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DOA estimation based on the multipath of the MIMO radar target

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Abstract. The DOA Estimation of the MIMO radar is widely used to determine the position of the objects. Having been considered the multipath communication environment, this paper estimates the DOA information of low elevation targets using beam space MUSIC algorithm based on the model of uniform linear array of MIMO radar. Simulations have shown that the algorithm is effective in the multipath spread environment, and the resolution of the DOA estimation of angular is about 0.5°.

Introduction

Currently, Many scholars have already applied many algorithms in the spatial spectrum estimation to estimate MIMO radar DOA. Among them, Literature [1]used ESPRIT in MIMO radar. The simulation result shows its effectiveness. Literature [2]used weighted MUSIC algorithm in MIMO radar, and completed the DOA estimate of the target. Literature [3] used Classical MUSIC algorithm and Improved MSWF algorithm in MIMO radar, and compared the performance difference between them. However, many of them are in the ideal case to doing the DOA estimation. Not taking the economic environment into account. Some problems can not truly reflect the reality.

This article is in the existing research on the basis of them, Using uniform linear array of MIMO radar and beam space MUSIC algorithm Simulating of multipath effects environment to doing DOA Estimation of low-altitude targets. Not considering the effect of multipath model is closer to the actual situation than the previous one.

MIMO radar signal and DOA estimation

According to Literature[4] ,Transmitted signal is reflected by the target Model is shown in figure 1.

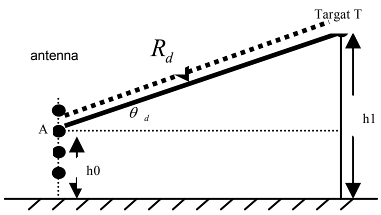

Figure 1. The co-location transceiver element linear array MIMO radar signal model

The n-th array element received signal is:

$$x_n(t) = \alpha \bullet a^T(\theta) \bullet s(t) e^{-j\varphi_n} + v_n(t) \tag{1}$$

There are many beamforming ways. One kind of the simplest and most convenient way is to form B receive beam through the array receiving data. If the M / B is a positive integer, $v = [1 \quad 1 ... 1]^T$ is a (M / B) × 1 column vector. The normalized weighted matrix is:

$$T_1 = \frac{1}{\sqrt{M/B}} \begin{bmatrix} v & 0 & ... & 0 \\ 0 & \text{v} & ... & 0 \\ ... & ... & v & ... \\ 0 & 0 & ... & 0 \end{bmatrix}_{M \times B} \tag{2}$$

And the matrix satisfies:

$$T^H T = I \tag{3}$$

There is another beamforming way. The normalized weighted matrix is

$$T_2 = \frac{1}{\sqrt{M}}\left[a\left(m\frac{2}{M}\right), a\left((m+1)\frac{2}{M}\right), \ldots, a\left((m+B-1)\frac{2}{M}\right)\right] \tag{4}$$

It also satisfies formula(4).

For a general array space, after beam-space transformation, the output covariance matrix[5] is:

$$R_Y = T^H R_X T = T^H A R_S A^H T + \sigma^2 I \tag{5}$$

According to the principle of the beam space method, The dimension of Steering vector[6]are equal to the number of formed beams. For MIMO radar, If the number of emission beam is B, its launch steering vector should be:

$$B(\theta) = T^H a(\theta) \tag{6}$$

The form of the received signal of the receiver array [7]should be:

$$x(t) = \alpha \bullet b(\theta) \bullet B^T(\theta) \bullet s(t) + v(t) \tag{7}$$

Multipath MIMO radar model and algorithm

MIMO radar is a multi-input multi-output, so in the general we should consideration on the basis of receiving a multipath signal, also need to consider the emission signal multipath effects. It can be seen that an antenna launch signal is equivalent to echo signal of 4 paths to the radar receiver antenna[8].

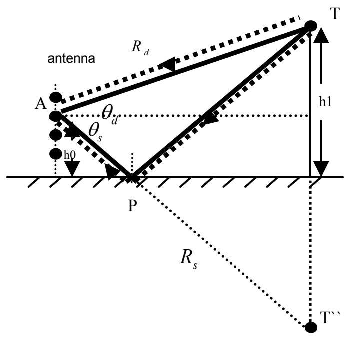

Figure 2. MIMO radar signal of multipath transceiver co-located element linear array model

The antenna array have N non-directional array in the vertical direction. Because the advantages of multi-input multi-output of MIMO radar, the multipath signals to sending and receiving two-way is considered. In figure 2, there are four paths of the antenna to receive the echo signal from the transmitter to the receiver. They are AT---TA, APT---TA, AT---TPA, APT---TPA.

