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Can we Reduce PAPR? OFDM+PTS+SLM+STEGO: A Novel Approach

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ABSTRACT
With the rabid development of the wireless technology, the gadgets that were once a luxury, have now become a necessity. The wireless technology was first developed for army utilisation. But later, because of the wide applications it had, it became a global obligation. But, today, with the advent of internet, the security of the wireless networks has been at a great stake. And also, the new generation of wireless network demands higher data requirements which is achieved by higher data bits per unit bandwidth because of a variety of multimedia applications, cost efficiency, spectral efficiency and security. In this study all of these challenging requirements are met by Orthogonal Frequency Division Multiplexing (OFDM) along with steganography. It is an attractive and explorative area for the next and future generation of wireless multimedia applications. The major challenging issue in the design of an OFDM transceiver is its high Peak-to-Average Power Ratio (PAPR). In this study, design of an OFDM system adopting Partial Transmit Sequence (PTS) and Selected Mapping (SLM) techniques were concentrated. We analyse the system performance for various values of subcarriers and modulation schemes by computing Complementary Cumulative Distribution Function (CCDF) and analysing the Bit Error Rate (BER). PAPR value is low as the number of subcarriers has been increased. PTS outperforms SLM when complexity is considered and SLM is preferred when the redundant bits in the information are high and data embedding algorithm is included after modulation to ensure wireless security.

Key words: Orthogonal frequency distribution multiplexing, selected mapping, peak-to-average power ratio, complementary commulative distribution function, bit error rate, steganography, data embedding

INTRODUCTION
Communication playing the key role in daily lives has created revolutions since the Stone Age. Right from the stone carvings of the rock era to the early paper usages and to the desktops till tablet PC's. Technology develops for our good and gets better for our best. Communication enhances at every walk, say from mere communication to the digital communication to video conversation to even live talks! All this happens just as a product of high data rate offered by orthogonal frequency division multiplexing (OFDM) (Amirtharajan *et al*., 2010; Praveenkumar *et al*., 2012a-c).

OFDM is a Multicarrier multiplexing modulation technique (Amirtharajan *et al*., 2010; Praveenkumar *et al*., 2012a-c) which offers very good spectral efficiency (Cimini, 1985) making it suitable for high data rate in wireless, multimedia, Very Large Scale Integration (VLSI) technology and Digital Signal Processing (DSP) applications. Inverse Fast Fourier Transform (IFFT) and Fast Fourier Transform (FFT) pairs (Weinstein and Ebert, 1971; Li and Stuber, 2006; Arioua *et al.*, 2012) in OFDM (Kumar *et al.*, 2008; Li and Cimini, 1998; Thenmozhi *et al.*, 2011, 2012; Kumar *et al.*, 2011) reduces the receiver complexity and ensures orthogonality between subcarriers to reduce the Inter Symbol Interference (ISI) (Saltzberg, 1967; Elahmar. *et al.*, 2007) and Inter Carrier Interference(ICI). Robustness to the fading environment increases its attraction towards high speed mobile environment (Chang, 1966, 1970).

The potential limitation with OFDM is its PAPR (Latif and Gohar, 2008). SLM and PTS are the broadly used techniques to reduce PAPR (Wu, 2011; Liang *et al.*, 2010; Kasari and Dehghani, 2009). PTS provides better performance compared to SLM when complexity is considered while the PAPR value is decreased as the number of subcarriers are increased (Chen and Hu, 2010; Wang *et al.*, 2009; Latif and Gohar, 2003). PAPR causes degradation in system efficiency and its performance (Al-Kebsi, 2008). In PTS, the time domain input from the modulator is divided into smaller blocks, each multiplied by a constant phase value and then the value with the lowest PAPR is selected and given to the IFFT block (Sichao and Dongfeng, 2005; Wang and Tellambura, 2006; Han and Lee, 2004).

High PAPR results in out of band and in-band radiations and distortions and affects the BER of the system (Nguyen and Lampe, 2008; Gao and Xie, 2009). Side information is given to the receiver in PTS technique to inform about the phase optimization value. SLM is a probability based method where the input data has been rotated by a sequence set of phase vector values (Saltzberg, 1967; Singhal *et al.*, 2009; Badran and El-Helw, 2011).

PAPR reduction in OFDM has been attempted till date for PAPR reduction in OFDM using Partial Transmit Sequence (PTS) algorithm(Sichao and Dongfeng, 2005; Wang and Tellambura, 2006) and Selective Mapping algorithm (SLM) (Singhal *et al.*, 2009; Badran and El-Helw, 2011).

Steganography literally covered/secret writing that obscure the hidden data in digital media (Cheddad *et al.*, 2010; Amirtharajan and Rayappan, 2012a-d; Zanganeh and Ibrahim, 2011). For concealing and revealing the information, a stego key will be used (Stefan and Fabin, 2000; Amirtharajan and Rayappan, 2012a-d; Thanikaiselvan *et al.*, 2011a, b; Janakiraman *et al.*, 2012a). Cryptography, Steganography and Watermarking are multifarious in secret data communication (Schneier, 2007; Zaidan *et al.*, 2010). While Cryptography scrambles the message, Steganography conceals the existence and watermarking provides authorization (Amirtharajan and Rayappan, 2012a-d).

For sharing and transferring secret data over communication channel, either two or three of the above mentioned techniques can be combined to provide security at a higher level and reduces intrusion (Janakiraman *et al.*, 2012a, b). Amirtharajan and Rayappan (2012c) describes the data that can be embedded on a cover file which has to first identify the redundant bits, then embed the data without making explicit alteration to the cover file. However, while embedding the data on the cover, there always exists trade off between secret data extraction, capacity, robustness and security. A various review on data embedding methods in different domain have been analysed in Amirtharajan *et al.* (2012), Janakiraman *et al.* (2012b), Rajagopalan *et al.* (2012) and Thenmozhi *et al.* (2012).

But in literature, no attempt has made till date, to make comparison between SLM and PTS algorithms considering various subcarriers and different modulation schemes to reduce PAPR in OFDM incorporating data embedding after the modulator using the phase value as a key to maintain confidentiality and wireless security.

MATERIALS AND METHODS

Block description of OFDM system

Modulation: In an OFDM system as shown in Fig. 1, the serial input data as in Fig. 2 is converted to a parallel form and the bits are grouped based on the modulation scheme adopted. The mapping employed can be Quadrature Amplitude Modulation (QAM), Binary Phase Shift Keying (BPSK) or Quadrature Phase Shift Keying (QPSK). The number of bits per symbol for BPSK is 1 bit, for QPSK is 2 bits and for QAM it is 3 bits.

