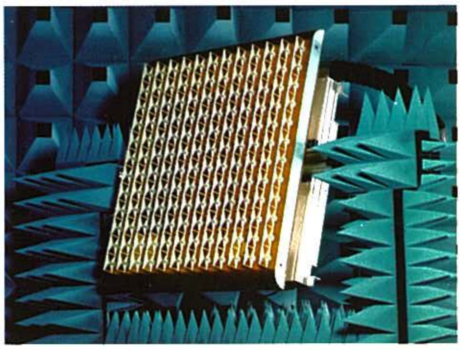
Netherlands Foundation for Research in Astronomy

Annual Report 1998



Netherlands Foundation for Research in Astronomy

Annual Report 1998

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Front Cover:

Top: OSMA in the Anechoic Room

Middle: WSRT at sunset (courtesy of M.L.A. Kouwenhoven)

Lower: NFRA's headquarters in Dwingeloo

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1. Report of the Board

Highlights of 1998

The pace of events of recent years continued unabated during 1998. The Ministry of Education, Culture and Science announced that Dutch universities will make an additional Mfl 46 available over a period of five years through the national graduate research school in astronomy, NOVA. The intention is to strengthen university programs in astronomy and to promote effective use of astronomical research facilities. Among other activities, plans were quickly agreed for an advanced pulsar back-end for the WSRT, and funds were committed for technical participation in the program of optical/infrared interferometry at the European Southern Observatory's Very Large Telescope in Chile (the VLTI project). The advanced pulsar back-end (called PuMa-2) is a cooperation with engineers at Utrecht University and astronomers in Utrecht and Amsterdam. The first VLTI instrument (the MIDI project) is a joint effort with the Max-Planck-Institut für Astronomie in Heidelberg and involves astronomers in Amsterdam, Groningen and Leiden as well as NFRA engineering staff.

At NFRA's Institute, delivery and commissioning took place of 13 of the 15 multi-frequency front end receiver systems, and the first hardware units of the new correlator system (the DZB) and new system control software (TMS) were brought into use. The program of major maintenance on the antennas, designed to provide an additional 10-15 years to the lifetime of the facility, was completed late in the year. Also, financing for a new broad-band IF system was secured, thereby completing the goals of the upgrade program as set out nearly a decade ago.

At a meeting in Calgary in July, the members of the international consortium working towards the construction of the next generation large radio telescope decided it was time to stop using different local names to describe what is essentially the same international project. The name that was finally chosen was: Square Kilometer Array (or SKA for short). During the fall, a second demonstrator in the series of antennas in NFRA's R&D program leading to the Square Kilometer Array was delivered. This device, called OSMA (for One Square Meter Array), consists of 64 element-antennas working in concert to produce dual, electronically steered beams that are adaptively shaped to suppress unwanted external interference. OSMA represents the basic building block or "tile" of the broad-band phased array concept for SKA being pursued at NFRA. At year's end, the study program utilising OSMA as a platform was well under way, and detailed design of OSMA's successor, THEA (for Thousand Element Array), had begun. THEA will operate out-of-doors and have to deal with real, strongly interfering signals from the environment. It will have enough sensitivity to detect strong celestial radio sources and will help us learn to calibrate such arrays in the non-laboratory environment.

Several other events during the year are particularly noteworthy.

NFRA hosts the secretariat of the European Science Foundation's efforts on radio spectrum management for astronomy in Europe. In August, after years of discussion and negotiation, agreement was reached with Iridium LLC on the amount of out-of-band radio emission the project's telecommunications satellite down-links may cause in the radio astronomy band at 1610.6 - 1613.8 MHz. This band contains the lines of cosmic OH masers and is particularly important to the research programs of several European radio observatories, including NFRA. It has been reserved by agreement at the International Telecommunications Union for the exclusive use of radio astronomy. Until March 1, 1999, and from January 1, 2006, Iridium has agreed to limit its interference in the radio astronomy band to ITU Radio Regulation levels (-238 dBm, corresponding to a celestial radio source of flux density 158 Jy). For the interim period agreement must still be reached, and discussions to this end are expected to continue well into 1999.

Figure 1.1 The New EVN MkIV Data Processor

On October 22, the Queen's Commissioner in Drenthe formally inaugurated the VLBI data processor of the Joint Institute of VLBI in Europe (JIVE). This processor is a sister-correlator to the new back-end at the WSRT (the DZB) and is located in the basement of NFRA's headquarters in Dwingeloo. Representatives of the observatories of the European VLBI Network (EVN) and of the funding agencies of EVN member countries, as well as dignitaries and friends from near and far, gathered to mark the event.

Only a few days later, on October 28, a major storm caused flooding of NFRA's building in Dwingeloo. Fortunately, through the quick action of NFRA personnel - to remove vulnerable equipment and install emergency pumps - and by the Dwingeloo volunteer fire brigade - to pump water away from the building - the resulting damage could be minimized. More serious was the delay to technical projects while repairs were made and apparatus was replaced.

Finally, something of a sad event for our community. After 42 years of faithful, continuous service, the year saw the 25-m Dwingeloo radio telescope make its last astronomical observations. There is no lack of proposals from the community to continue using the facility, but financial imperatives forced a decision to move all future requirements for observations with such an antenna to a single telescope of the Westerbork array. Indeed, the final observations of the Dwingeloo Obscured Galaxies Survey were transferred to the WSRT and, using 6 element telescopes in concert, the remaining fields of that survey were completed in a 14th of the time the 25-m would have taken. The ultimate fate of the Dwingeloo radio telescope will be decided in the coming year or so.

Policy development

On 15 and 16 June, NFRA's Board went into retreat to consider the future of its Institute in Dwingeloo. The parent organization, NWO, has let it be known that in future its institutes will be funded at a minimal level, in the expectation that funding for scientific activities will be won in competition with university groups and with institutes working in other fields. NWO also indicated its intention to remove the university grants program to a separate bureau that will combine the grants programs in astronomy, computing science, mathematics and physics. The island observatories (on La Palma in the Canary Islands and on Hawaii in the USA) will in future also be administered centrally at NWO. These developments will allow NFRA to focus its program to achieve maximum efficiency and coherence, but the latter requires a clear vision of where the Institute should be going and how it should plan to get there.

During its retreat the Board considered three possible future models for its Institute in Dwingeloo:

1. Focussed, research institute model, patterned loosely after the institutes of the Max Planck Society in Germany.

2. Facilities workshop model, providing instrument design and construction facilities for university researchers.

3. Combined model, in which the Radio Observatory and general administration and facilities support efforts would be financed from structural funding, and new instrumental and scientific projects would be funded via contracts and temporary grants.

After two long days considering the operational and financial consequences of the three options, the Board decided that the third option would provide the most satisfactory response to the new situation and that it might be implemented such that the community's scientific priorities can be well maintained. Specifically, NFRA's program will henceforth have three main elements:

1. Technical and organizational activities aimed at bringing about the Square Kilometer Array radio telescope as a major new international facility. Other instrumental development and commercially oriented activities using the technologies of radio astronomy should contribute demonstrably to promoting this program.

2. Operation of the Westerbork Radio Observatory and its maintenance at the state-of-the-art for at least another decade.

3. Development of forefront astronomical instrumentation using optical and infrared technologies. Priority in these efforts will go generally to projects in support of the instrumentation program of ESO's Very Large Telescope, and particularly to projects in that program funded through the national graduate research school, NOVA.

In the new situation the Radio Observatory will become separated organizationally and financially from the Technical Lab. A regime of contract acquisition and activity based costing will be implemented. New for our community will also be project financing including personnel and overhead costs. The necessary administrative procedures and budgetary restructuring are expected to be introduced gradually during the coming two years.

Personnel reorganization

The reorganization announced at the end of 1997 and carried out during 1998 set the stage for the program outlined above. Thanks to a generous grant from NWO it proved possible to guarantee some twenty-two redundant employees either a new job outside NFRA, early retirement with no loss of benefits or interim work until early retirement becomes possible. New staff could also be hired to strengthen the SKA technology development effort and to provide for system scientists and improved technical support in the Radio Observatory.

At management level, Willem Baan took over on 1 July as planned from Hans Kahlmann as director of the reconstituted Radio Observatory.

And on January 1, 1999, after ten years of service, a central role in two major restructurings and helping bring about extensive program evolution, NFRA's Adjunct Director, Wilfried Boland, will join the bureau of NWO's Physical Sciences Council in the Hague. He will also assume part time the role of assistant director at NOVA.

Board Matters

Prof. Jan Kuijpers (Utrecht and Nijmegen) has served on NFRA's Board since 1991. During the report year, he let it be known that his other commitments have increased to the point that he felt he should relinquish his seat on the Board. In keeping with recent Board policy of proposing astronomical Board members that are also department chairmen, Prof. Bram Achterberg, new chairman in Utrecht, was nominated to succeed Prof. Kuijpers.

During the June retreat, in recognition of the future importance of effective contacts with relevant sectors outside astronomy, the Board decided to increase its total membership to 8, to be made up of the 4 chairmen of university departments of astronomy and 4 members from relevant technology organizations, technical universities or telecom companies. Possible new Board members will be approached following the international visiting committee planned for spring 1999.

Forward Look

April 23, 1999, will mark the fiftieth anniversary of NFRA. The year will see both scientific and technology symposia to celebrate the event, as well as a birthday party for personnel and friends. In addition, NWO plans to invite an international visiting committee in the spring to evaluate the Institute's performance, management and future plans. The structural budget for the coming six years will be decided in the fall, based on the recommendations of this committee.

On the project front, WSRT Upgrade activities will wind down as the new systems go into routine operation. Only the broad band IF-system (IVC project, for which financing became available only in 1998) will continue to require manpower throughout the year. The plans in Europe and North America to build a mm-wave synthesis radio telescope in Chile will provide an opportunity to apply NFRA's technical expertise to that international project.

A proposal from the community to examine how a large, low frequency synthesis array (called LOFAR) might be constructed will be worked out in detail. LOFAR would operate at low frequencies (15 - 350 MHz) and have angular resolution equal to the limit set by scattering of signals by the Galaxy's interstellar medium (several arcseconds). The earliest radio telescopes in the 1930's operated at these frequencies, but ionospheric phase errors limited their usefulness as discovery instruments. New insights into calibration of these errors as well as the availability of new engineering approaches developed as part of NFRA's R&D program on phased array antennas make it timely to consider a return to this frequency region. Initial discussions were held among Dutch astronomers as well as with potential foreign partners during the report year, with a view to preparing a well worked out proposal for funding late in 1999.

One of the ways NFRA plans to carry out its program in future is to cooperate closely with local industry. A grant to pursue this intention was announced at the end of the year, to be made available by the Ministry of Economic Affairs starting in 1999. Early in the year a dedicated program officer will begin the process of identifying commercial opportunities as well as locating production capacity that might be interesting to future projects.

2. Technical Research and Development

2.1 General Remarks

In 1998 many of the Westerbork upgrade projects started delivering operational systems. The implementation process from the Technical Laboratory to the operational environment of the Westerbork Radio Telescope is a complex operation that requires careful planning and support, together with dedication from all the staff involved.

In the course of the year 14 complete MFFE's with outstanding performance were assembled and shipped to the Observatory only a few months later than originally planned in September 1994. Unexpected interference from newly installed TV transmitters, which was discovered in 1997 meant that all frontends needed to be equipped with dedicated filters to combat the interference. In the end, the installation of these filters was neatly woven into the MFFE installment process although for some frequency bands, new filters will continue to appear until the middle of next year. Early 1999 will see completion of the project with delivery of the last two frontends.

In late December, an important milestone was reached when the 10 MHz production system was completed. Although later than expected and hoped for, it combines elements of the following upgrade projects: the A/D convertor (DZB-ADC), correlator (DZB-COR) and new Telescope Management System (TMS), together with modules that form part of the AIPS++ package. At this point TMS controls both the MFFE's and the DZB, it configures the system using AIPS++ functionality and collects the data for analysis in AIPS++ (although at this stage with outlets to existing image processing packages with more functionality than AIPS++ currently has). This is a great success, not only for all involved but also because Westerbork is the first interferometer that now fully relies on AIPS++ for its operation! The DZB hardware that was installed at the end of 1997 and early in 1998, has shown almost uninterrupted operation so far.

Production of the 10 MHz system was achieved in parallel with the support given to the completion of the JIVE correlator, which has the same design as the DZB correlator and was developed as part of the efforts of the international correlator consortium (IACC).

The present correlator system is in fact capable of operating with a 20 MHz bandwidth thanks to broadbanding of the old DCB IF system. This 20 MHz option is very much in demand at the observatory and will be finished in the first quarter of 1999. Fortunately, NFRA received the good news in April that a new DZB-IVC system would be funded by NWO, and should be completed early in the year 2000. The new IF system will allow use of the full 160 MHz design capacity of both frontends and correlator. A new project team was set up and because of pre-development, started last year, this resulted in immediate success with the qualification of NFRA's first RF-IC. These integrated circuits are to be built into the IVC system and are an important step on the way to the higher levels of functional integration which are needed for the Square Kilometer Array.

Development of the One Square Meter Array (OSMA), the second instrument in the SKA concept study, made considerable progress. By the end of the year a number of system level tests had been completed, and showed some impressive results. Half the total number of elements that form a single beam over more than an octave in bandwidth (i.e. in the frequency range from 1.5 to 4 GHz), were operating and calibrated results compared favourably with predictions. When fully operational, OSMA will have 64 active elements (8x8) surrounded by two rows and two columns of passive elements. The remaining functionality will be added in the first quarter of 1999. The completed system will allow the simultaneous use of two digitally formed adaptive beams and two analogue ("RF-") beams.

During the development of OSMA, valuable experience was gained in important areas, such as array calibration and antenna development. This knowledge has already proved useful for the next stage of the SKA concept study, the Thousand Element Array (THEA) which is now in its functional design phase, after successfully passing the Concept Design Review in September. THEA will measure 4x4 meters and will operate with 16 simultaneous beams at lower frequencies (750-2000 MHz).

In the course of the year, quite some effort was spent on a pre-feasibility study for a low frequency array (LOFAR). This study also looked into overlap areas with the nominal SKA research and development work. Interest in a low frequency array originated at Dutch universities and was fuelled by scientists at international SKA meetings. Avenues for collaboration with foreign partners are being explored, and a common programme could well result from next year's activity. Areas of overlap also exist with efforts for a new programme at the SETI institute, to which NFRA staff also contributed during the year.

On the research side, efforts started in previous years resulted in a NFRA involvement in a proposal concerned with elements of optical implementations, in particular the RF-optics interface. The ties to non-European university groups in Boulder (University of Colorado), Amherst (University of Massachusetts) and MIT were intensified through cooperative programs while those with other institutes are also taking shape.

Nationally, work was done in the areas of optimum system architectures, integrated antennas & low noise amplifiers and integrated analogue-to-digital conversion techniques. At the same time work continued on development of RFI suppression techniques through an STW programme with the Technical University in Delft and with JIVE through an EU funded programme.

Excellent progress was made in building the IR spectrograph for VISIR in an international cooperation with the French Institute SAp. The Final Design Review will take place early in 1999. In the course of the year a swift start-up was necessary for the MIDI project; once again in collaboration with other institutes. MIDI will be the first instrument for ESO's VLT Interferometer. In this instance, the National Astronomy Research School, NOVA proved to be the facilitating partner. At NFRA, this project is being treated as an example of how the foundation would like to work and cooperate in these kind of projects with tight budgets and strict timelines.

Many of the activities described here were made possible by an increase in manpower. Staffing levels in the Technical Laboratory at the end of the year were 50% higher than early in 1997. The new building in Dwingeloo has played an important part in being able to provide enough room to accommodate all the new people. The reorganization of the institute that started in 1997 made it possible to recruit staff for technical support functions like a CAD/CAE designer and in the area of process control, in particular planning and documentation. These appointments are expected to increase the overall project control and efficiency of those involved in the technical R&D projects.

Technical Laboratory staff spent time on a large number of presentations at other institutes and at (inter)national meetings and symposia. It is pleasing to note that the year showed clear indications of an increase in cooperative research programs with universities and companies. Locally, NFRA has made a concerted effort to become an acknowledged institute for regional businesses and is likely to receive EU funds to support this activity.

2.2 WSRT Upgrade Projects

Multi Frequency Front Ends (MFFE's)

A major the milestone was reached on the 17th of April, 1998, when the first phase 2 Multi Frequency Front End (MFFE) was delivered to the Westerbork Radio observatory. By the end of the year fourteen phase 2 MFFE's were assembled and, with the exception of one, in use at the WSRT. The average interval between deliveries of phase 2 MFFE's reached a value of three weeks, which is high considering the complexity of the systems involved.

At this pace the 16th and last phase 2 MFFE is scheduled to be ready for delivery in February 1999 and would mean virtually no delay compared to the original project baseline. Total expenditure will remain within the agreed budget for the project.

In close cooperation with the Westerbork Radio Observatory the integration and commissioning had already been planned before delivery of the first phase 2 MFFE. Usual practice was that the front ends were assembled and tested in Dwingeloo, and then installed in one of the WRST antennas. After the necessary checks, the front end was put into operation for both commissioning and general astronomical observations.

The original commissioning plan was adapted in the course of the year; instead of performing separate commissioning observations the emphasis shifted to regular astronomical observations. This move was necessary because of the high pressure from WSRT users to benefit directly from the advantages given by the MFFE's. Both the performance and reliability of the front ends made this possible. In the adapted commissioning plan most data necessary for evaluation was collected during regular observations. Measurements that could not be made during regular observations were gathered in short dedicated observing sessions. This approach meant that VLBI and Pulsar observations already profited from this WSRT front end upgrade in 1998.

The performance of the MFFE's closely matches the original specifications, some even exceed the targeted values. A description of the commissioning phase of the MFFE project can be found in the Radio Observatory section of this report.

Reliability of the MFFE's turned out to be excellent; despite the complex cryogenic systems, only minor problems were encountered. One of the MFFE's that was installed in April 1998, kept running without failure for more than 7 months before it was taken out of operation for other reasons. The increased reliability is just one of the factors that will increase the efficiency of the WSRT after the upgrade.

LO- and Time Distribution

This year the decision was taken to develop and realize a new Local Oscillator- and Time Distribution System (LOTDS) for the WSRT. The general philosophy of the LOTDS is that all subsystems of the WSRT can in future use two signals in order to regenerate their own timing: a 10 MHz signal and a single pulse per 10 seconds. A second important point is that the Telescope Management System (TMS) will be master of all devices that generate timing information. This means that if a subsystem detects a discrepancy between the distributed signals and its own regenerated signal it can send an alarm to the TMS, which can then act upon that by resetting different parts of the LOTDS or the subsystem involved.

This year a concept project plan was made, and after some discussion was transformed into a definite project plan. The LOTDS consists of an analogue part and a digital part. The design of the digital part has already started; work on the analogue part will follow next year.

The NFRA and EVN Correlator Systems

Production of the hardware modules for the correlator systems for the WSRT and the European VLBI Network was completed in 1998. These modules were integrated into eight correlator units. Four of these units were installed in the EVN correlator system in the basement of the building in Dwingeloo. This system produced its first fringes in July and was inaugurated on October 22nd of the year. The full capacity of the correlator system will become available when the data distributor unit (a dedicated switching matrix) is completed. Production of the hardware for the data distributor has started and the unit will be installed in the first quarter of 1999.

After the first couple of correlator units that were shipped to Westerbork in 1997, the final two units are due to be moved early in 1999. They will be used, together with two analog-to-digital convertor units, to increase the bandwidth from the current 10 MHz to 20 MHz using the (modified) IF-to-Video convertors of the existing continuum backend. The data distributor for the WSRT will only be required when the new IF-system becomes available. It will be installed in the final quarter of 1999 after all its modes have been tested in the Lab in Dwingeloo.

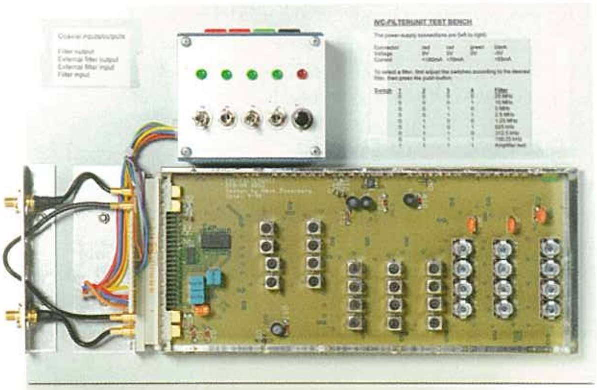


Figure 2.1 The pre-production IVC Filter module in a test fixture.

IF-to-Video Conversion (The IVC-system)

The IF-to-Video Converter (IVC) system is an extremely important link in the WSRT signal chain. It provides the interface between the MFFE's and the new digital correlator (DZB). Many of the exciting new possibilities of the new system can only be utilized to their full extent after completion of the IVC-system. Most important feature is its ability to process the 32 times 160 MHz instantaneous bandwidth from the IF-channels of 16 telescopes (this includes two spare channels for future extensions). As the signal processing in the DZB correlator is limited to a maximum of 20 MHz video bandwidth at each of its 256 inputs, the IVC-system has to split up each 160 MHz band into eight sections of 20 MHz and convert these bands from IF to video. This leads to a total of 256 converter modules in the IVC-system.

To allow optimum flexibility and maximum interference rejection, a double conversion scheme was chosen, allowing independent tuning of each 20 MHz band within the 160 MHz instantaneous bandwidth, for all 256 video channels.

The two-stage process consists of an up conversion, followed by a down conversion to video frequency. The image rejection mixer that is used in the second stage includes the ASTRON01 mixer IC described in the 1997 annual report and which achieves over 30 dB of image rejection. The IVC-system can also be used for video bandwidth selection. A total of 2048 video filters will be possible in future with bandwidths down from 20 MHz to 156 kHz in factors of two. To correct for the amplitude characteristics of the WSRT IF-cabling system between telescopes and main building, an equalization function is also included in the system.

