A SURVEY ON MITIGATION TECHNIQUES OF PAPR IN OFDM MIMO AND MASSIVE MIMO SYSTEMS

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Abstract
Orthogonal Frequency Division Multiplexing (OFDM) is considered to be a promising technique against the multipath fading channel for wireless communications. However, OFDM, OFDM-MIMO and OFDM MASSIVE MIMO systems faces the Peak-to-Average Power Ratio (PAPR) problem that is a major drawback of multicarrier transmission system which leads to power inefficiency in RF section of the transmitter. So many techniques were proposed to reduce PAPR in OFDM systems. Here we compared different techniques using different set of parameters.

Keywords : Orthogonal Frequency Division Multiplexing (OFDM), Peak-to-Average Power Ratio (PAPR),Multi Input Multi Output(MIMO)

I.INTRODUCTION: Method of encoding digital data on multiple carrier frequencies which developed for wideband digital communication. Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier modulation technique that divides the available spectrum into subcarriers, with each subcarrier containing a low rate data stream. The subcarriers have proper spacing and pass-band filter shape to satisfy orthogonality. OFDM will play an important role in realizing Cognitive Radio (CR) concept by providing a proven, scalable, adaptive technology for wireless communications.Despite of OFDM advantages, it has a major potential drawback in the form of high Peak-to-Average Power Ratio (PAPR). The high PAPR has nonlinear nature in the transmitter and it degrades the power efficiency of the system.OFDM is an FDM scheme used as a digital multicarrier modulation method. The subcarriers frequencies are chosen so that the subcarriers are orthogonal to each other crosstalk between the sub channels is eliminated and inter carrier guard bands are not required. The orthogonality also allows high spectral efficiency with a symbol rate near the Nyquist rate or equivalent base band signal. All the frequency band can be used. OFDM requires very accurate frequency synchronization between the receiver and the transmitter with frequency deviation the subcarriers will no longer be orthogonal causing “ICI”.**FDM**: Frequency Division Multiplexing is a technique by which the total bandwidth available in communication medium is divided into a series of non-overlapping frequency bands each of which is used to carry a separate signal. This allows a single transmission medium such as cable or optical fibre to be shared by multiple independent signals. Applications: Radio and television broadcasting.

MULTI INPUT MULTI OUTPUT SYSTEMS: This is a method for multiplying the capacity of a radio link using multiple transmission and receiving antennas to exploit multipath propagation. This has become most essential element in wireless communication. In modern usage MIMO specifically refers to a practical technique for sending and receiving more than one data signal simultaneously over the same radio channel by propagation exploiting multipath propagation .the MIMO has developed enhance the performance of a single data signal such as beamforming and diversity.MIMO is sub divided into three main categories:Precoding,Spatial multiplexing and Diversity.Beamforming is a signal processing technique used in sensor arrays for directional signal transmission or reception this is achieved by combining elements in an antenna array in such a way that signals at the particular angles experience constructive interfere while others experience destructive interfere this was used in both transmitting and receiving ends in order to achieve spacial selectivity.**Applications** : Radar,Sonar,Seismology,Wirelesscommunications.

PRECODING: This is multi stream beamforming in general terms it is considered to be all spatial processing that occurs at the transmitter .In beamforming the same signal is emitted from each of the transmit antennas with appropriative phase and gain weighting such that the signal power is maximized at the receiver input.The main aim is to increase the received signal gain by making signals emitted from different antennas add up constructively and to reduce the multipath fading effect.When the receiver has multiple antennas the transmit beamforming cannot simultaneously maximize the signal level at all the receiver antennas and precoding with multiple streams is often beneficial. Precoding requires knowledge of channel state information.

SPATIAL MULTIPLEXING: In spatial multiplexing a high rate configuration is split into multiple lower rate streams and each stream and each stream is transmitted from a different transmit antenna in the same frequency channel .If these signals arrive at the receiver antenna array with sufficiently different spatial different spatial signature and the receiver has accurate CSI, it can separate these stream into parallel channels .Very powerful technique for increasing channel capacity at the higher signal to noise ratio .The spacial multiplexing can be used without CSI at the transmitter but can be combined with precoding if CSI is available .Spacial multiplexing can also be used for simultaneous transmission to multiple receives known as space division multiple access or multiuser MIMO in which CSI is required at the transmitter.