The modulated and demodulated outputs are shown in Fig. 3 which indicates that the data has been demodulated correctly.

Inverse fast Fourier transform (IFFT): The modulated data is sent to IFFT which maps the frequency domain signal into the corresponding time domain signal. The output signal from IFFT will introduce Peak to Average Power Ratio (PAPR). Hence an Optimization technique to reduce PAPR has to be carried out. The IFFT output is shown in Fig. 4. It is mainly used in OFDM to provide orthogonal subcarriers to ensure high spectral efficiency.

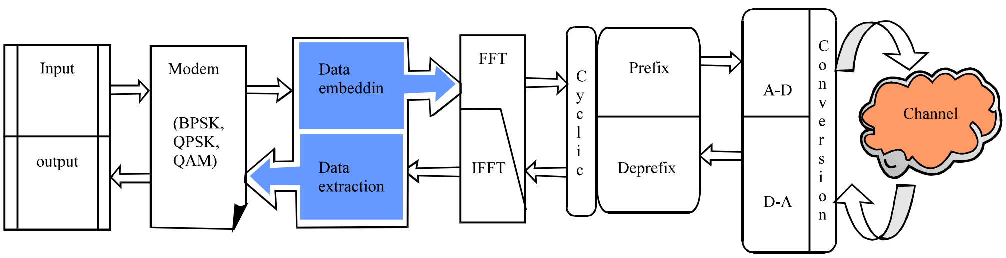

Fig. 1: Schematic diagram of the proposed OFDM system

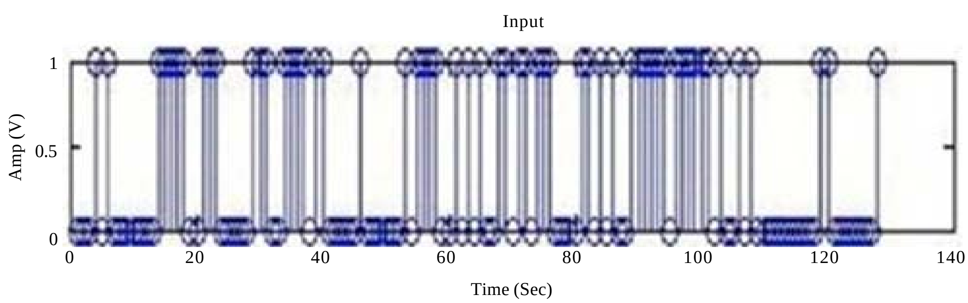

Fig. 2: Input bit stream to the OFDM system

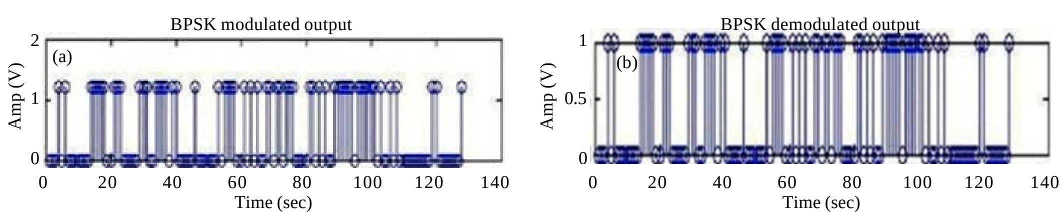

Fig. 3: Modulation and Demodulation of the input bit stream using BPSK

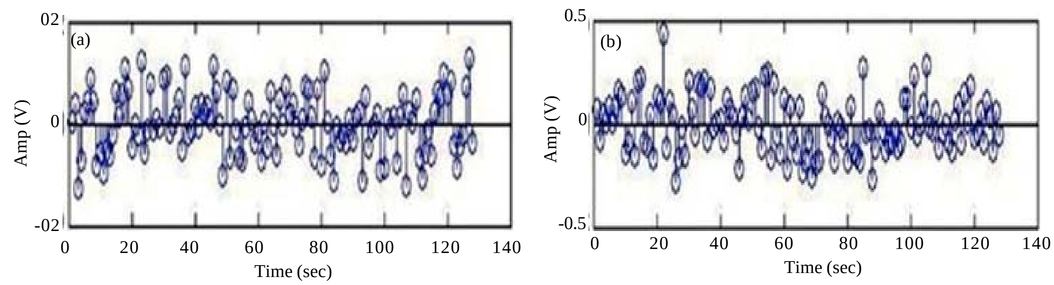

Fig. 4(a-b): (a) IFFT and (b) FFT outputs

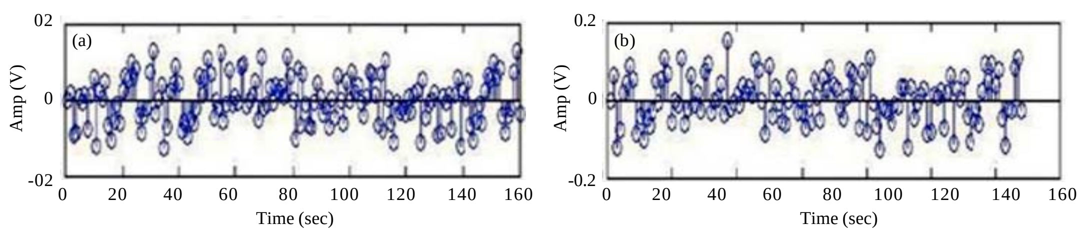

Fig. 5(a-b): Cyclic (a) Prefix and (b) De-prefix outputs

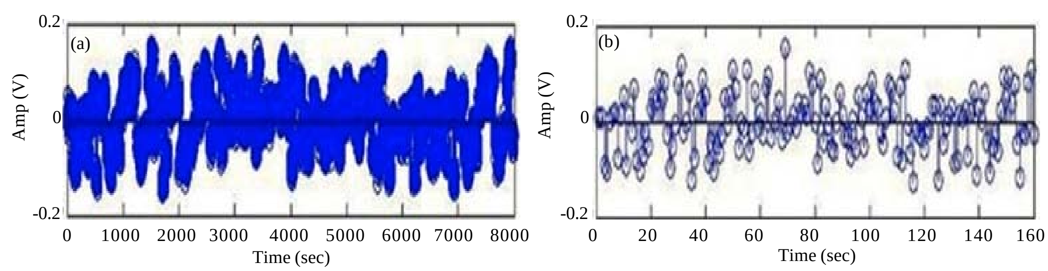

Fig. 6(a-b): (a) AWGN channel and (b) A/D conversion outputs

Cyclic prefix (CP): The CP is appended to the OFDM system by adding a part of the end symbol of the OFDM signal to the original signal. This reduces the Inter Symbol Interference (ISI) and improves the BER of the OFDM system. The CP and the cyclic de-prefix outputs are shown in Fig. 5.

