SPACE-TIME TRELLIS CODE'S PERFORMANCE EVALUATION CONSIDERING BOTH FEED FORWARD AND RECURSIVE STRUCTURE ACROSS WIRELESS CHANNELS

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ABSTRACT

The emerging new technologies demands for reliable communication of data at high data rates making wireless communication a challenging field. The major limitations in wireless communications are power, bandwidth and fading. Especially in the applications such as video broadcasting and image transmission requires high data rate and bandwidth. In such applications Space Time Trellis Code Modulation (STTCM) is used to improve the data rate, power efficiency, coding gain and diversity gain by maximizing spatial diversity. The available Space Time Trellis code Modulation technique uses MPSK STTC with different states and non-iterative decoder .In this paper, we iteratively decode MPSK STTCM with various states and with various number of receiving antennas. And the performance of non-iterative decoder and iterative decoder is analyzed individually and together. Based on the analysis some conclusion is obtained. The non-iterative decoder (STTCM) uses feed forward encoder structure and Viterbi algorithm. The iterative decoder (ST Turbo TCM) uses recursive encoder structure and Log-Likelihood value. The BER performance of iterative decoder and non-iterative decoder with 4-PSK and 8 PSK modulation is analyzed with various numbers of states and with variety of antennas which receives it. Outcomes of the simulation shows that the performance of the BER can be enhanced by raising the number of receiving antennas and raising the number of states. And the results also shows that the BER performance of Space Time Turbo Trellis codes are better than Space Time Trellis Codes.

Keywords: *Space Time Trellis Code, Feed Forward Structure, Recursive Structure, Space Time Turbo Trellis Code, BER Performance.*

1. INTRODUCTION

The Wireless Communication is one of the vibrant areas in the communication field today. Due to the need of Internet, cellular mobile and the services of Multimedia, the essential of wireless communication increased worldwide. Bin this regard, spectral efficiency is to be increased so that the communication capacity can be met for the need. The consistency and the need of mobility based communications is considerably restricted by attenuation disturbances, propagation losses and interferences. To stabilize the fading effects, diversity techniques are regularized. Recently, these methodologies are adapted in multiple transmitting which is adapted at transmitting edge and receiving points which is adapted at receiving edge, largely increases the capacity of a wireless link without expanding the bandwidth of the channel[1],[3].

The error performances of the multiple antennas transmission is improved by combining error control coding and transmit diversity. The above combination provides both coding gain and benefits of diversity. Because of code redundancy, it affects reduced bandwidth efficiency. This is focused as a major drawback in wireless communication areas [5][6][7][12]. To suppress the loss in bandwidth efficiency, alternative design is introduced. This model has transmit diversity and the bandwidth is not enhanced. Also, it has joint design code of error control. And there is a focus with multiple antennas which has Space time coding technique. In coding structures, three different approaches are used [2][13], which are:

i. Space-time trellis codes (STTC)
ii. Space-time block codes (STBC)
iii. Layered space-time codes (LST)
iv. Space-time turbo trellis codes (STTTC).

Obtaining a full diversity improvements with a simple coding algorithm is the important key feature of space-time block codes [4][5].It is very simple to implement but this scheme does not provides coding gain and the non- full rate STBC introduces expansion of the bandwidth [8][9]. STTC: space- time trellis codes are called as an effective signalling which is developed by transmit and receive diversity joint design of error control coding and modulation. STTC combats the fading effects [10][11]. STTC combines trellis coding and a selected constellation to achieve the maximum spatial diversity at high code rate. They provide both diversity and coding gain using high decoding complexity. It became extremely popular because it offers coding improvement with spectral efficiency and full diversity over fading channel.

Here, Section-II explains the general system model of STTCM, Section-III describes the encoder structure for STTCM and ST Turbo TCM, Section-IV explains the calculation for decoder using Veterbi algorithm and Log-Likelihood value, Section-V describes the Simulation results and finally Section-VI describes the conclusion of our proposed work.

2. STTCM SYSTEM MODEL

The schematic diagram of STTCM system in [1] is given in the Fig 1. In the system, the input binary stream $\boldsymbol{c}^k = (c_0, c_1, \ldots \ldots)$ was randomly generated. The data is passed via serial to parallel converter. Further, these are categorized as number of transmitting antennas, n_t, streams of data. Further, a channel encoder encodes the converted data for better clarity in encoding. The output of processed data is modulated and passed through MIMO channel. The MIMO channel considered here is frequency non- selective slow fading channel and frequency selective fast fading channel and it is expected that it is identified at the receiver. The MIMO channel transmits the modulated signal using transmitting antenna. The receiving antenna receives the transmitted signal along with noise signal and hence, the transmitted signal is corrupted by fading.

