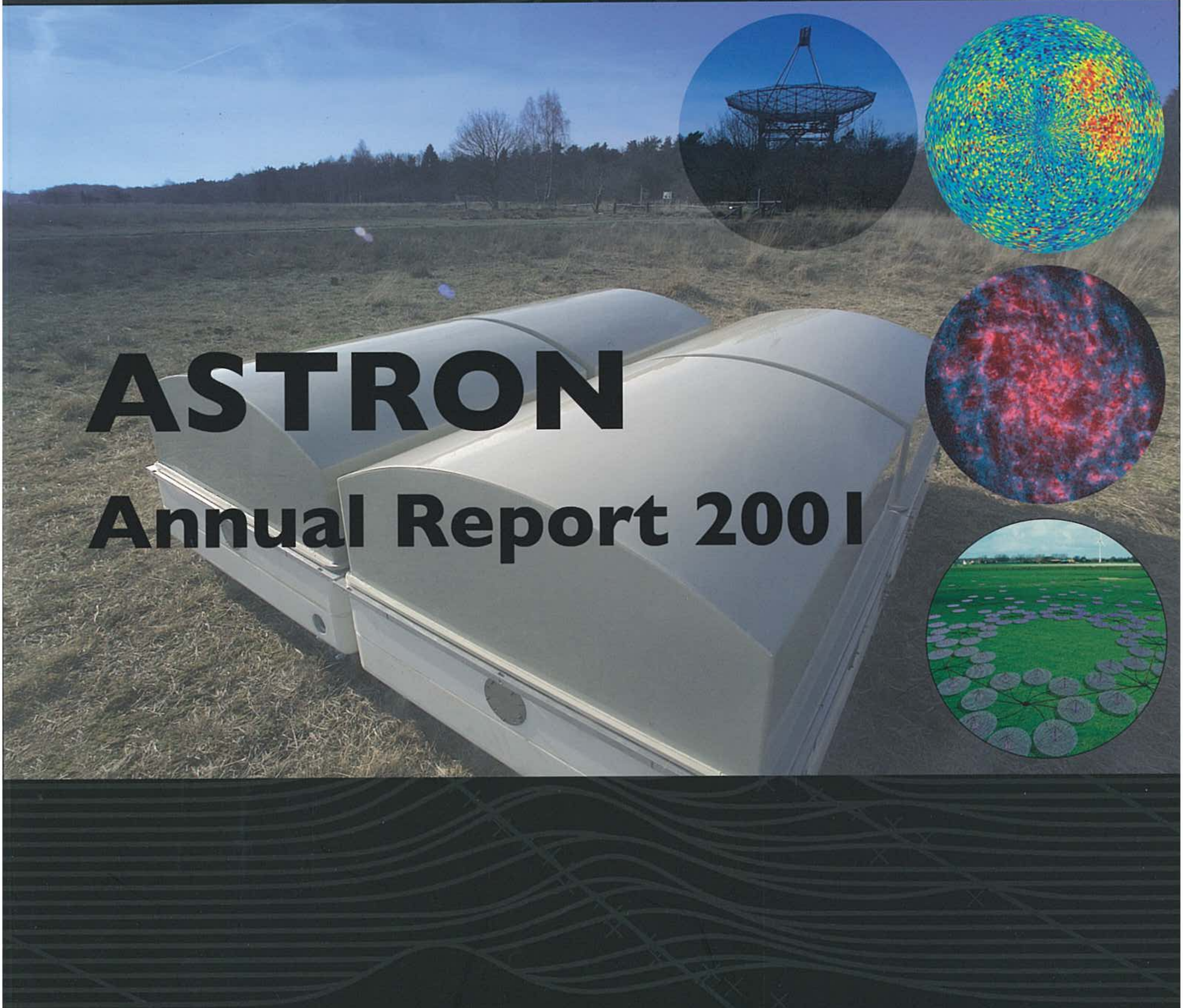
ASTRON

Annual Report 2001



ASTRON

Annual Report 2001

ASTRON

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Report of the Director

Our main challenge during 2001 was to bring the financing of our institute and its activities back to a healthy state. It is my pleasure to be able to report here that we were successful in this effort and that ASTRON can look forward to a financially healthy program for the foreseeable future. This report summarizes further the highlights of a busy year.

The year began with news that the LOFAR radio telescope project would receive initial financing from the Provinces of Drenthe, Friesland and Groningen. Shortly thereafter we signed a Memorandum of Understanding with our international partners at the Massachusetts Institute of Technology and U.S. Naval Research Laboratory. Agreements followed with the Fokker Space company, Lucent Technologies Nederland, KPN Research, Ordina UTM and with university groups in Amsterdam, Delft, Eindhoven, Groningen and Leiden to help plan and organize the design and development phase of the project. In early spring our Ministry of Economic Affairs provided additional financing for developing LOFAR's high-speed internal data transport network. And on May 18, LOFAR system engineer Marco de Vos received the prestigious Vosko Prize for Technical Innovation, recognizing his work together with K. van de Schaaf and J. Bregman on the overall LOFAR network design. By the year's end the project was well under way and attracting strong interest from scientific, technical and commercial groups both nationally and internationally.

The year also saw several major activities draw to a close. The system-wide upgrade programme at the Westerbork radio telescope achieved its final milestone as the 160 MHz wide-band IF system was successfully commissioned. It will now be possible to survey the Universe efficiently in cosmic time as well as in the usual angular coordinates on the sky. The upgrade programme has taken almost a decade to finance and the report year was deemed a good moment to consider the resulting productivity increase of the facility. Analysis showed that the annual output of refereed scientific publications has doubled relative to just prior to the start of upgrade in the early 1990's. And a comparison with other major radio observatories showed that the total cost per refereed scientific publication from the facility is currently half the international average. Together with an over-subscription of consistently a factor of two, we seem justified in concluding that the upgrade has been resounding success.

Also completed during the year were the wide-band array antenna tiles that make up THEA, the Thousand Element Array demonstrator in ASTRON's R&D programme for the Square Kilometre Array radio telescope. The tiles were commissioned out-of-doors adjacent to the 25-m Dwingeloo radio telescope and were successfully operated remotely over a 32 Giga-bit/sec data link into our laboratory building. In the coming year we will use THEA as a research platform and for starting to train a new generation of astronomers in the use multi-beam array antenna systems. Unfortunately, these activities will have to occur at a reduced budgetary level because our research council, NWO, reaffirmed during the year that it will be unable to finance such long term R&D toward future research facilities, beyond the basic operating budget it allocates to its institutes.

Our contributions to the VISIR and MIDI instruments for the ESO Very Large Telescope were delivered during the year to our collaborators at Saclay and Heidelberg, respectively, for integration and testing, which will continue throughout 2002. In the meantime, our opto-mechanical team began design studies for the MIRI instrument on NASA-ESA's Next Generation Space Telescope, the planned successor to the Hubble Space Telescope. By the year's end, a collaboration of European and American institutes had been formed to carry out the project and we were awaiting a decision on the financing of our part of the effort.

As in 2000, we filled out our programme by working with local enterprises on a variety of commercial development projects. We also demonstrated to interested groups the production advantages of our five-axis milling machine, and two subsequently acquired such machines of their own. During project discussions we identified a need for radio frequency engineers trained in the most modern technologies, so we set up a short training course for companies in the region.

In the area of policy development, our university community finished preparing its planning for the coming decade, including investment priorities for new instrumentation and facilities development. ASTRON is foreseen as participating in all of the proposed development efforts. An total increase of 13% in the national financing for astronomy will be required to implement the plan in its entirety, with a particular need being identified for the funding of strategic technology development at ASTRON and at SRON, our sister foundation for space research.

Our successful financial recovery was based partly but also importantly on several changes in internal procedures and administration. We expanded our administrative staff, thereby enabling us to provide improved forecasting and control. We completed implementation of activity-based costing for all our projects, and we made plans to acquire our own

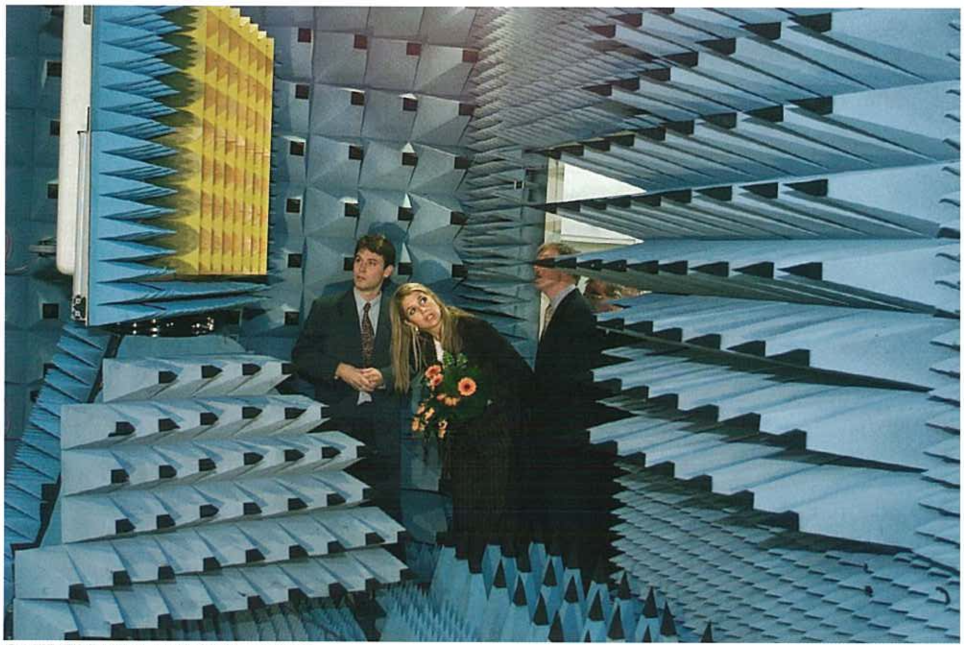

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Figure 1.1 The Crown Prince Willem-Alexander together with his fiancé, Ms. Máxima Zorreguieta were shown round ASTRON's laboratory. Here, they are seen visiting the Antenna measurement room, with the elements from one of the THEA tiles in place.

independent financial administration system. It became possible to employ new staff for an unlimited period subject to the availability of financing, and we began to introduce such contracts to expand our capabilities and permit us to take on additional new projects.

We have in recent years been increasing our public outreach efforts. These activities culminated this year in the fall with three separate events. We held open house on Sunday, 7 October, for the interested public. The weather was uncharacteristically fine and nearly 4000 people visited our Dwingeloo and Westerbork facilities to hear about what we do and how we do it. A grand success, the day also brought a moment of concern in the mid-afternoon when serious over-crowding threatened. Happily, enough of our staff had offered their Sunday up to participate that we could just manage the peak crush.

The next evening ASTRON employees were treated to a private premiere showing of "The Discovery of Heaven," a movie of the book of the same name by Dutch author, Harry Mulisch. The action is set partially at our observatory in Westerbork, where filming took place at the end of last year. We deemed the film version a great success, especially the part involving the observatory, and a fine evening was had by all.

And on the 15th of November, Crown Prince Willem-Alexander visited together with his fiancé, Ms. Máxima Zorreguieta. The visit formed part of a tour to introduce Ms. Zorreguieta to the Province of Drenthe, and the Province to her. At ASTRON, the couple received a brief presentation summarizing our activities and a tour of our CAD/CAM facilities, antenna test chamber and JIVE data processor. The Crown Prince recognized the flat panel array antennas as being similar to the phased array radar systems he used as a naval officer and Ms. Zorreguieta expressed surprise that a foundation for astronomical research should include such a high-tech development laboratory. In addition to the excellent press coverage, we appreciated the opportunity to meet our future king and queen in person.

As do many research institutes we periodically invite an external committee to evaluate our programme and comment on our plans for the future. This year, on 6 and 7 December, under the chairmanship of Prof. R. Genzel, an international committee of distinguished researchers visited and considered our programme in the light of international developments. The committee complimented us generally on having a well-balanced, productive program, and provided a number of comments and helpful suggestions. Financing for essential long term R&D and for necessary laboratory infrastructure were seen as problematical with our current financial structures, and our Board was advised that to achieve maximum synergy with ASTRON, university groups should be encouraged to invest additionally in instrumentalist astronomers and complementary laboratory facilities.

Two particular personnel changes are worthy of note. Many of our readers will recall having been helped by Ms. Ninie Oving, secretary in the office of the Director. In April, after 17 years of service, Ninie left us for a part time position closer to her home. We wish her well. And on 7 September, Board member Prof. Tjeerd van Albada of the Groningen University announced his retirement and consequent withdrawal from the Board. His scientific insights and collegial common sense will be missed.

Technical Research and Development

SKA Research & Development

The Thousand Element Array (THEA)

The Thousand Element Array (THEA) system is the third in a series of demonstrators that will show the feasibility of the phased array concept, seen by ASTRON as the most powerful for the realization of the Square Kilometre Array (SKA). All the important features of the phased array concept: multi-beam operation, adaptive nulling of interferers and reconfigurability of antennas, will be tested with THEA. Cost is recognized as a major issue in the design of the SKA. Therefore within the THEA project, advanced new technologies and integration have been used.

At the start of the year THEA had reached a crucial phase. The building blocks of the system, described in detail in the annual reports of 1999 and 2000, had all been manufactured and tested separately. However, progress on integration of the system was hampered by problems which were traced to one of the components: the column beamformer – consisting of the antenna's, low-noise amplifiers and beamformer electronics. The column beamformer boards are an example of one of the areas in which high levels of integration are being pursued. The problems which showed up in the completed system were absent in tests of the individual boards. The solution proved to be a major redesign of this board, which unfortunately has led to a delay in the completion of THEA. Still, by the end of 2001 four THEA tiles, containing a total of 256 antenna elements, had been assembled and initial system tests had begun. This milestone marked the end of the first stage of ASTRON's NWO funded 5-year SKA R&D programme, which started in 1996.

THEA System

A high level block diagram of the THEA system is shown in Figure 2.2. The THEA front-end, which consists of a number of tiles, receives the signal, performs the first (RF) beamforming stage and sends the data on a fibre to the THEA back-end. The back-end combines the signals received from the tiles in the digital beamformer and performs

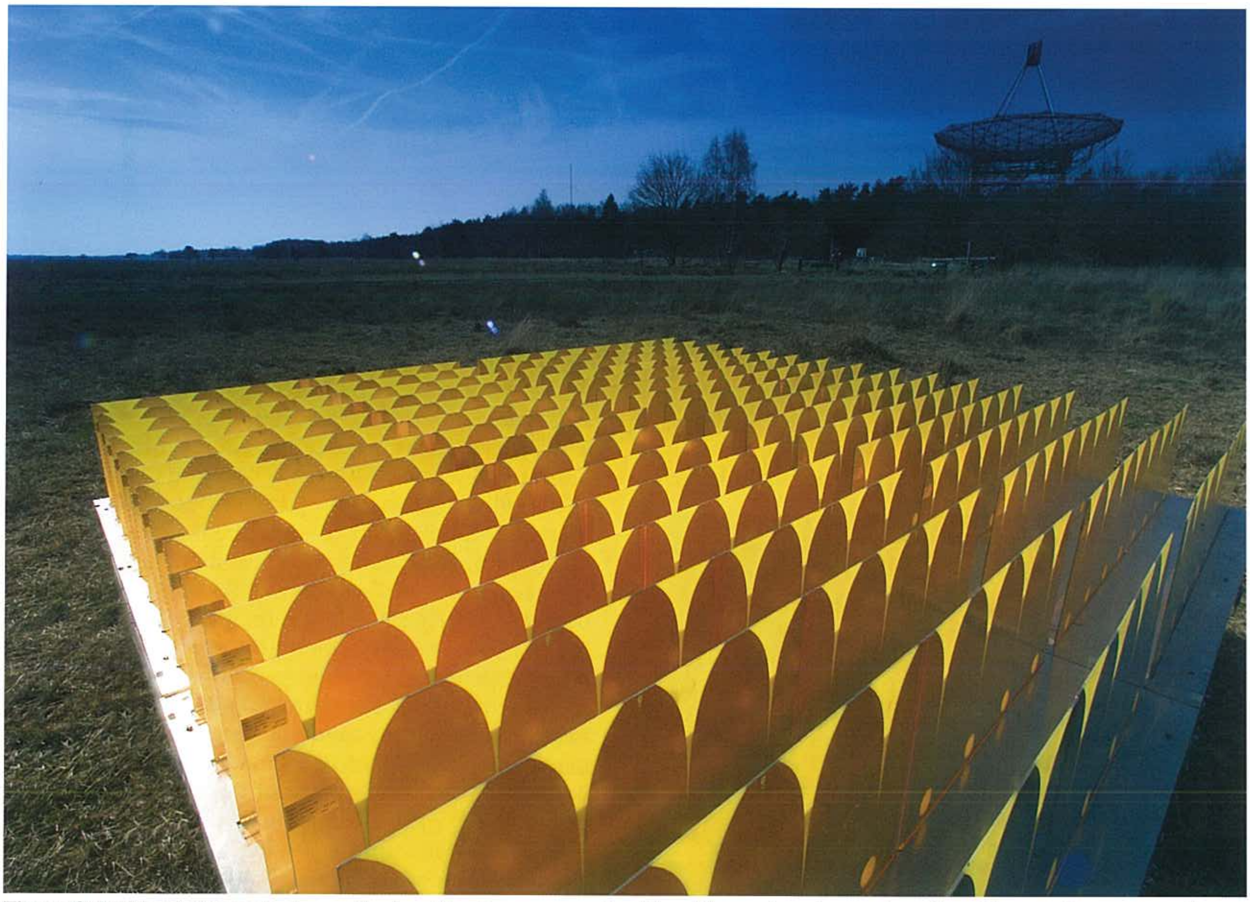


Figure 2.1 This photograph shows the four tiles in a compact setting. To create a longer baseline, tiles can be separated up to 25 meter. For the photograph, the protecting radomes have been removed.

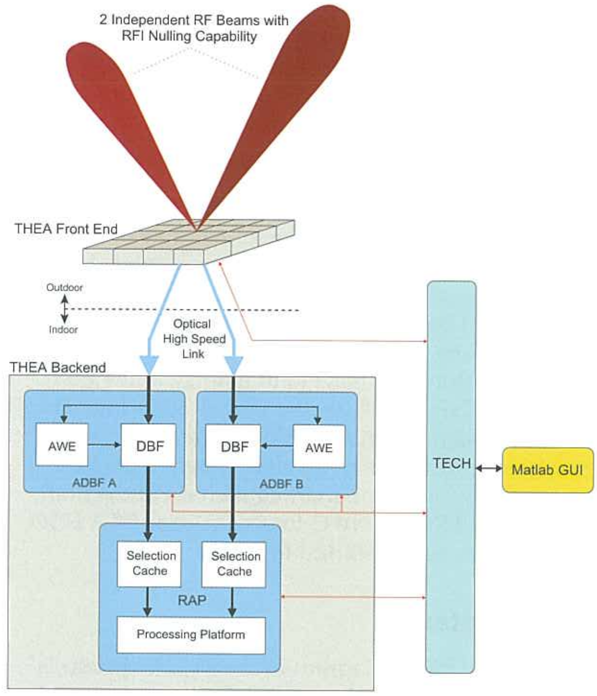


Figure 2.2 Block diagram of THEA – see text for details.

further data processing, e.g. correlation and integration. While the THEA tiles are placed on an outdoor platform, the THEA back-end is located in ASTRON's main building. The tiles contain the RF-beamformer together with a control computer and are fully remotely controlled. A total of 1400 beams can be pre-loaded in the tile in order to allow fast switching.

THEA Front-End Integration

The column board, the most important part of the RF-beamformer, was designed on a multi-function board. This novel structure integrates in a very compact fashion the antenna and RF-electronics, but also the power supply and control distribution. The use of this type of board in an open structure avoids the cost of separate boxes and multiple expensive connectors. The drawback of this concept is however that due to limitations in the simulation tools – each tool is optimized for the design of one aspect of the integrated structure – the board could not be fully verified without first building it. The final column board design therefore needed a number of iterations and turned out to be the most critical part of the system.

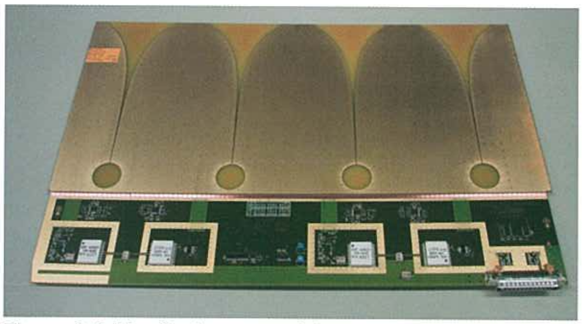


Figure 2.3 The final version of the column board shown here, combines four antenna elements with the Low Noise Amplifier, Phase modulation and signal addition. Coupling, a cause of oscillation problems, has been avoided by placing sensitive lines in inner layers.

The content of a completed tile can be seen in Figure 2.4. The power supply unit and the Front-End-Controller are located at the centre and on either side the receiver units for the two beams with the fibre output. Assembly and maintenance of the tile has been eased by using two levels: the top RF level opens up for access to the control and receiver level.

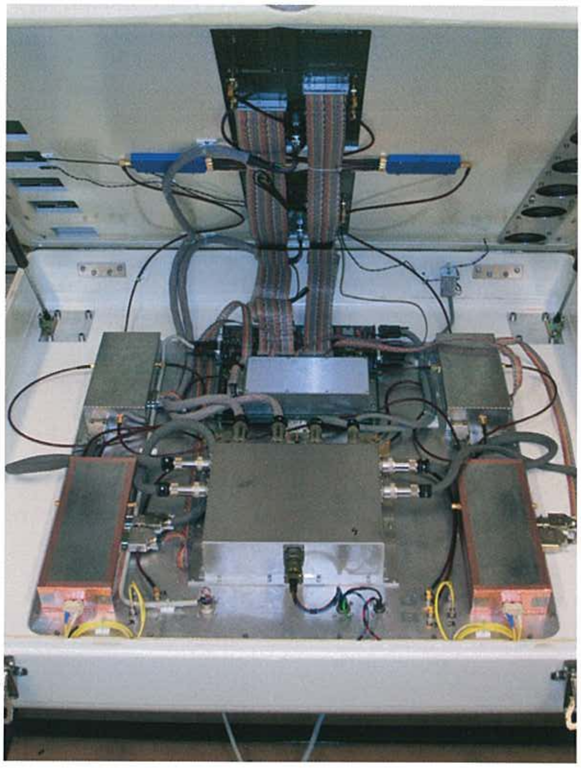
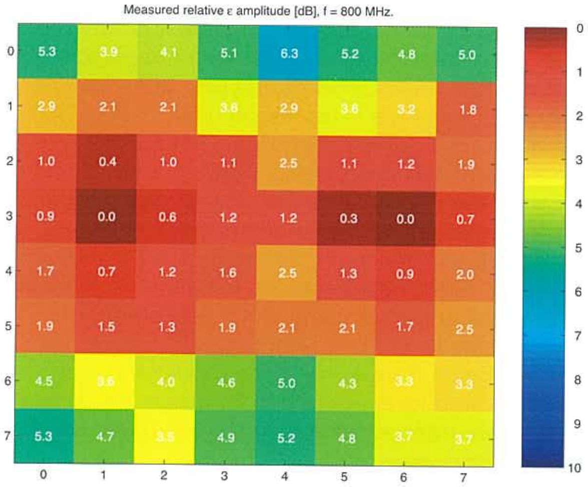


Figure 2.4 An opened tile makes it possible to perform maintenance – in the field if required.

Differences in signal path, components and in antenna location lead to variations in the antennas which result in changes of the effective amplitude and phase of each element. Therefore calibration of the phased array is very important. Figure 2.5 illustrates an example of a tile measurement before calibration. Each square represents an antenna element; one sees an 8x8 matrix filled with the gain in decibels. Noticeable are the relatively small differences between central elements and the significantly larger differences between central elements and edge elements. Due to the limited size of the array and the fact that the antenna design is based on an infinite repetition of elements, edge elements do not perform as well as central elements. In the case of THEA, lower gain of edge elements can be beneficial since it will improve the beam shape (resulting in lower sidelobes). The calibration will therefore not aim at a fully equal gain distribution.



	0	1	2	3	4	5	6	7
0	5.3	3.9	4.1	5.1	6.3	5.2	4.8	5.0
1	2.9	2.1	2.1	3.6	2.9	3.6	3.2	1.8
2	1.0	0.4	1.0	1.1	2.5	1.1	1.2	1.9
3	0.9	0.0	0.6	1.2	1.2	0.3	0.0	0.7
4	1.7	0.7	1.2	1.6	2.5	1.3	0.9	2.0
5	1.9	1.5	1.3	1.9	2.1	2.1	1.7	2.5
6	4.5	3.6	4.0	4.6	5.0	4.3	3.3	3.3
7	5.3	4.7	3.5	4.9	5.2	4.8	3.7	3.7

Figure 2.5 During the calibration procedure, the amplitude and phase differences (delta) between elements are measured. This plot shows the amplitude of each element with respect to the element with the highest gain: element [1,3] plotted with a delta of 0.0dB.

The THEA tiles have been used in a number of outdoor experiments. Because the back-end was not yet available, the observations were limited to the detection of a few celestial sources and other strong effects. After calibration of the tile in the antenna measurement room, full remote control of the two beams, with the tile placed on the platform, was achieved. Data-acquisition was done by means of a spectrum analyzer which was used as an experimental platform for test sky surveys. An example of intensity measurements with full sky coverage is shown in Figure 2.6. Signal power has been integrated and higher levels can be seen from two main signal sources, the Dwingeloo telescope which acts as a large reflector and ASTRON's main building which is a source of RFI (radio frequency interference).

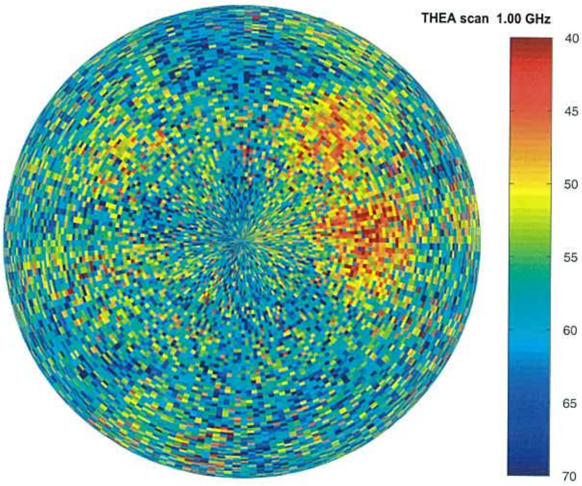


Figure 2.6 A plot of an all night full sky survey. The integrated signal power at 1GHz has been measured in all directions and is plotted in projection, with North at the top. The two areas of higher intensities are in the direction of the Dwingeloo telescope, east of THEA, and in the direction of the main building, north-east of THEA.

THEA Back-End Integration

The two major elements that can be distinguished in the (digital) data processing of THEA are the Adaptive Digital Beamformer (ADBF) and the Reduction and Acquisition unit (RAP). The ADBF consists of the Adaptive Weight Estimator (AWE) and the digital beamformer itself. The RAP consist of a memory/beam selection board and a digital signal processing board.

One of the design challenges of the digital back-end is the high data rate. The incoming serial data stream on the fibres is converted to a parallel stream on the High Speed Link (HSL) receiver. In order to handle the resulting parallel lines (up to 400 in total) a novel high density connector was used in combination with a dense 'sandwich' structure: the HSL fibre receiver board is plugged directly on the DBF which in turn is placed on top of the RAP unit. The complete assembly can be mounted in a standard PCI slot on an industrial PC. The final output of the system is stored on a hard-disk or on storage CD's.

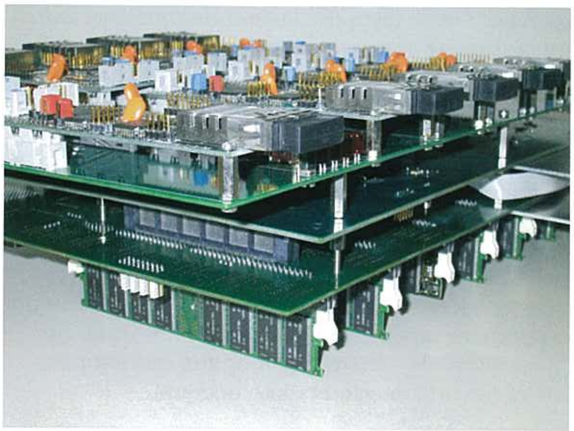


Figure 2.7 This close up shows the stack of three boards of the THEA back-end. At the top the High Speed Link Receiver board, with room for 10 fibers (not connected here). In the middle the Digital Beamformer and below the Selection board (with the memory modules as plug-ins.)

High Speed Link Receiver

The interface between the tile, the front-end, and the back-end has been realized with an optical transmitter: 24 bits parallel data at 40MHz are transmitted with a serial data rate of 1.2Gbit/s to the backend. The optical signal is converted and de-multiplexed on the receiver modules. The fibre link is used in bi-directional mode. Both the clock and synchronization signals are also transmitted to the tile. The receiver modules, one for each fibre link, are plugged into a carrier board which is a compact interconnection board. In this way a flexible and service friendly solution has been made. A total of 10 modules can be plugged onto the carrier, for two beams per tile and four tiles. A further two can be used for connection to a tile in the antenna measurement room. With the fibre link, excellent bit error rates (BER) of less than $1x10^{-15}$ have been achieved.

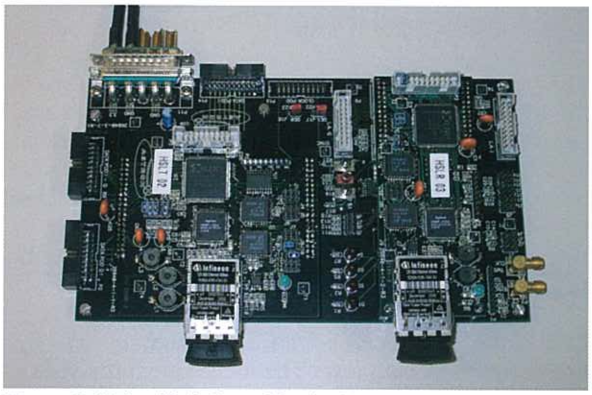
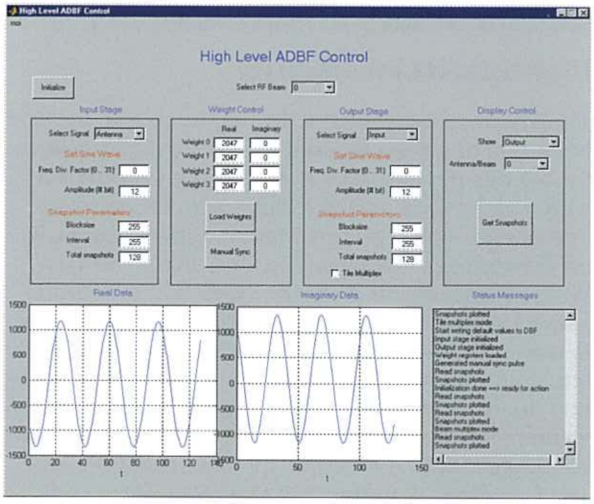


Figure 2.8 The High Speed Link, shown in this picture, performs the data transport between the THEA tiles and the THEA back-end.

Adaptive Digital Beamformer

The Adaptive Beamformer performs the spatial suppression of interfering radio signals. As a result, the celestial source information is cleaned up before image processing, which takes place in the correlator and in subsequent stages of the signal processing chain. On its own, the Digital Beamformer only suppresses the interference from non-moving radio sources. A snapshot of data (concurrent position-related signal samples) is converted into a set of beams (concurrent direction-related signal samples). The suppression is done by placing nulls in the main beam in the direction of interfering radio sources. Without the Adaptive Weight Estimator (AWE), this taper would remain constant in time. Spatial suppression of moving interferers is achieved by using a dedicated algorithm to compute the optimum taper for the Digital Beamformer at regular intervals – thereby taking the current positions of moving interferers into account.

With an eye on future developments for the SKA, the concept of the Digital Beamformer has been extended towards a so-called Generic Digital Beamformer which is both fully re-scalable and synchronous. It can therefore also be used for application in further SKA- and LOFAR prototypes. In its generic form each snapshot is represented by a set of NxN signal samples, where each signal sample is represented by a D+D bit complex number. Both N and D can chosen freely, as is the case for the sampling clock. Together these parameters determine the I/O bandwidth and hence the throughput of the digital back-end. The implementation used in THEA takes N=2, D=12 and a sampling clock rate of 40 MHz, which yields an I/O bandwidth of 3.84 Gbit/s. The Generic Beam Former has been modelled in the standard hardware description language VHDL, and is therefore transportable to any present and future silicon-technology.



Select RF Beam: 0

Input Stage — Select Signal: Antenna; Freq. Div. Factor [0 .. 31]: 0; Amplitude (# bit): 12; Blocksize: 255; Interval: 255; Total snapshots: 128

Weight Control (Real / Imaginary) — Weight 0: 2047 / 0; Weight 1: 2047 / 0; Weight 2: 2047 / 0; Weight 3: 2047 / 0

Output Stage — Select Signal: Input; Freq. Div. Factor [0 .. 31]: 0; Amplitude (# bit): 12; Blocksize: 255; Interval: 255; Total snapshots: 128; ☐ Tile Multiplex

Display Control — Show: Output; Antenna/Beam: 0

```
Snapshots plotted
Tile multiplex mode
Start writing default values to DBF
Input stage initialized
Output stage initialized
Weight registers loaded
Generated manual sync pulse
Read snapshots
Snapshots plotted
Initialization done ==> ready for action
Read snapshots
Snapshots plotted
Read snapshots
Snapshots plotted
Beam multiplex mode
Read snapshots
Snapshots plotted
```

Figure 2.9 This screen-shot shows the graphical user interface for the Digital Beam Former. The mode of operation and the beam control parameters can be set interactively.

With the code described above two beam formers, one for each of the two independent beams, of each of the 4 antenna-tile inputs are realized. A Graphical user interface (GUI) has been made for control of the DBF. With this GUI, the beam former can be set in different modes, and snapshots of the data at the input and output stage can be visualized. The handling speed of the DBF is 40MHz.

Reduction and Acquisition Unit

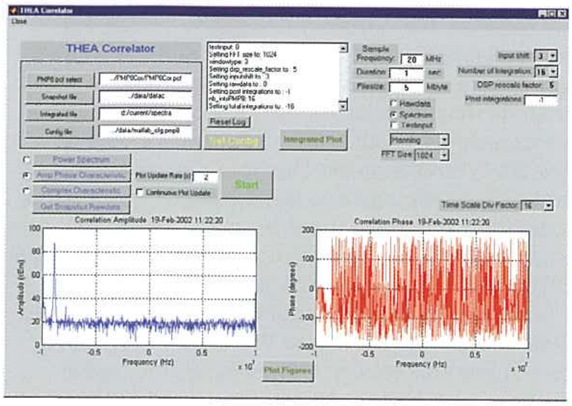
The selection board of the RAP unit was tested and a GUI has also been made. With this GUI one can select the beam that is to be processed. For RFI studies and multi-beam experiments, memory has been placed on the selection board. This memory allows storage of 16 channels (beams) for 0.8 seconds or for 12 seconds of data from a single channel.

The processing unit, a parallel processing board with 8 DSP's, performs a 1024 point FFT. The number of integrations can be set using the GUI, with a minimum of 32 spectra (100μs) and a maximum of 4000 spectra (100ms). The output data is stored on disk. With post processing the integration time can be increased up to 1hour.

On the processing unit the auto correlation of one channel has been tested. The processing unit is capable of processing 20 MHz bandwidth in real time. Extra functions will be implemented to perform cross correlation between two channels each with 20 MHz bandwidth and autocorrelations of two independent channels at the same time

Facilities for Testing of the THEA Backend

To increase the ability of testing the THEA backend, extra functions have been included throughout the system. On the IF-to-Digital converter (IDC) a 24 bits pseudo random (PSR) generator was implemented. The random code can be checked on the HSL receivers, and an error flag is given to the DBF. With the DBF test-GUI these errors can be visualized. The DBF has an error counter at both the input and output stage. These counters have been used to



```
testinput: 0
Setting FFT size to: 1024
windowtype: 2
Setting dsp_rescale_factor to : 5
Setting inputshift to : 3
Setting rawdata to : 0
Setting post integrations to : -1
nb_intsPMP8: 16
Setting total integrations to : -16
```

PMP8 pcl select: ../PMP8Cor/PMP8Cor.pcl
Snapshot file: ./data/datac
Integrated file: d:/current/spectra
Config file: ../data/matlab_cfg.pmp8
Sample Frequency: 20 MHz
Duration: 1 sec
Filesize: 5 Mbyte
Input shift: 3
Number of Integration: 16
DSP rescale factor: 5
Post integrations: -1
FFT Size: 1024
Plot Update Rate (s): 2
Time Scale Div Factor: 16

Figure 2.10 A screen-shot of the user interface of the back-end processing of THEA. Correlation control parameters can be set and a plot of the output data is given.

test the PSR from the IDC. For tests of the beamforming algorithm, four sine wave signals can be generated on the DBF. Snapshots are taken at the output stage of the DBF, and the results are verified. Also, test signals can be generated at the output stage of the DBF and used on both the selection board and the RAP unit.

Antennas for SKA

The SKA Antenna research activities at ASTRON concentrate on the design, feeding and modelling of actively phased array antennas. The focus is on developing simulation tools and knowledge that are needed to make antenna systems for the various projects the institute is involved in. Important subjects are truncation effects and noise coupling of actively steered phased arrays.

A broadband response is an important ingredient in the development of antennas for demonstrator projects such as THEA, as well as for antennas under study for the SKA. The behaviour of these antennas is often optimized using an infinite array approach, which automatically takes coupling effects into account. However, for arrays of small or intermediate dimensions, the antennas along the edges may exhibit strong deviations from the infinite array characteristics. Over recent years, developments have focused on the computation of broadband antenna arrays, and more specifically, on the study of truncation effects in arrays made of tapered slot antennas. Due to their three-dimensional structure, and due to the electrical connection between the elements, the coupling between antennas is extremely strong, and the behaviour of individual antennas strongly depends on their position within the array. Fast computation techniques have been developed to study this effect. They were developed along two different lines. First, at the Technical University Eindhoven (TU/e) and ASTRON, a code has been developed for arrays finite in one direction, and infinite in the orthogonal direction. Exploiting the periodicity of the array further accelerates the computations in the finite-array direction. Second, a code is under development at University of Massachusetts for the study of arrays using a time-domain integral equation technique. This technique is very promising, because of its ability to rapidly simulate the broadband behaviour of the array. Up to now, both techniques are based on elements made of metallic plates, fed by an idealized delta-gap source. The range of variability obtained for the gain of individual elements is in good correspondence with experimental data obtained at ASTRON with a THEA tile.

Further developments concern the study of problems specific to receiving arrays. The first one is a study on noise coupling: the noise generated by the LNA's towards their input couples back to the receiver via the other elements of the array. It has been proven at the University of Colorado (concurrently with work at ASTRON), that this effect can be described by the active reflection coefficient, which is also the quantity to be optimized for infinite-array conditions. For small arrays, the deviations from the infinite-array active input impedance can be quite large, which means that edge elements can contribute significantly to the total noise budget. Outdoor and indoor measurements (noise temperature of a THEA tile and characterization of amplifiers) have been performed to analyze this effect. Another study concerns the clarification of reciprocity applied to arrays. It has been shown how the active reflection coefficients and the open-circuit voltages both contribute to the edge effects observed in receiving conditions. This representation is equivalent to the use of individual element patterns.

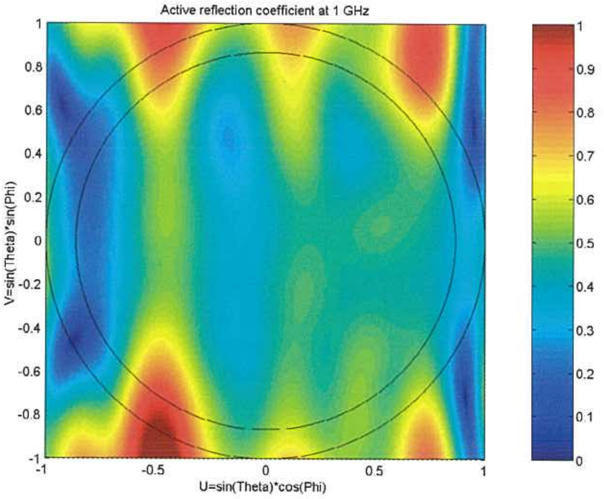


Figure 2.11 Active reflection coefficient of a single (centre) THEA element at 1 GHz. The active reflection coefficient is an important measure of its performance in the array as function of scan angle.

