PAPR Reduction in OFDM System using Adapting Coding Technique with Pre distortion Method

CHHAVI SHARMA[1], SHIV KUMAR TOMAR [2], A.K.GUPTA[3]
MJP Rohilkhand University, Bareilly, India[1]
Maya Institute of Technology and Management, Selaqui, Dehradun, India [2]
National Institute of Technology, Kurukshetra, India [3]
Email: yash_naina@yahoo.co.in, shivktomar@gmail.com,anilg699@rediffmail.com

Abstract: - In this paper we propose the Peak to Average Power ratio reduction (PAPR) in OFDM using adapting coding technique with pre-distortion method to decrease the nonlinear distortion and to improve the power efficiency of the non-linear high power amplifier (HPA). In the proposed method adaptive coding is used for error correction as well as PAPR reduction. The pre-distorter improves the bit error rate performance of the system.

Key-Words: - Complementary cumulative distribution function (CCDF), Peak to average power ratio (PAPR), High power amplifier (HPA), Orthogonal frequency division multiplexing (OFDM).

1 Introduction

Orthogonal frequency division multiplexing (OFDM) is a strong candidate for future wireless communication because it is marked by its higher frequency multiplicity and greater immunity to multipath fading. The OFDM based physical layer has been chosen for several wireless standards such as digital audio broadcasting (DAB), digital video broadcasting (DVB-T), the IEEE 802.11a [1] local area network (LAN) standard and the IEEE 802.16a [2] metropolitan area network (MAN) standard. However, one of the problems in OFDM system is peak to average power ratio (PAPR) of the transmitted signal. Several techniques have been proposed for reducing PAPR, such as clipping method, coding method, SLM and PTS. Clipping method is used to clip the peak above a certain prescribed level. The merit of this clipping method is that PAPR can be easily reduced, but the BER performance becomes poor due to many defected signals [4, 5].

SLM (Selected Mapping) and PTS (Partial Transmit Sequence) are considered two main phase control schemes to escape the high peak. In SLM, one signal of the lowest PAPR is selected as a set of several signals containing the same information data. In PTS, the lowest PAPR signal is achieved by optimally phase combining technique. Both techniques are very flexible scheme and have a better performance of the PAPR reduction without any signal distortion, however, they require more system complexity and computational burden by using many IFFT blocks. Coding is another important method for PAPR reduction. This method performs the error correction as well as to control PAPR [1-4], but main problem is to exhaustively search for effective codes, store large look-up tables & large computations.

In this paper, the author proposed adaptive coding technique with Pre-distortion. Coding technique is used for error correction as well as PAPR reduction and Pre-distortion technique provides the shape of the transmitted data symbols or the input signal of the HPA amplifier (signal pre-distortion) so that the output signal of the HPA is less distorted. Pre-distortion also improves the power density spectrum of the transmitted signal and bit error performance. All these systems have been studied in the presence of a non linear high power amplifier.

2 System Model

2.1. PAPR of an OFDM Signal

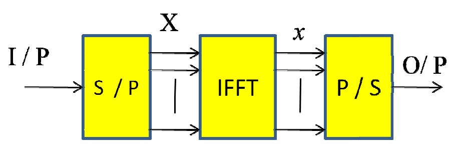

Fig1. Block diagram of basic OFDM system.

Fig.1 shows the block diagram of basic OFDM system. The input data symbols are first passed through serial to parallel converter, forming a complex vector of size N. We call this vector as X=[$X_0, X_1 \ldots X_{N-1}]^T$. After IFFT Transform the signal can be represented as equation (1).

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n \, e^{j2\pi kn/N}, \, 0 \le t \le N-1 \tag{1}$$

In matrix form,

$$\begin{bmatrix} x[0] \\ x[1] \\ \vdots \\ x[N-1] \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & \cdots & 1 \\ 1 & e^{j\frac{2\pi}{N}} & e^{j\frac{2\pi}{N^2}} & \cdots & e^{j\frac{2\pi}{N}(N-1)} \\ 1 & e^{j\frac{2\pi}{N^2}} & e^{j\frac{2\pi}{N^{2*2}}} & \cdots & e^{j\frac{2\pi}{N}(N-1)*2} \\ \cdot & \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdot & \cdots & \cdot \\ 1 & e^{j\frac{2\pi}{N}(N-1)} & e^{j\frac{2\pi}{N}(N-1)*2} & \cdots & e^{j\frac{2\pi}{N}(N-1)^2} \end{bmatrix} \begin{bmatrix} X[0] \\ X[1] \\ \cdot \\ \cdot \\ \cdot \\ X[N-1] \end{bmatrix} \tag{2}$$

where N is the number of IFFT points and X_n is the modulated data at k-th sub-carrier.

