Pseudo-random Phase Precoded Spatial Modulation

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by

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Abstract

Spatial modulation (SM) is a transmission scheme that uses multiple transmit antennas but only one transmit RF chain. At each time instant, only one among all the transmit antennas will be active and the others remain silent. The index of the active transmit antenna will also convey information bits in addition to the information bits conveyed through modulation symbols (e.g., QAM). Pseudo-random phase precoding (PRPP) is a technique that can achieve higher-order diversity even in single antenna systems. In this work, we simultaneously exploit the advantages of both SM and PRPP. We propose a novel precoded SM scheme, where both the modulation bits and the antenna index bits are precoded by *pseudo-random phases*. We refer to this system as PRPP-SM system. The proposed PRPP-SM system gives significant performance improvement over SM system without PRPP and PRPP system without SM. As maximum likelihood (ML) detection becomes exponentially complex in large dimensions, we propose a low complexity local search based detector (LSD) suited for PRPP-SM systems with large precoder sizes. Our simulation results show that the proposed PRPP-SM achieves better performance than SM. With 4 transmit antennas, 1 receive antenna, 5×20 pseudo-random phase precoder and BPSK modulation, the performance of PRPP-SM using ML detection is better than SM without PRPP with ML detection by about 9 dB at 10^{-2} BER. This performance advantage gets even better for large precoding sizes.

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Chapter 1

Introduction

1.1 Pseudo-random phase precoding

Transmissions on single-input-single-output (SISO) fading channels have poor reliability due to lack of diversity. One possible way to improve reliability is to achieve diversity gain through the use of multiple antennas. Pseudo-random phase precoding (PRPP) is an approach to achieve diversity gain without the use of multiple antennas. [1] proposed the PRPP approach for achieving diversity in a SISO system, by employing pseudo-random phase precoding of the modulation symbols prior to transmission.

The PRPP transmitter in a SISO system is shown in Fig. 1.1. In the PRPP transmitter, p modulated symbols are accumulated at the transmitter to form the symbol vector $\mathbf{s} \in \mathbb{A}^p$, where $\mathbb{A}$ is the modulation alphabet. The symbol vector $\mathbf{s}$ is then precoded using a $p \times p$ precoding matrix $\mathbf{P}$ to get the transmit vector $\mathbf{Ps}$. The (r, c)th entry of the precoder matrix $\mathbf{P}$ is $\frac{1}{\sqrt{p}}e^{j\theta_{r,c}}$, where the phases $\theta_{r,c}$s are generated using a pseudo-random sequence generator. The seed of this generator is pre-shared among the transmitter and receiver. Instead of transmitting the original sequence $\mathbf{s}$, the precoded sequence $\mathbf{Ps}$ is transmitted. The channel is assumed to be frequency flat-fading, where the channel fades are i.i.d from one channel use to the other. At the receiver, upon collecting the complex-valued received symbols over p channel uses, we have

The following notations are used in the report. Vectors are denoted by boldface lowercase letters and matrices are in boldface uppercase letters. $[.]^T$, $[.]^*$, $[.]^\dagger$ denote the transpose, conjugate, hermitian operations. E[.] denotes expectation, $||.||$ denotes the Euclidean norm, $||.||_F$ denotes the Frobenius norm, $diag(\mathbf{y})$ denotes a diagonal matrix with the elements of vector $\mathbf{y}$ along its diagonal, $\mathbf{I}_n$ is an $n \times n$ identity matrix.

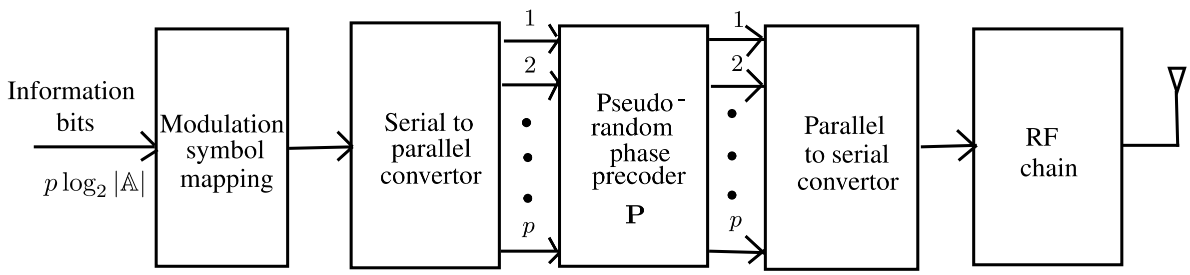

Fig. 1.1 PRPP transmitter.

