Using Channel Analysis Tool to Implement Multistatic Radar

TDSR UWB Radios

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Introduction

The purpose of this document is to describe how the Channel Analysis Tool can be used to implement Bistatic or Multistatic radars.

The Channel Analysis Tool (CAT) is a Microsoft Windows-based Graphical User Interface (GUI) developed by TDSR that allows the users to configure and operate TDSR's P400 series of Ultra Wideband (UWB) RF platforms such that the user can generate, capture, display, and log UWB RF waveforms as they propagate through an RF Channel. This process is well described in the *CAT User Guide*.

Users also have the ability to develop independent applications that interface directly with a P400 series module using the same CAT-P4xx interface. This interface is documented in the *CAT Application Programming Interface (API) Specification*. In addition, the user may also find benefit in reviewing the *MRM API Specification*. This document defines the interface associated with operation of a Monostatic Radar.

All these documents are readily available from TDSR and allow a user to implement a custom interface that supports mono-, bi-, and Multistatic radars.

In any event, CAT is useful in that it allows the user to easily and quickly capture a large set of Bistatic and Multistatic radar waveforms. This set of waveforms can then be evaluated by the user to confirm that the equipment or processing algorithms will be suitable for operation in a given application.

Basics of Operation

CAT has been designed to operate with any of the P400 family of UWB RF platforms. As of this date the family consists of the P400, P410, P412, P440 and P452. Since any platform can operate as a Multistatic radar or interface with CAT, the units will be referred to in this document as a Radar. The user should, however, keep in mind that these Radars can also be used as radios to communicate data or as ranging systems to measure the distance between Radars.

When a Radar transmits, it can broadcast to all units in the viewing area or it can specify that the broadcast is intended for a single unit. This capability allows the Radar to operate, respectively, as a Multistatic or Bistatic Radar.

In either case, the receiving Radar will use CAT to capture, display, and log a waveform. A sample waveform is shown in **Figure 1**.
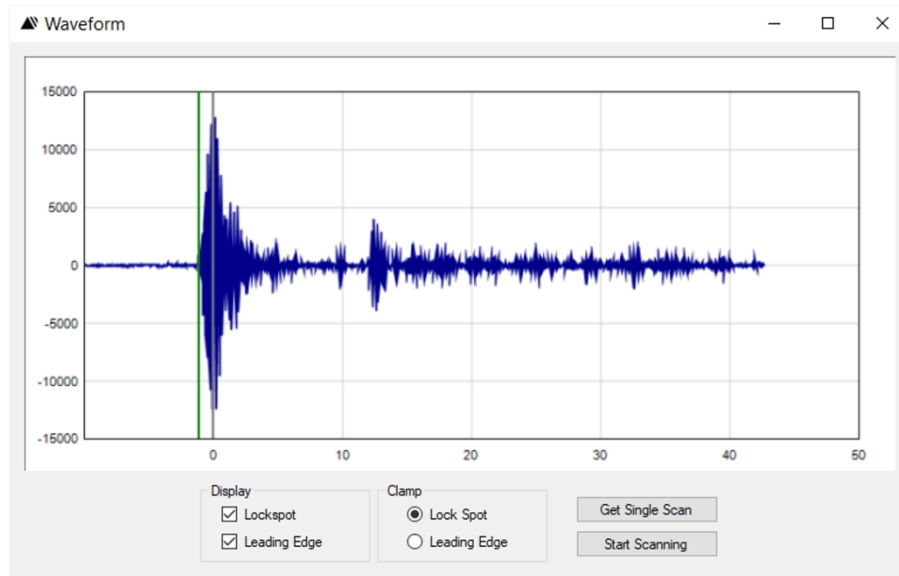
Fig. 1: Sample waveform captured using CAT (relative strength vs. time in nanoseconds)

Operating as a Bistatic Radar is relatively simple in principle. One collects a sequence of scans and compares how the waveforms have changed in time. The assumption being that any changes are indicative of the target moving in the area. In practice, the process is substantially more complex. The goal of this document is not to define how a robust, general purpose Radar can be developed, but rather to focus on making the user aware of details specific to the Radar operation that are important to any radar implementation. There are two limitations of note: Waveform Collection Rate and Comparison of Waveforms.

Waveform Collection Rate

The user will need to match the rate at which waveforms (or scans) will be collected such that the scan rate matches the movement rate of the targets of interest. For example, tracking high speed targets will require much more rapid scan generation than the tracking of low speed targets.   TDSR's Radar scan rate is a function of several items, including:

Scan Window Size: The user can specify the duration of the scan in nanoseconds (ns). For example, the waveform shown in **Figure 1** shows a waveform 50 ns long.   The longer the desired scan, the longer it will take to collect the data and the slower the update rate will be.

