



ELINT: Modern Radar Signals

Kyle Davidson, M.A.Sc.

This lab introduces modern radar signals and some jamming waveforms, describing their characteristics, and teaching you to measure them. The focus will be on identifying the type of modulation, both on continuous wave and pulsed radar signals.

1 Introduction

Prior to this lab you will have completed an introductory lab on ELINT and pulsed radar signals using the 89600B Vector Signal Analysis (VSA) software. Now, using that knowledge and the same VSA software we'll develop these skills further by examining a series of modern radar waveforms.

These signals will include:

- Frequency Modulate Continuous Wave (FMCW);
- Barker codes;
- Frequency Shift Keying (FSK);
- Costas codes; and

- Noise jamming waveforms.

This set of radar signals have been chosen due to their increasing application to Low Probability of Intercept (LPI) or Low Probability of Detection (LPD) radar systems. As a result, they are a very real threat to air operations.

Again, the goal of this lab is to gather enough information to create a Pulse Descriptor Word (PDW). This PDW would then be used by a EW system to identify and attack radar signals.

2 FMCW Radar

To start, load the file `Signal 1 - FMCW.sdf` into the VSA software. Then change the window type to uniform (`MeasSetup` → `ResBW` → `Window Type`).

The resulting display, after auto scaling, should show a peak moving left to right and back in the frequency spectrum, around 10 GHz. Similarly, in the time domain, the signal is clearly transmitting continuously, but changing in frequency.

Turning on digital persistence, and adjusting the time observed and span to 100 μ s and 40 MHz respectively, you should now observe a similar display to Fig. 1. This figure clearly shows the spectrum is flat over a 20 MHz bandwidth, with a frequency that is changing linearly (observe the linear shape of the delay, this indicates a linear frequency change).

To better observe the behaviour of the FMCW radar signal, viewing the power versus time and frequency is a very useful tool. Select the spectrum display, and click the `spectrogram` button. The resulting plot, shown in Fig. 2, clearly show the FMCW radar signal continuously transmitting, with a linear change in frequency and the repetition interval.

Using these displays, now measure the signal characteristics for the pulse descriptor word.

3 Barker Codes

Barker codes are the first of the phase shift keying waveforms we discussed. They're commonly used due to their unique property that allows for the elimination of side lobes in the time domain.

Start by loading the second waveform file, `Signal 2 - Barker Coded Pulse.sdf`, and setting an input playback trigger with a delay of -5μ s. This should place the pulse well into the observed area for measurement. At this point create two displays: a spectrum and a wrapped phase (main time).

