. Thus a plan for the progress of the construction and installation of the transmitter is available as displayed in Figure 8. The rate of progress shown depends on the funds being granted over a three year period. A faster allotment of funds could decrease the delivery time by some six months.

As similar development plans are not available for other major parts of the equipment, all that can be done at present is to determine at what time these items must be ready in order not to become the controlling factors in making the facility operational. The same applies for the employment of personnel. The staff should be gradually built up to supervise and accept the equipment as it becomes ready.

Figure 9 shows the development of major parts and their suggested time of readiness. Included in this table it will be noted, is the software development which must be started early since it often is the cause of unexpected delays.

Figure 10 shows the build-up of the staff during the construction phase. It is envisaged that the administrative council once formed appoints the director and the assistant director of technical matters. These two, together with the technical working group, are charged with the supervision of the awarding of contracts for the transmitter, the antennas and the data analysis equipment. About six months after commencement technicians are employed by the subcontractors to oversee the design and construction of the buildings. The full complement of technicians at Kiruna is explained by the fact that this group will assemble the receivers for all sites. The remainder of Figure 10 should require no further explanation particularly since the employment dates are uncertain as already indicated.

References:

Daveau, B.,

"Sondeur ionospherique auroral (UHF)", Thomson CSF Bagneux (1971) Reference Report 3.

Du Castel, F., Holt, O., Hultquist, B., Kohl, H., and Tiuri, M., "Proposal for A European Incoherent Scatter Facility in the Auroral Zone", Tromsø, June 1971.

Evans, J.V., "Post-War Developments in Ground-Based Radio Wave Sounding", Submitted to J. Atmos. Terr. Phys. (1974).

Hooghoudt, B.G., "UHF Transmitting Antenna, UHF Receiving Antennas", Max Planck Institute for Aeronomy, Lindau/Harz, April (1974)

Svennerus, G., "The UHF Transmitter Antenna", Res. Inst. of National Defence, Stockholm (1971).

