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Power Allocation For Phased Mimo Radar

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ABSTRACT

Background: Compressive sensing phased MIMO radar is used to estimate the location of target with fewer measurements which increases the performance as compared with traditional methods. Multiple-input multiple-output (MIMO) radar with colocated antennas is called phased-MIMO radar. It enjoys the advantage of both phased array and MIMO radar. This paper explains the convex optimization technique for power allocation. It allocates the power for transmit antennas depends upon sparse vector of received signal. It reduces the number of active transmit antenna with high performance.

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INTRODUCTION

Compressive sensing theory asserts that one can recover certain signals and images from fewer samples or measurements than traditional methods for target Estimation. It consists of two principles sparsity, uniform uncertainty principle (UUP). sparsity is nothing but fraction of zero elements in the matrix and UUP is no coherence between target signal from different search cell. The Transmit and Receive antennas are closely spaced and randomly distributed over small areas which are called colocated antennas. Here the antennas view the target from same angle. Widely separated antennas has a large distance of target from transmitter and receiver compare than distance between transmitter and receiver. Its application has been studied (Candes, E.J., and M.B. Wakin, 2008). Adaptive localization, detection techniques to be used to detect the target (Cai, T.T., and L. Wang, 2011). Principles of compressive sensing and types and its application has been studied (Godrich, H., *et al*., 2011). In (Gogineni, S., and A. Nehorai, 2011) potential target to be estimated by angle and Doppler information but more number of transmit antennas to be used. An adaptive mechanism used for power allocation at the different transmit antennas. Sparse modeling is used to find position and velocity of target (Stoica, P., and J. Li, 2007) but it is not suitable for moving targets. step frequency matched filter is used to find angle and Doppler information for angle (Yu, Y., *et al*., 2012). In (Yu, Y., *et al*., 2010) power is allocated based on minimum square estimation of target, MSE found by Cramer-Rao bound (CRB) method but it increases number of undetectable target and also had less resolution.

The paper is organized as follows. Section II contains system Model. Section III contains multiple target identification using Phased-MIMO radar while Section IV contains power allocation for Phased MIMO radar. Section V contains results and discussion Section VI provides concluding remarks.

II .System Model

A. Cs Based Mimo Radar:

In CS-based MIMO radar M_t Transmit antennas and N_r Receive antennas to be considered. In the far field of the antennas there are K targets that need to be estimated. For simplicity, assume that the targets are not moving, thus the only parameters that need to be estimated are the target azimuth angles θ_k k = 1, . . . , K; the results can be easily extended to the case of moving targets. The transmit antennas transmit narrowband waveforms,

$x_i(t)$,= 1, . . . , Mt .

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The Receive antennas obtain sub-Nyquist samples of the target returns, and subsequently transmit those samples to a fusion center, where the target estimation is carried out.

B.Phased Mimo Radar:

MIMO radar allows for beam forming at the transmit and receive arrays. The main idea behind is to partition the transmit array into K subarrays (1 ≤ K ≤ Mt) which are allowed to overlap. In general, each transmit subarray can be composed of any number of antennas ranging from 1 to Mt such that no sub array is exactly the same as another sub array. All antennas of the K th sub array are used to coherently emit the signal Φ_k (t) so that a beam is formed towards a certain direction in space, e.g., direction of the target. Then, the beam forming weight vector w is properly designed to maximize the coherent processing gain. At the same time, different waveforms are transmitted by different sub arrays. The uplink steering vector is denoted as a_k (θ)

Let the K × 1 transmit coherent processing vector be (a)

$$c(\theta) \triangleq [w_1^H a_1(\theta) \dots\dots\dots\dots w_k^H a_k(\theta)]^T \quad (1)$$

The waveform diversity is achieved by the phased- MIMO radar which significantly improves the direct applicability of adaptive arrays for target detection and much enhanced flexibility for transmit beam pattern design.

The K$\times 1$ waveform diversity vector is given as (b)

$$\theta) \triangleq [e^{-j\tau_1(\theta)} \dots\dots\dots\dots . e^{-j\tau_k(\theta)}]^T \quad (2)$$

Then, the reflected signal can be rewritten as

$$r(t,\theta) = \sqrt{\frac{M}{K}}\beta(\theta)(c(\theta)\odot d(\theta))^T\phi_k(t) \quad (3)$$

where $\phi_K(t) \triangleq [\phi_1(t) \dots\dots\dots\dots\dots \phi_k(t)]$ is the vector of K$\times 1$ waveforms.

