NOTES ON THE HARDWARE DESIGN REVIEW OF MARCH 1993

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An internal review of the status of the Green Bank OVLBI Earth Station electronic hardware design was held on March 26, 1993. The main purpose of the review was to identify those design details which remain uncertain and issues which remain undecided. In these notes, I summarize the list of such items derived from the review and, where possible, I indicate how they are expected to be resolved. Some information was added after the review meeting from discussions with the responsible engineers; this is given in square brackets []. In some cases, the items listed do not represent any uncertainties or problems, but merely indicate straightforward work not yet completed.

Also discussed during the review were design changes that have occurred since our Critical Design Review in October 1992; I do not cover these explicitly in the present notes.

1. Feeds and Optics (B. Shillue)
   1.1 The mounting structure designs are incomplete.
   [Design concepts are complete, and detailed design is in progress. The hyperboloid mount design should be complete by mid-April, and the feed/FSS/ellipsiod mount design should be complete by the end of April.]
   1.2 Should feeds be pressurized?
   The feeds themselves will be sealed and will have provisions for pressurization.

2. Front Ends (B. Shillue)
   2.1 The X-band switch needs to be replaced with a different type; the switch driver design is incomplete.
   We require a de-energizing type of coaxial relay in the dewar for switching one channel between transmit (Radioastron) and receive (astronomy) modes; the switches tested so far require continuous coil current. The required driver circuit is quite simple.

3. Cryogenics (B. Shillue)
   3.1 Modifications to compressor box need to be designed.
   This includes adding electrical circuitry to power both refrigerator motors and adding monitor circuitry (helium pressures, temperatures). Requirements are understood and the design is straightforward.
   3.2 Vacuum pump selection and mounting needs to be specified.
   This is straightforward and on schedule.

4. Downconverters (B. Shillue)
   4.1 Step attenuator performance is still uncertain.
   This is a fallback in case the Costas loop and/or phase detector do not have enough dynamic range to handle the worst case tracking pass. We would then adjust the gain with these attenuators during the pass, in which case we want them to introduce negligible phase shift and switching transients. GaAs step attenuator chips from Alpha look promising, but the pre-production samples provided to us showed some strange behaviour. [New devices are on order and additional tests are expected during April, with a final decision in early May.]
   4.2 X-band downconverter LO phase noise may be too high.
   This is a potential problem resulting from the desire to have a tuning range that covers nearly the whole VLBA band, rather than just the Radioastron frequency, implying the need to use a relatively low-Q VCO. [The actual phase noise of the present design will be checked when the prototype is assembled

in early May. If necessary, a lower-noise VCO will be substituted, perhaps as a composite of a fixed-frequency high-Q oscillator and a lower-frequency VCO. Final design expected by mid-May.]

5. Power Supplies (D. Burgess)
(A detailed design was presented for the selection, packaging, and mounting of the power supplies for the antenna-mounted equipment. No significant problems were identified.)

6. Focus/Rotation controls (D. Burgess)
6.1 Decision needed on whether old electronics is usable.
We want to preserve the existing mechanism for two-axis motion of the prime focus equipment, which for us is just the subreflector. This is based on stepper motors, and there is existing (old) electronics to drive them. An investigation of available new electronics has failed to turn up anything that is clearly suitable, in view of the large torque requirements. A decision on how to proceed is needed within one month.
[The old high-current motor drive circuitry is simple, well understood, and deemed to be maintainable. Furthermore, we have a complete spare set from the 300ft telescope. Therefore, we'll keep it. However, we'll develop new and modern control circuitry.]
6.2 Computer interface needs to be designed.
[Modern VLSI chips are available for stepper motor control that will allow a simple interface to the station computer. We'll use these to create a controller for each axis. Design should be complete by May 30, with prototype ready for testing by June 30.]

7. Reference Distribution (L. D'Addario)
7A--Clock Building To Earth Station:
7.1 Choice of fiber optic receivers and transmitters requires tests.
A two-way fiber optic link is planned, and a paper design exists. However, there is considerable uncertainty about the practical performance that can be achieved. The cost of optical components (particular laser transmitters) varies by a factor of more than 10, and it is not known whether the more expensive devices actually produce better performance for a short link like ours. [Low-end components are on order, and tests are planned for May. A final design should be available by mid-June, with implementation complete by mid-July.] An interim system will connect the maser at the Interferometer building to our station, but unlike earlier plans the optical and electronic components will be the same as in the final system; only the fiber length (and possibly type) will be different.
7.2 Whether to use 5 MHz or 10 MHz for the low frequency distribution.
At the ES, 5 MHz is needed only for the Astronomy System, and it could be obtained by dividing down 10 MHz. The 10 MHz reference is used more directly, and would require doubling 5 MHz if only the latter is transmitted. Also, 10 MHz is more tightly coupled to the Sigma Tau maser (whose 5 MHz output is merely 10 MHz divided down). These considerations favor distributing 10 MHz, which is our present decision. The point is mentioned here because the choice may be reversed if tests show any difficulties.
7.3 Whether to attempt wideband (10MHz + 500MHz) or narrowband (10MHz * 500MHz) encoding for transmission.
This refers to the method of multiplexing the two reference signals onto the optical fiber. The present design uses wideband modulation because it is simpler. Tests of the prototype [in mid June] will show whether the more complex (but potentially better performing) narrowband method is needed.

