# IX. Controls

## A. Pbar Camac Link

As with the other accelerators, the Antiproton Source is largely controlled and monitored from the Main Control Room via ACNET. Consoles send and receive information by means of the Accelerator Division's control system and the Pbar VME type front end computer. A dedicated serial link connects all of the service buildings, including F23 and F27, with the Pbar front end. In actuality there are six serial loops: PIOX, TCLK, PIOR BTR, MRBS, Pbar Beam Permit Loop, and a link for remote ACNET consoles.

The Pbar CAMAC link is connected within and between service buildings with repeaters (figure 9.1 shows the layout of the crates and repeaters in the service buildings). An applications program currently residing on D20 graphically displays the status of the link and the contents of each crate. Crates are numbered according to the service building they are located in. AP10 houses the $1n crates, the 30 and 50 houses contain the $3n and $5n crates respectively. Crates $70 through $74 are located in AP0, $80, $81 and $82 in F23, and $90 and $91 in F27 (see figure 9.1).

Not all Antiproton Source devices are controlled through the Pbar Camac front end. It is sometimes more convenient to control devices from nearby CAMAC crates attached to a different front end. For example, Pbar LCW parameters from CUB are read back through the Booster front-end. Sometimes a particular subsystem, such as the Accumulator or Debuncher BPMs, will have a VME crate system of their own. In these cases, the VME crate communicates directly to the control system instead of through the Pbar CAMAC front end. Similarly, there are also three utility VME crates (AP1001, AP1002, and AP5001) that connect all of the Pbar GPIB diagnostics to ACNET. In addition, some Pbar devices are calculated through pseudo front ends that run on Java controls computers. MACALC is an example of such a front end. It calculates a number of important parameters including the Accumulator emittances, stacking rate and production efficiency.

The Pbar source has a dedicated beam permit/abort loop. The Pbar Beam Permit Loop is a serial loop of CAMAC 200 modules which is sourced in the MCR back racks in a unique 201 card. The 201 sends out a 5 MHz signal, which, if each 200 module has no faults, is passed along and returned to the 201. If one of the eight inputs to a 200 module is low, the 5 MHz signal is not passed along and the loop collapses. There is no beam dump in the Rings into which beam can be aborted. The Beam Switch Sum Box (BSSB) in the Main Control Room inhibits beam using both Pbar and NuMI permits on Mixed-Mode stacking cycles ($23). This extra precaution is needed since the $23 event has beam destined for both Pbar and NuMI in the Main Injector at the same time. Tying the Pbar and NuMI permits together on the $23s prevents unwanted beam from going to Pbar or NuMI when either one of their permits drop. On Stacking only cycles ($29), the BSSB just monitors the Pbar permit (NuMI permit status is ignored). The Main Injector Beam Synch (MIBS) events associated with extraction from the Main Injector to Pbar ($79, $7D, and $7E) will also be disabled if the P1 line, P2 line or Pbar permit is down. Only a limited number of devices will pull down the permit loop. These inputs included the Rings and Transport Radiation Safety Systems, a summation of radiation monitors (chipmunks) located in the Antiproton Source service buildings, the I:F17B3 supply, AP1 power supplies, a number of Target Station devices, and the software inhibit. Analog inhibits for the AP1 power supplies are included with the help of a CAMAC 204 module at F23. The output of the Camac 204 module connects into the Camac 200 beam permit input. Each AP1 supply has a dedicated 204 module channel with its own settable alarm limits. Live data sampled on a particular event is compared to the alarm limit. If a device is outside of the alarm limit, the 204 module will trip, which in turn takes away the beam permit.

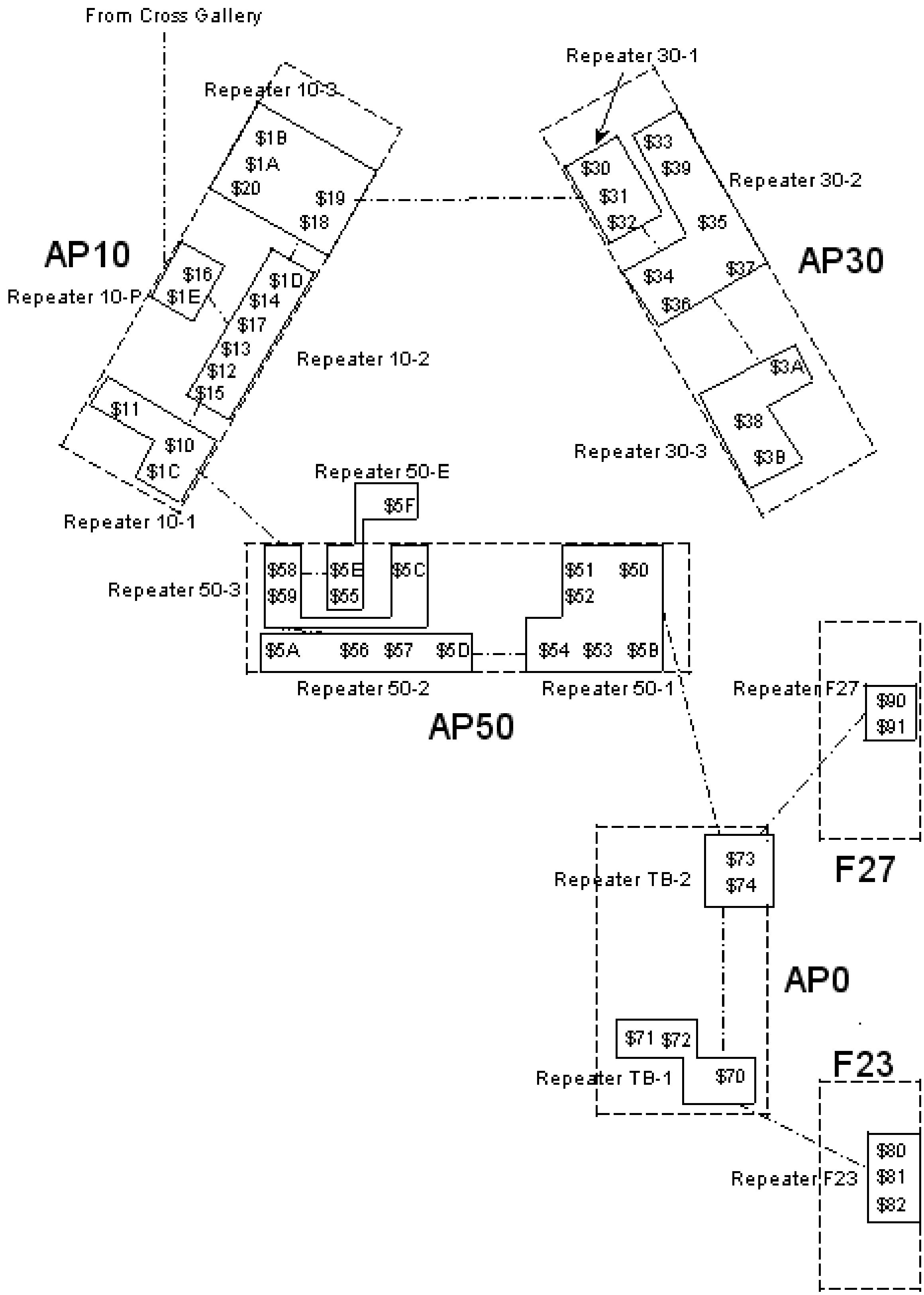


Figure 9.1 Pbar Source CAMAC serial link

### B. General Purpose Interface Bus

The Pbar control system is unique in the number of diagnostic devices such as spectrum analyzers, which can be controlled and displayed remotely. This is made possible through the use of the GPIB protocol. GPIB is an acronym for General Purpose Interface Bus and has been in use for over 30 years.

