A New Card Cage Design for the EVLA Front-End Systems

EVLA Memo 42
R. Hayward - 17 July 2002

Introduction:

This memo discusses the new Card Cage design that will be required for the Front-End systems being developed for the EVLA project. It is a somewhat random collection of thoughts on what features we will require as well as suggestions on how we might go about implementing it.

The Pseudo-Passive Scheme:

The newly proposed *Pseudo-Passive* scheme for the Front-End Monitor and Control (M&C) is a major change from the design concepts presented previously which explored the Card Cage cabling issue from the two most extreme viewpoints. The first of these looked at what would be required if each of the M&C parameters had a dedicated wire to or from the module which will be replacing the current "F14" unit (henceforth referred to as the *M&C Module*). In the worst case scenario, that of a W-Band style receiver, we'd need over 100 wires (consisting of a couple of dozen control and status bits plus nearly 70 analog read backs). This would require upwards of five DB-25 connectors - that's a lot of copper, considering we currently use only two DB-25's. The second scheme minimized the amount of cable connections by using a Serial Peripheral Interface (SPI) Bus to read and control *everything* in the Front-End. While this would limit the number of cables to a single DB-25, it would require an awful lot of clocking and toggling of digital bits inside the Card Cage. From the RFI and total power stability point of view, this would probably not be a good thing.

In order to eliminate, or at least minimize, any digital cross-talk getting into the LNA bias lines which might affect its total power gain stability we should strive to ensure that all of the digital bits going into and coming out off the Card Cage remain static while the receiver is taking data. Currently on the VLA all of the M&C digital traffic is hidden during the 1 ms blank time on each waveguide cycle (I expect this scheme hides numerous sins within our hardware as well, including possible spikes in our noise diodes as they switch on and off). The Pseudo-Passive scheme will give us the best of both worlds. It can be done with a single DB-25 cable, thus reducing the number of cables needed to interface with all 8 EVLA Front-Ends, and will allow the most important status bits and analog parameters to be monitored continuously without generating any digital cross-talk. The M&C will still be able to access all of the other parameters on demand. Doing so, however, will require the toggling of digital bits in the Card Cage. The idea now is that we only do this when it won't impact astronomical data.

Accordingly, we will need the Control System software to let the M&C Module know when it's is a good time for it to read the Card Cage monitored parameters. This could be done any time while the telescope is not taking data (say while it's slewing) or during a regularly scheduled dump time (on the order of once every 10 minutes or so). The Microcomputer Interface Board (MIB) should be able to grab all of the parameters in several milliseconds. I have talked to Barry Clark about this scheme and while he is worried about such things as the robustness of MIB-to-MIB communications and scheduling difficulties, he recognized it will help solve a potentially serious problem.

We will want to be able to log most, if not all, of the monitored points so we can look for any time fluctuations in the data. When plotted out, these can be used to analyze the health of the Front-End. For example, a 15°K stage which has been creeping slowly up in temperature or cycling up and down may be giving an indication that the receiver will soon warm up spontaneously. Or an LNA gate voltage which appears to be wandering around may indicate a receiver with a total power stability problem. As well as archiving this type of data, we'll also need to be able to access the data "on-demand". Often the Cryo Group will want to look at the current temperatures and pressures on a particular receiver, or sometimes the Front-End Group may want a instantaneous snapshot of all of the biases on an LNA. The question that will confront us in these circumstances is whether the Front-End M&C Module should generate a "data invalid" flag when it grabs data on-demand like this. If the digital cross-talk does indeed have a deleterious affect on the receiver gain stability, the WIDAR Correlator could momentarily blank out the astronomical data from that antenna.

The Pseudo-Passive scheme uses 5 multiplexed address bits for selecting which analog signals will be read back, three voltages at a time (thus giving us a maximum of 32 x 3 = 96 analog monitoring points). The parallel I/O is also accessed with the mux address, giving 4 status bits for the M&C to read and 4 command bits, which are latched into the Card Cage with a Parallel Data Strobe bit. During observing, the digital bits will not be toggled and the address mux will be set to 31 (ie: all 1's) and held static. This will allow the 3 most critical analog voltages (the average LNA Gate voltages for each polarization channel and the 15°K stage temperature) to be monitored constantly without worrying about digital cross-talk affecting the LNA bias settings. The 4 most important digital status bits will also be available continously, including the traditional C, X and H-bits, which indicate where the receiver is in its cool-down sequence (all 1's = normal cooled operation).

By asserting other mux addresses, the M&C can access all of the other monitored analog voltages (ie: the LNA Drain voltage & current and Gate voltage for each stage, the Cryogenic temperatures, the Dewar & Pump pressures, the Noise Diode voltage & current, and even Power Supply voltages). It will also be able to read the rest of the digital status bits (ie: the Pump, Solenoid, Fridge & Heater Request bits and the 12-bit ID code containing the Front-End, Serial Number & Mod Level information).

With the mux addresses, the M&C will also have "remote" control of the evacuation, cool-down and warm-up functions (through the C, X and H command bits), much like we do on the VLBA. Currently the VLA does not have this type of remote control. For the EVLA, the Cryo Group would like these bits to be handled somewhat more intelligently than the VLBA does. Sometimes they will instruct the Card Cage to go into a non-operational state, like leaving the Heater turned on while warming up the receiver or Pumping on the dewar for a long time to get a good vacuum purge. However, when a new Observe File is run, the VLBA has the annoying habit of taking charge, ignoring the mode the receiver had been remotely commanded to and automatically begin trying to cool the receiver back down again prematurely. For the EVLA, the M&C should not unilaterally change the receiver cryogenic state with out asking.

This is of particular importance if we decide to give the M&C the ability to take the new Card Cage out of "Manual" control and force it into "Remote" mode. Having a manual switch which can't be overridden will eventually mean somebody will accidently leave the Card Cage in Manual and he, or some other poor soul, will have to go all the way out to the antenna to switch the unit back into computer control. Accordingly, we should allow the M&C to be able to kick a unit back into Remote, but only on command from a Telescope Operator or by a member of the technical staff.

There will be a number of additional command bits that we may need. It would be nice to have an LNA Disable bit. Shutting off the LNA might be desirable when observing the Sun so as to insure the HEMT stages won't get overloaded and damaged. If an amplifier breaks into oscillation, it might radiate into other receiver bands, so being able to kill it remotely could come in handy. To implement Paul Lilie's wide dynamic range Solar Observing scheme we will require a step attenuator to adjust the level of the calibration Noise Diode as well as step attenuators following the "high-noise" amps. This may require up to 3 x 6-bits worth of attenuator control. Several more bits will be required for switching between the LNA and the "High Noise Amp". A number of mux addresses will be set aside to allow the M&C to load these command bits into the Card Cage, as well as for monitoring the actual status of the various attenuators and switches so that the M&C system can always determine what state the Front-End is actually in. There is also a possibility that CDL may start to integrate a variable attenuator into their LNA's. How this would be controlled is not yet certain.

As a self-test, Mux Address 0 will be used to provide a simple continuity check. The 4 digital command bits will be connected directly to the 4 status bits, thus allowing whatever the M&C writes to the Card Cage to be looped back and read (the Card Cage obviously ignores the content of the command bits). This can be used to detect open or shorts in the cable between the M&C Module and Card Cage, at least those which might occur on the digital signals.

The M&C/Card Cage interface will also include a SPI Bus. This will provide us with a future expansion path should we decide we need LNA biases which are remotely programmable. The current feeling in the Front-End Group is that, while it would be useful in the laboratory setting, it would be more of a headache on the telescope than it would be worth. The bias setting are usually only tweaked while the receiver is first being characterized in the lab and are rarely ever adjusted again in the field. That being the case, coming up with a system that will reload the bias settings when the Card Cage power is cycled or keeping the stored values straight as receivers are transferred from antenna to antenna is likely to be more of a problem than it's worth. However, keeping our options open, the SPI Bus would allow 16-bit data words to be written to a digitally programmable bias card for the numerous Drain voltage and current settings required for the 8-stages in a typical EVLA receiver (expandable to 16-stages to accommodate a W-Band receiver).

Appendix A shows the suggested pinout for the DB-25 cable used to connect the Card Cage to the M&C Module. Appendix B shows the multiplexer addresses used to read back the myriad of analog monitor points. Appendix C lists both the Command bits sent to the Card Cage and the Status bits returned to the M&C. Note that the Mux Address will normally be set to 31 during observing which allows the "passive" monitor voltages and status bits to be fed to the M&C. Appendix D & E show the digital I/O and Mux Addressing that would be used by the optional SPI Bus interface.