A feasibility study for the IVC-system was performed in 1995 and 1996 and subsequently preliminary design and development got underway on a modest scale. In 1997, a formal proposal was submitted to NWO and in April 1998 an amount of 3.47 MDfl was granted from the NWO-Groot budget. The figure shows a pre-production model of the IVC filter module in a test fixture.

The development of two parts of the system was farmed out to industry. The development and construction of 64 equalizer modules was successfully completed in 1998. Development of the LO-system had not been completed by the end of the year because of problems in achieving the required stability of the LO-modules. Current planning is aimed at completion of the entire project in the first half of the year 2000.

AIPS++

The AIPS++ project aims to produce an internationally supported data reduction and analysis environment for radio astronomy. It involves programmers and scientists at seven institutes in six countries. NFRA has been heavily and centrally involved since its inception, with a view to making the WSRT more accessible to astronomers from other countries, and to making other radio telescopes more accessible to the Dutch community.

AIPS++ plays an important role in the newly upgraded WSRT, at three distinct levels:

1. Self-contained AIPS++ modules like Tables, Measures and the scripting language Glish are part of the WSRT on-line system TMS. Their performance has been reliable and almost trouble-free. The data produced by TMS are stored directly into an AIPS++ Measurement Set.

2. A local mini-package has been written in Glish to take care of data-inspection and the determination of WSRT set-up parameters before observation. This replaces the existing programs. Some of these functions are generic, and will find their way eventually into the final (general) release of AIPS++.

3. Astronomical reduction of WSRT data will take place in AIPS++ as soon as a stable version of the general release is available. In the meantime, existing packages are still being used.

The pressures of the WSRT upgrade, have meant that NFRA has not been able to make a large contribution to the worldwide package. Nevertheless, NFRA has supplied the Technical Leader, a substantial amount of infrastructure software, and some research and predesign of ionospheric calibration in AIPS++. In addition, NFRA is placing a constant emphasis on the proper treatment of image-plane effects (roughly: individual antenna beamshapes) because of their vital importance for SKA.

TMS - A Telescope Management System for the WSRT

The increasing complexity of devices and procedures at the WSRT required a new Telescope Management System. In the TMS project all the old on-line and off-line software is to be gradually replaced by a coherent system developed using object oriented design and programming techniques. TMS uses various AIPS++ modules (in particular the Measures system and Tables). Data inspection and processing is done in the AIPS++ glish environment. TMS adopted the MeasurementSet format for data storage and as an interim archiving format. Final archiving will be as a MeasurementSet in standard FITS binary tables (the so called MS-FITS format).

The project went through a critical year in 1998, being the only route to control the new DZB correlator. Many operational issues had to be solved and problems in the interface with the correlator and the AIPS++ MeasurementSet definition had to be solved. By the end of the year a production version was released, covering full backend-read-out, system control/logging, basic calibration and archiving/export facilities.

Parallel to this effort, controller applications for the existing DCB continuum correlator were developed and tested. Also support for the PuMa pulsar machine was included. Both activities will be completed in 1999. In the future, TMS will not just control the correlator and its associated devices, but also the telescopes and frontends themselves. Among other things, this involves a change to the J2000 reference system for coordinates.

Early 1999 the 20 MHz correlator system will be delivered, and control/processing support for it will be added to TMS. By that time, a strong support group will be available within the Radio Observatory. This group will take over the maintenance and support of both TMS and the local AIPS++ implementation.

2.3 Optical Research and Development

VISIR for the ESO-VLT

As part of a French-Dutch Consortium, NFRA is a participant in the construction of VISIR (VLT Imaging and Spectroscopy in the InfraRed), an instrument to be installed in the Cassegrain focus of ESO's VLT Unit 3 Telescope in 2001. The Service d'Astrophysique (SAp) of CEA/DAPNIA at Saclay is responsible for the imager part and the instrument infrastructure while NFRA is developing and building the spectrometer. Smaller participants in the project are NIKHEF (Amsterdam) and SRON (Groningen) for the design and production of specific modules. The formal kickoff was in December 1996 and the first phase ended with a Preliminary Design Review

(PDR) at the end of 1997. The year 1998 was devoted to finalising the design and to prepare the production of the instrument. A Final Design Review will be held in March 1999.

Optical Design

The optical design of the spectrometer had in fact already been approved at the PDR. Only small changes were made to the re-imager, which is the subsystem closest to the imager. The change only concerned the folding of the optical beam thus creating more space between the imager and the spectrometer.

Mechanical Design and Prototypes

The largest effort this year was in the detailing of the mechanical design of the spectrometer. Before this year, most of this work had been done at NIKHEF, now all the design work and the complete assembly were carried out at NFRA. A large part of the Finite Element Modelling and the thermal modelling was also done in house, although NIKHEF still participated in these areas. The design of the instrument changed considerably in the course of the year, especially in order to reduce the weight of subsystems and to increase their stiffness. Meanwhile efforts were also directed toward starting production of the instrument.

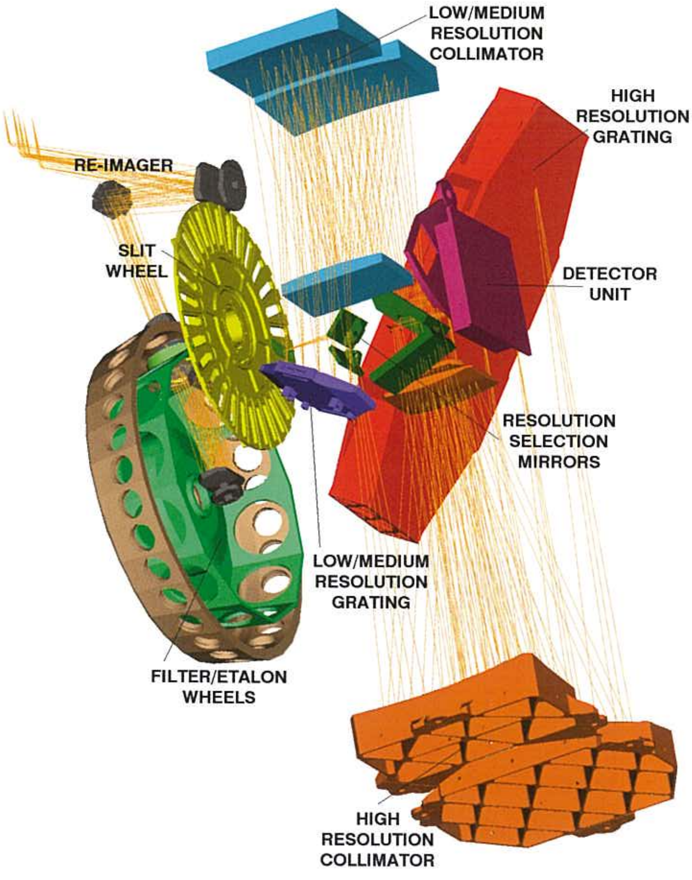


Figure 2.2 The optical lay-out of the VISIR spectrograph

The contacts with the Workshop at NFRA were intensified, which resulted in feedback on manufacturing methods and the production of several prototypes and test pieces. This was especially important for the VISIR mirror blanks because of their complicated curved shapes and the strict tolerances. It turned out that most of the milling can be done at NFRA and only a limited number of parts will have to be produced outside. The internal mechanical stability of the spectrometer is also very important. Several tests on prototype mirrors were done to verify the stability of the aluminium alloy that was used.

The first large piece of equipment produced by the workshop was the so-called spectrometer Mass and Thermal Model (spectro-MTM): an aluminium box with about the same outer dimensions and weight as the instrument itself. This spectro-MTM will be used, together with the imager-MTM provided by the French partners to test the mechanical stability of the support system and to do tests in the prototype VISIR cryostat. Other components already made in 1998 were the linearly variable differential transformers and linear motors used in the scanners and which were designed by SRON.

Opto-Mechanical Prototypes

The optical laboratory was involved in the development of a prototype etalon. This is a particularly difficult unit for which no external manufacturers were found. The combination of a mechanical workshop and optical laboratory with cryogenic test facilities turned out to be very useful: a series of tests using the prototype with intermediate adjustments resulted in a successful design. By using glass plates instead of the germanium plates that will eventually be needed, measurements using an interferometer working at visible light could be used. Meanwhile a technique for polishing germanium was also developed. So at the end of the year, a prototype fitted with two germanium plates was sent off to SRON Groningen to be tested at infrared wavelengths. SRON, acting as a subcontractor, also produced prototypes for the grating scanners. The small scanner is very similar to the ones designed and built by SRON for the ISO satellite.

Thermal Studies

The thermal behaviour of the instrument is essential for its performance as a background limited instrument and has important operational and safety considerations. Therefore a number of thermal modelling studies were done, wherever possible backed by experiments in the laboratory. These studies concerned the liquid nitrogen pre-cooling system, the overall cool-down with closed cycle coolers and the warm-up. This last phase is the most critical: condensation of gases on cold optics can cause severe damage to the optical surfaces. As the mechanical design was becoming more detailed, thermal modelling of subsystems was started. The results are an important input for the design of electronics and cabling: the heating power that has to be installed on the mirrors and structures was derived from these studies.

Test equipment

The biggest piece of test equipment to be used in the design of VISIR is the Integration Support, which is a 2000 kg dummy of the mechanical interface to the unit VLT telescope. Three of these units have been built, one is being used in Saclay to test the cable wrap, the others to integrate (and test) the imager and the spectrometer. NFRA received its copy at the beginning of November. The name "Integration Support" does not adequately describe its capabilities: it can also move the instrument around and thus will be used in testing the flexure (stiffness) of the instrument in different positions under the influence of gravity.

Science

The first meeting of the Dutch VISIR Science Team was held at NFRA on 18 September and was well attended. Presentations on the importance of VISIR for different areas of astronomy were given, followed by a discussion about the use of both the imager and the spectrometer. The most important conclusions were that the list of filters (especially for the imager) and the omission of the low resolution Q band of the spectrometer should be reconsidered. Coordinators for the different science areas were appointed and the goal is to come to a well-prepared discussion with the French community in June 1999.

The MIDI Project

MIDI is the Mid-Infrared Interferometer Instrument for the ESO VLT Interferometer. It will be built and used by a consortium which has as principal partners the Max Planck Institute for Astronomy (MPIA) in Heidelberg and the Netherlands Research School for Astronomy (NOVA) . The Dutch contribution to the hardware will be realised at NFRA. A feasibility study was completed in October and a Conceptual Design Review took place at ESO in December. This review was passed successfully and can be considered to be the official start of the project, although MPIA has been working on the MIDI concept since early 1997.

To do interferometry with ESO's Very Large Telescope, the telescopes will be equipped with Coudé optical trains, underground delay lines and at least two beam-combining instruments. MIDI is the beam-combining instrument for the N-band (around 10 micron) with provisions for the Q-band (around 20 micron), the longest (optical) wavelengths that can be used in observation from earth. The long wavelengths help in that the mechanical requirements on this complex system are considerably relaxed. On the other hand, the high thermal background does have to be coped with. As MIDI is the first beam-combining instrument on the VLT, it will be very exciting both to learn how to use the complicated VLTI system and to see what new science can be obtained.

NFRA entered the project in the second part of 1998 and is (through NOVA) responsible for the design, manufacturing and testing of the cold optics of MIDI. This is the heart of the instrument: where the two beams coming from the delay lines are re-imaged, spatially filtered, combined, dispersed and imaged onto a detector. Because of the background radiation, all of this has to be done at about 30 K like for VISIR and the experience of NFRA is therefore very useful. The rest of the instrument will be built by MPIA: warm optics, cryostat, cooling system, detector unit and electronics. The first activity undertaken by NFRA was a preliminary tolerance analysis of the optical design.

2.4 Research and Development for the Square Kilometer Array

2.4.1 Research

Antenna's

One of the key issues in the design of a phased-array system for SKA is the antenna, which in NFRA's concept consists of a large number of small receiving elements, e.g. broadband dipoles or Bunny-ear elements. The demands on the antenna array are that it should have a very broad bandwidth, a wide scan range and should preferably be made with low-cost technology. The OSMA demonstrator was selected as a testbed in order to find out whether it is possible to meet the SKA antenna specifications. OSMA contains 64 active elements and works in the frequency range from 1.75 GHz to 3.5 GHz, a more detailed description can be found below.

The first step in the design of the OSMA array antenna was the selection of an antenna element with wide-scan wide-band characteristics. In addition, a low-loss wide-band transition (balun) from the antenna to the RF beamformer was developed. Two possible antenna candidates were selected: a printed tapered-slot antenna (bunny ear) and a printed bow-tie element. Initial studies showed that these elements could meet the required specification of an octave

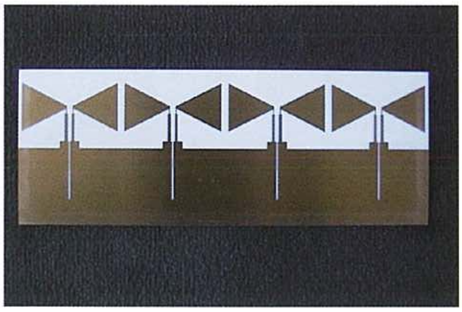


Figure 2.3 Bow-tie antenna sub array with four-elements with integrated balun.

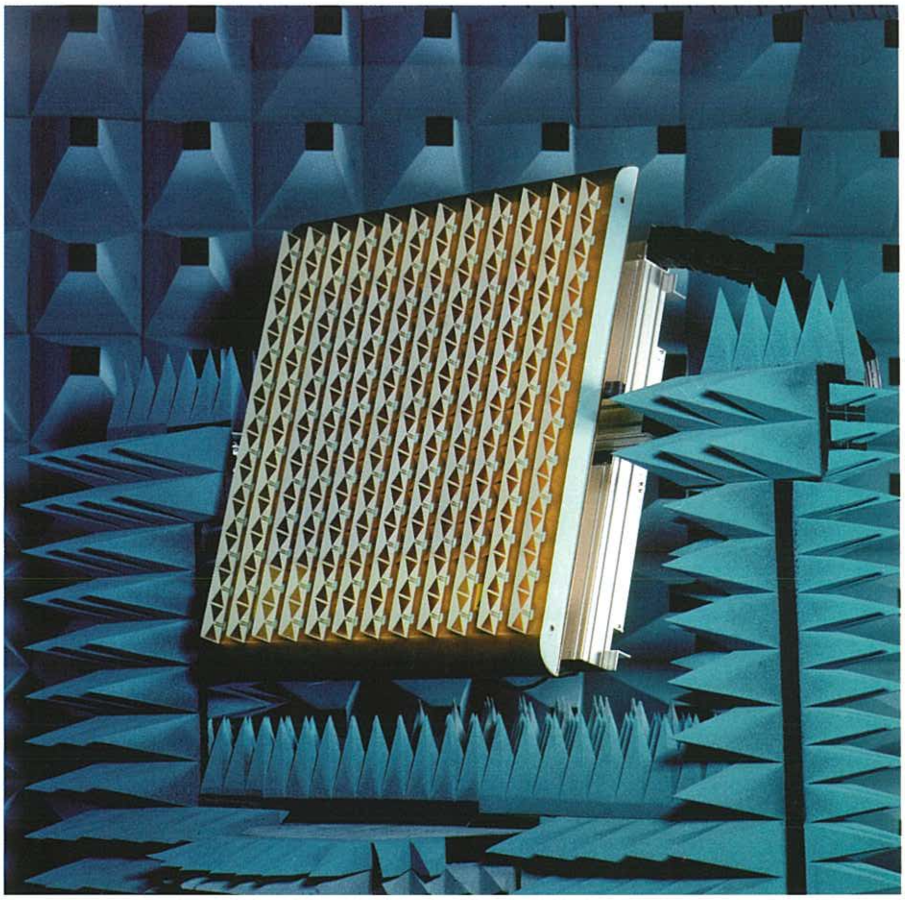


Figure 2.4 OSMA front-view in the antenna test facility at NFRA

bandwidth and the required wide-scan behaviour in an array environment. Another advantage of these printed elements is that they can be integrated with the RF beamformer modules, which reduces the costs significantly. The figure shows a bow-tie antenna element with an integrated balun.

The second step in the design was to optimise the antenna element shape and the distribution of the elements along the array. For that purpose electromagnetic field simulators are crucial. The electromagnetic behaviour of a large array of wide-band printed antenna elements was investigated with an accurate model that accounts for the periodicity of the array configuration. The unknown electric current distribution on the antenna elements was found by solving an integral equation with the method of moments. The electromagnetic field which appears in the integral equation is written in terms of the periodic Green's function of the structure. This way, mutual coupling and other effects are accounted for in a rigorous manner. The theoretical model was implemented in an in-house developed software package. Commercially available software (IE3D) was used to analyse single elements and finite arrays.

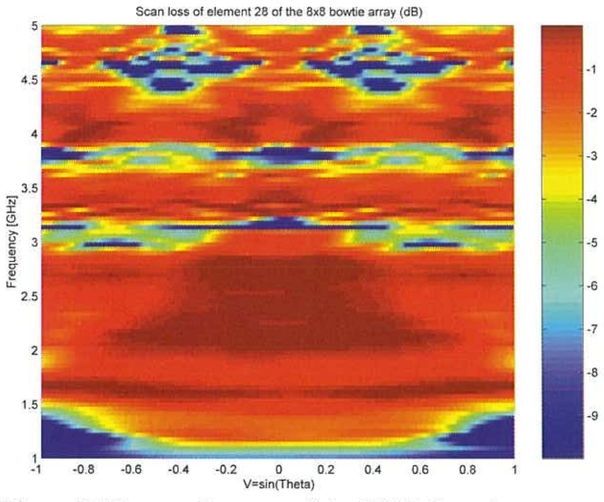


Figure 2.5 Scan performance of the OSMA bow-tie array. The scale is relative to the peak in dB. The blue areas are the blind scan regions.

Both of the candidates selected are to be built and tested. The figure shows OSMA with bow-tie antenna elements located in the anechoic test facility at NFRA. Element spacing in the OSMA antenna is half a wavelength at 2 GHz. This permits the study of array performance with and without grating lobes. The predicted and measured scan performance is also shown. The active reflection coefficient was determined by measuring the coupling coefficient between all the elements, and remains at acceptable levels over a wide frequency band for the bow-tie array. However, blind scan regions do appear just above 3 GHz.

The tapered-slot (bunny-ear) array showed results that are similar to the bow-tie array, so the conclusion is that both could be used within the specified OSMA frequency range, except for certain regions in which the array will be blind. For radio-astronomy applications, blind scan regions may be acceptable as long as these regions are not too large. Sparse array concepts could be used to avoid blind scan regions. The OSMA antenna will be used as a starting point for the next phase in the SKA antenna development program.

Integrated Front-End Receivers and Analogue Beamforming

i. Low noise amplifiers for SKA

The design and development of Low Noise Amplifiers at NFRA has in recent years concentrated mainly on application at the WSRT. For the MFFE's, a number of octave bandwidth room temperature and cryogenic LNA's were designed for 50Ω characteristic impedance. LNA's for the Square Kilometer Array will be

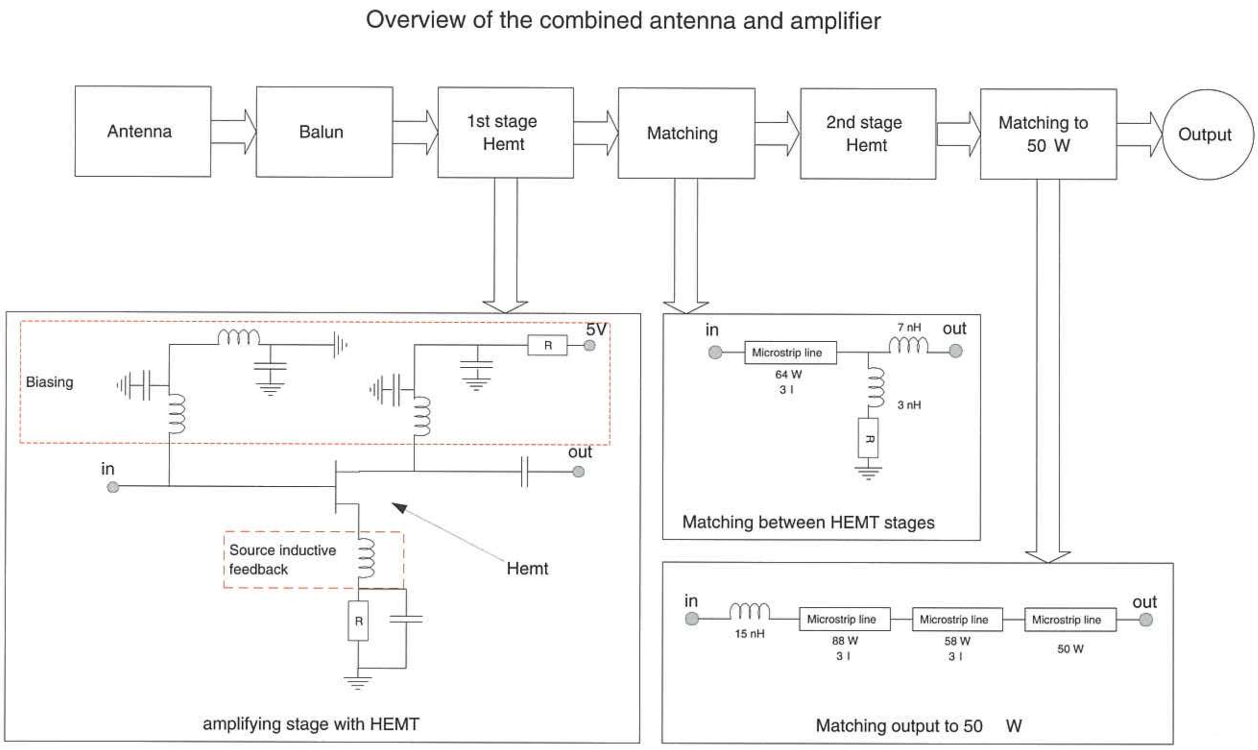


Figure 2.6 A schematic overview of the combined antenna and amplifier

required to process a much broader bandwidth (3 octaves), while a higher level of integration of components and sub-systems will also be needed. However, the design in a 50Ω characteristic impedance system may no longer be necessary or indeed desirable.