*GPIB Primer:*

Each GPIB device is assigned a unique GPIB address, ranging from 0-31, by setting address switches on the device. Up to 15 devices connect to one eight bit parallel bus. Connections to GPIB devices are made either via the 24-conductor GPIB cable with D-shaped male and female connectors at both ends (see Figure 9.2), or a standard Cat5 Ethernet cable with RJ-45 jack connectors. When the GPIB cabling is used, the connectors can be stacked up to four deep, so that devices can be linked using a linear configuration, star configuration, or combination of both. The GPIB bus can either connect directly to a GPIB connector on the front end, to a GPIB to Ethernet converter box (often called an ENET box), or directly to Ethernet. The Pbar GPIB implementation has examples of each of these three configurations.

Figure 9.2 Typical GPIB connector

Each GPIB device connects to a VME front end. The front end runs an operating system called VxWorks, which is a commercial multitasking operating system used by the AD/Controls Group to connect microcomputers to ACNET.

A controller is where the GPIB bus connects to the front end. Each front end can have up to eight controllers. There are six different types of controllers, where the controller type is called the interface. The GPIB_VME (also called GPIB1014) interface is the traditional GPIB implementation where the GPIB bus connects directly to the front end. This implementation is becoming obsolete, so there are no plans of adding any future GPIB devices using this interface. GPIB_ENET and GPIB_ENET 10/100 are interfaces where the GPIB bus connects to an ENET box. In this case there is no direct connection between the VME front end and the GPIB devices. Instead, communication occurs over the network through the ENET box. VXI11 is a newer interface where the front end talks directly to the GPIB device over the network. This interface requires that the GPIB device have an Ethernet port. There are a number of newer scopes that are configured in this manner. There are two additional interfaces (PMC-GPIB and LECROY) that will not be covered in this document since they are not used in Pbar.

*Pbar GPIB Device List:*

Table 9.1 is a listing of the Pbar GPIB devices. The device column is a listing of Pbar GPIB devices. The location column shows the service building and rack number for the GPIB device. The GPIB address shows the manually set GPIB number for that device. The GPIB device column shows the front end controller number. The Front End column lists the front end with the rack number in parenthesis below. The interface column indicates which GPIB interface is used and, where appropriate, that interface's network name and location. The table is organized by GPIB device location, then front end, then interface type and then GPIB address.

| Pbar GPIB Devices | | | | | |
|---|---|---|---|---|---|
| **Pbar GPIB Device** | **Device Location (Rack #)** | **GPIB Address** | **GPIB Device** | **Front End (Rack #)** | **Interface Type (network name) (Rack #)** |
| **Proton Torpedo Scope** (TDS 680B or TDS684A) | AP0 (THSBS R3) | 1 | 4 | AP5001 (B55R06) | GPIB-ENET (pbar-gpib-09.fnal.gov) (THSBS R3) |
| **A:QTPSI** Keithley 2000 DVM | AP10 (A:QT) | 2 | 6 | AP1001 (A14R05) | GPIB-ENET (pbar-gpib-05.fnal.gov) (A16R53) |
| **D/A VSA** HP 89410A VSA (vsa10b.fnal.gov) | AP10 (B14R07) | 4 | 5 | AP1001 (A14R05) | GPIB-ENET (pbar-gpib-01.fnal.gov) (B14R02) |
| **Acc Horizontal Emittances** 300 MHz freqency generator (D:FFTLOF) | AP10 (B14R06) | 7 | 5 | AP1001 (A14R05) | GPIB-ENET (pbar-gpib-01.fnal.gov) (B14R02) |
| **Acc Vertical Emittances** 300 MHz frequency generator (A:FFTLOF) | AP10 (B14R06) | 8 | 5 | AP1001 (A14R05) | GPIB-ENET (pbar-gpib-01.fnal.gov) (B14R02) |
| **A:IBEAM** Keithley 2000 DVM | AP10 (B14R03) | 9 | 5 | AP1001 (A14R05) | GPIB-ENET (pbar-gpib-01.fnal.gov) (B14R02) |
| **D:IBEAM** Keithley 2000 DVM | AP10 (B14R03) | 10 | 5 | AP1001 (A14R05) | GPIB-ENET (pbar-gpib-01.fnal.gov) |
| **Pbar Spectrum Analyzer #1** Agilent E4445A pbarsa1.fnal.gov | AP10 (B14R03) | 14 | 5 | AP1001 (A14R05) | GPIB-ENET (pbar-gpib-01.fnal.gov) (B14R02) |
| **Network Analyzer** HP8720B | AP10 (B140R2) | 16 | 5 | AP1001 (A14R05) | GPIB-ENET (pbar-gpib-01.fnal.gov) (B14R02) |
| **Former FFT Box** SR 785 FFT | AP10 (B14R04) | 20 | 5 | AP1001 (A14R05) | GPIB-ENET (pbar-gpib-01.fnal.gov) (B14R02) |
| **AP BPM Calibration** hp 8110A pulse generator | AP10 (B16R04) | 10 | 0 | APABPM10 (B16R04) | GPIB-ENET (adabpm10gpib.fnal.gov) (B16R04) |
| **AP BPM Cal Clock** Rohde & Schwarz 9kHz to 1.040 MHz Signal Generator | AP10 (B16R04) | 22 | 0 | APABPM10 (B16R04) | GPIB-ENET (adabpm10gpib.fnal.gov) (B16R04) |
| **AP BPM Cal Clock** Rohde & Schwarz 9kHz to 1.040 MHz Signal Generator | AP10 (B16R04) | 21 | 0 | APABPM10 (B16R04) | GPIB-ENET (adabpm10gpib.fnal.gov) (B16R04) |
| **AP BPM Cal Clock** Rohde & Schwarz 9kHz to 1.040 MHz Signal Generator | AP10 (B16R04) | 20 | 0 | APABPM10 (B16R04) | GPIB-ENET (adabpm10gpib.fnal.gov) (B16R04) |
| HP 54600B scope (lower) | AP10 (A14R05) | 1 | 0 | AP1001 (A14R05) | GPIB-VME |
| **Debuncher TBT Scope** (Tektronix TDS 3014B) (deb-tbt-scope) | AP10 (A14R04) | 2 | 0 | AP1001 (A14R05) | GPIB-VME |

