PROCEEDINGS
OF THE WORKING MEETING ON
EUROPEAN VLBI FOR GEODESY AND ASTROMETRY

HELD AT
ONSALA SPACE OBSERVATORY, SWEDEN
3 JUNE 1985

Edited by B. Rönnäng and G. Tang

O.S.O, 1985

Working meeting on European VLBI for Geodesy and Astrometry

Onsala, Sweden

June 3, 1985

CONTENTS

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

PREFACE

The main goal of the annual working meetings of European VLBI for geodesy and astrometry is to present and discuss status reports and scientific results of the various groups in Europe in order to stimulate European coorperation and activity. The meetings are one of the tasks of the European Working Group for Geodetic and Astrometric VLBI, which are 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.

European geodetic and astrometric VLBI research is now well-established, thanks to more than fifteen years of observations and technical development at Onsala Space Observatory, the extensive observing program at the dedicated Wettzell station and the post-processing possibility organized by the University of Bonn group. Together with the two planned facilities (radio telescopes, Mark-III receiver systems and H-masers) in southern Europe (Italy and Spain/France) - with the national laboratory of the Mediterranean region - Europe will be well-equipped for successful global as well as regional VLBI research.

We are therefore glad to see that new European groups are making efforts in geodetic VLBI and that many exciting projects have been carried through and important results been achieved since the third meeting in Delft in November 1983. The various plans and results were briefly reviewed at the meeting, though the one day session was obviously too short to include all the ongoing work.

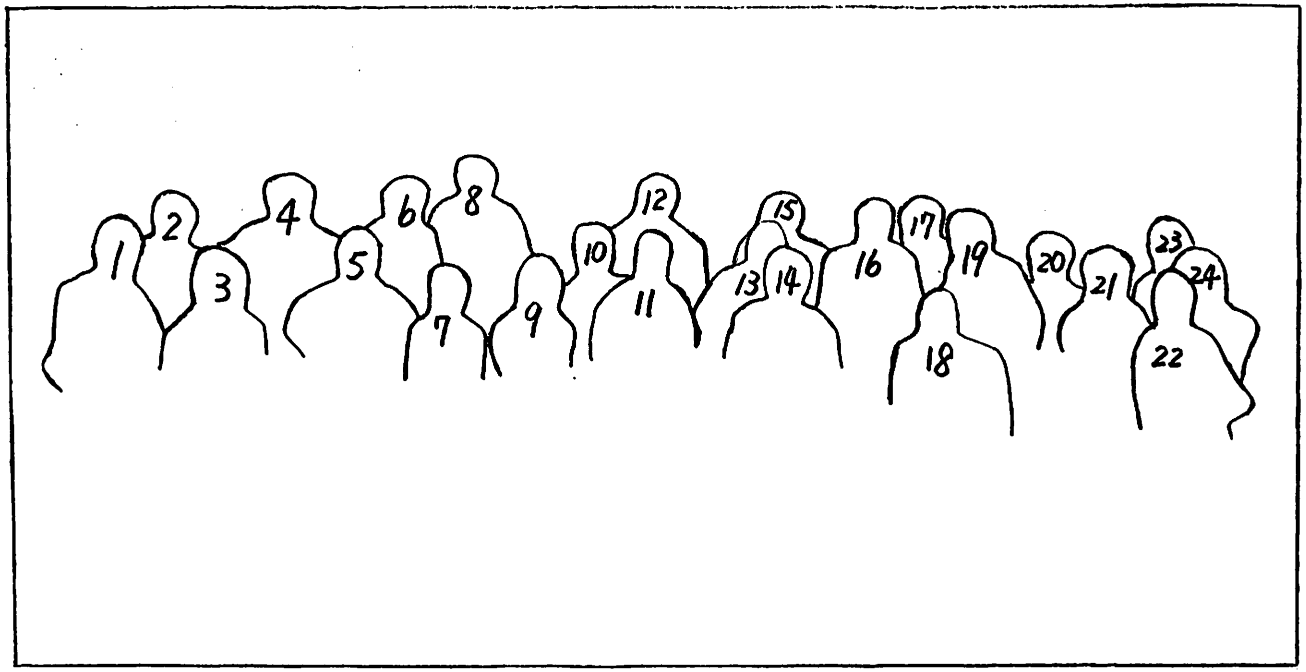
We thank all those who contributed to the success of the meeting and look forward with great optimism to the next meeting to be held in 1986 at the Wettzell station.

Bernt Rönnäng

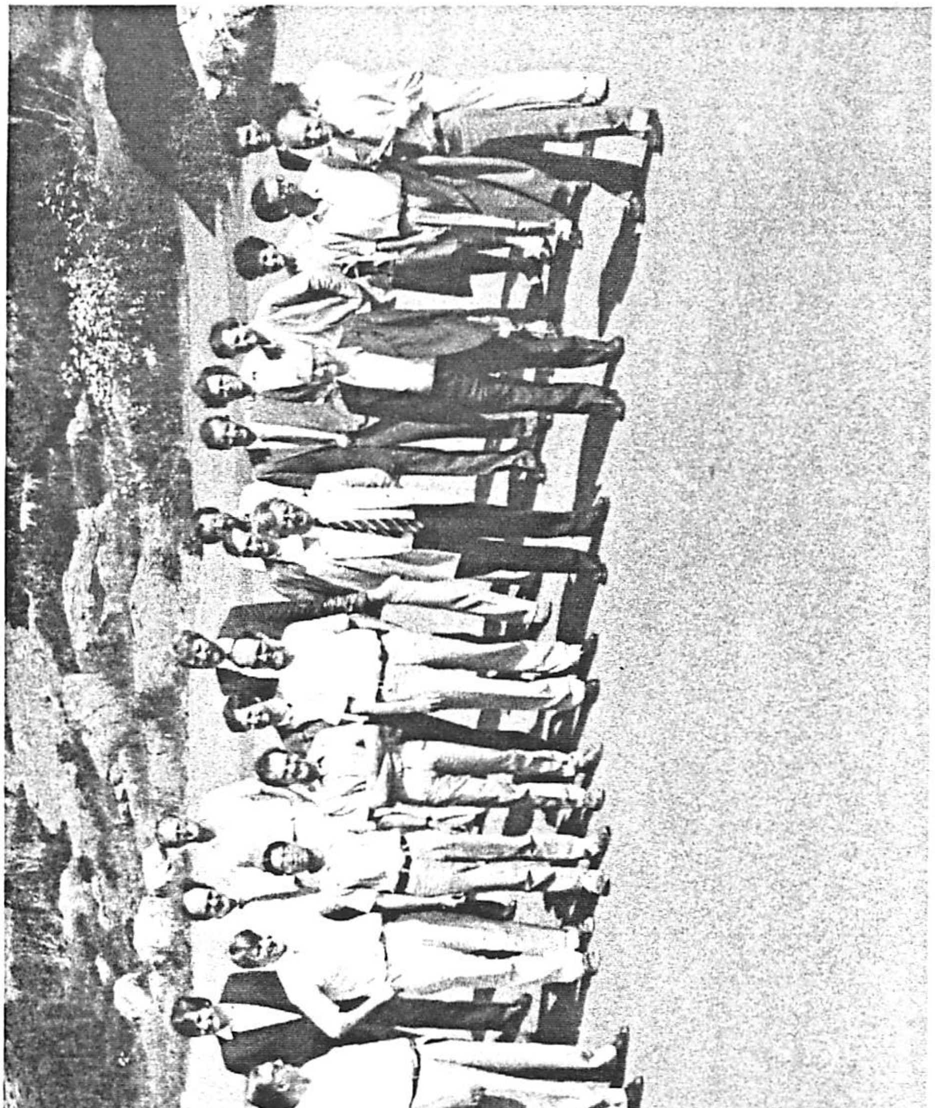
Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

PARTICIPANTS

Boucher, C., Institut Geographique National, St.Mande, France
Brouwer, F.J.J., Dept.of Geodesy, Delft Univ.of Techn. The Netherlands
Campbell, J., Geodetic Inst. Univ. of Bonn, F.R. Germany
Elgered, G., Onsala space Observatory, Sweden
Gorgolewski, S., Torun Radio Astronomy Observatory, Poland
Hill, C., Dept.of Civil Engineering, Nottingham Univ., England
Ifantis, I., Onsala Space Observatory, Sweden
Johansson, J., Onsala Space Observatory, Sweden
Kasser, M., Institut Geographique National, St.Mande, France
Kilger, R., Satellitenbeob. Stat. Wettzell, F.R. Germany
Nilsson, B., Onsala Space Observatory, Sweden
Nothnagel, A., RAO-Hartebeesthoek, NITR, S. Africa
Pernice, B., Dept. of Physics, Bari, Italy
Picard, P., Nancay Observatory, France
Reichert, G., Geodetic Inst., Univ. of Bonn, F.R. Germany
Rius, A., National Institute for Aerospace Tech., INTA/NASA, Spain
Rönnäng, R., Onsala Space Observatory, Sweden
Scherneck, H-G., Dept. of Geodesy, Uppsala Univ., Sweden
Schuh, H., Geodetic Inst., Univ. of Bonn, F.R. Germany
Seeger, H., Geodetic Inst., Univ. of Bonn, F.R. Germany
Tallqvist, S., Tekniska Högskolan, Metsähovi, Finland
Tang, G., Onsala Space Observatory, Sweden
Verrone, G., Dept. of Physics, Bari, Italy



1. F. Brouwer	2. J. Johansson	3. H. Seeger
4. A. Rius	5. G. Elgered	6. R. Kilger
7. G. Tang	8. B. Nilsson	9. C. Hill
10. S. Tallqvist	11. B. Rönnäng	12. G. Reichert
13. P. Picard	14. C. Boucher	15. H. Schuh
16. A. Nothnagel	17. H.-G. Scherneck	18. S. Gorgolewski
19. M. Kasser	20. G. Verrone	21. I. Ifantis
22. J. Campbell	23. B. Pernice	24. L. Bååth



Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

ROUTINE OPERATIONS AND STATUS OF THE RADIOTELESCOPE IN WETTZELL

Richard Kilger
Satellitenbeobachungsstation
Wettzell 8493 Kötzting
West Germany

ABSTRACT

The Radiotelescope in Wettzell is a Cassegrain antenna with en alt-azimuth mount built in 1982/83. The diameter of the main dish is 20 m, the diameter of the subreflector 2.7 m. The observation system consists of a HP-computer, handling the field system, a DEC 11/23 computer arranging the pointing of the antenna, a Mark III terminal, two hydrogen masers EFOS-1 and EFOS-3 from Oscilloquartz in Switzerland for frequency control, an uncooled parametric receiver and a dual frequency feedhorn for X+S-Band (JPL Design).

In July 1983 the hardware of the system had been completed and the phase of system testing started. On July 15th we detected the first radiosource 3C84 and on July 20th we did our first successful VLBI-experiment in X-Band together with Onsala; the Wettzell crew is still grateful to Dr. Rönnäng and the personnel of the radiotelescope in Onsala for helping us in this early state of proving all components of our measuring system. On October 7th we did our first successful VLBI-observation in X&S-Band across the Atlantic together with the POLARIS-stations Westford and Fort Davis. Finally on November 17th a successful 24^h POLARIS session took place. Though there were still some minor bugs detected later on, we feel, that with the session POLARIS-142 Wettzell had become an operational geodetic VLBI observatory.

From this time it was reasonable to allow the radiotelescope in Wettzell to take part in routine geodetic VLBI observations. Starting from January 9th, 1984, with POLARIS-148 Wettzell tried to participate in every POLARIS-IRIS session in the normal 5-day interval. Since that date we missed only 3 observations in 1984:

- POLARIS-160, February 13-14, due to implementation of a better pointing software,
- IRIS-192, July 22-23, due to a failure of our hydrogen maser
- IRIS-193, July 29-30, due to a failure of our hydrogen maser

At that time we had only one hydrogen maser EFOS-1. With our second maser EFOS-3 we should have a good chance avoiding failures in this field.

In order to report all our operational problems in year 1984 I should mention, that Haystack could not correlate our tapes of session POLARIS-154, January 13-14. The reason could not be determined. Probably explanations are the extremely bad weather with severe snowfall on that day or the possibility, that our tapes had been controlled with magnetic devices at the civil airport.

Simply due to the fact, that we did not get enough tapes we could participate in POLARIS-161, February 18-19, 1984 with only 8 tapes.
These are almost all major, negative aspects of our observing activity in 1984.
The major, positive aspects of our participation in POLARIS/IRIS-projects during the first year of participation are:

- 67 successful correlated 24^h-POLARIS/IRIS-sessions in relation to 71 observations, totally scheduled;
- during MERIT-INTENSIVE-CAMPAIGN Wettzell did not miss a single POLARIS-IRIS-session;
- thus we helped to supply the scientific, geodetic community with valuable results referring to polar motion, delta (UT1 - UTC) and plate motion;
- simply due to the fact of enlarging the POLARIS-IRIS-VLBI-net significantly, the continuous participation of Wettzell improves the standard error of the determined earth orientation parameters X, Y and delta (UT1 - UTC) by a factor of 2 to 3.

  Of course, the same effect happens, whenever Onsala takes place in IRIS-sessions;
- as documented in IRIS-Bulletin A and B series the radiotelescope in Wettzell has proved to be a reliable partner of the radiotelescopes in Westford, Fort Davis, Richmond and Onsala in the IRIS-project.

During the MERIT-INTENSIVE-CAMPAIGN in 1984 from April 1st until June 30th the radiotelescopes in Westford and Wettzell made daily measurements to determine delta (UT1 - UTC). Every day 8 observations were made with a recording time of 400 seconds per source. The tapes were correlated at Haystack and evaluated at NGS. The results of this session were published by NGS and showed a lot of interesting details, encouraging to continue these series in 1985.
To complete our observing activities in 1984 I should mention our first participation in the CDP-project of GSFC, on August 30-31st with POLAR-1 and on September 2-3rd with POLAR - 2, giving NASA the possibility to tie the radiotelescope of Wettzell to the existing VLBI-net all over the world.

Only of episodic character seem some short observations to answer the question, in what angular distance from the sun radiosources can be successfully recorded and determining the relativistic deflection of radiowaves passing the gravity field of the sun and thus confirming Einstein's theory of general relativity. The observations were performed together with Onsala and partly with Westford.

The year 1985 brought no major changes into our routine observations. The performance of IRIS-sessions still has priority in Wettzell. In 1985 we did not miss a single IRIS-session yet. We have already participated in 100 IRIS-sessions of totally 254 up till now.

Starting from April 1st Wettzell carries out daily measurements to determine delta (UT1 - UTC) together with the radiotelescope in Westford. The observing schedule is similar to the described schedule in 1984.

The scope of the observations in the CDP-project will increase in 1985. We participated already in:

- X-ATL, for 24^h, in January 24+25th
- N.ATL-1, for 40^h, in March 05+06+07th,
- X-ATL, for 24^h, in April 24+25th,
- N.ATL-2, for 40^h, in May 09+10+11th,

and will participate in additional 7 CDP-sessions scheduled for 1985.

Another important field of our activities is maintenance, and wherever possible, upgrading of the performance of the antenna. The major items are:

- the installation of a cooled GaAsFET-S-X-Band receiver instead of the uncooled parametric receiver about in December 1985. This new, cryogenic cooled receiver has been or shall be installed in all IRIS-observatories Westford, Fort Davis, Richmond, Onsala and Wettzell. With this more powerful receiver the system temperatures will be decreased
  from 175 K to about 75 K in X-band and
  from 105 K to about 70 K in S-band
  enabling the scheduler either to shorten the duration of observations or to choose even weaker pointsources;
- the installation of a high density tape driver in early 1986.
  High density technique will drop the consumption of tapes and decrease the cost of tape shipments, not influence the accuracy of the measurements;
- the installation of Mark II recording terminal; the fabrication of this terminal is performed in Wettzell in close cooperation with MPIfR in Bonn. The date, when Mark II will be operable depends also on MPIfR and will be probably not before 1986.

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

ONGOING GEODESY-VLBI RESEARCH AT OSO

B. O. Rönnäng
Onsala Space Observatory, Sweden

ABSTRACT

The research activity in the field of geodetic and astrometric VLBI is maintained at the same level as last years, i.e. about 10% of the available observing time at the 20 m and the 25 m Onsala telescopes is devoted to this research area.

The group, consisting of B. Rönnäng, G. Elgered, G. Tang, J. Johansson, I. Ifantis and B. Nilsson (the Mark-III and HP computer technician), is involved in
(a) the Crustal Dynamics Projects through observations about once every two months (Projects: North-atlantic, X-atlantic, and Polar) with the goal to measure global baselines;
(b) IRIS, with observations once per month for polar motion and earth rotation measurements;
(c) technical development and evaluation of water vapour radiometry (also thanks to an ESA/ESTEC study contract).

In addition, several special - both European and global - observational projects are carried through every year.