In the second half of 1998, manpower was recruited and facilitary & design efforts were started that should lead to LNA's with a high level of integration at the component level. Meanwhile, a study of the integration on a subsystem level was started with the Low Noise Active Antenna (LNAA), a design of an LNA with direct noise and power matching to an antenna, without intermediate matching to 50Ω.

ii. The Low Noise Active Antenna

In view of the requirements for broadband low noise and power matching, a study was performed to find the optimum value for the characteristic impedance to be presented to a HEMT (High Electron Mobility Transistor) to meet these requirements. The study showed that broadband low noise performance would profit from matching to a higher characteristic impedance than 50Ω. For the particular HEMT used in this investigation a value of around 120Ω was found. This was promising, considering that the real part of the impedance of the antenna structures that are under study for SKA are of the same order. This alleviates the broadband noise matching problem for direct matching of antenna and HEMT in an LNAA.

On the basis of these results an LNAA was designed for the 500 to 1500 MHz frequency range of THEA (see above), using the 'bunny ear' microstrip antenna design of OSMA, scaled to the THEA frequency range. The two-stage amplifier design was realised on microstrip with discrete components, using source inductive feedback, with matching of the first stage HEMT directly to the antenna impedance. Figure 2.6 shows an overview of the combined antenna and amplifier. The balun between antenna and first stage HEMT includes the input matching circuit. The overall properties were optimized for noise and power matching to the antenna. The LNAA output is matched to 50Ω.

A major problem that arises with active antennas is the accurate measurement of their noise and gain performance for which standard equipment with 50Ω characteristic impedance is not adequate. In the literature a method for such measurements was suggested, which is being further developed in the Technical Laboratory. The method uses a reference antenna similar to the antenna in the LNAA for both gain and noise measurements. At the end of 1998 the measurement setup was being installed in the anechoic room. Preliminary gain measurements showed promising results, in close agreement with the simulated performance. More accurate results, including noise measurements, will be obtained early in 1999.

iii. RF-IC's

The second half of 1998 saw the start of RF-IC design at NFRA. The Hewlett Packard RF design tool was upgraded to a version capable of handling large-signals and transient analyses; functionality that is required to make the design of RFI robust IC's possible.

Agreements were signed with European foundries that opened up the way to using Silicon-Germanium and Gallium-Arsenide processes. NFRA will use the 0.25 micron PsHEMT process, that is capable of reaching very low noise figures. A study was also made of design software that will be used for different runs. Through Europractice, the possibility of participating in a multi-project wafer run is being explored. These low-volume runs are relatively inexpensive because the processing costs are shared between different users.

Design activity has started on a wide band Low Noise Amplifier Integrated Circuit using Gallium Arsenide technology. A masters student at the Technical University in Delft has started work on a wide-band LNA IC. This project will use the DIMES03 process, a 1 micron Silicon Bipolar process. The emphasis will be on conceptual evaluation.

A/D Conversion Techniques

In 1996 a collaboration with the IC-Technology & Electronics Group of the Faculty of Electrical Engineering of the University of Twente was started, in order to investigate the integration aspects of A/D converters. The aim was to realize an integrated converter with the same specifications as the converters used in the DZB. The design of this chip was finished at the end of 1997 and the first Integrated Circuits were received from Philips Semiconductors at the beginning of 1998. Meanwhile, a dedicated test-print and test-programme had been developed for assessment of the chip. Although the performance was not completely satisfactory, the experience gained in producing the chip was extremely useful for the future.

During the year, a second line of research also got underway. The aim was to investigate the use of standard (commercially available) A/D converters for astronomical purposes. A graduate student from the University of Twente (EE, IC-T&E) has modelled and analysed the digitization, by means of multi-bit A/D converters, of astronomical signals without Electro-Magnetic Interference (EMI). Extending the model to the situation where besides the astronomical signal strong interferers are present will be the second part of his research.

NOEMI

Array Signal Processing is the technique where signals are received through multiple sensor elements and are jointly processed to extract features of interest. Over the last decade, this technique has broken frontiers of performance with respect to high-resolution spatio-temporal signal detection and separation. Within Radio Astronomy array signal processing can be used for interference detection, estimation and rejection.

For that reason, the faculty of Electrical Engineering of the University of Delft/DIMES together with NFRA applied for an STW grant for the project named "Nulling Obstructing Electromagnetic Interferers" (noEMI). This project was granted by STW in 1997. The objectives are:

1. To study the characteristics of interference and select the most promising array signal processing algorithms to detect and reject such interference.

2. To "engineer" the selected algorithms. The aim is to build a small-scale demonstrator which performs adaptive beamforming at high speed and low cost using the WSRT.

3. To conduct a pre-study for on-line interference rejection for SKA.

The project is expected to last for about 4 years during which one PhD student, 2 post-doctoral researchers and one support engineer are involved.

This year research has concentrated on producing an overview of sources of interference and their characteristics, studying general designs of existing phased arrays for astronomy and to list candidate algorithms for interference detection and rejection. Furthermore theoretical investigations were conducted into detection and rejection algorithms for different types of interference, e.g. GSM signals. In order to be able to make real-life recordings of interference as received by the WSRT, the specifications of a recording system were set out and a suitable configuration has been selected and ordered.

Adaptive Digital Beamforming

An Adaptive Digital Beamformer (ADBF) takes the output signals (after A/D conversion) from the RF Beamformers and generates the signals that are fed into the correlator for image processing. The selectivity of the digital beamforming stage can be used to suppress e.g. time-dependent RFI effects.

The ADBF-system that is being used in both OSMA and THEA consists of two subsystems:

1. A Conventional Beam Former performs a spatial weighting operation on the snapshot. The digital beam one is left with, is narrower than the RF-beam. In THEA the RF beamwidth is 17 degrees, the digital beamwidth is four degrees.

2. An Adaptive Algorithm calculates the optimum value of the weight vector depending on the current RFI-situation. The weights are used to update the Conventional Beam Former at regular intervals.

The contrasting nature of these two steps means that a different approach is required for each. Modelling of the conventional beamformer is being done in the VHDL environment, with the likely implementation on an FPGA platform. The adaptive algorithm is being developed as embedded software in C that will run on DSP's.

Work has so far concentrated on modelling and exploring the boundaries for implementation of the ADBF stage. Of particular interest are the problems of sub-space beam processing and improvement of the adaptive control mechanism and its impact on the overall ADBF performance (accuracy, convergence speed and stability). FFT-based algorithms are being explored that open up the possibility of generating a set of beams that fill the RF-beam.

Photonics for SKA

A photonics work programme has been defined that concentrates on signal distribution over fibre stretches of up a few hundred meters using RF modulation techniques and up to a few Giga-Hertz of bandwidth. Current emphasis is on processing of the optical signals before conversion back to the electrical domain. In its simplest form this is an optical combiner with appropriate delay in each modulated input channel. Such a system has advantages over combining the electrical signals after detection, since strong interference can be reduced before detection, which relaxes the dynamic range requirements for detector and electronic amplification stages.

The effective gain of a photonics link can be further increased by using a single laser source instead of an independent one for each receptor in a phased array. This so called 'coherent approach', not only requires proper delay control with a precision related to the wavelength of the RF modulation, but an additional phase control for the optical carrier. This can in principle be provided by holograms that can be dynamically created in photorefractive crystals, as proposed by the Multi University Research Initiative (MURI) team at the University of Colorado in Boulder. A key element in such an approach is the modulator. In the context of our cooperation with the Department of Electrical Engineering in Boulder, one of their graduate students spent the summer at NFRA producing a design for a resonant electro-optic modulator integrated with a high efficiency driver. An article has been submitted and manufacture of such an integrated device on a lithium niobate substrate is in progress.

The joint study with TNO-FEL on key components in photonic architectures for phased-array receivers has received support from the Dutch Navy and will start in 1999. The literature part of the study has to reveal short term and long term feasibility aspects for coherent as well as incoherent approaches. Some components will be developed and implemented in OSMA, where part of the RF subsystems will be replaced by photonics equivalents, to test their viability and to compare the performance with electronic components.

Software Engineering/Image Processing for SKA

Software Engineering and Image Processing efforts concentrated this year on building a tooling and knowledge environment necessary for the various SKA efforts. Static and dynamic code checking tools are in routine use for some existing projects. Modelling tools for the Unified Modelling Language (UML) were evaluated to replace the current Object Modelling Techniques (OMT) tools. Some initial experiments with Java development tools were made. The use of Linux systems was further extended, in particular as an inexpensive alternative for inspection machines at the WSRT, but also as a major development platform.

Initial plans were made for a SKA End-to-End Simulation Environment (SENSE). This environment will be used to evaluate system aspects and exercise the challenge of making images based on data from inhomogeneous, time-variant voltage beams. In the coming year, research in the area of multi-parameter/ multi-patch selfcalibration for such beams will continue.

LOFAR

In response to a proposal by Dutch university astronomers, a study was performed into the feasibility of building a large low frequency array that operates in the 15-300 MHz range. Continuum observations below 100 MHz with baselines of up to 300 km, would open up one of the last unexplored regions of frequency/resolution space. Spectral observations, like those of the epoch of reionization of the Universe, would tend to favour a more compact array operating at frequencies between 100 and 300 MHz. Neither of these regimes can be covered by the current generation of radio telescopes.

One of the main goals of the pre-feasibility study that was carried out in the course of the year, was to see whether an operational telescope could be finished by the year 2005, and so bridge the gap between the upgrade of current facilities and completion of the Square Kilometer Array, which could well be some 10-15 years from now. Discussions with astronomers from the US Naval Research Laboratory have made it clear that interest in such an array is not confined to the Netherlands. In preparation for future discussions, the Dutch community has set up a working group (chaired by a Leiden astronomer) to investigate the scientific drivers for a low frequency array.

The continuum sensitivity of an aperture-bandwidth synthesis array is basically confusion limited. Below 300 MHz the sky brightness increases faster than the square of the wavelength, which leads to almost frequency independent sensitivity for antenna stations with constant beam receptors in a sparse array configuration. In such an array, the performance is dictated purely by imaging principles and sky properties (e.g. brightness and source intensity distribution). This can be conveniently handled by fractal-like geometries for the phased array antenna. The synthesis array will need to provide full u,v-coverage so that a robust multi-patch self-calibration procedure produces a high dynamic range sky brightness distribution within the field of view defined by the primary beam of a single antenna station.

Several key issues in a possible array have been identified and will need careful further study:

1. The choice of wide-band receptor (with a constant beamshape)

2. Interference suppression by spatio-spectral beam forming at the antenna stations

3. The considerable computer power required for beamforming, correlation and synthesis processing

In particular the last point is important. The computing power required for the successful processing of aperture synthesis data is comparable to the computer power required for digital beamforming and for correlation. Assuming that software development continues and that workstation processing power keeps growing as over the past decade, the "processing window of opportunity" will not be reached until the year 2005. At that time a low frequency sky survey can be processed in a few years with a battery of powerful workstations.

Preliminary cost estimates for a thirty-two station array, with only a single long (> 300 km) baseline look promising. More than fifty percent of the total manpower will be required for the design and development of digital systems like the spatio-spectral beam-former and the correlator, and most especially their associated software.

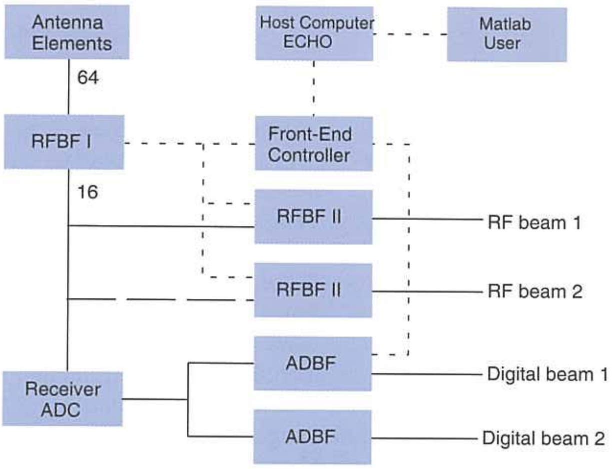


Figure 2.7 The OSMA Beamforming architecture.

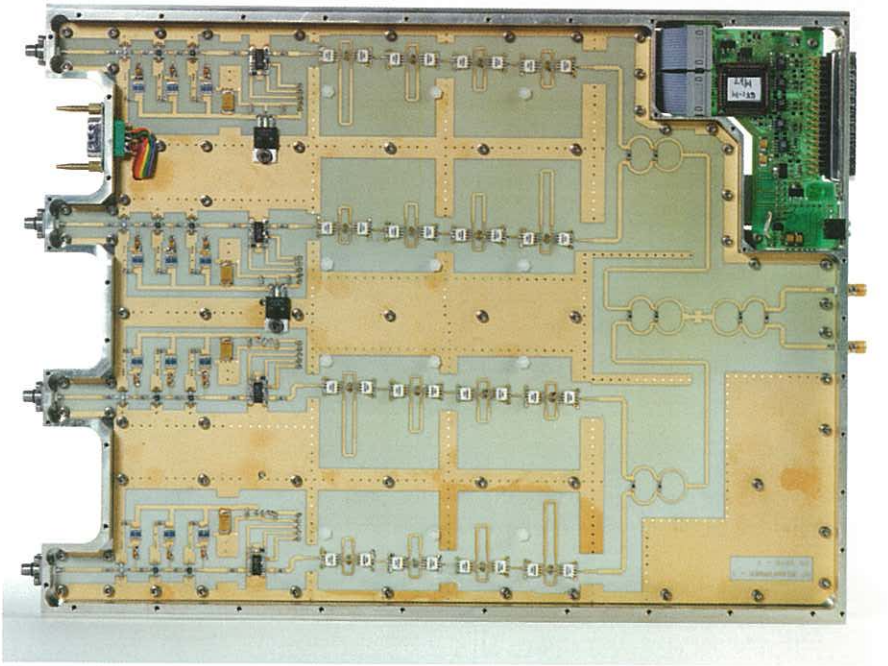


Figure 2.8 One of the RF Beamformer units, four antenna's (which are attached to the connectors to the left) are combined.

2.4.2 Demonstrators

OSMA - The One Square Meter Array

During the year considerable progress was made in the design and construction of the One Square Metre Array (OSMA), the second demonstrator that is part of Phase I of the SKA development programme. Thanks to a lot of effort from NFRA staff, the first RF beamforming results became available before the end of the year.

OSMA is a phased-array receive-only antenna with a mixed RF and digital adaptive beamforming architecture. The array will operate in the frequency range from 1.75 to 3.5 GHz, and will be used to demonstrate multibeaming, deterministic RF nulling and adaptive digital nulling. The linearly polarised antenna consists of an 8x8 element active central region, surrounded by two rows of passive elements (144 elements in total), as shown in the figure in Section 2.4.1. Initially, the array is being built up with broadband bow-tie antenna's with an integrated balun and a distance between adjacent array elements of 75mm in both directions. OSMA operates in the transition zone between sparse and dense arrays. The array is backed by a ground plane which is rounded at the array edges to reduce diffraction effects. In addition, the array has four calibration elements that will be used for on-line calibration of the active elements. The system has been mounted in the antenna measurement facility at NFRA.

OSMA can be used in two different modes: an RF beamforming mode, and a mixed RF/digital adaptive beamforming mode. These two modes of operation can occur simultaneously, either generating two RF

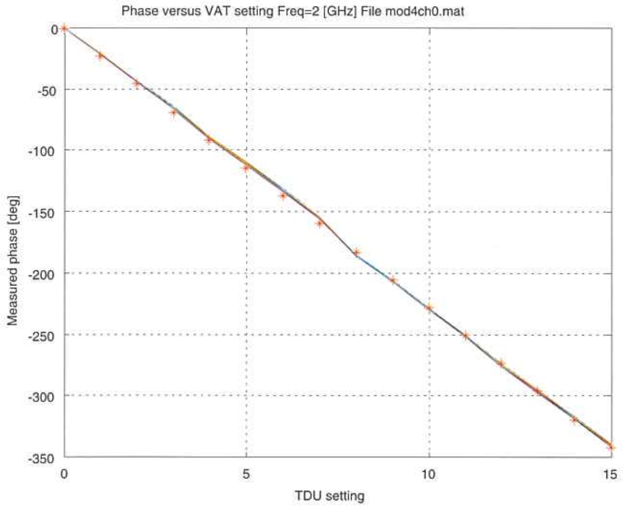


Figure 2.9 Phase test results of module 4 channel 0 at 2 GHz.

beams or alternatively a single RF and two digital beams. The top-level beamforming architecture of OSMA is illustrated in Figure 2.7.

The 64 active (antenna) elements are connected to 16 RF beamformer units (RFBF I), while the passive elements are terminated with matched loads. The outputs of the RFBF I units can be fed into to a 16-channel receiver followed by a 16-channel adaptive digital beamformer (ADBF) or into a second stage 16-channel RF beamformer (RFBF II).

The receiver units convert the input RF signals to 8-bit complex digital data which the Adaptive Digital BeamFormer (ADBF) system operates on. Either a dual DSP module or the OSMA chip (an ASIC developed by DIMES with a CORDIC implementation of the Minimum Variance algorithm) calculate the adaptive weights based on the channel data with an update rate of approximately 10ms. The weights are sent to the four beamforming ASICs, producing 32 bit complex beam data. The outputs are then captured using the Data Acquisition system (DAQ) and further manipulated by post-processing algorithms.

A photograph of an RFBF I module is shown in figure 2.8. Figure 2.9 shows a typical example of the performance of the in-house developed RFBF modules. The realised phase is shown versus Time Delay Unit (TDU) setting and versus the Variable ATtenuator (VAT) setting. Note that the TDU has 4 bits (16 settings). From this figure it is clear that the remaining phase errors are very small.

Finally, figure 2.10 illustrates the measured RF pattern of the OSMA array with 32 active elements in operation. The main beam is scanned towards broadside. A novel calibration method was used in order to correct for all amplitude and phase errors in the OSMA system. The proposed *"Multi-Element Phase-toggle"* (MEP) method is an extension of the well-known phase-toggle scheme and allows groups of elements to be calibrated simultaneously by using FFT signal-processing techniques.

THEA - The THousand Element Array

The THousand Element Array (THEA) is the third demonstrator phased-array system that is being developed during the initial phase of the SKA programme at NFRA. The feasibility phase of THEA started officially with a kick-off meeting that was held on 25 September 1998 at NFRA's headquarters. On that occasion, the project plan and a preliminary version of the system specifications were released. These specifications will be completed during the feasibility phase. The final system will be operational by the end of 2000.

THEA is an outdoor phased-array system that will be able to detect astronomical signals from multiple strong sources simultaneously (i.e. using multi-beaming) in an environment with a number of different RFI sources. The unwanted RFI sources will be suppressed with the adaptive nulling capability that THEA will be equipped with. The system consists of 1024 receiving antenna elements distributed on a regular grid over a surface of approximately 16 m^2. Performance of THEA will be optimised for the frequency band from 750 MHz to 1500 MHz. Electronic beamsteering is to be done with a mixed RF/ digital beamforming archi-

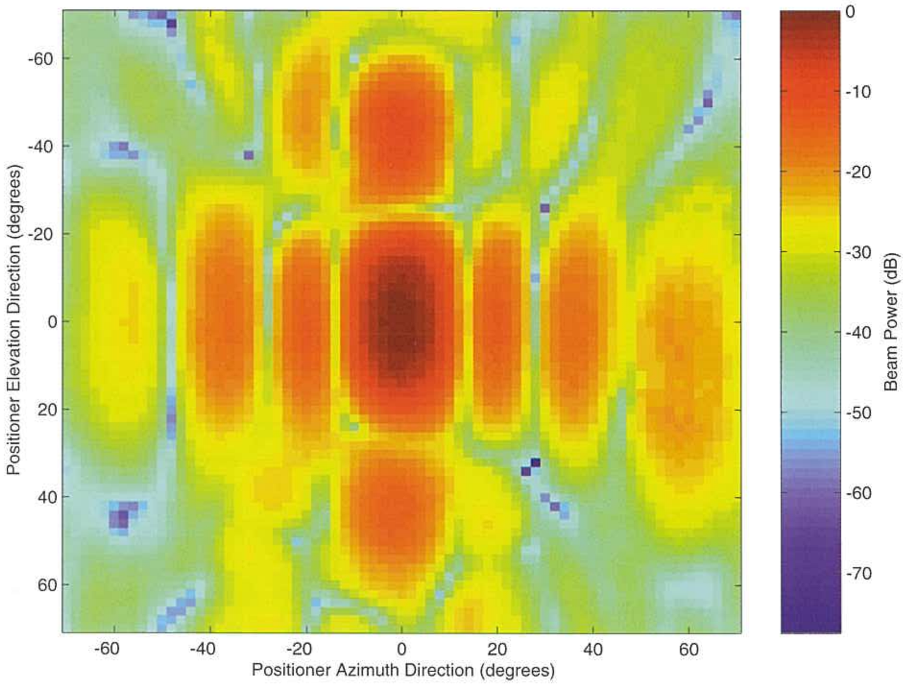


Figure 2.10 2D measured pattern at 2 GHz, (E-Plane is along vertical axis.)

tecture. Multiple beams (max. 32) can be made simultaneously without loss of sensitivity. In addition, the system will be used to test different RFI rejection concepts (e.g. RF deterministic nulling and adaptive digital nulling).

The basic building-block of the proposed system is a tile, that is approximately 1m^2 in size. THEA consists of 16 of such tiles, each with 8x8=64 receiving elements. The mechanical construction should allow the distance between the tiles to be changed. In this way, a sparse (random) array could be tested. The received signals of the 64 elements in each tile are coherently combined by an RF Beamforming unit and down-converted to a digital signal. The 16 digital output signals of the tiles are then distributed to a central digital adaptive beamforming unit. Each tile will have two separate RF beamforming units. In this way, two independent *RF beams* can be made simultaneously with each tile. Within each RF-beam multiple beams (max. 16) can be made simultaneously with the digital beamforming unit. An on-line calibration facility will be available to monitor and correct the performance of each receiving element. A summary of the system specifications of THEA is given in Table 2.1 below.