At every moment of time t, the output of the encoder x_t^p for the pth antenna is given by,

$$x_t^p = \sum_{k=1}^{m} \sum_{R=0}^{v_k} g_{R,p}^k c_{t-R}^k \bmod 2^m \qquad (1)$$

Here, $p = 1,2,3 \ldots n_t$. The system transmits the signal over slow and flat fading MIMO channel. With the number of transmitting antennas as $1 < T < n_t$, and the number of receiving antennas as $1 < R < n_r$, so, the antenna 'j' receives this signal in a said time't'. Which is shown below,

$$r_t^R = \sum_{T=1}^{n_t} h_{T,R} * x_t^T + \eta_t^R \qquad (2)$$

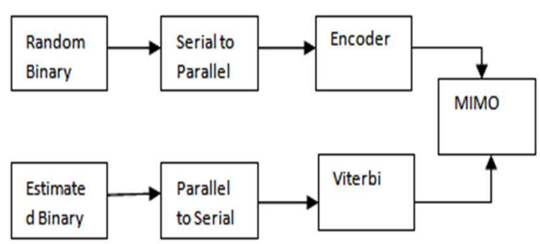

Fig 1. Sttcm System Model

Here, $h_{T,R}$ is the complex route gain for the route from acquiring antenna R to broadcasting antenna T, x_t^T is a transmitted signal from respective antenna T at time t, η_t^R . The received signal in matrix form is given by,

$$\boldsymbol{Y} = \boldsymbol{Hx} + \boldsymbol{\eta} \qquad (3)$$

where $,\boldsymbol{x} = [x_t^1, x_t^2, x_t^3 \ldots, x_t^{n_t}]$

$$\boldsymbol{\eta} = [\ \eta_t^1,\ \eta_t^2,\ \eta_t^3 \ldots\ \eta_t^{n_r}]$$

$$\boldsymbol{H} = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1n_t} \\ h_{21} & h_{22} & \cdots & h_{2n_t} \\ \vdots & \cdots & \cdots & \vdots \\ h_{n_r1} & h_{n_r2} & \cdots & h_{n_rn_t} \end{bmatrix}$$

This is said to be Additive White Gaussian Noise component of the signal.

3. ENCODER STRUCTURE

The encoder is classified as feed forward STTC encoder and Recursive STTC encoder. Feed forward structure is used in STTCM and Recursive structure is used in ST Turbo TCM.

A. Construction of Feed forward encoder

In the modulation of space-time trellis codes, the encoder function of this appropriately fits the binary-detailed information data to the modulation based information symbols.

And, this mapping function is thoroughly explained by diagram [1]. So, the given input for message M is defined by,

$$\boldsymbol{M}^k = (M_0, M_1, \ldots, M_t \ldots)$$

Here, M_t is represented as block of m= $\log_2$M. Further, At time t, the information bits and encoded symbol of the sequences are transmitted from the specified antenna value 'i' is represented as,

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

So the given signals which are modulated that is, $\mathrm{x}_t^1, \mathrm{x}_t^2, \ldots, \mathrm{x}_t^{n_t}$, are continuously transmitted through $\mathrm{n_t}$ based transmit antennas. Fig.2 Shows the 4-PSK scheme encoder structure attached with two transmit antennas with 'v' memory order.

The M-PSK scheme($\mathrm{M} = 2^{\mathrm{m}}$), at the specified time t, the given transmitting antennas of two quantities, m binary inputs $M_t^1, M_t^2, \ldots M_t^m$ are placed into the branches; Mc_t^1 is shown as MSB (most significant bit). The required quantity values of a memory element in every given branches are $v_1, v_2, \ldots, and\ v_m$. Finally, the available total available memory $v = v_1 + v_2 + \cdots + v_m$.