7.4 Whether round-trip should be on the same fiber with wavelength multiplexing, or on separate fibers.
The present design, and the prototype, will use a single fiber because of its inherent reciprocity. But the actual reciprocity achieved may be limited by dispersion due to the wavelength multiplexing (1300nm out, 1550nm back), so the fallback is to use separate fibers with the same wavelength each way. Tests of the prototype will determine which choice is best.

7.5 Cost: are expensive optical parts like isolators and DFB lasers needed?
Discussed under 7.1, above.

7.6 Coordination with others: GBT, USNO.
The GBT and new USNO antenna are also in need of precise timing signal distribution from a central clock. But our schedule is way ahead of theirs, so the development burden seems to be falling on us. Some cost sharing should be possible, but this needs to be worked out. Especially the installation of buried fiber can be shared, but details of cable type choices and schedule still need to be finalized.

7B--Within the Earth Station:

7.7 Need to develop 100 MHz PLXO locked to 5 or 10 MHz reference.
[This device has been designed, parts have been ordered, and construction will proceed in April.]

7.8 Can we run the fiber all the way to antenna vertex, eliminating the coax link?
The block diagram is simplified if we bring the optical fiber to the antenna vertex rather than to the equipment building; those references needed downstairs are then sent on coax, but nothing higher than 10 MHz is needed.
We have now decided to pursue this approach (a major change), even though it represents a higher risk. The coax transfer of 500 MHz to the vertex (previous design) used proven circuitry from the VLBA, whereas the two-way optical fiber approach is presently untried. If the latter has difficulties, a one-way transfer over buried fiber to the equipment building might provide adequate performance, but a two-way link is almost sure to be needed for the exposed run up the antenna.

7.9 Can we operate for testing with no maser signal at all?
In order to get things running, it would be valuable to have all reference signals available from local crystal oscillators. Addition of a single 10 MHz free-running crystal would achieve this, but then the 10 and 100 MHz would not be coherent with the 500 MHz; we think this is acceptable for most tests.

8. Two-way Timing (L. D'Addario)

8.1 Final choice of DDS chips and boards not yet made.
For the DDS chips that we have tested for phase stability (STEL and AD), operation at 100 MHz clock is marginal; yet our system design makes use of this speed highly desirable. The AD9955 prototype works fine at 115 MHz, and AD says that most chips will do this, but they can't guarantee it. [We'll try to obtain four of these that test good at >100 MHz (2 system and 2 spare). If we cannot, we'll have to fall back to using 50MHz clock with STEL chips. Final decision by mid-April.]

8.2 Digital interface needs detailed design and layout.
This is straightforward, but it depends on the choice of DDS. [Should be complete by May 1.]

8.3 Digital filter algorithm needs simulation; might imply need for a more powerful DSP.
It appears that numerical considerations will require very long word length in the phase filter computations (perhaps 48 bits). This is triple-precision in the ADSP2101 processor now planned. The filter design needs to be finalized and then simulated at various word lengths to see what is really needed. It is possible that a faster processor will be

required, but at present this does not seem likely so we will continue to plan on using the 2101. [Results of the simulations should be available by the end of June.]

8.4 The detailed coding of DSP needs to be done. [Hardware design and integration will proceed with the ADSP2101, but coding will be limited to test routines until the filter design mentioned in 8.3 above is finalized.]

8.5 Transmitter PLL may produce too much phase noise, in which case a lower noise VCO is needed.
This is the same effect described under 4.2 earlier. Test data on the transmitter prototype already shows that the phase noise is marginal. Lower-noise VCOs are being investigated. [Final decision is expected by mid May.]

8.6 500-800 MHz synthesizer needs cleanup and new PCB layout. Straightforward work. [Expected to be completed by late June.]

