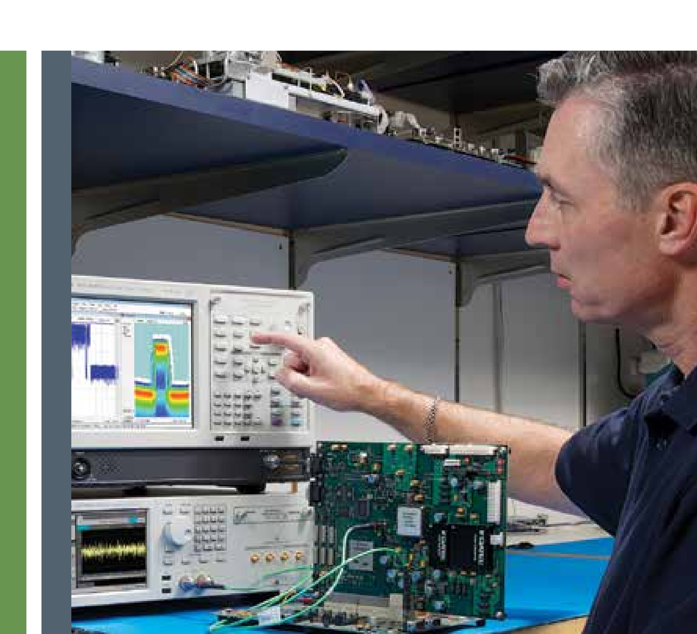
Pulse Compression Fundamentals in Today's Radar



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Contact List Updated June 2013

For Further Information
Tektronix maintains a comprehensive, constantly expanding collection of application notes, technical briefs and other resources to help engineers working on the cutting edge of technology. Please visit **www.tektronix.com**

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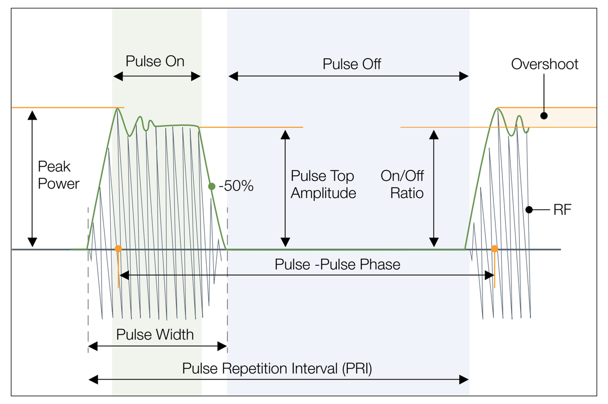
Basic Pulse Parameters



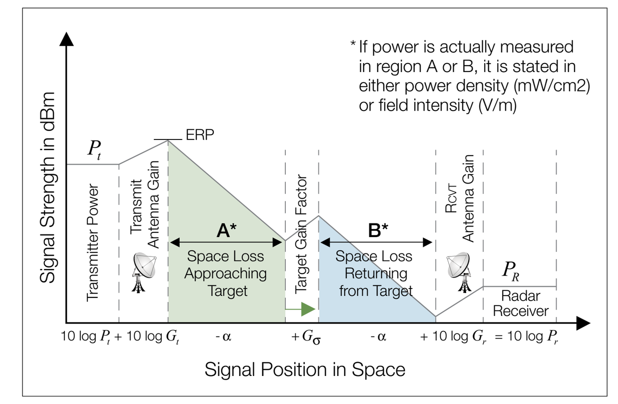
The Radar Equation

Equation 1: The Radar equation is typically expressed in general terms.

$$P_r = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 R^4} = \frac{P_t G^2 c^2 \sigma}{fo^2 (4\pi)^3 R^4}$$

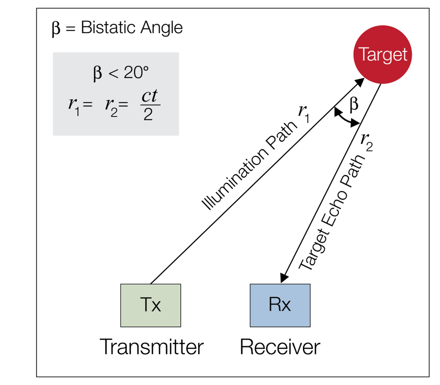
Equation 2: This equation is used to calculate other terms, such as the maximum effective range based on gain and loss through the round-trip signal path.

