ACCOUNT OF THE WORKING MEETING

ON

EUROPEAN VLBI FOR GEODESY AND ASTROMETRY

UNDER THE AUSPICES OF THE

NETHERLANDS GEODETIC COMMISSION

HELD AT THE

DEPARTMENT OF GEODESY

DELFT UNIVERSITY OF TECHNOLOGY

ON 3 - 4 NOVEMBER 1983

EDITED BY FRITS J.J. BROUWER

Account of the Working Meeting on European VLBI for Geodesy and Astronomy

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Preface

Geodetic and astrometric VLBI in Europe has come of age. This is - as I see it - the main conclusion of the third annual "Working Meeting on European VLBI for Geodesy and Astrometry". Under the auspices of the Netherlands Geodetic Commission this meeting was held on 3-4 November 1983 at the Department of Geodesy of the Delft University of Technology.

The Thursday session was devoted to VLBI results achieved so far, including the status reports of the observatories and results of measurement campaigns. The Friday session was concerned with prospects and plans for astro-geodetic VLBI in Europe, with emphasis on combining the various efforts.

The present account of the meeting starts with a letter on the main achievement of the meeting, the formation of an official European Working Group for Geodetic and Astrometric VLBI. Short minutes of the two sessions form the second part of this report, whereas the third section includes the abstracts of most of the talks presented at the meeting.

I thank all who contributed to the success of this meeting and to the compilation of this report, especially the two session chairmen: James Campbell and Richard Schilizzi.

I am sure that this meeting has contributed substantially to the process of promoting geodetic VLBI, as other meetings of this kind have done in the past or will do in the future.

I hope till the next one in Onsala.

Frits J.J. Brouwer,

January, 1984.

Netherlands Geodetic Commission
Thijsseweg 11
2629 JA Delft
The Netherlands

Participants

1.	L. Aardoom[x]	Dept. of Geodesy, Delft Univ. of Techn., The Netherlands
2.	W. Alef	Max-Planck-Inst. f. Radioastronomie, Bonn, W.-Germany
3.	W. Baarda	Dept. of Geodesy, Delft Univ. of Techn., The Netherlands
4.	R. Booth	Onsala Space Observatory, Sweden
5.	C. Boucher	IGN, Paris, France
6.	W. Brouw	Neth. Found. f. Radioastronomy, Dwingeloo, The Netherlands
7.	F. Brouwer	Dept. of Geodesy, Delft Univ. of Techn., The Netherlands
8.	E. Calero	Instituto Geográfico Nacional, Madrid, Spain
9.	J. Campbell	Geod. Inst. Univ. of Bonn, W.-Germany
10.	A. Caporali[x]	Dept. of Physics, Univ. of Padova, Italy
11.	H. Cloppenburg	Geod. Inst. Univ. of Bonn, W.-Germany
12.	R. Estalella	Universidad de Barcelona, Spain
13.	P. Howard	Nottingham University, U.K.
14.	G. de Jong	IJkwezen, Delft, The Netherlands
15.	G. Lundqvist	Onsala Space Observatory, Sweden
16.	J. Marcaide	Max-Planck-Inst. f. Radioastronomie, Bonn, W.-Germany
17.	A. Müskens[x]	Geod. Inst. Univ. of Bonn, W.-Germany
18.	A. Nothnagel	Nat. Inst. f. Telecommunications Research, S.-Africa
19.	F. Palutan[x]	Telespazio, Roma, Italy
20.	E. Raimond	Neth. Found. f. Radioastronomy, Dwingeloo, The Netherlands
21.	B. Rönnäng	Onsala Space Observatory, Sweden
22.	R. Rummel	Dept. of Geodesy, Delft Univ. of Techn., The Netherlands
23.	R. Schilizzi	Neth. Found. f. Radioastronomy, Dwingeloo, The Netherlands
24.	H. Schuh	Geod. Inst. Univ. of Bonn, W.-Germany
25.	H. Seeger[x]	Geod. Inst. Univ. of Bonn, W.-Germany
26.	G. Tang	Dept. of Geodesy, Uppsala Univ., Sweden
27.	C. de Vegt	Hamburger Sternwarte, Univ. Hamburg, W.-Germany

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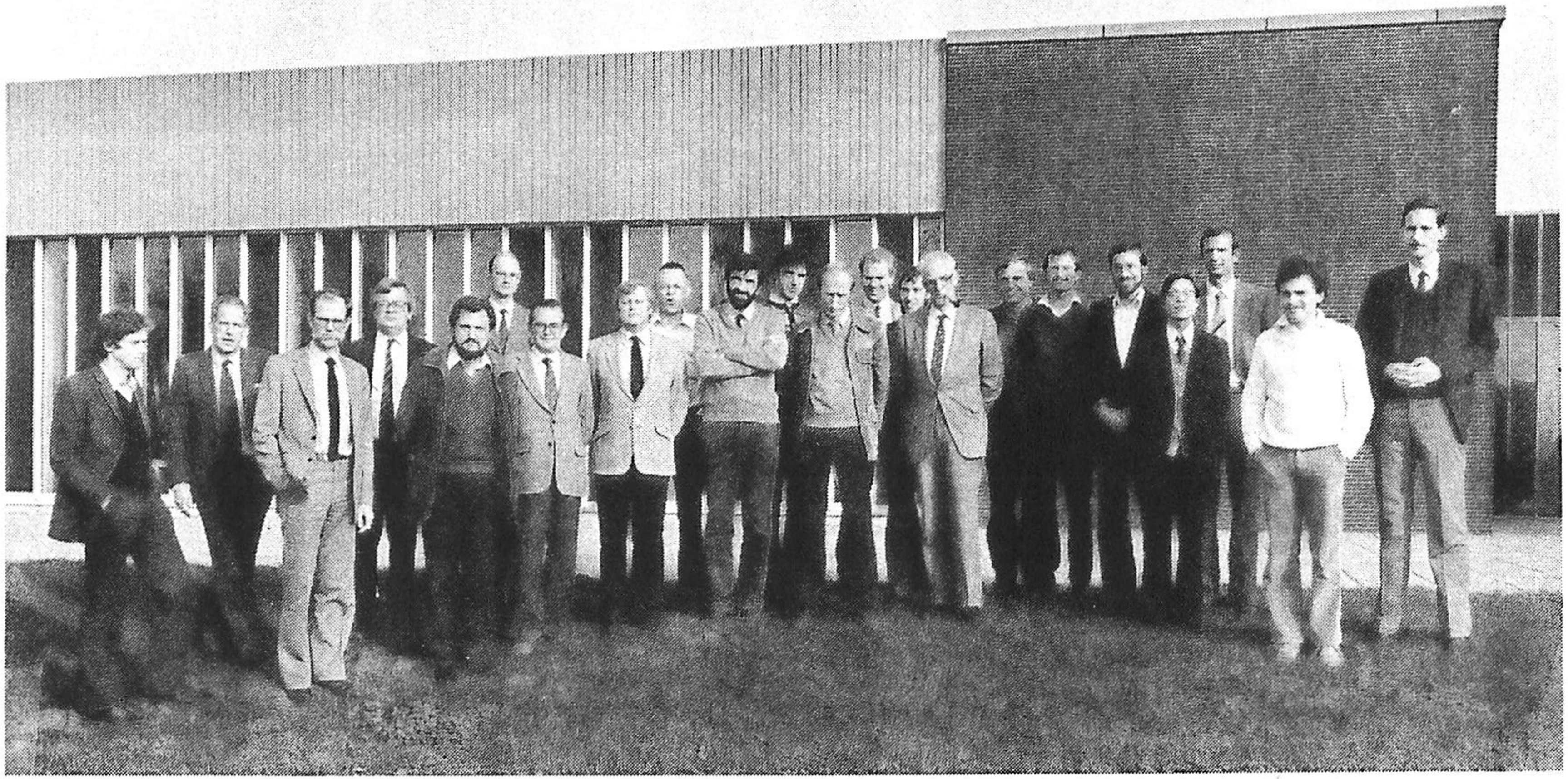

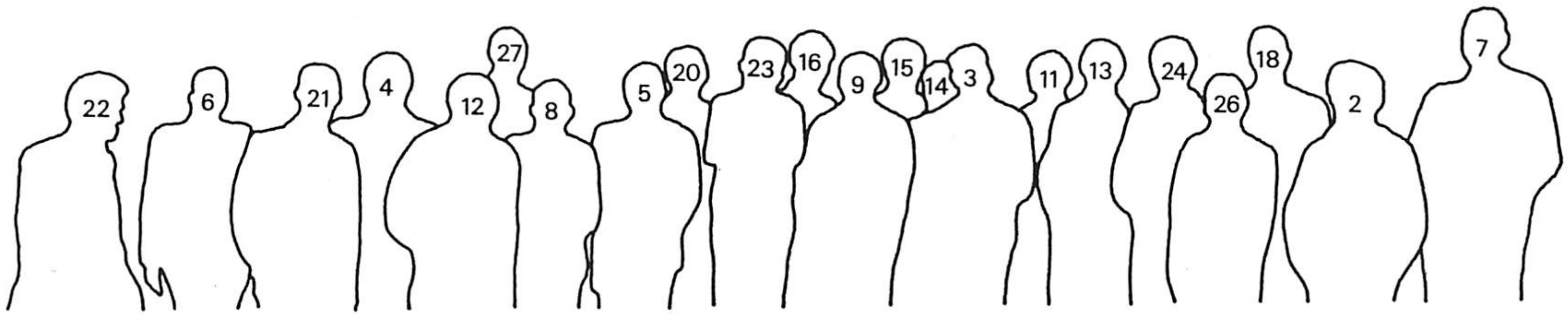
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ON

