Performance Improvement of Coded Dual Hop Two Way Space Time Block Code Spatial Modulation

تحسين الأداء للتضمين الكتلي الزماني ـ المكاني للمنظومات المشفرة ثنائية القفزة ذات الطريقين

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Abstract:-

This paper presents two scenarios to improve the performance of Distributed Space Time Block Code Spatial Modulation (DSTBC-SM). The first scenario is achieved by using a simple X-OR coding at sources and relays with simple decoding algorithm in relays and destinations sides. It is found that the system using X-OR with DSTBC and DSTBC-SM half encoding at the relay offers increased performance gain with low complexity. The second scenario uses turbo code to improve the performance of DSTBC-SM, where encoding is performed in sources, while relays detect received signal without decoding. Iterative turbo decoder is done in destination to reduce complexity of overall system. The simulation results have shown that the cooperative transmission with coded DSTBC-SM can achieve BER of 10^{-4} at a level of energy per bit of about 14 dB which is lower level than the cooperative transmission uncoded DSTBC-SM

Keywords:- DSTBC-SM, X-OR code and Turbo code.

I. Introduction

To mitigate the effect of fading in wireless communication systems, multiple transmit and receive antennas are used. Due to size and power limitation considerations for mobile phones, cooperative diversity (spatial diversity) can be achieved by using the antennas of other users or relays in the network to aid the communication of messages from a single source [1]. A new form of diversity is proposed in [2] and [3], whereby diversity gains are achieved via the cooperation of in-cell users.Cooperation in cellular networks and for ad hoc networks was investigated by in [4] and [5], whereas, the information theoretical capacity of relay channel was investigated in [6] and [7]. In [8], the new strategy of cooperative system is proposed, called distributed space-time coding. A two phase amplify and forward (AF) based cooperative protocol was introduced in [9].

Relay based cooperative systems can offer significant benefits for the next generation wireless networks, including increase spectral and power efficiency, network coverage area and outage probability [10]. The main components of the cooperative communication system are source, relay and destination nodes which seem as a virtual Multiple- Input Multiple Output (MIMO) system to provide diversity gains without implementing multiple antennas at wireless nodes. The popular protocols which are used in relay are either Amplify and Forward (AF) or Decoded and Forward (DF) [10]. Another major classification is based on whether the transmission from source and relay interfere at the destination or not. In a conventional orthogonal DF (ODF) protocol, relay terminal decodes the received message from the source before forwarding it to the destination and the source and relay transmit in orthogonal time intervals [11]. Due to this orthogonality, co-channel interference is avoided and the destination terminal can employ a simple receiver.

Cooperative strategy type space-time coding for one-way wireless networks can only achieve half transmission rate. In order to achieve the full unity rate, a two-way (TW) communication scheme is used, by which two parties transmit information to each other [12]. The TW channel over a relay network (TWRC) are taken considering academic and industrial communities due to its potential application to enable range rate enhancements of future cellular systems [13].

Recently, spatial modulation (SM) was investigated in [14] and [15], where the signal dimension is extended from two to three. Therefore, the information is conveyed not only by the amplitude/phase modulation techniques, but also by the antenna indices.

Transmission scheme, called space-time block coded spatial modulation(STBC-SM),cancombine spatial modulation(SM) and space-time block coding (STBC) to take advantage of the benefits of both while avoiding their drawback [16]. In order to combat inevitable channel impairments, forward error correction (FEC) coding schemes are mandatory in the digital communication systems, especially for wireless mobile systems. For this reason, turbo codes, employing iterative decoding and showing a performance close to the Shannon limit, are specified as FEC schemes for most of the future wireless mobile systems [17].

This paper investigates the performance of the coded and uncodeddistributed space time block code spatial modulations using two types of coding. The first one is the simple coding technique [18], which uses two hopes with simple decoding algorithm in relay and destination nodes. The second one is achieved by using turbo code in the source and iterative decoding in destination node with simple detection in relay nodes.

