RDA 8.08 Release Notes (3 Jan 2005)

These release notes cover changes made to the SIGMET Radar Data Acquisition platform, including primarily the RVP8 and RCP8 products. The last public release was RDA-8.07.3 dated 22 December 2004. If you are upgrading from an earlier version please also read the release notes that have been published since then.

New Features

1. The **DspExport** program now has a heartbeat feature. This allows it to detect a sudden failure of the network link to one of its clients. During quiet times it will poll every 30 seconds. If there is no responding data it will disconnect. This feature is enabled by adding the **`–heartbeat`** command line option to the DspExport call. This has been added to our example startup script, but when upgrading you will need to turn it on explicitly. Note that this requires cooperation from the client program. That means the client IRIS must be at least version 8.07.5. Similarly, if you are running a non-IRIS application check with the manufacturer before turning it on. The source code for the dsp_lib support is in the file libs/dsp/SocketOpen.c.
2. The trigger pattern RAM allocation has been doubled on the Rev.C (72MHz) RVP8/Rx card, making it possible to store twice as much timing information (user triggers, phase control lines, PRF sectors, etc).
3. The RVP8 now supports six fundamental IFD and RVP8/Rx configurations which allow you to choose the best style of IF processing for your particular site. The following table summarizes the options where, ***BW*** is the net IF sampling rate (full 72MHz, or halfband filtered 36MHz), ***DynR*** is the dynamic range (normal single channel, or extra wide dual channel), ***Pol*** is the number of polarizations, ***Freq*** is the number of distinct intermediate frequencies, and ***IFD*** is the number of IFD's, along with their corresponding RVP8/Rx cards.

#	BW	DynR	Filt	Pol	Freq	IFD	Description
0	Full	Norm	Norm	1	1	1	Standard single channel
1	Full	Norm	Norm	2	2	1	Dual Pol on two frequencies
2	Full	Norm	Norm	2	1	2	Dual Pol on separate IFDs
3	Half	Norm	Norm	2	1	1	Dual Pol on single IFD
4	Half	Wide	Norm	1	1	1	Extra wide dynamic range
5	Half	Norm	Long	1	1	1	Extra long/fast FIR filters

The first three modes were already supported by the RVP8, but their new implementation has made many subtle improvements (better thermal management within the FPGAs, and closer attention to integer rounding noise). The last three modes are brand new and bring some exciting additional capabilities to the signal processor.

Important: The receiver mode is chosen in the "Mc" menu, but changes do not take effect until they are saved and the RVP8 is restarted.

Important: The factory default receiver mode "0" will be set after upgrading to this release. If you have a dual polarization radar, please be sure to select either "1" or "2" to continue operating as before.

The six receiver modes are summarized below. Please see the *Discussion of Halfband Filtering* later in these notes as it applies to Modes 3-5, and the *Discussion of Wide Dynamic Range* for additional details on using Mode-4.

Mode-0: Standard Single Channel This is the most common "vanilla" mode that is used by single-polarization CW-pulsed radars whose front-end LNA has a dynamic range less than ≈92dB. The (I,Q) data are computed from IF samples at their full acquisition rate (32MHz for Rev.D IFDs, and 72MHz for Rev.F), and the resulting dynamic range from 14-bit IFD samples is well matched to the RF components.

Mode-1: Dual-Pol On Two Frequencies This was the original dual-Pol configuration used by the RVP7 several years ago. A single IFD A/D converter receives the "H" and "V" channels using two distinct intermediate frequencies. Two different STALOs are required in this configuration, making the RF/IF components a bit more expensive, but only one IFD is required.

Mode-2: Dual-Pol On Separate IFDs This mode was introduced into the RVP8 in 2003, and provides dual polarization data using two IFDs connected to two RVP8/Rx cards in the same PCI chassis. A single intermediate frequency is used, hence only one STALO is required.

Mode-3: Dual-Pol On Single IFD This is the recommended dual polarization mode for all new RVP8 installations. The "H" and "V" channels are fed into the Primary and Secondary IFD inputs using a single intermediate frequency. System cost and complexity are both optimized in this design since only a single IFD, RVP8/Rx card, and STALO are required to process both polarization channels.

Mode-4: Extra Wide Dynamic Range Radars having very high performance front-end LNAs can preserve the full benefit of that investment by running two separate IF signals into the Primary (HiGain) and Secondary (LoGain) IFD inputs. A nominal channel separation of 25–30dB might be used to achieve an overall dynamic range of up to 110dB.

