Novel Space Time Spreading Scheme

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Abstract

In this paper two spreading schemes and their detection methods were proposed and compared. The comparison depends on the performance of each scheme in Rayleigh flat fading channel. Space Time Spreading (STS) codes are used with Layered Space Time Codes (LST), with Vertical Bell Laboratories Space Time codes (V-BLAST) in particular. Also, Direct Sequence Code Division Multiple Access system (DS-CDMA) was used as a multi-user criterion. As a result of this spreading, a simple decoding algorithm was used. The simulation shows that STS-LST-DS-CDMA system with 3TX-3RX (3 transmitting antennas-3 receiving antennas) using all paths between transmitter and receiver was better than LST-DS-CDMA system by about 4dB in SNR at BER of 10^{-4}. More detailed results are shown in Table 1. Also, the proposed scheme (may be partially) solves the problem of the code reuse.

Keywords: Space time spreading, Direct sequence code division multiple access, Layered space time coding, Bit error rate, Flat fading.

المستخلص

في هذا البحث تم اقتراح ومقارنة نموذجين لتوزيع المعلومات و طرق استرجاعها. المقارنة اعتمدت على الاداء في قناةRayleigh flat fading . وتم استخدام شيفرة التوزيع الزماني والفضائيSTS بالإضافة الى شيفرة التوزيع الفضائي والزماني الطبقيةLST والتي تم اخذ احد انواعها وهي V-BLAST. كذلك تم استعمال نظام DS-CDMA لدمج عدة مستخدمين بالإضافة للشيفرات المذكورة. اوضحت المحاكاة ان نظام STS-LST-DS-CDMA الذي يستعمل ثلاثة هوائيات في الارسال و الاستلام مع استعمال كل المسارات بين المرسل و المستقبل كان افضل من نظام LST-DS-CDMA بمقدار 4dB عند نسبة خطأ 10^{-4}. نتائج مفصلة اكثر ممكن الحصول عليها من الجدول 1. كذلك فأن نظام STS-LST-DS-CDMA قد حل مشكلة اعادة استخدام الشيفرة ولو جزئيا.

1. Introduction

CDMA is a multiplexing technique where a number of users simultaneously and asynchronously access a channel by modulating and spread their information-bearing signals with preassigned signature sequences [1]. In the DS-CDMA technique, the serial to-parallel converted data stream is multiplied with the spreading sequence and then the chips belonging to the same symbol modulate the same carrier, the spreading is done in the time domain. The modulator for DS-CDMA is shown in Figure (1) [2].

Foschini [3] proposed a layered space-time (LST) architecture that can attain a tight lower bound on the MIMO channel capacity. The distinguishing feature of this architecture is that it allows processing of multidimensional signals in the space domain by 1-D processing steps, where 1-D refers to one dimension in space. The method relies on powerful signal processing techniques at the receiver and conventional 1-D channel codes [4]. There is a number of various LST architectures, depending on whether error control coding is used or not and on the way the modulated symbols are assigned to transmit antennas. An uncoded LST structure, known as Vertical Layered Space-Time (VLST) or Vertical Bell Laboratories Layered Space-Ttime (VBLAST) scheme [4,5], is illustrated in Figure (2).

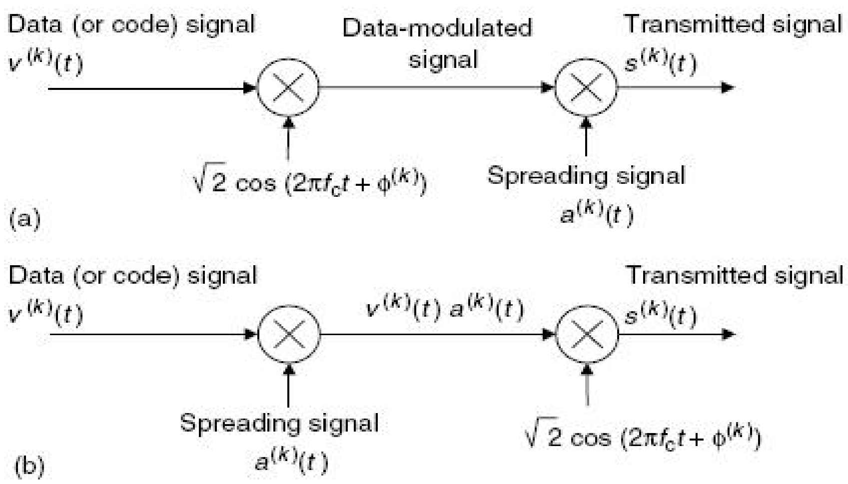

Figure (1). BPSK modulator for the kth user in the DS-CDMA system.

