VLB ARRAY MEMO No. 500

BANDWIDTH EXPANSION PATHS

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The total bandwidth capability of the VLBA is, according to present plans, 256 MHz per station. This is organized into 16 channels of up to 16 MHz bandwidth each. With Nyquist sampling and 2-bit/sample encoding, this would amount to 1.024 Gb/sec, compared with our presently planned recording capacity of 128 Mb/sec average and 512 Mb/sec peak (where the latter assumes that simultaneous use of two transports per station would be allowed). The peak rate is achieved with Nyquist rate sampling using half the channels, or using 1 bit/sample, or using half the maximum bandwidth per channel. The allowed average rate is achieved, assuming that all channels are used, by reducing the channel bandwidth to 2 MHz (1/8 of maximum) for 2-bit encoding, or 4 MHz (1/4 of maximum) for 1-bit encoding. Since the average rate cannot be exceeded much of the time, the capacity of each channel is mostly underutilized. The specifications of all of the components that work on a per-channel basis must be adequate to support the widest bandwidth, which is rarely used, and yet they must be duplicated by the number of channels. This is inefficient.

To better match the channelization to the recording capacity, we should have a smaller number of wider-bandwidth channels. We should also allow for the expansion of the recording capacity in the future. In fact, it is widely hoped that expansion of the *average* recording rate may be in the near future; this is because it is presently limited by the length of tape that can fit on one reel, and the use of thin tapes and large reels looks promising. Expansion of the *peak* recording rate, however, would require considerably more hardware (formatters and head stacks, in present technology). If we build the initial equipment to allow for doubling the average rate to 256 Mb/sec, we still need only half of the planned channels at 1 bit/sample. This is also enough to support the peak rate of 512 Mb/sec at 2 bits/sample.

It would thus be very reasonable to reduce the number of channels in the initial VLBA to 8, retaining the planned maximum bandwidth per channel of 16 MHz. The channels could include both upper and lower sidebands of the final LO, so only 4 baseband converters are needed. I propose that this be done. It supports recording rates (both average and peak) that are 2.5 times our original specification (100 and 200 Mb/sec, respectively), and produces no degradation in capabilities until such time as the recording capacity is further expanded.

Next, it is necessary to allow for such future expansion. Unless there is a fundamental reason to want more channels than 8 (as discussed below), the preferred expansion path is in bandwidth per channel rather than number of channels. This is because there is a considerable amount of equipment that must be duplicated according to the number of channels (IF distribution and switching, baseband converter LOs, digitizers, fringe rotators), and in all cases the technology permits wider bandwidths at little cost. After digitization, most of the hardware requirements (with the notable exception of fringe rotation, if done then) are proportional to total data rate and independent of channelization, but there may be significant simplification of interconnections when there are fewer but faster signals.

The trouble with allowing for expansion of channel bandwidths is that provisions must be made for it in the initial design, since adding it later would require redesign of modules. Adding more channels later just involves duplicating existing designs. I propose that we make the necessary provisions, at least by a factor of two. That is, all 8 channels should be designed for 32 MHz bandwidth. This includes making the bandwidth of the image reject mixers in the baseband converter large enough, and making provisions for (although not necessarily installing) a 32 MHz baseband filter in each baseband channel. It also requires ensuring that the digitizers are sufficiently fast to accomodate a 64 MHz sampling rate. These changes in the present specifications are quite feasible to achieve, but may cause schedule slippage if adopted this late in the project. Nevertheless, in the long run (if expansion is ever required) we will be far ahead.

In case expansion beyond a factor of two is needed (i.e. beyond 512 Mb/sec average and 1.024 Gb/sec peak), construction of additional channels would be reasonable. This is because further expansion of the channel bandwidth would be somewhat beyond the capabilities of the technologies used now. If significantly improved technologies are then available, the new channels could be built with more bandwidth and/or the old channels could be replaced.

It might be objected that there are scientific reasons to prefer many, narrow channels to few, wide channels. These involve requirements for (a) bandwidth synthesis and (b) pulsar de-dispersion. In the first case, it is really tunability that matters and my proposal has reduced us to four separately tunable channels. I submit that this is enough, and that more could not be efficiently used in this application. There are two rather different kinds of "bandwidth synthesis": resolving of lobe ambiguities in astrometry, and filling in uv-plane holes in mapping. In astrometry, efficient observing requires frequency switching, since most of the integrating time should be spent at the extreme frequencies; given that frequency switching will be used, four tunable channels is easily enough. For mapping, since VLBA bands have only about 10% RF bandwidth, only very small improvements in uv coverage are possible with more than four frequencies. Regarding pulsar de-dispersion, handling the worst cases (low frequencies) would require a much larger number of channels than ever proposed for the VLBA, and 8 channels allows useful total bandwidth for most cases. Besides, pulsar observations will be a small fraction of VLBA use, and some post-correlation de-dispersion is possible.

To summarize, I have two proposals:

(a) The number of VLBA baseband channels per station should be 8, with 4 USB and 4 LSB channels for each tunable LO. The maximum bandwidth of each channel could be 16 MHz.

(b) The circuitry for each channel, from IF through digitization, should be designed to support 32 MHz bandwidth. This is to allow for future expansion.

These proposals can be considered independently. Neither would affect initial capabilities of the VLBA. Adoption of the first proposal would reduce the construction cost and would preserve an expansion path involving increasing the number of channels. Adoption of the second would preserve an additional expansion path involving increasing the bandwidth per channel.