Step Size: The user can specify the spacing between measurements. The waveform generated in **Figure 1** was taken with a reading to reading sampling interval of 61 picoseconds (ps). Since this is approximately twice the Nyquist rate, this should be sufficient.   CAT also allows the user to collect data at other settings. Step size can be defined in powers of 2.   The minimum step size is 1.907 ps, so the user is free to set the step size to $1.907*2^n$ where n is an integer between 1 and 8.   However, this comes at a severe penalty. The receive circuits have been architected for optimum operation with a sampling interval of 61 ps. Any other setting will increase the sampling time by a factor of roughly 10.   TDSR has some ability to tune operation to settings other than 61 ps. If the user sees great value in other rates, then he or she should contact TDSR to discuss options.

Integration Rate: The Radar platform is fully coherent. But it is coherent in a fashion that is a different from traditional radars. This Radar transmits coherent pulses at a high rate (typically 10 MHz) and then coherently integrates many pulses to form high SNR signals. This is accomplished using a mechanism similar to that used in a Digital Sampling Scope. The higher the integration, the higher the system SNR will be, with each doubling of integration increasing the system SNR by 3dB.

Regardless, the user has the ability to change the rate at which pulses are integrated. The choices are all based on powers of 2. The minimum integration rate is 16:1, while the highest integration allowed is 32k:1.

Increasing the integration rate will increase the system SNR but it will proportionally increase the amount of time needed to collect a given scan.

Communications Throughput: While the Radar is responsible for generating waveforms, the Host PC will be responsible for processing the data. This flow of waveforms from Radar to Host will be limited by the communications throughput of the hardware interface. The Host can communicate with the Radar through Ethernet (P400 and P440 only), USB, and Serial interfaces. These interfaces will limit the communications rate to roughly a few 10s of Mbps, a few Mbps, and 100 kbps respectively. Care should be taken not to pick waveform sampling parameters such that they flood the com link.

Comparison of Waveforms

Ideally the user should be able to subtract one scan from another and observe how much the waveforms differ. There are then a multitude of approaches one could implement to relate these changes to target detections.

But the ability to subtract directly is limited by the manner in which the Radar will acquire the signal. The Radar does not have a hardwired trigger that connects the transmitter to the receiver and thereby allows captured waveforms to be synchronized to the transmitter. Instead, the transmitting Radar will embed a synchronization signal in the transmitted pulse train. The receiving Radar will go through an acquisition process quite similar to that of a cell phone. In this process the Radar will lock on to the received signal.

The lock spot is a specific point on the received waveform. In fact, any zero crossing is a potential lock spot. The Radar has been designed to find a zero crossing close to one of the largest amplitude signals. For example, any of the points marked in **Figure 2** with a red circle are likely (and desirable) lock points.

As a side note, it is also possible that the Radar will occasionally lock on a signal distant from the leading edge, for example the green point at 3.5 ns. While this is a very unusual occurrence, it does happen from time to time. Unless the signal is unusually strong, the radio will have difficulty maintaining lock on such a weak signal and will likely drop the packet.
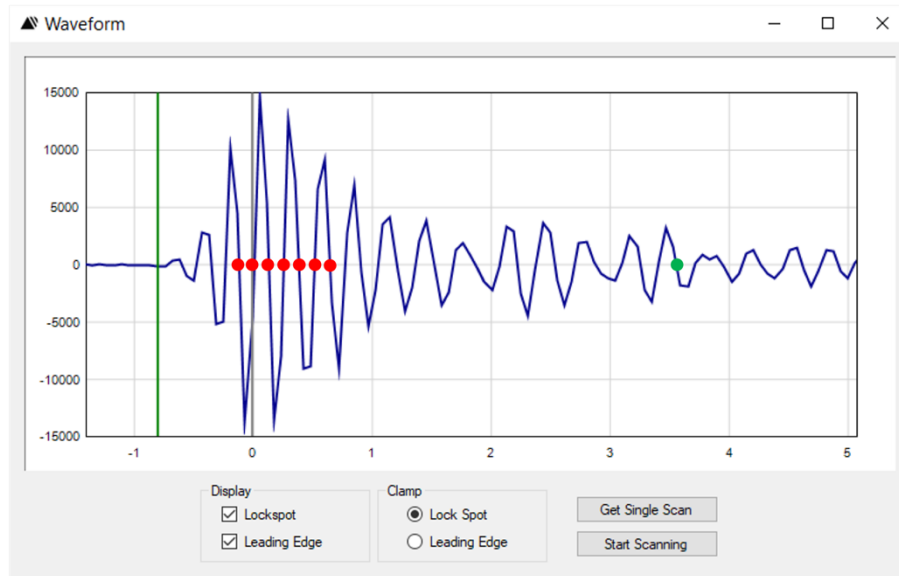
Figure 2: Sample captured waveform showing potential lock spots

The issue from the standpoint of a Multistatic radar, is that the captured waveform is measured relative to the lock spot. If two scans have the same lock spot, then subtraction will be straightforward. However the probability of this happening for the scan shown in **Figure 2** is only 1 chance in 7.   Therefore it will be necessary for the user to implement an algorithm that checks to see if the waveforms were taken with the same lock point and if not, then shift or realign one waveform relative to the other prior to subtraction. One way of implementing this would be to do an envelope detection on both waveforms, measure the time between the peaks of the two envelopes, and then shift one raw waveform by that amount.