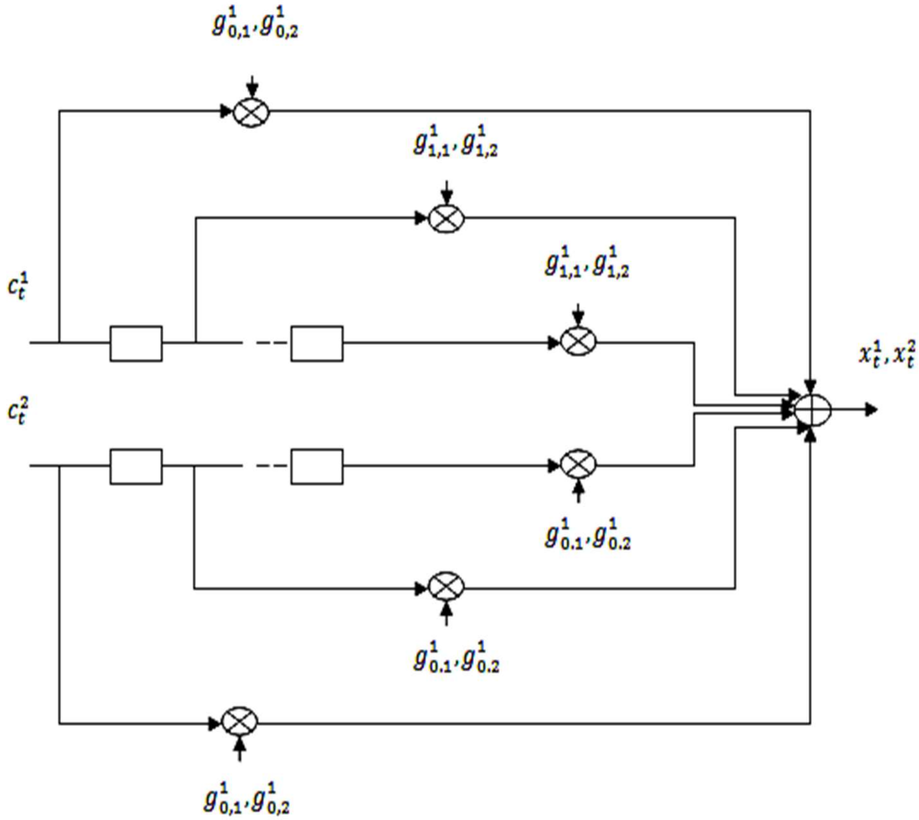

Fig 2. Feed Forward STTC Encoder Of STTCM For 4-PSK Scheme

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The v_i value is identified by,

$$v_i = \left\lfloor \frac{v+T-1}{m} \right\rfloor, \; T = 1, 2 \ldots m \qquad (4)$$

Here, $\lfloor k \rfloor$ is a integer which is largest one and this is lesser value than the identified *k value*. Further, input bits 'm' are little delayed. And then these are multiplied by the coefficient pairs $(g^1_{x,1}, g^1_{x,2})$, $(g^2_{y,1}, g^2_{y,2})$ for m = 2, and $(g^1_{x,1}, g^1_{x,2})$, $(g^2_{y,1}, g^2_{y,2})$, $(g^3_{z,1}, g^3_{z,2})$ for m = 3, Here, value of $x = 0, 1, \ldots v_1$, $value\ of\ y = 0, 1, \ldots v_2$, $and\ value\ of\ z = 0, 1, \ldots v_3$. The outputs of Multiplier are received and the same is added with modulo M. Added to that to receive our required output x_t^1 and x_t^2. The output x_t^1 is transferred by the first antenna. Further, second antenna transmits x_t^2 concurrently. So, the trellis encoder acquires the total number of states with 2^v. Here, coefficient pairs are identified by generator matrix. Fig.3 shows about trellis diagram and it is received from the earlier discussed encoder for the given QPSK 4-state.

