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A Review on Some Channel Prediction Techniques for MIMO-OFDM Wireless Systems

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ABSTRACT: Orthogonal Frequency Division Multiplexing (OFDM) is used to improve spectral efficiency and Multiple Input Multiple Output (MIMO) is used to improve spatial diversity in today wireless communications systems. Therefore, for proper detection of all data symbols channel prediction techniques play great role to system performance. This paper provides a review of channel prediction techniques for MIMO-OFDM systems.

I. INTRODUCTION

MIMO-OFDM (multiple input multiple output- orthogonal frequency division multiplexing) is a modern wireless broad band technology which has great capability of high rate data transmission and its robustness against multi-path fading and other channel impairments.

In MIMO system, multiple numbers of transmitting antennas at one end and multiple numbers of receiving antennas at the other end are effectively combined to improve the channel capacity of wireless system. This technology highly improves the spectrum efficiency, reliability of system & coverage area. A simple block diagram of MIMO-OFDM system is shown in Figure1.

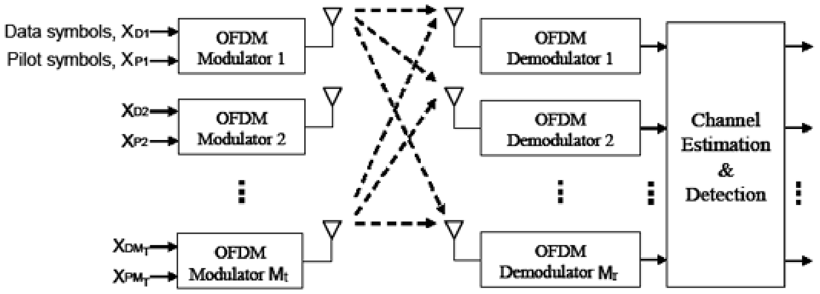

Figure1

In 1991, transmission diversity technique is used to improve wireless communication performance. Transmission diversity is investigated using space time coding for OFDM. They develop channel parameter estimation approaches, which are crucial for the decoding of space time codes, and author derives the MSE bound of the estimators [1].

In 2001, Rick S Blum et al, proposed an improved space time coding for multiple input and multiple output orthogonal frequency division multiplexing (MIMO-OFDM) using QPSK modulation for four transmit and four receive antennas. Furthermore they showed a 4-antenna, 16 state codes that achieve an additional 2-dB improvement with lower complexity and a 256 state code that achieves an additional 2-dB gain. The 256-state code performed within 3db of outage capacity [2].

In 2004, Geoffrey J. Byers [3] presented a geometric MIMO channel model which considers motion of the receivers and non isotropic scattering at both ends of the radio links. A joint space time cross correlation function is derived from this model and variates with this joint correlation are generated by using the vector autoregressive stochastic model.

In 2005, authors [4] treats channel estimation in MIMO-OFDM systems with correlation at the receive antenna arrays. A two step channel estimation algorithm is proposed. Firstly the iterative quadrature maximum likelihood based time delay and spatial signature estimation is presented by utilizing special training signal with a cyclic structure. The JST (joint spatio-temporal) filtering based MMSE estimator is derived by virtue of the spatial correlation. In addition effect of channel estimation on the bit error probability performance of space time block code OFDM system over correlated MIMO channels is derived.

In 2006, Toufiqual Islam [5] presented multiuser channel prediction technique for space time block coded orthogonal frequency division multiplexing (STBC-OFDM) systems based on simple blocked pilot grid. The prediction of multiuser channels is based on least square (LS) and Minimum mean square estimation (MMSE) schemes. The simulation result shows that for a slowly faded quasi-static channel predicted characteristics closely agree with the actual channel characteristics.

In 2006, Thomas svantesson [6] derives a performance bound for MIMO channel prediction. A vector formulation of the cramer-rao bound for functions of parameter is used to found a lower bound on the prediction error. Numerical evaluation of this bound shows that substantially longer prediction lengths are possible for MIMO channel than single antenna channels.

In 2007, MIMO system using OFDM technique has became a promising method for high data rate transmission. A robust and improved channel estimation algorithm is proposed in this paper for MIMO system based on the LS (least squares) algorithm. The improved LS called ILS employs the noise correlation in order to reduce the variance of the LS estimation error by estimating and suppressing the noise in signal subspace [7].

In 2008, Authors [8] proposes a wireless fading channel prediction algorithm for a pilot symbol aided OFDM technique. Assuming a doubly selective (time and frequency varying) ray-based physical channel model and equispaced pilot subcarrier in time and frequency. This algorithm performs channel model parameter acquisition using a 2-step1-D ESPRIT (estimation of signal parameters via rotational invariance techniques) as a first stage and channel prediction via model extrapolation as a second stage.

