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SNR ESTIMATION FOR HIGH LEVEL MODULATION SCHEME IN OFDM SYSTEM

B.Santhosh, R.Naraiah
Vaageswari College Of Engineering Department of Electronics & Communication Engg.
Vaageswari College Of Engineering
E-mail: santhosh.b443@gmail.com
Department of Electronics & Communication Engg. Vaageswari College Of Engineering
E-mail: rayiralanaraiah@gmail.com

Abstract- *It is very important to estimate the 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).*

I propose a SNR estimation 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 through Rayleigh fading channel. 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 estimation method and they show more stable estimation performance than the previous SNR estimation methods.

Index Terms — SNR estimation, OFDM, QAM, correlation

1.INTRODUCTION

Objective and goal of the thesis

Existing SNR estimators can be classified according to a number of criteria. Data-aided (DA) estimators can be used when the receiver has knowledge of the transmitted symbols, in contrast to non-data-aided (NDA) estimators, which do not require such knowledge.

Maximum likelihood estimator is one of DA estimator, and squared signal-to-noise variance (SNV), second and fourth order moment (M2M4)-based and signal-to variance ratio (SVR) has been proposed. Although ML estimators provide good statistical performance, 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 (BPSK) with M-ary amplitude and phase shift keying (APSK) or 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.

Existing Systems

Estimation of the signal-to-noise ratio (SNR) at the receiver side is an important task in existing and emerging communication systems, as many of them require SNR knowledge in order to achieve different goals, such as power control or adaptive coding and modulation and soft decoding. Whereas SNR estimation is a relatively easy task with simple modulation formats such as quadrature phase-shift keying (QPSK), the increasing complexity of the modulation schemes used in modern systems poses significant challenges to current methods.

Existing SNR estimators can be classified according to a number of criteria. Data-aided (DA) estimators can be used when the receiver has knowledge of the transmitted symbols, in contrast to non-data-aided (NDA) estimators, which do not require such knowledge. 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. This is important in applications in which the SNR must be estimated even if its value is so low as to preclude accurate synchronization and decoding. Concerning the sampling rate of the received signal, most estimators operate on baud-sampled data, although several estimators for oversampled data are also available. Most approaches focus on the single-input single-output (SISO) channel with additive white Gaussian noise (AWGN) and (quasi)static flat fading. SNR estimators for multi antenna receivers have also been recently proposed.

Proposed System

We propose a SNR estimation method based on decision feedback that amenable to practical implementation and significantly improves on previous estimation methods for high level modulation signal.

Proposed method uses zero point auto-correlation of received signal per block and auto cross- correlation of decision feedback signal in OFDM system through Rayleigh fading channel. 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 previous SNR estimation methods. QAM signal of multilevel constellation which has various Amplitude and phase is difficult to apply estimation approach based on EVB. So, estimators for QAM are requiring either more complicated algorithm, or signal processing. But, proposed method shows good estimates performance close to CBR as well as it is simple due to estimation method by correlation relation of decision feedback signal corresponding to bit error rate.

2.SNR ESTIMATION ON CORRELATION

Introduction

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. A ratio higher than 1:1 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). The signal-to-noise ratio, the bandwidth, and the channel capacity of a communication channel are connected by the Shannon–Hartley theorem.

Signal-to-noise ratio is sometimes used informally to refer to the ratio of useful information to false or irrelevant data in a conversation or exchange. For example, in online discussion forums and other online communities, off-topic posts and spam are regarded as "noise" that interferes with the "signal" of appropriate discussion.

