

IF system upgrade for the SMT V.5

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Introduction

The IF system at the SMT needs work.

The current IF system is a result of 10 years of organic growth. The IF frequency changes several times from the receiver to the spectrometers, and the signal snakes across the building. It is optimized for the AOSes and the vintage 1-2 GHz wet-dewar receivers. The 4-6 GHz IF band is an afterthought.

This document discusses a proposal to improve the IF signal processing at the SMT. The need for this proposal is a result of the new sideband-separating receiver that produces four channels of IF signal at 4-8 GHz. The current IF system at the SMT is unable to handle such signals, and has been in need of improvement for some time.

This document is split into two parts: the IF infrastructure and the spectrometer interface.

The IF infrastructure is considered to be that equipment which takes signals from the receivers at both flanges and passes them to the spectrometer interface in the third floor computer room. The IF infrastructure is currently implemented as two channels at 3-4 GHz. It is proposed to instead use four channels at 4-8 GHz.

The spectrometer interface is considered to be that equipment which receives the IF signals in the computer room and processes them for use by the individual spectrometers. This processing is currently done by some equipment in the AOS controller rack and in the filterbank racks. It is proposed to add equipment to render the four 4-8 GHz IF signals usable by the existing spectrometers. Some modifications to the existing spectrometers may be necessary for optimal flexibility.

The current situation

There are currently two receivers on the left flange, both working at 1-2 GHz. One of these receivers, the 345 GHz receiver, is being converted to the 4-6 GHz IF band. We may add future receivers to this flange in the 4-8 GHz band.

The left Rx room equipment racks contain an IF/LO switch that is used to select the receiver. Also present is a box called the TP/attenuator/converter box that amplifies the IF signal, converts it to 3-4 GHz, and attenuates the signal according to commands received from the HOST1 computer. This box provides a pair of analog total-power measurement signals that are used for continuum observing and to calculate Y-factors for the receivers.

The telescope currently has two total power detector (TP)/attenuator boxes: one on the left Rx room and one in the JT receiver frame in the right Rx room. The one in the left Rx room is older yet is currently used for receiver calibration, as it has a usable software interface. The one in the JT rack has or had some TP data quality issues.

The left Rx room total-power display and IF converter box was made by MPI. It converts the receiver IF in either the 1-2 GHz or 4.5-5.5 GHz band to 3-4 GHz. This frequency band was proposed as a standard about 10 years ago, but was never implemented in a receiver. It is compatible with the AOS spectrometers. This box is still usable with the left flange legacy receivers. It would need reworking for use with any new 4-8 GHz receivers, however.

The dual-channel 4.5-5.5 GHz TP/attenuator box in the JT receiver frame was built a few years ago. Its total power display is sufficient for tuning but not for a facility continuum instrument, and it contains 1 GHz wide IF filters. Its lack of support for four channels is a major problem for use with the new four-channel receiver system.

The current JT-FFB IF path sends the 5 GHz signal from right Rx room to left Rx room, through the IF/LO switch, through the TP/attenuator/IF converter down to 3-4 GHz, from the left Rx room down to the AOS rack in the computer room, through the backend switch in AOS rack, through a converter to 5 GHz and through the ceiling to FFB rack.

When using the ALMA receivers, the 4-8 GHz receiver passband exceeds the range of the 4-6 GHz spectrometers. This problem has been solved temporarily with a cobbled-together IF frequency conversion system consisting of a pair of 12M MAC IF converters in line with the filterbanks, using a pair of HP synthesizers for setting the AOS center frequencies.

IF system upgrade

The proposed IF system

The upgrade plan for the IF infrastructure is to provide a facility total power monitor box in the right Rx room for use with all receivers. The reason to locate it there is to provide the shortest IF signal path possible for all receivers. This new box will provide for four IF channels at 4-8 GHz band. It will select the left or right flange receiver and pass the IF signals down to the spectrometer interface in the computer room on the third floor.