DIVERSITY CODING: This technique is used where there is no channel knowledge at the transmitter. In this a single stream is transmitted but the signal is coded using techniques called space time coding (STC). employed to improve the reliability of data transmission in wireless communication systems using multiple transmit antennas. Space time codes may split into two main types “space time trellis codes (STTC)”. describes a trellis code over multiple antennas and multiple slots and provide both coding gain and diversity gain.Space time block codes (STBCs): act on a block of data at once and provide diversity gain but does not provide coding gain.The signal is emitted from each of the transmit antennas with full or near orthogonal coding this exploits the independent fading in the multiple antenna links to enhance signal diversity.Because there is no channel knowledge there is no beamforming or array gain from diversity coding.Diversity coding can be combined with spatial multiplexing when some channel knowledge is available at the transmitter.

CSI: This term refers to known channel properties from of a communication link.This information describes how signal propagation from the transmitter to receiver and represents the combined effect. This method is called channel estimation.The CSI makes it possible to adapt transmission to current channel conditions, which is crucial for achieving reliable communication with high data rates in multiantenna systems.The CSI needs to be estimated at the receiver and usually quantized and feedback to transmitter therefore the transmitter and receiver had different CSI.

MULTI ANTENNA TYPES: Multi antenna MIMO technology has been developed and implemented in some standards.Special cases:Multi input and single output (MISO) is a special case when receiver has a single has a single antenna,Single input and multiple output (SIMO) is a special case when transmitter has a single output (SISO) is a conventional radio system where neither transmitter nor receiver has multiple antenna,Single input and single output (SISO) is a conventional radio systems where neither transmitter nor receiver has multiple antenna.some limitations:The physical antenna spacing is selected to be large multiple wavelength at the base station the antennas separation at the receiver is heavily space constrained on handsets though advanced antenna design an algorithm technique are under discussion.Multi user types are Multi user MIMO,Cooperative MIMO,Macrodiversity MIMO,MIMO Routing andMassive MIMO.

MASSIVE MIMO: stands for Multiple-input multiple-output. While it involves multiple technologies, MIMO can essentially be boiled down to this single principle: a wireless network that allows the transmitting and receiving of more than one data signal simultaneously over the same radio channel, typically using a separate antenna for the transmitting and receiving of each data signal. Standard MIMO networks tend to use two or four antennas to transmit data and the same number to receive it. Massive MIMO, on the other hand, is a MIMO system with an especially high number of antennas.There's no set figure for what constitutes a Massive MIMO set-up, but the description tends to be applied to systems with tens or even hundreds of antennas. For example, Huawei, ZTE, and Facebook have demonstrated Massive MIMO systems with as many as 96 to 128 antennas.Because MIMO systems need to physically pack more antennas into a small area, they require the use of higher frequencies (and hence shorter wavelengths) than current mobile network standards. In MIMO, there are two concepts based on how Base station antennas are used to serve Mobile subscribers or users of the cellular service or service provider network. They are classified as single user MIMO and multi-user MIMO. In Single user MIMO, All the streams from Base station antennas are focused to one single user. In Multi user MIMO, different streams produced using combination of different antennas are focused to different users or subscribers. Moreover one stream can serve more than one users or subscribers. Massive MIMO uses multi user MIMO concept. This is depicted in the figure-1 above. As shown different antenna configurations such as spherical, cylindrical, distributed, linear, rectangular etc. are used in massive MIMO based wireless cellular systems. In Massive MIMO concept, large number of antennas (usually 32 to 64) are used at base station simultaneously to serve tens of users or mobile subscribers (MSs) in the same time-frequency grid. M-MIMO has many benefits over conventional MIMO system. Massive MIMO can also be known by other names such as "Large Scale Antenna Systems", "Hyper MIMO", "Very Large MIMO", "ARGOS" and "Full Dimension MIMO".Applications include 4G LTE,LTE advanced and advanced WLAN.

