The IFP Signal Path

15/9/97

Introduction

The LBA DAS contains two IF processors, IFP 1 and IFP 2, usually connected to LCP and RCP IF outputs from a common receiver, and programmed in tandem. However apart from sharing an S2 port (and common time and frequency references), there is no linkage between them and they may be configured and operated completely independently. The available resources in the DAS are therefore twice that in the following description, except where the capacity of the S2 recorder (128Mbps) would be exceeded.

The signal path through an IFP contains three processing stages which effect the frequency and bandwidth of various data streams derived from the incoming IF. In order they are a High Resolution Sampler, a Band Splitter and a Fine Tuner. The derived data streams are independently available at an S2 port (shared between two IFPs), a correlator port, two analog monitor ports, and a digital monitor port.

Filter type, filter bandwidth, signal routing through the system, spectrum inversion and data format are all controlled by software running in an external computer. Up to 80 parameters may be required to fully configure an IFP. These may be set directly from a low-level "engineering" program, from a high-level program which hides all internal details, by loading a predetermined "profile" file, or some combination of these as required. The computer does not participate in the signal processing. Once the IFPs are set up it continues to monitor signal levels and system parameters such as clock status, internal temperatures etc. It may be disconnected without disturbing DAS operation.

High Resolution Sampler ('Sampler')

The IF signal goes first to a broadband AGC amplifier to remove amplitude variations, and then to a 128MHz sampler followed by an eight-bit digitiser. The sampler acts as a harmonic mixer, shifting signals at all frequencies down to baseband, ie. 0-64MHz. If the input spectrum is considered as a series of alias bands, such that N*64 <= IF <= (N+1)*64MHz for some N=0,1,2,..., then for odd values of N the band is inverted at the sampler output while for even values it is not.

To ensure single-signal response the IF must be bandlimited to a single alias, either externally or by means of the switchable image-reject filter in front of the AGC amplifier. The value of N is an installation dependent parameter. It must be known in order to determine the complete mapping from the IF spectrum onto the output data stream(s).

The digitiser output is connected to the Band Splitter input, and may also be routed directly to the correlator and/or S2 output ports. In the latter cases the data bandwidth is determined entirely by the bandlimiting filter (plus incidental aliasing in the sampler). This is the only way to obtain a bandwidth greater than 32MHz.

Band Splitter

This processor is analogous to a set of bandpass filters of various bandwidths placed at strategic frequencies across the 0-64MHz input band. Output bandwidths range from 32MHz down to 1MHz, decreasing by factors of two. One or two outputs may be selected at any time for further processing, but the selection is not arbitrary. The two algorithms used produce either a single passband in the centre of the input band, or a pair of passbands symmetrically placed about the band centre. The dual response functions include contiguous bands and separated bands at two different spacings. See [1] Figs. 4 & 5.

The filtering process always results in the signal spectrum being shifted such that one edge of the output band is at DC. When necessary it is always possible to 'flip' the spectrum of each output individually so that DC corresponds to the other edge. It is also possible to 'flip' the entire spectrum at the input to the Band Splitter. The unfiltered (ie. 64MHz) data stream may also be inverted as required.

Selected outputs are independently available to the S2, correlator and monitor ports. Any one output of 16MHz or less bandwidth may be selected as input to the Fine Tuner for further processing.

Fine Tuner

The Fine Tuner may be regarded as a set of tunable filters, or as a complete tunable receiver in its own right. It takes as its input one of the outputs (<= 16MHz) from the Band Splitter and uses similar algorithms to produce single or dual filter responses. Unlike the Band Splitter the outputs are not symmetric with respect to the input band centre but to the "Local Oscillator" (LO) frequency which may be tuned anywhere across the band. The LO is tunable in 1Hz steps and supports phase-continuous frequency switching. Output bandwidths are proportional to the input, and may be equal (single response only), 1/2, 1/4, 1/8 or 1/16 of the input bandwidth. See [1] Fig. 5.

As in the Band Splitter, output spectra may be flipped if necessary.

Output signals are independently available to the S2, correlator and monitor ports. The Fine Tuner may also be put in a transparent mode in which case its analog monitor may be used to display a second Band Splitter passband.

S2 Port

IFP 1 and IFP 2 share an S2 Recorder port, fully formatted to connect directly to the S2's C1 input cable. Data is encoded optionally as 1-bit (polarity only) or 2-bit, in either AT (sign and magnitude) or VLBA (offset binary) formats. The statistics of the magnitude bit may be adjusted to suit either ternary or quaternary codes.

