ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
Volume 2, Issue 12, December 2013

JOINT SOURCE CHANNEL CODING WITH SPACE TIME TRELLIS CODE MODULATION

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Abstract- **Video broadcasting and image transmission are emerging technologies which require high data rate for their implementation in wireless applications. The reliability of wireless communications is significantly limited by propagation loss, interference and attenuation disturbances (fading).The channel codes should combat fading and it should provide better performance .But existing channel codes do not meet the requirements. In order to satisfy the above requirement, Source coding is combined with MIMO channel coding technique. In this paper, source and channel coding techniques are combined and the performance is evaluated. Huffman code is used as source code and Space Time Trellis Code is used as channel code. The performance of Space Time Trellis Code modulation with and without joint source coding is analysed. And various states of MPSK STTC in combined source channel coding are compared.**

Index Terms- **Variable Length Code(VLC), Space Time Trellis Code(STTC), Bit error Rate(BER)**

I. INTRODUCTION

For high data rate communications, variable length codes (VLC) and Multiple Input Multiple Output (MIMO) techniques are required in the application layer and the physical layer, respectively[5]. We estimate the performance of source codes, channel codes separately in order to combine source and channel coding for high data rate applications. The objective of source coding is to achieve data compression. This is motivated in practice by the need to store data in its most efficient form, removing all superfluous or unwanted content. There are two types of source coding, lossy coding and lossless coding. Lossy coding assumes that the original data is not to be recovered in its entirety. Lossless coding on the other hand assumes full recovery of the original data. Source codes are generally split into two categories: constant length codes (CLC's) and variable length codes (VLC's). CLC's assume that a fixed codeword length is to be used for all data symbols while VLC's assume that variable codeword length is to be used. For sources with unequal symbol probabilities, it should be clear that most optimal codes are of the VLC. One such class of codes can be obtained through the well established method called the Huffman algorithm. Huffman codes are particularly interesting because they are easily implementable if one has access to the statistics of the data, but more importantly, they are optimal. Other algorithms such as the Lempel-Ziv algorithm, run-length limited coding also yield optimal source codes.

The fundamental goal of channel coding is to protect data against corruption during a wireless or wireline transmission. Corruption occurs for various reasons during a transmission, reasons that are outside the control of the sender and the receiver. Thermal noise, destructive interference caused by echoes or other transmissions, fading and data collision all contribute to errors in the received data stream. It is impossible to directly eliminate the causes of corruption at their source . The effect of noise can be reduced through the insertion of redundant information. If redundant information is sent along with the original data and the receiver is aware of the scheme, it becomes intuitively conceivable that some errors may be recovered at the receiving end. Two main types of channel codes are convolution codes and block codes. The existing system uses convolutional codes as channel code but it is not suitable for high data rate applications and for fading environments. And high data rate wireless communications uses Space Time codes as channel codes. The various type in Space time codes[6] are space time block codes ,space time trellis codes and layered space time codes. Space time trellis codes are considered here for estimation due to its advantages over other codes[5].

We estimate source coding , channel coding performance over wireless channels using Huffman code as a source code and space time trellis code as a channel code. Huffman codes uses entropy encoding algorithm for lossless data compression. It uses a specific method for choosing the representation for each symbol, resulting in a prefix code. Space time trellis codes (STTC) are a coded modulation technique for multiple transmit-and-receive antennas systems. With signal processing at the receiver, STTC achieves two to four times higher bandwidth efficiency than the conventional diversity techniques[5]. In addition to achieving the maximum diversity gain, coding gain may also be obtained with STTC.

In this paper Section II describes System model for Joint source Channel Coding, Section III describes trellis structure for STTC and VLC, Section IV explains viterbi decoding ,Section V

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shows the simulation results and Section VI gives the conclusion.

II. SYSTEM MODEL

The Block diagram for Source Channel Coder is shown in Fig.1 and its system model for encoder is shown in Fig. 2.Assume {ai, i = 0, 1, ...,K − 1} to be one packet of source symbols drawn from a finite alphabet set {0, 1, ...,N−1}, where K is the packet length and N is the source alphabet size. First, the VLC encoder is used to generate a bit sequence {bj, j =0, 1, ...,L − 1}, each source symbol sequentially mapped to a variable length codeword. The source coding efficiency is VLC = H/ l, where H is the entropy of the source and l is the average codeword length per source symbol. The codeword length ranges from l_{min} to l_{max} and K l_{min} ≤ L ≤ K l_{max}. Suppose M-ary modulation is used ($M = 2^p$).

