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Method of combining space-time block coding with adaptive beamforming

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Abstract: A method of space-time block coding (STBC) system based on adaptive beamforming of cyclostationarity signal algorithm is proposed. The method uses cyclostationarity of signals to achieve adaptive beamforming, then constructs a pair of low correlated transmit beams based on beamform estimation of multiple component signals of uplink. Using these two selected transmit beams, signals encoded by STBC are transmitted to achieve diversity gain and beamforming gain at the same time, and increase the signal to noise ratio (SNR) of downlink. With simple computation and fast convergence performance, the proposed scheme is applicable for time division multiple access (TDMA) wireless communication operated in a complex interference environment. Simulation results show that the proposed scheme has better performance than conventional STBC, and can obtain a gain of about 5 dB when the bit error ratio (BER) is 10^{-4}.

Key words: space-time coding; gain; adaptive beamforming; cyclostationary signal; transmit diversity

With the explosive development of wireless personal area networks, the requirement for radio channels is increasing rapidly. At the same time, the new generation wireless systems are required to have better quality, wider coverage, more power and bandwidth efficiency. Among the various solutions to the problem, space-division multiple access (SDMA) is a promising scheme for frequency re-use to increase the number of channels with a given frequency spectrum effectively. Similarly, the diversity technique can improve quality of reception signals through multipath fading channels.

Adaptive beamforming is one of the essential solutions in SDMA schemes. Recently, much research has been done for constructing more effectively adaptive beamforming antenna array to extract a signal of interest (SOI) in the presence of interference, which is based on utilization of cyclostationarity of man-made signals by many researchers. The advantages of an adaptive beamforming algorithm based on cyclostationarity of signals are: there is no need of advanced knowledge of the correlation properties of noise and interference, there is no need of calibration of antenna array, and it only needs knowledge of the cycle frequency of the signal of interest to realize the selection of the signals. Consider, for example, the self-coherence restoral (SCORE) of signals algorithm proposed by Agee et al. [1], maximum likelihood and common factor analysis-based adaptive spatial filtering for cyclostationary signals[2], and the cyclic adaptive beamforming algorithm proposed by Wong et al[3]. These algorithms can provide beamforming gain at a base station with multiple antennas, so as to increase the signal to noise ratio (SNR) of links.

More recently, space-time trellis coding proposed in Ref. [4] which combines signal processing at the receiver with coding techniques appropriate to multiple transmit antennas has been able to provide significant gain for reception signals. Alamouti[5] discovered a simple scheme for transmission using two transmit antennas in addressing the issue of decoding complexity, which can achieve the same diversity order as maximal-ratio receiver combining (MRRC) with one transmit antenna and two receive antennas. The performance of the space-time block codes is evaluated and details of the encoding and decoding procedures are provided from Ref. [6]. All this research shows that space-time block coding can provide transmission diversity and improve link quality of multipath fading channels effectively.

In order to obtain diversity gain and beamforming gain simultaneously, a natural idea may emerge to combine STBC with adaptive beamforming techniques, which use an adaptive beamforming antenna array instead of multiple diversity antennas. However, STBC based on a diverse antenna system usually requires the antenna spacing to be large enough, i. e. 10 wavelengths of the carrier for a uniform linear array in small

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angular spread environment to obtain low correlation or independent fading channels. Whereas the beamforming antenna requires the antenna spacing to be very small, i. e. half of the wavelength of the carrier to make the signals received or transmitted be correlated, nevertheless, in an environment where there exist independent multipath reception signals, a pair of transmit beams can be constructed according to the estimation of direction of arrival (DOA) of reception signals instead of two transmit diversity antennas, thus the same diversity order as that of conventional STBC can be achieved[7].

