

# Successful Configuration of HPx Cards

How to configure processing on an HPx card to get the most information from the incoming radar video

## Summary

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*It is important to configure the processing on the HPx card correctly in order to get the best out of the radar video data.*

*It is often too late to try and compensate for poor HPx configuration within the receiving software because information may have been lost by this stage.*

*Physical interfacing with the radar signals and appropriate configuration of the links on the HPx card is discussed within the product user manual.*

*This document is concerned with the higher-level software-controlled processing available on the HPx cards.*

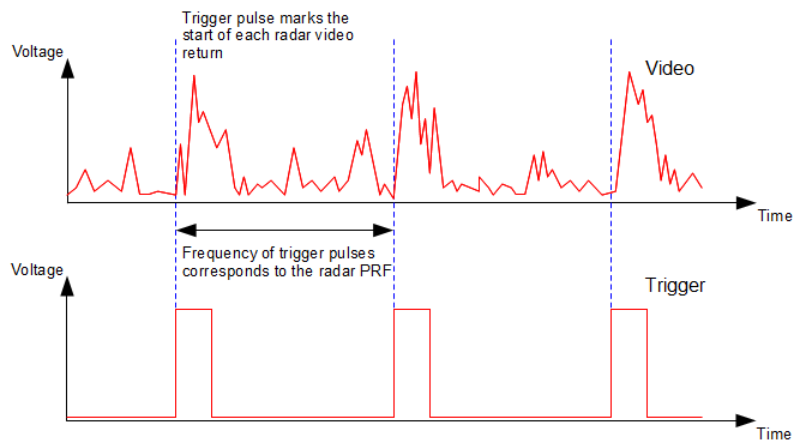
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## Understanding Radar Signals

Interfacing to a radar with an HPx card usually involves identifying and connecting to four separate signals from the radar:

- **Analogue radar video** is the baseband amplitude-versus-range signal, representing each radar return. This is the signal that would typically drive an analogue display. A PPI display is composed of successive radar video returns (or groups of returns) drawn as adjacent radial spokes.
- **Trigger (or Sync)** is a pulse signal that provides a time reference for the analogue radar video. The trigger pulse marks the zero range of the video, possibly with some fixed time offset.
- **ACP (or Bearing or Azimuth)** is a pulse that signifies a uniform incremental change in the radar antenna rotation. A typical radar may provide 2048 or 4096 ACP pulses per rotation of the antenna.
- **ARP (or Heading or Reference)** is a pulse that signifies the radar antenna has passed its reference mark and the rotation count should begin again.

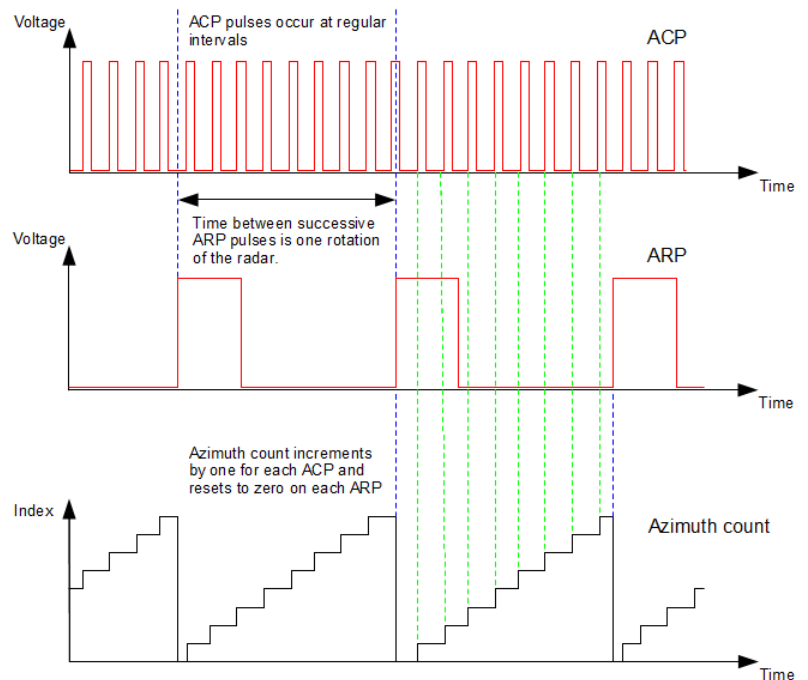
The radar continually produces a radar video signal and a set of trigger pulses that act to mark the start of each radar return. The primary function of the HPx card is to digitise the incoming radar video signal.