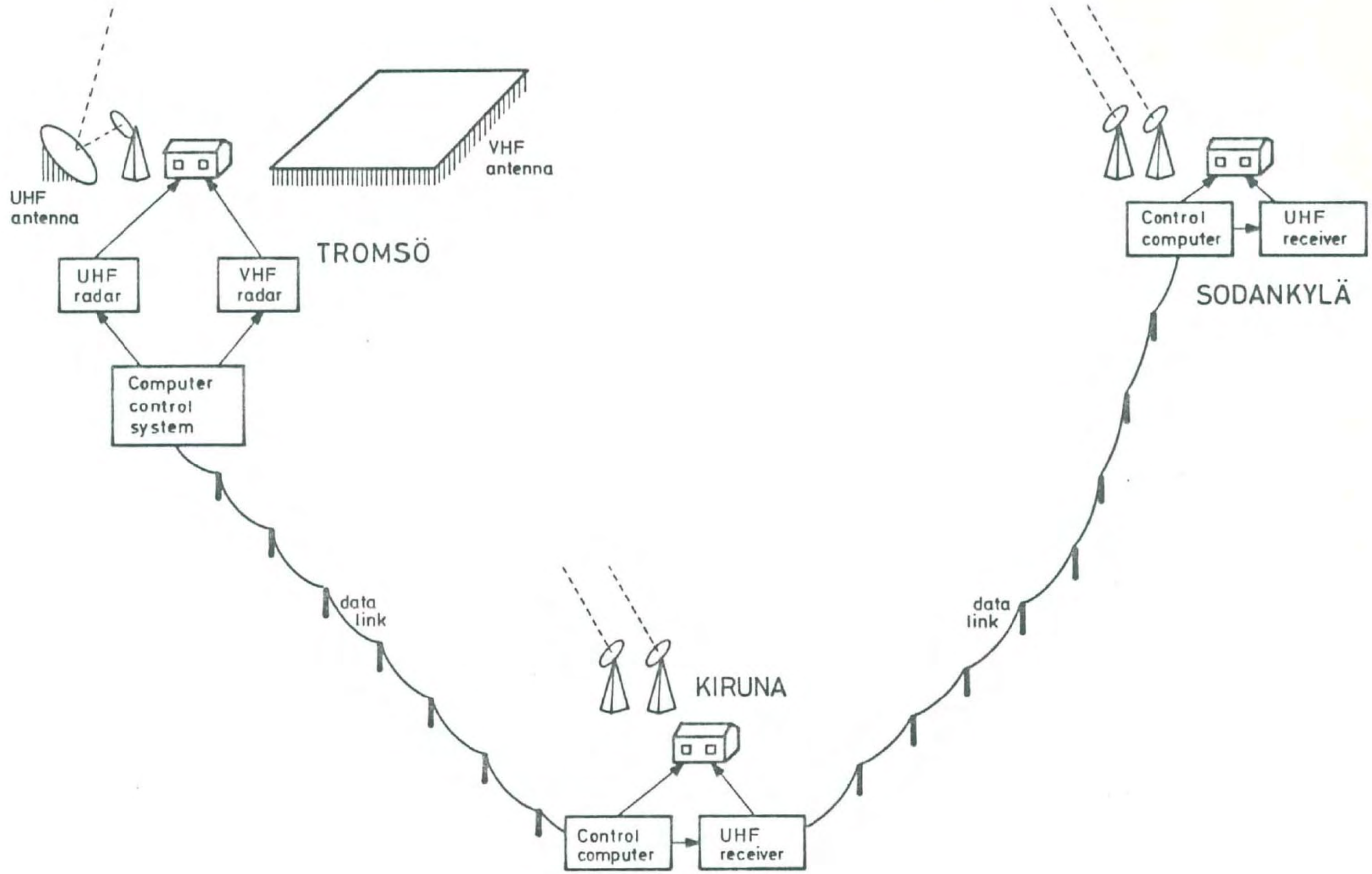



Fig. 1. Overall System

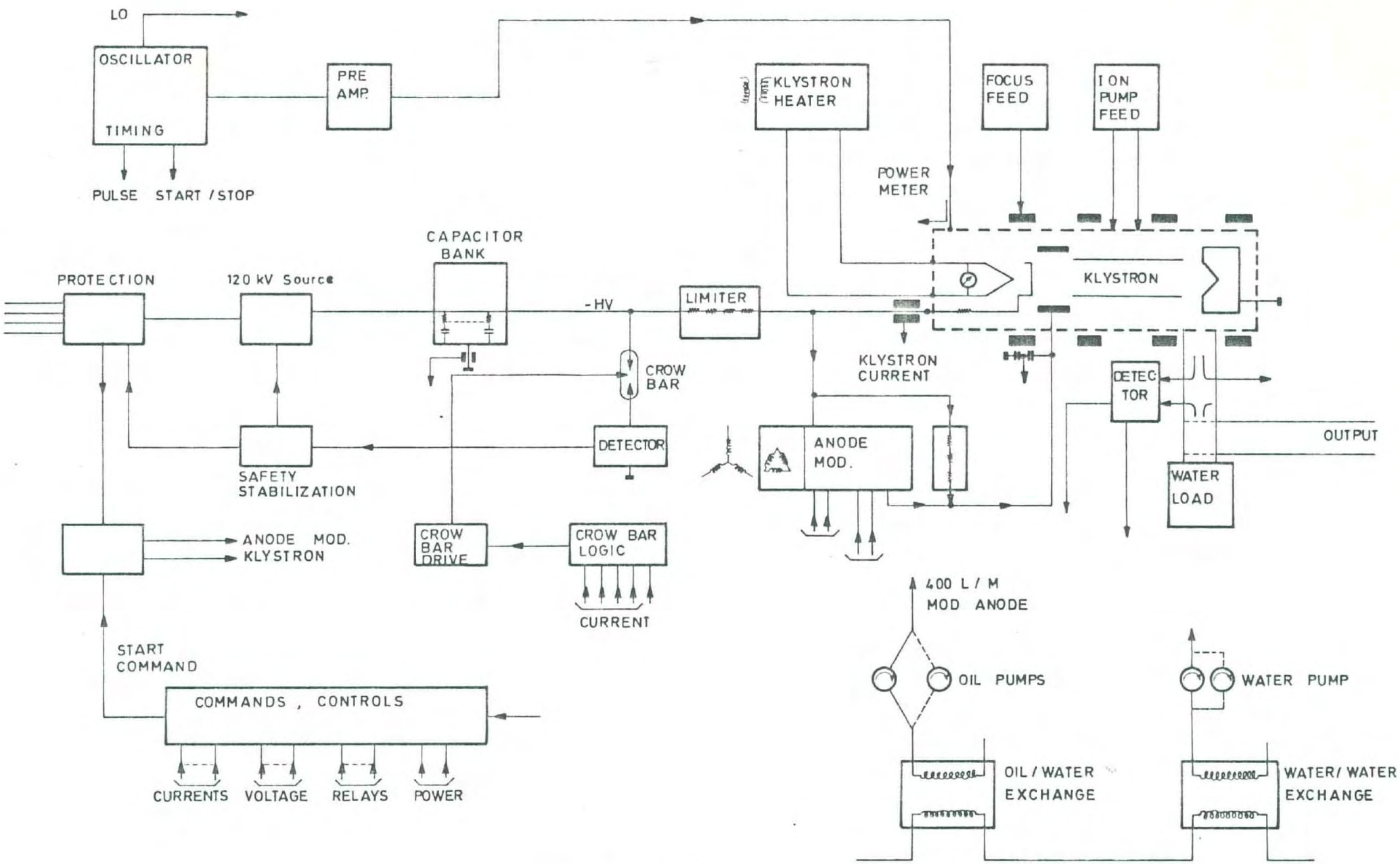



