XeThru X4 Phase Noise Correction

How to Improve Signal to Noise Ratio with Phase Noise Correction

XeThru Application Note **by Novelda AS**

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Summary

This document describes what sampling jitter is and proposes a phase noise correction algorithm.

1 What is Phase Noise?

Phase noise is when a radar frame has a small displacement when looking at it from frame to frame and is caused by jitter in the sampling system. In Fig. 1 you can see two subsequent raw RF radar frames, one in blue and one in orange, placed on top of each other with a significant amount of phase noise to illustrate the problem.

This is not a problem when looking at one frame independently but becomes a problem when looking at how the signal changes from frame to frame, since static objects might be interpreted as moving, even though being completely still. Phase noise correction is a technique for reducing this displacement.

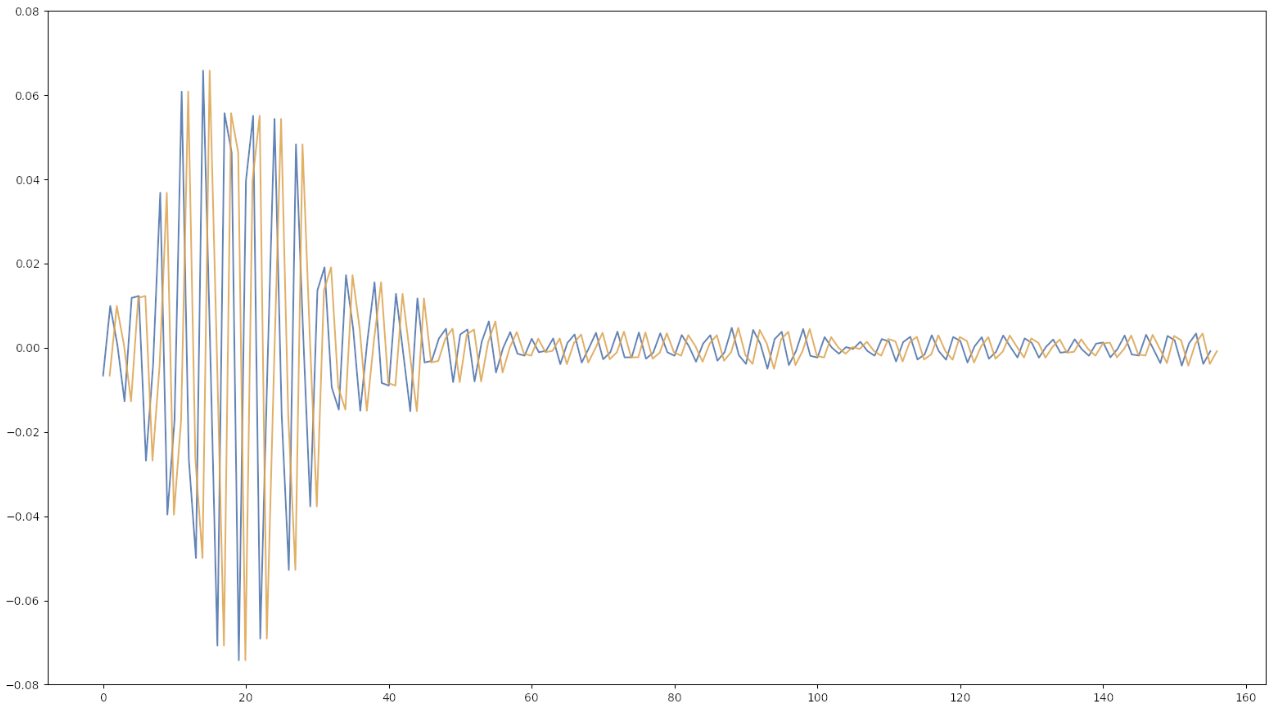

Fig 1. Phase noise between two RF radar frames.

2 Phase Noise Correction Algorithm Overview

It's an advantage to use downconverted baseband data when phase noise correcting, since phase shifting is easily achieved by multiplying the signal with a complex factor of the phase difference.