An alternative that would reduce the cost of the system is to use the current TP box for the legacy receivers on the left flange and the new receiver TP box for total power on the right flange, thereby eliminating the facility TP box in the right Rx room. We would still need a left/right Rx select switch set, which could be located on the third floor at the input to the channel steering box.

The AOS spectrometers are currently at an undesired frequency range of 3-4 GHz. It is proposed to modify them to use the frequency bands currently used by the filterbank and chirp spectrometers (5 GHz wideband, 2 GHz narrowband) so that all backends are compatible with each other. This will increase flexibility and ease of maintenance, as any backend may be substituted for another with minimal effort.

The description below is seen as providing the needed flexibility for handling a variety of receivers currently or soon to become available. The total bandwidth of the IF system is 16 GHz. The current array of spectrometers only covers 4 GHz of bandwidth, but it is possible to add spectrometers in the computer room to cover the wider bandwidth in front of the proposed spectrometer interface.

IF signal specification

A standard IF power level will be defined as part of the facility upgrade, with the purpose of allowing PI instruments to be easily specified and to make testing easier. The proposed power level is -20dBm total power over the receiver bandwidth. The receiver is expected to contain a bandpass filter to limit its IF signal to the 4-8 GHz band. Receivers with narrower bandwidth are expected to filter their output so that no out-of-band power is emitted. The signal slope shall be no more than +/-3dB over the receiver's IF band.

Further discussion of this matter has led to consideration of a power level more like -30dBm over the receiver bandwidth, which would facilitate the use of 10dB pads instead of isolators from the final amplifiers to the output connectors. This gives the advantage of better VSWR and therefore lower passband ripple, which is essential to flat baselines in the position-switched observing mode.

Left Rx room

The current left Rx IF processing consists of a converter/TP/attenuator box. This box accepts 1.5 GHz input and converts to 3-4 GHz. When we convert the AOSes to 5 GHz, we will have a leftover 3-4 to 5 GHz converter from the AOS rack. This will be placed after the left RX TP/attenuator box to produce 5 GHz for the telescope IF.

Some means of selection switch between the two left receivers is needed. We may keep the existing left Rx switch box, since it works and is integrated to the telescope. Eventually, when we produce 4-8 GHz receivers for the left flange, we can build a TP/attenuator box identical to the one for the ALMA receiver to use with the left flange receivers.

The left Rx room has a computer, HOST1, is due to be replaced with a computer similar to the JT receiver tuning computer.

Right Rx room

The right Rx room is characterized by using receivers each of which is a self-contained unit that gets bolted to the flange for use. As such, each receiver tends to be self-contained with regard to tuning and control equipment. Therefore, it makes sense to continue this tradition by incorporating all necessary tuning and power monitoring equipment into the receiver frame.

The right receiver is assumed to put out a signal of one to four channels at 4-8 GHz. There will be no facility receiver selection switch for this side - if a receiver frame has several receivers, it will be expected to contain the switch. There will, however, be a left/right Rx IF switch in the TP/switch box to select which flange is currently being used.

The right Rx is expected to have its own power monitor usable for tuning the receiver. A display, easily visible to the operator during the tuning procedure, is expected to exist on or near the receiver frame. The tuning computer display is the prime candidate for this display. To this end, it would be sensible to equip the tuning computer with a portable LCD display that can be easily moved around and clamped to any convenient support arm as needed.

The 1.3mm ALMA receiver will need its total power/attenuator box upgraded to cover the 4-8 GHz band and to contain four channels rather than two. A new box will be built to provide enhanced stability and ease of access to all parts. If it is decided to use the receiver TP box for the facility TP measurement, then this box will also have an analog facility TP output leading to the DBE computer.

IF selection and Total power

A new four-channel total power/switch box will be built to select between left flange and right flange receiver IF signals. A set of high-quality total power detectors will provide continuum power signals to the DBE computer for observations, pointing and Y-factor measurement. Total power monitor displays will be provided, as well as BNC outputs for connecting oscilloscopes or meters.

If this box is not built, then the switching function will be built into the channel steering box in the third floor rack and the TP function will be provided by the existing TP box on the left Rx room and by the new 4-channel TP/attenuator box on the right receiver flange. Note that the DesertStar receiver has its own TP function already, so the DBE connection is not needed there.