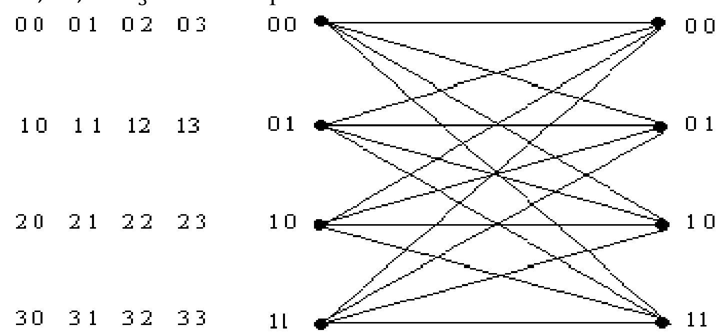

Fig 3. Trellis Diagram Of QPSK-4

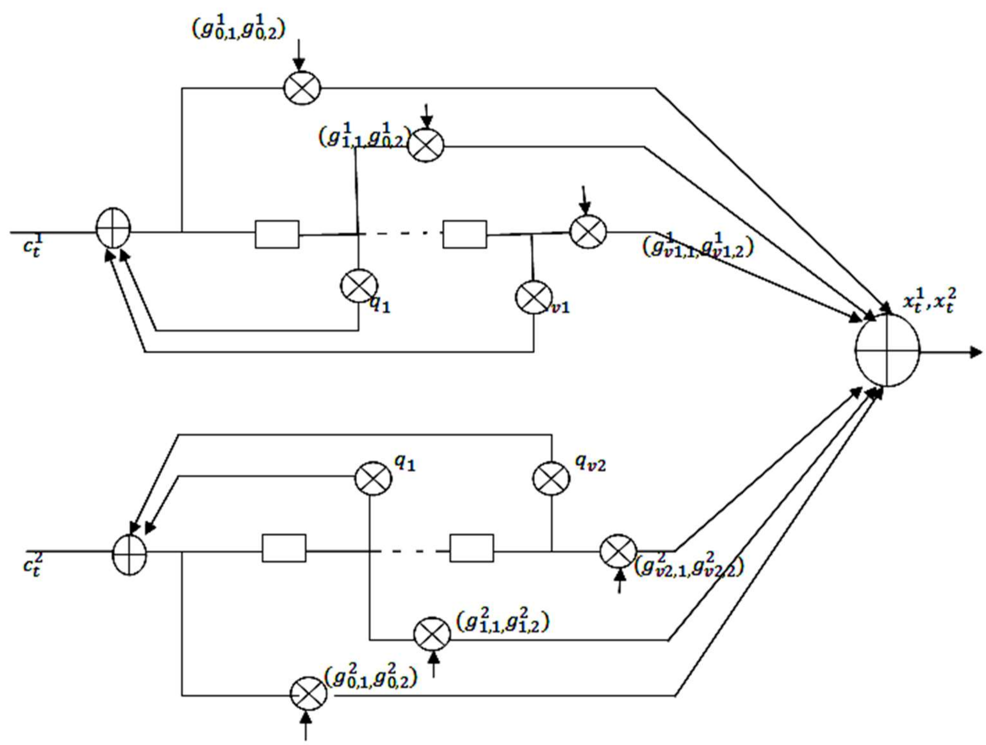

Fig.4. Recursive STTC Encoder For 4PSK Modulation

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A. Construction of Recursive encoder

We now assume a STTC: feed-forward encoder for two antennas and QPSK and the same is shown in Fig 2. Here, $v = v1 + v2$ *is the* memory order, where $v2 >= v1$ and $v_i = \left\lfloor \frac{v+T-1}{2} \right\rfloor$ *and* T = either 1 or 2 applied.

Antenna T transmits the sequence of encoded symbols as shown below,

$$x(D)^i = c^1(D)G_T^1(D) + c^2(D)G_T^2(D) mod\ 4 \quad (5)$$

Further, we can write the relationship (5) in the following pattern:

$$x^T(D) = c^1(D)c^2(D)\begin{bmatrix} G_T^1(D) \\ G_T^2(D) \end{bmatrix} \text{mod } 4 \quad (6)$$

The feed-forward generator matrix from equation (6)

$$G_T(D) = \begin{bmatrix} G_T^1(D) \\ G_T^2(D) \end{bmatrix} \quad (7)$$

These values are converted into like comparable value of recursive matrix. This is done by splitting the values by the binary-polynomial '**q***(D)'* degree which is less than or almost equal to $v1$. Further, **q***(D)*is selected as a primitive polynomial, result of recursive code should be with minimum of distance [2]. So, the given antenna, polynomial (generator) *i* is described:

$$G_T(D) = \begin{bmatrix} \frac{G_T^1(D)}{q(D)} \\ \frac{G_T^2(D)}{q(D)} \end{bmatrix} \quad (8)$$

Where,

$$q(D) = q_0 + q_1 D + q_2 D^2 + \cdots . + q_{v1} D^{v1}$$

Here, binary coefficients values are qR , R = 0, 1, 2, . . . , $v1$. STTC, systematic of recursive are received by setting$G_1(D) = \begin{bmatrix} 2 \\ 1 \end{bmatrix}$. That is, first antenna output is received by fixing the input sequences into a QPSK's **c**1 and **c**2 directly. The QPSK STTC recursive encoder attached with n_T antennas in [2] is described Fig 4. And its corresponding trellis diagram is shown in Fig 5.

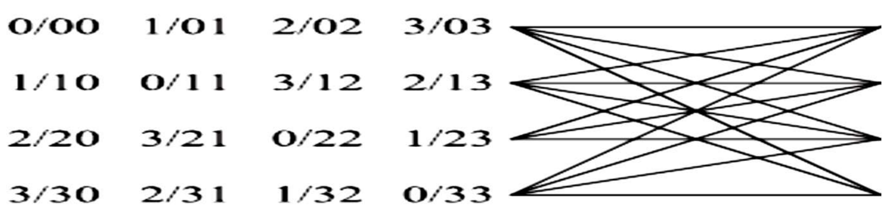

Fig 5. Trellis Diagram Of 4PSK 4 State Recursive STTCM

The code gain and diversity are same in construction method along with feed-forward coefficients with feed forward STTC.

B. Construction of Space-Time Turbo Trellis Code

STTCs which is shown previous method is specified in the parallel concatenated schemes and utilised as component codes. The same is benefits from inter-leaver gain and iterative decoding. ST's encoder structure ST turbo TC with n_T transmit antennas is shown in Fig.6, has two separate recursive STTC of encoder [2]. Every encoder operates on *m* information bits message in individual block, where *L* is the inter-leaver size.