Fig. 2. UHF transmitter

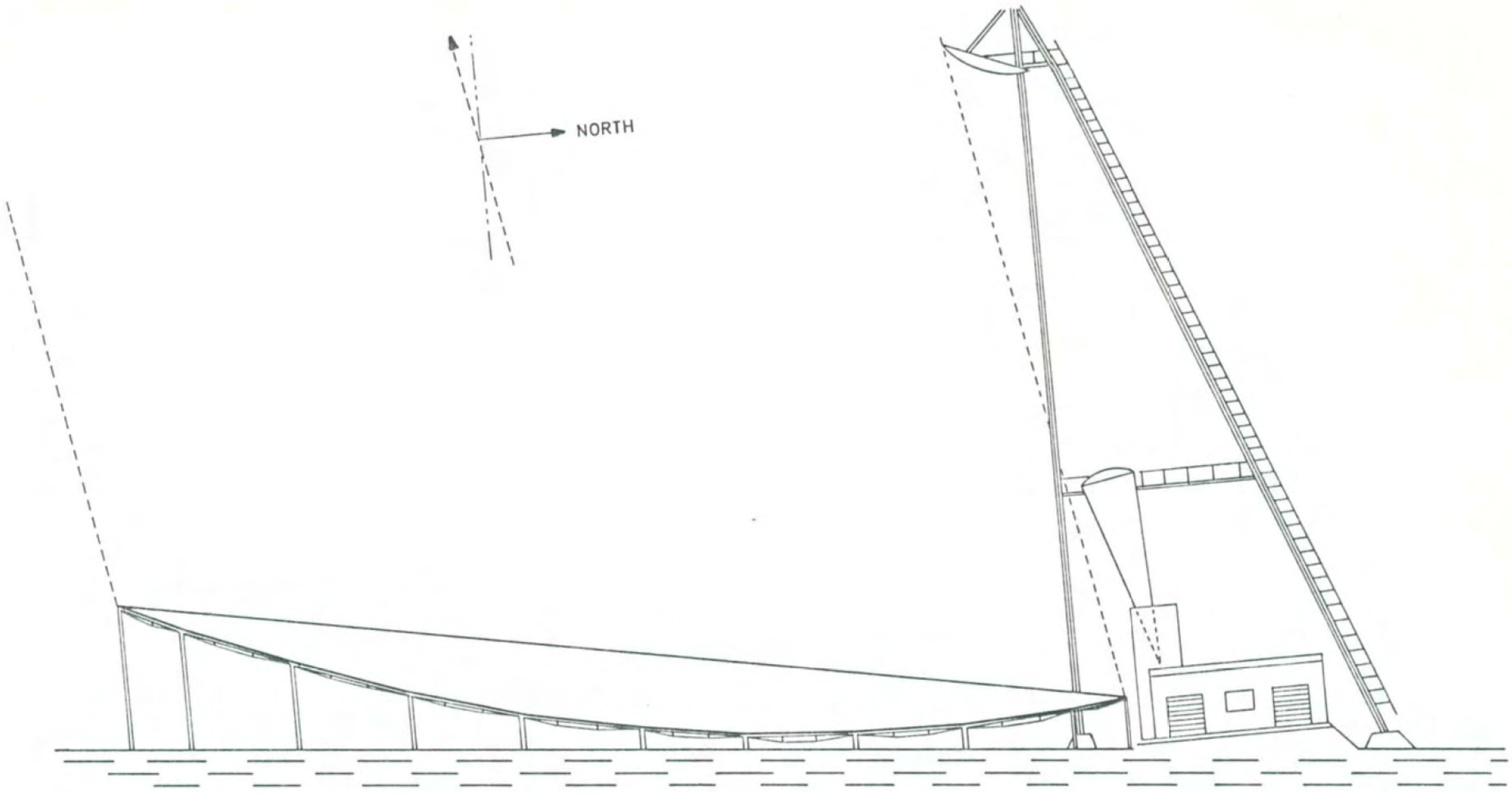



Fig. 3. UHF transmitter antenna

