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MIMO RADAR PERFORMANCE USING SWERLING SCATTERING MODELS

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Abstract — The performance of multiple input multiple output (MIMO) radar configurations of distributed antennas are analyzed. Statistical multiple input multiple output (MIMO) radar develops angular diversity to mitigate the impact of radar cross section fluctuations (RCF). The fluctuations can be modeled with scattering model consists of non-orthogonal waveforms for fast target or radar cross section fluctuations (RCF). Consider the performance of the statistical MIMO RADAR under the influence of the scattering model, which is commonly used in the radar community to model the distribution and the temporal correlation of the target radar cross section (RCS). In this project both target detection and direction of arrival estimation are considered.

Key words —Array signal processing, direction finding, multiple-input multiple-output (MIMO) systems, performance bounds, radar, target detection**.**

INTRODUCTION

The rapid changes in the radars are used for impairment caused by fluctuations in radar cross section of the target. In this process, the antennas are placed in different places, so that the target can be seen as of different angles. Such systems are commonly called statistical multi-input multi-output (MIMO) radar [1], [2] or with scattered antennas of MIMO radars. Colocated antennas, MIMO radar that uses this approach in contrast to [3] - [7]. By exploit the spatial diversity, using coherent processing can be achieved better performance compared to the conventional phased array systems.

In this paper, we aim to be normally distributed and the radar cross section (RCS) of the temporal correlation between the model used in the radar community i.e., Swerling scattering model which is considered as influencing the performance of the statistical MIMO radar. Swerling scattering model consists of four separate occasions [8] for RCS fluctuations in both slow and fast modeling.

We expected the arrival of the tasks in the four Swerling target scattering models to determine the Performance and direction of a variety of configurations to calculate the statistical MIMO radar. To our knowledge, only [9] present a statistical model for the scattering effect on the performance of MIMO radar addressed.

Neyman-Pearson sense [2], the statistical MIMO radar detector modified for the use of orthogonal waveforms. However, Swerling case 1 or 2 orthogonal waveforms are assumed upon the treatment of a single pulse. Swerling cases [10] measured the target, but it is not suitable to have 3 or 4 cases of the projected test statistic.

We have prepared optimal test for single and multiple pulses in all Swerling cases and without assume the waveforms are orthogonal. Additionally, assuming the orthogonal codes, we develop the optimal detector and its distribution in the Swerling cases 3 and 4, a linear distribution of a suboptimal detector [10] proposed similar. We have the right detector [10] have exposed that the suggested detector output forms. Distributions of the test statistics are derived under the null and other hypotheses. The numerical examples shown in the difference in performance between the optimal and the suboptimal detector is usually a small one.

Several studies have found the performance of MIMO radar direction finding. [11] With respect to the performance of the random scattering parameters Cramer-Rao bound (CRB) has been analyzed by the average, but it was Swerling case 1. Correlated scattering effect has been studied [12], although the Swerling cases 2 and 4 mentioned, the results are provided for case1 only. Cramer-Rao bounds derived in [13] and [14] but considered only the Colocated transmitters. We [9] The angular variation Swerling cases 2 and 4 of this paper is to improve the performance of finding the direction shown by using the CRB, we extend in the direction of finding a statistical MIMO radar configuration and phased array system by comparing the results and Swerling cases 1 and 3 in the phase range from CRB system SISO (phased-array) system is definite, the similarity is done in terms of the reliability of an upper bound of the squared estimation error. In this case, the angular difference in the detection of the case 1 and to some extent in case3 will be shown to be beneficial in finding.

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The rest of the paper is organized in the following. Section II discusses the signal model used in this paper. MIMO radar different configurations are described in Section II-A. In section III, the goal is to find the likelihood ratio and test statistic for target detection are derived. Numerical results are also provided. Section IV determines the direction finding performance. The final conclusions are made in Section V.

SIGNAL MODEL

Statistical MIMO radar is a signal model is developed in [2]. Small changes are made in the way that we use the signal pattern.