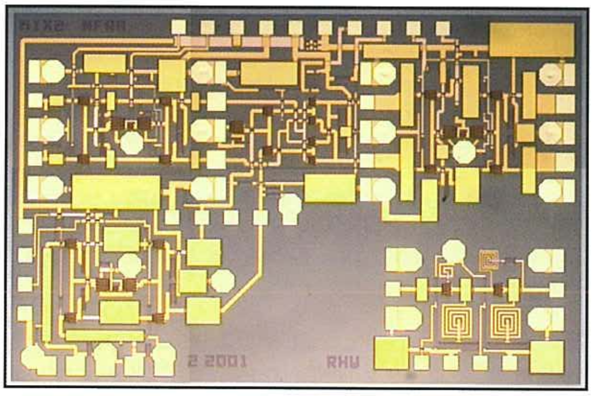


Figure 2.12 A microphotograph of a double balanced mixer, designed for the SETI Institute's Allen Telescope Array.

SETI RF-IC development work

ASTRON continued the work on mixer IC's for the Allen Telescope Array, a 500 dish SETI project. This mixer should up-convert the Radio Frequency signals in the 0.5 to 11GHz band to an intermediate frequency (IF) of 14 GHz. After a first iteration of the so called 'single balanced' concept, two new designs have been made. The first design is a second iteration and improved version of the single balanced design. The second design has been built according the double balanced concept.

The basic design of the single balanced concept consists of two multipliers, fed with a balanced Local Oscillator signal. The outputs are combined in order to suppress the common RF signal. The double balanced design consists of four multipliers, fed with a balanced local oscillator signal and a balanced RF signal. Combining these signals gives the double balanced concept the added advantage of also suppressing the local oscillator signals. The strength of the local oscillator signal gives the double balanced concept a clear advantage.

Figure 2.12 shows a microphotograph of the double balanced mixer. The IC's are processed in Gallium Arsenide (GaAs) using 0.2µm gate length transistors. The second iteration of the single balanced concept performs fully according to specifications. The double balanced concept will need a second iteration, although the basic performance has already been demonstrated on this design.

RFI Mitigation

RFI Mitigation, the Challenge

The use of the electromagnetic spectrum is changing rapidly due to an increasing demand for bandwidth, especially from the communications industry. Although there is a trend towards the use of higher frequencies, the UHF and L-band remain in great demand due to constraints in antenna size for personal mobile communications. Radio astronomy is a passive service – it does not transmit signals, but only receives them from outer space. These signals are usually many orders of magnitude weaker than communication signals. On the whole one can conclude that radio astronomy is confronted with an increasingly hostile radio frequency interference (RFI) environment. Due to a denser frequency band occupancy and due to new digital broadband modulation schemes, there is an increasing risk that spectrally adjacent spectrum users transmit residual (RFI) signals in radio astronomy bands. Due to technological advances, radio telescopes have also become more sensitive and therefore in principle more vulnerable to RFI. However, technological advances also have potential for new RFI mitigation techniques, to counteract the RFI threats.

ASTRON is involved in, and indeed initiated, many projects for the study of RFI mitigation in both the analogue and digital domains. In the past for example, analogue RFI mitigation was the topic of the LNIR project, aimed at supplying the WSRT radio telescope with filters to suppress non-linearities in the WSRT receivers, caused by nearby strong transmitters. For the same purpose, high temperature superconducting filter technology was developed in collaboration with the Delft Technical University (STW project), and a prototype filter was tested at the WSRT. In the digital domain, beamforming and RFI mitigation is a topic for study in the ASTRON SKA demonstrators.

The 2001 ASTRON projects which are fully dedicated to RFI mitigation, are the Robust Receiver project in the analogue domain and the NOEMI project and the WSRT RFI mitigation demonstrator in the digital domain. Other projects with RFI mitigation aspects are THEA, LOFAR, MASSIVE, the RFI-IC developments, and Faraday. The purpose of the current RFI activities is to increase the knowledge of the applicability of various techniques, of the attainable RFI suppression levels, and of the side effects of RFI mitigation schemes. The aim is to use this knowledge for the optimal design of future generations of radio telescopes.

NOEMI

The purpose of the Nulling Obstructing Electro Magnetic Interferers or NOEMI-project (a joint ASTRON – TU Delft project, supported by STW) is to investigate the effectiveness of digital array signal processing techniques for RFI mitigation. The main goals of the project are to study the RFI mitigation algorithms theoretically, to measure and characterize the interfering signals and to demonstrate the effectiveness of the algorithms in a small scale demonstrator at the WSRT. Finally, the implications of the acquired knowledge for the RFI mitigation aspects of the LOFAR and SKA radio telescopes will be reported.

Data Recorder

Early in the year, the DSP software of the NOEMI eight channel data recorder was largely rewritten in order to increase the observational duty cycle, as only a small fraction of the available online time could be used for data taking. After the software upgrade, the duty cycle reached the theoretical maximum, which was determined by the computer's PCI bus speed. In May and August, several test runs were carried out at the WSRT and datasets were obtained ranging from several seconds to thirty minutes. With the upgraded data recorder long term observations with a time resolution of 10ms are now available for the study of spatial filtering in which long term stationarity aspects are relevant. Both time-continuous transmitter signals (Glonass, GPS), and time-slotted transmitter signals (GSM, DME, amateur) were observed. This enabled the NOEMI team to study the effects of the RFI mitigation algorithms and stationarity aspects on both short and long timescales.

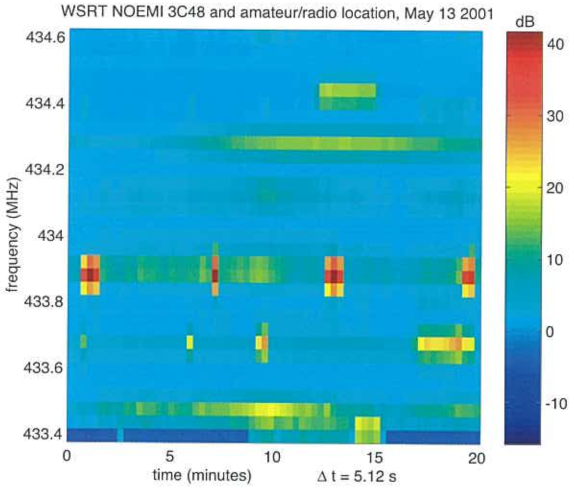


Figure 2.13a Spectrogram of amateur and walky-talky transmissions both time continuous and intermittent, in an observation of the astronomical source 3C48, as observed with the NOEMI data recorder connected to eight of the fourteen WSRT radio telescopes. The spectrogram is an eight telescope average.

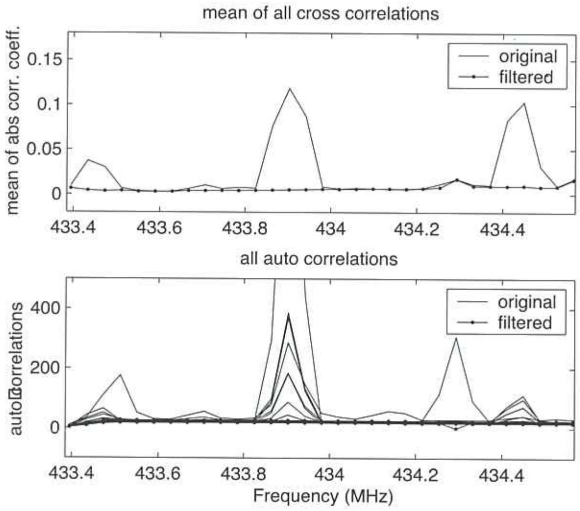


Figure 2.13b Spectra before and after applying the spatial filter to WSRT data, for the mean of all cross-correlations (upper figure), and for all autocorrelations (below).

Spatial Filtering

Most current RFI mitigation techniques address impulsive or intermittent interference and are based on time-frequency detection and blanking, using either a single sensor or multiple sensors. Continually present interferers cannot be cut out in the time-frequency plane and have to be removed using techniques such as spatial filtering. A start has been made applying adaptive filtering techniques in radio astronomy by using a reference signal, and by applying parametric signal models. In the NOEMI project the focus this year was on spatial filtering techniques for interference removal in radio astronomical telescope arrays.

The spatial filtering technique is based on the estimation of the spatial signature vector of the interferer from short-term covariance or correlation matrices (about 10 milliseconds), obtained by cross-correlation of the telescope array signals. Using a subspace projection technique, the interferer is removed from the short-term correlation data. This projection operation however, also affects the astronomical signals, and hence a correction has to be applied to the long-term correlation average (10-60 seconds) to compensate for this. This leads to almost unbiased estimates of the interference-free covariance matrix. The correction is possible under the assumption that the spatial signatures of interferers changes sufficiently over the 10 second period. This is expected since (a) ground-based interferers are subject to multipath fading, (b) satellite and aeroplane interferers move, and moreover (c) the telescopes slowly rotate while tracking a point in the sky, and continuously compensate the changing baseline lengths by delay tracking and a phase rotation (fringe correction) with a characteristic frequency on the order of a few Hertz. These effects cause even stationary interferers to show a change in their spatial signature vector over a 10 seconds period.

Figure 2.13 shows the results of applying the spatial filtering technique to time continuous and intermittent interference. Figure 2.13a shows a spectrogram of the observation, Figure 2.13b shows the spectra before and after applying the spatial filter and correcting for the filter distortions. The filter works well for both intermittent and time-continuous interference. The filter obviously does not work well if the interference is present in only one telescope, as can be seen at 434.3 MHz, where the interference was present in only one telescope.

It turns out that the performance of the spatial filter can be improved by applying a gain calibration step prior to filtering. For this purpose, a theoretical analysis was done, proving that the performance of the least squares gain calibration (ad-hoc) methods, developed earlier in the project, are comparable to the performance of maximum likelihood techniques. The advantage of the least squares technique is reduced complexity.

Project Extension

The NOEMI project formally ends in February 2002, but in order to capitalize on the utilisation aspects, and to fully exploit the knowledge present in the project, a one-year extension proposal was submitted to STW. The proposal included RFI mitigation tests at the WSRT with a fifth THEA tile, which has the advantage that RFI spatial filtering can be tested with a (THEA tile) reference antenna which has a high directional gain toward the interferer. The proposal was discussed in the November NOEMI user group meeting and was accepted by STW in December.

MASSIVE Project

For the next generation of radio telescopes (e.g. LOFAR and SKA) that are based on phased array principles, the embedded systems complexity is certain to grow. The main challenges are very high bandwidth, multi-beaming, RFI suppression and scaling to millions of elements. Considering the rapid improvements in both digital electronics and in signal processing techniques, the preliminary-designs must be adaptable and this is only possible with a design strategy. Within the MASSIVE project "system level modelling, simulation and exploration of large scale signal processing systems" is being proposed to ease and clarify the design steps. MASSIVE is a research programme carried out by ASTRON in collaboration with Leiden University, TNO-FEL and Frontier Design, supported by a government programme "Progress" in Embedded Systems and Software Research.

Distributed phased arrays are the pilot and target of the study. As a first step THEA has been used as a reference system. The digital back-end of THEA was designed using a building block approach. These building blocks can be specified at various levels of abstraction. A modelling/simulation methodology has been proposed using the generic blocks of THEA to model large scale systems.

Starting from the THEA specifications, methods and tools to model the application at a high level have been investigated. Several simulation frameworks have been evaluated to help fast application/architecture co-simulation, do performance analysis and explore alternatives. Modelling and simulating is only possible in multiple environments. In this first year of the project various environments have been identified and were successfully interfaced. The modelling of the THEA application and architecture was completed. The large scale architecture exploration for the ALMA correlator as well as the LOFAR and SKA stations was made possible by scaling the generic building blocks of THEA. Simplifying the architecture exploration of a phased array telescope, highlighting the cost drivers and the critical applications are the next challenges for the MASSIVE project. These developments should help the design of the next generation of large scale embedded systems such as LOFAR.

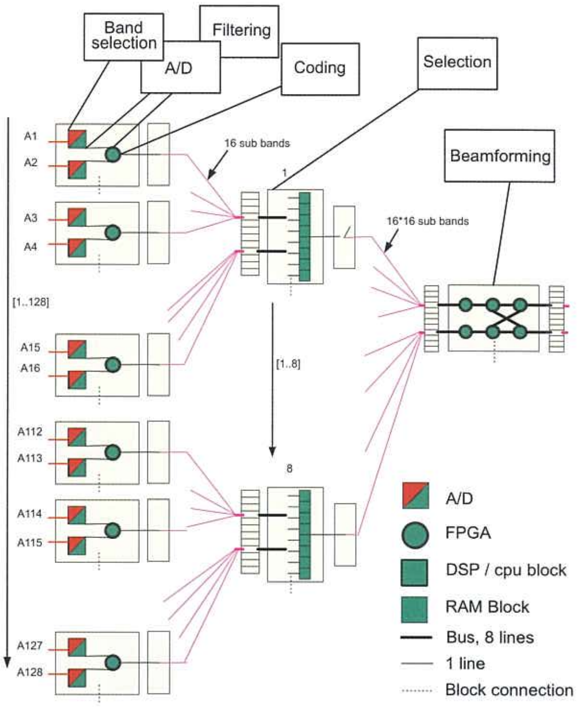


Figure 2.14 Example of an architectural model of a LOFAR station. The mapping of the processing requirements on generic architectural blocks is shown.

Photonics for SKA

The photonics activity covers three complementary approaches all in co-operation with external groups. The ASTRON activity concentrates on signal distribution via fibre over various ranges such as within equipment like phased array antennas, between subsystems such as antennas in a station (e.g. SKA and LOFAR), and between antenna stations over distances of up to hundreds of kilometres. The station interconnection is addressed in the LOFAR project and a progress report is given in the section on Wide Area Network and Data Transport.

Intra station connectivity was addressed in the THEA project. Based on components developed for the Gigabit Ethernet market, bi-directional links have been developed to connect the tiles on the platform with the digital beam-forming system that is about two hundred metres away. The data rate from a tile is 1.2 Gb/s and the return link is used for distribution of the clock signals for the analogue to digital converters in the tiles.

RF signal distribution via optical carriers allows coherent and incoherent detection schemes. Coherent applications are being investigated by colleagues from the University of Colorado in Boulder (USA). The research on dynamic holograms reported in previous years has been extended to Spatial Spectral Holograms that are integrated in Coherent Transient Crystals. A single crystal is a computational engine that allows wideband spectral imaging with resolutions of a tenth of a MHz over a bandwidth of tens of GHz and could replace a complete multi-station digital spectral wide-band correlator system. Our co-operation has led to a successful proposal for further investigation that could lead to a prototype system to be used by either the Allen Telescope Array or ALMA.

The local investigation on differential phase stability between two fibres in a 200m cable was concluded with experiments between the building and the THEA platform. It was shown that the optical phase variations and polarization changes are sufficiently slow that they can be tracked and corrected for by proposed optical processor systems based on dynamic holograms in crystals.

Incoherent optical processing is being pursued within a Navy supported joint study with TNO-FEL on key components in photonic architectures for phased-array receivers. Activity concentrated on improvement of the dynamic range of the optical combining network by introduction of a Semi-conductor Optical Amplifier as a preamplifier before the detector. The project has been successfully concluded with a literature overview of system approaches and technologies and discussion has started on a follow-up of the co-operation.

Discussion has also started with a group at the University of Twenthe to participate in the development of integrated photonic components that could be used in incoherent beam forming applications.

FARADAY

The project proposal for FARADAY ("Focal Arrays for Radio Astronomy; Design, Access and Yield") was positively evaluated by the EU and started as a project in November. It is a collaboration between ASTRON and a number of European radio astronomy institutes (Jodrell Bank Observatory in the UK, the Radio Astronomy Laboratories in Italy, the Radio Astronomy Group of Torun in Poland and as associate partner also ATNF/CSIRO in Australia). The objectives are to explore multibeam- and phased arrays in reflector systems, to address the critical design areas and to demonstrate the results with front-end technology using Indium Phosphide semiconductor Microwave Integrated Circuits. The ASTRON part focuses on the application of phased array technology in reflectors and will demonstrate the results using the Westerbork Synthesis Array. Co-operation with Universities and ESTEC are to support the ASTRON share. A related collaboration with CSIRO is being built up to explore the phased array in combination with a Luneberg Lens "Concentrator" as one of the SKA concepts.

LOFAR Design and Development

Introduction

The Low Frequency Array (LOFAR) is a high-sensitivity astronomical imaging and detection instrument for low radio frequencies (10-220 MHz). LOFAR will open a new science window on the Universe that is of interest for the study of cosmology and astrophysics, as well as for ionospheric studies and space weather applications. The instrument can be seen as the first radio telescope of a new generation, employing large numbers of low-cost omni-directional antennas and high-speed digital signal processing to get high sensitivity and spatial resolution.

LOFAR is being developed by ASTRON, MIT Haystack Observatory and the Naval Research Laboratory. In 2001 all three institutes secured initial funding for their LOFAR contributions. The collaboration between the organizations and details of the project took shape during two international meetings held in the course of the year. The first of these meetings took place at ASTRON, Dwingeloo in May 2001 and focussed on the scientific applications and the main technological areas of the instrument. In the second meeting at Haystack Observatory in October the details of the project structure were confirmed and progress in many aspects of the system design could be discussed.

The development of LOFAR will follow a well-defined system engineering approach, working towards a Preliminary Design Review early in 2003. The system has been broken down into several subsystems and study areas, each of which will deliver subsystem specifications and high-level designs. Each of the partner institutes has assumed the lead in several areas. The following sections report on those where activities took place at ASTRON.

Development Activities

In the course of 2001 design and engineering activities for LOFAR at ASTRON gradually increased. The development team, consisting of about four people initially, was brought up to strength and significant progress was made in most areas of the system.

ASTRON has assumed the main responsibility in the System Design & Engineering for LOFAR. A core team was set up to further establish the specification and architecture of the instrument. Work package teams were set up to work on the design of the various subsystems for which ASTRON has responsibility. Research activities on calibration and RFI mitigation continued over 2001, resulting in several reports and strategy documents. An RFI monitoring team was formed for site characterization in the Netherlands. Initial measurements made in December were promising and paved the way for more detailed studies at potential station sites.

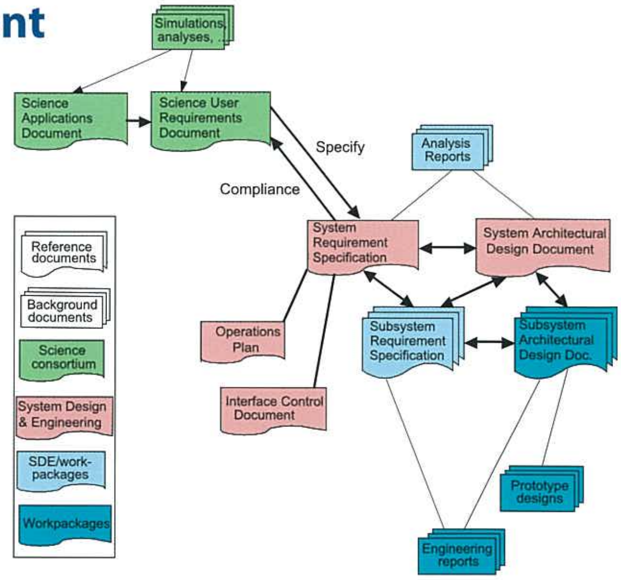
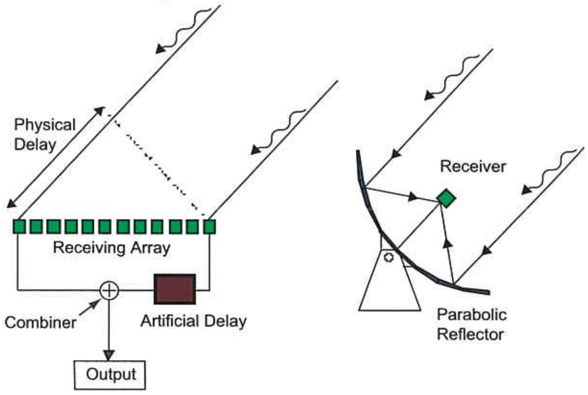


Figure 2.15 The document structure that has been adopted and that will define LOFAR in sufficient detail for PDR.

Contacts with industry and research groups at universities increased. The strategic collaboration on broad-band network infrastructure for LOFAR with Lucent, KPN Research and the Technical University of Eindhoven was formalized in the RETINA project. Research in RETINA focuses on 160Gbps networks in an operational environment, cover-

Figure 2.16 Artist's impression of a LOFAR Station in a generic landscape (above), and below an illustration of the way in which the receiving elements are combined to form beams on the sky.



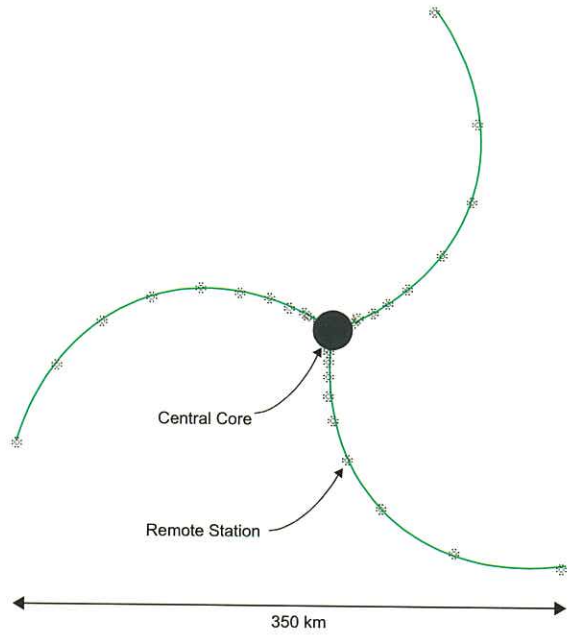


Figure 2.17 LOFAR Geometry showing the log-spiral distribution of the remote stations and the large Virtual Core in the centre, containing 25% of the collecting area.

ing both network architectures and pre-competitive research on fibre-optics network equipment. A collaboration with the knowledge centre ICT@NN was set up to develop virtual communities around LOFAR. Although no funding could be secured for this PARTICIPATE project it resulted in strategic relationships with several business partners (in this case Small/Medium size Enterprises). Several industrial parties expressed an interest in the development of LOFAR's Central Processor facility. These contacts will be further exploited in the course of 2002, when the requirements and design of the Central Processor have been more firmly established.

Architecture and System Design

LOFAR is to be realized as an aperture synthesis array composed of phased array stations. LOFAR uses a large number of low-cost antennas and relies on broad-band data links and advanced digital signal processing to implement the majority of its functionality in (embedded) software.

Figure 2.16 gives an artist's impression of a LOFAR station. The antennas in the station form a phased array, producing one or many station beams on the sky. Multi-beaming is a major advantage of the phased array concept. It is not only used to increase observational efficiency, but will be vital for calibration purposes. Effectively each station beam is a collection of about 4000 quasi-monochromatic beams in the digitized frequency band, all centred at the same position on the sky.

The physical size of the stations will be roughly 200m. Stations will be equipped with two types of receptors optimized for 10-90 MHz and for 110-220 MHz respectively. Both sets of receptors share the same digital signal path. RFI detection and mitigation will take place at station level.

Figure 2.17 shows how the phased array stations are combined into an aperture synthesis array. The stations are distributed over a large area with a maximum baseline of 360km. The log-spiral placement of the remote stations is chosen to obtain optimal imaging properties. The concentration of antennas towards the centre can be operated as a single large station. This so called Virtual Core is needed to calibrate the large ionospheric phase fluctuations that would otherwise lead to severe decorrelation. With 25% of the antennas, the Virtual Core has sufficient sensitivity in combination with the much smaller remote stations to allow calibration of the ionospheric phase screen.

Figure 2.17 also illustrates how the signals from the remote stations are transported to a central location. Note that the central processing facilities need not be co-located with the centre of the array. The bandwidth available on the network effectively limits the number of monochromatic station beams that can be processed centrally.

Accurate timing information is collected at each station based on rubidium clocks and GPS. Timing information is stored with the data stream. There is no central clock or LO signal that has to be distributed.

Figure 2.18 gives an overview of the main subsystems and elements in LOFAR. The data flow is from top-left to bottom-right. Three system wide functions are implemented in the subsystems in the upper-right corner.

The Scheduling & Specification function forms the interface with users during preparation of observations. It offers a high-level interface for the specification of LOFAR observations based on templates for each observational mode. The scheduling function offers computer assisted scheduling of multi-beaming, multi-user observations. The Monitoring & Control function forms the unique interface to all the hardware and software items in the dataflow. The Monitoring & Control function is highly distributed and includes facilities for early-warning and diagnosis. The Visualization function forms the interface with users during and after acquisition. It gives access to intermediate results and gives the user control over analysis done at the LOFAR central processing facility.

In the remainder of this section the data flow is followed, highlighting some features that are relevant to all Observational modes. The rounded square in the top-left of Figure 2.18 represents the Station Subsystems (only two stations are shown, with only a single set of antennas). As mentioned above, each station contains two types of antennas and receivers, each set optimized for a different wavelength

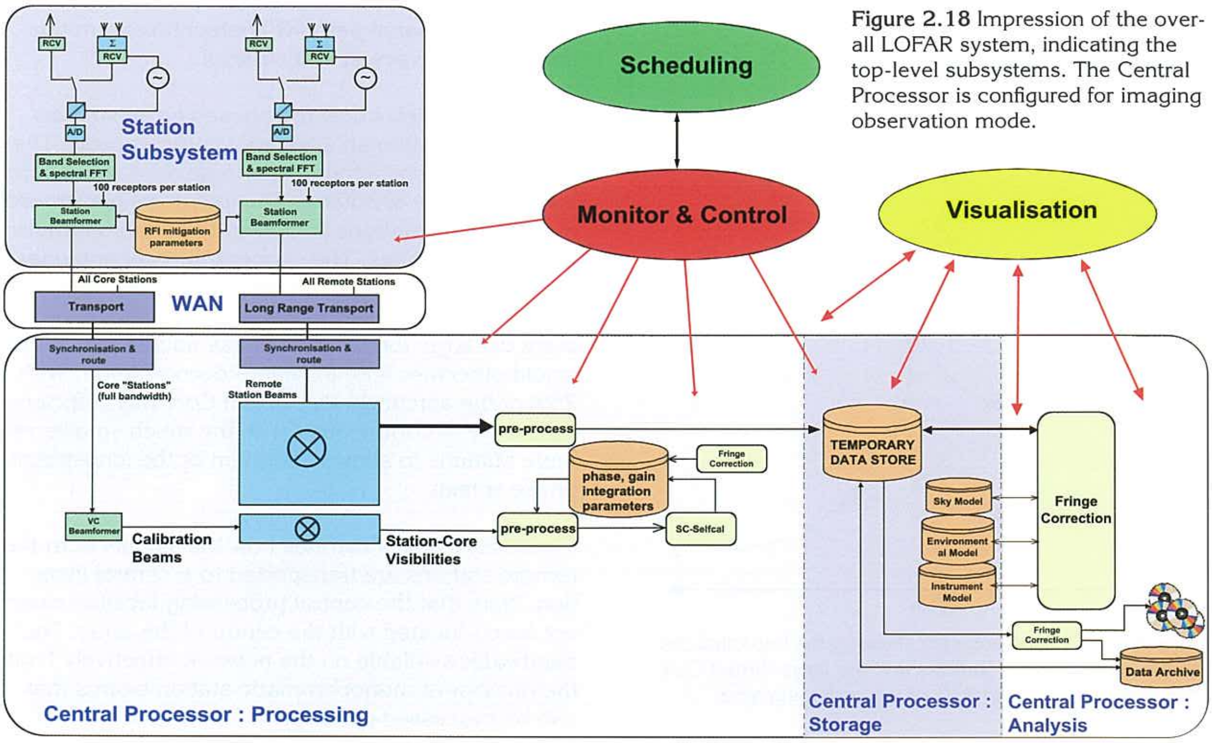


Figure 2.18 Impression of the overall LOFAR system, indicating the top-level subsystems. The Central Processor is configured for imaging observation mode.

range. The high frequency antenna is a compound element with an analogue RF beamformer, possibly integrated with the receiver.

The analogue signals of either of the two antennas is selected and digitized. The main function of the ensuing station digital processing is to form RFI-free monochromatic beams. The station digital processing has finite resources, matched to the capacity of the data transport network. It is possible to trade the number of frequency channels against the number of directions on the sky that can be observed simultaneously. So one can either process a large bandwidth with a limited number of beams, or a limited bandwidth for a larger number of beams. The station has a Clock and LO system for internal synchronization and accurate timing.

The block below the Station Subsystem represents the Wide Area Network (WAN) used to transport the station data to the central processing facility. The large block at the bottom of the figure is the Central Processor subsystem. This subsystem needs to be highly reconfigurable to accommodate the needs of the various science cases. The configuration shown here is for imaging observations. The Central Processor platform implements three main functions. In the Processing function data are sufficiently compressed to allow medium-term storage. The Storage function keeps the compressed raw data and makes it available for further off-line analysis. The Analysis function uses the stored data and calibrates it further, forming final data products for export.

Figure 2.19 singles out an essential part of the Central Processing: the Station-Core Self calibration. The Virtual Core beamformer combines the beams from the Virtual Core stations into a collection of pencil beams, pointed at the brightest calibrator sources within each station beam. These calibration beams are used to probe the ionospheric phase screen over the stations and are correlated with the remote station beams. The resulting Station-Core visibilities are processed in a Station-Core Self calibration process which yields the gains and phases over the remote station beam. The way this information is applied to the main data stream depends on the processing configuration. For imaging observations they are applied together with the fringe corrections right after the correlation. This makes it possible to integrate Station-Station visibilities up to

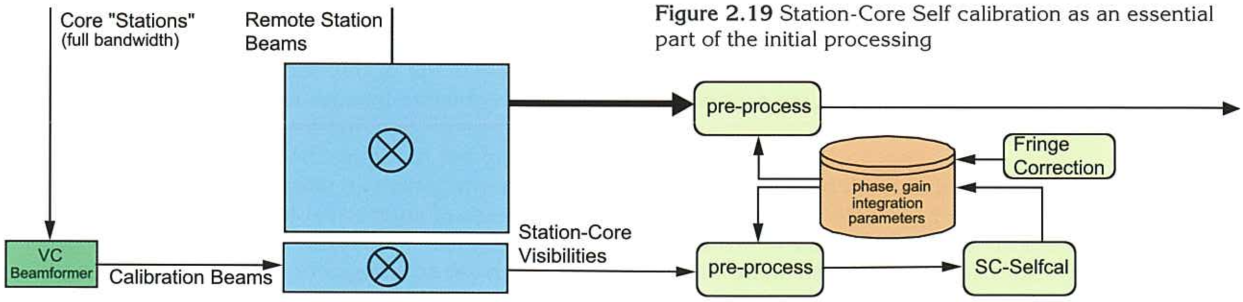


Figure 2.19 Station-Core Self calibration as an essential part of the initial processing

1 sec, making the DataStream manageable for further storage and analysis. Regardless of the way in which they are applied, the results from the Station-Core Selfcal are needed in all observational modes.

Antennas

When thinking about LOFAR started, some three or four years ago, the original frequency band of interest stretched from 10 to 150 MHz. Within this band, the reception of radio waves had to be sky noise limited, which means that in practice the noise produced by the system itself should be 10 times smaller than the received radio waves originating from the sky (see Figure 2.20). Because the antenna (including the first amplifier) determines the minimum noise temperature of the complete system, an effective antenna and amplifier design is crucial.

In 2000, a formal collaboration between Rohde & Schwarz and ASTRON resulted in the design of a prototype active antenna. This prototype has been evaluated at ASTRON. Simulation of this single polarized prototype showed that the real part of the antenna impedance, which directly relates the sky noise temperature to the receiver noise temperature, decreases rapidly for lower frequencies. For an antenna close to the (conducting) ground, the real part of the impedance decreases with frequency to the 4th power (as opposed to a power of 2 for antennas in free space). This effect, and the need for more sensitivity at frequencies above 130 MHz led to the separation of the LOFAR operational band into two parts: the High Frequency (HF) band and the Low Frequency (LF) band. Haystack/MIT will now develop the compound HF antenna, while the Naval Research Laboratory is primarily responsible for the design of the LF antenna. ASTRON is supporting these activities both at system level and through a parallel development for the low-frequency antenna.

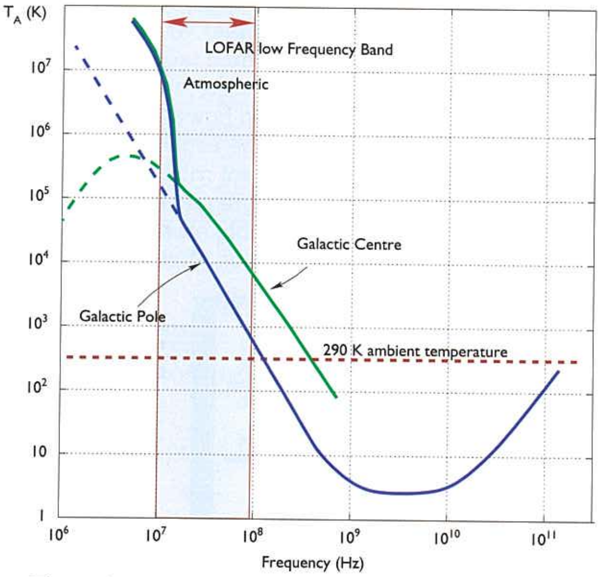


Figure 2.20 Antenna sky noise temperature as a function of frequency.

When compared with passive antennas, active antennas exhibit some very interesting advantages. Most noticeable is that they are much smaller than passive antennas designed for the same frequency range. Due to the fact that the radiator length is well below a quarter of a wavelength, their characteristics become independent of frequency. This allows to operate over a wide range in bandwidth. However, shortening the radiator will dramatically decrease its output impedance. This becomes mainly capacitive while the nominal impedance of a coaxial cable is usually 50 Ohms. Hence, an active device is attached directly to the radiator to transform the impedance to the cable impedance.

The radiation pattern of the prototype is nearly constant with frequency for both E- and H-plane, while the noise performance matches the objective closely. The –3 dB beam width of the prototype is approximately 90 degrees. This is less than the design goal of 120 degrees, and will therefore need additional investigation.

Simulations have been performed in order to optimize the gain pattern of the antenna using a small reflective plate (i.e. small with respect to the operating wavelength) and including a ground model. The 4 x 4 m plate was positioned below the antenna element, both with a tilt angle of 30°. The simulated radiation pattern at 10 MHz (wavelength of 30 m) is shown in Figure 2.21. The prototype has also been used to characterize the spectral occupancy of the LOFAR band (at Westerbork). The antenna turned out to be very sensitive for very low frequency RFI generated by the telescope system.

Summarizing, the construction of the prototype and its evaluation were very useful for the overall LOFAR antenna development because it has clearly shown the critical issues of the design. These issues will be investigated further in 2002 in order to satisfy the LOFAR requirements.

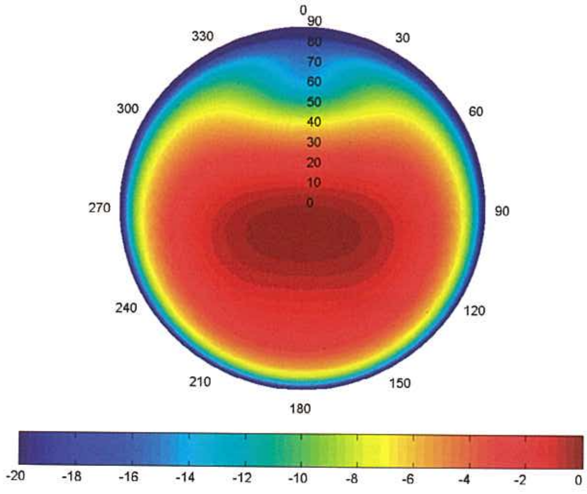


Figure 2.21 Radiation pattern of X-polarized dipole element at f = 10 MHz. Max(G) = 6.5 dBi.

Wide Area Network/Data Transport

Activities on the Wide Area Network required for LOFAR are taking place in the RETINA project, which is a collaboration of ASTRON, the Technical University of Eindhoven, Lucent Technologies and KPN Research. The RETINA project is part of the “BraBant BreedBand” (B4) initiative, formed to advance the development of high capacity digital networking and supported applications in the Netherlands. The scope of activities is to include early implementation of network hardware and software in a pre-competitive operational environment as well as the development of applications for future networks. The RETINA project is concerned with the physical realization and management of the scalable, very high capacity optical fibre networks in an application environment such as that of LOFAR.

Within the next two years, optical fibre systems capable of transporting 40 Gbit/s over a single fibre and in a single wavelength channel will become commercially available, as well as systems transporting 1.6 Tbit/s over a single fibre by carrying 40 wavelength channels at 40 Gbit/s each, or 160 channels at 10 Gbit/s. In the first phase of the RETINA project, a specific network architecture will be designed which provides the capacity required for LOFAR by deploying nearly-commercial systems using multiple fibres, each carrying multiple wavelength channels at data rates of up to 40 Gbit/s. In designing the transport network architecture, trade-offs need to be made between data rate per wavelength channel, number of wavelength channels, and the number of fibres. Precious wavelength and fibre resources can be saved when the data rate per wavelength channel is increased. Therefore, in the second phase of the project, investigations will be done into systems transporting 160 Gbit/s in a single or more wavelength channel(s). Also the impact on the network architecture will be analyzed.

The results of the first project phase will facilitate the first validation tests with the LOFAR system. When technical and economic feasibility has been demonstrated, the results of the second phase may provide an upgrade option for the LOFAR system ahead of its large-scale installation in 2004/2005.

In 2001, research focussed on network architectures and optical systems. In the architecture studies four different technologies, capable of high speed optical transport, were assessed. These technologies are Synchronous Digital Hierarchy (SDH), 10 Gigabit Ethernet (10GbE), Digital Wrapper and Wavelength Division Multiplexing (WDM). A comparison was performed to determine the ideal technology. The intermediate conclusion is that Digital Wrapper is not useful in RETINA. The other three technologies can each provide the transport of choice over different distances. The final decision however should be made after an assessment of the economic impact of each technology. Different multiplexing techniques can be used to aggregate the data streams of the stations. The possible multiplexing techniques are SDM (Space Division Multiplexing),

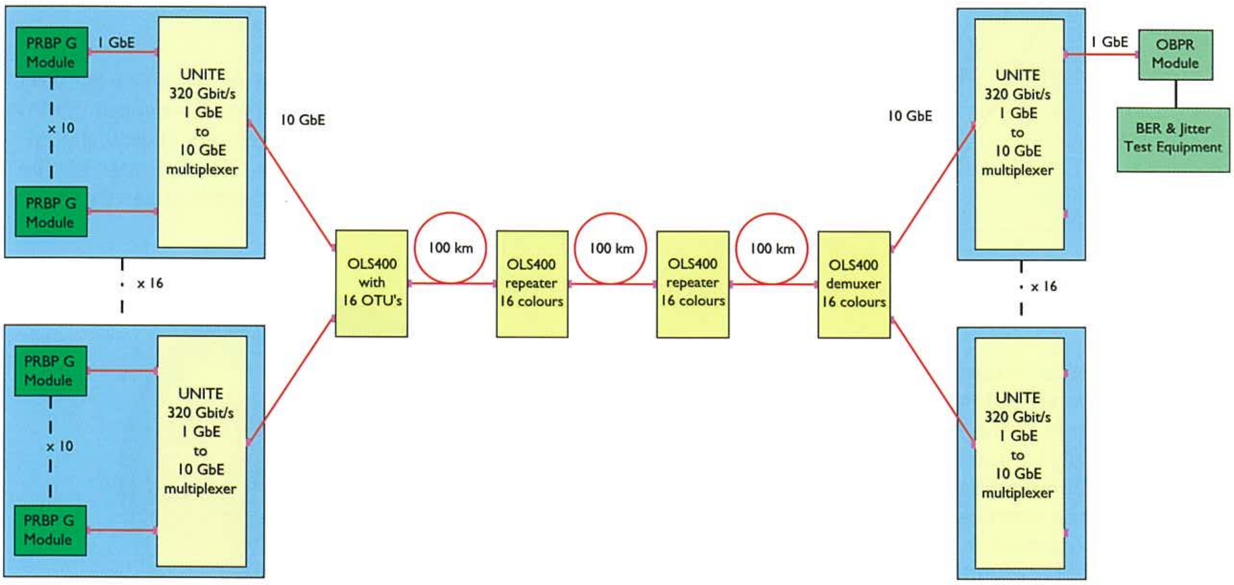
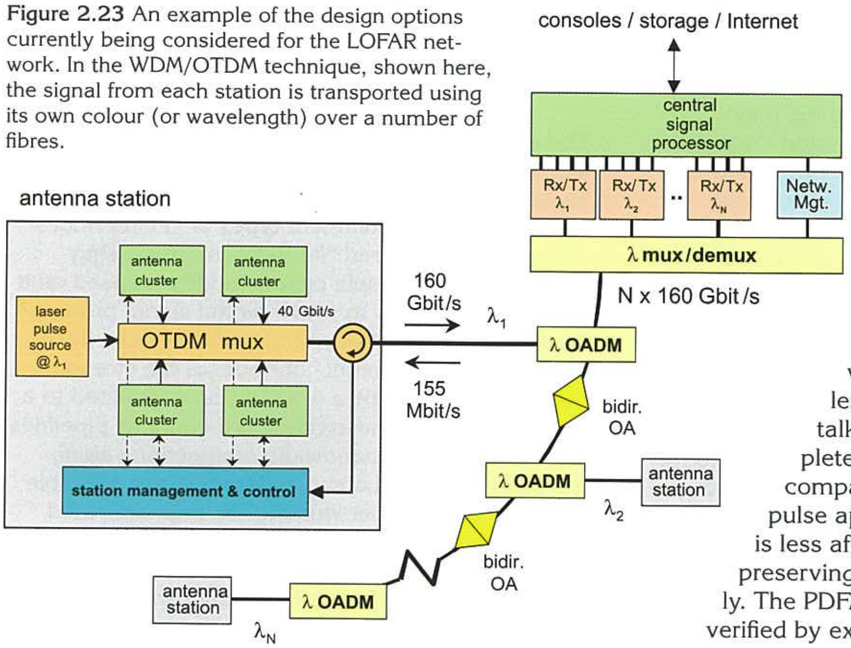


Figure 2.22 This block diagram represents a photonic system which demonstrates the data transport from a remote station to the central core of LOFAR . The demonstrator will be implemented in 2002 with (nearly) available commercial key components. On the left hand side, 160 Pseudo Random Bit Pattern Generator (PRBGP) modules, generate a continuous 160 Gbit/s data stream representing a full blown LOFAR station. The data stream is multiplexed in two stages onto one fibre carrying 16 different wavelengths. A total distance of 300 km is spanned, supported by two optical amplifiers (OLS400 repeaters). On the right hand side, the data from the fibre is de-multiplexed into 160 1 GbE streams. To evaluate the quality of the data transport system, the Bit Error Rates (BER) and Jitter characteristics of the optical 1 GbE channels are analysed. The BER and Jitter test equipment processes a 32 bit parallel electrical signal representation resulting from the Optical Bit Pattern Receiver (OBPR), which takes a 1 GbE signal as its input. The yellow modules are from Lucent's commercial product line and the green modules are based on developments of ASTRON.

