Simulation of OFDM/OQAM and Resource Allocation in OFDMA Systems

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ABSTRACT

Orthogonal frequency division multiplexing (OFDM) or Discrete Multi-tone with Cyclic Prefix is a multicarrier modulation scheme that provides high data rate transmission. It avoids both inter symbol and inter channel interferences by making use of a suitable cyclic extension of the transmitted data stream and allowing for a simple modulator structure. But it leads to the loss of spectral efficiency. An alternative is OFDM based on Offset QAM (OFDM/OQAM) modulation that uses efficient pulse shaping instead of a guard interval, which give a gain in spectral efficiency. Here we use the linear method that reduces the complexity of resource allocation. It linearizes the power allocation problem while achieving approximate rate proportionality among users. In this paper to generate OFDM/OQAM symbol, Extended Gaussian function (EGF) and Square Root Raised Cosine (SRRC) pulse shapes are used. The frequency spectra are compared with rectangular pulse shape spectrum. These functions reduced the out of band energy and improved the spectrum efficiency.

1. INTRODUCTION

Next generation wireless communication systems or Fourth Generation (4G) [1], systems aim to support interactive multimedia service and wireless Internet access at an ambitious data rate of 100Mbps or more. High data rate communication over wideband channels is significantly limited by inter-symbol interference (ISI), which is a result of multiple copies of the transmitted signal created by the reflection of objects. This phenomenon is commonly known as multipath fading. To combat ISI, multicarrier modulation techniques, as Orthogonal Frequency Division Multiplexing (OFDM) [2], are among the possible solutions that have been suggested.The OFDM is to used convert a frequency selective channel into a collection of frequency-flat sub-channels with partially overlapping spectra. This is achieved by splitting the input high-rate data stream into a number of sub-streams that are transmitted in parallel over orthogonal subcarriers. OFDM can be easily generated using an Inverse Fast Fourier Transform (IFFT) and reconstructed using a Fast Fourier Transform (FFT) [3]. OFDM increased robustness against multipath distortions as channel equalization can easily be performed in the frequency domain through a bank of one-tap multipliers. Also, it provides larger flexibility by allowing independent selection of the modulation parameters like the constellation size and coding scheme, across each subcarrier.

In most communication systems two-way communications is required and multiple users must be supported. OFDM can be used in a multiuser application producing a highly flexible, efficient communications system. In OFDMwe can use any coherent or differential, phase or amplitude modulation scheme. Each modulation scheme provides a tradeoff between Spectral Efficiency and the Bit Error Rate(BER).. The spectral efficiency can be maximized by choosing the highest modulation scheme that will give an acceptable Bit Error Rate (BER). The classic OFDM employing baseband Quadrature Amplitude Modulation (QAM) and rectangular pulse shape, denoted as OFDM/QAM, is most commonly used in today's applications, which refers to OFDM. In an ideal channel where no frequency offset is induced, Inter Carrier Interference (ICI) can be fully removed by orthogonality between sub-carriers. Inter Symbol Interference (ISI), which is caused by multipath propagation, can also be eliminated by adding a guard interval which is longer than the maximum time dispersion which leads to a loss of spectral efficiency and increases power consumption.OFDM scheme using offset QAM for each sub-carrier, denoted as OFDM/OQAM [4], [5] provides better spectral efficiency and meanwhile it reduces combined ISI/ICI. Contrary to OFDM/QAM which modulates each sub-carrier with a complex-valued symbol, OFDM/OQAM modulation carries a real-valued symbol in each sub-carrier and consequently allows time-frequency well localized pulse shape under denser system Time Frequency Localization (TFL) [6], requirement.By adopting various pulse shaping prototype functions such as Extended Gaussian Function (EGF) [7], Square Root Raised Cosine (SRRC) [8], with good TFL property, OFDM/OQAM can efficiently reduce both ISI and ICI without employing any guard interval. This enables a high efficient packing of time frequency symbols maximizing such as the throughput or the interference robustness in the communication link.

The extension of OFDM concept to multiuser communication scenarios can be represented by the Orthogonal Frequency Division Multiple Access (OFDMA) technology [9], which results from a combination of OFDM with a frequency division multiple access (FDMA) protocol. Most multiuser OFDM systems use clusters which consist of a number of adjacent OFDM subcarriers as basic units for channel assignment and power allocation. In OFDMA systems, the available subcarriers are divided into several mutually exclusive clusters or sub-channels that are assigned to distinct users for simultaneous transmission.The orthogonality among subcarriers gives intrinsic protection against multiple access interference (MAI). Also, OFDMA inherits from OFDM the ability to compensate channel distortions in the frequency domain without the need of computationally demanding time domain equalizers. It has emerged as one of the prime multiple access schemes for broadband wireless networks such as IEEE 802.16e [10] or Mobile WiMax.In OFDMA, first a subcarrier allocation algorithm assigns the sub-channels to the users, and a bit loading algorithm determines the constellation size and transmits power for each sub-channel. First, we estimate about how many subcarriers are conceded to each user is made, taking into account the users' mean Carrier to Noise Ratio (CNRs), the desired minimum bit rates and the users' maximum transmit powers. In the second step we determined which subcarriers are given to which user. The idea for the subcarrier distribution is that the users choose alternatively the subcarrier with the best CNR.