$$\begin{aligned}\mathbf{y}_p &= \begin{bmatrix} h_{(1)} & 0 & \cdots & 0 \\ 0 & h_{(2)} & \cdots & 0 \\ \vdots & & \ddots & \vdots \\ 0 & 0 & \cdots & h_{(p)} \end{bmatrix} \mathbf{P}\mathbf{s} + \mathbf{n}_p \\ &= \mathbf{D}\mathbf{P}\mathbf{s} + \mathbf{n}_p = \mathbf{G}\mathbf{s} + \mathbf{n}_p, \end{aligned} \tag{1.1}$$

where $\mathbf{D} = diag(h_{(1)}\, h_{(2)} \cdots h_{(p)})$, $\mathbf{G} = \mathbf{DP}$, and $\mathbf{n}_p$ is the noise vector $[\mathbf{n}_{(1)}^T\, \mathbf{n}_{(2)}^T \cdots \mathbf{n}_{(p)}^T]^T$. The entries of the matrix $\mathbf{G}$ are uncorrelated and $\|\mathbf{D}\|_F = \|\mathbf{G}\|_F$. This creates a $p \times p$ virtual large-MIMO system.

The performance of PRPP transmission in a SISO system with MMSE-LAS detection algorithm [1], [2] is shown in Fig. 1.2. It compares the average BER performance of the system without PRPP using ML detection against the performance of PRPP transmission with MMSE-LAS detection. In Fig. 1.2, we set the precoder size $p \in \{50, 400\}$. It is interesting to note that the performance of MMSE-LAS detector approaches close to the AWGN system's performance when p gets large.

1.2 Spatial modulation

Spatial modulation (SM) is a transmission scheme that uses multiple transmit antennas but only one transmit RF chain [3], [4]. At each time instant, only one among all the transmit antennas will be active and the others remain silent. The index of the active transmit antenna will also convey information bits in addition to the information bits conveyed through modulation symbols (e.g., QAM). The SM transmitter is shown in Fig. 1.3, where the transmitter has N_t transmit antennas but only one transmit RF chain. In a given channel use, the transmitter selects one of

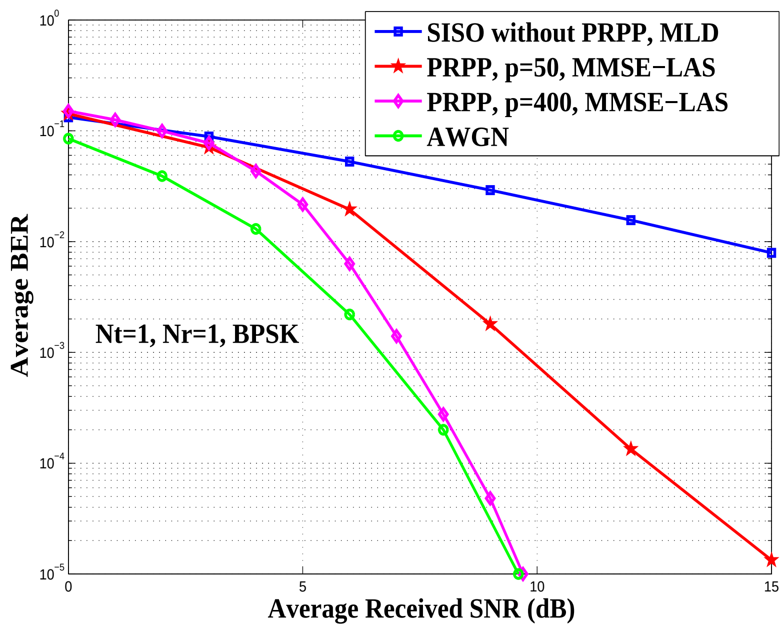

Fig. 1.2 Performance of PRPP on SISO fading channels.

its N_t transmit antennas, and transmits a modulation symbol from the modulation alphabet $\mathbb{A}$ on the selected antenna. The number of bits transmitted per channel use in the modulation symbols is $\lfloor \log_2 |\mathbb{A}| \rfloor$, and the number of bits transmitted per channel use by the index of the transmitting antenna is $\lfloor \log_2 N_t \rfloor$. Therefore, a total of $\lfloor \log_2 |\mathbb{A}| N_t \rfloor$ bits per channel use (bpcu) is achievable in an SM-MIMO system. For example, in a system with $N_t = 2$, and 8-QAM, the system throughput is 4 bpcu.

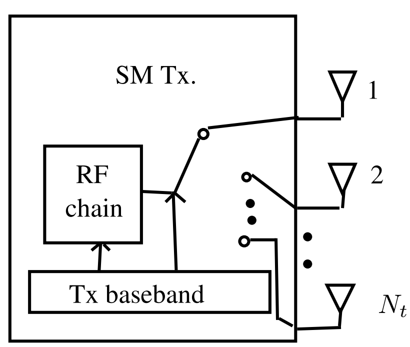

Fig. 1.3 SM transmitter.

