P4D.1 RANGE-TIME SIDELOBE CHARACTERIZATION OF THE ELDORA RADAR

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1. INTRODUCTION

All radars that employ pulse compression techniques suffer from range-time sidelobes to some extent; the dual beam scanning airborne ELDORA radar is no exception. The effects of range-time sidelobes are readily apparent in the ground return data which appear several range gates wide. This greatly limits the radar's ability to accurately measure near surface winds. This paper reviews the cause of range-time sidelobes in general and more specifically how they occur in ELDORA. A recent technique for reducing range-time sidelobes in ELDORA is discussed and supporting data from the IHOP-2002 research project is shown. In addition, a future plan for their complete mitigation is proposed.

2. BACKGROUND

Pulse compression enables a radar to transmit a long pulse to obtain high average power while retaining the range resolution of a short pulse (Skolnik 1980). This is done by using frequency or phase modulation to increase the signal bandwidth. The received signal is then compressed using a matched filter or a weighted matched filter. Range-time sidelobes are the result of convolving the radar return with the non-ideal filter response (i.e some energy remains outside the desired pulse bandwidth). This results in the "blurring" of returns in range near high reflectivity gradients, like ground clutter.

3. ELDORA ANALOGY

ELDORA transmits a "stepped chirp" pulse from both fore and aft radars as shown in Figure 1. To simplify discussion, we will address the case of a single radar (fore or aft). The pulse typically consists of four distinct frequencies or "chips" transmitted in succession. The frequency separation is a function of the pulsewidth of each chip and is a direct result of the processing performed in the digitization of the IF signal. This will be discussed in more detail later. For a one microsecond pulse the minimum chip separation is 10 MHz. Since the antenna pointing angle varies with frequency (~1 deg./100 MHz), it is highly desirable to minimize this separation.

Four individual receivers split the received waveform into four IF signals centered at 60 MHz. Quadrature down conversion of each IF is done digitally in a separate NCAR designed DIGIF Card. The inphase and quadrature samples for each chip are then processed independently (using a pulse-pair algorithm) and the results combined to yield the final spectral estimates (Loew & Walther 1995). In this way, the overall range resolution is increased to that corresponding to the pulsewidth of a single chip, while the average power is increased by a factor of 4. This is analogous to a conventional pulse compression radar except that the standard receiver and matched filter is replaced by four individual receivers and their respective DIGIF's.

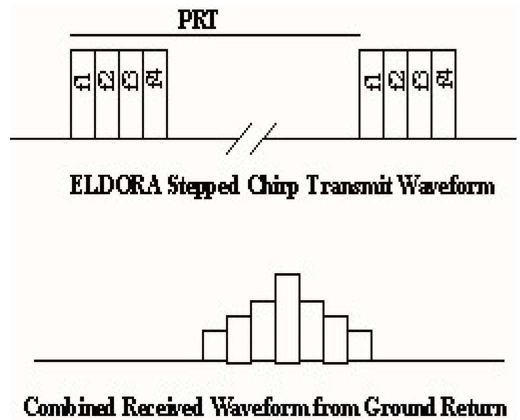

Figure 1. ELDORA transmit and received waveforms.

4. DIGIF AND RANGE-TIME SIDELOBES

By design the ELDORA receivers are fairly wideband (500 MHz), so isolation between chips is accomplished at IF using an 8 MHz bandpass anti-

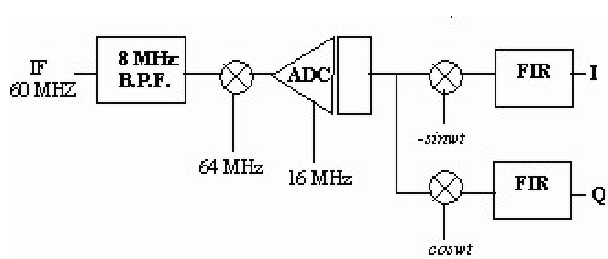

Figure 2: Block diagram DIGIF and Bandpass Filter.

