Design of WPM System using QPSK Modulation for Different Wavelets

M.B. Chakole, S. S. Dorle

Abstract: To achieve high-speed network is a challenging task. Wavelet packet Modulation (WPM) is the promising technology for high-speed data transfer between the nodes within the network. WPM comprises of multicarrier modulation technique that overcomes the disadvantages of OFDM for efficient data transfer between the nodes of the network. The selection of proper wavelets for the WPM system is also important to achieve efficient communication between the nodes.

In this paper, WPM based system has been established by using Quadrature Phase shift Keying (QPSK) modulation. In order to get a reliable and an efficient data transfer between the nodes, different wavelets were experimented by making use of the system. Almost, similar kinds of performances are observed for the wavelets (Daubechies, Haar, Symlet and Coiflet) in the proposed WPM system for values of SNR in range 0 to 20 db. If the value of SNR goes beyond 20 db then measurable differences are notable for the same wavelets in the system. Under different channel conditions, the WPM system was tested to conclude the final wavelet and channel condition for better performance of the system.

Keywords : OFDM, QPSK, Wavelets, WPMs.

I. INTRODUCTION

In Multi-Carrier Modulation (MCM) technique, to modulate the bit streams, multiple narrow bandwidth carriers are used. Pulses used in MCM were adjusted in time and frequency plane to maintain the orthogonality of signal. Still the orthogonality gets disturbed when the signal travels through the channel, resulting in intersymbol (ISI) and interchannel (ICI) interferences. There are several multicarrier modulation techniques to avoid the interferences, Orthogonal Frequency Division Multiplexing (OFDM) is considered as an efficient techniques in time domain of the signal. The availability of cyclic prefix in OFDM reduces the ISI and ICI but increases the symbol size, which finally results in occupying more bandwidth within the channel. So, in order to make efficient usage of channel bandwidth MCM technique must handle both time and frequency plane of the signal. Wavelet theory gives the promising MCM characteristics in which the signal can be well manage in time and frequency domain and satisfy the narrow bandwidth [1].

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* Correspondence Author
M. B. Chakole*, Department of Electonics & Telecommunication Engineering, Yeshwantrao Chavan College of Engineering, Nagpur, India. Email: mdorle@gmail.com
S.S. Dorle, Department of Electronics Engineering, G. H. Raisoni College of Engineering, Nagpur, India Email: sanjay.dorle@raaisoni.net

Wavelet is a small oscillating type wave in which by use of mathematics the frequency and time analysis can be done simultaneously. The wavelet theory is an additional part of Fourier analysis because the elementary idea of representation of function using set of other functions is same in both the transformations. In 1800s, Joseph Fourier exposed that sinusoidal functions might be superposed to represent other functions. Since then, for many applications and associated communication problems, engineers and scientists are using Fourier transform for analysis of the functions. However, Fourier analysis does not provide satisfactory results for all the problems. Infact, Fourier analysis provides satisfactory results for linear problem solutions and analysis of stationary signals. Fourier analysis fails to handle complicated non-stationary signals. Wavelet packet modulation found to be productive for non-challengeable and non-stationary signals. Wavelet packet consists of filter banks used for forming the orthogonal bases used for operating in time and frequency planes. By making use of different wavelets in the system the subcarriers results in different characteristics and as a result the bandwidth efficiency is improved.

II. RELATED WORK

The Continuous Wavelet Transform (CWT) is the combination of shifted and scaled description of wavelet function and product of signal. Wavelets can be change either compressing or stretching by using different scaling factors. One can also make use of varying translation parameter to achieve delay or stepping up the position of wavelet in time [3]-[4].

The value of translation parameter has no influence on wavelet bandwidth or duration but it also affects the location of the wavelet. Due to low frequency behavior, for increasing scales, wavelets behave to be more dilate as compared to input signal. For high frequency behavior of input signal, wavelets behave like more compressed for decreasing scale because of short time. Hence it has been concluded that the frequency is inversely proportional to scaling parameter. This scaling parameter corresponds to the low frequency.

In CWT, due to repeated wavelet coefficients and analytical calculation proven to be unuseful for practical problems. In addition, more time is required for wavelet transform and calculation of power. To overcome these issues discrete wavelets are popularly used [[5].

The discrete wavelets are continuous, scalable and translable wavelets.

They can be set at the beginning to make them scalable and translate in discrete steps.

When discrete wavelets are used, the output of wavelet transform would results in series of wavelet coefficients.