The New Card Cage:

Unlike the current VLA and VLBA Card Cages, the new design will not have a “local” digital panel meter display. As with the other electronics groups and many of their EVLA modules, we will have to use a Laptop (or maybe a Palm PC) to control & monitor everything when evaluating a receiver, both at the telescope and in the lab. There are several reasons for abandoning the local panel display:

- Since we need to build 240 new Card Cages, we want to keep them cheap and easy to construct.
- Since some of the receivers will mounted high up on the Vertex Room ceiling, trying to read a local front panel display will be next to impossible in most cases.
- The new EVLA Card Cage will be called on to control & monitor far more parameters than the current generation Card Cages. The number of switches and buttons we’d require to access all of them would make the front panel costly if not just outright unworkable.
- Since we’re attempting to minimize digital cross-talk within the Card Cage, we probably don’t want a LCD panel meter and its clocking signals anywhere nearby in the first place.

A block diagram of the new front-end M&C is shown in Figure 1. Briefly, the new EVLA receivers will have 3 main sub-systems which will essentially replace the large Card Cage unit now in use. One “box” will contain the Control, Sensor & LNA bias circuits, and will carry out the primary function of the contemporary Card Cage. Another box will hold the RF/IF components, much like the current K-Band does (all of the post-amps, mixers and filters are mounted inside a commercial 8" x 10" enclosure). Finally, there is the AC Relay Box. This contains the switches for controlling the AC power to the Solenoid, Fridge & Heater. One of the principal goals of the new Card Cage is to remove the high-voltage AC that exists inside the current design. This layout has been known to cause 60 Hz pick up on the LNA bias lines causing total power gain fluctuations.

The Card Cage itself will contain all of the Control, Sensor and LNA Bias circuitry and will be made as small as feasible, probably about a quarter the size of the current units. More importantly it will be built from commercially available components to the maximum extent possible. This will avoid the need for having the Machine Shop making up 240 sets of plates, panels, rails and sheet-metal covers like we do nowadays. Rather than our current large 4.5" x 8.5" custom boards with their problem prone card-edge connectors, we should use an industry standard card footprint. The 4" x 6.5" Eurocard with its reliable pin and socket connector looks very desirable.

One possible solution to the mechanical configuration of the Card Cage is to use extruded aluminum boxes. There are several manufacturers which provide this style of enclosure, including Concept Engineering, Extrusion Technology, Lansing Instrument Corp. and Lincoln Binns Ltd. My preferred choice so far is Lansing’s E-Style MicroPak Enclosure which consists of an extruded base with slide-in flat panel. See Figure 2 for a 3D illustration as well as a cross-sectional diagram. This unit is specifically designed to accommodate a 3U high Eurocard. The enclosure is available in both anodized (clear or black) and vinyl-clad (white, gray, platinum or black) aluminum. They also offer a selection of various front and rear panels. The maximum standard length is 6.3". For our purposes, we will likely need something closer to 10 or 12 inches. However, Lansing (as well as the other companies mentioned above) are prepared to fabricate non-standard lengths at the request of the customer. Cost appears to be about $25 for a standard enclosure.

Figure 1 : EVLA Front-End M&C Block Diagram

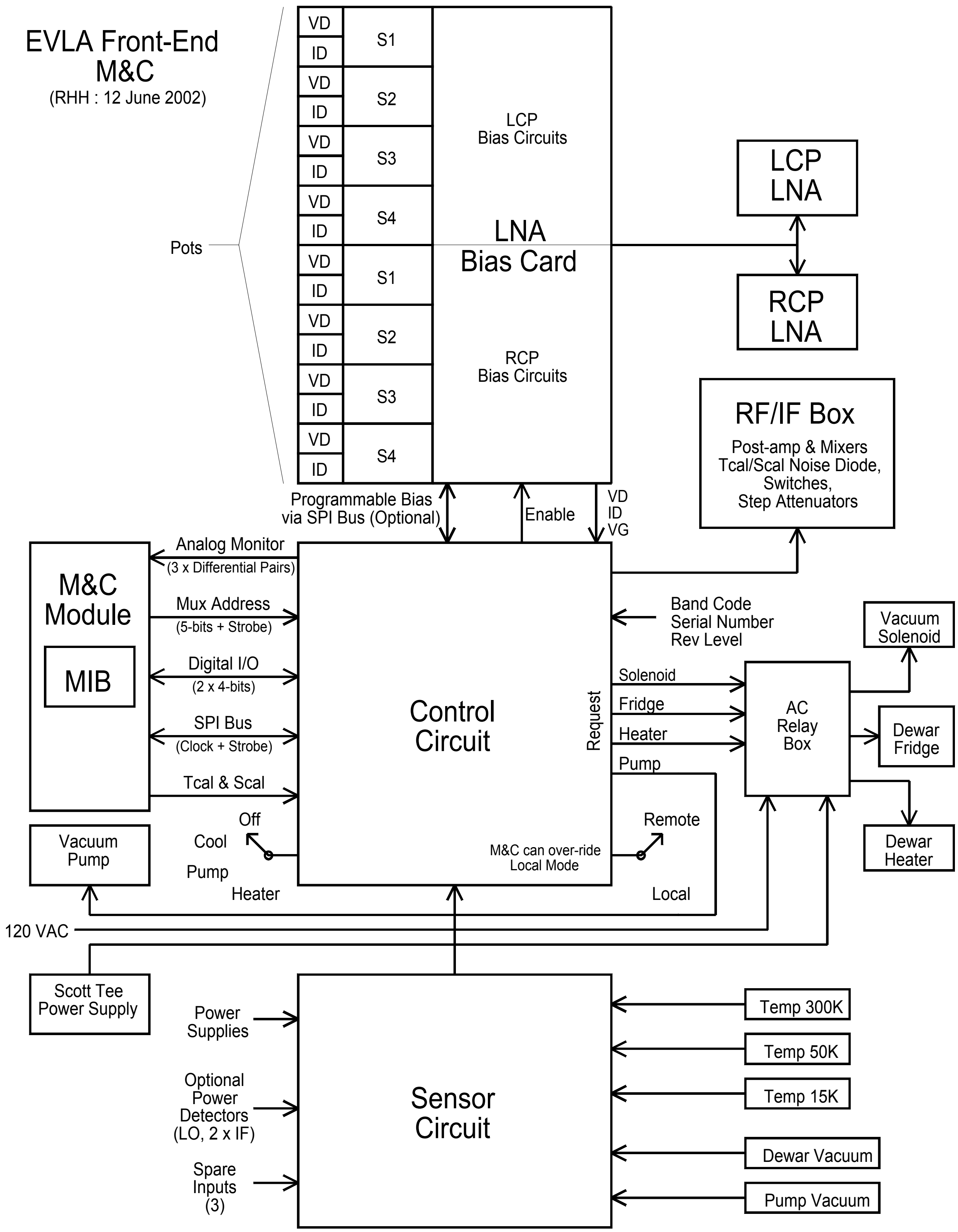
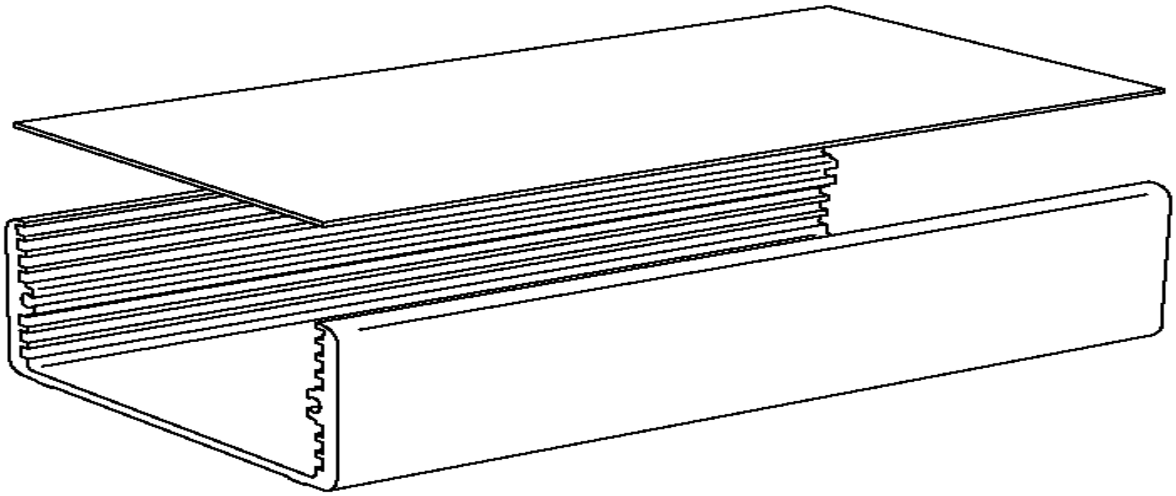
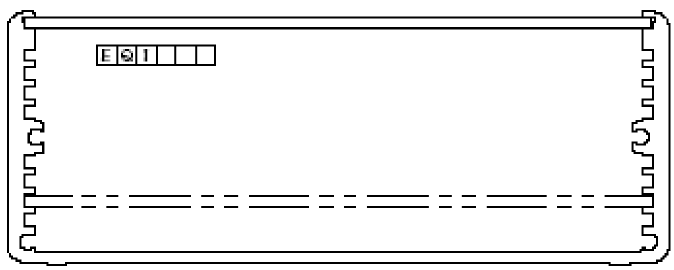