The PAPR of an OFDM signal, is represented as

$$PAPR = \frac{\max |x(t)|^2}{E[|x(t)|^2]} \tag{3}$$

Where $\max|x(t)|^2$ the peak is signal power, and $E[|x(t)|^2]$ is the average signal power. According to Central Limit Theorem, x is approximately independently and identically distributed (i.i.d).

2.2 HPA Model

2.2.1 Solid State Power Amplifier (SSPA) Model

In this section, we described the memory less model for the nonlinear HPA. The AM/AM and AM/PM conversion of a solid-state power amplifier (SSPA) can be approximated as [2]

$$f[B(t)] = \frac{vB(t)}{\left(1 + \left[\frac{vB(t)}{B_0}\right]^{2r}\right)^{\frac{1}{2r}}} \tag{4}$$

$$\Phi[B(t)] \approx 0,$$

Where $v \ge 0$ is the small signaling gain, $B_0 \ge 0$ is the output saturating amplitude and $r \ge 0$ is a parameter to control the smoothness of the transition from the linear region to the saturation level .

The nonlinear distortion at the transmitter causes interferences both inside and outside the signal band-width. The inside component determines the amount of bit error rate degradation of the system, whereas the out-side component affects the adjacent frequency bands. In other words outside component increases the out of band radiation of the signal. The transmitter nonlinear distortion include signal clipping in the analog to digital (A/D) converter, signal clipping in the IFFT and FFT processors with a limited word length, amplitude modulation to amplitude modulation distortion (AM/AM), and amplitude modulation to phase modulation distortion (AM/PM) in the radiofrequency (RF) amplifiers. The out-off-band (OBN) of OFDM signals increases due to nonlinear power amplifiers operating at lower back-offs. The high PAPR of OFDM requires high back-offs at the amplifiers.

Fig.2 shows a typical AM/AM response for an HPA, with the associated input and output back-off regions (IBO and OBO), respectively.

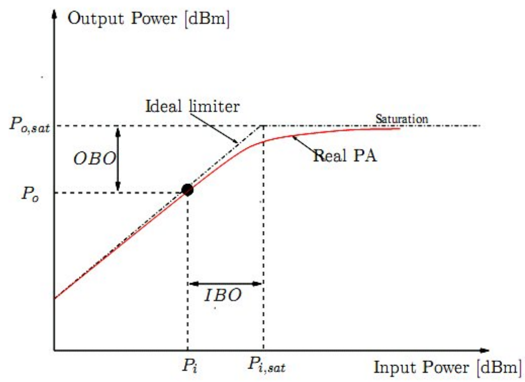

Fig 2. A typical power amplifier response for IBO and OBO.

To avoid such undesirable nonlinear effects, a waveform with high peak power must be transmitted in the linear region of the HPA by decreasing the average power of the input signal. This is called input back-off (IBO) and results in a proportional output back-off (OBO), but high back-off reduces the power efficiency of the HPA and may limit the battery life for mobile applications. In addition to inefficiency in terms of power, the coverage range is reduced, and the cost of the HPA is higher than would be mandated by the average power requirements. The input back-off and output back-off are defined in [4] as

$$IBO = 10\log_{10}\frac{P_{i,sat}}{\overline{P_i}} \quad (5)$$

and

$$OBO = 10\log_{10}\frac{P_{o,sat}}{\overline{P_o}} \quad (6)$$

Where $P_{i,sat}$ and $P_{o,sat}$ are the input and output saturation powers, $\overline{P_i}$ and $\overline{P_o}$ are the average power of the input and output signals.