Figure 2.23 An example of the design options currently being considered for the LOFAR network. In the WDM/OTDM technique, shown here, the signal from each station is transported using its own colour (or wavelength) over a number of fibres.



WDM (Wavelength DM), OTDM (Optical Time DM) and TDM (Time DM). In theory, it is possible to combine any of these techniques. A tool was developed which could calculate the number of required elements per technology combination. Elements include transponder types, multiplexers, switches and fibre. In this way, both the manageability and usefulness can be calculated. The tool is in the process of being extended to include proper calculation of insertion loss of the elements and effects in optical regenerators. The research on optical systems focussed on wide band optical amplifiers, dispersion compensation and OTDM issues.

Within the LOFAR network, optical amplification is a necessity to compensate for the fibre losses and the losses due to (de)muxprocesses and dispersion compensation. The LOFAR network configuration studied in RETINA comprises long arms (up to 225 km), short arms (60 km) and a short distance core area. The long arms argue for the lowest fibre loss possible which determines the use of the 1550 nm wavelength window. Appropriate amplifier technologies here are the Erbium-Doped Fibre Amplifier (EDFA) and/or Raman amplification. The short arms can tolerate a slightly higher fibre loss and can benefit from the virtual absence of fibre dispersion in the 1310 nm wavelength window. Here the use of Semiconductor Optical Amplifiers (SOA) or Praseodymium Doped Fibre Amplifiers (PDFA) can be considered.

Semiconductor optical amplifiers at 1310 nm are characterized for booster, in-line and preamplifier purposes and used in a Dense-WDM (D-WDM) test bed with 100 km Lucent All-Wave fibre and 4 x 10 Gbit/s optical channels. Special emphasis was devoted to the impact of cross-talk induced by four wave mixing (FWM). At a channel spacing of 100 GHz, the channels were corrupted heavily by four wave mixing. Nearly complete mitigation of FWM was achieved by increasing the channel spacing to 200 GHz. The link experiments suffered the most by FWM generated in the fibre. The FWM generated in the SOA's appeared far less substantial.

For comparison with the SOA's, an experimental PDFA was developed. A PDFA, by nature, is far less prone to inter-channel crosstalk under saturation due to the complete difference in carrier dynamics compared to SOA's. Moreover, in short pulse applications the signal spectrum is less affected by self-phase modulation preserving the pulse shape more adequately. The PDFA was analysed by modelling and verified by experimental characterization.

Initial work has been started to the performance of Raman amplification in both single- and multi-channel 160 Gbit/s OTDM transmission. Here, the Raman amplification is modelled with the help of the software environment Virtual Photonics, enabling link simulations in various configurations. For dispersion studies, a MATLAB-based software tool has been developed to enable eye-closure analyses due to polarization mode dispersion at 160 Gbit/s data rate. Preliminary results indicate a remarkable performance difference between single polarization schemes and alternating polarization schemes.

A large scale survey was carried out into possible design options for OTDM 160 Gbit/s transmission. The survey comprises design options for the transmitter, both in the 1550 nm window for the long arms and the 1310 nm window for the short arms. For the 1550 nm window a granularity of 4x40 Gbit/s was adopted, whereas at 1310 nm a scheme of 16x10 Gbit/s appeared the best option for realisation. A number of options for optical and electrical clock recovery were identified, from which a few will be explored further. Channel demultiplex options with Electro-Absorption modulators as gating devices for the 1550 nm window and a SOA-based Sagnac interferometric structure for the 1310 nm window have been described. Add- and Drop functions, configured with passive 3 dB couplers or optical circulators are proposed. The area of chromatic dispersion compensation, both pre- and post compensation, has been addressed.

Central Processor

LOFAR can be considered the first facility of a new generation of radio telescopes where the major emphasis is on a flexible data processing. Signals are digitized immediately after the antenna and are treated in a highly configurable data processing chain. The processing architecture has to be scaleable and has to allow for an optimal distribution of the total processing power over signal processing and calibration tasks. In a data-flow processing view on the LOFAR instrument, one can identify 13,000 distributed data production nodes (the antennas), resulting in a total data volume on the order of 250 GByte/s that is input to the Hybrid Data Processing Site. This site consists of a re-configurable combination of microcomputers with added data-flow coprocessors, amounting to a total processing capacity of order 40 TFlops. Most of this processing power is needed for typical dataflow processing, gradually combining and reducing the data. Iterative processing of the total collected data volume is needed during the calibration process.

The central processor should provide the necessary processing and storage capacity for the applications running on it. The science applications of LOFAR lead to three key processing types:

- For imaging applications, the central processor is used for correlation, beamforming, integration and, after short term storage, calibration and image creation.
- For pulsar observations, an "extended core" of up to 50% of the stations produce data for a central beamformer. A major processing task is the dedispersion of the measurements.
- For transient detection and analysis of time scales of a second or more, a series of snapshot images can be analysed using Fourier techniques. For shorter time scales, detection algorithms operate directly on the station beams or antenna data.

The aim of the central processor architecture is to provide first of all enough processing power, data transport bandwidth and storage capacity to allow for continuous operation of the observation facility. Secondly, the central processor will be built as a signal processing cluster aimed at multiple types of astronomical data processing

The architectural design for the central processor is shown in Figure 2.24. The hardware architecture is based on cluster computer techniques with hybrid cluster nodes. The different types of cluster nodes represent the required "flavours" of processing capacity. One example of such nodes is based on a normal workstation to which digital signal processing boards (e.g. FPGA or DSP boards) have been added. Another "flavour" of nodes is the storage node, which could be a workstation connected to a RAID disk array. The architecture contains pipelines of nodes with high bandwidth connections along the pipeline. Based on an estimate of the available processing power per workstation and dedicated chips at the time of procurement of the LOFAR instrument, some 200 pipelines each containing 6-10 cluster nodes is envisaged. Together with the signal processing chips, this produces the equivalent of 20 TFlops.

The FX correlator architecture of LOFAR requires a transpose operation on all input signals at the central site. With 100 stations each providing 32000 spectral channels, this is a gigantic routing task. In the central processor design this transpose function is executed in two steps. In the first step, packages of multiple frequency channels are routed on a switching network, implemented with a 3D torus switching fabric. The remaining fine-grained transpose operation can be efficiently executed by the node processors in cache memory. Other applications that do not require extensive use of the correlator may use the switching fabric to distribute large processing tasks over multiple pipelines. The combination of the switching fabric used both for the transpose function and the supply of input data to the pipelines offers a completely scalable hardware structure. The available processing power can easily be distributed over multiple applications running in parallel. More pipelines can be added to the switch fabric operating as data farmer.

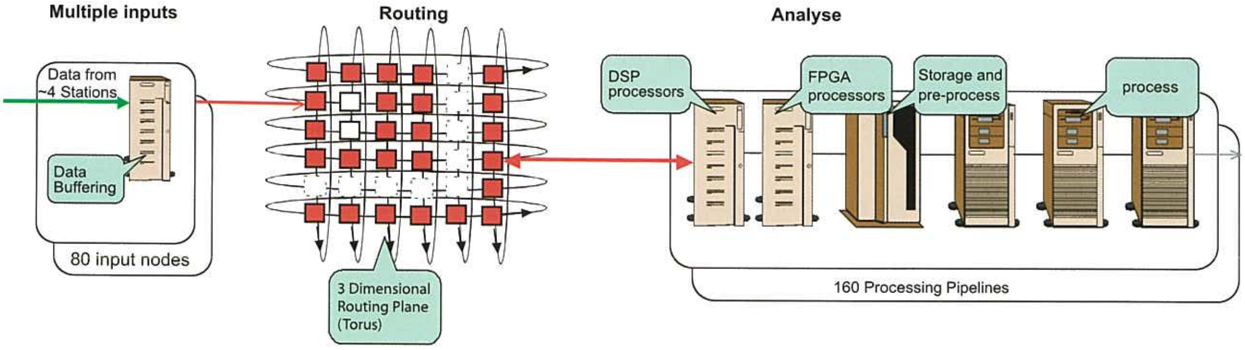


Figure 2.24 The Central processor architecture. A switching fabric farms out data to 160 data processing pipelines in a hybrid cluster computer. The cluster nodes hardware is optimized for the specific processing tasks in the processing pipelines.

As noted above, the central processor facility is designed as a large hybrid cluster computer with hot-swappable functionality in the cluster nodes. This cluster is inhomogeneous in nodal hardware since the processing and data demands vary for the successive stages of the applications. Part of the application will benefit from specialized hardware available for particular processing tasks. For example, the correlation task in an imaging type application can be executed very efficiently on (programmable) logic arrays such as an FPGA. On the other hand, Self-calibration is best executed on microprocessor hardware. Therefore, specialized hardware is added to microprocessor-based computers. This extra hardware should then be transparently available for the application programmers.

The current central processor design uses an abstract model of the hybrid cluster nodes. This model is shown in Figure 2.25. The attached processors are located on one or more boards connected to the node machine's backplane, e.g. the PCI bus. The local CPUs run programmes interacting with both the control platform and the programming platform. The attached boards contain a controller that interacts with the cluster control platform. Programme model tasks are executed on the processors on the attached board. The cluster nodes are connected to each other with backplane interconnects, for example SCI or Myrinet interfaces connected to PCI busses. A middleware library is used to control these interconnects from the programming model. The connection between local processors and the attached processors is also controlled by a software layer and made available in the programming model.

Part of the concepts described above have been verified on a small Beowulf cluster with SCI backplane interconnects. This cluster will be gradually extended in 2002 to verify the architecture in more detail and to provide a prototype platform for processing and calibration experiments.

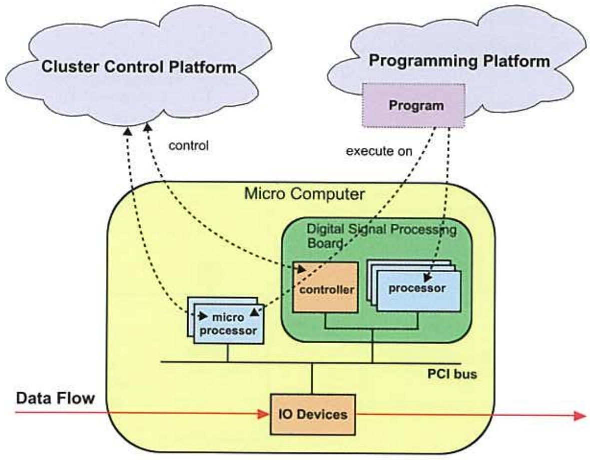


Figure 2.25 Model of hybrid cluster node. A digital signal processing board containing a controller and one or more dedicated processors is attached to the backplane of the cluster node. Processing steps from the programming model are executed on the local node CPU or on the attached processors.

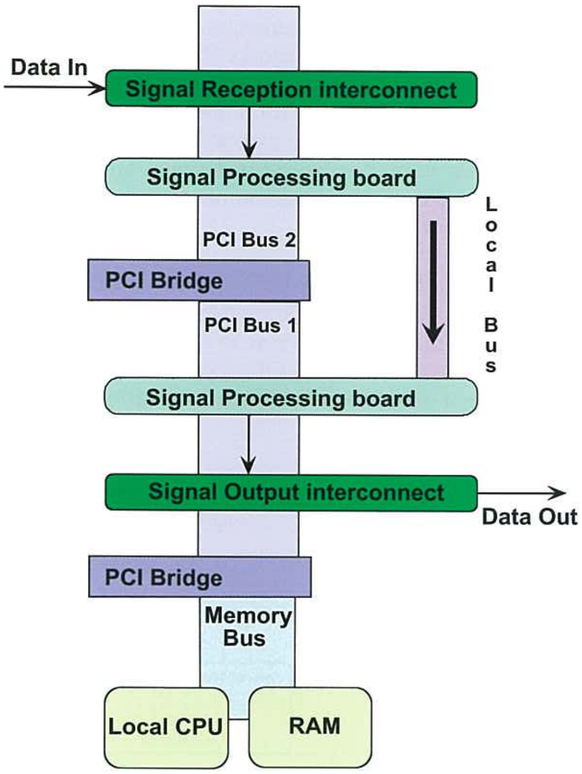


Figure 2.26 Bandwidth limitations on PCI busses can be avoided by direct data transport between signal processing boards over a local bus. In this example, the input and output data flows to other nodes can each consume the full PCI bandwidth.

The LOFARSim functional simulator has been further worked out to support these studies. In the coming year the use of LOFARSim will be extended to the RFI mitigation studies and the station level digital processing.

Calibration

Calibratability has long been recognized as one of the main design drivers for LOFAR. The main complications are:

- ionospheric phase variations (especially at the lower frequencies)
- individually variable station primary beam shapes
- fields that are very crowded with sources

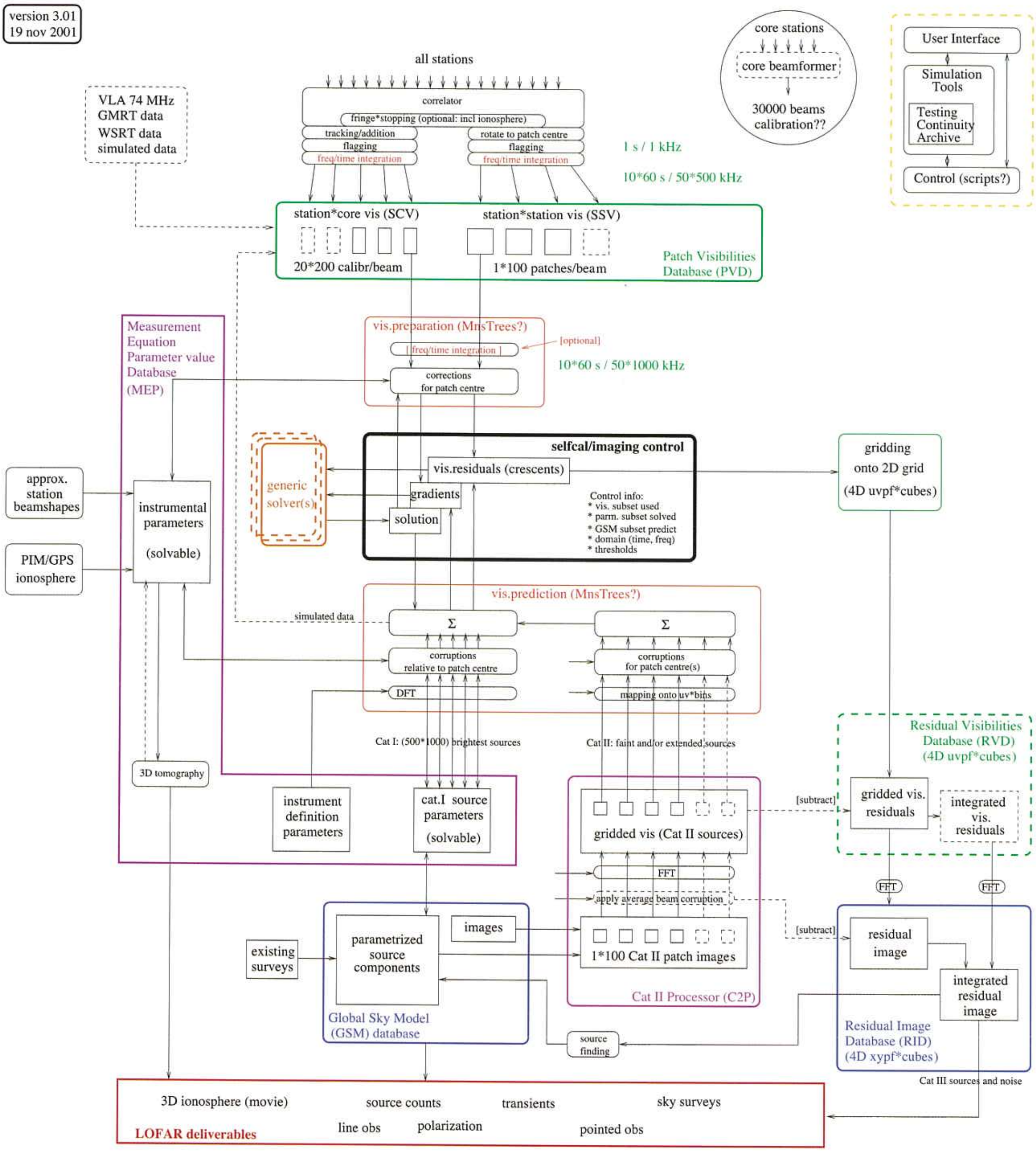
Fortunately, the latter also provides the bright sources that must be used to 'self-calibrate' LOFAR. The central question is how to distribute the available dipoles in such a way that all stations can be calibrated, while still achieving a good distribution of baseline lengths and orientation.

The currently favoured solution is to concentrate 25% of the dipoles into a super-station with a diameter of 2 km, while distributing the rest over 75-100 stations in 3-5 arms. The combination of a station with the core will then be sensitive enough to yield sufficient signal-to-noise ratio in 10-60 sec, on a large enough number of bright sources to ensure calibratability. A possible complication is that the brighter sources tend to be extended, which makes them appear fainter at longer baselines. This can be compensated by a combination of 'sub-cores' and extra bandwidth.

It is expected that 'station-core selfcal', which is relatively cheap in terms of processing requirements, will not only play a central role in imaging, but also in the calibration of other LOFAR observing modes like transient detection of pulsar observation.

A functional block diagram of the calibration for the interferometric imaging mode of LOFAR has emerged over the year as the result of intensive discussions, internally and with the international partners. This diagram enshrines the concept of 'generalized self-calibration', which is a necessary evolution of a widely used technique in radio aperture synthesis. A prototype version of the processing system will be developed to help answer important design questions in time for the PDR review.

Figure 2.27 The overall block diagram for calibration of the LOFAR interferometric imaging mode.



Functional Block Diagram for Calibration

Stated in a somewhat unconventional way, the basic function of the calibration system is to produce residual visibilities, i.e. visibilities from which the brighter sources have been subtracted. These uv-residuals are then used either to estimate Measurement Equation (ME) parameter values (Self Calibration), or to make residual images. The same software modules are used for producing uv-crescent residuals for the two main modes of self-calibration and imaging. The differences lie in the number of sources subtracted (fewer for selfcal), and the amount of integration of uv-data over frequency and time (more for selfcal).

Residual imaging is necessary, because it is pointless to make an image directly from uv-data observed with LOFAR. The reason is that uv-data can only be corrected for a single point in the sky, while instrumental 'image-plane' effects like the beam shape and the ionosphere vary considerably across the field of view (and in time). Since it is impossible to subtract the many bright 'foreground' sources from an image, they have to be subtracted from the uv-data before making an image. This is already standard practice for existing telescopes like WSRT and VLA, but it is much more necessary (and challenging) for LOFAR, which has to deal with many more sources in the field, and much larger image-plane effects. In order to deal with the crowded fields the following categories of sources are distinguished:

Cat I: The brightest 500-1000 sources in the sky. Their contributions to the uv-data are calculated (predicted) with full position-dependent sophistication, because they must be subtracted completely from the uv-data, irrespective of whether they are in the main lobe or the side-lobes of the station beams. Selfcal prediction deals exclusively with the Cat I sources, and their parameters may be solved for. But since Cat I prediction is an expensive operation, one can only afford it for the 1000 (or so) brightest sources when imaging.

Cat II: The millions of fainter sources in the Global Sky Model (GSM). The 100,000 or so that are relevant to a particular image are subtracted 'as well as possible' from its uv-data, using more efficient methods. Unsuccessful subtraction increases the noise level (side lobe confusion). Cat II sources usually do not play a role in Self-calibration: they are not necessary for prediction, and their parameters are estimated from residual images.

Cat III: All the sources (billions, all-sky!) that are not subtracted from the uv-data because they are too faint to be identified for inclusion in the Sky Model. They will be imaged 'perfectly' at the field/patch centre, but the image quality will progressively degrade towards its edges and beyond. Their sidelobes will increase the noise level (side lobe confusion).

The dividing line between these source categories is flexible. If more computing power is available, more sources can be subtracted as Cat I. If a deeper image is available, more faint sources can be identified for inclusion in the Sky Model, so they can be subtracted as Cat II.

In order to deal with the large image-plane effects, one must resort to patch processing, i.e. splitting up the field-of-view (primary beam) into 1-100 smaller patches. The optimum size of a patch is a compromise between processing power and image quality. An important consideration is the angular distance over which the ionospheric phase changes by a radian, which can vary from day to day. For each patch, a separate 'patch dataset' of visibilities is generated from the same input data, and stored temporarily. The fringe-stopping centre of each patch-set is shifted to the patch centre, and the uv-data are integrated as much as possible in frequency and time. From there on, each patch set is treated independently from the others, and leads to its own residual image. In all processing of patch datasets, their uv-data are first corrected for the best available values of instrumental errors (including ionospheric errors) at the patch centre. This allows 'reasonable' subtraction of Cat II sources, and 'reasonable' imaging of Cat III sources. The self-calibration used for LOFAR is a generalized form of the technique employed to date.

RFI Measurement and Mitigation

For the development of the LOFAR telescope, RFI and EMC studies are essential as the RFI/EMC environments will have a large impact on many LOFAR design aspects. The RFI environment also influences the siting choice of the LOFAR telescope as a whole, and affects the specific locations of the LOFAR telescope stations. In order to optimally manage these issues, the RFI related LOFAR studies were split into several work packages.

A work package was defined for LOFAR RFI mitigation. One of the objectives in this work package is to make an inventory of the computational consequences of applying RFI mitigation algorithms in LOFAR. The goal is to ensure that the LOFAR system is set-up in such a way that future RFI mitigation algorithms can be applied without redesigning parts of LOFAR. Relevant issues here are for example computational cost, and transfer speed and data size of (loop) parameters. Another objective of this work package is to investigate and/or simulate in detail relatively simple beamforming and RFI mitigation algorithms. A third goal of is to perform limited propagation and shielding studies, in order to develop optimal site infrastructure (e.g. fencing). Finally, an analysis is planned (theoretical, simulations, and if possible by measurements) of the effects of the RFI environment on the beams, maps and other data that is produced.

The aim of the LOFAR RFI monitoring work package is to measure the RFI environments (field strengths, time- and frequency occupancy statistics) in situ, and to carry out dedicated field studies on selected objects, such as pulsed fences and high voltage power lines. In the Netherlands, initial monitoring measurements were carried out in Drenthe, using the standard antenna set-up defined by the Site Evaluation committee. The ASTRON mobile monitoring station was deployed on an ad-hoc basis as not all equipment was in place. At the beginning 2002, the mobile station will be finished and regular monitoring measurements will start. In addition to the ASTRON monitoring data, the Inspectie Verkeer en Waterstaat (IVW), division Telecom, provided monitoring data from their monitoring stations (VMN), which supported our RFI studies. ASTRON developed reduction software for these datasets (shared with IVW) for extracting those statistics that are relevant for LOFAR.

In international context, the LOFAR Site Evaluation and Selection activities are aimed at characterising the potential LOFAR sites (Netherlands, West Texas, VLA-New Mexico, and Western Australia) in a uniform manner. Issues which are being addressed include geographical impact on science capabilities (e.g. fraction of total sky accessible), radio conditions (RFI environment, ionospheric conditions), infrastructure, physical characteristics (e.g. soil type, weather conditions), and legal issues. In the course of the year, the committee agreed on a uniform approach and protocols and characterization templates were defined. A start was also made in gathering the required siting data.

Other Radio and Millimeter Projects

ALMA

The Atacama Large Millimetre Array (ALMA) is a 64 station wideband (sub-)millimetre interferometer that will provide astronomers with unprecedented resolution, sensitivity and bandwidth at these frequencies. ALMA was originally planned as a joint European and USA instrument. In April 2001 Japan formally joined the collaboration when a resolution was signed by representatives from Europe, Japan and North America affirming their intent to proceed with construction of ALMA at the Chajnantor site – a high-altitude plain (elevation 5000m) in the Chilean Andes mountains.

The European ALMA Design and Development Phase (Phase I, February 2000 – March 2002) is to lead to joint programme for the construction and operation of ALMA. In order to achieve these goals, a number of prototype design and feasibility studies have been defined, covering all subsystems. This work is being carried out in seven project teams, one of which is the ALMA Back-end Electronics Subsystem team (ALMA-BEE). ASTRON is a participant in this team, which is led by the Obervatoire de Bordeaux. The main objective of the ASTRON involvement in this programme is to carry out feasibility and prototype design studies for an ALMA correlator: the ALMA Future Correlator (ALMA FC). ASTRON's activities are partly sponsored by ESO and NWO-GBE.

In parallel with the European Phase I activities, NRAO is developing a Baseline Correlator for initial ALMA operations. The experience with this development and the results of the ALMA FC study will be used to define the final correlator. The rationale behind this two step approach is that a large facility like ALMA should make optimal use of the rapid developments in digital signal processing technologies. On the one hand there has to be an initial correlator when the first antennas arrive. On the other hand the full correlator capacity can probably be realized more optimally by using newer technology and more scalable designs.

The ALMA FC study follows a two track approach. In the first place the European concept of a Digital Hybrid Correlator (HXF) is being worked out in detail, including prototypes of critical subsystems. Secondly a broad range of correlator architectures are being compared in a generic correlator study. This study aims at a parameterized comparison in terms of cost, power consumption and functionality.

After a short description of the Future Correlator straw man design, subsequent sections will provide a summary of a sub-set of the studies carried out at ASTRON in 2001.

Baseline Design of the Future Correlator

The HXF approach handles the wide input band by splitting it in several sub-bands using Finite Impulse Response filters. Fringe and delay tracking are integrated within the filter section. The sub bands can be handled by correlator sections running at a 150 MHz clock, enabling the use of low-power circuits. The correlator sections offer sufficient on-board general purpose processing power to handle the time-to-frequency FFT and on-line calibration. This could include the compensation for phase fluctuations based on water vapour radiometer data, provided this information is routed to the correlator on-line. The correlator will be four-bit, leading to >10% sensitivity improvement over a two-bit system and will provide at least 256 spectral channels over the base band (2 GHz) in full polarization (which is a factor of four greater than the Baseline Correlator).

Architecture Exploration Based on Generic Blocks

Using techniques also employed in the MASSIVE project, a study was carried out to explore the system design possibilities of a correlator based on generic building blocks that included both routing and processing devices. These blocks represent the elements that make up the correlator. The technique that was used describes the correlator as a network of concurrently executing processes. By approaching the problem at a high level of abstraction and by modelling the large scale structure of the system, it proved possible to both optimize and visualize the resulting design. The model was also extended to include (cost) factors, such as computing power, data rates, power dissipation and technology choices (e.g. the types of digital hardware that can be used).

The end result is a possible implementation for the ALMA FC correlator based on a combination of existing and generic blocks. After the construction of a first correlator model, investigation of the performance numbers and feedback for the next iteration of the model was carried out. This approach allowed both the tuning and optimization as well as the testing of the generic (new) functions. Despite inevitable changes in technology between now and when the future correlator is built, this architecture model can be adapted to accommodate these changes. Moreover, after tests on a small scale prototype, the concept itself can be validated. The approach taken here was designed to allow the model to be upgraded: the generic blocks can be fully reprogrammed and can host future generations of pin-to-pin compatible devices. The same techniques can also be used to explore different architectures.

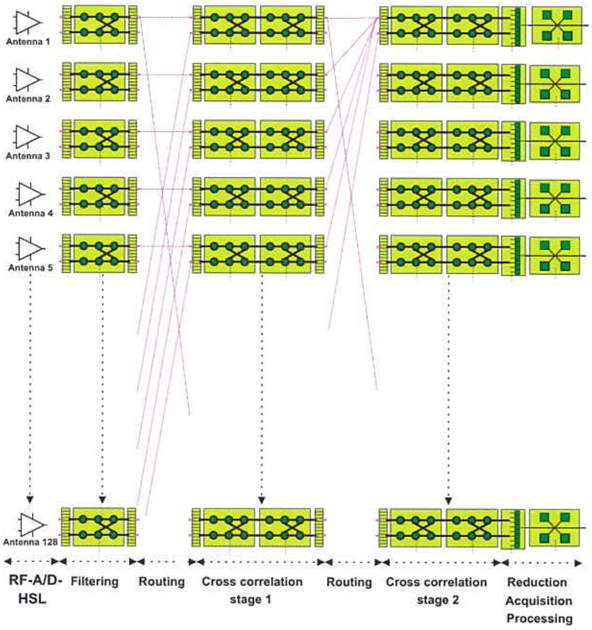


Figure 2.28 A proposed ALMA FC correlator topology using the generic blocks developed in the context of the THEA project. The blocks are combinations of processing elements at board level with interfaces and memories. Various correlation strategies were compared with different platform configurations. Here an HXF architecture composition is presented.

Other benefits of architecture explorations based on generic blocks include the ability to perform fast system comparisons and the possibility of tracing the flow of information and communication throughout the design. The current analysis has shown that future comparisons should pay particular attention to cost drivers. The high flexibility of the generic blocks can reduce the development time and help fast prototyping before final implementation. Even after the production stage has started, changes are possible and further upgrades are facilitated.

ALMA Interconnections and Fast Serial Backplane

The data rates that must be accommodated by the future correlator form a considerable challenge for the realization of a successful design. Cabinet-to-cabinet interfaces run from the filter cabinet to the correlator cabinets. The 32 digital sub-bands of the filter boards have to be distributed to 32 correlator boards. These point-to-point connections can be made with coaxial cables or with optical interconnections. Combining more filter boards in a cabinet will allow the combination of the output of more than one sub-band filter and transmission on a single link to the correlator board. Within the filter and the correlator units the processing boards have to be connected to the input- or output boards. These connections can be made via a backplane. The backplane interconnections are not only point-to-point but can also be multi-drop (i.e. a single signal is distributed to more than one input).

With high speed serial interconnections, the number of interconnections in the ALMA-FC can be reduced. The serial interconnections can run not only between cabinets but also on serial backplanes or even between devices on a Printed Circuit Board. Once a better estimate of the size of the filter- and correlator boards can be made, a better overview of the cabinet-to-cabinet interconnections will also be possible. The available solutions for these interconnections are either single or parallel fibres. If five filter boards can be combined in a single cabinet, each correlator input board will have 52 inputs. Using a serial backplane in the correlator can lead to a reduction in the number of interconnections by more than 75% - a significant reduction in complexity. An initial demonstrator was made to test both multi-drop and point-to-point serial interconnections. Tests show that multi-drop of one driver to two receivers is feasible even for a data rate as high as 3.125 Gbit/s.

Following this first study, further possibilities were examined in more detail and a hardware test setup was built to determine the reliability of the interconnects. These tests revealed that the point-to-point architecture is the most reliable despite the fact that for ALMA a multi-drop architecture is more convenient. Further tests showed that reliable interconnects can be made with a multi-drop topology were the impedance crossings (caused by splits in the signal paths) are matched. In such a topology, bit error rates as low as $1x10^{-13}$ over a 3.0 Gbit/s link (2.4 Gbit/s effective) can be reached. Using two drivers to drive four correlator boards of the ALMA-FC with the multi-drop matched impedance topology requires 96 interconnects of 3.0 Gbit/s each.

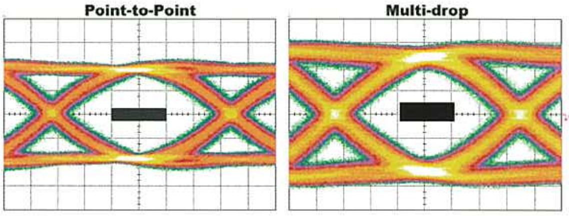


Figure 2.29 The ALMA backplane demonstrator was used to test different kinds of serial interconnections. To measure the difference between the connections Eye-patterns are used. These diagrams reveal the margins of the connections. The black rectangles in the diagrams represent the minimum margins for the receiver (differences in their shape and size reflect different scaling in the two diagrams). Using the test set-up it has been possible to make multiple serial interconnects running at 3.125Gbps. The total throughput of the serial backplane demonstrator is 30 Gbps.

The tests also showed that the quality of the clock is important. The high-speed serial clock (3 GHz) is derived from the data clock. This implies that the absolute stability of the data clock (150 MHz) must be as accurate as the absolute stability of the serial data clock. Proper decoupling is crucial for generating a stable clock.

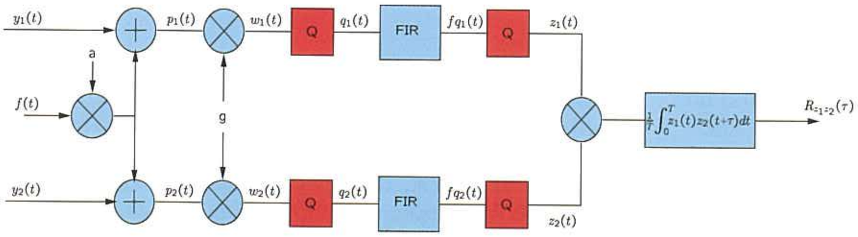
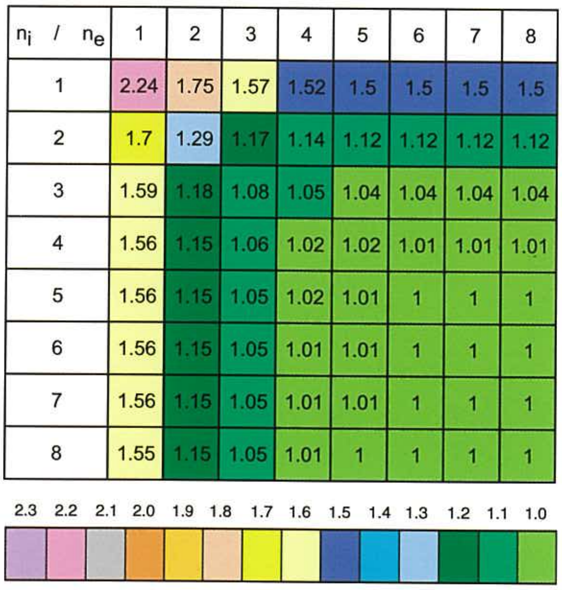


Figure 2.30 Simulation model used to determine the total degradation after correlation of a system including an input quantizer, FIR filter and re-quantizer. As input signal two noise sources $y_1(t)$ and $y_2(t)$ are considered. A common periodic signal f(t) can be added to the noise signals. With a gain factor g the signals are amplified, in order to drive the input quantizers in an optimal way.

Effects of Re-quantization for ALMA-FC

The filters used in the HXF architecture generate additional bits. Since the size of the correlator increases with the square of the number of bits, a bit reduction before correlation is necessary. A study was carried out to determine the amount of degradation of the system when quantization before filtering and re-quantization after filtering is applied.

To first order one can approximate the total degradation factor of a system that consists of a quantizer, filter and a re-quantizer by cascading (essentially multiplying) the degradation factors of the quantizer and of the re-quantizer. Because the input quantizer also adds quantization noise, a scaling must be introduced before the re-quantizer. Furthermore, the scaling of the filtering stage must be incorporated. When doing so, the same optimal levels used in the quantizer are also used in the re-quantizer. This shows that, to first order, the operation of the re-quantizer does not depend on the quantizer. Furthermore a first order estimation was done, representing the quantization noise as an additive noise source. The results of the estimation approximate the simulation.



n_i / n_e	1	2	3	4	5	6	7	8
1	2.24	1.75	1.57	1.52	1.5	1.5	1.5	1.5
2	1.7	1.29	1.17	1.14	1.12	1.12	1.12	1.12
3	1.59	1.18	1.08	1.05	1.04	1.04	1.04	1.04
4	1.56	1.15	1.06	1.02	1.02	1.01	1.01	1.01
5	1.56	1.15	1.05	1.02	1.01	1	1	1
6	1.56	1.15	1.05	1.01	1.01	1	1	1
7	1.56	1.15	1.05	1.01	1.01	1	1	1
8	1.55	1.15	1.05	1.01	1	1	1	1

Table 2.1 Table of the total degradation after correlation of the system depicted in Figure 2.30 . The number of input bits ni increase in the vertical direction, while the number of output bits ne are listed horizontally. The degradation is defined as the Signal to Noise Ratio of a continuous correlator over the Signal to Noise Ratio of the correlator under consideration.

From the results (see Table 2.1) it appears that the best strategy is to use the same number of input bits as re-quantization bits. Just like a single quantizer, the performance increase for a low number of bits is much higher than for a high number of bits. For a single quantizer, the performance increase from 2 to 3 bit is about 10 percent. Going from a 2 bit quantizer and re-quantizer to a 3 bit quantizer and re-quantizer in the simulation model results in a performance increase of 21 percent. And from 3 to 4 bit in a performance increase of a further 7 percent. These numbers can be translated directly to an increase in sensitivity of the telescope.

IVC & DZB

The IF-to-Video Converter (IVC) provides the interface between the WSRT's Multi Frequency Front Ends (MFFE's) and the new digital correlator, the DZB. The most important feature of the IVC will be the increase in instantaneously accessible bandwidth, which will go to 160 MHz.

The installation of the IVC-system hardware at the WSRT was completed at the beginning of January. From then on system tests and technical commissioning started, resulting in the first 12 hour measurement with the 20 MHz bandwidth system at the end of the first quarter. In parallel with the technical commissioning of the 20 MHz system, efforts continued to make the full 160 MHz bandwidth available. For that purpose a number of improvements to individual Local Oscillator and Converter Modules were implemented during the first half of the year. The successful technical commissioning resulted in the official handover and the acceptance of the IVC-system hardware by the Radio Observatory in September. This ended a long period of design and development, followed by the production and installation of the IVC-system hardware.

After September the emphasis was on making available the complete 160 MHz system for astronomical commissioning. This included other DZB hard- and software, as well as TMS software. In December the first 160 MHz observation was done successfully, marking the start of a period of astronomical commissioning, which should lead to full availability of the IVC-system for astronomical observations in the second quarter of 2002.