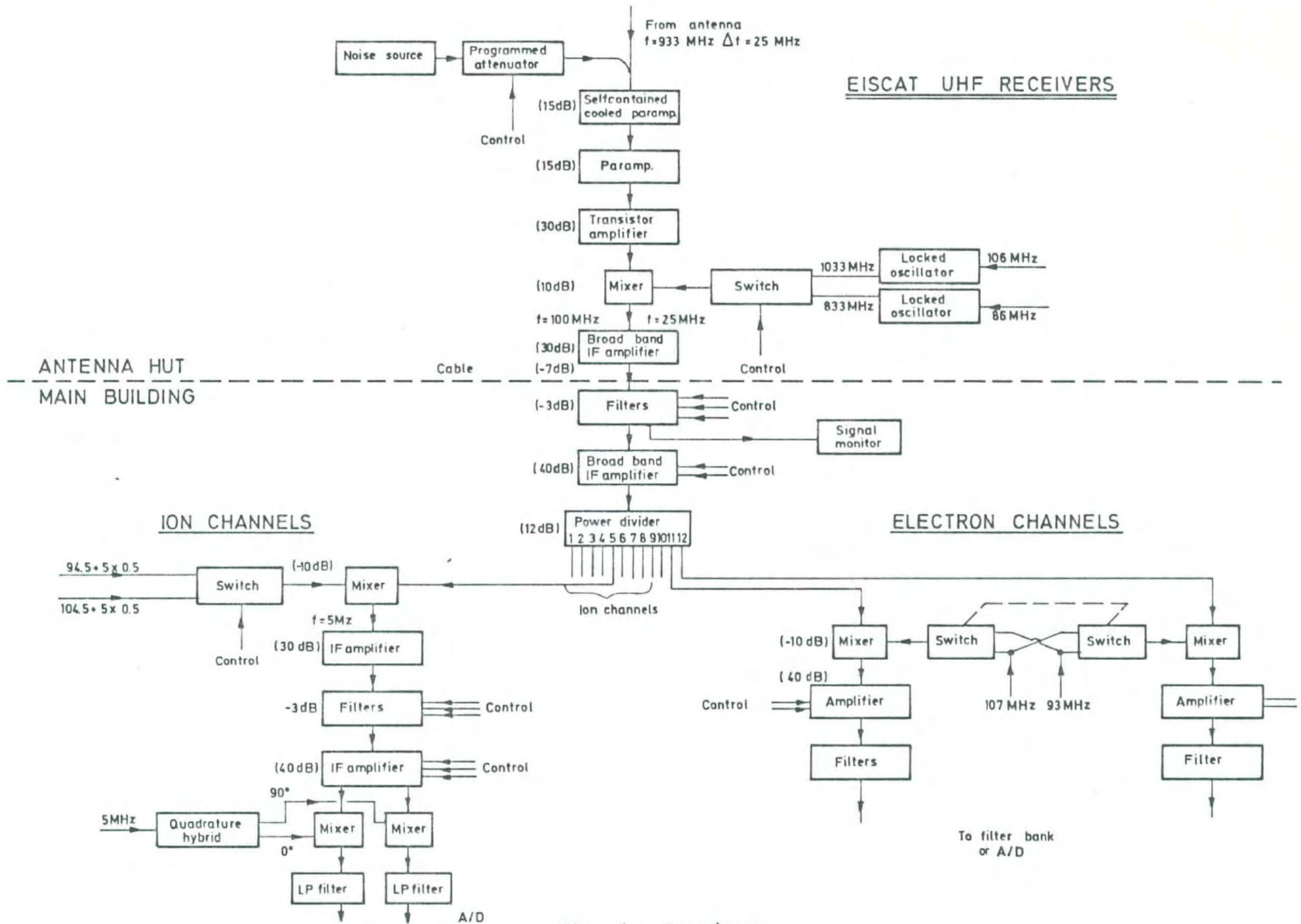



Fig. 4. Receiver

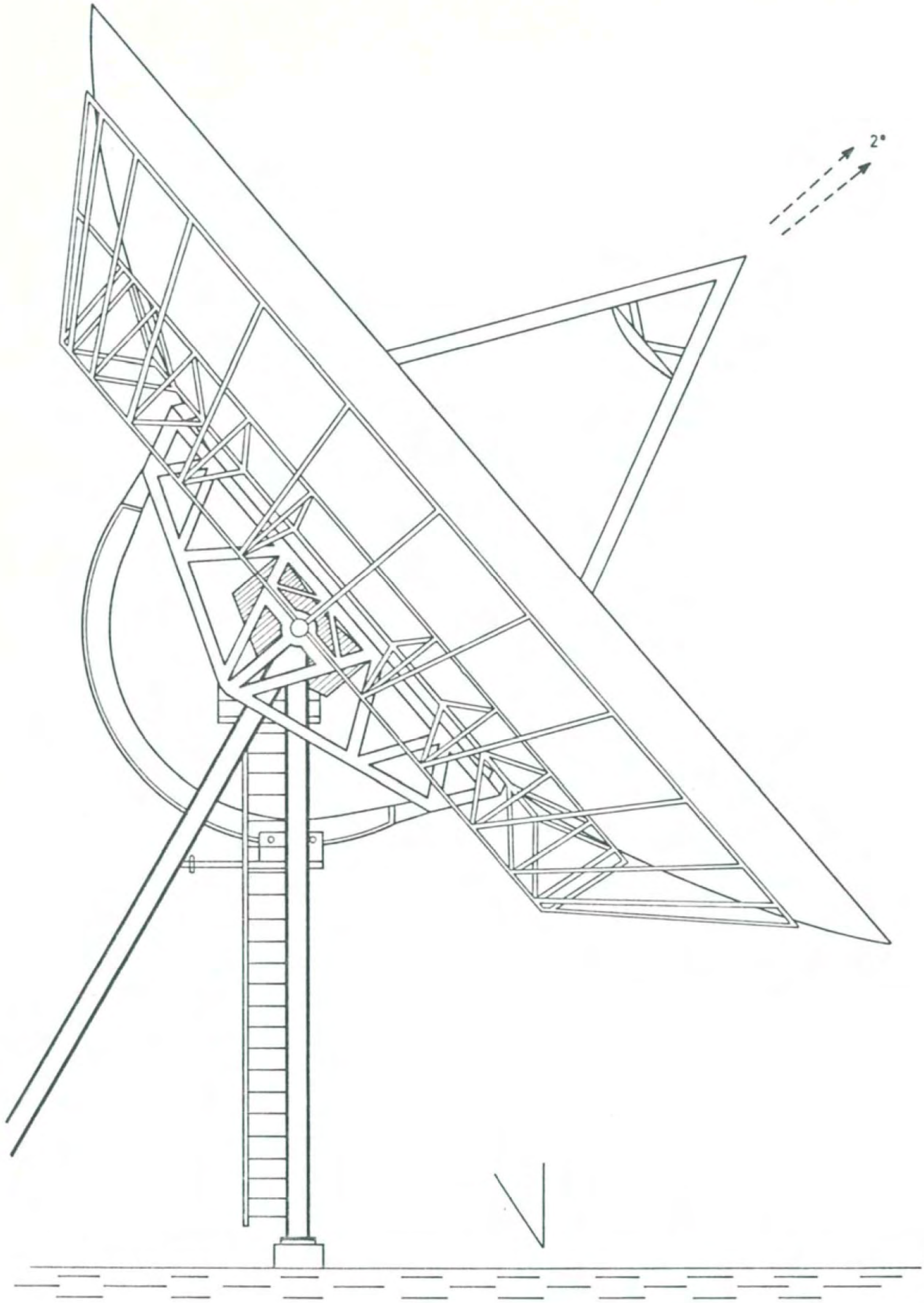



Fig. 5. Receiver antenna element