To start off, a reference bin must be selected. The reference bin must be static, i.e. there should not be any movement at this distance and should contain signal. The direct path energy in the beginning of the frame is often preferred. In Fig. 2 a downconverted frame is shown, containing direct path energy in the first ~8 bins. The peak of the amplitude, at bin 3, is a good choice as reference bin.

The mean phase of the reference bin from a few frames is stored to be used as a reference when phase correcting the frame. Then, to phase correct a frame:

1. Calculate the difference between the reference bin's current phase and the stored reference value
2. Adjust the phase of all bins with the calculated difference

The phase noise is correlated throughout the frame, thus correcting the phase of all bins compared to the reference bin, improves phase noise substantially.

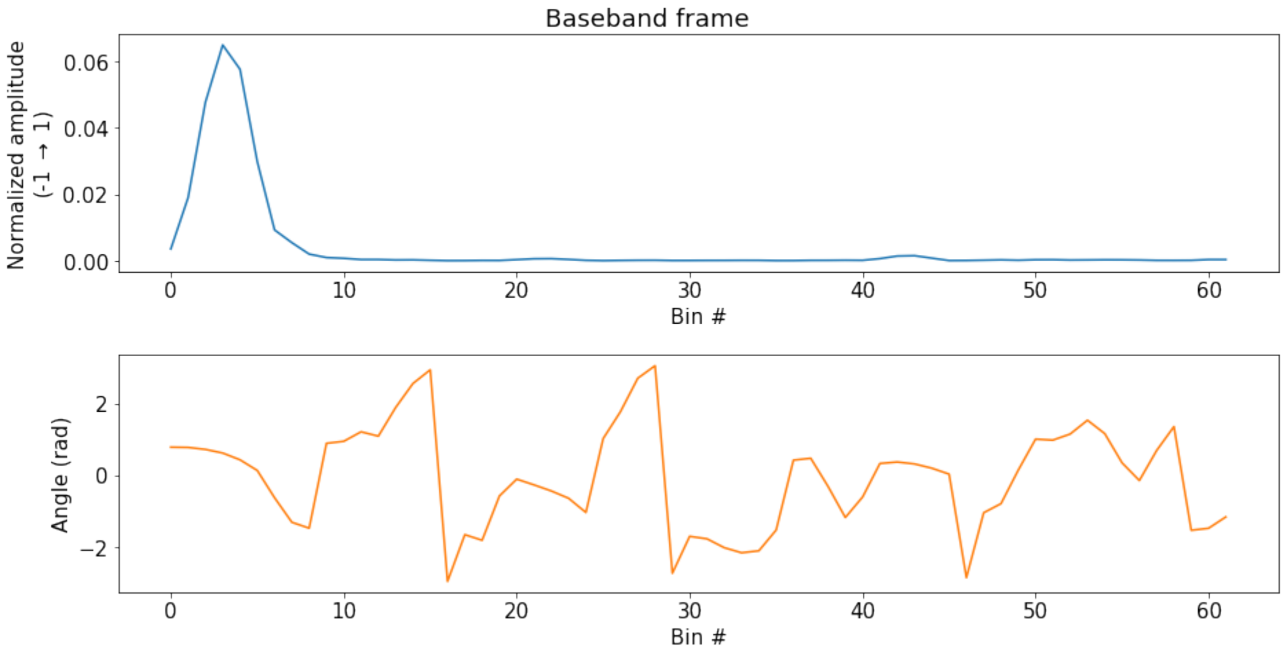

Fig. 2: The amplitude and angle of a downconverted baseband frame.

