TEST Engineering & Management

January-February 2020
ISSN: 0193-4120 Page No. 2199- 2203

An OFDM Sub-carrier Number Estimation Method Based on Novel Distance

[1]Kanne Naveen, [2]Shekar Yedunuri, [3]M.Anand

[1,2]Assistant Professor, Department of Electronics and Communication Engineering, S R Engineering College, Warangal, India
[3]Professor, Department of Electronics and Communication Engineering, Dr M.G.R Educational and Research Institute, Chennai
[1]kanne.naveen@gmail.com, [2]Shekar4b3@gmail.com, [3]worldcommunication25@gmail.com

Article Info
Volume 82
Page Number: 2199 - 2203
Publication Issue:
January-February 2020

Article History
Article Received: *14 March 2019*
Revised: *27 May 2019*
Accepted: *16 October 2019*
Publication: *12 January 2020*

Abstract

Aiming at the problem of orthogonal frequency Division multiplexing (OFDM) signal subcarrier number estimation, a subcarrier number estimation method based on Novel Test (NT) distance is proposed using the Gaussian nature of OFDM signal. The NT distance output at detection-end DFT module is smallest when DFT points match the transmitter. Theoretical analysis and simulation results show that this method can distinguish Gaussian distribution from non-Gaussian distribution, and correctly estimate the number of subcarriers of OFDM signal.

Keywords: *Novel test (NT); Empirical Distribution Function (EDF); sub-carrier number estimation; blind estimation; Orthogonal Frequency Division Multiplexing (OFDM).*

1. Introduction

Orthogonal Frequency Division multiplexing (OFDM) allocates high-speed data streams to orthogonal subcarrier for transmission, effectively reducing the symbol rate of each path. In actual communication, OFDM can select a sub-channel with better conditions according to the channel situation, instead of using [1] per-path carrier. In OFDM blind parameter estimation, modulation recognition is carried out first, and it is confirmed that parameters are estimated only after OFDM modulation, such as carrier frequency, symbol width, cyclic prefix length, sub-carrier number and so on. Among them, estimation of the number of sub-carriers is an important item. At present, it is mostly the length estimation and cyclic prefix estimation of IFFT when OFDM modulation is produced, instead of the number of subcarrier actually used by OFDM. If number of subcarrier is further estimated, subcarrier interval can be estimated.

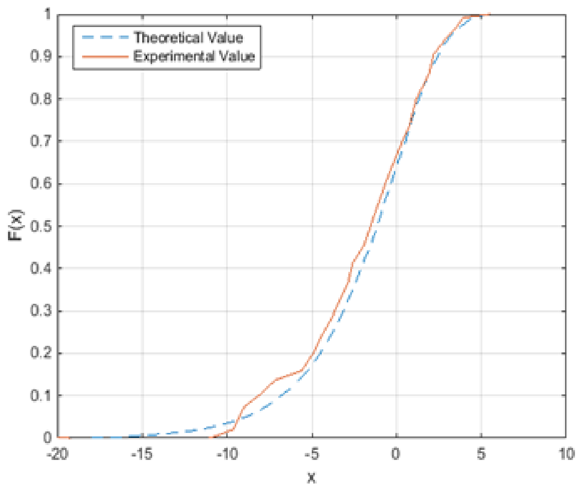

Figure 1: Empirical distribution function and theoretical distribution function

Small research has been done on sub-carrier estimation. In the literature [2], the inverted spectrum is introduced into the estimation of OFDM subcarrier number, but this method does not perform well under the condition of low signal-to-noise ratio. Literature [3] a method is proposed to estimate using high-order cyclic cumulates. These methods are essentially high-order statistics, resulting in a large amount of computation, which is not conducive to practical use. In the literature [4], OFDM signal subcarrier number blind recognition algorithm based on AWGN channel is proposed. The algorithm utilizes the characteristics of strong normality of baseband OFDM modulation signal when FFT points mismatch, and uses Gaussian detection algorithm to estimate the number of OFDM signal subcarrier.