In Section II, the system model is presented. Section III presents the coding schemes that were used in this work. In Section IV, simulation results are presented. Finally, conclusions are offered in Section V.

II. System Model

The wireless communication relay network for two-way communications is shown in Figure.1. It consists of two terminal nodes T_m, m = 1, 2 and *N* relays with relay nodes R_i, i = 1, 2….*N*. Each node has one half-duplex antenna for either transmission or reception. Each terminal node comprises a pair of co-located source node (*s*) and destination node (*d*), which operates in time-division half-duplex so that the transmission and reception of radio signals are not allowed at the same time instant. Note that the source node for the data stream emanating from T_1 also acts as the destination node for the signal flow transmitted from T_2, and vice-versa. The two terminals T_1 and T_2 exchange their information between each other through two phases which are the broadcasting and relaying phases [19]. For simplicity, the channel coefficients are unchanged during the transmission of a signal code block (quasi-static Rayleigh flat fading) between any two nodes and they are known to the receiving terminals but not to the transmitting nodes. It is assumed that the uplink channel gain fromT_m to R_i is identical to the downlink channel gain from R_i to T_m. It is also assumed that terminal T_m sends the signal $x_m= [x_{m,1}, ..., x_{m,T}]^T$ to the other terminal, where $x_{m,t} \in A_m$, $m = 1, 2$, $t = 1, ..., T$, A_m is a finite constellation with a unitary average power, and T is the length of the time slot therefore [14],

$$E\{x^H{}_m x_m\} = T \qquad (1)$$

In order to minimize the system complexity as well as power consumption, each terminal and relay node is equipped with a single antenna. All communication channels are subject not only to long-term free-space path loss, but also to short-term frequency non-selective Rayleigh fading.

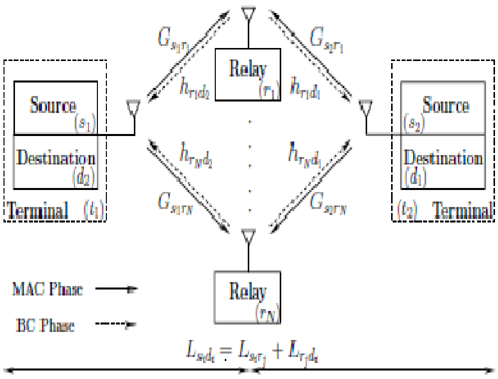

Figure.1: Two-way dual hope wireless communication relay network

The geometrical-gain or path-gain experienced by the link between the *i*-th source node and the *j*-th relay node with respect to the source-to-destination link can be defined as[19]:

$$G_{s_i r_i} = \left(\frac{L_{s_i d_i}}{L_{s_i r_j}} \right)^{\alpha} \qquad (2)$$

where $i = \{1, 2\}$, $j = \{1, 2, \ldots, N\}$, and $L_{a,b}$represents the geometrical distance between arbitrary nodes a and b, while α is the path-loss exponent, which gives $\alpha = 2$ if a free-space path loss model is invoked. The geometrical-gain of the *j*-th relay to the *i*-th destination link with respect to the source-to destination link can be computed similarly, yielding:

$$G_{r_j d_i} = \left(\frac{L_{s_i d_i}}{L_{r_j d_i}} \right)^{2} \qquad (3)$$

Let us now consider the two-stage information exchange process, where the information transmitted by source node s_i is modeled as memoryless binary bit sequences with uniform distribution denoted by $x_{s_i} = \{x_{s_{i,1}}, x_{s_{i,2}}, \ldots \ldots \ldots ..\}$, $i = \{1, 2\}$. During the Multiple Access (MAC) stage, the information bits x_{s_i} are modulated to a frame of Binary Phase Shift Keying (BPSK) symbols v_{s_i} and transmitted to *N* number of relay nodes. The channel-contaminated and superimposed signal received at the *j*-th relay node can be formulated as

