Raspberry Pis in the wSMA

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What Raspberry Pis bring to the wSMA

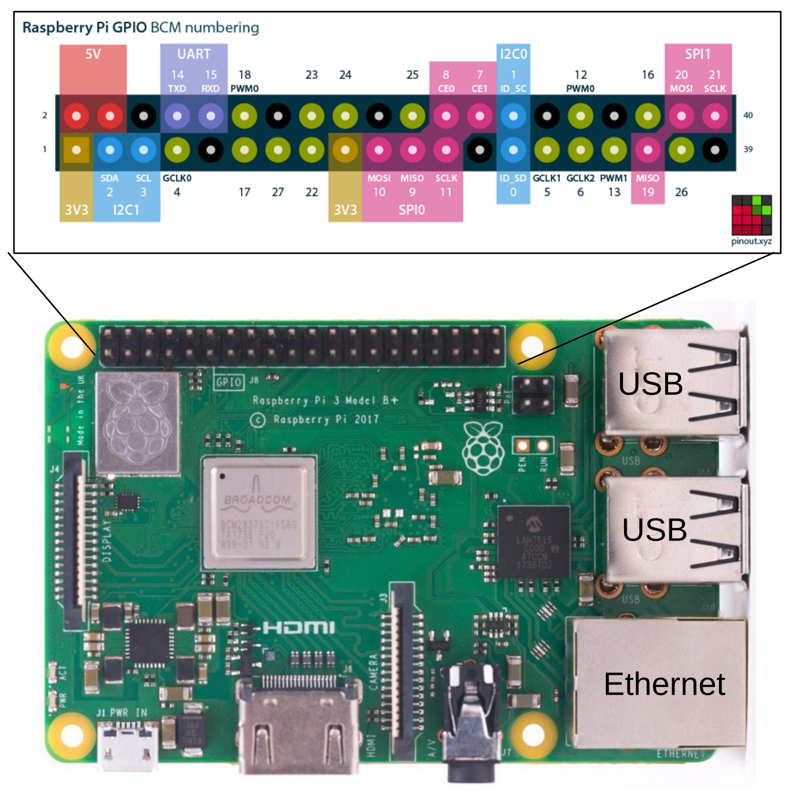
The Raspberry Pi computer platform has built a considerable following among hobbyists and educators since its first release in 2012. This is because of its low price, small form-factor, and – most importantly – the ease of connecting external hardware and interfacing software to that hardware within the Raspbian Linux operating system.

The latest Raspberry Pi 3B+ consists of a Broadcom System on a Chip (SoC) computer assembled on a small PCB with a WiFi/Bluetooth module (which will be disabled for our uses), and a number of interfaces, including a native camera and display interface, SD card slot, HDMI, USB and Ethernet.

The most important interface for our applications is the 40 pin General Purpose Input/Output (GPIO) interface, which gives access to a number of low level buses that communicate with the SoC directly.

This GPIO interface allows the easy construction of custom daughterboard or "Hats" with custom hardware such as ADC/DACs, serial communications and signal line level switching designed for specific purposes.

For the wSMA, Raspberry Pi based hardware offers a single computing device that can be easily and quickly programmed in Python, C and other languages using standard Linux software infrastructure, and that can form the basis of much of the custom electronics required to control the new receivers and ancillary hardware within the wSMA system.