In the near future there are two technical improvements of special importance, i.e.
(a) a new cryogenic cooled S/X - band receiver for the 20m telescope. This will increase the sensitivity by about a factor of 2 and make the measurements independent of the 25m telescope. The new system will hopefully be operational in early 1986;
(b) a new compact and transportable H-maser, hopefully financed by the Research Council.

The block diagrams of the present system are shown on the next pages.

COMPUTER & ANTENNA SYSTEM IN OSO

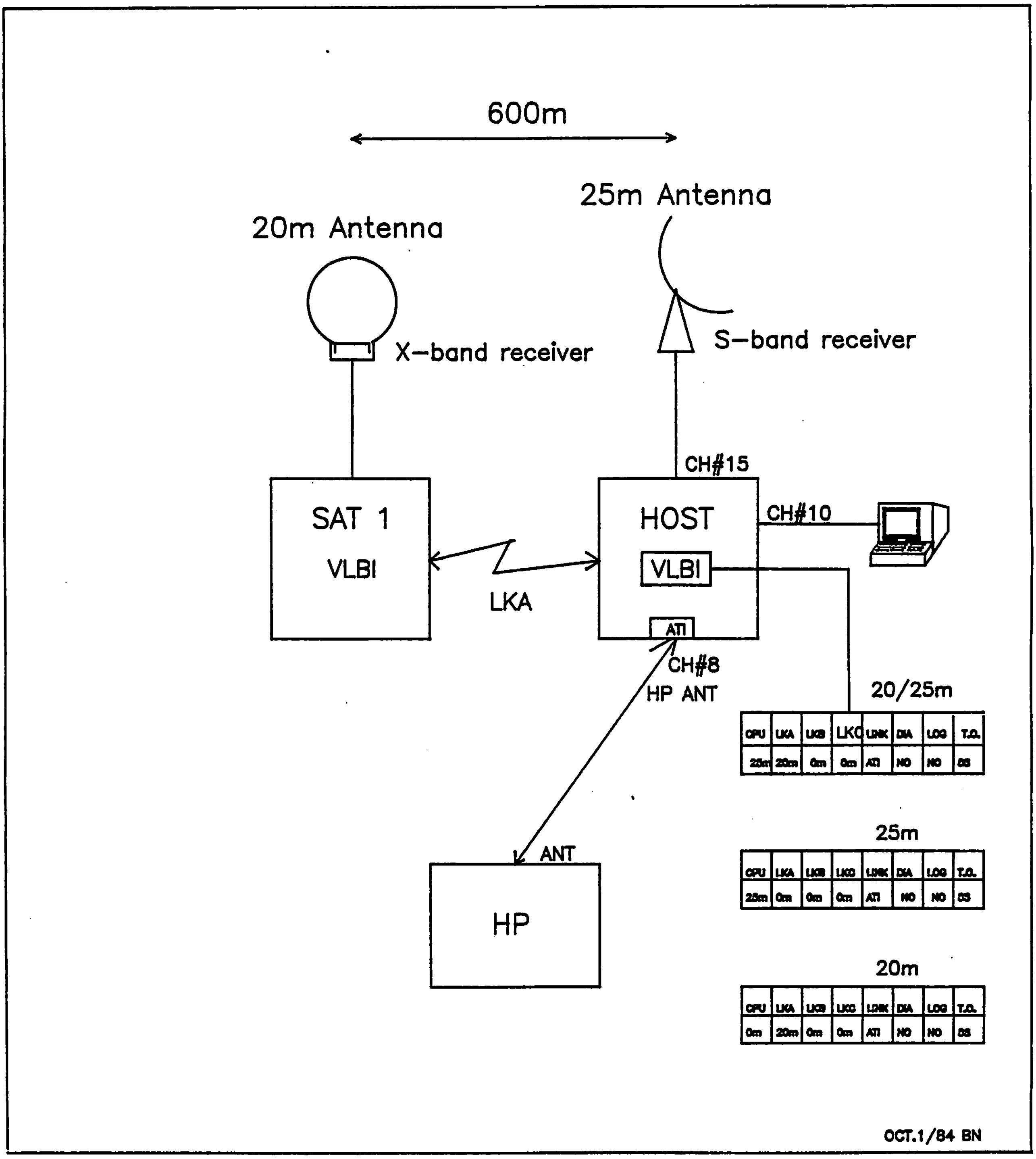


Fig.1

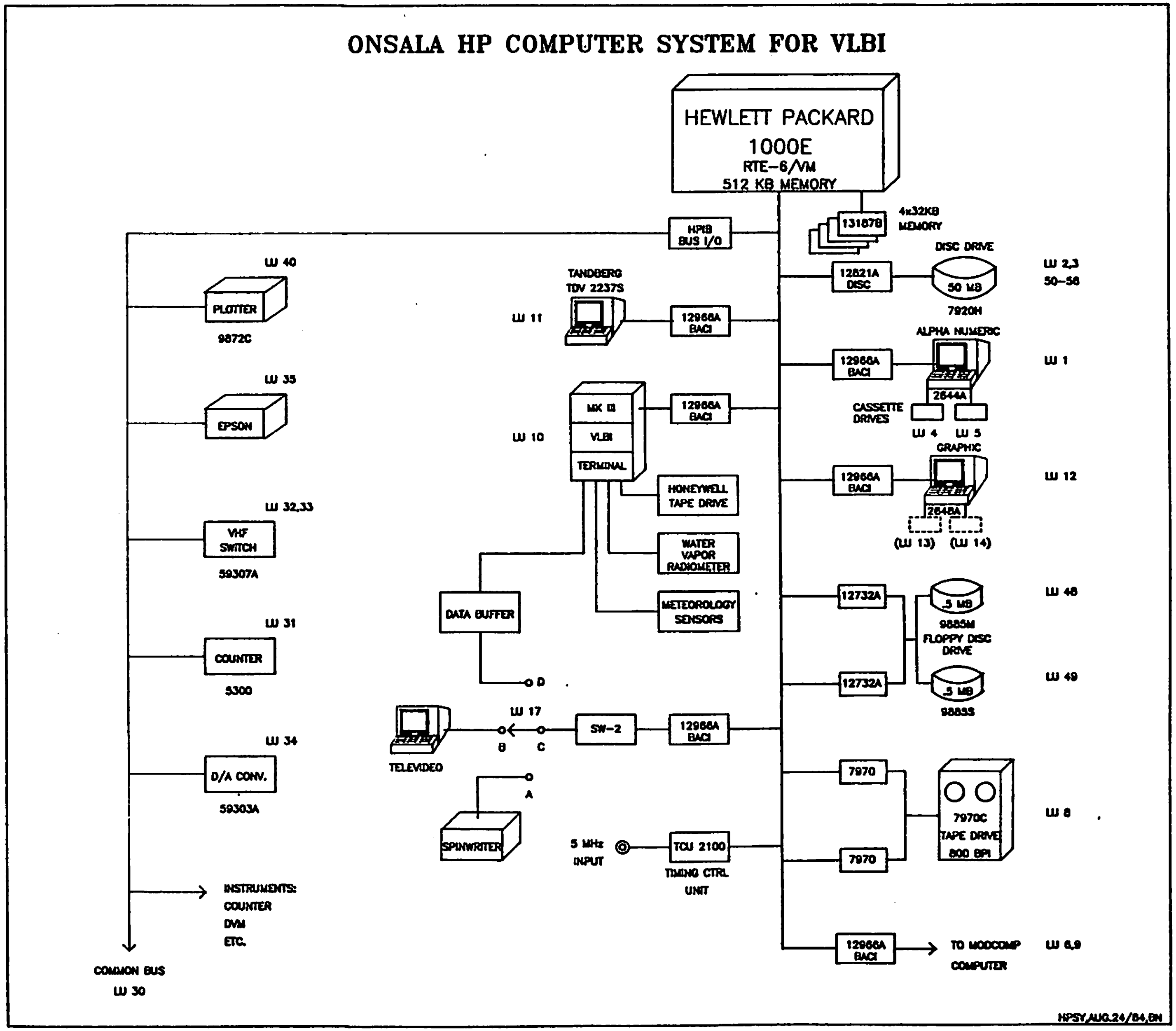

ONSALA HP COMPUTER SYSTEM FOR VLBI
HEWLETT PACKARD
1000E
RTE-6/VM
512 KB MEMORY
HPIB BUS I/O
131678
4x32KB MEMORY
12821A DISC
DISC DRIVE
50 MB
7920H
LU 2,3
50-58
TANDBERG TDV 2237S
LU 11
12966A BACI
ALPHA NUMERIC
2644A
CASSETTE DRIVES
LU 4
LU 5
LU 1
GRAPHIC
2648A
(LU 13)
(LU 14)
LU 12
MK III
VLBI
TERMINAL
LU 10
HONEYWELL TAPE DRIVE
WATER VAPOR RADIOMETER
METEOROLOGY SENSORS
DATA BUFFER
12732A
.5 MB
9885M
FLOPPY DISC DRIVE
9885S
LU 48
LU 49
LU 17
SW-2
TELEVIDEO
SPINWRITER
5 MHz INPUT
TCU 2100
TIMING CTRL UNIT
7970
7970C
TAPE DRIVE
800 BPI
LU 8
TO MODCOMP COMPUTER
LU 6,9
PLOTTER
9872C
LU 40
EPSON
LU 35
VHF SWITCH
59307A
LU 32,33
COUNTER
5300
LU 31
D/A CONV.
59303A
LU 34
INSTRUMENTS:
COUNTER
DVM
ETC.
COMMON BUS
LU 30
HPSY,AUG.24/84,BN

Fig.2

ACTIVITY REPORT OF FRENCH GROUPS IN THE FIELD OF GEODETIC VLBI

Claude Boucher
Institut Géographique National
SGNM/DTIG 02, Avenue Pasteur
94160 Saint-Mandé, France

ABSTRACT

1. INSTRUMENTAL DEVELOPMENTS

Two Mark II BWS terminals has been built by the Observatory of Meudon. They have been tested at Nancay and Atibaia, Brasil at 18 cm (EVN and VEGA sessions).

Two compact H masers will be available in fall 1985, built by the Laboratoire de l'Horloge Atomique, Orsay and the Observatory of Meudon. Stability of 1.E-15 has been found on the first prototype.

A 18 cm receiver has been built for the Atibaia station (VEGA experiment) by the Meudon Observatory. This group could built other receivers (S/X for Atibaia, L and C for Cebreros...)

A technical proposal to realize Mark III terminal (s) has been done by a group (G. Daigne, M. Kasser). A first equipment is planned for 1987 at Cebreros.

2. DATA ANALYSIS

The JPL MASTERFIT software is implemented on a DEC VAX 11/780 of IGN. It is used by a analysis group (IGN, BDL) for radio-star astrometry and geodesy (MERIT...)

A new software is under design by the same group.

Two members of this group are presently at JPL (G. Petit) and NGS (P. Willis).

3. FUTURE PLANS

A 18 cm VLBI experiment is planned in July with Madrid DSS-63, Onsala, Atibaia, Nancay, and Hartebeesthoek.

A Spanish-French cooperation has been established to equip and utilize the Cebreros antenna for geodetic and astronomical work (S/X, Mark II and III, L and C,H maser). This station would be a member of the IRIS network.

In a next step, we consider to build a mobile unit, in possible cooperation with other European groups.

We intend to participate in European VLBI projects which are proposed for discussion:

-densification of the VLBI extragalactic reference frame, in coordination with the groups already working on this field (JPL, NASA/GSFC)

-Mark III VLBI observations of radio stars for astrometric and astrophysical studies, J.F. Lestrade, BDL being presently working on this topic at JPL in the frame of HIPPARCOS

-determination of Earth rotation parameters by establishing a second network within the IRIS commission, eg Polaris-Europe (Wettzell, Onsala, Matera, Cebreros..) or two transatlantic nets, or also including Hartebeesthoek. The two 1 day-sessions could be done each 5 day shifted by 2.5 day.

-monitoring the baselines within Europe and connecting Europe to other stations, especially to Hartebeesthoek and Atibaia, this being within the Crustal Dynamics Project

-monitoring the baselines across the Mediterranean Sea with fixed (Matera, Medicina, Noto, Madrid..) and mobile stations supplied by NGS or some European source.

Status report on geodetic VLBI in Spain
June 3, 1985
Presented by A. Rius

Introduction

Since 1978 some geodetic VLBI activities have taken place in Spain using the Madrid Space Communications Complex of NASA by a small research group headed by the Instituto Geografico Nacional of Spain.

The main results of these activities have been:

- Intercomparison between BWS MKII VLBI and conventional geodetic tecniques in a local network of three antennas.
- Participation in international geodetic VLBI campaigns (MKII and MKIII)(2),(3)

Other related activities have been developped by the Departamento de Fisica de la Tierra y Cosmos from the Barcelona University with the objective of obtaining information about the flux density and spectral index of a selected set of radiostars(4).

All these activities have been performed as projects aproved by INTA and NASA in the frame of the "Host Country" activities.

Present Instrumentation

The following table describes the VLBI Instrumentation located in Spain.

	DSS-61	DSS-63	Cebreros
Agency	NASA	NASA	INTA
Diameter	34 m	64 m	26 m
Frequency Bands	S and X	L,S and X (*)	S
Recording System	MKII	MKII	
Clock	H- Maser	H- Maser	Rubidium

(*) In the next few months it is expected a JPL decision about the installation of a 22 GHz Receiver at DSS-63.

All this instrumentation is normally committed to the tracking of spacecrafts but it is occasionally available for other uses.

Plans

In order to increase the availability of the VLBI technique to the interested groups in Spain, the Instituto Geografico Nacional and the Instituto Nacional de Tecnica Aeroespacial (INTA) are conjontly developping a plan with the objective of using the Cebreros Facility as a dedicated geodetic and astrometric VLBI instrument.

The Spanish IGN has obtained funds to improve the Cebreros instrumentation and is very interested to reach a formal agreement with the French institutions in order to arrive to the proposed objective of upgrading Cebreros.

The legal and administrative problems are expected to be solved before next October.

References

(1) A. Rius, A, Calero E. : "Comparison of VLBI and Conventional Surveying of the Madrid DSN Antennas" in "Techniques d'interferometrie a tres grande base" CNES, Toulouse 1982.

(2) Nothnagel A., et al : "VLBI for Geodynamics Involving the Hartebeesthoek Radio Observatory" presented at the 1984 AGU Spring Meeting, Cincinnatti, Ohio.

(3) Petit G, et al : Proposal for "Geodetic VLBI observations between DSS-63, Onsala, Atibaia, Nancay and Hartebeesthoek".

(4) Estalella, R., et al : "Flux density monitoring of radio stars observable by Hipparcos at S-Band and X-Band", Astron. Astrophys. 124, 309 (1983).

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

THE ITALIAN INVOLVEMENT IN GEODETIC VLBI

B. PERNICE	Dipartimento di Fisica - Bari
D. PICCA	Dipartimento fi Fisica - Bari
G. VERRONE	Dipartimento di Fisica - Bari
A. CAPORALI	Istituto di Fisica Teorica - Padova
G. SYLOS-LABINI	Piano Spaziale Nazionale-CNR - Roma

ABSTRACT

Introduction

The complex crustal structure and the evident seismic activity of the Mediterranean region are of particular concern for Italian geophysicists.

The accuracy of VLBI technique, based on precise and reliable experimental data, can approach problems of both global and regional geodesy.

The relations, if any, between Polar Motion and earthquakes is of special interest for us. Moreover geodetic VLBI network will be usefully completed by Italian stations, so that intracontinental and intercontinental tectonic plates drifts could be monitored.

Instrumental facilities

Two fixed VLBI antennas will be soon operating in Italy; the first one is located near Bologna (North of Italy) and primarily dedicated to astrophysics; it is a 32 m diameter antenna equipped with a S-X feed in the primary focus. The acquisition of the front-end hardware and amplifier is now in progress.

The second antenna will be located in Matera (South of Italy) to be primarily dedicated to geodesy. The design will be completed on July 1985; its construction is planned to be terminated on July 1986 and the validation tests are planned at the end of the same year to make the antenna fully operational during 1987.

It has been entirely designed and will be entirely constructed in Italy with the following characteristics:

basis	wheel and track
diameter	20 m
reflector system	Cassegrain
mounting	altazimuthal
feed	dual frequency
rms on main dish surface	0.4 mm
max veloc, in elevation	2^{o}/sec
max acceleration	$1^{o}/sec^{2}$

It will be equipped with a MARK III system, an H-maser as frequency standard, cooled electronics and four motor-driven wheel to overcome operative problems. These characteristics have been adopted on the basis of some concurring considerations: antenna high gain; good mechanical control; required high accuracy; thermal stability; possibility to control axis orthogonality and intersection (to reduce axis-offset); working frequency up to 30 GHz (for mapping of high frequency sources); costs.

The research group in Bari

Through grants of Piano Spaziale Nazionale (Italian Space Agency) one research group started in 1982 a training program to be acquainted with the VLBI phylosophy and technique to learn and master VLBI data analysis for geodesy at Physics Dept. in Bari.