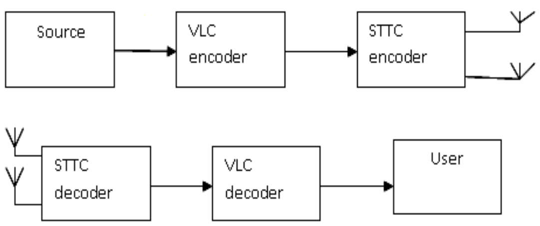

Fig.1 Block diagram for Joint Source channel Coding

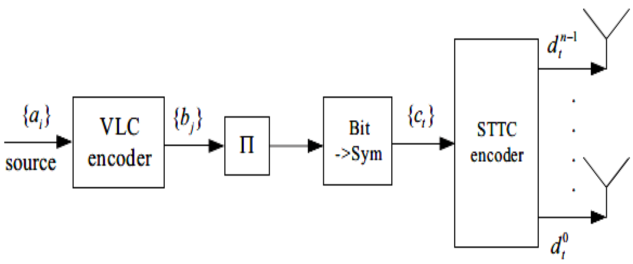

Fig.2 Serial concatenation of VLC and STTC

The bit stream is grouped every p bits and converted to a modulation symbol stream

$c_t, t = 0,1, \ldots \left\lceil \frac{L}{p} \right\rceil - 1$ as the input to the STTC encoder. If necessary, bit "0"s can be added to the end of the bit stream to form the last symbol. The outputs from the STTC are n modulated symbol sequences, $\left\{ d_t = [d_t^0, \ldots . d_t^i, \ldots d_t^{m-1}]^T, t = 0,1, \ldots . \left\lceil \frac{L}{p} \right\rceil - 1 \right\}$ which are sent to the radio channel through n transmit antennas.

Suppose there are m receive antennas, at time t, the received signals are represented by a m × 1 vector

$$r_t = H_t d_t + \eta_t \qquad (1)$$

Where, $H_t = [h_t^{i,j}]$ is the channel fading coefficient matrix $h_t^{i,j}$ is the path gain between the ith transmit antenna and the jth receive antenna at time t.

$\eta_t = [\eta_t^j]$ is the white Gaussian noise on the jth receive antenna at time t.

III. TRELLIS STRUCTURE

A. Trellis for VLC

VLC can be represented by a bit-based trellis structure [7]. Fig.3 shows the tree structure and trellis structure of a Huffman code with codebook C = {00, 11, 101, 010, 0110}. The nodes in the tree can be divided into three classes, root

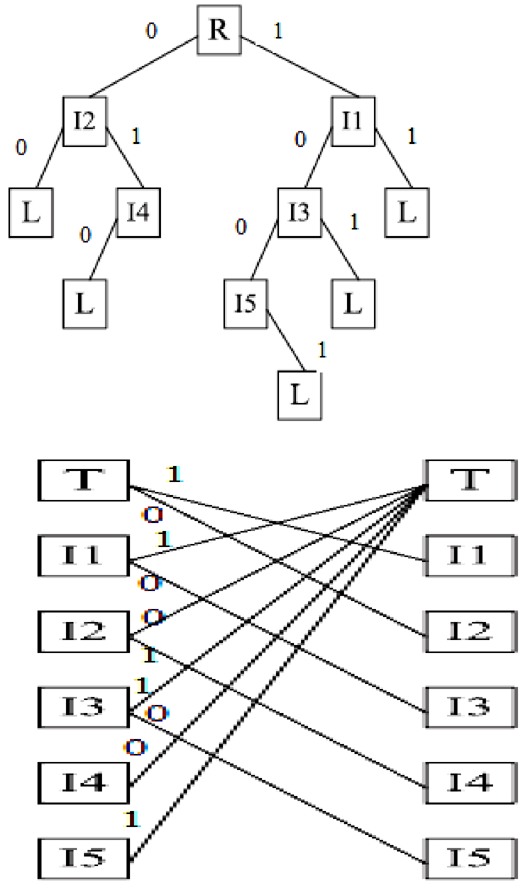

Fig.3 Trellis representations of VLC

node "R", internal nodes ("I1" to "I5") and leaf nodes "L". The VLC trellis consists of a terminal state "T" and several internal states. Each internal state corresponds to each internal node. However, both root node "R" and leaf nodes "L" are represented by a single "T" state that indicates the end of current codeword and the beginning of the next codeword. The trellis is bit-based and time-invariant. At each bit instant, each state has one or two outgoing branches. While each internal state has only one incoming branch, the "T" state has the same number of incoming branches as the codebook size. This trellis can be used for estimating either the source sequence (using Viterbi decoding) or the individual source bits (using MAP decoding)[8].