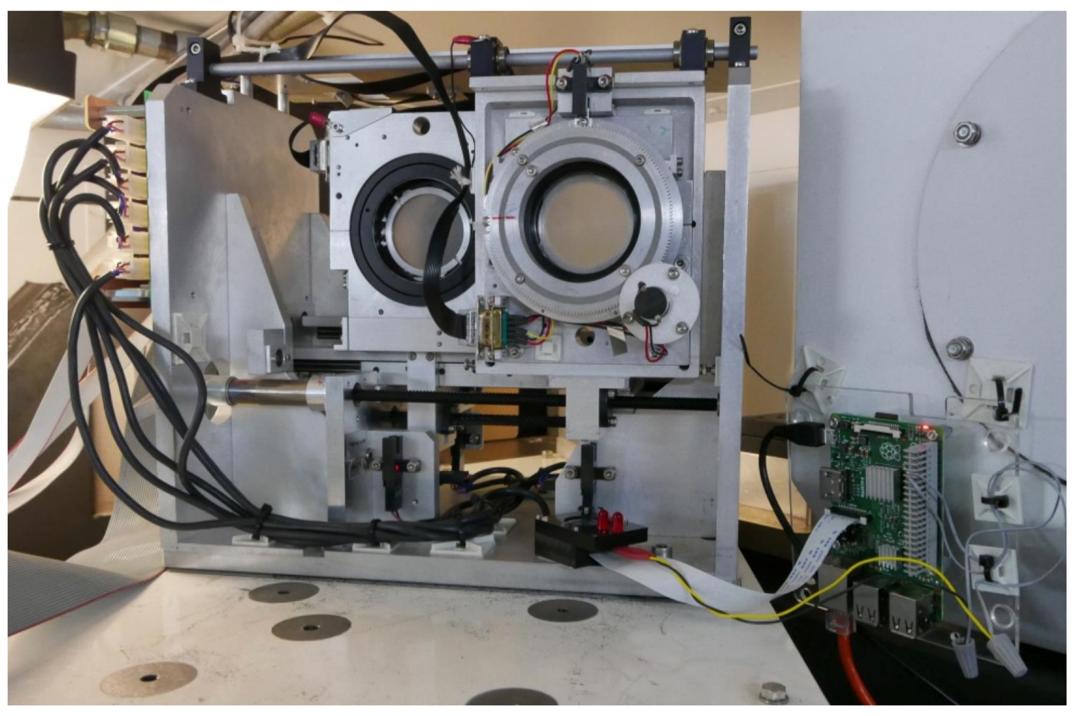


A Raspberry Pi model 3b+ showing the main connectors, including the 40 pin GPIO connector that gives a number of different buses for communication with "Hats" and daughter boards.

Pi Based Hardware In Action

We have used Raspberry Pis as the basis of several small instruments deployed at the SMA for diagnostic purposes.

The availability of camera hardware and open software for the Pi has allowed us to quickly develop and deploy these instruments.



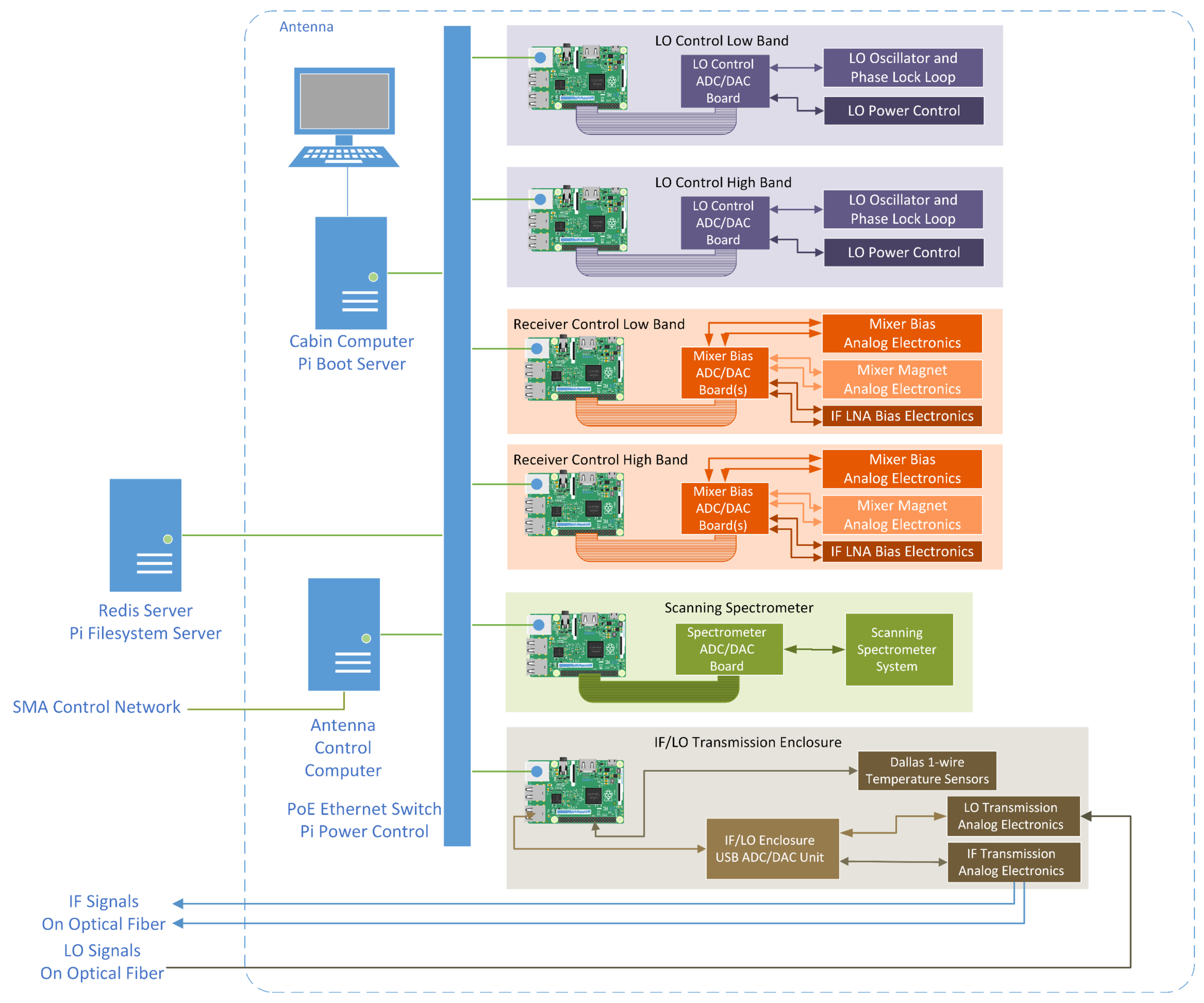
Above: A Raspberry Pi (lower right) with attached camera has been installed on the SMA to monitor the position of the waveplates in the Waveplate/Cal Load assembly. This camera allows the angular scale on the waveplate mounting hardware to be read while characterizing the instrumental polarization of the SMA during dual-polarization testing.

