Pulse compression

Pulse compression for solid-state weather radars explained in a nutshell

Pulse compression is a radar technique that combines the advantages of long pulses and short pulses. It improves the range resolution and enables adequate sensitivity for lower peak power solid-state transmitters. A tool developed by GAMIC generates an optimal pulse waveform to improve ground clutter suppression and weather detection while reducing false detection of weather echoes.

APPROACH

» Solid state radars need to compensate lower peak power.

» Longer pulses are used, resulting in lower range resolution and sensitivity.

» With the pulse compression technique the transmitted pulse is modulated and cross-correlated with the received signal (see also other page).

» Very short (in time) peak in the correlation shows the increased range resolution.

» Noise has different frequency than transmitted pulse, it is suppressed during the correlation. The increased signal-to-noise ratio (SNR) compensates the reduced sensitivity.

» The pulse compression gain is defined by the time bandwidth product: pulse width × frequency span.

BACKGROUND

» Pulse compression has been invented to enhance the performance of tracking radars for point targets (distinguish targets in close range with high range resolution).

» For tracking radars, moderate range sidelobes are acceptable (typically ~40dB) since they only need to track the position of the peak relative to the noise.

» Weather radars need to quantitatively measure the amplitude and phase of the sample volume (defined by beam width and range resolution).

» More sophisticated pulse compression is needed, the influence of neighboring volumes needs to be minimized (range sidelobes).

NEED FOR SHORT PULSE

» Disadvantage of long pulse: large blind zone close to the radar.

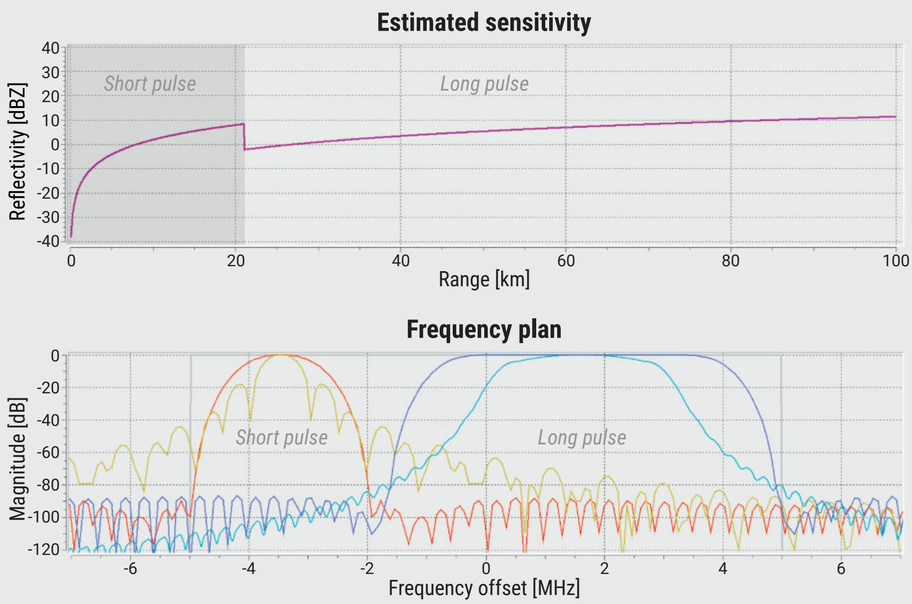
» To fill the blind zone, a shorter second pulse is transmitted at a different frequency (see figures below).

» Echoes from the short pulse are used to fill the gap while simultaneously receiving the returned signal from the long pulse, both are then combined.

EXAMPLE PLOTS

The graphs on the right show an example estimated sensitivity curve (top) and an example frequency plan (bottom) for a typical short pulse / long pulse transmission scheme of a solid-state weather radar.