The SM alphabet set for a fixed N_t and $\mathbb{A}$ is given by

$$\begin{aligned} \mathbb{S}_{N_t,\mathbb{A}} &= \left\{\mathbf{x}_{j,l} : j = 1, \cdots, N_t, \quad l = 1, \cdots, |\mathbb{A}|\right\}, \\ \text{s.t.} \quad \mathbf{x}_{j,l} &= [0, \cdots, 0, \underbrace{s_l}_{j\text{th coordinate}}, 0, \cdots, 0]^T, \quad x_l \in \mathbb{A}. \end{aligned} \tag{1.2}$$

For example, for $N_t = 2$ and 4-QAM, $\mathbb{S}_{N_t,\mathbb{A}}$ is given by

$$\begin{aligned} \mathbb{S}_{2,\text{4-QAM}} = \Bigg\{ & \begin{bmatrix} +1+j \\ 0 \end{bmatrix}, \begin{bmatrix} +1-j \\ 0 \end{bmatrix}, \begin{bmatrix} -1+j \\ 0 \end{bmatrix}, \begin{bmatrix} -1-j \\ 0 \end{bmatrix}, \\ & \begin{bmatrix} 0 \\ +1+j \end{bmatrix}, \begin{bmatrix} 0 \\ +1-j \end{bmatrix}, \begin{bmatrix} 0 \\ -1+j \end{bmatrix}, \begin{bmatrix} 0 \\ -1-j \end{bmatrix} \Bigg\}. \end{aligned} \tag{1.3}$$

Let $\mathbf{x} \in \mathbb{S}_{N_t,\mathbb{A}}$ denote the transmit vector. Let $\mathbf{H} \in \mathbb{C}^{N_r \times N_t}$ denote the channel gain matrix, where $H_{i,j}$ denotes the channel gain from the jth transmit antenna to the ith receive antenna and these channel gains are i.i.d complex Gaussian random variables. The received signal at the ith receive antenna is given by

$$y_i = H_{i,j} x_l + n_i, \tag{1.4}$$

where x_l is the lth symbol in $\mathbb{A}$, transmitted by the jth antenna, and n_i is the noise which is distributed as $\mathbb{C}\mathcal{N}(0, \sigma^2)$. The signal at the receiver can be written in vector form as

$$\mathbf{y} = \mathbf{H}\mathbf{x} + \mathbf{n}, \tag{1.5}$$

For this system model, the maximum-likelihood (ML) detection rule is given by

$$\hat{\mathbf{x}} = \underset{\mathbf{x} \in \mathbb{S}_{N_t,\mathbb{A}}}{\operatorname{argmin}} \ \|\mathbf{y} - \mathbf{H}\mathbf{x}\|^2, \tag{1.6}$$

In this work, we simultaneously exploit the advantages of both SM and PRPP. We propose a novel precoded SM scheme, where both the modulation bits and the antenna index bits are precoded using *pseudo-random phases*. We refer to this system as PRPP-SM system. The proposed PRPP-SM system gives significant performance improvement over SM system without PRPP and PRPP system without SM. Since ML detection becomes exponentially complex in large dimensions, we propose a low complexity local search based detector (LSD) suited for PRPP-SM systems with large precoder sizes. Our simulation results show that the proposed PRPP-SM achieves better performance than SM system without PRPP.

Chapter 2

Proposed PRPP-SM system

In this work, we propose a novel precoded SM scheme, where both the modulation bits and the antenna index bits are precoded by pseudo-random phases. This gives an improvement in BER performance over SM system without PRPP. This improvement increases as the precoder size increases. As ML detection becomes exponentially complex in large dimensions, we propose a local search detector (LSD) which scales well for large precoder sizes.

2.1 System model

The proposed PRPP-SM transmitter is shown in Fig. 2.1. First, p modulated symbols are accumulated to form the symbol vector $\mathbf{x}_s \in \mathbb{A}^p$, where $\mathbb{A}$ denotes the modulation alphabet. Let the matrix $\mathbf{A}$ denote the antenna activation pattern, such that $\mathbf{A}\mathbf{x}_s \in \mathbb{S}^p_{N_t,\mathbb{A}}$, where $\mathbb{S}_{N_t,\mathbb{A}}$ denotes the SM alphabet set for a fixed N_t and $\mathbb{A}$ is given by

$$\begin{aligned} &\mathbb{S}_{N_t,\mathbb{A}} = \big\{\mathbf{x}_{j,l} : j = 1, \cdots, N_t, \quad l = 1, \cdots, |\mathbb{A}|\big\}, \\ \text{s.t.} \ \ &\mathbf{x}_{j,l} = [0, \cdots, 0, \underbrace{s_l}_{j\text{th coordinate}}, 0, \cdots, 0]^T, \quad x_l \in \mathbb{A}. \end{aligned} \tag{2.1}$$