3 Proposed Technique

3.1 Adaptive Coding

In this paper, we consider OFDM modulation with n-subcarriers. Let a message block with k symbols are represented as m= (m_0, m_1...,m_{k-1}). Now consider a linear code (n, K), such that every K-symbol message word is mapped onto a n-symbol codeword. Thus, the coding rate is given by r = K/n. Elements of our linear code belong to alphabet of size *l*. Let us consider k message symbols and attach γ symbols at the beginning such that k + γ = K symbols. Depending upon the values of γ symbols, l^{γ} new message sequences of length K are exhaustively formed .Thus, for any message word of length k, l^{γ} new message sequences can be generated of length *K*. The new message sequences are encoded using linear code (n, K), generating different codewords for each message sequence. The different codewords thus generated have different PAPR characteristics, presenting an opportunity to choose a codeword with PAPR value of choice. Our method can be elaborated using detailed notations. Consider a block **m** = (m_0,m_1... m_{k-1}), consisting of k symbols and a new block $\grave{\mathbf{m}}$ = (m_k... $m_{k+\gamma-1}$, m_0, m_1...m_{k-1}) is formed, by affixing γ symbols to the preexisting block **m**. The γ value should be less than k. Each one of the representations of the message $\grave{\mathbf{m}}$ is encoded using linear code (n, K) in systematic or nonsystematic form. Now we start selecting one such representation from **m** to encode the data and find PAPR of that OFDM symbol. If the PAPR value of the OFDM symbol is less than the preset threshold *Z*, then the symbol is transmitted. If the PAPR value of the OFDM symbols is greater than the preset threshold Z, then a different representation is selected from **m** and the PAPR value is evaluated again. This process is repeated until a representation is found that satisfies the condition of the PAPR value.

Fig.3 shows the algorithm for adaptive coding scheme.

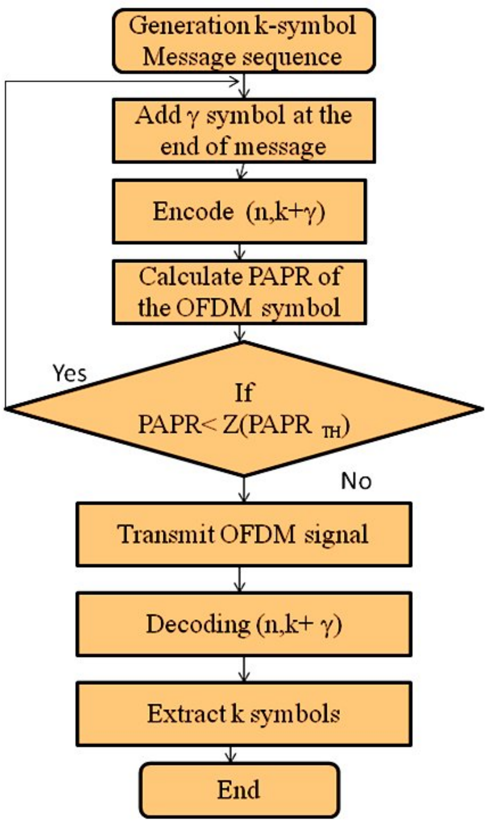

Fig.3 Algorithm for New Coding Scheme

3.2 Pre-distortion Technique

Although PAPR reduction method can reduce the peak power, it is not enough to suppress the out-of-band emission. Pre-distorter should be used to limit the spectral re-growth. The pre-distortion is a linearization method in which the input signals are conversely pre-distorted before the HPA. Through the pre-distortion and nonlinear HPA, the overall characteristic can be linearized. If the modulated OFDM signal is again denoted as $s(t) = B(t).e^{j\theta(t)}$, the output samples of the pre-distorter can be written as

$$s_p(t) = f[B(t)].e^{j\{\theta(t)+\Psi[B(t)]\}} \quad (7)$$

Where $f[B(t)]$ and $\Psi[B(t)]$ are the AM/AM and AM/PM conversion of the pre-distorter, respectively. The combination of a given memory less HPA and the corresponding pre-distorter will result in

$$s_{HPA}(t) = g(f[B(t)]).e^{j\{\theta(t)+\Psi[B(t)]+\Phi[f(B(t))]\}} \quad (8)$$

Ideal pre-distortion is characterized as

$$g(f[B(t)]) = \begin{cases} \alpha B(t), & if\, \alpha B(t) \le B_0, \\ B_0 & , otherwise \end{cases} \quad (9)$$

Where α is a real-valued constant (α > 0). In this case, the combination of the HPA and the corresponding pre-distorter (i.e., the total transmitter-side nonlinearity) is equivalent with the hard limiter.