New IF cable routing

The proposed IF path sends the four 4-8 GHz signals from the receiver selection switch in the left Rx room and from the right flange to the new 4-channel TP box in the right Rx room to the new spectrometer interface to be placed in the AOS rack in computer room. Four IF cables are needed to send the signal from the new TP/attenuator box in the right Rx room to the AOS rack on the third floor.

If we choose to omit the TP/switch box in the right Rx room, then we'll need two sets of IF cables to a left/right Rx selection switch on the third floor.

Spectrometer interface

We now have in hand one broadband receiver developed for ALMA, and another is on the way. The output band of these receivers is two channels each of 4-8 GHz. Since our current spectrometers do not support this band, we are limited to using such receivers at 4-6 GHz using the current spectrometers.

The proposed spectrometer interface has the task of converting the four 4-8 GHz IF channels to frequencies usable by the existing AOS and FFB spectrometers. Since there are only four GHz of spectrometer available to observe the 16 GHz of available receiver IF bandwidth, some hardware has to be built to steer the four IF channels to the various spectrometers at the frequencies that they will accept. Since astronomers may desire either dual or single sideband spectra from one or both channels in varying bandwidths, the spectrometer steering equipment must be agile in both channel selection and frequency.

The spectrometers

The FFB filterbank spectrometer system input consists of two IF channels over a 4-6 GHz band. These two inputs are further split up and subdivided in the filterbank racks to feed eight 1-MHz resolution filterbank sections of 256 MHz each, two 250-KHz resolution filterbank sections of 64 MHz each and two 40 KHz resolution, 200-MHz wide chirp spectrometers.

The AOS input is three channels over a 3-4 GHz band. There are two 1 GHz wide AOS units called A and B, and a 250 MHz wide unit called AOS C. AOS C currently has an input centered at 3.5 GHz

It is highly desirable to eliminate the 3-4 GHz band from the system, as no other devices use it. The first modification proposed is to convert the two wideband AOSes to 5 GHz input band, and to convert AOS C to 2.0 GHz input frequency.

The proposal to connect the above spectrometers to the four 4-8 GHz IF channels involves building a channel steering box to select which IF signals are observed and a frequency steering box to convert 1 GHz wide portions of the selected IF channels to the frequency range expected by the spectrometers. These two items are described in detail below.

Channel steering box

The four IF channels must be routed to the four wideband spectrometer channels. This could be as simple as a USB/LSB selector switch, or it can be a switching matrix that allows any combination of IF channels to go to the spectrometers. Analysis of the requirements leads to the conclusion that the matrix switch described below provides both the most flexible solution and the lowest implementation cost.

The proposed solution is to build a switch box that allows each spectrometer to observe any of the four IF channels from the receiver. This would be built from four four-way power dividers and four SP6T RF switches. It would be controlled by computer.