$$R_{max} = \sqrt[4]{\frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 P_{min}}} = \sqrt[4]{\frac{P_t G^2 c^2 \sigma}{fo^2 (4\pi)^3 P_{min}}}$$

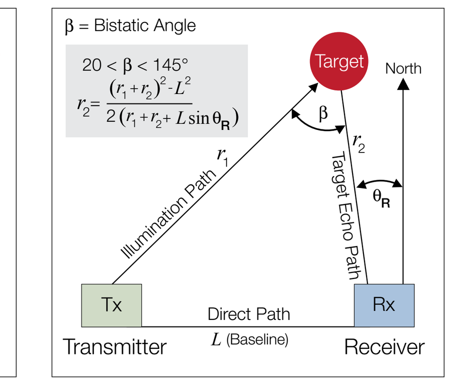


P_t = Transmit power (W)
P_{min} = Minimum detectable power (W)
P_r = Received power (W)
λ = Transmit wavelength (m)
σ = Target Radar cross section (factor)
f_o = Transmit frequency (Hz)
G = Antenna gain (factor)
c = Speed of light (m/s)

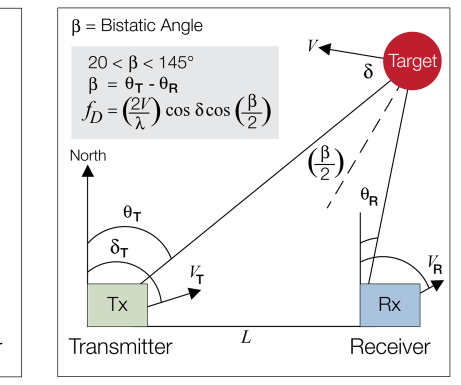
Types of Radar



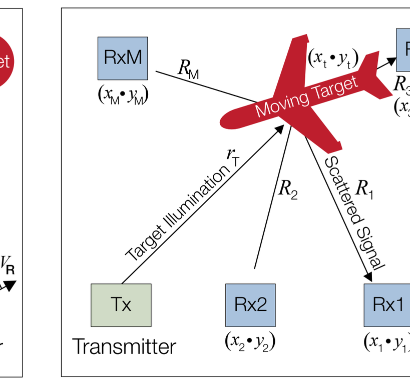
Monostatic



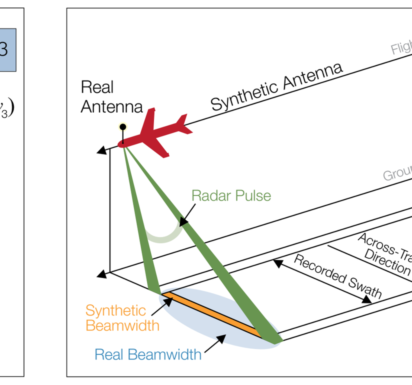
Bistatic



Bistatic Doppler



Passive Multistatic



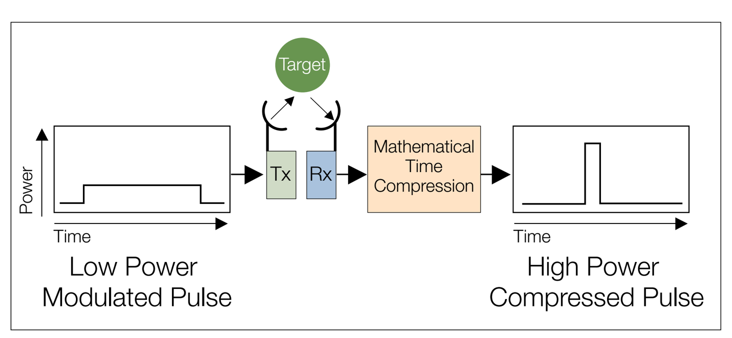
Synthetic Aperture

Pulse Compression Waveforms

Pulse Compression

Following the "see and not be seen" guideline for Radar, the energy in a pulse can be spread over a longer time at a lower power, if the pulse is modulated in some way. Modulation also spreads the signal in the frequncy domain, increasing the information bandwidth of each pulse.

For pulse compression to work, a waveform is constructed such that the energy can be "piled up" in a narrower time window. Any modulation which can be mathematically time-compressed can be used.



