Combined Selective Mapping and Turbo Codes for PAPR Reduction in OFDM Signals

S.P.Vimal [1] and K.R. Shankar Kumar [2]
Department of Electronics and Communication Engineering,
Sri Ramakrishna Engineering college, Tamil Nadu, India
Email: mahin.v.k@gmail.com

Abstract - Orthogonal frequency division multiplexing (OFDM) is a multicarrier modulation technique where the 4G wireless applications are focused towards this technology. The major drawback of OFDM system is high Peak to average power ratio .The proposed work is based on peak to average power ratio (PAPR) reduction by the implementation of turbo codes. Comparison of PAPR is carried out for different types of turbo codes. Simulation results shows that the Hybrid convolutional concatenated codes (HCCC) gives a better reduction of PAPR when compared to other convolutional concatenated codes applied in this paper.

Keywords: Orthogonal frequency division multiplexing, Hybrid convolutional concatenated codes, Peak average power ratio, Selective mapping technique.

I. INTRODUCTION

Nowadays the wireless applications are focused towards high data rates. The concept of multi carrier transmission provides high data rates in communication channel. The OFDM is a special kind of multi carrier transmission technique that divides the communication channel into several equally spaced frequency bands. Here the bit streams are divided into many sub streams and send the information over different sub channels. A sub-carrier carrying the user information is transmitted in each band. Each sub carrier is orthogonal with other sub carrier and it is carried out by a modulation scheme. Data's are transmitted simultaneously in super imposed and parallel form. The sub carriers are closely spaced and overlapped to achieve high bandwidth efficiency. The main disadvantage of OFDM systems is high peak to average power ratio. The peak values of some of the transmitted signals are larger than the typical values. High PAPR of the OFDM transmitted signals results in bit error rate performance degradation, inter modulation effects on the sub carriers, energy spilling into adjacent channels and also causes non linear distortion in the power amplifiers. The main work of this paper is to reduce the high peak powers in OFDM systems. Several PAPR techniques like clipping, coding, partial transmit sequence, tone reservation and tone injection are there to reduce high peak signals [1,2 , 3]. In this study the concept of selective mapping technique (SLM) is applied to the OFDM symbols to reduce high peak signals. SLM method effectively reduces PAPR without any signal distortion[4], but it has higher system complexity and computational burden. This complexity can be solved by reducing the number of Inverse fast fourier transforms (IFFT) blocks. The literature survey defines the usage of turbo codes based on parallel concatenated convolutional codes for PAPR reduction [5]. The powerful error correction capability of turbo codes was recognized and accepted for almost all types of channels leading to increased data rates and improved Quality of Service. Turbo codes can operate at 0.1 dB from the Shannon capacity limit outperforming any other coding technique known today and performs good role in the PAPR reduction of OFDM systems. The proposed work is based on the utilization of hybrid concatenated convolutional codes. The encoding procedure is carried out for serial, parallel, multiple, tail biting and hybrid concatenated convolutional codes in OFDM transmitter section [9, 10,15] . Peak to average power reduction ratio is calculated and compared with all the five codes. The power signals of all the above codes are viewed in complementary cumulative distribution function (CCDF) plot [11]. The results state that the application of hybrid concatenated convolutional codes attains a good PAPR reduction when compared to other types turbo codes.

II. SLM AND PAPR

In selected mapping method (SLM) a whole set of candidate signals is generated representing the same information, and then the most favorable signal as regards to PAPR is chosen and transmitted. SLM scheme is one of the initial probabilistic approaches for reducing the PAPR problem, with a goal of making occurrence of the peaks less frequent, not to eliminate the peaks [11].The scheme can handle any number of subcarriers and drawback associated with the scheme is the overhead of side information that needs to be transmitted to the receiver.