| Pbar GPIB Devices (continued) | | | | | |
|---|---|---|---|---|---|
| **Pbar GPIB Device** | **Device Location (Rack #)** | **GPIB Address** | **GPIB Device** | **Front End (Rack #)** | **Interface Type (network name) (Rack #)** |
| **Accumulator TBT**<br>TDS7104 | AP10<br>(A14R02) | 3 | 0 | AP1001<br>(A14R05) | GPIB-VME |
| **Flux Capacitor Scope**<br>(Tektronix TDS 3034B)<br>(ap10-flux-scope) | AP10<br>(A14R05) | 7 | 0 | AP1001<br>(A14R05) | GPIB-VME |
| HP 54600B scope (upper) | AP10<br>(A14R05) | 8 | 0 | AP1001<br>(A14R05) | GPIB-VME |
| **Pbar Spectrum Analyzer #4**<br>Agilent E4445A<br>(pbarsa4.fnal.gov) | AP10<br>(A14R01) | 9 | 0 | AP1001<br>(A14R05) | GPIB-VME |
| **Pbar Spectrum Analyzer #5**<br>HP8568B | AP10<br>(A14R02) | 10 | 0 | AP1001<br>(A14R05) | GPIB-VME |
| **Stacking VSA**<br>HP VSA89440A<br>(vsa10.fnal.gov) | AP10<br>(A14R04) | 18 | 0 | AP1001<br>(A14R05) | GPIB-VME |
| **Accumulator bakeout system**<br>HP 37204 GPIB extender | AP10<br>(B11R06) | 1 | 0 | BAKER<br>(B11R06) | GPIB-VME |
| **Accumulator bakeout system**<br>HP 37204 GPIB extender<br>to 10 Stub | AP10<br>(B11R06) | 3 | 0 | BAKER<br>(B11R06) | GPIB-VME |
| **Accumulator bakeout system**<br>HP 37204 GPIB extender<br>to 50 Stub | AP10<br>(B11R06) | 5 | 0 | BAKER<br>(B11R06) | GPIB-VME |
| **Debuncher TBT Scope**<br>Tektronix TDS 3014B | AP10<br>(A14R04) | 0 | 0 | AP1002<br>(A14R05) | VXI11<br>(deb-tbt-scope.fnal.gov) |
| **Flux Capacitor Scope**<br>Tektronix TDS 3034B<br>(pledgepin.fnal.gov) | AP10<br>(A14R05) | 1 | 0 | AP1002<br>(A14R05) | VXI11<br>(ap10-flux-scope.fnal.gov) |
| **Debuncher EKIK Scope**<br>Tektronix TDS 3014B | AP10<br>(A13R01) | 3 | 0 | AP1002<br>(A14R05) | VXI11<br>(deb-ekik-scope.fnal.gov) |
| **Accumulator EKIK Scope**<br>Tektronix TDS 3014B | AP10<br>(A:KIK) | 4 | 0 | AP1002<br>(A14R05) | VXI11<br>(acc-ekik-scope.fnal.gov) |
| **Pbar Spectrum Analyzer #2**<br>Agilent E4445A<br>Spectrum Analyzer | AP30<br>(B33R01) | 14 | 7 | AP1001<br>(A14R05) | GPIB-ENET<br>(pbar-gpib-06.fnal.gov) |
| **AP BPM Calibration**<br>HP 8110A pulse generator | AP30<br>(B32R02) | 10 | 0 | APABPM20<br>(B32R02) | GPIB-ENET<br>(adabpm20gpib.fnal.gov)<br>(B32R02) |
| **Debuncher Horizontal IPM**<br>MCP Power Supply | AP30<br>(A33R05) | 6 | 0 | MWDIPM<br>(A33R04) | GPIB-ENET<br>(dipm-gpib.fnal.gov)<br>(A33R05) |
| **Debuncher Horizontal IPM**<br>Clearing Field Power Supply | AP30<br>(A33R05) | 7 | 0 | MWDIPM<br>(A33R04) | GPIB-ENET<br>(dipm-gpib.fnal.gov)<br>(A33R05) |

| Pbar GPIB Devices (continued) | | | | | |
|---|---|---|---|---|---|
| **Pbar GPIB Device** | **Device Location (Rack #)** | **GPIB Address** | **GPIB Device** | **Front End (Rack #)** | **Interface Type (network name) (Rack #)** |
| **Debuncher Vertical IPM** MCP Power Supply | AP30 (A33R06) | 4 | 0 | MWDIPM (A33R04) | GPIB-ENET (dipm-gpib.fnal.gov) (A33R05) |
| **Debuncher Vertical IPM** Clearing Field Power Supply | AP30 (A33R06) | 5 | 0 | MWDIPM (A33R04) | GPIB-ENET (dipm-gpib.fnal.gov) (A33R05) |
| **Accumulator IKIK Scope** Tektronix TDS 3014B | AP30 (A32R01) | 6 | 0 | AP1002 (A14R05) | VXI11 (acc-ikik-scope.fnal.gov) |
| **Accumulator NMR Scope** Tektronix TDS 3012B | AP30 (B37R03) | 8 | 0 | AP1002 (A14R05) | VXI11 (acc-nmr-scope.fnal.gov) |
| **A:IBPSI** Keithly 2000 DVM | AP50 (A:IB) | 1 | 1 | AP5001 (B55R06) | GPIB-ENET (pbar-gpib-07.fnal.gov) (B56R02) |
| **D:IBPSI** Keithley 2000 DVM | AP50 (D:IB) | 2 | 1 | AP5001 (B55R06) | GPIB-ENET (pbar-gpib-07.fnal.gov) (B56R02) |
| **A:LQPSI** Keithly 2000 DVM | AP50 (D:LQ) | 3 | 1 | AP5001 (B55R06) | GPIB-ENET (pbar-gpib-07.fnal.gov) (B56R02) |
| **A:QDFPSI** Keithly 2000 DVM | AP50 (D:QDF) | 2 | 2 | AP5001 (B55R06) | GPIB-ENET (pbar-gpib-08.fnal.gov) (B53R03) |
| **A:NMR50/D:NMR50** Metrolab NMR Tesla Meter | AP50 (B51R07) | 0 | 0 | AP5001 (B55R06) | GPIB-ENET (pbar-gpib-10.fnal.gov) (B51R07) |
| **AP BPM Calibration** hp 8110A pulse generator | AP50 (B56R03) | 10 | 0 | APABPM50 (B56R03) | GPIB-ENET (adabpm50gpib.fnal.gov) (B56R03) |
| **Debuncher IKIK Scope** Tektronix TDS 3014B | AP50 (A52R03) | 5 | 0 | AP1002 (A14R05) | VXI11 (deb-ikik-scope.fnal.gov) |
| Roaming Tektronix scope for general testing. | Mobile | 2 | 0 | AP1002 (A14R05) | VXI11 (pbar-scope233.fnal.gov) |

Table 9.1 Pbar GPIB devices

*Pbar VME Front Ends for GPIB Busses:*

AP1001, AP1002 and AP5001 are VME/GPIB utility front ends that interface most of the GPIB Pbar diagnostics. There are a few other front ends that interface GPIB devices for specific systems. Examples of this include BAKER (Accumulator bake out system), MWDIPM (Debuncher IPM), and ABPM## (Accumulator BPM calibration system).

