A Fractional Lower Order Statistics-Based MIMO Detection Method in Impulse Noise for Power Line Channel

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***Abstract*—Impulse noise in power line communication (PLC) channel seriously degrades the performance of Multiple-Input Multiple-Output (MIMO) system. To remedy this problem, a MIMO detection method based on fractional lower order statistics (FLOS) for PLC channel with impulse noise is proposed in this paper. The alpha stable distribution is used to model impulse noise, and FLOS is applied to construct the criteria of MIMO detection. Then the optimal detection solution is obtained by recursive least squares algorithm. Finally, the transmitted signals in PLC MIMO system are restored with the obtained detection matrix. The proposed method does not require channel estimation and has low computational complexity. The simulation results show that the proposed method has a better PLC MIMO detection performance than the existing ones under impulsive noise environment.**

***Index Terms*—alpha stable distribution, fractional lower order statistics, impulse noise, MIMO, power line channel.**

I. Introduction

Power line communication (PLC) is used for information transmission over the lines installed for delivering the electrical power. As the power line network has some advantages such as no rewiring, wide coverage and convenient connection, PLC has emerged as a potential candidate for domestic high speed communications. However, the capacity of power line channel is also limited. In order to further improve the data throughput of PLC system, the Multiple-Input Multiple-Output (MIMO) technique has been applied into the PLC system in recent years [1]. The indoor single phase power line usually consists of three wires, which can provide multiple feeding and receiving ports, and this is the physical basis of the application of MIMO in PLC system [1, 2]. MIMO in PLC can significantly improve the channel capacity [1, 3] and the transmission performance of PLC system [4-5].

In MIMO communication system, the transmitted signals will be mixed together when they arrive at the receiving ports. Thus the restoration of the transmitted signals from the receiving ones is necessary. This process is the so-called MIMO detection. The existing MIMO signal detection methods are based on AWGN channel for wireless communication. They mainly include [6]: maximum likelihood (ML) method [7], forced to zero (ZF) method [8], minimum mean square error (MMSE) method [9], the V-BLAST (ZF-OSIC) method [10], QR decomposition method [11] and sphere decoding (SD) method [12]. Among them, the ZF and MMSE detection methods are more practical because of their simpler algorithm and less computational burden. Especially, MMSE can trade off between detection performance and computational complexity. V-BLAST, naturally a kind of ZF method, can cancel interference between transmitted signals from two different antennas and has a better performance than ZF and MMSE methods. The QR decomposition method is a complexity-reduced detection algorithm based on applying the QR decomposition on the channel matrix; but it has worse performance than ZF, MMSE and V-BLAST methods. The ML method is an optimal method with the best detection performance; whereas it is difficult to be applied in an actual MIMO system due to high computational complexity. The SD method is a special kind of ML method, first proposed by Viterbo [13]. It obtains a lower complexity by reducing the detection points and has a performance near to the traditional ML method. Nowadays, it still needs further study to apply SD method into an actual system.

It should be notable, compared with the wireless channel, the power line channel is not an ideal signal transmission carrier due to the presence of impulse noise. The obvious impulsive characteristics of power line channel make the performance of the existing MIMO detection methods decline significantly. To remedy this problem, a novel MIMO detection method based on the fractional lower order statistics (FLOS) is proposed for power line channel. In this method, the fractional lower order correlation (FLOC) is used to construct the criteria for MIMO detection, and recursive least squares (RLS) algorithm is used to obtain the optimal detection matrix. The proposed method has a good detection performance even under impulse noise environment due to the introducing of FLOC.

The rest of this paper is organized as follows. The alpha stable distribution is given in Section II. The PLC MIMO channel model is introduced in Section III. The FLOC-based MIMO detection method is proposed in Section IV. The simulation results are presented in Section V. Finally, some conclusions are drawn in Section VI.

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II. Alpha Stable Distribution

The alpha stable distribution is a kind of non-Gaussian distribution, which can be used to describe non-Gaussian signal, such as impulse noise. Reference [14] has pointed out that the impulse noise in PLC channel can be described by alpha stable distribution.

