Proposal

"Near-Real-Time" for VLBI-Intensive-Series

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1 Introduction

VLBI is the superior geodetic space technique to determine Earth orientation parameters (see Beutler et al., [1]) Earth orientation parameters play a key role in the maintenance of reference systems. Any satellite based geodetic technique such as GPS relies on precise Earth orientation parameters determined with VLBI.

Since 1984 between Wettzell and previously Westford, now Greenbank, daily VLBI-experiments are being carried out for the precise determination of $UT1 - UTC$ parameter called "Intensive". The turn-around of VLBI based results is about 3 days on normal workdays - worse during weekends, while it is for GPS about 1 day.

Progresses in the digital technology of telecommunication enable nowadays the realisation of real-time VLBI (RT-VLBI) as it is demonstrated in the Japanese Key-Stone-Project (Kurihara et al., [3]). In Europe the use of broadband communication lines for VLBI had been proposed (see Schuh [4], Hase [2]).

For more than a decade the recorded magnetic tapes with Intensive data are being shipped from the stations to the USNO VLBI correlator in Washington. The one-hour, two-stations VLBI experiment between Wettzell and Greenbank is an ideal candidate for the beginning of implementation and testing of real-time technology on intercontinental baselines in order to reduce the turn-around time.

2 Proposal on Real-Time VLBI

Real-Time VLBI is characterized by the replacement of magnetic tapes, tape recorders and tape shipping with the use of digital communication lines. Nowadays transmission technologies with bandwidth up to $10 Gbit/s$ are available. The necessary bandwidth required by

standard VLBI observations is provided by telecom companies. While the costs for gigabit services are prohibitive for the budgets of various VLBI partner institutions, it is already possible to approach the Real-Time VLBI goal with the use of smaller bandwidth for data transmission, e.g. $2Mbit/s$, and the intermediate storage of VLBI-data on an appropiate memory medium, e.g. fixdisks, at the stations and at the correlator. This approach should be called **"near-real-time"-VLBI** since it implies still a significant delay of several hours after observation until the correlator output can be made available.

With decreasing prices for larger bandwidth, e.g. $> 2Mbit/s$, the intermediate storage at the stations might become unnecessary and the **"true-real-time"-VLBI** will become reality.

3 Project: Near-Real-Time Intensive

Our estimation of the feasibility of near-real-time VLBI is based on a recent Intensive schedule (I97277).

Typically Mode A with 28 recorded channels is used for a better usage of tape during the short observation time. The bandwidth of each channel is $2MHz$ which corresponds to a data output of $112Mbit/s$. The schedule itself needed $2100s$ recording time, which produced a data volume of $29.4GByte$ resp. $2.1GByte$ per video converter.

The communication providers offer the available bandwidth of either $64kbit/s$ (ISDN) or $2Mbit/s$, which can be realized also on existing copper wires. Higher bandwidths like $34Mbit/s$, $155Mbit/s$ and $622Mbit/s$ require optical fibres and are used in backbone networks today. Recently first announcements of $40Mbit/s$ bandwidth via commercial communication satellites were seen.

Data Volume Intensives (I97922)	
mode	A, upper and lower $2MHz$ sideband
bandwidth per videoconverter	$8Mbit/s$
total bandwidth of 14 VC	$112Mbit/s$
recording time / Intensive	$2100s$
number of bits / Intensive	$235.2GBit$
number of bytes / Intensive /VC	$2.1GByte$
data volume of 240 Intensive / a	$7000GBytes$
Transmission Time of $29.4GBytes$ Intensive Schedule	
$64kbit/s$	42.6 days
$2Mbit/s$	32.7 hours (without data compression)
$34Mbit/s$	1.9 hours (without data compression)

Table 1: A bandwidth of at least $2Mbit/s$ is necessary for the automatisation of VLBI by the introduction of real-time capabilities. Observation mode C, previously used, would reduce the data volume by a factor of 2 (but not the number of tape shipments).

The transmission time for an Intensive experiment should be less than $22h$ in order to enable daily experiments on (near-)real-time base. Table 1 shows that the current amount of data is too high by a factor of 2 for the transmission on a $2Mbit/s$ bandwidth line. The volume can be easily reduced by a factor of 2 with a different scheduling, e.g. using mode C which provides only $56Mbit/s$. Another approach is the use of data compression methods before the transmission. Investigations will be necessary to find out, whether a factor of 2 or more will be achieveable with data compression.

In 1997 a $2Mbit/s$ line costs within the DFN[1] about $250.000DM/a$ or as a shared bandwidth within $34Mbit/s$ (or higher) line only about $85.000DM/a$. These prices include a limited free data volume.

On January 1st, 1998, the data communication monopole of Deutsche Telekom was cancelled. With market competition a decrease in price and getting a special conditions for real-time VLBI projects seems to become possible, when a $2Mbit/s$ service needs to be acquired.

Advantages of real-time VLBI can be summarized:

- *no delay* of at least 3 days due to tape shipping; instead results become available on the same day,
- *automatic observation at remote sites* with less expensive operator involvement at nights, weekends, holidays,
- *higher reliability* of practical VLBI-measurements,
- *no tape recorder* involved with lots of critical and expensive mechanical parts, like heads, tape guiding system incl. vacuum, (thin) tapes,
- *lower biterror rates* because of a complete digital system,
- *cheaper operation* on the long term due to less maintenance of critical devices like tape recorders at the sites and correlator,
- *enforcement of VLBI-technique* in its Earth orientation domain.

Therefore we propose a first project phase:

3.1 Project Phase: Research and Development of "Near-Real-Time VLBI Techniques"

A cooperation of Bundesamt für Kartographie und Geodäsie with interested partners (NASA, USNO, MIT) about the following items should be established:

During 1998:

1. Investigation on data compression algorithms for VLBI-rawdata whether a factor of 2 or better can be achieved.
2. The hardware for two stations for intermediate recording on fixdisks will be purchased. (E.g. fourteen $4GByte$-fixdisks with $20Mbit/s$-SCSI-interface can intermediate store the formatted VLBI-data of each individual video converter channel.) The same hardware is used for each station at the correlator to store temporarily the transmitted data from the stations before correlation.
3. A controller is being developed for writing/reading data to/from fixdisk and transmit them to the correlator's fixdisks via $2Mbit/s$ network.
4. A controller and interface to link the fixdisk-storage-unit and the Mk4 correlators is being developed.
5. Software developments for automated data flow from the correlator into geodetic results are being made.

[1] DFN: Deutsches Forschungsnetz, current provider of Bundesamt für Kartographie und Geodäsie Wettzell

6. Wettzell, the partner station and correlator of Intensive negotiate with network providers about $2Mbit/s$ connections for the sites.

After delivery of the tested hardware envisaged in the end of 1998, the following items could happen during 1999:

- Installation of "Near-Real-Time"-VLBI devices at the stations and correlator.
- Test with the NRT[2]-VLBI-Intensives.
- Test and improvement of automated data flow from the correlator into geodetic results.
- Beginning of development of a TRT[3] data buffer for delay compensation at the correlator.

At the end of 1999 the Intensives will be carried out regularly, remote controlled via networks from the scheduling party and automatically Mk4-correlated at "idle"-times at the Mk4 correlator.

References

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[2]NRT: Near-Real-Time
[3]TRT: True-Real-Time