Definition

Signal-to-noise ratio is defined as the power ratio between a signal (meaningful information) and the background noise (unwanted signal):

$$SNR = P_{signal} / P_{noise}$$

where P is average power. Both signal and noise power must be measured at the same or equivalent points in a system, and within the same system bandwidth. If the signal and the noise are measured across the same impedance, then the SNR can be obtained by calculating the square of the amplitude ratio:

$$SNR = P_{signal} / P_{noise}$$

$$= (A_{signal} / A_{noise})^2$$

where A is root mean square (RMS) amplitude (for example, RMS voltage). Because many signals have a very wide dynamic range, SNRs are often expressed using the logarithmic decibel scale. In decibels, the SNR is defined as

$$SNR = 10log_{10} (P_{signal} / P_{noise})$$

$$= P_{signal(db)} - P_{noise(db)}$$

which may equivalently be written using amplitude ratios as

$$SNR_{db} = 10log_{10} (A_{signal} / A_{noise})^2$$

$$= 20log_{10} (A_{signal} / A_{noise})$$

The concepts of signal-to-noise ratio and dynamic range are closely related. Dynamic range measures the ratio between the strongest un-distorted signal on a channel and the minimum discernible signal, which for most purposes is the noise level. SNR measures the ratio between an arbitrary signal level (not necessarily the most powerful signal possible) and noise. Measuring signal-to-noise ratios requires the selection of a representative or *reference* signal. In audio engineering, the reference signal is usually a sine wave at a standardized nominal or alignment level, such as 1 kHz at +4 dBu (1.228 V_{RMS}).

3. IMPLEMENTATION OF PROPOSED ALGORITHM

SNR Estimation Based On Correlation:

The received signal at the front end of receiver is

$y(n) = x(n) + w(n)$ ---------------------------(1)

Where $x(n)$ and $y(n)$ are transmitted and received signal, respectively. $w(n)$ is additive noise which is assumed to be zero mean AWGN and uncorrelated with the signal. In this case, the autocorrelation of the measured data $y(n)$ is given as:

$r_y(k,l) = r_x(k,l) + r_w(k,l)$ ----------------------(2)

Assuming $y(n)$, a wide-sense stationary random process, the autocorrelation $ry(k,l)$ depends only on the difference,

$m = k - l$. Thus, (2) may be rewritten as

$r_y(m) = r_x(m) + r_w(m)$ -------------------(3)

Because a zero-mean AGWN $w(n)$ models the nondeterministic part of (1), this process is uncorrelated with itself for all lags, except at $m = 0$, and its autocorrelation sequence (ACS) has the following form:

$r_w(m) = \sigma^2 \delta(m)$ ---------------------------(4)

Where $\sigma 2$ is the variance of noise, and $\delta(m)$ is the discrete delta sequence. Since the autocorrelation sequence of $y(n)$ is a conjugate symmetric function of m, $r_y(m) = r^*_y(-m)$ with the amplitude upper bounded by its value at $m = 0$. SNR of received signal is defined as

$\rho = E[|x(n)|^2] / \sigma^2$ -----------------------(5)

When we consider transmit signal of random variable in set $\{+a, -a\}$ with equal probability and AWGN channel, auto-correlation value of transmit and received signal are as follows. It can be expressed as signal power S and noise power N.

$r_x(0) = E[\, x(n)x*(n)\,] = 2a^2 = S$ -----(6)

$r_y(0) = E[\, y(n)y*(n)\,] = 2a^2 + 2\sigma^2 = S + N$ -----(7)

Where auto-correlation value of $x(n)$ and $y(n)$ are transmit and receive signal power, respectively. By equation (3) and (4), noise power is $rw(0) = ry(0) - rx(0)$.

Therefore, SNR based on auto-correlation of equation (5) is given as

$\rho\hat{} = S/N = r_x(0) / r_y(0) - r_x(0)$ ----------(8)

Type II SNR estimation method estimates SNR using zero point correlation relation of received signal based on fourth moment. Fourth moment with square of zero point auto-/cross-correlation of transmit and receive signal. Zero point auto-cross correlation are given as

$r^2_x(0) = E[\, x(n)x*(n)\,]^2 = S^2$ -------------(9)

$r^2_y(0) = E[\, y(n)y*(n)\,]^2 = (S + N)^2$ ------(10)