Digital to analog conversion (D/A): The output digital data from the cyclic prefix should be converted into analog form before passing onto the channel.

Additive white Gaussian channel (AWGN): AWGN channel introduces additive white noise into the signal that passes through it. The signal output after passing on to the AWGN channel is shown in Fig. 6.

Analog to digital conversion (A/D): For data recovery at the receiver, the analog data output from the AWGN channel should be converted back to digital form. It includes sampling and quantization. The result is shown in Fig. 6.

Cyclic de-prefix: The reverse process of the cyclic prefix is implemented in the receiver. The data bits added to the OFDM symbol are removed to get back the original data. The implementation is shown in Fig. 5.

Fast Fourier transform (FFT): The time domain data is converted into frequency domain by the FFT process. For the demodulation to take place the data should be in frequency domain. The result of FFT is shown in Fig. 4.

Demodulation: The data in the frequency domain is demodulated at the receiver to recover the original input. The original bits sent at the transmitter end were recovered at the receiver end and is shown in Fig. 3.

Data embedding after modulator: The secret data has been embedded after modulator using the phase value as the key. Generally modulator output is given by:

$$\sqrt{\frac{E_s}{T}}\cos(2\pi f_c t + \varphi)$$

ϕ represents the phase angle, E_s represents signal energy, T represents symbol duration and ϕ value varies based on the modulation techniques adopted. The in phase and Quadrature component values before and after embedding 0 and 1 when bit 0 and 1 was transmitted using BPSK modulation respectively is tabulated in Table 1.

The in phase and Quadrature component values before and after embedding 0 and 1 when bit 0 and 1 was transmitted using QPSK modulation respectively is tabulated in Table 2.

PAPR-SLM and PTS algorithms: In OFDM, the large number of independent subcarriers when added result in high PAPR. It is the ratio of Peak power/average power:

$$\text{PAPR} = 10\log_{10}\frac{\text{Maximum}[a_k]^2}{E[a_k]^2}(\text{dB}) \tag{1}$$

where, Maximum represents the OFDM signal's peak power and E represents the expected value. a_k represents the data symbol with k=0 to k-1.

Table 1: BPSK constellation table

Bit 0	Bit 1
$\phi = 0$	$\phi = \pi$
In phase component before embedding =1	In phase component before embedding = -1
In phase component after embedding =1 if the embedding bit is 0	In phase component after embedding = -1 if the embedding bit is 0
In phase component after embedding =1 if the embedding bit is 1	In phase component after embedding = -1 if the embedding bit is 1
Quadrature phase component before embedding =0	Quadrature phase component before embedding =0
Quadrature phase component after embedding =0.2 if the embedding bit is 0	Quadrature phase component after embedding =0.2 if the embedding bit is 0
Quadrature phase component after embedding =-0.2 if the embedding bit is 1	Quadrature phase component after embedding =-0.2 if the embedding bit is 1

Table 2: QPSK constellation table

Bits 00	Bits 01	Bits 11	Bits 10
$\phi = \pi/4$	$\phi = 3\pi/4$	$\phi = 5\pi/4$	$\phi = 7\pi/4$
In phase component before embedding = 1	In phase component before embedding = -1	In phase component before embedding = 0	In phase component before embedding = 0
In phase component after embedding = 1 if the embedding bit is 0	In phase component after embedding = -1 if the embedding bit is 0	In phase component after embedding = 0.2 if the embedding bit is 0	In phase component after embedding = 0.2 if the embedding bit is 0
In phase component after embedding =1 if the embedding bit is 1	In phase component after embedding = -1 if the embedding bit is 1	In phase component after embedding =-0.2 if the embedding bit is 1	In phase component after embedding = - 0.2 if the embedding bit is 1
Quadrature phase component before embedding = 0	Quadrature phase component before embedding = 0	Quadrature phase component before embedding = -1	Quadrature phase component before embedding = 1
Quadrature phase component after embedding = 0.2 if the embedding bit is 0	Quadrature phase component after embedding = 0.2 if the embedding bit is 0	Quadrature phase component after embedding = -1 if the embedding bit is 0	Quadrature phase component after embedding = 1 if the embedding bit is 0
Quadrature phase component after embedding =-0.2 if the embedding bit is 1	Quadrature phase component after embedding = -0.2 if the embedding bit is 1	Quadrature phase component after embedding = -1 if the embedding bit is 1	Quadrature phase component after embedding = 1 if the embedding bit is 1

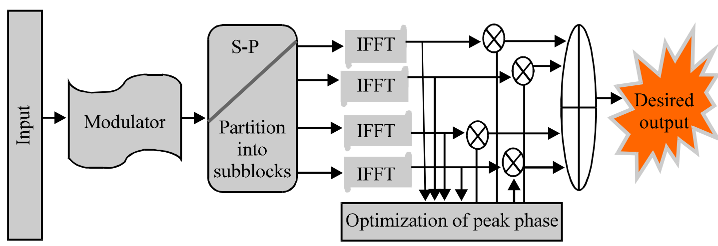

Fig. 7: Block diagram for PTS algorithm

The modulated output in frequency domain is represented in complex form and is given as:

$$p(t)=\frac{1}{\sqrt{l}}\sum_{k=0}^{k-1} a_k\, e^{i2\pi\Delta_f t} \tag{2}$$

where, 0 = t = lT where l denotes the subcarrier and Δ_f represents subcarrier spacing.

CCDF is the performance measure to analyse PAPR. CCDF indicates that the probability ($PAPR_{data}$) should exceed threshold. CCDF =P(PAPR > Z) = 1- P(PAPR = Z).