In the used signal model, the receiver array snapshot of a MIMO radar configuration with M transmitters and N receivers can be written as

$$\mathbf{r}(t) = \sqrt{\frac{P}{M}}\text{diag}(\mathbf{b})\mathbf{C}\text{diag}(\mathbf{a}^{*})\mathbf{s}(t-\tau) + \mathbf{n}(t)$$

Statistical MIMO Radar Configurations

If the distance is close to all the transmitters, they are transmitted in the form of the wave, which means that each target scatters from the target in the same way as others see the same aspect. If the receivers are also located close to the same as the received waveforms are scattered from the target, and require only one scattering model for scattering amplitude. This type of configuration is a single-input single-output (SISO) configuration.

$$\mathbf{r}_{SISO}(t) = \sqrt{\frac{P}{M}} c\,\mathbf{b}(\theta)\mathbf{a}\,\mathbf{s}(t-\tau) - \mathbf{n}(t)$$

A single-input multiple outputs (SIMO), the configuration, allows the transmitters to transmit beam forming, but the goal of each aspect of an individual is to be independently sees than the scattered signal which will be placed to the receivers.

These four configurations to cover cases in which the scattering is independent or correlated fully. The scattering of the need to fully characterize the distribution of scattering amplitudes. In this paper, we assume Swerling scattering model.

Scattering Model

A simple model of the target RCS fluctuation Swerling model [8]. Two different distribution and slow or rapid fluctuations in the four different cases. The radar cross-section σ, the probability density function (pdf) is

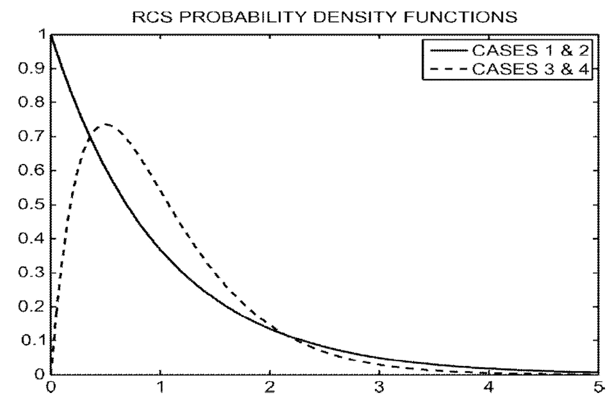

Fig. 1 shows Probability density functions of the Swerling cases when fluctuations are slow in cases 1 and 3, fast in cases 2 and 4

The pulse-to-pulse (fast) fluctuations target RCS back to each individual pulse, scan-to scan (slow) fluctuations in the target RCS is a scan of each pulse is constant, however, to understand the individual scans. Omni directionally MIMO radar transmits a scan is not well defined, however, we notice that the RCS to detect the direction of the target's identity, or to assume that RCS is stable within the time scale.

DETECTION PERFORMANCE

Used for radar target detection is a major task. Therefore, the detection is done in a group is important. Optimality criterion is commonly used in the detection of the target with a certain probability of false alarm which maximizes the probability of detection is the Neyman-Pearson optimality.

It has been shown [2] the goal of the test statistic for the detection of transmitted signals are orthogonal, that is, when the matched filter output vector of the squared norm. Swerling case 1 or 2 [2] would think that, and the test statistics, the statistical MIMO radar configurations derived using orthogonal waveforms. In this paper, we have Swerling cases, the test statistic for non-orthogonal codes. Cases 3 and 4, when the test statistic is orthogonal signals for them to be collected and for cases 1 and 2.

Likelihood ratio test is a harmonic function, which is usually done using a test statistic. Test statistics for a single pulse is received, the following is obtained. First, the likelihood ratio for each configuration. This expression is then used to obtain all of the configurations of the test statistics. The Likelihood function can be written as

$$L\left(\mathbf{r}(t_1), \mathbf{r}(t_2), \ldots |\mathcal{H}_k\right) = \prod_i f\left(\mathbf{r}(t_i)|\mathcal{H}_k\right)$$

Test statistics

In order to derive the test statistics and distributions, we have to determine the likelihood functions first. Let assume that noise is independent and identically distributed white and Gaussian noise is present

Multi-Pulse Test Statistics

The detectors for single pulse derived in the previous section can be easily generalized to multiple pulses. In the fast fading Swerling cases, the scattering amplitudes are independent in the pulses.