Number of array elements	1024
Antenna area	16 m^2
Array grid type within tile	Rectangular or triangular
Polarisation	linear
Number of re-configurable RF tiles	16
Number of simultaneous (independent) RF beams	2
Maximum number of simultaneous digital beams	32 (divided over 2 RF beams)
Sensitivity (10 sec. integrations broadside)	> 30 Jy @ 1GHz, T_{sys}=290 K
Operational frequency band (complete system)	750-1500 MHz (Minimum)
Instantaneous (IF) frequency bandwidth	20 MHz
Electronic scan volume of main beam	>100 degrees (2D scan)
Scan loss (additional to cos loss)	< 1 dB rms
Beam width of RF beam (of single tile)	< 17°/(f_{GHz}*cosʊ)
Cross polarisation level	< -20 dB w.r.t. Co-polar level
RFI suppression w.r.t. received source signal	
Element pattern at horizon	> 20 dB
- with RF beamformer (deterministic)	> 20 dB (outside main beam region)
- with digital beamformer (adaptive nulling)	> 25 dB
Max. RFI power received per antenna element	-25 dBm at broadside
System noise figure	< 3 dB (T_{sys}<290 K)
Dynamic range of AD convertor	46 dB above thermal noise
Number of bits AD convertor	> 10 bits, effective
Second-order intercept point (IP2) at input first LNA	+45 dBm
Third-order intercept point (IP3) at input first LNA	0 dBm

Table 2.1 Summary of the THEA system specifications

3. Radio Observatory

3.1 General Remarks

Dramatic changes have been taking place at the Radio Observatory. The implementation phase of many of the upgrade projects were in progress in 1998 and the improved technical capabilities have already started to make an impact on the operations and the scientific output. The first part of the new correlator was completed, almost all the final versions of the multi-frequency frontends, and the new telescope operating system. New scientific programmes have started that will push the envelope of our knowledge of the Universe.

On July 1, the Radio Observatory experienced a change of leadership when Hans Kahlmann, after 22 years as the head of the Observatory, handed over the helm to Willem Baan. Baan returned to his native country after some 27 years in the USA. During the tenure of Hans Kahlmann the Observatory grew to the internationally recognized scientific research facility that it now is. Along the way, the WSRT has made many contributions to our knowledge of the structure and the dynamics of galaxies, of the hidden mass distribution in galaxies, and of the early Universe.

The reorganization of the Observatory took place as part of the restructuring that started at NFRA in 1997 and is still underway. The most important part of the reorganization is that the operational part of the Westerbork Observatory and the scientific division of NFRA would be pulled together in a single department. The objective of this operation is to improve the interaction and collaboration on scientific and operational aspects. The implementation of most of the organizational changes were left for the new director. The operational side of the observatory is now organized into four groups:

1. The operations group under leadership of the telescope astronomer who has responsibility for scheduling the WSRT,

2. The system support group that deals with system performance issues such as on-line software, computer hardware, and frontend performance,

3. The electronics group responsible for digital and analogue electronics, and

4. The mechanical group responsible for the mechanical, electrical and cryogenic maintenance.

Within the scientific group a number of system scientist positions were created with specific responsibility for particular areas of the scientific research at the WSRT. These system scientists will be involved in visitor support, system testing of the telescope, and will help to optimize the WSRT system. Currently the heads of the four groups and the Director of the observatory form a Westerbork Management team. The system scientists function directly under the Director of the observatory.

3.2 The WSRT Upgrade

Commissioning of the Multi Frequency Front Ends (MFFE's)

This year saw the delivery of most of the Multi Frequency Front Ends (MFFE's) in their final form, and the installation on the WSRT. This process did not proceed entirely without hiccoughs, but in the closing months of the year MFFE's were being delivered and installed at a steady pace. Below is a summary of some of the highlights of the project during 1998.

Delivery of the first complete MFFE took place in late April, and by May it was possible to make the first interferometer link-up. The initial tests went smoothly, for the most part, although there were intermittent problems with the feed revolvers which would occasionally become jammed in certain orientations.

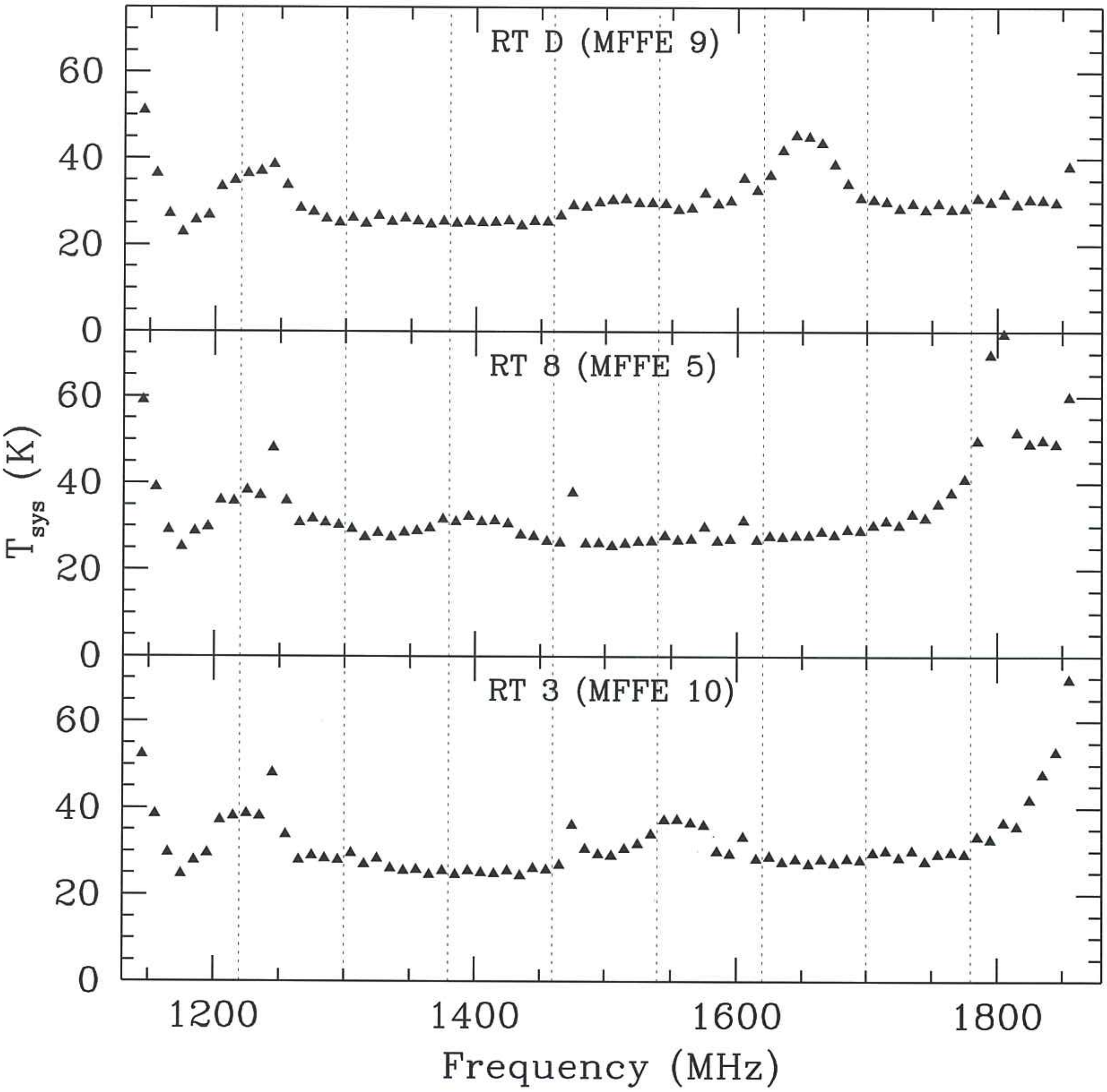


Figure 3.1 The run of system temperature over the new MFFE L-band (1140-1860 MHz), averaged over two linear polarizations as obtained from a series of nine 10-minute (8x10 MHz) observations of the source 3C286. A nominal aperture efficiency of 54% is assumed. The performance is extremely good at about 25-27 K over those parts of the band not affected by (presumably) satellite transmissions.

A problem was uncovered during lab tests early in the summer: some of the 3.6 and 6 cm LNA's (low-noise amplifiers) were found to have a high noise temperature, and to be unstable. This had not been the case when they were tested before integration in the MFFE cryostat. A matching problem was suspected, and a team was formed to investigate the problem further and propose possible solutions. Rather than delay delivery of the MFFE's, it was decided to go ahead with assembly as planned, but without the 3.6 and 6 cm systems. They would be added once the problem had been understood. (As they were less complete than the phase 2 MFFE's - phase 1 had been the two UHF systems alone - they were referred to as phase 1.5.)

In the end the main cause was traced to high resistance of the voltage supply leads, with the result that the potential drop was too low which led to a reduced amplifier gain. There was also a (less severe) matching problem. By the end of the summer a solution had been found and delivery of the phase 2 MFFE's was quickly resumed. The phase 1.5 frontends were recalled one-by-one for installation of the improved LNA's, a procedure largely completed by the year's end. The LNA's of the remaining systems operated smoothly, achieving sensitivities as good as, and in some cases better than, their design specifications.

The L-band (21 and 18 cm) system was found to be particularly good (see the system temperature values in Figure 3.1). For this reason, coupled with problems with the Dwingeloo Telescope and some delays in the DZB, it was decided in September to complete the DOGS (Dwingeloo Obscured Galaxy Survey) project with the then available WSRT dishes, half of the array. Because of the excellent sensitivity at 21 cm, the equivalent of a more than half a year's observing with the Dwingeloo telescope was finished in a matter of weeks at the WSRT.

The L-band system extends, at the low side, to 1200 MHz, where it can be used for observing HI redshifted to z=0.18. The behaviour of the system below 1200 MHz was looked into, and it was found to be usable to at least 1150 MHz. In this region of overlap with the UHF(high) receivers, the L-band system is much more sensitive. The lowest usable frequency is still a matter of investigation, but it seems that redshifted hydrogen to z=0.25 should be observable, making the WSRT an even more suitable instrument for such investigations.

By the end of the year, 10 of the WSRT dishes were outfitted with phase 2, and two with phase 1.5 MFFE's. Two dishes were unavailable for regular observing, because of mechanical maintenance. By mid-February of 1999 there should be enough phase 2 frontends for all 14 dishes. Apart from a small number of minor problems that remain to be tackled, the MFFE's generally function well. Their sensitivities are good, they are stable, and high-quality astronomical observations are being produced. The completion of this very substantial, challenging project is in sight.

A PuMa in Westerbork

The first half of the new WSRT Pulsar Machine, PuMa, arrived in Westerbork in May. It was built at the Instrumental Physics Group of the University of Utrecht by engineers and astronomers from Utrecht and Amsterdam. The second half of the machine should be completed in 1999. The first observations were performed on 28 May with nine dishes of the WSRT in tied array mode at 840 MHz using a 10 MHz bandwidth (one-eighth of what the full PuMa will be capable of). In the period that followed, several test observations were performed, and teething problems were solved by further testing and adjustment.

Figure 3.2 The Pulsar Machine (PuMa) in the Faraday cage at the Westerbork Observatory.

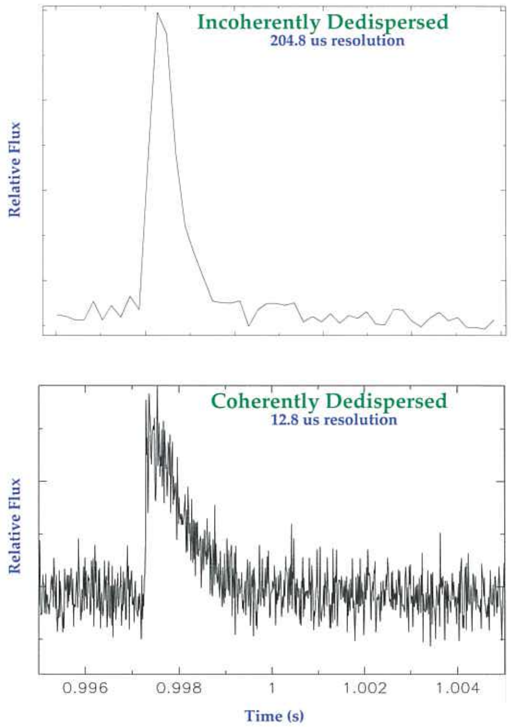


Figure 3.3 A giant pulse from the Crab Nebula pulsar (PSR 0531+21), both with and without coherent dedispersion.

The full PuMa system can be configured in different ways, with up to 8192 frequency channels, a total bandwidth of 80 MHz, and time resolution of 1.6 μs. It can be used in search mode, recording just two polarization channels, or for observations of known pulsars, determining all four Stokes parameters and correcting for dispersion and Faraday rotation on-line. A series of commissioning tests, held at roughly fortnightly intervals, began in the autumn. These have uncovered further problems that require solution before PuMa can be considered ready for regular observations. Among the most important are the presence of several interfering signals (some of which are intermittent) at frequencies of a few Hz. Some of these originate in PuMa itself; all are being intently looked into.

During the last sessions of the year, observations were performed to establish a flux density scale, by observing pulsars with a range of known flux densities. In addition, there are plans to establish a sample of polarized pulsars, observe them over the wide range of frequencies which the WSRT offers, and establish the instrumental parameters that are required for correcting polarization observations of other pulsars. It is now possible to output all Stokes parameters, and a number of observations have been carried out. While testing of PuMa itself has been going on, there have also been intensive efforts to get the required off-line software in shape. Figure 3.3 shows an example of a giant pulse from the Crab Nebula pulsar (PSR 0531+21) with and without coherent dedispersion applied.

It is hoped that PuMa commissioning will be completed early in 1999. There will then be a period of astronomical observing and if all goes well, new proposals can be submitted starting spring 1999. There is also a new project, PuMa II, which will greatly expand the instrument's capability. It will be able to handle twice the bandwidth, with real-time dedispersion. It should be particularly suitable for high-precision (nanosecond) timing, searches for binaries in tight orbits, and nanosecond polarimetry. PuMa II is being financed through NOVA.

The DZB Correlator System

The new WSRT correlator system will be the most powerful backend of any synthesis array now in operation. Its capacity will support a maximum bandwidth of 160 MHz with 512 spectral channels and four polarizations for 136 baselines. A variety of software configurations will deploy this capacity where it is required for specific observations, providing a wide range of options for spectral resolution and coverage, including the ability to simultaneously tune to eight independently steerable frequency windows. The correlator consists of several subsystems:

1. An IF-to-Video Converter system (IVC) that takes eight bands of 20 MHz width from the receivers and mixes these to base band,

2. The eight corresponding modules of the analogue-to-digital converter system (ADC),

3. Eight correlator modules and

4. The tied array distribution unit (TADU) which is used to form the summed array output for various applications that require this (including VLBI, pulsar observing, compound interferometry, etc.)

During 1998, all of the ADC and correlator modules were effectively completed. The IVC subsystem received funding approval in May of this year and is now in a final design and production phase, with anticipated delivery early in 2000. The TADU subsystem has undergone continued design and is also expected to undergo integration in early 2000.

Since not all of the correlator subsystems have yet been completed, the new system is being implemented at the WSRT in three distinct phases. In the first phase, a single ADC and correlator module is being used in conjunction with the 10 MHz IF system of the previous generation spectral line correlator (the DLB) to provide a basic spectral line capability (the 10 MHz System). In phase 2, one of the IF channels of the previous generation continuum correlator (the DCB) is being modified to provide a 20 MHz bandwidth, albeit superposed in a dual sideband mode. A single ADC and several correlator modules then reconstruct a single sideband spectrum over 20 MHz bandwidth (this is referred to as the 20 MHz System). In the third phase, the IVC and TADU will be integrated with the complete set of ADC and correlator modules, and options for recirculation will be implemented.

While the first results from the 10 MHz System were already obtained in the autumn of 1997, the entire year 1998 was devoted to carrying out technical and astronomical commissioning, interspersed with the continuing scheduled observations of our user community. Software synchronization of the many hardware subsystems, both the new and especially the old, has proven quite challenging. Even at the end of the year, there were still a number of aspects that require further tuning to optimize both the astrometric precision and the calibration quality of the data.

Even so, a significant number of useful observations were obtained, yielding a wide range of exciting discoveries. The 10 MHz System has already done much to alleviate the spectral channel bottleneck that has afflicted users of the WSRT for many years. Up to 16 telescopes can now be correlated (providing room for growth from the current 14 in place) with a product of polarizations and spectral channels of 256 across the desired bandwidth. Since all cross-correlations of the array antennas are now formed (with 2 bits), rather than only a small subset (with 1 bit), the sensitivity has also been significantly improved (over and above the great improvement in receiver performance of the MFFE's). The enhanced correlator capacity has also made it possible to routinely obtain auto-correlation spectra with the array in parallel with cross-correlation data. This has led to new observing modes (such as the one employed to complete the Dwingeloo Obscured Galaxy Survey at the WSRT).

The planning and first preparations for the 20 MHz System also got underway in 1998. Technical commissioning of this system is expected to begin in March 1999. This system should make it possible to support those spectral line programs that require a rather broad bandwidth at moderate spectral resolution (like imaging galaxy clusters at red-shifts of 0.2 in HI emission).

Planning for the complete DZB 160 MHz System also continues to progress. Integration of this system is dependent on completion of the IVC and TADU subsystems noted above, and is anticipated for mid-2000. In the mean time, users requiring the highest continuum sensitivity will continue to use the DCB correlator providing a maximum bandwidth of 90 MHz. An interesting option for the coming 18 months will be the possibility of obtaining parallel DCB and DZB 10 or 20 MHz data, so that a deep continuum database would accompany every spectral line observation, and vice versa.

The Telescope Management System

The focus of activities this year was the integration of TMS with the DZB. The first result, the 10 MHz DZB system - which has only an eighth of the full DZB capacity - has already taken a lot of useful, high quality, data. In the autumn a special mode of TMS and the DZB allowed the DOGS survey to be completed with the WSRT.

The second phase of TMS formally ended in February 1998, although integration of the DZB within TMS will continue in Release 3. An important step in Release 3 is the phasing out the current on-line HP1000 software. This major operation has many implications, relating to both software (e.g. test programs and control operations) but also to special hardware that controls a number of devices. Controllers for the VME/MUX interface were successfully completed during the year. Test programs and most of the DCB software have also been transferred. What remains for 1999 is extensive testing and integration of the overall control in TMS. In Release 3 WSRT Database functionality will also be taken over by TMS. Database browsers written in glish will be used in addition to web-based browsers that will make the TMS databases accessible via the web.

Export and administration tools were taken into production at the end of 1998. Although the final implementation is not completely ready, day-to-day operations are possible. TMS now also checks the status of crucial parts of the WSRT, like the cryogenic temperatures of the frontends, the functioning of computer systems and software. If problems arise, TMS sends alarm messages to persons concerned. In 1999 this feature will be extended by monitoring of other crucial parts of the WSRT, such as the maser and the temperature control of the Faraday cage.

The TMS and backend infrastructure was upgraded in 1998 in anticipation for the full DZB system. The real-time acquisition net (called DZB-net) was separated from the regular WSRT net. A switch in the DZB-net takes care of all data traffic and has enough power for the full DZB system. To prevent problems on crucial machines due to compiling/linking actions, the TMS development machine was transported to Westerbork and is now connected to the WSRT-net. Development and testing as well as building new versions of TMS (and AIPS++) can now be done on a non-crucial local machine.

3.3 The Dwingeloo Radio Telescope – A Tribute

The Dwingeloo Telescope, at the edge of the Dwingelder Field, has been a familiar sight for the inhabitants of Dwingeloo and the many tourists that have visited our corner of the country. This telescope was built 42 years ago, and has aged considerably. During the spring of 1999 it was decided to cease observations and not accept any new observing proposals. The last science projects on the telescope were the Dwingeloo Obscured Galaxy Survey (DOGS), by scientists from the University of New Mexico, and a survey of strong Galactic OH maser emission by scientists of the University of Bristol (UK) and NFRA with the help of a summer student from the University of the Canarias (Spain).

As a result of the emphasis placed on the WSRT Upgrade, instrumentation of the Dwingeloo Telescope has lagged behind in recent years. It has now aged so much that a single WSRT telescope can do the work of the Dwingeloo telescope in a fraction of the time. For this reason, it was decided during the summer of to shift the running DOGS project to the WSRT. The DOGS project was finished with only six WSRT telescopes in three weeks, which would have taken the Dwingeloo telescope until June 1999. Upon completion of the other project (noted above), the receiver was removed for the last time on October 8, 1998. It was the end of a long and honourable period of service for the Netherlands astronomy community. The HI structure of the Galaxy, High Velocity Clouds and detection the Dwingeloo 1 and 2 galaxies are just a few of the many projects from the past. There has also been a long list of researchers and students that have used the telescope: Harm Habing, Hugo van Woerden, Mike Davis, and many other students of Jan Oort, Henk van der Hulst, and Butler Burton.

It is important to emphasize that the Dwingeloo telescope could operate for so many years, only because of the love and dedication of the members of the technical and computer staff at NFRA, they made sure it was always in good shape. For the time being the telescope will look at the sky in parked position, until a permanent solution can be found for its future. We hope to keep the telescope in Dwingeloo as a historical technological monument.

3.4 VLBI with the WSRT

During the first half of 1998 Westerbork took part in VLBI sessions as a single dish. Circular polarization (needed for VLBI observing) was produced in the frontend by modifications to the linear polarization originally in the prototype MFFE. Only a single dish was used because of the lack of sufficient MFFE's with 6cm and 18cm capabilities to phase up a tied-array. In tied-array mode, outputs from the telescopes are added together in phase (with phase and delay tracking done for the source of interest) so that a much better signal to noise ratio is reached for a point on the sky.