The alpha stable distribution has no probability density function. In 1978, the characteristic function was put forward to describe it by Stuck, and the function is shown as [15]

$$\psi(t) = \exp\{jat - \gamma|t|^{\alpha}[1 + j\beta\,\mathrm{sgn}(t)\omega(t,\alpha)]\} \quad (1)$$

where sgn(t) is sign function, and

$$\omega(t,\alpha) = \begin{cases} \tan\dfrac{\pi\alpha}{2}\ , & \alpha \neq 1 \\ \dfrac{2}{\pi}\log|t|\ , & \alpha = 1 \end{cases} \quad (2)$$

α ($0<\alpha\leq 2$) is the characteristic index denoting the pulse degree of alpha stable distribution. The smaller the alpha, the stronger the pulse is. The alpha stable distribution is the Gaussian distribution when $\alpha = 2$, and in this paper, the alpha stable distribution is the distribution with α ($0<\alpha<2$); γ ($\gamma>0$) is the dispersion coefficient denoting the dispersion degree, and it is similar to the variance of Gaussian distribution; β ($-1\leq\beta\leq 1$) is known as skewness parameter. It is the so-called symmetric alpha stable distribution ($S\alpha S$) when $\beta = 0$; a ($-\infty < a < \infty$) is the position parameter defining the center of the distribution.

Impulse noise is usually described by $S\alpha S$ in simulations [16]. Its characteristic function is given by

$$\psi(t) = \exp\{jat - \gamma|t|^{\alpha}\} \quad (3)$$

And without loss of generality, set $a = 0$, leading to the simple characteristic function

$$\psi(t) = \exp\{-\gamma|t|^{\alpha}\} \quad (4)$$

For alpha stable distribution, the p-th order statistical moment $E[|X|^p]$ is limited only if $p < \alpha$. As a result, there are not second order statistical moment and higher order statistical moments for alpha stable distribution. It usually uses the fractional lower order statistics (FLOS) to deal with α stable distribution signal. The p-th order statistical moment of a $S\alpha S$ random variable X is given by

$$E(|X|^p) = C(p,\alpha)\gamma_x^{p/\alpha}, \quad 0 < p < \alpha \quad (5)$$

where γ_x is the dispersion coefficient of random variable X, and

$$C(p,\alpha) = \frac{2^{p+1}\Gamma((p+1)/2)\Gamma(-p/\alpha)}{\alpha\sqrt{\pi}\Gamma(-p/2)} \quad (6)$$

Note that $C(p, \alpha)$ does not depend on X. Γ is the usual Gamma function defined as

$$\Gamma(x) = \int_0^{\infty} t^{x-1}\mathrm{e}^{-t}dt \quad (7)$$

FLOS includes fractional lower order moments, negative order moment, 0-th order moment, covariance, fractional lower order covariance, fractional lower order correlation, phase fractional lower order moment, and phase fractional lower order covariance [14]. The proposed method employs the fractional lower order correlation (FLOC). The p-th FLOC of random variables X and Y that obey $S\alpha S$ distribution is [17]

$$R_{XY}^{p} = E[XY^{\langle p-1\rangle}], \quad 1 \leq p < \alpha \quad (8)$$

where the operation symbol $<\cdot>$ denotes the operation $z^{\langle a\rangle} = |z|^{a-1} z^{*}$.

Under alpha stable distribution noise condition, the traditional SNR can not be available because there is no variance (i.e. noise power). Then the generalized signal to noise ratio (GSNR) is defined as [18]

$$\mathrm{GSNR} = 10\lg\frac{\sigma_s^2}{\gamma} \quad (9)$$

where σ_s^2 is signal power, and γ is the dispersion coefficient of alpha stable distribution noise.

