

Investigation and Analysis of SNR Estimation in OFDM system

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Abstract: Estimation of signal to noise ratio (SNR) of received signal and to transmit the signal effectively for the modern communication system. The performance of existing non-data-aided (NDA) SNR estimation methods are substantially degraded for high level modulation scheme such as M-ary amplitude and phase shift keying (APSK) or quadrature amplitude modulation (QAM). In this paper SNR estimation proposed method which uses zero point auto-correlation of received signal per block and auto/cross- correlation of decision feedback signal in orthogonal frequency division multiplexing (OFDM) system. Proposed method can be studied into two types; Type 1 can estimate SNR by zero point auto-correlation of decision feedback signal based on the second moment property. Type 2 uses both zero point auto-correlation and cross-correlation based on the fourth moment property. In block-by-block reception of OFDM system, these two SNR estimation methods can be possible for the practical implementation due to correlation based the estimation method and they show more stable estimation performance than the earlier SNR estimation methods.

Keywords: SNR estimation, OFDM, QAM, correlation

I. INTRODUCTION

Knowledge of the signal-to-noise ratio (SNR) is a requirement in many communication systems in order to perform efficient signal detection and/or link adaptation. A number of non-data-aided (NDA) SNR estimators, have been proposed for constant modulus (CM) constellations. Most of them, however, cannot be applied to non-CM constellations. Decision directed (DD) can be used by substituting the true transmitted symbols by the outputs of the decoder. Maximum likelihood estimator is one of DA estimator, and squared signal-to-noise variance (SNV), Although ML estimators provide good statistical performance, and they tend to be computationally intensive. Under a different classification, I/Q-based estimators make use of both the in-phase and quadrature components of the received signal, and thus require coherent detection; in contrast, envelope based (EVB) estimators only make use of the received signal magnitude, and thus can be applied even if the carrier phase has not been completely acquired. The more signal has high modulation level, therefore, the more SNR estimation is difficult when we compare simple modulation signal such as binary phase shift keying. SNR estimation method estimates SNR using zero point correlation relation of received signal based on fourth moment with square of zero point auto-/cross-correlation of transmit and receive signal. (BPSK) with M-ary amplitude and phase shift keying quadrature amplitude modulation (QAM) modulation signal. Even if SNR estimation algorithm could apply efficiently to BPSK signal, there is much difficulty just as it is about high dimensional signal. There for a new estimator is required, for this a novel method is proposed in this paper.

II. Ofdm System Model

As for mentioned, OFDM is a special form of MCM and the OFDM time domain waveforms are chosen such that mutual orthogonality is ensured even though sub-carrier spectra may over-lap. With respect to OFDM, it can be stated that orthogonality is an implication of a definite and fixed relationship between all carriers in the collection. It means that each carrier is positioned such that it occurs at the zero energy frequency point of all other carriers. The sine function, illustrated in **Fig.1** exhibits this property and it is used as a carrier in an OFDM system..

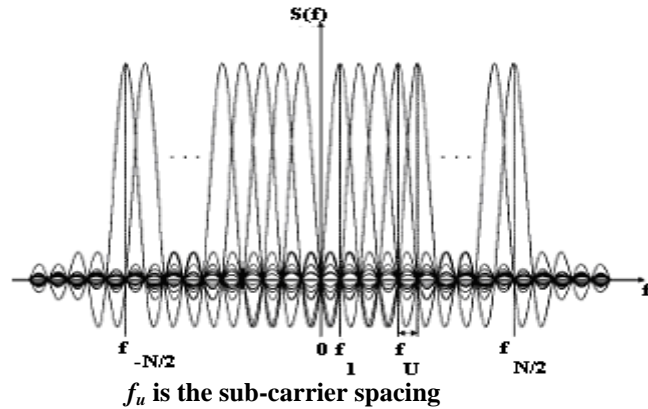


Figure-1 OFDM sub carriers in the frequency domain

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier transmission technique, which divides the available spectrum into many carriers, each one being modulated by a low rate data stream. OFDM is similar to FDMA in that the multiple user access is achieved by subdividing the available bandwidth into multiple channels that are then allocated to users. However, OFDM uses the spectrum much more efficiently by spacing the channels much closer together. This is achieved by making all the carriers orthogonal to one another, preventing interference between the closely spaced carriers. Coded Orthogonal Frequency Division Multiplexing (COFDM) is the same as OFDM except that forward error correction is applied to the signal before transmission. This is to overcome errors in the transmission due to lost carriers from frequency selective fading, channel noise and other propagation effects. For this discussion the terms OFDM and COFDM are used interchangeably, as the main focus of this thesis is on OFDM, but it is assumed that any practical system will use forward error correction, thus would be COFDM. In FDMA each user is typically allocated a single channel, which is used to transmit all the user information. The bandwidth of each channel is typically 10 kHz-30 kHz for voice communications. However, the minimum required bandwidth for speech is only 3 kHz. The allocated bandwidth is made wider than the minimum amount required preventing channels from interfering with one another. This extra bandwidth is to allow for signals from neighboring channels to be filtered out, and to allow for any drift in the center frequency of the transmitter or receiver. In a typical system up to 50% of the total spectrum is wasted due to the extra spacing between channels. This problem becomes worse as the channel bandwidth becomes narrower, and the frequency band increases. Most digital phone systems use vocoders to compress the digitized speech. This allows for an increased system capacity due to a reduction in the bandwidth required for each user. Current vocoders require a data rate somewhere between 4- 13kbps, with depending on the quality of the sound and the type used. Thus each user only requires a minimum bandwidth of somewhere between 2-7 kHz, using QPSK modulation. However, simple FDMA does not handle such narrow bandwidths very efficiently.

