



# ELINT: Pulsed Radar Signals

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This lab serves as an introduction to the Agilent 89600 Vector Signal Analysis software, and how it can be used as a tool for analyzing pulsed radar signals for the purposes of gathering Electronic Intelligence (ELINT). This will occur in two parts, the first is a progressive walk-through of a signal analysis for three different cases. Then, a series unknown signals will be presented for independent study and analysis.

## 1 Introduction

This lab serves as a mechanism for you to learn how to apply the Agilent 89600B Vector Signal Analysis (VSA) software to the process of gathering ELINT on pulsed radar signals.

In order to learn these skills, you'll be presented with a series of progressively more complex radar signals for analysis. Starting with a pulsed radar signal, we'll then examine Linear Frequency Modulation (LFM), and finally, frequency hopping. You'll then be on your own to analyze several unknown radar signals.

The goal at all stages of this lab is to gather enough information to completely characterize the signal, in order to create a Pulse Descriptor Word (PDW). This PDW would then be used by a EW system to identify and attack radar signals.

## 2 Pulsed Radar Signal

To start, we will analyze the simplest class of radar signal, an unmodulated pulse. This will show you how to use the basic measurement features of the VSA for radar applications.

**Note** — For more details on any of these processes, see the video Introduction to Radar ELINT and the 89600 VSA Software on YouTube.

### 2.1 Setting up the VSA

Begin by loading the recorded signal file and setup four plots:

- File → Recall → Recall Recording... → Radar 1 - Simple Pulse.sdf
- Setup the VSA to display 4 plots of the following:
  - A: Ch1 Spectrum - Log Mag
  - B: Ch1 Main Time - Log Mag
  - C: Ch1 Spectrum - Spectrogram
  - D: Ch1 Main Time - Wr Phs

The **Spectrum** or **Main Time** choice is found through the plot tabs, in their upper right. The specific data to be plotted is then easily changed by left clicking on the label for the y-axis, and either double clicking for a set of options, or simply scrolling the mouse wheel. The results will start to resemble, Fig. 1.

The next step is to setup a trigger to capture the pulse in the time domain. Essentially the VSA software is only looking at a very limited set amount of time, and the radar is often no transmitting within that window. Knowing this we set a trigger that goes off under certain conditions, in this case the presence of a pulse.

- Go to Input → Playback Trigger...
- Change the style to **Magnitude = 10 mV**
- Change the Delay to  $-1\mu s$  (This shifts the frame of reference slightly, showing the signal starting at  $1\mu s$  before the trigger.)

At this point we need to adjust the measurement parameters to view multiple pulses at once. Simply, we're increasing the length of time the VSA software is looking at.

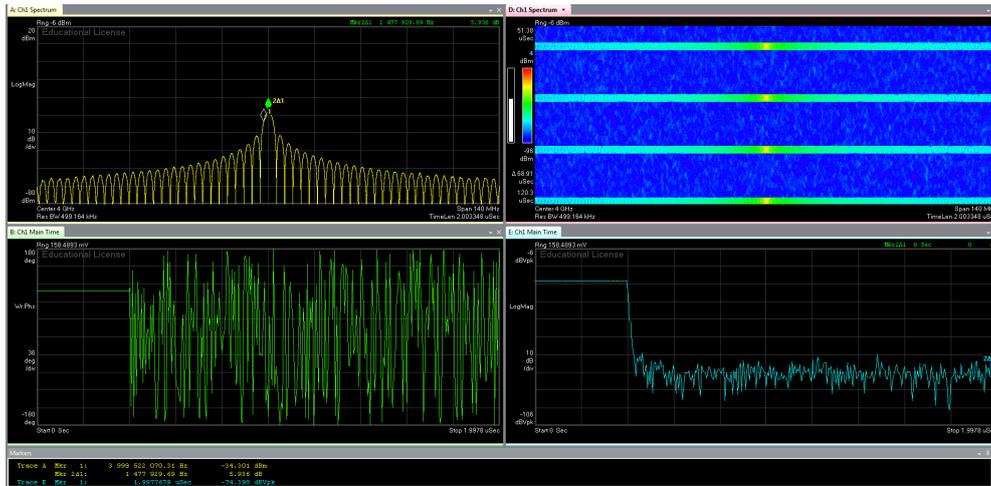


Figure 1: VSA display of the pulsed radar signal.

- Go to Measurement Setup → ResBW (Resolution Bandwidth).
- Select Window Type: Uniform window.
- Set frequency points to 102401.
- In the Time tab, set the Main Time Length to  $77 \mu s$ .

Alternatively, the length of time displayed can be changed on the lower right of your main plot, it will say TimeLen and now have  $77 \mu s$  next to it. At this point it is also recommended to right click on each plot, and select Auto Scale to optimize the graph's scales.

Now, if you'd like to slow down the signal playback (this is optional).

- Go to Measurement Setup → Time
- Change the Max Overlap (Avg Off) to 99 %

Four pulses should now be visible on the display, which you should pause. We can now view all the aspects of the pulse, and characterize it.