In presence of large number of independently modulated sub-carriers in OFDM systems, the peak value of the some signals can be very high as compared to the average of the whole system. The complex envelope of an OFDM signal is an overlap of' N' complex oscillations with different frequencies, phases and amplitudes. As a result, we get a time domain signal with high Peak to Average Power Ratio. These peaks may cause signal clipping at high levels and may force the amplifier in the transmitter side to work in the non linear region, thereby producing frequency components in addition to the original and results in out of band radiation [7,8]. The major concept of this paper is to reduce the high peak value before the transmission is carried out. The ratio of the peak to average power value is termed as Peak-to-Average Power Ratio. Mathematically PAPR can be given as

$$\mathbf{PAPR} = \frac{\max|x(t)|^2}{E\left[|x(t)|^2\right]} \tag{1}$$

In Equation (1), the $\max|x(t)|^2$ is the peak signal power and $E\left[|x(t)|^2\right]$ is the average signal power. The average power is calculated using the formula as in Equation (2)

$$\text{Average Power} = \frac{\text{Sum of magnitude of all the symbols}}{\text{Number of symbols}} \quad (2)$$

III. PROPOSED SLM TRANSMITTER WITH TURBOCODES

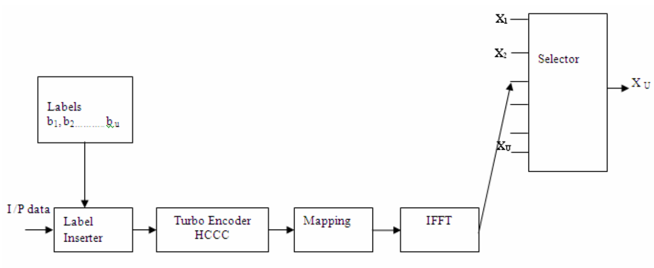

Fig.1. Block diagram of the proposed SLM Transmitter

Figure1 represents the block diagram of the proposed system. Input bits are applied randomly and passed to the label inserter. Labels are used to generate the same data in different form in the selective mapping technique. The number of labels depends on the 'U' value, where 'U' is the number of SLM paths. The SLM path may vary from 1, 2, 4, 8……U paths where $U=2^m$ different sequences and 'm' defines the length of the inserted bits [6, 14]. Insertion is nothing but the concatenation of each of the labels to the same data.

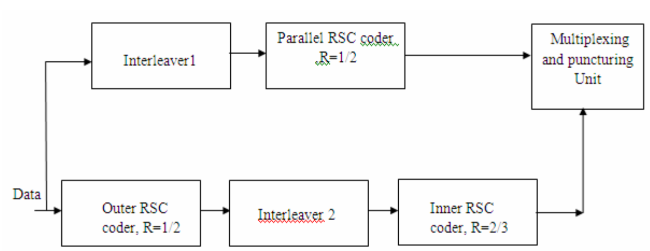

Fig .2.HCCC-Turbo encoder

Figure 2 represents the HCCC encoder. The Parallel concatenation and serial concatenation turbo encoders are combined to form HCCC .The block diagram consists of two interleavers , three RSC(inner, outer and parallel RSC), multiplexer and puncturing unit. Interleaving is basically a way to arrange the input data in order to protect against burst errors and to increase the latency of the system. A hybrid concatenated convolution code with two interleavers is the parallel concatenation of an encoder which accepts the permuted version of the information sequence as its input and with serially concatenated code which accepts the un-permuted information sequence[12,13] .The serially concatenated code consists of an outer encoder, an interleaver and an inner encoder. A recursive systematic convolutional codes (RSC) produces a low weight output with low probability however some inputs still causes a low weight outputs .The code description and generator polynomial for hybrid concatenated convolutional codes is given in table 1.

Table 1: Code Description and Generator Polynomial of HCCC

Code Description	Generator Polynomial
Rate 1/2 Recursive Parallel	[1,5/7]
Rate 1/2 Non Recursive outer	[7,5]
Rate 2/3 Recursive Inner	[1,0,5/7] ,[0,1,6/7]