**Figure 1: Video signal and corresponding trigger pulses**

The trigger pulse is the time reference that tells the HPx card when to begin digitising each radar video return. The card will then begin digitising radar video for a fixed time period (specified by the user) or until the next trigger pulse is received, marking the start of the next return.

As the antenna rotates, the radar will generate ACP pulses to denote that the antenna has turned by a fixed, incremental value. The ACP pulses are completely independent of the trigger pulses. Typically the ACP pulses are derived from a shaft encoder that measures angles, and the trigger pulses are derived from an oscillator driving the radar pulse. The HPx card keeps an internal count of the number of ACP pulses received since the last reference time. This internal count, combined with a knowledge of how many ACPs are expected within a full radar rotation, defines the angular position of the antenna.



**Figure 2: ACP and ARP pulses and the internal azimuth index**

Each time the HPx card receives an ARP pulse the azimuth count is reset to zero. The ARP pulse is therefore the angular reference point defining the start of each rotation of the radar. Each radar return output from the HPx card is labelled with the current azimuth count.

In most cases the ARP pulse is generated as the antenna passes a fixed point relative to its own mounting. For example, on a moving platform the radar would normally be mounted such that the ARP coincides with the antenna passing the ship's bow. In this case the azimuth count is always referenced to the ship's heading. On land-based installations, where the radar is fixed in a static location, the ARP will normally coincide with the antenna passing north, meaning that the azimuth count is relative to north.

It is important to understand that the trigger and ACP pulses are unrelated.

The trigger pulse frequency is generally the same as the radar's PRF. Whereas the frequency of ACP pulses is dictated by the rotation rate of the radar together with fixed the number of ACP pulses per antenna rotation.

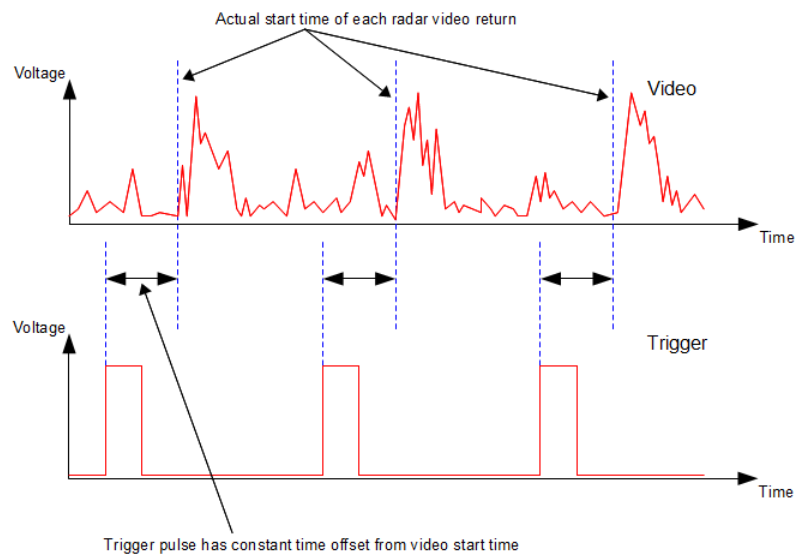
For example, if a radar has a rotation period of 10 seconds and produces 2000 ACP pulses per rotation, then each ACP pulse represents  $360/2000 = 0.18$  degrees and they will have a frequency of  $2000/10 = 200\text{Hz}$ .

Significantly, there could be many trigger pulses (and video returns) between successive ACP pulses. For example, if the radar described above has a PRF of 1kHz then there will be groups of five returns all sharing the same azimuth index number.

The trigger pulse provides the time reference to mark the start of each radar video return. It will sometimes coincide perfectly with the zero range but this is not necessarily the case.

It is likely that each trigger pulse will actually occur at a fixed time (before or after) the start range of the corresponding radar video return. This fixed time offset is sometimes referred to as a pre-trigger delay.

A consequence of this time offset is that radar video returns will appear at the wrong range if this timing is not accounted for.