Prof. I.I. Shapiro and his collaborators in Cambridge (USA) gave all the needed support during two stages at MIT and SAO respectively. Thanks to his courtesy a copy of the VLBI3 program could be brought to Italy and installed on a VAX/VMS.

The validation tests were performed with good results but the software has to be continuously updated because of the refinements and changes in the physical models adopted. Moreover the original batch-mode form of VLBI3 was turned into interactive form to better exploit the VAX/VMS facilities and to give it the capability to better support updatings; at the end a new graphical package has been created to better analyze VLBI3 output.

Research program

Before starting to analyze geodetic VLBI data including Italian stations the research program includes three main goals:

a) updating and extension of the VLBI3 software

b) development of physical and mathematical models of the solid earth structure aiming to gain a deeper insight of the Polar Motion; filtering methods

c) data analysis and Laser Ranging/VLBI results comparison

a) The VLBI3 software including the new nutation series (Wahr) is now available in Italy on a VAX computer. The VAX/VMS operating system is known to be particularly suited for executing programs in interactive rather than batch mode.

In adapting VLBI3 to our VAX we considered convenient to introduce changes in the program in order to give an interactive structure to it and add a new graphical package to make the analysis of the results clearer.

One of the tasks has been to extend the compatibility with VLBI3 of data coming from different sources (NGS, JPL and so on). At the moment routines have been implemented to convert data from NGS-format data files, with the aim to generalize this to the other data format.

Interactivity permits to define control parameters in input, to introduce last-moment changes or to abort the job while the program is "in run". The results analysis too is more interactive using the graphic program linked to the Caltech plot package and displayed on any graphic device available to the user.

b) Several evidences support the coupled shell model of the solid earth. We are studying a particular version of the model based on the visco-elastic coupling of the rotating shells.

We are aware this version is not completely new but we hope to give proper analytical insight of the problem and not only numerical solutions. Analytical solutions, though approximated, are needed in order to start perturbing refinements in the perspective of a Polar Motion deeper insight.

To improve geodetic VLBI parameters estimation, recently attention has been turned to more objective filtering methods than the up to now generally used weighted least squares.

We plan to implement a Kalman filter but we are interested also in the formulation of filtering procedures based on Maximum Entropy Principle.

c) To be acquainted with the geodetic VLBI data analysis before data containing Italian stations become available, we have some data sets to work with.

In particular a NGS data set will be used to estimate Polar Motion and to compare the results with the ones obtained by Laser Ranging technique, A. Caporali in Padova is working on.

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

Status Report of the Hartebeesthoek Radio Astronomy Observatory

by

Axel Nothnagel
Hartebeesthoek Radio Astronomy
Observatory / NITR
PO Box 3718
Johannesburg 2000
South Africa

Important progress has been made at HartRAO since the last report at the meeting in Delft in 1983.

An Oszilloquartz EFOS H-Maser has arrived recently and is beeing tested at the moment.

The receiver performance was improved for the 18 and 13 cm wavelengths. Cooled GaAsFETs for 6 cm and 3.6 cm are to be assembled. (Specifications see Table 1)

The JVC video tape recorder was replaced by a RCA VJT 250 cassette recorder.

A device similar to the JPL dicroic plate assembly is under investigation for simultaneous S- and X-band recording.

A Mark III terminal is still under consideration but the financial situation is very tough at the moment.

HartRAO Receiver Status (June 1985)

Wavelength	Receiver	System Temperature	Bandwidth	Efficiency Aperture	Efficiency Jy/K	Status
18 cm	Amb GaAsFET	125K	400 MHz	45%	11.8	Operational
	Cooled GaAsFET	40K	400 MHz			Operational
13 cm	Amb GaAsFET	125K	100 MHz	60%	8.8	Operational
	Cooled GaAsFET	40K	100 MHz			Operational
6 cm	Amb GaAsFET	140K	250 MHz	40%	13.2	Operational
	Cooled GaAsFET	60K	250 MHz			Op. by 12/85
3.6 cm	Amb GaAsFET	250K	1000 MHz	31%	16.4	Operational
	Cooled GaAsFET	80K	800 MHz			Op. by 12/85

Table 1

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

MPIfR correlator expansion and related topics

J. Campbell

Summary:

Since November 1982 the Mk III correlator of the Max-Planck-Institut für Radioastronomie has been operating with 3 baselines at a maximum bandwidth of 56MHz, three tape drives and one control (and processing computer) HP 1000F. A fourth recorder has been installed and is expected to be operational as of July this year. In this configuration 4 stations with 6 baselines can be processed in modes B and C with a maximum bandwidth of 28MHz(14 channels). The postprocessing bottleneck will be relieved by the end of this summer with an additional HP A900 computer, which will take care of the fringe analysis.

The geodetic user group (German Science Foundation SFB 78) has purchased a fifth tape drive to be installed by the end of this year.

In 1986 the new Haystack designed correlator boards will replace the old ones to increase the processing speed by a factor of two and to accommodate future new applications such as QUASAT-and mm-VLBI. The new boards will provide a correlator expansion capability of up to 8 stations.

The incorporation of the new high density heads (quoted at $25,000.- each) still poses some financial problems. The german geodetic VLBI group will be able to secure funds for one or two units while the remaining units will have to be procured via a cooperative effort of the european VLBI consortium.

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

On the Principles, Assumptions and Methods of Geodetic VLBI

Frits J.J. Brouwer
Dept. of Geodesy, Delft Univ. of Tech., The Netherlands

ABSTRACT of Ph.D. Thesis

The accurary of geodetic VLBI point positioning measurements is assessed. The assessment is based on a software package developed for the purpose which incorporates all possible computing models for geodetic VLBI data analysis. Analysis of real and simulated data with this package shows that an accuracy of 10 cm in point positioning has been achieved with the ERIDOC and MERIT Short Campaign observing campaigns. This analysis has also led to the formulation of criteria for optimum design of a geodetic VLBI observing campaign, and to a general approach for evaluating experiments designed to compare VLBI with other geodetic techniques, because the ultimate accuracy of world-wide geodetic measurements for geodynamics and positioning can only be achieved by a combination of several techniques.

The DEGRIAS (DElft Geodetic Radio Interferometry Adjustment System) software package and the background of its development are described in the first three chapters of this publication. The package is the outcome of a desire to incorporate geodetic VLBI into the system for the design and computation of geodetic networks developed at the Delft Department of Geodesy, commonly known as the Delft Approach. Chapters 2 and 3 provide descriptions of the general and specific features of DEGRIAS respectively. Under general features is included a sketch of all physical phenomena relevant to VLBI observations, and the basic equations for the delay and delay rate observables in the commonly used computing model, the kinematic model. An analysis is given of the achieved level of precision of DEGRIAS in modelling the phenomena that constitute the "real world" of geodetic VLBI. The more detailed description in chapter 3 includes discussion of linearisation of the equations for delay and delay rate and a discussion on the rank deficiences of the system of normal equations in the Least Squares adjustment. Chapter 3 also presents the results of applying DEGRIAS to the VLBI data of ERIDOC (European Radio Interferometry and DOppler Campaign) and part of the MERIT (to Monitor Earth Rotation and Intercompare the Techniques of observation and analysis) Short Campaign.

The experience gained with this data analysis led to the consideration in chapter 4 of an optimized design for geodetic VLBI experiments. The SCHED-module of DEGRIAS generates a schedule of observations starting from visibility considerations for the sources and optimizing for slewing time. The design of an observing session also has to be optimized with respect to precision and reliability. The literature is mainly concerned with the precision of geodetic VLBI, hence in this study, much attention has been paid to its reliability. Simulation studies and analysis of real data has uncovered estimates of magnitudes of errors that may be present in individual observations, or in groups of observations, and which cannot be detected by statistical testing. Based on studies performed on the network designs for global networks from [Dermanis,1977], for the MERIT Short Campaign and for a possible European Geodynamics Network, the following conclusions have been reached concerning the design of an experiment:

1. The reliability is generally poor due to the large difference between the number of scheduled observations and the number of weighted observations in the final Least Squares fit; small errors may therefore have a relatively large impact on the final results for, for instance, station coordinates.
2. Low elevation observations (below about 10 degrees) should be excluded from the VLBI schedule since the magnitude of the correction for tropospheric refraction becomes less certain and since these observations are of poor reliability.
3. For accurate measurements, the operation of a network with more than two baselines (so that closed triangles can be formed) has the advantage of improved likelihood of error detection and is therefore to be recommended.
4. Furthermore, it is concluded that much can be gained from a careful design of the experiment with respect to precision and reliability, in particular when the recommendation is followed to observe for 48 hours instead of 24.

In chapter 5, the main computing models for geodetic VLBI are investigated. As discussed in chapter 2, modelling of nutation in the kinematic model is a troublesome aspect, together with refraction due to the wet component of the troposphere and to the dry component at low elevations, and instrumental effects. Ways of minimizing the risks of these errors have been sought by considering alternative computing models. The model with the least number of possible hypotheses for the description of the physical phenomena is the <u>geometric model</u>. This model makes use only of the simultaneity of measurements of several co-observing baselines. The ideosyncrasies of this model regarding precision and reliability are discussed. On practical grounds, an intermediate model, called <u>short-arc computing model</u>, is also presented, which models precession etc. only during short intervals of time. Computing results with the three types of models (geometric, short-arc, kinematic) are presented both for the European Geodynamics Network and for the MERIT Short Campaign.
It is concluded that the geometric model - although very attractive from a theoretical point of view - is hardly applicable in practice. The short-arc model, however, can be considered as a promising alternative to the common kinematic one.

In Part II, a general approach is studied to combine and compare two sets of 3-dimensional Euclidean coordinates for a number of stations. The differences in coordinates can, apart from their random character, be the result of either a systematic bias between two applied measurement techniques (<u>intercomparison of techniques</u>) or of a shift in position of one or more of the stations (<u>deformation analysis</u>). It is concluded that any comparison method should rest on a sound statistical basis. In chapter 6 an approach to intercomparison, based on the similarity transformation, is discussed which combines all the required qualities. The software developed for this approach (called FUSION) is also described in this chapter. It has been applied to analyse the differences between the Doppler and VLBI coordinates determined in the ERIDOC campaign, which were comparable at the 0.5 metre level. FUSION has also been applied to the European Geodynamics Network to establish what precision of measurement is required to detect possible (tectonic) motions of stations in the Mediterranean area reliably.

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

The Influence of Ocean Loading and Atmospheric Loading on VLBI - Observations

Harald Schuh
Geodetic Institute
Univ. of Bonn

Wolfgang Rabbel
Instit. for Geophysics
Univ. of Kiel

In connection with the rapid increase of VLBI-accuracy, geophysical effects of second order have now to be considered in the model used for VLBI data analysis. Among those the loading effects of the ocean tides as well as displacements of the VLBI-stations caused by air pressure variations are of high importance.
The influences of ocean loading on the most important VLBI-stations have been computed independently by several authors. All investigations were based on the fundamental paper of Farrell (1972) and have used the Schwiderski ocean maps. For inland stations the total effect with its main component in radial direction will not exceed 2 cm, for islands however it can reach 10 cm.
The ocean loading correction model had been entered into the Bonn VLBI Software System (BVSS), was tested out in detail and the influence on VLBI-results was investigated. The ocean loading subroutines were then implemented into the program CALC of the MarkIII Data Analysis System and have been officially accepted in its latest version CALC 6.0.

The effect of air pressure variations on the fixed earth can be split up into a long periodic (seasonal) term and into short time variations of a few days caused by (anti-)cyclones. An explicit computation of the total displacements can be done by convolving Green's funtions with the load distributions. Air pressure values within a radius of 2000 km are needed. For first approximation a two-coefficient correction equation can be used (Rabbel and Zschau, 1985).

The atmospheric loading modul was implemented in the Bonn VLBI program (BVSS) and several test computations using real and simulated displacements were done (Rabbel and Schuh, 1985). The most important conclusions of these investigations are:

- The effects of short period atmospheric loads on VLBI-stations can cause errors in the delay observations which even in worst case are below the actual VLBI-precision of +-3cm ($\hat{=}$100psec). However, to reach the general scope of the so called "1cm-accuracy" they have to be considered in any case.
- These delay errors τ_{al} can affect the baseline components derived in a geodetic solution and therefore they can falsify the baseline length within a few millimeters, in extreme cases up to a few centimeters.

It is recommended to implement an atmospheric loading correction into the other VLBI-programs as well. Then the following procedure could be applied: short examination of the air pressure values measured on the VLBI-stations during the experiment. If the variations exceed a certain limit (15 or 20 mbar), regional air pressure maps have to be used to determine the station displacements either by the approximation formula or by the exact convolution method.

In the future it will be inavoidable to refer the coordinates of every station to a mean air pressure value of for example 1013 mbar.

Lit.:

Farrell, W.E.: Deformation of the Earth by Surface Loads, Rev. of Geophys. and Space Phys., Vol 10, No.3, 1972

Rabbel, W. : Schuh, H. The Effect of Atmospheric Loading on VLBI-Experiments, (in prep.), 1985

Rabbel, W. : Zschau, J. Static deformation and gravity changes at the earth's surface due to atmospheric loading, J Geophys 56: 81-99, 1985

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

MONITOR THE SOURCE STRUCTURE USING GEODESY VLBI DATA

Tang Guoqiang, B.O. Rönnäng, L.B. Bååth
Onsala Space Observatory, Sweden

and

P.J. Diamond
M.P.I. fur Radioastronomie

ABSTRACT

This is a report on an ongoing project designed to study the variations of the spatial structure of the extragalactic radio sources used as reference sources in geodesy and astrometry VLBI measurement.

One of the error sources for the geodetic VLBI measurement is the radio source structure and its variations. Most of the compact radio sources show structures on the milli-arc second scale and most of them vary with time. The error due to the source structure for the intermediate and intercontinental baseline measurements is estimated to be small but in order to reach an accuracy of 3 cm or better, it is interesting to study structure variations and take the source structure effect into account.

At the moment, it is almost impossible to predict or to model the source structure variations. One can study the source structure and its variations only from the map of the source. The errors caused by source variation can be explained and its magnitude can be estimated if the map of the source at the same epoch and same frequency is produced.

For this purpose, we try to map the sources from geodetic VLBI data with AIPS (Astronomical Imagine Processing System). The procedures of the data preprocessing are shown in Fig.1, and the mapping with AIPS is shown in Fig.2.

Two examples of the preliminary results, i.e. the maps of 3C345 and 0212+735 are shown in Fig.3 and Fig.4 respectively. Both of the maps are made from the Mark-III geodetic VLBI observations during June 18-20, 1982. The following stations are involved: Fort Davis (26m, Texas); Haystack (37m, Massachusetts); Maryland Point (26m, Maryland); Owens Valley (40m, California); Westford (14m, Massachusetts) and Onsala (20m, Sweden).

Since the observations are not optimized for mapping purposes, the source maps made from geodesy VLBI data have the following features,

1. low dynamical range;
2. a beam with sidelobes caused by holes in the U-V plane;
3. lack of good data for the amplitude calibration;
4. quite good resolution due to the intercontinental observations.

Further work will be done to map the same sources at other epochs in order to check whether there are source structure variations or not. If there are, we shall study how this affects the baseline length measurements.

REFERENCES

Bååth, L.B. et al.,1980, Astro. Astrophys. 86, 364-372.

Bååth, L.B. et al., 1981, A.J.(Letters), 243, 123-126.

Cotton,W.D., 1980, NASA Conf.Publ. 2115, 193-197.

Fomalont, E.B., 1982, in Image Display Processing and Analysis in Synthesis Mapping. Proceedings of NRAO-VLA Workshop, Socorro, N.M., June 1982.

Johnston, K.J., 1983, IAU Symp.110, 339-346.