II PAPR Problem

An OFDM signal exhibits a high peak to average power ratio because the independent phases of subcarriers mean that they will often combine constructively. Handling this high PAPR requires:DAC in the transmitter,ADC in the receiver and A linear signal chain.Describes a series of signal conditioning electronic components' that receive input in tandem, with the output of one portion of the chain supplying input to the next .Any non-linearity in the signal chain will cause intermodulation distortion that raises the noise floor may cause ICI.In practical OFDM systems a small amount of peak clipping is allowed to limit the PAPR in a judicious tradeoff against the above consequences however ,the transmitter output filter which is required to reduce out of band spurs to legal levels has the effect of restoring peak levels that were clipped so clipping is not an effective way to reduce PAPR. Definition of PAPR is given below

$$\text{PAPR}=\frac{P(peak\ )}{P(average\ )} \quad \text{----------------(1)}$$

Increase in average power present in the denominator of the equation should never be done for reduction of PAPR. PAPR can be measured either in continuous time or in discrete time .

$$\text{PAPR}=\frac{[\max|x(a)|^2]}{E[x(a)^2]} \quad \text{------------------- (2)}$$

Where $E[|x(a)|^2]$represents the average power of the signal x(n).

Where x_n = Complex sequence at the output of IDFT block, and E [·] = Averaging operator. For measurement of PAPR, Complementary Cumulative Distribution Function (CCDF) is used. When discrete sequence is considered for PAPR measurement then oversampling factor must be at least 4 as per the literature reported earlier. Then only PAPR measurement is accurate. Basically, CCDF indicates the probability that PAPR will cross the set threshold value. CCDF graphs are used as a performance indicator for PAPR reduction technique.

Spectral efficiency: Refers to information rate that can be transmitted over a given bandwidth in a communication system.ISI:This is the form of distortion of the signal in which systems of a signal in which one symbols interferes with subsequent symbols this is unwanted phenomenon as the previous symbol have similar effect as noise thus making the communication less reliable. Ways to reduce ISI :Adaptative equalization : this is an equalizer that automatically adapts to time varying properties of the communication channel it is frequently used with coherent modulations such as psk mitigating the effects of multipath propagation and dopples spreading .Error correcting codes: error detection and correction or error control are techniques that enable reliable delivery of digital data over unreliable communication channels and thus errors may be introduced during transmission from the source to receiver. Doppler effect: This is the change in frequency or wavelength of a wave in relation to the observe who is moving relative to the wave source. Frequency synchronization: This is a process that adjusts the relative frequency of one or more signals based on the frequency reference of another signal.

Zhonglou Meng[1]proposed Large-scale multiple-input multiple-output orthogonal frequency division multiplexing (MIMO-OFDM) has become a promising technology for 5G communication systems.A new linear precoder design for large-scale multiuser MIMO-OFDM systems has been developed. Unlike existing precoder designs, the proposed precoding algorithm, by introducing phase factors, can not only remove MUI but also effectively reduce the PAPR. Besides, a suboptimal algorithm with low complexity has been proposed. Simulation results have verified the efficacy of proposed precoding algorithms.

StephenP.DelMarco[2] proposed a family of multi-component companders for PAPR reduction in OFDM signals using a constrained optimization approach. The new companders provide an improvement in out-of-band power rejection performance. This performance improvement was shown to persist across channel type, power amplifier use, and number of subcarriers. The new companders can also provide solutions over ranges of the cut-off values where current state-of-the-art companders fail to exist. The set of companders developed in this paper increases the solution space of companders, thereby providing a wider space of tradeoffs between demodulation performance, PAPR reduction, and out-of-band power rejection**.**

Renukua Bhandari[3] proposed Massive MIMO is nothing but high-speed wireless communication standards. The performance of MIMO systems is based on techniques used for channel estimation. Efficient channel estimation leads to spectral efficient wireless communications. HICA method is showing the BER and MSE efficiency as compared to ICA technique with different antennas with both QPSK and QAM modulation methods. A modulation method does not have any impact on HICA and ICA methods performances. However, the PAPR performance is not reduced in both ICA and HICA techniques. This means that there is excessive energy consumption while transmission of data in MIMO-OFDM.

Alok joshi[4] proposed the major difference between FFT based OFDM and DWT based OFDM is the DWT based OFDM is an extension of FFT OFDM without the requirement of cyclic prefix and guard interval as DWT has robustness against ICI and ISI due to finite length of its subcarriers. The Theoretical analysis and simulation outcome show the proposed scheme out performs the FFT OFDM scheme in the PAPR discount performance with an affordable computation complexity decreases because of removal of guard band and cyclic prefix insertion block and hence increases the rate of OFDM block and shows superior performance of DWT over the FFT OFDM in terms of spectral efficiency and bandwidth usage without decreasing the bandwidth efficiency.

