INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN: 2278 – 0211 (Online)

Design And Development Of Hybrid Adaptation Techniques In Mimo Ofdm System For 4G Wireless Networks

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Abstract:
This paper presents the strategy of applying Hybrid adaption techniques in MIMO OFDM system. With the rapid growth of digital communication in recent years, the need for high-speed data transmission is increased. Multiple-input-multiple-output (MIMO) antenna architecture has the ability to increase capacity and reliability of a wireless communication system. Orthogonal frequency division multiplexing (OFDM) is another popular technique in wireless communication which is famous for the efficient high speed transmission and robustness to frequency selective channels. Therefore, the integration of the two technologies probably has the potential to meet the ever growing demands of future communication systems. First focusing on OFDM in which the bit error rate (BER) of multilevel quadrature amplitude modulation (M-QAM) in flat Rayleigh fading channel for 128,256,512 subcarriers was calculated and also channel estimation can be done by using different algorithms which is carried out through Matlab software. The channel estimation of MIMO OFDM system is calculated by using Minimum mean square error algorithm (MMSE) and compares the actual value and estimation errors using Matlab simulation.
Then take the feedback from the channel estimation and apply hybrid adaptation techniques to improve the spectral efficiency and to reduce the transmit power. This system is used in wireless LAN i.e. IEEE 802.11a/g, HYPERLAN etc.,

Key words: *MIMO, OFDM, BER, M-QAM, MMSE, MIMO OFDM*

1.Introduction

Physical limitations of the wireless medium create a technical challenge for reliable wireless communication. Techniques that improve spectral efficiency and overcome various channel impairments such as signal fading and interference have made an enormous contribution to the growth of wireless communications. Moreover, the need for high-speed wireless Internet has led to the demand for technologies deliveringhigher capacities and link reliability than achieved by current systems. Multiple-input multiple-output (MIMO) based communication systems are capable accomplishing these objectives. The multiple antennas configuration exploits the multipath effect to accomplish the additional spatial diversity.

However, the multipath effect also causes the negative effect of frequency selectivity of the channel. Orthogonal frequency division multiplexing (OFDM) is a promising multi-carrier modulation scheme that shows high spectral Efficiency and robustness to frequency selective channels. In OFDM, a frequency-selective channel is divided into a number of parallel frequency-flat sub channels, Thereby reducing the receiver signal processing of the system. The combination of OFDM and MIMO is a promising technique to achieve high bandwidth efficiencies and System performance. In fact, MIMO-OFDM is being considered for the upcoming IEEE 802.11n standard, a developing standard for high data rate WLANs

2.Paper Review

C.Poongodi,P.Ramya,A.Shanmugam,(2010) "BER Analysis of MIMO OFDM System using M-QAM over Rayleigh Fading Channel" Proceedings of the International Conference on Communication and Computational Intelligence, explains the BER of MIMO OFDM over the Rayleigh fading channel for M-QAM Modulation. and also the estimation of channel at high frequencies with conventional least squares(LS) and Minimum Mean Square(MMSE) estimation algorithms which is carried out through MATLAB simulation. The performance of MIMO OFDM is evaluated on the basics of Bit Error Rate (BER) andMeansquareError (MSE) level. Dr.JayaKumari.J,(2010) "MIMO OFDM for 4G Wireless Systems", International Journal of Engineering Science and Technology VOL.2 (7)., explains the OFDM may be combined with antenna arrays at the transmitter and receiver to increase the diversity gain and/or to enhances the system capacity on time variant and frequency-selective channels, resulting in MIMO Configuration. As a promising technology for the future broadband communication, and the simulation results show that this is a promising technology for next generation wireless systems and used in applications such as HYPERLAN,WLAN and DSL etc. Pallavi Bhatnagar ,Jaikaran Singh,Mukesh Tiwari (2011) “Performance of MIMO-OFDM System for Rayleigh fading channel” (ISSN 2221-8386) Volume No 3 May 2011 explains the efficient simulation for MIMO OFDM system with channel equalization. BPSK modulation is used to detect the behavior of the Rayleigh fading channels in presence of additive white Gaussian noise and performance is evaluated. This paper shows that the addition of equalizer reduces the BER and the channel output becomes more pronounced.