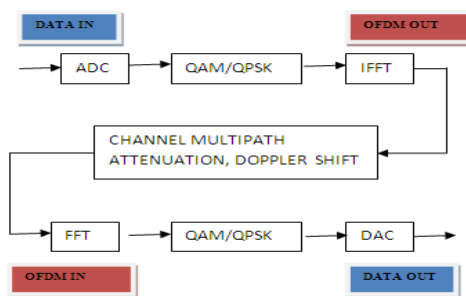


Figure-2 OFDM Block Diagram

III. Quadrature Amplitude Modulation (Qam)

Quadrature amplitude modulation (QAM) is both an analog and a digital modulation scheme. It conveys two analog message signals, or two digital bit streams, by changing (modulating) the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme. The two carrier waves, usually sinusoids, are out of phase with each other by 90° and are thus called quadrature carriers or quadrature components, hence the name of the scheme. The modulated waves are summed, and the resulting waveform is a combination of both phase-shift keying (PSK) and amplitude-shift keying (ASK), or (in the analog case) of phase modulation (PM) and amplitude modulation. In the digital QAM case, a finite number of at least two phases and at least two amplitudes are used. PSK

modulators are often designed using the QAM principle, but are not considered as QAM since the amplitude of the modulated carrier signal is constant. QAM is used extensively as a modulation scheme for digital telecommunication systems. Spectral efficiencies of 6 bits/s/Hz can be achieved with QAM. QAM modulation is being used in optical fiber systems as bit rates increase QAM16 and QAM64 can be optically emulated with a 3-path interferometer

IV. Correlation And Estimation

Signal-to-noise ratio (often abbreviated SNR or S/N) is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power, often expressed in decibels. A ratio higher than 1:1 (greater than 0 dB) indicates more signal than noise. While SNR is commonly quoted for electrical signals, it can be applied to any form of signal (such as isotope levels in an ice core or biochemical signaling between cells).signal-to-noise ratio, the bandwidth, and the channel capacity of a communication channel are connected by the Shannon–Hartley theorem.

There are several different correlation techniques. The Survey System's optional Statistics Module includes the most common type, called the Pearson or product-moment correlation. The module also includes a variation on this type called partial correlation. The latter is useful when you want to look at the relationship between two variables while removing the effect of one or two other variables. Like all statistical techniques, correlation is only appropriate for certain kinds of data. Correlation works for quantifiable data in which numbers are meaningful, usually quantities of some sort. It cannot be used for purely categorical data, such as gender, brands purchased, or favorite color. Data input into mapping block and modulate to complex data symbol such as QPSK or QAM. And, then, serial data stream converts to parallel data and this parallel data pass IFFT (inverse fast Fourier transform).

$$X(t) = \sum_{k=0}^{K-1} X_k \cdot e^{2\pi f_k t} = \sum_{k=0}^{K-1} X_k \cdot e^{\frac{2\pi}{KT_s} Kt}$$

Where K is total sub-carrier number, T_s is symbol duration, frequency of sub-carrier is $f_k = k/KT_s$, and t is $n \cdot T_s$ ($n = 0, \dots, K - 1$). Also, X_k is data symbol at k -th sub-carrier. Transmit signal $x(t)$ can be expressed to discrete signal as follows.

1. AUTO CORRELATION

It is the same as calculating the correlation between two different time series, except that the same time series is used twice - once in its original form and once lagged one or more time periods. The term can also be referred to as "lagged correlation" or "serial correlation". When computed, the resulting number can range from +1 to -1. An autocorrelation of +1 represents perfect positive correlation (an increase seen in one time series will lead to a proportionate increase in the other time series), while a value of -1 represents perfect negative correlation (an increase seen in one time series results in a proportionate decrease in the other time series). This value can be useful for computing for security analysis.

