

A Recognition Method for MIMO DUSTC Signals

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Abstract. For recognizing the MIMO DUSTC signals without a priori knowledge, a blind recognition method is presented. By estimating the number of transmitting antennas, separating the mixed signals, and recognizing modulation, the unitary matrices \mathcal{S} is estimated by statistics and DUSTC signals are recognized. The simulation results showed that the method was effectively to recognize DUSTC signals with the SNR no less than 4dB.

1 Introduction

The blind recognition of communication signals is an important research topic in the communication countermeasure fields. In the last decade, the Multiple-Input Multiple-Output (MIMO) technology is widely used in the field of civilian and military communication [1-4]. The capacity and performance of system are enhanced by Space-Time Codes (STC). The composite signals are received by each receiving antenna because the MIMO signals are transmitted by multi-antenna array, so it increases the complexity and difficulty of recognition MIMO signals. So the blind recognition methods for MIMO signals are a key research issue in communication countermeasure fields.

At present, there are many algorithms for recognizing STC. The methods of recognizing STBC are proposed using the second-order and higher-order statistics in [5,6]. In [7], a blind recognition algorithm of orthogonal space-time block codes (OSTBC) is proposed based on a cross-correlation analysis over linear combinations of the transmitted signals. The most existing methods focused on recognition STBC. To our knowledge, no method exists in literature for the blind recognition of DUSTC.

In this paper, we propose a method to recognition differential unitary space-time code but without a priori knowledge about the number of antenna array, the modulation and so on. Section II of this paper presents the signal model and characterization of the DUSTC. In Section III, the blind recognition method for DUSTC is presented. Finally, the performances of our proposed method are simulated and analyzed in section IV.

2 Signal Model

DUSTC is an approach to differential modulation for multi-antennas, based on space-time block codes with a group structure [8-10]. Consider the MIMO system with t transmit antennas and constellation C . let \mathcal{S} be any group of $n \times n$ unitary matrices, where $SS^H = S^H S = I$ for all

$S \in \mathcal{S}$. Let D be a $t \times n$ matrix such that $DS \in C^{t \times n}$ for all $S \in \mathcal{S}$. A matrix collection M is defined as

$$M = \{ DS : S \in \mathcal{S} \} \quad (1)$$

where D is a fixed matrix that satisfies $DD^H = tI$. M is a group code of length n over the constellation C .

At time $k=0$, the block $M_0=D$ is sent to initialize the transmission. In successive blocks, the matrix block M_k is differentially encoded which is given by

$$M_k = \begin{cases} D, & k = 0 \\ M_{k-1}S_k, & k = 1, 2, 3, \dots \end{cases} \quad (2)$$

where S_k is the $n \times n$ unitary matrices which is determined by transmitted data.

At the receiver, the signal Y which is received by antenna is given by

$$Y = HM + N \quad (3)$$

where H is the channel transfer matrix, M is the matrix block collection $\{M_0, M_1, M_2, \dots\}$ and N is zero-mean Gaussian noise.

It can be seen from the formula (3) that each receiving antenna received the multi composite signal which transmitted by multi-antennas. The multi-component signal can lead to signal that's difficult to distinguish, so it increase the difficulty to recognize DUSTC signal.

3 DUSTC Recognizing Mechanism

3.1 Signals Separation

Table 1. The transmitted M_k

k	0	1	2	...	K
M_k	D	DS_1	DS_1S_2	...	$DS_1S_2 \dots S_K$

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According to the formula (2), the transmitted block M_k is showed as in table 1 with k increase from 0 to K .

At the transmitter side, when we multiply the M_{k-1} by S_1 , we get the matrix block M_k . The reason that the receiving antenna received multi composite signal is because the multi signals are transmitted in wireless channel. So if we can get the matrix block M_k , we can estimate the S_k as

$$S_k = M_{k-1}^{-1} M_k = (DS_1 S_2 \cdots S_{k-1})^{-1} DS_1 S_2 \cdots S_{k-1} S_k \quad (4)$$

In order to get M_k , we use the blind source separation (BSS) [11,12]. BSS is the approach to estimate original source signals without any prior information. There are many algorithms to separate the multi composite signal, such as FAST ICA, JADE and so on. The process of blind source separation is showed as Fig.1.