Lingyin Wang[5]proposedadditive scrambling PAPR reductionscheme for BPSK-OFDM systems. In proposed additivescrambling scheme, a set of additive scrambling sequences arefirstly generated. Then, by adding each scrambling sequence tothe original OFDM signal, a set ofOFDM candidate signals aregained. In the end, the OFDM candidate sequence with thelowest PAPR is chosen. The proposed additive scramblingscheme reduces computational complexity clearly with thesame performance in PAPR reduction compared with the existing SLM scheme.

Samriti Kalia[6] proposed a novel PTS scheme, which reduces PAPR to a large extent with reduced complexity and without side information. The scheme is based on adding a complex level shift to the time domain samples of one subblock which changes both the phase and amplitude of these data samples.

Andrey Ivanov[7] proposed a new UBR algorithm is proposed for PAPR reduction in the downlink channel of multi-user Massive MIMO system. The algorithm is based on the

MMSE estimation of unused beams complex amplitudes on each subcarrier. Unused beams are defined by excluding active UEs precoding matrixes from the full set of precoding matrixes. It is shown by calculation that the UBR guarantees the max leakage of PAPR compensation signal less then IPAPR = −42dBc in a typical application scenario. Simulation results with 64 antennas of the virtual Massive MIMO cell demonstrates that the joint (STR+UBR) algorithm outperforms the STR method in Massive MU-MIMO scenario without performance degradation of QAM1024 users. Finally, the proposed method has the following benefits: excellent PAPR reduction gain (about 1.5 dB better compared with a common clipping & filtering), non-iterative solution, without out of band emission, has no performance losses of QAM1024 users in DL, fits in 5G.

Sen-Hung Wang[8] proposed a novel PAPR reduction scheme for SFBC MIMO-OFDM systems, where five time-domain signal properties are exploited to construct a low-complexity architecture. Compared to the conventional PAPR reduction schemes for SFBC MIMO-OFDM systems, where at least two IFFTsare required, the proposed scheme only needs one IFFT since it fully utilizes time-domain signal relationships between the two antennas.

M.Vasantha lakshmi[9]proposed the lossy coding method has been analyzed for the values of N ranging from 6 to 16. observation has been made for different values of N and with the different set of carrier frequencies. If we toggle any one bit in any of the 4 combinations say for 000000 will be toggled to 000001 Peak value will be reduced from 36 to 16 for N=6. Similarly if we toggle 00000000 to 00000001 peak value will be reduced from 64 to 36 for N=8 with the BER of $1.9x10^{-3}$ introduced which is of high value. Typical OFDM symbols will be of larger length and by increasing the value of the symbol length we can reduce the BER introduced. The proposed method can be implemented by a simple Combinational Logic by toggling the LSB of the Bit patterns. Research work is in progress to implement the proposed method for different modulation techniques.

H.Bao[10] proposed the problem of joint PAPR reduction and multiuser interference (MUI) cancelation in OFDM based massive MIMO downlink systems. A hierarchical truncated Gaussian mixture prior model was proposed to encourage a low PAPR solution/signal. A variational EM algorithm was developed to obtain estimates of the hyper parameters associated with the prior model, as well as the signal. Specifically, the GAMP technique was embedded into the variational EM framework to facilitate the algorithm development. The proposed algorithm only involves simple matrix vector multiplications at each iteration, and thus has a low computational complexity. The proposed algorithm also demonstrates a fast convergence rate, which makes it attractive for practical real-time systems.

III PAPR REDUCTION TECHNIQUES:

Signal Scrambling Technique

In this technique each OFDM symbol will be scrambled with the different sequences and it will select the low value of PAPR for transmission. This is the principle behind this method. This technique reduces the probability of appearance of the high PAPR value to a greater extent. This method does not reduce the value of the PAPR based on the threshold. This approach includes different types of coding schemes with error corrections. This technique is not discussed in detail as the proposed technique is based on signal distortion.

Signal Distortion Techniques

Signal distortion technique distorts the OFDM signal to reduce the PAPR. The PAPR reduction level achieved in these techniques are high but at the cost of Signal distortion and Bit Error Rate. This type of approach includes Peak Windowing, Envelope scaling, Peak reduction carrier, Clipping and filtering.