The concept of multiplexing denotes the reordering of output bits of an encoder into a composite form .The output from the multiplexing unit is in the form of matrix which contains systematic bits in first row, Parity bits I in the second row and parity bits II in the third row .The outputs from the multiplexing unit represents the coding rate 1/3. In order to reduce the coding rate from 1/3 to 1/2, the concept of puncturing is done. In error correction codes puncturing is done to remove some of the parity bits after encoding the data. Puncturing increases the flexibility of the system without increasing its complexity. The puncturing principle applied in this work is to minimize the systematic bits and to provide approximately equal puncturing of parity bits for the two encoders [16]. The encoded data is mapped with QAM 16 which is best suited for the SLM technique with OFDM symbol. After mapping N point IFFT is performed .The IFFT process the 'N' symbols at a time where 'N' is the number of subcarriers in the system. Each of the 'N' input symbols has a symbol period of 'T' seconds which acts like a complex weight for the corresponding sinusoidal basis function. Since the input symbols are complex, the value of the symbol determines both the amplitude and phase of the sinusoid signals. The IFFT outputs is the summation of all 'N' sinusoids The IFFT block provides a simple way to modulate data into 'N' orthogonal subcarriers .The signal from the IFFT block is fed to the selector. Then PAPR is calculated and the selector selects the path with lowest PAPR and assigned for transmitting the OFDM signal.

IV ALGORITHM

STEP 1: Get the No. of Symbols (N)

STEP 2: Get the No. of SLM paths (U)

STEP 3: Enter 0 for puncturing and 1 for no-puncturing. If puncturing data rate of the encoder is 1/2 else data rate is 1/3.

STEP 4: Initialize the threshold values and count values for plotting $PAPR_0$ vs Probability graph

STEP 5: Generate the input bits of N symbols of length 4 bits each (4 * N bits) such that 0's and 1's are of equal probability.

STEP 6: From the 'U' value, calculate the length of the labels and initialize the labels.

STEP 7: Turbo encoding (parallel, serial, Multiple, Hybrid, tail biting) function to be performed is called. The parameters passed are N, U, labels, data and puncture. The output of the encoder is returned from the function.

STEP 8: Once the bits are encoded, Mapping is done. Before mapping, check for zero padding.

STEP 9: Re-assemble the zero padded bits symbol-wise, so that mapping becomes easier. Map the zero-padded bits using QAM-16.

STEP 10: Compute N point IFFT of the mapped sequence.

STEP 11: Calculate the PAPR value

STEP 12: Calculate minimum PAPR for each iteration. Calculate the probability that the PAPR exceeds the threshold values in the case of U=1, 8, 16, 32 .

STEP 13: Plot the CCDF graph between threshold and probability values (threshold on x-axis and Probability (PAPR>threshold) on y-axis

STEP 14 : Compare the output results for (parallel, serial, Multiple, Hybrid, tail biting) with HCCC.

STEP 15 : Stop the program

A. ALGORITHM FOR HYBRID CONCATENATED CONVOLUTIONAL CODES

STEP 1: Get the parameters N, U, Labels, data and puncture. Concatenate the data and labels such that labels are inserted before data. Therefore 'U' SLM paths are created.

STEP 2: Define the trellis structure for inner encoder 1 with its respective constraint length & Generator polynomial

STEP 3: Convolutionally encode (RSC 1) the concatenated bits according to the trellis structure defined. Feedback is given to the convolutional encoder such that it becomes recursive systematic convolutional encoder.

STEP 4: Generate a random interleaved pattern (variable: rand). Interleave the convolutional encoder RSC1 output (parity bits) using the generated interleaved pattern

STEP 5: Define the trellis structure for outer encoder 1 with its respective constraint length & Generator polynomial. Convolutionally encode the interleaved data (RSC2), according to the new trellis structure defined.

STEP 6: Generate a random interleaved pattern (variable: rand 2).Define the trellis structure for parallel encoder with its respective constraint length & generator polynomial. Convolutionally encode the interleaved data, according to the new trellis structure defined.

STEP 7: The output of the serial inner and outer encoders are converted into a rate ½ encoder output using the general puncturing pattern.

STEP 8: Re-organize the output bits from the two encoders (serial and parallel). Separate the systematic & parity bits from serial output and parallel output. The systematic bits of parallel encoder can be left since it is an interleaved version input/systematic bits .

STEP 9: Re-organize the systematic bits, parity bits (serial RSC), parity bits (parallel RSC) into a matrix form (multiplexed output) forming row 1, row 2, row 3 respectively.

STEP 10: If puncture='0' go to step 10.If puncture='1' go to step 11.