III. Multiple Target Detection Using Phased Mimo Radar:

Beamforming is a signal processing technique used in directional signal transmission or reception. This is achieved by combining elements in a phased array in such a way that signals at particular angles experience constructive interference while others experience destructive interference. Beamforming can be used at both the transmitting and receiving ends in order to achieve spatial selectivity. The improvement compared with Omni directional reception/transmission is known as the receive/transmit gain. To change the directionality of the array when transmitting, a beamformer controls the phase and relative amplitude of the signal at each transmitter, in order to create a pattern of constructive and destructive interference in the wavefront. When receiving, information from different antennas is combined in a way where the expected pattern of radiation is preferentially observed.The conventional transmit or receive beamforming technique is used to identify the target using phased-MIMO radar. The phased-MIMO radar , the phased-array radar and the MIMO radar are compared in terms of their transmit-receive beampatterns.

The non adaptive transmit/receive beamforming techniques are used for the phased-MIMO radar. The transmit beamforming weight matrix is given as

$$W \triangleq \begin{pmatrix} w_{1,1} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & w_{k,M-k+1} \end{pmatrix} \quad (4)$$

where $w_{k,m}$ is the m^th^ weight of the k^th^ subarray beamforming weight vector. The beamformer weight vectors for conventional uplink beam forming, are given by

$$w_k = \frac{a_k(\theta_s)}{\|a_k(\theta_s)\|} \quad k = 1 \dots . K \quad (5)$$

At the receive array, the conventional beamformer is applied to the virtual array and, therefore, the KN$\times 1$ receive beamformer weight vector is given by

$$w_d \triangleq u(\theta_s) = [c(\theta_s)\odot d(\theta_s)\otimes b(\theta_s)] \quad (6)$$

Let $G_k(\theta)$ be the normalized phased-MIMO radar beampattern, that is

$$\sqrt{G_k(\theta)} = \frac{|a_k^H(\theta_s)\, a_k(\theta)|\, |d_k^H(\theta_s)\, d_k(\theta)|\, |a_k^H(\theta_s)\, a_k(\theta)|}{\|a_k^H(\theta_s)\|} \quad (7)$$

The overall beam pattern of the phased-MIMO radar $G_k(\theta)$ is proportional to the multiplication of the transmit beam pattern c(θ)and the waveform diversity beam pattern d(θ). From the target reflected beam pattern of overall beam pattern, the direction or angle of target is identified.

IV.Power Allocation:

Convex Optimization:

Convex optimization technique is used to minimize or maximize the convex function over convex sets. There are three methods available to find sparse vector. Those are log heuristic method,l_1 norm method,l_2 norm method. Based on the received signal the sparse vector is recovered from following equation (8) using l_1 norm method in convex optimization technique The least-norm 1 problem has the form

$$\text{Minimize} \|x\| \quad (8)$$
$$\text{Subject to} \quad Ax=b$$

where the data are A $\epsilon\, R^{m\times n}$ and b $\epsilon\, R^{m}$, the variable is x $\epsilon\, R^{n}$, and $\|.\|$ is a norm on R^{n} . A solution of the problem, which always exists if the linear equations Ax = b have a solution, is called a least-norm solution of Ax = b. The least-norm problem is a convex optimization problem, the rows of A are independent, so m > n. When m = n, the only feasible point is x = A^{-1}b. if m < n, the equation Ax = b is underdetermined, the linear functions of the design variables x to be assumed. ℓ1-norm gives the sparse vector with some zero components.

$$\underbrace{\min}_{p}\ p(x)^{T} \quad (9)$$
$$p=[p1\ldots\ldots\ldots\ldots p_{M_t}]$$
$$\text{s.t } 1_{M_{tx1}}^{T}p = P_t, p \geq 0, p \leq p_m 1_{M_{tx1}}$$

Power allocation of transmit antennas depends upon sparse vector of received signal. The transmit power is allocated for transmit antenna using(9) in convex optimization method. The sparse vector is zero means there is no target is present at an angle otherwise the reflection coefficient of the target is present The power is allocated for appropriate transmit antenna where the target is present.

RESULTS AND DISCUSSION

A phased- MIMO radar system with the 30 transmit and 30 receive antennas are considered. If the number of sub array antenna decreases, the phased MIMO radar produces higher sidelobes. It reduces the accuracy of target detection. so only 30 transmit and receive antennas used here . The number of radar pulses for fast time is 400 and for slow time is 200. The transmitter spacing are assumed to be 0.5λ. The search space for phased MIMO radar is in the range from -90° to 90° ,the size of search grid cell is 0.0001 , the target is placed in any angle as a increment of 0.0001 with in search space, so target is assumed in angle position as -20° 10° 30° . Assume two interfering targets located at directions of -30^{o} and -10^{o}. The target of interest is assumed to reflect a plane-wave that impinges on the array from $\theta_s = -20^{\circ}, 10^{\circ}$ and 30° direction. The uplink and downlink steering vectors are found using following equation

(a)

$$\theta_s) =$$
$$[e^{-j2\pi 0.5\sin(\theta_s)}\ldots\ldots\ldots\ldots e^{-j2\pi 0.5\sin(\theta_s)M}]$$