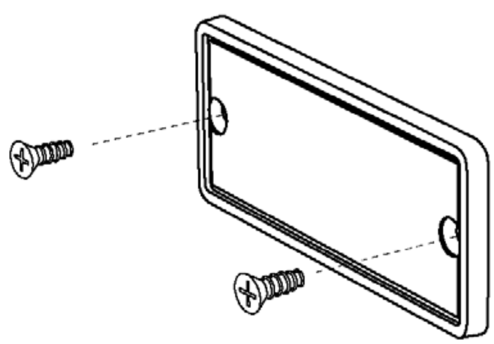
Figure 2 : Commercial Card Cage Enclosure



a) Lansing Instrument Corp. E-Style MicroPak Enclosure



b) "Q-Width" Enclosure Cross Section (4.17" x 2.52")



c) Solid End Cap

What I like about this style over the other enclosures which use one-piece seamless extruded tubular bodies, is the removable top panel. This will provide easy access to the wiring which will have to run between the cards and the bulkhead connectors mounted on the enclosure. It may also come in handy for getting at the numerous potentiometers and test-points required on the LNA Bias card.

This brings up the question on how many cards we will require. We're hoping that we can design a new LNA Bias Card that will handle 2 HEMT amplifiers with 4-stages each. As will be described later, the Sensor circuitry will be much simpler than the current VLA Sensor Card. However, the Control circuitry will be much more complicated since it will have to do everything the current Control Card does as well as handle the address multiplexing function required for the new Pseudo-Passive interface. Fortunately the availability of FPGA's should make our lives much easier here. So, at worst, we may need 3 cards - the Control, Sensor and LNA Bias - in each Card Cage. That would be a tight squeeze, although not necessarily impossible, inside the 1½" high extruded enclosure. But with some careful design we should be able to integrate all of the Control and Sensor functions onto a single card.

As an aside, if we were to adopt a larger card cage footprint, we probably could come up with a single board which does everything, the Control, Sensor and LNA Bias. This would eliminate all the wiring that would otherwise have to go back and forth between separate cards and thus make the cabling internal to the Card Cage much simpler. The big drawback that arises is when there is a problem in the Control or Sensor circuitry which requires the board to be swapped out. You would then have to run through the adjustment procedure for all 16 bias parameters on the LNA's so that the new card would be configured properly. All this effort just to address a problem that had nothing to do with the LNA's in the first place. This is the only case I can think of that argues for remotely programmable biases (unless it can be proven that we can effectively reduce the LNA gain for Solar observing by dynamically adjusting the Drain settings). Accordingly, we should endeavor to design two new boards: an integrated Control/Sensor Card and an 8-stage LNA Bias Card, both on an Eurocard footprint using 64-pin DIN 41612 connectors.

The Control / Sensor Card:

As noted before, the Card Cage will not have a local front panel display (we will have to access all the engineering monitoring points via the M&C system). This will make the Sensor circuitry much simpler. The 15°K and 50°K temperature monitoring feature in the current VLA Card Cage uses a great deal of additional circuitry to "linearize" the voltage vs. temperature curve of the diode sensors using two piecewise straight-line approximations. While this circuit generally works well, it does requires a lengthy calibration effort and is not particularly accurate near 25-30°K. Since the Lakeshore DT-471 temperature diodes we use come with a standard calibration curve based on Chebychev polynomials, we will let the MIB do the Volt-to-°Kelvin calculation. This will result in a much more accurate temperature value as well as eliminating a sizable chunk of analog circuitry. Essentially all the Sensor circuitry has to do is provide the 10µA current to the DT-471's. Note that these diodes have a relatively high output level (~1.3V at 15°K and ~0.5V at 300°K), so all we need to do is amplify the signal slightly (say x5) and ship it off through the analog multiplexers to the M&C Module where it gets received by an instrumentation amp (to improve common mode rejection).

The 300°K Temperature sensor will continue to be the National Semiconductor LM335. This two-terminal zener diode has a much simpler interface than the DT-471 cryogenic diode and is a whole lot cheaper. The current 10mV/°K scaling will be retained. Some of the current VLA receivers have the 300°K sensor mounted within the Card Cage. The EVLA systems should have it located in the warm RF/IF Box.

The circuitry for the Dewar and Pump Pressure monitoring will be little different from the current version, although more modern IC components will be used. The Hasting DV-6R Pressure sensors require an18.9 KHz oscillator to excite the thermocouples (unfortunately this is the one clocked waveform in the Card Cage we can't eliminate, although we can reduce any deleterious impact with proper board and cable layout techniques). The output from the sensor is fairly low level and requires a gain factor of about 500. As in the case of the Temperature sensors, the MIB can apply a standard curve to the monitored voltage to determine the pressure. This will be an improvement over the current system where we read so many millivolts on the front panel display and then attempt to convert it to Microns or Torr using that good old non-linear computer built into our heads.

So the real estate on the Control/Sensor Card required to interface with the Temperature and Pressure sensors will be rather small and should leave lots of room for the Control circuitry. It will have to retain a good subset of the functions that the current Control Card does, with the important exception that there is no 150 VAC inside the Card Cage anymore. Rather than having relays mounted on the Control Card to switch on or off the 150/120 VAC to the Fridge, Solenoid or Heater, the new Control/Sensor Card will generate digital bits which are shipped over to the AC Relay Box where the solid-state relays will be located.

In order to achieve the same autonomous cool-down capability that the current Card Cages have, the Control/Sensor Card will require a small amount of analog circuitry to provide status information for the sequencing logic. In order for the state machine to determine when to request the Pump to come on or the Solenoid to open, it needs to know if the 15°K Stage is warmer than 30 or 280°K, if the Dewar pressure is greater than 3, 5 or 50 microns, or if the Pump pressure is lower than that of the Dewar. These threshold levels will be determined using analog comparitors which generate a TTL bit for the control logic.

The Control/Sensor Card will also have to manage the parallel data bus and select what digital bits are to be read or written (latched) depending on the multiplexer address. It will also have to decode the addresses for the analog signal monitoring. A number of the signals to be shipped back to the M&C Model originate on the Control/Sensor Card, so these are straight forward. The LNA monitor points arise on the LNA Bias Card, and since there are 24 of them associated with a pair of amplifiers, it doesn't make a lot of sense to feed all of them all over to a humongous analog multiplexer on the Control/Sensor Card. Instead, the LNA Bias Card should have its own multiplexer, controlled by the same mux address, to pre-select the 3 appropriate monitor voltages and feed them over to the Control/Sensor Card. This way a 2nd Bias Card could be added to handle a W-Band receiver and its extra monitor points. The Control/Sensor Card would have to figure out if the mux addresses are specific to its group of analog monitor voltages or whether they belong to the LNA Bias Card(s).

The LNA Bias Card:

The basic circuit design of the current LNA Bias Card functions adequately for our purposes however the components it uses are getting rather old. Plus it is much bigger than it needs to be to handle only 4 HEMT amplifier stages. Using modern surface mount technology and multilayer board layout, it should be feasible to shrink the 4.5" x 8.5" card down to a 4" x 6.5" Eurocard footprint and more importantly, accommodate 8 stages. Thus a single card is all we will need to bias two LNA's. Note that we still have some early generation 5-stage Q-Band amps out in the field but these are slated to be replaced by lower noise 4-stage devices as part of the EVLA upgrade.