$$y^{(r_j)} = \sum_{1}^{2} \left(\sqrt{G_{s_i r_j}}\, h_{s_i r_j} v_{s_i} \right) + n^{(r_j)} \qquad (4)$$

where $j \in \{1, 2, \ldots, N\}$and $h_{s_i r_j}$is the quasi-static frequency-flat Rayleigh fading coefficients of the communication link between the *i*-th source node and the *j*-th relay node, while$n^{(r_j)}$ is the Additive White Gaussian Noise (AWGN) introduced in the *j*-th relay node with zero mean and variance of $N_0/2$ per dimension. Conventionally, each relay node has to first detect and recover the information transmitted from both source nodes separately by employing various kinds of multi-user detection (MUD) techniques, and then perform the network coding on the demodulated bits. At the j-th relay node, if $\hat{x}_{s_j}^{(r_j)}$ is the estimation of information bits transmitted from the i-th source node, the product of network coding can be expressed as:

$$u^{(r_j)} = \hat{x}_{s_1}^{(r_j)} \oplus \hat{x}_{s_2}^{(r_j)} \qquad (5)$$

where $\oplus$represents the addition operation in the Galois field GF(2^m), which can be simplified to the exclusive or arithmetic when $m = 1$. By contrast, instead of detecting the information individually, it is only necessary to estimate the summation of information bits received at the j-th relay node, which can be transformed to the equivalent network coded bits shown in Equation (5) with the assistance of physical-layer network coding.

During the Broadcast (BC) stage, after detection and (may be decoding) at relay. the network coding bits $u^{(r_j)}$are modulated to a frame of Binary Phase Shift Keying (BPSK) symbols $w^{(r_j)}$and transmitted to i-th destinationnodes. The received signal at the i-th destination node is given by:

$$y^{(d_i)} = \sum_{1}^{N} \left(\sqrt{G_{r_j d_i}} h_{r_j d_i} w^{(r_j)} \right) + n^{(d_i)} \qquad (6)$$

where $i \in \{1, 2\}$and$h_{r_j d_i}$denotes the complex-valued Rayleigh block fading coefficients of the channel between the j-th relay node and the i-th destination node, while $n^{(d_i)}$ is the AWGN induced in the i-th destination node having zero mean and variance of $N_0/2$ per dimension. The notation $w^{(r_j)}$represents the re-encoded bits transmitted from the j-th relay node, where a frame of virtual STBC or STBC-SM codewords. $W^{(r_j)}$ is constructed by N cooperating relay nodes in a distributed fashion, i.e.$W^{(r_j)} = [w^{(r_1)}, w^{(r_2)}, \dots \dots, w^{(r_N)}]^T$. At the destination node, a serial-concatenated conventional STBC or STBC-SM decoder, PSK demapper and PNC demapper are invoked to perform the final decision and recover the information transmitted from the source nodes. Note that it is assumed the transmit power of each source node is normalized to unity. Hence, each relay nodetransmits at 1/2 of the overall power to ensure that $\sum_{j=1}^{N} |w^{(r_j)}|^2 = 1$ in terms of a fair comparison [19].

III. Coding schemes

A. X-OR CODE

Sources encode the information by X-OR (exclusive-or) encoder like as shown in Table.1 with rate 1/2. The coded data may be interleaved by random interleaver. Sources transmit encoded/interleaved symbol after modulation at $s_i \rightarrow$ R_1, R_2or si→ R_1, R_2, R_3 . As shown in Figure 2, or 3 each relay station decode the detected received data using decoding algorithm which to be present in section A.2. In each relay network, the product code bits $u^{(r_j)}$shown in Equation 5are performed[18]. During the Broadcast (BC) stage, the information bits $u^{(r_j)}$are coded using X-OR coding again and modulated to a frame of Binary Phase Shift Keying (BPSK) symbols $w^{(r_j)}$and transmitted to i-th destinationnodes by using STBC or STBC-SM encoder scheme.