$r^2_{xy}(0) = E[\, x(n)y*(n)\,]^2 = S(S + N)$ -----(11)

SNR based on fourth moment can calculate as auto- cross correlation relation of transmit and receive signal, and is derived as follows.

$$\frac{r_x^2(0)}{r_y^2(0)-2r_{xy}^2(0)+r_x^2(0)}=\frac{S^2}{S^2+N^2-2S^2+S^2} \\ =\left(\frac{S}{N}\right)^2 .$$

------ (12)

Therefore, final SNR of Type II SNR estimation method based on correlation relation can be expressed by

$$\hat{\rho}=\frac{S}{N}=\sqrt{\frac{r_x^2(0)}{r_y^2(0)-2r_{xy}^2(0)+r_x^2(0)}} .$$

------ (13)

Correlation refers to any of a broad class of statistical relationships involving dependence. Familiar examples of dependent phenomena include the correlation between the physical statures of parents and their offspring, and the correlation between the demand for a product and its price. Correlations are useful because they can indicate a predictive relationship that can be exploited in practice. For example, an electrical utility may produce less power on a mild day based on the correlation between electricity demand and weather. In this example there is a causal relationship, because extreme weather causes people to use more electricity for heating or cooling; however, statistical dependence is not sufficient to demonstrate the presence of such a causal relationship.

3.1 Techniques in Determining Correlation

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.

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). Then, the transmit signal of general OFDM (orthogonal frequency division multiplexing) is

$$x(t)=\sum_{k=0}^{K-1} X_k \cdot e^{2\pi f_k t}=\sum_{k=0}^{K-1} X_k \cdot e^{\frac{2\pi}{KTs}kt}$$

------- (14)

Where K is total sub-carrier number, Ts is symbol duration, frequency of sub-carrier is

$f_k = k / KT_s$, and t is $n \cdot Ts$ $(n = 0, \ldots, K - 1)$. Also, Xk is data symbol at k-th sub-carrier. Transmit signal $x(t)$ can be expressed to discrete signal as follows.

$$x(n) = \sum_{k=0}^{K-1} X_k \cdot e^{j\frac{2\pi}{K}kn}.$$ --------- (15)

To simplify analysis of system, communication channel assume to AWGN.

$$r(n) = x(n) \otimes h(n) + w(n)$$ ---------------- (16)

Considering AWGN channel to analyze mathematically, channel response *h*(*n*) equals to 1 and phase synchronization supposes to be perfect. After removing cyclic prefix, after FFT, the recovered output for the *k*-th sub-carrier is as follows:

$$Y_k = \frac{1}{\sqrt{K}} \sum_{n \in K} r[n] \cdot e^{-j\frac{2\pi}{K}kn} = X_k + N_k.$$ ---------- (17)

Figure3.1 Block Diagram: SNR estimation method in OFDM system.

