Time Frequency Modulated Pulse for improving capabilities of Pulse Compression Meteorological Radars

Fritz O’Hora, Sergey Panov, and Jason Selzler

Vaisala Inc., Westford, MA, USA

1 BACKGROUND

Pulse Compression capability has been incorporated into the Vaisala RVP8 and RVP900 meteorological radar signal processors for more than ten years having been used in over 60 weather radar systems. Pulse widths up to 80 microseconds in the RVP8 and 160 microseconds in the RVP900 are possible while retaining sub microsecond resolution, down to 5 meter gates spacing, if desired. The processing gain associated with such compression results in sensitivity improvement on the order of 20 dB as compared with the corresponding uncompressed short pulse of the same range resolution. Range time sidelobe levels are suppressed by more than 50 dB as compared to the main lobe over the full range of Doppler velocities expected to be measured by the meteorological radar. Non Linear Frequency Modulation (NLFM), a window weighted downconversion filter and careful tapering of the pulse envelope is used to achieve this performance. A graphical user interface optimizer tool is used on the processor to allow the user to set the pulse characteristics and see the resulting waveform and ambiguity diagram in real-time.

2 PROBLEM STATEMENT

A drawback to the pulse compression is that reception was not possible until full duration of the transmitted pulse was completed, thus limiting the start range of data processing. This problem is illustrated in Figure 1.

The goal of this work was to overcome this problem by developing a Time Frequency Modulated Pulse Compression scheme for the RVP900 Signal Processor. This allows equivalent data as compared to a radar not using pulse compression, but achieving the range resolution and sensitivity of a radar using pulse compression.

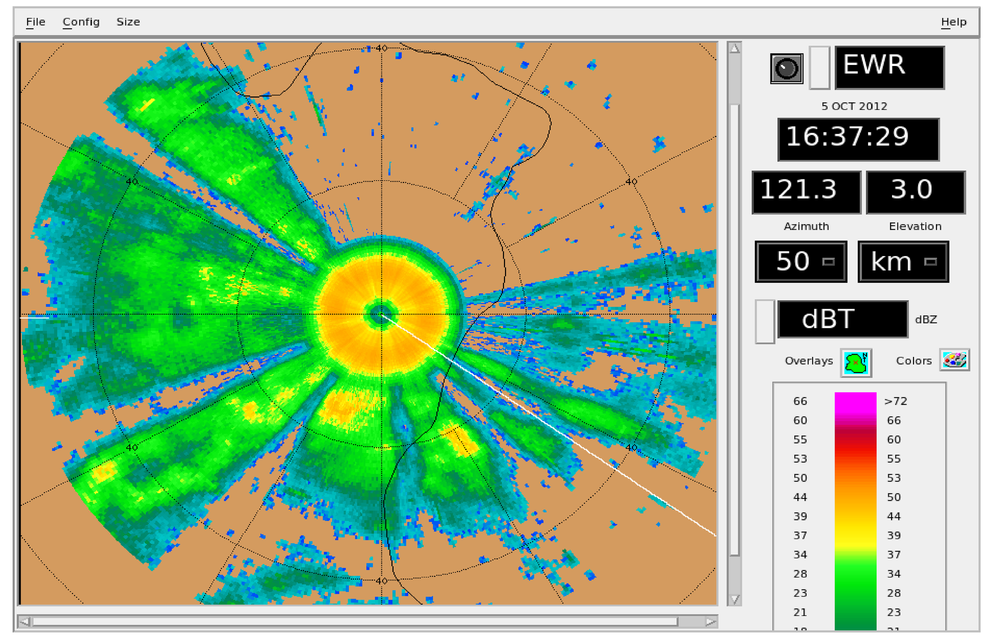


Figure 1 Long NLFM Compressed Pulse - Short ranges are unusable due to receiver being saturated by the transmitter.