A.1 The combining schemes

Alamouti STBC proposed in [20] employs two transmit antennas and one receive antenna. With the application of maximum ratio combining scheme and maximum likelihood detection, full transmit diversity can be achieved in Alamouti scheme. The combiner of destination builds the two combined signals that are sent to the decoder for performance. In other words, the combiner provides diversity gain of STBC half encoder of this system, Moreover, STBC-SM proposed in [16] employs three transmit antennas and one receive antenna. With the application of maximum ratio combining scheme, maximum likelihood detection and partial interference cancellation group decoding, full transmit diversity can be achieved in STBC_SM schemes.

Table1: Simple encoding Algorithm [18]

Symbol	1st	2nd	3rd	4th
S_o	A	B	C	D
S_1	A	A⊕B	B⊕C	C⊕D

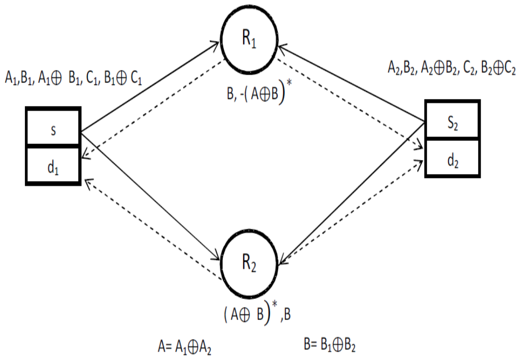

Figure 2: DSTBC transmission

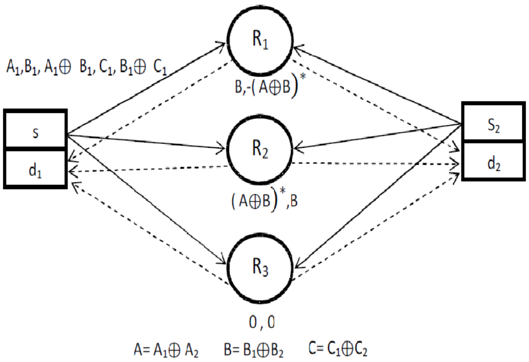

Figure 3: Virtual STBC-SM transmission example when C=0.
if C=1R1 transmit (0,0) , R2 transmit (B. –(A□B)*) and R3 transmit ((A□B)*,B)

A.2 The decoding scheme

The scheme can be seen very simple with messages and parities from the relays [18]. Figure 4 shows that the relay / destination can separate the two combined signals (S_0, S_1) into S_0 (A, B, C) and S_1 (A, A ⊕B, B ⊕ C). To derive the increased performance gain in the BER, let us focus on bit B.

- First case (B=0)

If there are no error in (A,B,C), they are sure as following

A⊕B=A,B⊕C=C ,B=0

When B=0 , A⊕B ≠A and B⊕C ≠C. In this case, correct B=0 to B=1.

- Second case (B=1)

Like the preceding, they are sure as following

A⊕B ≠A, B⊕C ≠ C ,B=1

Correct B=l to B=0 When B=l, A⊕B=A and B⊕C=C.

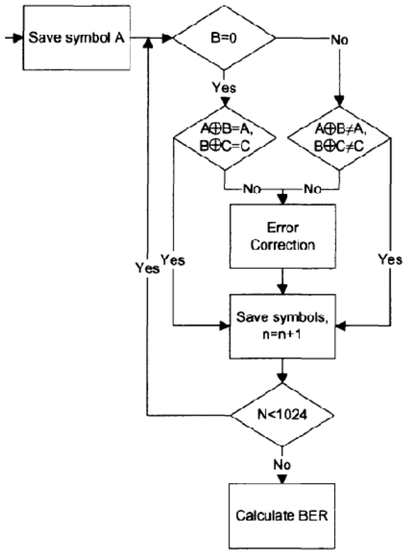

Figure 4: Decoding Algorithm

B. TURBO CODE

Turbo code is known to have the most powerful error correcting capability up to now. Generally, turbo codes can be classified into two categories according to the type of constituent encoder such as convolutional turbo code and block turbo code or turbo product code. In this paper, a convolutional turbo code is considered which consists of a parallel concatenation of Recursive Systematic Convolutional (RSC) encoders separated by a pseudo-random interleaver. The turbo product codes are built from the product of two systematic block codes, separated by a uniform interleaver [21].

