Window Function Analysis for Multicarrier Transmission

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Abstract— Due to too much complexity of the equalizer at the receiver and to overcome the frequency selectivity of the wide band channel experienced by single carrier transmission, arise the need for Multi carrier Transmission. Orthogonal Frequency Division Multiplexing (OFDM) is an efficient method of data transmission for high speed communication systems. OFDM signal is the superposition of a high number of modulated sub channel signal and it may exhibit a high instantaneous signal peak with respect to average level. In this paper several windows are being simulated and compared and concluded that the appropriate window to be used in OFDM system.

Key words: Multicarrier Transmission, OFDM Multicarrier Transmission

I. INTRODUCTION

Now a days there is a great interest in Multi Carrier modulation scheme ranges from wire-line to wireless communications. However the goal is to achieve high data rate but for the mobile communications it is quite difficult because of the mobility of the mobile users. From the limitation of the single carrier transmission for achieving high data rate, the complexity of the equalizer is increased from that need for the multi carrier transmission is arise.

In multi carrier modulation the information stream is divided into M substream and each of them is transmitted over a sub channel of the transmission bandwidth. This is achieved by using bank modulation filters which shifts the corresponding sub stream spectra to the desired sub bands. Hence, differently from a single carrier modulation in which the information stream carried at rate R is modulated by a filter that employs all the available bandwidth, in MC modulation there are M distinct sub stream carried a rate R/M which are transmitted in parallel over M sub bands of the transmission bandwidth.

This kind of modulation better known as orthogonal frequency division multiplexing, has so the capability of converting a frequency selective fading channel into several narrow band channel, whose equalization in some situations can be performed independently. If the available spectrum is divided into sub bands with equal bandwidth and each sub channel is shaped using the same filter, the digital implementation of both OFDM modulator and demodulator can be efficiently realized making use of FFT and poly phase filtering.

Whenever a rectangular pulse that lasts one OFDM symbol is used as prototype filter, no poly phase filtering is needed. This solution known as Discrete multitone modulation (DMT) uses a cyclic extension of the OFDM symbol in order with copy with both inter symbol interference and inter channel interference that are due to the loss orthogonality among the sub channels caused by frequency selective radio channel.

II. MULTICARRIER TRANSMISSION SYSTEM MODEL

Figure shows the basic structure and concept of multicarrier transmission system Here, a wideband signal is analysed (through multiple narrowband filter Hk f’s) into several narrowband signals at the transmitter and is synthesized (through multiple narrowband filter Gk f’s, each being matched to Hk (f)) at the receiver so that the frequency-selective wide- band channel can be approximated by multiple frequency-flat narrowband channels.