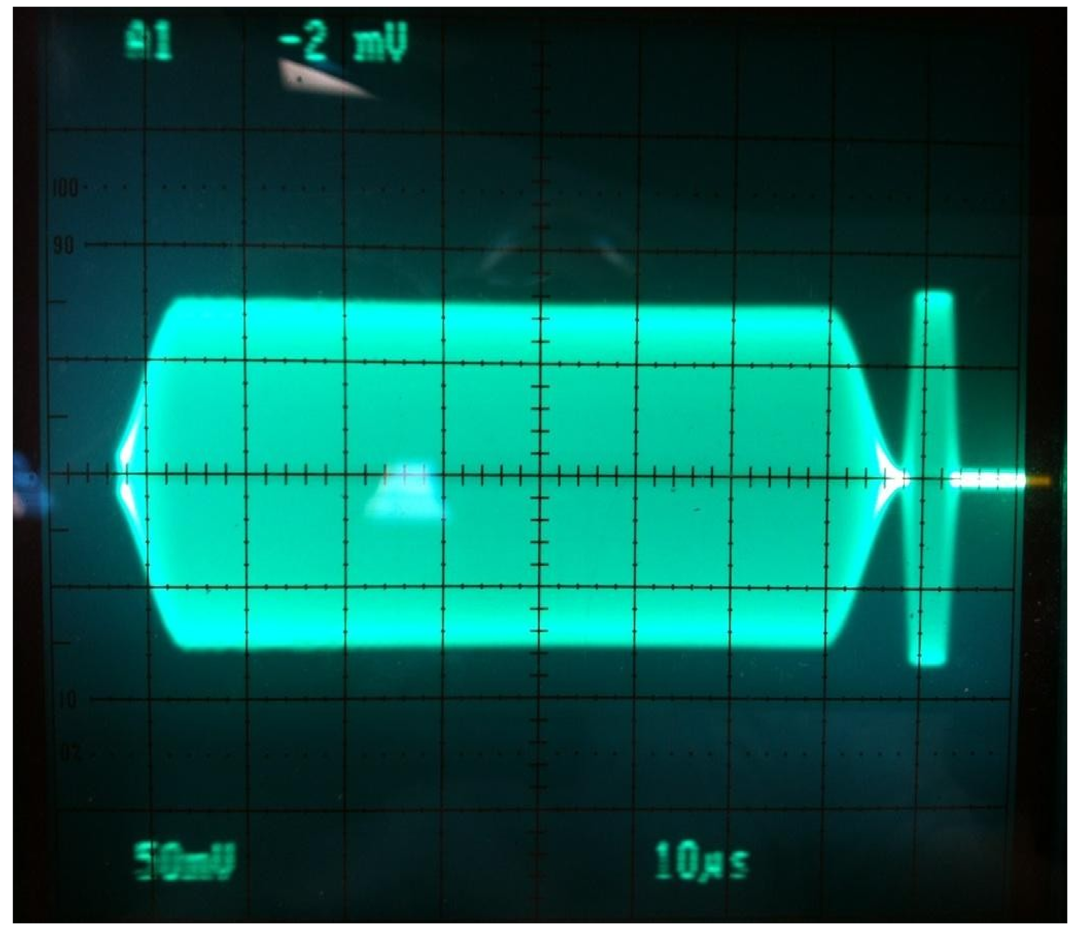


Figure 2 Time domain plot showing 80 microsecond NLFM raised COS pulse immediately followed by 5 microsecond non-modulated pulse.