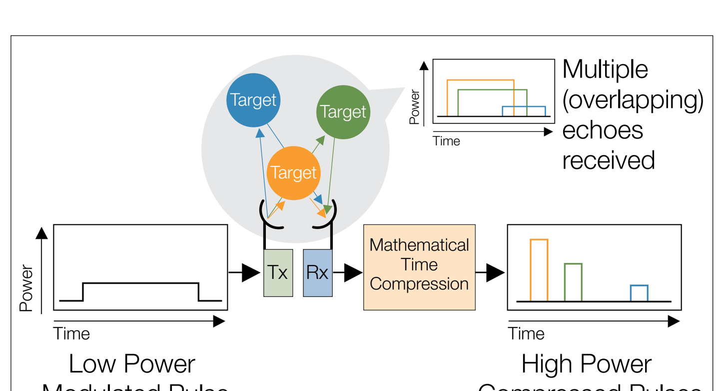
Seeing Without Being Seen

Lowering the power over a longer time period means we are more difficult to "be seen."

By compressing the pulse at the receiver, the received signal is higher in amplitude (we can "see" easier) and has a finer time resolution (we can "see" more clearly).

Pulse Compression (2)

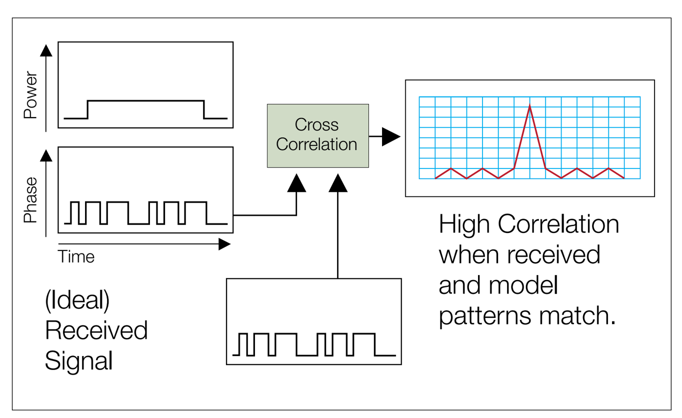
Since multiple objects at different distances could be reflecting the transmitted pulse, Pulse can also separate these echoes due to their varying time-of-arrival.

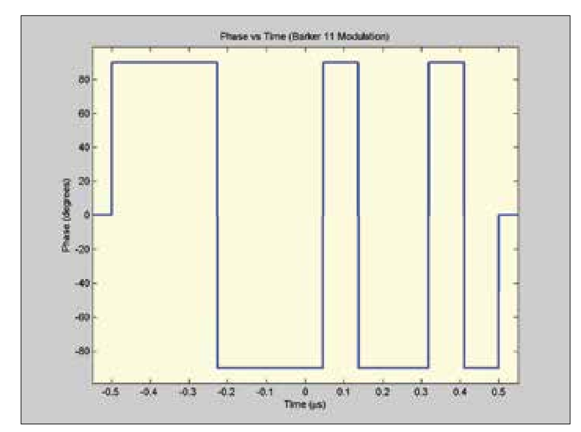


Phase Coded

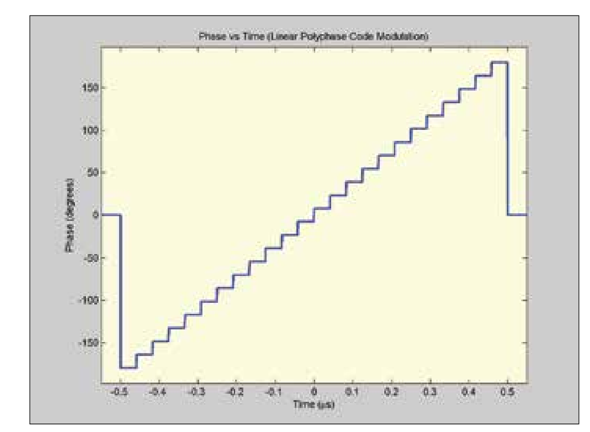
Pulse Compression Using Phase Modulation

For a Phase Coded pulse, the received signal is compressed by cross-correlating it with an ideal modulation model:

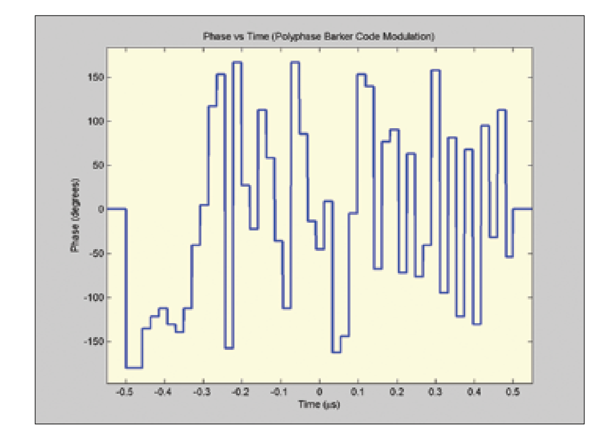




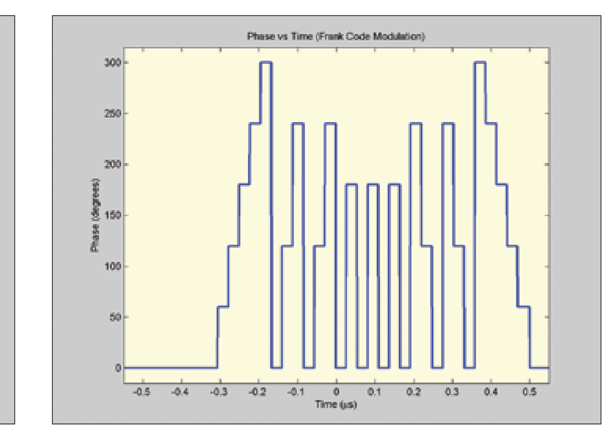
Barker 11 Modulation: Barker-coded pulses have been used for decades to construct compressible pulses. Codes or length 2, 3, 4, 5, 7, 11, and 13 are known.



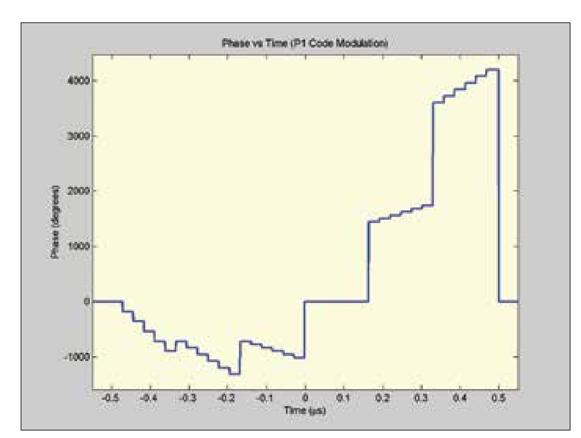
Linear Polyphase Code Modulation: Linear polyphase codes are a fairly simple phase-domain version of a linear frequency modulated (LFM) compression technique. The phase space of -180 to +180 degrees is traversed in a finite number of steps.

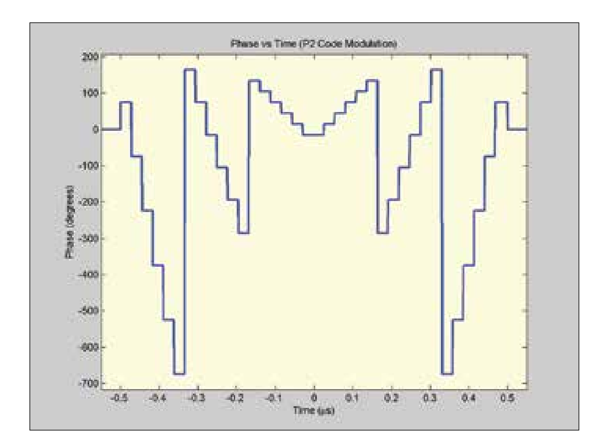


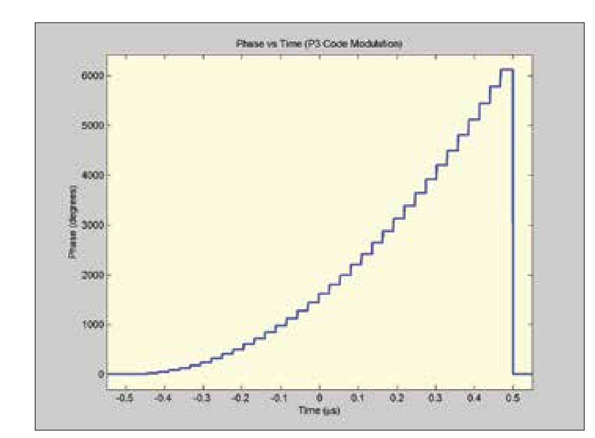
Polyphase Barker Code Modulation: Barker codes also have a polyphase version, which can be made much longer than the longest binary Barker sequence. By using more phase steps the autocorrelation side lobes can be reduced.