3.Methodology

Orthogonal frequency division multiplexing (OFDM) transforms a frequency selective channel into a large set of individual frequency non-selective narrowband channels, which is suited for a multiple-input multiple-output (MIMO) structure that requires a frequency non-selective characteristic at each channel when the transmission rate is high enough to make the whole channel frequency selective. Therefore, a MIMO system employing OFDM, denoted MIMO-OFDM, is able to achieve high spectral efficiency. However, the adoption of multiple antenna elements at the transmitter for spatial transmission results in a superposition of multiple transmitted signals at the receiver weighted by their corresponding multipath channels and makes the reception more difficult. This imposes a real challenge on how to design a practical system that can offer a true spectral efficiency improvement. If the channel is frequency selective, the received signals are distorted by ISI, which makes the detection of transmitted signals difficult. OFDM has emerged as one of most efficient ways to remove such ISI. The delay spread and Doppler spread are the most important factors to consider in thee characterizing the SISO system. In the MIMO system which employs multiple antennas in the transmitter and/or receiver, the correlation between the transmitter and receiver antenna is an important aspect of the MIMO channel.it depends on the angle of arrival of each multipath component In fact, MIMO technique is an essential means of increasing capacity in the high SNR regime, providing at most N spatial degrees of freedom. A typical multi-user MIMO communication environment in which the multiple mobile stations are served by single base station in the cellular system. Fig 5.1 and fig 5.2 shows the block diagram of MIMO OFDM transmitter and receiver. This system is modification of OFDM, which provides high BER and used in many applications such as DAB, DVB, DSL.

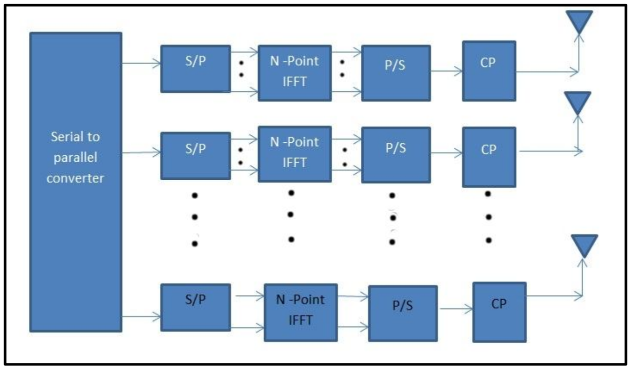


Figure 1: Transmitter Block Diagram Of MIMO OFDM

3.1.Channel Estimation

The ultimate goal at the receiver is to recover the signal that was originally transmitted. A variety of equalization and signal detection techniques has been developed for MIMO systems depending on whether it is a diversity or spatial multiplexing system.

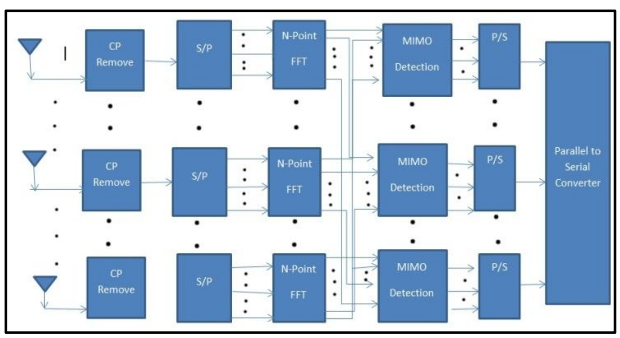


Figure 2: Receiver block diagram of MIMO OFDM

Regardless of the type of MIMO system, most of the equalization/detection schemes require knowledge of the channel information in order to recover the signal. Hence, developing an efficient method of approximating the transmission channel between the transmitter and receiver is an essential component of the receiver design. In this chapter the channel estimation for MIMO-OFDM is briefly explained fundamentally. First, a general overview on classical estimation theory is provided then OFDM channel estimation is briefly explained in the next step MIMO-OFDM channel estimation is investigated. The problem of MIMO-OFDM system channel estimation in frequency domain is addressed, and the solution for this problem is well interpreted.

Finally The MMSE algorithm as an alternative to decrease the computational complexity of LS channel estimation is investigated.

