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# Taylor expansion MUSIC method for joint DOD and DOA estimation in a bistatic MIMO array

**Key words:** Bistatic multiple-input multiple-output array; Direction of departure; Direction of arrival; Multiple signal classification; Taylor expansion; Computational complexity

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# Motivation

- Multiple-input multiple-output (MIMO) array has been a subject of considerable research and development for its potential advantages over conventional phased-array systems.
- The two-dimensional multiple signal classification (2D MUSIC) method was to estimate DODs and DOAs in MIMO arrays. The 2D MUSIC method shows excellent joint DOD and DOA estimation performance, but there is a requirement for 2D angle peak searching renders which create high computational complexity.

# Main idea

- An improved MUSIC estimator is proposed based on the Taylor expansion multiple signal classification (TE MUSIC) method. By exploiting the Taylor expansion of the steering vector, the proposed method can avoid high computational cost of the 2D MUSIC method for DOD and DOA estimations in bistatic MIMO arrays and reduce the 2D search of the 2D MUSIC method to two 1D searches. Furthermore, this estimator automatically achieves paired estimates of DODs and DOAs.

# Method

- First, using a Taylor expansion of the steering vector, a 2D search in the conventional MUSIC method for MIMO arrays is reduced to a two-step 1D search in the proposed TE MUSIC method.
- Then, DOAs of the targets can be achieved via a Lagrange multiplier by a 1D search.
- Finally, substituting the DOA estimates into the 2D MUSIC spectrum function, DODs of the targets are obtained by another 1D search.

# Method

Steps of the TE MUSIC method are given as follows:

Step 1: Compute  $\hat{R}$ , the covariance matrix of  $\mathbf{y}(t)$ .

Step 2: Obtain  $\Theta(\theta)$  using an  $L$ -order Taylor expansion of  $\mathbf{a}(\theta, \phi)$  with respect to variable  $\phi$  at  $\phi = \phi_0$ .

Step 3: Calculate  $Q(\theta) = \Theta^H(\theta)\hat{R}^{-1}\Theta(\theta)$ .

Step 4: By searching  $\phi$ , we obtain the  $P$  largest peaks of the (1, 1) element of  $Q^{-1}(\theta)$  to obtain the estimates of DOAs.

Step 5: Substitute the DOAs into the spectrum function and do another 1D search, and then we obtain the estimates of DODs.