A method of STBC system based on adaptive beamforming of a cyclostationarity signal algorithm is proposed. The method uses the cyclostationarity nature of man-made signals to achieve adaptive beamforming, then constructs a pair of low correlated transmit beams based on beamform estimation of multiple components of SOI of the uplink. Using these two selected transmit beams, signals encoded by STBC are transmitted to achieve diversity gain and beamforming gain at the same time, and increase the SNR of the downlink. The method combines STBC with adaptive beamforming of cyclic signals. Without knowledge of characteristics of noise and interference, this adaptive beamforming algorithm can obtain the desired beamforming with simple computation and feasible implementation. Meanwhile, a space-time block coding algorithm based on two transmit beams can provide the same transmit diversity gain as conventional transmit diversity antenna systems. Simulation shows that it can provide better performance improvement compared with a single STBC system using the gains of beamforming and diversity with simple algorithm.

1 STBC Systems and Adaptive Beamforming System

The two-branch transmit diversity scheme with single reception antenna[5] uses two transmit antennas and one receive antenna. Fig. 1 shows the baseband representation of the scheme. Two transmit antennas are equipped at the base station, and one reception antenna is adopted at a mobile terminal. The transmitted signals are encoded in the STBC module according to Tab. 1 firstly. At a given symbol period n, two antennas simultaneously transmit signals $s(n)$ and $s(n+1)$ respectively. During the next symbol period, $-s^*(n+1)$ and $s^*(n)$ are transmitted. Symbols are input in serial and output in parallel. Assuming that fading is constant across two consecutive symbols, the reception signals can be represented as

$$\begin{Bmatrix} r(n) \\ r^*(n+1) \end{Bmatrix} = \begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix} \begin{Bmatrix} s(n) \\ s(n+1) \end{Bmatrix} + \begin{Bmatrix} v(n) \\ v^*(n+1) \end{Bmatrix} \quad (1)$$

where superscript * denotes a complex conjugate operator; h_1 and h_2 are channel response from two transmit antennas to the reception antenna, which are modeled as samples of independent complex Gaussian random variables with variance 0.5. The noise samples $v(n)$ and $v(n+1)$ are independent samples of zero-mean complex Gaussian random variables with variance 1/SNR per complex dimension.

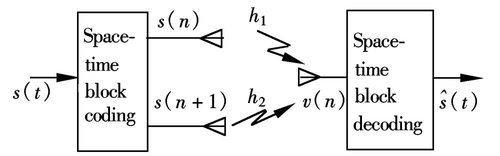

Fig. 1 Two-branch STBC scheme

Tab. 1 Encoding and transmission sequence for two-branch STBC scheme

Time	Antenna 1	Antenna 2
n	$s(n)$	$s(n+1)$
$n+1$	$-s^*(n+1)$	$s^*(n)$

The combiner at reception constructs two combining signals as follows:

$$\begin{Bmatrix} \hat{s}(n) \\ \hat{s}(n+1) \end{Bmatrix} = \begin{bmatrix} h_1^* & h_2 \\ h_2^* & -h_1 \end{bmatrix} \begin{Bmatrix} r(n) \\ r^*(n+1) \end{Bmatrix} \quad (2)$$

The channel coefficients can be estimated by

$$\begin{Bmatrix} \hat{h}_1 \\ \hat{h}_2 \end{Bmatrix} = \begin{bmatrix} \hat{s}(n) & \hat{s}(n+1) \\ -\hat{s}^*(n+1) & s^*(n) \end{bmatrix}^{-1} \begin{Bmatrix} r(n) \\ r(n+1) \end{Bmatrix} \quad (3)$$

Substituting (1) into (2) we have

$$\begin{Bmatrix} \hat{s}(n) \\ \hat{s}(n+1) \end{Bmatrix} = \begin{bmatrix} h_1^* h_1 + h_2 h_2^* & h_1^* h_2 - h_2 h_1^* \\ h_2^* h_1 - h_1 h_2^* & h_2^* h_2 + h_1 h_1^* \end{bmatrix} \times \begin{Bmatrix} s(n) \\ s(n+1) \end{Bmatrix} + \begin{bmatrix} h_1^* & h_2^* \\ h_2^* & -h_1^* \end{bmatrix} \begin{Bmatrix} v(n) \\ v(n+1) \end{Bmatrix} \quad (4)$$

These combined signals are then sent to the maximum likelihood detector. For PSK signals, the maximum likelihood decision rule for received signals selects s_i if and only if

$$d^2(\hat{s}(n),\ s_i) \leqslant d^2(\hat{s}(n),\ s_k) \qquad \forall\, i \neq k \quad (5)$$

where $d^2(x, y)$ is the squared Euclidean distance between signals x and y.

