International Journal of Electronics Signals and Systems

Manuscript 1034

Channel Equalization with Single Interference Technique based on FFT for efficient OFDM System

Jyoti Asnani

Channel Equalization with Single Interference Technique based on FFT for efficient OFDM System

Jyoti Asnani, Shazia Shireen, Ravi Shankar Mishra, Rajesh Nema
PG Scholar, Dept. of Electronics and Communication, NIIST, Bhopal, India
E-mail : asnanijyoti911@gmail.com,

Abstract**—** In today's scenario the over sampled OFDM system performance is significantly improved if the deep faded symbols on the sub carriers of each over sampled OFDM signal are discarded and then reconstructed from the remaining OFDM signal by a time domain iterative algorithm. Base on the results of FFT in OFDM demodulation, one new single frequency interference estimation scheme is proposed, which can estimate accurately the parameters of single frequency interference by analyzing and comparing two spectrum lines having higher energy and power consumption ratio than others. The complexity of the scheme is very low and its accuracy is much higher than that of the conventional scheme which using only single spectra line possessing maximum energy to estimate interference parameters.

Keywords – *OFDM, FFT, Spectrum and Single Frequency*

I. INTRODUCTION

Orthogonal frequency-division multiplexing (OFDM), essentially identical to coded OFDM (COFDM) and discrete multi-tone modulation (DMT), is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. A large number of closely-spaced orthogonal sub-carriers are used to carry data. The data is divided into several parallel data streams or channels, one for each sub-carrier. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrate amplitude modulation or phase-shift keying) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth.

OFDM has developed into a popular scheme for wideband digital communication, whether wireless or over copper wires, used in applications such as digital television and audio broadcasting, wireless networking and broadband internet access.

The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions (for example, attenuation of high frequencies in a long copper wire, narrowband interference and frequency-selective fading due to multipath) without complex equalization filters. Channel equalization is simplified because OFDM may be viewed as using many slowly-modulated narrowband signals rather than one rapidly-modulated wideband signal. The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to handle time-spreading and eliminate intersymbol interference (ISI). This mechanism also facilitates the design of single frequency networks (SFNs), where several adjacent transmitters send the same signal simultaneously at the same frequency, as the signals from multiple distant transmitters may be combined constructively, rather than interfering as would typically occur in a traditional single-carrier system.

In a typical multi-cellular environment a signal transmitted from a handset to the basestation is subjected to a variety of impairments. The most obvious impairment is the contemination of the transmitted signal by thermal noise at the receiver. Secondly, the signal quality suffers from multipath propagation, which implies that several delayed replicas of the same signal arrive at the receiver antenna. This inflicts inter-symbol interference, which heavily degrades the signal quality and hence must be compensated by equalization. In addition the channel might impose time variant fading due to the mobility of the users or the deflectors and scatterers. In a multi-cellular environment we additionally encounter interference from other users and basestations.

The problem of inter-symbol interference can be elegantly addressed by employing OFDM (Orthogonal Frequency Division Multiplexing), which is a multi-carrier transmission scheme conceived back in the 60's. With the availability of high-performance signal-processing devices it has been re-discovered since the operation of multi-carrier modulation can be efficiently implemented by means of a Fast Fourier Transform (FFT). As opposed to single-carrier transmission, OFDM seeks to avoid inter-symbol interference by appending a guard interval to each FFT output block - before signal interpolation and up-conversion to the HF (High Frequency) stage - at the cost of a slight reduction in bandwidth efficiency. The block diagram of OFDM based transmission system is shown in fig 1.