The scaling function that overcome the problem of using infinite number of wavelet function is created by making use of time shifted version of scaling function is given by equation 1.

$$\varphi_{\alpha,\beta}(t) = 2^{\alpha/2}\varphi(2^{\alpha}t-\beta) \quad \beta \in Z,\ \alpha \in M^{2} \text{ --- (1)}$$

Where,

M^2 represents the integral of the modulus square.

'α' have low or high values. Lower values represent uneven detail whereas higher value represents the even detail.

The scaling function $\varphi(t)$ can be refined if the uniform shift of $\varphi(2t)$ exists and is generally given by equation 2.

$$\varphi(t) = \sum g(n)\sqrt{2}\ \varphi(2t-n), \quad n \in Z \text{ -------- } (2)$$

Where, $g(n)$ represents the scaling coefficients.

The above equation (2) shows the scaling function created due to summation of half-length translations.

Similarly, wavelet functions $\psi(t)$ can be refined (as shown in equation (3) if the uniform shift of $\psi(2t)$ exists.

$$\psi(t) = \sum h(n)\sqrt{2}\varphi(2t-n), \qquad n \in Z \text{ -------- } \quad (3)$$

h(n) denotes coefficients of wavelet function.

Therefore, the condition of orthogonality gives the relation between the wavelet and scaling coefficients as given in equation 4.

$$p\ (n) = (-1)^{n}\ g(M-1-n), \qquad |g(n)| = M \text{ -------- } (4)$$

Filter banks can efficiently represent the discrete wavelet transform. Low pass filter represents the scaling coefficients h (n) given in above equation (2). Similarly, High Pass filter represents the wavelet function g (n) given in above equation in (3)[6]. Generally filtering means the convolution of signal with filter's coefficient. Equation (5) indicates the filtering operation for an input signal x(n) of the Finite Impulse Response (FIR) filter 'H' and length 'M'.

$$x(n) * g(n) = \sum_{k=0}^{M-1} x(k)g(n-k) \text{ ---------- } (5)$$

According to above equation (5) the scaling and wavelet filter are relate to each other due to orthogonality condition. Practically the spectrum of wavelet filter in frequency domain is the mirror image of the scaling filter spectrum by $\pi/2$. Hence, the wavelet filter frequency response is half of the High-band-Pass Filter (HBPF) and the scaling filter frequency response is the half Low-band-Pass Filter (LBPF). Both HBPF and LBPF are complementary to each other.

Half band pass filtering increases the possibility of redundant samples of input signal. Down-sampling process can remove these redundant samples. Considering every sample of input signal, the input signal is down-sampled by factor of two and discarding unwanted samples.

$$y(n) = x(2n) \text{ --------------- } (6)$$

The signal is stretched by up sampling by inserting the zeros in samples. In up sampling the information is not destroyed but it is inverted. The factor of two is used for up-sampling process in which the numbers of samples are doubled by inserting one zero in every pair of samples.

III. WAVELET PACKET MODULATION

In WPM system, the presence of the subcarriers are represented in term of levels which are obtained due to analysis and synthesis tree and expressed by:

$$S = 2^{n} \text{ ----------------- } (7)$$

Where, '***S***' – subcarriers (In Numbers)

'***n***' - Level of Filter banks

The wavelet packet analysis and synthesis tree is explained in equation 8.

$$\xi_{n+1}^{2p}(t) = \sqrt{2}\sum_{m} h(m)\,\xi_{n}^{p}\left(t-2^{n}m\right)$$
$$\text{------------------ } (8)$$
$$\xi_{n+1}^{2p+1}(t) = \sqrt{2}\sum_{m} g(m)\,\xi_{n}^{p}\left(t-2^{n}m\right)$$

The subscripts '*m'* in equation (8) represents level of the tree structure and superscript '*p'* represents the subcarrier index (level *n*)

The filter used for WPM system has selected in such a manner that they do not meet the requirements of the communication system. Perfect reconstruction is required to synchronize with orthogonality of subcarriers. Filters that fulfill the orthogonality constraint can only generate these.

The transmitted signal in WPM consists of modulated WPM symbols generated due to summation of modulated subcarriers.

In wavelet-based transformation, the used waveform no longer remains same as that of duration of one symbol. As a result, symbols overlap with each other in time domain. Since the used waveforms are orthogonal in nature, the Inter Symbol Interference (ISI) does not occur, even if the symbols are overlapped and they do not cause problem. In addition, use of longer duration symbols results in better frequency localization within subcarriers in WPM system.