MIMO radar requirements of the transmit signal mutually orthogonal, so

$$\int_{-\infty}^{+\infty} S_{ek}(t-\tau_i) S_{ej}^*(t-\tau_j)\,dt = 0, \qquad k \neq j \tag{8}$$

Setting to meet on k-th antenna signal[10] is:

$$S_{ek}(t) = Ag(t)\,\mathrm{e}^{j2\pi f_k t + j\phi_k}, \qquad k = 0,1,\ldots,N-1 \tag{9}$$

Where: ϕ_k is the initial phase. Without loss of generality, it is set to 0. In order to avoid a fuzzy goniometer[9].The array element spacing is half wavelength. Assuming that the target does not exist the Doppler information. Taking into account the multipath effect in the emission process, the received signal[10] of the target is the sum of the direct wave signal AT and the reflected signal APT.

$$S(t) = \sum_{k=0}^{N-1}\left[S_{ek}(t-\tau_{dk}) + \rho S_{ek}(t-\tau_{sk})\right] = \sum_{k=0}^{N-1} A\left[g(t-\tau_{dk})e^{j2\pi f_k(t-\tau_{dk})} + \rho g(t-\tau_{sk})e^{j2\pi f_k(t-\tau_{sk})}\right] \tag{10}$$

In the formula: ρ is the surface reflection coefficient of the ground (sea). $\tau_k(\theta_d) = \dfrac{dk\sin\theta_d}{C}$, $\tau_k(\theta_s) = \dfrac{dk\sin\theta_s}{C}$, $\tau_{dk} = \tau_0 + \tau_k(\theta_d)$, $\tau_{sk} = \tau_0 + \tau_k(\theta_s) + \Delta\tau$, $\Delta\tau = \dfrac{R_d}{C}(\dfrac{\cos\theta_d}{\cos\theta_s} - 1)$.

Assume that the reflection coefficient unchanged. $S(t)$ after the target to the reflected echo signals reach the antenna, including direct access to the signals TA and the reflected signal TPA. At this point the n-th receiving antenna receives the echo signal[11] is:

$$x_n(t)=c\left[a_n(\theta_d)+\chi a_n(\theta_s)\right]\bullet\left[a^T(\theta_d)+\chi a^T(\theta_s)\right]G(t)+n_n(t) \quad (11)$$

In the formula: $\chi=\rho e^{-j2\pi f_0\Delta\tau}$, $a(\theta_d)=[a_0(\theta_d)\ \ a_1(\theta_d)\ \ \ldots\ \ a_{N-1}(\theta_d)]^T$, $a(\theta_s)=[a_0(\theta_s)\ \ a_1(\theta_s)\ \ \ldots\ \ a_{N-1}(\theta_s)]^T$ $G(t)=[g_0(t)\ \ g_1(t)\ \ \ldots\ \ g_{N-1}(t)]^T$, $a_n(\theta_d)=e^{-j2\pi f_0\frac{dn\sin\theta_d}{C}}$, $a_n(\theta_s)=e^{-j2\pi f_0\frac{dn\sin\theta_s}{C}}$, $c=e^{-j2\pi f_0\tau_0}$ And $x(t)=\left[x_1(t)\ \ x_2(t)\ \ \ldots\ \ x_n(t)\right]$. If the receiving array to receive signals written in vector form, it should be

$$x(t)=c\bullet\left[a(\theta)+\chi a(\theta)\right]\bullet\left[a^T(\theta)+\chi a^T(\theta)\right]g(t)+n(t) \quad (12)$$

Based on the above analysis, the signal through the matched filter, collecting signals in beam space, and then eigenvalue decomposition after calculate the beam space covariance matrix, determining the number of signal automatically, here in MATLAB using the AIC criterion to judge. If the result is incorrect, repeated, if correct, after seeking the noise subspace, the last peak search, DOA estimates. Flow chart is shown in figure 3.

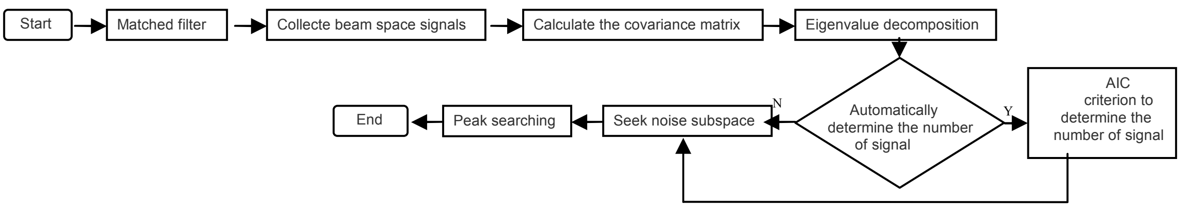

Figure 3. Algorithm flowchart

Simulation results and analysis

Experimental conditions: Transmitting array and receiving array element is 8, the array element spacing is half wavelength, the beam number B = 4, the noise obey Gaussian distribution, two objectives in the sky, the azimuth angle of 60 ° and a nearly 60 °point of view, signal-to-noise ratio is 20dB.