The EVLA isn't the only group in NRAO interested in a new and improved Bias Card. Wes Grammer in Tucson has designed a *Quad LNA Bias Board* for the ALMA Evaluation Receiver. This single board can handle up to 16 stages (ie: a 5-stage W-Band LNA followed by a 3-stage 4-12 GHz IF amp in both polarizations). It uses an Analog Devices 32-channel 14-bit DAC (AD5532), has 8 layers and over 800 components all on a Eurocard style footprint. Both the Drain voltage and Drain current are programmable for each stage (which is why it needs 32 DAC's) over a SPI Bus interface.

This design is a bit of an overkill for our purposes but Wes's experience in miniaturization and integration should be invaluable for our effort. As for remote programmability, we couldn't come up with a real good reason for this feature in the field. It would be nice but certainly is not necessary. Historically with the current 3 & 4-stage bias cards, after we set the pots they are rarely ever touched until the receiver comes back to the lab for a repair job (usually due to a failed amp or bad wiring). One thing we would like to add which we currently don't have is an "on/off" feature which would power down all the stages (the ALMA Quad LNA Bias Board has implemented this feature).

The folks at Green Bank are working on a new LNA bias card design as well. According to Roger Norrod, they intend to use the same basic analog constant-current bias circuit but will use a different op-amp which can supply sufficient current to eliminate the 2N2219 current booster. They plan two versions with appropriate voltage limits and clamping diodes for GaAs or InP based amplifiers. There will be one layout but with some differences in a few components. We will likely have to do the same since L & S-Band will use GaAs-based LNA's while C, X, Ku, K, Ka & Q-Band will use InP devices. By using surface-mount components, Roger hopes to get six stages in the same card size as the current design. We'd like 8 stages, of course, and since we're throwing away the old Card Cage, we aren't stuck with the same ancient form factor for our cards. Note that we will still need the Diode Protection Card in the dewar. This is required by the newer InP style of HEMT's (too bad these diodes couldn't be built right into the amplifier case).

So the manually adjusted 8-stage LNA Bias Card we need seems quite feasible - it really comes down to real estate and just how much time we want to spend miniaturizing it all. The biggest difficulty will be in gaining access to all of the potentiometers and the test points required for tweaking and monitoring the bias parameters. Traditionally, on our 4-stage cards, the 8 pots and 12 test points have been mounted on the forward edge of the card where they can be easily reached. For the new design, we'll need twice that (ie: 16 pots and 24 test points). Either we'll have to use both sides of the board or we can design them to be accessible from the top of the card. This is where the removable lid on the Lansing's E-Style MicroPak Enclosure would come in handy.

However, unlike the old card, where we couldn't monitor any of the Drain and Gate biases except through its test points using a DVM, the new LNA Bias Card will allow all of them to be read out remotely. So during the optimization adjustment in the lab, we can use a Laptop or general purpose PC with a analog/digital card to look at all of them in one fell swoop, or with a dedicated test fixture which generates the proper mux address. Thus if there isn't room for all the test points on the front card-edge like we have now, we can still monitor them thru the M&C system.

One final item concerning the LNA Bias Card, it will need a circuit for summing the Gate voltages on all (active) stages in the amplifier. This is so we can generate the average LNA Gate voltages for each polarization which is essential for the Pseudo-Passive monitoring scheme. Any deviation out of spec will cause a flag to be asserted somewhere in the M&C system. Since some receivers will only have 3-stage amplifiers, we'll have to be careful not to sum in the unused stage.

The RF/IF Enclosure:

Many of the current VLA receivers have their RF post-amps and IF down-converters mounted inside the Card Cage. These can often be a real pain to disassemble during troubleshooting. The new K-Band receivers, on the other hand, have all these components mounted inside a commercially fabricated, RFI tight, 8" x 10" enclosure. These are made by Compac and come in kaleidoscope of sizes so we can match the enclosure to the amount of RF plumbing needed. All the receivers, except for Q-Band and (maybe) Ka-Band which use waveguide signal transmission, could use similar style enclosures. These RF/IF Boxes will need SMA connectors for the LCP & RCP signals coming from the dewar and for the amplified output signals, as well as the Cal signal which gets injected into the front-end. For the higher frequency receivers (ie: K, Ka, Q & W-Band), a LO Reference will be required by the internal mixers. For interfacing to the Card Cage, a standard DB-25 connector should do the trick (it might be wise to use filtered versions to help reduce RFI).

Paul Lilie's wide-dynamic range Solar Observing scheme will require a whole slew of extra components that the current generation of receivers don't have (a step attenuator to adjust the level of the calibration Noise Diode, step attenuators on the Solar path signal, and switches for selecting between the "Low-Noise" and the "High-Noise" Amps). Obviously the enclosure for this feature will need 2 additional SMA connectors for getting the Solar path signals into the box. Hopefully this scheme can be implemented as an "add-on" subsystem with the judicious use of MMIC's and multi-function modules which can be done cheaply and with minimal changes to the receiver.

The AC Relay Box:

This is the box that allows us to get rid of the high voltage AC running around inside the current Card Cages. It will be a fairly simple unit with relays for turning on and off the 150 VAC going to the Fridge and the 120 VAC going to the Solenoid and the Heater. It will incorporate several modern solid-state switches which will replace the old Teledyne relays which are getting difficult to find. The Fridge, Solenoid and Heater Request TTL control bits will come from the Card Cage on a circular 4-pin connector. The box will need to get the 2-phase,150 VAC from the Fridge Driver (likely a Scott-Tee) plus the120 VAC from the Mains. It also needs output connectors for interfacing with the Fridge as well as for delivering the 120 VAC to the Solenoid and Heater.

Card Cage Input/Output:

Several of the current front-end systems, specifically the Q, K and L-Band systems, will be retained for use on the EVLA. Although they will be modified to some extent, the basic signals in and out of the dewar will remain largely the same. The first question that comes to mind is how much commonality is there on the connector pinouts of these receivers. Appendix F thru J show the connector pinouts for the Card Cages on the current L, X, K, Q and W-Band receivers. This allows a comparison of the earliest generation of receivers (L & X-Band) to the most recent VLA systems (Q & K-Band) to the most complicated VLBA receiver (W-Band). Note that the X-Band is included here on the slim (very, very slim) possibility that its dewar could be reused after the receiver is upgraded from its current 8.0-8.8 GHz tuning range to the EVLA 8-12 GHz specification. While it is not expected that the average reader stare at the various tables and columns with any serious intent, these appendices were added so that this information got written down in one place and would be available for future reference as we formulate the new design.

Appendix F & G show the J2 *Monitor* and J5 *Control* DB-25 Connectors. The new Card Cage will replace this with a single *Monitor & Control* DB-25 (see Appendix A). Appendix H shows the J4 *Aux Monitor* connector. This will remain unchanged in the new system. Appendix I shows the J15 *Vacuum Gauge & Solenoid* connector, which is only used on K & W-Bands at the moment. This will become standardized on the EVLA Card Cage, except that the Solenoid drive will be eliminated (it will be handled by the AC Relay Box). Note that the older receivers tended to use hardwired connections for the Tcal & Scal drives, Vacuum sensors, Solenoid control and Fridge 150 VAC. It would be desirable for the new Card Cage to be fully compatible with all front-end systems, so a common connector scheme will have to be adopted. Finally, Appendix J shows the J3 *Dewar Power* connector. Harmony between the various receivers totally breaks down here, with the L & X-Band using a DB-25, Q-Band using a DB-37 and K & W-Band using a DB-50 connector (note that the K-Band designers adopted the Card Cage developed for the W-Band with only slight modifications). It's obvious that the new Card Cage will have to have a DB-50 connector to be compatible with the K-Band (and potential W-Band) systems. That being said, it means that the L and Q-Band systems would have to have their DB-25 and DB-37 connectors replaced with a DB-50. Doing this, and changing some of the other wiring details, will allow the new Card Cage to be used on all the old receivers (once suitable modified) as well as any of the brand new EVLA front-ends.