3 Example of Phase Noise Correction on Real-World Data

A recording was done with the following settings:

```
Python example:

xep.x4driver_init()
xep.x4driver_set_downconversion(1)
xep.x4driver_set_frame_area_offset(0.18)
xep.x4driver_set_frame_area(-0.5,3)
xep.x4driver_set_dac_min(949)
xep.x4driver_set_dac_max(1100)
xep.x4driver_set_iterations(32)
xep.x4driver_set_pulses_per_step(150)
xep.x4driver_set_fps(20)
```

There are two objects in the scene, shown in Fig. 3:

1. A small static reflector at ~1 meter
2. A large static reflector at ~2 meters

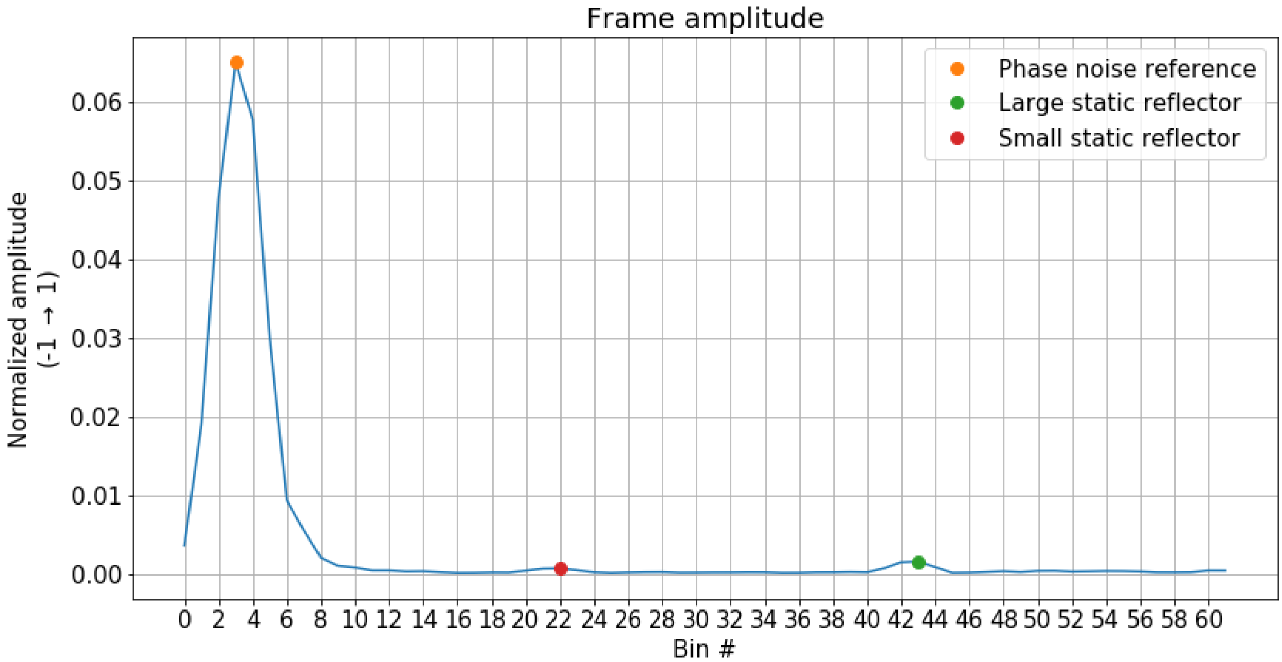

Fig. 3: The amplitude of one frame.

3.1 The Filter

The filter calculates the phase correction needed by taking the difference in angle between the reference bin at the current frame, and the stored reference value. Then it multiplies the frame with a complex factor of the phase difference.