The Gaussian test of samples in statistics has been widely studied. In this paper, based on the practical application, using the asymptotic Gaussianity of OFDM signals, the Novel Test (NT) method in mathematical statistics is introduced to realize the fast identification of number of OFDM signal subcarriers.

2. Empirical distribution function and NT test

Empirical distribution function

Let $(x_1, x_2, \dots, x_n)$ be a set of sample observations of the population X, and arrange them in order of magnitude $x_{(1)} \le x_{(2)} \le \cdots \le x_{(n)}$, x is any real number and its weighing function is:

$$F_{(n)}(x) = \begin{cases} 0 & x < x_{(1)} \\ \frac{k}{n} x_{(k)} \le x < x_{(k+1)} & \\ 1 & x \ge x_{(n)} \end{cases} \quad (1)$$

It is an Empirical Distribution Function (EDF). The graph of the empirical distribution function is a step curve. If the observed value is not repeated, each hop of the step is $1/n$; if there is a repetition, it is stepped up by a multiple of $1/n$. For any real number x, the value of $F_{(n)}(x)$ is equal to the frequency of the sample observation $(x_1, x_2, \dots, x_n)$ that does not exceed x. From the relationship between frequency and probability, $F_{(n)}(x)$ can be used as an approximation of the distribution function $F(x)$ of the population X. As n increases, the degree of approximation is better. For the empirical distribution function $F_{(n)}(x)$, the following result is proved: for any real number x, when $n \to \infty$, then $F_{(n)}(x)$ converges to the distribution function $F(x)$ with probability 1 , i.e., :

$$P\left\{ \lim_{n\to\infty} \underbrace{\sup}_{\text{all } x} (|F_n(x) - F(x)|) = 0 \right\} = 1 \quad (2)$$

The empirical distribution function is defined by equation (1). Figure 1 depicts an EDF with a sample size of 100 for the signal sample sequence to be tested. The purpose is to test whether the sample is from a standard normal population, and the distribution function (CDF) of $N(0,1)$ is also depicted in Figure 1. In short, the object of the EDF test is the maximum distance between the two curves in Figure 1. If the maximum distance of the signal sampling sequence EDF from the ideal normal distribution is small, it can be considered as a Gaussian distribution.

There are several options for $F_{(n)}(x)$, such as $F_{1(n)}(x)$, $F_{2(n)}(x)$, etc. [5-6], this article uses the following $F_{(n)}(x)$:

$$F_n(x) = \begin{cases} \frac{1}{n+2} & x < x_{(1)} \\ \frac{k+1}{n+2} x_{(k)} \le x \le x_{(k+1)} & \\ \frac{n+1}{n+2} & x \ge x_{(n)} \end{cases} \quad (3)$$

NT test

The NT test is based on EDF and is used to determine if a sample is from a population of a particular distribution [7].

Let $(x_1, x_2, \dots, x_n)$ be a sample from the total X sample size n, sort them in ascending order, and form order statistics $x_{(1)} \le x_{(2)} \le \cdots \le x_{(n)}$, Then construct the NT test statistic (NT distance) as:

$$D_n = \underbrace{max}_{all\ x} (|F_n(x_i) - F(x_i, \theta)|) \quad (4)$$

where $F_n(x_i)$the empirical distribution is function of the signal sample; $F(x_i, \theta)$ is theoretical distribution of the parameter vector θ estimated by the signal sample. The normal distribution is taken as an example $\hat{\theta} = (\hat{u}, \hat{\sigma})$, which is the sample mean and standard deviation. The null hypothesis is accepted or rejected at significance level α by calculating the maximum distance between $F_n(x_i)$ and $F(x_i, \theta)$ and then comparing it with normal distribution threshold. If the NT test statistic is smaller than the critical value, accept the null hypothesis that the sample is from a normal distribution population [8].