The way the current receivers get their DC Power is unsatisfactory, especially for the higher frequency receivers which have a fairly hefty current requirement on their +15 volt power supplies. Much of the extra current is needed for the medium power amplifiers in the LO chains used to drive their frequency multipliers. The post-amps can also be quite greedy. The total current draw can often exceed a couple of amperes. We currently ship the ±15V over to the Card Cage on a single wire in the *Control* cable. These are typically computer grade DB-25 cables with AWG-26 gauge wires. The resistance over the long 25 foot length, although small, can still cause a 2 to 3 volt drop. This means that the Card Cage may only be able to provide +12 to13V to the various components which are expecting to see +15V. The LO and post-amps may deliver less output signal under this low voltage condition. This could easily result in the mixers being starved of LO power or lower saturation levels on the post-amps. Some of the receivers, particularly the K and W-Bands, use a heaver gauge AWG-22 Control cable as well as paralleling the +15V rail on 3 wires to minimize this detrimental effect.

The preferred solution for the EVLA receivers would be to use a dedicated *DC Power Supply* cable. This brings up the question on what voltages we should ship over to the receiver. Is giving it ±15V adequate or should we deliver ±18V and use regulators inside the Card Cage to derive a much better conditioned ±15V? Also, do we want to ship over +5V rather than deriving it from the +15V like we do now. If we want a dedicated +5V, do we ship over +7V and then regulate it down to +5V. Since the Tcal and Scal Noise Diode drive signals will now be generated on the Control Card, we'll need +28V (and if we ever install W-Band receivers on the EVLA, we will also need +28V for biasing their mixers).

So depending on how many DC power supply voltages are needed, we might have to accommodate up to four different voltage rails (ie: ±15/18, +5/7, +28V) and their ground returns. Back during my days at both the Algonquin 150-foot and the JCMT 10-meter telescopes, we used a Bendix (now ITT/Cannon) circular connector that had 12-pins in total with the inner 4 contacts specifically designed for heavy gauge wiring. The illustration in Figure 3 shows the pin layout. We usually used the big pins for the ground returns to help minimize voltage offsets and ground loops between racks and modules The extra pins would provide us with future expansion capability (the WVR's on the K-Band receivers may need additional voltage rails. This connector may be somewhat of an overkill for our application but we should investigate how much this would cost in comparison with other types of connectors.

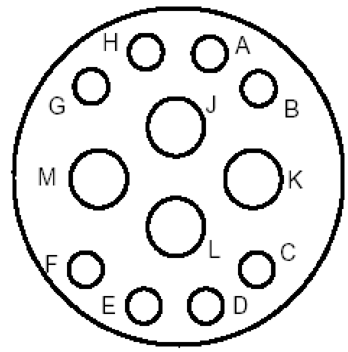


Figure 3
12-pin DC Power Circular Connector

The following is a tentative list of all the connectors that will be required between the Card Cage, RF/IF Plate, AC Relay Box and the outside world:

Card Cage:

DB-25 (m)	Interface to/from M&C Module
DB-9 (f)	Pump Request output to the Pump controller
DB-50 (f)	Interface to/from Dewar for the LNA Biases & Temperature sensors
DB-9 (m)	Interface to the Pressure sensors
Cannon 4-pin (f)	Solenoid, Fridge & Heater Request to the AC Relay Box
DB-25 (f)	Interface to RF/IF Box (Tcal/Scal, 300°K, step attenuators & DC Power)
Cannon 12-pin (m)	Power Cable (TBD : ±15V (or ±18V?), +5V (or +6.5V), +28V)

RF/IF Box:

2 x SMA (f)	LCP & RCP RF Inputs from Dewar
2 x SMA (f)	LCP & RCP RF Solar Path Input from Dewar (optional)
1 x SMA (f)	LO Reference Input from L301 Synthesizer (for Q, Ka & K-Band only)
1 x SMA (f)	Noise Diode Output to Dewar
2 x SMA (f)	LCP & RCP RF/IF Outputs to Up/Down-Converters
DB-25 (m)	Interface to the RF/IF Box (Tcal & Scal, step attenuators & DC Power) (We may need to contemplate a dedicated DC Power connector)

AC Relay Box:

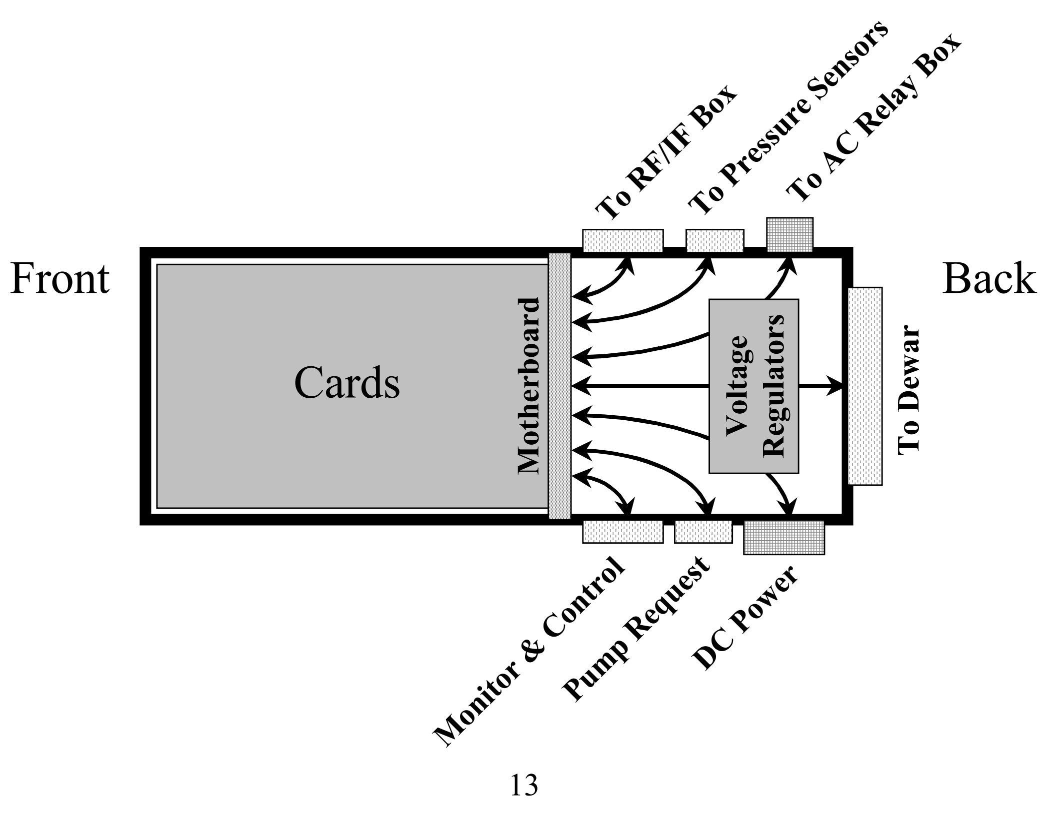
Cannon 4-pin (f)	Fridge, Solenoid & Heater Request bits from the Card Cage
Deutch 3-pin (m)	150 VAC input from Scott-Tee driver unit
Cannon 3-pin (m)	120 VAC input from the Mains
Deutch 3-pin (m)	150 VAC output to the Fridge
Cannon 5-pin (f)	120 VAC to the Solenoid and Heater

Some of these connectors, particularly the DC Power and the RF/IF Box interface, will need a little more thought. The others seem relatively straight forward.

The New Card Cage Physical Layout:

Picture the enclosure shown in Figure 2 containing two Eurocards, with the Control/Sensor board on the bottom and the LNA Bias card on the top. A custom "motherboard" will be mounted about ⅔'s of the way to the back. It will contain the 64-pin DIN 41612 socket connectors which our cards will plug into. It must be robustly secured inside the enclosure so it won't move when the cards are installed. The motherboard will handle all of the signals which must go from one board to the other. The motherboard will also allow us to group the various signals which must make their way to the seven connectors mounted at and along the rear of the enclosure. Figure 4 attempts to illustrate this. The back of the motherboard could have several IDC headers connectors so that ribbon cable could be used in order to minimize the amount of hand assembly. Since the top plate of the enclosure can be removed, there will be easy access to the IDC and bulkhead connectors.

Figure 4 : EVLA Card Cage Layout



The motherboard may require more than two layers to accommodate all the crisscrossing of signal paths, but should otherwise be simple to layout once an orderly wiring schedule is determined. If this Card Cage scheme is ever adapted to a W-Band system, we might need a taller enclosure to handle the 2nd LNA Bias Card as well as the extra IDC connectors which might be needed on the motherboard. Finally, if we decide to feed the Card Cage with ±18V and +7V DC Power, linear regulators for deriving the ±15V and +5V rails could be mounted on the bottom of the enclosure near the back. Small 8-pin Molex PCB connectors could be used to provide power to the motherboard.