2. PRINCIPLES OF OFDM

Wireless local-area networks (WLANs) are designed for local high-speed wireless communications, which require high transmission rates over mobile radio channels. In the case of Frequency Division Multiplexing (FDM) [11], used in radio stations, all stations transmit at the same time over a single transmission path but do not interfere with each other because they transmit using different carrier frequencies, which is modulated by data. Additionally they are bandwidth limited and are spaced sufficiently far apart in frequency so that their transmitted signals do not overlap in the frequency domain. At the receiver, each signal is individually received by using a frequency tunable band pass filter to selectively remove all the signals except for the station of interest. This filtered signal can then be demodulated to recover the original transmitted information.All the subcarriers within the OFDM signal are time and frequency synchronized to each other, allowing the interference between subcarriers to be carefully controlled. These multiple subcarriers overlap in the frequency domain, but do not cause ICI due to the orthogonal nature of the modulation. In OFDM the orthogonal packing of the subcarriers greatly reduces this guard band, improving the spectral efficiency.In OFDM, the entire channel is divided into many narrow sub-channels that are utilized in parallel transmission, thereby increasing a symbol period to an OFDM period that is much larger than the channel delay spread and thus reducing the effect of inter block interference (IBI) caused by the dispersive Rayleigh-fading environment. Therefore, OFDM is an effective technique for combating multipath fading and for high-bit-rate transmission over mobile wireless channels. OFDM can achieve adaptive allocation of transmission load in different sub-channels to achieve optimum entire transmission rate.

To generate OFDM successfully the relationship between all the carriers must be carefully controlled to maintain the orthogonality of the carriers. so, OFDM is generated by firstly choosing the spectrum required, based on the input information data, and modulation scheme used. Each carrier to be generated is assigned some data to transmit. The desire amplitude and phase of the carrier is then calculated based on the modulation scheme like Quadrature Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (QAM). The required spectrum is then converted back to its time domain signal using an Inverse Fast Fourier Transform. The IFFT performs the transformation very efficiently, and ensure the carrier signals produced are orthogonal.The FFT transforms a cyclic time domain signal into its equivalent frequency spectrum. This is done by finding the equivalent waveform, generated by a sum of orthogonal sinusoidal components. The amplitude and phase of the sinusoidal components represent the frequency spectrum of the time domain signal. An IFFT converts a number of complex data points, of length that is a power of 2, into the time domain signal of the same number of points.

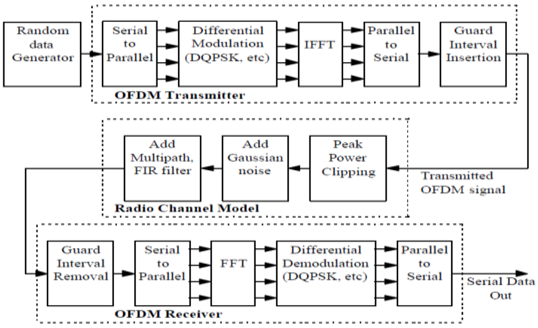

Figure 2.5: Block diagram showing a basic OFDM transceiver

3. OFDM BASED ON OFFSET QAM

Classical OFDM/QAM modulation uses a guard interval (or cyclic prefix) to efficiently combat the multi-path effect, at the price of spectral efficiency. To remove this guard interval, the prototype function modulating each sub-carrier must be very well localized both in the time and in the frequency domain, to limit the inter-symbol and inter carrier interferences. This function must also guarantee orthogonality between sub-carriers.Contrary to the conventional OFDM system [12], OFDM/OQAM which utilizes well designed pulse shapes and/or system lattice can achieve smaller ISI/ICI without using the cyclic prefix. The OFDM/QAM system modulates each sub-carrier with a complex-valued symbol; OFDM/OQAM modulation carries a real-valued symbol in each sub-carrier and consequently allows time-frequency well localized pulse shape under denser system TFL requirement.By adopting various pulse shaping prototype functions with good TFL property, OFDM/OQAM [13], can efficiently reduce both ISI and ICI without employing any guard interval. This enables a high efficient packing of time frequency symbols maximizing the throughput or the interference robustness in the communication link.