The received message blocks are arranged and the sequence of this **is**,

$$c = (c_1, c_2, \ldots . c_t \ldots .. , c_L),$$

Here, **c***t* value is at time *t,* the block of information bits 'm', which is described: $c_t = (c_{t,0}, c_{t,1}, \ldots . c_{t,m-1})$, the input sequence is mapped by given upper value of recursive STTC encoder which is shown in Fig. 6. Further, this is mapped with L M-PSK symbols' n_T streams $x_1^1, x_1^2, \ldots . x_1^{n_T}$ and here, $x_1^T = (x_{1,1}^T, x_{1,2}^T, \ldots .. x_{1,L}^T, T \in \{1,2, \ldots .. n_T\}$ and $M = 2^m$; symbol inter-leaver interleaves the information bits which is specified earlier for the encoding done by another lower encoder.

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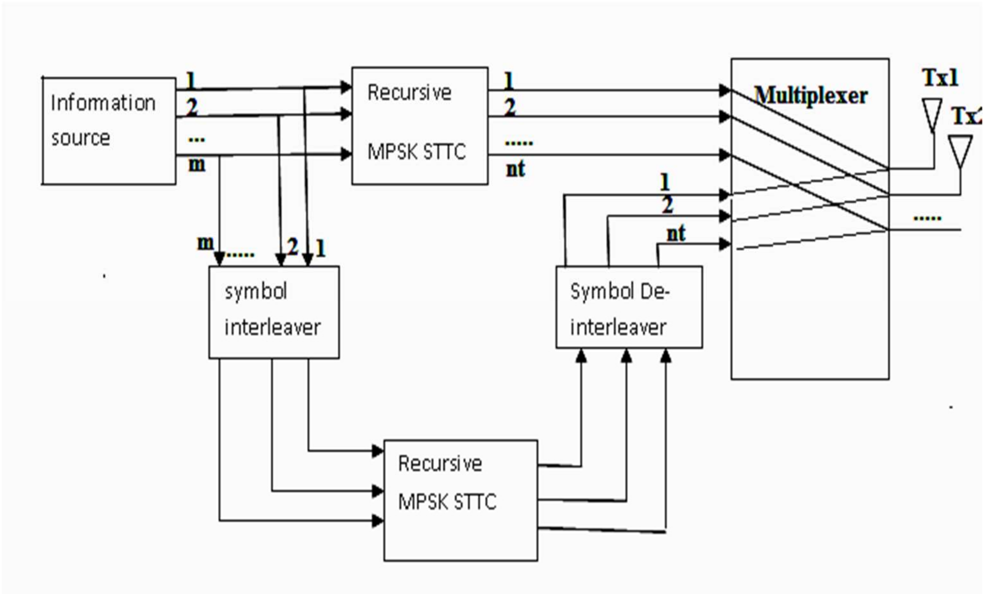

Fig 6.Encoder For ST Trellis Coded Modulation

When we calculate bits, symbol inter-leaver functions on symbols of m bits. But, it should be with single identity bits. Further, lower encoder delivers n_T streams of lower L M-PSK. Before multiplexing and puncturing, each stream is de-interleaved. De-interleaved stream is been characterized as

$$x_1^1, \quad x_1^2, \quad \ldots.\ x_1^{n_T}$$

Where, $x_1^i = (x_{2,1}^i, x_{2,2}^i, \ldots..x_{2,L}^i,$ and the value $i \in \{1,2, \ldots..n_T\}$. So, the specified sequence of symbols created by the upper encoder followed by the lower encoders, x_1^i and x_2^i . And that is a reason the output received from this encoder is attached to antennas (n_T) on the specified symbols interval time t .

4. DECODER

A. A Viterbi-algorithm used for Space Time Trellis Codes

To decode Space-Time Trellis Code, Viterbi algorithm utilises Trellis pattern code format. When the set of channel symbols are received, decoder receives it and calculates it. Sometime, for the result Hamming distances are also used in Viterbi decoding for hard decision. Further, Euclidean distances are used in Viterbi decoding for soft decision. Further, branch metrics are calculated. These branch metrics are called as the connecting paths at earlier time and the states are at present time. We have to assume that information of the channel pattern is identified to specified decoder. So, the path gains know $h_{T,R}$, where $1 \le T \le n_t$ and $1 \le R \le n_r$. Also, branch metric of the transition is labelled $s_t^1, s_t^2, \ldots\ s_t^{n_t}$ and the same is given by,

$$\sum_{R=1}^{n_r} \left| r_t^R - \sum_{T=1}^{n_t} h_{T,R} * s_t^T \right|^2 \qquad (9)$$

To calculate the path with accumulated metric with lowest value, the Viterbi algorithm is proposed.

B. Calculation of Log-Likelihood Ratio (LLR) for Space-Time Turbo Trellis Codes

The decoder structure in [2] is given in Fig 7. Antenna R, receives the signal where $R = 1, 2, \ldots, n_R$, at time t , the same is calculated as,

$$r\,{}_t^R = \sum_{i=1}^{n_t} h_{T,R}{}^t * x_{p,t}^T + \eta_t^R \qquad (10)$$

Where component encoder's output is $x_{p,t}^T$; p value of t when value $p = 1$ at t (odd-time instants). Further, at t $p = 2$ (even-time instants),.