The proposed turbo encoding is performed in the sources. Relay does not decode (only detect the received signal) and provide network coding. Turbo decoder exists in the destination side only because iterative decoding operation requires time and more system complexity in relays. In pervious coding scheme and due to the simplicity of decoding technique, the decoding is performed in relays and destination.

B.1 Turbo encoder

The turbo encoder can use two different or identical Recursive Systematic Convolutional (RSC) encoders, connected in parallel [22] as shown in Figure 5. Two component codes are used to code the same input bits, but an interleaver is placed between the encoders. Generally RSC codes are used as the component code1 and component code 2 [21].

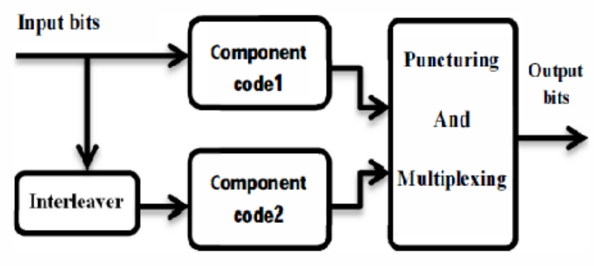

Figure 5: Turbo Encoder

B.2 Turbo decoder

There are two main algorithms for Turbo decoding: The maximum *aposteriori* algorithm (MAP) and the soft output Viterbi algorithm (SOVA). The SOVA based decoder is computationally less complex since it chooses the branch in the trellis with the highest probability and discards the other. MAP, on the other hand, does not reject any path and calculates the probabilities of each point in the trellis. In order to reduce the computational complexity of MAP, it is generally implemented in the logarithmic domain and the corresponding algorithm is referred to as the log-MAP algorithm [23].The general structure used in turbo decoders is shown in Figure 6.

This paper is focused on Log-MAP since it has lesscomplexity compared with the Max-Log-MAP algorithm, but it gives exactly the same performance as the MAP algorithm.

IV. Simulation Results

In this section, simulation results of the two scenarios are presented. In the simulation, BPSK modulation is used and the propagation channels of mobile network undergo the complex additive white Gaussian noise (AWGN) and Rayleigh fading. Furthermore, the estimated channels are assumed to be perfect channels state of information CSI.

In the first scenario, a (DSTBC) is used in which $N = 2$ relay nodes are located and fixed at the mid-point of the source-to-destination link. Hence, the geometrical-gain for the source-to-relay link as well as the relay-to-destination link both equals to 4, i.e. $G_{sirj}= G_{rjdi}= 4$. As seen from Figure 7, the BER of the DSTBC with simple coding technique has coding gain of about 6dB at BER=10^{-4}. Random interleaver is used to improve the performance of coded system with different frame sizes. In this work, tested frame sizes were assumed as (100, 250, 500 and 1000) bits. It is found that the performance improvement can be increased when the frame size is increased. About 11-13 dB advantagesis obtain with respect to uncoded system when interlaever is used.

In the second scenario, a DSTBC-SM is used in which $N = 3$ relay nodes are located and fixed at the mid-point of the source-to-destination link. The geometrical-gain is assumed to besimilar to that used in the first scenario. Figure 8 shows the BER performance of coded and uncoded system. It is clear that the coded system with interleaver (frame size = 250) system has 14dB compared with uncoded system at a BER of 10^{-4}. While, Turbo coded system has a 10dB advantage at same error rate. Therefore, system with turbo code has better performance compared with the simple coded system by about 2dB at a BER of 10^{-5}.