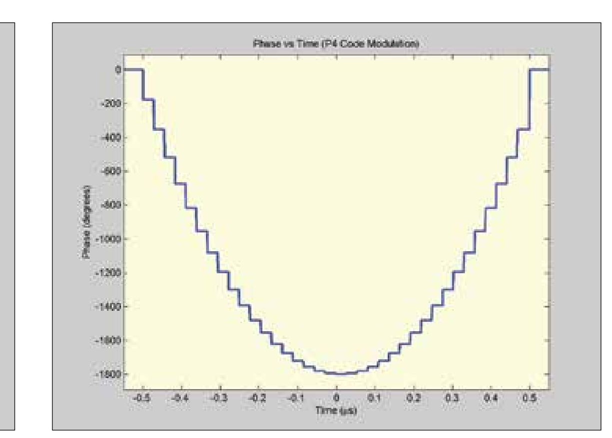


Frank Code Modulation: Frank codes are 2-dimensional polyphase codes with similar range sidelobe characteristics as Barker codes. However, these codes can be much longer than the maximum length Barker code, so the range sidelobes can be lower overall.







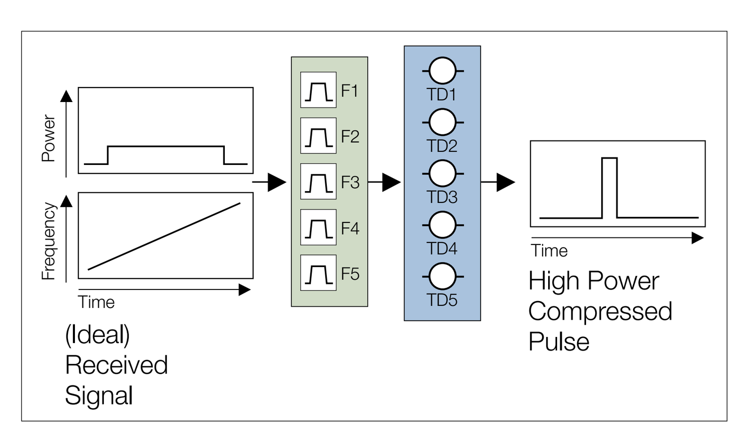


P1, P2, P3, and P4 Code Modulation: The "P" codes all model a parabolic phase change, by steps. This does not produce an LFM pulse, but instead produces a pulse with properties similar to LFM.

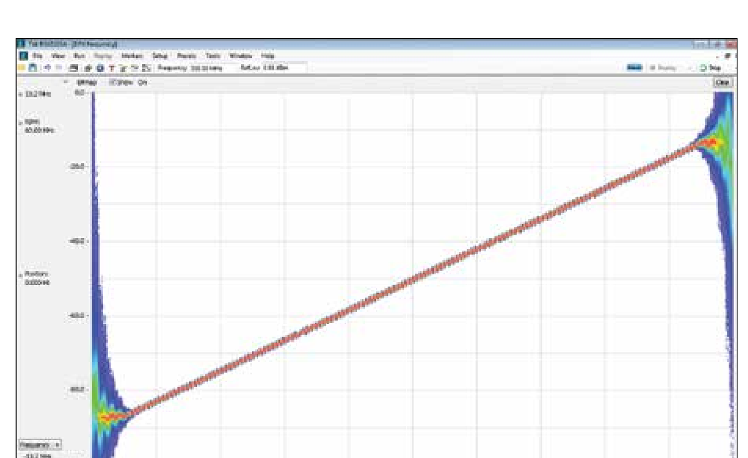
Frequency Modulated

Pulse Compression Using Frequency Modulation

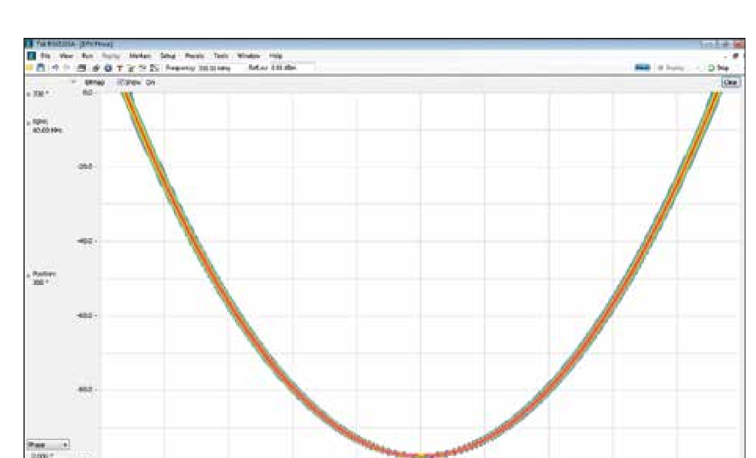
For a Linear Frequncy Modulation (LFM) pulse, compression of the pulse can be performed using a bank of bandpass filters, each filter followed by a different time delay:



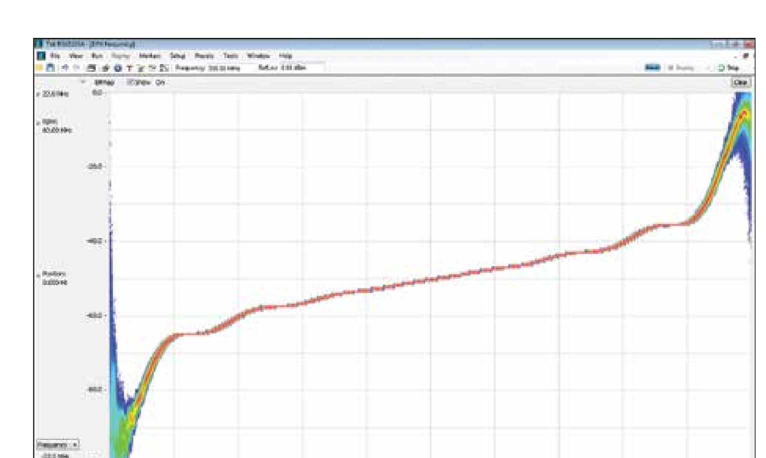
The RSA5126B Signal Analyzer includes many tools required to analyze and troubleshoot Radar signals. In addition to the Real-time Frequency and Phase displays shown below, an in-depth Pulse Analysis suite is available to make 28 parametric measurements on each of thousands of pulses, as well as Trend Plotting of each measurement over the entire ensemble of pulses.



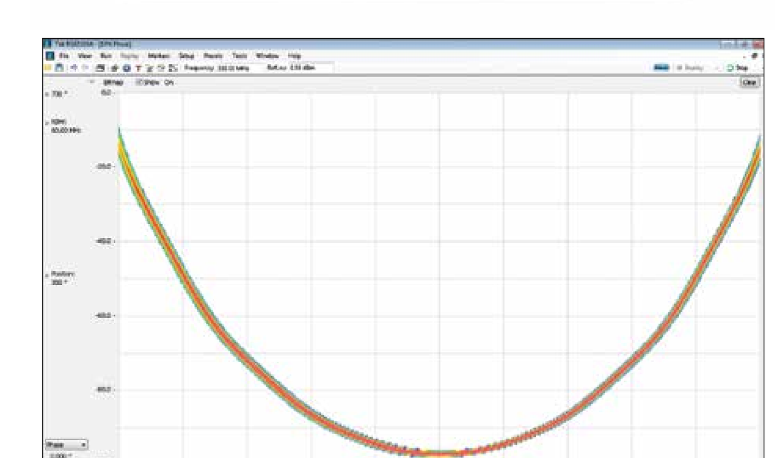
LFM Modulation: The frequency of the signal is changed constantly from the beginning to the end of Ton. [Ed. Ton as in "T"<subscript "on"> In this real-time view of frequency versus time, part of the rising and falling edges are seen.



LFM Modulation: Since the frequency changes linearly, the phase changes along a parabolic path.



Non-Linear Frequency Modulation (NLFM): An LFM pulse typically required weighting in the frequency domain to reduce ambiguity sidelobes. By changing the time spent at each frequency such that less time is spent at the ends of the pulse, this weighting is not required.



Non-Linear Frequency Modulation (NLFM): Since the frequency does not change linearly, the phase change over time is far from parabolic.

Radar Examples

Doppler Weather Radar

Air Traffic Control Radar

PAVE/PAWS Long Range Early Warning Radar*

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1. Pace, P.E. *Detecting and Classifying Low Probability of Intercept Radar.* Norwood MA Artech House; 2009. Print.
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3. Tektronix, et al. *RFXpress Online Help*, Version 5.1. Beaverton, OR: Tektronix, Inc. ebook (PDF).

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