The new MFFE's have the following noticeable differences with respect to the previous generation of frontends:

- Improved sensitivity at standard VLBI 6 and 18cm bands.
- New capability in one of the standard VLBI observing bands at 3.6cm (in addition to other (non-standard) VLBI bands.
- The capability of rapid switching between wavelengths.

One disadvantage of the MFFE's is that their dipoles cannot be rotated. In the past this procedure was used to make the necessary phase corrections to produce circular polarization (standard in VLBI) from the

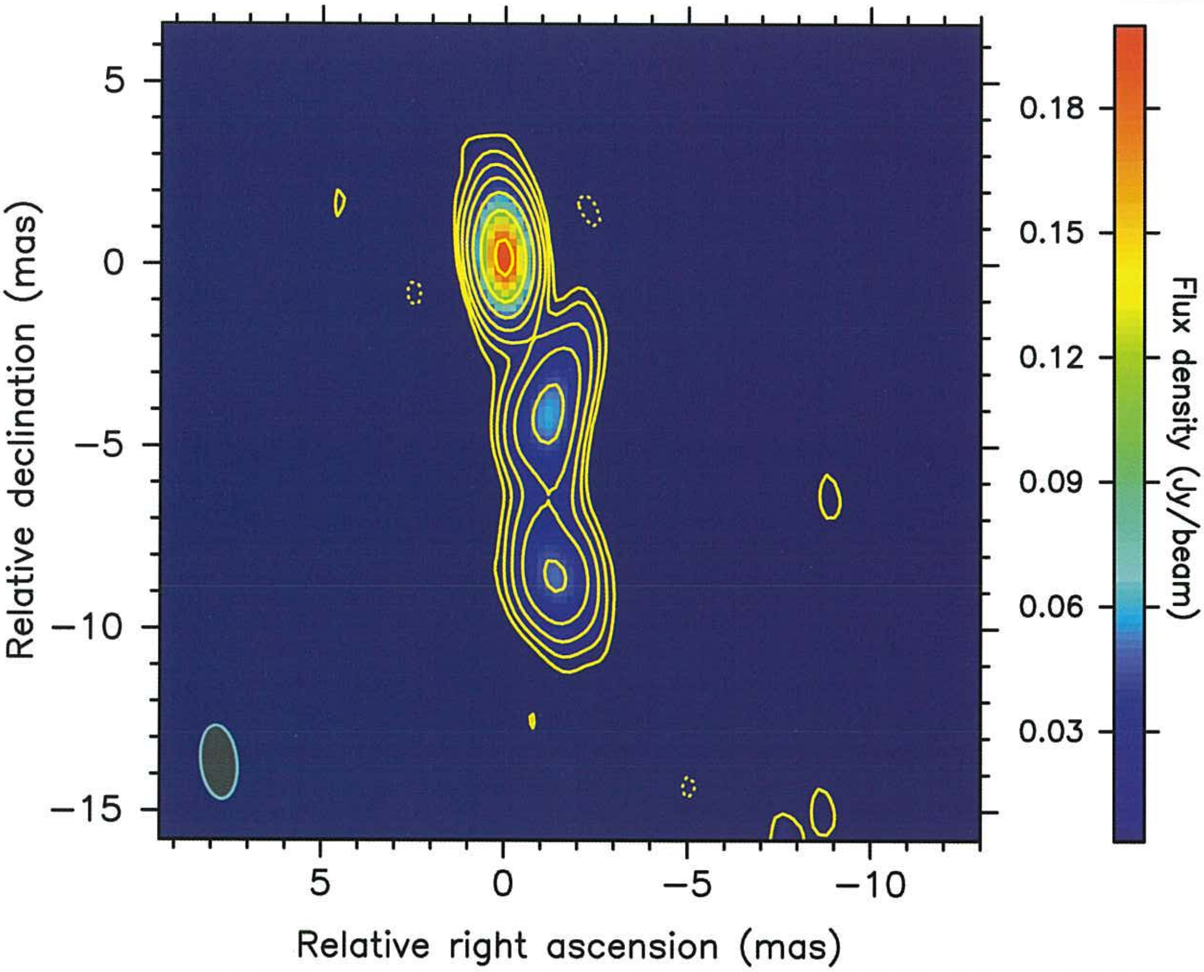


Figure 3.4 0014+813 is one of the most luminous quasars known, lying at a distance of 13.6 billion light years. This 1.6GHz image shows a well resolved core-jet structure. The observations were made with HALCA, six telescopes of the European VLBI Network, and the NRAO Green Bank 43m telescope. Reproduced with permission of Prof. Hisashi Hirabayashi.

linear polarizations that are standard in Westerbork. In order to check on the polarization characteristics, a phase-calibration system was therefore produced. This apex phase-cal system consists of a conical antenna placed at the apex of the dish. The signal from this antenna arrives at the feed along with the sky signals and travels through the electronics, but as each tone has a known phase relationship to the others, it can be used to determine phase and delay characteristics of the array from one frequency band to the next. Since the antenna used was also circularly polarized (it is a conical spiral) the polarization properties of the array (via the telescope into which it is introduced) can also be checked. The relative phase at all frequencies can be used to align different frequency bands, and check on phase jumps through the whole observing system. The tied array mode for which phase calibration is essential, was first used in October.

During the first EVN session (in February) Westerbork participated as a single-dish in 6cm and 18cm experiments; a problem with the HALCA satellite caused all VSOP-mode observations at 6cm to be lost. The second EVN Session of the year took place in May, with Westerbork once again participating in single dish mode at 6cm and 18cm. An attempt was made to use a new real-time fringe test mode (dumping a small section of data to a buffer and sending it via Internet to a central site for correlation there). The data transfer worked, but the "software correlator" was not ready to process the data. The third EVN session, in September, had been planned as a major VSOP observing run, but a repeat of satellite problems caused this to be reduced to just 2 observations. The final EVN session of the year took place in November. This was the first time that the phase calibration system was used to check on the polarization properties of the tied-array. It was also the first time that the tied-array had been used for standard VLBI observing bands. As well as doing 6cm and 18cm observations the tied array was used for a test at 3.6cm.

In addition to these EVN sessions two non-EVN VLBI sessions took place in the course of the year. In March, a single VSOP observation at 18cm of an outburst in Orion-KL with a single dish at Westerbork was scheduled to run in parallel with a 1.3cm observation to determine if the loss in efficiency with VSOP at 1.3cm was purely a pointing offset. In October a week of VLBI was done with the tied array for a large UHF project. These were high resolution follow-up observations on UHF absorption lines found with the new MFFE's at Westerbork. This was the first use of the tied array for VLBI in 1998.

3.5 WSRT Projects and Time Awards

The scientific production over 1998 totaled a modest 3557 hours, which means an average efficiency of 41% or 9.75 hours/day (this includes calibration and applies only to the WSRT projects to which time was allocated by the NFRA-PC). Production was clearly limited by the complex WSRT upgrade still in progress in 1998. It is encouraging that by the last quarter the efficiency had risen to 56% (13.5 hours/day), and it is hoped that the scientific production will show a further substantial increase over the course of 1999, as the upgrade operations wind down.

The table below gives a summary of the projects that were observed in 1998.

Project	1998 hrs.	Backend	Frontend	P.I.	Title
1234	111	DZB	21cm	Szomoru	Emission Line Imaging of HI in the Cluster Abell 963 at z=0.2
R.97B.01	229	PuM	UHF-h	O'Dea	Testing Models for the Evolution of Powerful Extragalactic Radio Sources
R.97B.13	120	DZB	UHF-1	Pentericci	A Search for Neutral Gas in the Most Distant CSS Radio Galaxies
R.97B.14	212	DZB	UHF-h	Vermeulen	Neutral Gas in Luminous Compact Radio Galaxies: Inventory of CJ-Sample
R.97B.17	42	DCB	multi	Galama	Rapid Follow-up of Arcminute-sized GRB Error Boxes
R.97B.18	56	PuM	multi	Kouwenhoven	Simultaneous Single-Pulse Observations of Pulsars
R.97B.21	40	PuM	multi	Voute	Testtijd for PuMa
R.98A.01	571	DCB	92cm	Miley	A Westerbork Survey in the Southern Hemisphere (WISH)
R.98A.02	163	DZB	UHF-h	Lane	Low Redshift HI 21cm Absorption im MgII Selected Systems
R.98A.03	30	DZB	UHF-h	Lane	Followup Observations of two New HI 21cm Absorbers at Low Redshit
R.98A.05	124	TVL	UHF-h	Briggs	VLBI Spectral Line Observations in the UHF Band
R.98A.06	14	DCB	21cm	Keenan	High Velocity Insterstallar Gas Towards the Globular Cluster M15
R.98A.07	106	DCB	multi	Galama	Continuation of Rapid Follow-up of GRB Error Boxes
R.98A.15	14	DZB	UHF-h	Hagiwara	The HI Gas Distribution in Radoi-loud QSO 3C48
R.98A.16	19	DZB	UHF-h	Baan	A Preliminary Survey of OH absorption with the WSRT
R.98A.17	26	DZB	UHF-1	Braun	Molecular Gas in the Early Universe
R.98A.18	105	DCB	multi	Stappers	Radio Monitoring of the Bursting X-ray Binary CI Cam
R.98A.19	7	DCB	UHF-h	Ramachandran	Simultaneous Observations of the X-ray Transient XTE J1806-246
EVN1998/1	150	1VL	multi	EVN	
EVN1998/2	255	1VL	multi	EVN	
R.98B.02	35	DZB	UHF-h	Baker	Search for HI Absorption Towards High-Redshift Quasars
R.98B.03	23	DCB	multi	Fender	Long-wavelength Radio Observations of Radio-emitting X-ray Binaries
R.98B.05	40	DCB	multi	de Pater	Jupiter's Radio Spectrum from 74 to 8500 MHz
R.98B.07	36	DZB	UHF-1	de Bruyn	Is the Star-forming Galaxy 53W002 a Damped Ly-alpha Absorber ?
R.98B.08	13	DZB	UHF-h	de Bruyn	Ionised Gas Densities Inside/Outside 'Double-Double' Giant Radio Galaxies
R.98B.09	17	DZB	UHF-h	Chengalur	The HI Profile of the 0218+357 Lens
R.98B.13	42	DZB	UHF-h	Briggs	Kinematics in a Damped Lyman-alpha Absorber at z=0.4
R.98B.15	18	DZB	UHF-h	Kanekar	HI 21cm Absorption from Damped Ly-alpha Systems
R.98B.21	43	DCB	multi	Koopmans	Dark Lenses and H0 from the CLASS Survey
R.98B.23	144	DZB	UHF-h	Koopmans	A Search for HI in Gravitational Lens Galaxies
R.98B.24	28	DZB	UHF-h	Hagiwara	A Possible Detection of HI in Radio-loud QSO 3C48
R.98B.25	205	DZB	UHF-h	Vermeulen	A Systematic View of Neutral Gas in Compact Radio Sources out to z=0.8
R.98B.27	102	DZB	UHF-h	Vermeulen	Are Radio Lobes Good Probes of Neutral Gas in Their Hosts?
R.98B.28	31	DZB	UHF-h	Snellen	A Search for HI in GPS Galaxies
R.98B.30	100	DZB	UHF-h	Conway	HI Absorption in FRII Radio Galaxies
R.98B.31	26	DZB	UHF-h	Briggs	Contd Monitoring of Variable 21cm Absn Lines in AO0235+164 During Radio Burst
R.98B.32	26	DZB	21cm	Pihlstroem	HI Absorption in the FRII Galaxies 4C29.30 and 3C321
R.98B.33	364	DZB	21cm	Henning	Completion of the Dwingeloo Obscured Galaxy Survey with the WSRT
R.98B.34	3	TVL	21cm	Lane	VLBI Observations of a z=0.091 HI 21cm Absorber Towards B0738+313
R.98B.36	4	FFB	multi	Voute	Tests for a Possible Pulsar Concert
EVN1998/3	15	1VL	6cm	EVN	
R.99A.01	78	DZB	21cm	Dwarakanath	HI Absorption in the WNM of the Galaxy
R.99A.04	4	DZB	21cm	Rivers	Follow-up Observations for Dwingeloo 25-m and WSRT Zone of Avoidance Surveys
R.99A.08	44	DZB	21cm	Lane	HI Emission in a z=0.0912 Damped Ly-alpha Absorber
R.99A.10	78	DZB	21cm	Braun	Compact HVCs: Primitive Constituents of the Local Group
R.99A.12	115	DCB	multi	Galama	Continuation of Rapid Follow-up of GRB Error Boxes
R.99A.13	19	DCB	multi	Galama	Search for Late Emission from GRBs
R.99A.14	14	DZB	21cm	Hagiwara	Detecting OH in Radio-loud QSO 3C48
R.99A.21	14	DZB	18cm	Sjouwerman	1612 MHz Observations of M31
R.99A.22	14	DZB	21cm	Schoenmaker	HI Absorption Towards Two GPS Sources With MPC-scale Radio Lobes
R.99A.26	13	DZB	UHF-h	Peck	Search For Circumnuclear Tori in 3 Fainter Compact Symmetric Objects
R.99A.29	24	DZB	UHF-h	de Bruyn	Variable HI and OH Absorption in 1830-211
R.99A.34	24	DZB	multi	Baan	OH Emission and HI Absorption at High Redshifts
R.99A.37	16	DZB	21cm	v.Albada	WHISP (Westerbork Survey of Neutral Hydrogen in Irregular and Spiral Galaxies)
EVN1998/4	176	TVL	multi	EVN	

4. The Joint Institute for VLBI in Europe

Highlight of the year was the official inauguration of the new EVN Mark IV Data Processor at JIVE on 22 October (see Figure 4.1). The 300 guests from 25 countries were treated to a number of short speeches on subjects ranging from the importance of radio astronomy and VLBI for science in general, the funding processes for science in Europe, to the prominent position enjoyed by radio astronomy in the northern part of the Netherlands and expectations for future developments. The Queen's Commissioner for the Province of Drenthe, Mr A. L. ter Beek, was the guest of honour whose duties included the formal commencement of Data Processor operations as well as the final speech. After loading the tape from his local radio telescope, Westerbork, on one of the playback drives, Mr ter Beek activated the central computer to start the correlation of the data from the 16 telescopes in the observation.

The inauguration was the culmination of almost six years of design and construction work by an international consortium involving JIVE, NFRA, Haystack Observatory in the USA, the Nuffield radio Astronomy Laboratories in Jodrell Bank, UK, and the Institute of Radioastronomy in Bologna and Noto in Italy. Financing the construction of the data processor was made possible by a grant from the Netherlands Ministry of Education, Culture and Science via NWO, and substantial additional grants by the CNRS in France and the Wallenberg Foundation in Sweden. A total of 5.4 M Euros and 75 manyears were needed to complete the construction. The Data Processor has now entered its Commissioning Phase, and is expected to be operational for a restricted set of modes in mid-1999.

The fourth EVN/JIVE Symposium was held in Dwingeloo from 22 to 24 October to coincide with the inauguration of the processor. There were 93 external participants amongst the 110 attendees; 62 papers were presented including 18 posters. The Proceedings are to be published in the refereed journal, New Astronomy Reviews.

The commitment of JIVE to support the operations of the European VLBI Network (EVN) continued during the year with the support scientists in Dwingeloo, Bonn, Socorro, Jodrell Bank, Onsala, Alcala, Medicina, and Westerbork all contributing in different ways to the observation process with Network Monitoring Experiments, correlation of experiments, operational and technical support for observing at

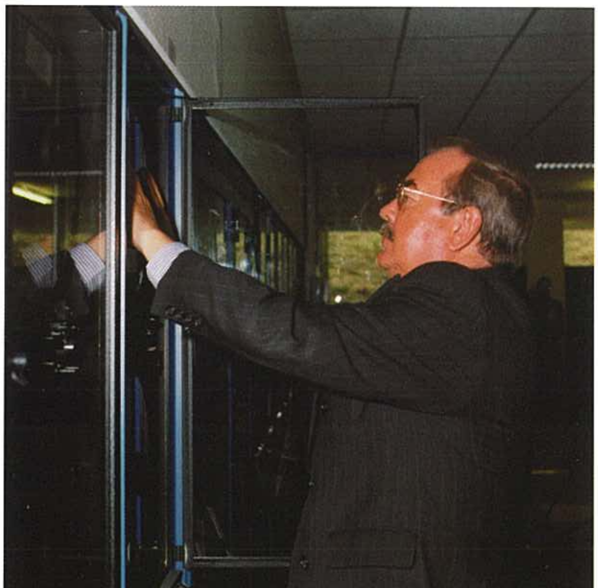


Figure 4.1 The Queen's Commissioner for Drenthe places the Westerbork tape on one of the tape drives of the new EVN Mark IV Data Processor at JIVE (inset).

individual telescopes, space VLBI support, preparation of calibration data files for the astronomers, and the development of a real-time fringe check system. Many of these same support scientists provided assistance to individual astronomers in Europe in the preparation of their observing schedules and in data analysis. Support for access to the EVN by astronomers not working at EVN institutes is provided in part by a grant from the European Commission.

5. The Astrometric/Geodetic Station at Westerbork

Since 1996 Westerbork has been the host of a satellite geodetic observatory initiated by Delft University of Technology. The geodetic community has for many years had a great interest in connecting the various referencing systems with that of Westerbork Synthesis Radio Telescope and its relation to geodetic VLBI. This observatory currently consists of the following parts:

1. A 9 x 9 m^2 concrete platform for transportable VLBI and satellite ranging observing (SLR) systems.

2. Global Positioning System (GPS) receivers as part of the International GPS Network and the Active GPR Reference System in the Netherlands.

3. A 24 meter steel tower mounted in concrete as support for a permanent GPS system, which overlooks the WSRT antennae and the trees of the Westerbork forests.

4. An underground 3 x 3 x 3 m^3 concrete block with climate control for absolute and relative gravity measurements.

5. An underground height marker for the Normal Amsterdam Height, the Netherlands height referencing system.

Together with the geodetic function of the WSRT, using one nearby telescope (RT7) for geodetic VLBI, the observatory will become an "astrometric-geodetic observatory". Besides using existing space technologies (SLR, GPS and VLBI) and gravity measurements, new applications are also being considered such as GLONASS, the new European Global Navigation Satellite Service (GNSS) concept, and the French orbit determination and locating system DORIS.

Plans are also being made to further integrate the geodetic and astrometric efforts in the Netherlands. By having the geodetic and radio observatory equipment co-located, the efficiency of both operations will be increased because the modelling exercises of both can be combined. Measurements are of course done from the same spot on Earth and through the same refractive piece of atmosphere.

Astronomical and geodetic measurements complement each other in parameter space. Bringing the experimental equipment together also provides a meeting ground for researchers form both communities which can lead to mutual enrichment and an increase of efficiency.

Projects of interest for the geodetic community include:

1. Current motions of the Earth's crust and of the sea level.

2. Improvement of the determination of the vertical component of the Earth's surface.

3. Dynamic satellite methods, absolute gravity measurements, and accurate vertical distance determinations will allow the definition of a consistent global 3-dimensional reference system.

The global geodetic community, Westerbork Observatory, and NFRA feel that a close collaboration is of mutual interest for the scientific community in The Netherlands.

6. Spectrum Management

IUCAF - The Commission on the Allocation of Frequencies for Radio Astronomy and Space Science

IUCAF is a Commission that works on spectrum matters related to the scientific use of the radio spectrum under the ICSU, the International Council for Science, which is part of UNESCO. IUCAF is sponsored by the IAU (International Astronomical Union), URSI (Union for Radio Scientists), and COSPAR (Commission on Space Research). The Secretariat of IUCAF has been hosted by NFRA in Dwingeloo during the year. IUCAF is a non-voting "sector member" of the ITU-R, the International Telecommunication Union – Radiocommunication sector, and actively works within its Task Groups and Study Groups. IUCAF has participated in all recent World Radiotelecommunication Conferences. The new director of the Radio Observatory, Dr. Willem Baan, has been its chairman since the autumn of 1995.

During the year, IUCAF participated actively in the work and the meetings of ITU-R Task Group 1-5 on setting standards for unwanted emissions, which significantly contribute to the pollution of the electromagnetic spectrum. Although radio astronomers actively participate in these proceedings, the results are affected strongly by political decisions and by the demands of the telecom industries, particularly those using space platforms. IUCAF also actively supported the work of ITU-R Working Party 7D on radio astronomy. The radio astronomy community faces many challenges and needs to work harder at preparing the legal foundation for continued protection of radio astronomical observations in the future.

IUCAF has also supported and contributed to Commsphere, which is a series of meetings organized by URSI to provide a forum for open discussion on matters of spectrum use between regulators, scientists, and people from industry. Commsphere Africa was held in Dakar in 1998 in an attempt to start up the dialogue in Africa and to make the challenges of the science services more visible.

CRAF - The Committee on Radio Astronomy Frequencies

The CRAF Secretariat and its "clearing house" are also housed at NFRA in Dwingeloo, managed by dr.Titus Spoelstra. CRAF has worked on the protection of radio astronomy frequencies in Europe since 1988 and has become a recognized body at national and international level. This is visible in CRAF's membership of the ITU-R (since 1998), the intensive cooperation with the CEPT (Conférence Européene des Postes et des Télécommunications) and with various administrations in Europe and elsewhere.

Spoelstra is also the European frequency manager. In this function he participated in 1998 in about 40 meetings on various frequency protection and regulation issues at different locations in Europe. Negotiations took place with the satellite operator Iridium LLC on the protection of radio astronomy at 1.6 GHz from unwanted emissions from transmissions of the Iridium system, which consists of 66 low earth orbiting satellites and operating in the band 1621.35-1626.5 MHz. These negotiations were a major and time consuming undertaking which led in the summer to a framework agreement between the European Science Foundation and Iridium (see CRAF Newsletter 1998-3 - http://www.nfra.nl/craf). Before the summer of 1998, these discussions took place under auspices of the Milestone Review Committee, MRC, of the CEPT, with participation of The Netherlands, France and the United Kingdom administrations and of the European Commission.