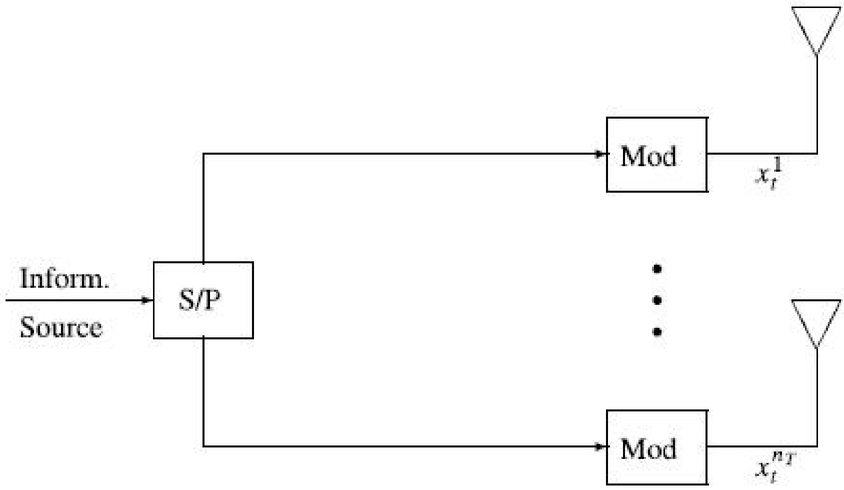

Figure (2). A VLST architecture.

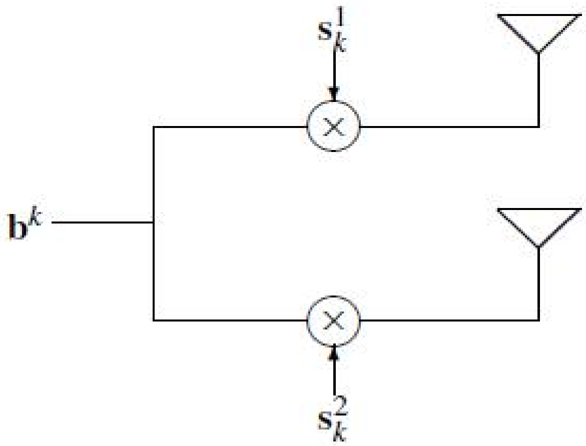

Figure (3). An open-loop transmit diversity.

The Open Loop Transmit Diversity proposed in [6] and the block diagram of an open-loop transmit diversity scheme is shown in Figure3. In this scheme, two different spreading sequences are assigned to each user. The same BPSK modulated symbols are transmitted from two transmit antennas [4]. There are other space time spreading schemes can be found in [4,6].

The proposed LST-STS-DS-CDMA system increases the SNR at each receiver antenna by using all the available paths between the transmitter and the receiver antennas not like the usual LST system which suppress the contribution of the other antennas [4] . It doesn't require any CSI information to be sent back to the transmitter as with MIMO beamforming system [7]. The multi-user detection also performed using the CSI at receiver only not like the Singular Value Decomposition (SVD) procedure proposed in [8].

The STS scheme proposed by [6] transmits the same signal over two different spreading codes over different antennas. This scheme uses M spreading sequences for M transmitting antennas to each user [4]. Since the spreading sequences are the resources in CDMA systems and the number of orthogonal codes is limited for a given spreading gain, this will reduce the number of users that can be simultaneously supported by the system[4]. On the other hand LST-STS-DS-CDMA system uses one spreading sequence to each antenna to all users and another spreading sequence to each user. So, if we are using the system in [6] and we have 3TX antennas and 3-users then we will need to each user 3 different spreading sequences. While in LST-STS-DS-CDMA system with the same inputs we'll need one spreading sequence to each user only at the DS-CDMA phase. And this spreading sequence can be reused as a spreading sequence at one of the transmitting antennas.

The LST-DS-CDMA system is equivalent to MIMO beam former [7] from the number of paths between the transmitter and the receiver it used, but still having the advantage of not needing any CSI at the transmitter.

The drawback of this scheme is the need for perfect CSI information at the receiver, and care should be taken when implement it in frequency selective channel. That is because any shift in the spreading codes will lead to destroy the orthogonality between them, which leads to serious errors.

We didn't use 2TX-2RX system in this paper because it is believed that using Alamouti scheme would be more advantageous from complexity, and decoding aspects.