B.Trellis for STTC

The construction of Feed forward encoder is explained in[6].In space-time trellis coded modulation, the encoder maps binary data to modulation symbols, where the mapping function is described by a trellis diagram. Here, The input message stream c ,is given by,

$$\boldsymbol{c}^k = (c_0, c_1, \dots, c_t \dots)$$

where c_t is a group of m= $\log_2 M$ information bits at time t and the encoded symbol sequence transmitted from antenna i is given by,

$$\mathrm{x} = (\mathrm{x}_0, \mathrm{x}_1, \mathrm{x}_2, \dots, \mathrm{x}_t, \dots)$$

The modulated signals, $\mathrm{x}_t^1, \mathrm{x}_t^2, \dots, \mathrm{x}_t^{n_t}$, are transmitted simultaneously through n_t transmit antennas. At any time t, for M-PSK ($M = 2^m$) scheme and with two transmit antennas, m binary inputs $c_t^1, c_t^2, \dots c_t^m$ are fed into the branches; with c_t^1 being the most significant bit. The number of memory elements in each branch is $v_1, v_2, \dots, and\ v_m$ respectively and the total memory $v = v_1 + v_2 + \cdots + v_m$.

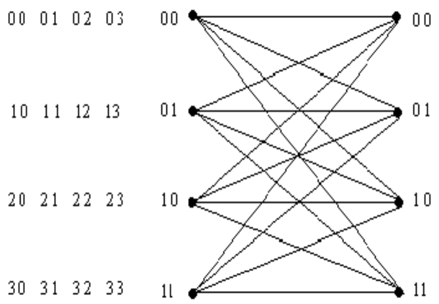

Fig .4 Trellis Diagram of QPSK 4 State STTCM

The value of v_i is determined by

$$v_i = \left\lfloor \frac{v+i-1}{m} \right\rfloor, \ i = 1, 2 \dots m \qquad (2)$$

where, $\lfloor k \rfloor$ denotes the largest integer smaller than k.The m input bits are delayed and multiplied by the coefficient pairs $(g_{x,1}^1, g_{x,2}^1)$, $(g_{y,1}^2, g_{y,2}^2)$ for m = 2, and $(g_{x,1}^1, g_{x,2}^1)$, $(g_{y,1}^2, g_{y,2}^2)$, $(g_{z,1}^3, g_{z,2}^3)$ for m = 3, where $x = 0, 1, \dots v_1$, $y = 0, 1, \dots v_2$, $z = 0, 1, \dots v_3$ The multiplier outputs from all shift registers are added by modulo M addition to produce the output x_t^1 and x_t^2. The output x_t^1 is transmitted on the first antenna and x_t^2 is transmitted on the second antenna simultaneously. The total number of states for trellis encoder is 2^v. The elements of the generator matrix are defined by the coefficient pairs described earlier in the encoder structure. The trellis diagram [5] obtained from the above encoder for QPSK 4- state is given in Fig.4.

IV. DECODER

Both Space Time trellis code and VLC uses viterbi algorithm for decoding.

A.Viterbi algorithm for Space Time Trellis Codes and VLC

The Viterbi algorithm is used to decode the Space Time Trellis Code. It uses the trellis structure of the code. Each time the decoder receives a pair of channel symbols and it computes a metric to measure the distance between the received and the transmitted signal[5]. For hard decision Viterbi decoding, the Hamming distance is used, and for soft decision Viterbi decoding, the Euclidean distance is used. The metric values computed for the paths between the states at the previous time instant and the states at the current time instant are called branch metrics. We assume that the channel state information is known to the decoder and thus knows the path gains $h_{i,j}$, where $1 \le i \le n_t$ and $1 \le j \le n_r$. The branch metric for a transition labeled $s_t^1, s_t^2, \dots s_t^{n_t}$ is given by,

$$\sum_{j=1}^{n_r} \left| r_t^j - \sum_{i=1}^{n_t} h_{i,j} * s_t^i \right|^2 \qquad (3)$$

The Viterbi algorithm is used to compute the path with the lowest accumulated metric. The methods for decoding VLCs are quite different in concept and implementation. The SISO VLC decoder receives as input a packet of known length containing VLC data that has been corrupted by additive white Gaussian noise (AWGN) and produces the codeword sequence which is most likely to have been input to the VLC encoder at the transmitter[8]. The SISO method performs best when a priori information regarding the number of symbols represented in the packet is available, though even in the case that the number of symbols is unknown, the performance is superior to hard decision methods.