EUROPEAN VLBI FOR GEODESY AND ASTROMETRY

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SECTION 1

LETTER TO THE EUROPEAN ASTRO-GEODETIC VLBI COMMUNITY

To the European astro-geodetic VLBI community

20-12-1983

The participants of the third Working Meeting on European VLBI for Geodesy and Astrometry in Delft, 3-4 Nov. 1983, agreed to form a working group as a means of articulation of the common interests of the different European groups involved in geodetic, geophysical and astrometric applications of the VLBI technique. The name that has been suggested for this working group is: "European Working Group for Geodetic and Astrometric VLBI". At the Delft meeting the following members have been appointed with the aim of having at least one representative of each national group:

Brian Anderson, University of Manchester, U.K.
James Campbell (Chairman), Bonn University, W.-Germany
Alessandro Caporali, University of Padova, Italy
Claude Boucher, Institut Geographique National, Paris, France
Frits Brouwer, Dept. of Geodesy, Delft Univ. of Techn., The Netherlands
Hermann Drewes, Deutsches Geodätisches Forschungsinst., München, W.-Germany
Axel Nothnagel, Radio Astronomy Observatory Hartebeesthoek, South Africa
Antonio Rius, INTA/NASA, Madrid, Spain
Bernt Rönnäng, Onsala Space Observatory, Sweden
Christian de Vegt, Hamburger Sternwarte, W.-Germany

The tasks of the working group will be to

- combine and concentrate the interests of the different groups with an emphasis on the European role in a concept of global and regional geophysical studies,
- coordinate the astro-geodetic VLBI activities, preventing unnecessary double efforts,
- provide guidelines for equipment standardization in high precision geodetic VLBI observations,
- provide suitable processing arrangements (for Mk-II BWS and Mk-III observations),
- provide endorsements for support of the different groups by their respective funding agencies.

It was decided that the Working Group should prepare a document containing a concise presentation of the scientific goals of astro-geodetic VLBI as well as an outline of the future courses of action to be taken. In particular the document should discuss the scientific relevance of the European involvement in global and regional projects.
A draft of this document will be circulated to the members of the working group with the aim of being able to present the final version at the next European VLBI Meeting in May

or June 1984. R. Booth and B. Rönnäng agreed to arrange for this meeting to take place at the Onsala Space Observatory (near Gothenburg, Sweden).

In case you have any comments concerning the results of the Delft meeting, please do not hesitate to contact the chairman.

With best wishes,

James Campbell

Geodätisches Institut der
Universität Bonn
Nussallee 17
D-5300 Bonn 1

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S E C T I O N   2

SHORT ACCOUNT OF THE SESSIONS

Short account of the two sessions at the Working Meeting on European VLBI for Geodesy and Astronomy

by Frits J.J. Brouwer

Session 1, Thursday 3th November

Chairman: James Campbell

The Chairman started the session sketching the following broad framework for problem areas in geodetic VLBI:

Network Design	- optimal network configuration
	- experiment scheduling procedures
	- support of new stations
	- equipment requirements
Data Collection	- wide band recording
	- simultaneous S/X observing
	- equipment standardization
	- H-maser standards
	- water vapour radiometry
Data Processing	- correlation: Mk-III, Mk-II-BWS
	- fringe phase and amplitude estimation
	- geodetic modelling/post-processing
Scientific Return	- polar motion/UT1
	- plate tectonics
	- fundamental astrometry

Next, the operational stations were invited to present a status report of their activities and instrumentation.

Onsala (B. Rönnäng) see abstract 1

Westerbork (R. Schilizzi) mentioned that the Mk-III-terminal was now operational. The hydrogen maser (oscilloquartz S.A.) is presently being completed and will be operational next spring. An S/X receiver and WVR might be available in 1986.

Italy (A. Caporali) mentioned that the construction of the 30 m Bologna telescope has been completed in October 1983. After the test phase, the telescope is hoped to be operational by the end of the MERIT-campaign. The frequency range is 1.4-23 GHz (but no S/X-system, a design study is being made). Both Mk-II and Mk-III are available. WVR may be available in 3 years time. Plans exist for a second 30 m telescope in Sicily and - maybe - even a third (smaller: 15-20 m) telescope for geodetic use will come into operation at the laser site of Matera in southern Italy (responsible group: Telespazio, Roma).

France (C. Boucher) The French VLBI group (GRGS) reported the construction of two Mk-II terminals and three hydrogen masers (of which two are for VLBI) which will be ready next spring.

Plans exist for a fixed VLBI telescope in France but these ideas are delayed because of funding problems. In the meantime a Mk-III terminal could be purchased and together with a hydrogen maser installed in a van as a mobile terminal to upgrade host-antennas which do not have this equipment (± 1986). The benefits of this idea were obvious for the participants of the meeting.

Spain (R. Estalella/E. Calero) reported that the Cebreros antenna (26 m) is now under military direction and therefore not available for geodetic VLBI. As regards the Robledo station (2 antennas, 64 m and 34 m of NASA DSN), there has been cooperation in two campaigns with South Africa and Onsala using Mk-II. In addition, in May 1983, a geodetic Mk-III experiment including Effelsberg, Onsala, Haystack, Westford and Fort Davis was observed using the Wettzell Mk III terminal on its way from the USA to Germany. As regards the astrometric and astrophysical VLBI, one is referred to abstract 2.

South Africa (A. Nothnagel) see abstract 4.

Wettzell (J. Campbell) The 20 m radio telescope is now fully operational, although the S/X receiver is still an uncooled paramp on loan from Haystack. The first baseline results are presented in abstract 9.

China (J. Campbell) The chairman reported about his visit to China. A summary is given in abstract 3.

The session then continued with a presentation on one most essential piece of hardware: the correlator. An abstract of the presentation of W. Alef is given as number 5.

The final part of the session was devoted to the third item of above mentioned framework: geodetic post-processing.

P. Howard reported on the MULTIBASE software package and some preliminary results of the MERIT Short Campaign (see abstract 6).

F.J.J. Brouwer gave an overview of the effort on geodetic VLBI in the Netherlands (see abstract 7) and reported also on the post-correlation analysis of the MERIT-Short Campaign. Using the DEGRIAS software package, for the data of the first 48 hours of the campaign, differences in baseline length of only a few centimetres were found w.r.t. previously published results.Only for the baselines including Haystack, an error in the pointing computer led a substantial loss of data and therefore to differences of up to 15 cm. He also summarized the results of the ERIDOC campaign (abstract 11).

H. Schuh reported the first successful experiment with the Wettzell-telescope (with Onsala as partner) on 27th July 1983 (abstract 9) and presented the first results of the transcontinental Mk-III experiment of May 1983 (abstract 10).

G. Lundqvist concluded the first session with an overview of the complete data flow in the Mk-III system, emphasizing the post-processing software (abstract 8).

Session 2, Friday 4th November

Chairman: Richard Schilizzi

The Friday session continued with two presentations on the geodetic post-processing and a special application of VLBI.

The first presentation was by J. Campbell (see abstract 12) who showed what still can be done using only Mk-II-BWS. It is advantageous to use Mk-II-BWS because it does not require so much tapes and correlation time on the overloaded Mk-III processor.

He thought the technique to be valuable 1) as an intermediate step to show what capabilities one has (e.g. ERIDOC, abstract 11) and 2) as a general purpose geodetic measuring technique for distances up to 1000 km, e.g. to check the scale of ED-50. An application of VLBI for doing gravitational wave experiments was presented by G. Tang (see abstract 13).

Next the Chairman asked J. Campbell, C. Boucher, L. Aardoom and R. Rummel to give their personal view with respect to the question "What is the large scale future view for geodetic VLBI and what should be done in Europe".

J. Campbell referred to the broad framework he presented during the first session: VLBI can be used for:

- monitoring polar motion/UT1, which requires dedicated instruments.
- measuring crustal movements, either global, regional or local, which requires campaigns a few times per year only.
- doing fundamental astrometry, including reference systems, relativity, etc.

For a European effort he saw as the main areas of interest: first - on the global scale - to serve as a major connecting point for baselines to the American continent, the African continent and the Eastern part of the Eurasian plate (China, Japan). Second - on the regional scale - to determine accurate positions for the (Northern) European telescopes to serve as reference positions for geodetic work in the Mediterranean area, also in support of the mobile laser-network.

C. Boucher started with mentioning the unique capability of VLBI to give the best possible definition of an inertial coordinate system and to couple this with a terrestrial system. He called it a key-position for VLBI, also because the technique is completely independent of the Earth's gravity field, and therefore complementary to satellite laser ranging. For Europe, he saw the following four possibilities:

- because of the dense distribution of stations, Europe has the best capability to do intercomparison studies (as ERIDOC, abstract 11) between VLBI, laser, Doppler and classical networks. This should be exploited.

- The Hipparcos project offers - also because so many geodesists are already involved in Hipparcos - a unique opportunity to look further in the matter of inertial coordinate system definition.
- The use of VLBI for interplanetary space craft tracking should be emphasized.
- Studies should be done to arrive at a better network configuration for geophysical work. Especially: where (and how) to go into Africa (with a mobile system?).