3.2.Ls Channel Estimation

The least-square (LS) channel estimation method finds the channel estimate $\hat{H}$ in such a way that the following cost function is minimized:

$J(\hat{H})$ =‖Y-X$\hat{H}$‖

= (Y-X$\hat{H}$) ^H(Y-X$\hat{H}$)

= Y^HY-Y^HX$\hat{H}$-$\hat{H}^H$ X^HY+$\hat{H}^H X^H$X$\hat{H}$

By setting the derivative of the function with respect to $\hat{H}$ to zero,

$\frac{\partial J(\hat{H})}{\partial \hat{H}}$ = -2$(X^H Y)^*$+2$(X^H X\hat{H})^*$ = 0

We have $X^H X\hat{H} = X^H Y$, which gives the solution to the LS channel estimation as

$\hat{H}_{LS}$=(X^HX)$X^H Y$=$X^{-1}Y$

Let us denote each component of the LS channel estimate $\widehat{H_{LS}}$ by $\widehat{H_{LS}}[k]$, k = 0,1,2,3,…..N-1.since X is assumed to be diagonal due to the ICI-free condition,the LS channel estimate H_{LS} can be written for each subcarrier as

$\hat{H}_{LS}[k] = Y[k]/X[k]$,k = 0,1,2,…N-1

The mean square error(MSE) of this LS channel estimation is given as

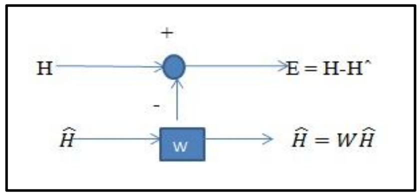
MSE_{LS}=E{$(H - \hat{H}_{LS})^H$ (H-H_{LS})}

= σ_z^2/σ_x^2

Note that the MMSE in the equation is inversely proportional to the SNRσ_x^2/ σ_z^2, which implies that it may be subject to noise enhancement, especially when the channel is in a deep null. Due to its simplicity, however, the LS method has been widely used for channel estimation.

3.3.Mmse Channel Estimation

Consider the LS solution in the equation,$\hat{H}_{LS}$ =$X^{-1}Y$. Using the weight matrix W.define $\hat{H}$==W$\hat{H}$, which corresponding to the MMSE estimate. Referring to the figure, MSE of the channel estimate $\hat{H}$ is given J ($\hat{H}$) = E {$\|e\|^2$} = E {$\|H - \hat{H}\|^2$}.



Then, the MMSE channel estimation method finds a better (linear) estimate in terms of W in such a way that the MSEin equation is minimized. The orthogonality principle states that the estimation error vector e = $H - \widehat{H}$ is orthogonal to $\widehat{H}$,such that

E{$\widehat{eH}^H$}= E{$(H - \widehat{H})H^{\hat{}H}$

$$= R_{H\widehat{H}} - WR_{H\widehat{H}} = 0$$

Where R_{AB} is the cross-correlation matrix of N*N matrices A and B, and$\widehat{H}$ is the LS channel estimate given as

$\widehat{H}= X^{-1}Y$

Solving equation for the W yields

$$W = R_{H\widehat{H}}R_{H\widehat{H}}^{-1}$$

Where $R_{H\widehat{H}}$ is the autocorrelation matrix of $\widehat{H}$ given as

$R_{H\widehat{H}}$=E{H$H^{\hat{}H}$}

$$=E\{HH^{\hat{}H}\}+ \sigma_z^2/\sigma_x^2 I$$

And$R_{H\widehat{H}}$ is the cross correlation matrix between the true channel vector and temporary channel estimate vector in the frequency domain. Using the equation the MMSE channel estimation follows as $\widehat{H}$ = W$\widehat{H}$.

$$= R_{H\widehat{H}}R_{H\widehat{H}}^{-1}\widehat{H}$$

$$= R_{H\widehat{H}}(R\_(HH\hat{}) + \sigma_z^2/\sigma_x^2 I)^{-1}\widehat{H}$$

The elements of $R_{H\widehat{H}}$ and R_{HH} in equation are E{$h_{k,l}h_{k',l'}$} = $r_f[k - K']r_t[l - l']$ Where k and l denote the subcarrier frequency index and OFDM symbol (time) index, respectively . In an exponentially – decreasing multipath PDP (power delay profile), the frequency- domain correlation $r_f[k]$ is given as $r_f[k]$ = 1/1+j2i$t_{rms}k\Delta f$