In the case of OFDM/OQAM systems if cyclic prefix is introduced near the channel i.e., after the bank of component filters, then removing the cyclic prefix at the receiver before passing through component filters will introduce discontinuity in the pulse shaping. Therefore orthogonality between transmit and receive pulse shapes seriously degraded, which will consequently cause extra distortion. If cyclic prefix is introduced near IFFT/FFT blocks i.e., the same as in OFDM systems, it will be no longer cyclic after passing through the bank of component filters and therefore it cannot help to diagonalise the multipath channel. On the other hand, however, it will increase the symbol duration and therefore relaxes the TFL requirement for pulse shape design.

OFDM/OQAM systems with pulse-shaping

Atime-continuous model for OFDM/OQAM systems is shown in figure 3.2. This model has N subchannels and subchannel spacing of 1/T. Let $a_k^R(n)$ represents the real part and $a_k^I(n)$ represents the imaginary part of input symbols. Each sub-channel transmits one QAM symbol $a_k(n) = a_k^R(n) + ja_k^I(n)$every T seconds. The Offset QAM symbols are obtained by shifting the imaginary part $a_k^I(n)$by T/2. Also g(t) and f(t) are respectively the transmitter and receiver filters, and h(t) is the channel impulse response.

$$s(t) = e^{\frac{j(m+n)\pi}{2}} e^{j2\pi m v_0 t} g(t - n\tau_0),$$
$$\nu_0\tau_0 = 1/2 \qquad 3.4$$

$$s(t) = \sum_{k=0}^{N-1} \sum_{n=-\infty}^{\infty} (a_k^R(n) g(t - nT) +$$
$$ja_k^I(n) g(t - nT - \tfrac{T}{2})) e^{j\left(\frac{2\pi}{T}t + \frac{\pi}{2}\right)k} \qquad 3.5$$

To make a fair comparison, the sampling frequency F_s is assumed to be identical in CP-OFDM and OFDM/OQAM systems. This also makes it easier to switch between these two systems. One can either set ν_0 = F and shorten symbol duration, or set τ_0 = T and double the number of subcarriers. At the transmitter side, by summing up all subchannels, the transmitted signal can be expressed as shown in equation (3.4) and the expanded form shown in equation (3.5).The prototype pulse shape g(t) is supposed to be a real and even function which can satisfy the perfect reconstruction condition in the absence of a channel. When there is a channel present, equalization has to be introduced to maintain the orthogonality between different bases. Note that the phase factor$e^{j\frac{\pi}{2}k}$ in the subchannel modulator $e^{j\left(\frac{2\pi}{T}t+\frac{\pi}{2}\right)k}$is important to maintain orthogonality between subchannels.Therefore the OFDM/OQAM modulator can be easily implemented by an IFFT block followed by a bank of component filters which are obtained by partitioning the polyphase representation of *g*(*t*).

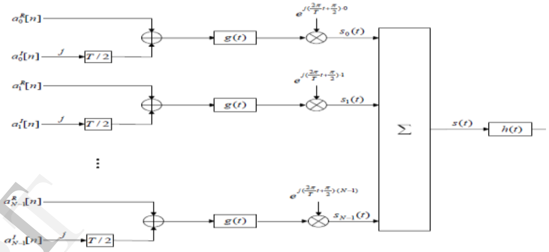

Figure 3.1: Time-continuous model for OFDM/OQAM transmitter systems

Similarly, the OFDM/OQAM demodulator can be implemented by filter component banks followed by an FFT block. For the receiver it is essentially important where to attach one tap equalizer coefficient since the receiver filter decomposes its input signal into real and imaginary parts and process them separately. Therefore the frequency domain equalization stage must be connected before the receiver filters and cannot be attached behind as it is possible for multicarrier modulation without offset.The implementation is done by the direct discretization of continuous time model. Assume the pulse shape prototype function *g*(*t*) has finite duration in$-M\tau_0 \le t \le M\tau_0$, its discrete version *g*[*n*] is nonzero when $n = -MN/2, \ldots, MN/2$, and therefore the length of *g*[*n*] will be *MN* +1. In order to have the same number of taps in each component filter, we just drop the last sample of *g*[*n*] so that the length of each component filter equals to *M*.

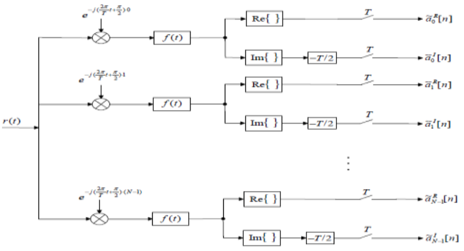

Figure 3.2: Time-continuous model for OFDM/OQAM receiver systems

$$y_k(t) = r(t)e^{-j\left(\frac{2\pi}{T}t+\frac{\pi}{2}k\right)} * f(t)$$
$$= \sum_{m=0}^{N-1}\sum_{n=-\infty}^{\infty}(a_m^R(n)p_{m.k}(t-nT) + ja_m^I(n)p_{m,k}(t-nT-\frac{T}{2}))$$
$$p_{m,k}(t) = j^{m-k}g(t)e^{j\frac{2\pi}{T}(m-k)t} * h(t)e^{-j\frac{2\pi}{T}kt} * f(t)$$