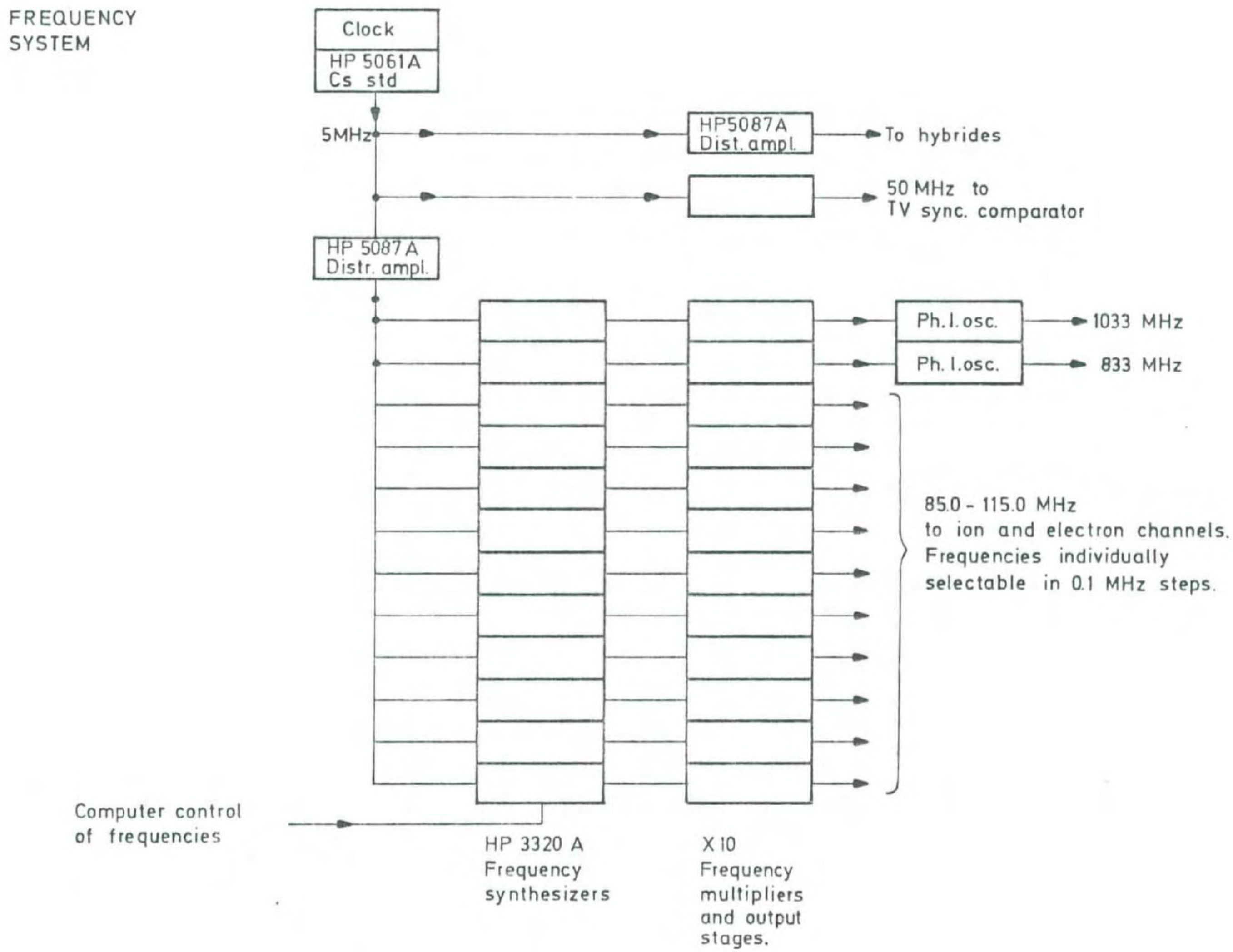



Fig. 6. Frequency generation system

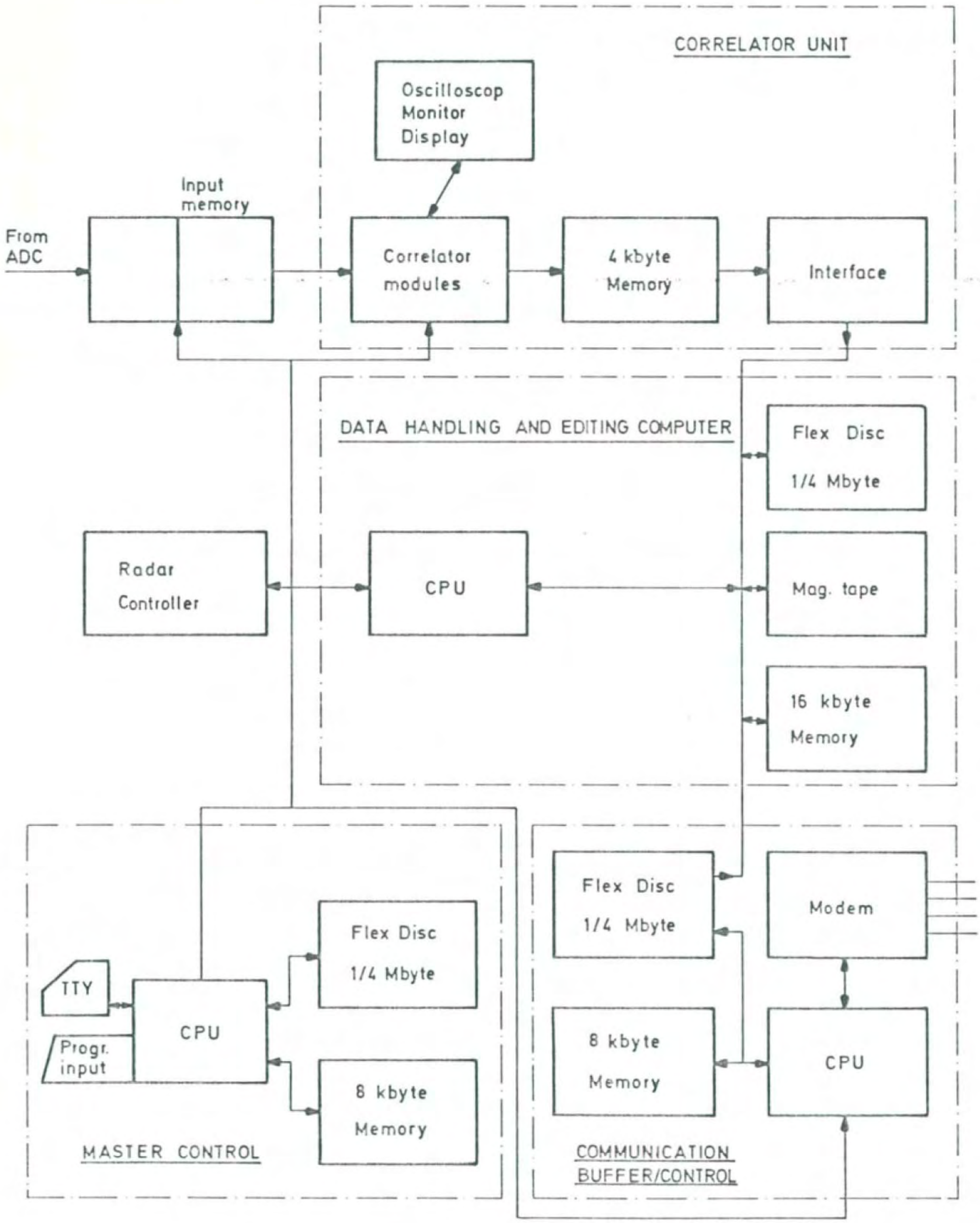