New Tied Array Mode

The Tied Array Distribution Unit (TADU) provides the interface between on one side the DZB and on the other the VLBI Mark IV recording system and the Pulsar Backend (PUMA). The basic functionality that will be implemented by the Tied Array Mode is the ability of converting the output from the DZB Tied Array Adders into analogue signals and to multiplex multiple analogue base band signals onto the inputs of the Mark IV recorder. The project is to be carried out in two stages. The first stage will result in a bandwidth of 18 MHz for VLBI and 20 MHz for PUMA observations. In the second stage the bandwidth of both modes will be increased to 20 MHz, but more importantly, the flexibility of the system will be enhanced (including for example the ability to freely programme the Local Oscillator signals which are used to mix the base band signals onto the IF channels).

In 2001 the hardware for the first stage was delivered to the WSRT. In November the hardware was used successfully for the first time during a VLBI session. Analysis of the recorded data is scheduled for early 2002. This analysis must prove the capability of the new mode.

For the second stage of the project a feasibility study review was held in July 2001. The feasibility of a video cross point switch (AD8116) had shown that this could be used as a simple solution for the switching matrix. The review concluded that besides the two IF-outputs of the tied array distribution unit, digital outputs were also required for communication with PUMA and other (future) digital systems. Therefore the concept based on the video cross point switch was rejected and a new concept study based on a digital cross point switch matrix was started. The results of this new concept study will be submitted to a feasibility review in 2002.

Optical and Infrared Projects

VISIR

In May 2001 the VISIR project passed an important milestone: delivery of the complete spectrometer subsystem to Service d' Astrophysique (SAp) at Saclay, France. VISIR is the Mid-Infrared Imager/ Spectrometer for the ESO Very Large Telescope that has been developed since 1995 by a French-Dutch consortium consisting of SAp and ASTRON, under ESO contract. SAp is responsible for the imager subsystem, the detectors, electronics, software and all peripheral equipment, ASTRON for the spectrometer. The team at ASTRON is led by a project manager and works in close collaboration with the instrument scientist from the Kapteyn Institute in Groningen. After several years of design, prototyping and manufacturing, the instrument has now entered the phase of final integration and cryogenic tests in the laboratory of SAp. In combination with the 8-meter aperture of the VLT telescopes and the excellent observing conditions on Cerro Paranal VISIR will offer unprecedented observing power in the relatively unexplored mid-infrared wavelength range.

The spectrometer is the most complex subsystem of VISIR. It consists of two spectrometer arms with gratings, collimator/camera optics and several cryogenic mechanisms for various modes of long-slit spectroscopy in the atmospheric windows around ten and twenty microns ('N'- and 'M'-band). Three ranges of spectroscopic resolutions are provided: 'low-resolution' (R=175-350), 'medium-resolution' (R=1600-3200) and 'high-resolution' (R=12000-24000). The imager subsystem has a choice of three magnifications for filtered imaging of fields up to 50x50 arc seconds. In order to achieve sky background-limited performance, the entire instrument is mounted inside a large vacuum cryostat and cooled to an operational temperature of about 20 K by means of three closed-cycle coolers. The imager and spectrometer have independent detector arrays cooled to 7 K (Boeing, 256x256 pixels of 50x50 microns). All optics are reflective and diffraction limited. More details on the design and development of VISIR can be found in previous annual reports.

At the moment of transfer to Saclay, a number of optical elements (some filters and cross-dispersion grisms) still had to be delivered. More importantly though, considerable effort was continuing to make final improvements to the high-resolution collimator-camera optics and echelle grating mechanism. In parallel with work in Dwingeloo many integration and verification activities could be performed on the spectrometer in the SAp laboratory during several expeditions of small ASTRON teams to Saclay. At the year's end the delicate work on the echelle system had been completed successfully. The problem with an offset between the spectra of the two sides of the duo-echelle had been cured. An unacceptably large flexure in the echelle mechanism had also been removed after extensive analysis and manufacture of a re-designed grating suspension. Two mirrors of the high-resolution collimator-camera system (diamond-cut at Philips Research Laboratories in Eindhoven) that had been out-of-spec due to problems with the diamond-cutting machine, had been re-machined and were close to delivery in early January 2002.

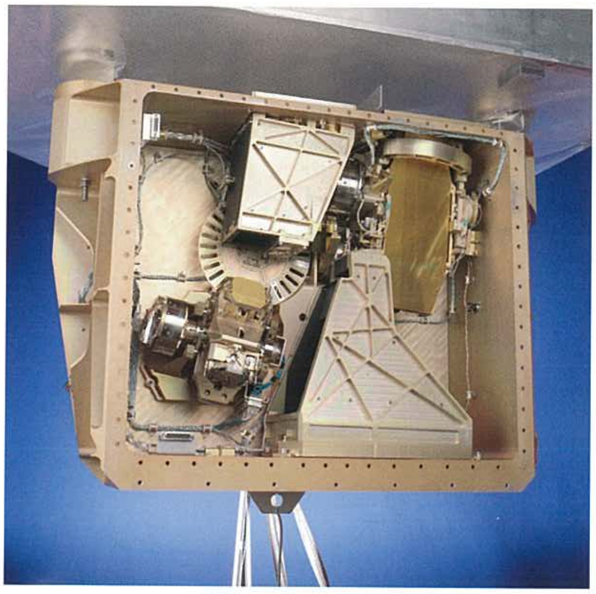


Figure 2.31 The complete VISIR spectrometer, as delivered in May. The huge dual Echelle is at the top right and the low and medium resolution scanners on a carrousel wheel at the bottom left. In the middle the slit wheel is clear to see. Above the slit wheel the low and medium resolution collimator (LMRC), at the bottom right the high resolution collimator (HRC). The filter- and etalon wheels are mounted on the other side and therefore not visible.

Although some final VISIR components still need to be installed, the instrument has already undergone a number of important tests in the final VISIR cryostat in Saclay. The first cooling runs demonstrated that an operational temperature as low as 20 K can indeed be achieved. The switch to Boeing detectors, which was decided after serious and very time-consuming problems with the initially chosen Raytheon arrays, appears to have been the best choice: in December 2001 the new Boeing array for the imager successfully passed its 'first light' tests in the real instrument. The spectrometer detector, delivered by Boeing in December, has by now undergone its laboratory tests and is ready for integration in the spectrometer. If the remaining integration and characterisation work in 2002 continues according to plan, the 'Preliminary Acceptance Europe' milestone could take place just after the summer, followed by the start of commissioning on the VLT in the autumn of 2002.

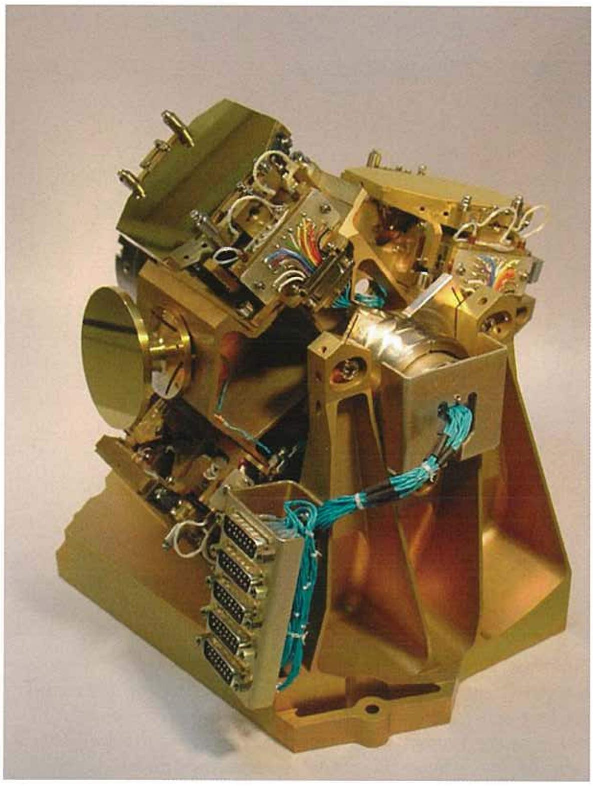


Figure 2.32 The Grating Unit Low and Medium Resolution (GULMR), showing clearly the relation between different disciplines (mechanical, optical and electrical components).

MIDI ESO – VLTI Project

A consortium consisting of the Max Planck Institute for Astronomy, Heidelberg, the Netherlands Research School for Astronomy (NOVA) and the Observatoire de Paris is building MIDI, the MID-infrared Interferometric instrument for the ESO-VLT Interferometer. MIDI combines the light from two VLT telescopes for the N-band (~10μm) with provision made for the Q-band (~20μm).

ASTRON is producing the "cold optics" at the heart of the instrument. The two beams coming from the VLTI delay lines are re-imaged, spatially filtered, combined, dispersed and imaged onto the detector. The rest of the instrument, warm optics, cryostat, cooling system, detector unit and electronics, is produced by MPIA. The instrument control and data analysis software is being developed jointly by MPIA, NEVEC (Leiden) and Observatoire de Paris (Meudon).

The start of the project was when the Conceptual Design Review was passed successfully in December 1998, though MPIA had been working since 1997 on the concept of MIDI. Since then MIDI has successfully passed both the first and second part of its Final Design Review. The third and final part involved the software and was successfully passed 2001.

In 2001, the MIDI cold optics were manufactured and assembled, culminating in the delivery of the cold bench to MPIA, Heidelberg in April. Although the cold bench successfully survived its first cool-down test a month later, several problems have been encountered.

There was a mistake in the optical model, which meant that the beam combiner plate was tilted by 0.8o. In order to correct this, the beam combiner carriage had to be remade. It was also found that access to several subsystems was difficult and so some redesign was done in order to improve this. After corrective actions all components are easily removable.

The main problems were that one of the photometric channels was not hitting the detector and that the 2 science beams were not overlapping correctly. The first was easily solved by re-aligning a mirror, M5. As for the overlap of the 2 beams, this was improved to a figure better than 90% for the 70μm pinholes (the smallest available) by going through the system element by element and performing a full alignment. The last few percent will be gained by some fine adjustments when it is clear that the warm alignment (at room temperature) is maintained after cooling to 40K. This test was done in December and the results should be available at the beginning of 2002.

And so in the autumn of 2001 MIDI recorded its first set of infrared fringes in the laboratory. MIDI is now on track to receive Preliminary Acceptance Europe (PAE) from ESO in September 2002 and go to Paranal for installation in the VLT interferometric laboratory in October 2002, obtaining first light in November 2002.

Science

In 2001, the MIDI guaranteed time observing programme was finalized and submitted to ESO. In total the programme fills 30 interferometric nights with the Unit Telescopes and over 100 using the Auxiliary

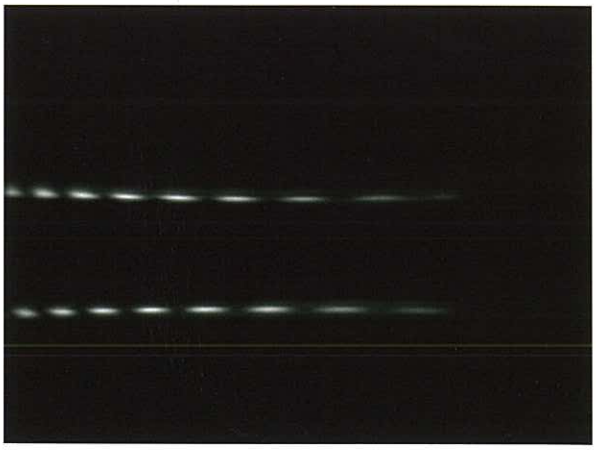


Figure 2.34 Results! An image showing multiple fringes for both MIDI science channels.

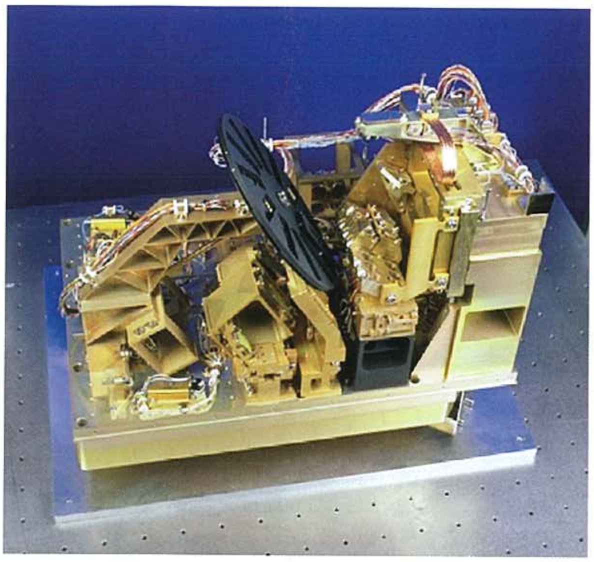


Figure 2.33 The MIDI cold optics fully assembled before transport to MPIA Heidelberg.

Telescopes (AT). The science programme roughly divides into three main themes, focussing on young stars, evolved stars and active galactic nuclei. Most of the evolved star programme will be executed using the AT's. As preparation for the observations, simulations of individual objects as they will be observed with MIDI have been performed, and on the basis of such simulations observing strategies are being defined. Work has also continued on obtaining a list of reliable calibrators. Several observing runs to ESO and to the South African Southern Observatory have been done to collect spectra and photometry of some 500 candidate calibrators. These data will be merged with literature data to construct full Spectral Energy Distributions and will then be used to obtain estimates on the angular size of the calibrators. There are also initiatives to observe these calibrators with existing near-IR interferometers.

10μm Fibre

The Observatoire de Paris, Meudon is developing a 10μm fibre to be used as a spatial input filter in MIDI. Some progress has been made, with an expected delivery date of a useable fibre in the final quarter of 2002. The mounting of such a fibre within MIDI is under investigation but might require a few minor alterations to the spatial filter carriage.

MIRI, the Mid-Infrared Instrument for the NGST

In 2001 the Mid Infrared Steering Committee (MISC) for the Next Generation Space Telescope made final recommendations for MIRI, the mid-infrared NGST instrument. In many respects MIRI will be the space equivalent of ground-based mid-IR instruments such as VISIR and Michelle. Like VISIR, MIRI will provide diffraction-limited imaging and spectroscopy in the 5-28 micron wavelength range. Although the spectroscopic resolution of MIRI is more modest (R=3000), the sensitivity of NGST-MIRI will surpass ground- based performance by orders of magnitude. The launch of NGST, for a 10-year lifetime near the Sun-Earth Lagrangian point L2, is expected in 2009/2010.

MIRI will be developed and funded by a multi-national collaboration with contributions from ESA (cooling system), NASA (detectors, electronics) and a European consortium that builds the actual instrument. As can be expected from the Dutch involvement in the space missions IRAS, ISO, Herschel and the ground-based instruments VISIR and MIDI, interest for NGST-MIRI in the Dutch astronomical community is high. In the summer of 2001 the joint Dutch astronomical institutes, coordinated by NOVA, submitted a proposal to NWO for funding of a significant contribution to MIRI. If this request is granted, a consortium of ASTRON, TNO-TPD and SRON, under supervision of NOVA will develop the spectrometer subsystem of MIRI. The other partners in the European MIRI effort will be the UK, France, Germany, Italy and Sweden, headed by the Astronomy Technology Centre at Edinburgh.

Pending the outcome of the NWO proposal, a small MIRI design team at ASTRON is already working on the MIRI Phase-A study. Although the Phase-A 'kick-off' was only in December 2001, the intense design effort by this group has already resulted in a much improved optical design for the spectrograph.

WYFFOS Long Camera

The WYFFOS long camera is a new camera for the existing spectrometer on the Isaac Newton Group's (ING) William Herschel Telescope (WHT) on La Palma. WYFFOS (Wide Field Fibre Optical Spectrograph) is being upgraded by the ING with more fibres at the entrance. A new camera with longer focal length is therefore required. The project started in June 2001 with a Concept Study on optical design and mechanical layout. This study was concluded in August with a report and further development was granted by the ING. The preliminary design phase which followed forms the basis for a good and stable instrument, therefore much effort was put into Optical tolerance analysis and Mechanical principles and analysis.

The preliminary design phase was completed according to plan with a review in December 2001. The Design was accepted and no changes or additions where required. ING requested an immediate start with the Final Design and asked ASTRON for an offer to complete the project (i.e. including final design, production, testing and integration). Final Design is planned for January to May 2002, followed by Production and integration in June to November 2002. Installation and commissioning is scheduled to take place in December 2002 and January 2003.

Optical Design

The WYFFOS instrument is fed by long fibres from the prime focus of the WHT. The instrument is located on a bench on a Nasmyth focus platform. After the fibres, which act as a slit, the light passes through a filter module, a double path collimator, a reflective grating and a relay mirror. The new camera is located after these optics and consists of (in order of the optical path): a Hartmann shutter, a meniscus lens, a flat mirror, a spherical mirror which images through a square hole in the flat mirror and through a field flattener lens onto an existing detector in a cryostat. The Spherical mirror is a relatively large optical component with a diameter of about 650 mm. This large and heavy mirror requires high position accuracy and is also the most sensitive for temperature change of its position. The optical design of the new camera is based on a pre-study by ING. The design has been improved and tolerance calculations for optical requirements, position accuracy of optics and thermal behaviour have been performed on all components.

Figure 2.35 This 3D view clearly shows the lay-out of the components that make up the spectrograph. The large spherical mirror (65 cm diameter) is at the top-right. The flat mirror and detector are visible in the lower left of the image. The low-thermal-expansion rod between flat- and spherical mirror is also clearly visible in this view.

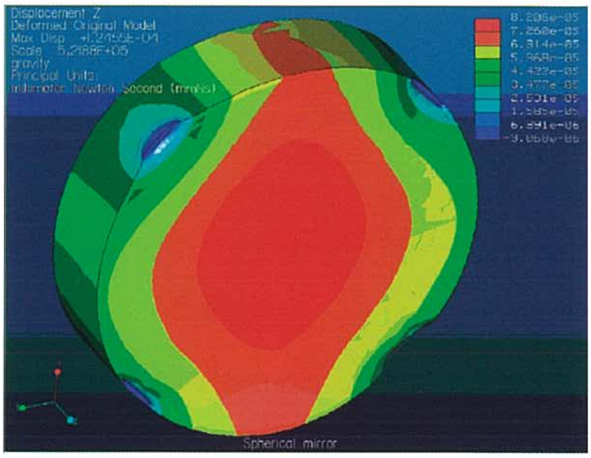


Figure 2.36 This image shows the calculated deformation of the large spherical mirror in the direction of the optical axis.

Mechanical Design

The preliminary mechanical design has concentrated on accurate positioning in respect to stiffness of the mechanical and optical structure and production of parts. For the large spherical mirror, adjustments are certainly needed. The rest of the optics can be positioned accurately enough by good production tolerances. The large spherical mirror can move a little along its optical axis and will have a connection close to the flat mirror with a special low thermal expansion rod to fulfil the thermal requirements. Stiffness and strength analysis has been performed on mechanics and optics. Also in this respect, the large spherical mirror and its structure is the most critical.

Radio Observatory

Introduction

The operational facility of ASTRON, the Westerbork Synthesis Radio Telescope (WSRT), has emerged victoriously from its extensive upgrade process. The year 2001 marks the transition from old-style observing to new-style observing. Already the steady production of high-quality data has resulted in spectacular new results in a number of astronomical research areas.

The new 8 band IF (Intermediate Frequency) system called IVC (Intermediate to Video Conversion) arrived in early January. The first 12-hour 20 MHz bandwidth observations were done in early April and before Christmas the first 160 MHz (8 bands with 20 MHz) observations were done. Astronomical commissioning of the integrated IVC-DZB correlator system has progressed well and the data quality has come up to standards. Although the Technical Laboratory and the Observatory identified a number of potential crosstalk problems in the IVC before delivery, the performance of the IVC-DZB system has been found to be quite satisfactory.

An important factor in this transition is the continuing implementation of the TMS (Telescope Management System), which integrates and controls the various hardware systems and controls the data taking processes. During this year some substantial computer hardware upgrades were made in order to adapt the computer network at the WSRT to highly increased data flows that are possible with the full IVC-DZB system, and to create a telescope control environment that is tamper proof.

The long (and short) term goal of the WSRT staff is to maintain the RRQ of the observing facility, which stands for Robustness, Reliability of the system, and Quality of the data for the astronomy customers. As the operational conditions have changed continually and dramatically, these RRQ aspects in particular are being considered. Hardware system failures are rather infrequent and occur mostly with the oldest hardware components that will be phased out after commissioning of the full IVC-DZB system. On the other hand, the MFEE systems have been working without major failures, such that preventive maintenance can be practiced.

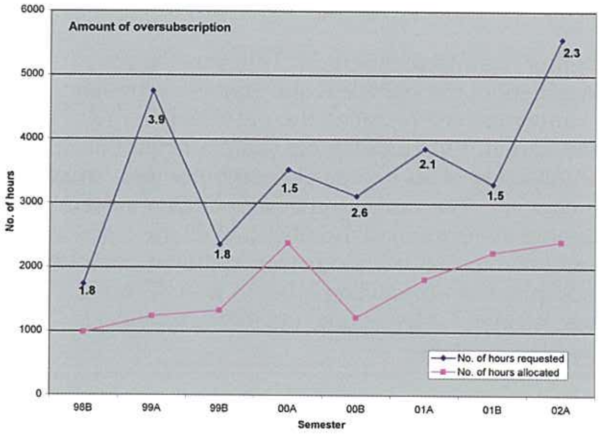


Figure 3.1 The number of allocated hours and requested hours for the Westerbork telescope. The over-subscription rate for the observing semesters have been indicated at each measurement point.

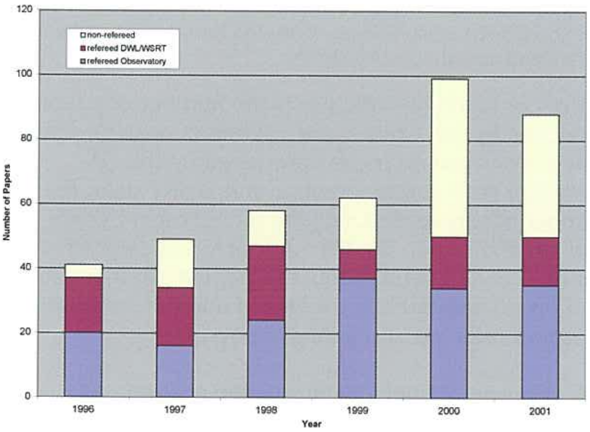


Figure 3.2 The variation of the number of refereed and non-refereed papers produced by the Observatory staff. The papers produced by others using data from the Dwingeloo or Westerbork telescopes have been indicated separately. In addition the total number of refereed plus non-refereed papers is indicated.

In evaluating the performance of the Observatory, a number of performance indicators may be used. Firstly, the time efficiency of production observations has been quite high during the periods of upgrading – for astronomical observations it has been as high as 70% to 80%. Careful scheduling by the WSRT Scheduler of system test time and the use of short filler programmes has made it possible to use the available time more efficiently for astronomical observations than in the times before the Upgrade. During the year 2001 the commissioning and implementation of the IVC and DZB hardware resulted in a 63% average over the year.

During recent years the WSRT Programme Committee has taken into account the anticipated availability of the instrument for each proposal period by changing the number of allocated hours. The number of allocated hours and the number of requested hours for the WSRT have been displayed in Figure 3.1 and the associated over-subscription rate has been given. This number has varied between 1.5 and 3.9 during the various stages of the upgrade with a mean on the order of 2.2 over the whole period.

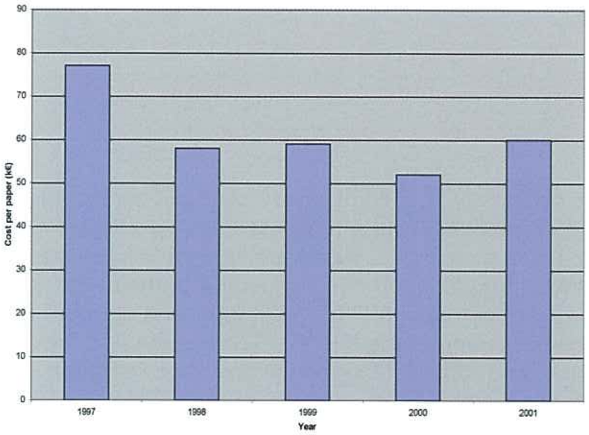


Figure 3.3 The variation of the cost per paper in kilo€. This diagram has been based on the number of refereed papers and the Observatory budget corrected for the cost of service-related activities in ASTRON.

A third operational indicator is the number of papers produced by the Observatory. When considering the number of refereed papers produced by the Observatory staff and by others using WSRT data, the number has increased steadily during recent years and has more than doubled in four years as given in Figure 3.2. The total number of papers produced in 2001 is 88 with 50 being refereed and the remainder being un-refereed and conference papers.

A fourth operational indicator is the cost per refereed paper. This number for recent years has been depicted in Figure 3.3. The cost per paper for the Observatory is typically 56 k€ during the last two years. This compares well with the other comparable radio astronomy observatories in the world, which have costs per paper that are at least a factor of two higher.

At the end of 2001, it is possible to start putting the worries of the WSRT upgrade behind us and to start concentrating further on dealing with the WSRT user base. User satisfaction is an important aspect in maintaining the user base for the Observatory. For instance, in order to improve transportability, all the export of WSRT can be done on CD or tape in a number of formats; also the raw databases from recent years have been converted to CD format.

WSRT Activities

Telescope Management System

In 2001 major steps in the ongoing development and deployment of the telescope management system (TMS) were made. By the end of the year an observation was performed with all the hardware of the complete new backend which was present at the WSRT. After the commissioning of the first 20 MHz of this system, a new TMS version was released (TMS4). In the second half of the year all efforts focussed on the integration of the rest of the system and carry out an observation with the full 160 MHz system (DZBnominal).

The IVC was delivered on January 8th and placed in the basement of the WSRT control building. First step in the integration was the realization of a one-band system, with a maximum bandwidth of 20 MHz. The target date of April 1st was missed by only 4 days: the first 12-hours 20 MHz observations were done on April 4th. Subsequent tests revealed a number of problems with the new system, most importantly crashes of the data acquisition programme. It took the TMS team a long time to finally find a solution. Although the commissioning of the 20 MHz system was delayed by a couple of months, it also meant that lots of small bugs (mainly memory leaks) were found and repaired. After the commissioning the old 10MHz system (DLB IF combined with the DZB backend) was removed.

Once part of the IVC was used in routine observations and the hardware problems in the rest of the IVC (RFI related problems) were under control, a new target was set: to carry out a 160 MHz observation before the end of the year. In order to do this, all the hardware in the backend had to be controlled by TMS (i.e. the complete IVC, 8 Analogue to Digital Converter units, the Data Distributor Unit and 4 CORrelator units) and the entire data path had to be processed. On Thursday December 20th a 17 minute 160 MHz observation was successfully performed. Not the full 12-hours as had been hoped, but nevertheless a success. The remaining problem was an unstable IVC-process (a software programme running on a VME board in the IVC). The steps to be taken before a stable 160 MHz production system is achieved are:

- Stable software that can handle a continuous data flow
- Software to setup the array (phase-zeroing, attenuator settings etc.)
- Phase switching capability (at least 180 degrees phase shifting in IVC – COR)

This production system is scheduled to be completed by the end of the first quarter in 2002.

Another big improvement for TMS was the replacement of the old telescope control computer. A Linux machine replaced the old HP9000-712 workstation. Although the old system never failed, the reliability of an 8-year-old computer was cause for concern. The move to a new operating system required checking and modifying of all the software. In addition to the new Linux workstation a complete backup system (including a board with 32 serial lines, needed for telescope and MFFE control) is now also available.

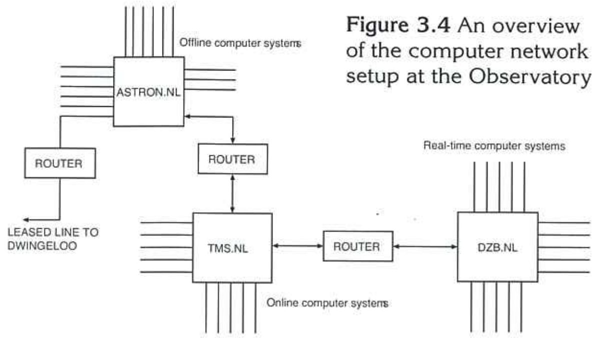


Figure 3.4 An overview of the computer network setup at the Observatory

Computer Systems & Network

In 2001 the network of the WSRT was completely reorganized. The original star-network of all computer systems gave problems for the observations. With use of the new backend in sight, it was decided to divide the network in three parts.

The first part is the real-time network (dzb.nl). This net connects all the hardware needed for controlling the data path. The data acquisition computer was also placed in this network. The second net is the online network (tms.nl) which contains all the remaining computer equipment necessary for doing observations with the WSRT, e.g. the telescope control computer, the central TMS workstation, the data archiving machines etc. The third net is the central astron.nl net in which all desktop computers and offline data processing workstations are connected. This net is also connected via a 2 Mbit/s line to Dwingeloo. This online-offline separation has had a great impact on operations. Even with the complete 160 MHz systems, network problems no longer occur. Figure 3.4 presents an overview is given of the new network setup.

One of the central parts of the network is the central fibre switch, the CoreBuilder5000. The supplier, 3COM, stopped supporting this machine and upgrades were no longer possible. A decision was taken to purchase a new central fibre switch, which is to replace all the current switches and routers. A Nortel Passport 8600 switch was chosen, which will be installed in the first quarter of 2002.

Multi Frequency Front Ends (MFFE)

The WSRT has 16 front-ends for 14 telescopes, with 2 spares. This fact, plus the proven high reliability of the front-ends, has been instrumental in achieving a very high array uptime. During the year all telescopes had working front-ends installed for 96% of the time. In fact the times that a telescope was without a front-end was not caused by a shortage of operational front-ends but by the occasional lengthy repairs of the cryogenic telescope infrastructure.

Naturally there have been a number of problems with the front-ends that made exchanges necessary. In the course of the year 23 front-end changes took place in order to carry out repairs. In 4 cases there was a problem with the local oscillator system requiring rather expensive repairs. Low noise amplifiers or their power supply units were to blame in 8 cases. Only two cryogenic failures in the MFFE's were encountered. The only changes that were made to the system during 2001 were measures to suppress harmonics generated inside the LO-system that were leaking into the L-band.

RFI and RFI Mitigation

Local RFI Studies

Cage Experiment

The Westerbork Radio Observatory increasingly has to deal with a variety of electromagnetic interfering sources. The most serious interferers are from the nearby surroundings, such as the broadcast signals coming from the TV tower in Smilde in the UHF-high band and the GSM traffic in the 900 MHz and 1800 MHz frequency bands. However, the equipment in the main building also contributes to the overall RFI situation. RFI originates in the internal digital circuitry and escapes through open apertures of the casing. In order to investigate the possibility to construct a high frequency cabin around the entire control building, an experiment was conducted using a radio source inside a wire-mesh cage and measuring the signal level at some distance from the cage. The effectiveness of the shield naturally depends strongly on the frequency of the RFI and several experiments were done with different types of cages (using different wire-mesh material), in different configurations (number of open sides of the cage), and by using different types of ground (cement and buried into the sand). Although a wire-mesh makes an excellent mirror for radio waves, the experiments show that it is not quite suitable as an RFI shield when more than 20 dB of attenuation is required.

Foil Experiment

Later in the year, heat-reflecting foil was applied to all the windows facing the telescope array and two other sides (the north, west and east sides of the building). This material is normally used for UV shielding (99% efficiency) but it also may serve as a radio screen. In addition, aluminium plates were added to the non-transparent parts of the windows frames. The front ends in the telescopes were used to measure the attenuation of the RF signals coming from the main building. Although there was hope that this would show a noticeable difference, there was only some improvement in the 92 cm band and an almost undetectable difference in the higher frequency bands. Most of the radiation originating from the control building is still leaking trough the walls and the roof to the outside world. The best approach still appears to be to combat the RFI at the local level by reducing the radiation at the source.

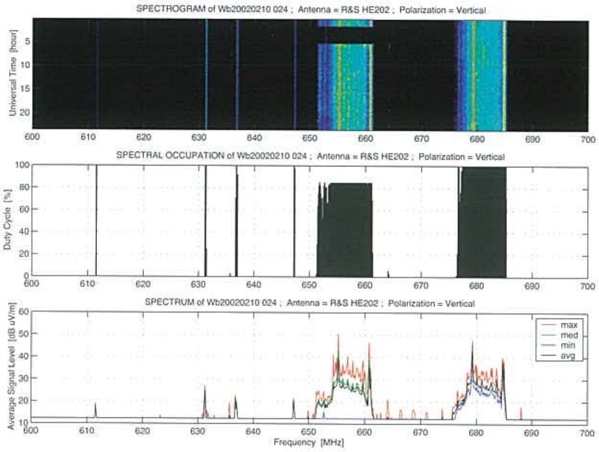


Figure 3.5 An example of a 24 hour spectrogram in the frequency range from 600-700 MHz. The highest signal levels come from the television stations broadcast by the nearby TV tower in Smilde (Nederland 3 at 655-660 MHz and Nederland 2 at 680-685 MHz). This spectrogram reveals that one of the TV stations (Nederland 3) is turned off a couple of hours during the night.

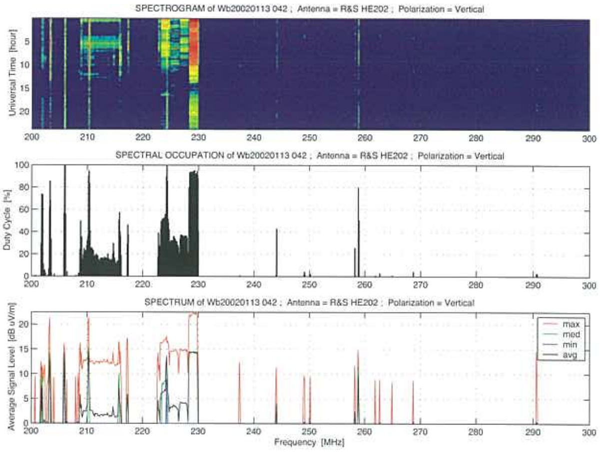


Figure 3.6 Digital broadband signals (in this case an experimental broadcast of digital radio at 224-230 MHz) are seen more frequently recently, occupying a rather large bandwidth in the electromagnetic spectrum with respect to the FM radio band.

RFI Analysis

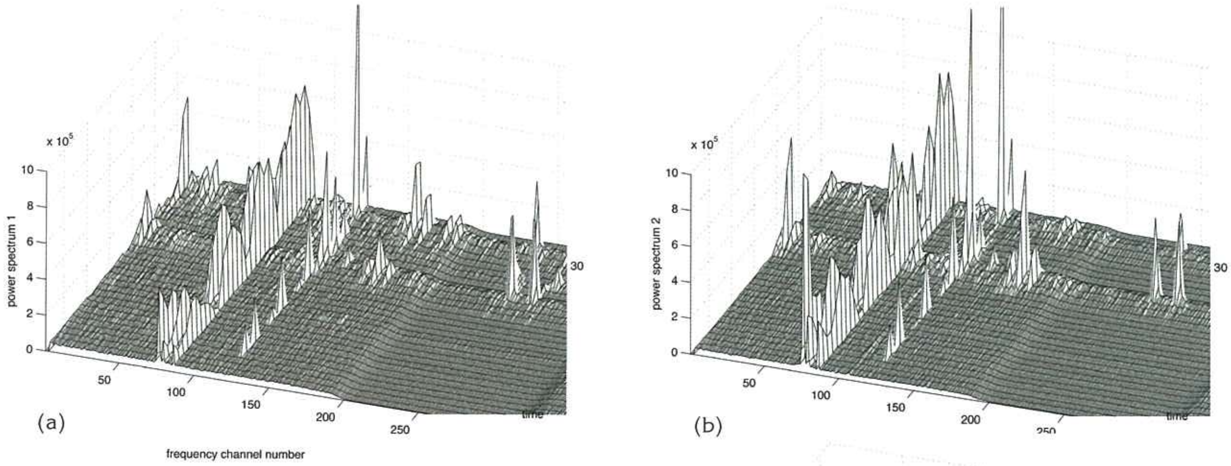
Software (RadioCom) has been purchased together with an extra receiver (AR5000 from AOR) to make the identification and analysis of some radio signals easier. It is an advanced graphical software package that decodes analogue and digital signals from the audio output of many different types of receivers going into the line input of a soundcard for any standard multimedia PC. The software includes a filter analyzer, time spectroscopy and a lot of decoding schemes like RTTY, CW, FAX and SSTV. This package also allows easy display of high-resolution satellite images (e.g. weather maps from Meteosat). This could also serve as a demonstration object for interested people on the next open day at the observatory.

RFI Monitoring

Considerable effort has been made to get the fixed WSRT monitor station running to produce local spectrum measurements over a broad bandwidth. Although most of the system hardware components were already available, these still had to be linked together and new software had to be written. Two receive antennas are mounted in a 10 meter high mast on top of the construction hall about 35 meters above ground level. This gives a free line-of-sight to the horizon just above the tallest tree tops. An active dipole (HE202 from Rohde &Schwarz) antenna covers the lower part of the spectrum (from 200 MHz to 1 GHz), whereas a dual polarized omni directional antenna (HF902 from R&S) is sensitive to the upper part of the spectrum (from 1 GHz to 3 GHz). The antenna coax cables are connected through a switch box to a relatively inexpensive commercial broadband receiver (AR5000; located in a metal measurement compartment just below the roof) with a scanning range from 5 kHz up to 2.6 GHz. This receiver is controlled via a fibre link by a (lightning protected) acquisition computer located on the ground floor. This computer is connected via one of the spare radio telescope IF cables to the main WSRT computer network. A daily measurement schedule is executed and the resulting data scans are sent back to a host computer in the main building for further processing. Spectrograms, spectrum occupancy diagrams, and CRAF RFI reports are produced automatically.

RFI Mitigation

The development of the pre-correlation real-time RFI mitigation techniques – algorithms and DSP implementation – continued in 2001. The PCI bus board with nine Texas Instruments DSP's TMS320C6201 (Signatec, USA) was used as the computing platform. A number of different algorithms were tested using WSRT-data: time-frequency analysis and RFI excision, RFI mitigation with adaptive noise cancellation (ANC) techniques, and higher-order statistics methods. Figures 3.7a, b, and c illustrate the results of using the ANC procedure with WSRT data at 428 MHz. Figure 3.7a and b show the power spectra at the outputs of the main and the reference channels. Figure 3.7c shows the cleaned power spectrum of the main channel. The positive results obtained with the Signatec equipment were encouraging enough to begin the design of a dedicated pre-correlation RFI mitigation sub-system based on digital signal processing with FPGA processing components.
In this sub-system the base band signals after the IF-to-video converter (IVC) will be digitized, processed with the FPGA, and then transformed back to analogue form. These cleaned signals will then be fed into the DZB correlator.



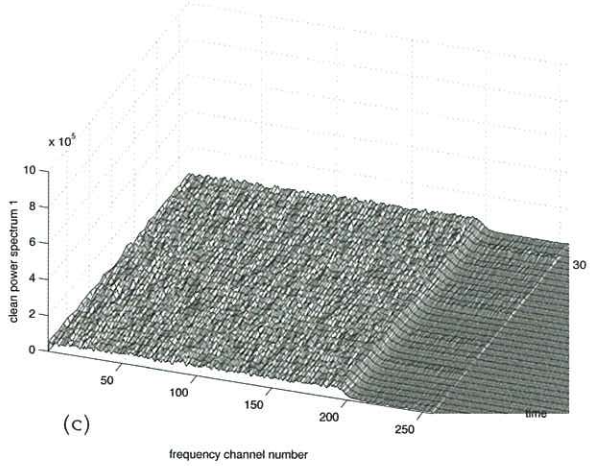


Figure 3.7 The time evolution of the power spectrum of the main channel of Radio Telescope 1 (RT1) is given in frame (a) and of the reference channel of RT2 in frame (b). This data is used to obtain effective adaptive noise cancellation using a reference channel. In frame (c) the time evolution of the "clean" power spectrum is given for the main channel RT1 after applying the adaptive noise cancellation.