3.7

$$a_k^R(n) = Re\{y_k(t)\}\ at\ t = nT$$

3.8

$$a_k^I(n) = Imag\{y_k(t)\}\ at\ t = (n+\frac{1}{2})T$$

3.9

In the subchannel k at the receiver side the received signal r(t)=s(t)*h(t) is first down converted by multiplying with $e^{-j\left(\frac{2\pi}{T}t+\frac{\pi}{2}\right)k}$, then filtered by the receiver filter f(t) to generate the received subchannel signal given by the equation (3.6). Equation (3.7) illustrates the overall response of the path from subchannel m at the transmitter side to subchannel k at the receiver side. Also the reconstructed symbols, both real and imaginary parts at the receiver side are obtained from the equation (3.8), (3.9) respectively. Note that pulse shaping is realized by cooperation of the IFFT/FFT block and the bank of component filters. Using only the bank of component filters cannot achieve perfect or near perfect reconstruction. The equalization block is exactly the same as in the classic CP-OFDM system (one-tap zero-forcing frequency domain equalizer (FDE)) to reduce complexity.

	OFDM/QAM	OFDM/OQAM
Complexity/QAM symbol	2log2N	2 log2 N + 4Lg + 4 - 8/N
Transmission delay	(2N-1)Ts	[(Lg + 3/2)N - 1] Ts
Normalized spectrum efficiency	(N - Ng)/(N + G)	N/(N + $α$)
Normalized power efficiency	N/(N + G)	1
Equalization	one-tap equalizer	multi-tap equalizer

Table 3.1 Comparison of OFDM/QAM and OFDM/OQAM

Prototype Functions

Digital filter banks are now widely used in source coding, for speech, audio and video signals, and for communication systems as well, for instance, in trans-multiplexers and multicarrier modulations. Transmitting a signal at high modulation rate through a band-limited channel can create ISI. As the modulation rate increases, the signal's bandwidth increases. As the signal's bandwidth becomes larger than the channel bandwidth, the channel starts to give distortion to the signal. This distortion is generally seen as inter symbol interference. Pulse shaping is the process of changing the waveform of transmitted pulses. Its intention is to make the transmitted signal suit better to the communication channel by limiting the effective bandwidth of the transmission. By filtering the transmitted pulses, the inter symbol interference caused by the channel can be kept in control. Raised-cosine filter is practical to implement and it is in wide use.

Raised Cosine Spectrum

3.6

Consider the parameter roll-off factor β is a real number in the interval 0 ≤ β ≤ 1, which determines the bandwidth of the spectrum. Then a family of spectra that satisfy the Nyquist Theorem is the raised cosine family whose spectra are given by the equation (3.10).

$$(f) = \begin{cases} T_s & 0 \le |f| \le \frac{1-\beta}{2T_s} \\ \frac{T_s}{2}\left\{1+\cos\left[\frac{\pi T_s}{\beta}\right]\left(|f| - \frac{1-\beta}{2T_s}\right)\right\} & \frac{1-\beta}{2T_s} \le |f| \le \frac{1+\beta}{2T_s} \\ 0 & |f| > \frac{1+\beta}{2T_s} \end{cases}$$

3.10

$$BW = \frac{1+\beta}{2T_s} = (1+\beta)R_s$$

3.11

$$z(t) = \frac{\cos(\pi\beta\frac{t}{T_s})}{1-(2\beta\frac{t}{T_s})^2} * \frac{\sin(\pi\frac{t}{T_s})}{\pi\frac{t}{T_s}}$$

3.12

Since the spectrum is zero for $|f| > \frac{1+\beta}{2T_s}$, the bandwidth of the baseband pulse is $\frac{1+\beta}{2T_s}$. Let R_s represents the transmitted symbol rate and the BW represents the bandwidth, then for a bandpass QAM modulation, the bandwidth is twice, which is given in equation (3.11). The ideal low-pass rectangular spectrum is the special case where β=0, which has a passband bandwidth equal to the symbol rate. The corresponding time domain signal is obtained from the equation (3.12).Observe that zero crossing at t=± T_s, ±2 T_s etc. The time series corresponding to the special case β=0 (the ideal low pass rectangular spectrum) is $\frac{\sin(\pi\frac{t}{T_s})}{\pi\frac{t}{T_s}}$ as expected. The spectra and corresponding time series for various values of are plotted in figure below. Note that larger values of β (larger bandwidths) are characterized by a time-domain signal that has faster side lobe decay rates.

$$H_R(f).H_T(f) = H(f)$$
$$|H_R(f)| = |H_T(f)| = \sqrt{|H(f)|}$$

3.13

When used to filter a symbol stream, a Nyquist filter has the attribute of eliminating ISI, since its impulse response is zero at all nT (where n is an integer), except $n = 0$. Therefore, if the transmitted waveform is correctly sampled at the receiver, the original symbol can be recovered completely. However, in many practical communications systems, a matched filter is applied in the receiver, due to the effects of white noise. For zero ISI, it is the response of the transmit and receive filters that must equal H(f) as given in equation (3.13). These filters are called root-raised-cosine filters.