(b)

$$\theta_s) =$$
$$[e^{-j2\pi 0.5\sin(\theta_s)}\ldots\ldots\ldots\ldots e^{-j2\pi 0.5\sin(\theta_s)M}]$$

The transmit beampattern c(θ) and waveform diversity beampattern d(θ) are simulated and compared with phased array radar and Bi-static MIMO radar (the distance between transmit antenna and target is higher than distance between transmit and receive antenna) .The simulated graph for the transmit beampattern is shown in Figure 1. It is found that the phased MIMO radar identifies the targets present at the three locations as that of phased-array radar but with minimum side lobe levels. In Figure 2 diversity pattern d(θ) of phased array radar is zero, the phased MIMO radar ,MIMO radar provides waveform diversity and accurate target identification. The product of transmit beampattern c(θ) and waveform diversity d(θ) is called over all beampattern or received beampattern G (θ) is shown in Figure 3, the phased- MIMO radar has a lower sidelobes compare than two radars in below figure which increases the accuracy of target estimation.

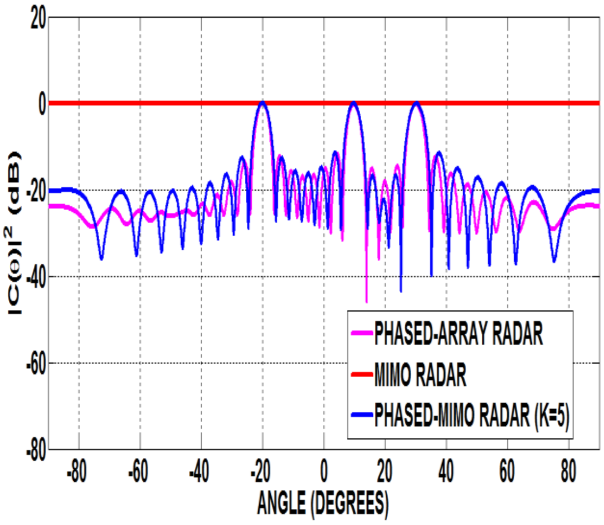

Fig. 1: Transmit BeamPattern

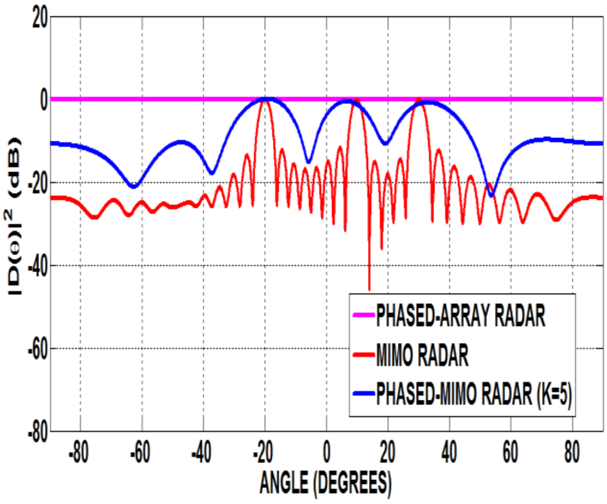

Fig. 2: Diversity BeamPattern

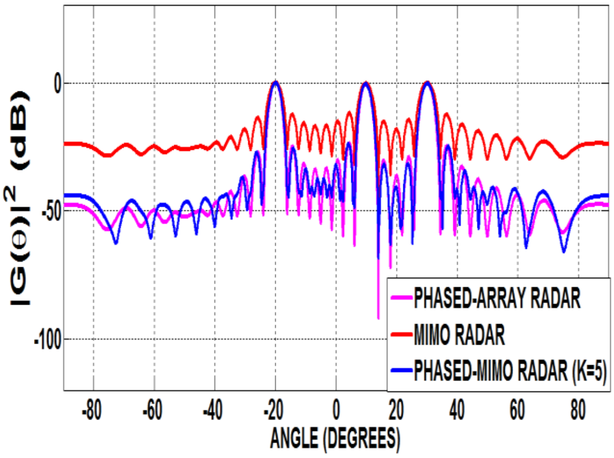

Fig. 3: Receive BeamPattern

If number of transmit antenna decreases height of side lobe also increases, it is shown in Figure 4,Figure 5 the over all beampattern of 20,10 transmit antenna has higher sidelobes compare than over all beampattern of 30 transmit antenna. The phased array radar has the width of mainlobe as π/M with the 0db gain.The number of Transmit antenna is denoted by M.