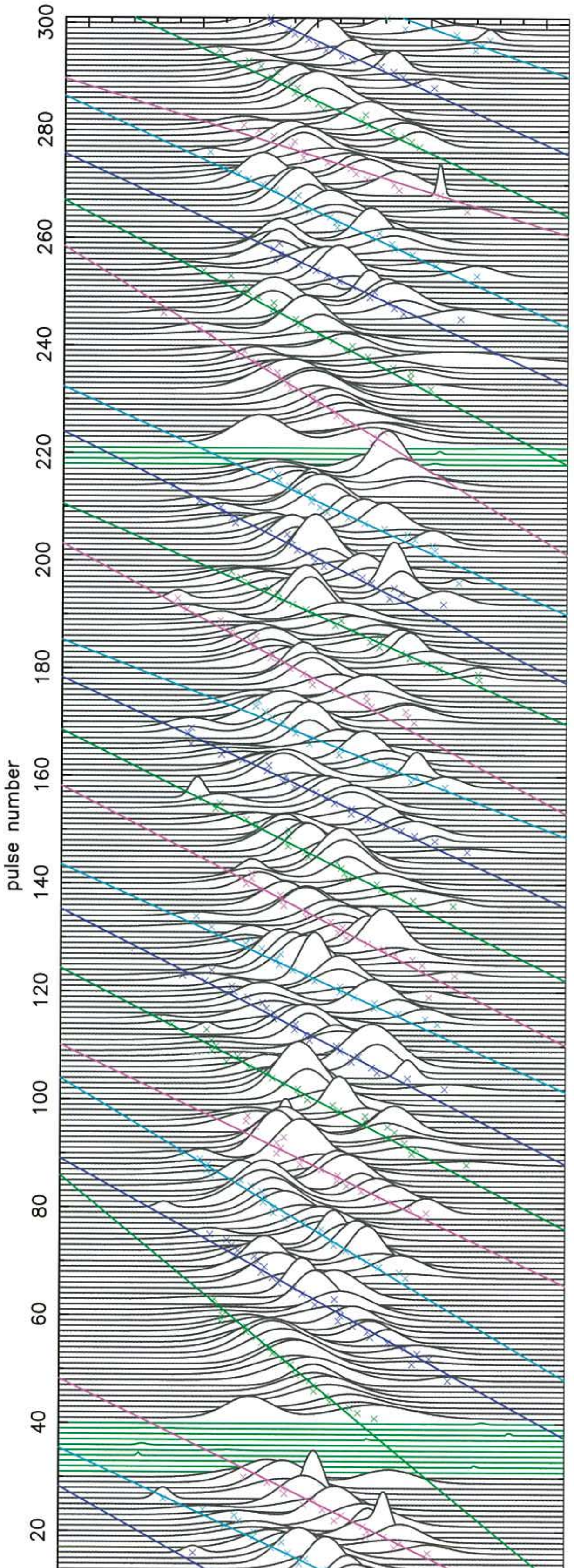
The RFI Robust Receiver Project

The RFI-robust receiver project is the working title of an EC-sponsored project 'Interference suppression in radio astronomy receivers', a sub-project of the TMR-LSF RTD project 'Enhancing the European VLBI network of Radio Telescopes', which started in 1998 and was successfully completed in October 2001. The goal of the project was to provide the European astronomical community with a set of measures that will lead to radio astronomical receivers able to operate in the presence of strong radio frequency interference (RFI) signals. The successful application of these measures has been demonstrated during the course of the project.

The project consisted of two major activities, investigation of design aspects of RFI-robust receivers for radio astronomy and RFI-monitoring. The participants in the project were ASTRON as project coordinator, Max Planck Institut für Radioastronomie (MPIfR) in Bonn (Germany), Jodrell Bank Observatory (JBO, UK) and Istituto di Radioastronomia (IRA-CNR, Bologna Italy). The research on RFI-robust receiver design aspects was mainly carried out at ASTRON. Monitoring activities involved collaboration among the four participants to set up and operate monitoring facilities for RFI-signals, partly based on funding by the European Commission through this project.

At the First International Workshop on RFI in Dwingeloo in 1998 specifications for the monitoring systems were established and preliminary work on design aspects of RFI-robust receivers began. Preliminary monitoring results were discussed at a subsequent Workshop in Medicina, Italy in 1999 and were used as information for the RFI-robust receiver design. This part of the project has been very successful in establishing monitoring systems and facilities between 50 MHz and 2 GHz with EC-funds, as well as coordination of activities in this field on a European scale. An important spin-off has been the definition and acceptance of a data format for storage and exchange of monitoring information on RFI-sources.

The study on RFI-robust receiver design aspects resulted in the application of low loss filters in the UHF-receivers of all MFFE's. Knowledge, emerging from a study on RF/IF-architecture, has been applied in the design of the IVC-system, as well as in THEA. The second part of the programme on RFI design aspects was essentially a research effort, mainly during the last year of the project, devoted to a study on one specific active RFI-suppression technique, the Feed Forward System (FFS). This resulted in the demonstration of a laboratory prototype system, from which conclusions have been drawn for application and further research.



PuMa

PuMa has come of age in 2001 as can be seen by the large and varied number of projects for which it has been used. These include high precision pulsar timing, single pulsar studies of a number of bright pulsars and high resolution polarimetry of millisecond pulsars. This latter project and any future accurate polarisation projects have become possible through the careful calibration and measurement of the polarisation purity of the complete signal path to PuMa that has been carried out this year. As well as being used to carry out traditional pulsar work PuMa has also been used as a spectrometer to measure the HI distances to a number of pulsars with superior sensitivity and frequency resolution compared with previous observations. Such observations highlight the versatility of PuMa. This year there have also been a couple of hardware improvements made to PuMa. The taping speed and capacity were enhanced now that regular use is made of the Linux taping machine and the 420 GByte tape jukebox. This improvement has enhanced both the observing capabilities (as more high resolution data can be obtained in one observing session) but has also increased observing efficiency, as there is now less downtime between observing sessions.

VLBI Operations

Westerbork has continued to operate routinely as a tied-array, and contribute to European and Global VLBI observing networks.

The MkIV formatter was upgraded with new PROM's to cope with barrel-roll, and so improve the compatibility with VLBA recording systems. This also improved the communication with the 'Field System' control computer. The old MkIII decoder was replaced with a MkIV decoder, which can cope with all MkIV recording modes, as well as giving more reliable local playback. The apex phase calibration system was upgraded as part of a student practical project, and the Field System software modified to make use of more control options. This is now a useful tool for testing and debugging the whole VLBI system.

Figure 3.8 One hundred smoothed single pulses from a series of several thousand obtained from the bright pulsar B0809+74 using WSRT and PuMa at 382 MHz. This pulsar shows the phenomenon of drifting sub-pulses, indicated by the crosses and joining lines, which drift through the pulse window (±10 degrees). Furthermore it is also known to null, that is the pulsar turns off completely for a number of pulses (indicated by the green region). The high quality data has been used to determine the most accurate ever distribution of null lengths and also to probe the nature of the large change in drift slope seen after a null (green crosses and line). An improved understanding of these phenomena links directly to a better understanding of the pulsar emission process.

Several 0.5Gbit/s test recordings were organized, using both recording heads, which were played back and correlated at JIVE. These proved successful, and it is expected that this will become a normal user mode when the thin tape supply allows. Local tests were made of the first section of the new tied-array adder (TADUmin) and observations were scheduled for the start of 2002.

The geodetic observations made in November 2000 were reduced by a colleague at the Observatoire de Bordeaux and gave a position error of 2cm of the standard single dish telescope (RT7).

Operations

WSRT production observations typically ran more smoothly in the year 2001 than in the previous couple of years. The time lost due to mishaps now averages 10%, and a further improvement should take place once the instabilities in the newest hardware and software under commissioning have been removed. Assorted front- and back-end hardware problems and software hitches in real-time as well as off-line (inspection, archive, export) software required substantial but not excessive detection and diagnosis efforts by the operations and systems groups: most problems were found and fixed within hours to a few days. The schemes of having ASTRON astronomers participate as "friend-of-the-project" as well as "inspector-of-the-week" worked very advantageously; they will be continued in 2002 at least as long as the commissioning of major equipment and software lasts.

Two personnel changes occurred in the operations group in 2001. The position of "data archivist" was removed from the formation as of Feb 28; the associated duties have been transferred to the operators. After an adjustment period, a routine procedure is now in place aimed at exporting data to the end users within two weeks of having been observed. At the end of the year, the "friend-of-VLBI" was permanently stationed at the WSRT as a member of the operations group, charged also with facilitating all aspects of operational robustness, and taking care of day-to-day scheduling matters.

Installation and commissioning activities picked up as the year progressed; in a flexible response, the production crew continued to give top priority to the needs of the development teams. Thus the fraction of net time in successful production went down from 75% in Q1 to 55% in Q4; the annual average was 63% – a trend which should be reversed once the nominal DZB/IVC system is fully commissioned. The production team foresaw these events, and ensured that an appropriate amount of time was accepted from the proposals, with proper account taken of working-day versus production-night disparities. Therefore, backlog queues are a thing of the past now: the Semester 2001A and 2001B allocations were completed on-target (i.e. within 6 months of having been accepted) except for projects intimately connected with the ongoing IVC-160 commissioning.

The single most heavily demanded mode of operation continues to be DZB local synthesis line imaging. This is most often at 21cm, but all bands were in regular use, except 49cm, where the RFI circumstances are very hostile. New capabilities are being put to excellent use as soon as they become available. A good example is one of the largest single programmes to run in 2001: mosaiced imaging of very faint HI to study gas and dark matter in the outskirts of M31, for which fully half of the complete DZB correlator capacity was brought to bear on a single IVC band, thus providing 512 spectral channels.

Some other large programmes still made good use of the DCB for continuum work: monitoring of the extreme intra-day variable source J1819+3845, rapid follow-up and long-term monitoring of GRB error boxes, and a very deep 21cm image of the Bootes field. The effort needed to monitor and fix small hardware problems for all of the DCB channels is slowly increasing. This means that, until TADU is operational, significant, regular attention will be needed for the DCB, even after local synthesis continuum work has switched to the DZB.

The pulsar machine, PuMa, fed with a Tied Array signal through the DCB and Wideband Adding System (WADDS) was in frequent, routine use throughout 2001; the high precision timing programme was a large user of time, and there was also a multitude of PuMa projects aimed at specific targets. The Tied Array was also used for VLBI during 3 sessions of 3 weeks each.

The Telescopes

The Westerbork telescope has continued to operate reliably during 2001. The mechanical upgrade work of recent years has given the WSRT a new lease of life. Besides the regular maintenance, some further preventive maintenance was done. As an exploratory project to investigate the standing wave behaviour at L-band, an additional 2,5 meter reflector was installed in the apex under 10 degrees angle between front-end box and the reflector of two telescopes. The first indications suggest that these reflectors further help to reduce standing waves.

Spectrum Management

WSRT, LOFAR, Global Activities

In the area of national policy making there are regular consultations with the various departments in Groningen and The Hague of the Ministry of Transport, Public Works & Water Management (V&W) and over the years an excellent working relationship has been built up. There is a national forum for determining the national and European position on agenda items of the International Telecommunication Union (ITU) World Radio communication Conference in 2003. Both the CRAF Frequency Manager (see below) and the Observatory's director are active participants in these proceedings. In addition, a new group has been set to advise the Minister on spectrum policy issues and ASTRON represents the passive spectrum users in this forum.

During this year three meetings were held of Task Group 1-7 of the ITU-R (Radio communication sector of the International Telecommunication Union). TG1-7 is preparing regulatory proposals on Unwanted Emissions and on the protection of radio astronomy bands from interference from satellites for the next ITU World Radio communication Conference in 2003. Two meetings were held in Geneva at the ITU headquarters and one in July in Maastricht. The Radio communication Agency of the Ministry of V&W was the host of this Maastricht meeting and together with the RDR and NewSkies Satellites, ASTRON hosted the meeting during a dinner-boat ride on the River Maas. On behalf of the Dutch Administration, the Observatory's director chaired these meetings together with a representative from Intelsat Corporation (Washington, D.C.). In addition, Observatory staff members participate in the proceedings of Project Team (Spectrum Engineering) SE-21 that is responsible for the European input to TG 1-7.

The Observatory and the Technical Laboratory contributed significantly to an RFI Mitigation Workshop organized by IUCAF at the Max Planck Institut für Radioastronomie in May in Bonn. The Observatory presented recent work on DSP processing applications of RFI mitigation in astronomical data at Westerbork.

In the context of LOFAR Site Evaluation and Site Selection several activities have been started in order to evaluate the electro-magnetic environment at Westerbork and in the province of Drenthe. In particular, the WSRT staff has taken the responsibility of the RFI Monitoring Work Package. A permanent monitoring station is now operational at the Observatory with two major tasks: systematic monitoring of the environment, and monitoring of spectral regions that are used for actual observations as controlled from the control room. In addition, a mobile station is being assembled together with the LOFAR team in order to do identify sources of RFI and to do remote monitoring. Well established contact within the Spectrum Monitoring and Inspection division of the Ministry of V&W have led to a valuable collaboration and an effective exchange of information on the RFI environment in The Netherlands

CRAF

The Committee on Radio Astronomy Frequencies (CRAF), as an Expert Committee of the European Science Foundation (ESF), is an integral part of the ESF. It acts as the scientific expert committee for the ESF on frequency issues for European radio astronomy and related sciences. The mission of CRAF is

a) to keep the frequency bands used for radio astronomical observations free from interference,
b) to argue the scientific needs of radio astronomy for continued access to and availability of the radio spectrum for radio astronomy within the European arena, and
c) to support related science communities in their needs of interference-free radio frequency bands for passive use.

CRAF works as member of the Radio communication Sector of the International Telecommunication Union (ITU) and has also the formal observer status within the Conference of European Post and Telecommunication administrations (CEPT). As a result, CRAF can function effectively within the European and international spectrum scene in serving the interests of the European radio astronomy community. The Committee Members are drawn from reputed experts active in all fields of radio astronomy and related sciences on the basis of scientific or technical expertise and recognition within the community, so as to ensure the authority and credibility of the Committee. A credible representation of the European radio astronomy observatories and a geographical balance of the Committee's membership needs to be ensured. CRAF employs a frequency manager, who coordinates the day-to-day work of CRAF and is the liaison between CRAF and European Administrations. The CRAF clearing house and secretariat, which are both run by the CRAF frequency manager, are hosted by ASTRON.

Because the range of issues for protecting radio astronomy observations is widening steadily, the number of meetings where attendance is required is also increasing. In 2001 the CRAF frequency manager participated in 39 meetings in places ranging from the Netherlands, Europe and the United States. He participates in the CEPT Working Group for Frequency Management (WG FM) which is the leading European policy group for frequency management issues and in various CEPT project teams which address various issues ranging from preparations for the ITU-R World Radio communication Conference 2003, Mobile-Satellite and Fixed-Satellite systems (e.g. Iridium, GLOBALSTAR, Teledesic), Ultra-Wide

Band technology, Short Range Radar, power line communications, to various coordination issues.

During the year, the activities of the CRAF frequency manager were funded for 30% by ASTRON. Observatories participating in CRAF or national research councils of countries that have radio astronomy stations participating in CRAF have contributed the rest of the operational costs for this activity.

The development of the new generation of radio telescopes currently requires special attention at frequencies below a few GHz. CRAF sees radio astronomy access to these frequencies as one of its urgent issues of attention.

Institute Science

Ultra-Compact Radio Sources and Interstellar Scintillation

Radio monitoring of the quasar J1819+3845 continued throughout the year with on average one observation every month. This ultra-compact quasar shows dramatic variations in its 6 cm flux density. The average flux density is about 200 mJy but values as low as 60 and as high as 500 mJy are often observed. These variations are not intrinsic to the source but are caused by propagation effects: interstellar scintillation, induced by density turbulence in a plasma only about 20 pc from the Sun.

On January 7 and 12, 2001, J1819+3845 was observed simultaneously with the VLA and the WSRT. The purpose of these experiments was to measure a time delay in the variations which would prove beyond a doubt that the variations are due to interstellar scintillation. The VLA and WSRT have the same distance from J1819+3845 (to within 6000 km) hence if the brightness variations were intrinsic to the quasar they should be arriving at the two telescopes with a time delay of at most 20 milliseconds. In fact, the intensity curves reveal delays of up to 100 seconds in a very systematic way (see Figure 4.1) fully consistent with scintillation. The observed time delay could also be used to determine a very accurate transverse velocity of 35 km/sec for the plasma screen responsible for the scintillation. The result was published in Nature on the January 3rd 2002.

A second comprehensive study, describing the systematic seasonal variations in the timescale of the modulations over a period of more than 2 years, was nearing completion at the end of the year. Using the precise value for the screen velocity from the time delay experiment, evidence was obtained for a very strong anisotropy in either the source structure (a core-jet?) and/or the screen turbulence.

J1819+3845 maintained its high level of modulations throughout the year. The (normalized) modulation index peaks at 6cm at a value of about 40%. To broaden the frequency coverage of the phenomenon, into the weak scattering (shorter wavelength) and strong scattering (longer wavelengths) regimes most observations in 2001 were done in a split-array mode with 5,4 and 5 telescopes tuned to 13 cm, 6 cm and 3.6 cm respectively.

Once averaged over a sufficiently large number of modulations J1819+3845 was found to increase slowly in brightness. This long-term variation must be due to changes intrinsic to the source. The extremely high brightness temperature (> a few 10^{12} K) and the lack of source expansion remain puzzling.

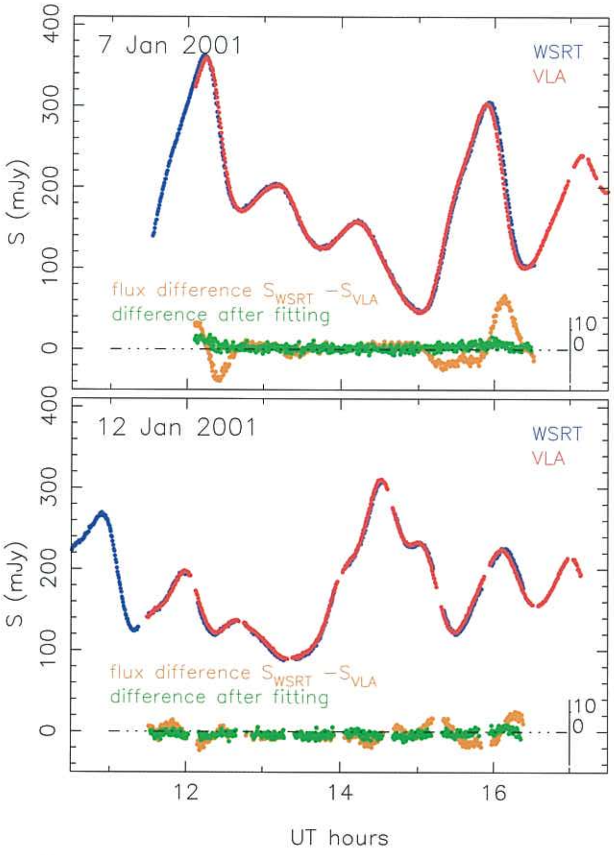


Figure 4.1 Results of VLA and WSRT 6 cm observations of the scintillating quasar J1819+3845 on 7 and 12 January 2001. Note how well the light curves agree. However, there is a small but very significant time delay of about 100 seconds at the start of the observations with the WSRT 'leading' the VLA. The time delay has changed sign at the end of the observation. These observations provide unambiguous proof that scintillation is the cause of the rapid variations. The change in the sense of the delay is due to the rotation of the earth as it moves through the scintillation pattern and has allowed an accurate determination of the transverse velocity of the plasma screen responsible for the scintillation.

The WSRT data on J819+3845 continue to explore new territories in the field of interstellar scintillation phenomena. The results are being interpreted in collaboration with scintillation specialists at the Kapteyn Institute in Groningen and the University of San Diego.

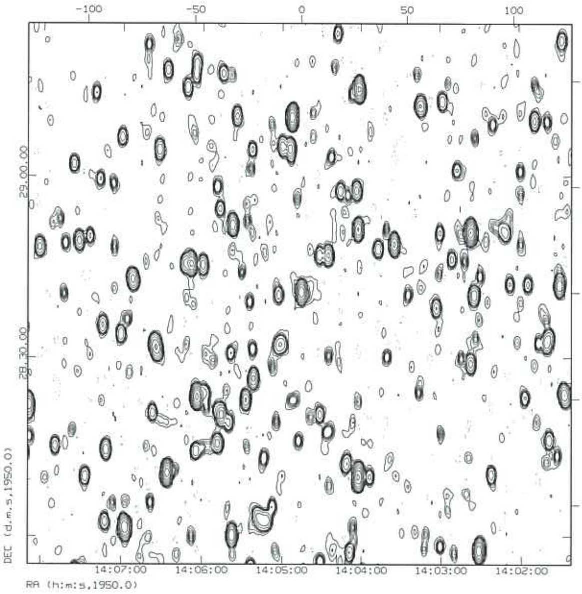


Figure 4.2 One of the deepest syntheses ever taken with the WSRT at 325 MHz is shown here. The image shown measures 1.5x1.5 degrees. The lowest contour levels are ±1mJy, which is about 3 times the noise. This image, which has a 54"x110" beam, is confusion noise limited. It takes higher angular resolution to go deeper. However, when subtracting the 325 MHz image from a similar image at a slightly higher frequency of 341 MHz all sources except a few sources with anomalous radio spectra disappear: i.e. differentially one can beat the confusion!

The Galactic Foreground and the Epoch of Reionization

The structure in the Galactic foreground, apart from being interesting in its own right, has also become important in connection with one of the key science drivers of LOFAR: the study of HI signals from the Epoch of Reionization. The diffuse Galactic foreground is about 4 orders of magnitude brighter than the narrowband HI signals. However its extremely smooth distribution and the fact that any fine scale structure is expected to be spectrally broadband gives us good hope that they can be filtered. Deep broadband 300-400 MHz WSRT data will be used to study the remaining shallow structures in greater detail.

Local Group Galaxies

A collaborative project directed at a broader understanding of the Local Group spirals M31 and M33 has been initiated by ASTRON astronomers together with colleagues at New Mexico State University, Arcetri and the US National Radio Astronomy Observatory (NRAO). In the case of M33, a six pointing HI mosaic was obtained with the B, C and D configurations of the VLA. This was supplemented with a wide-field HI total power observation (5 by 5 degrees) using WSRT auto-correlations. The combined database will have full response to extended emission components and a resolution of 20 pc and 1.3 km/s over the 25 kpc diameter of the M33 disk. Initial results from the WSRT auto-correlation data include detection of the warping HI disk out to very large radii toward the North-West as well as discovery of a possible gas-rich dark companion toward the South-East undergoing tidal interaction with M33. The combined cube provides an unprecedented combination of detail and sensitivity in characterizing the interstellar medium of a nearby galaxy.

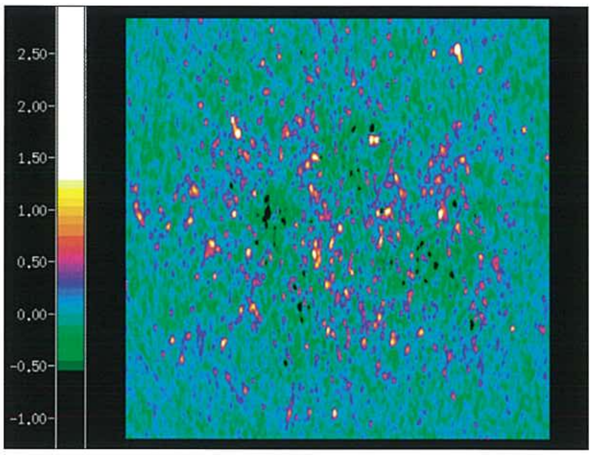


Figure 4.3 When a total of 600 discrete sources is 'removed' from the image shown in Figure 4.2 and the difference smoothed to a resolution of about 2'x4' a large number of faint source complexes appear. The area shown here measures 5x5 degrees. The weak large scale features that start to appear may result from feeble emission fluctuations (0.5-1 K) in the intense Galactic foreground emission which measures about 30 K brightness temperature in this direction. These fluctuations are also expected to be spectrally broadband, just like the discrete sources.

For M31, data acquisition has just been completed of a Nyquist-sampled WSRT HI mosaic of an extended region. More than 300 hours of WSRT observing time were utilized to obtain data for 163 different pointings covering a region some 85 kpc in diameter. The synthesis mosaic was preceded by sensitive total power imaging with WSRT auto-correlations of a 6 by 6 degree field. New features revealed by this total power survey were an extended low brightness gaseous tail extending to the South of the disk, a possible bridge of emission to the compact high velocity cloud to the North and the very extended and warped outer disk emission in the North-East. The final data cube will fill some 5000x5000x300 pixels, providing resolution of about 50 pc and 2 km/s (1 arcmin = 210 pc).

Among the many scientific goals of these surveys are (1) a determination of the extended HI rotation curve to better constrain the properties of the dark matter halos, (2) determining the radial decrease of column density in the outer disk and thereby constrain the extragalactic ionizing radiation field, (3) better elucidate the morphology and kinematics of the two distinct atomic phases, namely the Warm and Cool Neutral Media, and (4) search for evidence of continuing mergers and accretion.

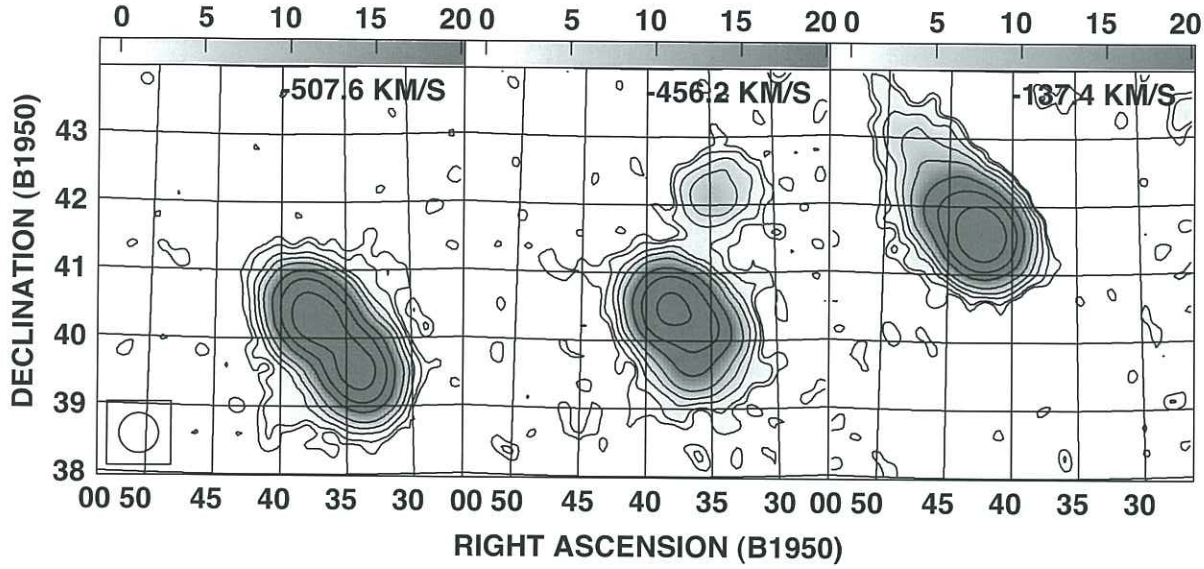


Figure 4.4 Three total power channel maps of HI in M31 show (1) a low brightness tail to the South coincident with a recently discovered stellar tail, (2) "Davies" CHVC to the North possibly connected by a bridge of emission to the M31 disk, and (3) the very extended warped disk component in the North-East.

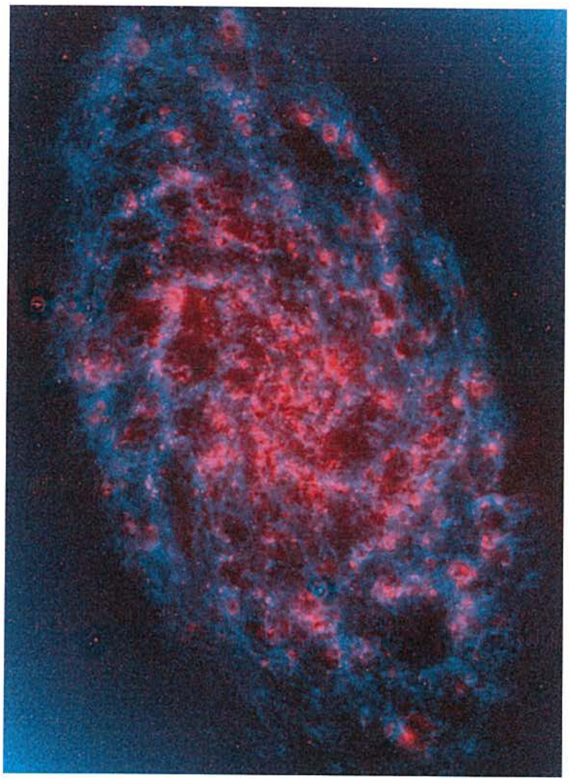


Figure 4.5 The integrated HI of M33 is presented at 10 arcsec resolution in blue overlaid on an H-alpha image in red. At this angular resolution only the network of Cool Neutral Medium (CNM) filaments can be easily seen, characterized by narrow intrinsic HI line widths and occasional high velocity outflows associated with regions of massive star formation. The radial extent of the CNM network defines the star-forming disk of the galaxy, since star formation requires such condensations. The filaments are enveloped in a diffuse atomic component, the Warm Neutral Medium (WNM), which can be detected in the gaps between the filaments and reaches out to much larger radii. The WNM component has the characteristic 25 km/s line width of a 10^4 K gas.

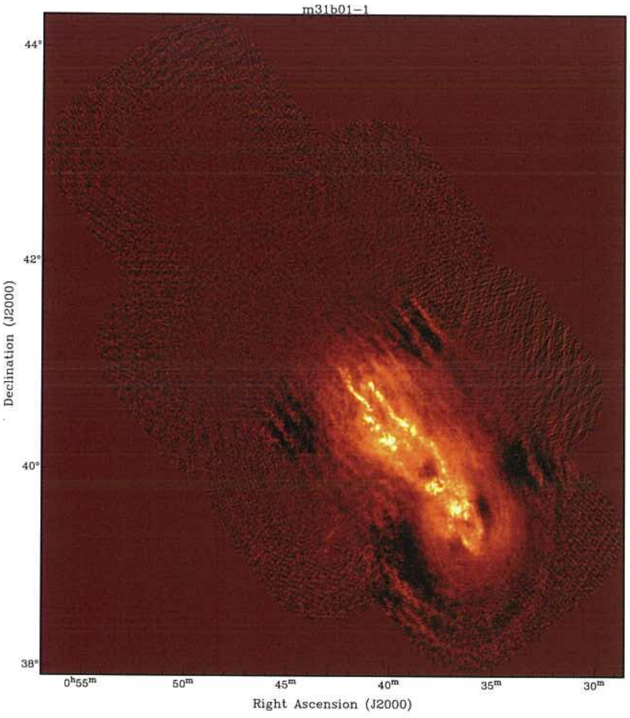


Figure 4.6 A single preliminary channel map of HI in M31 is shown at half the nominal angular resolution and spanning only 2 km/s of the total 600 km/s extent of emission associated with the galaxy. High column density emission in the M31 disk can be seen out to radii of about three degrees on either side of the nucleus, while earlier synthesis observations only had coverage out to about one degree. Faint emission can be seen at this velocity extending almost perpendicularly away from the disk toward the South. This is small-scale structure in the low brightness tail seen in the total power data.

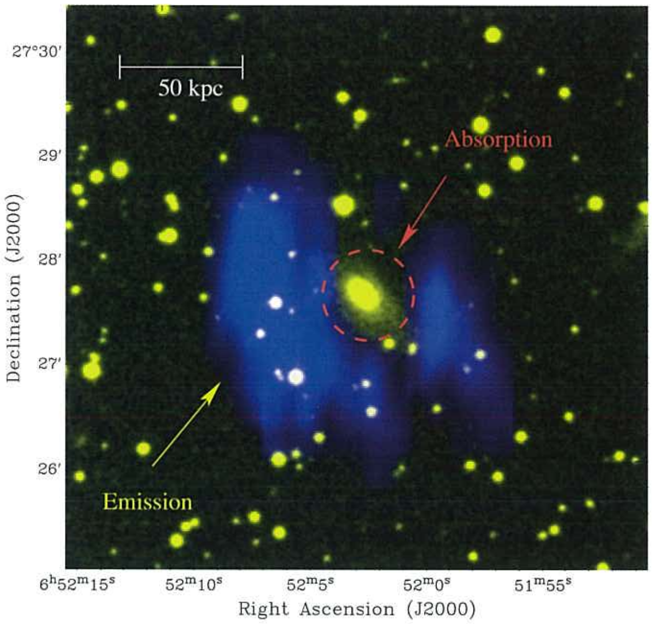


Figure 4.7 HI total intensity image (blue) obtained with the WSRT for the radio galaxy B2 0648+27 superimposed on an optical image (yellow). HI in absorption is observed against the unresolved radio source coincident with the optical galaxy.

Large Gas Disks in Radio Galaxies

Activity in powerful radio galaxies is believed to be triggered by galaxy mergers and interactions. However, the details of these processes are not quite understood. Astronomers from ASTRON, in collaboration with colleagues from the United Kingdom and from the NRAO in the United States, are using neutral hydrogen in radio galaxies to shed more light on this process. For example, it is not clear yet whether so-called "major" mergers, i.e. mergers between two large, gas-rich galaxies, are at the origin of radio galaxies or whether minor accretion events are more likely to supply the necessary fuel for the central "monster". Also not known for sure is whether an evolutionary sequence exists between radio galaxies and other type of mergers, like ultra-luminous infra-red galaxies or elliptical galaxies with large low surface density HI disks. Finally, it is not fully established at which phase of the merger the radio activity starts and whether every elliptical galaxy goes through such a phase. Such studies are also important because it may tell us more about the processes that are more efficiently and frequently happening at high redshift.

Detecting neutral hydrogen in radio galaxies is not an easy task because these are relatively distant objects. However, the exiting detection of HI in absorption against the extended radio lobes (tens of kpc from the nucleus) in some radio galaxies, has opened the possibility to further study neutral gas also in these objects. Coma A is the first radio galaxy in which, by using the WSRT, neutral hydrogen has been detected in absorption at such large distances from the nucleus. Follow up studies using the higher resolution of the VLA have allowed to better localise the regions where neutral hydrogen is present and to determine their characteristics. HI absorption has been found at about 30 kpc from the nucleus. The match between the velocities of the neutral hydrogen and those of the extended ionized gas suggests that they are part of the same disk-like structure of at least 60 kpc in diameter. Most likely, this gas disk is partly ionized by the bulk motion of the radio lobes expanding into it. The gas mass of this disk is at least 10^9 $M_\odot$.

Apart from Coma A, large-scale gas structures (up to 100 kpc in size) have now been detected in a few more radio galaxies. The most impressive case is B2 0648+27 ($z = 0.041$) where a large amount of HI ($\sim 10^{10}$ $M_\odot$) has been detected with the WSRT. In this galaxy, the neutral hydrogen is found both in emission and in absorption (see Figure 4.7). The large amount of neutral hydrogen detected in both Coma A and B2 0648+27 indicates that a major merger is likely to be at the origin of these systems. Moreover, the kinematics of the disks suggests that the merger must have happened more than 10^8 yr ago. This time scale is much longer than that of the radio emission, and therefore supporting the idea that the radio activity starts in a late phase of the merger.

WSRT Survey of the NOAO-Bootes Field

Very deep radio observations have been done so far for a few selected fields (e.g. the Hubble Deep Field-North). Although they reach the micro-Jy level noise, their main limitation is the areal coverage. To overcome this, ASTRON astronomers in collaboration with colleagues from Leiden University and Livermore Laboratory (University of California) have used the WSRT to image at 1.4 GHz a large area of a region in Bootes. This region was chosen because it is being observed as part of the NOAO Deep Wide-Field Survey. This will provide deep optical/near-IR images in many different filters. The detection limits will permit the study of faint galaxies out to large redshifts. Moreover, the Bootes field will be intensively studied by SIRTF's InfraRed Array Camera in four IR bands. With the WSRT, approximately 7 square degrees have been imaged with a mosaic of 42 pointings. The limiting sensitivity is 28 µJy/beam. A catalogue of 3172 sources has already been produced. Among these sources 73 are extended.

The survey is deep enough to sample the change in radio source population properties at the few mJy level. Deep radio surveys reaching few tens of µJy level have become an essential tool for the study of

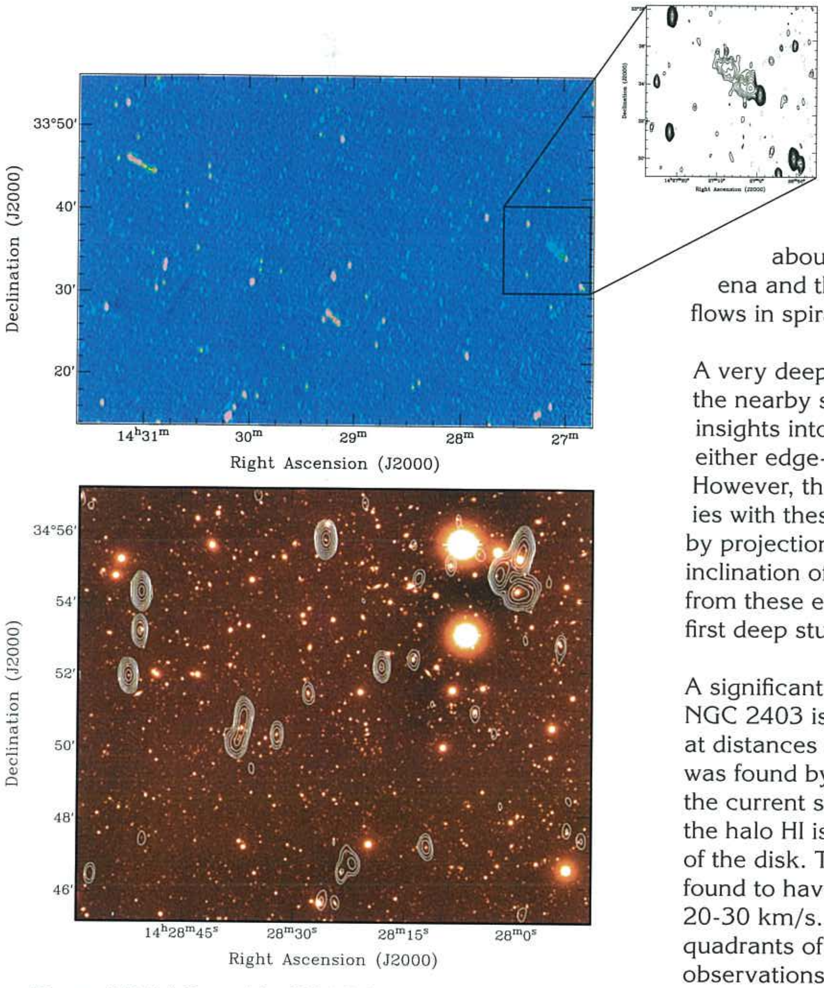


Figure 4.8 (a) One of the NOAO fields already publicly available for the region of Bootes with WSRT radio contours superimposed. (b) Part of the WSRT mosaic of the Bootes region showing a few extended sources.

star forming galaxies and for the understanding of obscured active galactic nuclei and distant young galaxies and quasars. At these faint level of radio emission, the radio sources are mainly identified with star bursting galaxies. Because the radio emission is unaffected by gas and dust obscuration, they can therefore provide key information on the star formation history of the Universe.

Moreover, the Bootes field has also been observed for 32^h with the VLA at 325 MHz. The combination of the two frequencies will provide important information on, among the other things, the nature and evolution of radio sources, both in the local and the high redshift Universe.

HI Gas in the Halo of Spiral Galaxies

Star formation can generate large-scale gas flows in spiral galaxies. Gas is ejected from the disk into the halo by energetic events associated with star formation. In the halo, this gas cools and, at a later stage, it falls back to the disk as neutral hydrogen. Such a phenomenon is called a galactic fountain. Much about these galactic fountains is still not understood. The study of the vertical structure and kinematics of these gaseous haloes can give important information about these galactic fountain type phenomena and the processes related to large-scale gas flows in spiral galaxies.

A very deep study of the neutral and ionized gas in the nearby spiral galaxy NGC 2403 has given new insights into this phenomenon. In previous studies, either edge-on or face-on galaxies had been used. However, the interpretation of the data on galaxies with these extreme orientations is complicated by projection effects. Because of the intermediate inclination of NGC 2403, these data do not suffer from these effects. The work on NGC 2403 is the first deep study of such a galaxy.

A significant fraction of the neutral hydrogen in NGC 2403 is found to be in the halo of this galaxy, at distances of a few kpc above the stellar disk. As was found by other groups in a few other galaxies, the current study finds that the rotation velocity of the halo HI is about 20-30 km/s lower than that of the disk. The new results are that this halo HI is found to have also a radial inward motion of about 20-30 km/s. Moreover, gas is found in the forbidden quadrants of the position-velocity diagrams. These observations imply that the standard models of the galactic fountains are not complete and that some of the assumptions, e.g. conservation of angular momentum, need to be reconsidered.

