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CONSIDERATIONS FOR DIGITIZING THE IFs AT THE ANTENNAS FOR THE A.T.

PETER NAPIER.

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INTRODUCTION

In an earlier study Little (1977) investigated possible communication links for the AST. The communication systems that he investigated were coaxial cable, VLA waveguide, radio links and fibre optics. Since 1977, the Japanese manufacturers have dismantled the equipment used to manufacture the VLA waveguide, so this no longer seems to be a viable option. There have been several significant changes in the design of the telescope since 1977. The length of the linear array has been increased from 2 to 6 km. The number of antenna locations along the array has increased from 16 to 43 (although this may change as a result of future studies of optimum arrays). The number of reconfigurations needed for a full synthesis has risen from 3 to up to 18 (again, this number may change). Finally, two distant antennas, Siding Spring and Parkes, will be brought into the array on radio links. The 6 km length of the array means that 22mm diameter coaxial cable loss will be 84dB and 144dB for IFs at 50-150MHz and 250-350MHz respectively and 168dB for an LO at 500MHz. These losses are large enough to significantly complicate a coaxial cable communication link design. Since the two intermediate baseline antennas must have radio links, using radio links for the 5 antennas in the linear array would require a very large amount of spectrum to be allocated to the AT. In addition, the need to move the radio towers with the antennas for each of up to 18 array configurations presents severe operational problems. Thus, neither coaxial cable nor radio link look particularly attractive for the communication link, leaving fibre optics as the most promising system. Modern commercially available single mode fibres have attenuations of less than 3dB/km, bandwidths of more than 400MHz and costs of approximately $1.70 per metre per fibre (see, for example, the extensive cable lists in IFOC, 1982). This is adequate for the IF link and it is worth noting that recent tests at JPL (Lutes, 1981) indicate that optical fibres can also be used for the LO link.

Although techniques for transmitting analogue signals of a few MHz bandwidth through optical fibres are available (Windus, 1981), it is not clear that they can be extended to the 100MHz bandwidths needed for the AT. The thrust of modern fibre optics development is towards digital transmission and these techniques can be used provided the IF signals are digitized at the antennas. The following points are the author's interpretation of the discussion at a meeting held on 15/7/82 to consider, amongst other things, the advantages and disadvantages of digitizing the IFs at the antenna for the AT. The meeting was attended by J.Ables, D. Cooper, R. Manchester, R. Schilizzi, M. Sinclair, K. Wellington and P. Napier. The points are approximately in order of importance.

Advantages of Digitizing the IFs at the Antenna

1. The IF communication link is removed as a source of phase instability.

2. The specifications on the flatness of the amplitude and phase response of the IF link are drastically relieved, as are the matching of these responses between antennas. Identical bandpass and phase responses are required for all IFs if closure amplitude and closure phase techniques (Cornwell and Wilkinson, 1981) are to be used for high accuracy data calibration (Thompson and D'Addario, 1982).

3. Allows the use of digital rather than analogue transmission techniques in a fibre optics link. Fibre optics digital communication is a rapidly developing and well supported technology.

4. Better suppression of crosstalk between the IFs from different antennas is provided. This is not clearly the case. It is based on the assumption that the most probable crosstalk mechanisms result from having low level analogue signals from different antennas physically close together in adjacent racks of equipment, which is prevented by digitizing at the antenna. An alternative crosstalk mechanism, pointed out by R.H. Frater, which is actually induced by digitizing at the antennas would be radiation of harmonics of the high level 200MHz sampling signal from one antenna directly into the low noise receiver of another antenna when the antennas are in a compact array. Actually,

neither mechanism may be important in practice. In principle the first mechanism is cured by phase switching and, if the variable frequency sampling scheme used in TEST is used for the AT, the sampling signals will not be coherent between antennas (except near the u axis in the uv plane - see Thompson, 1982).

5. The linearity specification on the link transmitter is relieved. This will be a significant problem for analogue transmission unless a pulse modulation scheme such as Pulse Frequency Modulation (PFM) is used.

Disadvantages

1. The amount of electronics hardware which must be maintained at the remote antennas is increased. The additional hardware which must be located at the antenna rather than in the central electronics room includes the IF to baseband mixers, the switchable narrow bandwidth filters, detectors for any injected noise temperature calibration signals, the ALC attenuators and digitizer driver amplifiers and the high speed digitizers themselves. In addition, all local oscillator phase and frequency corrections for fringe stopping, phase switching and Doppler correction must be performed at the antenna.

2. If one or two bit sampling is used significant sensitivity will be lost on the tied array output provided for VLBI and spectroscopy use by adding together the digitized signals from the five linear array antennas. This will be in addition to the sensitivity lost due to the one bit sampling of the VLBI taperecorder. This subject has been investigated by Van Ardenne (1979). For only 5 antennas added together, the sensitivity loss will be a somewhat less than the two antenna loss of 36% lost sensitivity for 2 level and 19% for 3 level sampling. Since the linear array will spend a significant fraction of its time in this VLBI mode, such sensitivity should not be thrown away lightly. If sensitivity were to be increased by increasing the diameter of the antennas, the cost would be approximately $80,000 per percent sensitivity (assuming the usual $(\text{diameter})^{2.7}$ cost for reflector antennas). To prevent this loss of sensitivity on the tied array output, digitization should be performed to a resolution of at least 3 bits. Of course, only the most significant one or two bits will be used as input to the correlator when using the linear array as a synthesis telescope. 3 bit sampling will significantly

increase the bit requirements for the fibre optics communication link.

3. In order not to lose sensitivity, two digital channels, for sine and cosine, must be transmitted over the communication link instead of one analog channel. Or, if only one channel is transmitted, the complex visibility must be obtained by Fourier Transforming the correlation function determined for many different lag steps, as is done for TEST. For the VLBI case, if only one channel is transmitted there will be a loss of sensitivity of approximately 20% if a second pass through the processor with a new phase center is required (see Schilizzi, 1982).

4. Unless multibit sampling of the type described in 2. above is used, there will be reduced flexibility to use analog signal processing developments which may be made in the future.

RECOMMENDATIONS

The author's recommendations are:

1. Digitization at the antenna is an advantage provided a solution to the tied array sensitivity loss is found. We need to make accurate estimates of sensitivity loss for the tied array for various sampling resolutions.

2. Investigate fibre optics analogue transmission systems sufficiently to determine if 100MHz bandwidth transmission is feasible. If necessary, the 100MHz can be subdivided into several narrow bands.

3. Investigate fibre optics digital transmission systems capable of data rates in the range 200 to 600 Mbits/sec.

4. Contact the JPL group (Lutes, 1981) to learn more about their phase stabilized fibre optics link for the LO distribution system.

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