At every individual antenna, the received sequence is R, $R = 1, 2, \ldots, n_R$, which is de-multiplexed into two separate vectors. and it is identified as and identified as upper, r_1^R ; lower encoder, r_2^R. So, the specified vector values are given to both first decoder and second decoders,

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respectively. These symbols in the decoder input vectors are identified as erasures and the same as listed below:

$$r_1^R = (r_1^R, 0, r_3^R, 0, r_5^R, \dots,)$$
$$r_2^R = (0, r_2^R, 0, r_4^R, 0, \dots,)$$

The vector r_1^Ra is placed into the beginning decoder directly which is placed first, while the vector $r_2^R$is placed into the next located via the symbol inter-leaver, which is placed second. The process of decoding is almost equal to value of binary codes. The probability value of symbol is calculated as information relatively to that probability value of bit, only except this others are proceeded. Since the non-binary values are proceeded, the algorithm to decode the MAP, for the same is defined as MAP symbol-by-symbol algorithm. Further, the functions of decoder on a trellis with *Ms* states.

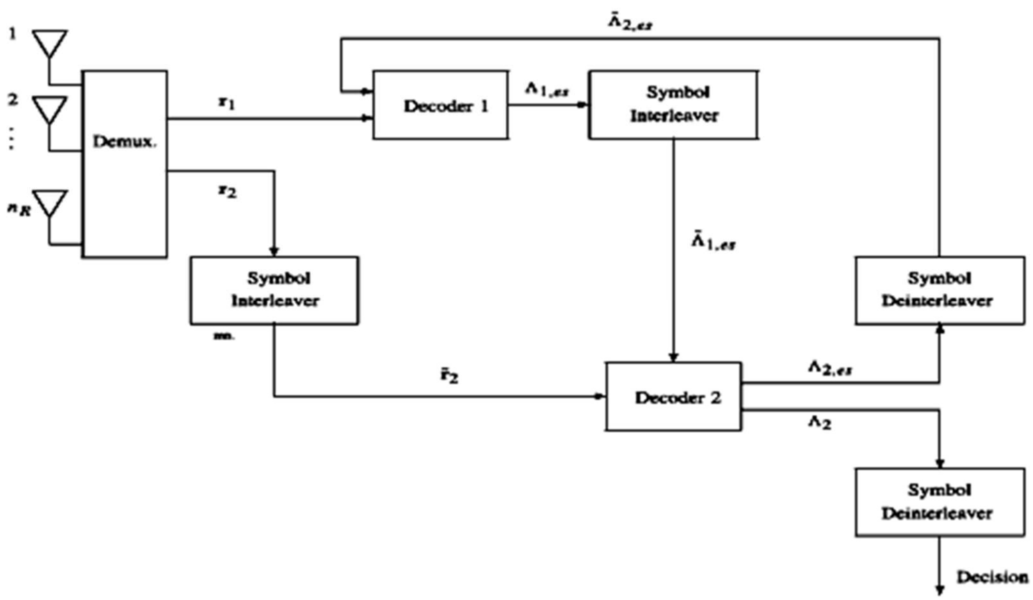

Fig.7 Decoder Structure For Space-Time Turbo Trellis Code

Recursive variables (forward) is calculated as,

$$\alpha_t(l) = \sum_{l'=0}^{M_s-1} \alpha_{t-1}(l') \sum_{T=0}^{2^m-1} \gamma_t^T(l', l) \qquad (11)$$

Initial values are assumed as, $(0) = 1$,
$\alpha_0(l) = 0, \ \ l \neq 0$
Backward recursive variable is calculated as
$$\beta_t(l) = \sum_{l'=0}^{M_s-1} \beta_{t+1}(l') \sum_{T=0}^{2^m-1} \gamma_{t+1}^T(l', l)$$
(12)

Initial values are assumed as,

$$\beta_\tau(0) = 1; \beta_\tau(l) = 0; \ \ l \neq 0$$

transition probability for the branch at time t is computed by,

$$\gamma_t^T(l', l) = \begin{cases} \frac{p_t(T)}{p_t(0)} exp\left(-\frac{\sum_{R=1}^{n_R} \left| r_t^R - \sum_{n=1}^{n_T} h_{R,n} x_t^n \right|}{2\sigma^2}\right), & for\ (l', l) \epsilon B_t^T \\ \gamma_t^T(l', l) = 0, otherwise \end{cases} \qquad (13)$$

5. SIMULATION RESULTS

The performance of BER M-PSK with Space Time Trellis Coded Modulation through Frequency non-selective channel and frequency selective channel is performed. Fig 8 shows the performance of M-PSK STTCM with One receive antenna. And the results shows that ,4PSK 16 state gains 10 dB than 4PSK 4state.Similarly 8PSK 16 state gains 4.7 dB than 8PSK 8state.By considering the overall performance 4PSK yields more gain than 8PSK.

