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COMPARISON OF CONVOLUTIONAL AND TRELLIS CODED OFDM FOR SATELLITE CHANNELS

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Abstract

Orthogonal frequency-division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. The data is divided into several parallel orthogonal sub-carriers. Each orthogonal sub-carrier signals are used to carry data and is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate. In this paper, Convolutional and Trellis Coded Modulation is considered with OFDM for a Rician fading channel according to the specifications given by the Iridium system. Bit error rate (BER) performance is analyzed for both the coding techniques with different modulation schemes for L and Ka bands. Trellis coded OFDM gives the better performance compared to convolutional coded (CC) OFDM systems. Peak to average power ratio (PAPR) of the transmitted message is reduced by using partial transmit sequence technique (PTS).

Keywords: OFDM, PAPR, Convolutional & Trellis coding, PTS, satellite channel, Rician channel, Hard Viterbi Decoding

Introduction

Properties like spectral efficiency and robustness to channel fading (Rician and Rayleigh fading environments) make OFDM favourable to be used in high speed digital communication for both wired (terrestrial communication) and wireless (satellite communication). Nowadays, Digital audio and video broadcasting are the applications in which OFDM is mainly used.

Advantages of OFDM in Satellite Communication

OFDM reduces the probability of error in received bits by dividing the channel into narrowband flat fading subchannels. Hence it is more resistant to frequency selective fading than single carrier systems such as FDMA and helps OFDM to provide good protection against co-channel interference. It increases reliability on satellite communication as modulation & demodulation is done using FFT and IFFT operations which are computationally efficient.

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Block Diagram of Convolutional and Trellis Coded OFDM system Model

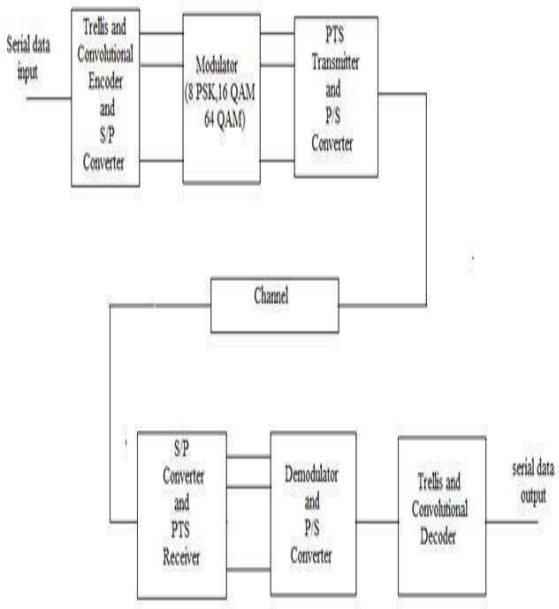

Figure1 Convolutional and Trellis Coded OFDM system Model

Convolutional Coding

A convolutional encoder can be realised by a shift register. It encodes the information (message) bits that are to be transmitted. The outputs of the encoder are modulo 2 sums of the values in the flip-flops of register denoted as (n,k,m) where „n" represents no. of modulo 2 adders used in encoder, „K" represents no. of bits passed in circuit at a time, „m" represents no. of flipflops used in encoder, k=m+1 represents number of shifts required for each single message bit to enter the shift register and finally come out and is called as constraint length, K/n represents code rate which implies that for each k input bits, there are n output bits.

Figure2 Convolutional Encoder

Trellis Coded Modulation

Trellis coded modulation(TCM) is a combination of coding and modulation which allows resourceful transmission of information over band-limited channels such as telephone lines.Compared to convolutional encoding method it is more efficient and consists of a Trellis code and a Constellation Mapper. It combines the functions of a convolutional coder of rate R=k/k+1 and a M-ary signal mapper that maps

M= 2^k input points into a larger constellation of M= 2^{k+1} constellation points.

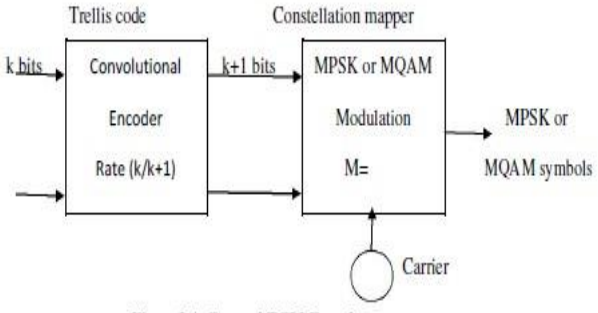

Figure3 A General TCM Encoder

PAPR Reduction Method

In addition to being robust against narrowband interference, OFDM is efficient in dealing with multipath and hence is an effective modulation