From the above analysis we can find that the signal estimation and channel measure algorithm of the two-branch transmit diversity scheme is quite simple and easy to implement.

The maximum likelihood decoding of STBC can be achieved using only linear processing at the receiver. The maximum likelihood detection amounts to minimizing the decision metric[6]

$$|r(n) - h_1 s(n) - h_2 s(n+1)|^2 + |r(n+1) + h_1 s^*(n+1) - h_2 s^*(n)|^2 \quad (6)$$

overall all the possible values of $s(n)$ and $s(n+1)$. The minimization of (6) is equivalent to minimizing the decision metric

$$|(r(n)h_1^* + r(n+1)h_2) - s(n)|^2 + (h_1 h_1^* + h_2 h_2^* - 1)s(n)s^*(n) \quad (7)$$

for detecting $s(n)$ and the decision metric

$$|(r(n)h_2^* - r^*(n+1)h_1) - s(n+1)|^2 + (h_1 h_1^* + h_2 h_2^* - 1)s(n+1)s^*(n+1) \quad (8)$$

for detecting $s(n+1)$. This simple decoding scheme is described in Ref. [6], and does not sacrifice performance as compared with MRRC with one transmit antenna and two receive antennas.

Since most man-made signals exhibit cyclostationarity in a wide sense with the cycle frequency not equaling zero[8], this cyclostationarity is only related to its own property. We may use this property of signals for signal extraction and interference suppression. In a beamforming technique, the cyclostationarity can be utilized to construct adaptive array beamforming.

A signal is called cyclostationary if its cyclic correlation or conjugate cyclic correlation is not equal to zero at some time delay τ or frequency shift α. The cyclic correlation is defined as

$$R_{xx}^{\alpha}(\tau) = \langle [\boldsymbol{x}(n)\boldsymbol{x}^{\dagger}(n+\tau)\mathrm{e}^{-\mathrm{j}2\pi\alpha n}] \rangle_{\infty} = \lim_{N\to\infty} \frac{1}{N} \sum_{n=1}^{N} \boldsymbol{x}(n)\boldsymbol{x}^{\dagger}(n+\tau)\mathrm{e}^{-\mathrm{j}2\pi\alpha n} \quad (9)$$

where $\langle [\cdot] \rangle_{\infty}$ denotes the time average over an infinite observation period, the superscript $\dagger$ denotes the conjugate transpose operator, and α is called the cyclic frequency of signal $x(t)$. Also, the conjugate cyclic correlation is defined as

$$R_{xx^*}^{\alpha}(\tau) = \langle [\boldsymbol{x}(n)\boldsymbol{x}^{\mathrm{T}}(n+\tau)\mathrm{e}^{-\mathrm{j}2\pi\alpha n}] \rangle_{\infty} \quad (10)$$

In practical application, the estimation of $R_{xx}^{\alpha}(\tau)$ is obtained by taking an average over N samples so that

$$\hat{R}_{xx}^{\alpha}(\tau) = \langle [\boldsymbol{x}(n)\boldsymbol{x}^{\dagger}(n+\tau)\mathrm{e}^{-\mathrm{j}2\pi\alpha n}] \rangle_{N} = \frac{1}{N} \sum_{n=1}^{N} \boldsymbol{x}(n)\boldsymbol{x}^{\dagger}(n+\tau)\mathrm{e}^{-\mathrm{j}2\pi\alpha n} \quad (11)$$

The cyclic frequency of a signal is usually dependent upon data rate and the carrier directly.

Assume that an antenna array is composed of M elements. The received signal vector is represented by $\boldsymbol{r}(n)$. Thus for K signals of interest, vector $\boldsymbol{r}(n)$ can be modeled as

$$\boldsymbol{r}(n) = \sum_{k=1}^{K} \boldsymbol{d}(\theta_k)s_k(n) + \boldsymbol{i}(n) + \boldsymbol{v}(n) \quad (12)$$

where $\boldsymbol{s}(n)$ is the signal of interest, $\boldsymbol{d}(\theta_k)$ is the steering vector at the direct of arrival θ_k, $\boldsymbol{i}(n)$ is the combination of interferences, and $\boldsymbol{v}(n)$ is an $M \times 1$ additive white Gaussian noise vector.