Fig 9 shows the Performance of 4-PSK STTCM with 4state and various receive antenna. It is simulated

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in both AWGN channel and Rayleigh fading channel with different number of receive antennas (1, 2, 3, 6, 10 and 20).The gain achieved by 20 receive antenna is 13dB compared with 1 receive antenna. The result shows, when the number of receive antenna is increased the diversity then gain is also increased.

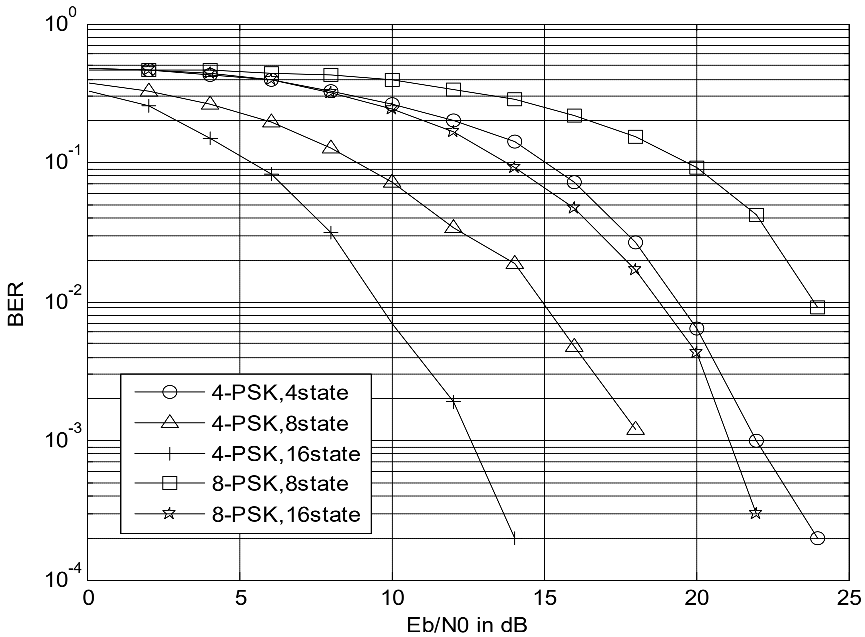

Fig 8. Performance Of BER M-PSK STTCM With One Receive Antenna

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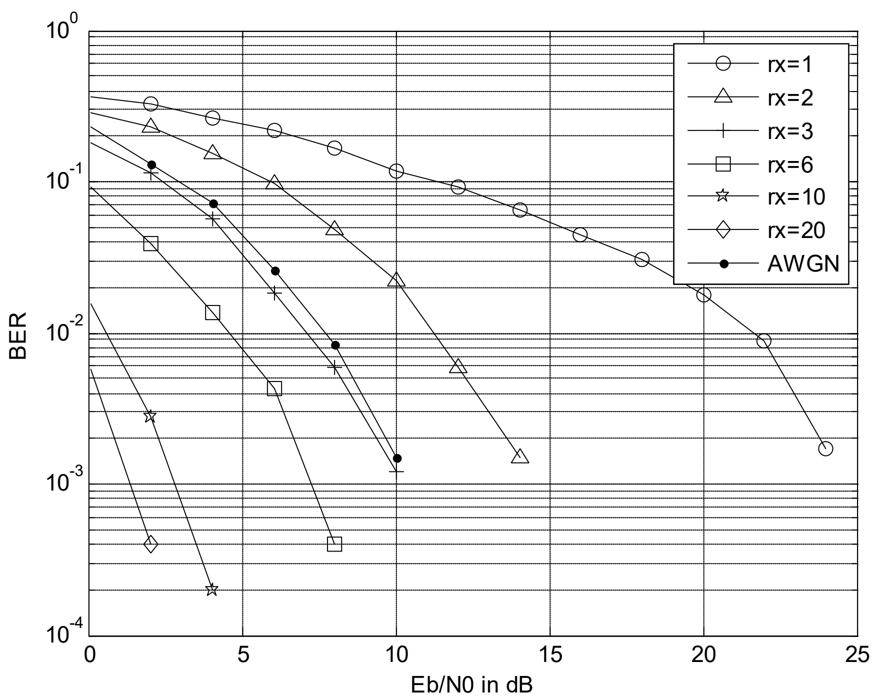

