THE EUROPEAN VLBI NETWORK

R. T. Schilizzi

Netherlands Foundation for Radio Astronomy

ABSTRACT

A brief review is given of the present capabilities of the European very long baseline interferometry (VLBI) network, including the range of baseline parameters, sensitivities, and recording and other equipment available. Plans for upgrading the recording facilities and the use of geostationary satellites for signal transfer and clock synchronisation are discussed.

INTRODUCTION

This paper presents information concerning the growing VLBI activities in Europe and some of the plans under discussion for future development. The highly mobile VLBI systems discussed elsewhere in these Proceedings are not considered in this paper.

VLBI FACILITIES IN EUROPE

The locations of the radio observatories are shown in figure 1. All but the Italian and Polish observatories have successfully taken part in observations. The Polish station is expected to be on the air by the end of 1979; the Italian, by 1981-1982. The Italian VLBI plans are far-reaching: at least one, maybe two, antennas of very large array (VLA) design, modern cooled receivers, and the latest in VLBI equipment. Their stations will be a valuable southern addition to the network. Other potential sites also exist, such as the EISCAT antennas in northern Scandinavia and former space tracking antennas in Germany.

The telescopes available for VLBI and some parameters of the European network are shown in tables 1(a) and 1(b). Table 1(a) shows the range of receivers available, the system temperatures, and the telescope diameters. There are a number of large antennas in Europe with moderately good system

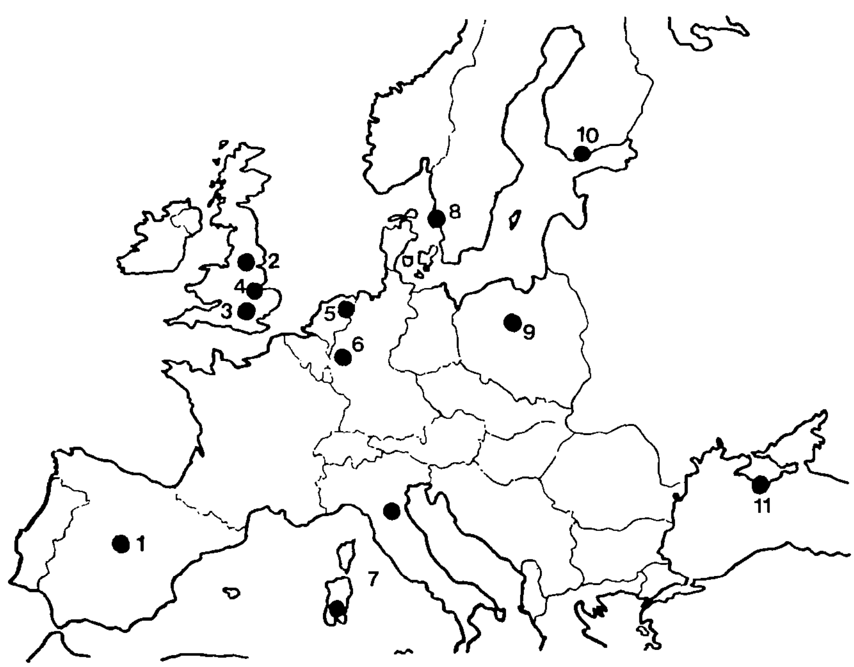

Figure 1. European VLBI observatories: 1. Madrid, 2. Jodrell Bank, 3. Chilbolton, 4. Cambridge, 5. Westerbork/Dwingeloo, 6. Effelsberg, 7. Bologna/Sardinia, 8. Onsala, 9. Torun, 10. Helsinki, 11. Crimea.

Table 1(a)
Observatories in Europe,
Telescope Diameters and System Temperatures

Country/ Observatory	Antenna Diam. (m)	Observing Wavelength (cm)					
		1.3	2.8	6	11	18	21
U.K.							
Jodrell Bank	76, 26, 25	500		60	100	60	60
Chilbolton	25	1300	180	100			
Cambridge	32 (equiv.)			90	75		
Netherlands							
Westerbork	93 (equiv.)		450*	80			95
Dwingeloo	25		480	60		37	42
Germany							
Effelsberg	100	200	75	80	100	60	100
Sweden							
Onsala	26,20	100		45		25	
Finland							
Helsinki	15			(200)			
U.S.S.R.							
Crimea	22	100	100	200		250	
Italy							
Bologna	25						
Sardinia/ Sicily	(25)						
Poland							
Torun	15						

*1 antenna

Note: The DSN station at Madrid (Spain) is also available for VLBI observations.

Table 1(b)
Range of Sensitivities (2 MHz bandwidth, 1 minute integration)
and Range of Baseline Lengths, for Interferometers in Europe

Observing Wavelength	Baseline lengths (10^6 λ)	Sensitivities (mJy)*
1.3 cm	26–212	210–2670
2.8	9–89	80–1030
6	4–46	14–410
11	1.8–6.3	24–150
18	1.4–15	25–360
21	1.2–3.3	16–120

*1 mJy = 10^{-29} Watt/m^2 Hz

temperatures, and a number of smaller antennas with quite low system temperatures. In interferometer configurations, this leads to high sensitivity – or alternatively, short integration times per source per hour angle. Moreover, a great number of sources are available for observations with high sensitivity systems.

The only dual-frequency S–X band receiver in Europe is at Onsala.

Table 1(b) further illustrates the range of interferometer sensitivities, assuming a 2-MHz recorded bandwidth and a 1-minute integration. Also shown are the range of baseline lengths at each wavelength; the baselines in kilometers range from about 200 km to about 3000 km.

All the observatories, with two or three exceptions, have the Mark II recording system based on Ampex or IVC recorders, and two observatories are experimenting with video cassette recorder. Hydrogen maser oscillators are not as widespread as in the United States; Onsala, Crimea, and Effelsberg are so endowed. The other stations have Rb standards.