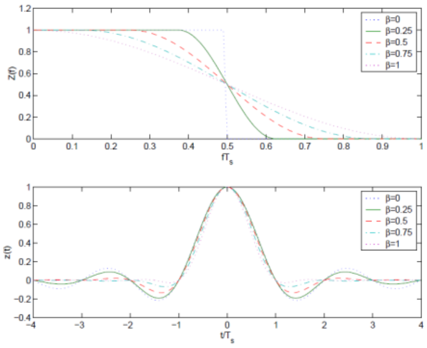

Figure 3.3: Raised cosine spectra and corresponding time-domain pulses for9various values of Roll of factor β

4. MULTIUSER OFDM

Multiuser OFDM (MU-OFDM) [14], adds multiple access to OFDM by allowing a number of users to share an OFDM symbol. In multiuser systems using static time-division multiple access (TDMA) or frequency-division multiple access (FDMA) as multiaccess schemes, a predetermined time slot or frequency bandis allocated toeach user to apply OFDM with adaptive modulation. Consequently, these unused subcarriers within the allocated time slot or frequency band of a user are wasted and are not used by other users. It leads to consider an adaptive multiuser subcarrier allocation scheme [15], where the subcarriers are assigned to the users based on instantaneous channel information. One of the major tasks for such a system would be to allocate subcarriers, bits and transmission power to the different users. Once the subcarrier allocation is determined, the bit and power allocation algorithm can be applied to each user on its allocated subcarriers. Two classes of resource allocation schemes exist, namely: fixed resource allocation and dynamic resource allocation.

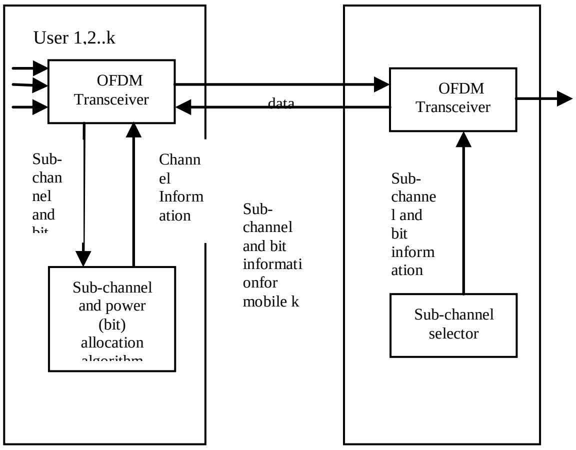

Figure 4.1: Multiuser OFDM Block Diagram

The configuration of a multiuser adaptive OFDM is shown in Figure 4.1. Consider a total of K users, in the system sharing N sub-channels, with noise power spectral density N0, the total transmit power constraint $P_{total.}$ and total available bandwidth B. The k^{th} user has a data rate equal to R_k bit per OFDM symbol. In the transmitter, the serial data from the users are fed into the subcarrier and bit allocation block which allocates bits from different users to different subcarriers. Assume each subcarrier has a bandwidth that is much smaller than the coherence bandwidth of the channel and that the instantaneous channel gains on all the subcarriers of all the users are known to the transmitter.

User Allocation

The simplest scheme is to group the carriers allocated to each user. Grouping carriers minimizes inter-user interference due to distortion, power level variation and frequency errors. Though, grouping the carrier makes the transmission likely to be affected by fading, as the whole group of carriers can be lost in a null in the spectrum. This difficulty can be partly overcome by frequency hopping the carriers. In user allocation plan shown in figure 4.2, carriers are transmitted in short time blocks. These blocks were randomly frequency hopped to ensure that the time period spent in a null would is relatively short, nearly 11 symbols. To recover data lost during a null, time interleaving and forward error correction was used. These come at the way of reduced capacity and an increased delay.