The matrix $\mathbf{A}$ consists of p submatrices such that $\mathbf{A} = [\mathbf{A}_{(1)}^T \, \mathbf{A}_{(2)}^T \, \cdots \, \mathbf{A}_{(p)}^T]^T$, where $\mathbf{A}_{(i)}$ is the ith submatrix. The submatrix $\mathbf{A}_{(i)}$ indicates the antenna activated in the ith channel use. $\mathbf{A}_{(i)}$ is a

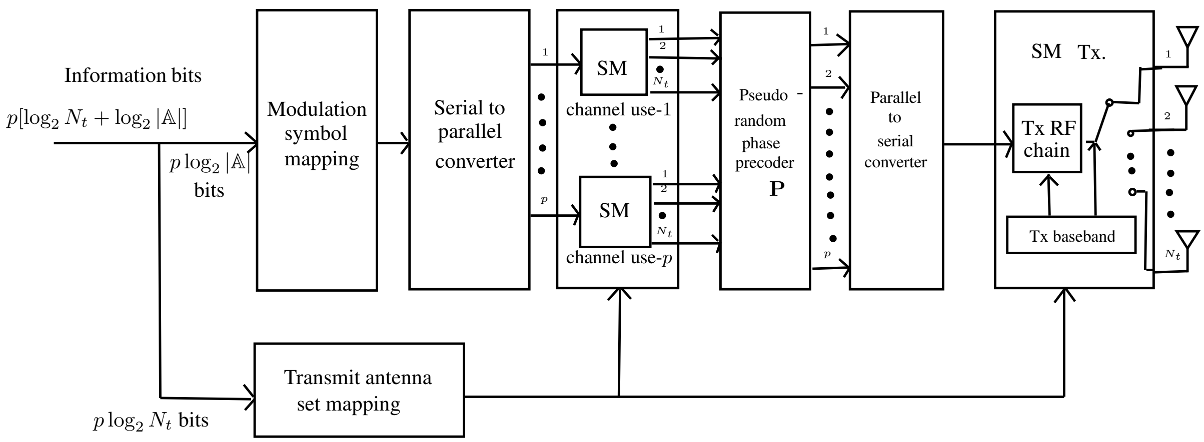

Fig. 2.1 Proposed PRPP-SM transmitter.

$N_t \times p$ matrix constructed as

$$\mathbf{A}_{(i)} = [\mathbf{0}_{(1)} \, \cdots \, \mathbf{0}_{(i-1)} \, \mathbf{a}_{(i)} \, \mathbf{0}_{(i+1)} \, \cdots \, \mathbf{0}_{(p)}], \tag{2.2}$$

where $\mathbf{0}_{(k)}$ is a $N_t \times 1$ vector of zeroes, and $\mathbf{a}_{(i)}$ is a $N_t \times 1$ vector constructed as $[0 \cdots 0 \underbrace{1}_{j_i\text{th coordinate}} 0 \cdots 0]^T$, and j_i is the index of the active antenna during the ith channel use.

For example, in a system with $N_t = 2$ and $p = 3$, to activate antennas 1, 2 and 1 in three consecutive channel uses, respectively, the matrix $\mathbf{A}$ is given by

$$\begin{bmatrix} \mathbf{A}_{(1)} \\ \mathbf{A}_{(2)} \\ \mathbf{A}_{(3)} \end{bmatrix} = \left[\begin{array}{ccc} 1 & 0 & 0 \\ 0 & 0 & 0 \\ \hline 0 & 0 & 0 \\ 0 & 1 & 0 \\ \hline 0 & 0 & 1 \\ 0 & 0 & 0 \end{array}\right] \tag{2.3}$$

The matrix $\mathbf{A}$ gives the support of the spatially modulated transmit vector. The vector $\mathbf{A}\mathbf{x}_s \in \mathbb{S}^p_{N_t,\mathbb{A}}$ is precoded using a $p \times pN_t$ matrix $\mathbf{P}$ to get $\mathbf{P}\mathbf{A}\mathbf{x}_s$. The (r, c)th entry of the matrix $\mathbf{P}$ is $\frac{1}{\sqrt{p}} e^{j\theta_{r,c}}$, where the phases $\theta_{r,c}$s are generated using a pseudo-random sequence generator. The seed of this generator is pre-shared among the transmitter and receiver. The output of the precoder is transmitted on the selected antenna in each channel use. The signal received at the receiver after

