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Waveform Design for Radar by Implementing phase and MIMO Features

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Abstract: The phased multiple input multiple output radar which was proposed is having several advantages when analyzed with the features of MIMO radar. The proposed technique having many advantages when compared with phased array and MIMO radar. The latest technique combines the advantages in phase-array, we are having advantage of coherent processing gain in the transmitting side and spatial diversity is the advantage for MIMO radar. Here we design a waveform of phase MIMO radar which has more efficiency. The simulation results analyzed give effort to the proposed methodology.

Keywords: Phased array radar, MIMO radar, Coherent processing gain, Spatial diversity.

1. INTRODUCTION

The basic functioning of the radar is to transmit the signal and receive the reflected signal and by this identifying the object parameters. The basic functions involve detecting the reflected signal of the object, estimating the parameters of the object, tracking the path of the object by this signaling the feature positions of the object becomes easier. [1][2]. Signal to noise ratio of the receiver is an important parameters. To identify the object exactly the differentiation between noise and target is necessary. The target movements, direction of arrival of target and the velocity of the target can be easily identified by using the target. By using a set of dedicated filters the radar can perform the tracking operation. As there are many advanced technologies, that are integrated in the radar technology such as improvement is computational capability, signal processing advancements and the advancement is radar imaging helps in viewing the three dimensional images. The advanced type of antennas, receivers, transmitters and processing units helps radar to work with its full functionality. According to the positions of the transmitters radars are divided into Monostatic and Bistatic radars. If the transmitter and receiver are situated at one place, then it is a monostatic radar and if the transmitters and receivers occupy two different places, then it is a bistatic radar. [3][4]. The amount of power required by any receiver [1] is

$$P_r = P_t G_t \sigma/(4\pi R^2)^2 \times A_e$$

P_t represents the transmitted power, G_t represents the gain of the transmitting antenna, R is the distance between object and radar (in meters). σ Represents target cross section. A_e Represents effective aperture of antenna.

2. MIMO RADAR

MIMO Radar is having multiple transmitter antenna and multiple receiver antennas. The separation between the antennas can be closely spaced or widely spaced. The different waveforms used in MIMO will be orthogonal to each other. The advantage of using orthogonal waveforms is that the fading effect will be reduced. Waveform diversity is the most important property in the MIMO waveform design. Auto correlation and cross correlation properties are of keen interest in the MIMO waveform design. [5], [7]. The importance of using collocated antennas is that slow moving targets are detected very easily [6]. Objects can be detected with high resolution by using collocated antenna concept. The advantage of using widely separated antennas is spatial diversity. Adaptive techniques are parameter identification techniques are used in MIMO Radar design. [10].

If Kt are number of transmitters elements

Kr are number of receiver elements

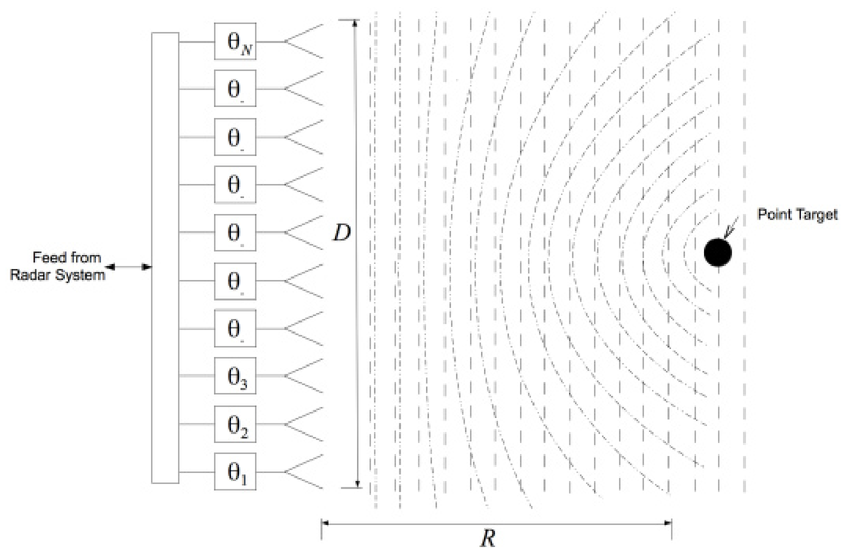
Kt directly proportional to Kr then represents the data matrix

Y = Hs + N

H represents the channel matrix

3. PHASED ARRAY RADAR

The phases of the different elements of the matrix phased array antenna are changed, so that the directivity and the radiation pattern can be maintained in the particular direction. The beam steering can be done by changing the phases of the elements. The weights of the each element can be changed accordingly such that the beam forming can be done. The beam formers are divided into two types. They are time domain and frequency domain beam formers. The process that will be undergone in time domain beam formers are delay the signal and after that add the signal. In other method, the frequency bins are divided using discrete Fourier transform concept and filter banks. There are other two methods which can be implemented, they are spatial frequency and dynamic



phase array. In spatial frequency, the samples are taken from the array elements, DFT is implemented, due to this multiple phase shifts during processing occur [8].