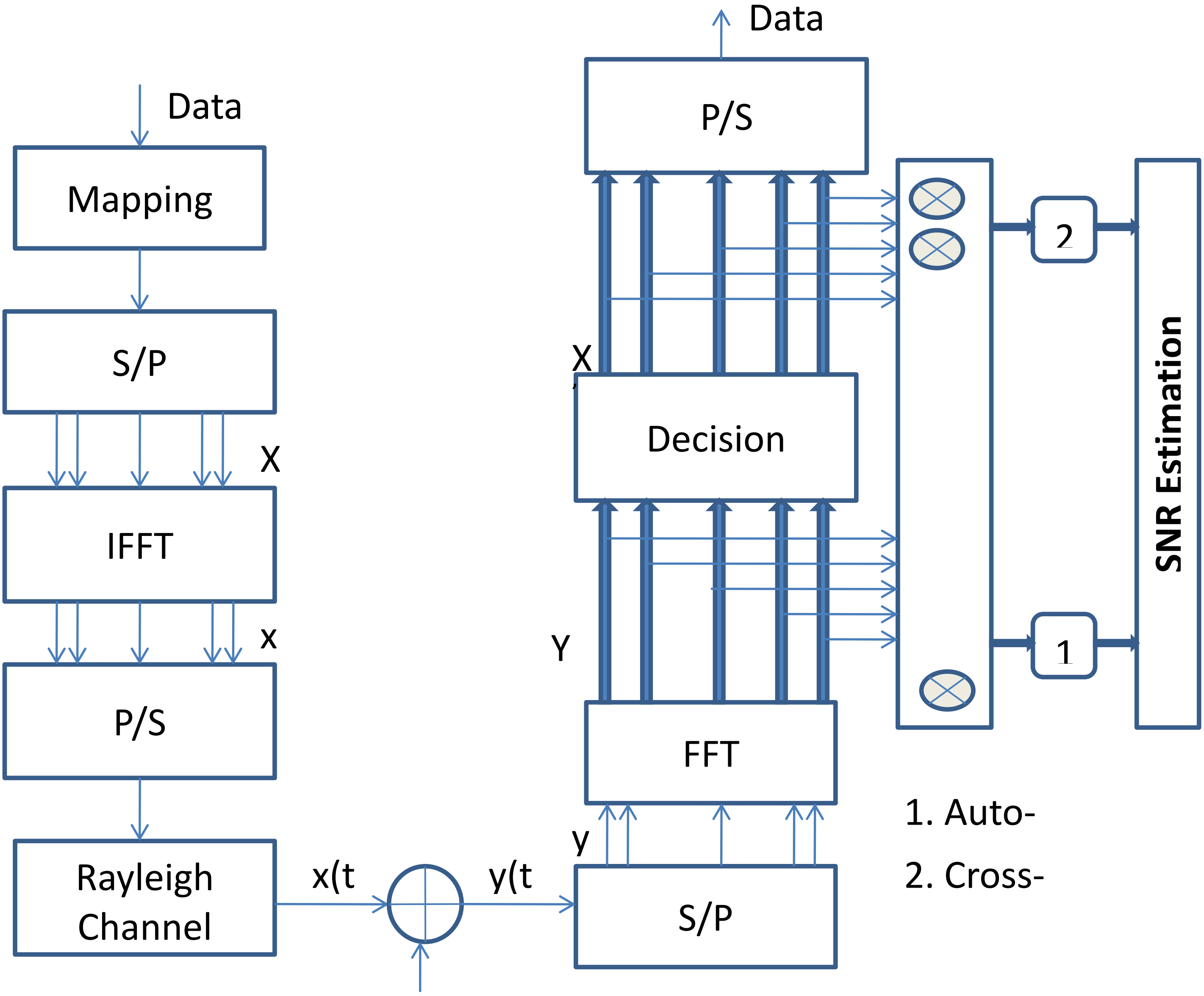
For M-QAM signal,

$$r_X(0) = \frac{1}{K}\left(\sum_{n_{c1}=1}^{N_{c1}} \left|X_{n_{c1}}\right|^2 + \sum_{n_{c2}=1}^{N_{c2}} \left|X_{n_{c2}}\right|^2 + \sum_{n_{c3}=1}^{N_{c3}} \left|X_{n_{c3}}\right|^2 + \sum_{n_{c4}=1}^{N_{c4}} \left|X_{n_{c4}}\right|^2 + \cdots \right).$$ --------- (18)

For 16QAM signal,

$$r_{X'}(0) = \sum \begin{pmatrix} corrected \\ decision \\ signal \end{pmatrix}^2 + \sum \begin{pmatrix} error \\ \pm1 \to \pm3 \end{pmatrix}^2 - \sum \begin{pmatrix} error \\ \pm3 \to \pm1 \end{pmatrix}^2$$
$$= \sum_{c_d=1}^{N-(E_n^{13}+E_n^{31})} \left(X'_{c_d}\right)^2 + \sum_{e=1}^{E_n^{13}} \left(X'_e\right)^2 - \sum_{e=1}^{E_n^{31}} \left(X'_e\right)^2.$$ -------- (19)