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scheme for high speed transmission links. However, large peak-to-average (PAPR) ratio is one major obstacle about OFDM as it distorts the signal if the transmitter contains nonlinear components such as power amplifiers (PAs).High PAPR is undesirable for it usually strains the analog circuitry and increases the Bit Error Rate (BER) of the system. The PAPR of OFDM signal can be written as

$$\text{PAPR} = \frac{max[|x_n|^2]}{E[|x_n|^2]}$$

Among PAPR reduction methods, the PTS (partial transmit sequences) offers high-quality PAPR reduction performance as it has no limitation to the number of subcarriers. In this scheme, the input symbols are divided into different non-overlapping subblocks and Inverse fast Fourier transform (IFFT) is applied to each subblock. Each corresponding time-domain signal is multiplied by a rotation factor (1,-1,j,-j) at the phase rotation stage and the time domain with the lowest PAPR is transmitted so that peak to average power will be minimized.

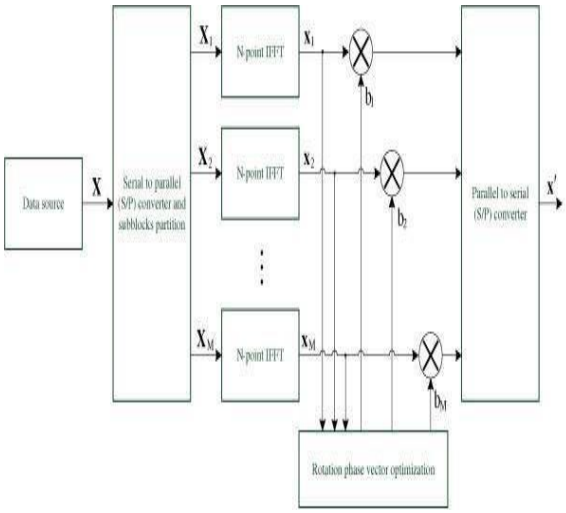

Figure4 Block Diagram of Partial Transmit Sequence

Channel Description

LEO Satellite channels are time-varying and thus cause significant fading. Iridium system with LEO satellite
channel is used with the following specifications:
Carrier frequency (fc): 1.62125 GHz (L-band) and 29.2 GHz (Ka-Band) Satellite
speed (v): 27100km/hr
Doppler frequency (fd): 40.68 KHz (L-band) and 732.7 KHz (Ka-band)

Viterbi decoding method

Viterbi decoding is an optimal Algorithm for decoding a code. It is utilized for relatively short codes as the decoding complexity grows exponentially with the code length. Hard viterbi is one of the way of viterbi decoding in which Hamming distance is calculated for the received bits and the final path is traced with survivor path.The convolved and trellis coded data can be decoded using hard viterbi decoding algorithm.

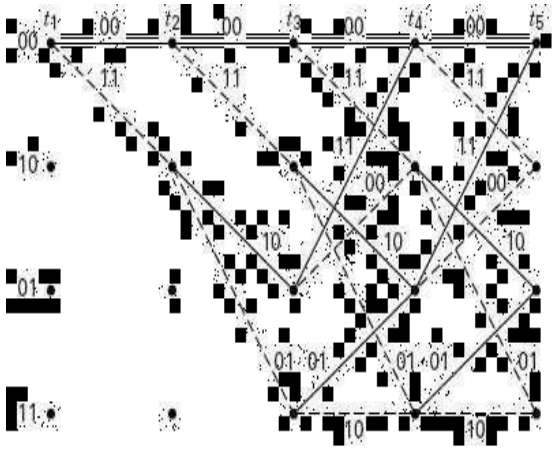

Figure5 Trellis Code Diagram for above Convolutional Encoder

Results and Discussion

1. Comparison of BER for different Modulation Schemes:

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Table1. Comparison using L-Band Channel

Modulation Scheme	Convolutional Coding	TCM Coding
BPSK	0.2236	-
QPSK	0.4839	0.1892
8-PSK	0.4883	0.2550
16-PSK	0.5133	0.4063
16-QAM	0.5167	0.4382

Table2. Comparison using Ka-Band Channel

Modulation Scheme	Convolutional Coding	TCM Coding
BPSK	0.2268	-
QPSK	0.4362	0.1872
8-PSK	0.4761	0.2578
16-PSK	0.5014	0.4072
16-QAM	0.5152	0.4278

From the above tables we infer that the BER performance for TCM is better than convolutional coding and as the order of modulation increases BER increases.

