Performance analysis of Trellis coded 16 QAM Mapping for CDMA

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Abstract : ***Code Division Multiple Access (CDMA) is a form of digital modulation technique uses spread spectrum for data transmission. This feature provides immunity from jamming, interference and facilitates multiuser access of spectrum. In general the spread spectrum signal occupies bandwidth greater than the required for sending information. Hence, there is a need to identify an efficient coding and modulation technique that compensates this high bandwidth usage. For this purpose conventional CDMA uses Trellis coded Quadrature Amplitude modulation. In practice, the interleaved Trellis encoded data in CDMA spreads the burst of errors caused by slow fading process and provides high flexibility in identifying the bit errors. On the other hand, QAM is an efficient modulation scheme for transmission of high bit rate without increasing bandwidth. So this paper focuses to improve the performance of conventional CDMA system with the implementation of Trellis coded 16 Quadrature Amplitude modulation. The adaptability to program on various cellular hardware modules, made this paper chose 16-QAM for implementation. AWGN channel with Rayleigh fading is considered while implementation and its performance for long burst and short burst errors with Viterbi decoding. Bit Error Rate (BER) is the metric used for performance evaluation of the proposed algorithm.***

Index Terms - CDMA, Soft Decoding, Trellis codes, Viterbi Decoding, 16QAM

I. INTRODUCTION

Random variations in the received power with respect to time is known as fading of the channel. Fading is due to multiple paths of the received signals and due to Doppler frequency shift. This gives time varying delays and attenuation of the signals at the receivers. The fading channels causes short burst of errors due to fast fading, long burst of errors due to slow fading in the channels. Fading occurs in the form of attenuation scattering and energy loss. This attenuation is due to vehicle speed, vegetation, concrete structures, hills and valleys, and also depends upon the location of the receiver[1]. The energy loss can be estimated by considering Additive White Gaussian Noise (AWGN) channel, or statistical model such as Rician fading channel, for village environment and Rayleigh channel for city environment. Trellis coding with16-QAM is proposed for cellular communications especially for correcting short and long burst errors.

II. Trellis coded modulation

Consider TS is the transmitted signal duration with a bandwidth of BS. Due to the behavioral change in the channel the signal duration changes to TC, which causes Doppler shift in bandwidth BD. When the signal duration is TS <<TC slow fading occurs that causes long burst errors. Where as if the signal duration is TS >> TC then the fast fading occurs and results in short burst errors[1]. Both the types of errors can be corrected by the convolutional coding and decoding techniques with 16-QAM. The process of signal encoding with 16-QAM[3], its transmitter and receiver sections along with the convolutional encoder are shown in Fig.1to 4 respectively.

III. Convolutional coding and 16-QAM

Convolutional encoding is an efficient bit wise mapping implemented with shift registers and modulo (2) adders as shown in Fig. 4. The encoder[4] is provided with an input bit stream u(n) in synchronous to a clock and provides the encoded bit stream v(n) at its output. The bit sequence u(n) is represented as [U0,U1,U2- - - - - - - -UK-N] with K as the length of the input sequence. The encoder has n number of D Flip Flops and has an output with bit length, n and will have 2^n states (i.e. 00,01,10,11)[2] .Eq.1 and Eq.2 represents the output bit sequence of the two convolutional encoders and the final coded bit stream from the encoder is given in Eq.3.

Output 1 of Convolutional encoder = $\boldsymbol{U_0}^{(1)}\boldsymbol{U_1}^{(1)}\boldsymbol{U_2}^{(1)}$- - - - - - - -$U_{k-1}{}^{(1)}\boldsymbol{U_k}^{(1)}\boldsymbol{U_{k+1}}{}^{(1)}$ (1)

Output 2 Convolutional Encoder = $\boldsymbol{U_0}^{(2)}\boldsymbol{U_1}^{(2)}\boldsymbol{U_2}^{(2)}$- - - - - - - -$\boldsymbol{U_{k-1}}^{(2)}\boldsymbol{U_k}^{(2)}\boldsymbol{U_{k+1}}^{(2)}$ (2)

Coded output = $\boldsymbol{V(n)}=\boldsymbol{U_0}^{(1)}\boldsymbol{U_0}^{(2)}\ \boldsymbol{U_1}^{(1)}\boldsymbol{U_1}^{(2)}$ - - - - - - - -$\boldsymbol{U_{k-1}}^{(1)}\boldsymbol{U_{k-1}}^{(2)}\ \boldsymbol{U_k}^{(1)}\boldsymbol{U_k}^{(2)}\ \boldsymbol{U_{k+1}}^{(1)}\boldsymbol{U_{k+1}}^{(2)}$ (3)

In order to modulate the encoded bits, v(n), they are fed to a mapper which generates a complex output, S1(t), from which the final 16-QAM output is generated and represented as S2(t) given in Eq.4 and 5 respectively[3]

$$S1(t) = \sum (aki - bki)\ \delta(t - kt) \quad (4)$$
$$S2(t) = \sum ak,i\ P(t-kt) \cos \omega ct - bk,i\ P(t-kt) \sin \omega ct) \quad (5)$$

Here , ak,i , bk,i follows the values ± d, ±3d ,where d is the distance between the symbols T represents the symbol duration δ(t) is the unit impulse S2(t) is the modulated signal and P(t) represents low pass equivalent impulse response.