In this paper we assume that the AM/PM conversion of the HPA is negligibly small and does not have to be compensated, i.e., $\Psi[A(t)] = 0$ .The AM/AM conversion of the pre-distorter is modeled by a polynomial as

$$f[B(t)] = f_1[B(t)] + f_2[B^2(t)] + ... + f_L[B^L(t)] \quad (10)$$
$$= fB^L(t)$$

where L is the order of the polynomial, $f = [f_1, f_2, ..., f_L]$ and

$B(k) = [B(t), B^2(t), ..., B^L(t)]$.

To find the coefficient set f , we apply the least mean square algorithm proposed in [10], which minimizes the mean squared error between the input and output amplitudes of the combined pre-distorter and HPA:

$$J(f) = E\left\{(g[fB^T(t)] - \alpha B(t))^2\right\}\sqrt{2} \quad (11)$$

In (9), averaging is done over time. The coefficient set can be calculated recursively according to

$$f[k+1] = f[k] - \mu\nabla fJ(f[k])$$
$$= f[k] + \mu B[k]g^{'}(f[k]B^T[k])(S_{HPA}[k] - \alpha B[k] \quad (12)$$

Where ∇f denotes the gradient, $g^{'}(.)$ is the derivative of $g(.)$ and μ a (small) positive step size. A suitable choice for the initial coefficient set is f[0]= [1,0,...,0]. The steady-state coefficient set is denoted as $f_{\infty} = \lim_{k-\infty} f(t)$. Convergence is obtained after a few thousand iterations. A drawback of this particular adaptation algorithm is the fact that $g'(.)$ and hence $g(.)$ has to be known a priori.

Fig.4 shows the complete schematic diagram of the PAPR reduction in OFDM system using adapting coding technique with pre distortion method.

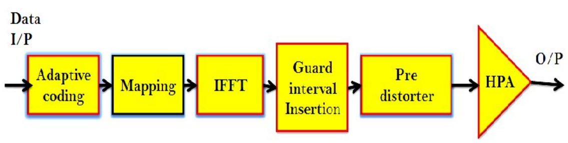

Fig 4. Block diagram of Proposed Scheme.

4 Simulation Results

This section presents the computer simulation result to evaluate the performance of the proposed scheme and to verify this technique; simulation parameters are shown in table 1.

4.1 PAPR Reduction Performance

Fig. 5 shows the CCDF performance curves of normal OFDM, adaptive coded OFDM without predistorter and adaptive coded OFDM with predistorter, for 8, 12, and 16 iterations. From the simulation result it is clear that for 8 number of iterations , PAPR is reduced by 1dB for adaptive coded OFDM without distorter and 3dB for adaptive coded OFDM with distorter at 10^{-3}CCDF, with respect to normal OFDM. The result shows performance improvement of 1.4 dB in PAPR, when we use adaptive coded OFDM with predistorter. Similarly the result for iterations 12 and 16 are also shown in the same figure which indicates that PAPR reduces as the number of iterations increased.

Table 1

Parameters for Simulation

PARAMETER	VALUE
Modulation	16 QAM
Number of data subcarriers	256
Number of pilot subcarriers	4
Number of FFT points	256
Number of data symbols	5
High power amplifier model (HPA)	SSPA
Smoothness parameter of HPA	r =2
Channel	AWGN
Input back-off	6dB

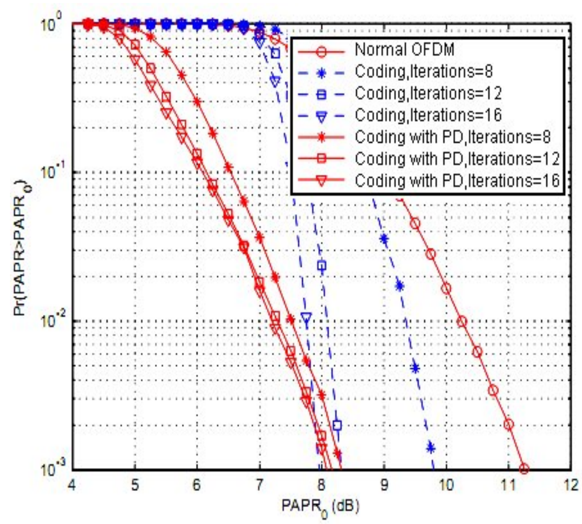

Fig.5 CCDF curve coding with pre distorter at different iterations

Similarly in fig. 6 the simulated result of the proposed method with *n* = 32, *k* = 27 and *γ* = 2 for different threshold levels 7,8,9 and 10 dB are depicted, which clearly indicates that only those OFDM symbols are selected, which have satisfied the PAPR threshold condition.