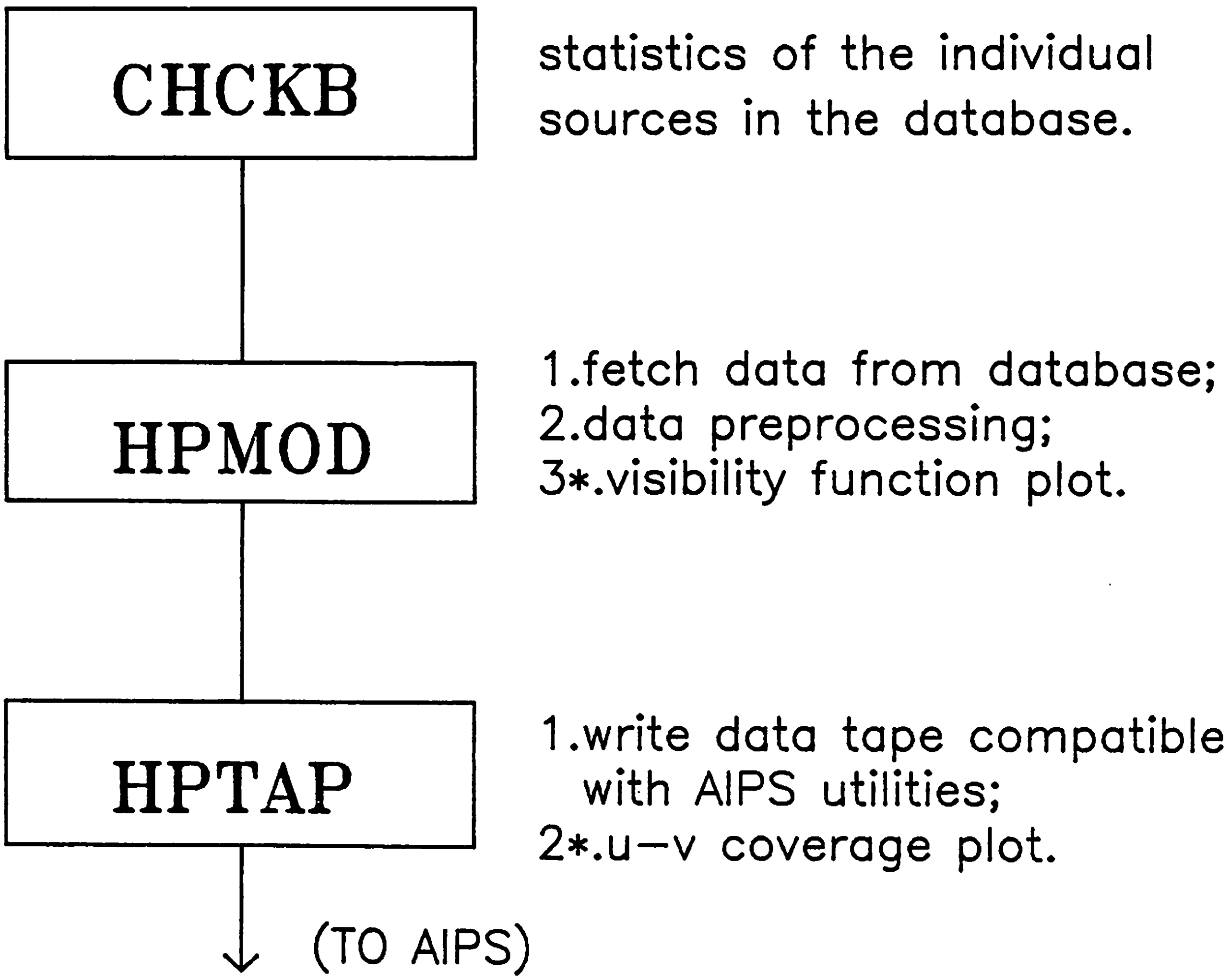
Robertson, D.C., 1981, Proc. of IAU 56th Colloq., 205-216.

Shaffer, D.B., IAU Symp.110, 365-374.

Shaffer, D.B., ibid. 135-136.

Wittels, J.J., et al., 1976, Ap.J. (Letters), 206, 75.

DATA PROCESSING



* Optional.

Fig. 1

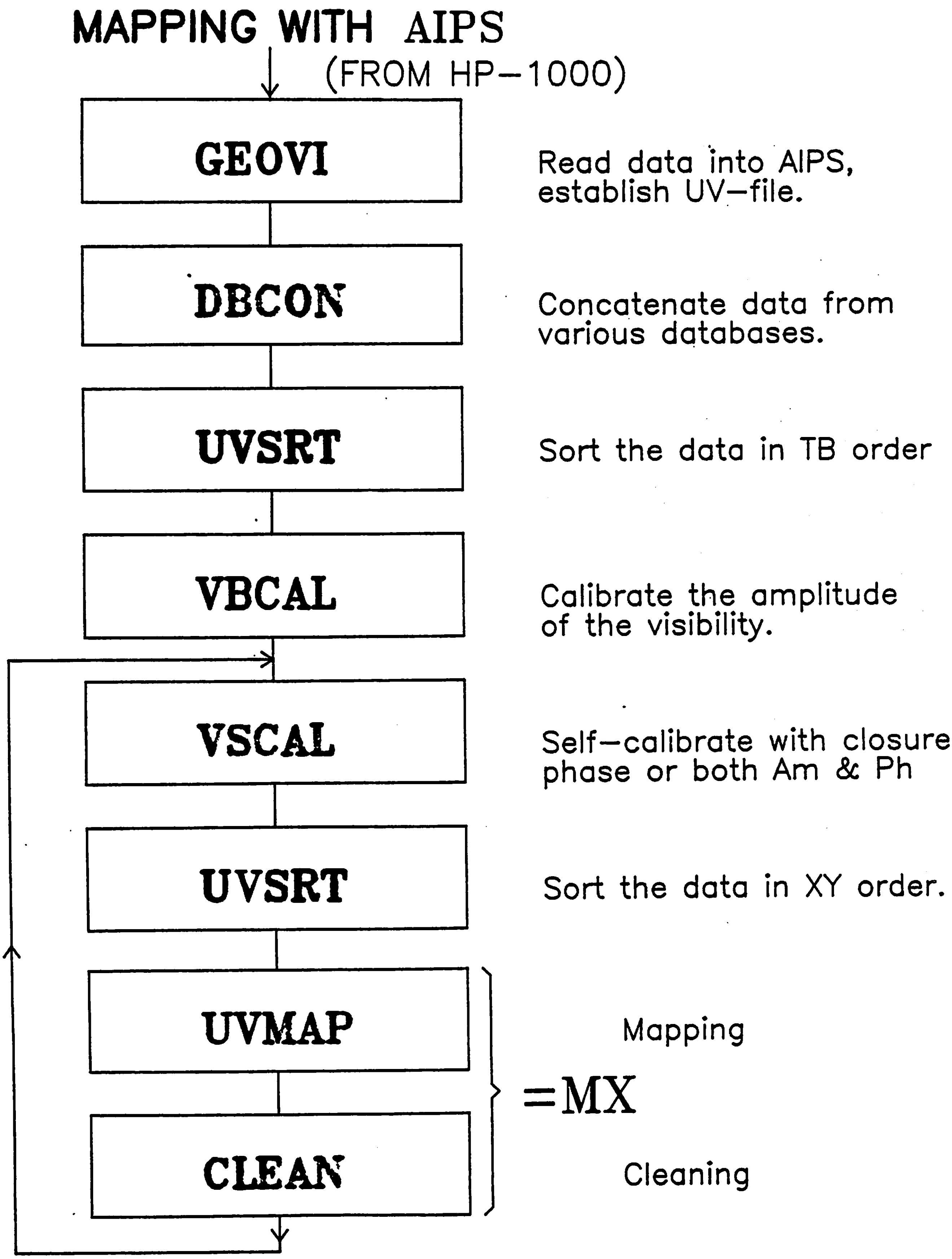

MAPPING WITH AIPS
(FROM HP-1000)
GEOVI
Read data into AIPS,
establish UV-file.
DBCON
Concatenate data from
various databases.
UVSRT
Sort the data in TB order
VBCAL
Calibrate the amplitude
of the visibility.
VSCAL
Self-calibrate with closure
phase or both Am & Ph
UVSRT
Sort the data in XY order.
UVMAP
Mapping
=MX
CLEAN
Cleaning

Figure 2

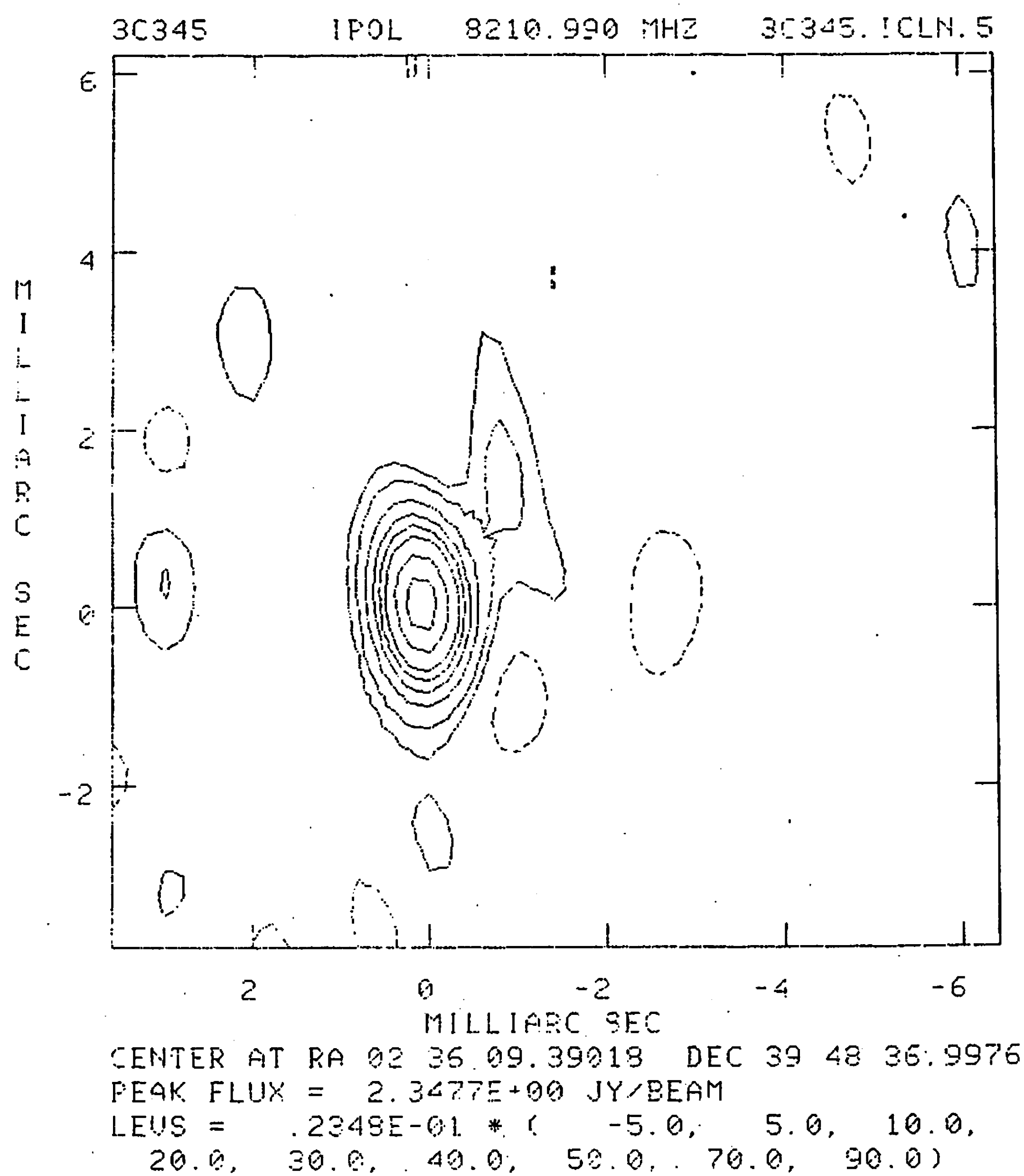
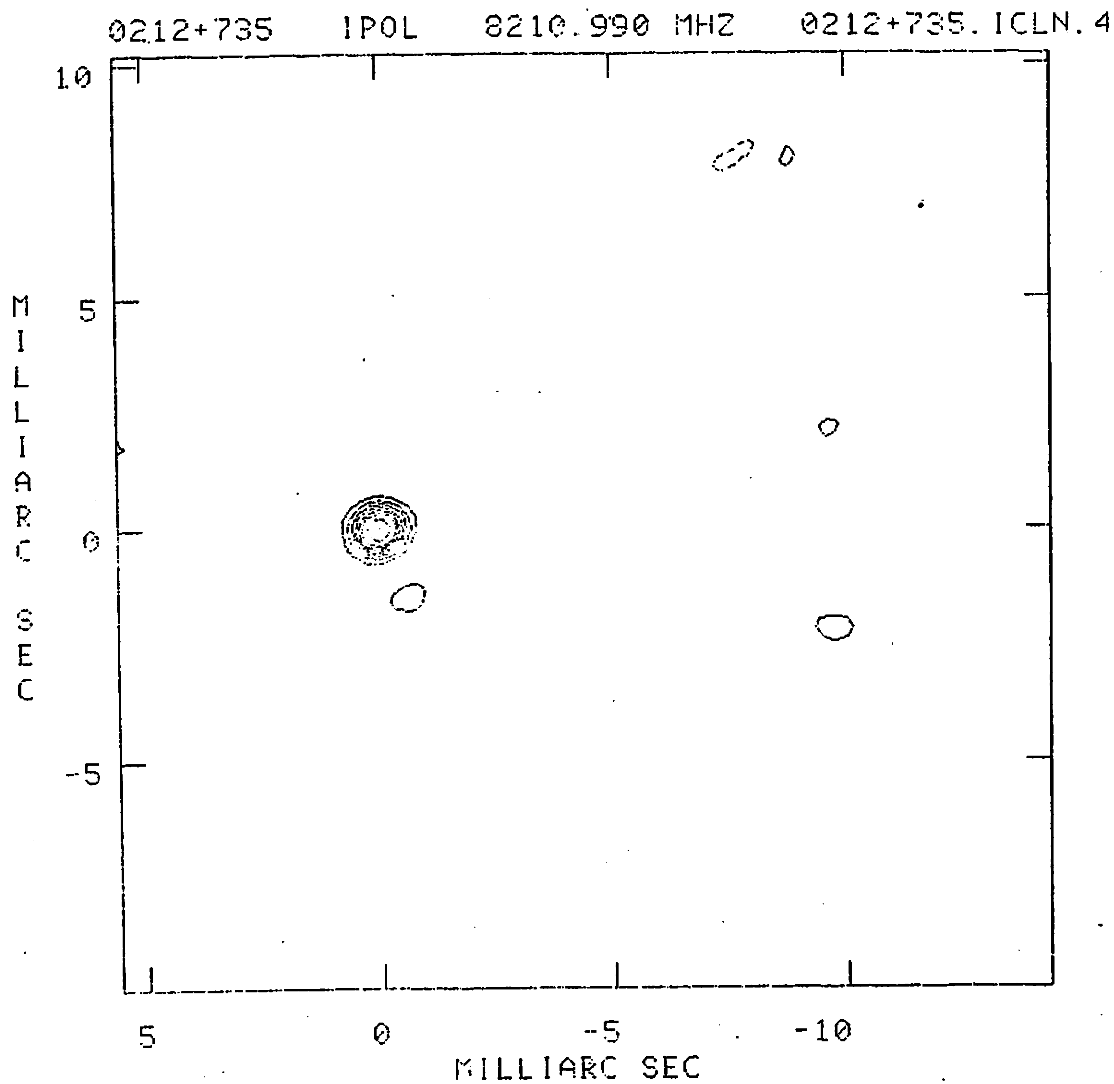

3C345 IPOL 8210.990 MHZ 3C345.ICLN.5
6
4
2
0
-2
MILLIARC SEC
2
0
-2
-4
-6
MILLIARC SEC
CENTER AT RA 02 36 09.39018 DEC 39 48 36.9976
PEAK FLUX = 2.3477E+00 JY/BEAM
LEVS = .2348E-01 * (-5.0, 5.0, 10.0,
20.0, 30.0, 40.0, 50.0, 70.0, 90.0)

Figure 3



CENTER AT RA 14 07 00.39564 DEC 73 49 32.6199
PEAK FLUX = 7.3666E-01 JY/BEAM
LEVS = .7367E-02 * (-10.0, 10.0, 20.0,
30.0, 40.0, 50.0, 60.0, 80.0, 100.0)

Figure 4

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

REVIEW OF WATER VAPOUR RADIOMETRY

by

Gunnar Elgered
Onsala Space Observatory
Chalmers University of Technology
S - 439 00 Onsala, Sweden

This work was done under European Space Agency Contract.
The reference to the complete final report is:

Elgered, G., B.O. Rönnäng, E. Winberg, and J.I.H. Askne (1985), "Satellite-Earth Range Measurements. I. Correction of the Excess Path Length due to Atmospheric Water Vapour by Ground Based Microwave Radiometry," ESTEC Contract No 5910/84/NL/MD Report, Research Report 147, Onsala Space Observatory, Chalmers University of Technology.

Summary

The excess propagation path of radio waves propagating through the neutral atmosphere of the earth can be expressed as one hydrostatic path delay, ΔL_h (m), and one wet path delay, ΔL_w (m), as

$$\Delta L_h = (\ 0.0022768 \pm 0.0000005 \text{ m mbar}^{-1}) \frac{P_0}{f(\phi, H)} \tag{1}$$

where

$$f(\phi,H) = (\ 1 - 0.00266 \cos 2\phi - 0.00028H) \tag{2}$$

and

$$\Delta L_w = (\ 3.82 \pm 0.04\ ) \cdot 10^{-1} \int \frac{e}{T^2}\, dh \tag{3}$$

where P_0 is the total pressure at the ground (mbar), ϕ is station latitude, h is the height (m), H is the station height above the geoid (km), e is the partial pressure of water vapour (mbar), and T is the temperature (K).

The hydrostatic path delay can be estimated with high accuracy from ground surface pressure measurement. The method of water vapour radiometry for the determination of the wet path delay is the most promising for the VLBI-application. In Table 1 seven different types of the Water Vapour Radiometer (WVR) are listed. The costs have been given by the developers.