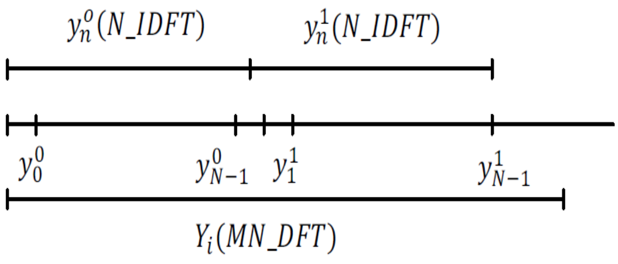

Figure 2: Schematic diagram of DFT transformation at the receiving end

3. OFDM Subcarrier Number Estimation Model

Analysis of OFDM received signals with unknown DFT points

Regardless of Gaussian white noise, it is assumed that the IDFT conversion point of the transmitting end is N, and the DFT point of the DFT module of the detecting end is MN, and M is a positive number. The OFDM transmit signal expression is:

$$y_n^m = \frac{1}{\sqrt{N}} \sum_{i=0}^{N-1} d_i^m \exp\left(j\frac{2\pi in}{N}\right), \quad i = 0,1,\dots,N-1 (5)$$

TEST Engineering & Management

January-February 2020
ISSN: 0193-4120 Page No. 2199- 2203

where y_n^m is the n^{th} IDFT output of the m^{th} OFDM symbol; d_i^m is the i^{th} bit of m^{th} baseband symbol. The signal processed by the data stream through DFT module of the detection end is:

$$Y_i = \frac{1}{\sqrt{MN}} \sum_{m=0}^{M-1} \sum_{i=0}^{N-1} y_n^m \exp\left(-j\frac{2\pi i}{MN}(mN+n)\right) = (6)$$

$$\frac{1}{\sqrt{MN}} \sum_{m=0}^{M-1} \sum_{l=0}^{N-1} d_l^m \exp\left(-j\frac{2\pi im}{M}\right) . \sum_{n=0}^{N-1} \exp\left(j\frac{2\pi n}{N}\left(l - \frac{i}{M}\right)\right)$$

The description of the derivation (6) is that if the transformation point of the receiver is assumed to be greater than the transformation points N of the transmitter, the receiving end of the DFT transformation will have more than one OFDM symbol, as shown in Figure 2.

If $\frac{i}{M}$ is a positive integer and $l = \frac{i}{M}$, equation (6) is further simplified:

$$Y_i = \frac{1}{\sqrt{M}} \sum_{m=0}^{M-1} \sum_{i=0}^{N-1} d_l^m \exp\left(-j\frac{2\pi im}{M}\right) \delta\left(l - \frac{i}{M}\right) = \frac{1}{\sqrt{M}} \sum_{m=0}^{M-1} d_{\frac{i}{M}}^m \qquad (7)$$

where $\delta()$ is a unit sample function. Equation (7) can be understood as follows. If i is an integer multiple of M, then the DFT output of MN point is only the sum of M binary symbols. In general, the multiple M is not too large, and Y_i will exhibit non-Gaussian. If $\frac{i}{M}$ is not an integer, i.e.,

$$\sum_{n=0}^{N-1} \exp\left(j\frac{2\pi n}{N}\left(l - \frac{i}{M}\right)\right) = \frac{1 - \exp\left(j2\pi\left(l - \frac{i}{M}\right)\right)}{1 - \exp\left(j\frac{2\pi}{N}\left(l - \frac{i}{M}\right)\right)} \quad (8)$$

Substituting equation (8) into equation (6) gives:

$$Y_i = \frac{1}{N\sqrt{M}} \sum_{n=0}^{N-1} \frac{1 - \exp\left(j2\pi\left(l - \frac{i}{M}\right)\right) \sin\left(\pi\left(l - \frac{i}{M}\right)\right)}{1 - \exp\left(j\frac{2\pi}{N}\left(l - \frac{i}{M}\right)\right) \sin\left(\pi\left(l - \frac{i}{M}\right)\right)} . \left[\sum_{i=0}^{M-1} d_l^m \exp\left(-j\frac{2\pi im}{M}\right)\right] \qquad (9)$$

Therefore, if i is a non-integer multiple of M, then the DFT output of MN point is that each point includes sum of code bits between code bits and OFDM symbols within each OFDM symbol, i.e., the sum of multiple random variables, and Y_i will show obvious Gaussian nature.