STEP 11: Puncture even parity bits for odd systematic bits and odd parity bits for even systematic bits and the output is returned.

V SIMULATION AND RESULTS

The complementary cumulative distribution function (CCDF) of the PAPR is one of the most frequently used methods to check how often the PAPR exceed the threshold values. Graph is plotted among threshold and CCDF values. The CCDF can be calculated by the relation P (PAPR>X) = 1-P(PAPR<X).The fixation of threshold value ranges from zero to maximum value. The formula for calculating the threshold value is

Threshold = 0:(Maximum PAPR - Minimum PAPR) / Maximum PAPR: Maximum PAPR

Turbo encoding was carried out for Serial, parallel, multiple, tail biting and hybrid concatenated convolutional codes. PAPR is calculated for all the above turbo codes using SLM technique and the path with lowest PAPR is selected for transmission .The constraint length and generator polynomials represented in octal base for the different types of turbo codes chosen is given in the table 2

Table 2: Generator Polynomial and constraint length representation for different types of turbo codes

Turbo codes	Constraint Length of RSC Block	Code Description	G(D)	Octal No
Parallel	4	RSC1	$[1+D^2 / 1+D+D^2 , 1]$	15/17 , 1
		RSC2	$[1+D^2 / 1+D+D^2 , 1]$	15/17,1
Serial	3	RSC1	$[1, 0, 1+D^2/1+D+D^2]$	[1,0,5/7]
		RSC2	$[0, 1, 1+D /1+D+D^2]$	[0,1,6/7]
Multiple	4	RSC1	$[1+D^2 / 1+D+D^2 , 1]$	15/17 , 1
		RSC2	$[1+D^2 / 1+D+D^2 , 1]$	15/17,1
		RSC n	$[1+D^2 / 1+D+D^2 , 1]$	15/17,1
Tail Biting	4	RSC1	$[1+D^2 / 1+D+D^2 , 1]$	15/17,1
		RSC2	$[1+D^2 / 1+D+D^2 , 1]$	15/17,1

Simulations were carried out by using MATLAB 7.6 software. The OFDM signal with N=128 subcarriers, 16 QAM mapping, coding rate 1/2 and 1/3 was considered .The SLM paths selected in this work is U=1, 8, 16, 32 .Simulation results are shown from figure 3 to figure 8 .