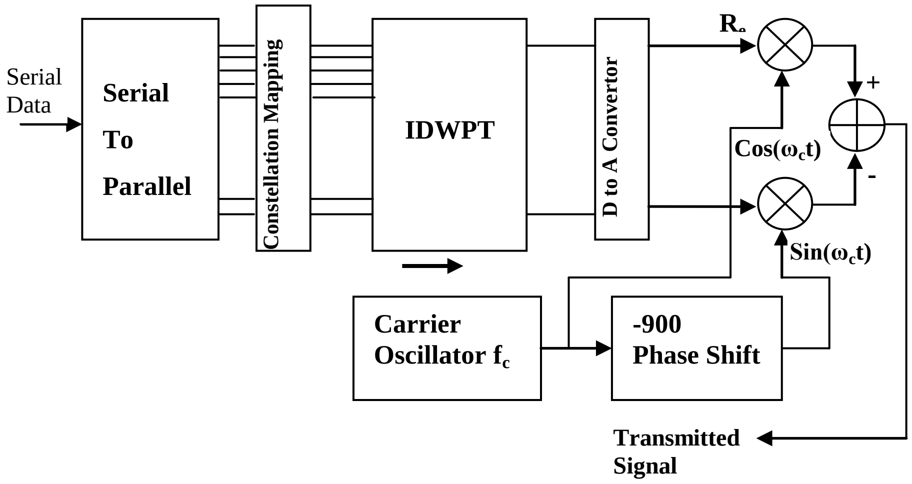

Figure 3-1. WPM Transmitter

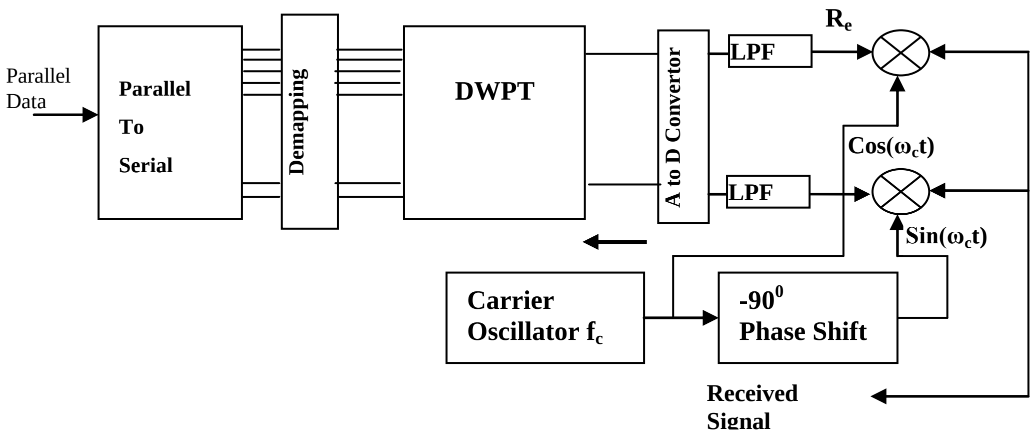

Figure 3-2. WPM Receiver

IV. SIMULATION RESULTS

For the proposed WPM system designed for communication network, simulation parameter has selected and shown in table 4-1. It is assumed that the distance between the nodes in communication network is 100 meters. Most suitable wavelets for evaluating the major performance parameters like BER, throughput and energy consumption has been identified. To identify the most suitable modulation scheme, efficient modulation technique QPSK tested for channel conditions like AWGN, Rayleigh, and Rician. Assuming 64 sub-carriers for the modulation scheme the communication network was tested for 1000 bits code length. Wavelets like Daubechies (db2), Coiflet (coif2), Haar, Symlet (sym4), was tested on WPM system.

Table 4-1. Simulation Parameters for WPM System

Modulation	QPSK, 16-PSK
Subcarriers	64
Code length	1000 bits
Number of Levels	4
Distance between Nodes in meters	100
Channels	AWGN, Rayleigh, Rician
Wavelets with filter length	Daubechies (db2), Haar, Symlet (sym4), Coiflet (coif2)

QPSK Modulation for WPM system:

By using QPSK modulation within the system BER (Bit Error Rate) was found using four wavelets (Daubechies, Haar, Symlet and Coiflet). After doing the comparative analysis of BER for four different wavelets it has been observed that for smaller values of SNR, performance of each of the wavelet is almost same. But for the increased values of SNR significant difference arises between performances of the system using different wavelets. Figure 5-10 gives the comparative performances of the wavelets for SNR values using channel condition as AWGN. Also, the performance of BER was tested for the Rician and Rayleigh. Channel conditions assuming higher values of SNR in QPSK modulation scheme and their comparative performances are shown in figure 4-1, 4-2 and 4-3 respectively.