III. PLC MIMO Channel Model

The indoor single phase power line consists of three wires: P (Phase or Live), N (Neutral), PE (Protective Earth). It can provide multiple feeding and receiving ports for communication system: P-N, P-PE, and N-PE. According to the well-known Kirchhoff's rule, two of the three feeding ports can be chosen as the sender of a MIMO system, and all of the three receiving ports can be used, thus a PLC MIMO system model is usually 2×2 or 2×3. Additionally, there is a fourth signal transmission path, called the common-mode (CM) path [1]. The existence of the CM path makes the number of feeding and receiving ports of the PLC MIMO system to increase by one. Generally, we use the 2×2 PLC MIMO model as an example to discuss, and the conclusions can be extended to other PLC MIMO models.

The channel model of the PLC MIMO system with 2 feeding ports and 2 receiving ports (2×2) is shown in Fig.1. Assume that h_{ij} denotes the complex channel transfer coefficient from the j-th feeding port to the i-th receiving port. Then its channel transfer matrix can be written as

$$\mathbf{H} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \quad (10)$$

Transmission channels denoted by h_{ij} with $i = j$ are called co-channels, and those denoted by h_{ij} with $i \neq j$ are called cross-channels. The transfer function of cross-channel is similar to that of co-channel, but transfer function of co-channel is bigger [1]. Accordingly, for co-channel modeling we use the typical "multipath model" for power line channel proposed by Zimmermann and Dostert [19], and cross-channel modeling is based on this model multiplied by an appropriate factor ε.

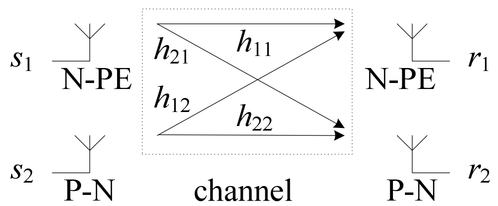

Figure.1 PLC MIMO channel model

Assume that $\mathbf{s} = [s_1\ \ s_2]^T$ is the transmitted signal of MIMO system, $\mathbf{r} = [r_1\ \ r_2]^T$ is the received signal, and $\mathbf{n} = [n_1\ \ n_2]^T$ is channel noise. Then the signal model of 2x2 PLC MIMO system is

$$\mathbf{r} = \mathbf{Hs} + \mathbf{n} \tag{11}$$

There are many different kinds of noise in power line channel. But the impulse noise plays a very important role. In impulse noise, the sudden impulse has large amplitude and its appearance is sudden. Due to these characteristics, the performance of MIMO detection algorithms based on AWGN channel will be unsuccessful under PLC impulse noise environment.

IV. FLOC-Based PLC MIMO Detection Method

MIMO detection is used to recover the transmitted signal $\mathbf{s}$ from the received signal $\mathbf{r}$. Let $\hat{\mathbf{s}} = [\hat{s}_1 \quad \hat{s}_2]^T$ be the recovered result of transmitted signal, $\mathbf{W}$ be the detection matrix, $\mathbf{r}$ be the received signal described in section II, then

$$\hat{\mathbf{s}} = \mathbf{W}^*\mathbf{r} \tag{12}$$

where $(\cdot)^*$ denotes the operator of conjugate.

For 2x2 PLC MIMO system, we have

$$\mathbf{W} = \begin{bmatrix} w_{11} & w_{12} \\ w_{21} & w_{22} \end{bmatrix}$$

Let $\mathbf{w_1} = [w_{11}\ \ w_{12}]^T$, $\mathbf{w_2} = [w_{21}\ \ w_{22}]^T$, then

$$\begin{cases} \hat{s}_1 = \mathbf{w}_1^H \mathbf{r} \\ \hat{s}_2 = \mathbf{w}_2^H \mathbf{r} \end{cases} \tag{13}$$

where $(\cdot)^H$ indicates the Hermitian transpose of a matrix. The detection method is shown in Fig.2