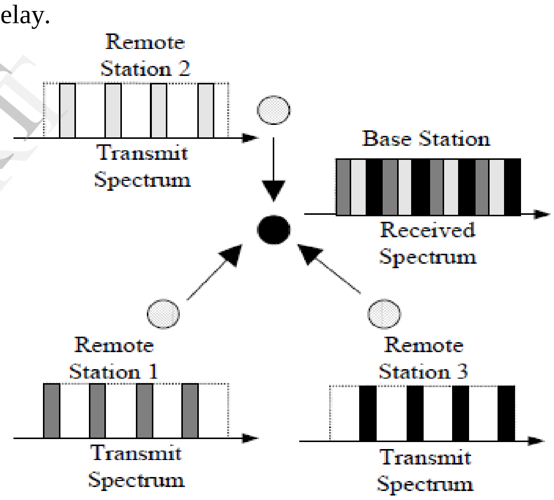

Figure 4.2: Reverse link of a multiuser OFDM system

In adaptive frequency hopping, after the radio channel has been characterized each user is allocated carriers which have the best SNR ratio for that user [16]. Thus most users can be allocated the best carriers for them with minimal clashes.Carriers can be allocated in a comb pattern, spreading them over the complete system bandwidth. This enhances the frequency diversity, preventing all the carriers used by a user being lost in a null in the spectrum. Though, this allocation scheme may be susceptible to inter-user interference. This way of user allocation is useful in applications that cannot use adaptive hopping.

5. RESOURCE ALLOCATIONS IN OFDMA SYSTEMS

OFDMA System Model

Figure 5.1 shows the block diagram for the downlink of a typical OFDMA system for K users. Each user is allocated to different set of subcarriers by the base station. The controller at base station receives downlink channel information from all users, and controls base station transmitter using “sub-channel allocation and bit-loading algorithm”. K users in a hexagonal cell, total bandwidth B, and total number of sub-channels N are assumed resulting in an OFDM sub-channel bandwidth of B/N. The total bandwidth B, need to be shared by K users. Maximum allowable total power for all users is P_{total}. Also, users are assumed to have uniform distribution of location within the hexagonal cell. For each user, channel is assumed to be frequency selective Rayleigh fading.In a fixed TDMA scheme where time slots are non-adaptively assigned, users who have good channel responses can reliably receive higher data rate while others suffer from poor channel responses. With large path loss, this discrepancy cannot be ignored, and the system becomes unfair for the users with poor channel gains. Assume VBR (Variable Bit Rate) services for all users, and maximize the smallest capacity of all users. We mean capacity of a user by the maximum error-free data throughput with a proper coding for the given assignment of sub-channels to the user. For different priority among users, or for different traffic models such as mixture of CBR (Constant Bit Rate), and VBR, only a slight change on the algorithm is needed.

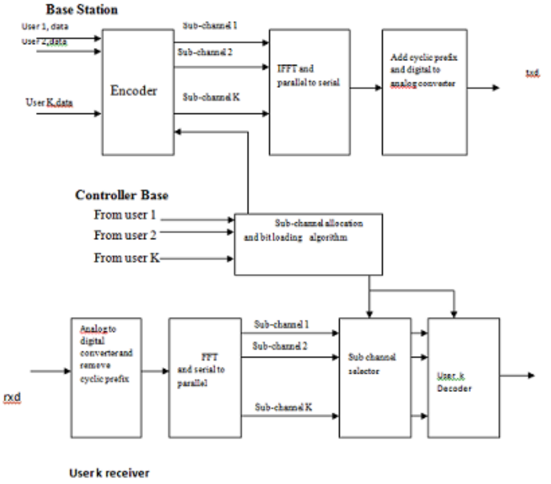

Figure 5.1: OFDMA System block diagram

Resource Allocation Algorithm

The steps used in resource algorithm are as follows:

1: Determine the number of subcarriers N_k to be initially assigned to each user;

2: Assign the subcarriers to each user in a way that ensures rough proportionality;

3: Assign the total power P_k for user k to maximize the capacity while enforcing the Proportionality.

4: Assign the powers pk,n for each user’s subcarriers subject to his total power constraint P_k.

The underlying premise behind these steps is that in practical systems, extent to the proportionality constraints need not be strictly enforced. The proportionality constraints are used to differentiate various services, wherein the service provider may choose to prioritize their customers based on different billing mechanisms. Since the proportion of rates is more of a soft guarantee than a hard one, a rough proportionality is acceptable as long as the capacity is maximized and the algorithm complexity is low.

6. IMPLEMENTATION IN MATLAB

OFDM/OQAM Simulation Results

The Simulation for OFDM/QAM and OFDM based on offset QAM is implemented in MATLAB 7.0. The OFDM is implemented by using rectangular pulses with cyclic prefix added. In the latter case SRRC and EGF are used as pulse shapes.

Simulation Parameter

The simulation parameters used are the number of subcarriers is N=5, FFT size 512, 1024 and 2048, 16-QAM and the roll of factor is 1.

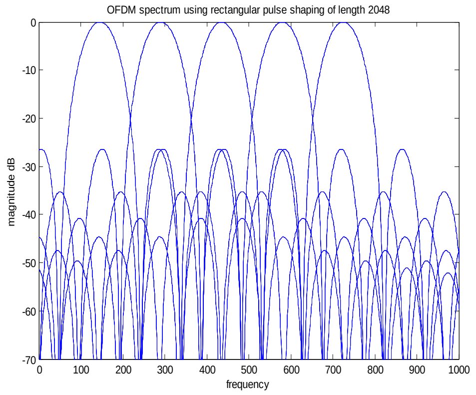

Figure 6.1 OFDM using rectangular pulses with FFT size 2048

Simulation using Rectangular Pulse shape: Numbers of side lobes are more, it leads to out of band energy. It uses cyclic prefix while generating OFDM symbols at the cost of spectrum efficiency.