p channel uses is given by

$$\begin{aligned}\mathbf{y}_p &= \begin{bmatrix}\mathbf{H}_{(1)} & \mathbf{0} & \cdots & \mathbf{0}\\ \mathbf{0} & \mathbf{H}_{(2)} & \cdots & \mathbf{0}\\ \vdots & & \ddots & \vdots\\ \mathbf{0} & \mathbf{0} & \cdots & \mathbf{H}_{(p)}\end{bmatrix}\mathbf{APx}_s + \mathbf{n}_p\\ &= \mathbf{DAPAx}_s + \mathbf{n}_p, \end{aligned} \tag{2.4}$$

where $\mathbf{D} = diag(\mathbf{H}_{(1)}\, \mathbf{H}_{(2)} \cdots \mathbf{H}_{(p)})$, and $\mathbf{n}_p$ is the noise vector $[\mathbf{n}_{(1)}^T\, \mathbf{n}_{(2)}^T \cdots \mathbf{n}_{(p)}^T]^T$. For this system model, the ML detection rule is given by

$$\{\hat{\mathbf{x}}_s, \hat{\mathbf{A}}\} = \underset{\mathbf{x}_s \in \mathbb{A}^p, \forall \mathbf{A}}{\operatorname{argmin}} \ \|\mathbf{y}_p - \mathbf{DAPAx}_s\|^2, \tag{2.5}$$

The index of the non-zero row in each submatrix of $\hat{\mathbf{A}}$ and values of $\hat{\mathbf{x}}_s$ are demapped to obtain the information bits.

2.2 Proposed detection algorithm

From (2.5), it can be seen that the ML detection of the transmitted bits in a precoded SM-MIMO system is exponential in complexity, i.e., $O(|\mathbb{A}|n_t)^p)$. We propose a local search based detector (LSD) that achieves near-ML detection at large p with a low computational complexity. The local search detector obtains a local minima in terms of the least ML cost among a local neighborhood. The neighborhood is defined as follows. The set of neighbors of a given pair of $\{\mathbf{A}, \mathbf{x}_s\}$, denoted by $\mathcal{N}(\mathbf{A}, \mathbf{x}_s)$, is defined as the set of all pairs $\{\mathbf{A}', \mathbf{x}_s'\}$ that satisfies one of the following three conditions:

1. $\mathbf{x}_s = \mathbf{x}_s'$ and $\mathbf{A}_{(i)} \neq \mathbf{A}'_{(i)}$ for exactly a single index i
2. $\mathbf{A} = \mathbf{A}'$ and $\mathbf{x}_s$ differs from $\mathbf{x}_s'$ in exactly one entry
3. $\mathbf{A}_{(i)} \neq \mathbf{A}'_{(i)}$ for exactly a single index i, and for that index i, $x_s(i) \neq x_s'(i)$.

For example, consider N_t=2, p=2, and $\mathbb{A} = \{\pm 1\}$. Then, we have

Algorithm 1 Listing of the proposed LSD

1: **Input** : $\mathbf{y}, \mathbf{H}, \mathbf{P}$
2: Intial solution : $\{\mathbf{A}^{(0)}, \mathbf{x}_s^{(0)}\}$, $\{\hat{\mathbf{A}}, \hat{\mathbf{x}}_s\} = \{\mathbf{A}^{(0)}, \mathbf{x}_s^{(0)}\}$
3: Compute $\mathcal{N}(\hat{\mathbf{A}}, \hat{\mathbf{x}}_s)$
4: $\{\mathbf{A}^c, \mathbf{x}_s^c\} = \underset{\{\mathbf{B},\mathbf{z}\} \in \mathcal{N}(\hat{\mathbf{A}}, \hat{\mathbf{x}}_s)}{\text{argmin}} \|\mathbf{y}_p - \mathbf{DBPBz}\|^2$
5: **if** $\|\mathbf{y}_p - \mathbf{D}\mathbf{A}^c\mathbf{P}\mathbf{A}^c\mathbf{x}_s^c\|^2 < \|\mathbf{y}_p - \mathbf{D}\hat{\mathbf{A}}\mathbf{P}\hat{\mathbf{A}}\hat{\mathbf{x}}_s\|^2$ **then**
6: $\quad\{\hat{\mathbf{A}}, \hat{\mathbf{x}}_s\} = \{\mathbf{A}^c, \mathbf{x}_s^c\}$
7: $\quad$Go to step 3
8: **end if**
9: **Output** : $\{\hat{\mathbf{A}}, \hat{\mathbf{s}}\}$