Fig. 7. Computer and control system

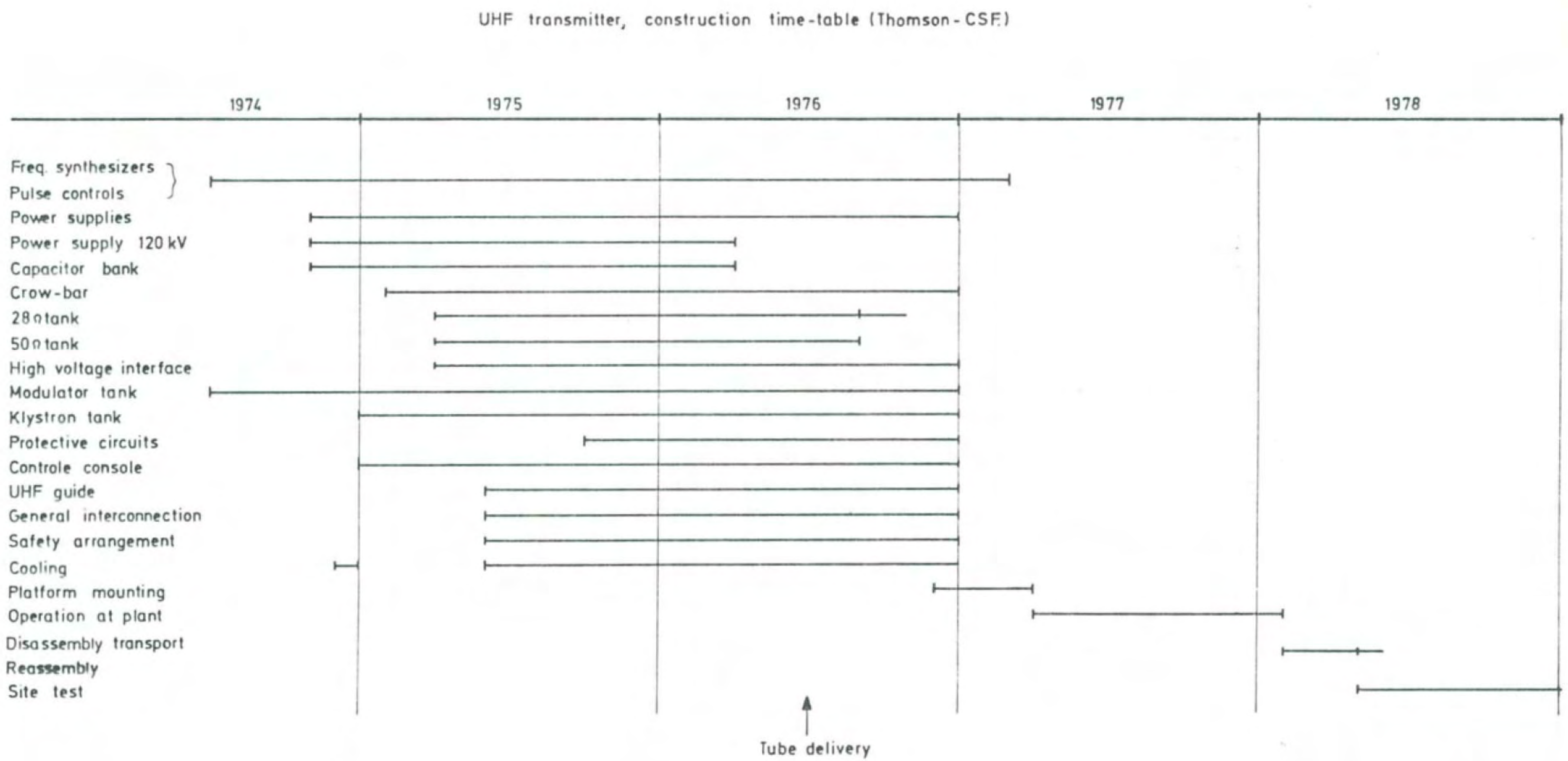