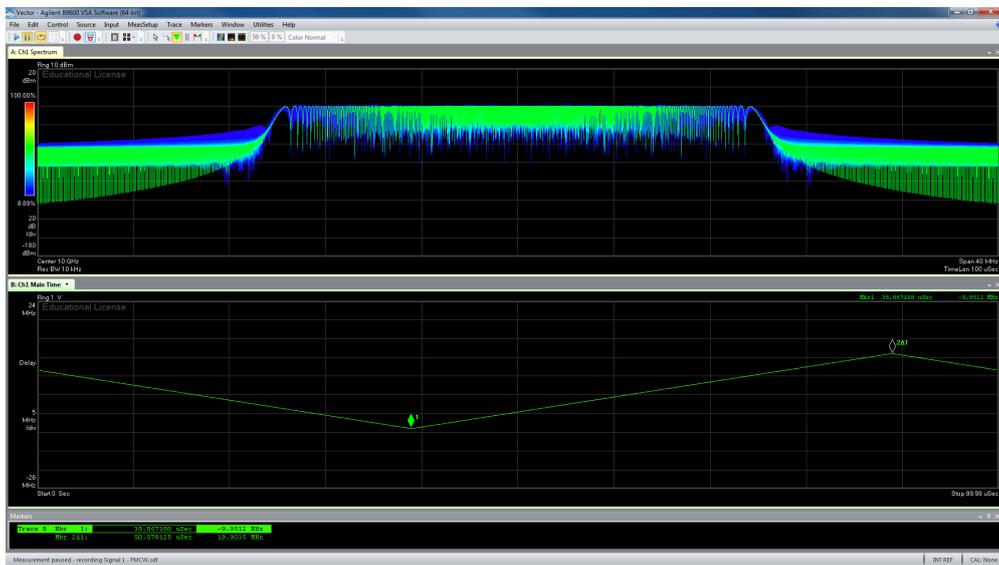


Figure 1: *The persistent spectrum and delay of the FMCW radar signal.*

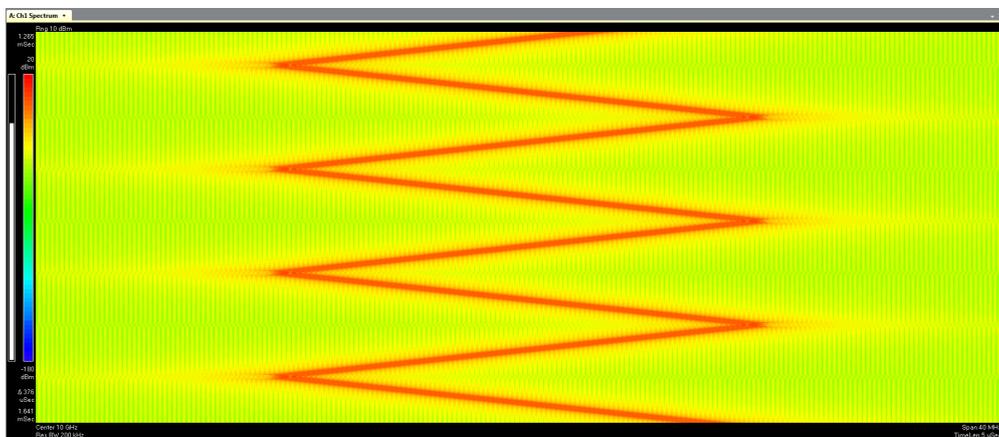


Figure 2: *The spectrogram of the FMCW radar signal.*



Figure 3: *The spectrum and phase of a pulse modulated with a Barker code.*

The results, shown in Fig. 3, strongly indicates this is a Barker code in two ways. The first is the spectrum, examining a 40 MHz bandwidth, we see a strong central peak with much lower side lobes. This spectrum is characteristic of a Barker code (LFM pulses have a much more flat spectrum).

The second indicator is the phase. As Barker codes a Phase Shift Keyed (PSK) modulation their phase oscillates between two binary states 180° apart, indicating a series of ones and zeroes. This can clearly be seen in the wrapped phase, with two states at 0° and 180° . In the phase plot we can also see they're is 5 bits with a $+++-+$ pattern, which is a Barker code of length 5.

Measuring the spectrum, we can further characterize this pulse by the side lobe level. Placing a marker at the central peak and the top of the first side lobe, the difference between the two is -13.4 dB, approximately the -14 dB expected for a Barker code of length 5.

Using these displays, measure the signal characteristics for the pulse descriptor word.

4 FSK Pulsed Signal

The next signal is a FSK waveform, located in the file `Signal 3 - FSK.sdf`. Once it is loaded remove the trigger, change the observed time to $50 \mu s$ and

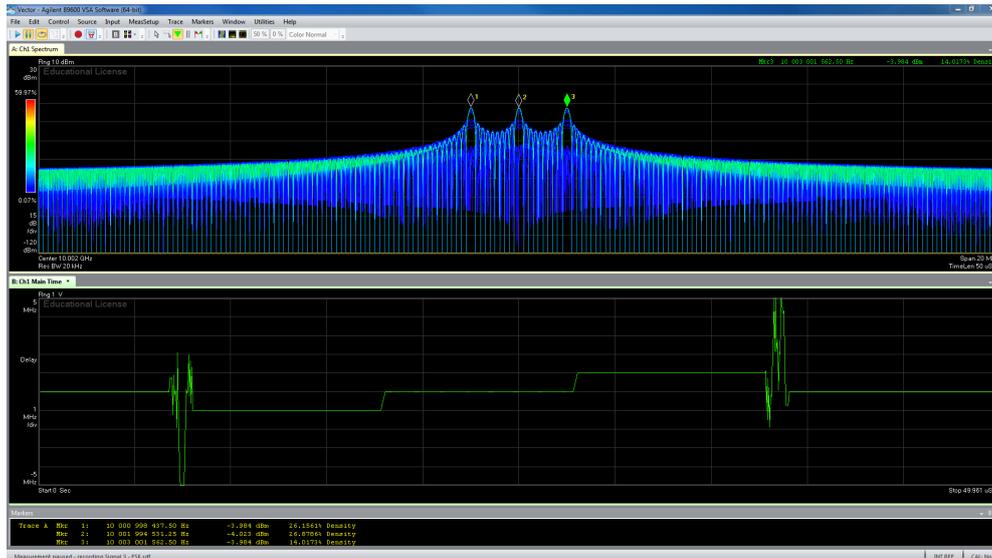


Figure 4: *The spectrum and delay of a pulsed FSK signal.*

the span to 20 MHz with digital persistence.

With the signal playing, you should see a spectrum similar to Fig. 4. The three peaks in the spectrum are the three different frequencies the FSK signal is transmitting. Using markers these can be identified as 10 001 MHz, 10 002 MHz, and 10 003 MHz.

While examining the delay plot, the frequency transmitted is observed to be constant for the three “bits” transmitted, with a step occurring between them that corresponds to the 1 MHz change in frequency.

Using these displays, measure the signal characteristics for the pulse descriptor word.

5 Costas Code

The signal contained in `Signal 4 - Costas Code.sdf` is a form of FSK that uses a unique hopping sequence known as a Costas code in order to reduce the side lobes. They have specific firing sequence that can be examined in the spectrum.

To observe this firing sequence, slow down the signal by changing the Max Overlap (Avg Off) to 99 % (found in MeasSetup → Time). The delay and spectrum of this signal are shown in Fig. 5.