L. Aardoom mentioned the value of VLBI time transfer experiments on a global scale. In agreement with the previous speaker he saw as a project of major importance: to go into Africa, either with a mobile terminal or with a complete transportable system. The project should then be directed at the crustal deformations in the Mediterranean area.

R. Rummel gave a sketch of the task of geodesy in relation to geophysics:

- to monitor movements
  - local or global
  - continuous or intermittent
  - vertical or horizontal
- to determine the orientation of the Earth in Space
- to determine the gravity field as a frozen picture of the processes in the Earth's interior.

Next, he mentioned that for a top-level contribution, a VLBI station should have: Mk-III, H-maser, S/X recording, and WVR. With this in view he discerned the following three aspects, balancing scientific benefits and costs:

1. What is the geophysical relevance?: checking hypotheses for the geophysicists, when measuring only a few years of periods of 200 million years. Here should be added that VLBI is much more expensive than the techniques (fieldwork) which the geophysicists use. What are the other possibilities?
2. We know VLBI can do the job, but now the question is: how to do it in Europe! There exist 3 possibilities:
   - use existing telescopes (inexpensive)
   - build dedicated telescopes (expensive)
   - build mobile equipment (moderately expensive)

3. Lastly, the question arises of the originality of our work: we should not copy the American efforts by e.g. organising an "EUROPOL" (European Polaris network).

The Chairman summarized the presentations in the following scheme:

item	earth rotation (space/terrestrial)	plate tectonics	regional deformation	astrometry + time transfer
code names	POLARIS/IRIS + "EUROPOL" .... COTES (VLBI + transp. laser)	crustal dynamics project	WEGENER Europe-Africa fault line	HIPPARCOS
stations	Onsala Wettzell (Bologna) (S. Africa)	Onsala, Wettzell Italy, Spain The Netherlands? Gr. Britain? close coop. with China/S. Africa/ Japan	see 2 + transportable VLBI	see 2
number of sessions	now 1 per 4 weeks future 1 per 5 days	4 per year	4 per year	2 per year

After that, J. Campbell stressed the importance of the cooperation with China and South Africa again: Europe is the turning table of the World for long East-West and North-South baselines, because of the poor simultaneous visibility of China and S-Africa with the US-telescopes.
L. Aardoom stipulated that - also in view of the remark of Campbell - originality (whatever the final decision for a European project would be) was guaranteed, if only, because we would do it as Europeans.
F. Brouwer stated - contrary to Rummel - that in his opinion, a lot could be done without S/X-recording and WVR. He urged for further research with respect to the following

question: why should one try to "save" all observations? If one knows e.g. that ionospheric influences are bad during sunrise, why measuring then during sunrise? Maybe it is possible to leave out these observations and correct the other observations for ionospheric influences with the aid of a model. In this way one would save both on S/X recording equipment and on correlation time.
Marcaide added that he thought that a lot could be done with measurements at 22 GHz (1.3 cm) only, where there is virtually no more ionospheric influence. The problem, however, is that there are relatively few strong sources at 22 GHz and that atmospheric absorption becomes significant. Anyway, he concluded, we shouldn't stick to S/X alone.
De Vegt stressed the importance of the comparison of the VLBI source catalogues and the Hipparcos results (see abstract 14).
R. Booth asked for a more cooperative scheduling of campaigns, so that the same observed data could serve more purposes.
H. Seeger questioned the matter of the costs of a transportable system, after which R. Rummel asked for a commitment of three stations to form a basic triangle in the tectonic stable part of Europe.
W. Baarda then remarked that a triangle would not be enough in view of reliability and repeatability over a period of 10 years.
F. Brouwer then announced that plans do exist in the Netherlands to equip either Westerbork or Dwingeloo as a geodetic VLBI station but not as a dedicated instrument. In this way it could form one of the European basic triangle stations (together with Onsala and Wettzell).

Summarizing the discussion, the Chairman concluded that the general opinion was that not "EUROPOL" but an effort directed at plate tectonics/regional deformation was generally favoured and proposed to form a working group to consider the scientific justification of VLBI, possible measuring programmes, network design and equipment specifications. This idea was welcomed by the participants and the composition was discussed. For the names of the members and a task description one is referred to section 1 of this report.
The session was concluded with an invitation from the Swedish VLBI group to have the next meeting in Onsala.

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S E C T I O N 3

ABSTRACTS OF PRESENTED PAPERS

ABSTRACT 1

STATUS REPORT on GEODESY-VLBI at ONSALA SPACE OBSERVATORY

by Bernt O. Rönnäng

BACKGROUND

Geodesy-VLBI is one of many spin-off projects of the radio astronomy programme at the Onsala Space Observatory. The research field was introduced in 1969 with the first transatlantic, bandwidth synthesis experiments performed in cooperation with the MIT - Haystack - Goddard Space Flight Center group. In 1973-78 a series of Mark I observations resulted in transatlantic distance measurements with decimetre accuracy (Herring et al., J. Geophys. Res., 86: 1647-1651, 1981). Dual frequency observations, necessary to obtain formal errors in the cm range, started as soon as the new 20 m millimetre wave telescope came into operation. Thanks to the fruitful cooperation with the US group a Mark III system became available a few years later on a long term loan basis.

EQUIPMENT

The present Onsala system consists of

1 ... S-band receiver system (T_s = 90 K) at the 25 m telescope
2 ... X-band receiver system (T_s = 200 K) at the 20 m telescope
3 ... Mark III data acquisition system
4 ... H-maser (ordered from Smithsonian in 1974/75)
5 ... Weather station (Mark III interfaced)
6 ... Water vapour radiometer (Mark III interfaced)
7 ... Hp 1000 computer system for Mark III terminal control and postprocessing

RESEARCH

The research goal has been to run or participate in a number of projects where technical developments are combined with interesting scientific output. The group is therefore coinvestigator of two projects in the Crustal Dynamics Programme (CDP), viz.

> I. Shapiro et al.: VLBI Determination and Interpretation of Relative Motions within a Network of Sites in North America and Europe,
>
> T. Clark et al.: Measurement of Contemporary Tectonic Plate Motions by Very Long Baseline Interferometry,

and has so far also participated in the POLARIS (IRIS) project with observations once a month. The CDP projects include approximately 10 days of observations per year.

The CDP projects are technically very broad. We have focused our interest on

- improvements of the Mark III field system,
- data analysis of the Westford - Onsala baseline, and
- methods to measure the excess path delay in the atmosphere.

RESULTS

As an example of results obtained so far I have chosen to report on the Onsala water vapour radiometer.

Water vapour radiometry is probably the best way to measure the excess propagation path delay caused by atmospheric water vapour. Figure 2 shows the radiometer built at Onsala (G. Elgered, Water Vapor Radiometry with applications to Radio Interferometry and Meteorology, Ph.D. thesis, 1983). It has now been in operation for two years with promising results. Two examples are shown in Figure 3 and Table 1. Figure 3 shows that there are clear differences between the calculated excess path delay using the Marini model and H_2O radiometer data. Table 1 presents evidence that H_2O radiometry really improves the accuracy by decreasing the formal errors in measured delays.

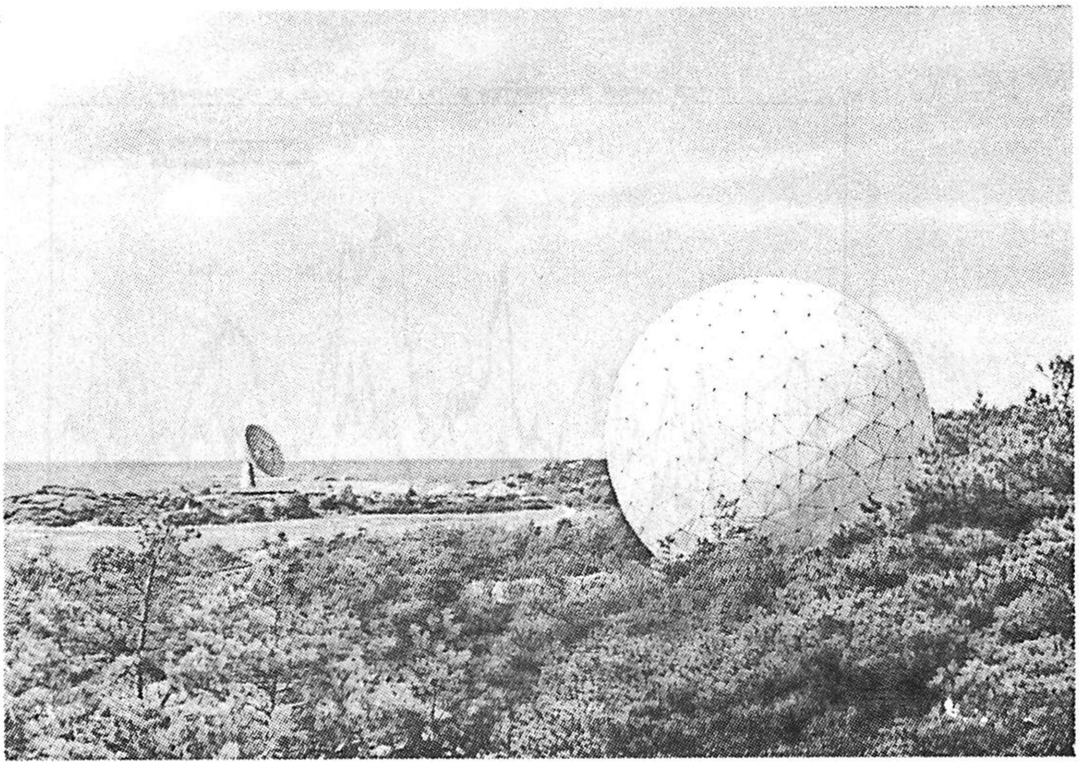

Figure 1. The two Onsala radio telescopes used in geodesy-VLBI for S-band and X-band observations.