Receiver frequency bandwidth
Short pulse frequency spectrum
Short pulse receiving filter
Long pulse frequency spectrum
Long pulse receiving filter



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DIGITAL VERSION

GAMIC information and facts

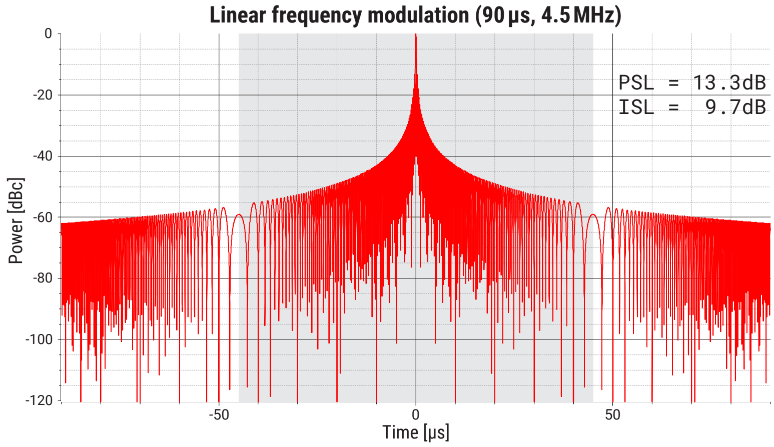
Pulse compression

Non-linear frequency modulation for optimized signal-to-noise ratio

FINDING THE BEST PULSE MODULATION

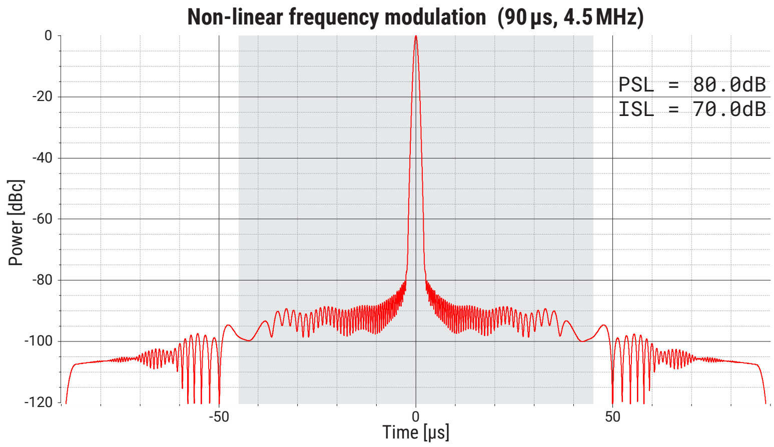
Linear frequency modulation

- Simplest modulation type
- Result is a cross-correlation with a short (in time) and sharp but quickly broadening peak
- Range resolution is increased and point targets can be clearly detected.
- **Useful for point target tracking radars, useless for weather radars (large range sidelobes).**
- The figure on the right shows a linear frequency modulation of a 90 µs pulse with a frequency span of 4.5 MHz



Non-linear frequency modulation (NLFM)

- For volume targets, a frequency modulation with good range resolution and very low range sidelobes is needed.
- This can be achieved by implementing a NLFM and careful mismatching of the receiver correlation function.
- Result is a cross-correlation with a much higher but still narrow peak
- Same pulse compression gain but increased range resolution and much better separation of nearby targets
- **Strong point targets (ground clutter) can be distinguished from lower intensity volume targets (weather).**
- The figure on the right shows a non-linear frequency modulation of a 90 µs pulse with a frequency span of 4.5 MHz



PSL = Peak Sidelobe Level: distance between correlation peak and first range sidelobe in dB
ISL = Integrated Sidelobe Level: difference of peak power and integral of all range sidelobes in dB

LONG PULSE CALIBRATION

The short pulse is similar to any other unmodulated pulse from a weather radar (e.g. magnetron). Short pulse calibration is easy and compatible with the traditional radar calibration.

The long pulse can not be calibrated in the traditional way because effective pulse width (width of the compressed pulse when interacting with a target) and numerical processing losses can only be estimated but not exactly measured.

Best approach: calibrate long pulse against the measured echoes in short pulse region.

- Overlap short and long pulse (receive short pulse longer than needed)
- Adjust the gain (with respect to weather echoes) and phase offset of the long pulse
- GAMIC signal processor ENIGMA performs long pulse calibration in the background during operation
- Clutter-free overlapping echoes
- Configurable minimum signal-to-noise ratio and radial velocity different from zero
- Measured offsets (average of 1 million samples) are output