CRAF actively participated in the technical discussions within the CEPT project teams PT33 on the development of an allocation table for frequencies above 71 GHz (in preparation of the World Radiocommunication Conference of 2000), PT34 on the protection of radio astronomy in various frequency domains such as 42.5-43.5 GHz, and SE28 on the spectrum sharing of the Radio Astronomy Service with stations of the Mobile-Satellite Service (currently in the frequency ranges below 1 GHz, around 1.6 GHz and 5 GHz).

The frequency management work is done in close cooperation with the IUCAF chairman. The CRAF secretariat maintains a Website (http://www.nfra.nl/craf) and in 1998 three Newsletters were published (which are all accessible on the CRAF website).

7. Institute Science

Giant Radio Galaxies

Giant radio galaxies are defined to be greater than 1 Mpc (for H_0=50km/s/Mpc). Several dozen have now been identified and studied. In 1998 work focused on the analysis of a special subclass of these giant radio sources which sheds light on recurrent activity and AGN dutycycles.

One of the outstanding issues concerning extragalactic radio sources is the total duration of their active phase. The issue of the activity lifetime is complicated by the possible presence of duty cycles in the nuclear activity. If nuclear activity is not continuous, how often do interruptions occur and how long do they last? This question of AGN activity can best be addressed by the study of extended radio sources because they present us with a record of their past activity.

During a search for Mpc-sized radio sources in the Westerbork Northern Sky Survey (WENSS), several large radio galaxies were discovered which are strongly suggestive of recurrent radio-activity. These giant radio sources have a radio morphology resembling that of two unequally sized FR-II type radio sources aligned along the same axis and with a coinciding radio core. The first source that drew attention to this very rare class of sources was WNB1834+62 (see Figure 7.1). Because the morphology of the source as a whole is that of a small double-lobed radio galaxy within a larger double-lobed radio galaxy, the name "double-double radio galaxies" (DDRG's) has been adopted for this type of source.

The source has a redshift of 0.51. The projected linear size is 1660 kpc for the outer source and 428 kpc for the inner source, which makes it the second largest radio source at redshifts above 0.5. (Using H_0= 50 km/s/Mpc and q_0=0.5). A detailed multi-frequency, polarimetric, study of WNB1834+62 was completed and submitted for publication in the course of the year. A separate article discussing the general properties of this unusual type of DD-radio galaxy was submitted in parallel.

The two-sidedness, and the relatively high symmetry of the inner sources, strongly suggests that the DDRG phenomenon is related to the activity of the nucleus, and almost eliminates any model which puts the primary cause well outside the nucleus. In the case of the DDRG's, the authors favour a model in which the nuclear jet thrust is temporarily strongly reduced, or even halted.

The class of DDRG's, and their association with sources of giant dimensions, has raised a number of interesting and important questions which may shed light on a range of long-standing questions such as the existence and cause of nuclear activity timescales, their duty cycles, the density of the intergalactic medium, the structure and stability of cocoons and the fading of energy-starved radio sources.

This work is a collaboration between NFRA astronomers and colleagues at the universities of Utrecht and Leiden.

The Reionization Epoch

The epoch of reionization marked the end of the "dark ages" during which the primordial background radiation cooled below 3000 K and shifted first into the infrared and then into the radio spectrum. We know reionization took place before $z \approx 5$, from the lack of hydrogen continuum absorption in the spectra of high-redshift quasars. The upper limit is less constrained but is generally thought to lie below z = 20-30.

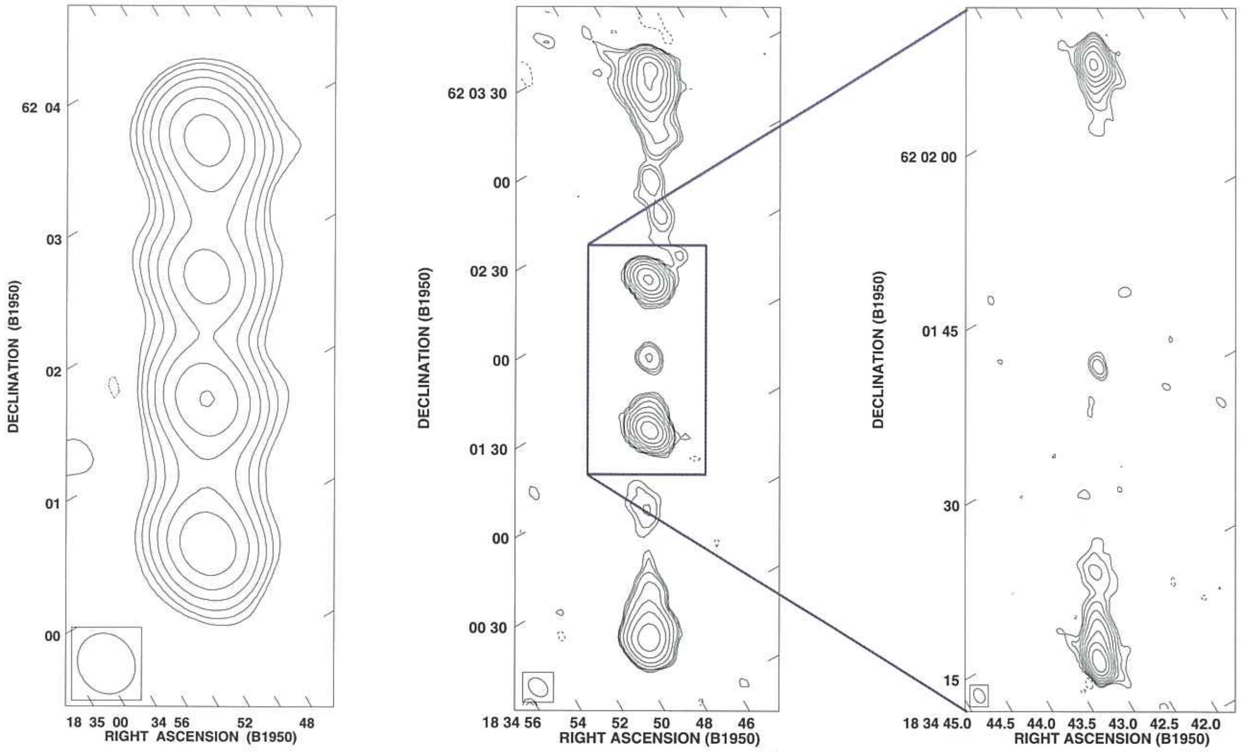


Figure 7.1 Radio contour plots of the source WNB 1834+620. The source has been rotated counter clock-wise by 30 degrees. Left: Contour plot from the 49-cm WENSS survey. Middle: Contour plot from our 8.4 GHz VLA observations. Right: Contour plot of the inner region from the 1.4 GHz VLA observations.

The question, then, is simply: Who switched on the lights in the Universe, and when? Or, how do we identify the epoch and the sources of re-ionization? For a short period after the dark ages (nobody knows how long) and before the beginning of the re-ionization of the Universe. The dominant constituent, neutral hydrogen, was temporarily visible in its 21cm line emission. Specific predictions for the intensity, spatial and spectral signature of the 21cm emission at high redshifts have been made. These predictions depend crucially on the source of re-ionization. In a paper accepted for publication by Astronomy and Astrophysics, the team involved in this study discuss the possibilities of detecting this "re-ionization" signal, a change in the cosmological brightness temperature of about 0.02 K (and more for a low-density Universe). They conclude that the best chances lie in the radio spectrum in the frequency range from 70 to 250 MHz (probing HI at redshifts from 5 to 20). Optical or near-infrared detection possibilities (with the Hubble Space Telescope) seem remote and may not even be within reach of the NGST.

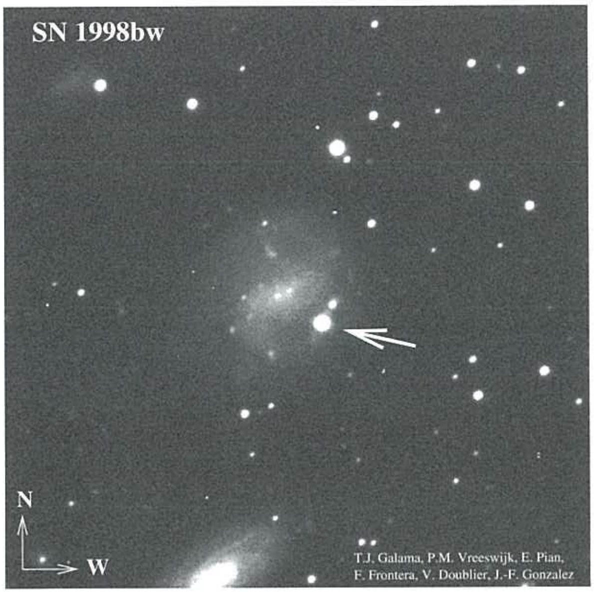
The expected amplitude of the 21cm line's signal is well above fundamental detection limits. The difficulties lie in contamination from galactic and extragalactic foregrounds, calibration, and terrestrial interference. It appears that complexities due to the frequency dependence of the galactic and extragalactic foregrounds may not be an insurmountable obstacle to identifying and measuring the reionization step. If that is the case, the experiment is possible in principle, and the remaining hurdles are purely technical. If the epoch of re-ionization can be detected, a direct measurement of the baryon content of the Universe may be possible. Follow-up studies of the spatial and spectral variations across the sky will then yield unique information on structure formation at redshifts before these structures became apparent in condensed (galaxies) form.

This is a collaboration between NFRA staff and colleagues at the European Southern Observatory in Garching (Germany), Arizona State University (USA) and the Space Telescope Science Institute (Baltimore, USA).

More Surprises from Gamma-Ray Bursts

After the excitement produced by the first detections of counterparts to the enigmatic gamma-ray bursts (GRB's) in other wavebands in 1997, one might have expected 1998 to be a less frenetic year. But it too was a year of surprise discovery as well as one of consolidation. The team composed of a group from Amsterdam, together with colleagues from NFRA continued to observe new GRB's at optical and radio wavelengths, as well as following-up on older ones from 1997.

GRB 970508 was the first event to be detected by the WSRT in a long series of observations made at 21 cm. These observations complemented detections by other telescopes made at shorter wavelengths. In the radio band this outburst followed the well-known pattern seen in many synchrotron variable sources, of the strongest emission being seen first at short wavelengths, and evolving to weaker outbursts with increasing wavelength. Because it was detected throughout the electromagnetic spectrum, from gamma-rays to radio, GRB 970508 made an interesting case study for testing proposed models for the GRB phenomenon. Using data from a variety of sources, it was possible to construct light curves of the early outburst at a range of wavelengths. At one epoch, two weeks after the outburst, a spectrum over the whole range of detectability could be determined. The analysis shows that the GRB emission is consistent with relativistic blast wave models.



T.J. Galama, P.M. Vreeswijk, E. Pian, F. Frontera, V. Doublier, J.-F. Gonzalez

Figure 7.2 An optical image of SN1998bw

In April of 1998, there was a strong GRB in the southern hemisphere. There was nothing particularly special about the properties of GRB 980425, apart from its intense gamma-ray emission. The first optical image (obtained with the Mount Stromlo 50-inch MACHO-project telescope), when compared with a survey exposure of the field, showed one new object, a bright star adjacent to a relatively nearby galaxy. Spectroscopy soon confirmed that the "star" was a supernova of an unusual but not unknown type. While on the face of it a candidate for the GRB, a chance coincidence cannot be ruled out. Observations with the Australia Telescope by another group (the GRB was too far south to observe with the WSRT) soon detected radio emission from the SNR (by now named SN 1998bw) which quickly developed into the most luminous radio SN ever seen. The development of its light curve can, in fact, only be reasonably understood if it has expanded at a relativistic speed: unprecedented for a supernova. However, the field of GRB 980425 also contains a transient X-ray source whose properties are consistent with the X-ray afterglow seen in other GRB's, but whose position rules out an association with SN 1998bw. It is possible that the GRB took place in a supernova, in which case GRB 980425 was some four orders of magnitude fainter than previously identified bursts. But it is also possible that the GRB was associated with the variable X-ray source, leaving the peculiar behaviour of SN 1998bw unexplained. We may never know which of these two possibilities is correct.

As the year finished, WSRT follow-up observations began of yet another new GRB. This time there were enough telescopes fitted out with the new MFFE receivers to permit sensitive observations at 13 cm, and for the first time the WSRT was the first radio telescope to discover emission from a gamma ray burst (GRB 981220). As had been long expected, this proved the capacity of the new receiver system for high sensitivity observations of variable sources. If the past two years are anything to go by, there will be many more observations to be made in the future.

Historical Oriental Records of Comets and (Super)novae

Oriental records of astronomical phenomena (meteors, comets, novae) have been well preserved in dynastic and other official archives for over two millennia. As is well known, such documents have been an invaluable source of first-hand observational material, having been used for studies of sunspots, comets like Halley's, and supernovae. There are a number of indications that such records are reliable, but relatively little is known about their completeness. These questions are being investigated by comparison of the (independent) observations of *hui xing* ("broom stars", generally taken to be comets), and *ke xing* ("guest stars", usually (super)novae) recorded in Chinese and Japanese annals. This suggests that the combined record was about two-thirds complete. By comparing the numbers observed with the number of comets and novae expected on the basis of modern observations, it is possible to estimate the limiting magnitude to which the Oriental astronomers regularly discovered new objects. The estimated value, V=+3 to +4, is fainter than has been thought in the past.

A Population of Local Group Sub-Dwarf Galaxies

In collaboration with a colleague from Leiden, NFRA staff have identified a class of high-velocity clouds which are compact and apparently isolated. The clouds are compact in that they have angular sizes less than 2 degrees FWHM and more typically less than about 30arcmin. They are isolated in that they are separated from neighbouring emission by expanses where no emission is seen to the detection limit of the available data. Candidates for inclusion in this class were extracted from the Leiden/Dwingeloo HI survey of Hartmann & Burton and from the Wakker & Van Woerden catalogue of high-velocity clouds. The candidates have all been subject to independent confirmation using either the 25-meter telescope in Dwingeloo or the 140-foot telescope in Green Bank. The resulting list of 66 sources, even if incomplete, is likely to be sufficiently representative of the ensemble of compact, isolated HVC's - CHVC's - that the characteristics of their disposition on the sky (they are in fact quite uniformly distributed in position above the declination limit of -30 degrees, and of their kinematics, are revealing of some physical aspects of the class. The sample is more likely to be representative of a single phenomenon than would a sample which included the major HVC complexes.

By considering the deployment of the ensemble of CHVC's in terms used by others to ascertain membership in the Local Group, it was shown that the positional and kinematic characteristics of the compact HVCs are similar in many ways to those of the Local Group galaxies. This is illustrated in Figure 7.3, where the velocity histograms of the CHVCs (open distributions) and the Local Group Galaxies (hatched distributions) are compared in various reference systems. Both distributions become narrower in going from the Local Standard of Rest (LSR), to the Galactic Standard of Rest (GSR) and then to the Local Group Standard of Rest (LGSR). In fact, the global minimization of velocity dispersion (69 km/s) of the CHVC sample defines a solar apex which agrees within the errors with that of the currently defined Local Group Standard of Rest, and even the Local Group galaxies form a more narrow distribution with this solar apex, as shown in the final panel of the figure.

Unlike the Local Group galaxies, the CHVCs have a significant mean infall velocity of 100 km/s in the Local Group reference frame. This infall velocity is comparable with the velocity dispersion, 76 km/s, of Local Group galaxies. This situation is consistent with the expectation for a population of primordial condensations which have as yet had little interaction with the more massive Local Group members but are experiencing the same gravitational potential. At a typical distance of about 1 Mpc these objects would have sizes of about 10 kpc and gas masses, M_{HI}, of a few times $10^7 M_\odot$, corresponding to those of (sub-)dwarf galaxies.

Just such a population of low mass objects has been predicted to form in the epoch preceding re-ionization of the universe. Re-ionization is predicted to interrupt the condensation process for a substantial time and lead to a discontinuity in the mass distribution, resulting in a large population of objects having total mass of $10^{7.5}$-$10^{8.5} M_\odot$. The exact value depends on the assumed epoch of reionization. Further study of these enigmatic sources locally as well as their detection in external groups of galaxies should provide substantial insight into the process of galaxy formation and important constraints on the epoch of re-ionization.

Discovery of a Nearby Low Surface Brightness Galaxy

During the course of a search for compact, isolated gas clouds moving with anomalous velocities in or near our own Galaxy, astronomers from NFRA, Leiden Observatory and the University of New Mexico have discovered the HI signature of a large nearby galaxy, moving at a recession velocity of only 282 km/s, in the Galactic Standard of Rest (GSR) frame. Deep multi-colour and spectroscopic optical observations obtained with the Apache Point Observatory (APO) 3.5m show the presence of star formation within scattered HII regions in a low surface brightness (LSB) spiral disk of at least 7 arcmin extent as shown in the figure (7.4). Relatively modest foreground extinctions (of about 2 magnitudes) have been reliably determined from Balmer decrements toward several of the HII regions. Deep integrations with the JCMT to detect CO emission have not met with success. HI synthesis data were obtained with the DRAO array, since the WSRT was still in the process of being equipped for 21cm observations in the spring of 1998. These data confirm that the source is rich in HI with a diameter (defined by an

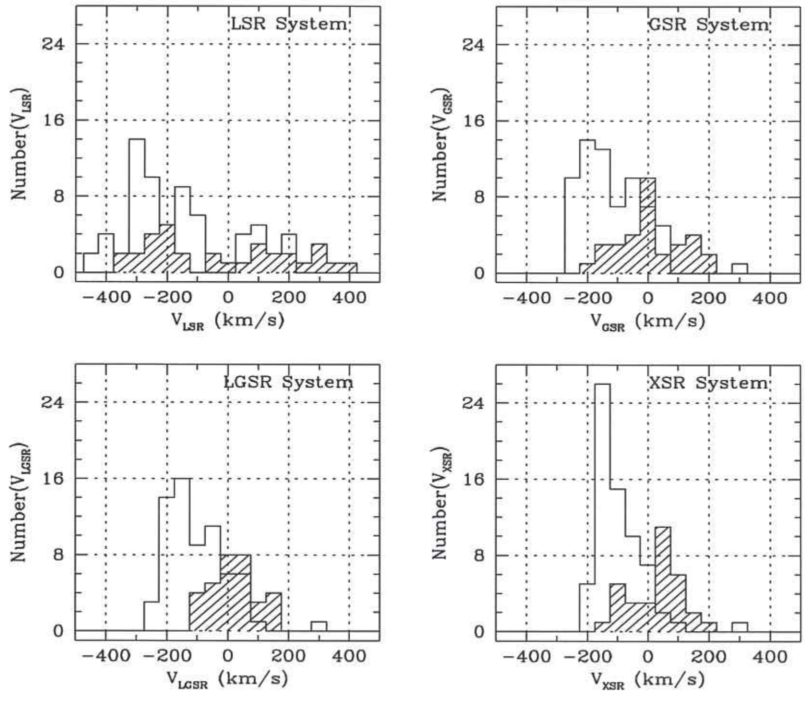


Figure 7.3 Histograms of distributions of the CHVC velocities, and of Local Group galaxy velocities, as measured in the reference frames indicated on the abscissae. The open histograms represent the CHVC ensemble; the hatched histograms, the Local Group galaxies. The dispersion of the histogram representing the LGSR-frame is significantly smaller than that in the LSR- and GSR-reference frames. The velocities labelled XSR refer to a frame which was found to minimize the dispersion of the CHVC velocity distribution.

Figure 7.4 Colour-coded composite of the I-, R-, and Hα-images of Cepheus 1 observed with the 3.5m telescope of the Apache Point Observatory. The field size is 4.4'x6.8' EW by NS. The red, green, and blue intensities in the image are proportional to the surface brightness in the I-band, R-band, and continuum-subtracted Hα-exposures, respectively. Note the bar-like concentration of stellar continuum emission and the HII regions which are visible rather uniformly scattered over a large portion of the field.

azimuthally averaged face-on surface density of $1 M_\odot/pc^2$) of almost 12 arcminutes and a rotation velocity in the range of 60-100 km/s.

The new galaxy, which was named Cepheus 1, is very likely associated with NGC 6946 at a distance of about 6 Mpc, with an angular separation of less than 4 degrees (corresponding to 410 kpc) and an identical recession velocity. The gaseous disk of Cepheus 1 is 40% larger than that of Messier 33. Its discovery marks the first time this century that such a large nearby galaxy has been found outside of the zone of avoidance (ZOA). It is the LSB nature of the galaxy that has allowed it to escape earlier detection, in contrast to the high foreground extinction which has hidden a few objects like Dwingeloo 1, the nearby barred spiral that was discovered in a ZOA survey in 1994.

Nuclear Classification of Hydroxyl (OH) and Formaldehyde (H_2CO) Megamasers

OH megamasers are a dominant subclass of the (super-) luminous far-infrared (FIR) galaxies, which at high luminosity show mostly optical characteristics of Active Galactic Nuclei (AGN) and are often interacting systems. At lower FIR luminosities the sample consists predominantly of starburst nuclei (SBN). Optical classification studies of OH megamasers support this general trend. On the other hand, radio classification of the OH megamaser sample suggests that a majority (75%) shows no or only weak AGN characteristics but rather resemble radio SBN's.

The clear discrepancy between the optical and radio classifications of OH/H_2CO megamasers confirms the uniqueness of these luminous FIR sources. On the other hand, the radio characteristics of the nuclei of OH and H_2O maser galaxies are found to be quite different. While OH sources have mostly relatively radio-quiet nuclei, that are powered by starbursts with only a few of them being radio-loud and powered by AGNs, the majority of the H_2O nuclei are mostly radio-loud but also have lower radio and FIR luminosities.

A general picture for the luminous FIR sources could be the combination of a circum-nuclear starburst and a central AGN with their relative activity level determining the total outward appearance. In addition, the large concentrations of molecular gas and dust further affect the optical emissions and the diagnostic line ratios, because different emission lines originate at different radial locations and at different obscuration depths within the galaxy. This picture is confirmed by an "infrared diagnostic diagram" that is based on ISO data and shows a comparison of the ratio of high- and low-excitation mid-IR emission lines and the strength of the 7.7μm PAH feature. The ultra-luminous FIR galaxies form a distinct AGN-SBN "mixing sequence" with about 70% - 80% of the luminous FIR galaxies being predominantly powered by starbursts rather than by AGNs.

