Pulse compression
for solid state weather radars

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

NEW TO PULSE COMPRESSION? START HERE

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 (fig. 1)
- **Range resolution is increased** and point targets can be clearly detected.
- Useful for point target tracking radars, **useless for weather radars** (large range sidelobes).

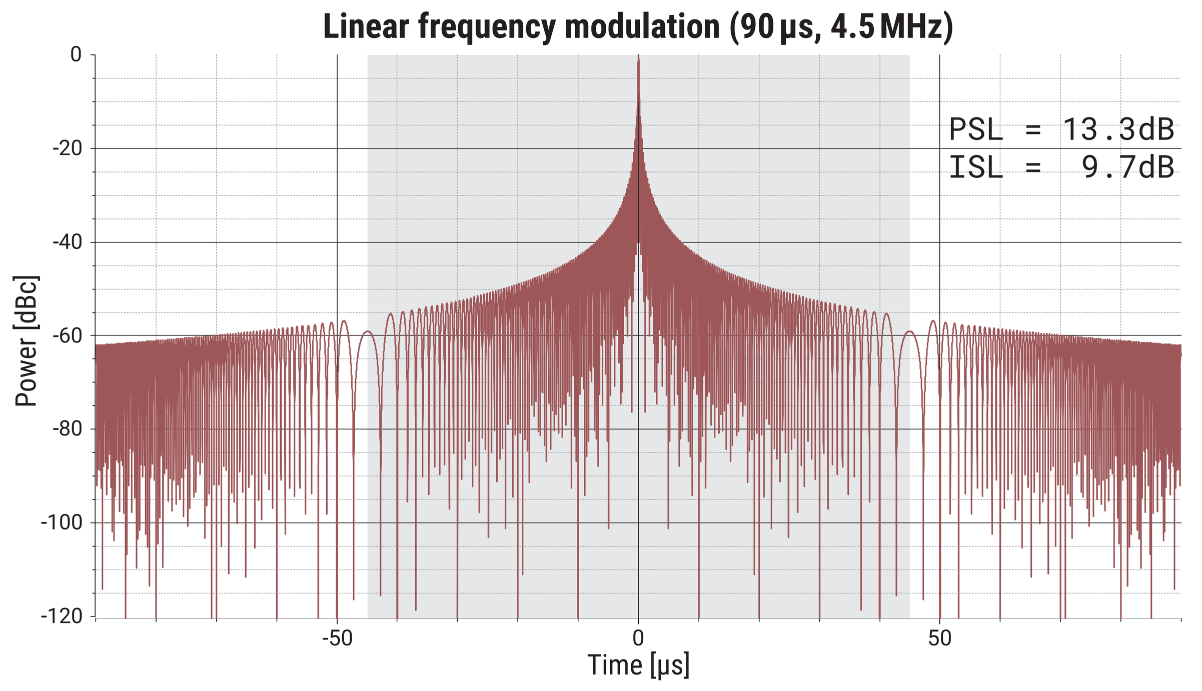

Fig. 1: Linear frequency modulation of a 90 µs pulse with a frequency span of 4.5 MHz; very high range resoluton and low signal-to-noise ratio, appropriate for point target tracking radar.

Non-linear frequency modulation (NLFM)

- For volume targets, a frequency modulation with good range resolution and verly 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 (fig. 2)
- 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).

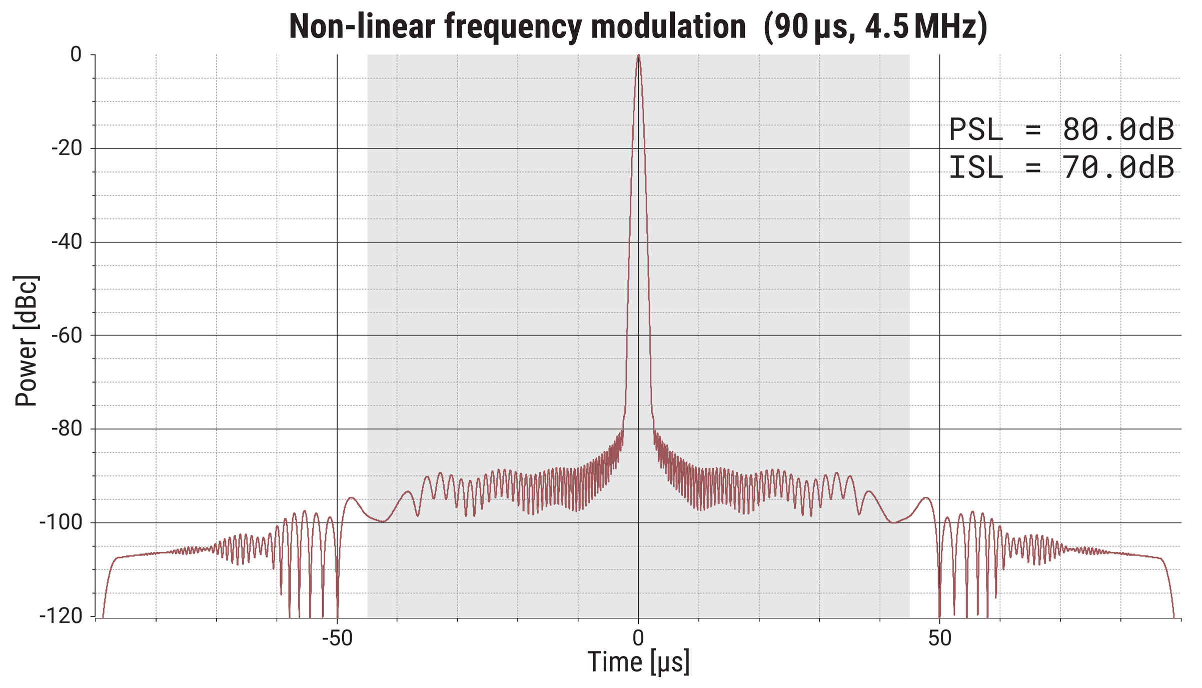

Fig. 2: Non-linear frequency modulation of a 90 µs pulse with a frequency span of 4.5 MHz; high range resoluton, high signal-to-noise ratio, appropriate for weather radar.