Another spreading scheme was proposed by [9], where a new method is proposed for designing the spreading permutations based on space time block code matrices for MIMO-CDMA systems.

2. Proposed System

2.1. Layered Space Time Code-Space Time Spreading-Direct Sequence Code Division Multiple Access (LST-STS-DS-CDMA) System

The block diagram is shown in Figure 4. The data is first modulated by Binary Phase Shift Keying (BPSK) modulator, then encoded using DS-CDMA encoder. It should be noted that the length of the resulting codeword used here + the length of the code used in STS-encoder = the length of the codeword that would be generated if using DS-CDMA system alone. So, the bandwidth used by both systems is the same. This criterion is applied in all proposed systems below. The data then mapped to several transmitting antennas according to LST- coding criteria. The code used for layering is Vertical Bell Laboratories Space Time Codes (V-BLAST). The data is then transmitted through Rayliegh flat fading channel and Additive White Gaussian Noise (AWGN) was added at the receiver.

On the receiver side (which is the antenna terminal of user1 (U1)), the usual way is to use for example QR- factorization to solve the interference caused by multiple signal received at each receiving antenna, but, here we do not need it because of using the spreading sequence and our need to this interference as it will be shown later. The De-space time spreading is used to prepare the data to the combiner. The combiner function is to combine the signal from the multiple transmitting and multiple receiving antennas and add the original signal and its copies together to enhance the Signal to Noise Ratio (SNR). In other words, it is using all the available paths between the transmitter side and the receiver side. Till now all the users have the same data, the next step is the DS-CDMA decoder which translates this data into different users. Then the decoded message is demodulated using BPSK-demodulator. Because this system uses all paths between the transmitter and the receiver we'll call it all paths system.

The function of STS-LST encoder is shown in Figure (5). The function of the combiner is demonstrated in Figure (6).