Miscellaneous Issues:

A number a issues remain to be discussed. The first is what kind of Front Panel switches and status indicators will be needed to provide us with local control of the Card Cage's vacuum and cooling functions. At a bare minimum we will need an *Off/Cool/Pump/Heat* rotary switch, similar to that now on the old style of Card Cage (note that we no longer see a need for the *Load* function, so that option has been eliminated). In order to place the Card Cage into autonomous operation, we might also need a *Remote/Manual* switch. However, since we intend to give the M&C system the ability to force the Card Cage into Remote mode, we won't be able to use a static two-position toggle switch. A momentary or pushbutton switch would be more appropriate - it will just reset a flip-flop which knocks the Card Cage into Manual mode. Whenever the M&C accesses the Card Cage, of course, it would clock the same flip-flop to get it back into Remote. If we want to get more complicated, we can use a circuit which detects any change of position in the *Off/Cool/Pump/Heat* switch setting and use that to force the Card Cage into Manual mode.

We'll also need a couple of status indicators on the Front Panel. A *Remote/Manual* dual-color LED is needed (with Green = Remote and Red = Manual). A three-color LED could be used for the *Cool* indicator (with Red = Warm, Orange = Solenoid Open and Green = Cool). The new Control Card should have more status LED's, similar to what the current board has, mounted on the front of the board which can be seen when the Front Panel is removed.

Note that we not only want the Card Cage to have autonomous control of the cool-down sequence, but we will want the AC Relay Box to keep the Fridge running should the DC Power ever go off. As in the current Card Cage design, this is to ensure that a crippled DC power supply won't cause the receiver to warm up. While it may sometimes seem inconvenient for the Fridge to start running whenever the DC Power is purposely disconnected, it is doubtful that the Fridge would be damaged even if the helium lines weren't hooked up.

Unlike our present VLA and VLBA receivers, the Tcal & Scal control signals from the M&C Module will no longer be a 28V switching waveform. Currently these waveforms come from the F14 or F117 modules. We would prefer the new M&C module to send a TTL-compatible drive to the receiver. There are two reasons for this. First it avoids distributing 28V squarewave signals all around the Vertex Room. Secondly, some of the calibration subsystems in the new EVLA receivers may use PIN switches to turn the noise source on and off rather than cycling the noise diode directly. This scheme would allow us the energize the noise diodes all the time and thus avoid possible turn-on and turn-off noise spikes. Noise diodes are typically biased with a constant current somewhere between 5 to 15 ma, depending on the frequency band. The manufacturer tries to determine a spot on the Excess Noise Ratio (ENR) versus current bias curve which is relatively flat so that the noise power output is relatively insensitive to small changes in current. The ENR usually peaks, however, at a much lower current setting, thus the noise power may increase momentarily while the bias current transitions between the on and off settings. In the current VLA system, the noise source transition occurs during the 1 ms blank time of every waveguide cycle at the canonical 19.2 Hz rate. So any spikes in Tcal or Scal signals are effectively hidden. The EVLA, however, will not have a regularly scheduled blank time to hide our sins. We have not yet made any measurements to determine just how big a problem, if any, this might be. However, the use of PIN switches would be an obvious solution. And if the Lilie wide-dynamic Solar observing scheme is adopted at some bands, incorporating a PIN switch with the required step attenuator and noise diode amplifier would be fairly straight forward, especially if the design is done using a multi-function MMIC module.

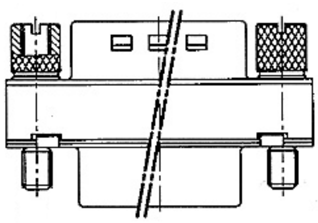
There are a couple of more issues concerning the calibration noise sources. The TTL-compatible Tcal & Scal signals from the M&C Module will have to be converted into the appropriate level required to drive either a noise diode (typically 28V although some noise diodes operate off of 15V) or a PIN switch (anywhere from -5 to +5V, depending on the switch and the manufacturer). The Control Card should be able to provide both types of drive voltages and allow us to select which ever one we want to use. Even if we are using a PIN switch, we will still have to give the noise diode a +28V bias (or the optional +15V). And just as we do in the F14 and F117 modules, the Control Card will also have to provide a noise diode voltage and current monitor. This feature allows us to look at the health of the noise diode.

One thing we will have to remember is to include enough funds in our budget for the purchase of a number of Laptops for our technicians to use at the antennas as part of their maintenance tool kit. We should assume we will need one for each technician assigned to full or part-time maintenance duty. If we could come up with a Handheld or Palm PC, this would likely be much more convenient and cheaper. Plus we'll need more Laptops and/or Desktop PC's for the lab environment here at the AOC. Perhaps we can upgrade each of the bench PC's which are normally allocated to each tech. All of these computers will require digital & analog interface cards (for the direct M&C interface) as well as an Ethernet link (for communication with the MIB). We should try to standardize on a common set of input/output cards for the Laptops (PCMCIA) and Desktops (PCI or whatever other bus is appropriate).

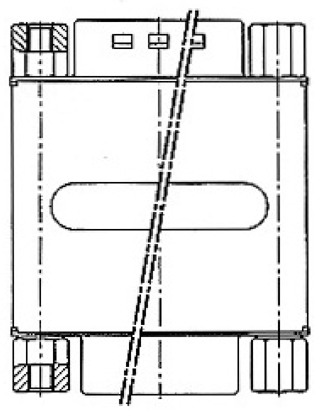
Obviously a fair amount of new software programs will be required, both for the M&C analog/digital interface as well as the "Screens"link over the Ethernet. Ideally the new generation receiver test system which I have been designing to supercede the old SOIDA test rack should have these features built in from day one. We should also contemplate upgrading SOIDA and its newer offspring, (affectionately named SOS, for "Son of SOIDA") assuming this is a feasible option. Someone will have to investigate if a Palm PC version is really practical for use at the site. The big problem is who will we get to do all of this. Are these good projects for Tech students to work on?

For the lab environment, we should probably build a simple test fixture that would simulate the M&C interface. It would generate the appropriate multiplexer addresses so we could look at any particular set of LNA biases on the bench (remember that the monitored temperatures & pressures will be in a raw form and have to be post-processed to convert millivolts to degrees K or microns).

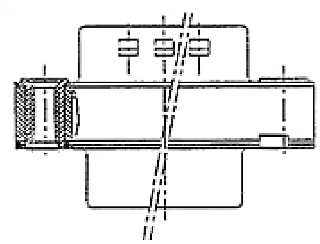
One small item to consider is whether we want to filter the signals going into the Card Cage & RF/IF Box from the outside world, particularly the cable from the M&C Module. At first I had hoped we could use filtered D-Subminiature connectors. While there are lots of solder-cup and PC-tail filtered connectors on the market, there do not appear to be any IDC (ie: ribbon cable) terminated versions, which would make the internal wiring of the Card Cage much simpler. However, there are some pin-to-socket adapters out there. The illustrations below show a representative selection available from Conec Corporation. The Capacitor-Filter has >50 dB of attenuation at 1 GHz while the Pi-Filter has >70 dB. The advantage of using these is that we could add them at any time without having to modify the Card Cage. Alternatively, the Panel Mount D-Sub Adapter connector might be worth considering. It is similar to the C-Filter version but could be mounted on the inside wall of the Card Cage, where an inexpensive ribbon D-Sub connector and cable would be used to make the jump over to the motherboard. These filter connectors are reasonably priced. The 25-pin C-Filter versions are less than $15 each while the Pi-Filter is closer to $25.



C-Filter Adapter



Pi-Filter Adapter



Panel Mount Adapter

Finally there is the issue of compatibility between the old and new L & X-Band receivers. Currently these systems are common to both the VLA and VLBA and are completely interchangeable. As the EVLA project progresses, we could end up with some of our old L and X-Band systems being modified to accommodate the new Card Cage. While they would not have the enhanced RF performance we hope to achieve with the final EVLA design, they would at least be compatible with the new Monitor & Control system. Conceivably the occasion might then arise when one of these quasi-EVLA receivers may have to be used on a VLBA antenna. Unfortunately the old and new Card Cages will be total incompatible. The new Card Cage would have to be removed and the old one reinstalled. Because the wiring will be slightly different, a number of cable adapters would have to be used. For example, the new Card Cage calls for a 50-pin Dewar Power connector, where as the old Card Cage uses a 25-pin. The AC Relay Box would also have to be removed since the Fridge, Solenoid and Heater relays are located on the old Control Cards. The RF/IF Box could probably be retained with only slight modifications required on the old Card Cage.