Clipping and Filtering

This method is used to reduce the PAPR in OFDM [11,12,13]systems. Clipping is done before amplification at the transmission end. This method clips the high peaks of the OFDM signal. This is done with the Clipper. Certain envelope level will be defined by the OFDM signal. If the signal level exceeds the envelope level, then the clipper level limits it. Otherwise the level of the signal will be maintained without any change . Clipping results in the signal distortion which is in band and out of band. In-band signal distortion results in the degradation in the performance of BER. By

Oversampling the signal considering longer IFFT can reduce the signal distortion where the portion of the noise will be reshaped outside the signal band. This method reduces the PAPR to a greater extent, but the shortcomings of this reduction technique is that the out-of-band signal distortion may results in peak power regrowth and the in-band signal distortion may degrade the BER performance. To improve the PAPR reduction, clipping technique has been combined along with precoding technique called Walsh Hadamard Transform (WHT) . WHT has been implemented using butterfly structure and it is a non-sinusoidal signal and has linear transformation.As compared with the transmitted OFDM signal, this will reduce the high peak values occurring at the output. This reduction in the peak value is achieved by reducing the autocorrelation of the input sequence that is being transmitted. The clipping unit will then process the data which is being transformed. This reduces the PAPR to a greater extent compared to the clipping technique.

Peak Windowing

In this method a threshold level will be set at the initial stage and if the envelope of the OFDM signal exceeds this threshold level then a window function will be applied to reduce the peak level of the OFDM signal which is known as the weighting function. The envelope of the signal will be smooth based on the window. When the window size is half and if the peak occurs successively with in this window size then it cannot smoothen the amplitude of the peaks which become a major drawback of this method. The samples of the signal will be distorted if the length of the window is too large. This results in the degradation of the BER. Hence the Advanced Peak Windowing (APW) method was proposed, high instantaneous peaks will be detected, and these high peaks will be reduced to the threshold level. Two new improved peak windowing methods like Sequential Asymmetric superposition (SAS) and Optimally Weighted Windowing (OWW) were proposed to deal with the closely spaced successive peaks to reduce the PAPR.

Envelope scaling

This has been implemented using QPSK modulation for 256 subcarriers. Before transmission we need to reduce the PAPR of the signal, hence in this method envelopes of some carriers will be scaled. The lowest value of the PAPR[14,15,16,17] will be sent as the input. The phase information will be same both in the input and the original sequence but there will be differences in their envelopes. Hence the receiver can demodulate the received sequence without any additional side information from the transmitter. The drawback of this technique is that higher order modulation cannot be used as the scaling of the carrier envelope will result in the degradation of the BER.

Peak Reduction carrier

In this technique, the sub-channles are specifically used for Peak reduction purpose. If we increase the number of the sub channels, the peak reduction carriers also increase proportionally. This significantly reduces the transmission efficiency of the system. In order to improve the efficiency of the transmission, Data Bearing Peak reduction carriers were proposed. This order scheme is used to represent the lower modulation symbol. The amplitude value and the phase value of the carriers will lie within the data symbol region. Hence, we need to maintain a tradeoff with the PAPR reduction effectiveness and the capability of the data bearing.

Comparison between OFDM,MIMO and Massive MIMO SYSTEMS

Tec hniq ue	COM PLEX ITY	PERF ORM ANCE	PA PR	BE R	Q OS	Sys tem
Con strai ned opti miza tion	LOW	Moder ate	Re duc ed	Mo der ate	Inc rea se	OF DM
scra mbli ng	LOW	Increas e	Re duc ed	De cre ase	Inc rea se	OF DM
Ton e reser vati on ratio	LOW	Increas e	Mo der ate	De cre ase	Inc rea se	OF DM
Nov el	Comp lex	Increas e	Re duc		Inc rea	OF DM

PTS technique			ed		se	
Lossy coding	LOW		Reduced		Increase	OFDM
Novel spectral efficient	Moderate	Moderate	Moderate	Moderate	Moderate	OFDM MIMO
ZF Precoder	LOW	Increase	Reduced	Decrease	Increase	OFDM MIMO
Efficient Bayesian	LOW	Increase	Reduced	Decrease	Increase	MASSIVE MIMO OFDM
Selected mapping scheme	LOW	Increase	Reduced	Decrease	Increase	MASSIVE MIMO OFDM