The S2's 128Mbps capacity allows either:

- one 64MHz (bandwidth) one-bit data stream from either IFP,
- one 32MHz 2-bit data stream from either IFP,
- one 32MHz 1-bit data stream from each IFP,
- one 16MHz 2-bit data stream from each IFP,
- two 16MHz 2-bit data streams from either IFP or
- two 8MHz 2-bit data streams from each IFP.

Smaller total bit rates are accommodated by reducing the number of active S2 transports. When data streams of different bandwidths (and hence sample rates) are recorded together the S2 mode must be selected according to the fastest bitstream in the set. The others will be multiply sampled on tape but excess samples are ignored at the correlator. A complete set of DAS-S2 configurations is described in [2].

Correlator Port

Each IFP has a connector programmable for connection to AT or " MultiBeam" correlators. In AT mode the bandwidth may be 32 through 4MHz, while in "MultiBeam" mode, 64MHz through 62.5kHz for a single data stream or 16MHz through 62.5kHz for dual streams.

Analog Monitor Ports

Two 10-bit DACs provide high resolution signal reconstruction to allow filter outputs to be monitored on a spectrum analyser or oscilloscope, or subjected to further processing in analog equipment. There is no correction for the underlying sine(x)/x factor, amounting to 4dB droop at the Nyquist frequency, nor is there any attempt to suppress high-order sidelobes, so some care is required when interpreting spectra or displaying test tones.

One DAC is attached to the Band Splitter output and is clocked at 64MHz in order to display up to 32MHz passbands, while the other is attached to the Fine Tuner and is clocked at the sample rate. If the Fine Tuner is put in transparent mode both DACs may be used to display Band Splitter passbands.

Spectrum flippers in both the Band Splitter an d Fine Tuner precede the monitor port connections, so the sense of the spectrum displayed is identical to that of the data streams sent to the S2 or correlator ports, and of the signal sent to the Fine Tuner from the Band Splitter.

Digital Monitor Port

Either data stream from the Fine Tuner may be selected for further processing. The format is 10-bit two's complement.

References

[1] 'The ATNF S2 Data Acquisition System',Rev. 18/07/97.
[2] 'LBA DAS to S2 Interface", Rev. 17/07/97.

Appendix A

Filter Function Types

More than 40 single and dual response filter functions (equivalent to an array of 50 or more analog bandpass filters) may be programmed into the IFP for use in the different processors. These functions fall naturally into a small number of families or 'Groups' whose members differ only in bandwidth. All possible bandwidths are not necessarily provided for each group as they do not (initially) appear to be necessary. Likewise not all groups are supported by each processor.

Users are encouraged to contact the author if they find the need for additional functions as these can be provided relatively easily by upgrading the firmware.

It is conventional to describe the filter f unction of each processor with respect to its baseband input spectrum. This extends from DC to the Nyquist frequency, ie 0 <= f <= 0.5 where f is signal frequency normalised to the sampling rate. Note that whereas the input spectrum to the Band Splitter is simply the 'Sampler output, the input to the Fine Tuner functions is the selected output spectrum from the Band Splitter already shifted such that signals at the "LO frequency" are placed at the band centre.

All signals are critically sampled, so that when an input bandwidth of 0.5 (sample rate =1) is reduced to an output bandwidth w, w <= 0.5, its sample rate becomes 2w.

The following descriptions of basic group characteristics show the spectrum of certain responses as inverted from input to output. This is the "natural" form of that function. In fact the spectrum of any data stream other than the raw sampler output may be flipped at will in order to provide the correct orientation at the output ports.

Group 1

A single response centred in the m iddle of the input spectrum, ie.

$$0.25-w/2 <= f <= 0.25+w/2$$ See Example 2.

The lower edge of the spectrum is shifted to DC.

Group 2

A pair of contiguous responses symmetrical about the input band centre. This includes the classic BBC mode, p roviding a USB + LSB pair, ie.

0.25-w <= fy <= 0.25   &   0.25 <= fx <= 0.25+w   See Ex 3

In both cases the band centre, f=0.25, is shifted to DC, so that the LSB spectrum (fx) is normally inverted.

Group 4

A pair of non contiguous responses sym metrical about the input band centre, with outer band edges fixed at the lower and upper quarter-band points respectively, which points are shifted to DC, ie.

0.125 <= fy <= 0.125+w &   0.375-w <= fx <= 0.375

Note that fx is LSB to f=0.375 and is normally inverted, while fy is USB to f=0.125 and is not.

Group 6

A pair of non contiguous responses symmetrical about the input band centre, with inner band edges fixed at the lower and upper quarter-band points respectively, which points are shift ed to DC, ie.

0.125-w <= fy <= 0.125 &   0.375 <= fx <= 0.375+w

Note that fy is LSB to f=0.125 and is normally inverted, while fx is USB to f=0.375 and is not.

