Motivation

Wind turbine operation is restricted when protected species might be endangered by it. A radar sensor is investigated aiming to avoid long-term wind turbine shut-off by providing an option for a shut-off on demand.

Bird Detection in Proximity of Wind Turbines

For the presented application of wind turbine shut-off on demand, a positive identification of the bird is crucial to avoid false alarms that cause unnecessary shut-offs.

Proposed discrimination feature in [1,2]: Micro-Doppler Signatures

Problem: LFM radar waveforms lead to ambiguities in Range and Doppler.

Proposed technology: Noise Radar


Noise Radar Signal Processing
Noise Radar Technology [3]

- Key features of noise radar technology (NRT) very briefly:
  - Considered radar waveform: (pseudo-)random CW and bandlimited noise
  - Its inherent aperiodicity leads to: absence of range ambiguities
- This presentation focuses on the common digital correlation receiver

\[
R_{sg}(\tau) = \int_{-\infty}^{\infty} s(t)g^*(t - \tau)dt.
\]


Range Filter Bank Method [3]

A Range Filter Bank (RFB) is formed by M matched filters \(g_m(t)\).

\[
g_m(t) = g(t - mT_r) \cdot \text{rect}\left(\frac{t}{T_r}\right)
\]

\[
R_{sg}(\tau) = \int_{-T_r}^{T_r} s(t)g^*(t - \tau)dt
\]

\[
\tilde{R}_{sg}(t) = \sum_{m=0}^{M-1} R_{sgm}(t - mT_r)
\]

The analysis interval of \(s(t)\) can be chosen far shorter than the round-trip delay of the maximum observable range:

\[T_r,<<(M-1)T_r\]
Features of the Range Filter Bank Algorithm

- The processing gain of the RFB during a single observation interval $T_r$
  - Is equal to $G_0 = BT_r$
  - While the observation range corresponds to a much longer round trip delay of $R_{\text{max}} = (M-1)T_r c/2$
- Coherent processing of $P$ subsequent range profiles of update rate $T_r$ thus leads to a combined processing gain of $G = PG_0 = PB T_r$
- In this context the Fast Fourier Transform (FFT) is the coherent processing method of choice
  - Application of an FFT of length $P$ results in a Range-Doppler Map with highly flexible parameters

Wind Turbine Measurements

- Experimental X-Band Noise Radar
- Emitted Waveform: Gaussian process filtered to $B=50$MHz ($\Delta R=3$m), ERP<$2$W

![Wind Farm](image)

![SNR vs Range](image)
Range-Doppler Analysis

PRF of 250kHz corresponds to $R_u = 600\text{m}$
RFB of $M=5$ matched filters leads to $R_{\text{max}} = 3\text{km}$

Result:
Although the PRF is as high as 250 kHz, no range ambiguities are observed in the output data due to the non-periodic characteristics of the radar waveform.

In the figure: the velocity scope of +/- 2000 km/h (almost Mach 2) was cropped to +/- 300 km/h.

Summary

Major Advantage:
NRT allows overcoming the intertwining of range and Doppler analysis.

Main Drawback:
NRT has extensively higher amount of computational effort when compared to FMCW radar.
Thank you.

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Passive Radar and Anti-Jamming Techniques

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