3.4.Channel Estimation Of Mimo Ofdm System

The problem of channel estimation for OFDM has been well researched however, the results are not directly applicable to MIMO-OFDM systems. In MIMO systems, the number of channels increases by M.Nr-folds, where M and Nr is the number of transmit and receive antenna, respectively. This significantly increases the number of unknowns to be solved. Using the MIMO-OFDM system model described in Chapter 4, the channel estimator for MIMO-OFDM can be developed. For doing so, MIMO-OFDM 2 by 2 antenna configuration is assumed. Similar to SISO the least square channel estimation is given as

$$\hat{H}_{L,S}{}^{(n,m)} = (X^{(n)})^{-1}Y^{m}$$

And the MMSE channel estimation for MIMO OFDM system for nth transmit antenna and nth receiver antenna is given$\hat{H}_{MMSE}{}^{(n,m)} = FR_{hY}R_{YY}{}^{-1}Y^{(m)}$Where

R_{hY}=$R_{hh}{}^{(m,n)}F^{H}(X^{(n)})^{H}$,

$R_{YY} = FX^{(n)}R_{hh}{}^{(n,m)}F^{H}(X^{(n)})^{H} + \sigma^{2}I$,Where n = 1, 2….NT, m = 1, 2….NR and NT, NR are the numbers of transmit and receive antennas, respectively, $X^{(n)}$ is an N X N diagonal matrix whose diagonal elements correspond to the pilots of the n^{th} transmit antenna and $Y^{(m)}$ is N length received vector at receiver antenna m.

3.5.Adaptive Modulation

Adaptive modulation is a powerful technique for maximizing the data throughput of subcarriers allocated to a user. Adaptive modulation involves measuring the SNR of each subcarrier in the transmission, then selecting a modulation scheme that will maximise the spectral efficiency, while maintaining an acceptable BER. This technique has been used in Asymmetric Digital Subscriber Line (ADSL), to maximise the system throughput. ADSL uses OFDM transmission over copper telephone cables. The channel frequency response of copper cables is relatively constant and so reallocation of the modulation scheme does not need to be performed very often, as a result the benefit greatly out ways the overhead required for measuring of the channel response. Using adaptivemodulation in a wireless environment is much more difficult as the channel response and SNR can change very rapidly, requiring frequent updates to track these changes. Adaptive modulation has not been used extensively in wireless applications due to the difficulty in tracking the radio channel effectively. In the effectiveness of amultiuser OFDM system using an adaptive subcarrier, bit and power allocation was investigated.

3.6.Adaptivemodulator Anddemodulator

At the transmitter the adaptive modulator block consists of different modulators which are used to provide different modulation orders. The switching between these modulators will depend on the instantaneous SNR. The goal of adaptive modulation is to choose the appropriate modulation mode for transmission depending on instantaneous SNR, in order to achieve good trade-off between spectral efficiency and overall BER. Adaptive modulation is a powerful technique for maximizing the data throughput of subcarriers allocated to a user. Adaptive modulation involves measuring the SNR of each subcarrier in the transmission, then selecting a modulation scheme that will maximize the spectral efficiency ,while maintaining an acceptable BER.

3.7.Water Filling Algorithm

The underlying key principle in frequency domain AMC is water filling or water pouring algorithm that allocates more (or less) bits and power to some subcarriers with larger (or smaller) SNR for maximizing the channel capacity.

Consider the OFDM system with N_{used} subcarriers, each subcarrier with spacing of Δf. the capacity of a subchannel corresponding to Kth subcarrier,f_k is given by the Hartley-Shannon capacity, such that

$c(f_k)$ =Δf log (1+$|H[k]|^2 p[k]/N_o$)

Where H[k], P[k] and N_o denote frequency, transmission power and noise variance of the Kth subchannel, respectively. Then the total capacity is given by the sum of the capacity for individual subcarriers, that is

$$C = \sum_{k=0}^{N_{used}-1} C(f_k)$$

Where N_{used} is large enough, which meansΔf is small enough to be narrower than the coherence bandwidth, H[k] can be considered constant for each subcarrier k. in other words, SNR can be imprecated as a constant for each subcarrier. Given the SNR for each subcarrier, we may allocate different powers to different subcarriers so as to maximize the total systemcapacity. In other words it can be formulated as the following optimization problem:

$$max_{p_0,\ldots\ldots p_{N_{used-1}}} \sum_{k=0}^{N_{used}-1} C(f_k) = \sum_{k=0}^{N_{used-1}} (\text{Log}(1+|H[k]|^2 p[k]/N_o))$$

$$\sum_{k=0}^{N_{used-1}} P[k] = N_{used.}p$$

Where p is average power per subcarrier available in the transmitter. Employing the Lagrange multiplier method for optimization with equality constraint in the above equation , the following solution is obtained :