As for the algorithm of cyclic adaptive beamforming (CAB)[3], the objective of the algorithm of spatial signal extraction is to find out the weighting $\boldsymbol{w}$ according to some certain rule, so as to extract K signals of interest using the following equation:

$$\hat{\boldsymbol{s}}_k(n) = \boldsymbol{W}_k^{\dagger}\boldsymbol{r}(n) \qquad k = 1, 2, \ldots, K \quad (13)$$

Let $\boldsymbol{u}(n) = \boldsymbol{r}(n+\tau)\mathrm{e}^{\mathrm{j}2\pi\alpha n}$, then $\boldsymbol{R}_{rr}^{\alpha}(\tau)$ can be represented by cross-correlation as $\boldsymbol{R}_{ru} = \boldsymbol{R}_{rr}^{\alpha}(\tau)$. $\boldsymbol{R}_{rr}$ and $\boldsymbol{R}_{uu}$ are defined as the autocorrelation of $\boldsymbol{r}(n)$ and $\boldsymbol{u}(n)$, respectively. The weighting vector $\boldsymbol{w}$ in the algorithm of adaptive beamforming of the cyclostationary signal is determined by selecting two $M \times 1$ vectors $\boldsymbol{w}$ and $\boldsymbol{c}$, so as to maximize the sample correlation between $\boldsymbol{w}^{\dagger}\boldsymbol{r}(n)$ and $\boldsymbol{c}^{\dagger}\boldsymbol{r}(n)$, namely

$$\max_{\boldsymbol{w},\boldsymbol{c}} |\langle [\boldsymbol{w}^{\dagger}\boldsymbol{r}(n)\boldsymbol{u}^{\dagger}(n)\boldsymbol{c}] \rangle_N|^2 \quad (14)$$

which is under the constraint condition of

$$\boldsymbol{w}^{\dagger}\boldsymbol{w} = 1, \qquad \boldsymbol{c}^{\dagger}\boldsymbol{c} = 1$$

This rule can be written as

$$\max_{\boldsymbol{w},\boldsymbol{c}} |\boldsymbol{w}^{\dagger}\hat{\boldsymbol{R}}_{ru}\boldsymbol{c}|^2 = \max_{\boldsymbol{w},\boldsymbol{c}} \boldsymbol{w}^{\dagger}\hat{\boldsymbol{R}}_{ru}\boldsymbol{c}\boldsymbol{c}^{\dagger}\hat{\boldsymbol{R}}_{ur}\boldsymbol{w} \quad (15)$$

It is shown that the solutions of $\boldsymbol{w}$ and $\boldsymbol{c}$ must satisfy

$$\delta^{\frac{1}{2}}\boldsymbol{w} = \hat{\boldsymbol{R}}_{ru}\boldsymbol{c} \quad (16)$$

$$\delta^{\frac{1}{2}}\boldsymbol{c} = \hat{\boldsymbol{R}}_{ur}\boldsymbol{w} \quad (17)$$

where δ is the singular eigenvalue of $\boldsymbol{R}_{ru}$. With Eqs. (16) and (17), $\boldsymbol{w}$ and $\boldsymbol{c}$ can be iteratively solved by the power method[1].

Assuming that for multiple signals of interest, all K SOI have the same cyclic frequency α and are different from the cyclic frequency of interferences $\boldsymbol{i}(n)$. For simplicity, assume that all K signals are non-correlation. In such cases, the matrix $\boldsymbol{R}_{ru}$ has K left singular vector of no-zero singular values vector. Thus, the cyclic adaptive beamforming algorithm uses the first K left singular vectors obtained from Eq. (16) to extract K signals of interest. In the presence of K non-correlation signals with the same cyclic frequency α, if the steering vectors of these signals are well separated with each other, that is

$$\boldsymbol{d}^{\dagger}(\theta_k)\boldsymbol{d}(\theta_l) \approx 0 \qquad k, l \in \{1, 2, \ldots, K\} \quad (18)$$