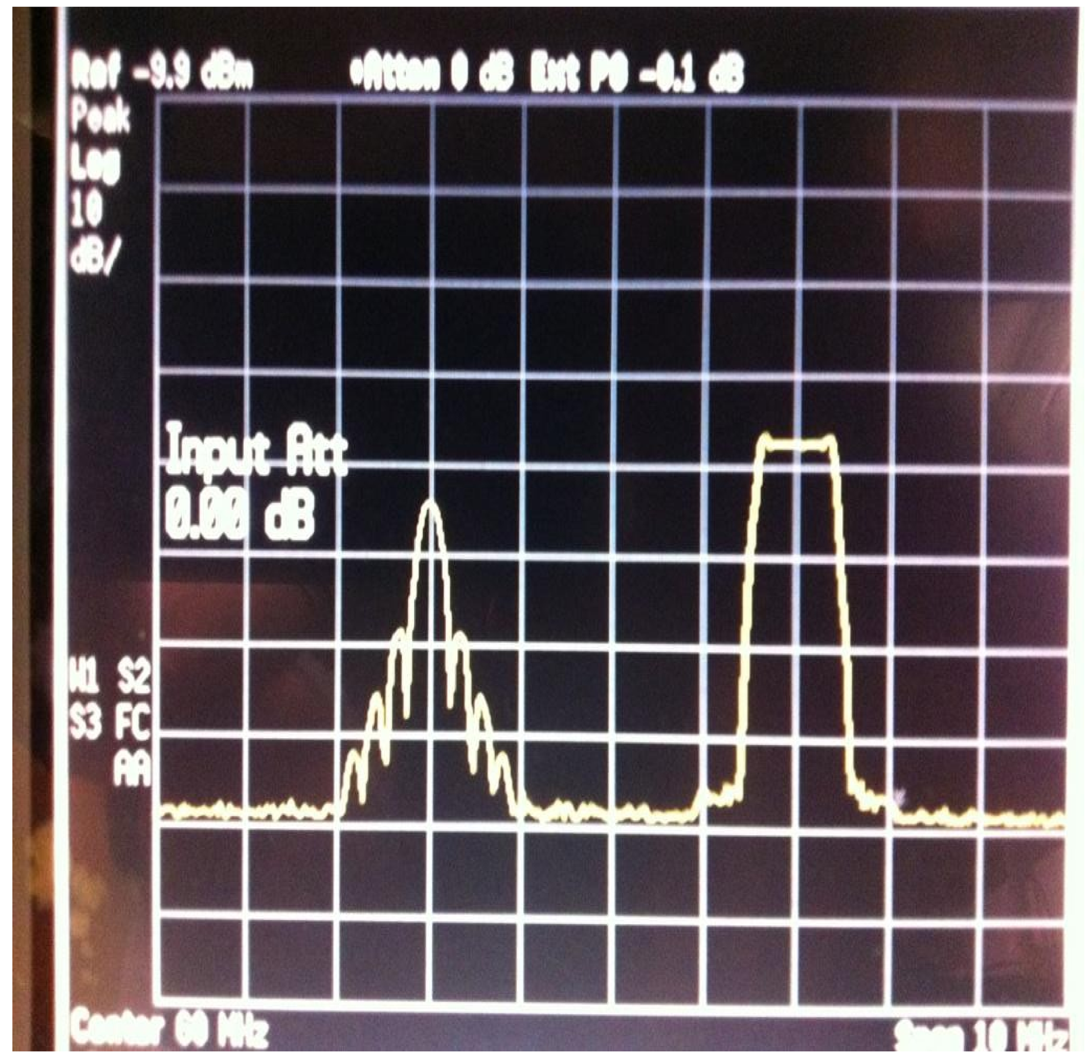


Figure 3 Frequency domain plot showing sin(X)/X spectrum of non-modulated pulse and rectangular spectrum of NLFM raised COS pulse. Pulses separated by a few megahertz guard band.

3 METHODOLOGY

The Time Frequency Modulated (TFM) waveform by:

a)Two consecutive pulses, the second immediately following the first in time. The first pulse is a long NLFM pulse and the second is a traditional short pulse without frequency modulation. See figure 2.

b)The digital IF (Intermediate Frequency) samples are passed into two parallel downconversion filters where one filter is the corresponding filter for the long NLFM pulse (that performs pulse compression) and the second filter is the corresponding matched filter to the short non-frequency modulated pulse. See figure 3

c) The two parallel I/Q data streams are then merged together in the downstream processing at the autocorrelation stage. The merging is done over a range of the I/Q samples where the results are valid for both the long and short pulses to avoid transition artifacts. And thus the result is data of improved sensitivity and range resolution from nearly range zero, to the full range based of the dwell. Figures 4 and 5.