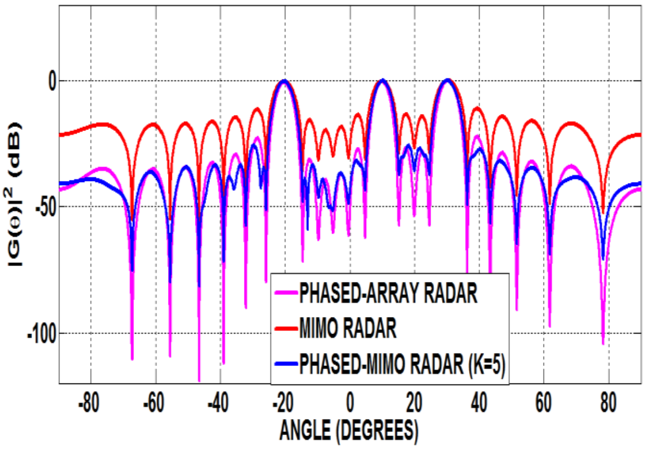

Fig. 4: Receive BeamPattern(20 antennas)

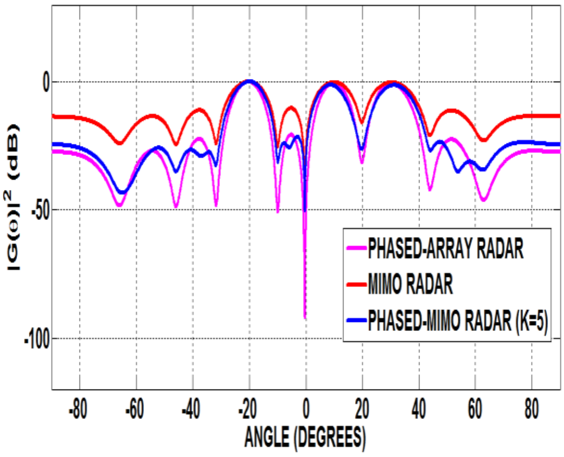

Fig. 5: Receive BeamPattern(10 antennas)

Table 1: Comparison Between Characteristics Of Transmit Antenna

Number of transmit antenna	Width of mainlobe (in degrees)	Minimum sidelobe level (in db)
10	18	-30
20	9	-39
30	6	-50

In (8) The matrix A subdivided into submatrix as $R^{m\times m}$ check the singularity condition then find sparse vector, it is shown in Figure 6, the transmit antenna 1,4,9,11 and 17 has zero sparse vector remaining has unit sparse vector.

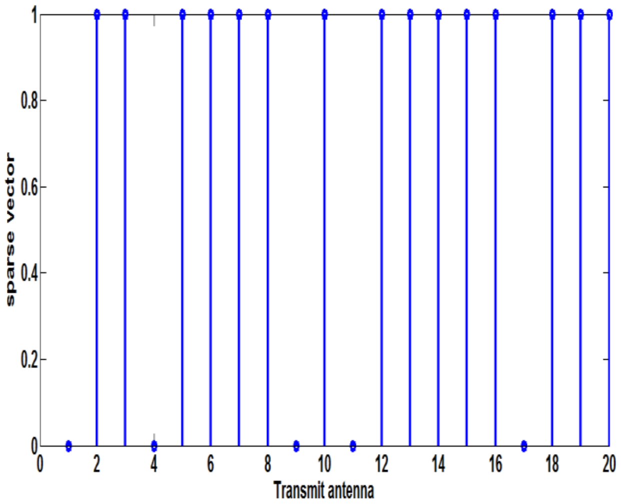

Fig. 6: Sparse vector

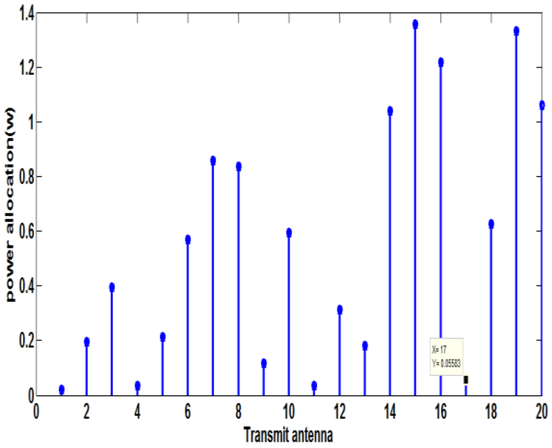

Fig. 7: Power Allocation

In Figure 7, it concluded that zero power is allocated for 1,4,9,11 and 17th transmit antenna because they have a transmit power as less than 0.16 and also no target location present at those transmit antenna(sparse vector zero), power is allocated for remaining antenna based on (9),it reduces the number of active antenna from 20 to 15.

Conclusion:

The Phased-MIMO radar combines the advantages of the phased-array radar and MIMO radar. Therefore , it has a superior performance, it can estimate target accurately because it has lower sidelobes compare than other radars, which is shown in simulation results.l_1 norm method is used to find sparse vector from received signal, power is optimized based on sparse vector using convex optimization method. It reduces number of active transmit antenna from 20 to 15.

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