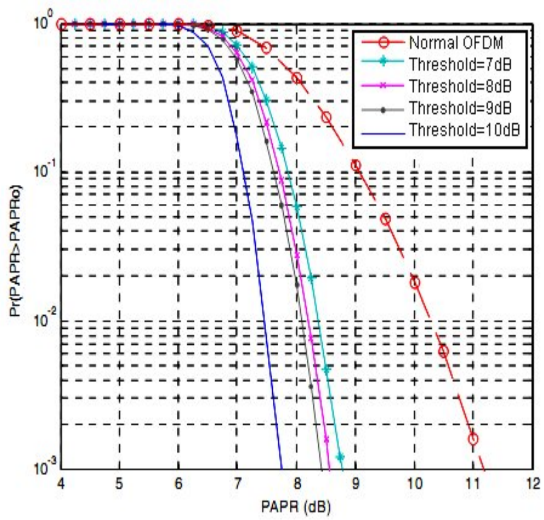

Fig.6 CCDF of OFDM at different Threshold values.

4.2 BER Performance

In Fig.7, the BER performance of normal OFDM and the proposed method with and without predistorter is compared. Here the SNR gain is improved by 4 dB at BER of 10^{-3}.

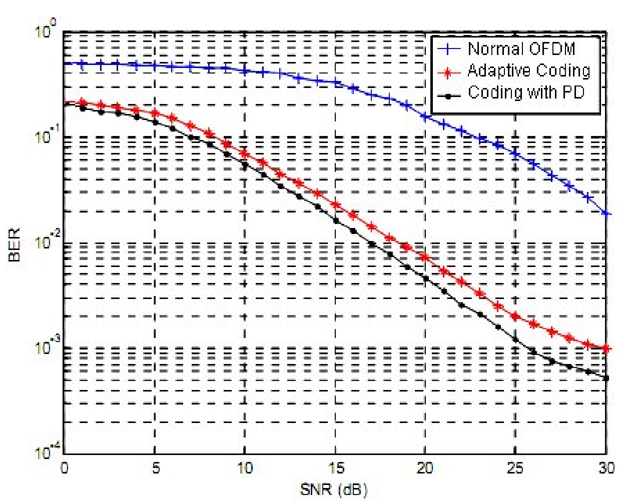

Fig.7 BER performance of OFDM and adaptive coding with pre distorter (PD)

5 Conclusion

In this paper, an adaptive coding with predistorter is proposed which reduces the PAPR of OFDM. From simulation results it can be easily seen that the proposed scheme improves PAPR and the BER performance, especially with small input back-off values.

References:

[1] W.Y. Zou and Y. Wu, "COFDM: An Overview", *IEEE Transactions on Broadcasting,* vol. 41, no. 1, Mar. 1995, pp. 1-8.

[2] P.Banelli and S. Cacopardi, "Theoretical analysis and performance of OFDM signals in nonlinear AWGN channels", *IEEE Transactions on Communications*, vol. 48, no. 3, Mar. 2000, pp. 430-441.

[3] C.van den Bos, M.H.L. Kouwenhoven, and W.A. Serdijin," Effect of smooth nonlinear distortion on OFDM symbol error rate", *IEEE Transactions on Communications* , vol. 49, no. 9, Sept. 2001, pp. 1510-1514.

[4] A.E. Jones, T.A. Wilkinson, and S.K. Barton, "Block Coding Scheme for Reduction of Peak to Mean Envelope Power Ratio of Multicarrier Transmission Scheme", *IEEE Electronic Letters*, vol.30, no.8, Dec. 1994, pp. 2098-99.

[5] E. Costa and S. Pupolin," M-QAM-OFDM system performance in the presence of a nonlinear amplifier and phase noise", *IEEE Transactions on Communications* , vol. 50, no. 3, Mar. 2002, pp. 462-472.

[6] H. Besbes and T. Le-Ngoc, "A fast adaptive predistorter for nonlinearly amplified M-QAM signals", *IEEE Global Communications Conference*

(GLOBECOM) San Francisco, California, Nov.-Dec. 2000, pp. 108-112.