Mode-5: Extra Long/Fast FIR Filters This mode is intended for pulse compression systems that require unusually long filters (up to 80µsec), or finer range resolution in order to employ higher compressed bandwidths without the risk of missing echoes between bins. For example, a 30µsec pulse could be processed at an incoming range resolution of 50 meters and then range averaged down to 150meter output spacing.

4. The following new setup questions appear in the **Mp** menu during RxMode-4 (Extra Wide Dynamic Range):

```
IFD Wide Dynamic Range Parameters
  Channel separation: 24.70 dB,  63.5 deg
  Maximum deviation :  0.50 dB,   5.0 deg
  Overlap/Interpolate interval: 30.00 dB
```

The *Channel Separation* and *Overlap/Interpolate Interval* should be determined from the **Pr** printout described below. Sweep a SigGen across the shared power region of the two channels to determine a representative channel separation, along with the size of the overlap region at the top of the HiGain channel within which that separation remains steady and constant, i.e., unaffected by eventually approaching the noise floor of the LoGain channel.

The RVP8 continually measures and updates the complex channel separation during its normal course of operation. Ratios of echoes that fall within the overlap/interpolate interval are averaged over several minutes, thereby tracking gain and phase variations that occur with temperature changes and component aging. If the channel separation ever exceeds the specified maximum deviation, the `GI4S_IFDCHANERR` bit (11) will be set in GPARM Immediate Status Word #4.

5. When the **Pr** plot command is used in RxMode-4 (Extra Wide Dynamic Range), the TTY printout shows the complex magnitude and phase between the IF samples of the HiGain and LoGain channels. This is very handy for monitoring the channel separation across a wide range of CW signal generator levels, and for determining the span within which reliable channel ratios can be measured. Be sure that you use the "R" key to move the **Pr** starting range safely away from zero so that none of the IF samples are influenced by the burst waveform.

Bug Repairs

1. The DAFC Fault Pin was not being selected properly in theRVP8 **Mb** menu.
2. The RVP8 would sometimes crash during subsequent data processing when the trigger waveforms did not fully fit into the RVP8/Rx pattern RAM.
3. The RVP8 IF phase unwinding versus range was not working properly when the **Mb** setup question *IF increases for an approaching target* was set to "No". The effects were minor and could only be observed in **ascope** plots of (I,Q) versus range.
4. A timing skew was repaired in the Rev.E/F IFD that may have caused occasional flurries of incorrect IF samples which might have been seen as brief fluctuations in dBZ.

Discussion of Halfband Filtering Modes 3-5

Traditionally, the IFD used by the RVP7 and RVP8 has sent raw 14-bit A/D samples from its Burst and IF inputs directly to either the RVP7/Main or RVP8/Rx cards for FIR filtering and conversion into complex (I,Q) values. The IFD would function simply as a waveform sampling device (hence the acronym **IF** **D**igitizer), and all of the front-end signal processing took place downstream of it.

This model has changed with the introduction of the Rev.F IFD which has the ability to carry out several billion multiply-accumulate cycles per second. This means that IF samples from multiple signals can be preprocessed entirely within the IFD and then encoded without loss onto the fixed bandwidth of its digital downlink. The new receiver modes 3 through 5 rely on this hardware capability and use a method known as "Halfband Filtering" to effectively double the downlink data rate.

Section 2.2.7 of the *RVP8 User's Manual* contains a detailed account of how A/D quantization noise affects the dynamic range of the IFD. Briefly, for the Rev.F A/D converter which runs at 72MHz, the contribution of A/D quantization noise within any given 1MHz interval is 72 times smaller than the total noise of the converter itself. This is an important property of all wideband sampling systems: the noise floor after processing, and hence the dynamic range, are improved by increasing the fundamental A/D sampling rate.

Normally the IFD sends 72MHz A/D samples from a single input channel directly down to the RVP8/Rx PCI card. The samples are sent at full speed in order to realize maximum reduction of the final (I,Q) noise floor. But suppose we wanted to send two A/D waveforms down the same data link by interleaving the samples together. Each channel would have to be downsampled to 36MHz in order to fit within this format, but that would cause its (I,Q) noise floor to increase by 3dB.

To avoid this, we do not create the 36MHz streams merely by discarding every other A/D sample, but rather, by passing the original 72MHz data through a halfband digital filter and then discarding every other point of this filtered A/D stream. The difference is important. Since the halfband filter has removed all of the A/D quantization noise from half of the original Nyquist interval, there will be no increase in noise density within the passband of the (I,Q) filter when the halfband stream is downsampled to 36MHz. Thus, the A/D noise that would normally have folded into the (I,Q) data at 36MHz is first removed by the halfband filter so that we're left with a 36MHz stream having *the same dynamic range* of the original 72MHz samples.