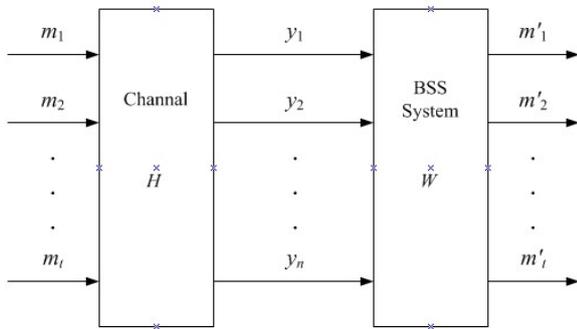


Fig. 1. The process of blind source separation

In Fig.1, m_i is the transmitted signal, y_n is the received signal, and m'_i is the signals after separating. The BSS algorithms need to meet that the number of receiver antennas is no lower than that of transmitter, and the number of signal sources is known. We can increase the number of receiver antennas to meet the first requirement. Based on Minimum Description Length (MDL) principle [13], the number of signal sources can be estimated.

The objective function of MDL principle is given by

$$MDL(k) = -\ln\left[\left(\prod_{i=k+1}^M \lambda_i^{\frac{1}{M-k}}\right) \left(\frac{1}{M-k} \sum_{i=k+1}^M \lambda_i\right)^{(M-k)N}\right] + \frac{k}{2}(2M-k)\ln N \quad (5)$$

where M is the number of receiver antennas for separating signals, λ_i is the eigenvalue of covariance matrix of received signal Y , and N is the number of data.

As k increase from 0 to $M-1$, we find the minimum value of $MDL(k)$ when k is equal to k' , and then k' is the number of source signals. It is given by

$$k' = \min\{MDL(k), \quad k = 0, 1, 2, \dots, M-1\} \quad (6)$$

By using MDL principle and BSS, we can separate the multi composite signal, and get the signal that send by each transmitted antenna.

3.2 Separated Signal Demodulation

Because the DUSTC signal is a digital modulation wave, so we need to demodulate the signal to get the transmitted constellation. Without a priori knowledge,

the modulation and carrier frequency is unknown. For demodulating the separated signal, we need to estimate the carrier frequency and recognize the modulation.

For estimating the carrier frequency, we can use the Fast Fourier Transmit, power spectrum estimation, and so on [14,15]. For recognizing the modulation, these methods are divided into two categories [16-18]. One is the decision theoretic approaches, and the other is pattern recognition. One classical method for modulation recognizing is proposed in [16]. There are five parameters such as the maximum value of the spectral power density of the normalized-centered instantaneous amplitude r_{max} , the standard deviation of the absolute value of the non-linear component of the instantaneous phase σ_{ap} , the standard deviation of the nonlinear component of the direct (not absolute) instantaneous phase σ_{dp} , the standard deviation of the absolute value of the normalized-centered instantaneous amplitude σ_{aa} , and the standard deviation of the absolute value of the normalized centered instantaneous frequency σ_{fa} . The 2FSK, 4FSK, 2ASK, 4ASK, BPSK and QPSK signals can be recognized by five parameters. The detailed pictorial representation for digital modulation identification is shown in Fig.2.

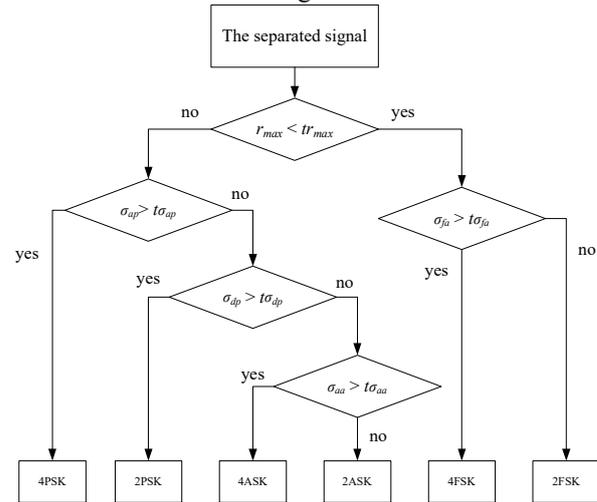


Fig. 2. Digital modulation identification

The separated signal is a pure signal by blind source separation, and the interference in identical, adjacent and multiple frequencies are eliminated. So it is suit for estimating the carrier frequency by power spectrum estimation and recognizing the modulation by using the method in [16].