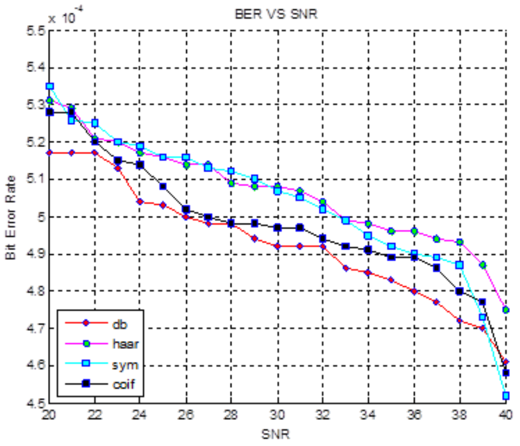

Figure 4-1. Performance analysis of different wavelets for Bit Error Rate using AWGN channel

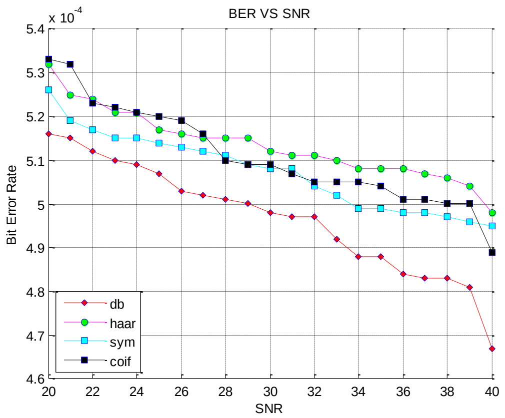

Figure 4-2. Performance using different wavelets for bit error rate in Rayleigh channel

BER, under different channel condition was obtained for higher values of SNR is shown in figures 4-1, 4-2 and 4-3. Figure above clearly indicates better performance of Daubechies wavelet. Also, it has been observed from figures that average performance of Daubechies (db2) wavelet for BER values was found low over AWGN, Rayleigh and Rician channel conditions as compare to Haar, Symlet and Coiflet wavelets. Also, the performance of Daubechies (db2) wavelet for BER over AWGN channel condition was found more suitable for efficient WPM system. All the above is true when QPSK modulation scheme is used.

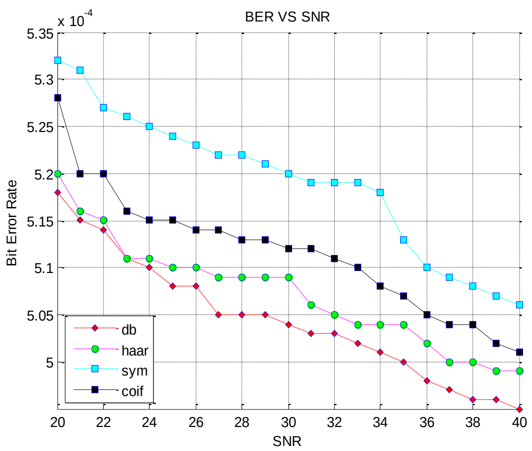

Figure 4-3. Performance analysis of different wavelets for bit error rate using Rician channel

Similarly, performance of the wavelets for throughput with higher values of SNR using QPSK modulation scheme over Rayleigh, AWGN and Rician channel conditions are shown in figure 4-4, figure 4-5 and figure 4-6 respectively.

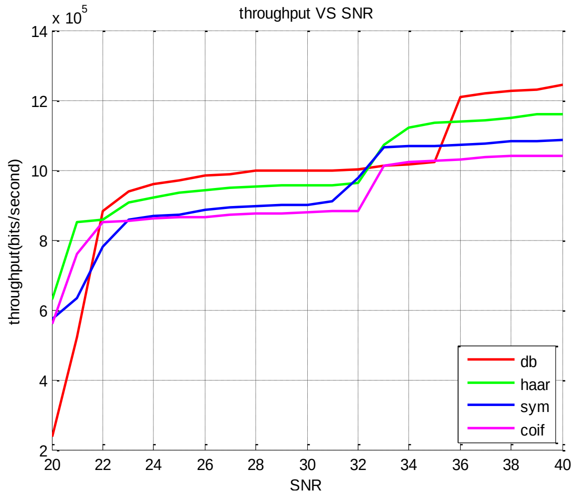

Figure 4-4. Performance analysis of different wavelets for Throughput using AWGN channel

From figures 4-4, 4-5 and 4-6, it is found that the Daubechies (db2) wavelet performance for higher values of SNR gives relatively high values for throughput. Also, db2 wavelet performance is relatively good as compared to Symlet, Haar and Coiflet wavelets over Rayleigh and Rician channel condition. By using AWGN channel the value of throughput found higher as compared to Rician and Rayleigh channel condition. So, under different channel conditions the performance of Daubechies wavelet for throughput in WPM system is satisfactory using QPSK modulation scheme in comparision with the Rician and Rayleigh channel conditions.