Python example:

```python
import numpy as np


class PhaseCorrection(object):
    def __init__(self, bbframes, bin_ref):
        """Takes a baseband frame buffer and stores mean phase of the given bin.

        The phase at the reference bin is later used as a reference when
        phase correcting the frame:

        1. Calculate the difference between the reference bin phase and
           the stored reference value
        2. Adjust phase of all bins with the calculated difference

        The phase noise is correlated throughout the frame, thus correcting
        the phase of all bins compared to the reference bin, improves
        phase noise substantially.

        The reference bin must be static and should contain signal, the
        direct coupled energy in the beginning of the frame is often preferred.
        """
        self.bin_ref = bin_ref
        self.bin_angle = np.angle(bbframes[:,bin_ref]).mean()

    def filter(self, frame):
        phase_correction = self.bin_angle - np.angle(frame[self.bin_ref])
        return frame * np.exp(1j*phase_correction)
```

3.2 The Result

The result of filtering the first 3.5 minutes of the recording can be seen in Fig. 4 below.

Fig. 4: Angle of static reflectors before and after phase noise correction.

Fig. 5 shows the power spectral density of the range bin with the reflection from the large static reflector. The lower plot shows the result after using a simple moving target indicator (MTI) filter, which simply differentiate the previous frame with current.

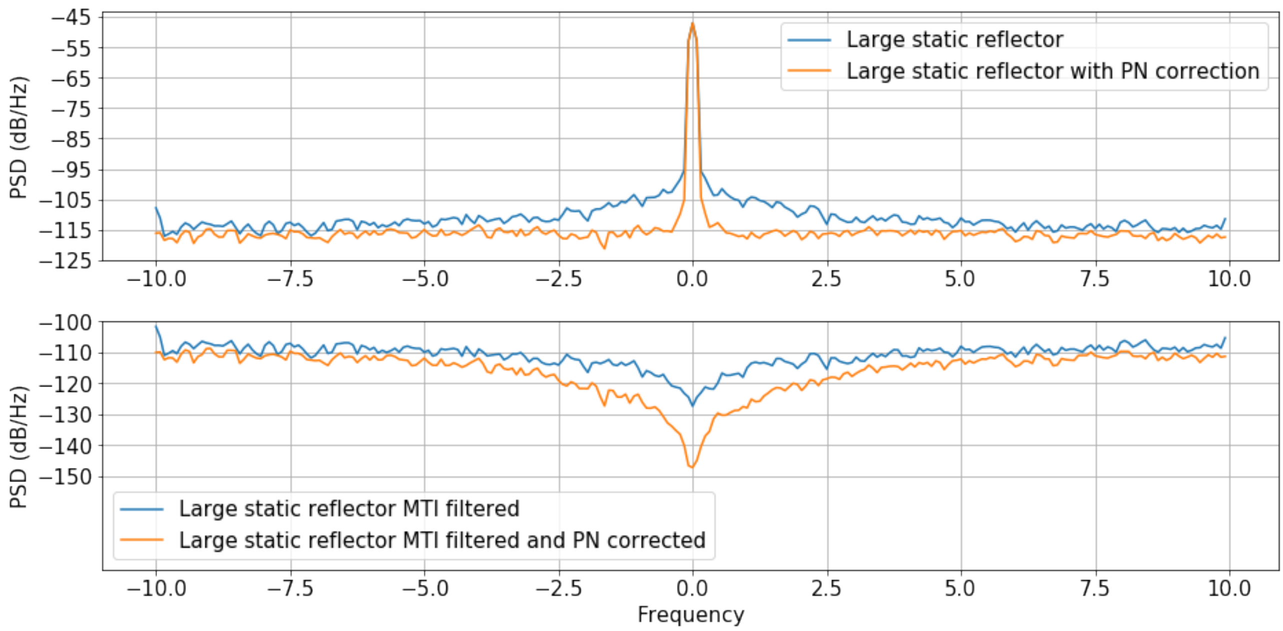

Fig. 5: Power Spectral Density of the range bin with the large static reflector.

4 Conclusion

In many applications, it's of great interest to look at the frame-to-frame difference in the radar data to detect movement. Phase noise causes static objects to appear as moving back and forth. By applying the Phase Noise Correction algorithm in the example data, the unwanted noise from the large static reflector was reduced about 20 dB at DC when MTI filtering.

5 Document History

Rev.	Release date	Change description
A	2018-Sept-27	Initial release

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