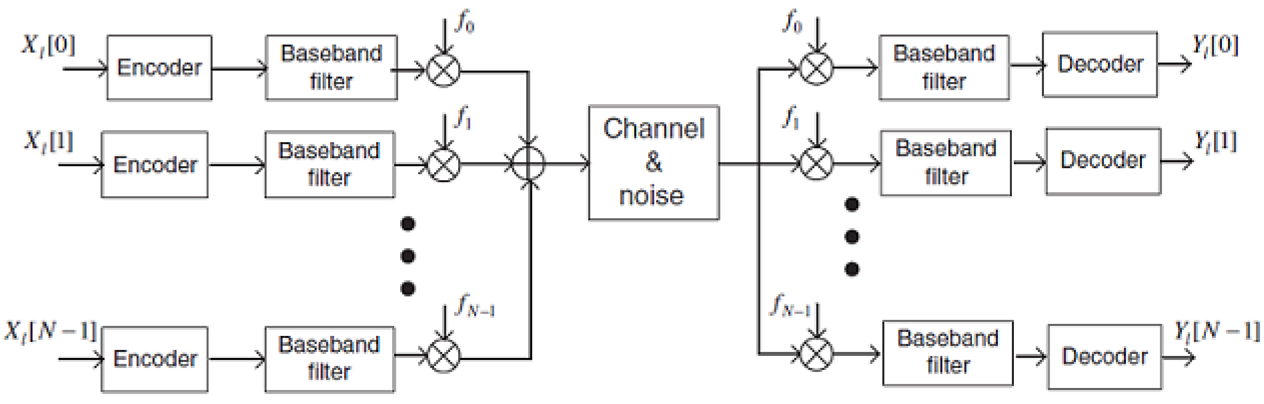

Fig. 1: Basic structure of multicarrier system

The frequency-no selectivity of narrowband channels reduces the complexity of the equalizer for each subchannel. As long as the orthogonality among the subchannels is maintained, the ICI (inter-carrier interference) can be sup- pressed, leading to distortionless transmission. In the multichannel system, let the wide band be divided into N narrowband subchannels, which have the subcarrier frequency of f_k ,k=0,1,2...N-1.The basic structure of a multi-carrier communication scheme, which is one specific form of the multichannel system, where the different symbols are transmitted with orthogonal sub channels in parallel form.

While a FMT type of multicarrier transmission system can cope with the frequency selectivity of a wideband channel, its implementation becomes complex since it involves more encoders/decoders and oscillators, and higher quality filters as the number of subcarriers increases.

III. OFDM MULTICARRIER TRANSMISSION SCHEME

Orthogonal Frequency Division Multiplexing is a combination of modulation and multiplexing both. Multiplexing is for independent signals, those produced by different sources. In OFDM the problem of multiplexing is applied to independent signals but these independent signals are part of the one main signal. In OFDM the signal is first split into independent channels then modulated by data and then re-multiplexed to create the OFDM carrier.

OFDM is an advance case of Frequency Division Multiplex (FDM). In an OFDM scheme, a large number of orthogonal, overlapping, narrow band sub-carriers are transmitted in parallel. These carriers divide the available transmission bandwidth. The separation of the sub-carriers is such that there can be efficient spectrum utilization.

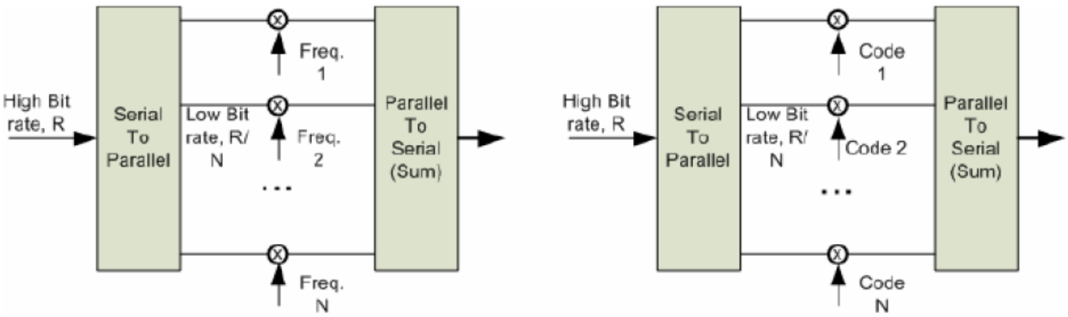

Fig. 2: Multi-carrier FDM and Multi-code division multiplex

These small streams when seen as signals are called the sub-carriers in an OFDM system and they must be orthogonal for this idea to work. The independent sub-channels can be multiplexed by frequency division multiplexing (FDM), called multi-carrier transmission or it can be based on a code division multiplex (CDM), in this case it is called multi-code transmission