Then weighting vector $\boldsymbol{w}_k$ can be asymptotic represented as

$$\boldsymbol{w}_k \approx \boldsymbol{d}(\theta_k) \qquad k \in \{1, 2, \ldots, K\} \tag{19}$$

Furthermore, if the j-th ($j \leqslant K$) left singular vector $\boldsymbol{w}_j$ is used to extract the k-th signal of interest, then the SNR of signal can be written as

$$R_{jk} = \frac{\boldsymbol{R}_{s_k s_k} \boldsymbol{d}^{+}(\theta_k) \boldsymbol{d}(\theta_k) \boldsymbol{w}_j^{\dagger} \boldsymbol{w}_j \cos^2[\boldsymbol{d}(\theta_k), \boldsymbol{w}_j, \boldsymbol{I}]}{\boldsymbol{w}_j^{\dagger} \boldsymbol{R}_{\boldsymbol{I}_k} \boldsymbol{w}_j} \tag{20}$$

where

$$\cos^2[\boldsymbol{d}(\theta_k), \boldsymbol{w}_j, \boldsymbol{I}] = \frac{\boldsymbol{d}^{+}(\theta_k) \boldsymbol{w}_j \boldsymbol{w}_j^{\dagger} \boldsymbol{d}(\theta_k)}{\boldsymbol{d}^{+}(\theta_k) \boldsymbol{d}(\theta_k) \boldsymbol{w}_j^{\dagger} \boldsymbol{w}_j}$$

$\boldsymbol{R}_{\boldsymbol{I}_k}$ is the auto-correlation matrix of the interference and noise when the k-th signal is taken as the signal of interest, and $\boldsymbol{R}_{s_k s_k}$ is the auto-correlation matrix of signal $\boldsymbol{s}_k$ [3].

From Eq. (19), it can be seen that the cyclic adaptive beamforming algorithm tries to set the beams at the direction of arrival of signals, which is the desired performance of a beamformer, so the algorithm can work well under the condition of adequate separation between interferences and signals of interest.

2 Method of Combined STBC with Adaptive Beamforming

Fig. 2 outlines the system construction of STBC combined with adaptive beamforming of cyclic signals. The transmitted signal $s(n)$ is encoded in the space-time block coding module firstly, the two-branch outputs are $s(n)$ and $s(n+1)$, which are denoted by $s_1(n) = s(n)$ and $s_2(n) = s(n+1)$, respectively. Then these two signals are sent to the adaptive beamforming module. The beamformer, based on cyclostationarity of signal, selects two non-correlated arrival multipaths $\boldsymbol{d}(\theta_1)$ and $\boldsymbol{d}(\theta_2)$ according to the direction of arrival of reception signals with Eq. (19). The according beamforming weightings are $\boldsymbol{w}_1$ and $\boldsymbol{w}_2$. In TDMA systems, the operation frequency of uplink is the same as that of downlink. When the mobile terminal moves at walking speed, it will arrive at a well approximated degree taking the DOA of uplink as that of downlink. In fact, since the cyclic adaptive algorithm has a fast convergence, when the mobile terminals are in the state of vehicle speed, there is still good performance with the algorithm. Thus, the transmitted signal vector can be written as

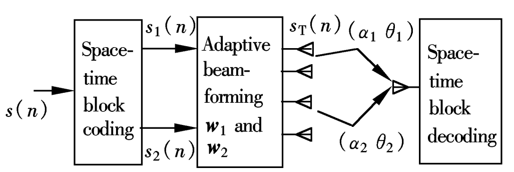

Fig. 2 Method of combined STBC with adaptive beamforming

$$s_{\mathrm{T}}(n) = \boldsymbol{w}_1^{\dagger} s_1(n) + \boldsymbol{w}_2^{\dagger} s_2(n) \tag{21}$$

Assuming that the channel is plain fading response, the reception vector at the mobile terminal is

$$\boldsymbol{r}(n) = \boldsymbol{w}_1^{\dagger} h_1 s_1(n) + \boldsymbol{w}_2^{\dagger} h_2 s_2(n) + \boldsymbol{v}(n) + \boldsymbol{i}(n) \tag{22}$$