2. Comparison of PAPR using Partial Transmit Sequence:

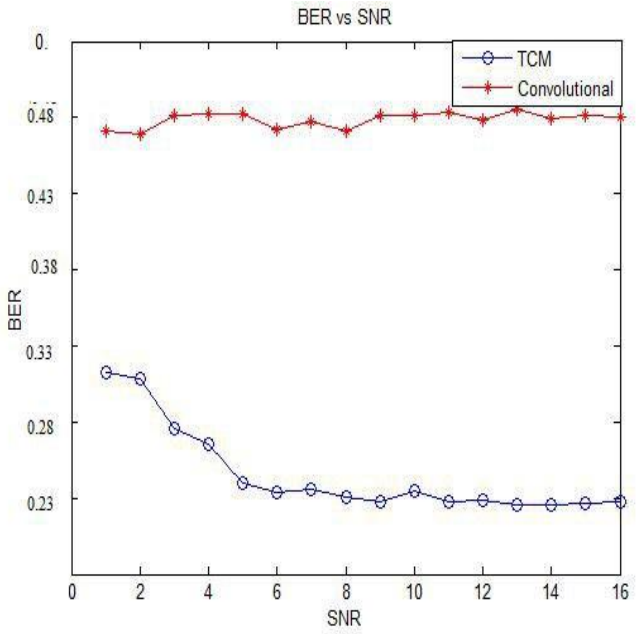
Table3. Comparison using L-Band Channel

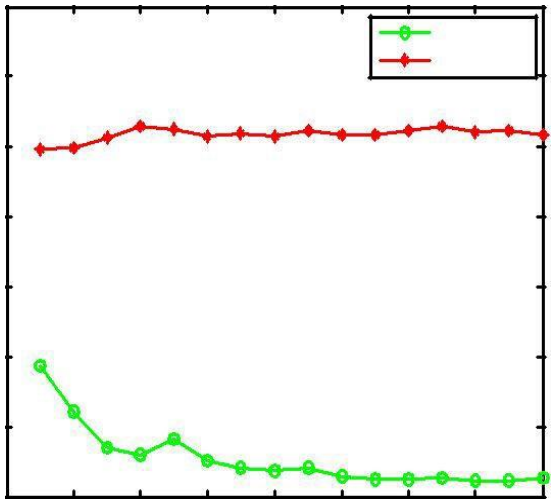
	Modulation Scheme	PAPR without PTS(dB)	PAPR with PTS(dB)
Convolutional Coding	BPSK	9.6754	9.2029
	QPSK	22.578	16.7821
	8-PSK	24.87	19.099
	16-PSK	25.39	19.4348
	16-QAM	25.37	19.3152
TCM Coding	QPSK	22.069	19.065
	8-PSK	1.7263	1.547
	16-PSK	2.3956	2.1803
	16-QAM	25.23	18.82

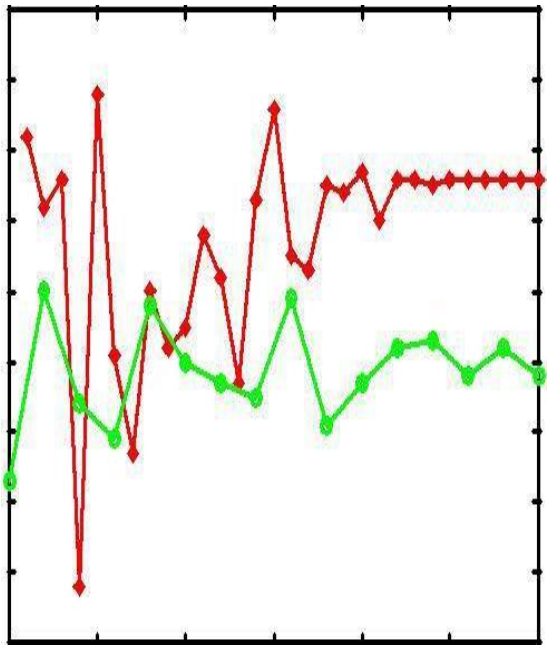
Table4. Comparison using Ka-Band Channel

From the above tables we infer that PAPR is reduced in range of 1-6 dB using PTS technique.

3. Comparison of BER and SNR:







Conclusion:

Performance of convolution and trellis coding techniques has been studied by simulation and results show that Trellis Coded Modulation gives the better performance compared to Convolution coding schemes for all modulation schemes considered .PAPR of the transmitted information is reduced in range
of 1-6 dB using PTS technique. The slope for trellis code is high for high SNR values and therefore, it can be concluded that decoding complexity of trellis is higher than that of convolution coding.

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