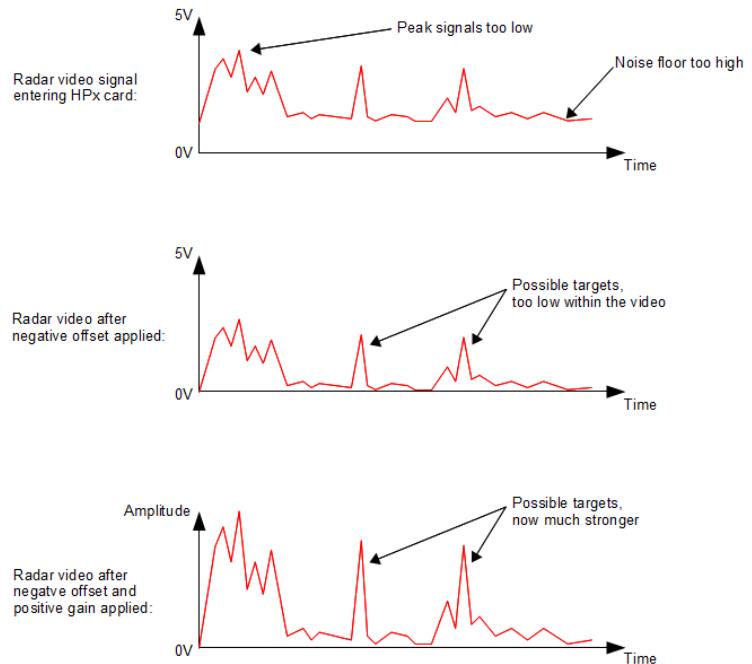
**Figure 3: Constant time offset between radar video start range and trigger pulse**

## Gain/Offset

HPx cards can digitise analogue radar video signals in the range -5V to +5V. Video outside of this range is effectively truncated. An analogue offset voltage may be applied on the card, to shift the incoming video level up or down to bring it into range. A digital gain may then be applied to the digitised data so that the samples occupy the full range of output amplitude values available.

Setting the gain and offset correctly on the HPx card is essential to making the best use of the available dynamic range. If these settings are not optimised it can result in the noise floor being too high, target returns being too low and only a fraction of the available dynamic range being utilised.

In most cases, the HPx card is used to provide 8-bit deep data samples, although 12-bit samples are also possible. This means that there are 256 discrete intensity levels available for each data sample. The gain and offset on the HPx card provides a control over the mapping of input voltages to output sample values.



**Figure 4: Example of using offset and gain to maximise signal-to-noise ratio**

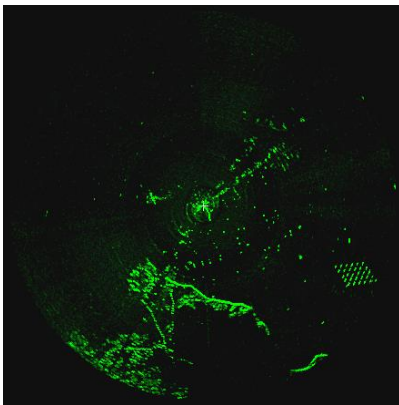
If a gain of 1 and an offset of 0 were chosen, it would result in video at the 5V level producing output data samples with a value of 255. Similarly, video at 2.5V would map to data samples of 128, video at 1V would map to samples of 51 and so on.

In practice, the radar video may not be in the range 0 to 5V, it may only fill a band within this range or it may be desirable to clip it at the upper or lower bounds.

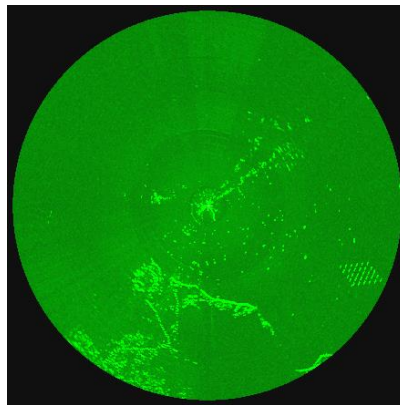
As shown in the example opposite, the offset and gain can be used to manipulate the radar video so that the full range of output values is utilised.

Software cannot compensate for poorly configured gain and offset.