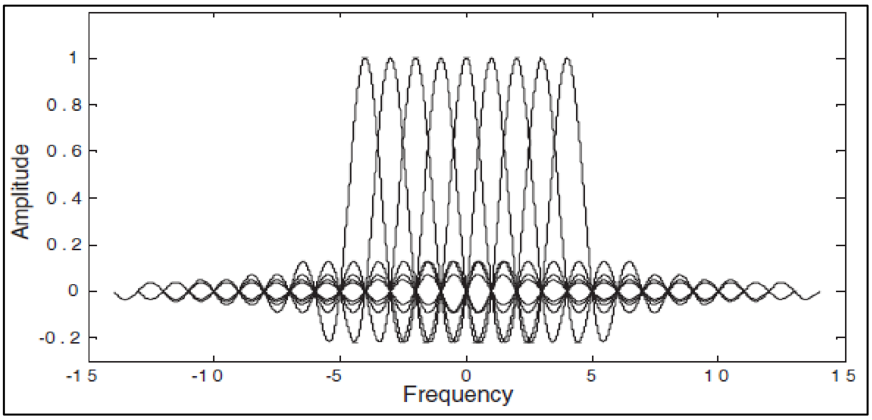

Fig. 3: Orthogonal Sub carriers

IV. WINDOW FUNCTION FOR MULTI CARRIER SCHEME

In order to maintain the out of band radiation within a certain level, it is benefit to increase the window length. On the other hand, the window should not be too long, because a long widow length implies that many signal samples are affected, which degrades the BER performance.

A. List of Window Function

1) Bartlett-Hann Window

$$\omega(n) = a_0 - a_1 \left|\frac{n}{N-1} - \frac{1}{2}\right| - a_2 \cos\frac{2\pi n}{N-1} \quad (1)$$

Like Bartlett, Hann, and Hamming windows, this window has a main lobe at the origin and asymptotically decaying side lobes on both sides. It is a linear combination of weighted Bartlett and Hann windows with near side lobes lower than both

Bartlett and Hann and with far side lobes lower than both Bartlett and Hamming windows. The main lobe width of the modified Bartlett- Hann window is not increased relative to either Bartlett or Hann window main lobes.

2) Rectangular window

$$\omega(n) = 1 \tag{2}$$

The rectangular window (sometimes known as the box-car or Dirichlet window) is the simplest window, equivalent to replacing all but N values of a data sequence by zeros, making it appear as though the waveform suddenly turns on and off. w = rectwin (L) returns a rectangular window of length L in the column vector w. This function is provided for completeness; a rectangular window is equivalent to no window at all.

3) Hann- Window

The Hann window named after Julius von Hann and also known as the Hanning for being similar in name and form to the Hamming window.

$$\omega(n) = 0.5\left(1 - \cos\frac{2\pi n}{N-1}\right) = hav\left(\frac{2\pi n}{N-1}\right) \tag{3}$$

4) Gaussian Window

$$\omega(n) = e^{-\frac{1}{2}\cdot\left(\frac{n-(N-1)/2}{\sigma(N-1)/2}\right)^2} \tag{4}$$

The Fourier transform of a Gaussian is also a Gaussian (it is an Eigen function of the Fourier Transform). Since the Gaussian function extends to infinity, it must either be truncated at the ends of the window, or itself windowed with another zero-ended window. Since the log of a Gaussian produces a parabola, this can be used for nearly exact quadratic interpolation in frequency estimation.

V. COMPARISON OF WINDOWS

A. Commonly used Parameters for Window Selection

1) Main Lobe Width

Main Lobe Width is directly connected to Frequency resolution. Narrower the main lobe, more will be its frequency resolution (Ability of selecting finest frequency components). Main Lobe Width is the measure at -3dB or-6dB below main lobe peak. When the main lobe width decreases, the remaining energy spreads out to side lobes thereby increasing spectral leakage/decreasing amplitude accuracy (decreasing detection ability). A compromise is needed to strike a balance between detection and resolution that would suit the application at hand.

2) Side Lobe Level

Side lobes are found at both side of the main lobe. It is found zero when integral multiples of F_s/N (where F_s=Sampling Frequency; N is the length of N-point FFT/DFT). Side Lobe Level is measure for that side lobe which has the maximum peak (compared to other side lobes). By reference to the peak of the main lobe it is measured in decibels. Detection ability of window is higher when side lobe level is less. The side lobe roll-off rate can be found by asymptotic decay rate in decibels per decade of frequency of the peaks of the side lobes.