The AP1001 VME crate houses both the AP1001 and AP1002 front ends. There are separate software reboot capabilities for both front ends, but a hardware reboot spans both front ends. AP1001 has an Ethernet connection to the Pbar Controls network as well as a GPIB connection with a stack of four GPIB connectors. The Ethernet connection allows for communications with the control system, GPIB ENET boxes and individual GPIB scopes. The GPIB stack is a combination star and linear configuration with each of the connectors in the stack having a series of attached devices. Devices that are on a GPIB bus that attach directly to AP1001 include Spectrum Analyzer #4, Spectrum Analyzer #5, the Stacking VSA, the Flux Capacitor Scope, the Debuncher TBT scope and the Accumulator TBT scope. AP1001 also interfaces ENET boxes named PBAR-GPIB-01, PBAR-GPIB-05 and PBAR-GPIB-06. PBAR-GPIB-01 connects to the Network Analyzer, Spectrum Analyzer #1, 300MHz frequency generators for horizontal and vertical Accumulator emittances, DVMs for the Accumulator and Debuncher beam intensity read backs, and the D/A FFT VSA. PBAR-GPIB-05 connects to the DVM that provides the A:QTPSI readback at AP10. PBAR-GPIB-06 connects to Pbar Spectrum Analyzer #2 at AP30, which is the Accumulator longitudinal profile that is viewed on Pbar CATV channel 28.

The AP1002 front end accesses Ethernet enabled scopes in AP10, AP30 and AP50 over the network. Scopes connected to this interface include the Debuncher TBT, Flux Capacitor, Debuncher extraction kicker, Accumulator extraction kicker, Accumulator injection kicker, Debuncher injection kicker and Accumulator NMR.

The AP5001 front end is located in the AP50 service building and interfaces ENET boxes named PBAR-GPIB-07, PBAR-GPIB-08, and PBAR-GPIB-09. PBAR-GPIB-07 connects to DVMs that provide the A:IBPSI, D:IBPSI, and A:LQPSI readbacks, PBAR-GPIB-08 connects to the DVM that provides the A:QDFPSI readback, and PBAR-GPIB-09 connects to the AP0 Wall Current Monitor scope that is used for the Proton Torpedo display.

The BAKER VME front end is used for the Accumulator bake-out system. It connects to three HP 37204 GPIB extenders that carry the GPIB bus to the 10, 30 and 50 stubs in the Pbar Rings tunnel. In the tunnel, the GPIB bus in each stub connects to an HP 3497A controller that interfaces thermocouple readbacks and relays for switching power to the electrical blankets used for the bake-out.

The Accumulator BPM Calibration and Debuncher IPM GPIB busses will be covered in the diagnostics chapter and need not be repeated here.

*Pbar GPIB Map:*

When troubleshooting GPIB problems it is helpful to know how the GPIB busses are connected to their respective front ends. This can be confusing since GPIB busses can connect directly to the front end or over the Ethernet. In addition, GPIB busses can be combinations of linear and star configurations. Figure 9.3 is a map of how the GPIB busses connect to the AP1001, AP1002 and AP5001 front ends in Pbar. The upper portion of the diagram shows the Ethernet connections to the Pbar Controls Network. This includes the front ends, the GPIB ENET boxes and the GPIB scopes that can talk directly over Ethernet (VXI11 interface). The bottom portion of the diagram shows the GPIB bus configurations for devices connecting directly to a front end (GPIB_VME interface) and devices connecting to an ENET box (GPIB_ENET interface). Using Figure 9.3 to determine the GPIB bus configuration and Table 9.1 to get specific details for that bus could prove to be of use when troubleshooting a GPIB problem.

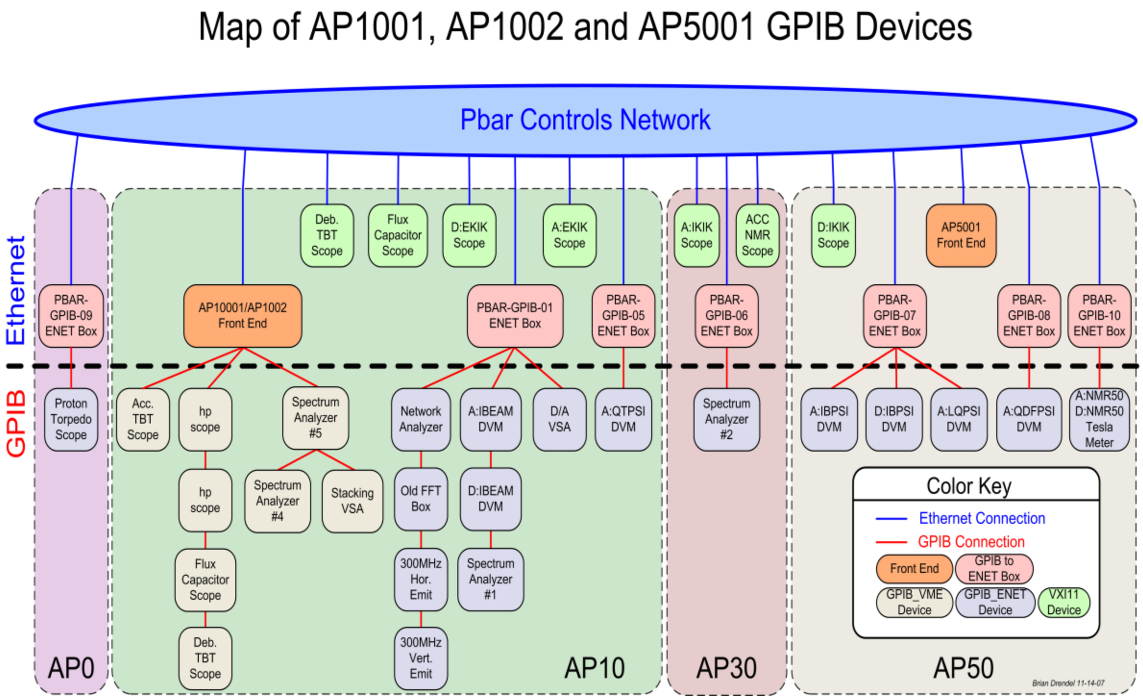


Figure 9.3 A map of the AP1001, AP1002 and AP5001 GPIB devices

*Other Front Ends:*

There are many other VME front ends that are not covered in this section since they are part of other systems and do not use GPIB. All can be polled on ACNET page D31. DBPM## (where the sector is specified by ## = 10, 20, 30, 40, 50, or 60) interfaces the Debuncher BPMs, ABPM## (where the sector is specified by ## = 10, 20, 30, 40, 50, or 60) interfaces Accumulator BPMs, ARF4 interfaces the Accumulator LLRF, DRF1 is used for DRF1 cavity temperature regulation, PBEAM is used to calculate the A:BEAM and D:BEAM intensity readbacks, FRIGPR is the AP30 Frig I/O and Thermometry interface, PBCOOL is used for stochastic cooling, TWTACC is used for Accumulator TWT protection, TWTCOM is used for Accumulator core momentum TWT protection, TWTDEB and TWTDB2 are used for Debuncher TWT protection, and PBVAC is used for Pbar vacuum.