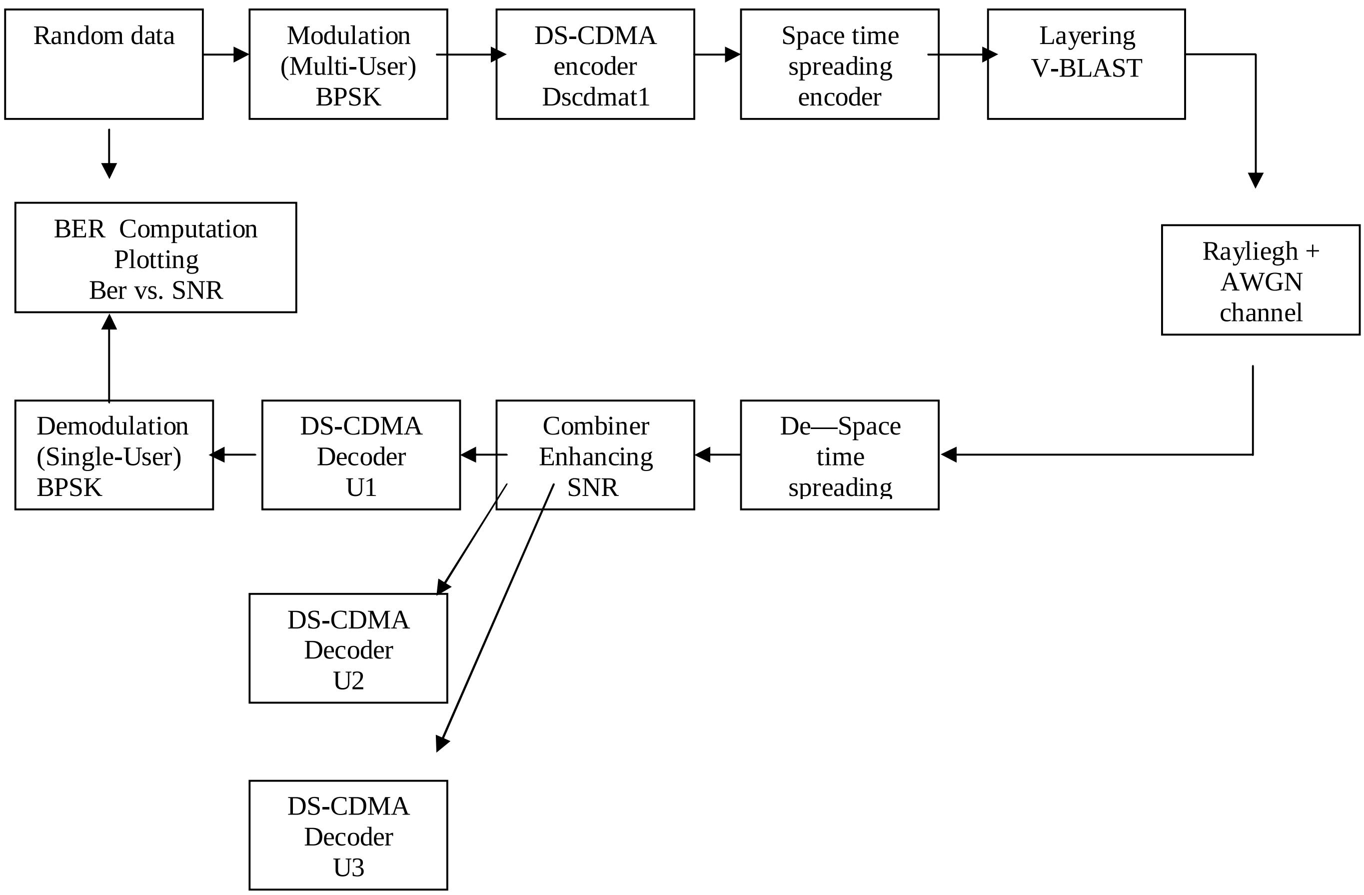

Figure (4). LST-STS-DS-CDMA System.

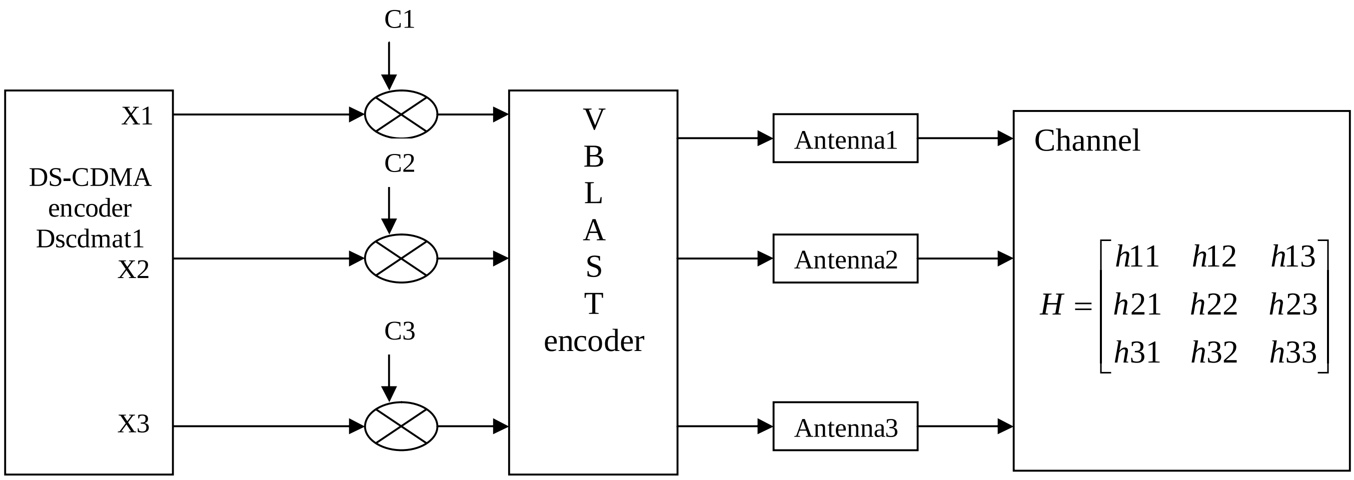

Figure (5). STS block + LST block.