Deep Hα spectroscopy of NGC 2403 was obtained with the William Herschel Telescope on La Palma. These observations revealed that the halo of NGC 2403 also contains ionized gas. The kinematics of this ionized gas is very similar to that of the neutral halo gas. This is a surprising result, because the general assumption was that the ionized gas corresponds to the outflow phase of the galactic fountain, while the neutral gas was thought to correspond to the inflow phase. Moreover, it was found that the mass of the ionized gas is much smaller than what one would expect based on such a model.

Deep Chandra observations were also performed of NGC 2403 and diffuse X-ray emitting gas was found throughout the galaxy. The temperature and the distribution of the X-ray gas are such that it is much more likely that this hot gas corresponds to the initial outflow phase of the galactic fountain, instead of the optically visible ionized gas.

In order to study these HI haloes in more spiral galaxies, a small number of nearby spirals were observed with the WSRT. The improved sensitivity of the upgraded WSRT, combined with its superior imaging properties, make it a very suitable instrument

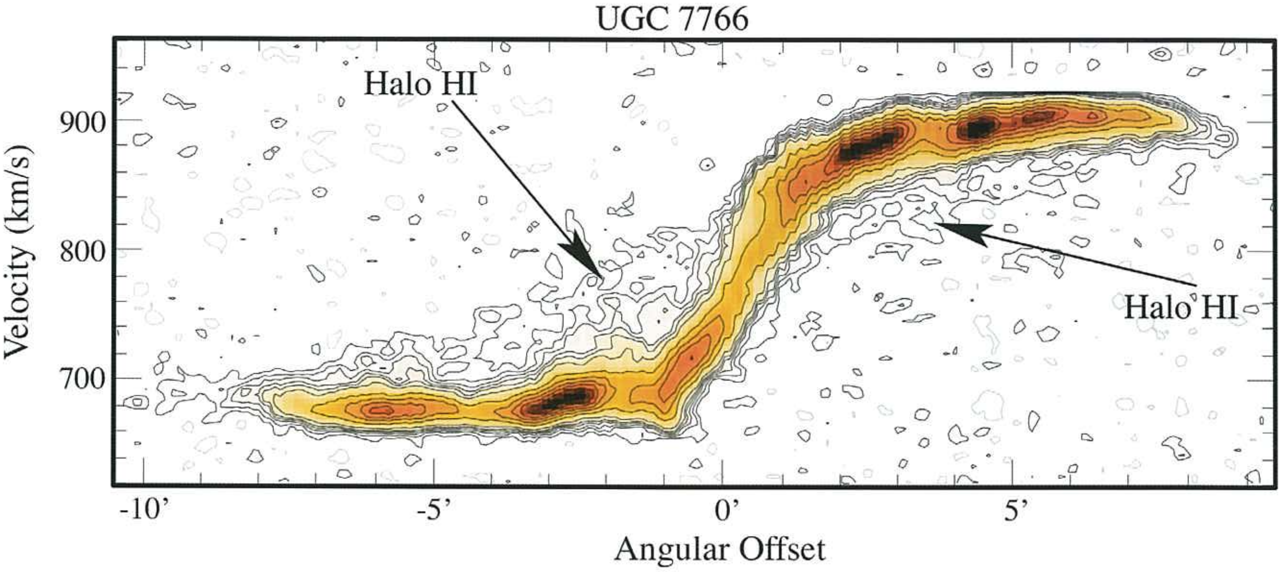


Figure 4.9 Position-velocity slice along the major axis of the nearby spiral galaxy NGC 4559 (=UGC 7766), as obtained with the WSRT, with the HI in the halo of this galaxy indicated.

for such studies. An extensive HI halo was found in the galaxy NGC 4459 and is illustrated in Figure 4.9. The properties of the HI halo in this galaxy are very similar to those of the HI halo in NGC 2403.

HI Search for Very Low-Mass Galaxies

The number of low-mass satellites observed around galaxies is much lower than predicted. For example, in the Local Group only ~36 dwarf galaxies are known, while Cold Dark Matter theories predict several hundreds of these low-mass galaxies. If the gas densities at the centres of these objects are high enough to prevent ionization of a significant fraction of the innate hydrogen gas by the metagalactic uv-background, they should be detectable at the present epoch in sensitive 21-cm HI emission line surveys.

Moreover, the neutral gas density Ω_{gas} of the Universe and the HI mass function are fundamental observational parameters that describe the formation and evolution of stars in galaxies and charts the processes that convert gas into stars and galaxies. Linked with other indicators that have recently received much attention, such as the cosmic star formation rate and the luminosity density, they give strong constraints on galaxy evolution models.

Obtaining an accurate census of the very lowest mass galaxies in the local Universe may shed light on these issues. A pilot project was performed in order to study the feasibility of a sensitive HI survey to be performed with the WSRT. The WSRT has the unique capability that in addition to the cross-correlation spectra, it also records the auto-correlation spectra. The low-mass objects may be extended on the sky and may have low column densities. Such objects will be more readily detectable in the auto-correlation spectra as they will be resolved out in most of the cross-correlation data. The brighter or the more compact objects can be imaged using the cross-correlation data. The pilot study shows that it is indeed quite feasible to make a survey covering a few hundred square degrees and that will go about an order of magnitude deeper than previous studies, while also much better imaging quality will be obtained. This underlines the great power of the upgraded WSRT. The large-area survey will start in 2002.

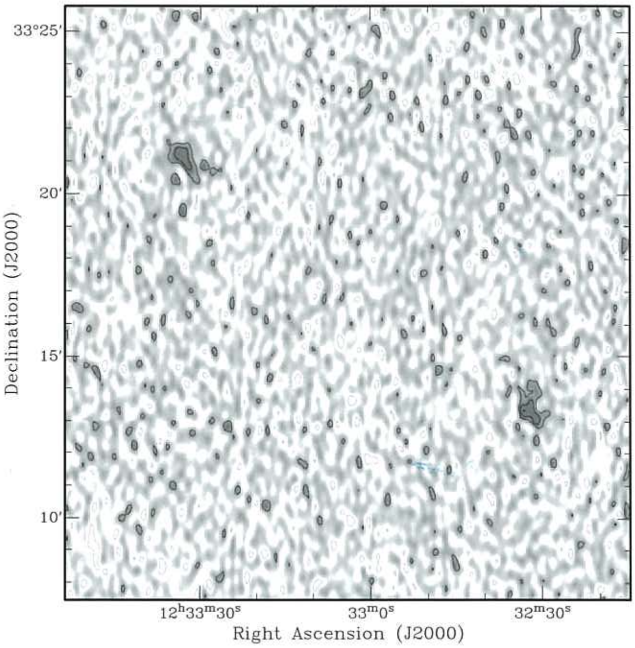


Figure 4.10 Channel of a mosaic observation centred on KUG 1230+334A and KUG 1230+336, the two small galaxies detected in the pilot. Contour levels are –1.5, 1.5, 3, 4.5 mJy/beam.

To illustrate the capabilities of the survey technique that was devised, the two figures show the faintest detection found in a small test area. It consists of a binary system of two small galaxies, both with MHI ~ 2 · 107 M at 11 Mpc distance for which no HI identifications were available. These small galaxies are detected at high significance levels, illustrating that much smaller galaxies can easily be detected.

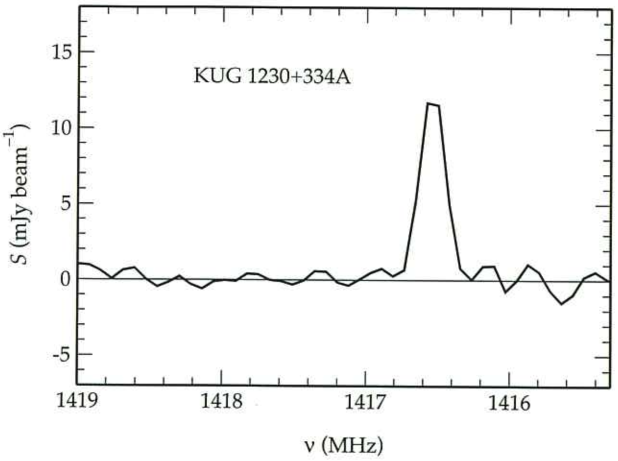


Figure 4.11 Spectrum of one of the two galaxies in Figure 4.10. The detection corresponds to $2 \cdot 10^7\ M_\odot$ of HI, assuming a distance of 11 Mpc.

Bow Shock Nebula Discovered Around PSR B0740-28

In January 2001 a mini-survey was started for Hα bow-shock nebulae around energetic and/or high velocity pulsars using the ESO-NTT telescope on La Silla. These nebulae can be used to determine the three dimensional pulsar velocity, some properties of the pulsar wind and to measure the density, temperature and composition of the ambient interstellar medium in which the pulsar is moving. However, they are scarce with only 4 such nebulae previously known. In observations made during the first part of the survey a new faint Hα pulsar wind nebula (PWN) powered by the radio pulsar B0740-28 was detected. The characteristic bow-shock morphology of the PWN implies a direction of motion consistent with the previously measured velocity vector for the pulsar. The PWN has a flux density more than an order of magnitude lower than for the H PWNe seen around other pulsars. If the pulsar is located at 2 kpc, the morphology and flux of the nebula is consistent with propagation through a medium with a density of $n_H = 0.25$ cm^{-3} and a neutral fraction of 1% indicating that the pulsar is located in the warm phase of the interstellar medium. The observed nebula shape is also most consistent with the pulsar only having a moderate radial velocity component. The morphology of the PWN in the area close to the pulsar is distinct from that in downstream regions, where it broadens significantly and becomes more rectilinear. The shape and nature of the intensity variations in these extended regions in Hα PWNe may provide interesting constraints on the density structure of the interstellar medium.

HI Distances to 10 Pulsars Using PuMa and WSRT

Measurements have been made of 21-cm absorption and emission spectra in the direction of 10 pulsars. The pulsar machine PuMa was effectively used as a gated-spectrometer to carry out these observations. In its digital filter bank mode 1024 channels across the 10 MHz were recorded and sampled every 819.2μs in total intensity (Stokes I). The correspondingly high frequency resolution provided very good velocity resolution which can be vital when distinguishing between emission components. The data were subsequently de-dispersed and folded at the pulse period using known ephemerides and for each frequency channel the resultant pulse profile was binned into 256 phase-bins. An “off” spectrum was formed by summing together the spectra for all pulsar phase bins which did not contain the pulse while the “on” spectrum was formed from the sum of all bins containing the pulse. In all cases sufficient bins across the on pulse were available to resolve it. This is an improvement over traditional methods where only a few, typically 16, phase bins are recorded and so the pulse is contained in usually one bin and thus a degree of unwanted noise is included in the on-spectrum.

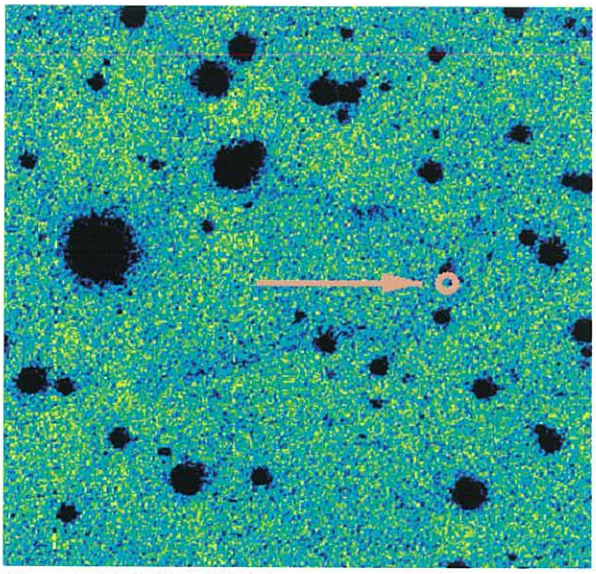


Figure 4.12 SUSI-2/NTT discovery image (Hα and continuum) of the nebula associated with PSR B0740–28. The image shown is 1 arc minute square and the arrow indicates the direction of motion and the distance travelled by the pulsar over 500 years.

For the first time successful HI absorption measurements have been obtained for PSRs B1815-14, B1831-04, B1844-04, B2106+44 and B2351+61. These observations have also significantly improved the sensitivity and resolution on PSRs B1818-04, B1826-17 and B2111+46, whose spectra have previously been measured. The resultant distance limits are significantly different for PSR B1818-04 which has important consequences for the models of distances to pulsars which are based in the distribution of electrons in the Galaxy. These spectra will also help better constrain pulsar distances and electron column densities in the direction of or behind the poorly studied Perseus spiral arm.

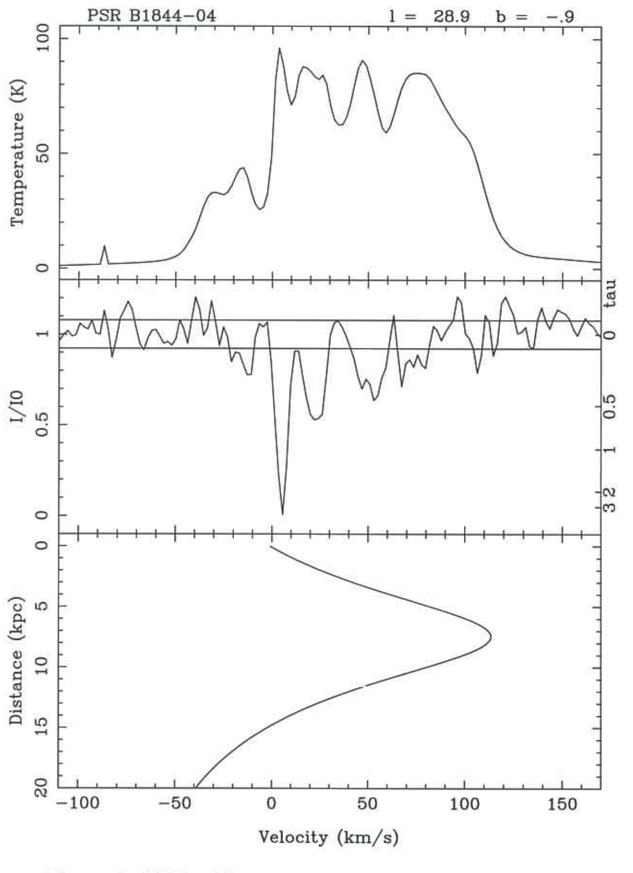


Figure 4.13 The HI spectrum in the direction of PSR B1818-04. The top panel shows the HI emission spectrum while the middle panel contains the absorption spectrum of the pulsar. This absorption spectrum can be compared with the model of the rotation curve of the Galaxy shown in the bottom panel to take the velocity of the emission and absorption features and determine a lower and in some cases upper distance limit to the pulsar. If there is a significant emission peak against which there is no absorption seen then the pulsar is located in front of this cloud, correspondingly the last emission feature against which absorption is seen is the lower distance limit. In the case of PSR B1818-04 a lower distance limit of 1.7 kpc was determined and no upper limit could be assigned.

Investigations of Giant and Double-Double Radio Sources

Giant radio galaxies (GRGs) are the largest structures in the Universe formed by an individual galaxy. Ejected by an Active Galactic Nucleus (AGN) in its centre, two highly collimated jets span a distance of more than 1 Mpc (H_0 = 50 km/s/Mpc).

The AGN themselves must be experiencing an extremely long period of 'radio-activity' in order to produce such large radio structures, and the jets they produce are so stable that they can transport particles almost without dissipation over distances of at least 500 kpc. Eventually, these jets terminate in a shock and inflate an enormous expanding bubble of shocked jet material. This so-called cocoon is well traced by the radio lobes. The jets are a strong source of energy, particle and magnetic field input for the hot Intergalactic Medium (IGM).

By their mere size, these sources stretch models of double radio sources to the limit in certain areas of parameter space. Since the radio jets of GRGs cross huge distances in intergalactic space, they can also be used as probes for the IGM.

Traditionally the study of giant radio sources has been a topic well suited to the WSRT and several members of the ASTRON staff are engaged in these studies. Since early this year, efforts have increased to select a well defined sample of GRGs at higher (z>0.3) redshift from the WENSS survey. New optical R-band images of the radio sources were obtained, vital for identifying the host galaxies and redshift determinations. Furthermore, for many of these sources multi-frequency radio data are now available, from both the WSRT and the VLA, allowing an in-depth investigation of their radio properties.

Detailed radio studies of three double-double radio galaxies (DDRGs) have continued. DDRGs are radio galaxies consisting of well aligned, co-centred, double-lobed radio sources of different size. The favoured explanation for this strange morphology is that of a radio source which underwent an interruption of its central jet-forming activity. In this model, the inner radio lobes are the youngest, and the outer radio lobes are currently fading because they are cut-off from the energy supply of the jet. The DDRGs allow us to investigate several poorly understood issues of radio source evolution.

In order to observationally constrain the ages of the different structures and the properties of the environment, an observational programme has continued which is aimed at studying their radio structure as completely as possible using a variety of frequencies and resolutions. New high-resolution and multi-

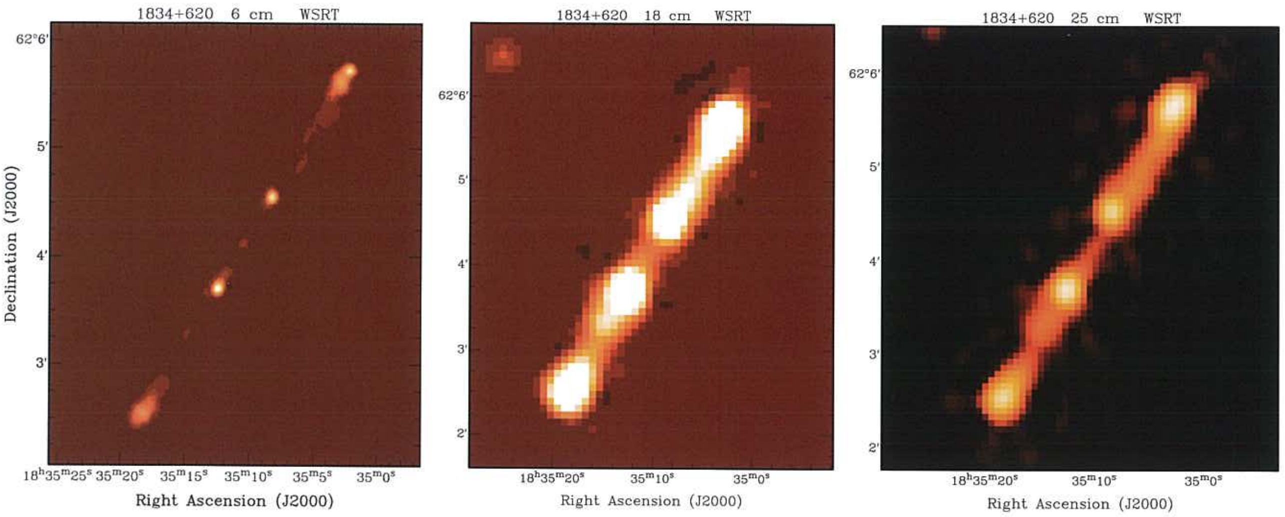


Figure 4.14 Total intensities of B1834+620 at 25 cm, 18 cm and 6cm. Both the 25 cm and the 18 cm maps show an extension to the northern outer lobe that could lead to very interesting, though, daring speculations, such as the remnant of an even older activity phase. This structure does not show up at 6 cm, but this only tells us, if it is indeed real, that the electrons are not energetic enough to be detected at the higher frequencies, which could be normal in an old structure. The 6cm map clearly shows the radio core and even the jets can be seen.

frequency VLA data, as well as WSRT data have been obtained. The WSRT data have been looked at carefully in the framework of the ASTRON/JIVE summer studentship programme and show interesting polarization features (Figure 4.14). The reduction of the VLA data is still ongoing.

Together with colleagues from the Institut d'Astrophysique de Paris a programme has been set up to compare optical observations of the host galaxies with Spectral Energy Distributions from stellar synthesis codes. Multi-band optical photometric data of various GRGs will be used to obtain ages for the stellar populations of these galaxies and to look for a relation between the onset of the radio activity and recent star formation.

Non-Thermal Emission from Jupiter's Radiation Belts

In an effort initiated by a colleague at the University of California (Berkeley), 11 different radio telescopes around the world participated in a campaign to definitively determine the spectrum of the non-thermal emission from Jupiter's radiation belts at one epoch. Because the emission is variable on many timescales, success required near-simultaneous observing with the different instruments. The goal was also to cover the widest possible frequency band, which is effectively set by the dominant decametric emission below about 50 MHz, and thermal emission from the planetary disk above 8 GHz or so. In the end, it was possible to obtain a well-sampled spectrum from 74-8600 MHz, using arrays (at the lower frequencies) and single dishes (at the higher ones). The WSRT participated at 380 and 610 MHz (observations at 840 and 1400 MHz were unusable because the source was too heavily resolved to obtain a reliable total flux density).

The spectrum is somewhat curved (convex), with a peak around 300 MHz, probably a slow decline to lower frequencies below 100 MHz, and a fall-off which becomes more rapid with increasing frequency above 2 GHz. It has been modelled by assuming the injection of an ensemble of electrons with some initial energy spectrum at some point in the magnetosphere, which is then allowed to diffuse, losing energy by radiation and other mechanisms, and then integrating the resulting synchrotron spectrum. Acceptable fits can be obtained, but they do depend upon the injection spectrum, which is something like two power laws: a flat one at low energies, a steeper one at higher energies. The data have also been compared with spectra obtained, over a limited range of frequencies, during the impact of the comet Shoemaker-Levy 9.

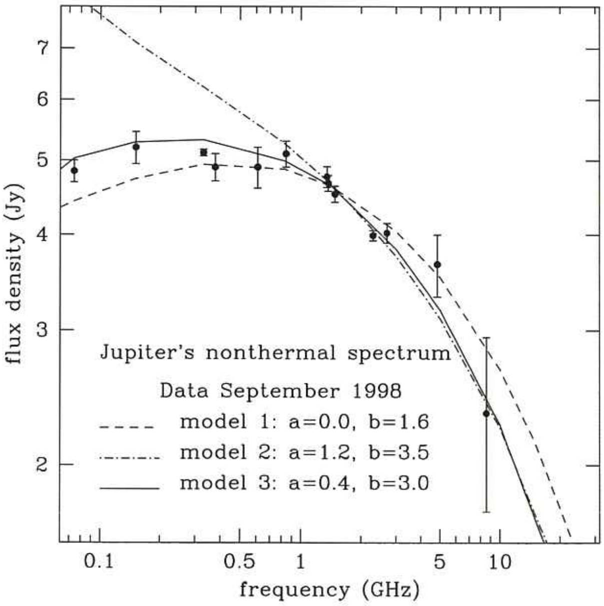


Figure 4.15 Radio spectrum of Jupiter based upon observations made in September 1998. Three model fits are shown for different values of the particle energy spectra.

Supernova Remnants

While investigating the supernova remnant (SNR) CTB 80, a colleague from the University of Crete found optical emission to the NE which is unrelated, but appears to be shock excited. ASTRON staff then used existing WSRT data at 92 cm to look for radio emission from this candidate SNR. In a few locations, weak emission was found, which is similar to what is also seen in a 6 cm single dish survey. The radio emission appears to be non-thermal, and together with the patches of optical nebulosity (see Figure 4.16) seems to form a large shell about 1° in diameter. There is nothing exceptional about this SNR apart from its very low surface brightness at both optical and radio wavelengths - which is why it has escaped detection until now. It would be interesting to know whether further research will shed light upon the reasons for its faintness.

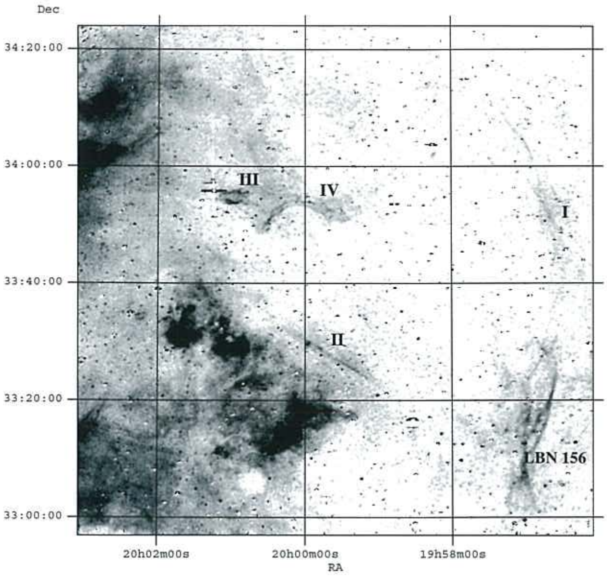


Figure 4.16 Nebulosity associated with a new supernova remnant northeast of CTB 80, marked with the Roman numerals I - IV.

Commercial Activities and Public Relations

Technology Transfer

ASTRON has set up a front office – the Bureau of Technology Transfer (BTT) – to coordinate relationships and collaborations with industrial parties. This activity emphasizes the fact that 'ASTRON-technology' is available and accessible to industrial/commercial parties.

The following projects are a direct result of the activities of BTT:

Course in "Applied RF technology"

ASTRON has developed a three-day course in Applied RF-technology. The course is intended for technicians and field support engineers who start (or are already) working with RF systems and/or RF-measuring techniques. The start-up costs for development of the course are partly covered by a subsidy from the "Kompas voor het Noorden" of the SNN ("Samenwerkingsverband Noord-Nederland). The first classes will be held in March 2002 in Dwingeloo.

Commercial Work

A number of commercial projects acquired by BTT were carried out in ASTRON.

- Machining of parts for the HIFI project was carried out for SRON by the mechanical workshop.
- Mechanical work for instruments used in a superconductive environment was carried for the University of Twente.
- ASTRON's outdoor test-facility was used for testing of commercial equipment. Particularly interesting for the tests were ASTRON's low EMI environment and availability of a sheltered platform.
- Mechanical design specialists at ASTRON successfully applied advanced CAD-CAM techniques in the automation of a production line for horseshoes.

Public Relations

BTT represented ASTRON on the following occasions:

- ICT conference in The Hague: ASTRON participated in the "ICT kenniscongres" on September 6 and 7. The subjects were ASTRON in general and LOFAR.
- ICT conference in Groningen: "Noord Nederland in de informatiemaatschappij" Focus here was on LOFAR and the opportunities for ICT in the North of the Netherlands.

Procurement and Legal Matters

Increasingly, ASTRON is collaborating with industry for research and development of instrumentation. This requires us to pay special attention to matters such as contractual arrangements and legal aspects. In particular this regards the issue of ownership and protection of intellectual property (IPR). In order to safeguard its interests, ASTRON has formulated clear agreements with other parties regarding confidentiality and protection of IPR. The increasing awareness of the importance of protection of ASTRON's IPR is also evident from the fact that ASTRON has started registering patents for some of its most interesting discoveries.

For a number of large projects the involvement of industrial partners is in the form of significant levels of procurement of supplies, services and works. Since ASTRON is a public institute, it is considered to be a contracting entity as defined under EU procurement law. This means that ASTRON needs to follow the formal European rules for procurements that exceed the monetary thresholds. Particularly in LOFAR the need for formal procedures according to the EU directives has been identified. ASTRON has therefore taken action to ensure that these activities are carried out in compliance with the EU directives. This also involves some adaptation of internal working practices. As part of the LOFAR programme ASTRON will formally issue a Procurement Plan, which lays down in a public document the guiding principles that ASTRON has adopted. This document will be available from the following web-site: http://www.lofar.nl.

Public Relations

ASTRON's work in 2001 has not gone unnoticed thanks to our public relations efforts. The various visits, press releases and interviews have had a positive effect. Often it was ASTRON that sought publicity to announce a new achievement, or to convey a specific message. The institute was also visited many times by groups interested in the work at ASTRON. In particular, our ambitions for the future, notably LOFAR, were at the centre of attention. Our public relations effort has two main goals. One is the general PR goal of bringing ASTRON's work and products to the attention of a wider audience. Second is the more specific and focussed job of informing and involving the various relevant networks in ASTRON's activities.

General PR

Visits

Below is a list of all organisations and groups that visited ASTRON. In general the programme consisted of a general introduction to ASTRON and astronomy, a description of the LOFAR project, a tour through our laboratory facilities, and of course a visit to JIVE. Whenever possible, groups also visited the radio telescopes in Westerbork.

- Nederlandse Maatschappij voor de Handel en Nijverheid (15/2)
- Deelnemers Natuurkundeolympiade (14/6)
- Afdeling Financiën provincie Drenthe (13/9) Provinciaal directeurenberaad Milieu en Waterstaat (21/9)
- Hoogleraren o.l.v. bestuurslid prof. E. v.d. Heuvel (22/9)
- Rabobank Dwingeloo met relaties (28/9)
- Provinciale medewerkers ruimtelijke ordening (28/9)
- Rijkswaterstaat civieltechnische werken Noord Nederland (28/9)
- Nederlandse Vereniging van Weer- en sterrenkundigen (17/10)
- Bijeenkomst voor docenten van de praktijkopleiding Elektrotechniek van het Drenthe College (20/11)
- Universiteit van Amsterdam, afdeling informatica (14/12)
- VNO/NCW Jong Management Kring Drenthe (17/12)
- CDA Statenfractie (19/12)

Two visits merit special attention.

Open Day (7 October)

During the national Science and Technology Week, ASTRON opened its doors to the public; both the labs in Dwingeloo and the radio observatory in Westerbork. Doing so caused major traffic jams in the village of Lhee, and in the woods of Hooghalen. In all, 2,500 people visited our Dwingeloo location and 1,500 people found their way to the Westerbork Synthesis Radio Telescope.
In Dwingeloo lectures on astronomy kept our colloquium room filled to capacity, explanations were given about LOFAR, tours were held through the lab, older children were assisted in soldering radio receivers and other electronic equipment in our "fun lab". In Westerbork visitors were given a ride in the cherry picker to see the telescopes up close, slides and films were shown, children were allowed to operate the telescopes using a joystick and pulsar observations were presented.

Royal Visitors

As part of their tour through Drenthe, His Royal Highness Crown Prince Willem Alexander and his fiancée Ms. Máxima Zorreguieta visited ASTRON on November 15th. The programme of their 45 minute visit had been planned and prepared to the smallest detail. The couple were given a presentation of the current work of ASTRON as well as a tour through the technical lab and a visit to JIVE. They were accompanied among others by the Commissaris van de Koningin in Drenthe, mr. Relus ter Beek, and the mayor of Westerveld, mr. Meijer.

Press and Publicity

General press attention was given to ASTRON on the following occasions.

- On July 10th, the KRO TV programme Markant Nederland showed a programme about Drenthe in which "tourists" visited the radio observatory.

- August 15th the programme "Daagse Dingen" aired on Drenthe radio on the subjects of astronomy in general and LOFAR in particular.

- Zwerftocht, an RTV Drenthe programme visited ASTRON on August 20th for a live radio interview during the day, and TV images in the evening.

- Regional broadcasts aired a programme on special architecture of the past 50 years, featuring the Westerbork radio telescope.

- Before and after the visit of HRH Prince Willem Alexander and Máxima, many interviews were given for local, regional and national TV and radio. Newspapers also paid a lot of attention to the visit.

Specific PR

Visits

On April 19th, ASTRON delivered two high-tech instruments to the European Southern Observatory: VISIR and MIDI. After final tests in France and Germany, these instruments will form the infrared eyes for the ESO Very Large Telescope (VLT) in Chile. On this occasion ASTRON organized a festive programme for the press.

In collaboration with the Dutch business organization VNO-NCW Noord, ASTRON organized an information session for businesses, on the subject of "Concurrentievoordelen voor Ondernemend Noord-Nederland in Dwingeloo. LOFAR: het Heelal in met Next-Generation Internet". Approximately 80 companies from the north of the Netherlands attended the presentation.

On November 6th, ASTRON and Fokker Space B.V. signed a contract for a collaboration on the LOFAR project. The agreement, running to the end of 2002, represented a total value of 3.5 million guilders (1.5 million Euro). The signing ceremony was attended by the press and was given attention in local and national media.

Press and Publicity

- The VISIR and MIDI presentation resulted in press coverage in regional media, and articles in the "Technisch Weekblad", the "Ingenieur", and the "Nederlands Tijdschrift voor Natuurkunde".

- On April 26th ASTRON and the Samenwerkingsverband Noord-Nederland (SNN) jointly submitted a press release announcing the 15 Mfl subsidy that ASTRON received from the SNN to start the work on the ambitious LOFAR project.

- The "Technisch Weekblad" published an article entitled "ASTRON start opleiding radiofrequentie ingenieur".

- On May 21st ASTRON's Marco de Vos received the prestigious Vosko Innovation Award. Press releases resulted in articles in various Dutch media.

- May 23rd saw the kick-off of RETINA, a technology development project together with Lucent Technologies, TU Eindhoven and KPN Research. Press releases resulted in articles in regional media, "Technisch Weekblad", Telecom Magazine, and Computable.

- The Dutch film "Discovery of Heaven", based on the Harry Mulish novel of the same title, was partly filmed at the Radio observatory in Westerbork. At the time of the premiere the press gave much regional and national attention to the observatory.

- On many occasions the developments around the LOFAR telescope resulted in press coverage, e.g. in the May 15th issue of Computable, the April and June issues of the KOMPAS Krant, the June-July issue of the Kamer Krant, the September issue of the VNO-NCW NoordNieuws.

ASTRON Facilities

Estate and Site Management

Emergency Procedures

For the past few years, a professionally trained emergency team has been on standby throughout the working day. However, frequent absence of personnel, either as a result of business related travel or holidays has made this a time consuming process to organize. In the course of the year, changes were made to the way the service operates. The "duty officer" system has been discarded in favour of an "everybody-on-call" system. A public address system has also been installed to ensure that communication is possible throughout the buildings. A new round of courses was held to train new staff that have joined the emergency team.

Helpdesk

The facilities helpdesk still works with a paper system: everyone who has some sort of facilities-related problem can fill in a form and hand it over to Reception. Over 2001 a total of 68 reports were filed, of which 39 had been solved by the year's end.

Transport and Guesthouse

Three company cars are now available for all sorts of business related transport. For visitors, a taxi service is available on call. Over 2001 the number of recorded nights in the ASTRON Guesthouse rose to 1575, up by 18% from the year before. This means an occupancy of around 45% of full capacity.

System Management

General matters

Improved Unix and Windows integration has been tackled in two ways. From the Linux side, Vmware has been installed, which means that Windows applications can be used on the Linux desktop. This works remarkably well, only a slight speed difference is noticeable. Also, a Samba server has been installed that makes it possible to mount Linux disks on a windows machine.

Remote connections

The Internet connection to Groningen was finally upgraded to 2 Mbit/s. We are now awaiting connection to the new Surfnet Gigaport network, which started operation with a number of pilot schemes in 2001. The Shiva dial-in system will need to be replaced next year since it is now hard to get support for the current system. Operating systems such as Windows 2000, that have been introduced since the Shiva system was installed, cannot make use of call-back mode.

Statistics of the use by ASTRON and JIVE staff of the Dial-in facilities in 2001 are listed below:

Quarter	Calls Made	Connection Hours
1	2400	1579
2	3537	2192
3	4658	1983
4	4634	2331
Total	15229	8086

Mail System

To stem the increasing number of malicious viruses, an e-mail scanning system was added to the institute's facilities. From June 2001 the system has been operational, and viruses lurking in e-mails are detected and set aside. Together, ASTRON and JIVE receive some 4000 e-mails per week. In the second half of 2001 when the mail sweeper system was fully operational, about 1% of incoming e-mails were set aside for inspection.

Computer Helpdesk

The more or less open ended system of user support based on e-mail, was replaced by an official helpdesk system called "Track-it", which can be accessed through a web interface and so is platform independent. Users can ask questions, report problems, request software installations and upgrades and the system then tracks the response and solution time. From each of ASTRON's departments and JIVE, a contact person is able to monitor the progress for his or her users. During 2001 about 1700 cases were handled.

Instrumentation

Control and supervisory tasks have now taken over from the more technical and specific tasks such as calibrating and repairing instruments used throughout ASTRON. In the course of the year, about 125 instruments were recalibrated and/or repaired within the section. A lot of time was used to make the system more transparent and reliable to the lab user.

The take-over of the telephone exchange has taken up a significant amount of time, since documentation of the patch and connection diagrams was not up-to-date. Further problems with the emergency sets were also corrected. Configuration manager software has been installed, which means that minor changes in the system can now be performed locally, without help from the telecom company, KPN. This is a far more flexible solution than before, giving us a lot more freedom and a faster response time.

Library

The library subscriptions of journals, magazines and other periodicals have been reviewed, especially since this takes up 75% of the total budget available to the library. Another important factor in this review was the rapid increase in the price of journals and magazines – prices are increasing well above the level of inflation. The objective of the review was to identify those journals and magazines that were no longer of interest to staff. In the end, only a single subscription was terminated. This was both good and bad news, because it means that no unnecessary costs were being made, but also that further cost reductions were not possible. In order to stay within budget, new subscriptions have therefore been frozen. In the course of the year about 90 new books were added to the collection.

Purchasing Section

A new structure was introduced which meant separating the roles of ASTRON's financial section and its purchasing department. The new purchasing section works from the office of the ASTRON purchaser. Now that a second workplace has been added, the section consists of a tactical purchaser – also head of the section – and a operational purchaser. The new operational purchaser is in charge of placing the actual orders. As a logical result of the move, the general store has been placed under this section.

ASTRON Programme Committee

Report and Membership

The Programme Committee serves to review proposals for observing time at the WSRT, which is operated by ASTRON, and the telescopes of the UK/NL collaboration on the islands of Hawaii (the James Clerk Maxwell Telescope – JCMT) and La Palma (the William Herschel Telescope – WHT, Isaac Newton Telescope – INT and Jacobus Kapteyn Telescope – JKT), which are the responsibility of the Gebiedsbestuur Exacte Wetenschappen (GBE) of NWO.

The PC conducts two reviews per year for the standard proposal stream. Delegates of the PC subsequently coordinate the scheduling of the proposals with the programmes of the other members of the Isaac Newton Group and the JCMT consortium. The PC is composed of eight members – seven from Dutch institutes plus one foreign member. Members normally serve a term of three years.