TABLE 1.
WATER VAPOUR RADIOMETERS.

Instrument	Cost (approximate)	Remarks
1. USNO WVR	50 k$ US	1984 prices, hardware only.
2. NOAA WVR	250 k$ US	to duplicate the unit incl. trailer
	200 k$ US	excluding trailer
	80 k$ US	assembled microwave package (available from Hughes Aircraft Co.)
3. JPL R-series	120 k$ US	1981 prices
	150 k$ US	upgraded unit, 1984 prices
4. Onsala WVR	500 kSEK	1979 prices
	120 k$ US	estimated in 1984 prices
5. Kashima WVR	25 k$ US	microwave components only
6. New JPL WVR	120 k$ US	estimated for an additional unit
7. Bonn WVR	222 kDM	1984 prices, hardware only (excl. proposed cold RF FET amplifiers)

The accuracy of the WVR method is of course a function of the accuracy of the measured sky-brightness temperatures and the operating frequencies but it is also dependent on the weather situation. This is shown in Fig. 1 and 2 for the two extreme climates of Barrow, Alaska, and Singapore.

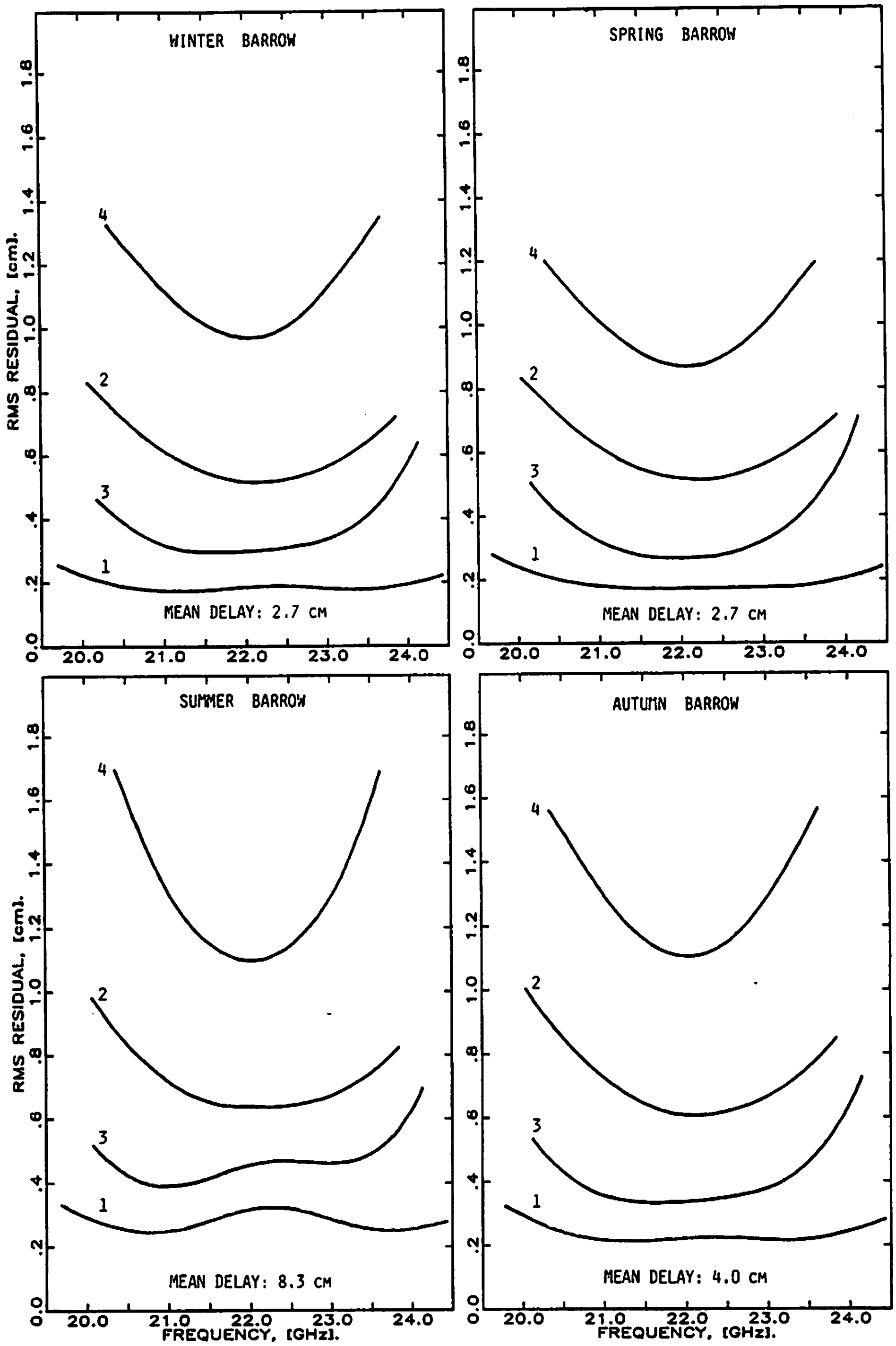


Figure 1. Rms residuals of the wet path delay obtained from radiosonde data at Barrow, Alaska, vs the frequency of the channel closest to the water vapour line for different instrumental errors, 0.2 K (1 and 3) or 1.0 K (2 and 4), and the second frequency band centred at either 31.5 GHz (1 and 2) or 18.0 GHz (3 and 4).

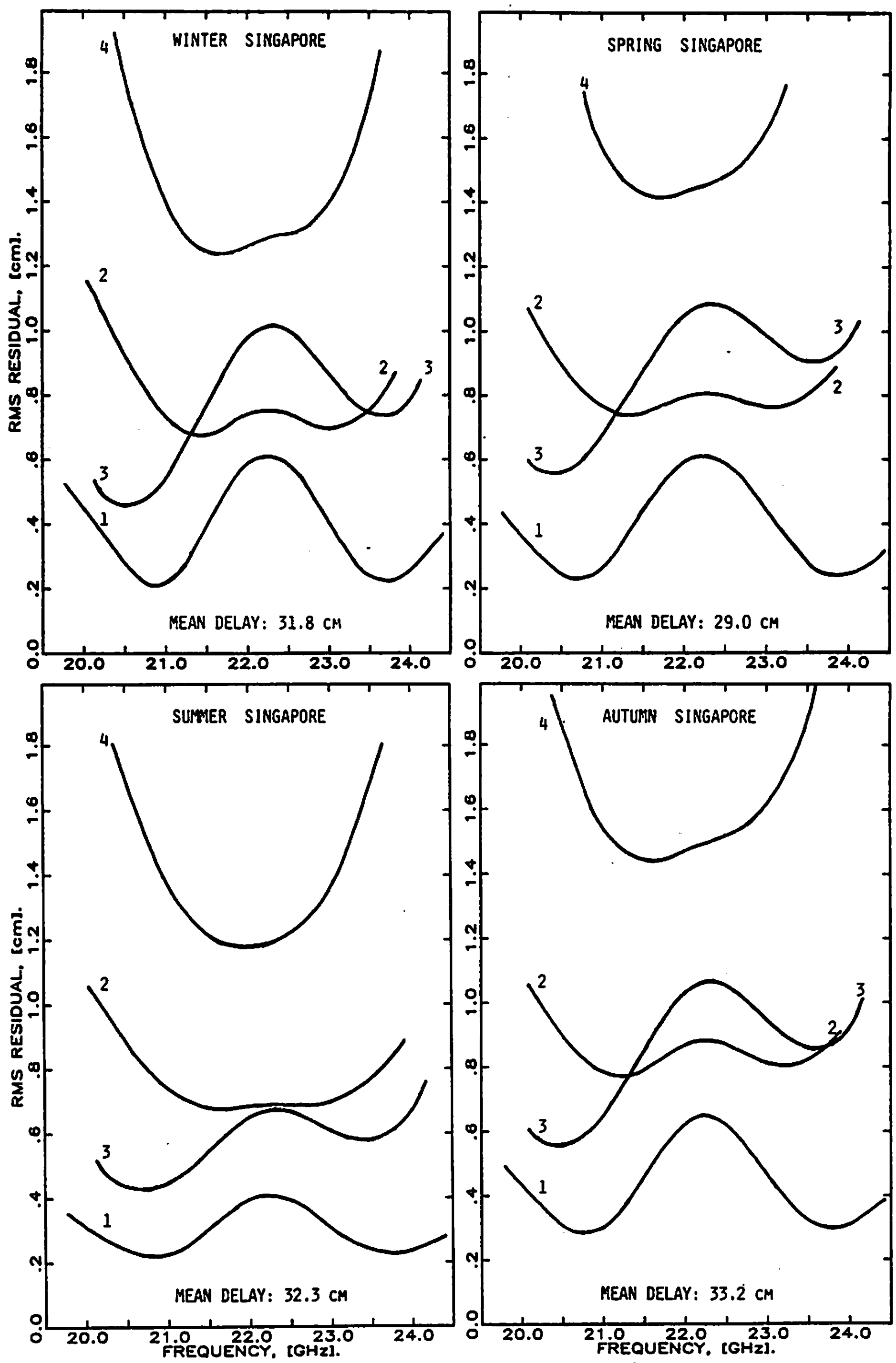


Figure 2. Rms residuals of the wet path delay obtained from radiosonde data at Singapore, vs the frequency of the channel closest to the water vapour line for different instrumental errors, 0.2 K (1 and 3) or 1.0 K (2 and 4), and the second frequency band centred at either 31.5 GHz (1 and 2) or 18.0 GHz (3 and 4).

Finally, as an over all average the following accuracies could be obtained by different types of WVR and existing atmospheric models. The accuracies are averaged over the seven sites and taken from the figures and tables in section V.3 of the complete final report. The procurement costs were obtained by taking the minimum costs, from Table VI.1 of the complete final report, times a factor of two.

Method	Elevation angle [degrees]	Total wet path delay [cm]	rms accuracy [cm]	Procurement cost [MSEK]
WVR at 23.8 and 31.5 GHz, instrumental error 0.5 K.	90	10	0.5	1.0
	30	20	0.6	
WVR at 18.0 and 22.0 GHz instrumental error 1.0 K.	90	10	1.2	0.7
	30	20	1.4	
Model	90	10	2.6	0.05
	30	20	5.2	

S T A T U S   O F   T H E   S F B 7 8
W A T E R   V A P O R   R A D I O M E T E R

Gundolf Reichert
Geodetic Institute of the University of Bonn

1) CONCEPT OF THE SFB 78 WVR

The SFB 78 WVR differs in some important topics from other concepts:

a) versatility; [->Fig.1] WVR may be used as
Dicke radiometer (hot/cold load)
noise adding radiometer (signal, signal+noise)
null-balanced radiometer (signal = cold ref + noise)

b) high sensitivity; use of cryogenic front end LN FET's will decrease system temperatures to some 120 K

c) antenna configuration; [->Fig.2] using 2 mechanically coupled steerable off axis paraboloid mirrors which are made of reinforced epoxi. These mirrors make the system system insensitive against rain droplets on its surface. The size of the mirrors produces high directivity (Beamwidth < 2°)
No tipping of the microwave/cryogenic part is necessary, resulting in high thermal end electrical stability.

d) high sophisticated computer control; [->Fig.3]
HP 9817 controller combined with modular hardware concept (MPI digital monitor backend equipped with MOTOROLA MC 68000, HP 3497A Data Acquisition Unit, independent step motor control unit).
Data and command transfer via HP-IB BUS EXTENDER and coax-cable between WVR and controller.

Interrupt capability (communication with HP 1000)

2) ACTUAL SYSTEM PARAMETERS

Y-factor measurements of front end :
Tsys (20.6 GHz) = 310 (+-5) K without RF-FET's
Tsys (31.4 GHz) = 490 (+-5) K without RF-FET's (mixer defect)
(should be 300 K after repair)

Frequency stability
spez. 20.6 GHz true: 20.67 GHz at 42 °C
df/dU = -1 MHz/U
df/dT = -.8 MHz/°

spez. 31.4 GHz; true: 31.37 GHz at 46 °C
df/dU = -20 MHz/U (?)
df/dT = - 5 MHz/°

BACKEND Parameters

channels	8
phases	max. 16
control signals	blanc, sync
input attributes	TTL, bipolar max. 20 MHz
counter res./channel	32
wordwidth/channel	32
integration mem.	2 X 512 byte
blanking	min. > 35 usec max. < 268 sec.
phase	min. > 1 usec max. < 268 sec
integration time	min: 200 usec max: 1.2 h
integration cycles	1 - 65535
time base	16 MHz
puls generator:	
blanking	1 - 999 * 10 usec
phase	1 - 999 * 10 msec
time base	16 MHz
logic	TTL, bipolar
data rate	500 kB/sec 40 bytes/phase resulting in 80 usec/phase

System will be completed in summer 1986.