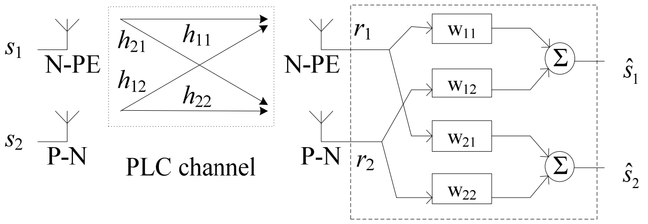

Figure.2 PLC MIMO detection method

The key of the proposed method is to obtain the optimal detection matrix $\mathbf{W}$ under impulse noise interference. In the process of obtaining $\mathbf{W}$, it is identical and independent to calculate $\mathbf{w_1}$ and $\mathbf{w_2}$. So it obtains $\mathbf{w_1}$ and $\mathbf{w_2}$ in the same way, respectively.

The optimal $\mathbf{W}$ should make the recovered transmitted signal $\hat{\mathbf{s}}$ as close as possible to the original one $\mathbf{s}$. Under Gaussian noise environment, it usually employs MMSE criterion to solve the problem of "best estimation". Under this criterion, it gets the optimal $\mathbf{W}$ by making the cost function $J = E[|\mathbf{s}-\hat{\mathbf{s}}|^2] = E[|\mathbf{s}-\mathbf{Wr}|^2]$ minimum. However, the traditional MMSE criterion can no longer be applied under alpha stable distribution impulse noise condition, as there is no limited variance. To solve this problem, two methods can be used: first, considering that the p-th ($0<p<\alpha<2$) order statistical moment of alpha stable distribution random variables exists, we can rewrite the cost function as $J = E[|\mathbf{s}-\mathbf{Wr}|^p]$; second, FLOS is the p-th order statistical average without any impulse characteristics, so we can change $\mathbf{s}$ and $\mathbf{r}$ in $E[|\mathbf{s}-\mathbf{Wr}|^2]$ into their fractional lower-order statistics $\mathbf{Fs}$ and $\mathbf{Fr}$, then the cost function can be rewritten as $J = E[|\mathbf{Fs}-\mathbf{WFr}|^2]$. Gradient descent algorithm or recursive least squares (RLS) algorithm can be used to optimize the cost function to obtain the optimal $\mathbf{W}$. In this paper, the RLS [20] algorithm is employed due to its faster convergence speed.

In RLS algorithm, statistical average in the cost function is replaced with cumulative time value. Then it calculates the first order derivative of the cost function on $\mathbf{W}$ and made equal to zero to work out the optimal $\mathbf{W}$. During the calculation process, the exponent of $\mathbf{W}$ will be $p-1$ ($0<p<\alpha<2$) in the first method. It cannot work out $\mathbf{W}$ by this method. Meanwhile, the second method is feasible, but it is prerequisite to find a kind of FLOS which has a linear relationship between $\hat{\mathbf{s}}$ and $\mathbf{r}$, namely $\mathbf{F}\hat{\mathbf{s}} = \mathbf{W}\cdot\mathbf{Fr}$. FLOC can meet this requirement with a simple calculation. Thus a novel FLOC-based MIMO detection method for PLC MIMO system is proposed, as shown in Fig.3.

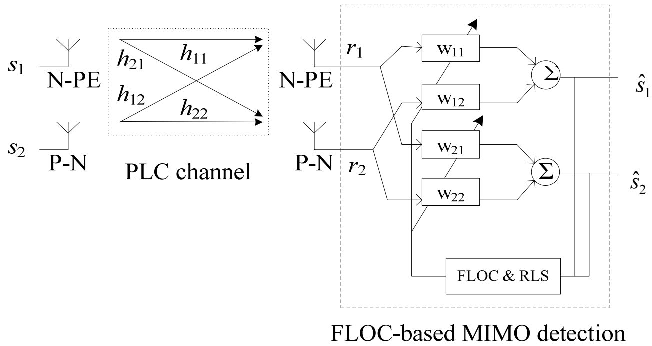

Figure.3 FLOC-based PLC MIMO detection method

FLOC of s_i and r_1 is defined as $R^p_{s_i r_1} = E[s_i r_1^{\langle p-1 \rangle}]$ (i = 1, 2). FLOC of r_1 itself is defined as $R^p_{r_1 r_1} = E[r_1 r_1^{\langle p-1 \rangle}]$, and FLOC of r_2 and r_1 is defined as $R^p_{r_2 r_1} = E[r_2 r_1^{\langle p-1 \rangle}]$. Then FLOC of $\hat{s}_i$ (i = 1, 2) and r_1 can be calculated from expressions (8) and (13)