V. SIMULATION RESULTS

The BER performance of Space Time Trellis Code Modulation with joint source coding and without joint source coding is analysed. Huffman code is used as source code and 3 symbols {a,b,c} with Probability{0.2,0.1,0.7}are considered for analysis of joint source coding.

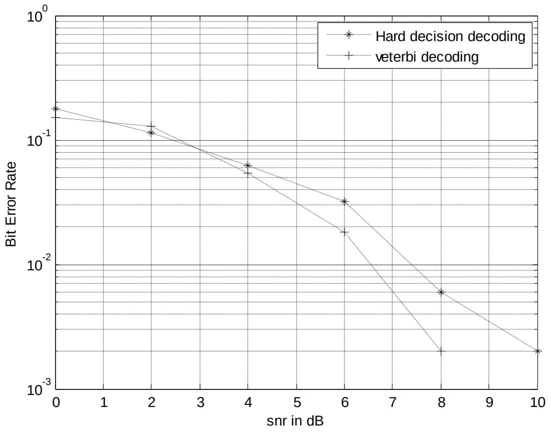

Fig.5 Comparison of VLC with hard decision Decoding and Soft decision decoding

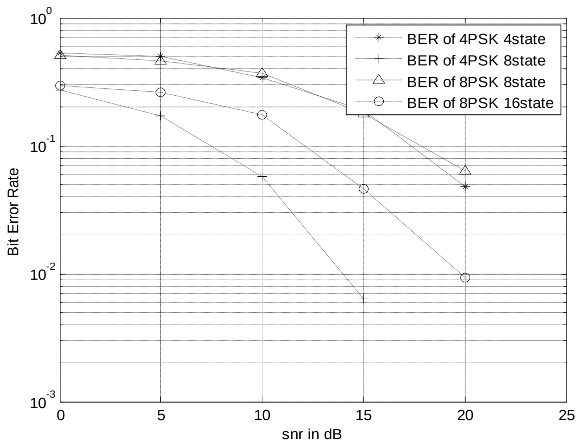

Fig.6 BER Performance of Joint Source Channel Coding with various State MPSK STTC modulation

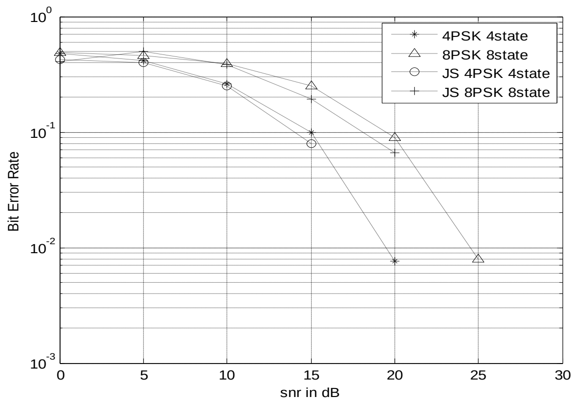

Fig.7 BER performance of STTC modulation with and without joint source coding

The AWGN channel and non-selective frequency fading channel is used for simulation. The VLC with soft decision decoding gives an extra 3dB gain than with hard decision decoding is shown in Fig.5. The BER performance of STTC modulation with different states is analysed. The simulation result in Fig. 6 shows that 4PSK, 8state yields an extra 6.98 dB gain than 8PSK ,16state. The analysis shows that by increasing the number of states, we could improve the BER performance. The simulation result (Fig.7) shows that STTC with joint source coding gives better BER performance than STTC without joint source coding.

VI. CONCLUSION

In this paper combined source channel coding using Space Time Trellis Code as channel code is implemented. The performance of Space Time Trellis Code with joint source channel coding and without joint source coding is analysed. From the simulation results it is inferred that Space Time Trellis Code with joint source coding gives better BER performance . And also the performance of various states of MPSK STTC is analysed. The results show that BER performance can be improved by increasing the number of states.

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