Subcarrier estimation process based on NT test

According to the above analysis, the OFDM signal can be subjected to DFT modules with different transform points to obtain DFT outputs with different transform points, and then NT check is performed to select the largest value, and the maximum number of transform points corresponding to the value is OFDM. The number of subcarriers with the rapid development of hardware technology, the speed of DFT computing is no longer a problem. Moreover, the number of existing OFDM signal subcarriers is basically a number of powers of two, then the subcarrier number set ($N = 2^K, K > 1, k \in Z$) can be constructed, so that a few special points (such as 16, 32, 64, 128, 256, etc.) and several points in the vicinity are tested to further speed up the identification process. Taking the 128 subcarrier OFDM signal as an example, the hypothesis test model is established as follows:

H_0: The OFDM signal subcarrier number is 128.
H_1: The OFDM signal subcarrier number is not 128.

Inductive rapid estimation of OFDM subcarrier number processing steps are:

Step1: DFT is performed on the input OFDM signal y_n^m and the real part (or imaginary part) of the output (Y_i) is obtained, and N samples ($x_1, x_2, \ldots, x_n$) are obtained.

Step 2: Estimate the parameter vector $\hat{\theta} = (\hat{u}, \hat{\sigma})$ by means of maximum likelihood estimation (MLE) or moment estimation to obtain a normal distribution function $F(x_i, \theta)$.

Step 3: The real part (or imaginary part) of N samples from large to small, composing order statistics, and calculating the empirical distribution function $F_n(x_i)$.

Step 4: Traverse the real part (or imaginary part) of the sample, and selects the maximum value of absolute value D_n of subtraction between the two in Step 2 and Step 3 as the NT distance under the N value.

Step 5: Change the value $N$and repeat Step1~Step4 to get the NT distance under different N. The largest one corresponds to N.

4. Numerical Analysis

NT distance with different DFT points

Simulation conditions: The number of OFDM signal subcarrier is 128, and the signal-to-noise ratio of Gaussian white noise channel in the transmission channel is more than dB. The DFT operation of the point 100~300 is obtained, and the output sequence of each transformation point is calculated, and then the maximum distance between the empirical distribution function and the theoretical distribution function of the corresponding sample points is calculated, that is, the NT distance. As shown in Figure 3, the NT distance has a maximum value of N=128, which is consistent with the theoretical analysis.

January-February 2020
ISSN: 0193-4120 Page No. 2199- 2203

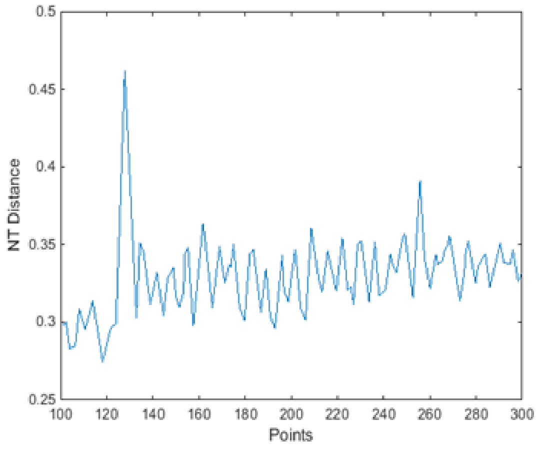

Figure 3: NT distance under different points

Simulation of sub-carrier number estimation performance

The simulation conditions are unchanged and 10 000 Monte-Carlo simulations are performed under different SNR conditions. If the maximum value of the simulation is 128, then this simulation is correct to determine the average correct estimation rate for this method. It can be seen from Fig. 4 that the OFDM subcarrier number estimation method based on the maximum NT distance has a probability of correctly estimating 0.8 when the signal-to-noise ratio is 10 dB, which is effective.