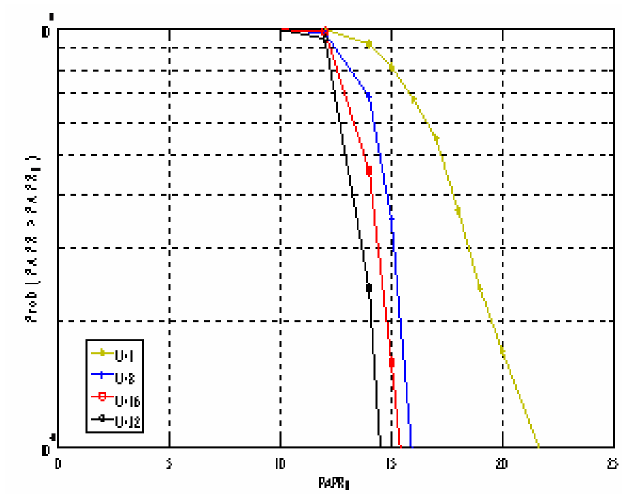

Fig .3. N=128; U=1, 8, 16, 32; Punctured (rate=1/2) HCCC

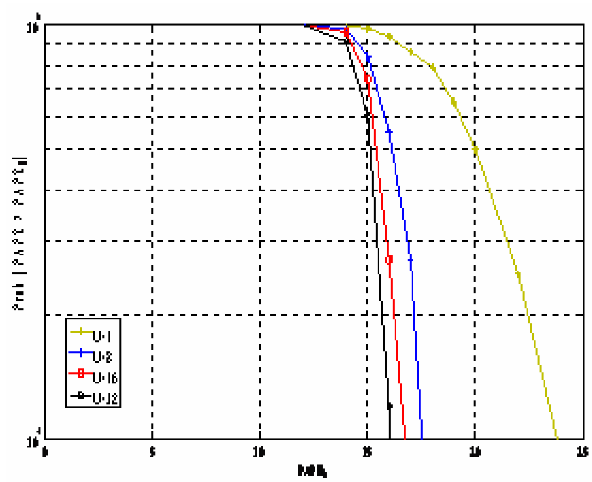

Fig .4 . N=128; U=1, 8, 16, 32; Un- Punctured (rate =1/3) HCCC

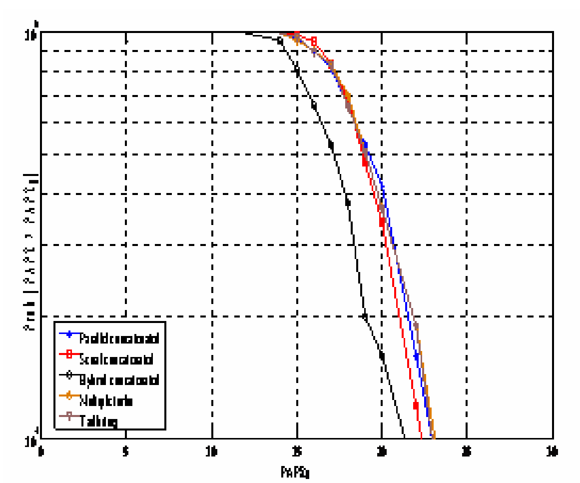

Fig. 5 N=128; U=1; Punctured (rate=1/2) Turbo codes (Parallel, Serial, Hybid, Multiple and Tail Biting)

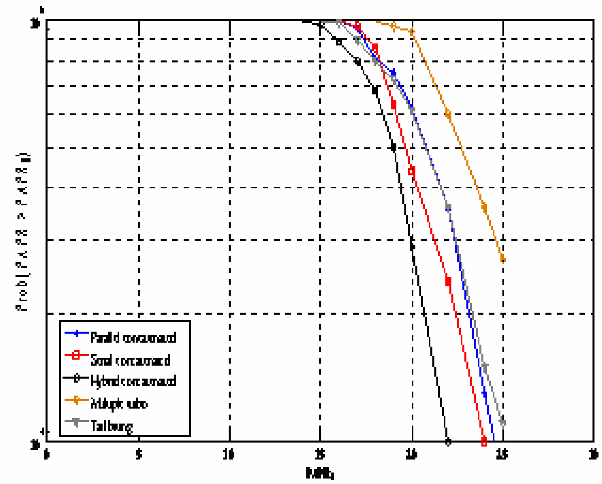

Fig .6. N=128;U=1;Un-Punctured(rate=1/3), Turbo codes (Parallel, Serial, Hybid, Multiple and Tail Biting)

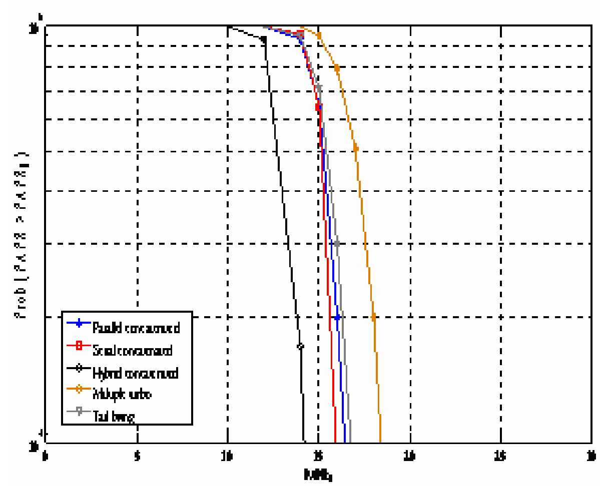

Fig .7. N=128; U=32; Punctured (rate=1/2), Turbo codes (Parallel, Serial, Hybid, Multiple and Tail Biting)