Let $\boldsymbol{a}_1(n) = \boldsymbol{w}_1^{\dagger} \boldsymbol{h}(n)$, $\boldsymbol{a}_2(n) = \boldsymbol{w}_2^{\dagger} \boldsymbol{h}(n)$. Comparing Eq. (22) with Eq. (1), the reception signal can be represented as

$$\begin{Bmatrix} r(n) \\ \boldsymbol{r}^{*}(n+1) \end{Bmatrix} = \begin{bmatrix} a_1 & a_2 \\ a_2^{*} & -a_1^{*} \end{bmatrix} \begin{Bmatrix} \boldsymbol{s}(n) \\ \boldsymbol{s}(n+1) \end{Bmatrix} + \begin{Bmatrix} \boldsymbol{v}(n) \\ \boldsymbol{v}^{*}(n+1) \end{Bmatrix} + \begin{Bmatrix} \boldsymbol{i}(n) \\ \boldsymbol{i}(n+1) \end{Bmatrix} \tag{23}$$

It can be seen that, by selecting beamforming weightings $\boldsymbol{w}_1$ and $\boldsymbol{w}_2$, the recovery of transmitted signals of the combined scheme, with both beamforming gain and transmit diversity, can be achieved by the decoding process of conventional STBC.

The weighting of transmit beamforming is obtained by maximizing Eq. (14) under the constraint condition of $\boldsymbol{w}^{+}\boldsymbol{w} = 1$ and $\boldsymbol{c}^{+}\boldsymbol{c} = 1$. The solutions of cost function are the eigenvectors corresponding to the two largest eigenvalues of the downlink channel covariance matrix. For a time-division duplex (TDD) system, the channel covariance matrix of downlink is the same as that of uplink, and can be obtained by

$$\boldsymbol{R} = \frac{1}{N} \sum_{n=1}^{N} \boldsymbol{x}(n) \boldsymbol{x}(n)^{+} \tag{24}$$

where $\boldsymbol{x}(n)$ denotes the array samples of uplink at time n, and N is the number of samples during the sampling time.

From the above analysis we can find that the encoding and decoding processes of the combined scheme are similar with that of the conventional STBC method, with the only difference lying in the addition of beamforming weightings $\boldsymbol{w}_1$ and $\boldsymbol{w}_2$.

The processing of the combined method is as follows:

1) The selection of transmitting beamforming weighting $\boldsymbol{w}_1$ and $\boldsymbol{w}_2$

Assuming that the multiple components of the reception signal are not correlated with each other, according to previous analysis, in the presence of K non-correlation signals with the same cyclic frequency and different cyclic correlation strengths, that is, $R_{s_k s_k}^{\alpha}(\tau) \neq R_{s_l s_l}^{\alpha}(\tau)$, $k \neq l$, if there is adequate separation among the steer vectors of these signals so that

$$d^{+}(\theta_k)d(\theta_l)\approx 0 \qquad k,l\in\{1,2,\ldots,K\} \quad (25)$$

$$R_{I_k}d(\theta_k)\approx 0 \quad (26)$$

then as $N\to\infty$, the weighting vector w_k can be used to extract the k-th signal of interest. Thus, the base station adopts a cyclic adaptive beamforming algorithm utilizing cyclostationarity of signal of interest to receive a pair of no-correlated multipath signals from the mobile terminal, then according to the direction of arrival of uplink, the base station uses the DOA of the uplink as the estimation of the direction of downlink beamforming. So these weightings can be used as transmit beamforming instead of the two transmit diversity antennas in the conventional STBC systems.

2) Space-time block coding based on beamforming weighting

This takes a pair of non-correlated beams obtained from the previous processing as the transmit antennas of a two-branch transmit diversity STBC system, then uses the method of conventional space-time block coding to transmit two signals $s_1(n)$ and $s_2(n)$ simultaneously from two transmit beams. The mobile terminal adopts a single reception antenna approach. The reception signals can achieve both beamforming gain and transmit diversity gain.