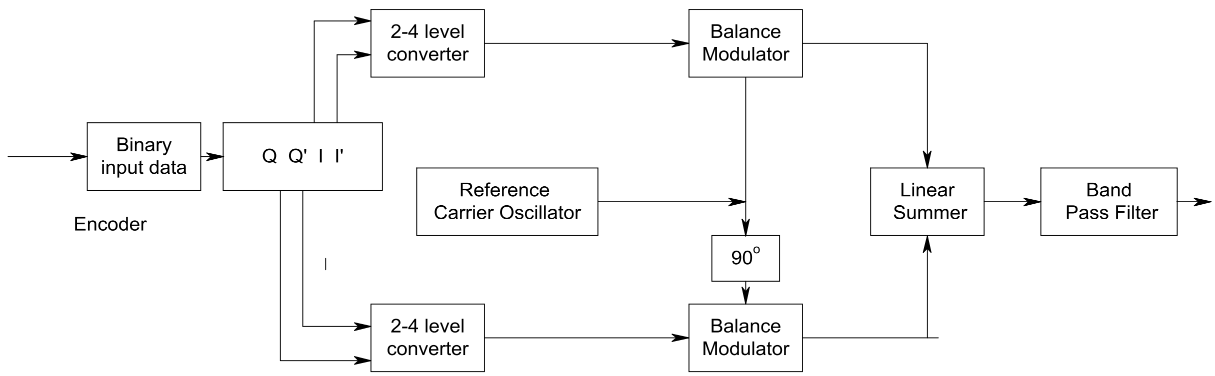
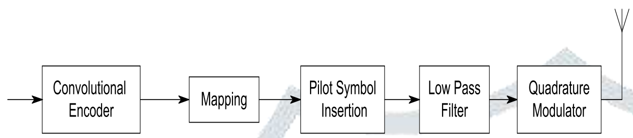


Fig .1 Encoder with 16 QAM Transmitter



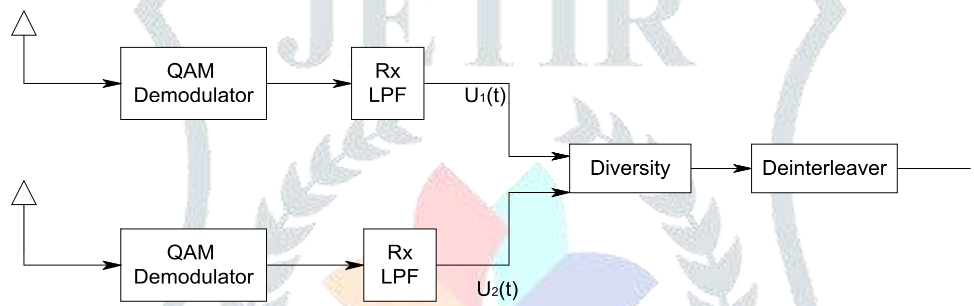


Fig. 3 Receiver

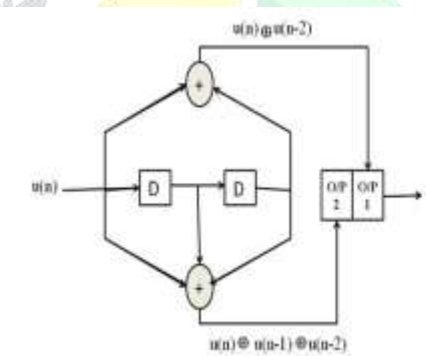


Fig. 4 convolutional encoder

In the proposed 16-QAM transmitter, the input binary data is divided into four channels i.e, inphase channels I,I' and quadrature phase channel Q,Q' respectively. The bit rate in each channel is equal to one fourth of input bit rate, Fb (i.e. Fb/4).[4] The I and Q bits determines the polarity at the output of 2 to 4 level converter in which logic 1 represents to positive polarity and logic 0 represents to negative polarity. Whereas the other two channel bits I',Q' determines the logic 1 with a magnitude of 0.821 V and logic 0 with 0.22 V. Table.1 provides the output magnitude levels of 16-QAM system for the corresponding I and Q channels.