8.7 IRM and phase detector need final design and layout. Straightforware work. [Expected to be completed by late May.]

9. Satellite Simulator (L. D'Addario)

9.1 No detailed design work has been done yet.
This device is expected to be a straightforward assembly of commercially available components, but there could be unforseen difficulties that will become apparent after a detailed design. Manpower limitations and higher priority work will prevent much effort on this until July.

9.2 Long-lead items may have impact on schedule.
Microwave parts often have long lead times, which may prevent this module from being ready for the first system tests. [For this reason, we'll try to move the design work up in the schedule as far as possible.]

9.3 No real cost estimate has been done.
The budgeted amount for parts ($15k) is just a guess; the actual cost could be substantially higher since some expensive microwave parts might be needed.

10. Demodulator (A. R. Thompson)

10.1 Lock detection in a Costas loop is not simple.
A proposed method exists, but it is fairly complex and untested. Alternatives need to be considered. The breadboard Costas loop does not always lock correctly, for unknown reasons.

10.2 A reliable lock acquisition scheme needs to be designed.
We need to ensure that false locks are avoided, including the theoretically expected ones at +-(clock freq)/4.

10.3 Achievable dynamic range is unknown.
To operate without gain adjustments or ALC over the worst-case tracking pass requires a 20 dB dynamic range. This is an unusual requirement for Costas loops, and it is not known whether it can be achieved.

10.4 No work has been done on bit synchronizer design.
These run at much faster rates than can be accomodated by simple techniques. Although commercial bit sync chips exist for even faster rates, they support only specific standard rates not including ours.

10.5 Should the bit syncs be moved to downstairs?
Although the Costas loop must be on the antenna (since its recovered carrier is needed as the VSOP phase downlink), it is not essential that the bit synchronizers be there; they could be located in the equipment building. In that case, the I and Q baseband signals (analog) would have to be sent down on cables, rather than the (digital) I,Q,clk. [We'll keep everything on the antenna unless a strong reason is found for moving the bit syncs.]

11. Decoder (R. Escoffier)

11.1 A non-standard VME interface is proposed and its acceptability needs to be decided.
It is intended to use the VME address modifier lines as

device-select and function-select codes. We are uncertain whether this will produce any compatibility problems with other modules, or any software difficulties. [Decision expected in April.]

11.2 Can the decoder for the VME address modifier be in PAL or are switches needed?

In case the addressing assignment for the decoder needs to be changed in the future, a new PAL would have to be made instead of just resetting some switches. But this saves board space. [This seems to be acceptable.]

11.3 What connectors should be used for high speed inputs/outputs?

Coax connectors would be best, but then they need to go on the front panel. Going through the P2 connector at the back is possible, but less desirable at 72 MHz.

11.4 Interface protocol to/from station computer is not yet specified.

[This is being given high priority and should be complete in April.]

11.5 Interface semantics (command set) to/from station computer is not yet specified.

[Same as 11.4 above.]

11.6 Downlink header processing required in the decoder is not yet specified.

This is difficult to specify precisely now, especially since the Russians and Japanese keep changing the format. The main worry at this point is that it might affect the choice of the 87C51 as the decoder's microprocessor, and this choice must be made firm very soon. [This item did not acutally come up during the review. Our subsequent decision is to stay with the 87C51 because we are reasonably assured that it can handle all the hardware control functions and station computer communication needed for the decoder. We'll also have it do as much header processing as possible, once that processing is better defined; if processing too complex for it is needed, such work will be allocated to the station computer.]

12. Packaging and Cabling (L. D'Addario)

12.1 Fiber optics or copper for the wideband data down and test data up?

Earlier designs specified optical fibers for the three digital signals being sent from the vertex to the equipment building, but the three transmitter/receiver pairs needed are somewhat expensive with no perceived benefit. Therefore, we will probably revert to using copper lines; whether they should be balanced (shielded twisted pair) or unbalanced (coax) is TBD. The test data streams going up to the satellite simulator are similar and will be handled the same way (5 fast digital signals altogether, 2 up and 3 down).

12.2 Is an underground conduit from antenna to trailer feasible?

We have a rough plan for maintaining fairly good environmental control of the critical cables by running them in an underground conduit from the trailer to the center of the antenna tower, and then in conduit to the elevated pedestal. But the practical feasibility of this needs some study. [Final decision should be possible by end of May, with implementation during June and July.]

12.3 Detailed design of wraps has not been done.

The azimuth arrangement is particularly uncertain in view of the limited space available for wrapping within the antenna pedestal. The elevation wrap is fairly straightforward, but detailed design is still needed. [Final decisions should be made by the end of May.]