Optimized Waveform for High-Sensitivity Weather Radars via Coordinate Descent

Mohammad Alaee-Kerahroodi[1], Bhavani Shankar Mysore[1], *Kumar Vijay Mishra[2], Anton Kruger[2], Witold F Krajewski[2], Bjorn Ottersten[1]

1. SnT, University of Luxembourg, 2. The University of Iowa, Iowa City, IA 52246, USA

Over the last decade, pulse compression (PC) processing has proven to be critical in improving the sensitivity of weather radars. This is largely because PC decouples the dependence of pulse length on range resolution, thereby allowing considerably higher resolution and sensitivity. Advances in PC-based weather radar waveform design have been complemented by the increasing use of solid-state transmitters in long-range weather radars. These systems have lower peak power and higher duty cycle, which makes PC implementation in hardware feasible.

Frequency-modulated pulses such as PC waveforms interfere incoherently during correlation processing at the receiver. As a result, peaks of false return power or sidelobes appear along the range for the duration of the correlated output pulse. This effect is accentuated in meteorological radars because volumetric nature of precipitation implies elevated false signal power throughout the pulse rather than individual peaks. There have been several attempts to mitigate this undesired phenomenon by adopting a di erent waveform or lter or both. In this paper, we focus on designing low sidelobe waveforms by exploiting some recent applications of optimization theory.

Unlike hard target radars, where PC-based waveforms are designed to have low peak sidelobes (PSL), a good design objective in case of weather radar is to minimize the integrated sidelobes (ISL). Conventionally, non-linear frequency modulated (NLFM) pulses and some of their variations, when employed with a mismatch lter obtained through least-squares solution of sidelobe minimization, have been shown to exhibit low ISL. However, theoretical guarantees in this approach are weak.

Recently, analytical methods have been proposed to design binary signals to find easily-constructed sequences such as m-sequences, Gold or Kasami sequences which are known for their perfect periodic autocorrelation function. When the constellation size increases, or the sequence has millions of elements, it becomes increasingly dicult to perform an exhaustive search to nd an optimized sequence. In such cases, it has been shown that derivation of optimal or nearly-optimal sequences is possible through weighted cyclic algorithm-new (WeCAN) yields constant-modulus sequences with good aperiodic and periodic ISL. The WeCAN algorithm approximates the quartic ISL function to an alternative quadratic objective and solves the resulting optimization through majorization-minimization (MM). Moreover, use of Fast Fourier Transform (FFT) renders the method computationally efficient.

In this paper, we design PC sequences with good ISL based on the MM approach for meteorological radar. We validate our approach through numerical experiments on data collected by the Iowa X-band POLarimetric (XPOL) radars.

Keywords: Waveform Design, lower Peak side lobe level, lower Integrated side lobe level, majorization minimization, computational efficient design, Iowa X-band POLarimetric radars