The following matrix shows several useful combinations of receiver to spectrometer switching...

```
both SB dual pol 500MHz BW all FFB
freq          4          5          6          7          8
USB A                FFBA, NFBA
USB B                FFBB, NFBB
LSB A                FFBC, CTSA
LSB B                FFBD, AOSC
```

```
both SB dual pol 1 GHz BW
freq          4          5          6          7          8
USB A                AOSA, CTSA
USB B                AOSB, AOSC
LSB A                FFBA, NFBA
LSB B                FFBB, NFBB
```

```
USB dual pol 2 GHz BW
freq          4          5          6          7          8
USB A                AOSA NFBA AOSB
USB B                FFBA NFBB FFBB
```

```
LSB dual pol 2 GHz BW
freq          4          5          6          7          8
LSB A                AOSA NFBA AOSB
LSB B                FFBA NFBB FFBB
```

```
both SB single pol 2 GHz BW 128MHz narrow BW
freq          4          5          6          7          8
USB A                AOSA AOSC AOSB
LSB A                FFBA NFBA, B FFBB
```

```
USB single pol 4 GHz BW two narrow lines
freq          4          5          6          7          8
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Frequency steering box

Since the AOSes are stuck at 3-4 GHz and the filterbanks at 4-6 GHz, both will need some form of IF conversion to achieve steerability over the 4-8 GHz band. This requires dual-conversion IF processors to allow tuning over such a broad range without worrying about IF images.

Several methods have been contemplated. The current choice uses four IF converters left over from the decommissioned 8-beam MAC IF processor to provide the frequency conversion of a 1.2 GHz segment in the 4-8 GHz IF band to 5 GHz center frequency.

The AOS input frequency of 3-4 GHz is determined by an internal brick oscillator. Since we would need to supply a separate second LO oscillator to accommodate this frequency range, a conversion of the AOSes to 5 GHz input band is being considered. The advantage is that all spectrometers share the same input frequency band, so that switching between them becomes easy.

There comes the question of what to do with the 250KHz filterbanks and the chirp units and AOS C. The scientists agree (per 5/31/06 ARO staff meeting) that the narrow spectrometers' tuning may be fixed at the center of the wideband spectrometers.

The approach considered here is to piggyback the narrow spectrometers on the wide spectrometers' IF converters. We just need to make sure that the frequency band selected for the wide spectrometer will overlap completely with the narrow spectrometer. The way to do this is to make the filters in the IF converters be more than 1 GHz wide, perhaps 1.2 GHz. Each narrow spectrometer then has a switch to select which of two wideband signals to be piggybacked onto.

AOS C will require its steering to work if it is to be used at the crossover point between AOS A and AOS B when stacking them for 2 GHz bandwidth. There is some steering capability for AOS C in its IF processor box, but the computer control has not been connected. A serial port and some software is needed. There are two filters in that IF processor box, one of which is useful at the center of the 3-4 GHz band but the other may need to be replaced with a filter in perhaps the 3.8-4.2 GHz band.

An alternative is to reconfigure AOS C to accept a 2.1 GHz input frequency, and use the CTS IF processing in the filterbank for frequency steering within the 4-6 GHz band. AOS C would replace a CTS unit. This makes sense now, as we currently have only one CTS unit on hand. In the future, if a CTS unit shows up, then we can declare one of the CTS or AOS C spectrometers to be a spare.

Filterbank IF distribution box

A new box may be added to the filterbank system to allow the use of all four IF channels to the filterbanks, for those observers who wish to have the frequency stability of the filterbank for all channels or for times when one or more AOSes is not working. In order for this to work, the AOSes must be converted to 5 GHz input.

This box contains four 3-way power dividers, two 2-way dividers and two transfer switches. It allows steering of pairs of IF signals to each filterbank rack. This is not useful without the following modifications to the filterbank IF processors to allow the use of four IFs by the filterbank system.

Filterbank IF processor modification

The four channel 500 MHz filterbank option is not achievable without some modifications to the FFB IF processors to allow selection of IF A by 512 channels and IF B by the other 512 channels. Five 2-way splitters and two more relays are needed per IF processor. The parts are not expensive, but it's a bit of work to retrofit.

The narrowband IF processor similarly needs work to accept four IF inputs. It requires five two-way splitters to provide four inputs and an extra relay to select the zero/test mode for the new input path.

AOS A,B LO upgrade

The AOS A and B use 5620 MHz LO bricks in the IF processor chassis in the chilled rack. Each of these bricks uses an internal reference and is not alarmed to the telescope control system, so there's no external indication of an oscillator problem. They also run at a frequency that's different from the filterbanks, necessitating the addition of a second LO in the IF converter to accommodate them.