A. Signal Model

Consider a phased array radar system with M_t represents number of transmitting and M_r represents receiving elements. The condition for collocated antennas $M_t = M_r$. Let each transmit element transmit a narrow band signal. The output of the transmitter is

$$x(t) = a(\theta)s(t)$$

Here (θ) is steering vector linked with the transmitter. The steering vector means the phase delays, with each transmit-receive pair. The steering vector (θ) can be written as,

$$a(\theta) = \begin{bmatrix} 1 \\ e^{j2\Pi d \sin\theta/\lambda} \\ e^{j2\Pi d (M_T - 1)\sin\theta/\lambda} \end{bmatrix}$$

The total signal at the target location is given by

$$X_t = a^H(\theta)\, x(t - T_t)$$

The signal at the receiver is given as

$$y(t) = \beta b(\theta) a^H(\theta) a(\theta) S(t - T) + e(t)$$

The total time taken from the transmitter to the receiver is

$$b(\theta) = \begin{bmatrix} 1 \\ e^{j2\Pi d \sin\theta/\lambda} \\ e^{j2\Pi d (M_r - 1)\sin\theta/\lambda} \end{bmatrix}$$

$e(t)$ is a noise signal vector

$$e(\theta) = \begin{bmatrix} e_1(t) \\ e_2(t) \\ e_N(t) \end{bmatrix}$$

The weighted sum given as

$$\begin{aligned} y(t) &= w^H x(t) \\ &= w^H a(\theta) s(t) \\ &= G(\theta) s(t) \end{aligned}$$

where, $G(\theta)$ is the gain of the beam former and W represents the beam forming weight vector [9].

4. PROPOSED PHASED-MIMO RADAR FORMULATION

The advantages of coherent processing and waveform diversity are achieved in the proposed method. In the proposed method all the transmitted antennas can be divided into equal number of sub arrays ($1 <= k < M$), where M represents the number of elements. Each sub array having certain antenna elements. The waveform is carried by each element in the sub array. The phase shift deviation maintained by the elements in the sub array such that the beam steering can be done towards the target.

The output of the sub array

$$s_k(t) = \sqrt{\frac{\mathrm{M}}{\mathrm{K}}}\, \varphi_{\mathrm{K}}(t) w_k$$

The energy calculation is given by

$$\mathrm{E_K} = \int s_k^{\mathrm{H}}(t) s_k(t)\, dt = \frac{\mathrm{M}}{\mathrm{K}}$$

The far field reflected signal is given by

$$r(t, \Theta) = \sqrt{\frac{\mathrm{M}}{\mathrm{K}}}\, \beta(\Theta) \sum_{k=1}^{k} w_k^{\mathrm{H}} a_k(\Theta) e^{-j\mathrm{T}k(\theta)} \varphi_{\mathrm{K}}(t)$$

The transmit coherent processing vector is given by

$$c(\Theta) = [w_1^{\mathrm{H}} a_1(\theta), \ldots, w_k^{\mathrm{H}} a_k(\theta)]^{\mathrm{T}}$$

The received complex vector can be represented as

$$x(t) = r(t, \theta_s) b(\theta_s) + \sum_{\mathrm{D}i=1} r(t, \theta_i) b(\theta_i) + n(t)$$

If K = M, the signal model acts like a MIMO Radar

5. END-TO-END RADAR SYSTEM

To understand the importance of using waveform design, we are implementing the waveform design and by using phase array tool box, the signal is sent through the source array. The targets are implemented in between and the reflected data is detected by the receiver array and after filtering the received signal from noise the resulted signals are plotted.

6. RESULTS

From Figure 1, the beam patterns of the MIMO, Phase array and phase MIMO radar are observed by mapping at one place. As per the observation the main lobe levels are high in the phase MIMO and having higher side lobe strength.

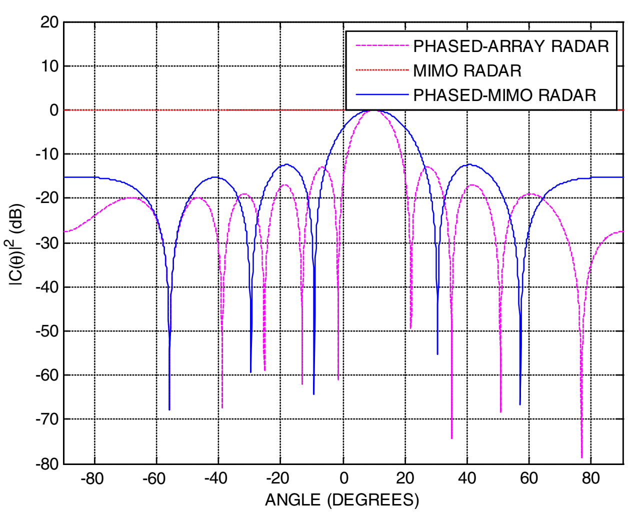


Figure 1: Transmit beam pattern obtained from conventional beam former

From Figure 2, when compared with the waveform diversity beam patterns of phase MIMO with MIMO, Phase MIMO is having higher side lobes.