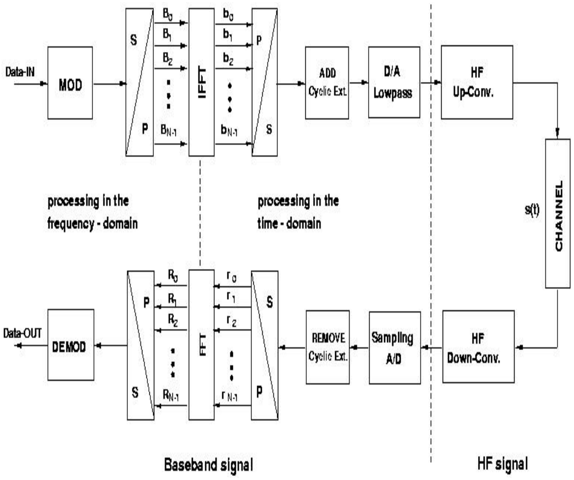

Fig 1. Block diagram of an OFDM based transmission system.

This paper is divided into five sections. In Section 2 the system description is described. In Section 3 the analysis based on FFT estimation is presented. In Section 4, domain equalization are carried out to prove the performance of new scheme. Finally, conclusion and future directions are given in Section 5.

II. SYSTEM DESCRIPTION

In multimedia communication, a demand emerges for high-speed, high-quality digital mobile portable reception and transmission. A receiver has to cope with a signal that is often weaker than desirable and that contains many echoes. Simple digital systems do not work well in the multipath environment.

In a conventional serial data system, the symbols are transmitted sequentially, with the frequency spectrum of each data symbol allowed to occupy the entire available bandwidth. In a parallel data transmission system several symbols are transmitted at the same time, what offers possibilities for alleviating many of the problems encountered with serial systems.

In OFDM, the data is divided among large number of closely spaced carriers. This accounts for the "frequency division multiplex" part of the name. This is not a multiple access technique, since there is no common medium to be shared. The entire bandwidth is filled from a single source of data. Instead of transmitting in serial way, data is transferred in a parallel way. Only a small amount of the data is carried on each carrier, and by this lowering of the bitrate per carrier (not the total bitrate), the influence of intersymbol interference is significantly reduced. In principle, many modulation schemes could be used to modulate the data at a low bit rate onto each carrier.

Usually, it is an important part of the OFDM system design that the bandwidth occupied is greater than the coherence bandwidth of the fading channel. Then, although some of the carriers are degraded by multipath fading, the majority of the carriers should still be adequately received. OFDM can effectively randomize burst errors caused by Rayleigh fading, which comes from interleaving due to parallelization. So, instead of several adjacent symbols being completely destroyed, many symbols are only slightly distorted. Because of dividing an entire channel bandwidth into many narrow subbands, the frequency response over each individual subband is relatively flat. Since each sub channel covers only a small fraction of the original bandwidth, equalization is potentially simpler than in a serial data system. A simple equalization algorithm can minimize mean-square distortion on each subchannel, and the implementation of differential encoding may make it possible to avoid equalization altogether. This allows the precise reconstruction of majority of them, even without forward error correction (FEC).

OFDM technique has attracted much interest for it's advantages, such as the high spectrum efficiency, interference rejection capability, security and so on [1-4]. OFDM modulation is done by IFFT and OFDM demodulation is done by FFT. IF the OFDM signal is disturbed by interference, the parameters of interference should be evaluated for further interference elimination processing. Single frequency interference [5, 10] is one typical interference, the parameter estimation of single frequency interference can be done by Kay method, Music method and Fitz method [6, 7, 8,9].

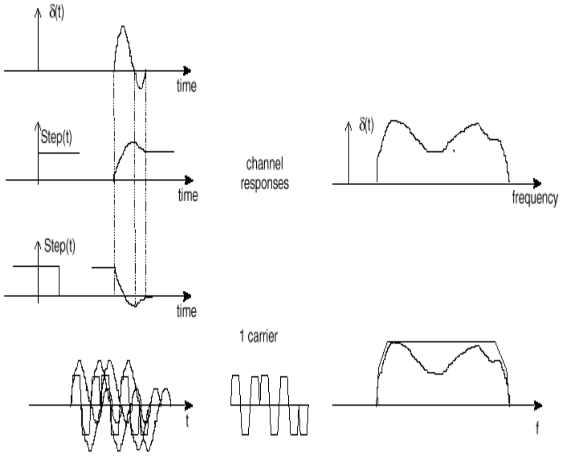

Fig 2. Quantitative analysis

III. ANALYSIS BASED ON FFT

First, we analyse the FFT computation of single frequency interference signal. When demodulation, we sample the received analog signal at the sampling rate of to get digital signal, and intercept the digital signal by rectangle window of length M. The intercepted digital signal Jd (n) is