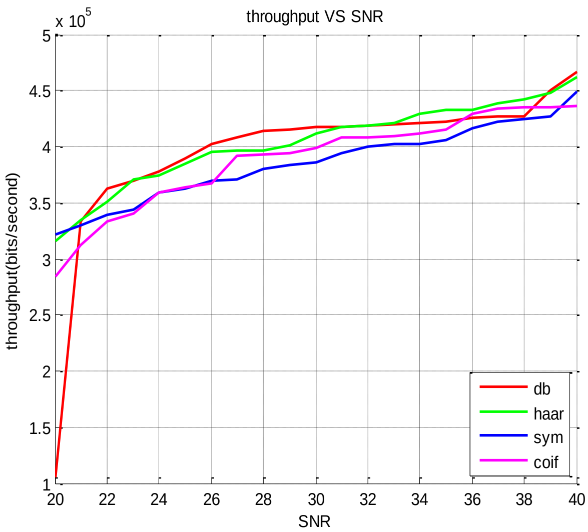

Figure 4-5. Performance analysis of different wavelets for Throughput using Rayleigh channel

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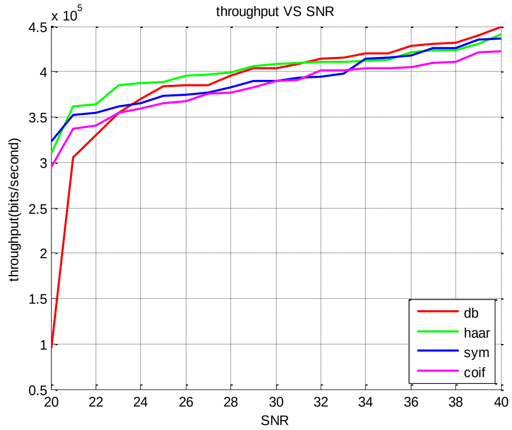

Figure 4-6. Different wavelets performance analysis for Throughput in Rician channel

Also, comparative performance of the wavelets (Haar, Coiflet, Daubechies and Symlet) for energy consumption during communication with higher values of SNR using QPSK modulation scheme under Rician, AWGN and Rayleigh channel conditions are cleared from figure 4-7, figure 4-8 and figure 4-9 respectively.

From the figures 4-7, 4-8 and 4-9 results that by using QPSK modulation, Daubechies (db2) wavelet performance for energy consumption gives lower values if used under AWGN, Rayleigh and Rician channel condition. As compared to other wavelets like Symlet, Haar, Coiflet, Daubechies (db2) wavelet performance is observed good.