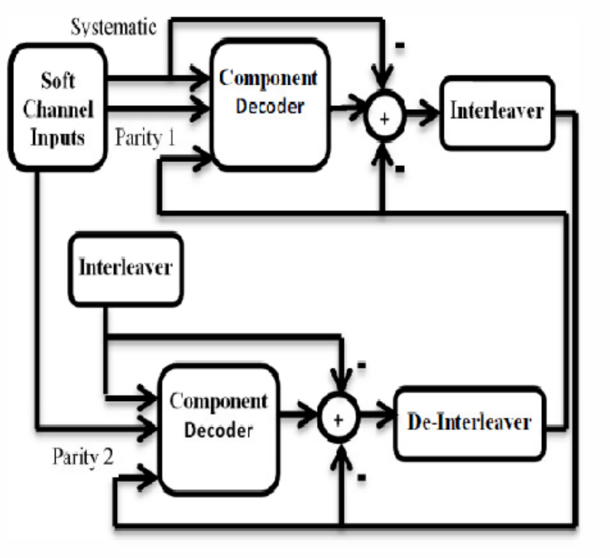

Figure 6: Iterative turbo decoder

V. CONCLUSIONS

In this paper, two scenarios to improve the performance of a DSTBC-SM are introduced. The first one isachieved by employing a simple X-OR coding in sources and relays with simple decoding algorithm in relays and destinations.The second one is achieved by using turbo coding in sources and relays have no ability to turbo decoding. Destinations perform decoding for encoded signals. For simplicity, the X-OR encoder/decoder is built in two places for encoding and two places for decoding, while turbo code has more complex decoders, therefore, it is built in destination side only.

In the simulation, a binary phase-shift keying (BPSK) is used and the propagation channel is assumed to undergo a complex additive white Gaussian noise (AWGN) and Rayleigh fading. The estimated channels are assumed to be perfect channels state of information (CSI). The simulation results of the first scenario show about 11-13 dB advantage coding gain of coded system compared with the uncoded one. Thesimulation results of the second scenario show that the system with turbo code has better performance compared with the simple coded system by about 2dB at a BER of 10^{-5}**.**

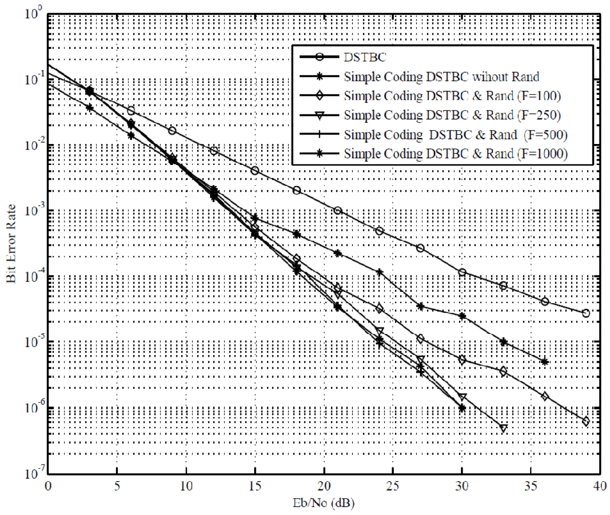

Figure 7: Bit error rate performance for coded and uncoded distributed space time block code