3.3 DUSTC Signals Recognition

After demodulating each separated signal, we can get the constellation M_k which sent by each transmitting antenna. According to the principle of DUSTC, the successive constellations M_k is equal to M_{k-1} multiply by S_k . If the separated signals are DUSTC signal, we will get S_k by formula (4). If we get enough separate signals, we can estimate S . If the separated signals are not DUSTC signal, there isn't S_k but random matrix. According to whether there is DUSTC signal, it is given by

$$\begin{aligned}
 H_1 : S_k &= M_{k-1}^{-1} M_k, \quad S_k \in \mathbf{S} \\
 H_0 : \text{randommatrix} &= M_{k-1}^{-1} M_k
 \end{aligned}
 \tag{7}$$

The unitary matrices \mathbf{S} can be estimated by statistical symbols, and the DUSTC is recognized. The process of recognition DUSTC is as shown in figure 3.

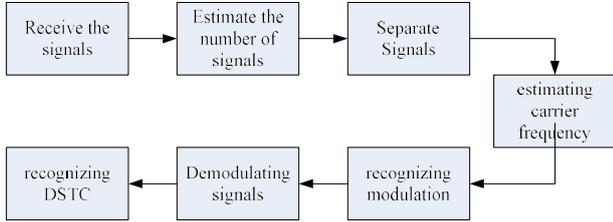


Fig. 3. The process of recognition DUSTC signals

4 Performance analysis

In order to verify that the method for recognizing DUSTC signals is effective, it is simulated in this paper. The number of transmitting antennas is 2, and the number of receiving antennas for recognizing is 8. The modulation is QPSK, and the number of sampling data is 120000.

Table 2 shows the results of the objective function of MDL principle with CNR=15dB. It is evident that $MDL(k)$ is the smallest when k is 3. Then, the estimated number of transmitting antennas is 2.

Table 2. The objective function of MDL principle

k	0	1	2	3
$MDL(k)$	1397.44	799.17	100.36	139.62
k	4	5	6	7
$MDL(k)$	171.77	196.79	214.65	225.37

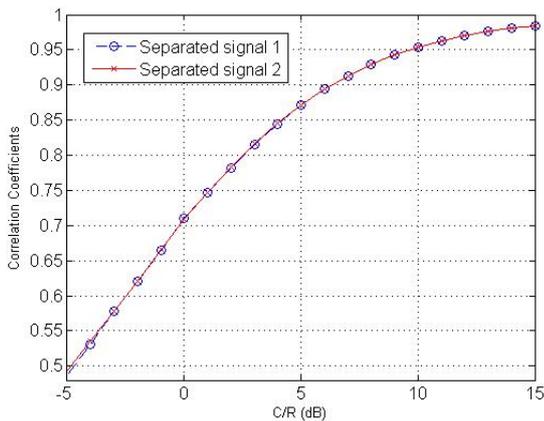
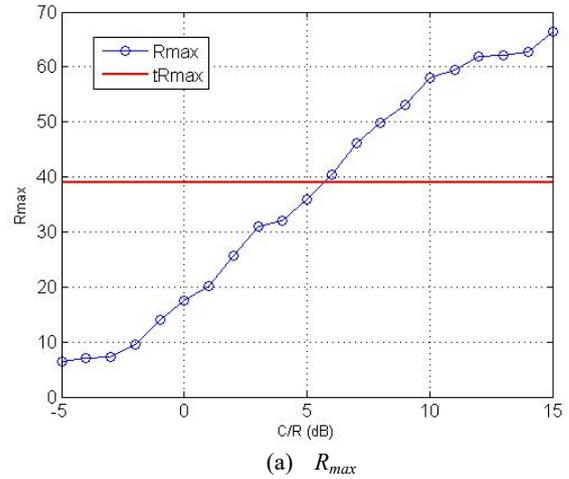


