Abstract

Multiple-Input Multiple-Output (MIMO) radar is a more general form of phased array radar, where each antenna in the array transmits linearly independent or mutually orthogonal signals. Sustained growth in computational power as well as the decline in the cost of integrated radio frequency (RF) components has made MIMO more viable than in the past. The potential emergence of practical MIMO radar has prompted an investigation into the detectability of MIMO radar signals using existing conventional Electronic warfare Support (ES) receivers such as the Crystal Video Receiver (CVR) and a specific type of superheterodyne receiver (superhet) known as the Zero IF Receiver (ZIFR). Literature on the detectability of MIMO radar signals is extremely scarce and this investigation aims to offer insights into the detectability of MIMO radar signals by means of computer simulations.

The fundamental theory necessary for this research includes phased array radar theory, MIMO array radar theory and ES receiver signal detection theory. The detection of MIMO radar signals is compared to a reference phased array case to provide relative context. This investigation focusses on co-located Uniform Linear Arrays (ULA) based radar systems. The result of interest is the relative Signal-to-Noise Ratio (SNR) at which each type of radar can be detected by the ES receiver. Therefore, a lossless transmission, without loss of generality, is assumed. Constraints such as the equal transmit power over all antenna elements in the arrays, are used for a fair comparison. Many different array simulation setups are simulated. These setups are achieved by varying the number of elements in the array and the inter-element spacing. The phased array radar transmitted complex linear chirp signals, and the MIMO radar transmitted Hadamard sequences, interpolated using a Constant Envelope Linear-Route-of-Unity (CE-LRU) technique. The CVR and ZIFR detection thresholds were determined for a Probability of False Alarm (PFA) of 10^{-4}.

For all of the setups, the phased array radar was found to be more detectable than the MIMO radar at values of Probability of Detection (PD) below 0.6. The in phase coherent combination of phased array radar signals in its main beam resulted in a signal gain caused by the constructive addition of the signals. This gain thus increases with the number of antenna elements. In contrast, the MIMO signals also add coherently, but the instantaneous phase for each signal is a function of the transmitted signal as well as the direction of propagation relative to the array face. The set of orthogonal signals thus add constructively and destructively, resulting in the average signal power remaining approximately constant

despite the number of antenna elements increasing. The difference in detectability of the phased array radar over MIMO radar therefore increases as the number of antenna elements is increased, due to the fact that each element is constrained to transmit a fixed power.

Comparing the performance of the ZIFR and CVR, the ZIFR outperforms the CVR. This is due to the fact that the ZIFR implements a quadrature ES receiver, and was able to detect both types of radar signals at a lower SNR than the CVR. However, both ES receivers struggle to detect MIMO radar signals in comparison to detecting phased array radar signals and this performance margin widens as the number of transmitting elements is increased. This result suggests that research into dedicated techniques for the detection of MIMO radar signals using ES receivers may be necessary should the need arise to detect MIMO radar signals in future. This is the first quantitative analysis of the detectability of MIMO radar signals using conventional ES receivers that the author is aware of.