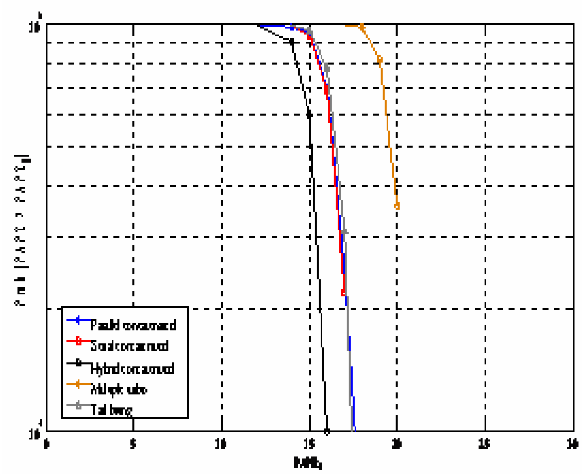

Fig.8 .N=128; U=32;Un-Punctured (rate=1/3), Turbo codes (Parallel, Serial, Hybid , Multiple and Tail Biting)

Figure 3 shows the CCDF plot for HCCC, N=128 (rate = 1/2) for the SLM paths U= 1, 8, 16 and 32. For U=1 the PAPR value is 21.7 dB. There is 0.5 dB difference between U= 8 and 16 and nearly 1dB difference between U=16 and 32. Figure 4 shows the CCDF plot for HCCC, N=128 (rate = 1/3) for the SLM paths U=1, 8, 16, and 32.For U=1 the PAPR value is 23.8 dB and for U=8 to 32 there is an average of 0.7dB difference of PAPR reduction is attained. Simulation results from '1/2' and '1/3' coding rate states that if 'U' value increased the PAPR value gets decreased .Similarly if the coding rate increases the PAPR also increases. Simulations results from Fig 3 and Fig 4 defines that the PAPR value for 1/2 coding rate is around 21 dB for U=1 and for 1/3 coding rate the PAPR value is 24 dB . For all the U values the PAPR increases as the coding rate increased. The PAPR value is calculated and CCDF is plotted for parallel, serial, multiple and tail biting turbo codes. Figure 5 shows the CCDF plot for N=128 for U=1 (1/2 rate).The HCCC attains a good PAPR reduction when compared to serial, parallel, tail biting and multiple turbo codes. There is a 1.6 dB difference of PAPR values between hybrid and parallel and 0.98 dB from serial convolutional concatenated codes. Figure 6 shows the CCDF plot for N=128 for U=1 (1/3 rate). There is 2dB PAPR difference is maintained between serial to hybrid and 0.5 dB differences for parallel, tail biting and multiple turbo codes. Figure 7 shows the CCDF plot for N=128, U=32(rate= 1/2) .The HCCC shows a good performance in PAPR reduction .There is a 4dB difference between multiple and Hybrid turbo codes. The HCCC attains a 22% of PAPR reduction when compared to multiple turbo codes, 15% from tail biting, 13% from parallel and 10% from serial convolutional concatenated codes. Figure 8 shows the CCDF plot for N=128,U=32 (rate=1/3) .The HCCC attains a 20 % of PAPR Reduction when compared to multiple turbo codes and 8.6% from tail biting and nearly 9% from serial and parallel convolutional concatenated codes. The PAPR comparison table for different types of turbo codes with coding rates 1/2 and 1/3 is given in table 3.

Table 3. Comparison Table for family of Turbo Codes with PAPR in dB

Turbo codes	PAPR(dB) for coding rate '1/2' (Punctured)				PAPR(dB) for coding rate '1/3' (Un-Punctured)			
No of Paths	U=1	U=8	U=16	U=32	U=1	U=8	U=16	U=32
Multiple	23.1	20	19	18.31	25	22.5	21.5	20
Tail Biting	23	18.5	17.5	16.71	24.6	18.5	18.2	17.6
Parallel	22.90	18.2	18	16.4	24	19.2	18	17.2
Serial	22.28	17.5	17.4	15.84	23.4	19	17.8	17
Hybrid	21.7	15.9	15.4	14.5	23	17.5	16.72	16.1

The PAPR values in the comparison table is obtained after performing several iterations . The above table defines that the usage of multiple turbo codes shows the highest PAPR values when compared to tail biting and all other codes in this study. The PAPR values of PCCC attains very closer to serial and shows a good improvement when compared to tail biting and multiple turbo codes. The utilization of HCCC gives a good PAPR reduction results when compared to serial, parallel, tail biting and multiple turbo codes. The work is designed for increased number of SLM paths, coding rates and different 'N' values. For all the above parameters the HCCC performs a good role in the PAPR reduction.