## D. Programmable Logic Controller

A number of Pbar devices are controlled and monitored using Programmable Logic Controllers (PLCs). This includes stochastic cooling devices, Debuncher motorized quadrupole stands, the Pbar Rings tunnel exhaust fans, Pbar Rings tunnel wireless Ethernet on/off switches, Accumulator BPM crate resets, DRF3 ENI control, ARF3 cavity short movement and AP3 line LCW leak detectors.

*PLC Primer*

PLCs are popular because they provide a cost-effective interface to hardware components. They are designed to withstand ambient temperature fluctuations, electrical noise and vibrations which might be encountered in the service buildings. A variety of commercially available analog and digital I/O modules allow the PLCs to connect to various external devices. Each PLC is capable of housing multiple I/O modules. When the number of available I/O module slots is not sufficient, additional modules can be added through the use of extender boards. PLCs have a CPU which allows programs to be written to control the external devices that the PLC interfaces. The PLCs have a battery backup to retain their memory contents during occasional power outages. Pbar PLCs communicate on the Pbar controls network through Ethernet to a single VME front end running VxWorks, which provides access to the AD control system.

*History*

The Antiproton Source utilizes a large number of military grade microwave components. Many of these operate from 24 to 28 volts DC. The large number of channels of control and status required new types of hardware from the Controls Department. The power distribution, control and status were originally provided by Fermi built cards and crates referred to as

"Beechy Boxes" in honor of Dave Beechy, the Controls Department engineer. Eventually Dave Beechy went to the SSC and Dave DuPuis, the technician who maintained the boxes, retired. By the late 1990's a large Stochastic Cooling upgrade was planned and it became evident that commercial controllers were cost effective and readily available. Inexpensive Koyo built PLCs from what was then called PLC Direct had performed well in the small He3 linac for P.E.T isotope production. Ethernet modules were becoming available so the interface to ACNET was fairly easy to implement. Currently, Pbar uses PLC CPU models DL-440, DL-450 and DL-260 purchased from Automation Direct

*Pbar PLCs*

All of the PLCs that interface the stochastic cooling systems have a status parameter that continually updates if the PLC is talking to the VME front end. The status parameters for the tunnel PLCs also have a digital status field which can be used to remotely reset the PLC. The PLCs in the service buildings do not have remote reset capability. A number of the PLC units for the stochastic cooling systems are located in the stub rooms in the Pbar Rings tunnel. A tunnel PLC failure could result in reduced stacking and/or inability to cool the core. Experience has shown a common, possibly radiation induced, failure mode is the loss of the PLC's internal 5 volt switching power supply. A set of four conductor 10 Ga. cables were added from each of the stub room PLCs to one of three backup + 5V Acopian power supplies located in service buildings. This arrangement allows for diagnosing and potentially correcting tunnel PLC power supply problems without accessing the tunnel.

# Pbar PLCs

| Network Name (*.fnal.gov) | PLC Status & Reset Device | PLC Location (Rack #) | Backup +5V Location (Rack #) | Front End(s) (Rack) | Devices interfaced through the PLC |
|---|---|---|---|---|---|
| **PbarPLC01** | **A:PLC01S** (status only) | **AP10** (B14R04) *back of rack | None | **PBCOOL** (B11R06) | PLC Resets (PLC2, PLC3, PLC9, PLC11), Accumulator BPM 10 and 60 house power reset (A:B1POWR & A:B6POWR), Switch Tree, and Accumulator horizontal and vertical damper reversing switches. |
| **PbarPLC02** | **A:PLC02** | **10-1 Stub** (A10-1SR1) | **AP10** (B13R04) | **PBCOOL** (B11R06) | Core Betatron Cooling Systems, wide band amps, 10 sector tunnel exhaust fan, and A10 Accumulator bakeout controls. |
| **PbarPLC03** | **A:PLC03** | **10-2 Stub** (A10-2SR) | **AP10** (B16R04) | **PBCOOL** (B11R06) | Debuncher stochastic cooling band 3 and 4 systems (A10-2 stub room medium level RF). |
| **PbarPLC04** | **A:PLC04S** (status only) | **AP10** (A14R07) | None | **PBCOOL** (B11R06) | Debuncher stochastic cooling (low level RF), and AP10 tunnel wireless on/off switch (D:WIFI10). |
| **PbarPLC05** | **A:PLC05** | **20-2 Stub** (A20-2SR) | **AP30** (B31R07) | **PBCOOL** (B11R06) | Core 4-8GHz momentum cooling (low level and medium level RF), and 20 sector tunnel exhaust fan. |
| **PbarPLC06** | **A:PLC06S** (status only) | **AP30** (A35R02) | None | **PBCOOL** (B11R06) | Debuncher stochastic cooling (high level RF), and AP3 line LCW leak detector (D:LKESUM), |
| **PbarPLC07** | **A:PLC07S** (status only) | **AP30** (B33R03) | None | **PBCOOL** (B11R06) | Accumulator Stacktail cooling (medium and high level RF), 2-4 GHz core momentum (high level RF), Debuncher Momentum medium level optical delay line (D:POTMF setting), Accumulator BPM 20 and 30 house crate resets (A:B2POWR & A:B3POWR), DRF3 ENI (D:R3HLSC), PLC resets (PLC 5 and 10), 40 location tunnel exhaust fan, and AP30 tunnel wireless on/off switch (D:WIFI30). |
| **PbarPLC08** | **A:PLC08S** (status only) | **AP50** (B51R06) | None | **PBCOOL** (B11R06) | Core 4-8GHz momentum (high level RF), Accumulator 50 bake, and Accumulator BPM 40 and 50 house crate resets (A:B4POWR & A:B5POWR). |
| **PbarPLC09** | **A:PLC09** | **60 Stub** (A60SR) | **AP10** (B13R04) | **PBCOOL** (B11R06) | Core 2-4GHz momentum (low level and medium level RF), Stacktail (low level RF), and 60 location tunnel exhaust fan. |
| **PbarPLC10** | **A:PLC10** | **30 Stub** (A30SR) | **AP30** (B31R07) | **PBCOOL** (B11R06) | Debuncher momentum (A30 stub room medium level RF: oven temp, pin attenuators, diodes, various amps) |
| **PbarPLC11** | **A:PLC11** | **10-1 Stub** (A10-1SR2) | **AP10** (B13R04) | **PBCOOL** (B11R06) | Debuncher cooling band 1 and 2 systems (A10-2 stub room medium level RF). |
| **PbarPLC12** | **A:PLC12S** (status only) | **AP50** (B55R07) | None | **PBCOOL** (B11R06) | ARF3. |
| **PbarPLC13** | **A:PLC13** (status only) | **AP30** (B34R05) | None | **PBCOOL** (B11R06) | Core 4-8GHz betatron (HLRF). |

| Pbar PLCs (continued) | | | | | |
|---|---|---|---|---|---|
| **Network Name** (*.fnal.gov) | **PLC Status & Reset Device** | **PLC Location (Rack #)** | **Backup +5V Location (Rack #)** | **Front End(s) (Rack)** | **Devices interfaced through the PLC** |
| **PbarPLC14** | None | **AP10** (A12R02) | None | **AP1002** (A14R05) | Motor controls for Debuncher quad (6Q2, 6Q7, 6Q14, 6Q17) and Debuncher extraction kicker stands. |
| **PbarPLC15** | None | **AP10** (A16R05) | None | **AP1002** (A14R05) | Motor controls for Debuncher quad (1Q3, 1Q5, 1Q8, 1Q11, and 1Q17) stands. |
| **PbarPLC16** | None | **AP50** (A53R05) | None | **AP1002** (A14R05) | Motor controls for Debuncher quad (4Q9, 4Q10, 4Q14, 4Q17, D4Q20, 5Q17, 5Q12, 5Q9, 5Q6, 5Q4 and 5Q3), Debuncher Injection Kicker, and Debuncher Injection Septum stands. AP50 tunnel wireless on/off switch (D:WIFI50). |
| **PbarPLC17** | None | **AP30** (A34R06) | None | **AP1002** (A14R05) | Motor controls for Debuncher quad (2Q2, 2Q10, 2Q14, 2Q17, 2Q20, 3Q6, 3Q9, 3Q12, and 3Q17) stands. |