Correlation and further processing of the data is carried out, for the most part, using the three-station Mark II processor at the Max Planck Institut für Radioastronomie in Bonn, Germany.

PLANS FOR FUTURE VLBI DEVELOPMENT IN EUROPE

Introduction

European plans for VLBI at the fixed observatories can be summarized in the following way. There is a need for a VLBI system which fully exploits the technique for geodesy, astronomy, and astrometry, and permits smooth, full-time observations with up to 10 radio telescopes. A smoothly operating system, in practice, is one in which all segments are matched; correlator, number of telescopes, computer system, observing time, correlating time.

The means of achieving these aims lie partly in the technical regime and partly in the political regime. On the technical side, there are three areas in which decisions have to be made. The first is the question of how to transfer the huge quantity of bits from remote sites to a central site for correlation. The second is how best to maintain the overall phase coherence of the system. The third is what form the data processor should take.

Included in these considerations are the different requirements of geodesy, astronomy, and astrometry for speed of data throughput, oscillator stability, and so on. From the geodetic point of view, we need only concern ourselves with global crustal dynamics and UT1/polar motion studies; the highly mobile systems discussed elsewhere in these Proceedings appear capable of catering for the needs of local crustal studies, independently of the fixed observatories.

Data Transfer

On this question, the decision to be made is whether the Mark III system or its successors are the best means of achieving a wide bandwidth capability, or if a satellite-linked system offers significant advantages. For the short and medium term, the decision to utilize the Mark III system is clear. A number of observatories in Europe are committing themselves in mind, if not yet on paper, to Mark III recording systems; Onsala and Effelsberg have orders on paper. For the longer term, though the question of satellite-linked systems needs to be considered. Two studies commissioned by the European Space Agency (ESA) have carried out a detailed investigation of the requirements for such a system ESA Doc. DP PS(78)15,1978; Phase A Study (in preparation).

Why consider the satellite-linked option at all? The primary reason is its operational "simplicity" compared with a tape-based system. This is particularly true for astronomical applications where wide bandwidth observations can be expected for a considerable fraction of the time. The contrasting prospect of a 10 station tape-based system producing 40 tapes an hour is daunting. Moreover, the cost of transporting the tapes to the central processor and return is considerable, in Europe ranging up to $250 K per year per observatory.

The real-time aspect of a satellite-linked system is secondary, allowing a check on operation of the system and its stability as the observations are progressing. A quick turnaround on the results is also a possibility which would allow changes in observing strategy if something interesting turned up.

From the geodetic point of view, a fast throughput would be useful, but not critical, for global crustal studies since observations are envisaged only on an intermittent basis. A tape-based system is adequate for this work. Polar motion and UT1 studies are envisaged as quasi-continuous (8 hours daily for the Polar-motion Analysis by Radio Interferometric Surveying (Polaris) project, see paper by W. E. Carter, these Proceedings) and would benefit from a rapid flow of bits through the correlator. A channel in the satellite-linked system dedicated to UT1/polar motion data transfer would probably have an advantage over a tape-based system. On the other hand, astronomers have a vested interest in obtaining geodetic and astrometric information on a regular basis since this provides the basic calibration of the interferometer system for astronomical work. It is likely that, independent of geodesists' needs, there will be a regular monitoring of the vector baseline and source position sets.

Local Oscillator Stability and the Use of the Phase Observable

Experience over the past few years has shown that present generation hydrogen maser oscillators deliver sufficient stability for geodetic purposes. They are also expensive items. Europe is sparsely populated with masers and heavily populated with observatories in countries with small budgets for radio astronomy. It is not clear whether a wide distribution of hydrogen masers is possible.

An alternative, possibly cheaper (for each observatory), scheme is to link remote oscillators of Rb quality via geostationary satellite, thus making VLBI a form of connected element interferometry. The Canadian-United States efforts and Canadian plans in this regard are described in papers by Waltman et al. and Cannon et al. (these Proceedings). Design work is also going on in Europe at the Dwingeloo Radio Observatory in the Netherlands on a local oscillator link scheme via satellite. This is scheduled for its first test in January 1980 using the Orbital Test Satellite. The estimated cost of the ground station plus associated electronics required at each laboratory is estimated to be a factor 5 or 6 cheaper than a hydrogen maser. If this is successful, it will be an attractive solution to the problem of local oscillator stability.

It is anticipated that the use of the phase observable will grow in the coming years both for geodesy and astrometry (e.g., J. Campbell, these Proceedings) and for astronomy. A full use of phase for geodesy and astrometry requires that the a priori knowledge of the vector baselines, the source positions, the troposphere and ionosphere, be sufficiently good to resolve the inherent 2π ambiguities. For well-established baseline and source position sets, narrow bandwidth observations utilizing phase should be sufficient for "fine-tuning" the baselines and position and for monitoring small scale changes in them.

The Data Processor

Ideally, the data processor should be designed to take inputs from either tapes or satellite links. Compatibility with Mark III could be assured by making the basic clock rate of the processor a multiple of 2 MHz, and providing parallel-to-serial interfaces for the 28 channel Mark III data before it entered the processor. For a satellite-linked system, the number of bit streams able to be correlated must be identical or greater than the number of stations; there is no opportunity for reprocessing. Design considerations for a wide bandwidth correlator are being evaluated at present.

Organizational Questions

Observatories must commit themselves to VLBI operations for a substantial fraction of the time and to support the operations with the required funding.

If a satellite-linked system for either clock synchronization or signal transfer, or both, shows substantial advantages in capability or efficiency over an independent station approach, then ways of ensuring the success of the project need to be found.

There are encouraging signs in Europe on at least the first, and perhaps also the second, of these items.