$$I_d(\bar{n}) = I(\bar{n})w(\bar{n})$$

A fast Fourier transform (FFT) is an efficient algorithm to compute the discrete Fourier transform (DFT) and its inverse. There are many distinct FFT algorithms involving a wide range of mathematics, from simple complex-number arithmetic to group theory and number theory; this article gives an overview of the available techniques and some of their general properties, while the specific algorithms are described in subsidiary articles linked below.

A DFT decomposes a sequence of values into components of different frequencies. This operation is useful in many fields (see discrete Fourier transform for properties and applications of the transform) but computing it directly from the definition is often too slow to be practical. An FFT is a way to compute the same result more quickly: computing a DFT of N points in the naive way, using the definition, takes O(N2) arithmetical operations, while an FFT can compute the same result in only O(N log N) operations. The difference in speed can be substantial, especially for long data sets where N may be in the thousands or millions—in practice, the computation time can be reduced by several orders of magnitude in such cases, and the improvement is roughly proportional to N / log(N). This huge improvement made many DFT-based algorithms practical; FFTs are of great importance to a wide variety of applications, from digital signal processing and solving partial differential equations to algorithms for quick multiplication of large integers.

The most well-known FFT algorithms depend upon the factorization of N, but (contrary to popular misconception) there are FFTs with O(N log N) complexity for all N, even for prime N. Many FFT algorithms only depend on the fact that is an Nth primitive root of unity, and thus can be applied to analogous transforms over any finite field, such as number-theoretic transforms.

where I(n) is the discrete sequence of I(t), w(n)is the rectangle window function, whose Discrete Time Fourier Transform (DTFT)

$$W(e^{j\omega}) = \frac{\sin(\omega M/2)}{\sin(\omega/2)} e^{-j\omega(M-1)/2}$$

An FFT computes the DFT and produces exactly the same result as evaluating the DFT definition directly; the only difference is that an FFT is much faster. (In the presence of round-off error, many FFT algorithms are also much more accurate than evaluating the DFT definition directly, as discussed below.)

Let x0, ..., xN-1 be complex numbers. The DFT is defined by the formula

Evaluating this definition directly requires O(N2) operations: there are N outputs Xk, and each output requires a sum of N terms. An FFT is any method to compute the same results in O(N log N) operations. More precisely, all known FFT algorithms require Θ(N log N) operations (technically, O only denotes an upper bound), although there is no proof that better complexity is impossible. where is the normalized angle frequency,

---

2f / fs , f denotes the frequency.

The DTFT of single frequency interference is

$$I(e^{j\omega}) = A\delta(\omega - \omega_I)e^{j\phi}$$

IV. DOMAIN EQUALIZATION WITH INTERFERENCE

If there is no noise, the receiver can completely restore the transmitted signal x(t). However, in the actual signal transmission system, the error always exists. Then the system can make the difference or mean square error D minimum between the receipt signal y(t) and sending signal x(t). That is:

$$D = E\{\sum_{i=-N}^{N} [y(t) - x(t)]^2\} = E\{\sum_{i=-N}^{N} [C_i x_{k-i} - x(t)]^2\}$$

D is a function of filtering coefficient Ci (i =-N... N).According to the mathematical method of seeking the minimum value, the partial derivatives of Ci can be solved and then the result is assumed to be zero, thus solving for the value of Ci.

$$\frac{\partial D}{\partial C_i} = 0 \Rightarrow E\{[x(t) - \sum_{i=-N}^{N} C_i x_{k-i}]x_{k-i}\} = 0$$

We can further deduce the FFT of I (n)

$$I_d FFT(m) = Ae^{j\phi}\frac{\sin[\pi(m-m_I)]}{\sin[\pi(m-m_I)/M]}e^{-j\pi(m-m_I)(M-1)/M}$$

Therefore, if fs is integer times of fI, in other words, the frequency of interference signal is the same as one of the subs carriers, the has only one non-zero bin which can actually reflect the amplitude, frequency and initial phase of interference signal. Otherwise, the interference signal parameters can not be accurately estimated.