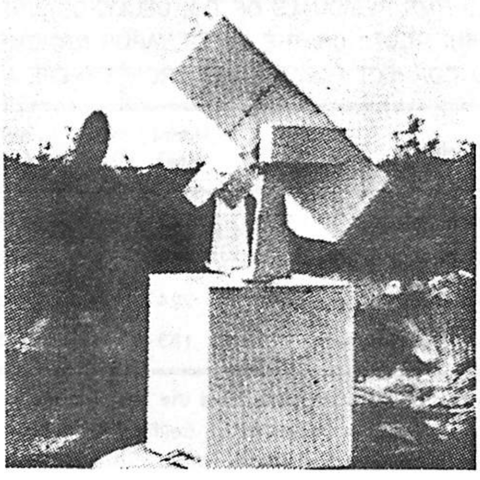

Figure 2. The water vapour radiometer which is interfaced to the Mark III VLBI system.

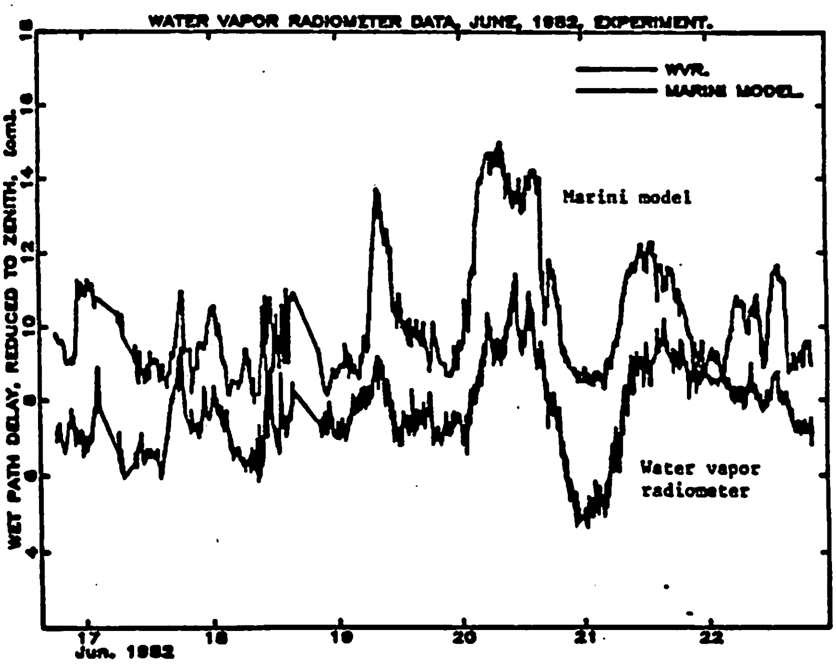

Figure 3. Plot of wet path delay a) calculated using the ground-based Marini model and b) from water vapour radiometer data.

WEIGHTED RMS RESIDUALS OF THE DELAY, OBTAINED WHEN THE MARINI MODEL OR THE WATER VAPOR RADIOMETER IS USED TO CORRECT FOR THE WET TROPOSPHERE AT ONSALA.

Part of solution	Marini (ps)	WVR (ps)
Whole solution	122	114
OVRO – Onsala baseline	188	155
Westford – Onsala baseline	224	195
HRAS – Onsala baseline	185	145

Remarks: all other stations have the Marini model
OVRO = Owens Valley, California
HRAS = Fort Davis, Texas
Westford = Westford, Massachusetts

Table 1. Results from the global CDP-experiment 22 June 1982.

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ABSTRACT 2

Report of the University of Barcelona VLBI group

R. Estalella

The Barcelona VLBI group has been working up to the moment in astrophysical VLBI. A first observation has been carried out recently at 18 cm with the European VLBI Network plus the Green Bank antenna in order to map the "optically quiet quasar" 1858+171, and another observation at 13 cm with the US Network plus the Madrid antenna is planned for this winter in order to detect superluminal expansion in 3C454.3. The software for mapping radio sources from VLBI data currently in use at Barcelona includes the VLBI CalTech Package and a Maximum Entropy Hybrid Mapping algorithm (Sanroma and Estalella 1983). In a near future we will be also able to run the NRAO package AIPS.

The Barcelona group is also involved in the Hipparcos project, in the linkage of the Hipparcos reference frame to the VLBI extragalactic reference frame. An observational campaign monitoring the flux density of radio stars suitable for this purpose is being carried out with the 64 m dish at Madrid at S Band (13 cm) and X Band (3.6 cm) (Estalella et al. 1983). We are specially interested in doing astrometric VLBI observations of some selected radio stars, but Mark III will not be available at Madrid probably before 1986. By the moment, we are able to make a proposal for the observation of a selected list of radio stars.

References:

Estalella, R., Paredes, J.M., Rius, A.: 1983, "Flux density monitoring of radio stars observable by Hipparcos at S-Band and X-Band", Astron. Astrophys. 124, 309.

Sanroma, M., Estalella, R.: 1983, "Hybrid mapping using the Maximum Entropy Method", submitted to Astron. Astrophys.

ABSTRACT 3

Chinese Involvement in VLBI

(Report on a visit to the People's Republic of China)

by J. Campbell, Geodetic Institute, Bonn

In recent years Radio Astronomy in China has experienced a period of vigorous activity laying the foundations for a set of ambitious research programmes. Three different observatories are presently involved in the construction of new telescopes which cover the full observational range from meter to millimeter wavelengths. For VLBI in particular there is a growing interest promoted by the increasing ease and openness to international communication. Next an overview of the principal radioastronomic centres in China is given:

- Beijing Observatory: Construction of a tied array with 16 antennas of 9 m diameter each, due to be completed in 1986. Main interest: meter wavelength observations, possibly also VLBI.
- Purple Mountain Observatory: Construction of a 13.7 m telescope for mm-observations (range: 2.6 mm - 1.3 cm). Selected site at a height of about 3000 m near Delingha in Qinhai Province (Completion in 1986). Main interest: Molecular spectroscopy.
- Yünnan Observatory, Kunming: A 10 m radio telescope completed in 1982 ($\lambda \geq 3$ cm) is available for cooperative programs.
- Shanghai Observatory: Operation of a 6 m antenna on the premises of the institute at Shanghai (Zi-Ka-wei Section) and construction of a new 25 m antenna at the observing base (Zô-Sê Section) 25 km southwest of the city (completion in 1984/85). The 6 m antenna has been used successfully in a Mk II VLBI experiment with the Effelsberg 100 m antenna in 1981.

  The main research field of Shanghai Observatory, which belongs to the Chinese Academy of Sciences (Academia

Sinica), is fundamental astrometry including all related observational activities and using classical as well as modern space techniques (satellite laser ranging and VLBI).

In relation to the scientific goals of astrogeodetic VLBI, the Shanghai Observatory research program clearly represents an optimal basis for cooperation between Europe and China. The observational program for the new 25 m antenna is primarily oriented towards geodynamical and astrometric projects, although astrophysical work is also included. The antenna equipment is designed to guarantee full compatibility with the international Mk III-VLBI standard for high precision geodesy:

- S/X receiver system
- hydrogen maser clocks (developed at Zi-Ka-Wei-Section)
- Mk III terminal (on order in the U. S.).

The technical data of the new telescope fabricated by a firm specialized on telecommunications antennae near Xian in Shaan-xi Province are listed below:

Type	cassegrain with beam waveguide feed
Mount	az-el with weel and track mount
Diameter	25 m
Surface tolerance	0.8 mm
Slewing rates	az: 0.5 deg/sec el: 0.3 deg/sec
Planned wavelengths	21, 18, 13/3.7, 6, 2.8, 1.3 cm

Presently at Shanghai Observatory a Mk II terminal has been built and the 6 m antenna is being used in test experiments to gain more experience in actual VLBI observing.

This year the 6 cm receiving system will be tested in the dual channel bandwith synthesis mode. A series of Mk II BWS-experiments at 6 cm has been planned for 1984 involving the stations of Effelsberg (West Germany), Toruń (Poland), Shanghai (China) and Nobeyama (Japan) to form a Eurasian VLBI-network. In these experiments the stations of Effelsberg and Nobeyama are scheduled to record simultaneously with the Mk II and Mk III systems. After completion of the new Shanghai telescope a different network configuration at S/X-band comprising the stations of Wettzell (West Germany), Shanghai (China) and Kashima (Japan) will be used. On these same frequencies a network across the Pacific Ocean has been planned in cooperation with the NASA/Jet Propulsion Laboratories. The stations in this net include Shanghai, Tidbinbilla (Australia) and Goldstone (California, U. S. A.).

Working Meeting on European VLBI for Geodesy and Astrometry; Delft, November 3-4, 1983.