3) Normalized Equivalent Noise Bandwidth

The windowing of a signal in time can affects the resolution bandwidth that can be achieved. When calculating the spectrum of a signal segment the resolution bandwidth achieved with a window is always lower (worse) than the resolution bandwidth achieved without a window. The normalized equivalent noise bandwidth (NENBW) of a window is one measure of how much it reduces the resolution bandwidth that can be achieved. To compensate for this a longer signal segment should be processed. Equivalent noise bandwidth (ENBW) will compare the window to an ideal, rectangular filter. It is the equivalent width of a rectangular filter that passes the same amount of white noise as the window passes. The normalized ENBW (NENBW) is achieved by multiplying the ENBW to the time duration of the signal being windowed. NENBW values for windows available in Spectrum Analyzer ResBW are listed in the following table through the references. For our computation we have assumed that the time duration is of unit duration therefore ENBW and NENBW will be equal.

4) Calculation of Equivalent Noise Bandwidth

Equivalent Noise Bandwidth is calculated as a ratio of inherent power gain over coherent power gain. The equation is particularly useful for simulations as we do not have to bother about the transfer functions of each window functions in frequency domain.

VI. SIMULATION RESULTS

In the simulation, we are considering the OFDM system with 1024 subcarriers with 16-QAM. We also assume that the oversampling factor is four. We also assume that the guard interval is one by four. If we oversample the OFDM signal by a factor of four, the PAPR of the discrete signal is almost the same as that of continuous signal.

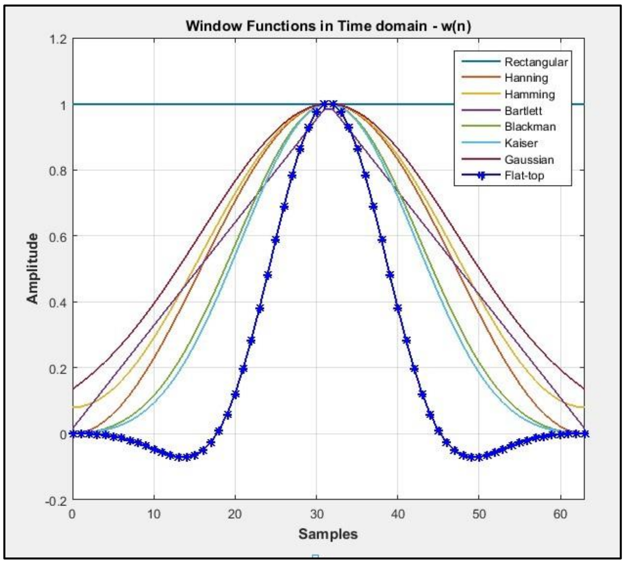

Fig. 4: Window Function in Time Domain

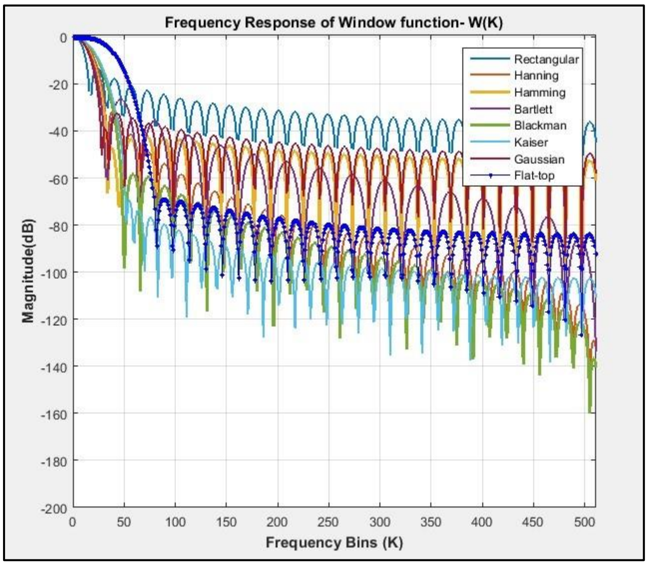

Fig. 5: Window Function in Frequency Domain

Signal Content	Window Function
Sine wave or Combination of sine wave	Hann
Sine wave(When Amplitude accuracy is Important)	Flat top
Narrow band random signal	Hann
Broadband random (White noise)	Uniform
Closely spaced sine wave(Orthogonally exist)	**Hamming**
Unknown content	Hann

Fig. 6: Window Function based on signal content

Window Function	Side lobe Level-(db)
Rectangular	-13.26
Hanning	-32.17
Hamming	-43.5
Bartlet	-26.5
Blackman	-58.1
Kaiser	-69.5
Gaussian	-32.3
Flop top	-68.75

Fig. 7: Sidelobe level of window function

In ideal case window should be as marrow band as possible. The window should not be long in time domain, it means that many signals are affected which can increase BER. The OFDM signal multiplied with one of the windows and result spectrum is a convolution of original with the spectrum of applied window.