IV CONCLUSION:

We have studied different PAPR reductions techniques in OFDM, OFDM-MIMO and OFDM- MASSSIVEMIMO systems. From literature survey, we have observed that some PAPR reduction techniques like scrambling, constrained optimization approach in OFDM systems improved required parameters such as BER, PAPR and QOS.In OFDM MIMO Systems techniques like ZF precoding and in OFDM MASSIVE MIMO Systems techniques like Bayesian, selected mapping techniques reduced the PAPR problem to a large extent.

REFERENCES

[1] Zhonglou Meng,Yi Gong, Xiaodong Zhu, XiaodongTu and Jun Xie," Low-PAPR Precoder Design for Large-scale MIMO OFDM Systems",Springer 2019.

[2]Stephen Stephen P.DelMarco,"A Constrained Optimization Approach to Compander Design for OFDM PAPR Reduction",IEEE 2018.

[3]Renukua Bhandari,Sangeeta Jadhav,"Novel Spectral Efficient Technique for MIMO-OFDM Channel Estimation with Reference to PAPR and BER Analysis", IEEE 2018.

[4]Alok joshi,Apoorv Manas,Samarth Garg and Rahul Wason", PAPR Reduction Comparison in FFT-Based OFDM Versus DWT-Based OFDM", IEEE 2018.

[5]Lingyin Wang,"Additive Scrambling PAPR Reduction scheme in BPSK-OFDM Systems",IEEE2018.

[6]Samriti Kalia and Alok Joshi,"Low-Complexity Side Information-Free Novel PTS Technique for PAPR Reduction in OFDM Systems,"IEEE 2018.

[7]Andrey Ivanov, Artyom Volokhatyi, Dmitry Lakontsev, Dmitry Yarotsky," Unused beam reservation for PAPR reduction in Massive MIMO system",IEEE 2018.

[8]Sen-Hung Wang,Chih-Peng Li "A Low-complexity PAPR reduction scheme SFBC MIMO-OFDM SYSTEMS",IEEE signal processing lettters,VOL. 16,NO. 11,november 2009

[9]M.Vasantha lakshmi,B.Kanmani "PAPR reduction through lossy coding",IEEE

[10]H. Bao, J. Fang, Z. Chen, H. Li, and S. Li, "An efficient Bayesian PAPR reduction method for OFDM-based massive MIMO systems",IEEE Trans. Wireless Communication., vol. 15, no. 6, pp. 4183–4195, Jun. 2016.

[11]BO LI,Lingna Hu,Feng Yang,Lianghuiu Ding,Tao Song",Tone Reservation Ratio

Optimization for PAPR Reduction in OFDM Systems”,IEEE 2018.

[12]Chunxingni,taojinag and weipeng,”joint PAPR reduction and sidellobesupperssion using signal cancellation in NC-OFDM basecognitive radio systems”,IEEE transactions on vehicular technology,vol x,no.y,2014.

[13]Tao jiang,chunxingni,and Lili guan,”a Novel phase offset SLM scheme for PAPR reducion in alamouti MIMO-OFDM systems without side information”.IEEE SIGNAL PROCESSING LETTERS,VOL. 20,NO. 4,APRIL 2013.

[14]Li Li and daiming qu,”joint decoding of LDPC code and phase factors for OFDM systems with PTS PAPR reduction “,IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY,VOL.62,NO.1,JANUARY 2013.

[15]Vivek Yenamandra,Feivanlei, Sahel Al Araji, Nazar Ali, Mohammed Ismail,"Adaptive slope and threshold companding technique for PAPR reduction in OFDM systems",IEEE 2012.

[16]Y.C. wang and Z.Q luo, “Optimised and iterative clipping and filtering of PAPR reduction of OFDM signals”,IEEE transactions on communications,VOL .59,NO.1,JANUARY 2011.

[17]Lili guan,tao jiang,daiming qu and yang zhou,”joint channel estimation and PTS to reduce peak-to-Average-Power radio in OFDM systems without side information”,IEEE SIGNAL PROCESSING LETTERS, VOL.17,NO.10,OCTOBER 2010.