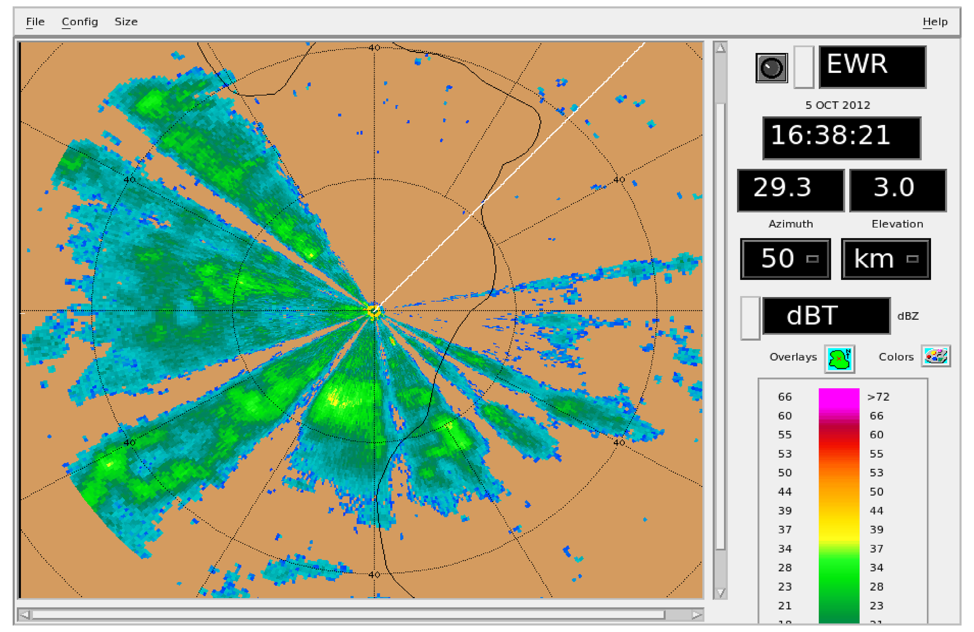


Figure 4 Short Pulse only. Good short range data, but poor sensitivity at long range

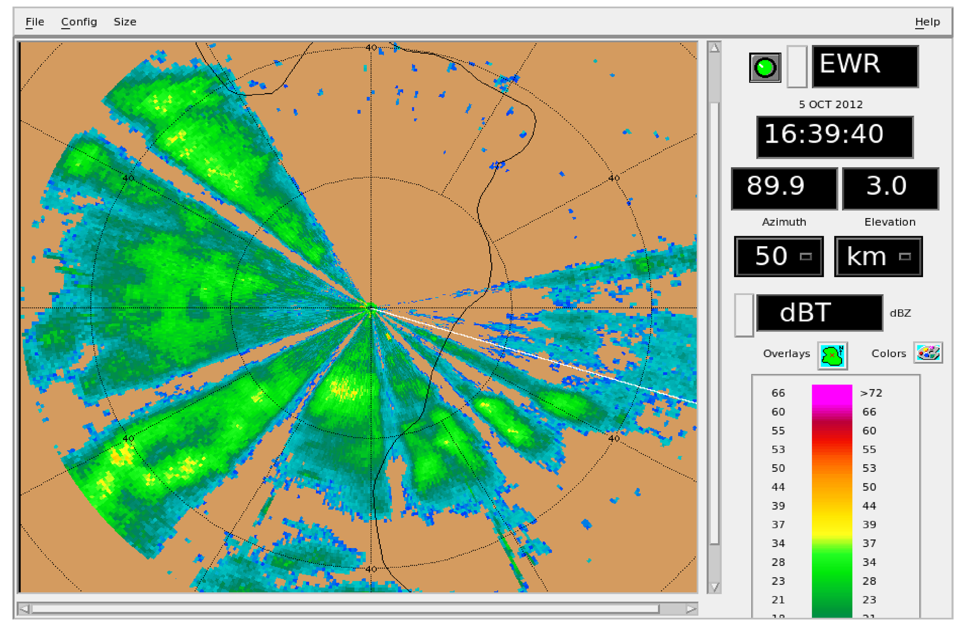
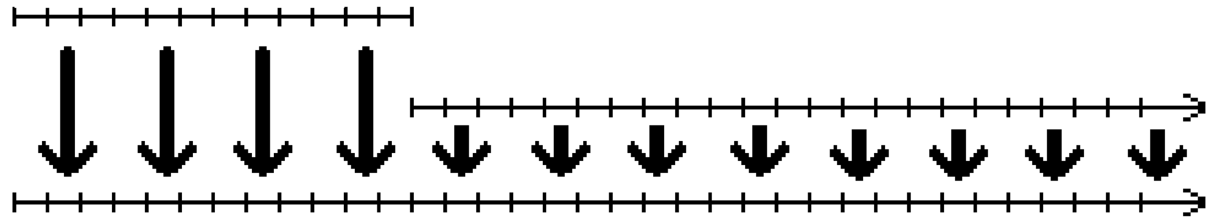


Figure 5 Merged TFM Pulse. Data from Figure 1 and Figure 4 are merged together at the autocorrelation level. Good data at short range and good sensitivity at long range.