3.2 RAYLEIGH FADING CHANNEL MODELING



The field of mobile communications is changing the way people interact in their daily lives. The wireless industry has developed and deployed an infrastructure that aims at providing diverse services for the market. New wireless communications services offer people the possibility of being connected almost anywhere they go. However the design, production and deployment of such technological infrastructure come along with a high cost. This high cost may hinder manufacturers from building actual systems to test their initial designs. Therefore manufacturers look at different alternatives to avoid high costs; one of these alternatives is simulating a real wireless system. The advantage of simulations is that they could allow less expensive testing of designs, although they could require previous investments on computing resources.

A simulation of a wireless system could depend on various components. For example an end to end simulation of a discrete system could include blocks to study voice encoding, channel coding, interleaving and modulation issues. A key component of a wireless system simulation is the wireless channel model. The modeling of the wireless channel in a simulation will dictate, for example, how bits or packets are lost. These factors will definitely influence the overall performance of the system. Different approaches could be used to simulate diverse types of channels and their conditions. For example some models can be used to study and represent physical layer conditions like SNR or BER while others may be used to study higher layer issues like packet or segment error rates as a function of time.

4. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

OFDM is of great interest by researchers and research laboratories all over the world. It has already been accepted for the new wireless local area network standards IEEE 802.11a, High Performance LAN type 2 (HIPERLAN/2) and Mobile Multimedia Access Communication (MMAC) Systems. Also, it is expected to be used for wireless broadband multimedia communications.

Data rate is really what broadband is about. The new standard specifies bit rates of up to 54 Mbps. Such high rate imposes large bandwidth, thus pushing carriers for values higher than UHF band. For instance, IEEE802.11a has frequencies allocated in the 5- and 17- GHz bands.

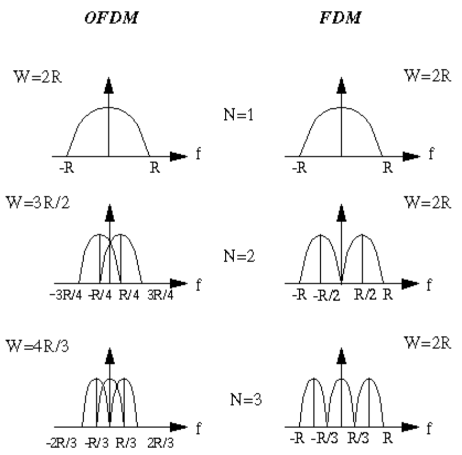
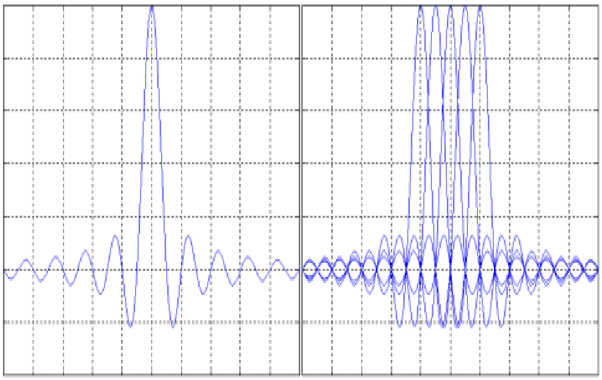


Figure4.1 Concept of OFDM signal: orthogonal multicarrier technique versus conventional multicarrier technique



(a) (b)

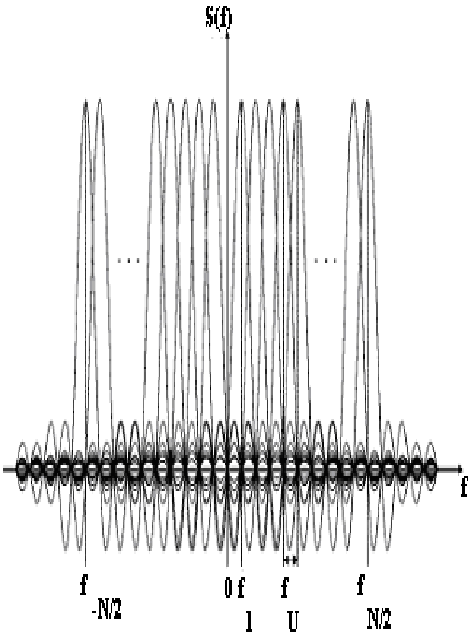
Figure4.2 Spectra of (a) an OFDM sub-channel and (b) and OFDM signal.