Furthermore, the shape of the received waveform is also a function of the quantization of the measurement steps. While the curves shown in **Figure 2** appear smooth, that is an artifact of the plotting process. Each cycle of the waveform is composed of only 4 points. Since the waveforms are not identical, locking on a different zero crossing will result in the 4 points being measured at a slightly different point in the curve. The result will be that the waveforms have a slightly different shape. Subtracting the two waveforms will therefore result in a meaningless residual.

The waveforms shown in **Figure 3** and **Figure 4** illustrate both phenomena.
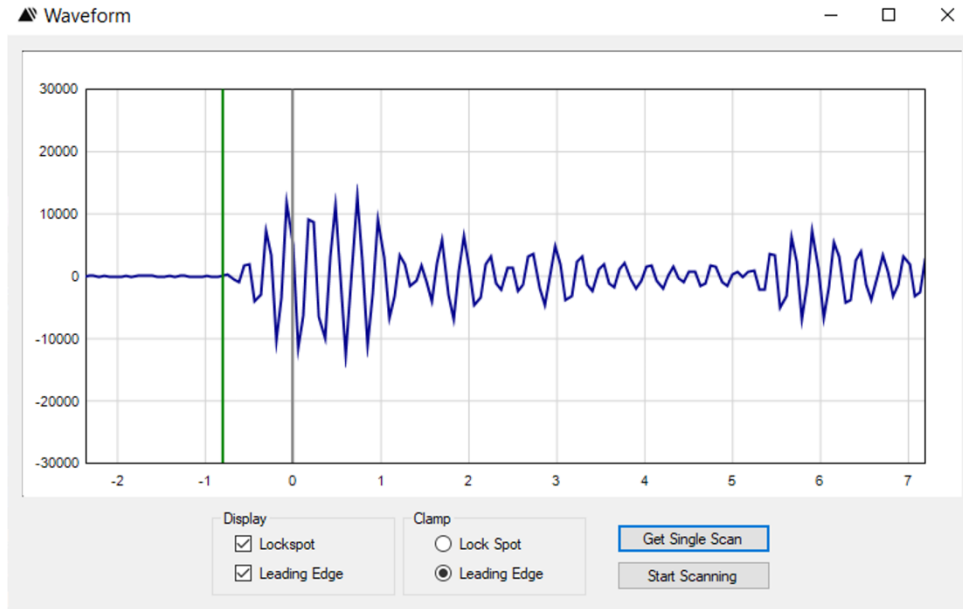
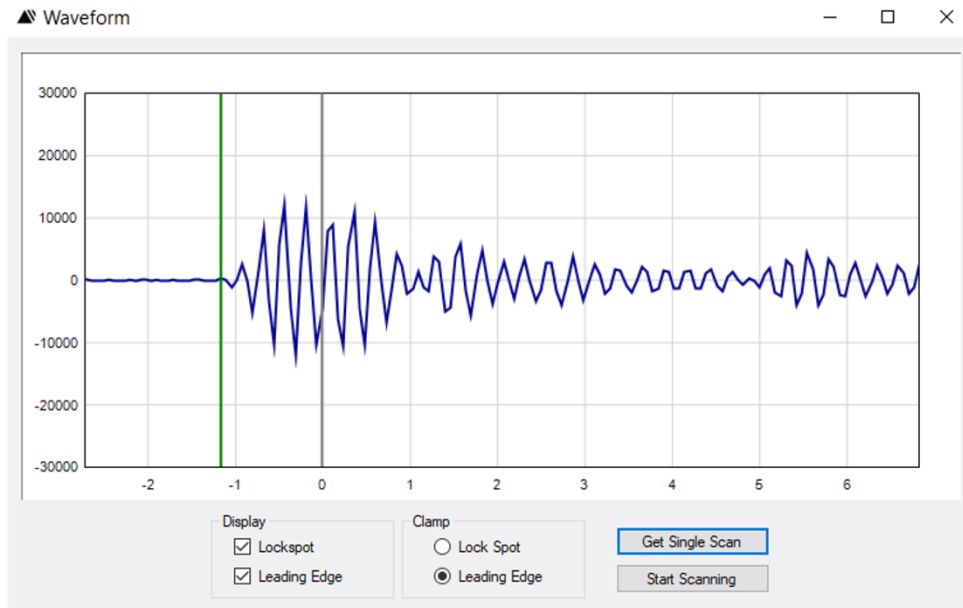**Figure 3: Captured waveform locked on 6th zero crossing.**

Figure 4: Captured waveform locked on 9th zero crossing

Note the two differences between these two waveforms taken less than 100 milliseconds (ms) apart in a stationary environment. First, the waveform in **Figure 3** is locked on the 6th zero crossing, while the waveform in **Figure 4** is locked on to the 9th zero crossing. This introduces a shift of approximately 6 measurements, or 366 ps. Second, the shapes of the two waveforms are slightly different. The fourth positive lobe of **Figure 3** is substantially lower than the third lobe, while in **Figure 4** both of these lobes are approximately the same height. Shifting the two waveforms by 366 ps and then subtracting would produce a waveform with a non-zero magnitude.