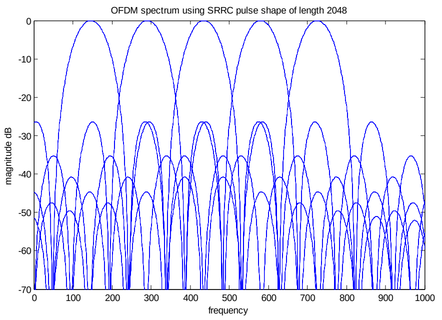

Figure 6.2 OFDM/OQAM using SRRC pulses with FFT size 2048

Simulation using SRRC: As compared with rectangular pulse shape the numbers of side lobes are less. So comparatively reduces the out of band energy.

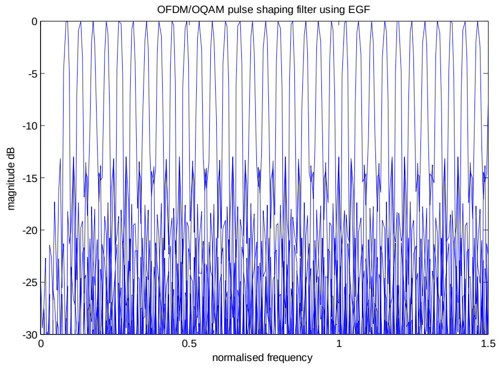

Figure 6.3 OFDM/OQAM using EGF pulses with FFT size 1024

Simulation using EGF: OFDM/OQAM symbols generated with N=32.With its good time frequency localization property, it is limited in both time domain and frequency domain. It improves spectrum efficiency by generating OFDM symbols without cyclic prefix.

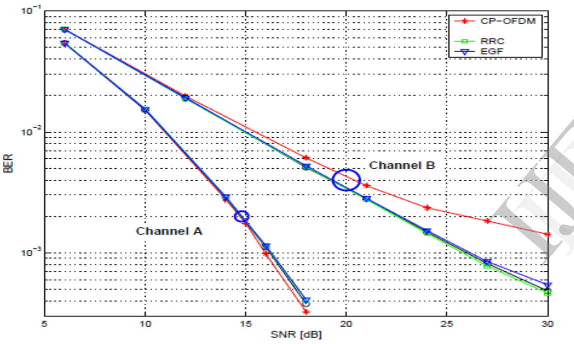

Figure 6.4 Comparison between OFDM and OFDM/OQAM using EGF.

Simulation carried out for 2 kinds of channels. Channel A with time delay 700 ns, time delay spread 700ns and frequency shift 10^{-5}. Channel B with time delay 500 ns, time delay spread 700ns and frequency shift 10^{-5}. From figure we can say that OFDM/OQAM outperforms CP-OFDM as the interference from early arrived paths cannot be removed by the cyclic prefix.

Table 6.1 TFL and orthogonality parameters

pulse	OFDM Rect	SRRC	EGF α=1	EGF α=2
TFL	0.178	0.888	0.874	0.977
γ2	-314	-69	-96	-178

Table 5.1 list the Heisenberg parameter and orthogonality parameter for different pulse shapes.

Note that EGF with α = 2 achieves the best TFL among pulse shapes and better reconstruction than EGF with α = 1.

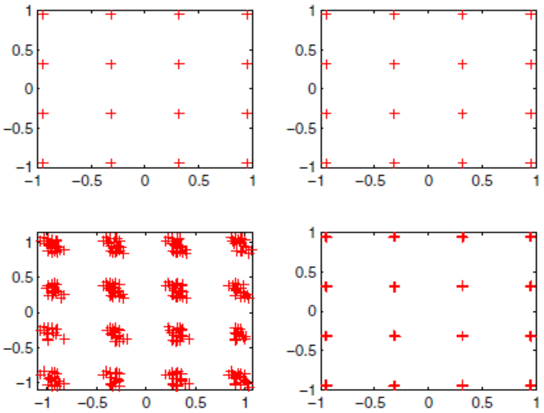

Figure 6.5 Signal constellation with 16QAM modulation for EGF α=1, α=2,Rectangular pulse and SRRC.

From figure we can say that EGF and Square Root Raised Cosine prototypes can achieve almost perfect reconstruction while the Rectangular prototype will result in some distortion.