The above discussion suggests that contrary to the suggestions of the optical line characteristics, the majority of megamaser galaxies are predominantly powered by nuclear starbursts. Due to a variety of circumstances the intense starburst regions in the (super-) luminous FIR/OH galaxies appear to mimic radio-quiet AGNs in their optical appearance. If there are any AGNs present in these nuclei, they must be radio-quiet but optically-loud. This result further implies that the standard optical classification scheme may not be accurate enough as a diagnostic for high-activity super-luminous FIR galaxies.

OH and H_2CO Emission and Radio Continuum Structure of Arp 220

The prototype megamaser galaxy Arp 220 (IC 4553) has its most prominent OH and H_2CO emission at the western nucleus, with some less prominent emission at the eastern nucleus. Early spectral line VLBI studies with the EVN reveal three high brightness OH components: two components south of the eastern radio nucleus separated by 40 pc and one north of the western radio nucleus. These components did not to coincide with the radio nuclei themselves as predicted for any scenario involving a compact nuclear torus and an AGN. More recent VLBI results reveal a cluster of compact radio continuum sources at both nuclei of Arp 220, that resemble powerful supernova remnants. In spectral line data, the two extended OH emission regions at the western nucleus straddle this cluster of supernova remnants and could together form a north-south torus structure with radius of 45 pc. At the eastern nucleus, two OH emission components also straddle the cluster but lie slightly south of the radio peak.

However, the OH megamaser emission found (to date) at the two nuclei is at almost the same velocity, while for other molecular lines they have significantly different velocities. Thus the OH emitting gas at the eastern nucleus may be in the foreground and may thus be unrelated to the nucleus itself. Because the VLBI features only reveal about 40% of the single dish flux, there must be more diffuse emission between the VLBI components, particularly at the western nucleus. A simple orbital model explaining the dynamics of the two nuclei has been based on molecular line characteristics. The observed OH emission shows the 1665-1667 MHz emission pair of lines from both nuclei at the systemic velocity of 5300 km/s for the western nucleus, and another weaker pair of lines associated with the eastern nucleus shifted by about 200 km/s.

The formaldehyde (4.83 GHz) emission in Arp 220 also comes predominantly from the western nucleus with only weak emission from a north-south double structure southeast from the eastern nucleus and from some more intervening regions between the two nuclei. Recent NIR images of Arp 220 made with HST-NICMOS show an emission structure almost identical to that of the H_2CO emission. These coincidences confirm that (a) the obscuring dust in Arp 220 plays havoc with the nuclear emissions and that large fractions of the nuclear regions are heavily obscured, (b) the OH and formaldehyde masers both appear to be pumped by the FIR/NIR radiation fields, and (c) the detailed emission characteristics of OH and H_2CO may serve as a valuable diagnostic of the physical conditions within prominent active nuclei.

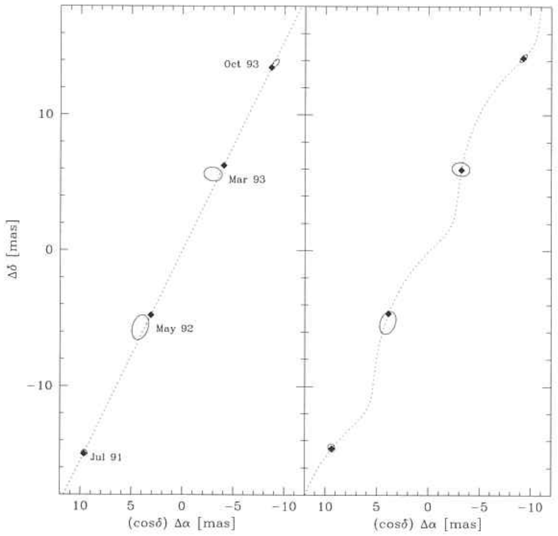


Figure 7.5 Observed and modelled positions for the first four epochs of VLBI observations of PSRB 2021+51. The origin corresponds to the modelled position at 1992.723. The model in the left-hand panel comprises only zero-point and proper motion; that in the right-hand panel also includes trigonometric parallax. The ellipses represent 1s uncertainties in the position estimate at each epoch (as labelled), the filled diamonds are the modelled pulsar positions at these times, and the dotted lines show the models as a function of time.

Pulsar Proper Motions

Accurate pulsar proper motions and parallaxes (and hence model-independent distances) can be exploited to study a variety of problems in galactic astronomy. One question that has long interested Dutch astronomers addresses whether OB association stars are sufficient to form the observed pulsar population. The proper motion and distance, together with an independent age estimate, can provide bounds on the birthplace of the pulsar and help characterize its progenitor. Furthermore, the length of time a pulsar remains visible hinges on the decay timescale of its magnetic field (t_D). A more precise birthplace would allow better constraint of kinetic age (t_k) with which to infer t_D via comparison with the pulsar's spin-down age. Therefore, an improved definition of the low-velocity end of the pulsar space-velocity distribution could help distinguish among pulsar population-synthesis models. The nature of pulsar radiation (pulsed and unresolved) can also be used to study the ISM via pulsar astrometry. Distances, along with dispersion measures, can yield integrated electron densities (n_e) along the lines of sight to the pulsars, providing checks on models of galactic n_e distribution. Distances and measurements of the angular diameter of the pulsars' scattering disks would allow determination of the (similarly integrated) coefficient and exponent of the power-law spectrum for n_e spatial fluctuations, which may provide insights into mechanisms driving ISM turbulence.

VLBI is currently the only means to obtain resolutions necessary for parallax determination, and provides proper-motion uncertainties up to an order of magnitude lower than those from existing linked-interferometers. A program of VLBI pulsar astrometry has been started, strengthened by ties with colleagues at the Harvard-Smithsonian Center for Astrophysics and York University (Toronto) who had experience with an earlier such program. During the year a number of trips to MPIfR in Bonn have been undertaken to oversee the (gated) correlation of observations from September 1997 and February 1998 (together, 1 new epoch for 9 Pulsars). Additional observations, that form a new epoch for four of these objects, took place in November 1998.

As an example of the astrometric results, Figure 7.5 shows the first four epochs for PSRB 2021+51, highlighting the importance of the ability to estimate a parallax. At a distance D=1.06(+0.67)(-0.29) kpc, this is currently the most distant source for which a trigonometric parallax has been published. Future epochs will benefit from the improved sensitivities of the new WSRT MFFE's.

Ionospheric Modelling

The faintness and steep spectra of pulsar radiation preclude standard astrometric/geodetic dual-frequency observations; hence one is vulnerable to dispersive effects from propagation through the ionosphere. Much of this is removed by use of nearby reference sources and the resulting difference phases as the principal observables, but some residual trends have persisted. An approach has therefore been developed for removing ionospheric contributions from single-frequency VLBI data. The technique consists of two components: an ionospheric climatology model (PIM) developed by aeronomers in the USA and the capability to incorporate contemporaneous ionospheric data, if available, to update the modelled electron densities (n_e). The PIM code has been modified to give the desired results.

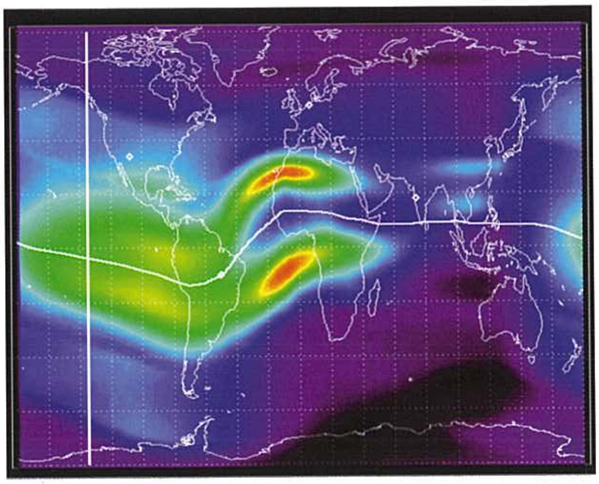


Figure 7.6 Vertical total electron content (TEC) calculated by PIM at 21UT around the vernal equinox during solar maximum. The longitude grid marks correspond to 2-hr segments of local (mean) time; the latitude grid marks fall every 20 degrees. The thick vertical line represents the longitude of the sun; the thick curved line the magnetic equator.

Figure 7.6 shows a global map of vertical total electron content (TEC) which is proportional to delay, to first order. The ionospheric calibration efforts were undertaken specifically with the application to the pulsar astrometry observations in mind, but ionospheric calculations have also been provided to groups in Spain and the US for their astrometric projects. However, since ionospheric effects scale as ν^{-2}, they will grow ever more significant as observations progress towards lower frequencies. Future telescopes such as SKA, and especially LOFAR may benefit significantly from corrections derived from atmospheric models. There has also been interest to include ionospheric calibration capabilities as a standard feature in AIPS++.

The CJF Survey: First Results on Superluminal Motion

This year the first results were presented from a systematic analysis of the kinematics of sources in the Caltech-Jodrell Bank flat-spectrum sample (hereafter CJF), which is based on global VLBI and VLBA observations performed at 5 GHz.

One of the major goals of CJF is to make a statistical study of the apparent speeds of the sources, in order to investigate superluminal motion statistics with cosmic epoch and to place constraints on q_0 and H_0. So far, 245 out of 293 sources have been investigated and the jet velocities for 189 sources could be determined. The results allow correlations of superluminal motion statistics with respect to source classifications to be explored.

VLBI monitoring is being performed with a typical period between observations of about two years. Goal is to measure internal proper motions in the parsec-scale radio sources. The most recent observations (February 1998) form the second or third epoch for a sample of 120 sources. Currently 245 sources have observations at three epochs, and 48 sources have two observations. All observations were carried out with the VLBA in snapshot mode. In order to create a homogeneous, statistically valid database, a start was made with a systematic reanalysis of all previous epochs for all the sources obtained in the 1990s.

Inspection of the data currently available shows that the internal proper motions decrease with redshift, as expected in a Friedmann cosmology. The apparent velocities observed for quasars seem to show a slight increase with redshift The BL Lac objects, on the basis of velocities for 9 sources, show slower motions (average value: 0.62±0.49c) when compared with quasars (average value: 2.43±1.70c; 130 objects) but a similar increase with redshift. A final evaluation and discussion of the results will have to wait until the analysis of the CJF data has been completed.

The Large Scale Structure of 1803+784

A 17-station VLBI array, plus the phased VLA, and the 7-station MERLIN array simultaneously observed the BL Lac object 1803+784 for 11 hours at 18cm. These observations provide images of the transition region between the misaligned milliarcsecond- and arcsecond-jet. 1803+784 is a BL Lacertae object with a redshift of z=0.68 and particularly luminous emission lines. This source is a member of the complete S5 sample of 13 flat-spectrum radio sources which have been observed repeatedly at many frequencies and angular resolutions since the late 1970's. It is a radio source with remarkable properties, most notably an enormous projected size, flux-density and structural variability. Jet components move with apparent superluminal velocities on helical trajectories that can be traced with mm-VLBI to the innermost regions of the AGN.

Another remarkable property is the difference in position angle between parsec- and kiloparsec-scale jets. In only a few similar cases have VLBI maps been able to trace the jets in the transition region, and hence to determine the speed, expansion and accompanying changes in flux density along the jet. In order to study the jet and its helical appearance at high resolution over its entire length and to detect the bending towards the southern kpc-component, a combined VLBI-MERLIN array was used. The large scale structure seen by the MERLIN array exhibits the core and a jet extending towards the west that bends towards the south at a separation of approximately 0.5 arcseconds. This bending probably indicates the transition region between the pc-jet and kpc-jet.

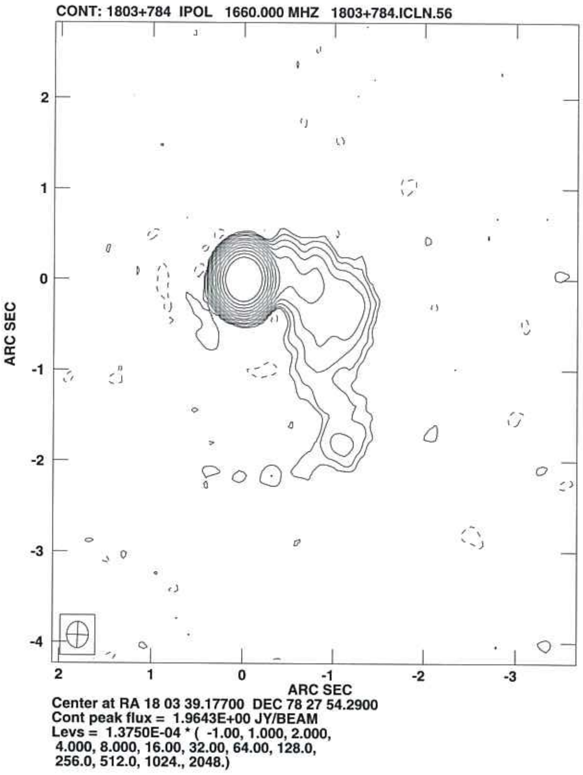


Figure 7.7 The large scale structure of 1803+784 seen by the MERLIN array.

8. NFRA Facilities

This year has been one of consolidation. A lot of new plans already in the works have been carried out and were completed in the course of the year. The highlights are listed below:

8.1 General Facilities

Library

Facilities and Management now enjoys the services of a department secretary, who is also responsible for the library. During the year some 300 books have been added to the collection. In future, more and more content will be on electronic media instead of paper. This gives more shelf- room and better search facilities.

Purchasing Department

A general set of rules has been adopted. In the near future all purchasing orders will be routed through this department. In general, this structure will give us more possibilities for obtaining goods at the best price.

System management

All PC-workstations were converted to Windows-NT and Groupwise has been appointed as the general mail handling and document sharing system. This works well, calendar sharing is in progress, indeed all meeting facilities are now booked in the calendar facility of Groupwise.

On the UNIX side, LINUX was added as an official supported platform, and the first machines are already operational. Two private networks were added as special branches, mainly because transport of data between correlators and workstations are synchronous and do have to be isolated from the broadcasts of the main network.

The Westerbork-Dwingeloo link was upgraded from 64 Kb/s to 2 Mb/s. This means that on-line testing and data inspection from Dwingeloo is now possible and already in heavy use. In discussions with the provincial authorities of Drenthe, NFRA has stated many times that good electronic connections are paramount for the development of a rural area like Drenthe. This has been acknowledged, but no grants have been forthcoming to alleviate the problem. At the end of the year the decision was taken that further delay in upgrading the internet connection was not acceptable. Early in the new year, the line to Groningen will be upgraded to 512 Kb/s. This means that our isolation will be less severe from an electronic point of view.

At the end of 1998 there were 170 workstations in Dwingeloo (roughly 30% UNIX and 70% NT) and 35 in Westerbork (80% UNIX and 20% NT).

Time Registration System

NFRA has successfully implemented the ATLAS time registration system in Dwingeloo. The system counts the working hours of staff and is also being used for the administration of days-off. This has allowed staff to make use of flexible working hours around a certain block. The system also registers all staff present in the building as required by the calamity plan.

Flooding in Dwingeloo

On 28 October, after three days of heavy rain, the ground floor of the new building was flooded by about five centimetres of water. This was mainly caused by construction faults in the concrete structure of the building and bad waterlocks in the floor.

Considerable damage was done to the antenna measurement facility. In total about 100 working days were lost due to the flooding. Emergency repairs were carried out immediately, and plans are being made to improve this situation and have a better "early warning system" in case of future trouble.

Calamity Plan

Since the combined workforce of NFRA and JIVE exceeds 100 people, there is a legal requirement for a calamity plan to be drawn up, for use in case of trouble. The plan was completed in the course of the year and training of staff will start in February 1999. All staff will be trained in emergency procedures.

Millennium Problems

Investigation of expected trouble due to the millennium problem has been carried out. Nearly all workstations and network components are millennium proof. The small number that are not, have been identified and will be replaced in 1999. One of the main problems happened to be our telephone exchange, which was replaced in December.

8.2 Technical Facilities

New Telephone Exchange

Installation of the new telephone exchange has given us the opportunity to improve communication between Dwingeloo and Westerbork. From now on it is possible to use extension numbers from both sides. This will greatly improve the collaboration of staff from both locations. All phone calls from outside are now routed through the reception in Dwingeloo.

NFRA Guesthouse

The new guesthouse was used for a total number of 1580 booked nights in 1998.

CAD/CAM capabilities

The reorganisation of 1997 and 1998 called for significant changes in the way NFRA designs its equipment and therefore also in the mechanical shop. In general terms this has meant a change from in-house construction of all equipment to a system where NFRA only makes the prototypes and all other work is contracted out.

This not only calls for a better and higher educated staff, but also for a much better equipped machine shop with (for instance) very precise CNC-machines that are tightly coupled to the CAD-system. So far, control of the existing CNC machine has been successful, but more elaborate equipment is needed. Plans for educating staff have been made but will wait until a second CNC-machine is in place.

NFRA Laboratory Instrumentation

The NFRA Instrument Committee advises the Management Team on all laboratory instrument matters. It became clear in 1998 that due to financial constraints there is severe pressure on the lab. This may mean that in future, the principle of a well-founded lab may not be achieved due to financial constraints. The only exception is the following: with the help of a special grant from NWO, the microwave calibration equipment was brought up-to-date.

9. NFRA Funded University Research

NFRA's grants programme provides financing for graduate students and postdoctoral fellows to work in the university research groups. Applications can be made, either for specific projects involving a single graduate student or postdoc, or for larger scale programmes of research that include several temporary research positions and can include non-salary funding as well. The longer programmes can be funded for a maximum period of five years.

From 1st January 1999, administration of the grants programme will revert to NWO's Physical Sciences Council.

9.1 Project Subsidies

Stellar Systems

Project ID	Supervisors	Project Title	Institute	Name
781-71-048	Lamers	A study of the variability of Luminous Blue Variables	UU	J.S. Vink
781-71-050	Achterberg	The Highest-Energy Cosmic Rays	UU	Y.A. Gallant
781-71-051	Lamers	The winds of B[e]-supergiants s and B-supergiant	UU	T.M. Lanz
781-71-052	Waters de Jong Waelkens	The evolution of Post-AGB stars	UvA	F.J. Molster
781-71-053	Henrichs	Origin of wind variability in massive stars	UvA	J.A. de Jong
781-71-054	de Bruyn Schilizzi Verbunt	Motion and birthplaces of pulsars through VLBI astrometry	NFRA	R.M. Campbell

Interstellar Medium

Project ID	Supervisor(s)	Project Title	Institute	Name
781-72-034	van Dishoeck Habing de Graauw	Nature and Evolution of interstellar dust studied by laboratory infrared spectroscopy	RUL	W. Schutte
781-72-038	Bloemen Habing	Gamma-ray spectroscopy of the interstellar medium using COMPTEL	ROU	R.D. van der Meulen
781-72-039	Katgert de Bruyn	Structure and strength of the Magnetic Field in the Galactic ISM	RUL	M. Haverkorn
781-72-040	van Langevelde	VLBI observations of the fundamental properties of nearby AGB stars	RUL	W.H.T. Vlemmings

Galaxies

Project ID	Supervisor(s)	Project Title	Institute	Name
781-73-059	de Zeeuw Perryman	HIPPARCOS study of the structure of OB Associations	RUL	R. Hoogerwerf
781-73-061	Kuijken	Warps in disk galaxies	RUG	I. Garcia
781-73-063	de Weygaert	Tidal Fields as shaping force of the Large Scale Structure in the Universe: the formation of the cosmic foam	RUG	W. Schaap

9.2 Programme Subsidies

Project ID	Supervisor(s)	Project Title	Institute	Name
781-76-010	Miley de Bruyn Katgert Schilizzi	Studies of the early Universe using radio sources	RUL/ RUG	Röttgering Koopmans Fullager
781-76-011	van Paradijs van den Heuvel van der Klis	Structure and evolution of close binary systems with a compact companion	UvA	van der Hooft Galama Ford
781-76-014 MPR	Goedbloed Hearn van der Vorst	Magnetohydrodynamics: parallel computation of the dynamics of thermonuclear and astrophysical plasmas	RUU	Toth Downes Gallant
781-76-015	Habing van Dishoeck Waters	Physical and chemical evolution of young stellar objects	RUL	Dominik van der Tak Wright Wesselius Boonman Win Fai Thi van den Ancker
781-76-016	de Zeeuw	Formation, Structure and Evolution of Elliptical Galaxies	RUL	Miller Bureau
781-76-017	van der Klis Verbunt	Fundamental properties of neutron stars and black holes	UU UvA	van den Berg Fender
781-76-018	Sackett Pel	Studying Galactic Microlensing through High Temporal Resolution, Multi Band Monitoring	RUG	Beaulieu Naber
781-76-019	Strom	Massive Parallel Computing: Scalable I/O for the data analysis in pulsar research	UvA/ NFRA	Ramachandran
781-76-020	Rutten	Solar Physics with the Dutch Open Telescope	UU	Krijger

10. Allocations of Telescope Time by the NFRA Programme Committee

The NFRA Programme Committee allocates the Telescope Time at the major observatories to which astronomers in the Netherlands have access (excluding ESO). Below, as summary is given of the proposals that were awarded time for the two 1998 semesters. Semester 1998a ran from February-July 1998, 1998b from August 1998- January 1999.