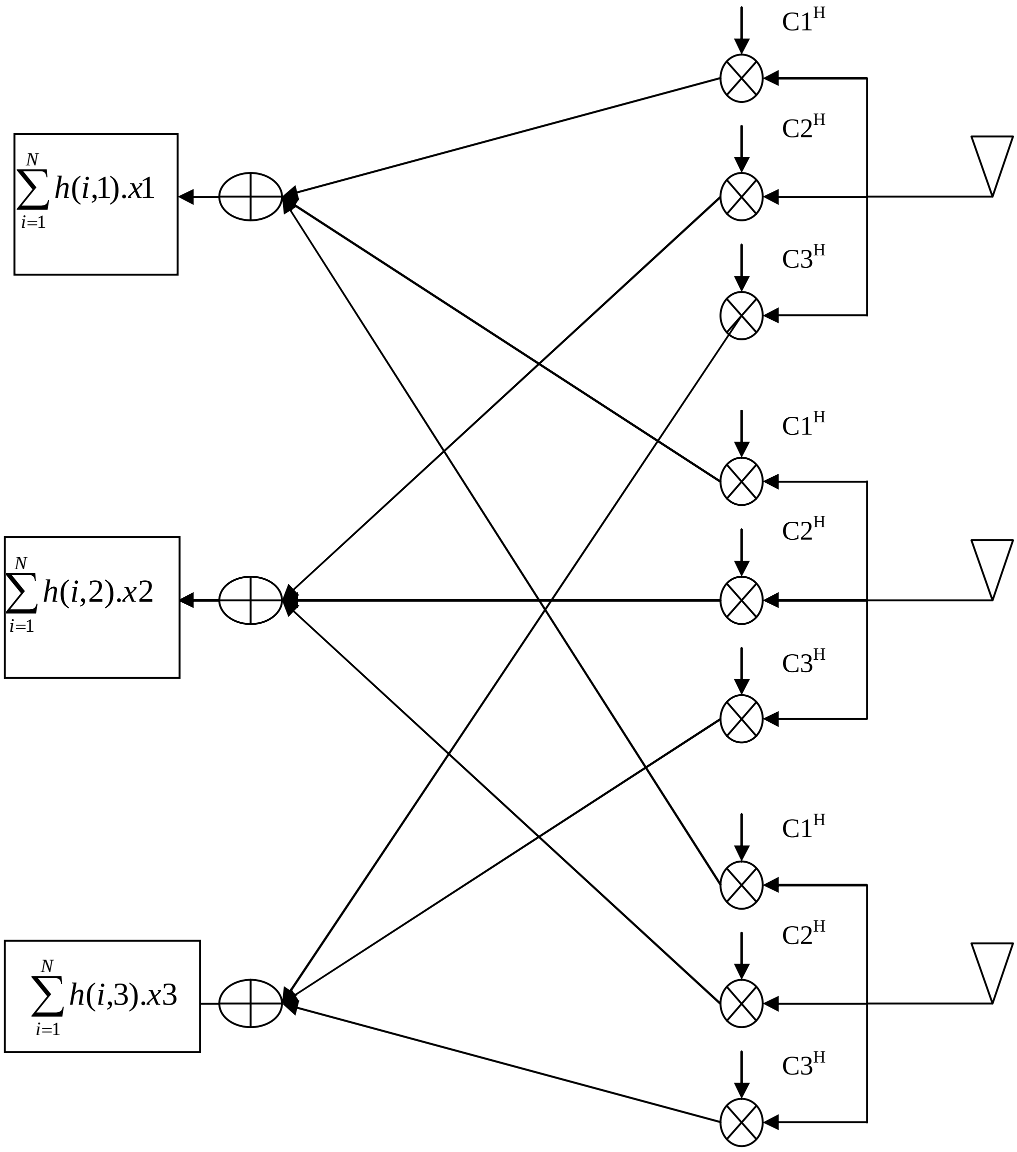

Figure (6). ST-dispreading and combiner block diagram.

The combiner in Figure (6) can be simplified to give a similar structure to SVD decoder with the advantage of not using the channel state information at the transmitter side. This is done by multiplying each received signal at each receiving antenna by its spreading code only, i.e.:

Let ri be the received signal at antenna i. We'll take the case where there are 3TX-3RX antennas, and take the signal received by the first antenna as a demonstration example:

$$r1C1^H = h11x1C1^H + h12x2C1^H + h13x3C1^H + n1C1^H$$

$$Ci.Cj^H = 0$$

$$Ci.Ci^H = 1$$

$$r1C1^H = h11d1 + n1C1^H$$

Where n1 is AWGN at receiving antenna 1.

Since the channel coefficients are assumed perfectly estimated, the last equation gives the data transmitted from the first antenna. This data still having the multi-user information and must be processed further by DS-CDMA dispreading to give each user his information. Because this system uses one channel coefficient we'll call it one-path system.

2.2. Layered space time code- direct sequence code division multiple access (LST-DS-CDMA) system

The block diagram of this system is similar to the block diagram in Figure (3) with removing the STS-blocks from the transmitter and receiver.

3. Simulation results

All simulations carried out in Rayielgh flat fading channel + AWGN. The channel coefficients are assumed perfectly estimated at the receiver. The MATLAB2009 is used as a programming package. The Spreading Factor (SF) (Processing Gain) is 16. The results are shown in Figure (7). The Table (1) shows the SNR values for all systems at BER of 10^{-4}.