4.1.OFDM Carriers

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 sinc function, illustrated in Figure2.1 exhibits this property and it is used as a carrier in an OFDM system.



f_u is the sub-carrier spacing

Figure4.1 OFDM sub carriers in the frequency domain

4.2.OFDM Technique

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.

4.3.OFDM Generation

To generate OFDM successfully the relationship between all the carriers must be carefully controlled to maintain the orthogonality of the carriers. For this reason, OFDM is generated by firstly choosing the spectrum required, based on the input data, and modulation scheme used. Each carrier to be produced is assigned some data to transmit. The required amplitude and phase of the carrier is then calculated based on the modulation scheme.

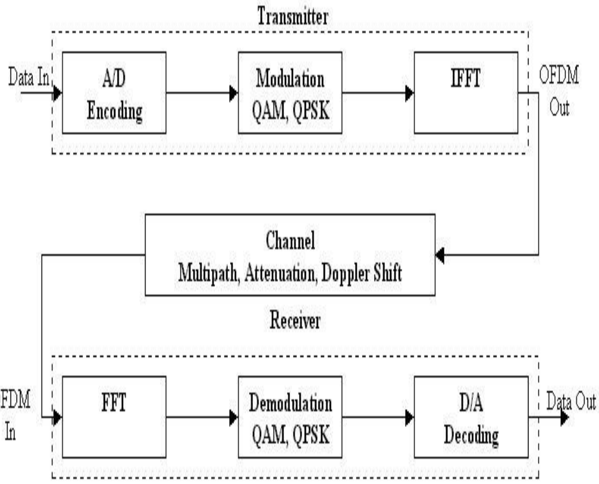


Figure4.3 OFDM Block Diagram

5.QUADRATURE AMPLITUDE MODULATION

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.

5.1.Digital QAM

Like all modulation schemes, QAM conveys data by changing some aspect of a carrier signal, or the carrier wave, (usually a sinusoid) in response to a data signal. In the case of QAM, the amplitude of two waves, 90 degrees out-of-phase with each other (in quadrature) are changed (*modulated* or *keyed*) to represent the data signal. Amplitude modulating two carriers in quadrature can be equivalently viewed as both amplitude modulating and phase modulating a single carrier.

5.2.Analog QAM

When transmitting two signals by modulating them with QAM, the transmitted signal will be of the form:

$$s(t) = I(t)\cos(2\pi f_0 t) + Q(t)\sin(2\pi f_0 t),$$

Where $I(t)$ and $Q(t)$ are the modulating signals and f_0 is the carrier frequency.

At the receiver, these two modulating signals can be demodulated using a coherent demodulator. Such a receiver multiplies the received signal separately with both a cosine and sine signal to produce the received estimates of $I(t)$ and $Q(t)$ respectively. Because of the orthogonality property of the carrier signals, it is possible to detect the modulating signals independently.

6.RESULT

Firstly, I use the MSE (mean squared error) to evaluate the performance of SNR estimation algorithm. The best SNR estimator is unbiased (or exhibits the smallest bias) and has the smallest variance. The statistical MSE reflects both the bias and the variance of an SNR estimate and is given by

$$MSE\{\hat{\rho}\} = E\{(\hat{\rho} - \rho)2\} \text{ ------------ } (29)$$

Where $\hat{\rho}$ is an estimate of the SNR, and ρ is the true SNR. And I compare estimated performance and MSE with existing considerable NDA estimators; moment-based SNR estimation method of second and fourth moment (M2M4). These methods belong to the class of NDA envelope based (EVB) estimators, requiring neither accurate carrier recovery, nor knowledge of the transmitted symbols. This flexibility, together with implementation simplicity, makes these estimators attractive for practical applications.