Spring meeting to schedule proposals for semester 2001B

Member	Institute
F. Briggs, chair	Groningen
U. Klein, foreign member	Bonn
M. van Kerkwijk	Utrecht
L. Kaper	Amsterdam
J. Luu	Leiden
H. Röttgering	Leiden
R. Morganti	ASTRON
J. Higdon	Groningen

Autumn meeting to schedule proposals for semester 2002A

Member	Institute
F. Briggs, chair	Groningen
U. Klein, foreign member	Bonn
R. Fender	Amsterdam
L. Kaper	Amsterdam
W. Schutte	Leiden
H. Röttgering	Leiden
R. Morganti	ASTRON
E. Tolstoy	Groningen

Allocation of Observing Time

Semester 2001A

WHT

Programme	Principal Applicant	Title	Allocation (nights)
w01an001	Lacerda	Rotational Properties of (smaller) Kuiper Belt Objects	2G 4B
w01an002	de Zeeuw	Mapping Early-Type Galaxies along the Hubble Sequence	5D 2G
w01an004	Orosz	The mass of the black hole in the X-ray nova XTE J1118+480	2D
w01an005	Spruit	Circumbinary material in Cataclysmic Variables	3B
w01an008	Vreeswijk	Rapid imaging of GRB error boxes and spectroscopy of GRB-related optical transients	25 GRB override hours
w01an009	Higdon	Metal abundances in extragalactic tails and bridges	1G backup
w01an010	Higdon	Tidal dwarf galaxies in Arp 143's Plume	1G
w01an011	Kuijken	Planetary nebula kinematics of round elliptical galaxies	2D

INT

Programme	Principal Applicant	Title	Allocation (nights)
i01an001	Lacerda	Rotational Properties of (larger) Kuiper Belt objects	1D 3G 4B
i01an002	Jimenez	A much-improved stellar library for stellar population synthesis	6B
i01an003	Noordermeer	Optical spectroscopy of galaxies in the WHISP sample	3D
w01an008	Vreeswijk	Rapid imaging of GRB error boxes and spectroscopy of GRB-related optical/IR transients	25 GRB override hours

JKT

Programme	Principal Applicant	Title	Allocation (nights)
j01an001	Schoenmakers	R-band imaging of a sample of high-z giant radio galaxy candidates	4D 1G
j01an002	Orosz	The mass of the black hole in the X-ray nova XTE J1118+480	5D
j01bn001	Ferguson	Star formation in nuclear and outer regions in barred spirals	6B
w01an008	Vreeswijk	Rapid imaging of GRB error boxes and spectroscopy of GRB-related optical/IR transients	25 GRB override hours

JCMT

Programme	Principal Applicant	Title	Allocation (hrs/instrument/ weather)
m01an001	Papadopoulos	12CO J=3-2 emission in two extreme IRAS galaxies	40 B 3,4
m01an003	Cimatti	Searching for high-z ultraluminous IR galaxies among the reddest EROs30 S 2	30 S 2
m01an004	Kemper	Probing the superwind phase in asymptotic giant branch stars	18 MPI 1
m01an006	Israel	12CO/13CO ratios in galaxies	39 A/B 3,4
m01an007	Helmich	Evolution in high-mass star-forming regions	11 ABCDS/MPI 2
m01an008	Israel	Very warm gas in NGC 6946 and IC 342	36 SPIFI 1
m01an009	Boonman	Physical and chemical structure of the inner regions of massive protostars	29 ABD/MPI 1,2,3,4
m01an010	Jaffe	Cold neutral gas in cooling flows	12 C 1
m01an014	Bolatto	The molecular ISM in primitive galaxies	16 A/B/C/S 2
m01an015	Röttgering	Highly obscured radio galaxies	24 S 1,2
m01an016	Röttgering	Dust and the formation of massive galaxies at z > 3	44 S 1
m01an017	Knudsen	Resolving the submm background at sub-mJy levels	16 S 2
m01an018	van der Werf	Complete and accurate spectral energy distributions of ultraluminous IR galaxies	28 S 2
m01an019	van Dishoeck	Tracing the evolution of low-mass protostars	56 A/B/C/D 1,2,3,4
m01an020	Stark	Deuterium chemistry in young stellar objects	6 B 1
m01an020	Smith	SCUBA observations of gamma-ray burster counterparts	24 S 1,2,3 override

WSRT

Programme	Principal Applicant	Title	Allocation (hours)
r01a001	Snellen	Neutral hydrogen absorption towards nearby CSO/GPS galaxies	104
r01a002	van Leeuwen	The geometry of the emission region of radio pulsar B0809+74	15
r01a004	Fender	Circular polarisation and rapid variability of Cygnus X-3	28
r01a006	Chengalur	HI iaging of extremely metal poor dwarf galaxies	28
r01a007	Schoenmakers	The structure and formation of 'double-double' radio galaxies	156
r01a008	Schoenmakers	High-redshift giant radio galaxies: Evolution of the diffuse intergalactic medium	98
r01a009	Stappers	High precision timing program	150
r01a010	Kramer	Unique temporal and spectral variations in the pulse shape of the millisecond pulsar J1022+1001	21
r01a013	Haverkorn	ISM Rotation Measure distributions in a region of highly complex polarized structure	78
r01a015	Camilo	Measuring Scattering Timescales for New Inner Galactic Pulsars	10
r01a017	Rol	Continuation of rapid follow-up and long-term monitoring of GRB error boxes	360
r01a018	Walker	Lensing of Radio Pulsars	76
r01a019	Oosterloo	A Pilot Project for an All-Sky HI Survey	108

Programme	Principal Applicant	Title	Allocation
r01a021	de Bruyn	A second year of monitoring of J1819+3845	104
r01a022	Röttgering	A deep WSRT mosaic and the nature of extragalactic radio sources	224
r01a023	Tavarez	Nearby Galaxies and MoND: Does a Falsifiable Case Exist?	26
r01a024	van Albada	WHISP	78
r01a025	Snellen	Testing self-similar evolution in young radio-loud AGN: A progress report	24
r01a026	de Bruyn	Radiomicrolensing in the double lens B1600+434: constraining macho's at z=0.4	198

Semester 2001B

WHT

Programme	Principal Applicant	Title	Allocation (nights)
w01bn001	Ferguson	A Search for Recent Massive Star Formation in Gas-Rich Ellipticals/Sos	2G
w01bn003	Lacerda	Rotational Properties of (smaller) Kuiper Belt Objects	2G 1B
w01bn009	de Zeeuw	Mapping Early-Type Galaxies along the Hubble Sequence	2D
w01bn011	Hulleman	What powers the Anomalous X-ray Pulsar 4U~0142+61?	3D
w01bn012	Kuijken	Planetary Nebula kinematics of flattened galaxies	3D
w01bn014	Förster Schreiber	Near-infrared Snapshot Survey for Bright Lensed Red High-redshift Galaxies	3B
w01bn019	Vreeswijk	Rapid imaging of GRB error boxes and spectroscopy of GRB related optical/IR transients	25 GRB override hours
w01bn021	Mengel	Star formation history in nearby mergers	1G 1B
w01bn022	Nelemans	Identification of Low-Luminosity Cataclysmic Variable	4B

INT

Programme	Principal Applicant	Title	Allocation (nights)
i01bn001	Lacerda	Rotational Properties of (larger) Kuiper Belt Objects	2D 2G
i01bn002	Jimenez	A much-improved stellar library for stellar population synthesis	4B
i01bn004	Nelemans	Follow-up of possible type Ia supernova progenitors	7B
w01bn019	Vreeswijk	Rapid imaging of GRB error boxes and spectroscopy of GRB related optical/IR transients	25 GRB override hours

JKT

Programme	Principal Applicant	Title	Allocation (nights)
j01bn001	Ferguson	Star formation in nuclear and outer regions in barred spirals	4D 3G 6B
j01bn002	Noordermeer	Multi-color imaging of galaxies in the WHISP sample	4D 4G
w01bn019	Vreeswijk	Rapid imaging of GRB error boxes and spectroscopy of GRB related optical/IR transients	50 GRB override hours

JCMT

Programme	Principal Applicant	Title	Allocation (hrs/instrument/ weather)
m01bn001	Henning	Magnetic fields and star formation: Bok globules as a case study	36 SCUBA 2
m01bn002	Israel	Hot molecular gas in nearby galaxy centers	20 C,D 1,2
m01bn003	Israel	Molecular gas concentrations in galaxy centers	46 A,B 4
m01bn004	Helmich F	Unravelling the star-formation in Onsala 1	7 A,B,C,D,SCUBA 1,3,4,5
m01bn005	Helmich F	W3 & K3-50 – probing continuum density peaks	7 A,B,C,D,SCUBA 1,2,4,5
m01bn010	Kemper	Probing the superwind phase in Asymptotic Giant Branch stars	34 C,D 1
m01bn011	Boonman	Physical and chemical structure of the inner Regions of Massive protostars	5 A,B,D 1,3,4
m01bn012	van Dishoeck	Tracing the evolution of low-mass protostars	64 A,B,C,D,SCUBA 1,2,3,4
m01bn013	van Dishoeck	SCUBA/SIRTF studies of low mass star formation	38 SCUBA 1,2
m01bn014	van der Werf	CO J=3-2, 4-3 in luminous IRAS galaxies	20 B,C 1,2
m01bn015	Bolatto	The Molecular ISM in Primitive Galaxies	20 SCUBA 1
m01bn021	van der Werf	Gravitational lensing of high redshift starburst	24 SCUBA 1,2
m01bn023	Thi	The Chemical Composition of the FU~Orionis Binary System RNO 1B/1C	11 B 3
m01bn026	Röttgering	Dust and the formation of massive galaxies at z>3	20 SCUBA 1
m01bn030	Smith	SCUBA Observations of Gamma-Ray Burster Counterparts	24 SCUBA 1,2,3 override
m01bn031	Ehrenfreund	Interstellar biomolecules: a search for aziridine and pyrimidine	40 A,B 3
m01bn032	Stark	Deuterium chemistry in the early phases of star formation	32 A,C 2,3

WSRT

Programme	Principal Applicant	Title	Allocation (hours)
r01b001	Wakker	Deriving D/H and abundances for HVC complex C	56
r01b002	Bottema	The flattening of dark halos	84
r01b003	Best	Deep imaging of galaxies in the z=0.9 supercluster CL1604+43	78
r01b004	Rekhesh Mohan	HI absorption from the Warm Neutral Medium of the Galaxy	120
r01b006	Oosterloo	Spirals with beards	78
r01b007	Fender	Circular polarisation and rapid variability from radio-bright X-ray transients	39
r01b008	Fender	Radio counterparts of very hard neutron star and black hole X-ray binaries	26
r01b010	van Langevelde	A search for Formaldehyde in radio galaxies with known VLBI scale circumnuclear gas	54
r01b011	Kregel	HI structure and kinematics of the edge-on spiral NGC 5529	13
r01b012	Braun	Gas and Dark Matter in the Outskirts of M31	299
r01b013	de Bruyn	Continued monitoring of J1819+3845	119
r01b014	Kilborn	High Resolution HI Follow-up Observations of HIJASS Sources	96
r01b015	Neininger	The detailed magnetic field structure in the arms of M51	14
r01b016	De Breuck	A Sensitive Study of the Classic Synchrotron Halo Galaxy NGC 891	26
r01b019	Strom	Multi-frequency high-resolution polarimetry of millisecond pulsars	12
r01b020	Ramachandran	Time-variability of interstellar masers	26
r01b022	Mack	A Complete Sample of Neutral Hydrogen Absorbers Towards Nearby CSO/GPS Galaxies	130
r01b024	Rol	Continuation of rapid follow-up and long-term monitoring of GRB error boxes	351
r01b030	Stappers	High Precision Timing Program	200

Programme	Principal Applicant	Title	Allocation (hours)
r01b038	Garrett	Deep WSRT observations of the SIRTF first look survey, verification strip	78
r01b039	Johnston	Determining new and improved HI distances to pulsars	55
r01b040	Stappers	Simultaneous Multi-Wavelength Studies of an Eclipsing Binary Millisecond Pulsar	13
r01b041	Zwaan	The Evolution of HI in galaxies between z=0.01 and z=0.2	240
r01b042	van der Hulst	Tidally induced dwarf galaxies in Abell 1367?	13
r01b043	van der Hulst	Accretion of HI onto spiral disks	39
r01b044	Morganti	Looking for neutral hydrogen in starburst, far-IR bright radio galaxies	91
r01b047	de Bruyn	Radio microlensing in the double lens B1600+434	148
r01b048	Baan	Powerful OH megamasers in ultra-lunious infrared galaxies	16

ASTRON Organization and Financial Report

ASTRON Organization

Board

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Financial Report 2001

ASTRON Institute

Financial Report of 2001, compared with 2000

				2001	2000
		Budget	Actual	Difference	Actual
<u>INCOME</u>					
Government Grants-Min. of Education,Culture & Science		7,719,214	7,719,214	0	8,132,298
Subsidies/Contributions by third parties		4,086,833	4,106,893	20,060	1,195,485
Cash Management		68,521	101,472	32,951	130,979
Other Income		0	187,555	187,555	156,366
Total Income		11,874,568	12,115,134	240,566	9,615,128
<u>EXPENDITURE</u>					
Grants/Expenditure	Operations	8,184,564	8,281,856	97,292	7,133,989
	Provisions	34,034	34,034	0	34,034
	Projects	3,655,970	3,626,056	-29,914	4,006,010
Total Expenditures		11,874,568	11,941,946	67,378	11,174,033
BALANCE		0	**173,188**	**173,188**	**-1,558,905**

all amounts in EURO's (€)

Publications

Publications by Astronomical Staff

Baan W.A., Kloeckner H.-R., Properties of OH Megamasers and Ultra-Luminous Infrared Galaxies, in: The Central Kiloparsec of Starbursts and AGN: The La Palma Connection ASP Conference Series, Vol. 249, 2001, J.H. Knapen, J.E. Beckman, I. Shlosman, and T.J. Mahoney, eds.

Barnes D. G., Staveley-Smith L., de Blok W. J. G., **Oosterloo T.**, Stewart I. M., Wright A. E., Banks G. D., Bhathal R., Boyce P. J., Calabretta M. R., Disney M. J., Drinkwater M. J., Ekers R. D., Freeman K. C., Gibson B. K., Green A. J., Haynes R. F., te Lintel Hekkert P., Henning P. A., Jerjen H., Juraszek S., Kesteven M. J., Kilborn V. A., Knezek P. M., Koribalski B., Kraan-Korteweg R. C., Malin D. F., Marquarding M., Minchin R. F., Mould J. R., Price R. M., Putman M. E., Ryder S. D., Sadler E. M., Schröder A., Stootman F., Webster R. L., Wilson W. E., Ye T. "The Hi Parkes All Sky Survey: southern observations, calibration and robust imaging" Monthly Notices of the Royal Astronomical Society, Volume 322, Issue 3, pp. 486-498. (2001)

Bradley L. D., Kaiser M. E., **Baan W. A.** "Physical Conditions in the Narrow Line Region of M51" American Astronomical Society Meeting 199, #99.03 (2001)

Braun R. "Compact High Velocity Clouds" Gas and Galaxy Evolution, ASP Conference Proceedings, Vol. 240. Edited by John E. Hibbard, Michael Rupen, and Jacqueline H. van Gorkom. San Francisco: Astronomical Society of the Pacific, ISBN: 1-58381-077-3, p. 479 (2001)

Braun R., Burton W. B. "Status of H I searches for CHVCs beyond the Local Group" Astronomy and Astrophysics, v.375, p.219-226 (2001)

Briggs F. H., **de Bruyn A. G.**, **Vermeulen R. C.** "Cold gas kinematics in an L_* spiral Galaxy at $z = 0.437$: The nature of Damped Lyman-alpha absorbers" Astronomy and Astrophysics, v.373, p.113-121 (2001)

Britzen S., **Vermeulen R. C.**, Taylor G. B., Campbell R. M., Browne I. W., Wilkinson P., Pearson T. J., Readhead A. C. S. "The Properties of the Gamma-ray Blazars in the CJ-F VLBI Sample" High Energy Gamma-Ray Astronomy, International Symposium held 26-30 June, 2000, in Heidelberg, Germany. American Institute of Physics (AIP) Proceedings, volume 558. Edited by Felix A. Aharonian and Heinz J. Völk. Published by American Institute of Physics, Melville, New York, ISBN 1-56396-990-4, p.721 (2001)

Burton W. B., **Braun R.**, Chengalur J. N. "Arecibo imaging of compact high-velocity clouds" Astronomy and Astrophysics, v.369, p.616-642 (2001)

Burton W. B., **Braun R.**, Chengalur J. N. "Arecibo imaging of compact high-velocity clouds" Astronomy and Astrophysics, v.375, p.227 (2001)

Chengalur J. N., **Braun R.**, Wieringa M. "HI in Abell 3128" Astronomy and Astrophysics, v.372, p.768-774 (2001)

de Bruyn A. G., Dennett-Thorpe J. "The Microarcsecond Quasar J1819+3845: Polarization Observations and Detailed Lightcurve Analysis" Astrophysics and Space Science, v. 278, Issue 1/2, p. 139-142 (2001).

Dennett-Thorpe J., **de Bruyn A. G.** "Monitoring the Microarcsecond Quasar J1819+3845" Astrophysics and Space Science, v. 278, Issue 1/2, p. 101-104 (2001).

Dickel J. R., **Strom R. G.**, Milne D. K. "The Radio Structure of the Supernova Remnant G315.4-2.3 (MSH 14-63)" The Astrophysical Journal, Volume 546, Issue 1, pp. 447-454. (2001)

Ensslin T. A., Simon P., Biermann P. L., Klein U., Kohle S., Kronberg P. P., **Mack K.** "Signatures in a Giant Radio Galaxy of a Cosmological Shock Wave at Intersecting Filaments of Galaxies" The Astrophysical Journal, Volume 549, Issue 1, pp. L39-L42. (2001)

Fraternali F., **Oosterloo T.**, Sancisi R., van Moorsel G. "The HI Halo of NGC 2403" Gas and Galaxy Evolution, ASP Conference Proceedings, Vol. 240. Edited by John E. Hibbard, Michael Rupen, and Jacqueline H. van Gorkom. San Francisco: Astronomical Society of the Pacific, ISBN: 1-58381-077-3, 2001, p. 286 (2001)

Fraternali F., **Oosterloo T.**, Sancisi R., van Moorsel G. "A New, Kinematically Anomalous H I Component in the Spiral Galaxy NGC 2403" The Astrophysical Journal, Volume 562, Issue 1, pp. L47-L50. (2001)

Fridman P. A., **Baan W. A.** "RFI mitigation methods in radio astronomy" Astronomy and Astrophysics, v.378, p.327-344 (2001)

Gaensler B. M., **Stappers B. W.**, Kaspi V. M., van der Klis M., Lewin W. H. G. "Chandra Imaging of the Black Widow Pulsar B1957+20" American Astronomical Society Meeting 199, #17.03 (2001)

Garrett M. A., Muxlow T. W. B., Garrington S. T., Alef W., Alberdi A., van Langevelde H. J., Venturi T., Polatidis A. G., Kellermann K. I., **Baan W. A.**, Kus A., Wilkinson P. N., Richards A. M. S. "AGN and starbursts at high redshift: High resolution EVN radio observations of the Hubble Deep Field" Astronomy and Astrophysics, v.366, p.L5-L8 (2001)

Jones H., **Stappers B.**, Gaensler B. "Discovery of a bow-shock nebula around the pulsar B0740-28" The Messenger, No. 103, p. 27 (March 2001)

Koopmans L. V. E., **de Bruyn A. G.** "Microlensing & Scintillation of Gravitationally Lensed Compact Radio Sources: Evidence for MACHOs?" Gravitational Lensing: Recent Progress and Future Go, ASP Conference Proceedings, Vol. 237. Edited by Tereasa G. Brainerd and Christopher S. Kochanek. San Francisco: Astronomical Society of the Pacific, ISBN: 1-58381-074-9, p.193 (2001)

Koopmans L. V. E., Blandford R. D., **de Bruyn A. G.**, Fassnacht C. D., Wambsganss J. "Microlensing and Stellar Remnants" American Astronomical Society Meeting 198, #37.02 (2001)

Marlow D. R., Rusin D., Norbury M., Jackson N., Browne I. W. A., Wilkinson P. N., Fassnacht C. D., Myers S. T., Koopmans L. V. E., Blandford R. D., Pearson T. J., Readhead A. C. S., **de Bruyn A. G.** "CLASS B0739+366: A New Two-Image Gravitational Lens System" The Astronomical Journal, Volume 121, Issue 2, pp. 619-624 (2001).

Menéndez-Delmestre K., **Mack K.-H.**, **Schoenmakers A. P.**, **de Bruyn A. G.** "B1834+620 - a Double-Double Radio Galaxy" Astronomische Gesellschaft Abstract Series, Vol. 18. Abstracts of Contributed Talks and Posters presented at the Annual Scientific Meeting of the Astronomische Gesellschaft at the Joint European and National Meeting JENAM 2001 of the European Astronomical Society and the Astronomische Gesellschaft at Munich, September 10-15, 2001, abstract #P171 (2001).

Mitra D., **Ramachandran R.** "Scatter broadening of pulsars in the direction of the Gum nebula" Astronomy and Astrophysics, v.370, p.586-590 (2001).

Morganti R., Oosterloo T., Tadhunter C. N., Wills K. A. "Neutral and Ionized Gas Distribution In and Around the Radio Galaxy Coma A" Gas and Galaxy Evolution, ASP Conference Proceedings, Vol. 240. Edited by John E. Hibbard, Michael Rupen, and Jacqueline H. van Gorkom. San Francisco: Astronomical Society of the Pacific, ISBN: 1-58381-077-3, p. 236 (2001).

Morganti R., Oosterloo T. A., Tadhunter C. N., van Moorsel G., Killeen N., Wills K. A. "Hi absorption in radio galaxies: effect of orientation or interstellar medium?" Monthly Notices of the Royal Astronomical Society, Volume 323, Issue 2, pp. 331-342 (2001).

Oosterloo T., Morganti R., Sadler E. M. "H I in Early-Type Galaxies" Gas and Galaxy Evolution, ASP Conference Proceedings, Vol. 240. Edited by John E. Hibbard, Michael Rupen, and Jacqueline H. van Gorkom. San Francisco: Astronomical Society of the Pacific, ISBN: 1-58381-077-3, p. 251 (2001).

Paragi Z., Fejes I., **Vermeulen R. C.**, Schilizzi R. T., Spencer R. E., Stirling A. M. "Radio Properties of the Compact Jets and the Equatorial Emission Region in SS433" Astrophysics and Space Science, v. 276, p. 131-132 (2001).

Paragi Z., Fejes I., **Vermeulen R. C.**, Schilizzi R. T., Spencer R. E., Stirling A. M. "Radio properties of the compact jets and the equatorial emission region in SS 433." Astrophys. Space Sci. Suppl., 276, 131-132 (2001).

Pihlström Y. M., Conway J. E., **Vermeulen R. C.**, Taylor G. B. "Probing Neutral Gas in Radio Sources with $0.2<z<1$" Gas and Galaxy Evolution, ASP Conference Proceedings, Vol. 240. Edited by John E. Hibbard, Michael Rupen, and Jacqueline H. van Gorkom. San Francisco: Astronomical Society of the Pacific, ISBN: 1-58381-077-3, p. 64 (2001)

Rol E., Vreeswijk P., Salamanca I., Kaper L., Wijers R., **Strom R.**, **Foley T.** "GRB 011030, WSRT radio observations." GRB Circular Network, 1124, 1 (2001).

Rusin D., Marlow D. R., Norbury M., Browne I. W. A., Jackson N., Wilkinson P. N., Fassnacht C. D., Myers S. T., Koopmans L. V. E., Blandford R. D., Pearson T. J., Readhead A. C. S., **de Bruyn A. G.** "The New Two-Image Gravitational Lens System CLASS B2319+051" The Astronomical Journal, Volume 122, Issue 2, pp. 591-597 (2001).

Ryder S. D., Koribalski B., Staveley-Smith L., Kilborn V. A., Malin D. F., Banks G. D., Barnes D. G., Bhatal R., de Blok W. J. G., Boyce P. J., Disney M. J., Drinkwater M. J., Ekers R. D., Freeman K. C., Gibson B. K., Henning P. A., Jerjen H., Knezek P. M., Marquarding M., Minchin R. F., Mould J. R., **Oosterloo T.**, Price R. M., Putman M. E., Sadler E. M., Stewart I., Stootman F., Webster R. L., Wright A. E. "HIPASS Detection of an Intergalactic Gas Cloud in the NGC 2442 Group" The Astrophysical Journal, Volume 555, Issue 1, pp. 232-239. (2001)

Sadler E. M., **Oosterloo T., Morganti R.** "HI Gas Disks in Elliptical Galaxies" in Galaxy Disks and Disk Galaxies, proceeding of a conference held in Rome, Italy, June 12-16, 2000 at the Pontifical Gregorian University and sponsored by the Vatican Observatory. ASP Conference Series, Vol. 230. Edited by José G. Funes, S. J. and Enrico Maria Corsini. San Francisco: Astronomical Society of the Pacific. ISBN: 1-58381-063-3, pp. 285-288 (2001).

Sancisi R., Fraternali F., **Oosterloo T.**, van Moorsel G. "The Vertical Structure and Kinematics of HI in Spiral Galaxies" in Galaxy Disks and Disk Galaxies, proceeding of a conference held in Rome, Italy, June 12-16, 2000 at the Pontifical Gregorian University and sponsored by the Vatican Observatory. ASP Conference Series, Vol. 230. Edited by José G. Funes, S. J. and Enrico Maria Corsini. San Francisco: Astronomical Society of the Pacific. ISBN: 1-58381-063-3, pp. 111-118 (2001).

Sancisi R., Fraternali F., **Oosterloo T.**, van Moorsel G. "The HI Halos of Spiral Galaxies" Gas and Galaxy Evolution, ASP Conference Proceedings, Vol. 240. Edited by John E. Hibbard, Michael Rupen, and Jacqueline H. van Gorkom. San Francisco: Astronomical Society of the Pacific, ISBN: 1-58381-077-3, p. 241 (2001).

Schoenmakers A. P., de Bruyn A. G., Röttgering H. J. A., van der Laan H. “A new sample of giant radio galaxies from the WENSS survey. I. Sample definition, selection effects and first results” Astronomy and Astrophysics, v.374, p.861-870 (2001) .

Setia Gunawan D. Y. A., **de Bruyn A. G.**, van der Hucht K. A., Williams P. M. “WSRT 1.4 and 5-GHz light curves for WR 147 (AS 431, WN8(h)+OB)” Astronomy and Astrophysics, v.368, p.484-496 (2001) .

Snellen I. A. G., McMahon R. G., Dennett-Thorpe J., Jackson N., **Mack K.-H.**, Xanthopoulos E. “A search for distant radio-loud quasars in the CLASS survey: three new radio-selected quasars at z > 4” Monthly Notices of the Royal Astronomical Society, Volume 325, Issue 3, pp. 1167-1172. (2001).

Sohn B. W., Klein U., **Mack K.-H.** “The Spectral-curvature Parameter: A New Tool for the Analysis of Synchrotron Spectra” Astronomische Gesellschaft Abstract Series, Vol. 18. Abstracts of Contributed Talks and Posters presented at the Annual Scientific Meeting of the Astronomische Gesellschaft at the Joint European and National Meeting JENAM 2001 of the European Astronomical Society and the Astronomische Gesellschaft at Munich, September 10-15, 2001 abstract #P170 (2001).

Stappers B. W., van Kerkwijk M. H., Bell J. F., Kulkarni S. R. “Intrinsic and Reprocessed Optical Emission from the Companion to PSR J2051-0827” The Astrophysical Journal, Volume 548, Issue 2, pp. L183-L186 (2001).

Stappers B. W., Bailes M., Lyne A. G., Camilo F., Manchester R. N., Sandhu J. S., Toscano M., Bell J. F. “The nature of the PSR J2051-0827 eclipses” Monthly Notices of the Royal Astronomical Society, Volume 321, Issue 3, pp. 576-584 (2001).

Strom R. G., Smolders B., van Ardenne A. “Active Adaptive Arrays: The ASTRON Approach to SKA” Astrophysics and Space Science, v. 278, Issue 1/2, p. 209-212 (2001).

Tadhunter C., Wills K., **Morganti R., Oosterloo T.**, Dickson R. “Emission-line outflows in PKS1549-79: the effects of the early stages of radio-source evolution?” Monthly Notices of the Royal Astronomical Society, Volume 327, Issue 1, pp. 227-232 (2001).

Thilker D. A., **Braun R.**, Walterbos R. A. M. “A High-Resolution VLA Mosaic of HI in M 33” Gas and Galaxy Evolution, ASP Conference Proceedings, Vol. 240. Edited by John E. Hibbard, Michael Rupen, and Jacqueline H. van Gorkom. San Francisco: Astronomical Society of the Pacific, ISBN: 1-58381-077-3, p. 456 (2001).

Venturi T., Bardelli S., Zambelli G., **Morganti R.**, Hunstead R. W. “Radio properties of the Shapley Concentration - IV.The A3528 cluster complex” Monthly Notices of the Royal Astronomical Society, Volume 324, Issue 4, pp. 1131-1146 (2001).

Wilkinson P. N., Henstock D. R., Browne I. W. A., Readhead A. C. S., Pearson T. J., Taylor G. B., **Vermeulen R. C.** “Are There any Millilenses?” Gravitational Lensing: Recent Progress and Future Go, ASP Conference Proceedings, Vol. 237. Edited by Tereasa G. Brainerd and Christopher S. Kochanek. San Francisco: Astronomical Society of the Pacific, ISBN: 1-58381-074-9, p.37 (2001).

Wilkinson P. N., Henstock D. R., Browne I. W., Polatidis A. G., Augusto P., Readhead A. C., Pearson T. J., Xu W., Taylor G. B., **Vermeulen R. C.** “Limits on the Cosmological Abundance of Supermassive Compact Objects from a Search for Multiple Imaging in Compact Radio Sources” Physical Review Letters, vol. 86, Issue 4, pp. 584-587 (2001)

Technical Laboratory

Publications

Achterop S., **de Vos C.M., van der Schaaf K.**, Spaanenburg L., “Architectural Requirements for a LOFAR Generic Node”, Proceedings of ProRise 2001, ISBN 90-73461-29-4.

Alliot S., Deprettere E., **de Vos C.M.**, “A model for architecture exploration, scaling generic blocks for very large phased array telescopes”, accepted for SPIE workshop on integrated modeling, Lund, Sweden, 6-7 Feb 2002.

Alliot S., Soudani M., **Bregman J.**, “Comparison of filters with a polyphase structure applied to large embedded systems for telescopes”, accepted for IEEE SPS conference, Leuven, 21-22 march 2002.

Bij de Vaate J. G., From the Adaptive Antenna Demonstrator to SKA, invited for the SMi conference: Adaptive Antennas, 29th & 30th October 2001, London.

Bij de Vaate J.G., Geskus D., Witvers R.H., “Integrated Active Antenna Noise Figure Characterization Using a Cryogenic Anechoic Noise Source”, London, 31st European Microwave Conference, Proceedings Volume I, pg. 425-428, September 24-28, 2001.

Boonstra A.J. and van der Veen A.J., “Gain Decomposition Methods for Radio Telescope Arrays”, accepted for the 11th IEEE Workshop on Statistical Signal Processing, Singapore, 6-8 August 2001

Boonstra A.J., “Radio frequency monitoring for radio astronomy, Purpose, Methods and formats”, IUCAF RFI Mitigation workshop, MPIfR, Bonn, Germany, 28-30 March 2001

Boonstra A.J., "RFI suppressie onderzoek (NOEMI project) "Radiotelescoop leert ethervervuiling omzeilen", Universiteitskrant TU Delft, Jaargang 33, nummer 8, 07-03-01

Boonstra A.J., van der Veen A.J., Leshem A., Raza J., Calders R., **Schoonderbeek G.**, "Exploiting the spatial signature of communications signals received at the WSRT", IUCAF RFI Mitigation workshop, MPIfR, Bonn, Germany, 28-30 March 2001

Craeye C., **Smolders A.B.**, Tijhuis A.G., Schaubert D.H., "Computation of finite array effects in the framework of the square kilometre array project" IEE Conference on Antennas and Propagation, Manchester, UK, April 2000, Proc., pp. 298-301

de Vos C.M., **van der Schaaf, K.**, **Bregman J.**, " Cluster Computers and Grid Processing in the First Radio-Telescope of a New Generation", IEEE Conference CCGrid 2001, Brisbane, May 2001

de Vos, C.M., Baudry, A. Proceedings of 2nd ALMA BEE team meeting, 02-02-01

Fleurke S.R., Dehling H.G., **Boonstra A.J.**, Brinkerink A.D.,. den Besten R, "Monte-Carlo methods for measuring spectrum occupancy", IUCAF RFI Mitigation workshop, MPIfR, Bonn, Germany, 28-30 March 2001

G.A., **Hampson**, **Bij de Vaate J.G.**, "Initial Calibration and Beamforming Results from the Thousand Element Phased Array", 2001 IEEE AP-S International Symposium and USNC/URSI National Radio Science Meeting, Boston, Proceedings Pg. 610-613, July 8-13, 2001.

Gunst A.W., **Kant G.W.**, "Application of digital wide band mismatch calibration to an I/Q receiver", accepted for ISCAS 2002 Conference, Phoenix, Arizona May 26-29, 2002.

Hampson G.A., **Bij de Vaate J.G.**, "Verification of THEA Tile Calibration and Beamforming Results using a Near Field Scanner", London, 31st European Microwave Conference, Proceedings Volume III Pg. 141-144, September 24-28, 2001.

Kokkeler A.B.J., **Fridman P.**, **van Ardenne A.**, "Degradation due to quantization noise in radio astronomy phased arrays", Aceepted 5 February 2001 for publication in Experimental Astronomy 11: 33-56, 2001

Nicolae L., **Alliot S.**, Deprettre E., "Distributed Massively Parallel Real-Tim Computing: Deriving Specifications from Requirements", accepted for MPCS 2002 The 4th International Conference on Massively Parallel Computing Systems, Ischia, Italy April 9-12, 2002,

Notaros, B.M., Popovic, B.D., **Peeters Weem, J.P.**, Brown, R.A., Popovic, Z. "Efficient large-domain MoM solutions to electrically large practical EM problems", IEEE transactions on microwave theory and techniques", Vol. 49, no. 1, Jan. 01

Peeters Weem J.P., Popovic Z., "A method for determining noise coupling in a phased array antenna, June 2001 IEEE International Microwave Symposium 2001 A Microwave Odyssey, Phoenix, Arizona 20-25 May 2001

Strom R.G., **Smolders B.**, **van Ardenne A.**, "Active Adaptive Arrays: The ASTRON approach to SKA", Astrophysics and Space Science September 29, 2001

Van Voorst P.D., **Bregman J.D.**, "Stability of coherent signal transport in few mode fibres", proceedings of IEEE/LEOS Benelux Chapter Symposium 2001, 3 Dec, Brussels

Witvers R.H., **Bij de Vaate, J.G.**," DC to 11 GHz fully Integrated GaAs Up Conversion Mixer, 31st European Microwave Conference", GAAS 21001, London, Proceedings Pg. 599-602, September 24-25, 2001.

Reports

Alliot S., "Scalability and extension of the THEA blocks towards very large phased arrays", Report Massive-00409, 01-Nov-2001

Alliot S., Soudani M., "Comparison of filters with a polyphase structure and correlation", Doc.nr. Report-010 ASTRON-28000-R1, 04-09-01

Alliot S., "Coherent Dedispersion Feasibility Study Plan", Plan PUMA II-00202, 17-01-01

Apeldoorn O.. "The Poly-Phase network", Doc.nr. Report-001 26500-R1, 11-07-01

Apeldoorn O., "Design and measurement Report D LNA 0699", Doc.nr. 26500-R1, 07-09-01

Apeldoorn O., "Design Report SiGe MPW RUN 05-2000, Design report-002 26500-R1, 09-07-01

Beuving J., "Procedures and User Manual for the technical R & D documentation", Description TL-00417, 16-Nov-2001

Beuving,J., "The ASTRON Science Instrument Development Process", Description TL-00197, 08-01-01

Bij de Vaate J.G., "SETI ATA Down Conversion Unit Project Plan", Report SETI-00224, 20-02-01

Borsboon M.S., "Kijk op Kwaliteit", Report TL-00400, 19-Oct-2001

Butcher H.R., LOFAR-ASTRON-PLN-002 1.0 ICES/KIS Expression of Interest SDE 26-Nov-2001

Craeye C., "A note on Noise Coupling in Antenna Arrays", Report SKA-00435, 18-Dec-2001

Craeye C., "A Note on the Polarization Sensitivity of a Pair of Antennas", Report SKA-00438, 18-Dec-2001

Craeye C., "An Efficient Computation Scheme for the free space Green's Function of a ..", Report SKA-00439, 18-Dec-2001

Craeye C., "Basics on THEA Calibration", Report SKA-00437, 18-Dec-2001

Craeye C., “On the Effect of Couplings in LOFAR beamforming: Basic Concepts”, ASTRON-LOFAR-00434, 18-Dec-2001

Craeye C., “On the Significance of the Active Input Impedance in Receiving Arrays”, Report SKA-00436, 18-Dec-2001

Damstra S., “Circuit diagrams of the MIDI wiring”, Doc.nr. Report 27000-8-3-1-R1, 03-07-01

De Haas J., “MIDI Project Status Rapport”, Note MIDI-00223, 19-02-01

de Vos C.M., “System Engineering Support”, Doc.nr. Report ASTRON-LOFAR-00359, 14-09-01

De Vos, C.M., “Specification and Scheduling System, up to PDR”, Doc.nr. Report ASTRON-LOFAR-00360, 14-09-01

De Vos C.M., LOFAR-ASTRON-PLN-001 1.0 “LOFAR Design & Engineering Project Plan up to PDR: ASTRON activities” SDE 26-Nov-2001

De Vos C.M., LOFAR-ASTRON-PRC-001 1.0 “Procedures for LOFAR Document Server” SDE 26-Nov-2001

Doorduin A. “Test plan and production documentation TFEC”, Doc.nr. 26640-1-5-3-R1”, 05-09-01

Doorduin A., “Design Ideas about the HSL transmitter and receiver boards”, Doc.nr. Report 26640-4-1-R1SKA Project ASTRON Dwingeloo, 31-08-01

Doorduin A., “The THEA High-Speed-Link”, Doc.nr. 26640-4-1-R1, 05-09-01

Doorduin A., “THEA Front-end Processor”, Doc.nr. 26640-1-5-3-3-R1, 05-09-01

Ebbendorf N., “Description of the IVC LO-Module”, W382-03-02-02-06 dok4, November 2001

Ebbendorf N., “IVC Control Functions”, W382-03-02-02-04 3iudok1, December 2001

Ebbendorf N., “Description of the IVC LO module”, Doc W382-03-02-02-06, 31-Oct-2001

Ebbendorf N., “IVC Cabinet wiring”, Doc W382-03-02-04, 20-Dec-2001

Elswijk E.J., “Test Report Prototype Slider”, Doc.nr. 27000-9-1-R1, 25-09-01

Elswijk E.J., “Test Report Switch”, Doc.nr. 27000-R1, 25-09-01

Elswijk E.J., “Test Report: Acceptance Tests Spectrometer Cryomechanisms”, VLT-TRE-VIS-14321 5062, 14-Nov-2001

Eybergen A., “Temperature stability of IVC LO-modules”, Doc.nr. W382-03-02-02-06, 19-07-01

Glazenborg A.W., “MIDI Cold Optics Safety and Handling Instructions”, Doc.nr. Report-001 27000-R1, 20-09-01

Gunst A., “Test results of the IDC”, Test Report 26640-1-6-2-R1, 18-Dec-2001

Gunst A.W., “ALMA Filter Bank Specifications and Delay Tracking”, Report-006 ASTRON-280000-R1, 09-Nov-2001

Gunst A.W., “Cascading FIR Filters for ALMA”, Report-009 ASTRON-28000-R1, 14-Nov-2001

Halfwerk R., “Beschrijving van het EM gedrag van een tag als functie van de afstand tot de reader”, Report Skai-high-00205, 26-01-01

Hamaker J.J., “A matrix-based polarimetric model for the proposed PLANCK CMBP experiment”. Submitted to ESTEC, December 13

Hampson G., “Initial Calibration and Beamforming Results from the Thousand Element Phased-Array”, Paper THEA-00208, 01-02-01

Hampson G., “Verification of THEA Tile Calibration and Beamforming Results using a Near Field Scanner”, Paper THEA-00209, 01-02-01

Kant G.W., “Voorstel voor een miniaturisatieconcept voor een optisch sensorsysteem”, Report Skai-high-00198, 08-01-01

Koopman Y., “OmegaCam Assistance”, Memo OmegaCam-00445, 19-Dec-2001

Kragt J., “Long Camera Spherical Mirror Unit Preliminary design report”, Report 001 28500-4 000-R1, 14-Dec-2001

Lawerman E., LOFAR-ASTRON-ADD-005 1.0 “Software Design Description for LOFAR MAC architecture” MAC 27-Dec-2001

Lawerman E., LOFAR-ASTRON-MEM-004 1.0 “MAC-SAS interface studies” SDE 29-Nov-2001

LOFAR-ASTRON-ADD-001 1.0 “LOFAR System Definition v2.0” SDE WPM 21-Nov-2001

LOFAR-ASTRON-RPT-001 1.0 “Performance measurements in the LOFARSim/CEPFrame programming environment” CEP WPM 18-Dec-2001

LOFAR-ASTRON-SRS-001 1.0 “LOFAR System Requirements Specification” SDE 20-Nov-2001

Loose G.M., “Status TECH Software”, Report-001-26640-2-2-2-R1, 11-Oct-2001

Loose G.M., “THEA Tracking Control Requirements”, Report-001-26640-2-2-3-R1, 11-Oct-2001

Montero M.J., “Beam Scanning and Nulling Performance of a reflector antennas with phased array feed”, Master’s thesis, October 2001, Eindhoven University of Technology

Montero M.J., “Feasibility study on reflector antennas with phased array feed”, Interim rapport 3, 02-01

Morawietz J., “THEA Design Review: Status of the THEA Receiver Unit”, Report THEA-00331, 03-07-01

Morawietz J. , “THEA Receiver Test Report” 26640-1-6-1-R1, 29-Nov-2001

Mulder E., “LO1 band Pass Filter. Info form for PCB manufacturing”, Note IVC-000137, October 2001

Noordam J., “Guidelines for the LOFAR Station Configuration”, Report ASTRON-LOFAR-00226, 26-02-01

Noordam J., LOFAR-ASTRON-MEM-001 1.0 “LOFAR Calibration and Calibratability” SDE 27-Nov-2001

Noordam J., LOFAR-ASTRON-MEM-002 1.0 “Guidelines for the LOFAR Array Configuration” SDE 27-Nov-2001

Noordam J., LOFAR-ASTRON-MEM-003 1.0 “Calibration Block Diagram for the LOFAR Imaging Mode” SDE 27-Nov-2001