Fig. 8. UHF transmitter construction schedule

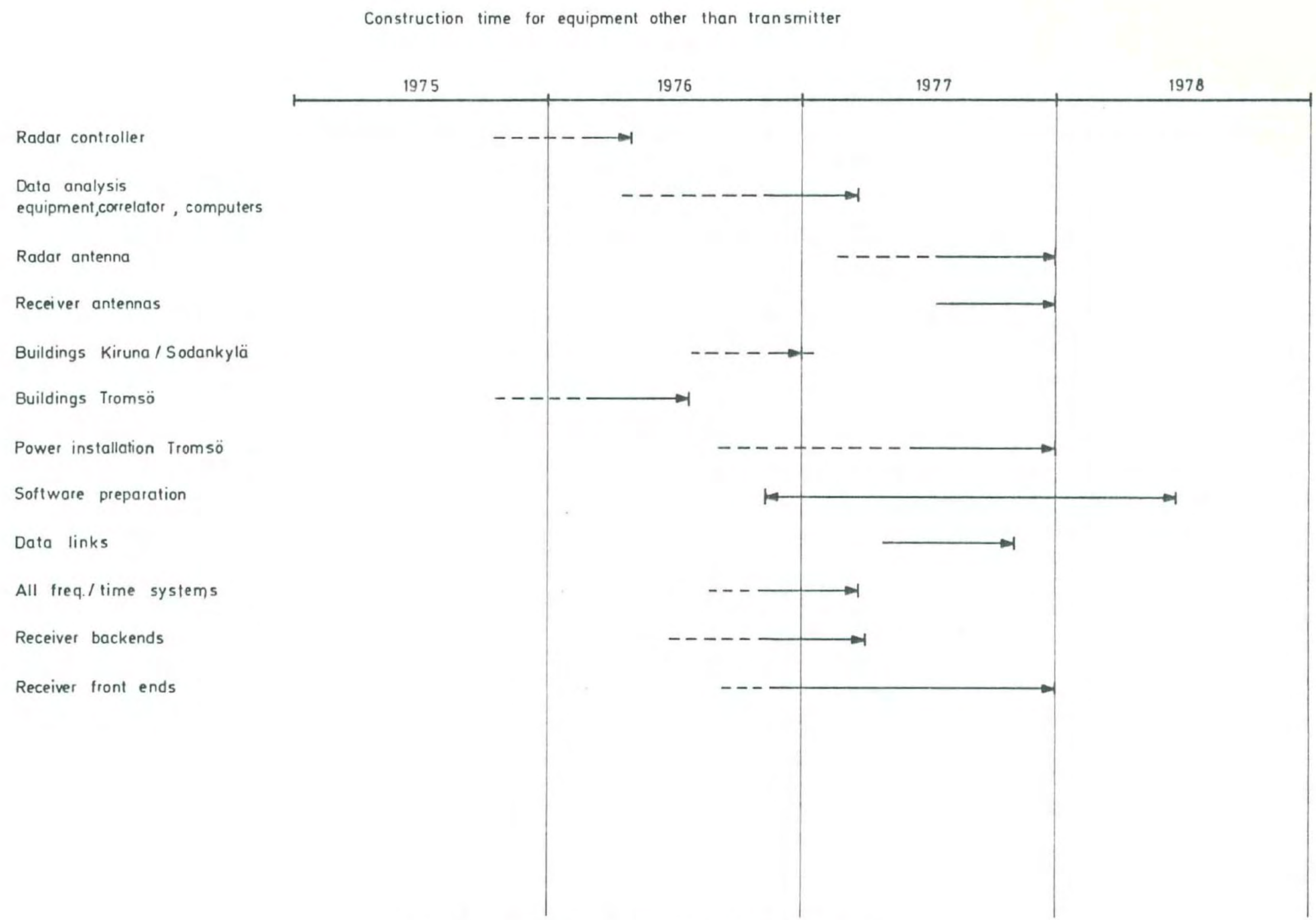



Fig. 9. Equipment construction schedule