When only a single response is required a Group 1 filter should be chosen in preference to one of a pair of Group 2 filters, as it will have both reduced ripple in the passband and wider shoulders at the band edges.

A special set of Group 1 filters, denoted by an "S" ("smooth") suffix, is provided chiefly for use in the Band Splitter when driving the Fine Tuner. It features greatly reduced passband ripple at the expense of somewhat narrower shoulders. This not only avoids an increase in total ripple but minimises changes in the passband shape as the LO is scanned during techniques such as doppler tracking. 1S filters should also be used in the Fine Tuner when a flat baseline is more important than effective bandwidth.

Group 0

Null filtering ("transparent mode"), output spectrum = input spectrum, ie.

0 <= f <= 0.5   See Example 1.

Appendix B

Filter Function Names

A specific filter function is identified by the notation

<processor><group>*<passband>,

where <processor> is S,B or F for 'Sampler, Band Splitter or Fine Tuner,
<group>   is 0..6 as above, and
<passband> is the nominal bandwidth in MHz and may be followed by a letter suffix to indicate a variant.

eg. B1*16, pronounced "B1 by 16".

Currently available functions are:

S0*64	Unfiltered output from the 'Sampler
B1*32 B1*16 B1*8 B1*4 B1*2 B1*1	Standard Band Splitter single bandpass responses
B1*32S B1*16S B1*8S B1*4S B1*2S B1*1S	Special "Smooth" Band Splitter single bandpass responses
B2*16 B2*8 B2*4 B2*2 B2*1	Standard Band Splitter dual (contiguous) bandpass responses
B4*8	Band Splitter dual separated bandpass responses
B6*8	Band Splitter dual separated bandpass responses
F0*16 F0*8 F0*4 F0*2 F0*1	Fine Tuner transparent modes
F1*16 F1*8 F1*4 F1*2 F1*1 F1*0.5 F1*0.25 F1*0.125 F1*0.0625	Fine Tuner single bandpass responses
F1*16S F1*8S F1*4S F1*2S F1*1S F1*0.5S F1*0.25S F1*0.125S F1*0.0625S	Special "Smooth" Fine Tuner single bandpass responses
F2*8 F2*4 F2*2 F2*1 F2*0.5 F2*0.25 F2*0.125 F2*0.0625	Fine Tuner dual (contiguous) bandpass responses

N.B.

1. The ratio between BS bandwidth (B) and FT bandwidth (b) may not exceed 16:1. i.e. B/b =1,2,4,8 or 16.

2. The ratio between B<n> and F1 bandwidths may be 1:1 but is normally 2:1 or more. In the 1:1 case tuning the LO away from band centre causes a corresponding amount of aliasing of the spectrum at the outer band edges. A limit of +/- B/32 is recommended.

3. The ratio between B<n> and F2 bandwidths may be 2:1 but is normally 4:1 or more. In the 2:1 case tuning the LO away from band centre causes a corresponding amount of aliasing of the spectra at their outer band edges. A limit of +/- B/32 is recommended.

4. The S0 response is always available to the S2 and Correlator ports regardless of which responses are selected for the Band Splitter and Fine Tuner.

Examples:

1. S0*64 is 0 <= f <= 64MHz directly out of the sampler.

2. BI*8 is 28MHz <= f <= 36MHz with 28 -> DC and 36 -> 8MHz

3. (B1*4S, F2*0.25, LO=1.1, F.Y=flipped) gives
   30.85 <= fy <= 31.1MHz & 31.1 <= fy <= 31.35MHz

Appendix C

Suggested filter selections

Class	Passbands	Combination	Typical Application
Full band	1	S0	64MHz bandwidth, Pulsars
BS O/P(s)	1	(B1,F0)	General 2-polar Interferometry, Pulsars
	1	(B1S,F0)	2-polar Spectral Line
	2	(B2,F0)	VSOP, VLBA compatibility
	2	(B4,F0)	Split lines, Faraday rot'n, Spectral index
	2	(B6,F0)	" " " " " " " "
FT O/P(s)	1	(B1S,F1)	General Tuneable 2-polar Interferometry
	1	(B1S,F1S)	Tuneable, Narrow Spectral Line
	2	(B1S,F2)	VLBA, RadioAstron compatibility
Mixed O/Ps	2	(B1S,F1S)	Simultaneous Continuum & Spectral Line

Other filter combinations may of course be selected as necessary. e.g. use an F1 response instead of F0 in order to monitor in-band interference, or B2 instead of B1 in order to monitor adjacent-band interference, or (B2,F1S) in order to record one 'wide' line and one 'narrow' line simultaneously.