Conclusion:

This ends my long diatribe on the new EVLA Card Cage. I'm open, however, to other alternative solutions. Any and all comments, suggestions or recommendations are welcome.

Appendix A : EVLA Card Cage ↔ M&C Module Cable

Pin	Signal	Function
1	Parallel Data Out	DO-0 / SDO (Serial Data Out)
14		DO-1
2		DO-2
15		DO-3
3	Parallel Data In	DI-0 / SDI (Serial Data In)
16		DI-1
4		DI-2
17		DI-3
5	Address Mux	A-0
18		A-1
6		A-2
19		A-3
7		A-4
20	Parallel Data Strobe	PDS (Parallel Data Strobe)
8	Optional SPI Bus Data Strobe	SDS (Serial Data Strobe)
21		SCK (Serial Clock)
9	Cal Drive	TCAL
22	Solar Cal Drive	SCAL
10	Analog Monitor	+Analog-1
23	#1	-Analog-1
11	Analog Monitor	+Analog-2
24	#2	-Analog-2
1	Analog Monitor	+Analog-3
25	#3	-Analog-3
13	Return	

Appendix B : Analog Monitor & Mux Addressing

Mux Address	Analog Signal	Analog-1	Analog-2	Analog-3
0	RCP LNA Stage 1	VD1	ID1	VG1
1	RCP LNA Stage 2	VD2	ID2	VG2
2	RCP LNA Stage 3	VD3	ID3	VG3
3	RCP LNA Stage 4	VD4	ID4	VG4
4	LCP LNA Stage 1	VD1	ID1	VG1
5	LCP LNA Stage 2	VD2	ID2	VG2
6	LCP LNA Stage 3	VD3	ID3	VG3
7	LCP LNA Stage 4	VD4	ID4	VG4
8	Temperatures	15K	50K	300K
9	Vacuum Pressures	Dewar	Pump	-
10	Noise Source Cal	Voltage	Current	-
11	Solar Noise Cal	Voltage	Current	-
12	Power Supply Voltage	+15V	-15V	RCP LED
13	Power Supply Voltage	+5V	+28V	LCP LED
14	Optional Power Detector	RCP - IF	LCP - IF	LO
15	Spare Analog Monitors	Spare-1	Spare-2	Spare-3
16	Optional RCP LNA Stage 1	VD1	ID1	VG1
17	Optional RCP LNA Stage 2	VD2	ID2	VG2
18	Optional RCP LNA Stage 3	VD3	ID3	VG3
19	Optional RCP LNA Stage 4	VD4	ID4	VG4
20	Optional LCP LNA Stage 1	VD1	ID1	VG1
21	Optional LCP LNA Stage 2	VD2	ID2	VG2
22	Optional LCP LNA Stage 3	VD3	ID3	VG3
23	Optional LCP LNA Stage 4	VD4	ID4	VG4
31	Passive Monitor Points	RF-Av	LF-Av	15K

Appendix C : Digital I/O Data & Mux Addressing

Mux Address	Digital I/O Bit 3		Digital I/O Bit 2		Digital I/O Bit 1		Digital I/O Bit 0	
	DO-3	DI-3	DO-2	DI-2	DO-1	DI-1	DO-0	DI-0
0	Data Out DO-3 →	Data In - DI-3	Data Out DO-2 →	Data In - DI-2	Data Out DO-1 →	Data In - DI-1	Data Out DO-0 →	Data In - DI-0
1	-	-	-	-	-	-	-	-
2	-	Heater Request Status - H	-	Fridge Request Status - F	-	Solenoid Valve Request Status - S	-	Pump Request Status - P
3	-	Band Code - F3	-	Band Code - F2	-	Band Code - F1	-	Band Code - F0
4	-	Serial Num - S3	-	Serial Num - S2	-	Serial Num - S1	-	Serial Num - S0
5	-	Mod Level - M1	-	Mod Level - M0	-	Serial Num - S5	-	Serial Num - S4
6	-	-	Set LCP Enable LNA - EL	LCP Enable LNA Status - EL	-	-	Set RCP Enable LNA - EL	RCP Enable LNA Status - EL
7	-	-	-	-	-	-	-	-
8	Set Noise Diode Step Att - NA3	Noise Diode Step Att Status - NA3	Set Noise Diode Step Att - NA2	Noise Diode Step Att Status - NA2	Set Noise Diode Step Att - NA1	Noise Diode Step Att Status - NA1	Set Noise Diode Step Att - NA0	Noise Diode Step Att Status - NA0
9	-	-	-	-	Set Noise Diode Step Att - NA5	Noise Diode Step Att Status - NA5	Set Noise Diode Step Att - NA4	Noise Diode Step Att Status - NA4
10	Set RCP Solar Step Att - RA3	RCP Solar Step Att Status - RA3	Set RCP Solar Step Att - RA2	RCP Solar Step Att Status - RA2	Set RCP Solar Step Att - RA1	RCP Solar Status Step Att - RA1	Set RCP Solar Step Att - RA0	RCP Solar Step Att Status - RA0
11	Set RCP Solar Switch - RS	RCP Solar Switch Status - RS	-	-	Set RCP Solar Step Att - RA5	RCP Solar Step Att Status - RA5	Set RCP Solar Step Att - RA4	RCP Solar Step Att Status - RA4
12	Set LCP Solar Step Att - LA3	LCP Solar Step Att Status - LA3	Set LCP Solar Step Att - LA2	LCP Solar Step Att Status - LA2	Set LCP Solar Step Att - LA1	LCP Solar Status Step Att - LA1	Set LCP Solar Step Att - LA0	LCP Solar Step Att Status - RA0
13	Set LCP Solar Switch - LS	LCP Solar Switch Status- LS	-	-	Set LCP Solar Step Att - RA5	LCP Solar Step Att Status - RA5	Set LCP Solar Step Att - RA4	LCP Solar Step Att Status - RA4
14	-	-	-	-	-	-	-	-
15	Command M	Monitor M	Command H	Monitor H	Command C	Monitor C	Command X	Monitor X
31	-	Monitor M	-	Monitor H	-	Monitor C	-	Monitor X

Appendix D : SPI Bus Digital I/O

Data Bit	LNA Bias	
	Write	**Read**
D0	**Set V_D / I_D DAC-0**	**Mon V_D / I_D DAC-0**
D1	**Set V_D / I_D DAC-1**	**Mon V_D / I_D DAC-1**
D2	**Set V_D / I_D DAC-2**	**Mon V_D / I_D DAC-2**
D3	**Set V_D / I_D DAC-3**	**Mon V_D / I_D DAC-3**
D4	**Set V_D / I_D DAC-4**	**Mon V_D / I_D DAC-4**
D5	**Set V_D / I_D DAC-5**	**Mon V_D / I_D DAC-5**
D6	**Set V_D / I_D DAC-6**	**Mon V_D / I_D DAC-6**
D7	**Set V_D / I_D DAC-7**	**Mon V_D / I_D DAC-7**
D8	**Set V_D / I_D DAC-8**	**Mon V_D / I_D DAC-8**
D9	**Set V_D / I_D DAC-9**	**Mon V_D / I_D DAC-9**
D10	**Set V_D / I_D DAC-10**	**Mon V_D / I_D DAC-10**
D11	**Set V_D / I_D DAC-11**	**Mon V_D / I_D DAC-11**
D12	**Set V_D / I_D DAC-12**	**Mon V_D / I_D DAC-12**
D13	**Set V_D / I_D DAC-13**	**Mon V_D / I_D DAC-13**
D14	**Set V_D / I_D DAC-14**	**Mon V_D / I_D DAC-14**
D15	**Set V_D / I_D DAC-15**	**Mon V_D / I_D DAC-15**