Steps in PTS algorithm:

- Divide the OFDM symbol into set of independent sub blocks as in Fig. 7
- PAPR reduction can be achieved by rotating the subcarriers in each by some set of phase sequences
- The frequency domain output of the signal mapper is denoted as A and is partitioned in to 'i*' set of sub blocks and is denoted as a^{i^*} where i*=1, 2... I
- $A=\sum_{i=1}^{I} a^i$ A is the frequency domain output

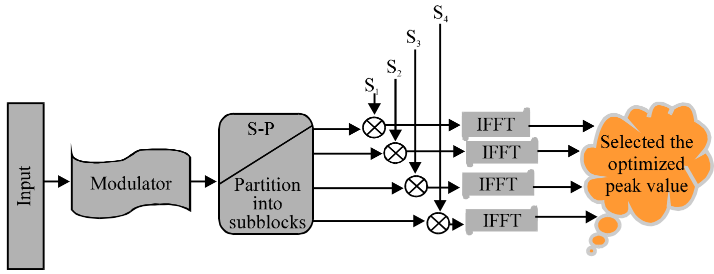

Fig. 8: Block diagram of SLM algorithm

- $a^i = \left[a_0^i \; a_1^i .... a_{N-1}^i\right]$
- A^i are independently phase rotated by
- $c_i = ce^{j\phi i}$
- So $A' = \sum_{i=1}^{I} c_i \; a^i$
- Then after passing onto the IFFT, it is given by y' = IFFT (A^I)

$$y' = \sum_{i=1}^{I} c_i \; \text{IFFT}\left(a^i\right) = \sum_{i=1}^{I} e^{j\phi i} \; a^i$$

If i-1 are the sub blocks and c is the phase vector, then c^{i-1} values have to be verified to provide minimum PAPR.

Steps in SLM algorithm:

- The input data is divided into many number of different sets as in Fig. 8, holding the same original information and are converted to parallel form
- They are then subjected to phase vector multiplication. The phase vector is represented by B_v and v=0, 1... v-1
- V different phase vector values are selected, in which each set contains and N be the number of elements in the original information $B_v = [B_{v0}, B_{v1}.... B_{vN-1}]$
- The phase vectors are selected to provide optimized PAPR
- Normally the phase vectors can be selected from the set {±i, ±1}
- After performing multiplication, the modified set will be $B = [B_0, B_1.... B_{u-1}]$

They are then passed through IFFT and the PAPR value is computed. The set with minimum value of PAPR is chosen and transmitted to D/A converter.

RESULTS AND DISCUSSION

Figure 9 shows the performance comparison of SLM and PTS using BPSK modulation for subcarrier values of 2, 4 and 8 in terms of Complementary Cumulative Distribution Function (CCDF) (Nguyen and Lampe, 2008; Gao and Xie, 2009) and Bit Error Rate (BER).

The performance comparison of SLM and PTS using QPSK modulation for subcarrier values of 2, 4 and 8 in terms of Complementary Cumulative Distribution Function (CCDF) and Bit error rate (BER) is given in Fig. 10.

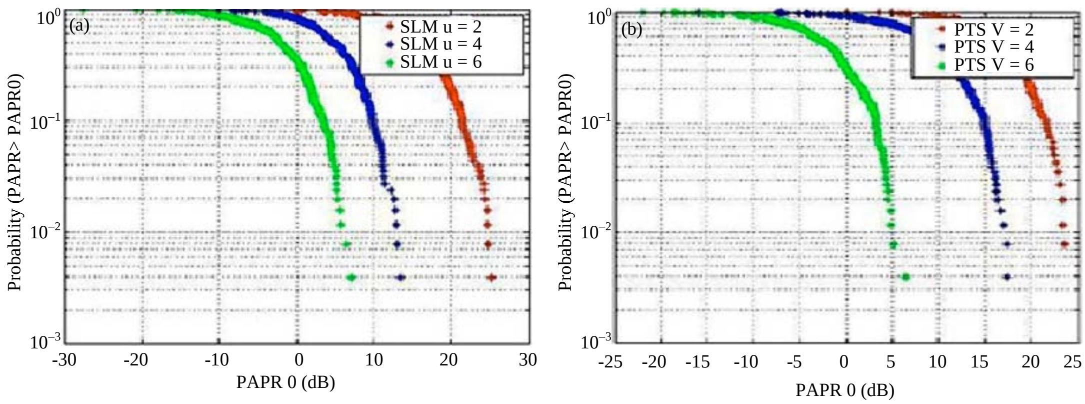

Fig. 9(a-b): CCDF plot for various subcarriers of 2, 4 and 8 using BPSK modulation for (a) SLM and (b) PTS

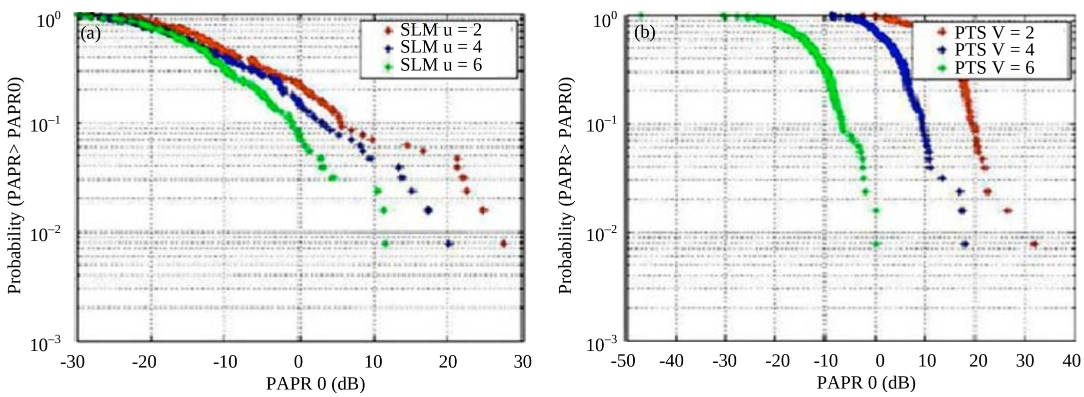

Fig. 10(a-b): CCDF plot for various subcarriers of 2, 4 and 8 using QPSK modulation for (a) SLM and (b) PTS

Figure 11 shows the performance comparison of SLM and PTS using QAM modulation for subcarrier values of 2, 4 and 8 in terms of complementary cumulative distribution function (CCDF)) and Bit error rate (BER)

From Fig. 9-11 it is noted that the PAPR reduction is at its best for U = 8 and comparatively low for U = 2 (Singhal *et al*., 2009; Badran and El-Helw, 2011). When the number of phase vectors is increased, a better reduction of PAPR can be achieved as discussed in (Chen and Hu, 2010; Wang *et al*., 2009; Latif and Gohar, 2003). The phase vectors U = 2, 4 and 8 are used for SLM while V = 2, 4, 8 are considered for PTS. It is seen that the PAPR decreases as the number of U and V values are increased in SLM and PTS respectively as mentioned in (Wu, 2011; Liang *et al*., 2010; Kasari and Dehghani, 2009). From the results obtained, QAM provides better PAPR reduction compared to QPSK and BPSK. Similarly PTS with U = 8 provides better PAPR reduction.

Figure 12 shows the BER comparison between SLM and PTS techniques for the subcarrier value of 8.