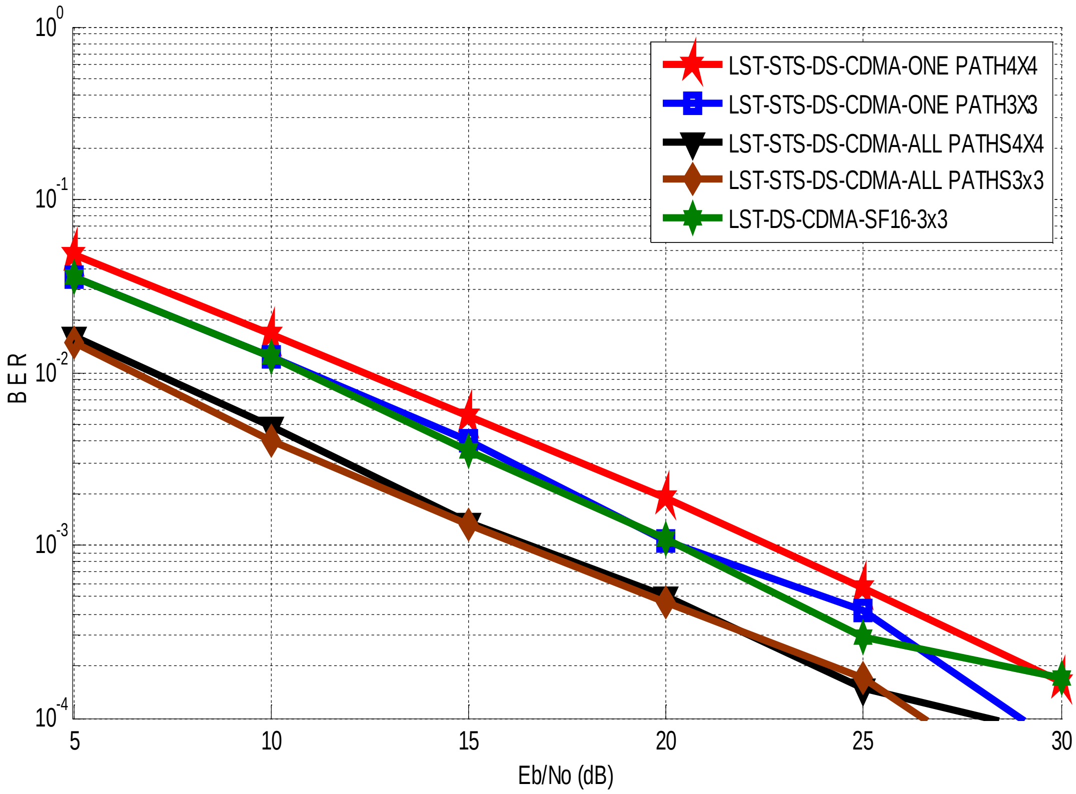

Figure (7). BER Vs. SNR in flat fading + WAGN channel.

Table (1). The SNR values for all systems at BER of 10^{-4}.

System used	SNR (E_b/N_0) dB
LST-STS-DS-CDMA-One Path-4X4	>30
LST-STS-DS-CDMA-One Path-3X3	29
LST-STS-DS-CDMA-All Paths-4X4	28.25
LST-STS-DS-CDMA-All Paths-3X3	26.5
LST -DS-CDMA-SF16-3X3	>30

4. Discussion

From Figure (7), it can be seen that the LST-STS-DS-CDMA with 3TX-3RX system is the best one. The LST-STS-DS-CDMA with 4TX-4RX achieves relatively the same as the LST-STS-DS-CDMA with 3TX-3RX system. Maybe this loss of performance is due to the amount added by using one more path (channel coefficient) and doesn't contribute too much to the received power.

The same thing can be said about the LST-DS-CDMA with 3TX-3RX system and LST-STS-DS-CDMA with 4TX-4RX-one path. Also, we should note that the amount of information conveyed by the 4TX-4RX systems is 25% higher than the 3TX-3RX systems because of the nature of signal spreading codes that requires more information processed.

The LST-DS-CDMA with 3TX-3RX system achieves a comparable performance to LST-STS-DS-CDMA with 3TX-3RX with one path system, with some advantage of the last one at higher SNRs. This is because the LST-STS-DS-CDMA with 3TX-3RX system uses two stages of spreading which leads to spread the noise then adding it and spreading it again. As a result, some noise components may cancel each other and at the same time the SNR increased.

5. References

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