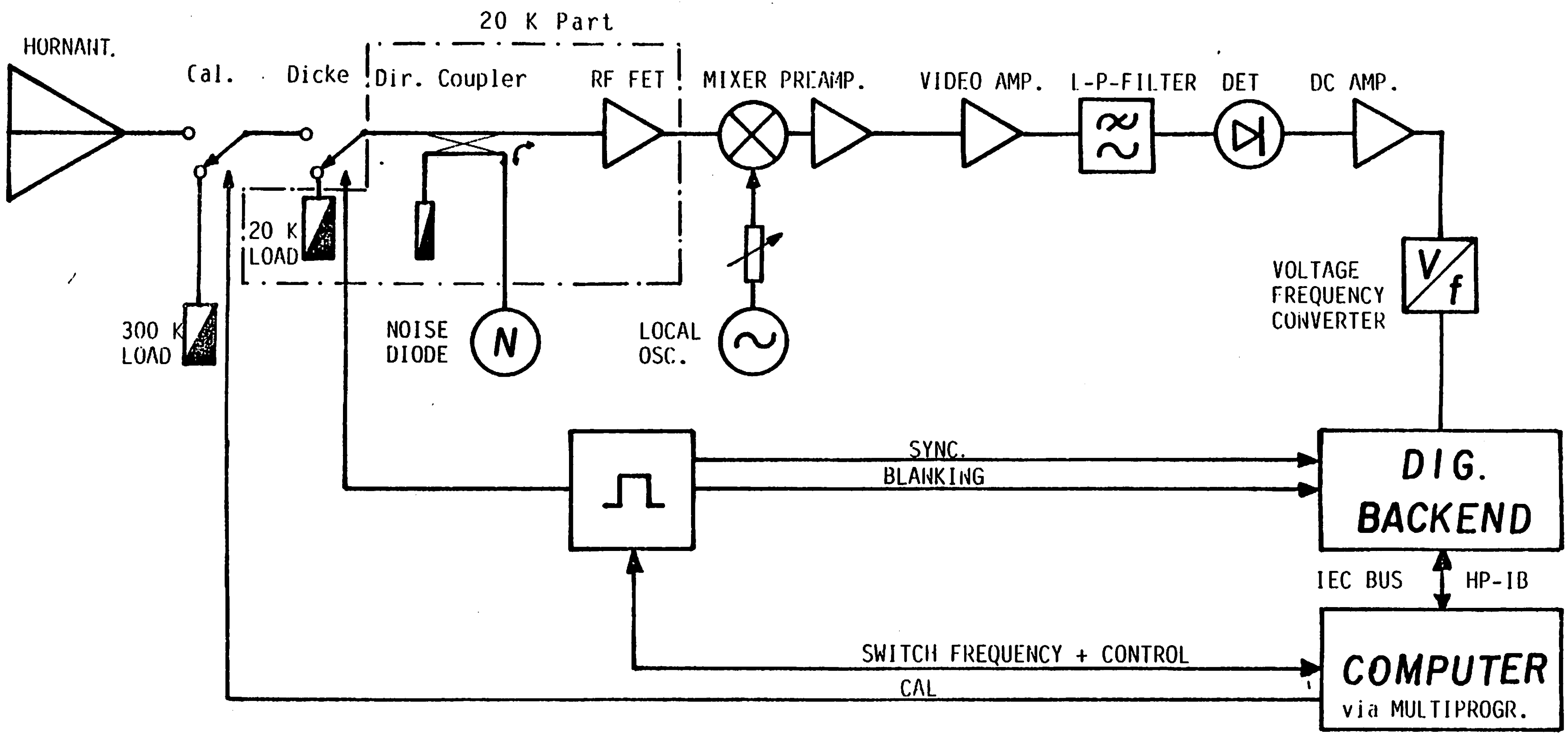


Fig. 1 Block diagram of one WVR channel

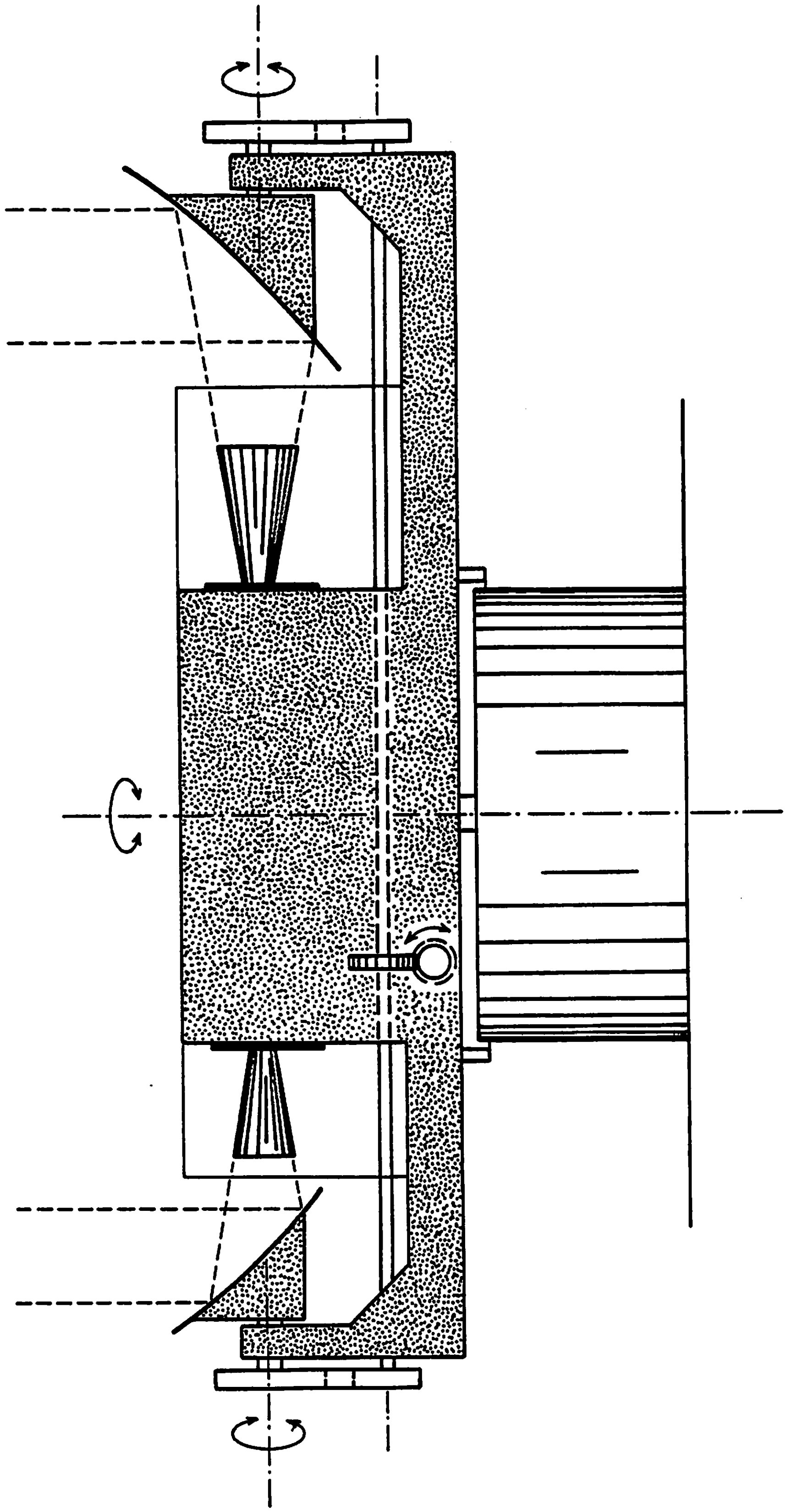


Fig.2

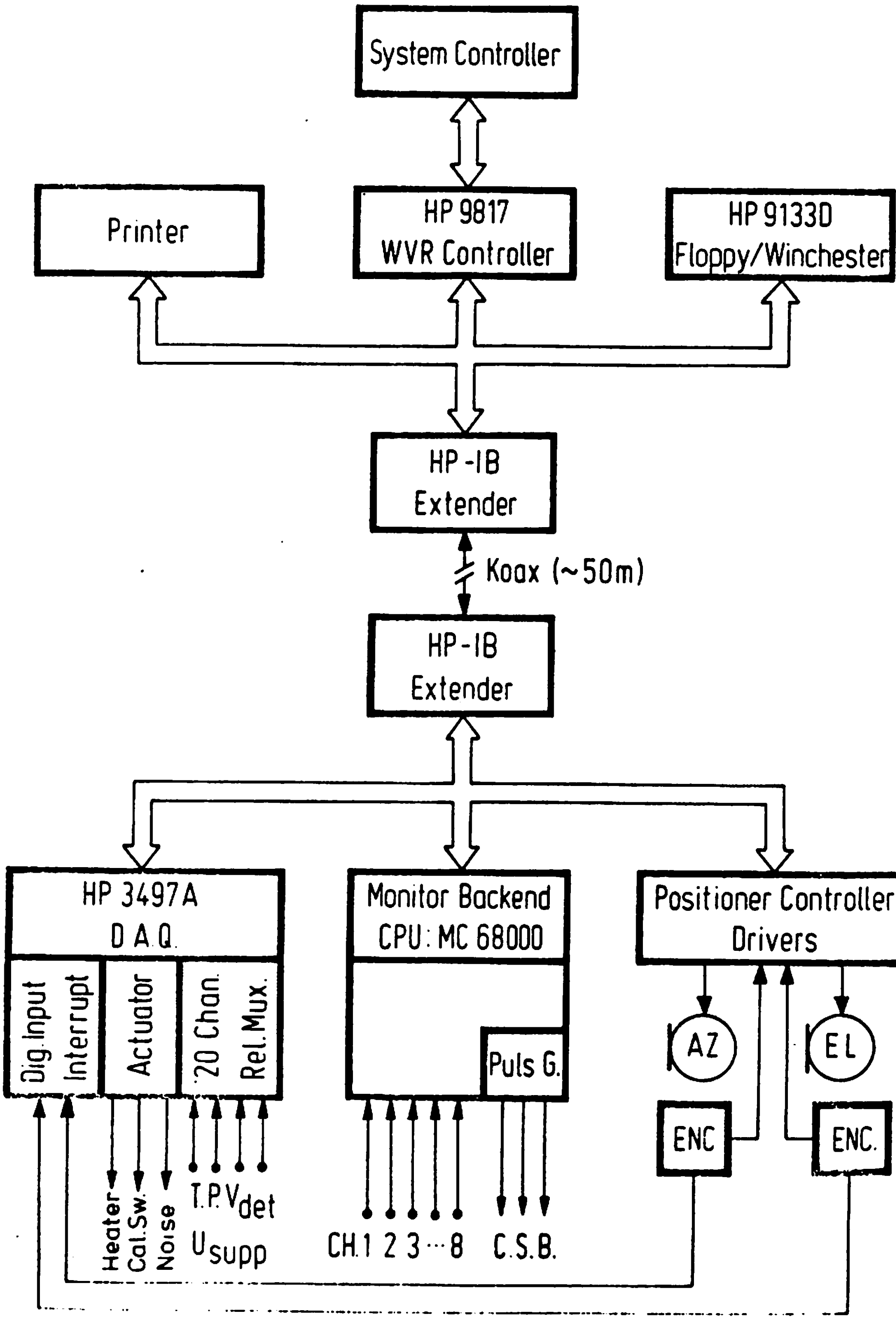

System Controller
Printer
HP 9817
WVR Controller
HP 9133D
Floppy/Winchester
HP-IB
Extender
Koax (~50m)
HP-IB
Extender
HP 3497A
D A Q.
Dig. Input
Interrupt
Actuator
20 Chan.
Rel. Mux.
Monitor Backend
CPU: MC 68000
Puls G.
Positioner Controller
Drivers
AZ
EL
ENC
ENC.
Heater
Cal.Sw.
Noise
T.P. Vdet
Usupp
CH.1 2 3 ··· 8
C.S.B.

Fig. 3

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

WATER VAPOUR RADIOMETER DATA COMPARED TO VLBI DATA

by
Gunnar Elgered
Onsala Space Observatory
Chalmers University of Technology
S - 439 00 Onsala, Sweden
and
Jim Davis
Department of Earth, Atmospheric, and Planetary Sciences,
Massachusetts Institute of Technology
Cambridge, MA 02139, U. S. A.

Summary

A method recently applied in VLBI-post-processing is Kalman filtering (Herring, personal communication 1985), which makes it possible to estimate the residual tropospheric delay for each observing epoch during a VLBI experiment. If the pressure variations at the ground are taken into account the hydrostatic path delay will be determined and the remaining residual will be an estimate of the wet path delay. The disadvantage of solving for the wet path delay instead of using Water Vapour Radiometer (WVR) measurements is larger formal errors of the other unknowns determined in the solve process. The technique will, however, give an independent estimate of the wet path delay which can be compared with the results from WVR observations.

An example of the wet path delay estimated by the VLBI-post-processing is shown in Fig. 1 for the Onsala site during a VLBI-experiment across the North-Atlantic Ocean in May, 1984. An estimate of the wet path delay is of course also done for the Haystack Observatory site at the other end of the baseline. Fig. 2 shows the measured wet path delay using the WVR at Onsala. Even though all estimates and observations are made in the direction of the sources, all values are referred to the zenith direction in the two figures.

It is clear from this example that most of the variations of the wet path delay predicted by the post-processing are also detected by the real WVR measurements. The difference has a mean of 7 mm and an rms of 9 mm.

It should be mentioned that it is important to have high absolute accuracy of the measurements of the ground pressure (an error of 1 mbar in the pressure corresponds to an error of 2.3 mm in the zenith path

delay) when the wet path delay are determined in the post-processing. Since the hydrostatic term has approximately the same elevation dependence as the wet term, the accuracy of the residual wet path delay will be degraded by uncertainties of the ground pressure.

The developed method used to predict the wet path delay is of great importance in order to verify the result from WVR observations.

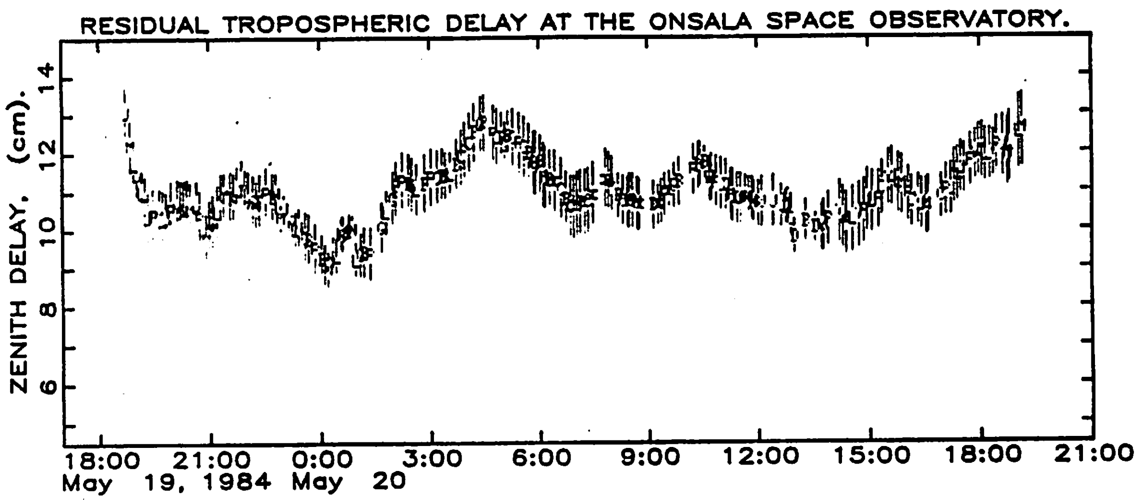


Figure 1. Estimated equivalent zenith wet path delays at the Onsala Space Observatory.

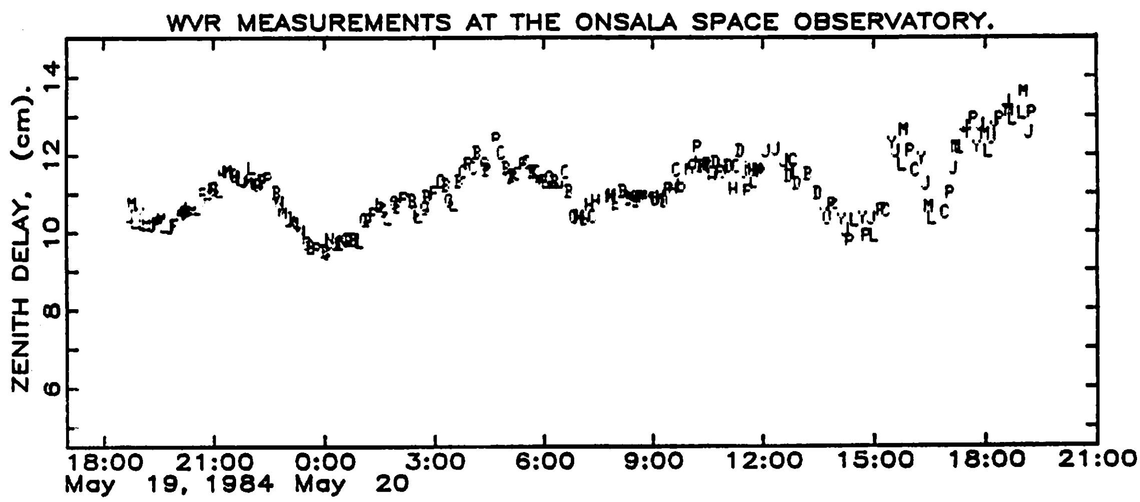


Figure 2. Equivalent zenith wet path delays determined from WVR measurements at the Onsala Space Observatory.

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

The site and seasonal dependence of the wet path delay algorithm used in Water Vapour Radiometry.

by

Jan Johansson
Onsala Space Observatory
Chalmers University of Technology
S-439 00 Onsala , Sweden

Summary

The accuracy of geodetic Very-Long-Baseline-Interferometry (VLBI) experiments has reached a level where one of the main errors is the excess propagation path caused by water vapour (wet path delay) through the troposphere. A recently developed method is to use Water Vapour Radiometry (WVR) to estimate the line-of-sight wet path delay. The WVR measures the emission from the sky (called sky brightness temperature) at two frequencies around the water vapour emission line centered at 22.235 GHz. The algorithm used in this study is presented by Wu (1979):

$$\Delta L_W = C_0 + C_1 \left[T'_{A,f_1}\left(\frac{f_2}{f_1}\right)^2 - T'_{A,f_2}\right] \qquad (1)$$

where ΔL_W is the wet path delay, $T'_{A,f}$ is the linearized sky brightness temperature measured at the frequencies f_1 and f_2. Previously the two coefficients, C_0 and C_1, have often been determined independent of site and with no variations allowed over the year.

This study will result in optimized algorithm parameters to be used at VLBI-stations where WVR data exist or are likely to be taken in the near future. It will make use of simulated WVR measurements calculated from radiosonde data in order to estimate the coefficients in the algorithm. The radiosonde data will be obtained from a launching site as close as possible to the VLBI-station. Noise-free instruments are also assumed in order to examine the noise from the algorithm only. The coefficients are determined by means of a least squares fit of the linearized sky brightness temperatures and to the wet path delay. All quantities are calculated from the radiosonde profiles. Since C_0 is caused by the oxygen content of the atmosphere and the cosmic background radiation its value can be determined with high accuracy from ground pressure and temperature and only C_1 has to be solved for in the fitting process.

All calculations will be done by using the frequencies of the existing WVRs (20.7 and 31.4 GHz in the USA and 21.0 and 31.4 GHz in Sweden). In order to obtain good meteorological statistics it is important to use several years of radiosonde data from each site. It is also of great importance to estimate possible differences in C_1 for a certain month between different years.

The results so far show that the difference between a seasonal dependent coefficient vs. an average value is about ± 5% in the worst case. Since the coefficient C_0 varies from -0.7 to -1.5 this is equivalent to an error of approximatly 4.5 mm when the wet path delay is 9 cm (the mean wet delay of the Landvetter data). The result presented in Fig. 1 was obtained using three years (1981-83) of radiosonde data from Gothenburg-Landvetter Airport (37 km away from the Onsala Space Observatory). The coefficient C_1 shows a smooth seasonal variation. The result from Portland, Maine (130 km away from the Haystack Observatory) is presented in Fig. 2. In this case it is also possible to see a seasonal dependence, although not as smooth as in Fig. 1 because the result is based on data from only one year (1981). This shows, as mentioned above, that it is of great importance to use more than one year of radiosonde data.

Within the next month more radiosonde data will be studied, taken at other sites and climates in order to obtain a specific wet path delay algorithm for each VLBI-station.

Reference

Wu S.C. (1979) , "Optimum Frequencies of a Passive Microwave Radiometer for Tropospheric Path-Length Correction," IEEE Trans. Antennas and Propagation , Vol. AP-27 , pp. 233-238.