2. CROSS CORRELATION

is a measure of similarity of two waveforms as a function of a time-lag applied to one of them. This is also known as a sliding dot product or sliding inner-product. It is commonly used for searching a long signal for a shorter, known feature. It has applications in pattern recognition, single particle analysis, electron tomographic averaging, cryptanalysis and neurophysiology

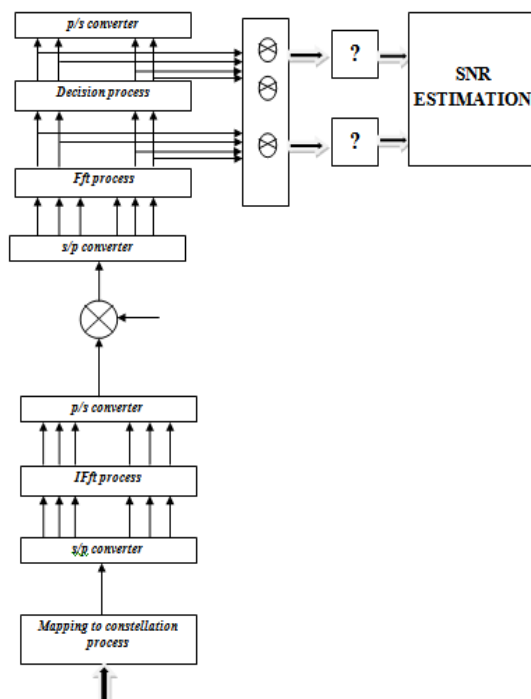


Figure 3: SNR Estimation methods in OFDM system

V. Result & Discussion

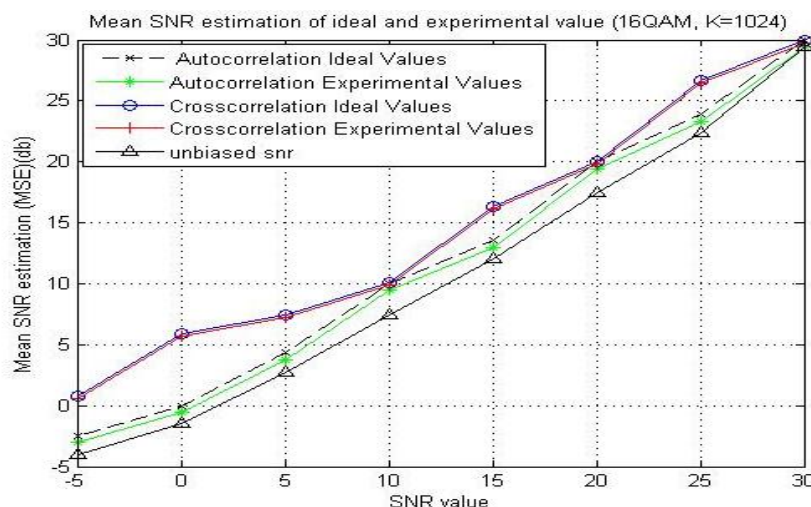


Figure.4 Mean SNR estimation of ideal and experimental value

MSE (mean squared error) is used to evaluate the performance of SNR estimation algorithm. The statistical MSE reflects both the bias and the variance of an SNR estimate and is given by

$$MSE\{\hat{\rho}\} = E\{(\hat{\rho} - \rho)^2\}$$

where $\hat{\rho}$ is an estimate of the SNR, and ρ is the true SNR compare estimated performance and MSE with existing considerable NDA estimators. The auto and cross correlation requiring neither accurate carrier recovery, nor knowledge of the transmitted symbols. This flexibility, together with implementation simplicity, makes these estimators attractive for practical applications compared with previous SNR estimated NDA which substantially gets degraded in high level modulation scheme such M-are amplitude and phase shift keying or quadrature amplitude modulation(QAM). Fig(4.4) shows mean SNR estimate performance of ideal and experimental value for proposed SNR estimation method in 16QAM-OFDM system. In 4QAM or QPSK, proposed method is the same performance between ideal and experimental results because correlation relation of decision feedback signal doesn't change from transmit signal's one. But the higher modulation level, estimation error is bigger. In case of 16QAM, SNR estimation method the performance NMSE under 0.005 in wide SNR

range of from -10dB to 30dB. It is observed that the difference between ideal & experimental value in cross correlation is less than the difference in auto correlation. Also, higher SNR estimation is observed in cross correlation than in auto correlation method; therefore, cross correlation is better than auto correlation.

VI. CONCLUSION

A new correlation based method is proposed that is amenable to practical implementation and which significantly improves on existing estimators. The proposed method showed stable performance than earlier SNR estimation methods because this estimation method uses zero point auto-correlation of received signal per block and cross correlation of decision feedback signal in OFDM system. The SNR estimation method has similar performance for QPSK and QAM and had NMSE (normal mean square error) under 0.005 in wide SNR range from 10dB to 30dB. Type 1 method had an estimation error under 2dB even though the signal for less than 0dB and NMSE performance. Type 2 method has a NSER (normal square error rate) performance under 0.005 for more than 10dB SNR. Due to its simplicity and practicality, therefore, these new methods are an attractive choice, which recently proved competitive for high level modulation.

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