Pel J.W., “Anomalous behaviour of Cryomechanism #6 after cold tests”, VLT-MEM-VIS-14321 5030, 14-Nov-2001

Pepping H.J., “Assembling and Testing of a Data Acquisition System”, Doc.nr. Report-001 26640-2-R1, 20-09-01

Pragt J.H., “The Mechanical Design PDR”, Report 002 28500-0 000-R1, 05-Dec-2001

Pragt J., “SPIFFI 2Kx2K camera”, Project Plan SPIFFI-00424, 7-Dec-2001

Pul P., “Detector unit and Field flettener lens Preliminary design report”, Report 001 28500-6 000-R1, 17-Dec-2001

Pul P., “Flat Unit Preliminary Design Report”, Report 001 28500-3 000-R1, 13-Dec-2001

Pul P., “Hartmann Shutter Preliminary design”, Report 001 28500-1 000-R1, 07-Dec-2001

Pul P., “Meniscus Unit Preliminary Design Report”, Report 001 28500-2 000-R1, 29-Nov-2001

Pul P., “Parametrisch opzetten van een rits type DM m.b.v. 3D-CAD”, Report BTT-00444, 19-Dec-2001

Schoenmaker T., “Optical design at PDR”, Report 001 28500-0 000-R1, 16-Dec-2001

Schoonderbeek G., “Board Description of the DBF”, Description 26640-2-1-1-R1, 26-02-01

Smirnov O., “A Publish/Subschribe Communications Fabric for the LOFAR Central Processor. Design Proposal” ASTRON-LOFAR-00414, 12-Nov-2001

Smirnov O., “Data Management Techniques for the PSCF (LOFAR CPA)”, Report ASTRON-LOFAR-00425, 12-Dec-2001

Smirnov O., LOFAR-ASTRON-ADD-002 1.0 “A Publish/Subscribe Communications Fabric For The LOFAR Central Processor” SDE 07-Dec-2001

Smirnov O., LOFAR-ASTRON-ADD-003 1.0 “Data Management Techniques For The PSCF SDE” 07-Dec-2001

Tromp N., “Associatief 5-assig simultaan frezen van een rits type DM m.b.v. 3D-CAD”, Report BTT-0443, 19-Dec-2001

van de Meulen M., ”Mixer Fundamentals”, Doc.nr. Report-002 26500-R1, 20-07-01

van der Meulen M., “Measurement Report Feed Forward Linearized RF Low Noise Amplifier”, Doc.nr. Measurement Report RFIRobust-00349, September 2001

van der Meulen M., “Modelling of Feed Forward Linearized RF Low Noise Amplifiers”, Doc.nr. Report RFIRobust-00246, ASTRON Dwingeloo, April 2001

van der Meulen M., “Feedforward Linearized RF Low Noise Amplifier”, Measurement Report RFIRobust-00349, 11-09-01

Van der Schaaf K., ”LOFAR Central Processor pre-design”, Doc.nr. Report ASTRON-LOFAR-00335, 09-07-01

van der Schaaf K., “Integration of the LOFAR Central Processing computer System”, ASTRON-LOFAR000395, 17-Oct-2001

Van der Schaaf K., “LOFAR Central Processor Cluster System Administration”, ASTRON-LOFAR-00407 31-Oct-2001

Van der Schaaf K., LOFAR-ASTRON-ADD-004 1.0 “LOFAR Central Processor pre-design” CEP 18-Dec-2001

Van der Schaaf K., LOFAR-ASTRON-MEM-007 1.0 “Publish-subscribe mechanisms in LOFARSim” CEP 10-Dec-2001

Van der Schaaf K., LOFAR-ASTRON-MEM-008 1.0 “LOFAR CEP Software development Coding Standard” CEP 18-Dec-2001

Van der Schaaf K., LOFAR-ASTRON-MEM-009 1.0 “Central Platform Corba interfaces” CEP 19-Dec-2001

Van der Schaaf K., LOFAR-ASTRON-SER-001 1.0 LOFARSim Architecture SDE 07-Dec-2001

van Diepen G., LOFAR-ASTRON-MEM-006 1.0 LOFAR Build Environment SDE 07-Dec-2001

Van Es A., THEA deliverables aan andere projecten, report TL-0431, 14-Dec-2001

Van Es A., “Introduktie nieuwe processen”, Memo TL-00225, 26-02-01

van Haarlem M.P., “LOFAR Scientific Applications”, Report ASTRON-LOFAR-00230, 06-03-01

Wierenga K.J., LOFAR-ASTRON-MEM-005 1.0 “MAC Use Case Workshop Guidelines” MAC 07-Dec-2001

Wierenga K.J., LOFAR-ASTRON-PLN-003 1.0 “MAC Use Case Workshops Planning” MAC 07-Dec-2001

Wierenga K.J., LOFAR-ASTRON-UCD-002 1.0 “MAC Use Case - Antenna Defect” MAC 05-Dec-2001

Woestenburg E.E.M, “IVC System tree structure”, W382-03 dok10.doc, October 2001

Woestenburg E.E.M. , “Composition IVC Splitter/selector Module”, Doc W382-03-02-02-04, 23-Oct-2001

Woestenburg E.E.M. et al, “Verslag en sheets overdracht IVC”, W382-03 dok9, October 2001

Woestenburg E.E.M., “Composition IVC Power Supply Monitor Module”, W382-03-02-02-09 dok3.doc, October 2001

Woestenburg E.E.M., “Composition IVC Converter Controller Module”, W382-03-02-02-05 dok3.doc, October 2001

Woestenburg E.E.M., “Composition IVC Filter Module”, W382-03-02-02-07 dok5.doc, October 2001

Woestenburg E.E.M., “Composition IVC LO Module”, W382-03-02-02-06 dok3.doc, October 2001

Woestenburg E.E.M., “Composition IVC Splitter/selector Module”, W382-03-02-02-04 dok1.doc, October 2001

Woestenburg E.E.M., “Composition of the IVC Converter Module”, W382-03-02-02-03 dok4.doc, October 2001
Woestenburg E.E.M., “Description of the realised IVC-system”, W382-03 dok11, October 2001
Woestenburg E.E.M., “Final Report on Interference suppression in radio astronomy receivers. Sub-project 2 of TMR-LSF RTD Project “Enhancing the European VLBI Network of Radio Telescopes”, Report-004 29300-R1, October 2001
Woestenburg E.E.M., “IVC technische commissioning”, Doc.nr. W383-03 dok7.wpd, ASTRON Dwingeloo, May 2001
Woestenburg E.E.M., “IVC Technische Commissioning”, Doc.Nr. W382-03, 17-07-01
Woestenburg E.E.M., “Opbouw van het IVC-systeem”, Doc.nr. W382-03, 06-09-01
Woestenburg E.E.M., “Composition IVC Converter Controller Module”, Doc W382-03-02-02-05, 23-Oct-2001
Woestenburg E.E.M., “Composition IVC Filter Module”, Doc W382-03-02-02-07, 23-Oct-2001
Woestenburg E.E.M., “Composition IVC LO Module”, Doc W382-03-02-02-06, 31-Oct-2001
Woestenburg E.E.M., “Composition IVC Power Supply Monitor Module”, Doc W382-03-02-02-09, 23-Oct-2001
Woestenburg E.E.M., “Composition IVC, Converter Module”, Doc W382-03-02-02-03, 23-Oct-2001
Woestenburg E.E.M., “Description of the realised IVC-system”, Doc W382-03, 24-Oct-2001
Woestenburg E.E.M., “Final Report on Interference Suppression in Radio Astronomy Receivers”, Report-004 29300-R1, 31-Oct-2001
Woestenburg E.E.M., “IVC System tree structure”, Doc W382-03, 24-Oct-2001

Publications Based on WSRT and Dwingeloo Observations

Brüns C., Kerp J., Pagels A. “Deep HI observations of the compact high-velocity cloud HVC 125+41-207” Astronomy and Astrophysics, v.370, p.L26-L30 (2001)
Briggs F. H., de Bruyn A. G., Vermeulen R. C. “Cold gas kinematics in an L$_*$ spiral Galaxy at z = 0.437: The nature of Damped Lyman-alpha absorbers” Astronomy and Astrophysics, v.373, p.113-121 (2001)
Briggs F. H., Möller O., Higdon J. L., Trentham N., Ramirez-Ruiz E. “Did VV 29 collide with a dark Dark-Matter halo?” Astronomy and Astrophysics, v.380, p.418-424 (2001)
de Breuck C., van Breugel W., Rottgering H., Miley G. “A Sample of Ultra Steep Stectrum sources to find High Redshift Radio Galaxies” AGN Surveys, Proceedings of IAU Colloquium 184. Edited by R.F. Green, E.Ye. Khachikian, and D.B. Sanders. Publisher: ASP, Dates: June 18-22, 2001, Location: Byurakan, Armenia (2001)
de Pater I., Butler B. “Jupiter’s Radio Spectrum from 0.074 up to 15 GHz” American Geophysical Union, Fall Meeting 2001, abstract #SM12A-0834 (2001)
Dennett-Thorpe J., de Bruyn A. G. “Monitoring the Microarcsecond Quasar J1819+3845” Astrophysics and Space Science, v. 278, Issue 1/2, p. 101-104 (2001).
Dickel H. ;. ;. R., Goss W. M., De Pree C. G. “WSRT and VLA Observations of the 6 Centimeter and 2 Centimeter Lines of H_2CO in the Direction of W58C1 (ON 3) and W58C2” The Astronomical Journal, Volume 121, Issue 1, pp. 391-398. (2001)
Fridman P. A. “RFI excision using a higher order statistics analysis of the power spectrum” Astronomy and Astrophysics, v.368, p.369-376 (2001)
Garrido O. “GHASP: survey of H Alpha in spiral galaxies” Abstracts from SF2A-2001: Semaine de l’Astrophysique Francaise, meeting held in Lyon, France, May 28-June 1st, 2001, Eds.: Societe Francaise d’Astronomie et d’Astrophysique, to be published by EdP-Sciences, Conference Series, p.64 (2001)
Kempner J. C., Sarazin C. L. “Radio Halo and Relic Candidates from the Westerbork Northern Sky Survey” The Astrophysical Journal, Volume 548, Issue 2, pp. 639-651. (2001)
Kempner J. C. “Thermal and Nonthermal Effects in Galaxy Cluster Mergers” American Astronomical Society Meeting 199, #69.05 (2001)
Kouwenhoven M. L. A., Voûte J. L. L. “The effect of digitisation on the signal-to-noise ratio of a pulsed radio signal} of a pulsed radio signal” Astronomy and Astrophysics, v.378, p.700-709 (2001)
Kronberg P. P. “The Importance of Low Frequency Radio Emission for Probing Intergalactic Plasma” American Astronomical Society Meeting 199, #81.04 (2001)
Kuijken K., Garcia-Ruiz I. “Galactic Disk Warps” in Galaxy Disks and Disk Galaxies, proceeding of a conference held in Rome, Italy, June 12-16, 2000 at the Pontifical Gregorian University and sponsored by the Vatican Observatory. ASP Conference Series, Vol. 230. Edited by José G. Funes, S. J. and Enrico Maria Corsini. San Francisco: Astronomical Society of the Pacific. ISBN: 1-58381-063-3, 2001, pp. 401-408 (2001)
Lane W. M., Briggs F. H. “H I 21 cm Absorption in Mg II-Selected Systems at Moderate” Gas and Galaxy Evolution, ASP Conference Proceedings, Vol. 240. Edited by John E. Hibbard, Michael Rupen, and Jacqueline H. van Gorkom. San Francisco: Astronomical Society of the Pacific, ISBN: 1-58381-077-3, 2001, p. 66 (2001)

Lane W. M., Briggs F. H. "Two New Low-Redshift 21 Centimeter Absorbers" The Astrophysical Journal, Volume 561, Issue 1, pp. L27-L30. (2001)

Menéndez-Delmestre K., Mack K.-H., Schoenmakers A. P., de Bruyn A. G. "B1834+620 - a Double-Double Radio Galaxy" Astronomische Gesellschaft Abstract Series, Vol. 18. Abstracts of Contributed Talks and Posters presented at the Annual Scientific Meeting of the Astronomische Gesellschaft at the Joint European and National Meeting JENAM 2001 of the European Astronomical Society and the Astronomische Gesellschaft at Munich, September 10-15, 2001, abstract #P171. (2001)

Morganti R., Oosterloo T., Tadhunter C. N., Wills K. A. "Neutral and Ionized Gas Distribution In and Around the Radio Galaxy Coma A" Gas and Galaxy Evolution, ASP Conference Proceedings, Vol. 240. Edited by John E. Hibbard, Michael Rupen, and Jacqueline H. van Gorkom. San Francisco: Astronomical Society of the Pacific, ISBN: 1-58381-077-3, 2001, p. 236 (2001)

Morganti R., Oosterloo T. A., Tadhunter C. N., van Moorsel G., Killeen N., Wills K. A. "Hi absorption in radio galaxies: effect of orientation or interstellar medium?" Monthly Notices of the Royal Astronomical Society, Volume 323, Issue 2, pp. 331-342. (2001)

Pihlström Y. M., Conway J. E., Vermeulen R. C., Taylor G. B. "Probing Neutral Gas in Radio Sources with $0.2<z<1$" Gas and Galaxy Evolution, ASP Conference Proceedings, Vol. 240. Edited by John E. Hibbard, Michael Rupen, and Jacqueline H. van Gorkom. San Francisco: Astronomical Society of the Pacific, ISBN: 1-58381-077-3, 2001, p. 64 (2001)

Robishaw T., Blitz L. "A Catalog of High-Velocity Clouds in the Leiden/Dwingeloo Survey" American Astronomical Society Meeting 199, #117.04 (2001)

Rol E., Vreeswijk P., Salamanca I., Kaper L., Wijers R., Strom R., Foley T. "GRB 011030, WSRT radio observations." GRB Circular Network, 1124, 1 (2001) (2001)

Schilizzi R. T., Tian W. W., Conway J. E., Nan R., Miley G. K., Barthel P. D., Normandeau M., Dallacasa D., Gurvits L. I. "VLBI, MERLIN and HST observations of the giant radio galaxy 3C 236" Astronomy and Astrophysics, v.368, p.398-407 (2001)

Schoenmakers A. P., de Bruyn A. G., Röttgering H. J. A., van der Laan H. "A new sample of giant radio galaxies from the WENSS survey. I. Sample definition, selection effects and first results" Astronomy and Astrophysics, v.374, p.861-870 (2001)

Setia Gunawan D. Y. A., de Bruyn A. G., van der Hucht K. A., Williams P. M. "WSRT 1.4 and 5-GHz light curves for WR 147 (AS 431, WN8(h)+OB)" Astronomy and Astrophysics, v.368, p.484-496 (2001)

van der Hulst J. M., van Albada T. S., Sancisi R. "The Westerbork HI Survey of Irregular and Spiral Galaxies, WHISP" Gas and Galaxy Evolution, ASP Conference Proceedings, Vol. 240. Edited by John E. Hibbard, Michael Rupen, and Jacqueline H. van Gorkom. San Francisco: Astronomical Society of the Pacific, ISBN: 1-58381-077-3, 2001, p. 451 (2001)

Verheijen M. A. W. "An HI Study of the Ursa Major Cluster of Galaxies" Gas and Galaxy Evolution, ASP Conference Proceedings, Vol. 240. Edited by John E. Hibbard, Michael Rupen, and Jacqueline H. van Gorkom. San Francisco: Astronomical Society of the Pacific, ISBN: 1-58381-077-3, 2001, p. 573 (2001)

Verheijen M. A. W., Sancisi R. "The Ursa Major cluster of galaxies. IV. HI synthesis observations" Astronomy and Astrophysics, v.370, p.765-867 (2001)

Wakker B. P., Kalberla P. M. W., van Woerden H., de Boer K. S., Putman M. E. "H I Spectra and Column Densities toward HVC and IVC Probes" The Astrophysical Journal Supplement Series, Volume 136, Issue 2, pp. 537-578. (2001)

Zwaan M., van Dokkum P. G., Verheijen M. A. W., Briggs F. H. "Deep HI Imaging of Galaxy Cluster Abell 2218 at $z=0.2$" Gas and Galaxy Evolution, ASP Conference Proceedings, Vol. 240. Edited by John E. Hibbard, Michael Rupen, and Jacqueline H. van Gorkom. San Francisco: Astronomical Society of the Pacific, ISBN: 1-58381-077-3, 2001, p. 640 (2001)

Zwaan M. A., van Dokkum P. G., Verheijen M. A. W. "Hydrogen 21-Centimeter Emission from a Galaxy at Cosmological Distance" Science, Volume 293, Issue 5536, pp. 1800-1803 (2001).

ASTRON/JIVE Colloquia

Date	Speaker	Institute	Title
January 19	Thijs van der Hulst	Kapteyn Institute, Groningen	HI in Elliptical Galaxies with Shells
January 26	Lister Staveley-Smith	ATNF	HI in the Local Universe
February 6	Andrea Lommen	University of California, Berkeley	Is the Galactic Centre a massive black hole binary?
February 9	Heino Falcke	MPIfR, Bonn	The silent majority - radio emission from weakly active black holes
February 16	Maria Marcha	University of Lisbon	Searching for low-luminosity blazars
February 23	Penny Sackett	Kapteyn Institute, Groningen	"Cool" Jupiters in the Milky Way
March 2	Bob Fosbury	ST-ECF, Garching	The $z \sim 2.5$ radio galaxies: the sites of massive spheroid assembly
March 8	Niruj Mohan Ramanujam	Raman Research Institute, Bangalore	A Radio recombination lines from starburst galaxies: possible connection to Super Star Clusters
March 16	Lex Kaper	University of Amsterdam	High-mass X-ray binaries and OB-runaway stars.
March 23	Maarten Boasson	University of Amsterdam	An alternative to OO for distributed systems
March 30	Joanna M Rankin	University of Vermont, Burlington (USA) & Universiteit van Amsterdam	Sub beam Systems and Their Circulation: Touching the Physics of Pulsar Radio Emission
April 6	Jan Noordam	ASTRON	LOFAR Calibration and Calibratability
April 27	Matt Jarvis	Sterrewacht Leiden	On the redshift cut-off for radio sources
May 4	Bev Oke	NCR	Observations of galaxies in clusters at Redshifts of 0.76 to 0.92
May 11	Ewine van Dishoeck	Sterrewacht Leiden	Gas and dust in proto-planetary disks
May 22	Peter Hofner	University of Puerto Rico	On the formation of massive stars
June 1	Imke de Pater	University of California, Berkeley	Adaptive Optics imaging of our Solar System
June 8	Jan Tauber	ESA, ESTEC	Planck: ESA's mission to map the Cosmic Microwave Background
June 11	Kelvin Wagner	University of Colorado in Boulder	Multiple Beam Forming and coherent optical processing
June 25	Sergei Kopeikin	University of Missouri	Experimental measurement of the speed of propagation of gravity by VLBI
July 5	Andew Parfitt	CSIRO	Progress with the Luneberg Lens for SKA
August 31	Ye Shuahua	Shanghai Observatory	Radio Astronomy stations and Projects in East Asia
September 7	Leon Koopmans	Caltech	The lens system MG2016+112; finally solved?
September 21	Leo Blitz	University of California, Berkeley	Science with the Allen Telescope Array
September 26	Alexandre Refregier	IoA, Cambridge UK	Shapelets, Cosmic Shear and Interferometers
October 12	Rob Kennicutt	University of Arizona	SIRTF SINGS: The SIRTF Nearby Galaxies Survey
November 2	Eline Tolstoy	Kapteyn Institute, Groningen	High-redshift star formation in the Local Group
November 23	Peter Kalberla	Radioastronomisches Institut der Universität Bonn	Spatial distribution and velocity dispersion of the dark matter in the Milky Way
November 30	Roberto Gilmozzi	ESO, Garching	Science and technology of a 100m telescope: ESO's OWL concept

Date	Speaker	Institute	Title
December 5	Govind Swarup	NCRA TIFR, India	GMRT and Recent Results
December 14	Ilse van Bemmel	Kapteyn Institute, Groningen	An infrared view of active galaxies
December 18	Ignas Snellen	Institute for Astronomy, Edinburgh	Distant FR-I radio galaxies in the HDF: implications for the cosmological evolution of radio-loud AGN

Visitors 2001

Name	Institute	Arrival	Departure	Contact
V. de Heij	Leiden Observatory	16-01-01	18-02-01	R. Braun
W. Tschager	Leiden Observatory	18-01-01	28-01-01	D. Gabuzda
N. Gizani	Univ. Madeira	21-01-01	04-02-01	M. Garrett
J.C. Barriere	Saclay	24-01-01	25-01-01	J. de Haas
G. Durand	Saclay	24-01-01	25-01-01	J. de Haas
|P.O. Lagage	Saclay	24-01-01	25-01-01	Morganti/Braun
L. Staveley Smith	ATNF	24-01-01	27-01-01	Morganti/Braun
C. Lyraud	Saclay	24-01-01	25-01-01	J. de Haas
A. Caccianiga	Leiden Observatory	05-02-01	17-02-01	D. Gabuzda
G. Deschans	Obs. de Bordeaux	05-02-01	08-02-01	M. de Vos
V. Douence	Obs. de Bordeaux	05-02-01	08-02-01	M. de Vos
M. Marcha	Univ. Of Lisbon	05-02-01	17-02-01	D. Gabuzda
G. Collodi	Oss. Astr. Di Arcetri	06-02-01	08-02-01	M. de Vos
F. Palagi	Oss. Astr. Di Arcetri	06-02-01	08-02-01	M. de Vos
G. Comoretto	Oss. Astr. Di Arcetri	06-02-01	08-02-01	M. de Vos
G. Tuccari	Bologna	06-02-01	07-02-01	M. de Vos
C. Leinert	MPIfA Heidelberg	07-02-01	08-02-01	A. Glazenborg
U. Graser	MPIfA Heidelberg	07-02-01	09-02-01	A. Glazenborg
H. Falcke	MPIfR Bonn	08-02-01	09-02-01	R. Morganti
V. Chernetsky	Moscow State Univ.	09-02-01	28-02-01	D. Gabuzda
A. Lommen	Berkeley	12-02-01	13-02-01	W. Baan
K. Ramesh	Westerbork	13-02-01	01-06-01	W. Baan
V. de Hey	Leiden Observatory	13-02-01	15-02-01	R. Braun
D. de Boer	SETI	19-02-01	22-02-01	J.G. Bij de Vaate
S. de Maas	SETI	19-02-01	22-02-01	J.G. Bij de Vaate
F. Sluiter	Leiden Observatory	20-02-01	22-02-01	S. Alliot
L.D. Nicolae	Leiden Observatory	20-02-01	22-02-01	S. Alliot
R. Dickman	NSF Washington	20-02-01	21-02-01	E. de Geus
W. Vlemmings	Leiden Observatory	22-02-01	23-02-01	H.J. van Langevelde
V. de Hey	Leiden Observatory	27-02-01	01-03-01	R. Braun
A. Moore	Cambridge Univ.	07-03-01	08-03-01	G. Hampson
N.M. Ramanujam	Raman Res. Inst.	07-03-01	09-03-01	G. de Bruyn
J. Raza	TU Delft	12-03-01	16-03-01	A.J. Boonstra
K. Berzins	Virac	12-03-01	25-03-01	L. Gurvits
C. Lyraud	Saclay	14-03-01	16-03-01	J. de Haas
Y. Rio	Saclay	14-03-01	16-03-01	J. de Haas
H.K. Kauefl	ESO Garching	15-03-01	16-03-01	J. de Haas
J.F. Pirard	ESO Garching	15-03-01	16-03-01	J. de Haas
J.L. Beckers	ESO Garching	15-03-01	16-03-01	J. de Haas
R. Siebenmorgen	ESO Garching	15-03-01	16-03-01	J. de Haas
V. de Hey	Leiden Observatory	20-03-01	22-03-01	R. Braun
A. Biggs		22-03-01	11-04-01	G. de Bruyn
F. Fraternali	Astr.Obs. Bologna	25-03-01	06-04-01	T. Oosterloo
G. van Moorsel	NRAO Socorro	25-03-01	01-04-01	R. Morganti
B. Sault		26-03-01	27-03-01	A.J. Boonstra
A. Kumar	TIFR India	30-03-01	01-06-01	A. van Ardenne
G. van Moorsel	NRAO Socorro	01-04-01	06-04-01	T. Oosterloo
M. Haverkorn	Leiden Observatory	02-04-01	05-04-01	G. de Bruyn
W. de Vries	Berkeley	02-04-01	28-04-01	R. Morganti/R. Vermeulen

Name	Institute	Arrival	Departure	Contact
F. Geerling	Fokker Space	03-04-01	04-04-01	A. van Es
M. Neefs	Fokker Space	03-04-01	04-04-01	A. van Es
R. Grim	Fokker Space	03-04-01	04-04-01	A. van Es
J. Peeters Weem	STRON/Boulder	04-04-01	05-04-01	A. van Ardenne
R. Grim	Fokker Space	11-04-01	12-04-01	A. van Es
V. de Hey	Leiden Observatory	22-04-01	25-04-01	R. Braun
J. Dennet-Thorpe	UvA	26-04-01	27-04-01	G. de Bruyn
J. Ulvestad	NRAO	01-05-01	03-05-01	R. Schilizzi
B. Corey	MIT/Haystack	06-05-01	10-05-01	M. van Haarlem
B. Hicks	NRL	06-05-01	10-05-01	M. van Haarlem
B. Phillips	MIT/Haystack	06-05-01	10-05-01	M. van Haarlem
C. Lonsdale	MIT/Haystack	06-05-01	10-05-01	M. van Haarlem
D. Chen	NRL	06-05-01	11-05-01	M. van Haarlem
N. Kassim	NRL	06-05-01	10-05-01	M. van Haarlem
P. Crane	NRL	06-05-01	10-05-01	M. van Haarlem
R. Cappallo	MIT/Haystack	06-05-01	10-05-01	M. van Haarlem
S. Dougherty	NRC Canada	09-05-01	11-05-01	D. Gabuzda
U. Klein	Univ. Bonn	10-05-01	11-05-01	K.H. Mack
M. Haverkorn	Leiden Observatory	15-05-01	17-05-01	G. de Bruyn
V. de Heij	Leiden Observatory	15-05-01	17-05-01	R. Braun
K. Menendez	McGill Univ.	17-05-01	16-08-01	Mack/Schoenmaker
E. Fomalont	NRAO Ch'ville	19-05-01	31-05-01	L. Gurvits
P. Hofner	NAIC	21-05-01	26-05-01	W. Baan
S. Tinti	Univ. Of Bologna	28-05-01	31-08-01	R. Morganti
Z. Paragi	Fomi SGO	29-05-01	11-06-01	L. Gurvits
I. de Pater	Berkeley	31-05-01	20-06-01	R. Strom
S. Fodor	Whittier college	01-06-01	31-08-01	L. Sjouwerman
A. Boryssenko	Univ. Of Mass.	04-06-01	15-06-01	C. Craye
M. Haverkom	Leiden Observatory	11-06-01	15-06-01	G. de Bruyn
J. Dennet-Thorpe	UvA	12-06-01	14-06-01	G. de Bruyn
S. Kahn	ProContra B.V.	12-06-01	13-06-01	E. de Geus
V. de Heij	Leiden Observatory	13-06-01	15-06-01	R. Braun
A. Reekers	Fa. Furore	18-06-01	21-06-01	B. Schipper
L. Pittroff		18-06-01	17-08-01	R. Strom
H. Xinyong	Shanghai & Urumgi	20-06-01	03-07-01	L. Gurvits
I. Fejes	NWO-OTKA	20-06-01	01-07-01	R. Schilizzi
J. Eisimbek	Shanghai & Urumgi	20-06-01	03-07-01	L. Gurvits
W. Weuren	Shanghai & Urumgi	20-06-01	03-07-01	L. Gurvits
S. Kopeikin	Univ. Of Missouri	23-06-01	26-06-01	B. Campbell
M. Caillat	Obs. de Paris	28-06-01	29-06-01	G. van Diepen
P. Kahrb	Indian Inst. Of Astr.	28-06-01	01-10-01	D. Gabuzda
Fam. Brouw	ATNF	01-07-01	07-07-01	A. van Ardenne
M. Soudani	JNP Grenoble	01-07-01	30-09-01	M. de Vos
M. Giroletti	Univ. Bologna	02-07-01	05-08-01	D. Gabuzda
A. Biggs	Jodrell Bank	04-07-01	17-07-01	G. de Bruyn
S. Kahn	ProContra B.V.	11-07-01	12-07-01	E. de Geus
A. Stirling	Univ. Of Lancashire	15-07-01	21-07-01	D. Gabuzda
A. Papgeorgiou	Univ. Of Lancashire	15-07-01	28-07-01	D. Gabuzda
L. Shinguang	Lisa conn. Peling	01-08-01	09-09-01	A. van Es
M. Haverkorn	Leiden Observatory	06-08-01	07-08-01	G. de Bruijn
P. Katgert	Leiden Observatory	06-08-01	07-08-01	G. de Bruijn
M. Messineo	Leiden Observatory	08-08-01	11-08-01	L. Sjouwerman
I. Snellen	Royal Obs. Edinburgh	13-08-01	17-08-01	G. de Bruyn

Name	Institute	Arrival	Departure	Contact
S. Muehle	Univ. Bonn	21-08-01	25-08-01	Univ. Bonn
K. Berzins	VIRAC Riga	22-08-01	09-11-01	L. Gurvits
A. Tarchi	Univ. Bonn	26-08-01	31-08-01	M. Garrett
Prof. Ye Shuhua	Shanghai Astr. Obs.	26-08-01	01-09-01	Gurvits/Schilizzi
L. Koopmans	Caltech	03-09-01	07-09-01	G. de Bruyn
M. Martin-Meira	ESA ESTEC	03-09-01	07-09-01	Bij de Vaate
S. Ribo	ESA ESTEC	03-09-01	07-09-01	Bij de Vaate
A. Montero	TU Eindhoven	04-09-01	05-09-01	J. Bregman
M. Haverkorn	Leiden Observatory	10-09-01	14-09-01	G. de Bruyn
S. Kahn	ProContra B.V.	10-09-01	11-09-01	E. de Geus
V. de Heij	Leiden Observatory	10-09-01	21-09-01	R. Braun
P. Katgert	Leiden Observatory	13-09-01	14-09-01	G. de Bruyn
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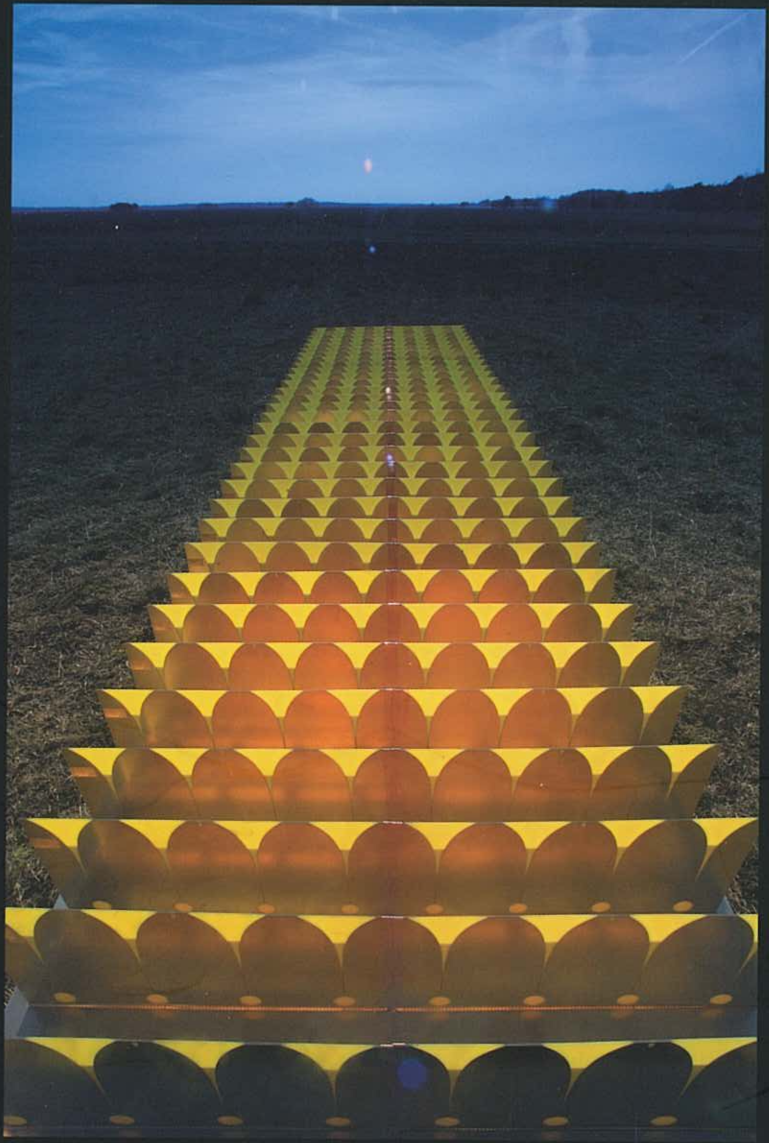
A. Refregier	Inst. Of Astr. Cambridge	25-09-01	27-09-01	G. de Bruyn
S. Kahn	ProContra B.V.	02-10-01	03-10-01	E. de Geus
A. Peck	MPIfR Bonn	08-10-01	10-10-01	R. Morganti
S. Peck	Tel Aviv Univ.	10-10-01	18-10-01	D. Gabuzda
S. Frey	FOMI Hungary	21-10-01	25-11-01	L. Gurvits
I. Kalberla	Univ. Bonn	22-10-01	26-10-01	K.H. Mack
P.Kalberla	Univ. Bonn	22-10-01	26-10-01	K.H. Mack
H. Ou	ASTRON	29-10-01	31-12-01	De Vos/D. Kant
R. Porcas	MPIfR Bonn	29-10-01	31-10-01	M. Garrett
W. Alef	MPIfR Bonn	29-10-01	31-10-01	M. Garrett
A. Horneffer	MPIfR Bonn	30-10-01	31-10-01	
H. Falcke	MPIfR Bonn	30-10-01	31-10-01	
Y. Hagiwara	MPIfR Bonn	30-10-01	31-10-01	M. Garrett
A. Biggs	JIVE	31-10-01	31-12-01	M. Garrett
E. Gilvray		31-10-01	31-12-01	M. Garrett
S. Kahn	ProContra B.V.	13-11-01	14-11-01	E. de Geus
L. Voute	U. v. Amsterdam	14-11-01	16-11-01	M. Bentum
W. Vlemmings	Leiden St.	20-11-01	22-11-01	A. Biggs
Y. Higwara	MPIfR Bonn	20-11-01	21-11-01	W. Baan
A. McGurk		22-11-01	26-11-01	A. Biggs
R. Gilhozzi	ESO Garching	28-11-01	30-11-01	R. Morganti
G. Swarup	NCRA TIFR	04-12-01	06-12-01	R. Morganti
J. Dennet-Thorpe		04-12-01	08-12-01	G. de Bruyn
S. Kahn	ProContra B.V.	04-12-01	05-12-01	E. de Geus
U. Klein	Univ. Bonn	09-12-01	10-12-01	
U. Meibold	Univ. Bonn	09-12-01	10-12-01	
V. de Heij	Leiden Observatory	10-12-01	11-12-01	R. Braun
I. Snellen	ROE Edinburgh	12-12-01	21-12-01	A. Biggs
S. Kahn	ProContra B.V.	17-12-01	18-12-01	E. de Geus
B. Garcia	ING	18-12-01	20-12-01	J. Pragt
G. Talbot	ING	18-12-01	20-12-01	J. Pragt
M. Blanken	ING	18-12-01	20-12-01	J. Pragt

Abbreviations

10GbE	10 Gigabit Ethernet
ADBF	Adaptive Digital Beam Former
AGN	Active Galactic Nucleus
ALMA	Atacama Large Millimeter Array
ALMA-BEE	ALMA Back-End Electronics Subsystem
ALMA-FC	Future correlator
ANC	Adaptice Noise Cancellation
AT	Auxiliary Telescope
AWE	Adaptive Weight Estimator
BER	Bit error rate
BTT	Bureau of Technology Transfer
CAD/CAM	Computer Aided Design & Manufacturing
CEPT	Conference of European Post and Telecommunication Administrations
CRAF	Commission on Radio Astronomy Frequencies
DBF	Digital Beam Former
DCB	Digital Contiuum Backend
DDRG	Double-Double Radio Galaxies
DLB	Digital Line Backend
DME	Distance Measuring Equipment
DSP	Digital Signal Processor
D-WDM	Dense WDM
DZB	WSRT Digital Correlator
EDFA	Erbium Doped Fibre Amplifier
EMC	Electromagnetic Compatibility
ESA	European Space Agency
ESF	European Science Foundation
ESO	European Southern Observatory
FARADAY	Focal Arrays for Radio Astronomy, Design Access and Yield
FEL	Fysisch en Elektronisch Laboratorium
FIR	Finite Impulse Response
FPGA	Field Programmable Gate Array
FWM	Four Wave Mixing
GBE	Gebiedsbestuur Exacte Wetenschappen
GPS	Global Positioning System
GRG	Giant Radio Galaxies
GUI	Graphical User Interface
HSL	High Speed Link
HXF	ALMA Digital Hybrid Correlator
ICT	Information and Communication Technology
ICT@NN	ICT in Noord Nederland
IF	Intermediate Frequency
IGM	Intergalactic Matter
INT	Isaac Newton Telescope
ITU	International Telecommunications Union
IUCAF	Commissionon the Allocation of Frequencies for Radio Astronomy and Space Science
IVC	IF to Video Converter
IVW	Inspectie Verkeer en Waterstaat
JIVE	Joint Institute for VLBI in Europe
JKT	Jacobus Kapteyn Telescope
LNA	Low Noise Amplifier
LNIR	Low Noise Interference Rejection
LO	Local Oscillator
LOFAR	Low Frequency Array
LSF	Large Scale Facilities
MFFE	Multi Frequency Front End
MIDI	Mid-Infrared Interferometry Instrument (for ESO's VLT)
MIRI	Mid-InfraRed Instrument
MIT	Massachusetts Institute of Technology
NASA	National Aeronautics and Space Administration
NEVEC	NOVA ESO VLTI Experise Center
NGST	Next Generation Space Telescope
NOEMI	Nulling Obstructing Electromagnetic Interferers
NOVA	Nederlands Onderzoeksschool voor Astronomie
NRAO	National Radio Astronomy Observatory
NRL	Naval Research Laboratory
NTT	New Technology Telescope
NWO	Nederlandse Organisatie voor Wetenschappelijk Onderzoek
OTDM	Optical Time Division Multiplexing
PCI	Peripheral Component Interconnect
PDFA	Praseodymium Doped Fibre Amplifiers
PRBPG	Pseudo Random Bit Pattern Generator
PROM	Programmable Read Only Memory
PSR	Pseudo Random Generator
PUMA	WSRT Pulsar Machine
PWN	Pulsar Wind Nebula
RAID	Redundant Array of Inexpensive Discs
RAP	Reduction, Acquisition and Processing Unit
RF	Radio Frequency
RFI	Radio Frequency Interference
RTD	Research and Technological Development
SDH	Synchronous Digital Hierarchy
SETI	Search for Extraterrestrial Intelligence
SKA	Square Kilometre Array
SNN	Samenwerkingsverband Noord Nederland
SNR	Supernova Remnant
SOA	Semiconductor Optical Amplifier
SRON	Space Research Organization of the Netherlands
STW	Stichting voor Technische Wetenschappen
TADU	Tied Array Distribution Unit
TDM	Time Division Multiplexing
TFlop	Tera Floating Point Operations
THEA	Thousand Element Array
TMR	Training and Mobility of Researchers
TMS	WSRT Telescope Management System

TNO	Nederlandse Organisatie voor Toegepaste Natuurwetenschappelijk Onderzoek
TU/e	Technical University Eindhoven
UHF	Ultra High Frequency
VISIR	VLT Imaging and Spectroscopy in the Infrared (for ESO's VLT)
VLA	Very Large Array
VLBI	Very Long Baseline Interferometry
VLBI	Very Long Baseline Interferometry
VLT	ESO's Very Large Telescope
VLTI	VLT Interferometer
VMN	Vast meetnet / Fixed Monitoring Stations
VNO-NCW	Verbond van Nederlandse Ondernemers & Nederlands Christelijk Werkgeversverbond
WADDS	Wideband Adding System
WAN	Wide Area Network
WDM	Wavelength Division Multiplexing
WHT	William Herschel Telescope
WSRT	Westerbork Synthesis Radio Telescope
WYFFOS	Wide Field Fibre Optical Spectrograph



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