OFDMA Simulation Results

Simulation parameters

The frequency selective multipath channel is modeled as consisting of six independent Rayleigh multipaths, with an exponentially decaying profile. A maximum delay spread of 5μs and maximum Doppler of 30Hz is assumed. The channel information is sampled every 0.5 ms to update the sub-channel and power allocation. The total power was assumed to be 1 W, the total bandwidth as 1 MHz, and total subcarriers as 64. The average sub-channel SNR is 38 dB, and BER ≤ 10−3, giving an SNR gap used as 3.3.

$$\Gamma = -\ln (5 \times 10-3)/1.6 = 3.3.$$

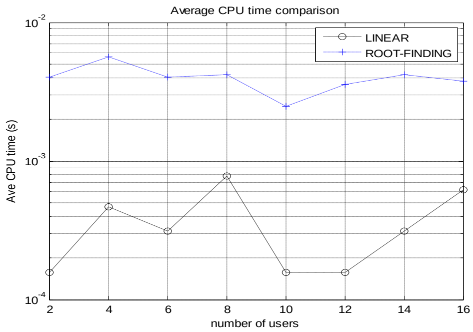

Figure 6.6 Execution Time comparisons between Linear and Root finding method

Figure 6.6 shows the comparison of the computational complexity of the Linearand Root-Findingmethods.The number of function evaluations needed for the power allocation of

Root-Findingto converge was found to be around 9. From Figure 6.6, Linearis an order of magnitude faster in execution time than Root-Finding.

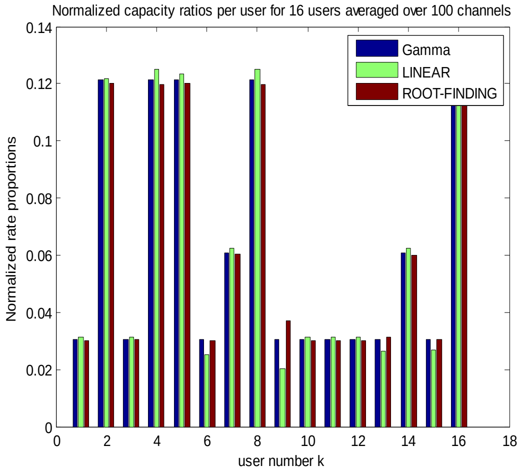

Figure 6.7 normalized proportion of capacities for each user in Linear and Root finding methods

Figure 6.7 showsthe normalized proportions of the capacities for each user for the case of 16 users averaged over100channel samples. The normalized capacities are observed for both Linear and Root-Finding. This is compared to the normalized proportionality constraints {φk} for k=1 to 16. In contrast to the Root-Finding method, the proportionality among the users for the linearmethod is no longer being strictly enforced.

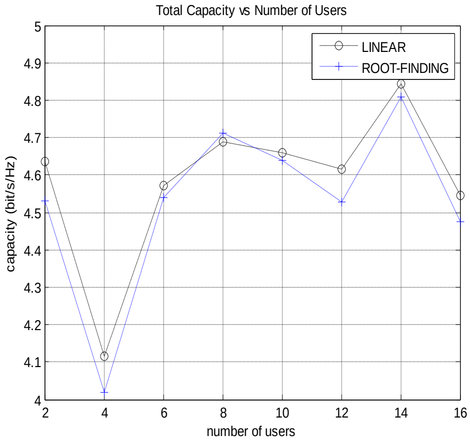

Figure 6.8 total capacity versus number of users

Figure 6.8 shows the comparison of total capacities between the proposed method Linear and Root-Finding. Notice that the capacities increase as the number of users increases. This is the effect of multiuser diversity gain, which is more prominent in systems with larger number of users. The proposedLINEAR method has a consistently higher total capacity than the Root-Finding method for all the numbers of users for this set of simulation parameters. This advantage can be attributed to the relaxation of the proportionality constraints, and the added freedom of assigning the N∗ subcarriers in Step 2 of the proposed algorithm.

7. CONCLUSIONS

In this work, the Square Root Raised cosine spectrum and its time domain pulses are simulated for various values of roll off factor values β = 0.25, 0.5 and 1. It is observed that larger values of β (larger bandwidths) are characterized by a time-domain signal that has faster side-lobe decay rates.
The good thing about the square-root raised cosine pulse shape is that the corresponding filter output has no ISI, but infinite support in time. So the pulse shape is truncated, which leads to non-zero side lobes in frequency domain. In general, the smaller the roll-off factor, the longer the pulse shape needs to be in order to achieve desired stop-band attenuation.The Extended Gaussian Function is simulated and observed that EGF with β = 2 achieves the best time frequency localization among pulse shapes and better reconstruction than EGF with β = 1. Instead of using cyclic prefix in order to avoid ISI, the OFDM/OQAM used these pulse shapes, which improves the spectral efficiency by 50%. A low complexity algorithm for resource allocation is implemented and observed that the LINEAR method has a consistently higher total capacity than the ROOTFINDINGmethod for all the numbers of users for this set of simulation parameters N=64, B=1MHz. Also power allocation complexity is reduced.

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