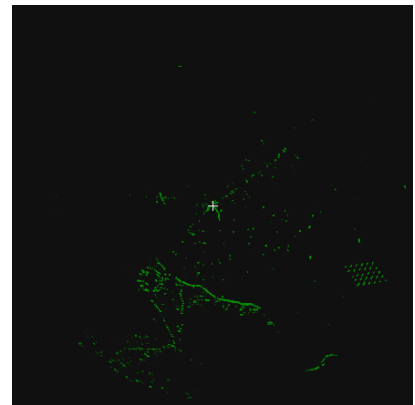
By the time the data leaves the HPx card information may be lost, so it is crucial to set these values properly. The following images demonstrate the effects of badly chosen gain and offset values on the radar video data.



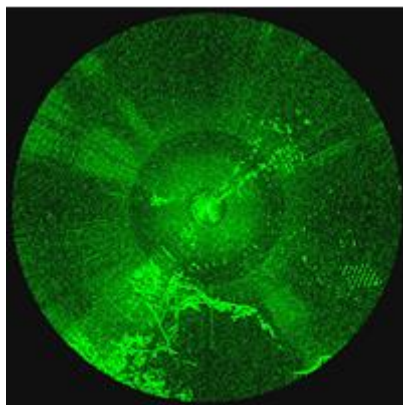
**Gain and offset correctly set.**  
 Target returns appear bright, even at longer range. Some low-level background noise is present, ensuring that small target returns are not lost.



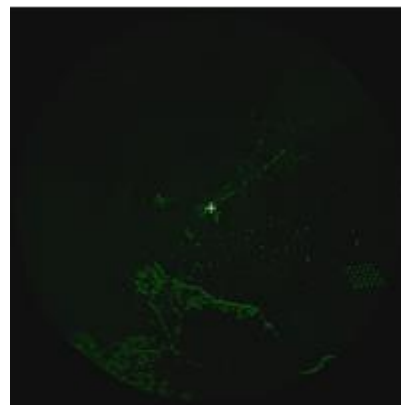
**Offset too high.**  
 The entire video, including the background noise, is shifted up in intensity. Effectively a DC offset has been applied. The lowest video value will be greater than zero and the highest values will be clipped. This means that the full dynamic range is not being used and the video appears saturated.



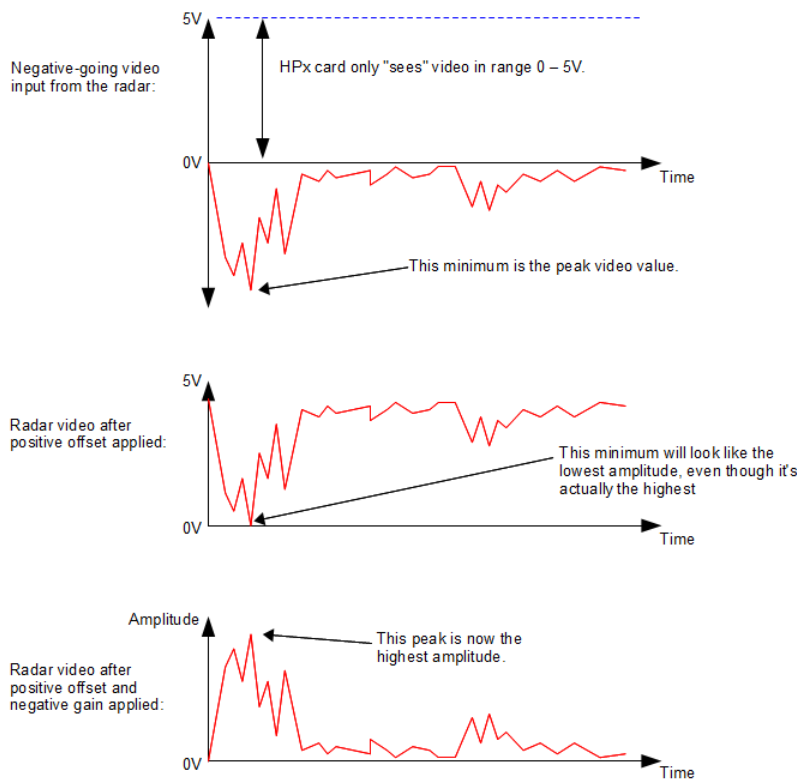
**Offset too low.**  
 The video intensity is shifted down too far so that small target returns and all of the background noise are below zero intensity and the HPx no longer sees them, resulting in a loss of data.