So the distribution of the test statistic can be obtained the same way as for the single-pulse test statistic. Since the scattering amplitudes are independent in each pulse, the diversity achieved with widely distributed transmitters or receivers can also be achieved in temporal domain by receiving several pulses.

Numerical Results

The optimal test statistic for the statistical MIMO radar configurations was derived in Section III-A. In this section, we com-pare the performance of the different statistical MIMO radar configurations by evaluating their receiver operating characteristic (ROC) curves numerically. Also, the optimal and suboptimal test statistic are compared in the Swerling cases 3 and 4. When the detection is done using one pulse the speed of the fluctuation does not impact the performance and cases 1 and 2 can be considered together, as can be cases 3 and 4. An example for detection using multiple pulses is shown for cases 2 and 4. Orthogonal signals were assumed in all the examples.

It can be seen from the receiver snapshots in (4) and (7)–(9) that the receiver SNR depends on the number of transmitting antennas M and also the beamforming gain in configurations that are capable of beamforming. In order to compare the configurations with different number of transmitters fairly, the comparison is done so that P/v is equal for all the systems. This quantity is essentially the SNR of a single-antenna system. We will refer to it just as the SNR for the rest of this paper, i.e.,

$$\text{SNR (dB)} = 10\log(P/v)$$

The ROC curves were evaluated for a system with four transmitters and six receivers. The curves with SNR $= 10$ dB are shown in Fig. 2. The ROC curves of both the optimal test statistic and the suboptimal test statistic in cases 3 and 4 are shown. The general trend is that for low probability of false alarm p_f, transmit beam forming results in higher probability of detection p_d, but as p_f increases, systems with angular diversity gain the advantage. This is clear for cases 1 and 2 but less pronounced for cases 3 and 4 as the probability of a deep fade is smaller in those cases. Accordingly, MIMO and MISO con-figurations are better than phased array SISO configuration in this simulation scenario when the probability of false alarm is greater than $2\times10_{-7}$ in cases 1 and 2. In cases 3 and 4, how-ever, the probability of false alarm must be greater than about 10_{-4} for the MISO and MIMO configurations to have higher probability of detection than the SISO configuration.

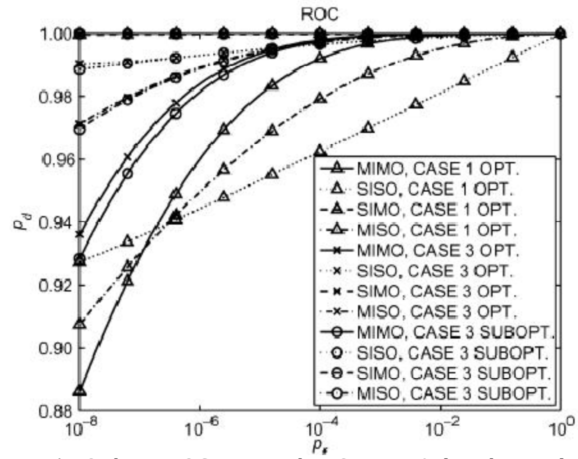

Fig. 2 shows ROC curves when SNR is 10 dB. The angular diversity in less beneficial in cases 3 and 4 as the probability of a deep fade is smaller compared to cases 1 and 2. The difference between the optimal and suboptimal test statistic is relatively small.

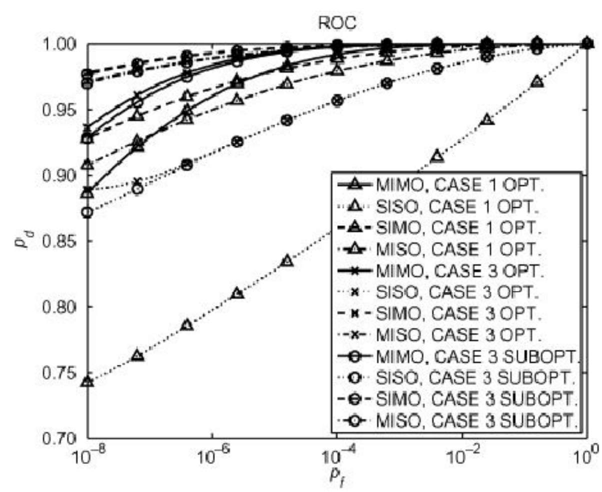

Fig. 3 shows ROC curves when SNR is 10 dB and no transmit beam forming gain. The performance of single input configuration has degraded less in cases 3&4 than in cases 1&2.