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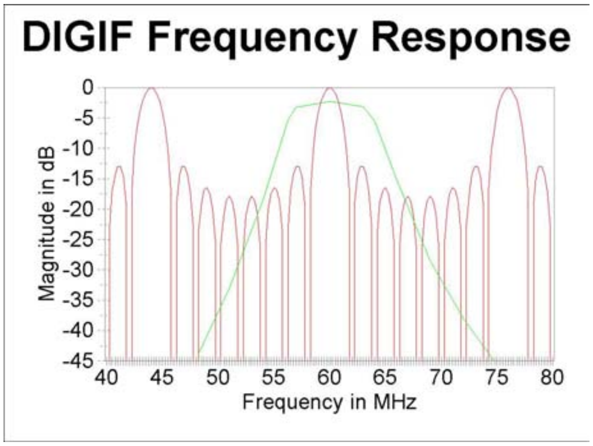

Figure 3: Digital IF Frequency Response.

aliasing filter and the Finite Impulse Response (FIR) filter inherent in the DIGIF card. Figure 2 shows a conceptual block diagram of this arrangement. The range-time sidelobes in ELDORA are the direct result of the “non-ideal” implimentations of the FIR and bandpass filters. The frequency response of both filters for a 0.5 microsecond pulse is given in Figure 3. The overall response can be obtained by multiplying the individual response functions of the FIR and bandpass filters. The important thing to note is that the chip separation frequency is chosen so that the adjacent frequencies lie in a “null” of the FIR response. In the example shown this separation would be 10 MHz. If the power spectrum from the ground return were a delta function, i.e zero

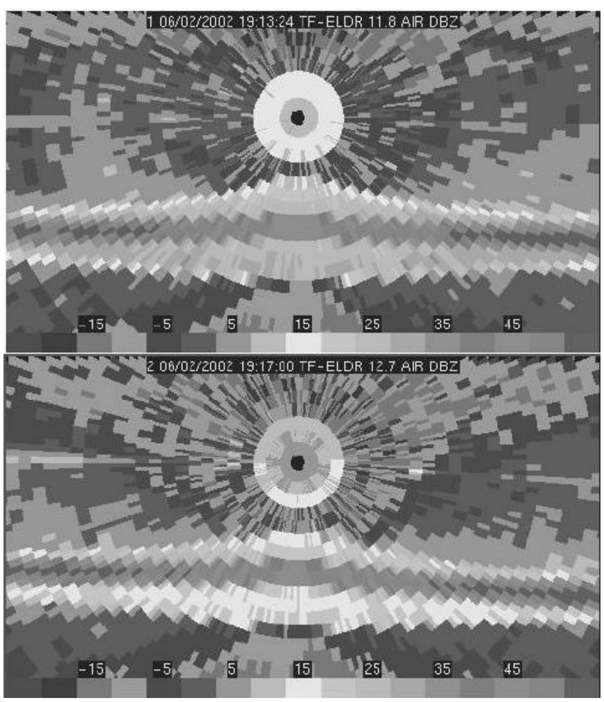

Figure 4: Reflectivity of Ground Return for 10 MHz Chip Separation (top) and 20 MHz chip separation (bottom).

spectrum width, then there would be no contamination from adjacent chips -- the FIR would attenuate all of the undesired signal. Since ELDORA is a rapidly scanning airborne radar, the spectrum width of the ground return is inherently broadened and the filter response of the 8 MHz bandpass filter defines the range-time sidelobes. In the example shown, ground clutter contamination from immediately adjacent chips (10 MHz separation) would be 20-25 dB down and much greater than 45 dB down for 20 MHz separation. Unfortunately, the typical ground clutter return is around 40-45 dBZ, so range-time sidelobes are present in several adjacent gates about the ground as illustrated in Figure 1.

5. WHAT CAN BE DONE

Since the range-time sidelobe level is defined by the bandpass filter response, we could double the chip separation, 20 MHz in this case, at the expense of slightly greater antenna pointing angle differences. Figure 4 shows the results of this experiment with reflectivity data taken during IHOP-2002. The top panel shows the ground return for the “standard” 10 MHz separation, while the bottom panel shows the same return with chips space 20 MHz apart. The data shows an 8-10 dB improvement by increasing the frequency separation -- not the 20+ dB that theory predicted. A possible explanation for this is that the analog to digital converter on the DIGIF is saturated by the ground return so the true reflectivity is higher than indicated. At any rate, the improvement achieved doesn’t significantly mitigate the “blurring” of the ground return caused by the range-time sidelobes.

6. FUTURE IMPROVEMENTS

It is planned to install programmable phase shifters in the fore and aft transmitters and impliment a SZ 8/64 phase code for each chip (Sachindanda & Zrnic 1999). This can potentially reduce the range-time sidelobes by an additional 40 dB with the additional benefit of reducing the second trip ground echo by the same amount.

7. REFERENCES

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