10.1 Allocations for Semester 1998a

WSRT	**1998a**		
Proposal	**PI**	**Title**	**Alloc. (hours)**
r.98a.01	Miley	WHISH	4 weeks
r.98a.02	Lane	HI abs. in MgII selected systems	20x12 hours
r.98a.03	Lane	Followup of two new HI 21cm absorbers	2x12
r.98a.04	Kouwenhoven	Polarisation of millisecond pulsars	1x12
r.98a.05	Briggs	UHF VLBI spectral line obs.	9x12
r.98a.06	Keenan	HVC towards the glob. cluster M 15	2x12
r.98a.07	Galama	Rapid follow-up of GRB error boxes	16x12
r.98a.08	Fender	Rapid radio variability of GRS1915+105	2x12
r.98a.09	de Bruyn	Linear pol. of 2 ms-pulsars	3x12
r.98a.10	de Bruyn	HI in the z=2.39 radiogalaxy 53W002	2x12 backup
r.98a.11	Ramachandra	A search for pulsars in glob. clusters	4x12
r.98a.12	Vermeulen	Survey of damped Lyman-alpha systems	30x12
r.98a.13	Ramachandra	Emission cone geometry of PSR B1822-09	10x12
r.98a.14	Vermeulen	The dark lensing mass of MG0751x2716	2x12 backup
r.98a.15	Hagiwara	The HI gas distribution in the QSO 3C48	1x12

JCMT	**1998a**		
Proposal	**PI**	**Title**	**Allocation**
m.98a.n01	Cimatti	ERO's: a new class of distant SB galaxies	17 B8
m.98a.n03	Röttgering	C+ in the most distant radio galaxies	36 A4
m.98a.n05	Röttgering	Dust in normal galaxies at z=3	16 A3
m.98a.n06	Israel	(SUB)mm continuum of dwarf galaxies	16 B1
m.98a.n08	Israel	Cool dust emission in nearby galaxies	24 B7
m.98a.n10	Stark	Gas-dust connection in protoplanetary disc	24 B2
m.98a.n11	v.d. Hulst	Cold Dust in LSB Galaxies	24 B6
m.98a.n13	Smith	Scuba observations of GRB counterparts	24 ToO
m.98a.n14	v.d. Werf	Dust in high-z, lensed star forming gal's	32 A1
m.98a.n15	Lehnert	The cold dust in of IR-bright SB galaxies	24 B5
m.98a.n16	v.d. Werf	Dust emission from 53W002	16 A2
m.98a.n17	v.d. Werf	The microwave background temp. at z=0.886	8 D1 backup
m.98a.n18	Tilanus	Survey of hot molecular gas in M51	48 C1
m.98a.n19	Tilanus	Sub-mm imaging of M 51 and M 83	40 B4
m.98a.n21	Dominik	Vega-like stars	27 B3
m.98a.n22	Wesselius	Phys. prop's of a protostellar core	37 D2 backup

WHT	**1998a**		
Proposal	**PI**	**Title**	**Allocation**
w.98a.n01	Best	The growth of massive galaxies	3B
w.98a.n04	Schoenmakers	Cosmological evolution of giant radio gal's	-> INT
w.98a.n05	Schoenmakers	Giant radio source evolution using K-band	2B
w.98a.n06	Best	Evolution of radio galaxies at $z=1$	2D
w.98a.n07	Voors	Kinematics of the G79.29+0.46 nebula	2G
w.98a.n08	Kuijken	Weak lensing from poor clusters	2D
w.98a.n09	Jaffe	The true line emission from cooling flows	3G
w.98a.n11	Kuijken	Dark matter in clusters	1B
w.98a.n12	Galama	Imaging and spectroscopy of GRB hosts	TOO
w.98a.n17	Briggs	ID's of low z damped lyman alpha galaxies	3D

INT	**1998a**		
Proposal	**PI**	**Title**	**Allocation**
w.98a.n04	Schoenmakers	Cosmological evolution of giant radio gal's	2D 3G
i.98a.n01	Oliveira	FK Com type fast rotating stars	5B 1G
i.98a.n02	Van Dokkum	Early-type galaxies in the Coma cluster	2D
i.98a.n03	Britzen	A high z sample for space VLBI	1D
i.98a.n04	Zwaan	Optical imaging of very LSB galaxies	2D
i.98a.n05	Telting	Non-radial pulsations in early-type stars	5B 1G

JKT	**1998a**		
Proposal	**PI**	**Title**	**Allocation**
j.98a.n02	Lehnert	Dust, stars and gas in SB galaxies	8B + 1B backup
j.98a.n03	Swaters	BRI broadband imaging of lopsided galaxies	3D4G
j.98a.n04	Britzen	Imaging of GPS and flat-spectrum objects	5D

10.2 Allocations for Semester 1998b

WSRT	**1998b**		
Proposal	**Proposer**	**Title**	**Allocation (hours)**
r98b001	Braun	Measuring B at intermediate redshift	60 backup
r98b002	Baker	Search for HI absorption toward high z QSOs	36
r98b003	Fender	Radio variability of GRS1915+105	240 backup
r98b005	de Pater	Jupiter's radio spectrum from 74 to 8500 MHz	80 backup
r98b007	de Bruyn	Is the 53W002 a damped Ly alpha absorber	26
r98b008	de Bruyn	Ionized gas in double-double radio galaxies	13
r98b009	Chengalur	The HI profile of the 0218+357 Lens	17
r98b010	Galama	Rapid follow-up of GRB error boxes	117
r98b013	Briggs	Kinematics in a damped dLya absorber at z=0.4	42
r98b015	Kanekar	HI 21cm absorption from damped Lya systems	18 backup
r98b020	Stappers	Radio pulsations from neutron emitting X-rays	12
r98b021	Koopmans	Dark lenses and H0 from the CLASS lens survey	104
r98b022	Strom	Giant pulses from PSR 0950+08	12
r98b023	Koopmans	Search for HI in gravitational lens galaxies	182
r98b024	Hagiwara	HI in the radio-loud QSO 3C48	28
r98b025	Vermeulen	HI in comapct radio sources out to z=0.85	200 *
r98b027	Vermeulen	Are radio lobes good probes of IH in hosts	51+ 51 backup
r98b028	Snellen	A search for HI in GPS quasars at z>2	70 backup
r98b030	Conway	HI absorption in FRII radio galaxies	100

JCMT 1998b

Proposal	PI	Title	Alloc.	Queue
m98bn002	v.d. Werf	Through the looking glass: the submm universe revealed	48	A1
			24	A3
m98bn003	v.d. Werf	A deep submm survey in the Lockman hole	48	A2
m98bn004	Wesselius	Deuterium chemistry in YSOs	7	D1
m98bn005	Stark	A search for H2D+ in the ISM	12	A4
m98bn006	Sandell	Dust in elephant trunks and cometary globules	14	A5
m98bn008	Cimatti	Extremely red and dusty star-forming galaxies at high redshift	21	B3
			14	D3
m98bn010	v.d. Tak	Dust around massive protostars	8	SBI
m98bn011	Israel	Cold dust emission from nearby galaxies	50	B4
m98bn013	Boonman	Massive protostars in Orion	12	B1
			2	C1
m98bn014	Burton	Search for CO in a obscured nearby galaxy	24	D2
m98bn016	Wesselius	Cold dust in a pre-protostellar cloud	4	C3
m98bn017	v. Dishoeck	Structure of circumstellar disks	48	C2
m98bn019	Röttgering	Lyman break galaxies at high z	24	B2
m98bn020	Lehnert	Lyman break galaxies at low z	25	B5/C4
m98bn021	Smith	SCUBA Observations of GRB counterparts	24	ToO

WHT 1998b

Proposal	PI	Title	Allocation
w98bn001	Jaffe	The optical signature of cooling flows	3G nights
w98bn002	Jaffe	Star forming at large radii in Abell 2597	0.4D
w98bn004	Best	The K-z relation and growth of galaxies	2B + 1Bbu
w98bn006	Galama	Imaging and spectroscopy of GRB's	ToO
w98bn007	Lehnert	Stellar pop. in E hosts of GPS sources	3G
w98bn008	Lane	ID's of low z damped Ly alpha galaxies	3D
w98bn010	Kuijken	Weak lensing from poor clusters	3D
w98bn011	Swaters	Stellar vel. disp. in late type spirals	
w98bn012	Ehrenfreund	High resolution spectroscopy of DIB's	3B
w98bn014	van Woerden	Distance and metallicity of HVC complexes	2B + 1Bbu

INT 1998b

Proposal	PI	Title	Allocation
i98bn001	Katgert	The fundamental plane in nearby clusters	4D
i98bn003	Dennet Thorpe	Spectroscopy of 10 GHz peakers	1D+1G
i98bn005	Telting	Non-radially pulsating early-B type stars	10B + 1Bbu
i98bn008	Swaters	The gaseous extent of dwarf Irr galaxies	2G

JKT 1998b

Proposal	PI	Title	Allocation
j98bn001	Dennett Thorpe	Imaging of 10 GHz peakers	4D
j98bn002	Tschager	The optical hosts of young radio sources	5D
j98bn003	Lehnert	Imaging of starburst galaxies	6B
j98bn004	LePoole	Photometric calibrators for the 2nd GSC	7G
j98bn005	Ford	Observations of a low mass X-ray binary	2B

11. NFRA Institute

11.1 Financial Report 1998

Expenditure (in kfl.)		
Operations Institute + WSRT		**12582**
Staff	9025	
Exploitation	3640	
Credit balance 1998	-83	
WSRT development and science projects		**1970**
Multi Frequency Front Ends	454	
New digital back-end	1457	
Telescope Management System	13	
AIPS++, Newstar	46	
WSRT maintenance		**846**
R&D projects		**1924**
Phased array study	1777	
Others	147	
International Cooperation		**5139**
UK/NL	3960	
JIVE	650	
ESO-VISIR	529	
Special project funds		**3119**
Total NFRA Institute		**25580**

Received funds (in kfl.)		
Operations		**17070**
NWO	13232	
NWO beleidsruimte GB-E	1400	
NWO dynamiseringsimpuls	800	
Credit balance 1997	306	
Business activities	211	
Contributions from others	1121	
Investment Capital		**8510**
NWO Middelgroot	2516	
NWO Qualitative Investment Incentive	1155	
Reservations project funds	4839	
Total NFRA Institute		**25580**

Grants Programme (in kfl.)		
Received Funds		**2796**
NWO grant	1397	
Contributions from others	381	
Credit balance 1997	65	
Reservations approved programmes	953	
Expenditures		**2796**
Projects	727	
Programmes	1334	
Credit Balance 1998	54	
Reservations approved programmes	681	

11.2 NFRA Organization

Board

Prof. dr. T. van Albada	University of Groningen	
Prof. dr. E.P.J. van den Heuvel	University of Amsterdam	chair
Dr. R. Hoekstra	Applied Physics Laboratory, TNO	
Prof. dr. W. Hoogland	University of Amsterdam	
Prof. dr. J.M.E. Kuipers	University of Utrecht	
Prof. dr. G.K. Miley	Leiden University	
Prof. dr. J.A. van Paradijs	University of Amsterdam	
Prof dr. H. R. Butcher	NFRA	Executive Secretary

Management Team

Ir. A. van Ardenne	Head of Technical Laboratory
Dr. W.H.W.M. Boland	Head, Administrative Affairs
Prof. dr. H.R. Butcher	General Director, chair
Dr. W.A. Baan	Head of Radio Observatory
Prof. dr. R.T. Schilizzi	Director JIVE
B.A.P. Schipper	Head of Facilities Management

Employees Council

Drs. J.P. Hamaker	chair
Ir. M.J. Arts	
A. Bennen	
J.W. Beuving	
R. Boesenkool	
L. Nieuwenhuis	
H. Verkouter	

11.3 Personnel

(31 December 1998)

POLICY AND ADMINISTRATION

H.R. Butcher	General Director
K.A.A. Oving	Secretary
W.H.W.M. Boland	Deputy Director
M.P. van Haarlem	

Spectrum Management

T.A.T. Spoelstra

Finance and Personnel

A. Bennen
P. Hellinga
A.E. de Jonge
A. Koster
F.H. Wekking

FACILITIES AND MANAGEMENT

B.A.P. Schipper	Head of Facilities and Management
J.E. van den Berg-van der Veen	Secretary

Computer Systems

R. Boesenkool
J. Slagter
K.J.C. Stuurwold
H.J. Vosmeyer

General Facilities

H. Bokhorst
N.H. Vermeulen-Bouman
D.J. Haanstra
P.C. Jager
R.H. Stevens-Kremers
D.P. Kuipers
M.W. Vos
B.J. Vriezenga
R.J. Wagner
A. Wieringh

Cafeteria/Cleaning

I. Grit
H. Braam-Piel
E. Oosterloo-Scheffer
I. Hoek-de Weerd
H. Eising-Zoer
G. Hofman-Sterk
L.J. Lenten-Streutker

Mechanical Workshop

J. Bakker
M. Bakker
H.J. Borkhuis
J.S. Dekker
G. Hagenauw
J. Idserda
T.J. de Jong
G.J.M. Koenderink
J.H. Nijboer
M.R. Schuil

LA PALMA/HAWAII

R.G.M. Rutten	Director La Palma
G.J.P. Benneker	
M.J.W. Broxterman	
R.J. Pit	
J.H. Telting	
P.H. van der Velde	
B.W.H. van Venrooy	
R.P.J. Tilanus	Support scientist Hawaii

RADIO OBSERVATORY

W.A. Baan	Director of Radio Observatory
A.L. de Vries	Secretary

Science Support

R. Braun
A.G. de Bruyn
A.R. Foley
G. Kuper
H.H.J. Lem
D.J.J. Moorrees
J.J. Sluman
R.G. Strom
Y. Tang
R.C. Vermeulen

Operations Group

M.J. Bentum
A.J. Boonstra
K. Brouwer
P. Donker
T. Grit
P.G. Gruppen
H.C. Kahlmann
J.P.R. de Reijer
H.J. Stiepel
J. Stolt
J. Weggemans

Postdoctoral Fellows

S.H. Britzen
R.M. Campbell

TECHNICAL LABORATORY

A. van Ardenne	Head of Technical Laboratory
C.B.M.B. Bartelds-Jager	Secretary

DZB-IVC Production
O.S.O. Apeldoorn
J. Morawietz

SKA Research and Development
A.B. Smolders
K.F. Dijkstra
I.J.H. Formanoy
M. Haller
G.A. Hampson
K.L. Venkatasubramani
R.H. Witvers

Digital Signal Processing
A. Bos
A. Doorduin
R. Kiers
A.B.J. Kokkeler
R.P. Millenaar
G.W. Schoonderbeek
R. de Wild
S.T. Zwier

Mechanical Design
R. van Dalen
M. Drost
W. van Emden
J.W. Kragt
G. Kroes

Development
N. Ebbendorf
A.M. Koster
E. Mulder
H. Snijder

Planning
J.W. Beuving

Antennas
M.J. Arts
G.W. Kant
P.H. Riemers

Low Noise Amplifiers
J.G. bij de Vaate
L. Nieuwenhuis
L.J. van der Ree
E.E.M. Woestenburg

Various Projects
J.D. Bregman
S. Damstra
R.G.B. Halfwerk
H. Heutink
Y.J. Koopman
J.A.E. Rosenberg
G.H. Tan

Software/Image Processing
A.H.W.M. Coolen
G.N.J. van Diepen
J.P. Hamaker
J.E. Noordam
H.W. van Someren Greve
C.M. de Vos

Optical Projects VISIR/MIDI
J.C.M. de Haas
A W Glazenborg-Kluttig
A.P.M. de Jong
A.A. Schoenmaker

Miscellaneous

P. van den Akker
S. Sijtsma
H.A. Versteege-Hensel
N.B.B. de Vries
K. Weerstra

12. Publications in 1998

12.1 Papers Published by NFRA Staff in Journals and Proceedings

Baan, W. A., Salzer, J. J. & Lewinter, R. D., "Optical Classification of Megamaser Galaxies", 1998, The Astrophysical Journal, Volume 509, Issue 2, pp. 633-645.

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9/1	Grant Hampson (NFRA) - A Hardware Beamformer based on the CORDIC Phase Shifting Technique"
16/1	Herman van de Stadt (SRON Groningen) - HIFI Heterodyne Instrument for FIRST
23/1	Ben Stappers (Anton Pannekoek Institute, UvA) - The Eclipsing Binary Millisecond Pulsar J2051-0827
30/1	Yanling Sun (Bell Labs Utrecht, Lucent Technologies) - Integrated RF Oscillator Design
6/2	NFRA/JIVE staff - Open Podium
13/2	Pedro Augusto (Univ. Madeira) - The population of kpc-scale flat-spectrum radio sources
20/2	Roeland van der Marel (STScI) - HST observations of black holes in galactic nuclei
27/2	Mike Masheder (JIVE) - CO survey of lambda-Ori
6/3	NFRA/JIVE staff - Open Podium
13/3	Lorant Sjouwerman (JIVE) - Ancient Startburst Activity at the Galactic Center
20/3	Rob Rutten (Utrecht) - Dutch Open Telescope: status and plans
25/3	Fernando Camillo (Jodrell Bank) - The Parkes/Jodrell Bank Multibeam Pulsar Survey
27/3	Felix Smits (NFRA) - Progress of the SKAI development projects
17/4	NFRA/JIVE staff - Open Podium
24/4	Paul van der Werf (Sterrewacht Leiden) - Ultraluminous infrared galaxies at low and high redshift
8/5	Jaap van de Loosdrecht (Noordelijke Hogeschool Leeuwarden) - An introduction to computer vision (incl. Demo)
15/5	Michiel Hogerheijde (Sterrewacht Leiden) - A high-resolution (sub) millimeter molecular line study of low-mass young stellar objects
29/5	NFRA/JIVE staff - Open Podium
2/6	Frank Stootman (Univ. of Western Sydney) - Southern serendip - a SETI search at Parkes
5/6	Alan Roy (NRAO Socorro) - Seyfert galaxies, compact radio cores, and unification: A VLBA Study
12/6	Chris Phillips (JIVE) - Class II methanol masers and their environment at high resolution
16/6	Imke de Pater (Berkeley) - The invisible Jupiter in 3D
10/7	Andrew Paplinski (Monash Univ, Melbourne) - Interpretation of Ophtalmological Images
13/7	John Dreher (SETI Institute) - SETI: Current Status and Future Plans
28/8	Rudolf Le Poole (Leiden) & Hans van Someren Greve (NFRA) - The DREAM Mode of SCUBA
4/9	Erik Bryerton (Colorado University) - High Efficiency Microwave/Millimeter wave Amplifiers, Oscillators and Multipliers for Integration in Active Antenna Arrays
11/9	NFRA/JIVE staff - Open Podium
8/10	Zoya Popovich (University of Colorado)
9/10	Erik Deul (Sterrewacht Leiden) - Imaging Surveys
16/10	Michiel Schipper (Anaxagoras Hengelo) - Toepassingen van "workflow" bij IT projecten
30/10	K.S.Dwarakanath (Raman Research Inst, Bangalore) - How hot is the intercloud medium?
10/11	Steve Ellingson (Ohio State University) - SETI at Ohio State University
20/11	Jan Geralt Bij de Vaate (NFRA)
25/11	P.S. Ramkumar (Raman Research Institute) - The GMRT and the Indian PUMA
27/11	Huub Röttgering (Sterrewacht Leiden) - The most distant radio galaxies: Probing the formation of brightest cluster galaxies
11/12	Anton Tijhuis (TU Eindhoven) - Computational Electromagnetics at the Eindhoven University of Technology
18/12	Annelie Glazenborg (NFRA) - Counting photons

14. Abbreviations

ADBF	Adaptive Digital Beamforming
ADC	Analogue to Digital Convertor
AGN	Active Galactic Nucleus
ASIC	Application Specific Integrated Circuit
COR	Correlator
CORDIC	Coordinate Rotation Digital Computer
COSPAR	Commission on Space Research
CRAF	Committee on Radio Astronomy Frequencies
DCB	Digital Continuum Back-end
DLB	Digital Line Back-end
DOGS	Dwingeloo Obscured Galaxy Survey
DRAO	Dominion Radio Astrophysical Observatory
DSP	Digital Signal Processor
DZB	Latest WSRT Back-end (correlator)
ESO	European Southern Observatory
EVN	European VLBI Network
FIR	Far Infrared
FPGA	Field Programmable Gate Array
GRB	Gamma Ray Burst
HEMT	High Electron Mobility Transistor
HST	Hubble Space Telescope
HVC	High Velocity Cloud
IACC	International Advanced Correlator Consortium
IAU	International Astronomical Union
IF	Intermediate Frequency
ISO	Infrared Space Observatory
ITU	International Telecommunications Union
IUCAF	Commission on the Allocation of Frequencies for Radio Astronomy and Space Science
IVC	IF-to-Video Convertor System
JCMT	James Clerk Maxwell Telescope
JIVE	Joint Institute for VLBI in Europe
LNA	Low Noise Amplifier
LNAA	Low Noise Active Antenna
LOFAR	Low Frequency Array
MFFE	Multi Frequency Front End
MIDI	Mid-Infrared Interferometry Instrument for ESO's VLTI
MIT	Massachusetts Institute of Technology
NICMOS	Near Infrared Camera and Multi-Object Spectrometer
NIR	Near Infrared
NOVA	Nederlandse Onderzoekschool voor Astronomie
NWO	Nederlandse organisatie voor Wetenschappelijk Onderzoek
OSMA	One Square Meter Array
PuMa	Pulsar Machine
RF	Radio Frequency
RF-IC	RF Integrated Circuit
RFBF	RF Beam Former
RFI	Radio Frequency Interference
SENSE	SKA End-to-End Simulation Environment
SKA	Square Kilometer Array
SRON	Space Research Organisation of the Netherlands
STW	Stichting voor de Technische Wetenschappen
TADU	Tied Array Distribution Unit
THEA	Thousand Element Array
TMS	Telescope Management System
UHF	Ultra High Frequency
URSI	International Union For Radio Scientists
VHDL	VHSIC Hardware Description Language
VHSIC	Very High Speed Integrated Circuit
VISIR	VLT Imaging and Spectroscopy in the Infrared
VLBA	Very Long Baseline Array
VLBI	Very Long Baseline Interferometry
VLT	ESO's Very Large Telescope
VLTI	VLT Interferometer
VSOP	VLBI Space Observatory Program
WENSS	Westerbork Northern Sky Survey
WSRT	Westerbork Synthesis Radio Telescope
ZOA	Zone of Avoidance

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