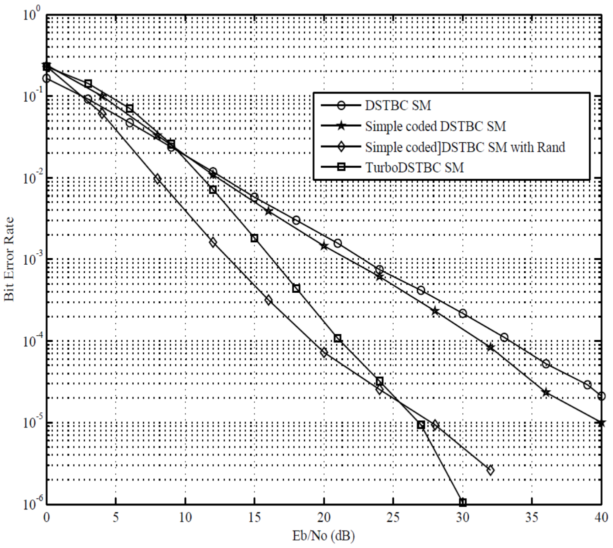

Figure 8: Bit error rate performance for coded and uncoded distributed space time block code-spatial modulation

الخلاصة:-

تحسين الاداء للتضمين الكتلي الزماني - المكاني للمنظومات المشفرة ثنائية القفزة ذات الطريقين

يقدم في هذه الورقة سيناريوهين لتحسين أداء المنظومات الموزعة لكتلةالمكان - الزمان المكانية التضمين (DSTBC-SM). ويتحقق السيناريو الأول باستخدام ترميز بسيط (X-OR) في المصادر والمرحلات مع خوارزمية فك التشفير بسيطة في المرحلات والوجهات. تبين أن النظام باستخدام النوع الاول من الترميز مع DSTBC-SM ومعدل ترميز بمقدار نصف في تتابع يوفر زيادة كسب الأداء معنسبة تعقيد في المنظومة منخفضة. السيناريو الثاني يستخدم المرمز النفاذ لتحسين أداء منظومة DSTBC-SM، حيثي تم تنفيذ الترميز في المصادر، في حين المرحلات تقوم بكشف الاشارة الواردة دون فك. فاك الشفرة النفاذ التكراري ينجز في الوجهات للحد منتعقيد النظام بشكل

عام. وقد أظهرت نَتائِجَ المحاكاةَ بأنّ الإرسالَ التعاونيَDSTBC-SM يمكن يحقق كسب في الطاقة للمنظومة المشفرة بحوالي ١٤ ديسبل عن المنظومة غير المشفرة لنسبة خطأ في المعلومات 10^{-4} .

REFERENCES

[1] L. P. Natarajan and B. S. Rajan, " Distributed STBCs with Full-diversity Partial Interference Cancellation Decoding," Proceedings IEEE Int.Symposium on Information Theory, 2011, pp. 2025-2029.

[2] A. Sendonaris, E. Erkip, and B. Aazhang, "Increasing uplink capacity via user cooperation diversity," *Proc.* IEEE Int. Symp. Inf. Theory, Aug 1998, pp. 156.

[3] A. Sendonaris, E. Erkip, and B. Aazhang, "User cooperation diversity. part I. system description, part II. Implementation aspects and performance analysis," IEEE Trans. Commun., Vol. 51, No. 11, Nov. 2003, pp. 1927–1948.

[4] J. Laneman and G. Wornell, "Distributed space-time-coded protocols for exploiting cooperative diversity in wireless networks," IEEE Trans. Inf. Theory, Vol. 49, No. 10, Oct. 2003, pp. 2415–2425.

[5] J. Laneman, D. Tse, and G. Wornell, "Cooperative diversity in wireless networks: Efficient protocols and outage behavior," IEEE Trans. Inf. Theory, Vol. 50, No. 12, Dec. 2004, pp. 3062–3080.

[6] E. C. Van der Meulen, "Three-terminal communication channels," Adv. Appl. Probab., Vol. 3, 1971 , pp. 120–154.

[7] T. Cover and A. Gamal, "Capacity theorems for the relay channel," IEEE Trans. Inf. Theory, Vol. 25, No. 5, Sep. 1979, pp. 572–584.

[8] Y. Jing and B. Hassibi, "Distributed space-time coding in wireless relay networks," IEEE Trans. Wireless Commun., Vol. 5, No. 12, Dec. 2006, pp. 3524– 3536..