# Major results

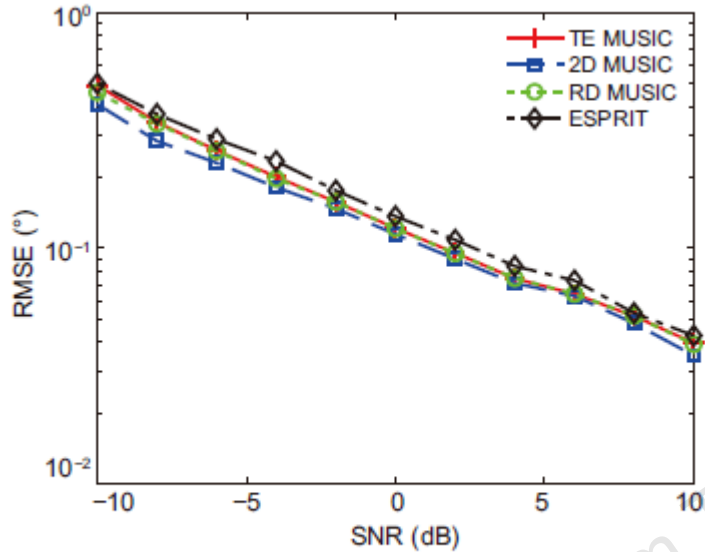


Fig. 3 RMSE of DOA estimation from 200 Monte-Carlo tests for four targets

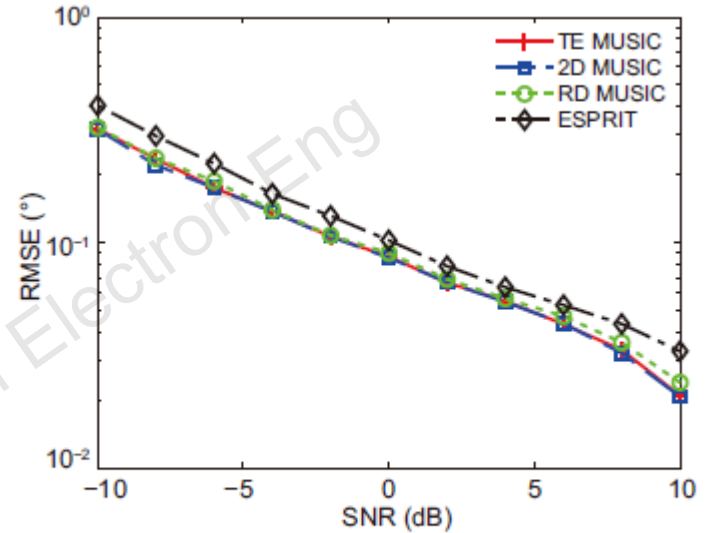


Fig. 4 RMSE of DOD estimation from 200 Monte-Carlo tests for four targets

Consider a bistatic MIMO array system with  $M_t = 8$  and  $M_r = 6$ , and assume that there are four uncorrelated targets located at angles of  $[\theta_1, \phi_1] = [10^\circ, 15^\circ]$ ,  $[\theta_2, \phi_2] = [40^\circ, 25^\circ]$ ,  $[\theta_3, \phi_3] = [20^\circ, 35^\circ]$ , and  $[\theta_4, \phi_4] = [30^\circ, 45^\circ]$ , respectively. Antennas of the arrays are spaced half a wavelength apart and the number of the snapshots is 200.  $\phi_0 = 30^\circ$  is for the fifth-order Taylor expansion.

# Major results (Cont'd)

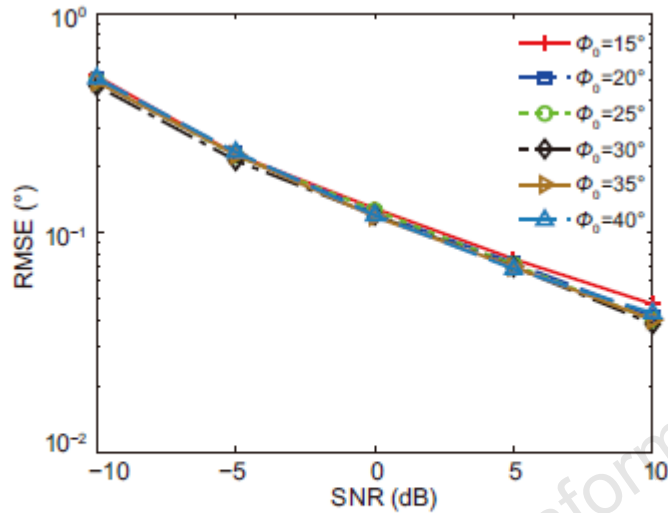


Fig. 5 RMSE of the DOA estimation from 200 Monte-Carlo tests with different  $\phi_0$  under the TE MUSIC method

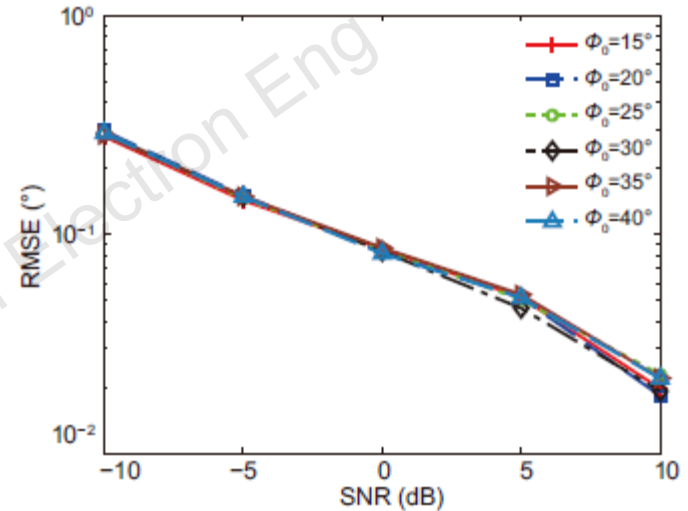


Fig. 6 RMSE of the DOD estimation from 200 Monte-Carlo tests with different  $\phi_0$  under the TE MUSIC method

Consider a bistatic MIMO array system with  $M_t=8$  and  $M_r=6$ . The number of snapshots is 200.

# Conclusions

1. An improved MUSIC method (TE MUSIC) has been proposed by exploiting the Taylor expansion of the steering vector.
2. The TE MUSIC method could reduce the 2D search of the 2D MUSIC method to two 1D searches.
3. The TE MUSIC method has better DOD and DOA estimation performances compared with the ESPRIT method, and has performances that are very close to those of the 2D MUSIC and RD MUSIC methods.
4. The TE MUSIC method can automatically achieve paired DOD and DOA estimates.