**Gain too high.**  
 Background noise is boosted to extremely high levels, target and land returns saturate. The resulting video only uses part of the available dynamic range and fine details may be lost.



**Gain too low.**  
 The radar video appears washed-out and even strong returns only give low intensity values.



**Figure 5: Using gain and offset to compensate for negative-going video**

## Negative-going Video

It is reasonably common for a radar to produce negative-going radar video, such that 0V represents the black-level and a negative voltage represents full intensity video. The digitisers on the HPx cards expect video in the range 0 to +5V. However, HPx cards can apply an analogue offset voltage to the incoming video signal and this may be used to shift the incoming video into this range.

Applying a positive analogue voltage offset prior to digitisation will bring the video up above 0V. This will then make the video signal accessible to the digitisers on the card.

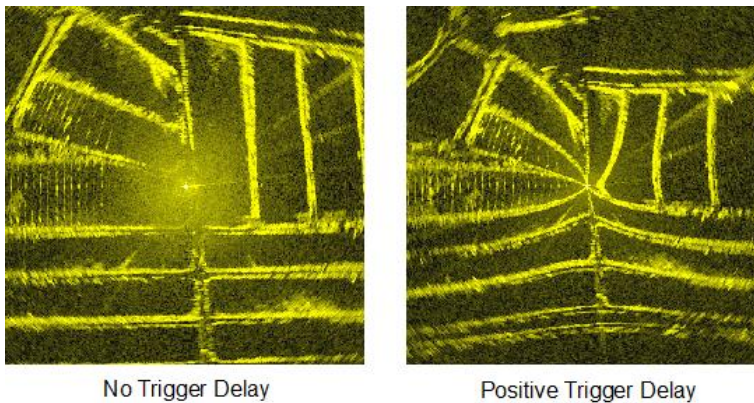
A negative gain value may then be applied to the resultant video data in order to invert it so that the black level and white level are transposed. This means that video that was formerly the most negative is now the most positive and therefore represents the strongest return.

## Trigger Delay

The trigger pulse tells the HPx card when the radar video is at zero range. The timing of the trigger pulse will rarely align perfectly with the zero range time. As shown in Figure 3, there will usually be a fixed time offset between the trigger pulse and the zero range.

A positive trigger delay means that the trigger pulse occurs at some time after the start of the radar video return. This will result in the radar samples appearing to be at shorter ranges than they actually are. A consequence of this is that short range samples, which fall within the trigger delay period, may be lost because the HPx card will not start sampling before the radar's apparent zero range.



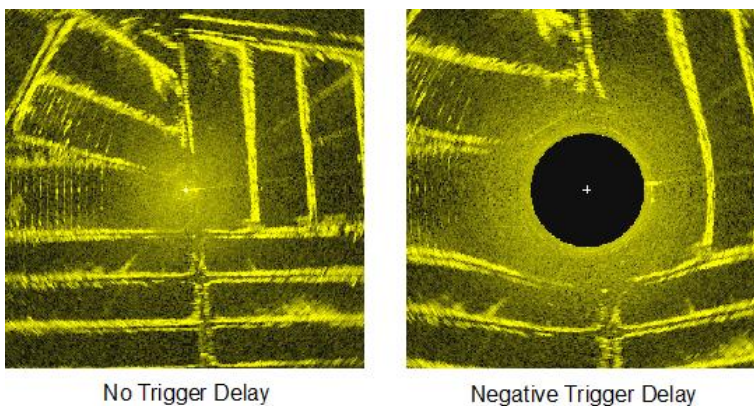


**Figure 6: The effect of a positive trigger delay on radar video**

The images in Figure 6 show the effects of a positive trigger delay on a radar video display. The image on the left shows the radar video with no trigger delay (or with the trigger delay corrected). The image on the right shows the radar video with a positive trigger delay.

With a positive trigger delay each radar sample appears to be at a shortened range. Tangential lines bend inwards towards the radar and samples within the delay period are lost.

A negative trigger delay means that the trigger pulse occurs at some time before the start of the radar video return. This will result in the radar samples appearing to be at longer ranges than they actually are. A consequence of this is that each radar return may begin with a number of blank samples during the delay period.