[9] Y. Jing and B. Hassibi, "Diversity analysis of distributed space-time codes in relay networks with multiple transmit/receive antennas," EURASIP J.Advances in Signal Processing, Vol. 2008, Article ID254573, 17 pages, 2008.

[10] P. Poonsawatt and P. lamjareekul, " Improving Dual-Hop Amplify-and-Forward Cooperative Mobile Network Based on Path selection and

STBC with Pre-Coding Scheme," Proceedings IEEE Eighth International Joint Conference on Computer Science and Software Engineering 2011, pp 409-413.

[11] J. N. Laneman, D. N. C. Tse, and G.W.Wornell, "Cooperative diversity in wireless networks: efficient protocols and outage behavior," IEEE Trans. Inform. Theory, Vol. 50, Dec. 2004, pp. 3062–3080.

[12] C. E. Shannon, "Two-way Communication Channels," in Proceedings of the Fourth Berkeley Symposium on Mathematical Statistics and Probability, Vol. 1, (Berkeley, USA), 1961, pp. 611–644.

[13] M.A.Manna, F.Abdurahman and J.A.Chambers, "Distributed Quasi-Orthogonal Space Time Block Coding with Maximum Distance property for Two Way Wireless Networks," IEEE 7th Internationawireless Communications and Mobile Computing Conference 2011, pp 1704-1707.

[14] R. Mesleh, H. Haas, C. W. Ahn, and S. Yun, "Spatial modulation–a new low complexity spectral efficiency enhancing technique," in Proc. IEEE Conf. Commun. Netw. China, Beijing, China, Oct. 2006, pp. 1-5.

[15] R. Mesleh, H. Haas, S. Sinanovic, C. W. Ahn, and S. Yun, "Spatial modulation," IEEE Trans. Veh. Technol., Vol. 57, No. 4, July 2008 , pp. 2228-2241.

[16] E. Basar, U. Aygölü, and E. Panayırcı, " Space-Time Block Coded Spatial Modulation," IEEETransactions on Communications, Vol. 59, No. 3, March 2011, pp. 823-832.

[17] Y. Kim and S. Kim, "Evaluation of soft detection of STBC schemes for turbo codes,"Proceedings of the IEEE 6th International Conferenceon wirerless and Mobile Computing, Networking and Communication, Oct. 2010, pp 744-748.

[18] Y. lang. , S. Bae, S. Shin and K. Kwak, "Two- hop Relay Technique Using STBC and Simple CodingAlgorithm in Wireless Fading Relay Channels,"ProceedingsIEEE11th Int.Conf. on Advanced Communication Technology, Feb. 15-19 2009, pp. 1332-1335.

[19] K. Zhu and A. G. Burr," Relay Selection Aided Distributed Space-Time Block Code for Two-Way Relay Channel with Physical-Layer Network Coding," Proceeding IEEE 73rd Conference on Vehicular Technology, May 2011, pp, 1-5.

[20] S. M. Alamouti, "A Simple Transmit Diversity Technique for Wireless Communications," IEEE Select. Areas Commun. Vol. l6, No. 8, 1998, pp.1451-1458.

[21] H. R. Ahamed and H. M. Elkamchouchi, " Improving Bit Error Rate of STBC-OFDM Using Convolutional and Turbo Codes Over Nakagami-m Fading Channel,"proceedings IEEE International Conf.on Consumer Electronics, Communications and Networks, 2011, pp,4140 - 4143.

[22] L. A. Perişoară, and R. Stoian, " The Decision Reliability of MAP, Log-MAP, Max-Log-MAP and SOVA Algorithms for Turbo Codes," IEEE. Proceedings International Journal of Communication , Vol. 2, 2008, pp. 65-74.

[23] J. Kazaand C. Chakrabarti,, ″ Design and Implementation of Low-Energy Turbo Decoders," IEEE, Transactions on Very large Scale Integration (VLSI) Systems. Vol. 12, No. 9, Sep. 2004, pp. 968-977.