ABSTRACT 4

VLBI CAPABILITIES OF THE RADIO ASTRONOMY OBSERVATORY HARTEBEESTHOEK

Axel Nothnagel
National Institute for
Telecommunications Research
P O Box 3718
JOHANNESBURG 2000
South Africa

The Radio Astronomy Observatory Hartebeesthoek is situated 65 Km N-W of Johannesburg. The telescope is 26 m in diameter with an equatorial mount and a Cassegrain focus is used.
At present the standard configuration has the 13 cm feed in the on-axis position. 18 cm, 6 cm and 3.6 cm feeds are mounted off-axis and are used in a beam offset mode. Thus, frequencies can be alternated in about half a minute, but simultaneous observations at two frequencies are not possible at the moment.
The slew rate of the antenna for both hour angle and declination is 0.4 - 0.5 deg/second.

The receivers presently availible are listed below:

Wavelength	Receiver	BW (MHz)	Temperature	Efficency K/Jy
18	Ambient GASFET	100	125 K	0.052
13	TW Maser	20	30 K	0.113
13	Ambient GASFET	100	125 K	0.113
6	Cryogenic Paramp	250	60 K	0.076
3.6	Ambient GASFET	1000	250 K	0.061

At present the primary frequency source is an HP 5065A rubidium standard and a MARK II c VLBI terminal with an IVC tape recorder is in use.
All necessary equipment for two channel bandwidth synthesis observations is available.

Activities

The first cooperative geodetic VLBI project was launched in 1980 with the VLBI group of the Bonn Geodetic Institute. In a 18 cm multi-station experiment with observatories of the European and the US networks a single channel MARK II system was used.

In April this year the cooperation with the Bonn VLBI group was intensified in several experiments.

Together with Madrid and Onsala we participated in a geodetic VLBI experiment subsisting of three sessions which was investigated by the Bonn group. The two channel bandwidth synthesis technique was used with a channel separation of 20 MHz at S - band. After a three hour test experiment to check the clocks and the whole switching configurations two observation periods of 10 and 7 hours at two different days was scheduled.
All tapes have not yet been correlated but strong fringes were found correlating the test experiment tapes. Thus, we also expect good fringes from the main experiment . First results are expected by the end of this year.

A second experiment took place at the 5./6. May 1983 between Effelsberg and Hartebeesthoek.
Originally this experiment was organised only for transatlantic baselines and stations equipped with MARK III systems but at Effelsberg also the MARK II recorder was operating with spare channels of the MARK III system. Therefore the schedule was prepared for sources very far north and west of us so that only 27 scans could be recorded. The same configuration as in the April experiment has been used over a period of 15 hours.
Nonetheless we hope to derive some useful results from this experiment.

Future Plans

During 1984 we plan to replace the ambient GASFET, used at 18cm, with a cooled receiver. A noise temperature of about 40 K is anticipated. Also it is intended to replace the feed with a high performance dual feed which should improve the efficiency to 0.113 K/Jy.
Improved feeds are also planned for 6 and 3.6 cm and it is hoped that the 3.6 cm ambient GASFET will be replaced with a cryogenic version to reduce the noise temperature to about 100 K.
An application for funds for a hydrogen maser has been made and stands a good chance of success. A decision is expected at the beginning of December so that the earliest time at which a hydrogen maser could be operational will be early 1985.
Also the implementation of a phase calibration system is investigated.

Prospects

Because of the unique position of our telescope at the southern end of the African tectonic plate it can contribute important data to both geodetic and geodynamic programmes.

At the moment about 10% of the total observing time is allocated for VLBI, both astronomical and geodetic. The observing schedule is organised by the Observatory itself so that the amount of time allocated to geodetic VLBI projects as well as the achievement of additional equipment will be influenced by the demand for cooperative experiments.
All groups interested in establishing such projects are invited to contact the observatory.

ABSTRACT 5

The New Mk 3 Processor in Bonn

Walter Alef, Max-Planck-Institut für Radioastronomie

Abstract

The Mk 3 processor in Bonn has been in operation now for 1 year. It is a replica of the Haystack system. A first stage is running consisting of 3 baselines with 56 MHz bandwidth, 3 station inputs (magnetic tape drives: Honeywell 96) and a control computer (HP 1000 F).

The investment till now is approximately 1,000,000 DM and 6 man-years. The processor is operated and maintained by 5 people. Correlation is done in one 8 hour shift per day on 5 days a week. About 100 scans, each of 13 minutes, can be correlated in one shift in 3 baseline mode.

Since the Mk 3 processor has become operational the demand for correlation time has increased more or less continuously. At the moment the processor is booked until February 1984.

By the end of 1985 the Max-Planck-Institut für Radioastronomie plans to expand the processor to 5 station inputs and 12 baselines with 28 MHz bandwidth. A necessary 2nd control computer will be installed in 1984. The planned expansion already includes a major contribution from the German geodesists: 1 station input, 1 baseline (28 MHz), 1 scientific supervisor.

A possible further expansion on a European basis could enlarge the system to 8 station inputs, 28 baselines, 3 computers and 8 personel by the end of the decade.

ABSTRACT 6

MULTIBASE - A GEODETIC VLBI ANALYSIS PACKAGE

P. D. Howard and V. Ashkenazi

MULTIBASE is a suite of software programs designed to process data from a multi-station network of radio telescopes observing in a geodetic VLBI mode. The software is operational with only several peripheral programs incomplete. Currently the package is being tested using data from the Short Merit Campaign (Nov. 1983).

MULTIBASE can be used to estimate least squares corrections for station coordinates, source positions, atmospheric zenith parameters, polar motion and variations in UT1. The reduction process is consistent with the IAU 1984 reference system and closely follows the Merit standards in the choice of models and corrections. A large selection of graphical output can be produced including plots of model parameters and adjustment residuals. The error analysis includes the production of a full variance-covariance matrix and reliability tests on the data. A program to automatically eliminate the group delay ambiquities from the raw data is under development and should result in considerable time saving during the reduction process.

After the validation stage MULTIBASE will be used to complete a full analysis of the Short Merit Campaign data and produce Earth rotation parameters for the two week period. In the future the package will be used during the main Merit campaign. It will also be used to adjust the ERIDOC data set and hopefully data from the intercontinental baseline experiments that have taken place since 1980.

Geodetic VLBI in the Netherlands

F.J.J. Brouwer, Dept. of Geodesy, Delft Univ. of Techn., Thijsseweg 11, 2629 JA Delft, The Netherlands

Geodetic VLBI in the Netherlands is tackled in a joint, now nearly finished, research project of the Delft University of Technology and the Netherlands Foundation for Radio Astronomy and is sponsored by the Netherlands Organisation for the Advancement of Pure Research (Z.W.O.). A Ph.D. thesis is to appear in 1984.

The main objectives of this research project were:

1. to study all physical phenomena where VLBI observations are sensitive for.
2. to build a software package capable to perform computations for an optimal design of a VLBI campaign and also capable to handle real VLBI observations.
3. to analyse the precision and reliability aspects of VLBI measurements in relation to the formulation of a computing model.
4. to cooperate in the organisation of VLBI campaigns and to carry out the adjustment of the observed data.
5. to compare VLBI results with some external reference.

ad 1. This is a very obvious task and includes all those phenomena as: precession, nutation, Earth tides, ionosphere, etc.

ad 2. The software package which has been built is called DEGRIAS for Delft Geodetic Radio Interferometry Adjustment System.
This is a multi-baseline program for - say - 10 000 observations and 1000 unknowns with options to do the adjustment of real data and to generate a schedule and do simulation studies.
With this software, parts of the MERIT Short Campaign have been analysed.

ad 3. Next to the above mentioned simulation studies for precision and reliability also different formulations of the computing model are examined. The standard model is the "kinematic" approach, where precession, nutation, Earth rotation and (diurnal) polar motion are used to relate the apparent positions of one source at different instants of time. Opposed to this, there exists a "geometric" approach where this is not done but additional unknowns are introduced in the adjustment for any moment that more than two baselines observe the same source position.

ad 4. This resulted in the ERIDOC-campaign, for which one is referred to another abstract in this account. The analysis of this campaign was also done with DEGRIAS.

ad 5. Intercomparison studies are sometimes rather "loosely" done. Software is developed to do a statistically based (w-test) investigations into systematical and random differences in shape, size, orientation and position of two 3-D networks, either measured at another moment of time by the same technique or at the same moment by different techniques. The latter is the case with the joint Doppler/VLBI ERIDOC-campaign.

Data Flow in the Mark III System.

Göran Lundqvist
Onsala Space Observatory

The Mark III VLBI system is a complete end-to-end system consisting of both hardware and software to conduct and analyze VLBI experiments. This paper will present a short overview of the software and dataflow in the Mark III system.

The first step in conducting an experiment is to create an observing schedule (Fig. 1). This is done with the highly interactive SKED program. From a set of catalogs the user can select stations, sources and frequency sequencies to be used in the experiment. After the schedule is created it is sent to the observatories on floppy discs.

The data acquisition at the various antennas is controlled by a sophisticated set of programs called The Field System. Besides the Mark III data tapes a machine readable logfile is produced with all information about the performance of the hardware at the stations. In the logfile is also written calibration information including such things as weather, cable cal and if available, WVR data. The raw data tapes are sent to the correlator and the logfiles are sent both to the correlator and the analysis center.