In 2011, Zangjie et al. [9] presents a simulation model of MIMO-OFDM system based on STBC which built and transmission performances under different channels area analyzes. The simulation results show that the MIMO-OFDM system based on STBC outperforms other MIMO-OFDM system without STBC in BER performance.

Melli, X.Wang, K.Zang [10] in 2014, analyzed the least mean square (LMS) and Recursive least square (RLS) algorithms. They applied these two algorithms to MIMO-OFDM system based on space time block coding (STBC). From the simulation results it is found that the RLS is better than LMS algorithm. They showed the practical aspect of analyzed scheme in MATLAB environment.

In 2014, authors [11] analyzed the parametric sparse MIMO-OFDM channel estimation scheme based on FRI (finite rate innovation) theory, by which super-resolution estimates of path delays with arbitrary values can be achieved.

II. SYSTEM MODEL

A generic block diagram of a basic baseband-equivalent MIMO-OFDM system is given in Figure 2. A MIMO-OFDM system with Ntx transmit and Nrx receive antennas is assumed. The information bits can be coded and interleaved. The coded bits are then mapped into data symbols depending on the modulation type. Another stage of interleaving and coding can be performed for the modulated symbols. Although the symbols are in time domain, the data up to this point is considered to be in the frequency domain. The data is then demultiplexed for different transmitter antennas. The serial data symbols are then converted to parallel blocks, and an IFFT is applied to these parallel blocks to obtain of an

OFDM symbol can be obtained from frequency domain symbols the time domain OFDM symbols. For the transmit antenna, Ntx, time domain samples as

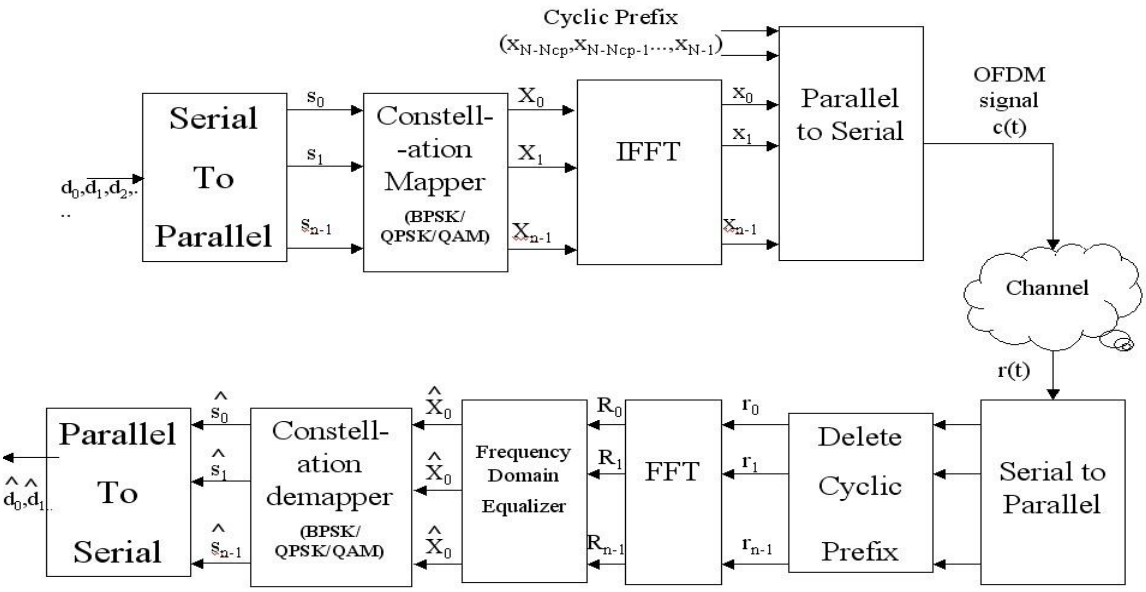

Figure 2

$$x_{tx}[n,m] = IFFT\{X_{tx}[n,k]\}$$

$$= \sum_{k=0}^{K-1} X_{tx}[n,k] e^{j2\pi mk/K} \quad 0 \le k, m \le K-1 \tag{1}$$

Where Xtx [n, k] is the data at the kth subcarrier of the nth OFDM symbol, K is the number of subcarriers, and m is the time domain sampling index.