VII. Conclusion and Future Scope

OFDM is a very efficient technique for multicarrier transmission due to its spectrum efficiency and channel robustness. One of the serious drawbacks of OFDM systems is that the composite transmit signal can exhibit a very high out of band radiation when the input sequences are highly correlated. In this paper, window function selection to achieve lowest out of band radiation analysis is provided. The usage of windows smoothens the observed signal over the edges of measured time interval and gradually reduces it to zero. This prevents glitches in the assumed signal repetitively reconstructed by the Fourier Transform. This phenomenon reduces the spectral leakage.

Each window has its own characteristics. Different windows are used for different applications based on the signal content. If the signal contains strong interfering frequency components distant from the frequency of interest, choose a window with a high side lobe roll-off rate. If there are strong interfering signals near the frequency of interest, choose a window with a low maximum side lobe level. In general, the Hamming window is satisfactory in most of cases for multi carrier transmission because it has good frequency resolution and needs the orthogonality hence it reduced spectral leakage.

References

[1] S. Brandes I. Cosovic and M. Schnell, Reduction of out-of-band radiation in OFDM systems by insertion of cancellation carriers, IEEE Communications Letters, Vol. 10, No. 6, 2006, pp. 420-422. doi:10.1109/LCOMM.2006. 1638602

[2] Tianwei Wen, Yafeng Wang "Sidelobe Suppression in CR-OFDM system by Adding Extended Data Carriers “Wireless Theory and Technology lab (WT and T), Beijing University of Posts and Telecommunications, Beijing, China Received July, 2013

[3] Ivan Cosovic, Member, IEEE, Sinja Brandes, Member, IEEE, and Michael Schnell, Senior Member, IEE" Subcarrier Weighting: A Method for Side- lobe Suppression in OFDM Systems" COMMUNICATIONS LETTERS, VOL. 10, NO. 6, JUNE 2006
[4] Hisham A. Mahmoud and Huseyin Arslan" Sidelobe Suppression in OFDM-Based Spectrum Sharing Systems Using Adaptive Symbol Transition" .IEEE COMMUNICATIONS LETTERS, VOL. 12, NO. 2, FEBRU- ARY 2008.
[5] Wireless communications by- Andreas. F. Molisch-ISBN 978-0-470-74186-3
[6] OFDM & MC-CDMA A primer by- L. Hanzo, T. keller. ISBN-13 978-0-470-03007-3 (HB) ISBN-10 0-470-03007-0 (HB
[7] Multi-Carrier and Spread Spectrum Systems From OFDM and MC- CDMA to LTE and WiMAX by K. faisel, S. Kaiser
[8] MIMO-OFDM Wireless Communications with MATLAB, Yong Soo Cho, Jaekwon Kim, Won Young Yang and Chung G. Kang,IEEE,2010, ISBN:978-0-470-82561-7
[9] Wireless Communications by Andrea Goldsmith, Stanford University.
[10] Coding for MIMO-OFDM in Future Wireless Systems-ISBN 978-3-319-52-2,Bannour Ahmed Mohammad Abdul Matin
[11] S. Pagadarai, et al "Sidelobe suppression for OFDM-based cognitive radios using constellation expansion, "IEEE Wireless Communications and Networking Conference, WCNC, 2008, pp. 888-893.
[12] Ahmed Selim, Linda Doyle-"Improved Out-of-Band Emissions Reduction for OFDM systems",2013 IEEE Military Communications Conference, Ahmed Selim, Linda Doyle The Telecommunications Research Center (CTVR) Trinity College, University of Dublin Dublin, Ireland
[13] S. Haykin, "Cognitive radio: brain-empowered wireless communications "IEEE Journal on Selected Areas in Communications, vol. 23, pp.201,220, Feb 2005