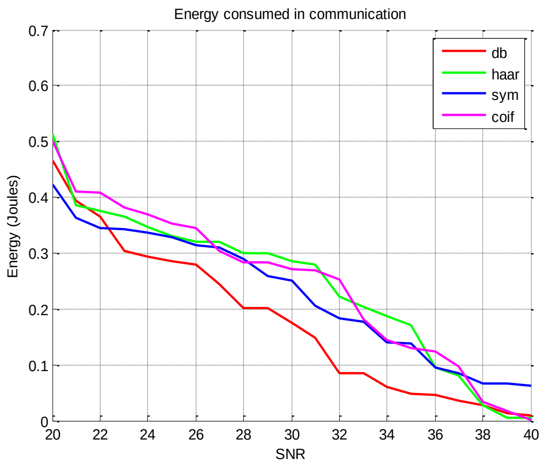

Figure 4-7. Performance analysis of different wavelets using AWGN channel

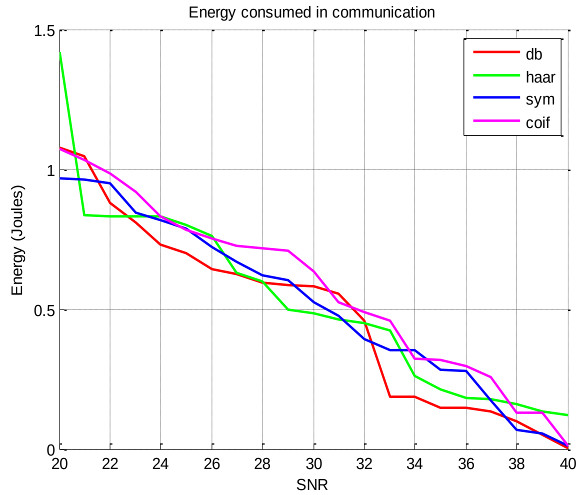

Figure 4-8. Performance analysis of different wavelets using Rayleigh channel

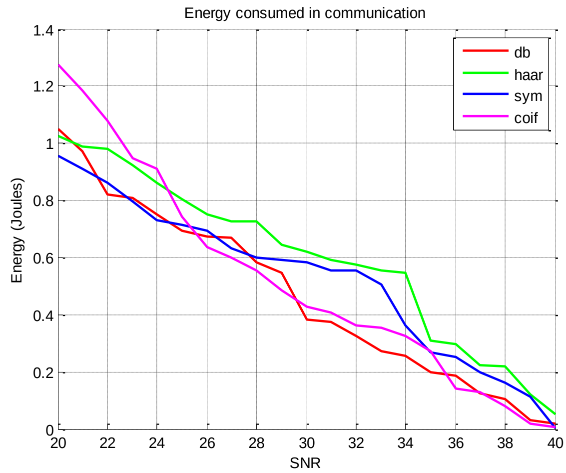

Figure 4-9. Different wavelets performance analysis using Rician channel

Also, the numerical values for performance parameters Bit Error Rate, Throughput and Energy consumption for WPM system are given as indicated by table 4-2. Average value gives the clear scenario about the of db2 wavelet performance in QPSK modulation scheme with respect to Haar, Symlet and Coiflet wavelets.

Table 4-2. WPM Performance Parameters using QPSK System

Performance parameters	Wavelets	SNR Range Average value	Rayleigh	Rician	AWGN
BER	db2	20 db - 40 db	0.000496	0.000505	0.000493
	haar		0.000514	0.000508	0.000506
	sym4		0.000508	0.000519	0.000504
	coif2		0.000510	0.000512	0.000497

Throughput (bits/sec)	db2	20 db - 40 db	420749.8	410838.0	1074505.8
	haar		417764.2	410886.8	1033363.6
	sym4		398568.9	400254.1	981825.8
	coif2		404266.3	393129.2	945987.8
Energy (Joules)	db2	20 db - 40 db	0.48932	0.46855	0.18232
	haar		0.55441	0.60528	0.24355
	sym4		0.51877	0.52342	0.22819
	coif2		0.56713	0.52723	0.24812

V. CONCLUSION

In this paper WPM system was designed for efficient communication. The effectiveness of the system was tested on QPSK modulation. In WPM transreceiver system four wavelets (db2, Haar, Symlet and Coiflet) was tested. The increased value of SNR affects the system performance. In this work suitable wavelet has been invetigated to improve the system performance for higher SNR. Results shows the Daubechies wavelet performance was comparatively good with respect to Haar, Symlet and Coiflet wavelet. BER, Throuhput and Energy are the three performance parameters tested on WPM system under Rician, AWGN, Rayleigh channel conditions. The performance of WPM system using Daubechies wavelet under AWGN channel condition was good with QPSK modulation. In future the WPM system will be created by making use of higher order modulations with the different set of wavelets

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AUTHORS PROFILE

Dr. Megha. B. Chakole, is working in Yeshwantrao Chavan College of Engineering, Nagpur as an Assistant Professor. She had completed her Ph.D from Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur. In Electronics Engineering. She has total 12 years of teaching experience. She is member of technical societies like IEEE, ISTE and IACSIT Member. Her research area is wireless Communication. She has presented 20 research papers in the reputed national and international conferences and Journals.

Dr. Sanjay. S. Dorle, has completed his Ph. D. in Electronics Engineering from VNIT. He has total 22 years of teaching and research experience. He is member of technical societies like IEEE, CSI, ISTE and IETE. Presently, he is working as Dean Academics and Professor of Electronics Engineering at G.H. Raisoni College of Engineering, Nagpur. His research area includes Embedded Systems, VANETs, Wireless Communication Systems.. He had received the grant from AICTE for the research work. He has published many research papers in the reputed international conferences and Journals.