$$
\mathcal{N}\left(\left[\begin{array}{cc}1&0\\0&0\\ \hdashline 0&0\\0&1\end{array}\right], \begin{bmatrix}+1\\-1\end{bmatrix}\right) = \left\{\begin{array}{c}
\{\left[\begin{array}{cc}1&0\\0&0\\ \hdashline 0&1\\0&0\end{array}\right], \begin{bmatrix}+1\\-1\end{bmatrix}\}, \{\left[\begin{array}{cc}1&0\\0&0\\ \hdashline 0&1\\0&0\end{array}\right], \begin{bmatrix}+1\\+1\end{bmatrix}\}, \{\left[\begin{array}{cc}1&0\\0&0\\ \hdashline 0&1\\0&0\end{array}\right], \begin{bmatrix}-1\\-1\end{bmatrix}\}, \{\left[\begin{array}{cc}1&0\\0&0\\ \hdashline 0&0\\0&1\end{array}\right], \begin{bmatrix}-1\\-1\end{bmatrix}\} \\
\{\left[\begin{array}{cc}1&0\\0&0\\ \hdashline 0&0\\0&1\end{array}\right], \begin{bmatrix}+1\\+1\end{bmatrix}\}, \{\left[\begin{array}{cc}0&0\\1&0\\ \hdashline 0&0\\0&1\end{array}\right], \begin{bmatrix}+1\\-1\end{bmatrix}\}, \{\left[\begin{array}{cc}0&0\\1&0\\ \hdashline 0&0\\0&1\end{array}\right], \begin{bmatrix}+1\\+1\end{bmatrix}\}, \{\left[\begin{array}{cc}0&0\\1&0\\ \hdashline 0&0\\0&1\end{array}\right], \begin{bmatrix}-1\\-1\end{bmatrix}\}
\end{array}\right\}.
$$

The proposed LSD algorithm starts with an intial solution $\{\mathbf{A}^{(0)}, \mathbf{x}_s^{(0)}\}$, which is also the current solution. Using the defined neighborhood, the algorithm considers all the neighbors of $\{\mathbf{A}^{(0)}, \mathbf{x}_s^{(0)}\}$ and searches for the neighbor with the least ML cost which also has a lower ML cost than the current solution. If such a neighbor is found, then this neighbor is designated as the current solution. This marks the completion of one iteration of LSD. The iterations are repeated till a local minima is reached (i.e., there is no neighbor better than the current solution). The solution corresponding to the local minima is declared as the final output $\{\hat{\mathbf{A}}, \hat{\mathbf{x}}_s\}$. This algorithm is listed in **Algorithm 1**.

Computing the intial solution: We use MMSE for estimating the support and to obtain the initial solution to the LSD algorithm. The MMSE estimate is a $pN_t \times 1$ vector given by $\mathbf{v} = (\mathbf{D}^H\mathbf{D} + \sigma^2\mathbf{I})^{-1}\mathbf{D}^H\mathbf{y}_p$. The vector $\mathbf{v}$ consists of p subvectors of size $N_t \times 1$, $\mathbf{v} = [\mathbf{v}_{(1)}^T\ \mathbf{v}_{(2)}^T\ \cdots\ \mathbf{v}_{(p)}^T]^T$. The indices of the elements with the largest amplitude in each $\mathbf{v}_{(i)}$ gives the initial solution for $\mathbf{A}^{(0)}$. The MMSE estimate of $\mathbf{x}_s^{(0)}$ is given by a $p \times 1$ vector given by $\mathbf{z} = (\mathbf{G}^H\mathbf{G} + \sigma^2\mathbf{I})^{-1}\mathbf{G}^H\mathbf{y}_p$, where $\mathbf{G} = \mathbf{H}\mathbf{A}^{(0)}\mathbf{P}\mathbf{A}^{(0)}$. The hard estimate of $\mathbf{x}_s^{(0)}$ is obtained by mapping each coordinate of $\mathbf{z}$

to nearest symbol in the alphabet in terms of Euclidean distance.

2.3 Simulation results

We present the simulation results on the performance of the proposed PRPP-SM system with ML detection and MMSE-LSD. In all our simulations, the channel is assumed to undergo temporally uncorrelated Rayleigh fading and independent between channel uses.

Figure 2.2 compares the performance of PRPP-SM against the performance of SM without PRPP at a spectral efficiency of 3 bpcu using ML detection. Here, $N_t = 4, N_r = 1$ and BPSK modulation is used with precoder size $p \in \{2, 4, 5\}$. It is interesting to note that the performance of PRPP-SM is better than SM without PRPP by about 9 dB at $p = 5$ and 10^{-2} BER. The performance of PRPP-SM gets even better as p increases.

Figure 2.3 compares the performance of PRPP-SM against the performance of PRPP without SM (i.e. $N_t = 1$) at a spectral efficiency 3 bpcu using ML detection. Here, the PRPP-SM system has $N_t = 4, N_r = 1$, BPSK modulation, and PRPP system without SM has $N_t = 1, N_r = 1$, 8-QAM with precoder size $p \in \{2, 4, 5\}$. It is noted that the performance of PRPP-SM is better than the PRPP without SM by about 4 dB at $p = 5$ and 10^{-2} BER.