**Figure 7: The effect of a negative trigger delay on radar video**

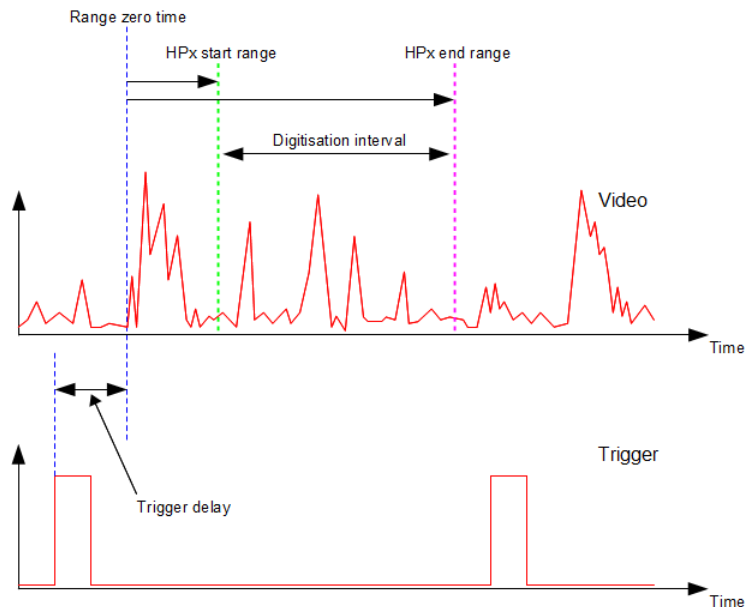
The images in Figure 7 show the effects of a negative trigger delay on a radar video display. The image on the left shows the radar video with no trigger delay (or with the trigger delay corrected). The image on the right shows the radar video with a negative trigger delay.

With a negative trigger delay each radar sample appears to be at a lengthened range. Tangential lines bend outwards from the radar and a blank disk is visible at the shortest ranges.

## Digitisation Range and Number of Samples

HPx cards allow the user to specify the start range and end range for capturing the radar video data. These ranges are set relative to the zero range of the radar video, which in turn is defined relative to the trigger pulse timing. This is illustrated in the simple diagram opposite.

The user may also specify the number of range samples that this interval should be divided into. The HPx card samples the analogue radar video at a fixed 50MHz\* sampling rate. In most cases the requested number of samples per return will be smaller than the number of samples that the HPx card is generating.



**Figure 8: HPx digitisation range settings**

A sampling rate of 50MHz produces samples that cover 3m in range, since this is the round-trip distance radio waves travel in the time between 50MHz samples.

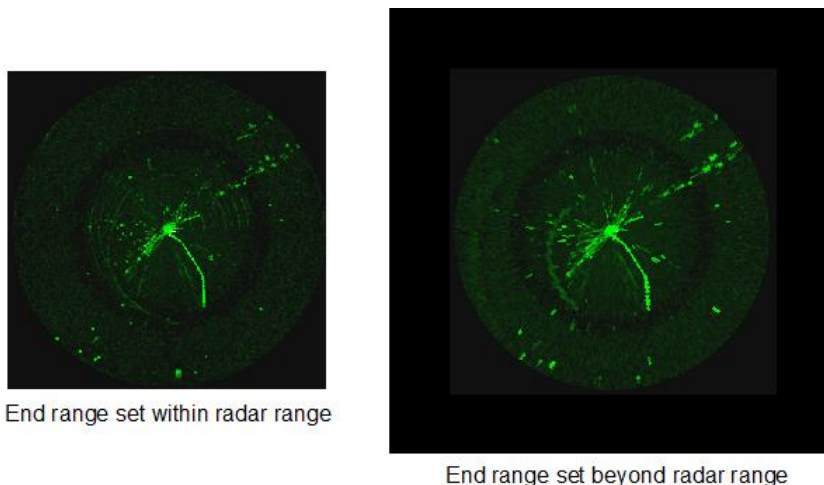
Groups of adjacent 50MHz samples are combined together by the HPx card in order to reduce the number of output samples down to the requested number.

For example, if a range interval of 50km has been selected and the user has requested 2000 range samples within this interval then each requested range sample covers 25m. Therefore each range sample requires approximately 8 (25/3) adjacent 50MHz samples to be combined together.

The highest value from each group of samples is used, to ensure that no target returns are lost. This is effectively a subsampling process.