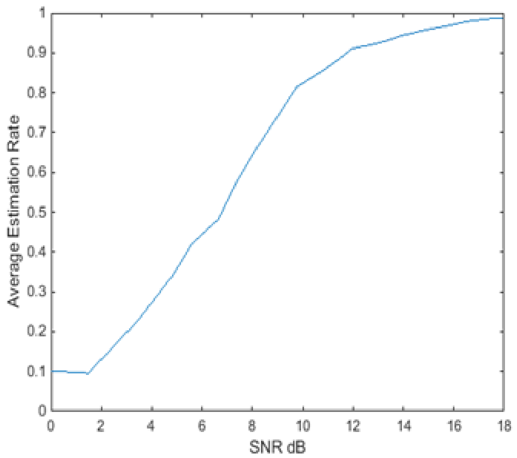

Figure 4: Relationship between average correct estimation rate and signal-to-noise ratio

5. Conclusion

Blind estimation of parameters for OFDM signals is becoming increasingly important with the widespread use of OFDM techniques. In the field of radio spectrum management, communication countermeasures, and cognitive radio, the estimation of the number of subcarriers is an important part of parameter estimation. Many studies have focused on OFDM symbol width and cyclic prefix length estimates with less carrier estimates. In this paper, the mature method of mathematical statistics is introduced into the OFDM signal subcarrier estimation. Through theoretical derivation, the feasibility of estimating the carrier number based on the maximum NT distance is proved. Finally, the simulation results show that the proposed method can effectively estimate the number of OFDM subcarriers. Introducing other methods of normality testing into subcarrier estimation is a problem to be studied in future research problem.

References

[1] Chen, Shaoping, and Tianren Yao. "Intercarrier interference suppression and channel estimation for OFDM systems in time-varying frequency-selective fading channels." *IEEE Transactions on Consumer Electronics* 50.2 (2004): 429-435.

[2] Liedtke, Ferdinand, and Ulrike Albers. "Evaluation of features for the automatic recognition of OFDM signals in monitoring or cognitive receivers." *Journal of telecommunications and information technology* (2008): 30-36.

[3] Guo-qing, Zheng Wen-xiu Zhao, and Luo Ming. "Blind Estimation of OFDM Sub-carrier Frequencies Based on the High-Order Cyclic Cumulants." *Journal of Electronics & Information Technology* 2 (2008).

[4] Shi, Miao, Yeheskel Bar-Ness, and Wei Su. "Blind OFDM systems parameters estimation for software defined radio." *2007 2nd IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks*. IEEE, 2007.

[5] Ghasemi, Asghar, and Saleh Zahediasl. "Normality tests for statistical analysis: a guide for non-statisticians." *International journal of endocrinology and metabolism* 10.2 (2012): 486.

[6] Bain, Lee. *Statistical analysis of reliability and life-testing models: theory and methods*. Routledge, 2017.

[7] Nguyen, Hung T., and Berlin Wu. *Fundamentals of statistics with fuzzy data*. Vol. 198. New York: Springer, 2006.

[8] Laird, Nan. "Nonparametric maximum likelihood estimation of a mixing distribution." *Journal of the American Statistical Association* 73.364 (1978): 805-811.

[9] Kanne Naveen, Shekar Yedunuri, M.Anand, “A Novel Sample Rate Conversion for Doppler Shift in OFDM Underwater Acoustic Communication” JARDCS Nov 2019.

[10] Dr.J.Tarun Kumar, M.Sampath Reddy and P.Ramchander rao, Equalizer Design to Compensate Impairments in OFDM System JARDCS Sep 2018

[11] Yedunuri Shekar, Kanne Naveen, Optimized Dynamic Threshold Adjustment Method for Cooperative Detection IJITEE June 2019

[12] Kanne Naveen, Yedunuri Shekar, Cooperative Spectrum Sensing Parameter Optimization Algorithm in Cognitive Radio System IJEAT April 2019

[13] S.Srinivas, case study on channel estimation techniques for OFDM systems international journal of creative research thoughts 2018