The post-processing software (Fig. 2) is an extensive set of interactive programs to read, calibrate and analyze the data produced by the correlator. Integral to the entire set of programs is a data base handler which provides a common interface among all of the programs. It also keeps a history of all processing as it is performed on the data, maintains a catalog which tracks the status and location of the data files, and archives all data of long term interest in a single set of well controlled files.

The post-processing part of the experiment starts with the program DBFT. It reads the A- and B-tapes with the observables produced by the correlator and creates a temporary data base. This data base together with the Skeleton data base, containing station positions, source coordinates and all physical and mathematical constants of interest, are read by the program KBMSG to form the first version of the experiment data base.

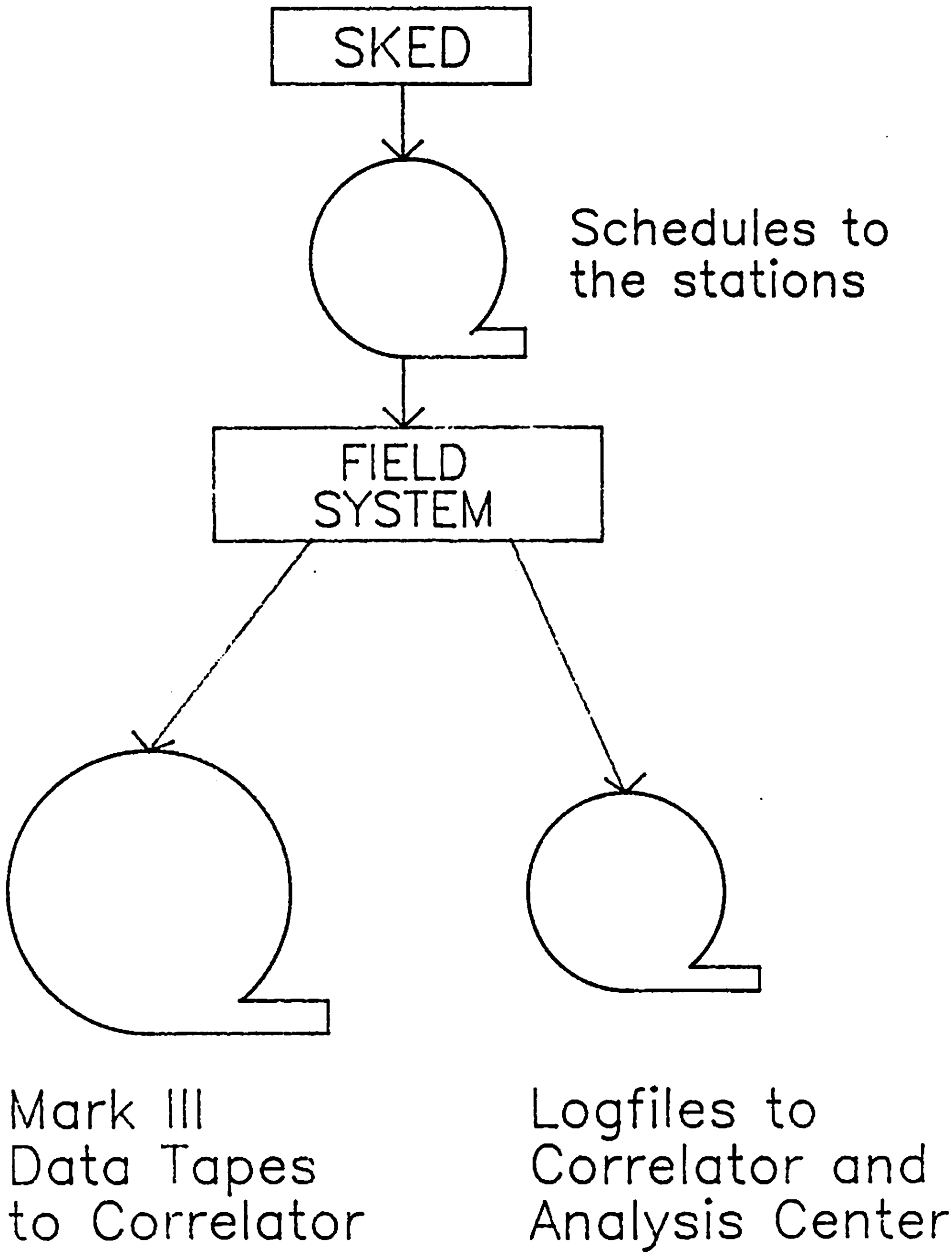
The next step is to run SETUP. This program will administrate the execution of three other programs. UT1PM will insert UT1 and polar motion values from data files normally containing BIH circular D information. EPHEM will insert ephemeries data for the solar system into the data base. Based on a priori values of the model parameters, CALC computes the theoretical delays, delay rates and partial derivatives and enters these into the data base.

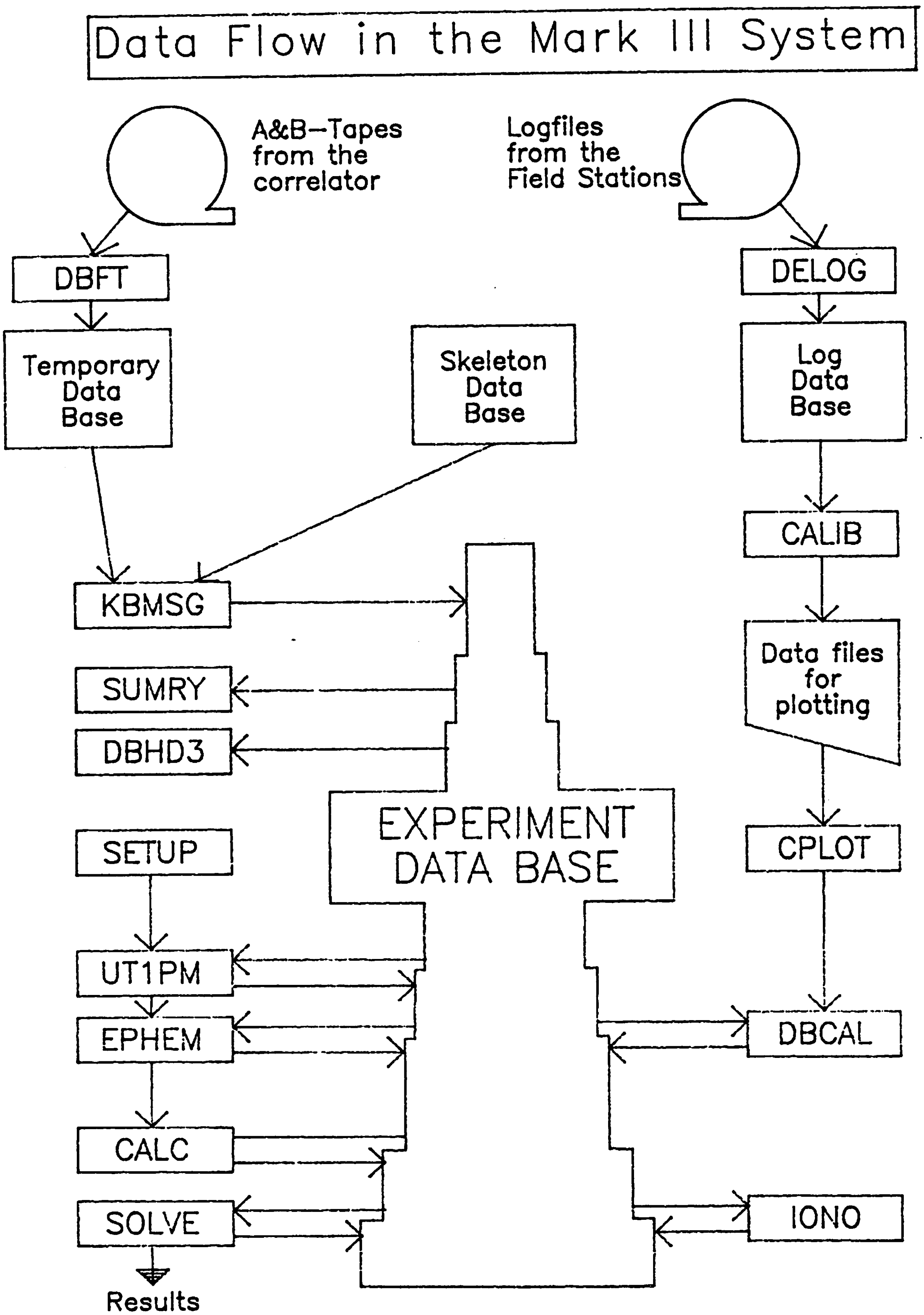
Finally SOLVE is the least squares estimation program. It has interactive data display, plotting and data editing capabilities. SOLVE will produce a printout of all estimated parameters turned on by the user.

The calibration of the experiment data base mainly consists of three parts. DELOG is the general delogging program. It reads the station logfiles and creates a log data base. This log data base is read by the program CALIB to create scratch data files with pressures, temperatures as well as humidities. Cable cal and WVR files are also produced. After plotting (Fg. 3) and editing DBCAL is executed to insert all the calibration information into the experiment data base.