We define the bin possessing the largest energy as the main peak,denoted by , the bin possessing the second largest energy as the second peak, denoted by . The location of the main peak is , where is the round function.

Using the sampling arithmetic average of the expectation substitute approximately, then the above equation is equivalent to:

$$\frac{1}{m}\sum_{j=1}^{m}\{[x(t) - \sum_{i=-N}^{N} C_i x_{k-i}]\, x_{k-i}\} = 0$$

According to the formula the value of the filtering coefficient Ci still can not be solved. Useful information can be sent before sending a feature known data sequence to adjust the filtering coefficients. When the mean square error tends to zero, send useful information. But as time goes on, the channel parameters change dynamically, the adjusted filtering coefficients may no longer apply to the current system, so adaptive equalizer can be introduced [11].

V. CONCLUSIONS AND FUTURE DIRECTIONS

The FFT of single frequency interference and equalization is discussed, which is a classical problem of digital signal processing. Afterwards, a novel FFT based estimation scheme of single frequency interference is proposed. The new scheme can cooperate with the FFT based OFDM demodulation very well, so the complexity is very low. Compared with the conventional scheme, the new scheme has much better performance. It detect a high-quality valid signal for the receiving end with some analysis. However, varieties of analysis is limited to , and no real use in underground cable to transmit information between ground, so its usefulness need to be further validated in practice.

REFERENCES

[1] Char-Dir Chung; Spectral precoding for constant-envelope OFDM, IEEE Transactions on Communications [J], 2010 Vol58 : 555 – 567.

[2] J.A.C.Bingham, Multicarrier modulation for the data transmission: An idea whose time has come, IEEE Communication Magazine [J], 28(1990)5, 5-14.

[3] Volker Aue, Gerhard.P.Fettweis, Higher-level multi-carrier modulation and its implementation, Proc.of IEEE Int.Symp.on Spread Spectrum Techniques implementations, Mainz, Germany, Sept.1996, 126-130.

[4] Nathan Yee, J.P.Linnartz, Gerhard Fettweis, Multicarrier CDMA in indoor wireless radio networks, IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, Yokohama, Japan, Sept. 1993, 109-113.

[5] Luise M, Reggiannini R.Carrier frequency recovery in all-digital modems for burst-mode transmissions[J]. IEEE Trans.on Comm, 1995, COM-43 (2/3/4): 1169-1177.

[6] P.Stoica, R.L.Moses. Introduction to Spectral Analysis. Upper Saddle River, NJ:Prentice-Hall, 1997.

[7] Kay S. A fast and accurate single frequency estimator [J]. IEEE Trans Acoustics, Speech and Signal Processing, 1989, ASSP-37(12): 1987-1990.

[8] Guangshu Hu, Digital Signal Processimg Theory, Algorithm and Implemention, Beijing,Tsinghua University Press, 1997, 55-99 (in Chinese).

[9] Fitz M and P.Further results in the fast estimation of a single frequency[J]. IEEE Trans Commun, 1994, COM-42 (2/3/4) : 863-864.

[10] SyUnji Nakahara Masahirookano, MasayukiTakada , and Toru Kuroda.Blind Training of a Decision Feedback Equalizer.IEEE.2008.

[11] Bernard Sklar,Digital Communications, Fundamentls and Applications , Prentice Hall PTR .Edition: 2 ,pp.149~160 (January , 2001).