Fig 9. Performance Of BER 4-PSK STTCM With 4 State And Various Receive Antennas

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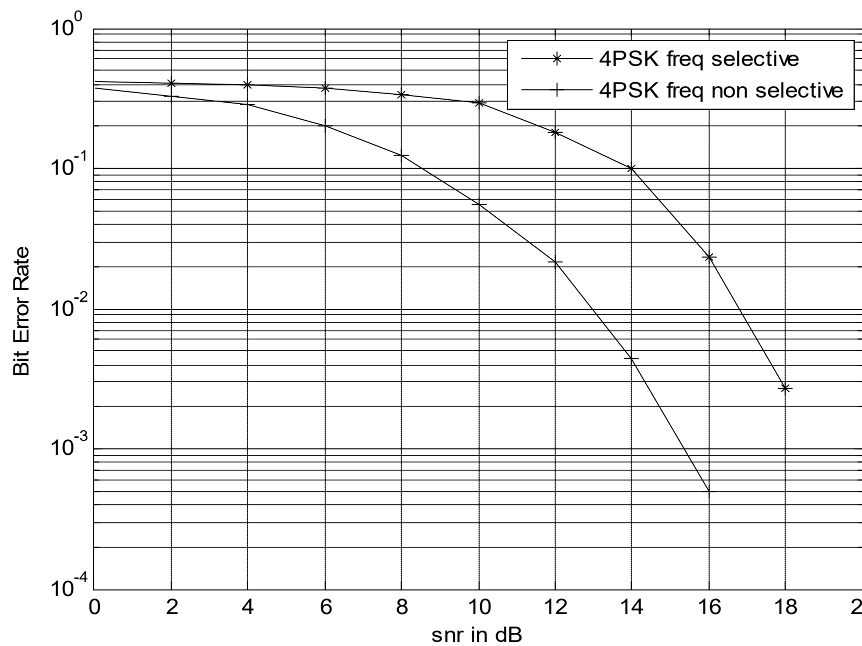

Fig 10. 4 PSK 4 State With Frequency Selective And Frequency Nonselective Channels

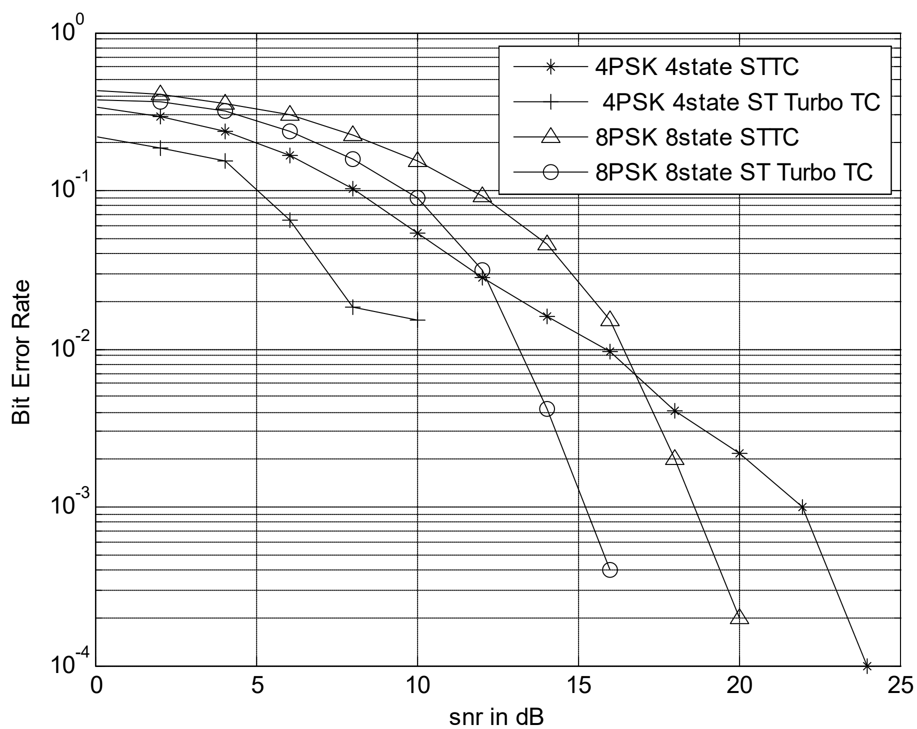

Fig 11. BER Performance Of STTC With Space-Time Turbo Trellis Code

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Fig 10 shows the performance of 4 PSK 4 State STTCM with frequency selective and frequency nonselective channels.And the results shows that frequency non-selective yields 3 dB gain than with frequency selective channel.The process of STTC is shown in Fig.11, with ST Turbo Trellis Code. And the results shows that ST Turbo TC gains 11 dB and 6 dB for 4 PSK 4state and with 8PSK 8state respectively than with STTC. The overall performance shows that Space Time Turbo Trellis code is better than Space Time Trellis Code.

6. CONCLUSION

In this paper we analysed the Performance of MPSK STTCM with various number of states and with various number of receiving antenna.Iterative decoder and non iterative decoder performance with recursive structure and with feedforward structue respectively, also compared. From the analysis we observed that the performance of BER is improved by increasing number receiving antennas and states. Further, it is observed that Iterative decoding gives better results than with non iterative decoding.

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