$$R^p_{\hat{s}_i r_1} = \mathbf{w}_i^H \begin{bmatrix} R^p_{r_1 r_1} \\ R^p_{r_2 r_1} \end{bmatrix} \tag{14}$$

Then FLOC of s_i and r_1 is employed to make the cost function as follows (adopting FLOC of s_i and r_2 to make the cost function is equivalent)

$$\begin{aligned} J(n) &= \sum_{k=0}^{n} \lambda^{n-k} \, | R^p_{s_i r_1}(k) - R^p_{\hat{s}_i r_1}(k) |^2 \\ &= \sum_{k=0}^{n} \lambda^{n-k} \left| R^p_{s_i r_1}(k) - \mathbf{w}_i^H(n) \begin{bmatrix} R^p_{r_1 r_1}(k) \\ R^p_{r_2 r_1}(k) \end{bmatrix} \right|^2 \end{aligned} \tag{15}$$

where λ is a step factor. For convenience, $R^p_{s_i r_1}(n)$ can be simply written as $R_{i1}(n)$, and $\begin{bmatrix} R^p_{r_1 r_1}(n) \\ R^p_{r_2 r_1}(n) \end{bmatrix}$ can be written as $\mathbf{R}_p(n)$. Then the cost function at time n can be written as

$$\begin{aligned} J(n) &= \sum_{k=0}^{n} \lambda^{n-k} \, | R_{i1}(k) - \mathbf{w}_i^H(\mathbf{n}) \mathbf{R}_p(k) |^2 \\ &= \sum_{k=0}^{n} \lambda^{n-k} [R_{i1}(k) - \mathbf{w}_i^H(\mathbf{n}) \mathbf{R}_p(k)][R_{i1}(k) - \mathbf{w}_i^H(\mathbf{n}) \mathbf{R}_p(k)]^* \end{aligned} \tag{16}$$

Next, the first derivative of $J(n)$ is calculated on $\mathbf{w}_i$ and made equal to zero to work out the optimal $\mathbf{w}_i$. However, it is difficult to calculate the derivative directly here due to the complex-valued parameters. Then we get the optimal $\mathbf{w}_i$ at time n depending on the solution of Wiener-Hopf equation in matrix form [21]

$$\mathbf{w}_i(n) = \mathbf{T}^{-1}(n)\mathbf{t}_i(n) \tag{17}$$

where $\mathbf{T}(n)$ represents the autocorrelation matrix of $\mathbf{R}_p(n)$, and $\mathbf{t}_i(n)$ represents the cross correlation vector between $\mathbf{R}_p(n)$ and R_{i1}(n).

$$\mathbf{t}_i(n) = \sum_{k=0}^{n} \lambda^{n-k} R_{i1}^*(k)\mathbf{R}_p(k) \tag{18}$$

$$\mathbf{T}(n) = \sum_{k=0}^{n} \lambda^{n-k} \mathbf{R}_p(k)\mathbf{R}_p^H(k) \tag{19}$$

According to the Eqs (18) and (19), iterative formulas of $\mathbf{t}_i(n)$ and $\mathbf{T}(n)$ are obtained, respectively

$$\mathbf{t}_i(n) = \lambda \mathbf{t}_i(n-1) + R_{i1}^*(n)\mathbf{R}_p(n) \tag{20}$$

$$\mathbf{T}(n) = \lambda \mathbf{T}(n-1) + \mathbf{R}_p(n)\mathbf{R}_p^H(n) \tag{21}$$