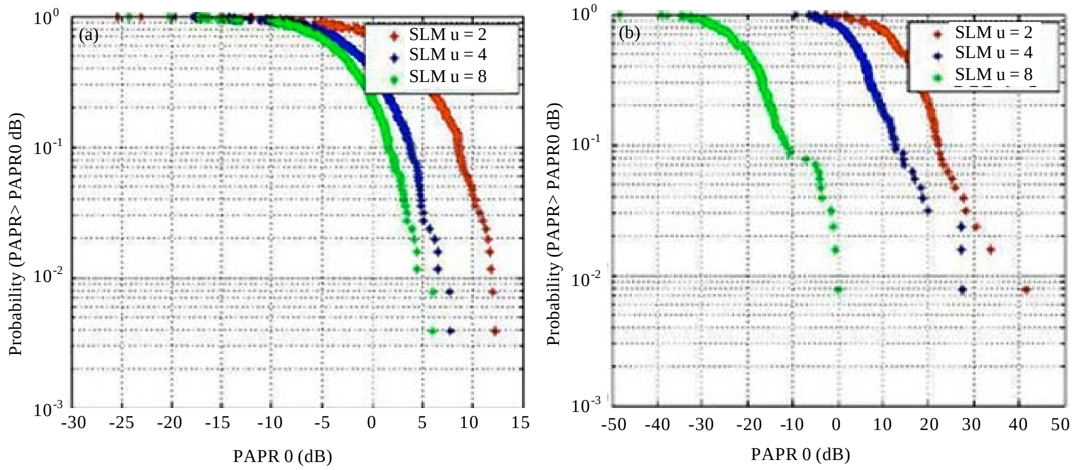

Fig. 11(a-b): CCDF plot for various subcarriers of 2, 4 and 8 using QAM modulation for (a) SLM and (b) PTS

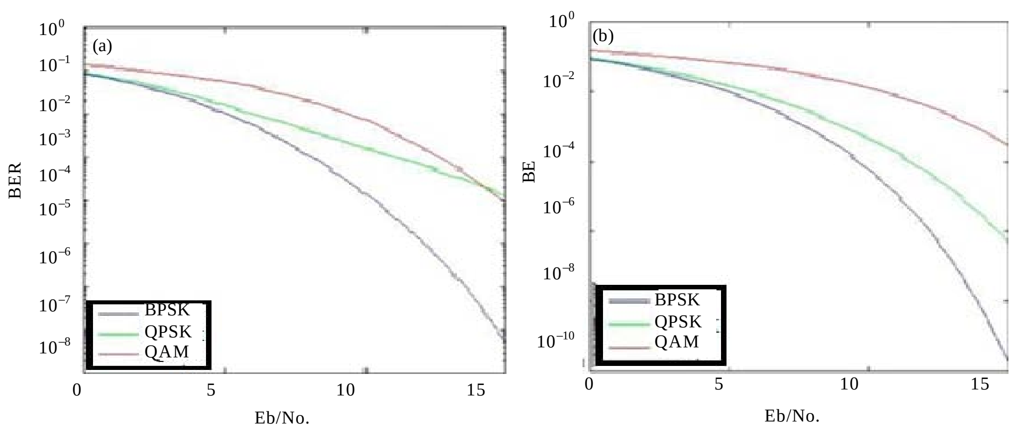

Fig. 12(a-b): Comparison between BPSK, QPSK and QAM for 8 subcarriers for (a) SLM and (b) PTS

The BER comparison between SLM and PTS techniques for the subcarrier value of 4 is given in Fig. 13.

Figure 14 shows the BER comparison between SLM and PTS techniques for the subcarrier value of 2.

The BER comparison between SLM and PTS techniques using QPSK for the subcarrier value of 8 and BPSK for the subcarrier value of 2 is given Fig. 15.

The comparison between SLM and PTS using QAM is plotted in Fig. 16.

From the results obtained through the plots 12 to 16, BPSK with U = 8 for PTS outperforms than the other two modulation schemes. As the phase vector values are increased, better reduction in PAPR is achieved for both SLM and PTS algorithms.

In PTS, all the elements present in the sub blocks are being multiplied by the equal phase values. In PTS, the phase rotation vectors are limited to specific values. In the case of SLM, data

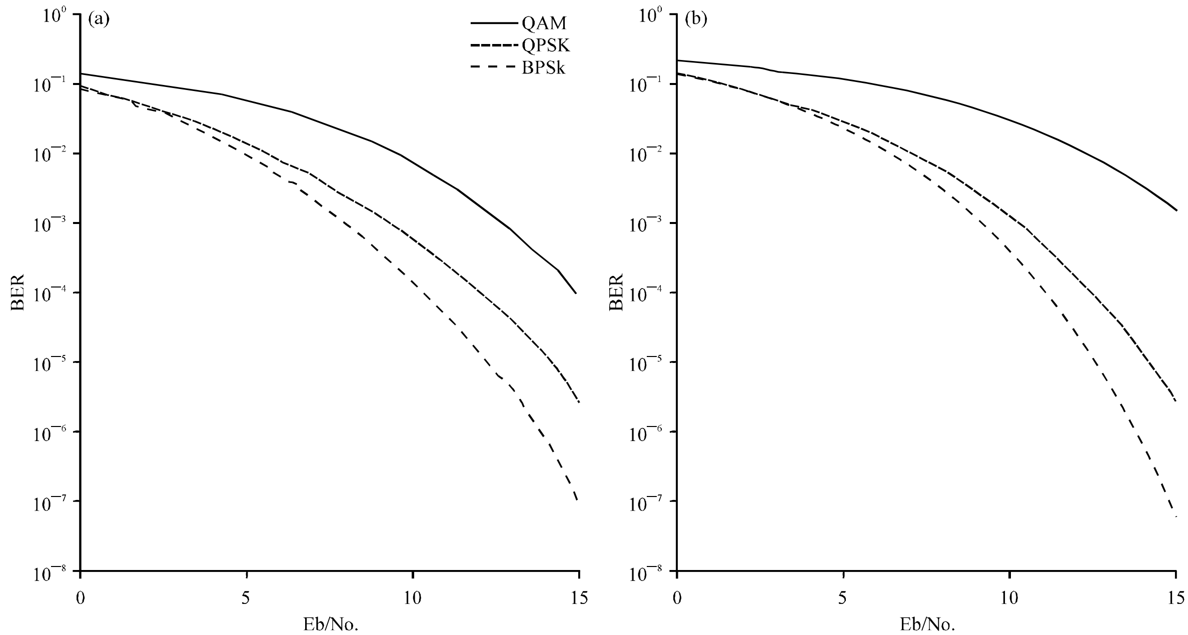

Fig. 13(a-b): Comparison between BPSK, QPSK and QAM for 4 subcarriers for (a) SLM and (b) PTS