$p^{*}[k] = (\frac{1}{\lambda} - N_o / |H[k]|^2)^+ = \{1/\lambda -- \frac{N_o}{H[k]^2}$,if $1/\lambda -- \frac{N_o}{H[k]^2} \geq 0$

Where λ is the Lagrange multiplier that is chosen to meet the power constraint in equation. This solution implies that the sums of power and NSR (noise to signal ratio) for each subcarrier must be the same for all subcarriers except for the subcarriers that have assigned no power just because $1/\lambda -- \frac{N_o}{H[k]^2} < 0$. According to this algorithm ,a subcarrier with larger SNR is allocated more transmission power. The figure represents a graphical representation of the optimal power allocation solution in the equation. The NSR $\frac{N_o}{H[k]^2}$,given in a function in a subcarrier index k , can be considered as the bottom of a water tank with an irregular shape. If each subcarrier pours with P units of water in the tank, the depth of the water at subcarrier n corresponds to power allocated to that subcarrier, while 1/λ is the height of water level. Since the algorithm has been described by filling a tank with water, it is called as a water- filling algorithm. In this water- filling analogy, it is interesting to note that no power must be allocated to subcarriers with the bottom of the tank above the given water level. In fact, this corresponds to a situation in which a poor channel must not be used for transmitting data.

4.Simulation Results

System	OFDM
FFT size	128
Guard band size	32
Symbol duration	160
Channel	Rayleigh Fading
No of symbols used	96
Modulation	QAM

Table1: Simulation parameters in OFDM system

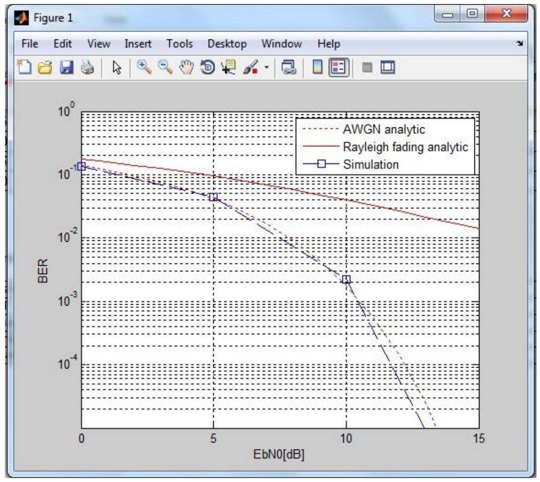


Figure 3:BER analysis of OFDM system

The Simulation Results Are

- Signal power= 5.860e-003,
- EbN0 = 0[dB], BER= 157/1152 = 1.363e-001
- EbN0 = 5[dB], BER= 154/3456 = 4.456e-002
- EbN0= 10[dB], BER= 104/47232 = 2.202e-003
- EbN0= 15[dB], BER= 27/115200000 = 2.344e-007

Sytem	OFDM Channel Estimation
FFT Size, Guard Band, OFDM Symbol and No.of Symbols used	Nfft=128; Ng=Nfft/8; Nofdm=Nfft+Ng; Nsym=100;
Pilot Spacing, Numbers of Pilots and Data per OFDM Symbol	Nps=4; Np=Nfft/Nps; Nd=Nfft-Np;
Number of Bits Per (modulated) Symbol	Nbps=4; M=2^Nbps;
Algorithm	LS and MMSE
Calculate	No of symbol Errors and MSE value

Table 2: Simulation Parameters for OFDM Channel Estimation

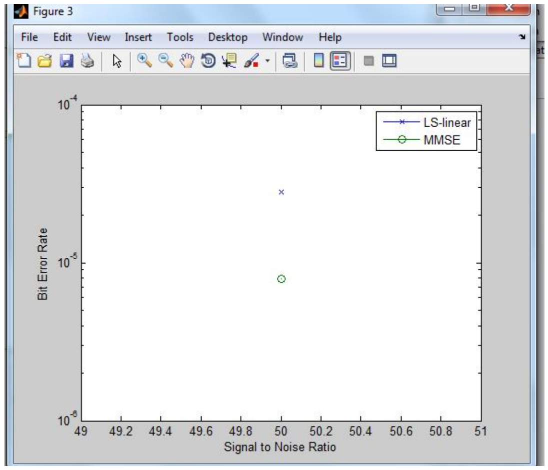


Figure 4: OFDM channel estimation

SNR	MSE Of Ls-Linear	MSE Of Ls-Splitter	MSE Of MMSE	No. Of Symbol Errors
25	5.8523e-003	7.3677e-003	1.4212e-003	84
30	1.8578e-003	2.3317e-003	5.2873e-004	32
35	5.9423e-004	7.3929e-004	1.9278e-004	15
40	1.9446e-004	2.3583e-004	6.5509e-005	11
45	6.7919e-005	7.6674e-005	2.1960e-005	4
50	2.7839e-005	2.6372e-005	7.8805e-006	0