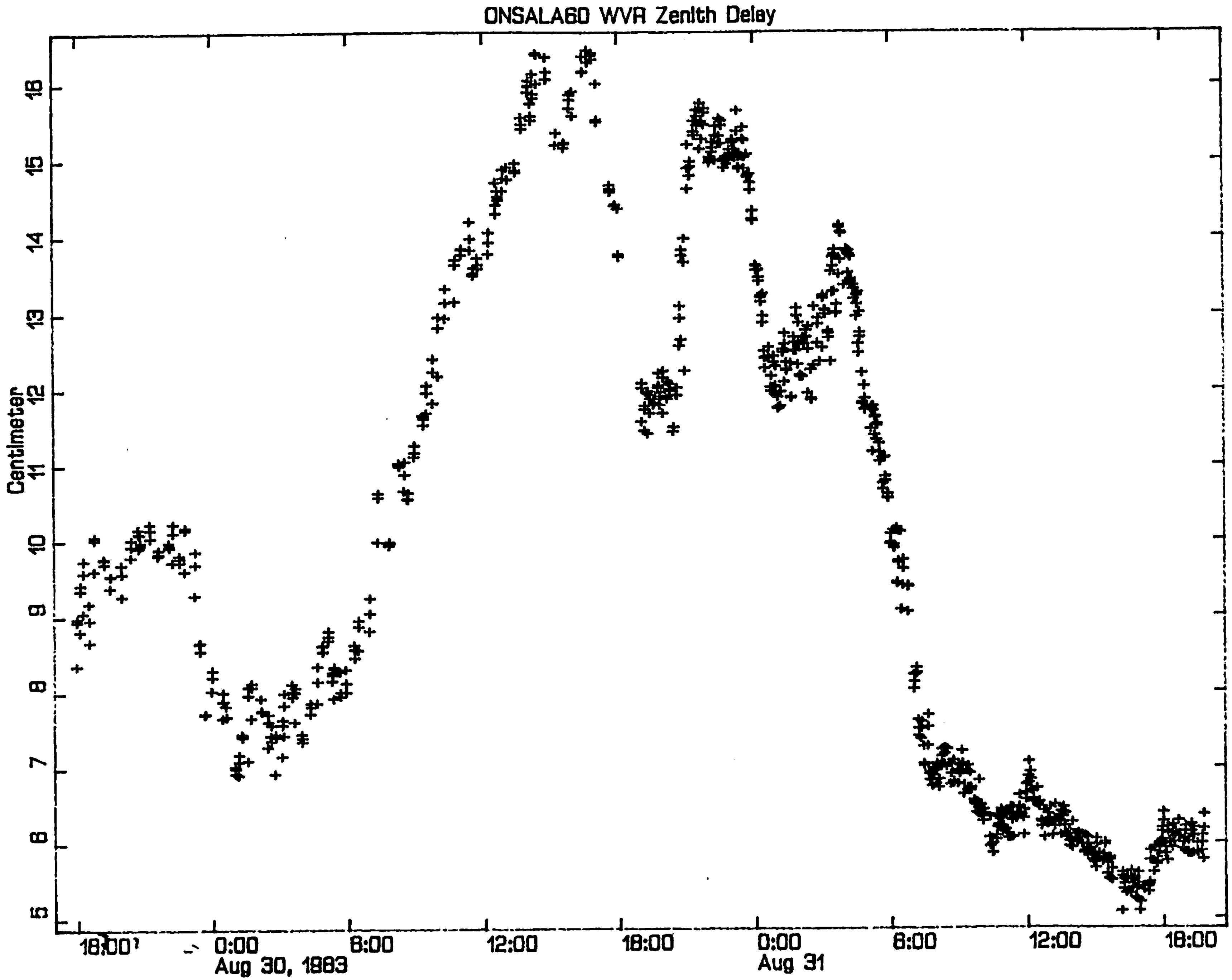
DATA FLOW IN THE MARK III SYSTEM.

1. Data Acquisition





Data Flow in the Mark III System
A&B–Tapes from the correlator
Logfiles from the Field Stations
DBFT
DELOG
Temporary Data Base
Skeleton Data Base
Log Data Base
CALIB
KBMSG
SUMRY
DBHD3
Data files for plotting
EXPERIMENT DATA BASE
SETUP
CPLOT
UT1PM
EPHEM
DBCAL
CALC
SOLVE
IONO
Results


ONSALA60 WVR Zenith Delay
Centimeter
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Aug 30, 1983
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Aug 31
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18:00

Working Meeting on European VLBI for Geodesy and Astrometry; Delft, November 3-4, 1983.

ABSTRACT 9

Results of the first VLBI - Experiment Using the New Radiotelescope of the Fundamental Station Wettzell

Harald Schuh
Geodätisches Institut
Universität Bonn

During the implementation of the MkIII - field system at the new, geodesy dedicated 20m - radiotelescope at Wettzell, two short VLBI - test experiments were performed together with the 20m - antenna at Onsala / Sweden.
The 39 successful observations of the second test experiment which had a duration of 7 hours were used for a first geodetic baseline determination.
For this purpose both, the "American East - coast VLBI software" (CALC/SOLVE) and the Bonn VLBI - baseline program were used.
From the least squares solution the delay observations got an rms of $\pm$ 0.066 nsec, the delay rate observations an rms of $\pm$ 0.125 ps/sec and the baseline length Onsala (20m) - Wettzell was determined to 919,660.990 $\pm$ 0.019 m.
For the future, a further considerable improvement in the accuracy can be expected.

ABSTRACT 10

Results of the European - American VLBI - Experiment May 83

Harald Schuh

Geodätisches Institut

Universität Bonn

From 5th to 7th of May 83, a transatlantic geodetic MkIII - experiment was performed with the following radiotelescopes : Haystack, Westford and Fort Davis (USA), Onsala (Sweden), Effelsberg (FRG), Robledo (Spain). It was the first time since September 80 that Effelsberg could participate again in a geodetic VLBI - campaign. The MkIII - tapes were correlated at the new MkIII - correlator at MPI/Bonn.
For the baseline determination, which has not yet been completely finished, the CALC/SOLVE - package as well as the Bonn VLBI - baseline program have been used. Already the preliminary results show that very high observational accuracies of ± 0.1 nsec and better could be achieved and confirm the MkIII VLBI - technique as a tool for high precision baseline determination.
The baseline Haystack - Effelsberg was calculated to 5 591 903.62 m ± 0.02, i. e. 6 cm longer than in the results of the experiments from July and September 1980.

ABSTRACT 11

SHORT ACCOUNT OF PROJECT ERIDOC

(European Radio Interferometry and DOppler Campaign)

FRITS J.J. BROUWER

Department of Geodesy
Delft University of Technology
Thijsseweg 11
2629 JA Delft
The Netherlands

ABSTRACT

At the first Working Meeting on European VLBI for Geodesy and Astrometry held in Bonn in April 1980, it was decided to start a programme of four geodetic VLBI experiments using a Mk-II bandwidth synthesis scheme, within the European network of radio astronomy observatories. This programme was designed to serve a number of objectives relevant to both geodesy, geophysics and astronomy. The measurements stood under the joint responsibility of the Geodetic Institute of the University of Bonn and the Department of Geodesy of the Delft University of Technology.

The main campaign took place in April 1981 and was called: Project ERIDOC (an acronym for: European Radio Interferometry and Doppler Campaign). The project was initiated to conduct simultaneous VLBI and satellite Doppler observations between those European radio observatories that were or would - possibly - be equipped with VLBI recording systems. Consequently, the most important objectives were: to test the performance of the VLBI-system on a European scale and to compare the results with the Doppler network.

Simultaneous VLBI and Doppler satellite observations were made at 5 radio observatories: Effelsberg (D), Westerbork (NL), Chilbolton (UK), Jodrell Bank (UK) and Onsala (S). In addition, 13 other Doppler stations took also part in the campaign, five of them stationed at satellite laser observatories, to have a connection to the laser network as well. Those stations were: Dwingeloo (NL), Robledo (E), Weilheim (D), Wettzell (D), Bologna (I), Graz (A), Leeuwarden (NL), Herstmonceux (GB), Kootwijk (NL), Dionysos (GR), Florence (I), Brussels (B) and Metsahovi (SF).

The data has been analysed independently at the two computing centres: Bonn and Delft. The results are in good agreement. They have been presented at the AIG General Assembly in Hamburg (Brouwer et al , 1983), including the multi-station solutions of both the VLBI and the Doppler measurements.
In general, for VLBI an accuracy level of around one decimetre was reached with the then available equipment. Only on the Effelsberg-Onsala baseline, the theoretically expected accuracy of 0.2 nsec could be reached.

Taking into account the ground survey ties, a comparison was made between the coordinates of the VLBI phase centres and the Doppler phase centres. The level of agreement between those coordinates is about 50 centimetres. From this, transformation parameters between the VLBI and the Doppler coordinate system were determined, using both Helmert's transformation and a transformation using the full variance/covariance matrices resulting from the multi-station solutions, to have better opportunities to trace possible errors in the coordinates.

The coordinates were also compared with the results of previous Doppler campaigns: EDOC-2, SEATOC, TIMEDOC and EROSDOC. Finally, an attempt has been made to compare the space technique results with the terrestrial ED-50 network. The discrepancy between the ERIDOC Doppler results and those of other origin is around one metre.

At the present Delft VLBI-meeting, an updated VLBI solution was presented without the wrongly applied axis offset correction at the Chilbolton telescope. But an investigation is still going on into possible other error sources corrupting the VLBI-Doppler comparison, the most prominent one being the ground survey ties. A final result will soon be published.