## 2.2 Measuring the Pulse Length and PRI

Now that we've setup our system to analyze the radar signal, the first step will be to conduct some time domain measurements: the pulse length ( $\tau$ ), and Pulse Repetition Interval (PRI).

- Right click on the LogMag plot in the time domain, and click on the green plus sign next to Marker1.
- You now have a green marker that you can move to the rising edge of the first radar pulse.
- Right clicking again, add a second marker and place it at the trailing edge of the first pulse.
- Now, right clicking to bring up the menu again, change marker 2 from a normal maker to a Delta, this measures the change in time from marker 1 to marker 2.

The second marker's measurement will now be in the upper right of this plot, indicating the measured change in time of about  $1\mu s$ .

To find the PRI we simply place the same two markers at the start of two sequential pulses. The VSA will then display the time delta, approximately 20 us, which is the PRI. The PRF is the inverse of this number, or 50 kHz.

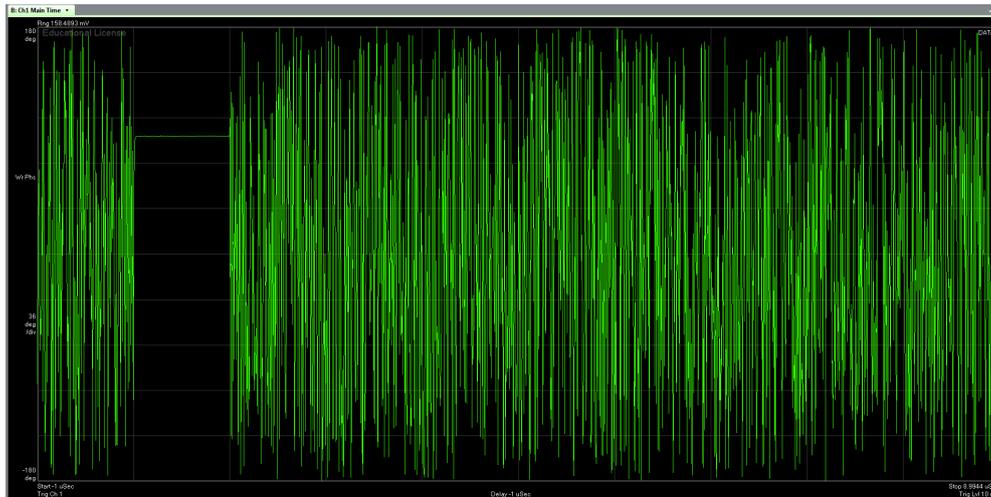
## 2.3 Measuring the Spectrum

The next stage is to gather some basic information on the signal in the frequency domain. This means the power, centre frequency, bandwidth, etc.

To reduce the computational overhead, change the observed time to 10  $\mu s$ . This will cover one pulse of the signal, and let us characterize some elements of it.

- In the Ch1: Spectrum - Log Mag window, right click and select Show Band Power.
- Then centre this marker over the peak, and move the left and right boundaries to cover the spectrum of interest.

From the spectrum display we can gain several pieces of information. The first is the transmitted frequency, it is 4.0 GHz, and the bandwidth can be read directly from the marker display, using the Show Band Power tool. The occupied band has a power of -24.5 dBm, and we can then use the delta marker again to measure the bandwidth (around 2.5 MHz).



**Figure 2:** *Phase versus time of a pulse radar signal.*

## 2.4 Measuring the Phase and Modulation

The basic radar signal is now characterized, with its PRI/PRF, pulse length, bandwidth, and centre frequency. This is enough information to attack it with basic noise jamming, but not deception jamming. To deceive this radar, we need to understand its modulation.

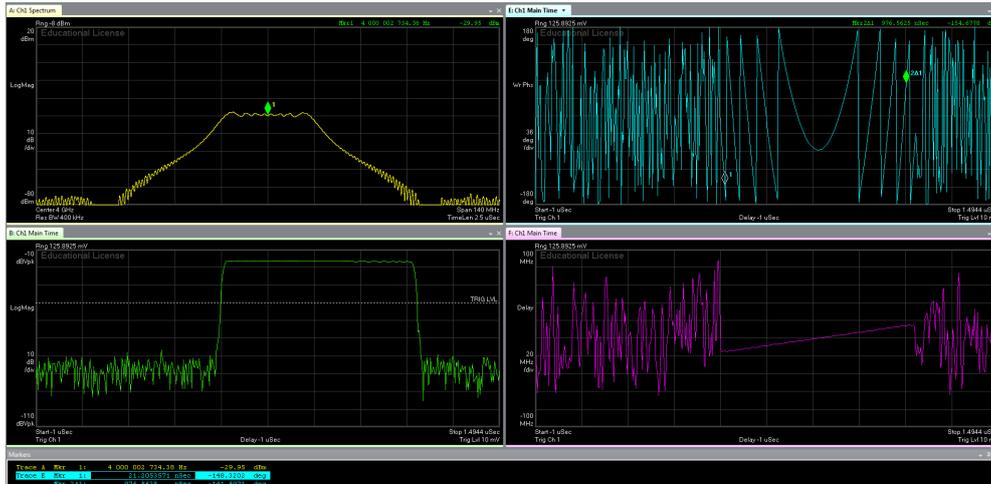
- Examine the `Ch1:Main Time - WrPhs` (wrapped phase) display.