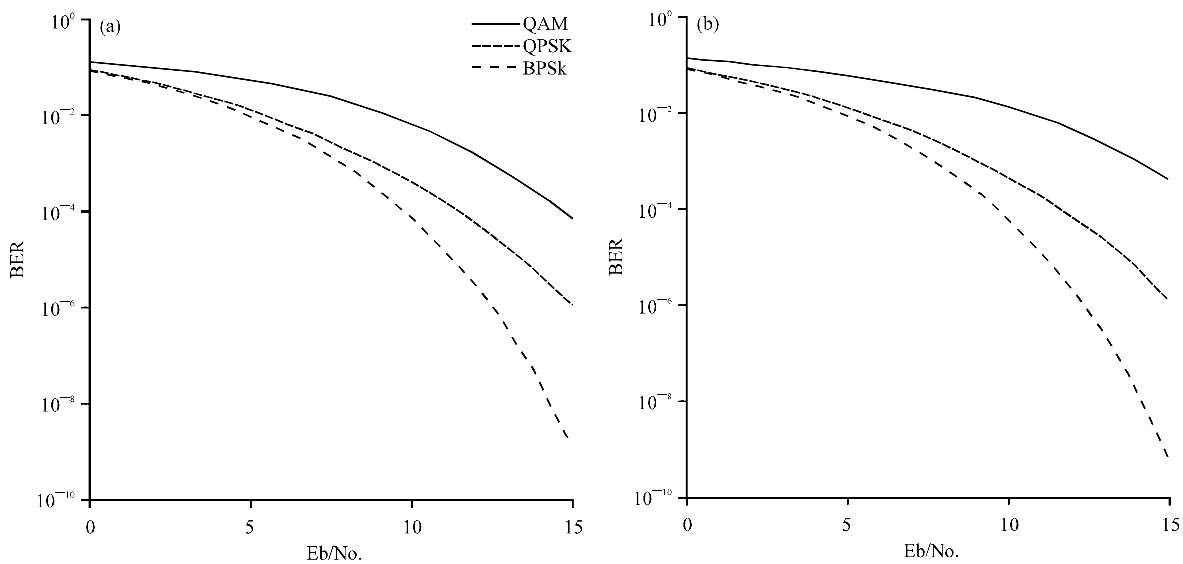

Fig. 14(a-b): Comparison between BPSK, QPSK and QAM for 2 subcarriers for (a) SLM and (b) PTS

sequences are required to be rotated with different phase sequences. PTS provides comparatively superior reduction in Peak values. In PTS, it is clear that the PAPR decreases obviously as the number of sub-blocks get increased with respect to primary OFDM. When there are redundant bits in OFDM symbol, SLM can be considered. PTS is more suitable when design complexity is

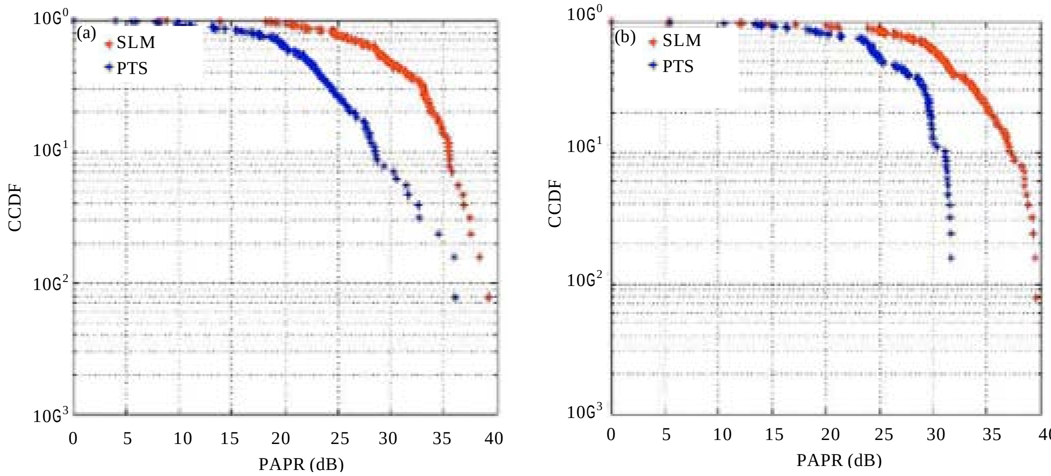

Fig. 15(a-b): Comparison between SLM and PTS using (a) QPSK modulation for 8 subcarriers and (b) BPSK modulation for 2 subcarriers

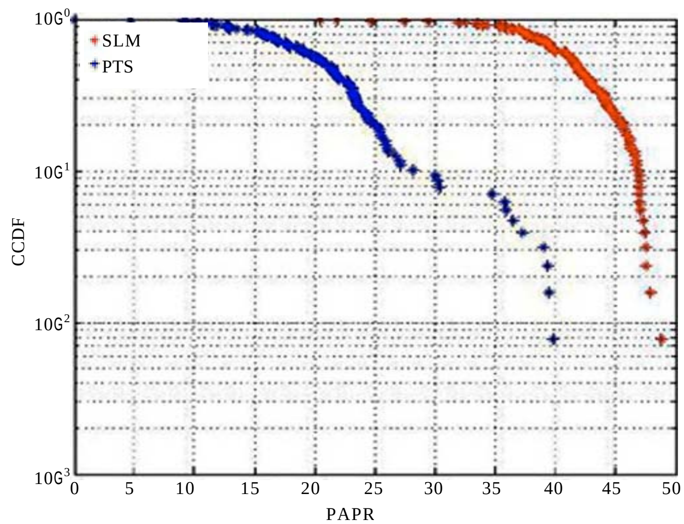

Fig. 16: Comparison between SLM and PTS using QAM

considered. Both the techniques scramble the serial data input symbols and the one with the lowest peak average power ratio is transmitted to reduce the probability of high Peak Average Power (PAP).

In SLM, phase sequences used are in a pseudorandom fashion, so no knowledge about the phase values at the transmitter end which increases the receiver complexity, are known. In PTS, the phase vector set consists of only few values which are known at the transmitter end reducing the complexity of designing the receiver. SLM requires more number of phase vector set to select the optimized one with least PAPR while in PTS, an efficient phase vector set is sufficient for reducing the PAP.

