



NATIONAL RADIO ASTRONOMY OBSERVATORY MEMORANDUM

DATE: November 18, 2002
FROM: Ron Maddalena and Dave Hogg
SUBJECT: Scope of I.F. balancing project

The commissioning plan that was distributed a few weeks ago has a project that is labeled "I.F. Balancing". This memo describes the scope of the first stage of the project and, in particular, how requirements will be obtained, and what resources and efforts might be required. We hope that the following outline will determine a strategy as well as help in setting aside resources.

I.F. Balancing Defined

A large fraction of the current proposal queue are for observations toward strong continuum sources, where proper setting of I.F. attenuators is important. The optical drivers in the I.F. rack and all of our backends only work well when the input power levels are within an optimum range. To achieve these optimum levels requires setting attenuators at various places in the I.F. chain of the GBT. In many types of observing, the difference in power from one source to the next, on and off a source, or at different elevations will drive some devices out of range unless attenuators are changed somewhere in the system. Unfortunately, changing attenuators will alter bandpass shapes, possibly introducing undesired baselines shapes, and observing becomes a compromise of trying to achieve proper power levels while maintaining good baselines.

The first stage of the I.F. balancing project is to provide requirements on where and how attenuators in the system are to be adjusted. The rest of this document will concentrate on what tests and information we will need in order to provide sufficiently detailed requirements. Once requirements are known, we can then better plan on how I.F. balancing can be automated or presented as options to the observer. Finally, the necessary documentation must be written, the applicable software written followed by a round of astronomical testing.

Obtaining Requirements

We currently do not have enough information or experience to create a set of requirements that are detailed enough for someone to implement. To obtain this information, we have broken the problem down into the following steps:

1. Determining how far out of range can a backend be before noise characteristics and calibration suffer.

The first step is devoted to finding out how badly one can set the input power level to a backend before the data suffers. One way to determine the range of usable input levels is to do On-Off observations of a source with well-know characteristics and vary an attenuator in front of the backend by 1, 2, 3, 4, 10 dB and noting at what attenuator values the data start to get corrupted.

Dave Hogg has already obtained a data set for the Spectrometer where he varied the attenuator settings in the Converter Rack. Dave has not yet had the opportunity to fully explore the data but his preliminary examination suggests that the Spectrometer can be run something like 3 dB out of

range before the data suffer. His results suggests that I.F. balancing will need to occur whenever one uses On-Off observing with any source whose source temperature is comparable to the system temperature or when observing multiple sources at very different elevations at high frequencies.

We will try to determine from the engineer what the range of input power can be for all of the backends and, if deemed necessary, determine the range empirically.

2. Determining optimum range in power levels for the I.F. Rack

The optical drivers in the I.F. rack must have sufficient input power so as to minimize their contribution to the noise level in an observation. Yet, they cannot have too much input power or they will start to saturate or go nonlinear. Currently, the I.F. rack has an automatic balancing feature where attenuators are set to achieve a specified input power level. Almost everyone has been using 1 Volt as the target balance level. Yet, for some types of observing this is far from the optimum level.

For example, in On-Off or beam-switched observing toward a moderately strong continuum source, one should set the I.F. Rack power balance point such that, when on blank sky the input power level is high enough so as to not add noise but low enough so that, when on source, the optical drivers are still linear. In this situation, the optimum blank sky target level may be less than 1 Volt.

If the source is a very strong, then no one attenuator setting can achieve the goal of low noise when off source and linear behavior when on source. In these cases, beam switching would always produce corrupted data and On-Off observing will require resetting the I.F. Rack attenuators between the on and off observation. Currently, I.F. Rack balancing can only be done through CLEO and cannot be coordinated with the start of observations. Probably at some point we will ask M&C for a way the observer can select the option of balancing the I.F. Rack from within GO.

The minimum input power level depends upon the bandwidth of the input signal – the narrower the bandwidth, the lower one can run the input power on blank sky before noise is added. Thus, the optimum target power level is a function not only of expected source intensity but also of either receiver or I.F. bandwidth filters. Roger Norrod believes that one can determine the optimum balance target level from the optical driver specifications and we have assumed this to be true. If this is not the case, then empirical measurements will have to be planned and executed.

3. Determining where to balance to produce the best data

Depending upon the backend, there are a number of places where one can change attenuators to achieve proper levels. I'll consider the three common backends:

- DCR – For some types of observing, balancing can occur solely in the I.F. Rack. For others (e.g., multi-frequency continuum observing), balancing can also occur in the converter rack.
- Spectrometer – Probably the I.F. Rack balancing will be crude, maybe to within 10 dB of optimum, with finer balancing performed by the Converter Rack. The Spectrometer has the capability to set the Converter Rack attenuators automatically, a feature which currently has a bug which balances when the manager is in “activating” when it should do so in “committed.” Essentially, the bug balances the backend on the wrong phase of an On-Off observing, doubling the amount by which the backend is out of balance. The optimum input levels have already been determined by Fred Schwab and Mark Clark has implemented these in the M&C manager.

- Spectral Processor – Probably both the I.F. Rack and Converter Rack balancing can be crude with fine balancing performed by the attenuators in the Spectral Processor. The Spectral Processor already has the capability of automatically balancing itself but we may need some investigating as to what are the proper input levels.

We do not know whether fine balancing in the I.F. Rack or Converter Rack (or Spectral Processor) produces better baseline shapes. Thus, we propose observations that will compare baseline shapes using the various balancing options. Hopefully, the current automatic balancing in the Spectrometer and Spectral Processor will produce better data. If not, then M&C probably will have to automate the balancing of the I.F. Rack from the Spectrometer and Spectral Processor managers.

4. Other possible tests

To determine whether or not attenuator levels are set properly, other tests might be necessary. For example, in the first round of tests power meters can be placed at various places in the system under various observing conditions to determine whether the most significant source to the noise spectral density is the frontend and not some component in the I.F. system. The results of these tests might suggest the need for other tests.

Summary

It is clear that the specifications to implement proper I.F. balancing cannot be fully listed at this point. We think that empirical measurements and looking at device specifications will provide the necessary information. We propose the following sequence of events:

- Dave continues his work on determining the range of Spectrometer power levels.
- M&C should fix the bug of balancing occurring during “activating” instead of “committed”. This will facilitate the observations needed to further determine the scope of the work.
- Empirically or from instrument specifications, the engineers and commissioners will determine the range of input power levels for the remaining backends.
- Empirically or from instrument specifications, the engineers and commissioners will determine the range of input power levels for the I.F. Rack as a function of bandwidth and expected source strength.
- Check the noise spectral density at various places in the I.F. system.
- Concurrent with the above activities, the commissioners will explore where is the best place for balancing with regards to baseline shapes and data quality.

At this stage we should know enough to further specify the necessary work. We conjecture that the following might be needed.

- GO will probably need to alter the I.F. Rack target power levels either as a user-specified parameter or according to the I.F. bandwidth.
- M&C will probably need to add the option of automatically balancing the I.F. Rack during the “committed” stage of observing.
- GO will probably need to add an option where the user can select I.F. Rack and backend balancing – how the user specifies balancing will differ from one observing procedure to the next. For example, for Off-On observing GO will probably need a way of specifying whether I.F. Rack and/or backend balancing is to be done before On and Off, before the On, or before the Off observations.