[7] Davis and Jebwab, "Peak-to-mean powers control in OFDM, Golay complementary sequences, and Reed-Muller codes", *IEEE Transactions on Information Theory,* vol.45, Nov. 1999, pp. 2397-2417.

[8] Pankaj Kumar Sharma, R.K. Nagaria , T. N. Sharma, "Power Efficiency Improvement in OFDM System using SLM with Adaptive Nonlinear Estimator", *World Applied Science Journal (WASJ)*, vol.07, 2010, pp.145-151.

[9] Y.Guo and J.R. Cavallaro, "A novel adaptive pre-distorter using LS estimation of SSPA non-linearity in mobile OFDM systems", *IEEE Int. Symposium on Circuits and Systems (ISCAS)*, Phoenix, Arizona, May 2002, pp. 453-456.

[10] G. Karam and H. Sari, "Analysis of pre-distortion, equalization, and ISI cancellation techniques in digital radio systems with nonlinear transmit amplifier", *IEEE Transactions on Communications*, vol. 37, no. 12, Dec. 1989, pp. 1245-1253.

[11] K.Wesolowski and J. Pochmara, "Efficient algorithm for adjustment of adaptive predistorter in OFDM transmitter", *IEEE Vehicular Technology conference (VTC),* Boston, assachusetts, Sept. 2000, pp. 2491-2496.

[12] Pankaj Kumar Sharma, R.K. Nagaria , T.N.Sharma, " A Novel Approach for Power Saving in OFDM System using SLM PAPR Reduction Technique" , *International Journal of Computers, Information Technology and Engineering*, vol.03,no-01, January-June-09, pp-23-26.

[13] A.E. Jones, and T.A. Wilkinson, "Combined Coding for Error Control and Increased Robustness to System Non-linearities in OFDM", *IEEE VTC,* May 1996, pp.904-908.

[14] Omar, "PAPR reduction of coded OFDM signals based on iterative code-word construction", *First Intl. Symp. on Communication, Control, and Signal Processing*, Mar. 2004, pp. 763-766.

[15] Y. Guo and J.R. Cavallaro, "A novel adaptive pre-distorter using LS estimation of SSPA non-linearity in mobile OFDM systems", *IEEE Int. Symposium on Circuits and Systems (ISCAS)*, Phoenix, Arizona, May 2002, pp. 453-456.

[16] R. D. J. van Nee, "OFDM codes for peak-to-average power reduction and error correction", in Proc. *IEEE GLOBECOM-96*, London, U.K, Nov. 1996, pp. 740–744.

[17] J.Minkoff, "The role of AM-to-PM conversion in memory less nonlinear systems", *IEEE Transaction on Communication*,vol.33,Feb.1985, pp.139-144

[18] M. Friese, "On the degradation of OFDM-signals due to peak-clipping in optimally predistorted power amplifier", in Proc. *IEEE GLOBECOM 98*, Sydney, Australia, Nov. 1998, pp. 939-944.

Chhavi Sharma received her B.E degree in Electronics Engineering from NMU, Jalgaon (MS) India in 2001, the M. Tech. degree in Microwave &Radar Engineering from DR. B.R. Ambedkar University, Agra, India in 2007. Presently, she is Assistant Professor in the Department of Electronics and Communication Engineering at Faculty of Engineering &Technology, MJP Rohilkhand University, Bareilly (UP), India. She has more than nine years experience in academics. She has published research papers in National & International journals. She is a life member of Institution of Engineers (India), Institution of Electronics and Telecommunication Engineers (India), International Association of Engineers (IAENG) and Member of Wireless Communication Technical committee (WTC). Her current research interest is in MC-CDMA, OFDM System, Multi-Input Multi-Output (MIMO) Communication and Congnitive Radio. Currently, she is a Research Scholar at National Institute of Technology (NIT), Kurukshetra, India.

Shiv Kumar Tomar received his B. Tech. and M. Tech. degrees in Electronics and Communication Engineering from AMU Aligarh, India, in 1983 and 1988 respectively and PhD in Electrical Engineering from IIT Roorkee, India in 2010. He served as head of the Department of Electronics and Communication Engineering at Faculty of Engineering & Technology, MJP Rohilkhand University, Bareilly (UP) India for more than 12 years. Presently, he is Director, Maya Institute of Technology and Management Selaqui, Dehradun, India. He has more than 26 years of teaching and research experience in the area of Control system, Digital Signal Processing, Signal & System. He has published more than twenty five research papers.