Table 9.2 Pbar PLC's

*PLC Device List:*

Table 9.2 provides details for each of the 17 PLCs used in Pbar. The network name column lists the network name, minus the ".fnal.gov" to save space. The PLC status and reset device column lists and, where applicable, the ACNET device used to monitor and/or reset the PLC. Remember that only the tunnel PLCs have remote reset capability. The PLC location column lists the service building and rack number where the PLC resides. The backup +5V rack column lists which PLCs have backup +5V supplies and the rack number of the supply. This only applies to PLCs located in the tunnel. The front end column lists which VME front end is used to provide the interface between that PLC and the control system. The last column lists the devices interfaced through the PLC.

**D. Ethernet**

The Pbar network is divided into two separate Ethernet networks. There is a controls network that is protected by the Accelerator Division controls firewall, and a general network that is not protected by the firewall. Both networks are separated from the general Fermilab network and Internet via an Accelerator Division border router which provides some additional security restrictions. The two Pbar networks are composed of a diverse set of components containing many different varieties of Ethernet including Gigabit, FastEthernet, Ethernet, Thinwire, Thickwire and 802.11 wireless, with network speeds ranging from switched 1,000 Mbit/sec all the way down to shared 10Mbit/s. Communication with Pbar network devices requires an understanding of which network both the accessing and destination computer are located on as well as the network path between the devices. Below is an outline of both the Pbar controls and Pbar general networks.

*Pbar Controls Network:*

The Pbar Controls network is a secure network for devices associated with accelerator components or the control system. The Accelerator Division controls firewall stops computers outside the firewall from direct access to computers inside and restricts computers inside the firewall from direct access to networks outside the firewall. Computers inside the firewall not only are restricted from accessing the Internet, but also are restricted from access to other Fermilab network devices including the Fermilab email servers. Access to the outside networks can be made indirectly through the use of a terminal server called Beams-TS.

Figure 9.4 shows an overview of the Pbar controls network. 1000Base-LH/LX gigabit Ethernet is run over multi-mode fiber optic cable from the controls Cisco 6509 router/switch in the Cross Gallery computer to a Cisco Catalyst 3508 switch at AP10. The “LH” in this Ethernet spec stands for "long haul" which is a special spec needed to extend Ethernet on long paths like that from the computer room to AP10. Ideally for these distances, it would be better to run the 1000Base-LH/LX over single-mode fiber optic cable, which allows even longer path lengths, but Pbar only has multi-mode fiber available. It turns out the distance between the computer room and AP10 is about as long as possible for stable Ethernet over multi-mode fiber.

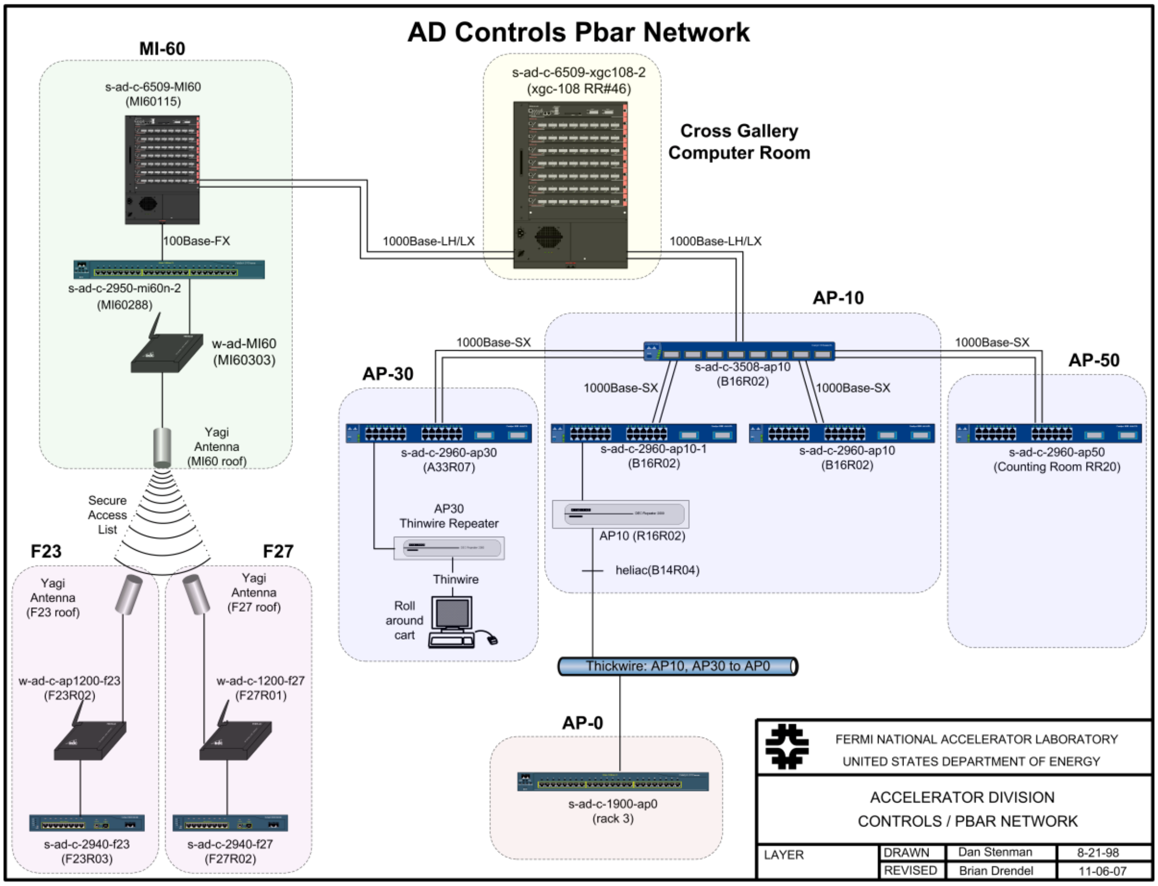


Figure 9.4 Pbar controls network

From the Cisco Catalyst 3508 switch at AP10, we branch out with 1000Base-SX gigabit over multi-mode fiber optic cable to two Cisco Catalyst 2960 switches at AP10, one Cisco Catalyst 2960 switch at AP30, and one Cisco Catalyst 2960 switch at AP50. In this case the standard 1000Base-SX gigabit is used instead of the long haul variety since the distances between services buildings are short enough. The service building Cisco Catalyst 2960 switches provide all of the 100Mbit/s FastEthernet and 10Mbit/s Ethernet connections over Category 5 (usually called Cat 5) cable. This is the standard network cable, which contains four twisted pairs in a single cable jacket with end connectors that look like extra wide phone jacks, used for most Ethernet connections.