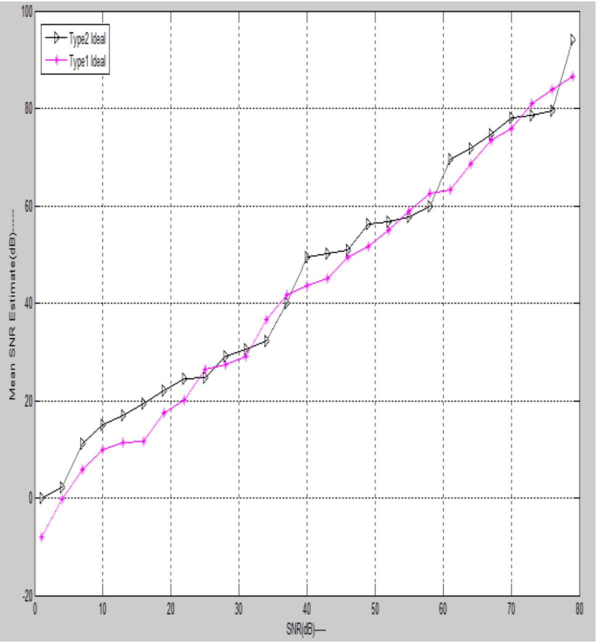


Figure6.1 Ideal SNR

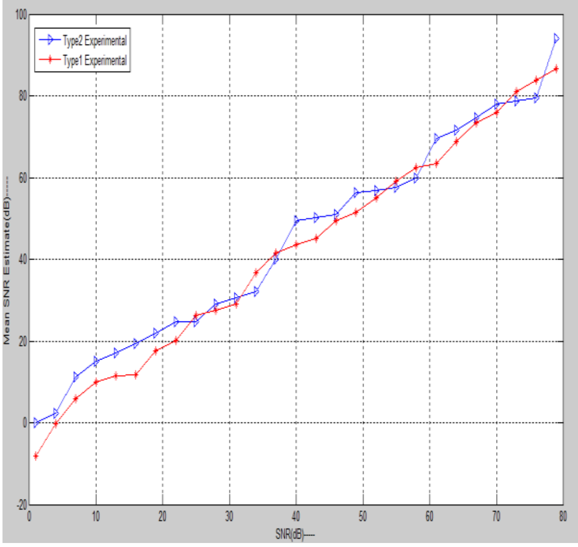


Figure9.2 Data at receiver side

7.CONCLUSION AND FUTURE SCOPE

Conclusion

I proposed a correlation relation-based approach that is amenable to practical implementation and significantly improves on previous estimators. Proposed method of this paper showed stable performance than previous SNR estimation method because this estimation method uses zero point auto-correlation of received signal per block and auto-/cross- correlation of decision feedback signal in OFDM system. Proposed SNR estimation method had similar performance with CRLB for QPSK and QAM. Especially, Type 1 method had an estimation error under 2dB even though the signal is less than 0dB. Type 2 method has a performance under 0.005 for more than 10dB SNR. Due to its simplicity and practicality, therefore, proposed method is an attractive choice, which recently proved competitive for high level modulation.

Future scope

Future scope of this project involves analyzing a p-weighted noise reduction algorithm to improve the accuracy of channel estimation in Orthogonal Frequency Division Multiplexing (OFDM) systems. A SNR and speed adaptive weighting factor p is introduced, which can efficiently reduce the noise. A p-weighted algorithm obtains a SNR gain at low SNR and maintains the variation of channel at high SNR. It may achieve the optimal tradeoff between noise reduction and maintenance of channel variation.

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