Figure 2.4 compares the performance of PRPP-SM using MMSE-LSD detection against the performance of SM without PRPP using MLD at a spectral efficiency of 2 bpcu. Here PRPP-SM with $N_t = 2, N_r = 4$, and BPSK modulation is used with precoder size $p \in \{10, 20, 70\}$. It is seen that for smaller precoder sizes, PRPP-SM performs poorer than SM without PRPP. But as the precoder size increases, PRPP-SM performs better than SM without PRPP. At 10^{-5} BER, PRPP-SM with $p = 70$ using MMSE-LSD detection is 1 dB better than SM without PRPP using ML detection. This performance advantage in favor of PRPP-SM is expected to be even better for large values of p.

Figure 2.5 compares the performance of PRPP-SM using MMSE-LSD detection against the performance of PRPP without SM using MMSE-LAS detection, at a spectral efficiency 3 bpcu. For PRPP-SM we have used $N_t = 4, N_r = 8$, BPSK modulation. For PRPP without SM we have used $N_t = 1, N_r = 8$, 8-QAM. The precoder size $p \in \{10, 20, 70\}$ in both systems. The spectral efficiency in both systems is 3 bpcu. It is observed that the performance of PRPP-SM system is better than the PRPP system without SM by about 10 dB at $p = 70$ and 10^{-2} BER.

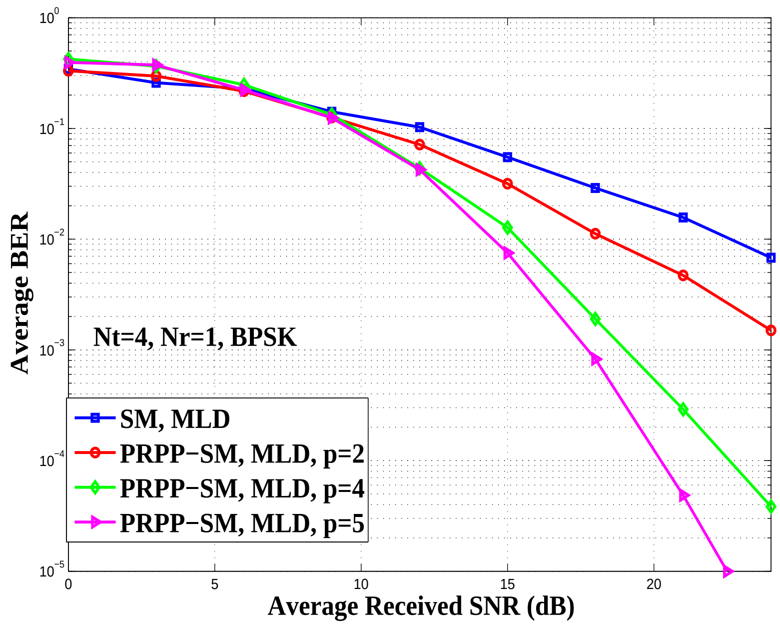

Fig. 2.2 Performance comparison between PRPP-SM system ($N_t = 4, N_r = 1$, BPSK) with ML detection and SM system without PRPP with ML detection. 3 bpcu.

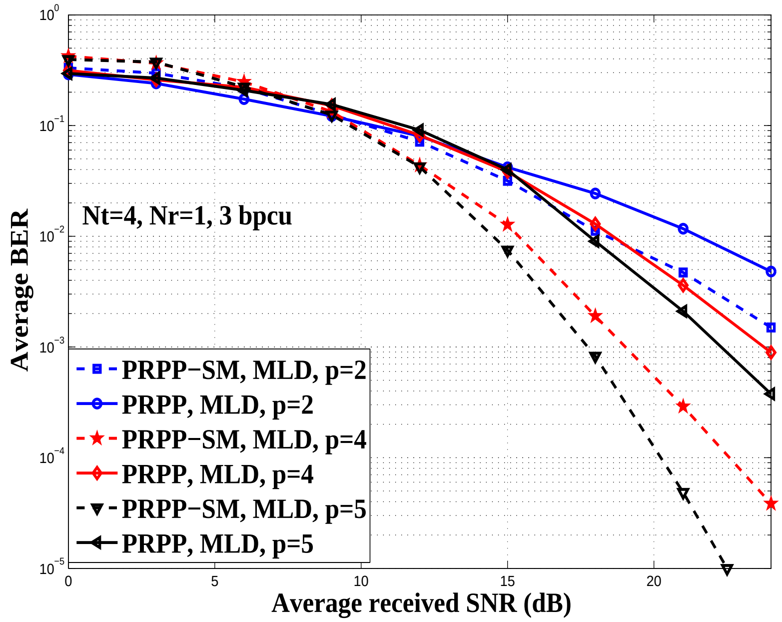

Fig. 2.3 Performance comparison between PRPP-SM system ($N_t = 4, N_r = 1$, BPSK) with ML detection and PRPP without SM ($N_t = 1, N_r = 1$, 8-QAM) with ML detection. 3 bpcu.