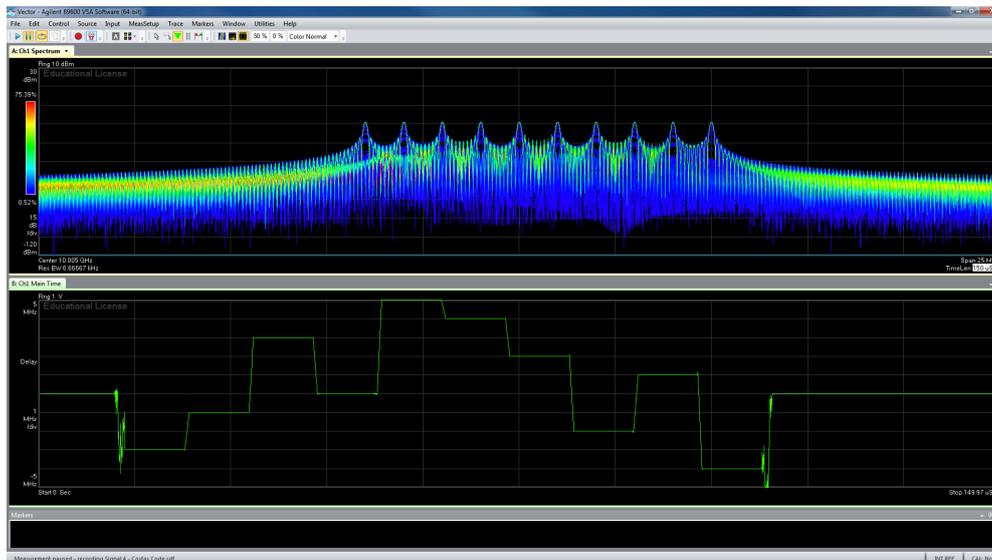


Figure 5: *The spectrum and delay of a pulsed Costas coded signal.*

The delay clearly indicates the hopping sequence, and the amount by which each frequency change occurs. The flat lines between hops indicate that it is at a stable frequency for that duration. This plot can be used to measure most of the relevant information, and verify, based on the firing sequence, if the signal is a Costas code.

More intuitively, the reduced speed, combined with the digital persistence on the spectrum will allow you to see the firing sequence in the frequency domain.

Using these displays, measure the signal characteristics for the pulse descriptor word.

6 Spot Jamming

While not a radar signal, identifying and characterizing jammers is an essential task as well. This is our next task.

Load the data in `Signal 5 - Spot Jamming.sdf` and examine the signal in the frequency and time domain. The results, as shown in Fig. 6 don't show much, which is the point.

In the time domain, there is no observable pattern, just random noise, as we would expect from a noise jammer. In the frequency domain, and specifically the spectrogram, the signal is observed to be stable and covering a specific

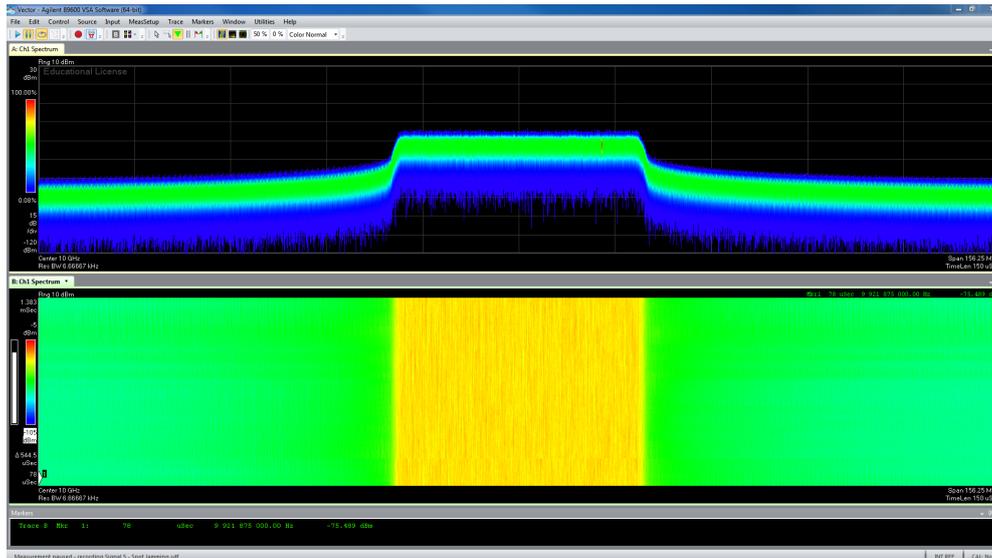


Figure 6: *The spectrum and spectrogram of a spot jamming signal.*

bandwidth.

Using these displays, measure the signal characteristics for the pulse descriptor word.

7 Unknown Signals

Now that you've been guided through the observation of some modern radar signal characteristics, you will find the following sdf files on the course web page:

- signal — unknown A;
- signal — unknown B; and
- signal — unknown C.

As you did with the previous signals, identify them and measure their characteristics for addition to the electronic order of battle.