VLB ARRAY MEMO No. 23

ALTERNATIVE DATA COMMUNICATION SYSTEMS

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All existing VLBI systems use broadband magnetic tape as the communication medium between telescopes and central data processor.

A fundamental difficulty with the tape recording system is the lack of information in real time concerning the performance of the individual telescopes and peripheral equipment. Frequently a subtle failure of a minor yet vital component will be unrecognized until after tape processing has commenced, perhaps weeks or months after the observations. Such occurrences have resulted in much wasted observing time and scientific and technical effort. Program changes during an observing session, based on preliminary examination of the correlated data, are frequently desirable; such changes are impossible with the VLBI systems currently in use.

The postobservational tape processing usually requires considerably more time than the observing itself, especially for multibaseline sessions, and so the amount of scientific labor involved in an experiment is inordinately large. Furthermore, the time interval between the observing session and the production of processed data can run to several months. Large amounts of magnetic tape are involved in a major observing program, and there are thus significant logistical problems.

Short-baseline interferometer systems, whose antennas are interconnected by guided-wave transmission systems, suffer from none of the disadvantages mentioned above. The contrast in efficiency and convenience with current VLBI systems has led to consideration of suitable long-distance, broadband communications media for VLBI use. These include dedicated microwave radio links, the continental television network, and communications satellites, all of which could permit real-time, long-baseline interferometry, although they are apparently much more expensive than the magnetic tape system.

No substantial study of a dedicated, terrestrial, microwave-link communication system for a VLBI network has been made; it seems obvious from superficial considerations of the economics, politics, and frequency-management problems involved that there is little point in considering this medium as a solution to the data communication problem. While terrestrial microwave systems well serve intermediate-baseline interferometer systems, of the order of one hundred kilometers or so, they do not provide an attractive possibility for the transcontinental or intercontinental network.

An initial inquiry into the characteristics of the network television transmission system operated by the American Telephone and Telegraph Long Lines division suggests that it would provide a technically feasible communication medium for VLBI. It is widespread throughout the country, and methods are in practice for real-time transmission from locations (such as football stadiums) other than established studios. Presumably the same services could be extended to radio observatories. It is apparent that many redundant television transmission channels are available as insurance against failure; these could conceivably be used for scientific purposes on a second-priority basis if suitable tariffs could be negotiated.

The television network has some serious disadvantages, of course. The chief one is its limited bandwidth. While the most widely-used VLBI system (Mark II) at present uses television format and bandwidth, there are strong motivations toward much broader bandwidths, and new VLBI systems are utilizing such bandwidths. There are also questions of phase and time-delay stability which are potentially troublesome. In any case, the television network has not presented an attractive-enough alternative to the magnetic-tape system to have merited intensive attention by the VLBI community, although its potential has been recognized.

Probably the most promising communication medium for a transcontinental VLBI network is the optical fiber system, which has been developed to the point at which it offers outstanding technical advantages. Ultimately, it is possible that a national optical fiber network will be established to supplement or supplant the existing microwave, coaxial cable, and satellite communication system. At that time, adequate bandwidth at low-enough cost should be available through the commercial network to serve a national VLBI network. This situation probably will not be realized for many years, perhaps decades. In the interim, a dedicated fiber-optic system is clearly economically infeasible for scientific use.

The final possibility for real-time VLBI data transmission is the communication satellite. While the real costs of such a system are undoubtedly comparable with those of the media discussed above, particularly if space in the radio frequency spectrum is considered as an economic good, satellite communications systems are frequently subsidized by national governments for reasons of policy. Hence, from the point of view of the user the satellite often appears to be the most economical broad-band, long-distance transmission medium.

To test the feasibility of satellite VLBI, a group of U.S. and Canadian radio astronomers (Yen, Kellermann, Rayhrer, Broten, Fort, Knowles, Waltman, and Swenson, Science 198 289, 21 Oct. 1977) utilized donated time on the experimental CTS (Hermes) satellite to conduct interferometer observations on baselines between Algonquin Park, Ontario, and Green Bank, West Virginia, and Owens Valley, California, respectively. The experiment was successful. Real-time fringes were routinely obtained on both baselines, using an effective bandwidth of 10 MHz. A total of over 150 sources were observed, of which approximately 25 percent exhibited fringes in real time. No determined attempt was made to extract fringe information on the remaining sources by post-observational processing. Such an effort would have almost certainly been successful in many cases. Promising results were also obtained in the transmission of precise time signals over transcontinental baselines, a technology of central importance to VLBI. Experimenters of the U.S. Naval Research Lab and the Canadian National Research Council are continuing these time- and phase-transmission experiments with another satellite.

The CTS VLBI experiment involved transmission from the remote radio telescope to the satellite and thence to the correlator at Algonquin Park. The signal from the local telescope was sent directly to the correlator. The signal from the remote telescope was thus delayed by approximately 0.25 second in addition to the delay resulting from the geometry of baseline and source-direction. The differential delay was equalized by passing the local signal through a digital delay line, probably the most elaborate one ever built, which aligned the two bit streams to an accuracy of 0.05 microsecond before presenting them to the correlator.

In a satellite system specifically designed for multistation VLBI, all telescope signals would be transmitted to the processing station via the satellite, thus eliminating the largest part of the differential delay. The delay-line problem is thus relatively minor. Present-day satellite technology is perfectly capable of accommodating eight telescope channels of approximately 30 MHz bandwidth each (European Space Agency, Phase A Study on satellite VLBI, Document No. SC1(80)1, Paris, February 1980). Whether the attendant frequency allocation problems could be solved is an open question. The European Space Agency has planned a satellite-assisted VLBI system involving existing telescopes in eight countries, with a proposed completion date of 1985.

Should the United States wish for political reasons to provide a geostationary communication satellite for astronomical use, it is technically feasible to do so, and such a facility would greatly expedite the establishment and operation of a VLBI network. In the interim, particularly if real costs are a major consideration, magnetic tape appears to be the most practical communication medium. A satellite communication system could be added at any time in the operating life of a VLBI network without a major reconversion of existing facilities, by adding the uplink transmission facilities at the radio telescopes and the downlink reception facilities at the processing center. If such an evolution is a reasonable possiblity, it would be well to plan the processing center in such a way as to minimize retrofitting of delay lines, correlators, data buffers, etc.