DIRECTION FINDING PERFORMANCE

The performance of MIMO radar, direction finding [9] Swerling has been studied using the scattering model. The performance can be compared using the Cramér–Rao bound in cases 2 and 4. The CRB depends on the scattering parameters in cases 1 and 3 because the slowly varying scattering parameters affect the average power of the signal. In cases 1 and 3 of the slow fluctuations, a uniformly minimum-variance unbiased estimator

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(UMVUE) is equal to the averaged Cramer-Rao bound. (The average in the CRB, CRB is considered a random variable of the scattering amplitude and the average of the scattering amplitude [11] is obtained by taking the expected value with respect to the scattering amplitudes.) However, the variance of the UMVUE is not defined for the SISO configuration or MISO configuration with less than three transmitters because the averaged CRB diverges [9], [12]. Therefore, in this paper, direction of arrival (DOA) estimates the direction of the upper confidence bound using the square error and compares the performance of these systems.

The task of finding a direction in order to compare the performance of SISO and MISO configurations, confidence bounds were calculated with 1000 independent trails using Monte-Carlo method. DOA estimation of the subspace-based estimation method, which is done with MUSIC. The number of transmitters was two, four, or eight, and the receiver was six-element uniform linear array. Eighty samples matched filter outputs, and then 0, which is the product DOA, used for the assessment. [9] Fast fading cases, the number of samples, regardless of the CRB with a MISO configuration is shown in more than a SISO configuration.

CRB numeric values and the confidence bound cannot be compared, as it is possible to change all of the most one-sided bounds. However, we do a qualitative comparison to demonstrate that the confidence bound can be used as a performance metric similarly to the CRB. Obviously, the same confidence level can only be used to compare the performance of different configurations bounds of same confidence level.

RESULTS

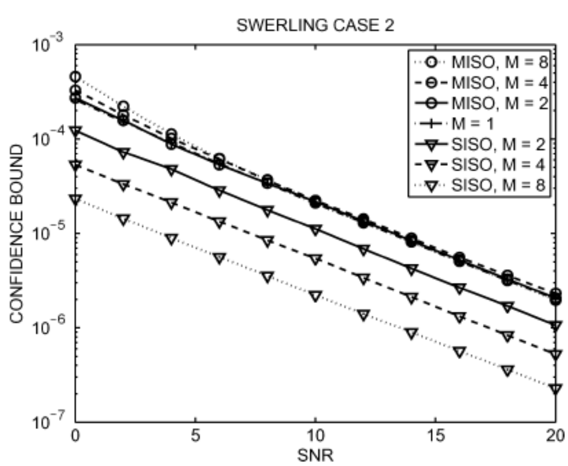

Fig.4 shows level 0.98 confidence bound of the DOA estimate the swelling case 2.This shows the performance .The angular diversity cannot compensate the loss of snr in case 2.

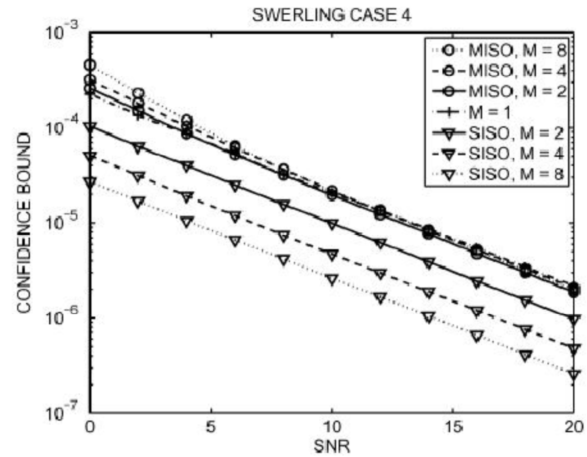

Fig.6 shows level 0.98 confidence bound of the DOA estimate the swelling case 4.The angular diversity cannot compensate the loss of SNR in case 4.