The end range for digitisation should be set to a value no greater than the operating range of the radar. If a longer value is selected the radar samples outside of the radar operating range will be empty. The range resolution will also be adversely affected, since the chosen number of range samples will be spread over a longer range. This can be seen in the images in Figure 9.



**Figure 9: Effect of selecting an end range beyond the radar range**

The HPx cards support automatic selection of sampling end range, based on the measured PRF (trigger frequency). The theoretical unambiguous end range for a radar operating at PRF,  $P$ , is given by:

$$R = c / 2P$$

where  $c$  is the speed of light. The HPx card may then set the sampling end range to be a user-specified fraction of this maximum range.

In many cases, the number of range samples selected is typically 2048 or 4096.

In some circumstances, more range samples may be desirable, but consideration should be given to the increased processing load resulting from increasing the number of range samples. There is an ultimate limit on the range sample size of 3m, because of the sampling rate.

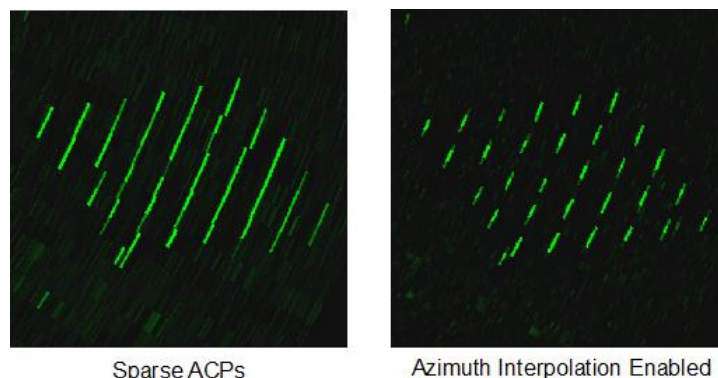
Requesting a number of range samples that would imply a shorter sample size will be futile and the HPx card will simply output 3m wide samples. Also, if the radar's pulse length is long this will dictate the range resolution and there is no benefit from trying to sample at finer resolutions, since the radar video will not contain detail on a finer scale.

\* HPx-200H and HPx-200He models have the option of 100MHz sampling

## Azimuth Interpolation

Some radars only produce relatively small numbers of ACP pulses per rotation of the antenna, possibly 360 pulses or fewer. In this situation the HPx card would treat each ACP as a large increment in the rotation of the radar, resulting in many adjacent radar returns being tagged with the same azimuth index value. Consequently, the radar display will have poor angular resolution.

In reality, the antenna is not stepping around by discrete jumps, it is turning continuously and smoothly. Therefore it is legitimate to interpolate between ACP pulses to improve the azimuth fidelity of the data. HPx cards provide the option of azimuth interpolation between ACP pulses. By interpolating between the ACP pulses fewer radar returns will share the same azimuth value and the radar display will have a finer azimuth appearance. The effect of this can be seen in Figure 10, where much more detail is visible after azimuth interpolation is enabled.



**Figure 10: Effect of azimuth interpolation on a radar video display**

If configured appropriately, the HPx card will interpolate the number of discrete azimuth values up to match the measured PRF of the radar. This means that there will then be a single return per unique azimuth index value.

In some circumstances it is possible to configure the HPx card to generate all of the azimuth increments internally without relying on an ACP signal. This is achieved by specifying the number of azimuth increments within a complete radar scan and relying on the ARP to mark the start/end of a rotation. However, this requires an extremely reliable and accurate ARP and in the majority of case having ACP pulses available is best.

## Absence of Radar Signals

If there is no video signal present, but all other signals are available then the HPx card will continue to operate but each return that it processes will contain samples at zero amplitude (or at least a level of electrical noise on the input). The radar video image will simply appear as a blank disk.

If the trigger signal is missing, the HPx card will be unable to process the incoming radar video because it will have no reference to mark the start of a return. The board will raise an alarm in software if this is the case. Please refer to the user manual for details of alarms.

In the absence of an ACP signal, the HPx card will generally not have any knowledge about the angular position of the radar. This will result in all radar returns output by the card being marked at the same azimuth. The board will raise an alarm in software if this is the case.

If the ARP signal is missing, the HPx card may appear to function correctly, at least for part of a scan. However, since there is no angular reference point, the radar video may appear at different rotational offsets each time the system starts or the video image may drift in azimuth over time. The board will raise a software alarm if no ARP is received for more than 10 seconds.

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