3 Simulation Results

Fig. 3 depicts the beam pattern of the cyclic adaptive beamforming algorithm with seven elements of antenna array in the presence of interference. The SOI arrives at the array from 40° and 60°. The narrow band interference (NBI) signal impinges on the array at 95°. Both signals of interest and interference are BPSK signals. The SNR equals 10 dB, and SINR is −30 dB. Assume that noise is AWGN.

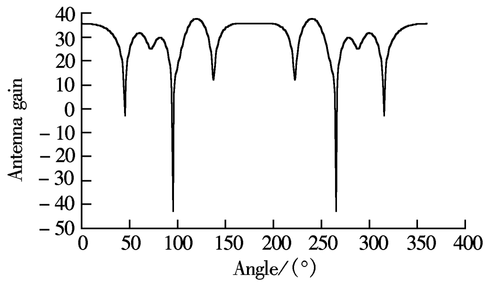

Fig. 3 Beam pattern of reception signal of cyclic adaptive beamforming algorithm with seven elements antenna array

From Fig. 3, it can be seen that the adaptive beamforming algorithm utilizing cyclostationarity can provide beamforming gain as well as interference suppression.

Fig. 4 describes the bit error rate (BER) performance of the method of STBC combined with adaptive beamforming in comparison to the conventional STBC scheme. The communication channel is assumed to be Rayleigth fading. From the figure it can be seen that the combined system has a significant improvement in performance compared with conventional STBC systems. Fig. 5 shows the BER performance of the proposed method in the case of different interferences. It can be seen that when the arrival angle of interference is different from that of signal of interest, the proposed method exhibits good performance, which is the same as that of no interference. However, when the DOA of interference is the same as SOI, the BER performance degenerates seriously.

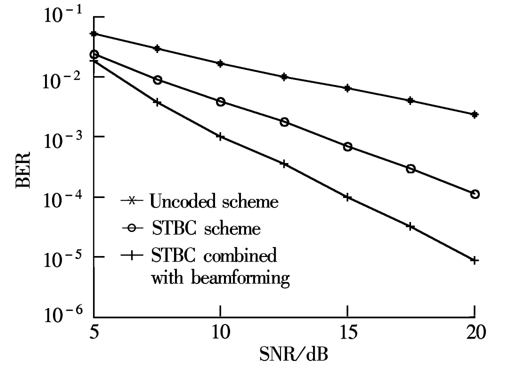

Fig. 4 Performance comparison of average BER between conventional STBC and combined scheme

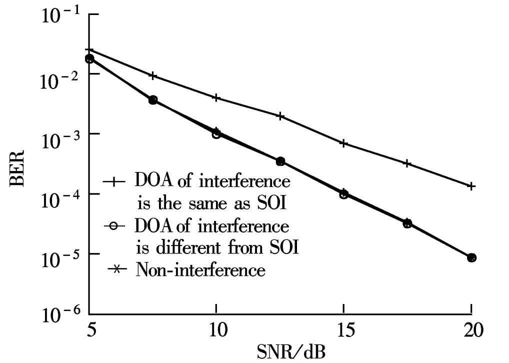

Fig. 5 BER performance of STBC combined with adaptive beamforming with different interferences

4 Conclusion

In this paper, a new method of combined STBC with adaptive beamforming is proposed. The detail of signal processing is outlined. Simulations show that the combined method exhibits better performance than that of conventional STBC systems.

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一种联合空时分组编码和自适应波束形成的方法

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摘要:提出一种基于自适应波束形成循环平稳信号算法的 STBC 系统,首先利用信号的循环平稳性质实现自适应波束形成,然后基于对上行链路感兴趣信号的多个分量的波束形成的估计来构造一对低相关的发送波束,经 STBC 编码后的即可发送以同时达到分集增益和波束形成增益,并增加下行链路的 SNR. 提出的方法具有计算简单和快速收敛的性能,可应用于复杂干扰环境下的 TDMA 无线通信. 仿真结果表明这个方法比常规 STBC 有更好的性能,在误码率为 10^{-4} 时,可获得 5 dB 增益.

关键词:空时编码;增益;自适应波束形成;循环平稳信号;发送分集

中图分类号:TN914