Working Meeting on European VLBI for Geodesy and Astrometry;
Delft, November 3-4, 1983.

ABSTRACT 12

Future uses of Mk II System (J.Campbell)

A. Observing modes and uses

1. Mk II single channel mode
   - equipment test experiments
   - phase referencing techniques

2. Mk II bandwidth synthesis (BWS-) mode
   - geodetic experiments with stations that are not yet eqipped with Mk III
   - development of geodetic station equipment accessories(i.e. phase calibration system, dual frequency receiving capability, H-maser performance tests)
   - development of alternative multiband recording schemes using the video cassett medium

B. Mk II - BWS processing

The processing of Mk II - BWS data is intimately tied to the JPL/ Caltech Block O system and only guarantees good results in connection with the Mk II correlator at Caltech, Pasadena. The PHASOR output tapes can be read in Bonn and are translated into geodetic delay and delay rate observations. The latter are treated in Bonn (and other analysis centres such as Delft and Nottingham) with the geodetic baseline fitting software.

C. Main advantages

Low investment and operating costs

D. Main system limitations

Spanned bandwidth and channel number lead to contrdictory requirements in sequential recording techniques:

- Ambiguity resolution requests six to eight channels in case of large spanned bandwidth(>50MHz),
- Conservation of SNR requests small number of channels in BWS - switching cycle

Further studies are desirable to find optimum configuration.

Working Meeting on European VLBI for Geodesy and Astrometry;
Delft, November 3-4, 1983.

ABSTRACT 13

VLBI DOPPLER TRACKING OF PLANETARY SPACECRAFT AND GRAVITATIONAL WAVE EXPERIMENTS

Allen Joel Anderson

and

Tang Guoqiang

Department of Geodesy
The University of Uppsala
S-755 90 Uppsala, Sweden

Introduction.

The need to place space geodetic observations in a general relativistic framework has become more and more apparent in recent years. Both satellite and VLBI measurements made within NASA's Crustal Dynamics Project require such a framework (Shapiro, 1982). Others have shown how certain relativistic effects must be taken into account when reducing precise satellite data for geodetic applications (Boucher, 1978; Martin et al, 1982; Laubscher, 1983; and others). Theoretical studies on a relativistic reference frame for geodetic observation, such as Blais (1977), Moritz (1981), and Grafarend (1982), have shown the need for further work in this area.

One of the most fascinating research subjects in recent times has been the experimental search for gravitational wave radiation (Davies, 1980). Here work has preceeded along several independent lines and the knowledge and experience gained from precise geodetic measurement has been of great value. In fact, much of this work has been an extension of understanding gained through the operation of recording gravimeters, quartz suspension accelerometers, and gradiometer research. The area of precise tracking of interplanetary spacecraft can also provide interesting results (Anderson, 1971; Estabrook & Wahlquist, 1975; Anderson, 1977; Hellings, 1978; Mashhoon & Grishchuk, 1980).

Space geodetic experiments to search for a cosmic background of gravitational waves have now been accepted for both the European Space Agency's ISPM and NASA's Galileo projects. Data acquisition for this experiment will be planned and analysis will be made at The University of Uppsala (Sweden), The University of Pavia (Italy), and at the Jet Propulsion Laboratory in Pasadena (USA).

It has been planned to have for the first time a simultaneous tracking experiment using both spacecraft, and a search will be made for both wave pulses and a cosmic background. For the background search a special configuration of radio antennae could be employed (Anderson, 1978; 1982). Here receiving equipment using VLBI MK III systems (Rogers, 1983) and a special digital tone extractor can be used to record X-band Doppler data free of correlated ionospheric and tropospheric effects (Anderson, 1977; Hellings et al, 1981; Caporali, 1982). This is sometimes referred to as 3-way tracking.

This should produce data useful for the search for the special autocorrelated noise signature caused by an isotropic gravitational wave background at a level of spatial strain of about 1 part in 10^{15}.

At the present moment there is a great deal of interest among astrophysicists that the space science and space geodetic community improve the microwave tracking systems and analysis procedure in order to detect the cosmic background.

From the theoretical point of view, the study of a four-dimensional space-time and relativistic reference frames are an ever more important part of geodetic investigation, not the least from a practical necessity in their applications to space geodesy. The insight gained from a study of these matters is sometimes surprising.

This paper will give some background useful in the understanding of some measurable quantities obtained in these spacecraft tracking experiments. For further reading, see for example Melborne, 1976. We shall discuss various parameters which can be obtained by these methods, and also discuss several noise sources which must be minimized.

Working Meeting on European VLBI for Geodesy and Astrometry; Delft, November 3-4, 1983.

ABSTRACT 14

Current Optical - and Radioastrometry at Hamburg Observatory

by Chr. de Vegt

The Hamburg Observatory has been involved in optical astrometry, especially photographic astrometry, since the early beginnings. The large catalogues of positions and proper motions AGK2 ,AGK3 are well known examples.
The present instrumentation for astrometry has been updated to the most advanced standard (New astrographic camera, PDS1010G measuring machine).
In the last years main efforts have been directed to the problem of connecting the optical and radio reference frames with special emphasis on source structure, both in the optical- and radiodomain.
We have already participated in VLBI and CERI experiments with Bonn and NRL(VLA).
Within the tasks of the IAU-Commission 24 Working Group on optical/radio reference frame a list of 234 selected compact extragalactic radio sources which display optical counterparts and which shall provide the basis for the establishment of a new, quasi-inertial extragalactic reference frame has just been finished.(Astronomy&Astrophysies ,in press.
Furthermore we are involved in the HIPPARCOS-Astrometry-Satellite-Project as a member of the Input-Catalogue-Consortium.
In particular we are working on the extragalactic reference link (subgroup 2130) providing new optical and radio observations of radio stars and extragalactic link objects.
We now plan ,in extension of our present astrometry group, to establish a small radio astrometry group in close cooperation with Wettzell ,Bonn and NRL.

ACCOUNT OF THE WORKING MEETING

ON

EUROPEAN VLBI FOR GEODESY AND ASTROMETRY

DELFT, NOVEMBER 3-4, 1983

SECTION 4

ADDRESSES OF PARTICIPANTS

Addresses

L. Aardoom
Kootwijk Satellite Observatory
P.O. Box 581
7300 AN Apeldoorn
The Netherlands

W. Alef
Max-Planck Institut für Radioastronomie
Auf den Hügel 69
D-5300 Bonn
W. Germany

W. Baarda
Chairman of
The Netherlands Geodetic Commission
Thijsseweg 11
2629 JA DELFT
The Netherlands

R. Booth
Onsala Space Observatory
S-43900 Onsala
Sweden

C. Boucher
Institut Géographique National
2, Av. Pasteur
F-94160 St. Mandé
France

W.N. Brouw
Netherlands Foundation for Radio-Astronomy
Oude Hoogeveensedijk 4
7991 PD Dwingeloo
The Netherlands

F.J.J. Brouwer
Dept. of Geodesy
Thijsseweg 11
2629 JA Delft
The Netherlands

E. Calero Posada
National Geographical Institute of Spain
General Ibañez de Ibero 3
Madrid-3
Spain

J. Campbell
Geodetic Institute
Nussallee 17
D-5300 Bonn
W. Germany

A. Caporali
Istituto di Fisica
Via Marzolo 8
I-35100 Padova
Italy

H. Cloppenburg
Geodetic Institute
Nussallee 17
D-5300 Bonn
W. Germany

R. Estalella
Depto. Fîsica Tierra y Cosmos
Universidad de Barcelona
Avda. Diagonal, 645
Barcelona 28
Spain

P. Howard
University of Nottingham
Dept. of Civil Engineering
University Park
Nottingham NG7-2RD
England

G. de Jong
Afd. Electrom. en tijd
Dienst v/h IJkwezen
Schoemakerstraat 97
2600 AR Delft
The Netherlands

G. Lundqvist
Onsala Space Observatory
S-43900 Onsala
Sweden

J. Marcaide
Max-Planck Institut für Radioastronomie
Auf den Hügel 69
D-5300 Bonn
W. Germany

A. Müskens
Geodetic Institute
Nussallee 17
D-5300 Bonn
W. Germany

A. Nothnagel
RAO-Hartebeesthoek
NITR
P.O. Box 3718
Johannesburg 2000
South Africa

F. Palutan
Telespazio S.P.A.
Data processing division
Via Bergamini 50
I-00158 Roma
Italy

E. Raimond
Netherlands Foundation for Radio-Astronomy
Oude Hoogeveensedijk 4
7991 PD Dwingeloo
The Netherlands

B. Rönnäng
Onsala Space Observatory
S-43900 Onsala
Sweden

R. Rummel
Dept. of Geodesy
Thijsseweg 11
2629 JA Delft
The Netherlands

R.T. Schilizzi
Netherlands Foundation for Radio-Astronomy
Oude Hoogeveensedijk 4
7991 PD Dwingeloo
The Netherlands

H. Schuh
Geodetic Institute
Nussallee 17
D-5300 Bonn
W. Germany

H. Seeger
Geodetic Institute
Nussallee 17
D-5300 Bonn 1
W. Germany

G. Tang
Dept. of Geodesy
Uppsala University
Hällby
S-75590 Uppsala
Sweden

C. de Vegt
Hamburger Sternwarte
Gojenbergsweg 112
D - 205 Hamburg 80
W.-Germany