*Controls Thinwire:*

At AP30, one of the Catalyst 2960 Ethernet connections goes to a 10Base2 repeater. 10Base2 is a legacy 10Mbit/s network that is most often referred to as Thinwire because it runs on thin flexible coaxial cable, often RG-58 or similar. On a Thinwire network, segments of coax cable with BNC end connectors are connected in series, BNC T-connectors allow the insertion of devices to the network, and the physical end of the network contains a 50-ohm BNC terminator. Thinwire is a shared network, meaning that all of the computer network cards on the network will see all of the traffic to and from all other computers on that network. As a result, if there are a lot of computers on a Thinwire nework, network performance will suffer. In this case, there isn't a problem since the portable ACNET console (often found at AP30) is the only device that is connected to this network. The Thinwire remains in place due to the legacy network card in the console as well as the existing Thinwire infrastructure that allows connecting the console to various locations in the building.

*Controls Thickwire:*

At AP10, one of the Catalyst 2960 Ethernet connections goes to a 10Base5 repeater. 10Base5 is another legacy 10Mbit/s shared network that is most often referred to as Thickwire because it runs on a rigid 50-ohm coax cable that is 0.375 inches in diameter, noticeably larger than the Thinwire mentioned earlier. Thickwire is used to get network to AP0 since no fiber optic cable path is available. It should also be noted that there is no Pbar general network at AP0, so the controls Thickwire is the only network available. A Thickwire network consists of a long Thickwire spool of cable, called a heliac, with network connectivity provided via transceivers attached to the cable. The transceiver is connected to the cable using what is called a vampire tap, which is a spike that pierces through the outer shielding of the cable to the center conductor, with other spikes contacting the outer conductor. The Thickwire at AP10 connects via a DEMPR (acronym for Digital Ethernet Multi-Port Repeater) to a heliac line that goes to AP30. At AP30 there is a heliac patch panel that includes the heliacs for AP10 and AP0. The heliac line that has the 10base5 from AP10 is a jumpered through the heliac panel to AP0. The distance is short enough that no repeater is needed at AP30. A transceiver is attached to the Thickwire at AP0 that connects to a Cisco Catalyst 1900 via an Attachment Unit Interface (AUI) connection. The AUI is a 15 pin, two-row D-style connector, with sliding clips that allow the connector to lock into place. The Cisco Catalyst 1900 switch provides 10Mbit/s Ethernet connectivity via the standard Cat 5 network cable.

*F23 & F27 Controls Wireless:*

The F23 and F27 networks are unique due to infrastructure limitations. There is no easy network path to these buildings. The closest buildings are F2 and AP0, neither of which currently have unused fiber optic network cables. Both buildings run shared 10Mbit/s Thickwire networks, so tapping off of either of these networks would not be desirable. The closest fiber optic network is at F0, which would be a long and expensive network run which involves finding a cable path along the Tevatron berm. To get network to these buildings, a unique wireless network solution was employed that involves connecting to the MI60 controls network via 802.11b wireless as is described below.

1000Base-LH/LX gigabit Ethernet is run over single-mode fiber optic cable from the controls Cisco 6509 router/switch in the Cross Gallery computer to another Cisco Catalyst 6509 router/switch in the south end of MI-60. Unlike, the network to AP10, the more current Main Injector fiber optic cable infrastructure allows the more ideal single-mode cable, which is better suited for long path lengths. The MI60 Cisco 6509 router/switch then connects to a Cisco Catalyst 2950 switch at the far north end of MI60 using 100Base-FX over multi-mode fiber optic cable. The 100Base in the spec is also called FastEthernet which runs at 100Mbit/s. From the Cisco 2950, Cat 5 cable is run to a Cisco Aironet 1200 802.11 wireless access point in the middle of the building. The access point is not used for wireless connectivity inside the MI60 service building, but instead is used to get the MI60 controls network out to F23 and F27. There is a long antenna cable that runs from the MI60 wireless access point to a Yagi antenna on the roof of MI-60. The MI60 Yagi antenna is a directional antenna that is pointed at single Yagi antennas on the roofs of the F23 and F27 service buildings. The F23 and F27 roof antennas connect to Cisco Aironet wireless access points inside of the F23 and F27 service buildings. The MI60 wireless access point has a secure access list that only allows wireless network connections from the F23 and F27 wireless access points. The wireless access points at both F23 and F27 connect to Cisco Catalyst 2940 switches which provide Ethernet connectivity via the standard Cat 5 network cable.

*Pbar General Network:*

The Pbar general network is used for desktop computers and other devices that are not part of the control system. Computers on this network are outside of the firewall. This means they have access to the Internet and most Fermilab networks such as the Fermilab mail, but are restricted from access inside of the controls firewall. To gain access to nodes inside the firewall, these computers need to use additional security tools such as SSH tunnels or the Controls VPN. When a computer is connected via the Controls VPN, it becomes a part of the controls network and no longer has outside network access until the VPN connection is disconnected.