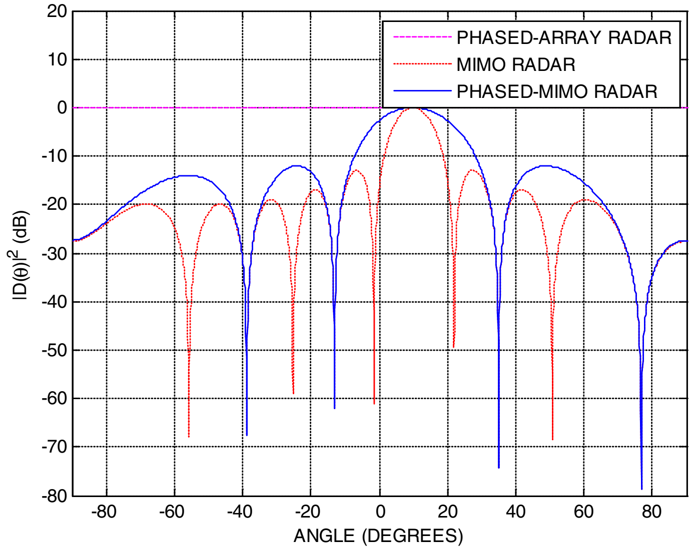


Figure 2: Wave form diversity beam pattern obtained from conventional beam former

From Figure 3, In the overall beam pattern, the beam pattern of MIMO and phase array are almost same and in Phase MIMO, the less side lobes are established.

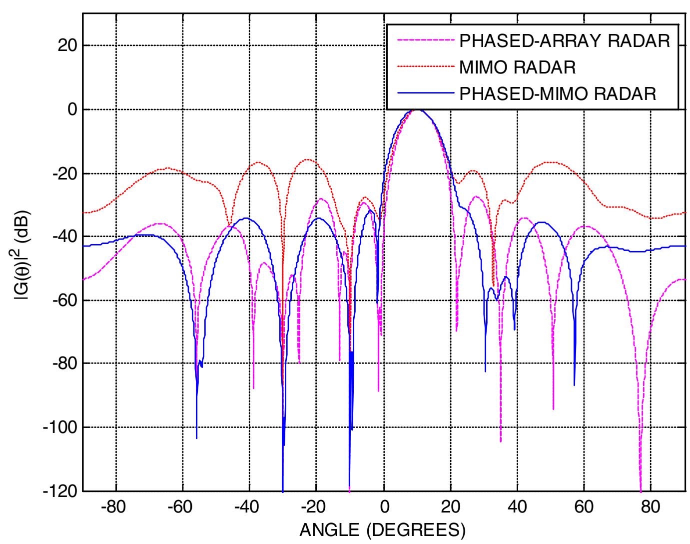


Figure 3: Over all beam patterns using conventional beam former

End-to-End radar system simulated result: From Figure 4 the final targets are plotted and on comparison they are equivalent to the targets generated in the tool.

7. CONCLUSION

A new technique which includes the advantages of phased array antenna and MIMO radar was proposed in this paper. In this the transmitter array was divided into a number of sub-arrays. Each sub-array having the signals which are phase shifted. The signals in different sub-arrays are maintained the condition of orthogonality coherent gain and angular resolution are achieved. The simulation results conclude the effectiveness of the proposed methodology.

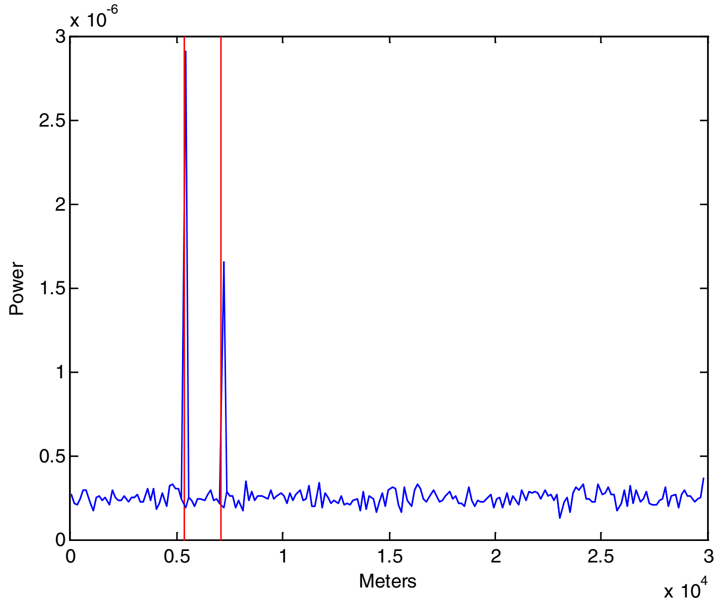


Figure 4: Final detecting targets

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