This graph shows the plot of the signal's phase, and in the case of the simple pulsed radar, and should look like Fig. 2.

As you can see, the signal is very noisy for long periods, as the VSA attempts to measure the phase of noise between pulses. Then, while the pulse is transmitting, a flat line is present representing no change in phase. The same line can be seen if the plot is changed to `Ch1:Main Time - Delay`. In both cases the implication is simple, the constant phase during the pulse implies zero phase or frequency modulation.

## 3 Analysis of a Chirped Pulse

Having measured the characteristics of a simple unmodulated radar pulse, we can move onto more practical radar signals. In this case we will analyze a very similar radar signal, but with a Linear Frequency Modulation (LFM), or



**Figure 3:** The VSA display for the chirped radar pulse.

“chirp”, applied to the pulse. This will increase the signal bandwidth and, as a result, the range resolution.

- Load the Radar 2 - Chirp file, while keeping the same displays open.

The resulting VSA display should look like Fig. 3. Here we can see some major changes from the previous signal. The process to measure the PRI, pulse length, bandwidth, centre frequency, etc. are all the same with the chirped signal. The key differences can be seen on the right-hand side of Fig. 3, where the phase versus time is measured.

During the length of the pulse, we can see two issues affecting the phase. First, in the wrapped phase display, the phase is clearly changing in a symmetric manner. Second, in the delay plot, a straight diagonal line is present. This is the characteristic of a Linearly Frequency Modulated (LFM) radar pulse.

In the Delay plot, we can measure the actual bandwidth it is sweeping over, and knowing the pulse length, how fast it does so.

- To measure this we place two markers on the Ch1:Main Time - Delay plot, at either edge of the straight line.
- Change the second marker to a delta of the first, and read the difference off the plot.

The result should be approximately 30 MHz. This is the bandwidth the LFM signal is sweeping over for the duration of the pulse.

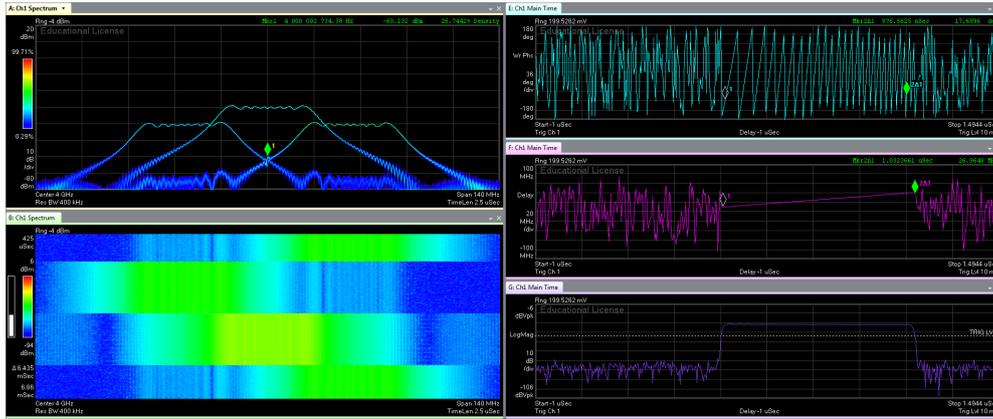


Figure 4: The VSA display of the frequency hopping radar signal.

## 4 Frequency Hopping Waveforms

To further complicate matters, we now going to deal with frequency hopping signals. This will provide a signal with a much more complicated analysis in the frequency domain.

- Load the file Radar 2 - Chirp Hopping.
- Change your displays to show:
  - A: Ch1 Spectrum - Log Mag – then press the show cumulative history button
  - B: Ch1 Main Time - Log Mag – then press the Spectrogram button
  - C: Ch1 Main Time - Wr Phs
  - D: Ch1 Main Time - Delay
  - E: Ch1 Main Time - Log Mag
- Maintain the 10 mV playback trigger

The display should then look like Fig. 4.

The VSA is triggering on each pulse, but as you can see in the spectrogram, and due to the digital persistence, each pulse hops to another centre frequency. If you change the time observed to around 100  $\mu s$ , the hop pattern becomes visible.

In this case, it is the same 30 MHz chirp you saw in the last signal, but the centre frequency sequentially hops from 3.975 GHz, to 4.000 GHz, then 4.025 GHz, before looping through from 3.975 GHz all over again.

## 5 Unknown Signals

Now that you understand how to use the 89600B software to analyze radar signals, here are two files to examine:

- Radar 4 - Unknown Signal 1
- Radar 5 - Unknown Signal 2

Note — In the second signal, the PRF and pulse length are inconsistent...