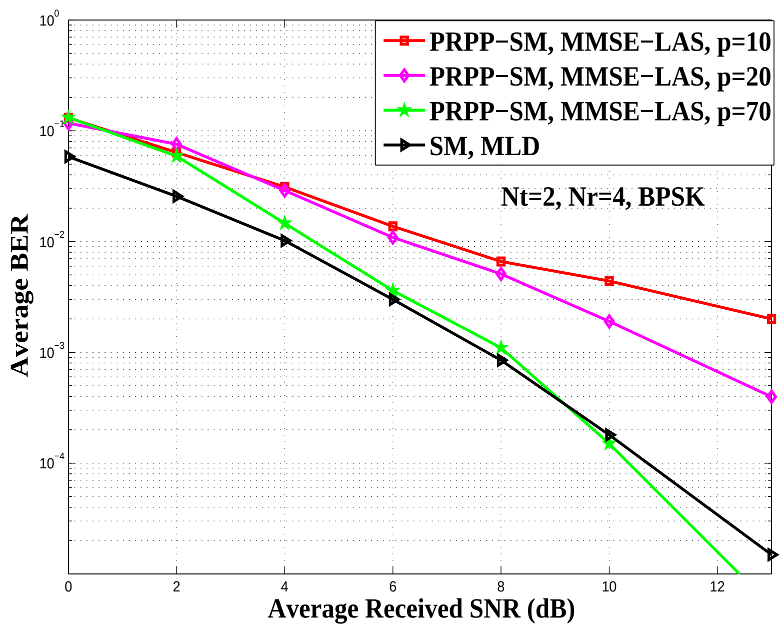

Fig. 2.4 Performance comparison between PRPP-SM ($N_t = 2, N_r = 4$, BPSK) with LSD detection and SM system without PRPP using ML detection. 2 bpcu.

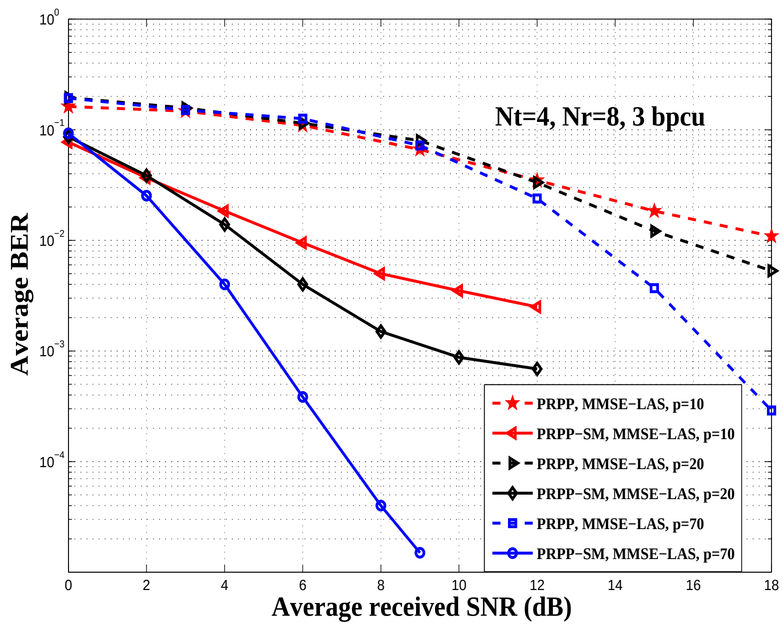

Fig. 2.5 Performance comparison between PRPP-SM system ($N_t = 4, N_r = 8$, BPSK) with LSD detection and PRPP without SM ($N_t = 1, N_r = 8$, 8-QAM) with LSD detection. 3 bpcu.

Chapter 3

Conclusions and future work

We proposed a novel pseudo-random phase precoder based spatial modulation (PRPP-SM) scheme-for uncoded transmissions over fading channels. We assumed channel fades are independent and identically distributed across channel uses. With $N_t = 4, N_r = 1$, BPSK modulation, and ML detection, we demonstrated that the proposed PRPP-SM system achieves better performance than SM system without precoding and PRPP system without SM. We also proposed low complexity local search algorithm for detection in PRPP-SM systems with large precoder sizes. With $N_t = 4, N_r = 1$, BPSK modulation, 5×20 precoder matrix and ML detection, we demonstrated that the proposed PRPP-SM system achieves better performance than the SM system without PRPP with ML detection by about 9 dB at 10^{-2} BER. The proposed system achieves increased diversity as the precoder size increases. In future, we will investigate the effect of time correlation on the performance of the PRPP-SM system.

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