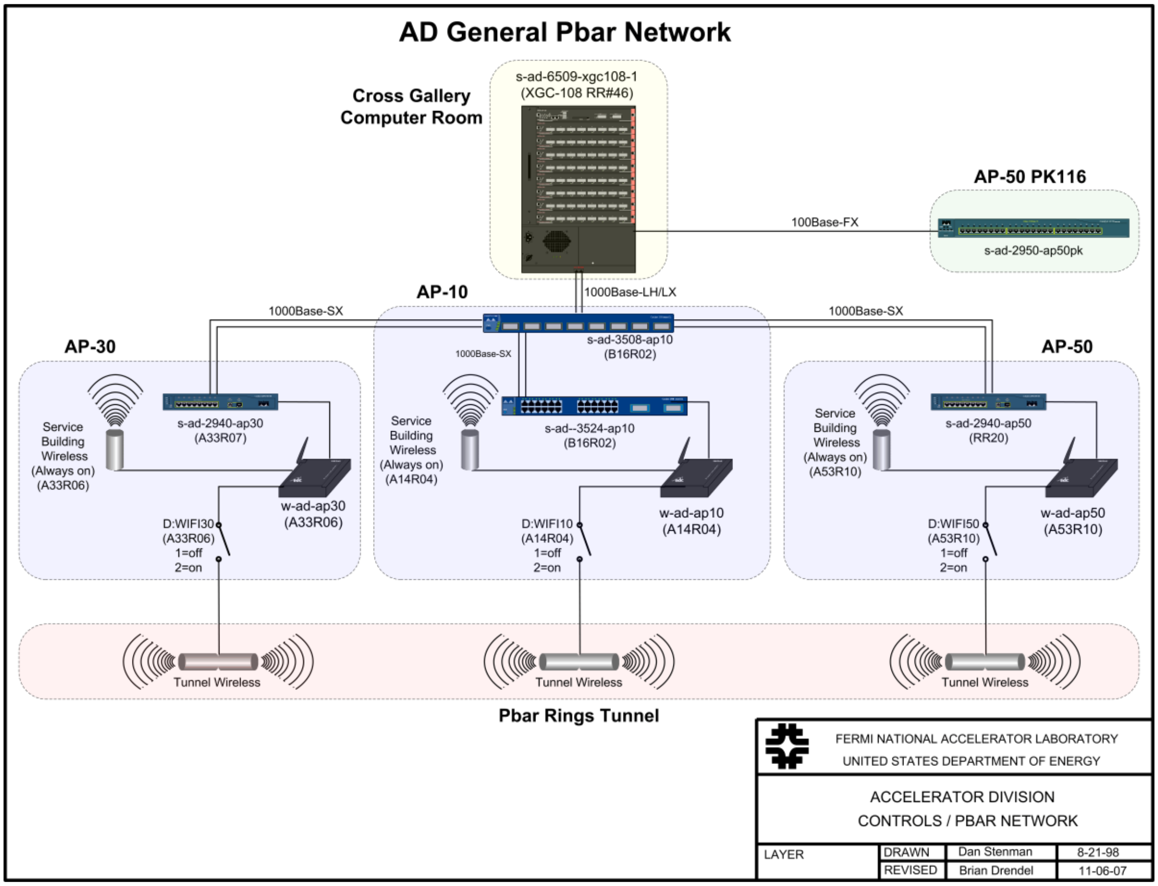


Figure 9.5 Pbar general network

Figure 9.5 shows an overview of the Pbar general network. 1000Base-LH/LX gigabit Ethernet is run over multi-mode fiber optic cable from the general Cisco 6509 router/switch in the Cross Gallery computer to a Cisco Catalyst 3508 switch at AP10. From the Cisco Catalyst 3508, we branch out with 1000Base-SX gigabit over multi-mode fiber optic cable to a Cisco Catalyst 3524 at AP10, a Cisco Catalyst 2940 at AP30, and a Cisco Catalyst 2940 at AP50. These three Cisco network switches provide 100Mbit/s FastEthernet and 10Mbit/s Ethernet connections over the standard Cat 5 network cable. It should be pointed out that the AP50 network rack is in the AP50 counting room.

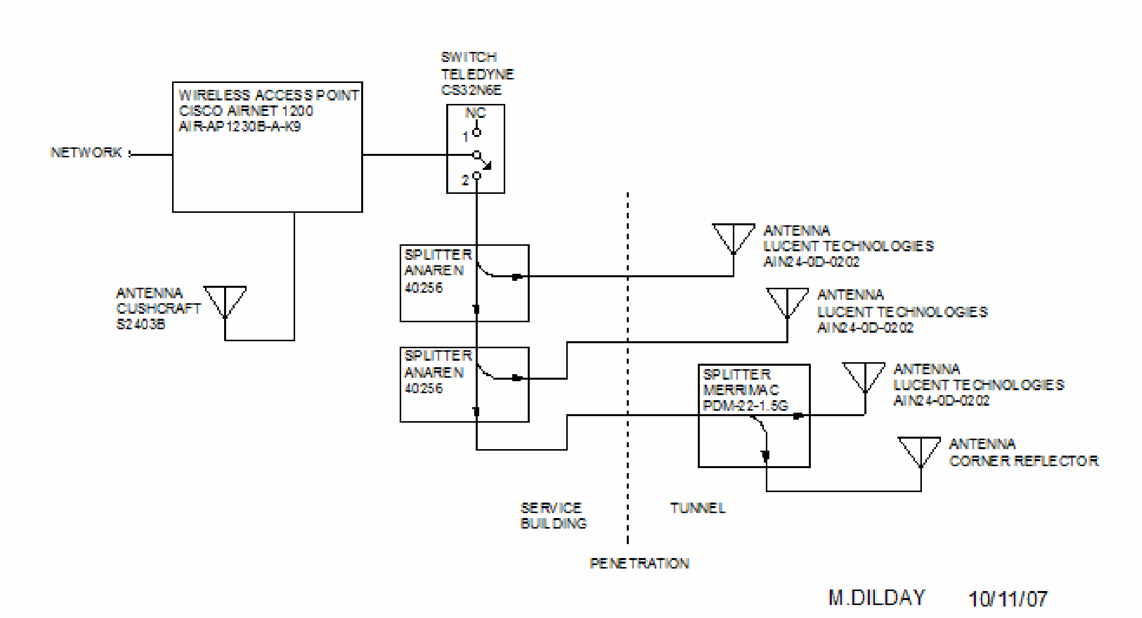


Figure 9.6 Pbar tunnel wireless details

At all three service buildings, the Cisco network switch connects to a Cisco Aironet 802.11 wireless access point which provides Pbar general network to both the service building and to the tunnel. One unique concern is the potential for unwanted interaction between the 802.11 wireless, which runs at 2.4 GHz, and our 2-4 GHz stochastic cooling systems. As a result, switches were installed at each service building to allow disabling or enabling the wireless antennas in the tunnel. When the ACNET parameters D:WIFI## (where ## is 10, 30 or 50) is set to 1, the switch is open and the tunnel wireless is disabled. When set to 2, the switch is closed in and the tunnel wireless is active. The wireless in the upstairs service building is always on.

Figure 9.6 shows a more detailed view of the Pbar tunnel wireless system. It is of note that each antenna line going to the tunnel is split into three antennas and a corner reflector. This allows wireless coverage all the way around the Pbar rings.

References

1) Conversations with Dan Stenman

2) Conversations with Greg Brown

3) Conversations with Dave Peterson

4) Input from Greg Vogel

5) Dan Stenman, AD/Controls Pbar Controls and General Network Map (March 2007). Expanded and broken into two drawings for this chapter.

6) Mark Dilday, Pbar Wireless Diagram (October 2007)

7) Dave Peterson, PLC Troubleshooting and Programming Instructions, www-bdnew.fnal.gov/pbar/documents/Eng_Info/PLC%20Instructions.html (June 2007)

8) Dave Peterson, Use of the Remote +5V Power Supply for PLC CPU's, wwwbdnew.fnal.gov/pbar/documents/Eng_Info/PLC%205%20volt%20remote%20backfeed.htm (October 2006)

9) Dave Peterson, Embedded Systems and Hardware Support, www-bdnew.fnal.gov/pbar/organizationalchart/peterson/Pbar%20Embedded%20Systems.ppt (November 19, 2003)

10) Ralph Pasquinelli and Wes Mueller, Antiproton Source Stochastic Cooling Diagrams, drawing numbers: 8000-ED-288110, 8000-ED-288111, 8000-EE-288112, 8000-EE-288113, 8000-ED-288274, 8000-EE-288114, 8000-EE-288115, 8000-EE-288116, 8000-EE-288117, 8000-ED-266130, 8000-ED-266131, 8000-ED-266132, 8000-EE-208480, 8000-EE-170265, 8000-EE-170266, 8000-ED-170271, 8000-ED-170272, 8000-ED-170273, 8000-ED-288201, 8000-ED-288202 (2002 – 2007).