4 EXAMPLE AND MERGING INFORMATION

Short Pulse Data for Twice duration of Long Pulse.

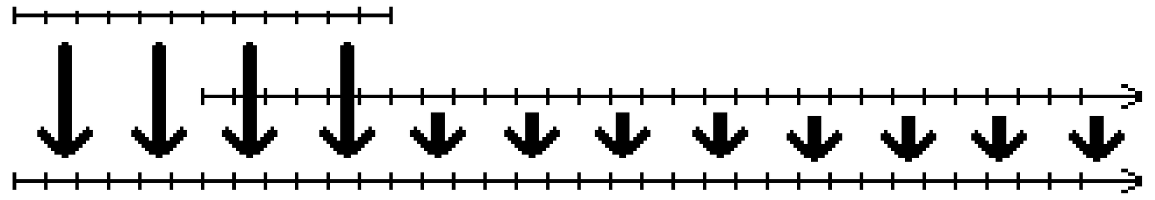
Long Pulse Data Starting at Twice duration of Long Pulse.



Merged I/Q data stream. No overlap in this case. No Blending.

Short Pulse Data for Twice duration of Long Pulse.

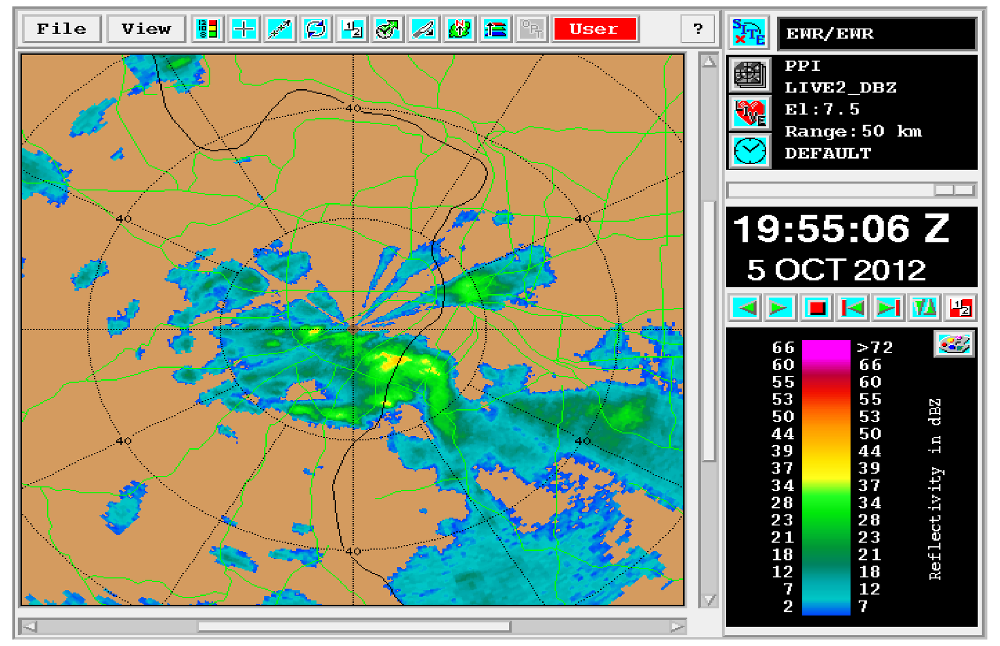
Long Pulse Data Starting at Once duration of Long Pulse.



Merged I/Q data stream. Overlapping and blending for duration of Long Pulse.

5 CONLCLUSION

The problem of sampling the short range when using pulse compression techniques has been overcome. This work illustrates that two pulses can be used successfully achieving greater than 60 dB isolation between the two downconversion filters. Little discrepency in the data values are apparent in the overlapping range areas between the two pulses.



Example showing an echo overlaping merge range.

References:

1) On the Performance of NLFM Pulse Compression with Polarimetric Doppler Radar, ERAD 2006, T. Puhakka, P. Puhakka, F. O’Hora.

- 2) Evaluation of FM Pulse Compression for Weather Radars, AMS 33rd Conference on Radar Meteorology, T. Puhakka, V. Chandrasekar, P. Puhakka
- 3) Wideband waveform design principles for solid-state weather radars. JAOT 29 (1), 14-31. N. Bharadwaj and V. Chandrasekar