Table 3: The Simulation Results of OFDM Channel Estimation

System	MIMO-OFDM Channel Estimation
No of receive antennas	3
No of transmit antennas	2
Channel	Rayleigh fading
Algorithm	MMSE

Table 4: Simulation Parameters for MIMO OFDM Channel Estimation

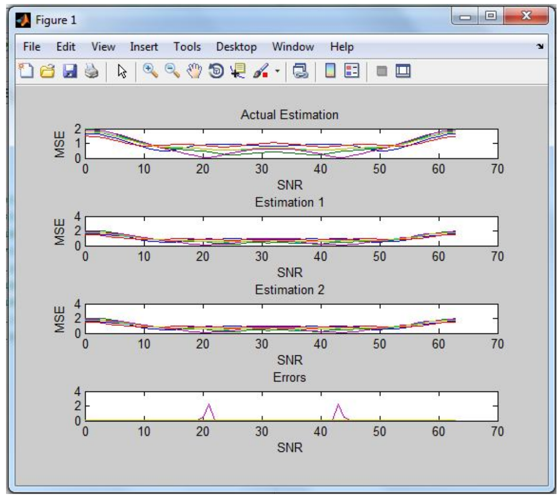


Figure 5: Channel Estimation of MIMO OFDM System

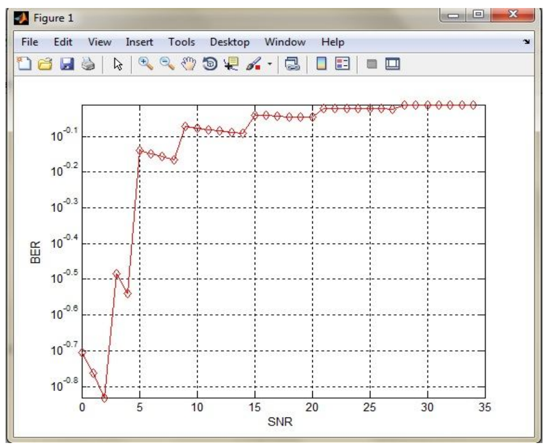


Figure 6: BER for Adaptive modulation in MIMO OFDM

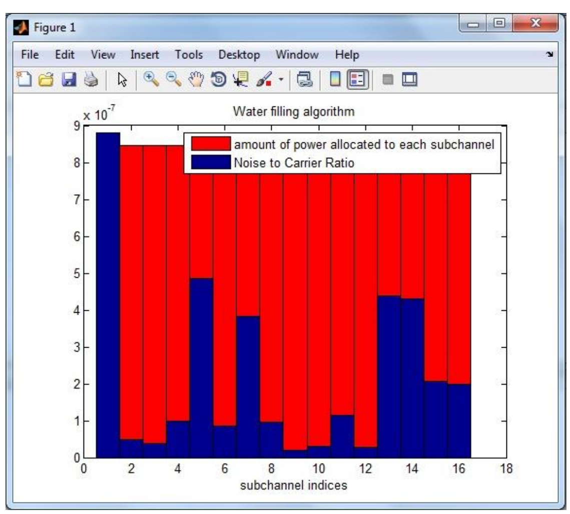


Figure 7: Water Filling Algorithm

5.Conclusion

Hence the each and every block of OFDM is studied and plotted the BER analysis under AWGN channel as well as Rayleigh fading channel and compare the simulation results for different EbN0[dB] values and BER value.

The channel estimation of MIMO OFDM system by using MMSE algorithm, which is quite complicated, and the simulation results shown that as the signal to noise ratio increases the error value slightly reduces. The actual estimation, estimation 1 and estimation 2 are plotted and the difference between estimation 1 and estimation 2 are also plotted. The simulation results shown that the channel condition is worst at 20 dB.

Then the hybrid adaptation techniques to the channel estimation of MIMO OFDM to improve the spectral efficiency and to reduce the transmission power of the system.

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