Time table for EISCAT employment

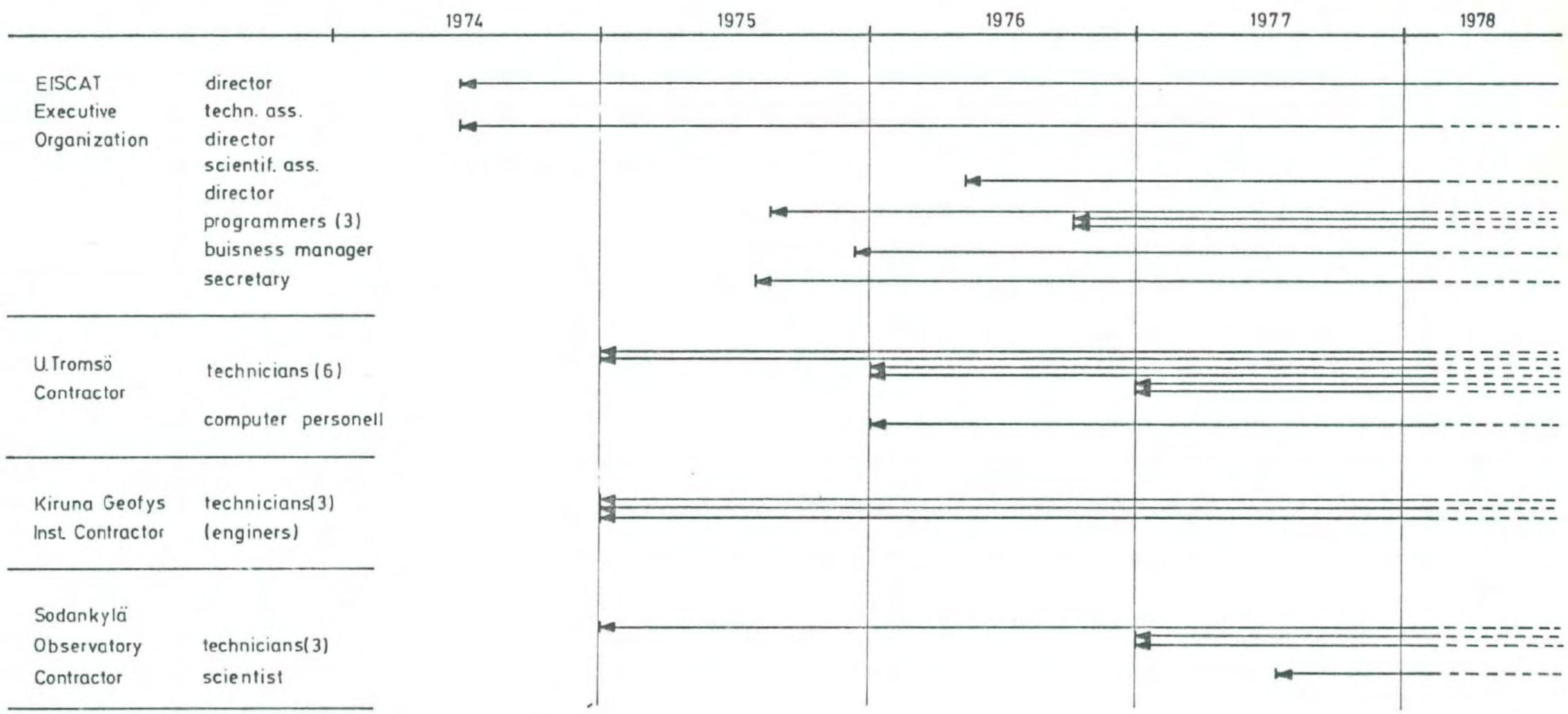



Fig. 10. Schedule for personnel hire