VI CONCLUSION

The different types of turbo codes were applied in this work to reduce the peak powers effectively in OFDM signals. These turbo types not only reduce the high peak powers but also it has a better error correction capability when compared to other codes. This advantages leads to reduce the hardware complexity of the system.

REFERENCES

[1] Seung Hee Han , Jae Hong Lee " An Overview of Peak-to-Average power ratio reduction techniques for multicarrier Transmission" IEEE Wireless Communications , 1536-1284, 2005

[2] Tao Jiang and Yiyan Wu "An Overview: Peak-to-Average Power Ratio Reduction Techniques for OFDM Signals" IEEE Transactions on Broadcasting, VOL. 54, 0018-9316, 2008

[3] K. Deergha Rao and T.S.N. Murthy "Analysis of Effects of Clipping and filtering on the performance of MB-OFDM UWB Signals" Proc. of the 15th Intl. Conf. on Digital Signal Processing, 559-562 , 2007

[4] R.W. Bguml , R.F.H. Fischer and J.B. Huber "Reducing the Peak-to-average power ratio of multicarrier modulation by Selected mapping" Electronics letters, 24th October ,Vol. 32 ,1996

[5] Pawan sharma and Seema Verma " PAPR Reduction of OFDM Signals using Selective Mapping with Turbo codes" International Journal of Wireless & Mobile Networks (IJWMN), Vol. 3, No. 4, 217-223, 2011

[6] A. Abdulla and Abouda " PAPR Reduction of OFDM signal using turbo coding and Selective mapping" Proceedings of the 6th Nordic Signal Processing Symposium, NORSI June 9 - 11, Espoo, Finland, 248-251, 2004

[7] P. Foomooljareon and W.A.C. Fernando "PAPR Reduction in OFDM Systems" ThammasaItn. J.Sc.Tech , 7: 70-79,2002

[8] V.Tarokh and H. Jafarkhani " On the computation and Reduction of the peak-to-average power ratio in Multicarrier Communications" IEEE Transactions on Communications, 48 (1), pp, 37– 44, 2000

[9] D. Divsalar and F. Pollara" Multiple turbo codes " Proc. IEEE Military Communications Conference, San Diego, CA, pp. 279-285, 1995

[10] Yung-Chih Tsai and Yeong-Luh Ueng " A Tail-biting Turbo Coded OFDM System for PAPR and BER Reduction" IEEE 1-4244- 0264, 2007

[11] S.P Vimal and K.R. Shankar Kumar."A New SLM

Technique for PAPR Reduction in OFDM systems” European Journal of Scientific Research, ISSN 1450-216X Vol.65, No.2, pp. 221-230,2011

[12] D. Divsalar and F. Pollara “ Serial and Hybrid Concatenated Codes with Applications ”Jet Propulsion Laboratory California Institute of Technology, under contract with the National Aeronautics and Space Administration.

[13] S.Crozier,P.Guinand,J. Lodge and A. Hunt.”Construction and Performance of New Tail-Biting turbo Codes” Communications research Centre, 3701 , Station H, Ottawa Canada.

[14] Marco Breiling , H.Stefan , Müller-Weinfurtner, and Johannes B. Huber “ SLM Peak-Power Reduction Without Explicit Side Information” IEEE Communications Letters, vol.5, NO. 6, 2001

[15] J. Daniel, Costello Jr, Adrish Banerjee, Ching He and Peter C. Massey” A Comparison of Low Complexity Turbo- likeCodes” NSF grants CCR00-75514 and CCR02-05310, Army contract DAAD16-02-C-0057, and NASA grant NAG5-10503.

[16] Maria Kovacil , Horia Baltal , Alexandre de Baynast , Miranda M. Nafomital ”Performance Comparison of Punctured Turbo Codes and Multi Binary Turbo Codes” 1-4244-0969-1 IEEE, 2007.