Writing $\mathbf{T}(n)^{-1}$ as $\mathbf{P}(n)$, then from Eq.(17) the update formula of $\mathbf{w}_i$ can be rewritten as

$$\mathbf{w}_i(n) = \mathbf{P}(n)\mathbf{t}_i(n) \tag{22}$$

By Frobenius matrix inversion formula [21]

$$(A+BCD)^{-1} = A^{-1} - A^{-1}B(C^{-1}+DA^{-1}B)^{-1}DA^{-1}$$

Let $A = \lambda\mathbf{T}(n\text{-}1)$, $B = \mathbf{R}_p(n)$, $C = 1$, $D = \mathbf{R}_p^H(n)$, then iterative formula of $\mathbf{P}(n)$ is

$$\mathbf{P}(n) = \lambda^{-1}\mathbf{P}(n-1) - \lambda^{-1}\mathbf{k}(n)\mathbf{R}_p^H(n)\mathbf{P}(n-1) \tag{23}$$

where

$$\mathbf{k}(n) = \frac{\mathbf{P}(n-1)\mathbf{R}_p(n)}{\lambda + \mathbf{R}_p^H(n)\mathbf{P}(n-1)\mathbf{R}_p(n)} \tag{24}$$

Finally, the update formula of $\mathbf{w}_i$ at time n can be obtained from expressions (20), (22) and (23)

$$\mathbf{w}_i(n) = \mathbf{w}_i(n-1) + \mathbf{k}(n)e_i^*(n) \tag{25}$$

where

$$e_i(n) = R_{i1}(n) - \mathbf{w}_i^H(n-1)\mathbf{R}_p(n) \tag{26}$$

TABLE I. PLC MIMO DETECTION ALGORITHM BASED ON FLOC

(1) Initialization: $\mathbf{w}_1(0) = \mathbf{0}$, $\mathbf{w}_2(0) = \mathbf{0}$, $\mathbf{P}(0) = \delta^{-1}\mathbf{I}$;

(2) Calculate FLOC:

$R_{s_1r_1}^p$, $R_{s_2r_1}^p$, $R_{r_1r_1}^p$ and $R_{r_2r_1}^p$ by $R_{XY}^p = E[XY^{\langle p-1\rangle}]$;

(3) **for** $n = 1$ to N **do** (N is the number of iterations)

$R_{i1}(n) = R_{s_ir_1}^p(n)$, $i = 1, 2$;

$\mathbf{R}_p(n) = \begin{bmatrix} R_{r_1r_1}^p(n) \\ R_{r_2r_1}^p(n) \end{bmatrix}$;

$e_i(n) = R_{i1}(n) - \mathbf{w}_i^H(n-1)\mathbf{R}_p(n)$, $i = 1, 2$;

$\mathbf{k}(n) = \dfrac{\mathbf{P}(n-1)\mathbf{R}_p(n)}{\lambda + \mathbf{R}_p^H(n)\mathbf{P}(n-1)\mathbf{R}_p(n)}$;

$\mathbf{P}(n) = \lambda^{-1}\mathbf{P}(n-1) - \lambda^{-1}\mathbf{k}(n)\mathbf{R}_p^H(n)\mathbf{P}(n-1)$;

$\mathbf{w}_i(n) = \mathbf{w}_i(n-1) + \mathbf{k}(n)e_i^*(n)$, $i = 1, 2$;

End do

(4) After obtaining the optimal matrix $\mathbf{W}$, the recovered results $\hat{s}_1$ and $\hat{s}_2$ of transmitted signal are computed by the following expressions

$$\begin{cases} \hat{s}_1 = \mathbf{w}_1^H\mathbf{r} \\ \hat{s}_2 = \mathbf{w}_2^H\mathbf{r} \end{cases}.$$

So far, the PLC MIMO detection has been carried out.