The simulation of estimated DOA to the different angles of the target with beam space MUSIC algorithm in the multipath environment is shown in figure 4 and figure 5 :

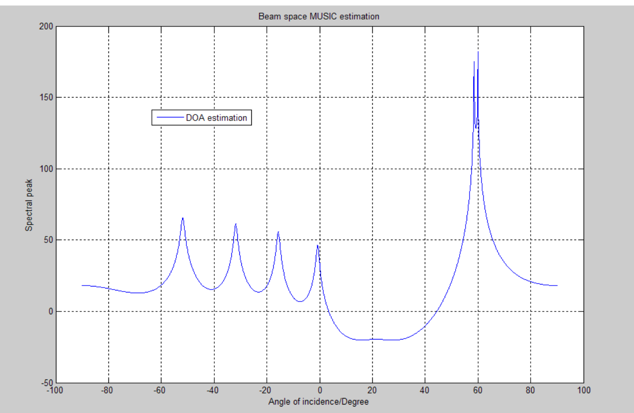

Figure 4. 59.5 ° and 60 ° DOA estimation

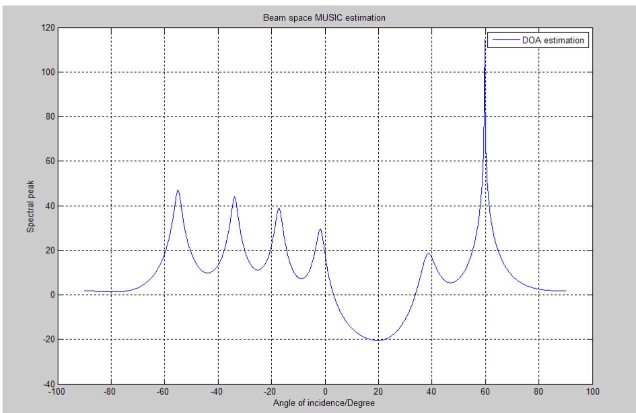

Figure 5. 59.6° and 60 ° DOA estimation

It can be seen from Figure 4, considering DOA estimation under multipath environment, resolution of the angle from 0.5°or more can be accurately estimated, but looking at Figure 5, the angular resolution of 0.4°, the wrong information appeared .Figure 6is the estimated figure to two goals of 59.6 ° and 60 °at the same time. This shows that it should be estimated in the degree of 59.6°, estimated at 39.8554 ° , the error is about 10.2 °,Proving the resolution between 0.5 ° to 0.4° to estimate on two goals simultaneously. so that the angular resolution of the beam space MUSIC algorithm in the multipath environment of low elevation model of the DOA estimated is 0.5° to the left, It is closer to the actual multi-path influence of the situation.

Conclusion

The paper based on MIMO radar to the objectives of the low elevation makes DOA estimation in the multipath environment, and emulating estimate of two goals in the air simultaneously. This article estimate location information effectively , and illustrates the angular resolution problem of DOA estimation in this model, making DOA estimation performance of MIMO radar to get a better understanding. The results are more closely to the actual DOA estimation results.

References

[1] DuoFang C,BaXiao C,GuoDong Q.Angle estimation using ESPRIT in MIMO radar[J].IEEE Electronics Letters, 2008,44(12): p.770-771.

[2] Peng Ma, Wei Wang, Jianyun Zhang, Non-cooperative sources of MIMO radar multiobjective targeting and Parameter Estimation[J]. Anhui University of Technology,2010,34(1)：p.69-73.

[3] Minghong Liu，Zishu He，Jun Li. Bistatic MIMO radar transmitting array target angle estimation [J]. Journal of Radio Science，2010,25(3)：p.499-503.

[4] Zhichao Sheng，Jisong Sheng. The radar beam space MUSIC DOA estimates [J]. Modern electronic technology，2011,9,1(34)17：p.18-24.

[5] XU L Z,Li J，Stoioa P. Adaptive techniques for MIMO radar[C]//Proc.of the IEEE International Conference on Radar,2008:p.258-262.

[6] Zhang X and Xu D.Angle estimation in MIMO radar using reduced-dimension Capon[J]. Electronics Letters, 2010,46(12):p.860-861.

[7] Bekkerman I,Tabrikian J. Target detection and localization using MIMO radars and sonars[J].IEEE Trans Signal Process, 2006,5(10):p.3873-3883.

[8] Furmann D R,Antonio G S.Transmit beamforming for MIMO radar systems using partial signal correlation[C]. Proc 38th Asilomar Conf on Signals,Systems and Computers.Pacific Grove, CA:[s.n.], 2004, l:p.295-299.

[9] Lehman N H,Fishler E,Haimovich A M,et al.Evaluation of transmit diversity in MIMO-radar direction finding[J].IEEE Trans. On Signal Processing 2007 (5):p.2215-2225.

[10] Zhang Yongshun,Guo Yiduo;Niu Xinliang,et al.Angle estimation of coherent multitarget for MIMO bistatic radar[A].Proc Processing[C].USA:IEEE,2010,p.146-149.

[11] Zhang Zhiwei,Wang Bo,Construction and Implementation of the Blocking Matrix Based on the Constraint Space. 2011 International Conference on Instrumentation, Measurement, Computer, Communication and Control, Beijing, China

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