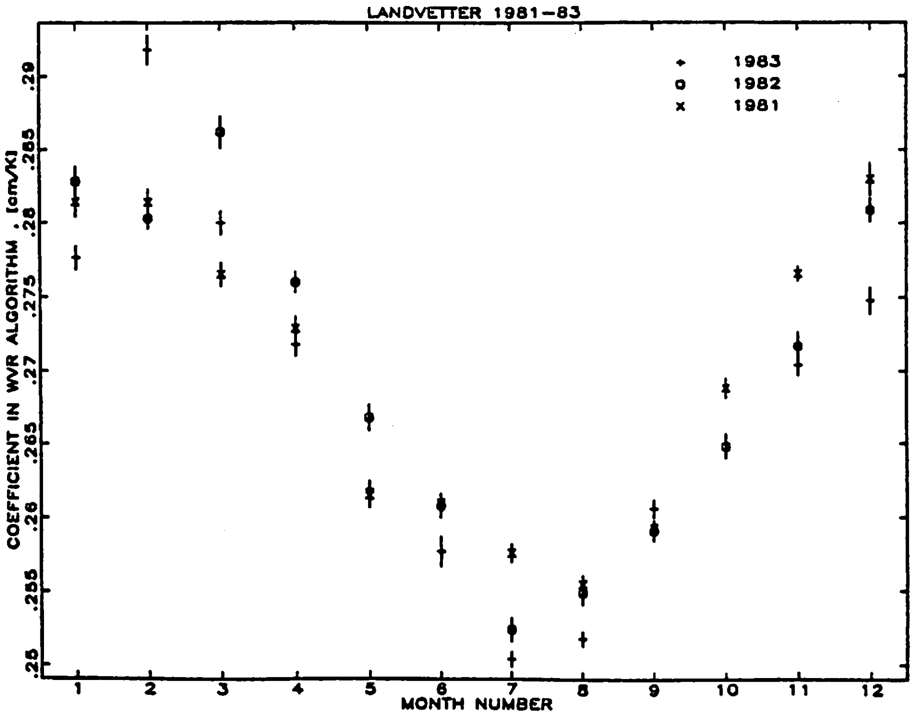


Figure 1. The seasonal dependence of the C_1 coefficient in the the wet path delay algorithm obtained by using three years (1981-83) of radiosonde data from Gothenburg-Landvetter Airport, Sweden. The WVR frequencies are 21.0 and 31.4 GHz.

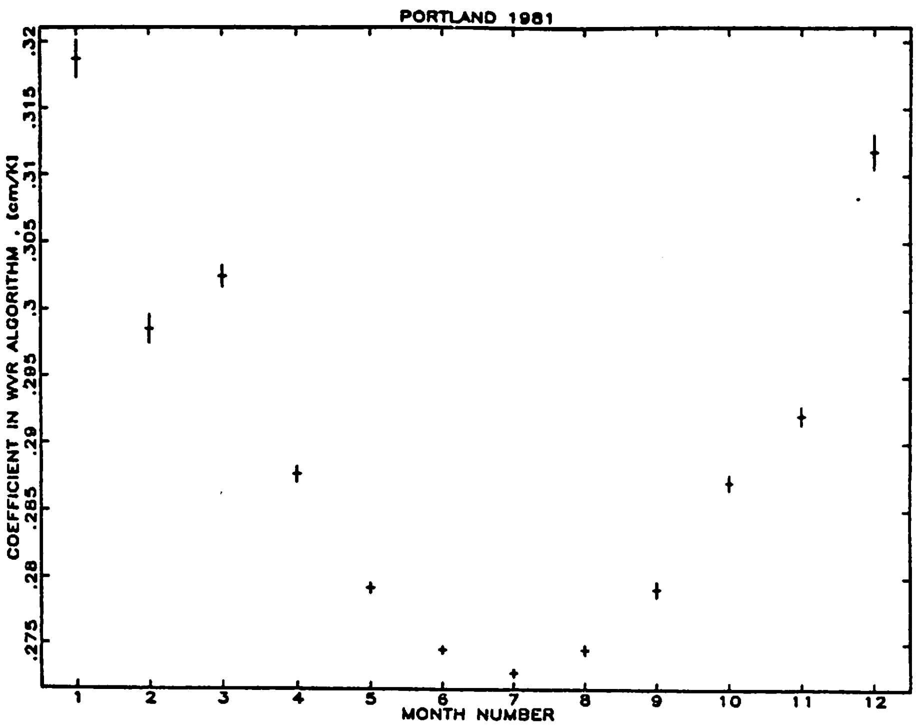


Figure 2. The seasonal dependence of the C_1 coefficient in the wet path delay algorithm obtained by using one year (1981) of radiosonde data from Portland, Maine, USA. The WVR frequencies are 20.7 and 31.4 GHz.

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

Mapping the tropospheric delay and the influence of horizontal variations

by

Ioannis Ifadis*

Summary

Presented are site dependent mapping functions derived using real atmospheric data (radiosondes) from Gothenburg-Landvetter Airport, Sweden (3 years of observations) and Portland, Maine, U.S.A. (1 year of observations). The type of mapping function used is presented by Davis et al. (1985) and gives the delay as a scaled zenith delay using the elevation angle.

First, ray-trace analysis has been made assuming only vertical variations of the refractivity in the atmosphere. The empirical parameters in the mapping function were obtained by the means of the method of least squares using the results from the ray-traced radiosonde profiles. Preliminary results show that we can predict the elevation dependence of the atmospheric delay with subcentimeter accuracy down to an angle of 5°. Note, however, that in practice the meteorological profiles are often unknown.

Thereafter, horizontal variations of the refractivity were studied, by analyzing 16 simultaneously recorded radiosonde launches at the Onsala Space Observatory and the Gothenburg Landvetter airport. Differences and their standard deviations between the delay obtained with and without horizontal gradients are shown in Table 1. It is clear that variations in the wet refractivity are more important than variations in the dry refractivity. However, these results are based on a limited data base. In another case the numbers could be quite different than those presented here.

The studies will be continued using almost four years of data from several stations.

*Univ. of Thessaloniki, Greece, now with a two year leave of absence at the Onsala Space Observatory, Chalmers Univ. of Tech., Sweden.

Table 1

DELAY CORRECTIONS CAUSED BY HORIZONTAL VARIATIONS.

elevation angle (degrees)	wet delay mean (m)	wet delay abs. mean (m)	wet delay rms (m)	dry delay mean (m)	dry delay abs. mean (m)	dry delay rms (m)
50.0	.001	.001	.001	.000	.001	.002
20.0	.008	.009	.008	.001	.004	.006
10.0	.033	.035	.030	.001	.007	.010
7.5	.056	.059	.048	.001	.008	.010
5.0	.110	.111	.088	-.001	.010	.013
2.5	.247	.253	.207	-.013	.023	.025
2.0	.297	.306	.256	-.024	.036	.034

General references

Bean, B.R., and E.J. Dutton (1966), "Radio Meteorology." National Bureau of Standards Monograph 92. pp. 1-44.

Chao, C.C. (1972), "A Model for Tropospheric Calibration from Daily Surface and Radiosonde Balloon Measurements," Tech. Mem. 391-350, Jet Propulsion Laboratory, Pasadena, California.

Chao, C.C. (1973), "A New Method to Predict Wet Zenith Range Refraction from Surface Measurements of Meteorological Parameters," in DSN Progress Report, No. 32-1526, Vol. XIV, Jet Propulsion Laboratory, Pasadena, California, 15 April 1973, pp. 33-41.

Davis, J.L., T.A. Herring, I.I. Shapiro, A.E.E. Rogers, and G. Elgered (1985), "Geodesy by Radio Interferometry: Effects of Atmospheric Modeling Errors on Estimates of Baseline Length," submitted to Radio Science.

Freehafer, J.E. (1951), "Geometrical Optics," in Propagation of Short Radiowaves, editor D.E. Kerr, McGraw-Hill, New York, pp. 41-58.

Gardner,C.S. (1976) , "Effects of horizontal refractivity gradients on the accurracy of laser ranging to satellites." in Radio Science,Vol. 11,Num. 12. pag. 1037-1044. December 1976.

Gardner,C.S. (1977), "Correction of laser tracking data for the effects of horizontal refractivity gradients." in Applied Optics, Vol.16, No 9, September 1977.

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

Recent results of the IRIS and CDP VLBI observations

James Campbell

Geodetic Institut, University Bonn

SUMMARY

A large part of the recent VLBI observations with the highest achievable geodetic accuracy has been performed within the IRIS (International Radio Interferometric Surveying) program which combines the cooperative efforts of groups in the US, Sweden and the Federal Republic of Germany to quasi-continuously operate the 5 participating observatories (Westford/Massachusetts, Ft Davis/Texas, Richmond/Florida, Onsala/Sweden and Wettzell/FRG). The full network has been completed in January 1984 and performs the regular 24-hour observing sessions at 5 day intervals providing a steady series of Earth rotation parameters as well as baseline lengths. The formal uncertainties are about ± 1 mas for both components of polar motion and about ± 0.2 ms of time for UT1. The rms differences between VLBI and LAGEOS Laser ERP-results are about twice these amounts.

During the MERIT intensive campaign daily VLBI observations on the baseline Westford-Wettzell have been carried out. The results of these measurements indicate that short term UT1-variations as large as 0.3 ms/day may occur.

The accuracy of the baseline length determinations, which include the global VLBI-experiments forming part of the NASA Crustal Dynamics Project, can now be estimated quite reliably from the growing number of repeat measurements. The error has been found to be slightly dependent on length (i. e. ± 1 cm at 1000 km, ± 2.5 cm at 6000 km, ± 5 cm at 8000 km). If observations can be continued at the present rate and level of accuracy it is expected that first reliable results of plate tectonic motion will be realized in one or two years from now.

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

Results of Mk II BWS experiments with South Africa

by

Axel Nothnagel
Hartebeesthoek Radio Astronomy
Observatory / NITR
PO Box 3718
Johannesburg 2000
South Africa

In the last two years the Hartebeesthoek Radio Astronomy Observatory (HartRAO) and the INTA/NASA group at the Madrid Deep Space Station have carried out 3 joint experiments with the assistance of the VLBI group at the Bonn Geodetic Institute.
The first two sessions were performed in April 1983, the third one in April 1984. A switching scheme with a synthesized bandwidth of 18.0 MHz was employed and the data was recorded on a Mark II system with IVC tape recorders at all stations.

Starting with the third experiment, the Madrid DSS61 34m and the HartRAO 26 m telescopes observed 8 hours in the X-band frequency (8400 MHz). The noise temperature at HartRAO was about 250K which degraded the sensitivity of the interferometer considerably. Even with a noise temperature of 30K at DSS61, the sensitivity was not high enough for most of the sources in the schedule. Only scans of OJ287 and 3C273B could be correlated succesfully. With 15 observations of only 2 sources a baseline solution could not be calculated.

Nevertheless, the phase plots produced with the PHASOR fringe analysis output show good coherence between the H-Maser used in Madrid and the Rubidium standard used at HartRAO. Therefore this experiment can be considered as partially successful. It has proven the feasibility of X-band experiments even with a stable Rubidium Standard but the noise temperature will have to be reduced.

More succesful were the first two experiments of 10 and 6 hours respectively in 1983. The Madrid DSS63 64 m, the Madrid DSS61 34 m and the HartRAO 26 m telescopes formed a 3 station net and in the two sessions 41 and 26 scans respectively were sampled in the S-band frequency (2300 MHz).

At HartRAO ionospheric total electron contents for the observing periods were derived from routine hourly ionosonde measurements which are made about 50 kms from the telescope. From this data the electron content could be calculated up to the true height of maximum electron density (F2 - layer). Above this layer the electron profile had to be modeled with a Chapman Alpha model.
For Madrid the ionospheric data was derived from Magnavox 1502 Doppler data recorded at Bonn during the time of the experiments.

After the correlation of the scans at the JPL/Caltech Mk II processor the baseline fits were performed with the single baseline fitting software system developed by the Bonn VLBI group. This software package is now also in use at HartRAO.
For each session and each baseline a separate baseline solution were calculated. For ease of comparison the baselines to DSS63 (64m) were transformed to DSS61 (34m) so that four independently determined values for the baseline DSS61 - HartRAO are available. (see Table 1)

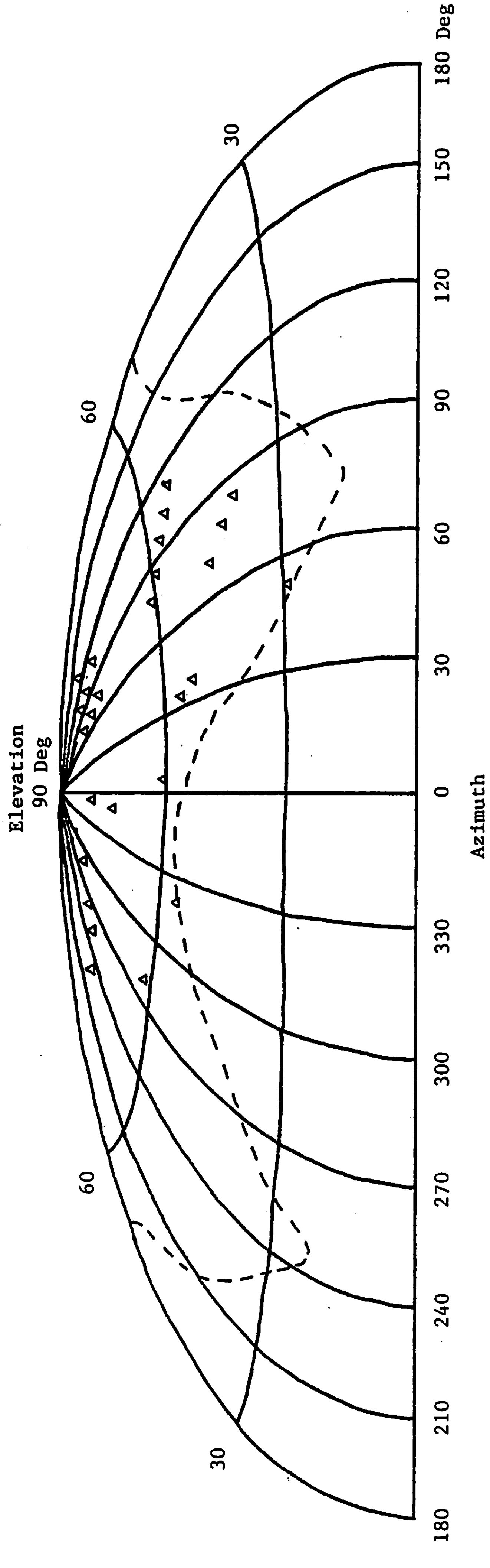
Baseline	Date	σ_τ [nsec]	$\sigma_{\dot{\tau}}$ [psec/sec]	b [m]
DSS 61 - HartRAO	83/04/24	1.84	1.33	7524066.78
	83/04/30	1.73	0.60	7524066.00
DSS 63 - HartRAO	83/04/24	1.88	1.02	7524064.00
	83/04/30	0.95	0.54	7524064.60
Average	all	1.6	0.9	7524065.35

Table 1: Baseline determinations Madrid - HartRAO (S-band)

The four baseline lengths do not agree very well and the three-dimensional positions of HartRAO derived from the different baseline deternінations disagree linearly to a maximum of 6 meters. The reason for this is the small number of observations but more important is the fact that these observations are clustered in one area of the sky.

A relatively easy way to visualize the baseline - source geometry is by creating a hemisphere with an azimuth - elevation grid above the midpoint of the baseline. The base - line then lies in the equatorial plane of this hemisphere. Now each source position can be recalculated in this azimuth - elevation system for the time of observation and can be depicted graphically.

The schedules for both days were produced with the Mark III SKED procedure and were almost identical. The second session had to be four hours shorter but in the first session more observations were unsuccessful, so the spatial distribution of the observations was almost the same for both sessions.



Elevation
90 Deg
Azimuth
180 Deg
150
120
90
60
30
0
330
300
270
240
210
180
30
60
60
30

Figure 1

Figure 1 shows the observations on day 120/1983 as an example. The dashed line limits the area which is available to observations owing to the horizon limits of the two telescopes.
Immediately one can see the unfortunate distribution of the observations. There are almost no observations between azimuth 120° and 240°. Half of the observations have an elevation higher than 70° in this system, which gives them only a minimal influence on the baseline length.

Another indicator for the quality of the configuration is the correlation between the important parameters in the fit:

DB1 = polar component of the baseline
DB2 = equatorial component of the baseline
DH = orientation of the baseline in the equatorial plane
DT0 = relative clock offset
DT1 = relative clock rate.

DB1	DB2	DH	DT0	DT1	
1.00	0.65	0.91	0.91	0.05	DB1
	1.00	0.81	0.81	-0.35	DB2
		1.00	0.99	-0.05	DH
			1.00	-0.15	DT0
				1.00	DT1

Table 2: Correlation Coefficients of DSS63 - HartRAO baseline

There are very high correlations between the clock offset and the polar component as well as between clock offset and orientation DH. This means that the baseline components could not be calculated independently from the relative clock behaviour. Since the experiments were so badly conditioned, the four baseline solutions are not consistent and therefore vary considerably.