Above is the derivation process of the proposed method. It needs to send an appropriate amount of training sequences, and then gets the convergent $\mathbf{w}_i$ as the optimal one under corresponding number of iterations. The initial conditions of the iteration are: $\mathbf{w}_i(0) = \mathbf{0}$, $\mathbf{P}(0) = \delta^{-1}\mathbf{I}$, where δ is a very small positive constant, and $\mathbf{I}$ is a 2×2 unit matrix. Eventually, the transmitted signal in power line channel is obtained with matrix $\mathbf{W}$. For sake of convenience, the proposed method is concluded in Table I.

In the proposed method, the detection matrix $\mathbf{W}$ is obtained in an iterative way. It results in detection time increase compared to some existing methods, such as ZF and MMSE. But the increase is not high. For the impulse noise in power line channel, the iteration number is usually just about 10. Meanwhile its performance has been improved much compared to existing methods in impulse noise environment. And it does not need channel information. In addition, the computation complexity is lower as there are no calculations for matrix inversion. Generally speaking, this is an effective MIMO detection method even under impulsive noise environment in PLC system.

V. SIMULATION AND RESULT DISCUSSION

To verify the effectiveness of the proposed method, some simulations are carried out with Matlab. The proposed method aims to improve detection performance, so ZF, MMSE, V-BLAST and the V-BLAST algorithm based on MMSE [22] are chosen to make comparisons. Impulse noise with alpha stable distribution has no variance, and its dispersion coefficient γ has the same meaning with variance of the Gaussian distribution, so γ is used to take place of the variance in MMSE detection algorithm in the simulation.

The 2×2 PLC MIMO system model is used for simulations with an input signal sequence of 8192 bits. It employs BPSK modulation and V-BLAST space-time coding with carrier frequencies from 0 to 100MHz. Multiple path model of 4 paths is used for channel modeling and other parameters of this model are listed on Table II, cross-channel factor $\varepsilon = 0.64$[23]. The amplitude response of PLC channel transfer function is shown in Fig.4. Impulse noise is modeled by alpha stable distribution with the parameter $\alpha = 1.6$, and the waveform of this model under GSNR of 5dB is shown in Fig.5. From Fig.5, we can see that the model has obvious pulse characteristics and can describe the impulse noise in PLC channel well. The key parameters of the proposed method are set as N = 100, $\delta = 10^{-6}$, $\lambda = 0.99$, and p=1.2, where p satisfies $1 \le p < \alpha$.

In the uncoded power line channel, comparisons of MIMO detection algorithms are made with the generalized signal to noise ratio (GSNR) of 0-20dB, as shown in Fig.6. It is observable that the performances of ZF, MMSE, V-BLAST and the V-BLAST based on MMSE methods almost have no differences. It means the advantages of MMSE and V-BLAST methods compared to ZF method do not exist any more in PLC channel. In fact, they all have poor performances due to the impulse noise interference. But the proposed method shows a significant performance improvement over all the existing ones, especially when GSNR is low. Under the same bit error rate (BER) conditions, the proposed method has a performance gain of about 8dB under low GSNR condition and also about 2dB in high GSNR condition. It concludes that the proposed method is more effective than existing ones under impulse noise environment in PLC MIMO system.

Impulse noise may seriously influence the performance of PLC communication system and make MIMO detection methods have high BER, as shown in Fig.6. To further improve the performance, the (1024, 512) regular LDPC [24] code is employed for channel coding. The performance of the proposed MIMO detection method is compared with existing ones in the LDPC-coded PLC channel, and the BER performance comparison are provided in Fig.7. It can be seen from Fig.7 that the proposed method also has an obviously better performance than existing ones. Fig.7 also shows that both the proposed method and existing ones have better performances with LDPC coding, but the improvement of coded channel compared to uncoded channel is much higher with the proposed detection method. So we can conclude that the FLOC-based MIMO detection method is effective and potential for PLC MIMO system.