Comparing all three modulation schemes, PTS outperforms SLM. Design complexity in the transmission and reception part decreases the rate of the data to provide distortion-less system in

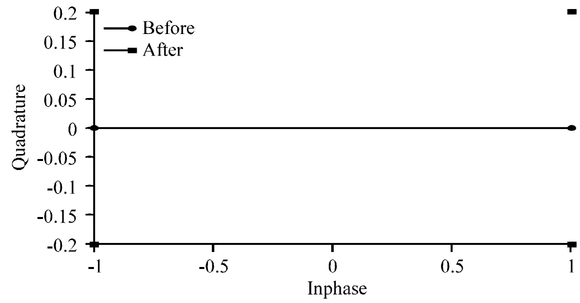

Fig. 17: Constellation diagram of BPSK before and after data embedding

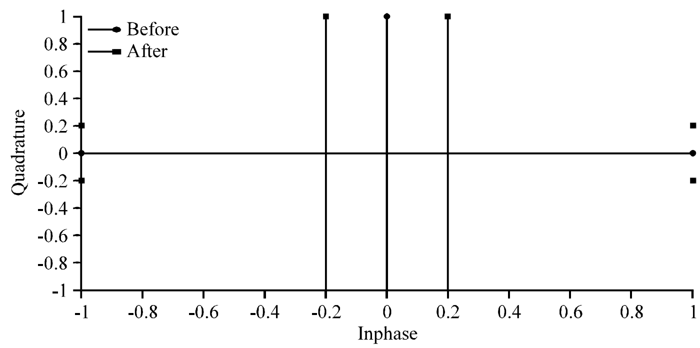

Fig. 18: Constellation diagram of QPSK before and after data embedding

SLM. Complexity is an important consideration as far as the OFDM system is considered. So PTS could be a better candidate in reducing PAPR. When both PAPR reduction and redundancy are taken into account, both the schemes provide almost the same results. SLM is more appropriate for the system that can withstand redundancy in the information. In both the techniques, phase vectors are added along with the information which helps in data recovery.

Constellation diagram before and after embedding 0 when input bit is 1 and 0 and before and after embedding when input bit is 1 and 0 using BPSK modulation is shown in Fig. 17.

In addition, Fig. 18 shows the constellation diagram before and after embedding 0 when input bit is 1 and 0 and before and after embedding when input bit is 1 and 0 using QPSK modulation.

From Fig. 17 and 18, it is clear that the secret data can be extracted before demodulator by knowing the in phase and quadrature phase components, the bit transmitted and the bit embedded during transmission otherwise secret will be maintained as secret itself.

CONCLUSION

OFDM is a multicarrier modulation scheme and is preferred for high-speed data transmission over fading channels. It has various merits but also has one major stumbling block of very high PAPR. In this paper, the different characteristics of OFDM System are analyzed. The graphs are plotted using CCDF against BER for different modulation schemes employing different subcarriers. We employed PAPR reduction techniques such as PTS and SLM which reduces the PAPR of the proposed system. Among the two techniques it is found that both the PTS and SLM techniques provide considerable reduction of PAPR without any loss of input data. From the comparison of the SLM and PTS techniques, it is inferred that PTS is more efficient in PAPR reduction. However, SLM is appropriate when there exists redundant data bits. In terms of complexity, PTS is the promising candidate. Also, the number of computational steps is less in the case of PTS. For providing wireless security and confidentiality secret data has been embedded after modulation using the in phase and quadrature phase values of the modulator as the key.

REFERENCES

Al-Kebsi, I.I.M., 2008. The impact of modulation adaptation and power control on peak to average power ratio clipping technique in orthogonal frequency division multiplexing of fourth generation systems. J. Applied Sci., 8: 2776-2780.

Amirtharajan, R. and J.B.B. Rayappan, 2012a. An intelligent chaotic embedding approach to enhance stego-image quality. Inform. Sci., 193: 115-124.

Amirtharajan, R. and J.B.B. Rayappan, 2012b. Brownian motion of binary and gray-binary and gray bits in image for stego. J. Applied Sci., 12: 428-439.

Amirtharajan, R. and J.B.B. Rayappan, 2012c. Inverted pattern in inverted time domain for icon steganography. Inform. Technol. J., 11: 587-595.

Amirtharajan, R. and J.B.B. Rayappan, 2012d. Pixel authorized by pixel to trace with SFC on image to sabotage data mugger: A comparative study on PI stego. Res. J. Inform. Technol., 4:: 124-139.

Amirtharajan, R., J. Qin and J.B.B. Rayappan, 2012. Random image steganography and steganalysis: Present status and future directions. Inform. Technol. J., 11: 566-576.

Amirtharajan, R., K. Thenmozhi and R.J.B. Balaguru, 2010. Multi carrier steg against omni attacks. Int. J. Comput. Applic., 5: 35-40.

Arioua, M., S. Belkouch and M.M. Hassani, 2012. Efficient 16-points FFT/IFFT architecture for OFDM based wireless broadband communication. Inform. Technol. J., 11: 118-125.

Badran, E.F. and A.M. El-Helw, 2011. A novel semi-blind selected mapping technique for PAPR reduction in OFDM. IEEE Signal Process. Mag., 18: 493-496.

Chang, R.W., 1966. Synthesis of band-limited orthogonal signals for multi channel data transmission. Bell Syst. Tech. J., 45: 1775-1796.

Chang, R.W., 1970. Orthogonal frequency division multiplexing. U.S. Patent No. 3488445.

Cheddad, A., J. Condell, K. Curran and P.M. Kevitt, 2010. Digital image steganography: Survey and analysis of current methods. Signal Process., 90: 727-752.

Chen, L. and X. Hu, 2010. Research on PAPR reduction in OFDM. Syst. J. Comput. Inf. Syst., 6: 3919-3927.

Cimini Jr., L.J., 1985. Analysis and simulation of a digital mobile channel using orthogonal frequency division multiplexing. IEEE Trans. Commun., 33: 665-675.

Elahmar, S., A. Djebbari, M. Bouziani and J.M. Rouvaen, 2007. New results with blind time domain equalization for OFDM system. Inform. Technol. J., 6: 207-211.

Gao, J. and J.K. Xie, 2009. On non-linear iterative partial transmit sequence for PAPR reduction in OFDM system. Proceedings of the Symposium on Electromagnetics Research, March 23-27, 2009, Beijing, China, pp: 431-435.

Han, S.H. and J.H. Lee, 2004. PAPR reduction of OFDM signals using a reduced complexity PTS technique. IEEE Signal Process. Lett., 11: 887-890.

Janakiraman, S., R. Amirtharajan, K. Thenmozhi and J.B.B. Rayappan, 2012a. Firmware for data security: A review. Res. J. Inform. Technol., 4: 61-72.