For comparison, a 24 hour experiment was simulated with about 100 scans scattered uniformly in the azimuth - elevation system of Fig. 1. It yielded a correlation matrix of the following form:

DB1	DB2	DH	DT0	DT1	
1.00	-0.04	-0.25	0.22	0.07	DB1
	1.00	-0.64	0.64	0.02	DB2
		1.00	-0.91	0.05	DH
			1.00	-0.38	DT0
				1.00	DT1

Table 3: Correlation Coefficients of optimized schedule

Here the strong correlations are eliminated and consistent results can be expected.

Simulations with a smaller number of observations but with a uniform distribution of the scans give a similar correlation matrix. The completeness of the 360° azimuth circle has a very high impact on this and all elevation areas should be covered.

So, for future experiments with not much observing time available, a scheduling procedure has been developed at HartRAO which automatically takes care of an optimized uniform distribution of the scans. This procedure has not yet been tested in practice but we hope to do this soon. Simulations of baseline solutions for schedules prepared with this scheduling program look promising.

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

TRANSATLANTIC BASELINE MEASUREMENT 1980-1985

B. O. Rönnäng
Onsala Space Observatory, Sweden

ABSTRACT

Transatlantic distance (plate motion) measurements between Onsala Space Observatory and Haystack/Westford Observatory using the wide-band Mark-III VLBI techniques have now gone on for five years (T). The measurement accuracy has recently reached the sub-cm range (σ_r formal error). The uncertainty σ_v in the relative velocity between two points is thus equal to

$$\sigma_v = \frac{\sigma_r}{T}\left\{\frac{12T/\Delta t}{(1+T/\Delta t)(2+T/\Delta t)}\right\}^{\frac{1}{2}}$$

where t is the time span between equally spaced measurements and slowly varying systematic errors are neglected.

In total there are about sixty successful distance measurements with formal errors ranging from 5 cm to 1 cm, if we combine data from the Crustal Dynamics Project (CDP) and the more regular POLARIS/IRIS experiments.

Assuming σ_r = 2.0 cm, T = 5 years and Δt = 0.2 years (the 60 measurements are not equally spanned), we obtain σ_v = 0.26 cm/year.

So far three compilations of the 1980-84 Mark III-data are available, i.e.

(1) G. Lundqvist: "Radio Interferometry as a Probe of Tectonic Plate Motion", Ph.D. thesis, Chalmers Univ. of Technology, Sweden, 1984.
Combined CDP and POLARIS/IRIS - data are used, giving a rate of 1.1±0.3 cm/year.

(2) W.E. Carter et al: "Geodetic Radio Interferometric Surveying: Applications and Results", J. Geophys. Res., 90, pp.4577-4587, 1985.
Only POLARIS/IRIS - data from Oct 81 - June 84 are included, resulting in a change of length of 1.4±0.3 cm/year.

(3) T. Herring et al: "Geodesy by Radio Interferometry: Evidence for Contemporary Plate Motion", to be published in J. Geophys. Res., 1985.
CDP-data from the period July 1980 - July 1984 are used, which together with improvements of various algorithms give 1.7±0.2 cm/year.

The data points (distance versus time) in (1) and (2) are not distributed randomly about the regression line defining the velocity but display quasi-periodic patterns on time scale of a few months. These variations, with an amplitude of about 2 cm, are mainly caused by an inadequate atmospheric model. These and other long term systematic errors are discussed and the measurements of other baselines are summarized.

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

First Baseline Determination between Wettzell and Kashima

Harald Schuh

Geodetic Institute
Univ. of Bonn

Nussallee 17
D-5300 Bonn 1
F.R.G.

In the Radio Research Laboratories Kashima, Japan a high precision Very Long Baseline Interferometry System, called K-3, had been developed since 1979. It consists of hardware and software and is designed to be compatible with the MkIII-system.
In Aug./Sept. 1984 the Kashima station participated in two global campaigns under the NASA Crustal Dynamics Project. During those two 30 h experiments, called POLAR1 (Aug. 30th, 1984) and POLAR2 (Sept. 2nd, 1984) the radiotelescopes at Haystack, Mojave, Fairbanks (USA) and Wettzell (FRG) were observing besides Kashima. The experiments allowed a first high-precise baseline determination between Europe and Japan. The results of an independent analysis of the two data-sets at the Bonn Geodetic Institute, are discussed as well as future aspects concerning the cooperation with Japan.

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

Joint GPS- and VLBI experiments, possibilities and plans

J. Campbell

Summary:

The main interest in bringing the VLBI- and GPS- techniques together resides in the necessity to establish a direct relationship between the inertial, i.e. extragalactic, and the dynamical, i.e. orbital reference frames. The wide variety of anticipated uses of the GPS system - especially in the high precision differential mode - will impose stringent requirements on the stability of the dynamical frame. This stability in turn can only be guaranteed by regular observations of distant radio sources to monitor the earth orientation parameters (e.g. in project POLARIS/IRIS).

The combination of both techniques can be achieved in two ways: first by operating GPS-receivers at the VLBI-stations (colocation), and second by observing directly the GPS-satellites and the quasars with the same telescopes (Δ-VLBI). Both methods should be tried and tested before more extensive projects are initiated. The baseline Onsala - Wettzell with its moderate length of about 900 km would be a suitable test field.

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

QUASAT - A POTENTIAL CONNECTION BETWEEN EGRS CIS AND DYNAMIC CIS

Tang Guoqiang* and Bernt Rönnäng

ONSALA SPACE OBSERVATORY
CHALMERS TECHNICAL UNIVERSITY
SWEDEN

ABSTRACT

The QUASAT concept currently under study by NASA and ESA [Schilizzi, R.T. et al, 1984] is a free-flying spacecraft carrying a 15m diameter radio telescope for space VLBI. The design goal of the QUASAT mission is to provide images of compact radio sources with higher angular resolution and better quality than attainable with Earth-based VLBI networks alone.

If one can measure the position of QUASAT accurately in the extra galactic radio source reference frame, it will be desirable to use QUASAT for geodynamic purposes, especially to establish a connection between the EGRS CIS and a geocentric dynamical CIS.

In principle there is no difference between space VLBI and ground-based VLBI observations. It is possible to derive the precise position and velocity information directly from QUASAT VLBI observations. The problem is that dedicated geodesy VLBI sessions with QUASAT are not foreseen.

There are, however, some possibilities to determine the QUASAT orbit accurately in the EGRS reference system, i.e. by fringe tracking [Tang,G.,1984] and differential VLBI [Hildebrand, C.E. et al, 1982].

1. FRINGE TRACKING. For VLBI mapping purpose, QUASAT together with some ground based antennae will be pointed to the source for a long time (several periods of orbit). By determining the interferometry fringe phase and fringe rate during the period the a priori orbit parameters can be improved if we assume the source position, the positions of the ground stations, the earth rotation and polar motion, the Earth tides etc. are known quite well.

Some a priori knowledge is required for fringe detection. The satellite position approximate to a hundred meters and the velocity to a few cm/sec will be known. This will be obtained by means of the planed two-way Doppler measurement.

---

* On leave from Shanghai Observatory, Academia Sinica.

The fringe tracking could achieve a decimeter accuracy depending on the wavelength, the accuracy of the dynamical models used for the spacecraft, the distribution of the observations, and the accuracies of the station positions etc.

2. **DIFFERENTIAL VLBI.** Differential VLBI (ΔVLBI) has been applied successfully, as a method for interplanetary navigation, for some space missions since last decade [Brown, D.C. et al,1980].

Suppose that two VLBI stations observe the spacecraft simultaneously first, then both antennae shift to a nearby extragalactic radio source and observe the source simultaneously. The observable is the group delay. ΔVLBI is formed from the algebraic difference of these two measurements. In the difference, errors common to the spacecraft and EGRS are cancelled. Of course, the cancellation of the errors achieved depends on the separation of the sources and the time span between two observations. The results contain precise information on the angular position and velocity of the spacecraft in the EGRS reference frame.

This method is feasible only if QUASAT transmits a signal observable by the ground-based VLBI network.

For a single baseline, one ΔVLBI observation from a single baseline measures only one component of the relative position of QUASAT to the radio sources. Therefore at least two baselines which form a nearly rectangular angle are needed to obtain the relative positions in two dimensions.

The differential VLBI mentioned above is usually called wideband ΔVLBI, because the observables are synthesized from a number of channels separated by several MHz. For wideband ΔVLBI, an accuracy of better than 10^{-4} arcseconds on angular position measurement could be achieved.

Since QUASAT is still a project under Assessment study, it is therefore too early to come to any conclusion about its scientific applications in geodesy and geodynamics.

It is worth mentioning that the high precision navigation of QUASAT is not only significant for geodynamics, but also necessary for some astronomy purposes, e.g., the phase reference mapping and the distance measurement using masers.

As an earth orbiting satellite, the orbit of QUASAT could be determined by some other satellite tracking techniques. It has been proposed, e.g., to use laser ranging [Fejes, I.,1985] to determine the orbit of QUASAT. If so, QUASAT could help in connecting the geocentric dynamical reference systems to the EGRS CIS. However, it should be pointed out that 15m antenna is in no way optimized for geodetic and astrometric research.

REFERENCES

Andersson, B., 1983, 'QUASAT: a discussion ducoment on phase stable radio links, data acquisition, and data processing', presented on Quasat working team meeting.

Brown, D.S., C.E. Hildebrand, and L.J. Skjerve,1980, 'Wideband ΔVLBI for Deep Space Navigation', Proceedings of the IEEE Position Location and Navigation Symposium, 389-396.

Fejes, I., 1985, private communication.

Hildebrand, C.E., J.S. Border, F.F.Donivan, S.G. Finley, B. Moultrie, X.X. Newhall, L.J. Skjerve, T.P. Yunck, 1982, 'Progress in the application of VLBI to interplanetary navigation', in "Very Long Baseline Interferometry Techniques", proceedings of an international conference held in Toulous, France, CEPADUES eds. 55-72.

Johnston, K.J., 1984, 'Radio Astrometry', Proceedings of IAU Symposium No.110, R. Fanti, K. Kellermann and G. Setti eds., D. Reidel Publ. Comp., 339-346.

Kovalevsky,J. and I.I. Mueller, 1981, 'Commonts on Conventional Terrestrial and Quasi-Inertial Reference Systens', in Proceedinfs of the 56th colloquium of IAU held in Warsaw, Poland, eds E.M. Gaposcnkin, B. Kolaczek, D.Reidel Publ. Comp., Dordrecht, 375-384.

Mueller, I.I.,1981, 'Reference Coordinate Systems for Earth Dynamics: A Preview', in Proceedings of the 56th colloquium of IAU held in Warsaw, Poland, eds. E.M.Gaposchkin, B. Kolaczek, D. Reidel Publ. Comp., Dordrecht, 1-22.

NASA and ESA study Team, 1984, 'Quasat: technical aspect of the proposed mission', Proceedings of Workshop on Quasat, Gr Enzersdorf, Austria, 18-22 June 1984, 27-99.

Schilizzi, R.T. et al, 1984, 'The Quasat mission: an overview', Proceedings of Workshop on Quasat, Gr Enzersdorf, Austria, 18-22 June, 13-18.

Tang, G., 1984, 'A short note on the high-precision navigation of Quasat', Proceedings of Workshop on Quasat, Gr Enzersdorf, Austria, 18-22 June 1984, 185-186.

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

FUTURE PROSPECTS FOR THE MARK II BWS GEODETIC VLBI

S. Gorgolewski
Radio Astronomy Institute
Nicolaus Copernic University
Torun Poland

ABSTRACT

The proliferation of Mark III recording systems in the European and the US VLBI Networks has overshadowed the Mark II usefulness. The Mark III is distinguished in sensitivity by a factor of 5.29, due to its up to 28 times wider bandwidth and rich inherent bandwidth synthesis capability, ensure it a bright and prosperous future in VLBI. The high operating and tape shipping cost of the Mark III leaves some living space to the Mark II. There is still another not only economical argument for the Mark II, it is the low frequency VLBI i.e. 1.66 and 1.42 GHz as well as the 0.610 and 0.327 GHz bands in particular, there, where the man made interference limits drastically the available frequency windows. This narrows down the Mark III to very nearly the Mark II capabilities. These lower frequencies are not inferior for geodetic applications, because with the prevailingly increasing signals at longer wavelengths, the sensitivity increases, perhaps not always as much as with Mark III, yet the Mark II may begin to approach the Mark III performance so vital at higher frequencies.

Another not really negligible factor, is the existence of some VLBI stations, that do not yet possess the Mark III and only own the Mark II. To begin with, the potential newcomers to VLBI, are also likely to start with the Mark II. This used to be a general case in the recent past, thus practically all existing VLBI stations continue to be in possession of the Mark II. Being the most widespread terminal, the Mark II, is still a potent tool, at low frequencies difficult to oust out - and one should use them wherever possible also for Geodesy and Astrometry.

As far as the sensitivity is important 1.42 GHz is probably optimal and 1.66 second best, yet 0.610 may still be quite satisfactory, at least for these sources that have steep spectra and are superimposed upon sky regions of low brightness temperature.

The lower frequencies are progressively less demanding in respect of atomic standard stabilities, permitting the use of rubidium rather than the hydrogen frequency standard. The last being vastly more expensive than rubidium, which permits one to operate cheaply at low frequencies.

In Europe we do have only two S/X band stations, which are more widespread in US and used for Astrometric and Geodetic VLBI. We may adopt the S/X band frequencies or try to use two widely available low frequencies as a substitute for S/X. The 1.66 and 1.42 GHz seems to be a reasonable choice. The snag is that very few if any stations do have feeds covering the required relatively wide bandwidth. These frequencies are relatively well protected from terrestrial man-made interferences as well as from tropospheric and ionospheric disturbances interference as well as from tropospheric and ionospheric irregularities, an important factor for high accuracy measurements. This justifies the expenditure for the wide band feed and filters. It seems that all the odds speak for the 1.42 and 1.66 GHz bandwidth synthesis of 240 MHz effective band. It is also a relatively inexpensive solution compared with the S/X approach, offering also some chance of eliminating of the ionospheric effects which is one of the features of the S/X system. Many stations already have the 1.42 and 1.66 GHz front ends with the wide band GaAs FET amplifiers with their excellent low noise temperatures along with the wide band gain. It thus seems natural to take advantage of this more easily implementable yet potent system than the 20 or 40 MHz BWS. It also seems to be a viable proposition even when compared with the 5, 8 or 10.7 GHz using Mark III.

One should note that in the late 70-ties Mark I BWS reached accuracies slightly in excess of 10 cm ; while Mark III gets close to 2 cm the Mark II BWS described above should go to values close to 5 cm or less.

This rather optimistic approach shows that we may still have some useful future for the Mark II BWS and should this be proved by experiments it clearly lets us see many profitable geodetic and astrometric VLBI experiments in the future reaching the early 90-ties. It also favours the new VLBI stations that shall provide hitherto unexplored baselines vital for the geodetic VLBI. All this would be available at relatively low cost as compared with the Mark III system.

It should be noted that the 240 MHz BWS is not fixed and may and should be designed flexible enough for adaptation to varying interference. The 240 MHz frequency spacing should be adjustable on short notice.

In conclusion: in some future to come one should make best possible use of the Mark II especially in the bands that naturally limit the usefulness of the Mark III i.e. in the low frequencies where of course 40 or 20 MHz BWS is the only choice. It would be fine to design a flexible system covering all the above mentioned and also intermediate and out of band frequencies.

Working Meeting on European VLBI for Geodesy and Astrometry
Onsala, Sweden
June 3, 1985

EUROPEAN VLBI FOR GEODESY AND ASTROMETRY SCIENTIFIC GOALS AND OBJECTIVES

A Scientific Memorandum
to be prepared by the
European Working Group on Geodetic and Astrometric VLBI

At the third Meeting on European VLBI for Geodesy and Astrometry in Delft in November 1983 the participants agreed to form a Working Group whose first task would be to prepare a document containing all relevant information on the scientific background and the possible objectives and justifications of a European effort in the fields of geodetic and astrometric applications of the VLBI technique. The aspect of justification appears of particular concern because of the comparatively large investment and operating costs involved in the use of VLBI.

The intention of the document is

- provide a reference work collecting the full scope of scientific goals that support the use of VLBI in geodesy, geophysics and astrometry and to put these goals into systematic order and perspective,
- create a basis for soliciting moral and financial support for the different European groups involved,
- define the particular aspects of a European role in VLBI related research projects,
- describe the scientific relevance of special VLBI related projects involving European Groups,
- open ways to coordinate the scientific and instrumental potential of European VLBI groups.

A division will be made between the geodetic and geophysical topics on the one side and the astrometric topics on the other. In spite of this separation it should however be stressed that the VLBI technique requires both aspects to be treated with equal importance because each one is the prerequisite of the other if any meaningful results are to be obtained from the VLBI data. A draft of the document will be presented and discussed at the next meeting on European VLBI for Geodesy and Astrometry.