It is proposed to convert these IF processors to use a 7100 or 7120 MHz LO provided by a brick oscillator fed from the station clock source. This will bring all spectrometers to a common 5 GHz input band and will allow us to monitor the LO etc.

The work involved is to buy the new LO(s), install them into the AOS IF processors, and add the monitor bits and reference inputs.

AOS C converter

AOS C is an odd duck. It provides only one polarization, and its 3-4 GHz input IF converter is ill-equipped to deal with the new IF frequency range.

As such, it is proposed to operate AOS C from the currently-unused 2.0 GHz chirp output of the FFB IF converter. This requires a fixed LO somewhere in the range of 2.58-2.74 GHz. Doing this would eliminate the current AOS C converter box.

When a second chirp spectrometer is delivered, we will consider the AOS C to be a spare narrow-band spectrometer and keep it on standby.

AOS BE switch box

This IF switching box was designed for the AOS spectrometers only, and it operates at 3-4 GHz. It currently swaps IF A vs IF B. It is proposed to eliminate the AOS BE switch from the system, as its only purpose in the new system is for locating faults in the system. It also has the problem of being limited to the 3-4 GHz band, which is being eliminated from the telescope.

Work to do

Capabilities and costs

There are several options with regard to the flexibility of the system; adding flexibility increases cost. There are also time limitations in building new hardware and integrating it into the telescope. We will not be able to completely upgrade the IF system by October; we don't have enough manpower and the needed new equipment takes too long to build and fully test.

The cost of certain observing modes is as follows:

Lowest: Two IF channels, one GHz per channel, <6 GHz IF frequency

Higher: Two IF channels, two GHz per channel, <8 GHz IF frequency, manual sideband selection

Higher: as above with computer sideband selection

Higher: Four IF channels, one GHz per channel, AOS on two channels and FFB on the other two

Highest: Four IF channels, 500 MHz per channel, FFB on all four channels

The narrowband spectrometers are proposed to be implemented on four IF channels in the final system, but may be used on only two IF channels to save time and money.

Schedule

The proposed hardware additions may be implemented in stages to ease the financial and engineering time burden. Following is a list of the order in which the work ought to get done. The sequence is designed to allow the use of the telescope with the old equipment while the new equipment is being built and checked out. The goal is to not do anything that will completely break the telescope if a new piece of equipment fails to be completed on time.

Upgrade telescope IF from 3-4 to 4-6

Summer 2006

- * Use JT TP signals for JT pointing, focus
- * Modify AOS A,B to 5 GHz
- * Modify AOS C to 2 GHz
- * Modify left Rx upconverter to 5 GHz

Two IF channels at 4-8 GHz

Summer/fall 2006

- * Build the MAC IF converter with two working channels
- * Build 4-channel TP/atten box for right Rx

Four IF channels at 4-8 GHz

Fall 2006

- * Build 4-channel facility TP box
- * Get four IF converters working
- * Build channel steering box

Narrow spectrometers usable on four IF channels

Winter break 2006/07

- * Modify narrow FFB IF processor for four inputs

Wide filterbanks usable on four IF channels

- * Build FFB IF switch box
- * Modify wide FFB IF processors for true dual input

The legacy receiver switch and converter are minimal effort, since we have the needed equipment on hand; it just needs to be rearranged in the boxes.

Computer interfaces

To control all these IF processors we plan to make, we need a PC board that will connect to the network and to a bunch of RF parts such as synthesizers, relays, DC signals, etc. It would be nice to make a single board design that can be used in every box we build for the foreseeable future.

RS-232 serial I/O is an obvious choice, as it has lower complexity and RF emissions than Ethernet etc. However, there are now Ethernet to serial port adapters such as the Lantronix XPort for \$50 which provide a complete TCP/IP stack in an Ethernet connector shell.

The CPU could be a simple PIC or other such microcontroller. It has to interface to many parallel I/O bits and perhaps an ADC or two. It needs a serial I/O port for communication with the XPort device. The code could be assembly language or microcontroller C. There may well be different code for each controller board, since it may have to talk to several types of synthesizers etc.

The relay control may be as simple as several SN75468 Darlington driver chips driven from 8-bit 74HCT273 registers. The synthesizer control would typically be an SPI or similar serial bus.

Revisions

V5 6/12/06:

1. The possibility of using the receiver TP boxes for facility TP was added
2. The description of work to make the individual boxes was removed to separate documents
3. The other IF converter options were eliminated as they were rejected at the 6/1 engineering meeting.

V4 6/2/06

1. Added power levels
2. Added options to the IF converter