The high-resolution and multipath-robust automatic modulation classification method for nonlinear frequency modulated radar signal

Abstract

This dissertation presents the novel method of automatic modulation classification (AMC) for nonlinear frequency modulated radar signal (NLFM). The recognition of the modulation embedded in the intercepted radar signal is particularly useful for electronic intelligence systems, as it gives the extra signature of the signal which augments the pulse descriptor word. This simplifies the recognition of specific type of radar in dense electromagnetic environment and supports pulse deinterleaving. Moreover, some capabilities of the hostile radar can be inferred from the modulation scheme. Despite some alternative radar AMC methods have been developed so far, they have not considered specifically NLFM signals. Meanwhile, besides traditional linear frequency modulation (LFM), this waveform is gaining more attention in radar community, what was proven during the research.

The overall task of a research was to implement the complete modulation classifier algorithm based on pattern-recognition approach. This involved the generation of the synthetic frequency-modulated radar signals, where as many as five different NLFM waveforms have been considered. Then, twenty potential signal features distinctive for the LFM/NLFM modulation pair have been proposed along with their extraction methods. Feature selection stage was comprised of Fisher score and minimal-redundancy-maximal-relevance analysis. In the effect two target features were chosen, both based on a complex signal processing methods – fractional Fourier transform and quasi-maximum likelihood instantaneous frequency estimation algorithm. Finally, these two metrics supplied the last block of the designed algorithm, i.e. naïve Bayes classifier, which decision boundary was determined using the synthetic training data.

The developed algorithm provides for multipath fading, the phenomenon which often occurs in case of land-based interception systems. The literature review has shown that no other radar AMC method has taken this issue into consideration and similar research was conducted only for communications signals. Despite few different means to mitigate the multipath effects has been proposed to date, i.e. direct signal extraction or applying the equalizer, this dissertation proposes simpler approach, which consists in utilizing only those features which remain robust to multipath distortions.

The accuracy of the developed method has been proven using both synthetic and real LFM and NLFM signals. Such exhaustive research involving real data has not been presented in publicly available literature so far. Among the primal application in electronic intelligence, the developed AMC method may be also useful for spectrum monitoring, cognitive radio or passive bistatic radars.