Metrics for the range sidelobe performance

Peak sidelobe level (PSL): distance between correlation peak and first range sidelobe in dB
Integrated sidelobe level (ISL): 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

PULSE COMPRESSION IN A NUTSHELL

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 (PC), **the transmitted pulse is modulated and cross-correlated with the received signal** (see for example fig. 2).
- 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

- PC 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), 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 PC 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 it, a **shorter second pulse** is transmitted at a different frequency (see fig. 3)
- 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

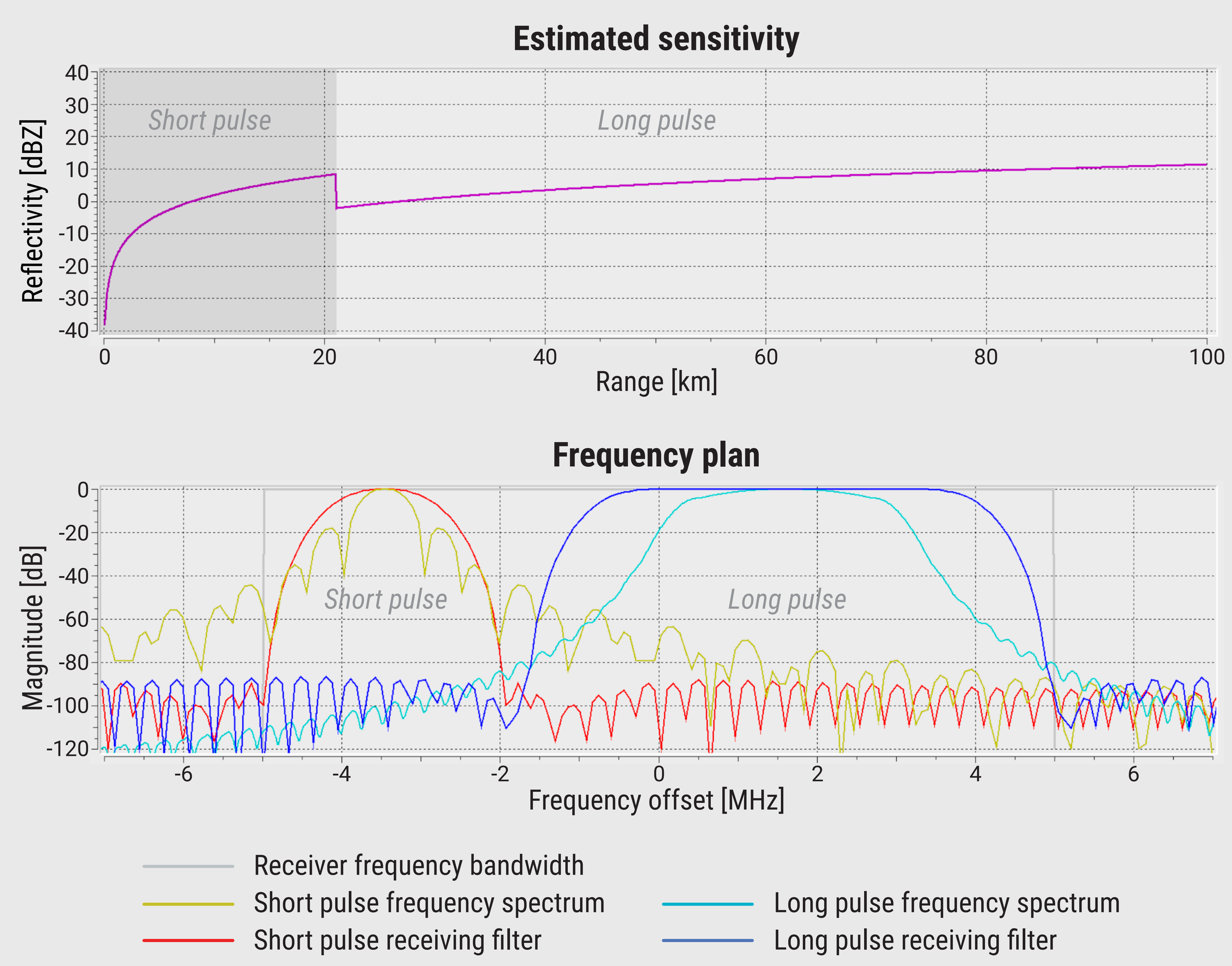

Fig. 3: Example estimated sensitivity (top) and frequency plan (bottom).

WEATHER RADAR & SIGNAL PROCESSING

GAMIC GmbH
Weather Radar & Signal Processing
Roermonder Str. 151
52072 Aachen, Germany

Authors:
Matthias Toussaint, Johannes Vieten
info@gamic.com
www.gamic.com

Download the poster