Fig.4. The correlation coefficients between original signals and separated signals

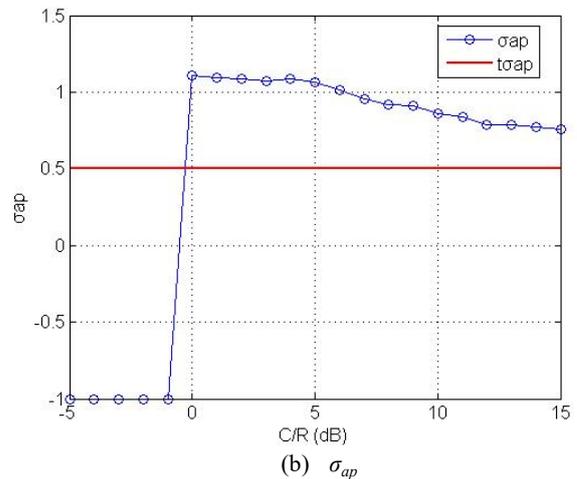
Figure 4 shows the correlation coefficients between original DUSTC signals and separated signals. From Fig. 6, we can see that the separated signals are similar to the original signals with a higher CNR. The correlation coefficients decrease as the CNR gradually decreases.

Figure 5 shows the results of r_{max} and σ_{ap} with different CNR. In this paper, because the modulation of DUSTC signals is QPSK, so it can be recognized by r_{max}

and σ_{ap} parameters. The thresholds are 39 and 0.5, for R_{max} and σ_{ap} respectively. From Fig.5 it is clear that for CNR > 6dB it is distinguished effectively FSK from other demodulations by R_{max} , and for CNR>0dB it is distinguished effectively QPSK from BPSK and ASK by σ_{ap} .



(a) R_{max}



(b) σ_{ap}

Fig.5.the results of r_{max} and σ_{ap} with different CNR

After separating, estimating carrier frequency, and recognizing the modulation of DUSTC signals, the transmitted constellation can be obtained. By statistics analysis, the maximum number of unitary matrices is shown in table 3 with CNR=15dB. It is evident that there are four unitary matrices, and the probability of each unitary matrix is similar to others. The probability is near to one-quarter, which accord with the character of DUSTC signals.

Table 3. The probability and constellation of unitary matrices

NO.	1	2	3	4
Constellation	1 0 0 1	-1 0 0 -1	j 0 0 j	-j 0 0 -j
Probability	0.2367	0.2317	0.2683	0.2617

Figure 6 shows the recognition probability of DUSTC with different CNR. From Fig.6, we can see that

the DUSTC signals can be recognition effectively with $CNR > 6\text{dB}$. For $CNR < 4\text{dB}$, the recognition probability decrease rapidly.

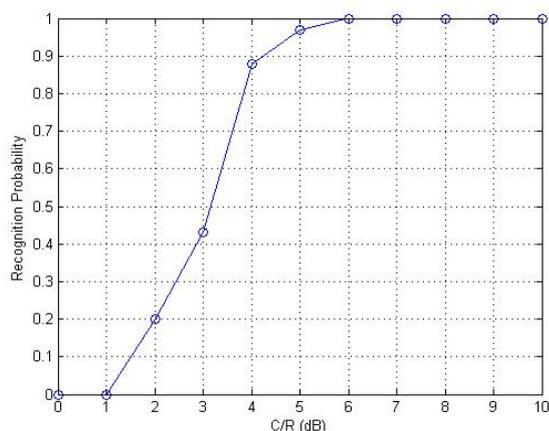


Fig.6. The recognition probability of DUSTC signals

Conclusion

The simulation results showed that the method of recognition DUSTC signals was effectively in this paper. However the recognition method is carried out with 2×2 antennas array. The further study will be needed to recognize DUSTC signals with more antennas.

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