TABLE II. PARAMETERS FOR MULTIPLE PATH MODEL OF POWER LINE CHANNEL

i-th path	g_i	d_i/m	k	a_0	a_1
1	0.553	6.0	1	-2.1×10^{-3}s/m	8.11×10^{-10}s/m
2	0.276	9.4			
3	-0.175	12.8			
4	0.080	16.2			

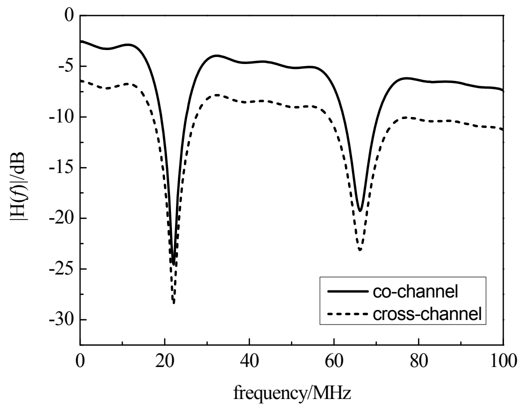

Figure.4 The amplitude response of PLC channel transfer function

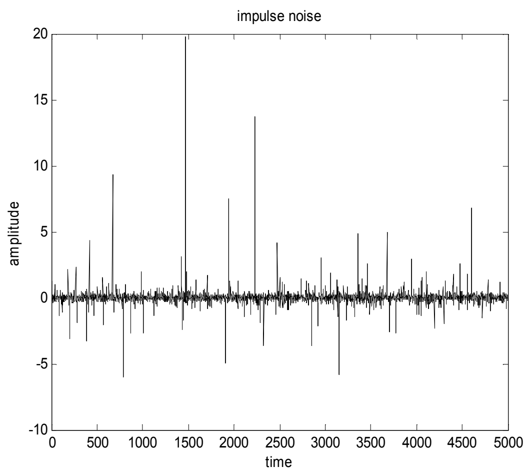

Figure.5 Impulse noise with alpha stable distribution

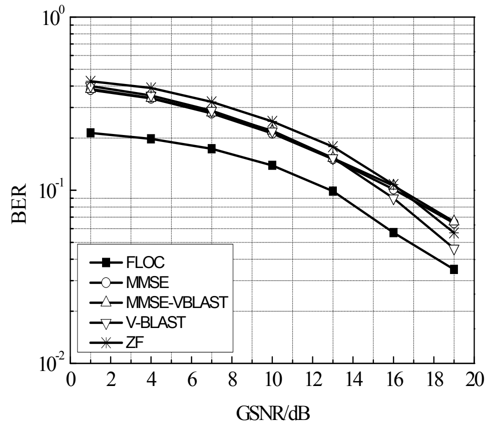

Figure.6 Comparison of MIMO detection algorithms in PLC channel

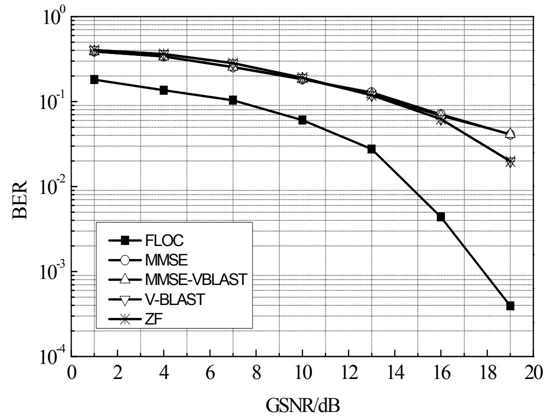

Figure.7 Comparison of MIMO detection algorithms with LDPC in PLC channel

VI. CONCLUSION

A novel MIMO detection method based on fractional lower order correlation (FLOC) for power line communication (PLC) MIMO system is proposed in this paper. It employs FLOC to construct the criteria of MIMO detection and uses RLS algorithm to get the optimal detection matrix. The proposed method needs no estimation about the channel information. And the simulation results show that the PLC MIMO detection performance of the proposed method is obviously better compared to the existing methods. So it is an effective and potential MIMO detection method for the PLC MIMO system.

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