Right: A reference optics insert has been built that uses a touch-screen integrated with a Raspberry Pi and dual camera setup. The cameras are used to compare the positions of the Combiner Grid and Mirror with reference images overlaid on the touchscreen to determine the nominal encoder positions for the Grid and Mirror. Since this system is powered with a USB power bank and is equipped with a touchscreen user interface, it can be used as a stand-alone unit to calibrate any receiver with minimal configuration.

Raspberry Pis in the wSMA

We are currently planning to use Raspberry Pis to control a number of systems in each SMA antenna, both for receiver control and for IF/LO signal monitoring and control.

A Pi will control each of the two receiver front ends (two SIS mixers, two magnets and two IF LNAs in each front end), with another Pi controller each of the two Local Oscillator units.



One Pi will run the scanning spectrometer (see right for details). Each of the above Pis will use a custom designed daughter board to provide the fast ADC/DAC required to operate these systems.

One further Pi will control the IF/LO electronics in the IF/LO Enclosure, which receives LO signals on optical fiber and sends them to the LO units, and which takes IF signals from the receivers and puts them on optical fiber for transmission to the SMA Control Building. This Pi will use a commercial off-the-shelf USB ADC/DAC unit to provide the large number of low data rate control signals and monitoring required. Temperatures throughout the enclosure will by monitored by Dallas 1-wire temperature sensors, which can be trivially connected to the Pi's GPIO interface.

As discussed below, the Pis will be booted from a boot server in the Antenna Cabin, and will mount their application software from a file server in the SMA Control Building.

Communication between the Pis and the SMA control system will be via the Redis system currently being implemented, although there may also be a direct connection required to the Antenna Control Computer.

Additional Pis may be used for controlling the Receiver Optics, or the Cal Load/Waveplate units

Above: The prototype Scanning Spectrometer system developed to measure the system temperature and gain of the wideband front-end receiver as a function IF frequency. This information will be used to weight the different frequency channels when forming continuum images from wSMA data, as well as for diagnostic purposes when setting up the receiver systems.

The two IF signals from the front-end receiver enter on the top right, are amplified and gain controlled before being filtered by YIG tunable filters and then detected by diode power detectors.

The Raspberry Pi with its daughter boards on the top right samples the detector outputs and provides the control signals to sweep the YIG filters. The sampled spectra are then sent to the SMA control system via Redis over the SMA network.

Testing reliability on Maunakea

The SMA site near the summit of Maunakea is a difficult environment for general purpose electronics and is well outside the usual testing range of consumer grade electronics. The low atmospheric pressure (~660 mBar) and dry atmosphere reduces the efficiency of air cooling both chips and power supplies, while mains power supply fluctuations and outages are common.

Since reliability of hardware is critical to keeping all eight SMA antennas working and the array operating efficiently, we are carrying out an extensive testing program before deploying Raspberry Pis in mission critical hardware.

Racks of six or seven Pis (known as "Pi Patches") have been running in two SMA antenna cabins for several months running simple scripts designed to load the CPU so that significant power consumption and heat dissipation occurs. During this time, no failures have been observed.

In addition to this testing, we have made a number of decisions that should reduce the likelihood of hardware or software/firmware failure, and simplify replacing Pis or their accessories when one fails.

1) All Pis will be fitted with aftermarket heatsinks on the SoC and Ethernet control chips to help control thermal loads.
2) The Pis will be powered by Power over Ethernet using remotely managed PoE switches and off-the-shelf PoE splitters to ensure that the Pis can be remotely power cycled.
3) Pis will be netbooted from bootservers in the antenna cabin and use remotely mounted file systems to avoid the known issue of SD Card corruption if power failure occurs during writing.

The most recent version of the Raspberry Pi Patch. This features 7 Pis with separate external Power over Ethernet (PoE) splitters and power supplies. Each Pi will be connected to a PoE switch that provides both Ethernet connectivity and power to the Pi, which can be switched on and off by the PoE switch.