Table .1 Truth table of I and Q channel for 16- QAM

Binary input				**16-QAM Output**	
Q	**Q'**	**I**	**I'**	**Amplitude**	**Phase**
0	0	0	0	0.311V	-135°
0	0	0	1	0.850V	-165°
0	0	1	0	0.311V	-45°

0	0	1	1	0.850V	-15°
0	1	0	0	0.850V	-105°
0	1	0	1	1.161V	-135°
0	1	1	0	0.850V	-75°
0	1	1	1	1.161V	-45°
1	0	0	0	0.311V	135°
1	0	0	1	0.850V	165°
1	0	1	0	0.311V	45°
1	0	1	1	0.850V	15°
1	1	0	0	0.850V	105°
1	1	0	1	1.161V	135°
1	1	1	0	0.850V	75°
1	1	1	1	1.161V	45°

IV. Viterbi Decoder

Viterbi decoding has the advantage that it has fixed decoding time. Its computational requirements grow exponentially as a function of the constraint length. With Trellis coded modulation (TCM) encoding, one can transmit binary data signals of 5 dB less power than without coding5.

The received signals are quadrature demodulated and applied to Viterbi decoder[5] after passing through low pass filter. It is an efficient implementation of maximum likelihood (ML) decoder. The search procedure passes through Trellis decoder. For each path Trellis compares the path metric between the receive sequence and possible code sequence and decides the shortest path.

Viterbi decoder choose the code vector which estimates the minimum hamming distance between the received vector,'r' and the transmitted vector,'c'. Maximum likelihood decoding for AWGN channel with soft decision decoding is to minimise the squared Euclidian distance between received vector given that 'c' is transmitted Hamming distance which will be used as a measure of closeness between two sequences.

V. Results and Discussion

The proposed Trellis coded 16 QAM technique for CDMA is implemented using Matlab R2010a software. RZ-Unipolar bit pattern of length 90000 is generated and are interleaved using Trellis coding. The implemented Trellis coder uses ½ Forward Error Code (FEC) rate, which represents two bits for every input bit provided. These interleaved bits are then used for modulation using 16-QAM modulator and provides the required voltage level according to Table.1.

For decoding purpose, Viterbi decoder with soft level (4-Level) and Hard level is implemented and their performance in terms of BER is given in Table.2. Also the obtained BER with varying Eb/No for Rayleigh fading AWGN channel is plotted in Fig.5.

Table. 2 BER Comparisons between Hard decision and soft decision decoding

Eb/No (dB)	**Bit error rate Hard decision**	**No of Errors in Hard decision**	**Bit error rate soft decision**	**No of Errors in soft decision**
1	0.4597	41354	0.3160	28430
2	0.4155	37386	0.1842	16569
3	0.3297	29663	0.0612	5510
4	0.2094	18841	0.0124	1117
5	0.0962	8658	0.0011	103
6	0.0283	2546	0.0000	2
7	0.0065	585	0	0
8	0.0010	91	0	0
9	0.0001	8	0	0
10	0	0	0	0

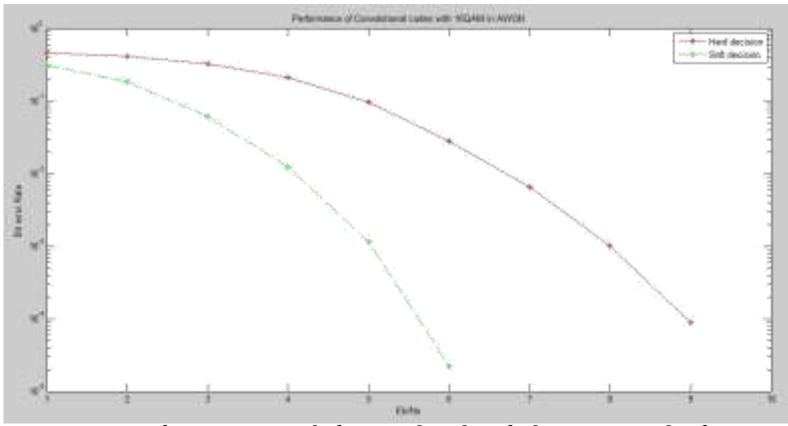


Fig .5 Error performance graph for Hard and Soft decision results for rate-1/2

VI. Conclusion

The performance of Trellis coded 16-QAM technique is observed for CDMA application. A convolutional encoder with FEC rate ½ is used as a Terllis encoder and the performance evaluation is carried with a Raleigh fading Additive White Gaussian Noise channel. The simulation results demonstrates that for various channel Eb/No the Trellis coding with 16-QAM improves BER performance. It is also observed that Trellis coding with 16- QAM with 90000 bits as a input, has a BER of 0.2094 (with errors 18841), 0.0124 (with errors 1117) for Hard and Soft decoding respectively. It can conclude that the proposed technique with soft decision decoding has an efficient utilization of bandwidth for a given error rate.

VII. References

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