Latched with SPI Data Strobe

Appendix E : SPI Bus LNA Bias Mux Addressing

Mux Address	LNA & Stage	Set Bias		Mux Address	Optional LNA & Stage	Set Bias
0	RCP LNA # S1	VD1		16	RCP LNA # S1	VD1
1	RCP LNA # S1	ID1		17	RCP LNA # S1	ID1
2	RCP LNA # S2	VD2		18	RCP LNA # S2	VD2
3	RCP LNA # S2	ID2		19	RCP LNA # S2	ID2
4	RCP LNA # S3	VD3		20	RCP LNA # S3	VD3
5	RCP LNA # S3	ID3		21	RCP LNA # S3	ID3
6	RCP LNA # S4	VD4		22	RCP LNA # S4	VD4
7	RCP LNA # S4	ID4		23	RCP LNA # S4	ID4
8	LCP LNA # S1	VD1		24	LCP LNA # S1	VD1
9	LCP LNA # S1	ID1		25	LCP LNA # S1	ID1
10	LCP LNA # S2	VD2		26	LCP LNA # S2	VD2
11	LCP LNA # S2	ID2		27	LCP LNA # S2	ID2
12	LCP LNA # S3	VD3		28	LCP LNA # S3	VD3
13	LCP LNA # S3	ID3		29	LCP LNA # S3	ID3
14	LCP LNA # S4	VD4		30	LCP LNA # S4	VD4
15	LCP LNA # S4	ID4		31	LCP LNA # S4	ID4

Appendix F : VLA/VLBA 'J' Monitor Connector

Monitor J2 DB-25 (female)	L-Band	X-Band	K-Band	Q-Band	W-Band
1	VP	VP	VP	VP	VP
2	VD	VD	VD	VD	VD
3	15K	15K	15K	15K	15K
4	50K	50K	50K	50K	50K
5	300K	300K	300K	300K	300K
6	AC1	AC1	AC1	AC1	AC1
7	RF1	RF1	RF1	RF1	RF1
8	RF2	RF2	RF2	RF2	RF2
9	LF1	LF1	LF1	LF1	LF1
10	LF2	LF2	LF2	LF2	LF2
11	LED	LED	LED	LED	LED
12	Not Used	Not Used	Not Used	Not Used	Not Used
13	Quality Gnd	Quality Gnd	Quality Gnd	Quality Gnd	Quality Gnd
14	SENS (15K)	SENS (15K)	Not Used	SENS (15K)	Not Used
15	Not Used	Not Used	Not Used	Not Used	Not Used
16	Not Used	Not Used	Not Used	Not Used	Not Used
17	Not Used	Not Used	Not Used	Not Used	Not Used
18	Not Used	Not Used	Not Used	Not Used	Not Used
19	Not Used	Not Used	Not Used	Not Used	Not Used
20	S	S	S	S	S
21	P	P	P	P	P
22	M	M	M	M	M
23	X	X	X	X	X
24	C	C	C	C	C
25	H	H	H	H	H

Appendix G : VLA/VLBA ‘J5' Control Connector

Control J5 DB-25 (male)	L-Band	X-Band	K-Band	Q-Band	W-Band
1	Gnd	Gnd	Gnd	Gnd	Gnd
2	+15V	+15V	+15V	+15V	+15V
3	-15V	-15V	-15V	-15V	-15V
4	Not Used	Not Used	+15V	+15V	+15V
5	Not Used	Not Used	+15V	+15V	+15V
6	X	X	X	X	X
7	C	C	C	C	C
8	H	H	H	H	H
9	PA	PA	PA	PA	PA
10	Spare	Spare	+28V	PWR GND	+28V
11	Cal	Cal	Cal	Cal	Cal
12	Hi Cal	Hi Cal	Hi Cal	Hi Cal	Hi Cal
13	Gnd †	Gnd †	Gnd †	Gnd †	Gnd †
14	F0	F0	F0	F0	F0
15	F1	F1	F1	F1	F1
16	F2	F2	F2	F2	F2
17	F3	F3	F3	F3	F3
18	S0	S0	S0	S0	S0
19	S1	S1	S1	S1	S1
20	S2	S2	S2	S2	S2
21	S3	S3	S3	S3	S3
22	S4	S4	S4	S4	S4
23	S5	S5	S5	S5	S5
24	M0	M0	M0	M0	M0
25	M1	M1	M1	M1	M1

† Not Used

Appendix H : VLA/VLBA 'J4' Aux Monitor Connector

Aux Monitor J4 DB-7 (female)	L-Band	X-Band	K-Band	Q-Band	W-Band
1	AC+	AC+		AC+	AC+
2	AC-	AC-		AC-	AC-
3	P	P		P	P
4	P Rtn	P Rtn		P Rtn	P Rtn
5					
6					
7					
8					
9					

Appendix I : 'J15' Vacuum Gauge & Solenoid Connector

Vacuum Gauge J15 DB-9 (Male)	L-Band (1)	X-Band (1)	K-Band (1)	Q-Band (1)	W-Band
1			Dewar VT-1		Dewar VT-1
2			Dewar VT-2		Dewar VT-2
3			Dewar VT-3		Dewar VT-3
4			Pump VT-1		Pump VT-1
5			Pump VT-2		Pump VT-2
6			Pump VT-3		Pump VT-3
7					
8			Solenoid Supply		Solenoid Supply
9			Solenoid Return		Solenoid Return

Notes - L, X & Q-Band have hardwired cables to the Vacuum sensors and Solenoid control.
- L, S and Q-Band have hardwired cables for the Fridge 150 VAC
- K & W-Band has Deutch Connectors for the Fridge 150 VAC
- Q-Band has hardwired cable for RF Plate DC Power, 300°K Sensor and Tcal & Scal
- K-Band has hardwired Tcal & Scal drives and +15V DC Power to RF/IF Box

Appendix J : VLA/VLBA 'J3' Dewar Power Connector

Dewar Power J3 DB-XX (female)	L-Band (DB-25)	X-Band (DB-25)	K-Band (DB-50)	Q-Band (DB-37)	W-Band (DB-50)
1	15K Rtn	15K Rtn	15K Rtn	15K Rtn	15K Rtn
2	15K	15K	15K	15K	15K
3	50K Rtn	50K Rtn	50K Rtn	50K Rtn	50K Rtn
4	50K	50K	50K	50K	50K
5	LCP G1	LCP G1	LCP G1	LCP G1	RF LCP G1
6	LCP D1	LCP D1	LCP G2	LCP D1	RF LCP G2
7	LCP G2	LCP G2	LCP G3	LCP G2	RF LCP G3
8	LCP D2	LCP D2	LCP G4	LCP D2	RF LCP G4
9	LCP G3	LCP G3	RCP G4	LCP G3	RF LCP G5
10	LCP D3	LCP D3	LCP D1	LCP D3	RF LCP D1
11	LCP G4	LCP G4	LCP D2	LCP G4	RF LCP D2
12	LCP D4	LCP D4	LCP D3	LCP D4	RF LCP D3
13	RCP G1	RCP G1	LCP D4	RCP G1	RF LCP D4
14	RCP D1	RCP D1	RCP D4	RCP D1	RF LCP D5
15	RCP G2	RCP G2		RCP G2	RF RCP G1
16	RCP D2	RCP D2		RCP D2	RF RCP G2
17	RCP G3	RCP G3		RCP G3	RF RCP G3
18	RCP D3	RCP D3		RCP D3	RF RCP G4
19	RCP G4	RCP G4		RCP G4	RF RCP G5
20	RCP D4	RCP D4		RCP D4	RF RCP D1
21	Dewar Gnd	Dewar Gnd		Dewar Gnd	RF RCP D2
22	LED	LED		LED	RF RCP D3
23	Not Used	Not Used		LED	RF RCP D4
24	Heater	Heater		Heater	RF RCP D5
25	Heater	Heater	RCP G1	Heater	IF LCP G1
26			RCP G2		IF LCP G2
27			RCP G3		IF LCP G3
28			RCP D1		IF LCP D1
29			RCP D2		IF LCP D2
30			RCP D3	LCP G5	IF LCP D3
31				LCP D5	IF RCP G1

32					**IF RCP G2**
33					**IF RCP G3**
34				**RCP G5**	**IF RCP D1**
35				**RCP D5**	**IF RCP D2**
36					**IF RCP D3**
37					**Not Used**
38			**Heater**		**Heater**
39			**Heater**		**Heater**
40			**LED**		
41					**Cal Drive**
42					**+15V**
43					**+15V**
44					**Gnd**
45			**LED Rtn**		**Gnd**
46					**Gnd**
47					
48					
49					**RCP Mixer Bias**
50					**LCP Mixer Bias**