The IFD halfband filter is a 49-Tap equiripple FIR filter having 40dB of stopband rejection and 0.175dB of passband ripple. The passband extends either from 0–16.5MHz when configured as a lowpass filter, or 19.5–36MHz when configured for highpass. The RVP8 automatically selects the correct type of filter depending on the intermediate frequency specified in the **Mb** menu. The halfband filter has linear phase and is therefore non-dispersive. This means that it is totally suitable for handling compressed pulses and other wideband Tx/Rx waveforms.

Discussion of Wide Dynamic Range Mode-4

When a two channel IFD is used as an extended dynamic range receiver there are some important decisions to make with respect to setting up the RF/IF levels that drive the IFD.

The first of these is the amount of signal level separation between the high gain and the low gain IFD inputs. There is an absolute minimum and absolute maximum channel separation that still allows the IFD to capture the full dynamic range of the receiver. If a signal level separation is made that is outside of these absolute limits valuable receiver dynamic range will be lost.

> ***The absolute minimum separation*** of the channels is equal to the total dynamic range of the receiver minus the dynamic range of a single channel of the IFD. Generally, the total dynamic range of the receiver is set by the LNA. For example, if we are considering a 1μsec pulse (1MHz bandwidth), the dynamic range of the LNA may be about 105dB, and the dynamic range of a single channel of the IFD is about 84dB (from –78dBm to +6dBm). In this case, the minimum separation would be 21dB. At minimum separation, the overlap of the low gain channel and the high gain channel will be maximized, and that overlap is equal to the dynamic range of a signal channel of the IFD minus the separation. In this case, the overlap is (84dB – 21dB) = 63dB.

> ***The absolute maximum separation*** of the channels is simply the dynamic range of a single channel of the IFD. In the above example this would be 84dB. At maximum separation, the

overlap of the low gain channel and the high gain channel is zero -- we begin using one as soon as the other has begun to saturate.

We see that there can be a large difference between the absolute minimum and maximum signal level separations; thus additional criteria must be considered to choose an optimum value that is between these diverse limits.

Choosing a proper separation value is a tradeoff of several factors. If the separation value is too low, the IFDs may end up operating very close to their noise floors. And if the separation is too high, then the overlap between the two channels is reduced which makes it difficult for the IFD to make a smooth transition as it combines the data from both channels. Too high a separation may also result in receiver components that are not practical to build.

As a rule of thumb, a channel separation value between 25 and 30dB is a good balance of the above criteria. In the case of a 1µsec pulse this results in an overlap interval of approximately 55-60dB, which is sufficient for good IFD transitions and also leads to receiver components that are practical to build.

Once a separation value has been chosen, one must consider how to build the receiver to achieve this. The basic receiver will take the form of an LNA and a mixer followed by a splitter resulting in a low gain channel and a high gain channel. We know the gain difference in the two channels (the separation value), but we must find the actual gain to use in each channel.

If we consider the total system dynamic range as generally set by the LNA (105dB in the above example), we can estimate the minimum detectable signal input to the LNA as well as the maximum usable linear level at the IFD. If the LNA has a noise figure of 1dB and we are using a 1µsec pulse, the minimum detectable signal at the LNA input is –113dBm, and thus the maximum signal is 105dB above this, or –8dBm. If we add to these number the gain of the LNA and the conversion loss of the mixer (and any other losses experienced through the power splitter for the low gain and high gain channels), we can use this information to determine the signal values of the components in these two channels.

For example, if the LNA has a gain of 17dB, the mixer has a conversion loss of 7dB, there is 1dB miscellaneous losses and 3dB loss in the power splitter, then the signal level at the output of the power splitter is (–113 + 18 – 7 – 1 – 3) = –106dBm for the minimum signal, and and –1dBm for the maximum signal. In the low gain channel, we need to bring the –1dBm up to the maximum input value of the IFD (+6dBm). To do this we need about 8dB of amplification (7dB plus one more deciBel to account for the anti–alias filter loss of the IFD). If we assume 25dB of channel separation, on the high gain channel we require about +33dB of amplification. Finally, this tells us that on the low gain channel, the minimum and maximum signals presented to the IFD are (–106 + 8) = –98dBm and (–1 + 8) = 7dBm. For the high gain channel, the signal levels are (–106 + 33) = –73dBm and (–1 + 33) = +32dBm. Note that as +32dBm is above the maximum input level tolerated by the IFD, the amplifier on the high gain channel must limit its output to less than +16dBm. Thus an amplifier with an output saturation value of between +10dBm and +15dBm should be used.