Janakiraman, S., R. Amirtharajan, K. Thenmozhi and J.B.B. Rayappan, 2012b. Pixel forefinger for gray in color: A layer by layer stego. Inform. Technol. J., 11: 9-19.

Kasari, K. and M.J. Dehghani, 2009. A blind SLM scheme for reduction of PAPR in OFDM systems. World Acad. Sci. Eng. Technol., 38: 399-402.

Kumar, P.P., R. Amirtharajan, K. Thenmozhi and J.B.B. Rayappan, 2011. Steg-OFDM blend for highly secure multi-user communication. Proceedings of the 2nd International Conference on Vehicular Technology, Information Theory and Aerospace and Electronic Systems Technology, February 28-March 3, 2011, IEEE, Chennai, India, pp: 1-5.

Kumar, R., S. Malarvizhi and S. Jayashri, 2008. Time-domain equalization technique for intercarrier interference suppression in OFDM systems. Inform. Technol. J., 7: 149-154.

Latif, A. and N.D. Gohar, 2003. Reducing peak-to-average power ratio (PAPR) using partial transmit sequence in OFDM systems. Proceedings of the 7th International Conference on Multi Topic, December 8-9, 2003, IEEE Computer Society, PP: 126-130.

Latif, A. and N.D. Gohar, 2008. On the PAPR reduction properties of hybrid QAM-FSK (HQFM) OFDM transceiver. J. Applied Sci., 8: 1061-1066.

Li, X. and L.J. Jr. Cimini, 1998. Effect of clipping and filtering on the performance of OFDM. IEEE Commun. Lett., 2: 131-133.

Li, Y. and G.L. Stuber, 2006. Orthogonal Frequency Division Multiplexing for Wireless Communications. Springer Science and Business Media, Inc., New York.

Liang, H., Z. Lin, H. Chen and C.Y. Yang, 2010. A modified genetic algorithm PTS technique with error corretion for PAPR reduction in OFDM systems. Proceedings of the International Symposium Information Theory and its Applications, October 17-20, 2010, Taichung, Taiwan, pp: 1050-1053.

Nguyen, T.T. and L. Lampe, 2008. On partial transmit sequences for PAR reduction in OFDM systems. IEEE Trans. Wirel. Commun., 7: 746-755.

Praveenkumar, P., R. Amirtharajan, K. Thenmozhi and J.B.B. Rayappan, 2012a. Phase for face saving: A multicarrier stego. Procedia Eng., 30: 790-797.

Praveenkumar, P., R. Amirtharajan, K. Thenmozhi and J.B.B. Rayappan, 2012b. Regulated OFDM-role of ECC and ANN: A review. J. Applied Sci., 12: 301-314.

Praveenkumar, P., R. Amirtharajan, Y. Ravishankar, K. Thenmozhi, J. Bosco and B. Rayappan, 2012c. Random and AWGN road for MC-CDMA and CDMA bus to phase hide: A MUX in MUX stego. Proceedings of the International Conference on Computer Communication and Informatics, January 10-12, 2012, Coimbatore, India.

Rajagopalan, S., R. Amirtharajan, H.N. Upadhyay and J.B.B. Rayappan, 2012. Survey and analysis of hardware cryptographic and steganographic systems on FPGA. J. Applied Sci., 12: 201-210.

Saltzberg, B., 1967. Performance of an efficient parallel data transmission system. IEEE Trans. Commun. Technol., 15: 805-811.

Schneier, B., 2007. Applied Cryptography: Protocols, Algorithm and Source Code in C. 2nd Edn., Wiley, India.

Sichao, L. and Y. Dongfeng, 2005. Reducing PAPR of OFDM with convolutional code and 8-ask mapping. Proceedings of the International Conference on Wireless Communications, Networking and Mobile Computing, September 23-26, 2005, China, pp: 253-256.

Singhal, A., M. Chandwani, N.I. Vishnukant and V. Chakka, 2009. A low complexity SLM technique for PAPR reduction in OFDM using thresholding of power amplifier. Proceedings of the Conference (INDICON), India, December 18-20, 2009, Gujarat, India, pp: 1-4.

Stefan, K. and A. Fabin, 2000. Information Hiding Techniques for Steganography and Digital Watermarking. Artech House, London, UK.

Thanikaiselvan, V., S. Kumar, N. Neelima and R. Amirtharajan, 2011a. Data battle on the digital field between horse cavalry and interlopers. J. Theor. Applied Inform. Technol., 29: 85-91.

Thanikaiselvan, V., P. Arulmozhivarman, R. Amirtharajan and J.B.B. Rayappan, 2011b. Wave (let) decide choosy pixel embedding for stego. Proceedings of the International Conference on Computer, Communication and Electrical Technology, March 18-19, 2011, India, pp: 157-162.

Thenmozhi, K., P. Praveenkumar, R. Amirtharajan, V. Prithiviraj, R. Varadarajan and J.B.B. Rayappan, 2012. OFDM+CDMA+Stego = Secure Communication: A Review. Res. J. Inform. Technol., 4: 31-46.

Thenmozhi, K., V.K. Konakalla, S.P.P. Vabbilisetty and R. Amirtharajan, 2011. Space Time Frequency coded (STF) OFDM for broadband wireless communication systems. J. Theor. Applied Inform. Technol., 3: 53-59.

Wang, L. and C. Tellambura, 2006. An overview of peak-to-average power ratio reduction techniques for OFDM systems. Proceedings of the IEEE International Symposium on Signal Processing and Information Technology, August 2006, Vancouver, BC, pp: 840-845.

Wang, L.X., K. Yang and B. Xu, 2009. Using the union algorithm of SLM and PTS to reduce PAPR in OFDM system. Comput. Commun. Control Manag., Int. Colloq., 3: 475-477.

Weinstein, S. and P. Ebert, 1971. Data transmission by frequency-division multiplexing using discrete fourier transforms. IEEE. Trans. Commun., 19: 628-634.

Wu, D.X., 2011. Selected mapping and partial transmit sequence schemes to reduce PAPR in OFDM systems. Proceedings of the 8th International Symposium on Image and Signal Processing and Analysis, September 4-6, 2011, Trieste Italy, pp: 1-5.

Zaidan, B.B., A.A. Zaidan, A.K. Al-Frajat and H.A. Jalab, 2010. On the differences between hiding information and cryptography techniques: An overview. J. Applied Sci., 10: 1650-1655.

Zanganeh, O. and S. Ibrahim, 2011. Adaptive image steganography based on optimal embedding and robust against chi-square attack. Inform. Technol. J., 10: 1285-1294.