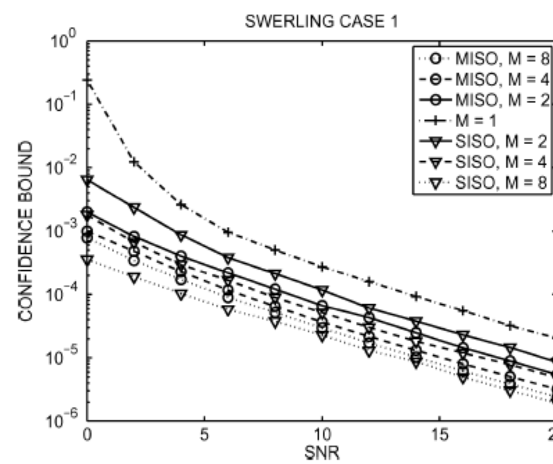

Fig.5 shows level 0.98 confidence bound of the DOA estimate the swelling case 1.In this case fluctuations are slow. The angular diversity increases average signal power decreases bound.

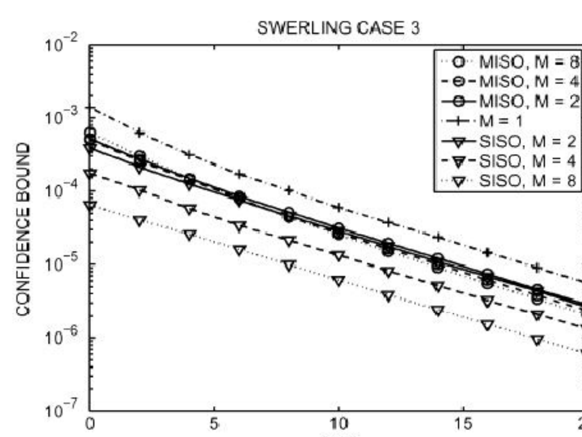

Fig.7 shows level 0.98 confidence bound of the DOA estimate the swelling case 3.MISO is better than one antenna system.

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Target detection, in the use of statistical MIMO radar angular variation shown to be limited by the power of the signal is available at all Swerling cases. If SNR is low, it is more useful to employ beam forming than try to exploit diversity. Beam forming and diversity gain, which is considered to be the two configurations that have performed well in the cases, appeared.

MIMO configuration, however, benefit from the slow fluctuations of the cases. The SNR improvement by using multiple pulses, fast Swerling RCS fluctuations in systems with low spatial diversity gain. Swerling examples of cases 3 and 4, and the test statistic is derived for the proposed suboptimal test statistic.

Analysis to determine the direction of the show, we [9] and the upper bound of the squared error of assessment in terms of the reliability of the results by comparing the performance of different configurations expanded. Similarly, [9], a comparison of the bounds of confidence in the fast color cases 2 and 4, which showed that there is no benefit in having an angular variation. However, in the slow fading case 1 demonstrated a clear benefit of using multiple-input configuration. The multiple-input outperformed single antenna-transmitter in case 3, but the phased-array approach was able to attain a lower confidence bound. In cases 1 and 3 step configuration to better transmit beam forming gain will depend on the range of the system.

Separately, without hindering the detection and assessment of the problems we have to compensate for the Doppler shift could imagine. Future work should evaluate the performance, taking into account the Doppler shift.

SUMMARY AND CONCLUSION

In this paper, we model the scattering Swerling MIMO radar detection and direction finding using a statistical analysis. We apply the model Swerling target detection and the use of non-orthogonal codes for Statistical MIMO radar derived. Optimal detectors four Swerling cases and for the detection of a single pulse and multi-pulse taken. A closed-form expression was derived for the density function of the optimal test statistic in cases 1 and 2. The density function was given as a convolution for orthogonal signals in cases 3 and 4.And we proposed a suboptimal detector with a closed form pdf.

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