The channel at time t is expressed as,

$$h(t,\tau) = \sum_{l=0}^{L-1} \alpha_l(t)\delta(\tau - \tau_l), \tag{2}$$

Where L is the number of taps, αl is the lth complex path gain, and τl is the corresponding path delay. The individual paths can be correlated, and the channel can be sparse. At time t, the CFR of the CIR is given by

$$H(t,f) = \int_{-\infty}^{+\infty} h(t,\tau) e^{-j2\pi f\tau} d\tau \tag{3}$$

CFR can be if proper path is found i.e.

$$H[n,k] \equiv H(nT_f, k\Delta f) = \sum_{l=0}^{L-1} h[n,l] F_K^{kl} \tag{4}$$

Where h[n, l] = h(nTf, kts), and FK = e–2πj/k,Tf is the symbol length including CP, Δf is the subcarrier spacing, and ts = 1/Df is the sample interval.

for the nth OFDM symbol, Eq 4 can be rewritten as

$$H = Fh \tag{5}$$

H is the column vector containing the channel at each subcarrier, F is the unitary FFT matrix, and h is the column vector containing the CIR taps.

At the receive antenna, rx, can be formulated as

$$y_{rx}[n,m] = \sum_{tx=1}^{N_{tx}} \sum_{l=0}^{L-1} x_{tx}[n,m-l] h_{rxtx}^{m}[n,l] + i_{rx}[n,m] + w_{rx}[n,m], \qquad (6)$$

whererx =1, …, Nrx,

After taking FFT of the time domain samples, the received samples in frequency domain can be expressed as,

$$\begin{aligned} Y_{rx}[n,k] &= \frac{1}{K} \sum_{m=0}^{K-1} y_{rx}[n,m] e^{-j\frac{2\pi km}{K}} \\ &= \frac{1}{K} \sum_{m=0}^{K-1} \left[\sum_{tx=1}^{N_{tx}} \sum_{l=0}^{L-1} x_{tx}[n,m-l] h_{rxtx}^{m}[n,l] \right. \\ &\quad \left. + i_{rx}[n,m] + w_{rx}[n,m] \right] e^{-j\frac{2\pi km}{K}} \\ &= \sum_{tx=1}^{N_{tx}} \frac{1}{K} \sum_{m=0}^{K-1} \left[\sum_{l=0}^{L-1} \left[\sum_{k'=0}^{K-1} x_{tx}[n,k'] e^{j2\pi(m-l)k'/K} \right] \right. \\ &\quad \left. h_{rxtx}^{m}[n,l] \right] e^{-j\frac{2\pi km}{K}} + I_{rx}[n,k] + W_{rx}[n,k] \end{aligned} \qquad (7)$$

whereIrx[n, k] and Wrx[n, k] are the corresponding frequency domain components calculated from irx[n, m] and wrx[n, m],respectively.

For rxtx receive antenna and nth OFDM symbol, we get

$$\begin{aligned} \mathbf{Y}_{rx} &= \sum_{tx=1}^{N_{tx}} \mathbf{F} \Xi_{rxtx} \mathbf{F}^{H} \mathbf{X}_{tx} + \mathbf{I}_{rx} + \mathbf{W}_{rx}, \\ &= \sum_{tx=1}^{N_{tx}} \Psi \mathbf{X}_{tx} + \mathbf{I}_{rx} + \mathbf{W}_{rx}. \end{aligned} \qquad (8)$$

Here, Yrx is column vector storing the received signal at each subcarrier, F is the unitary FFT matrix with entries e–j2πmk/K√Kwith m and k being the row and column index,which can be considered as the equivalent channel between each received and all the transmitted subcarriers.

Xtx denotes the column vector for transmitted symbols from txth transmit antenna, Irx is the column vector for interferers, Wrx is the column vector for noise, and Ξrxtx is the matrix with channel taps at each m index. The entries of Ξ are given by

$$\Xi_{rxtx} = \left[\begin{array}{ccc|ccc} h^{0}_{rxtx}[n,0] & 0 & 0 & \cdots & h^{0}_{rxtx}[n,2] & h^{0}_{rxtx}[n,1] \\ h^{1}_{rxtx}[n,1] & h^{1}_{rxtx}[n,0] & 0 & \cdots & h^{1}_{rxtx}[n,3] & h^{1}_{rxtx}[n,2] \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ h^{L-1}_{rxtx}[n,L-1] & h^{L-1}_{rxtx}[n,L-2] & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & h^{K-1}_{rxtx}[n,L-1] & h^{K-1}_{rxtx}[n,0] \end{array}\right]. \quad (9)$$

III. CHANNEL PREDICTION TECHNIQUES FOR MIMO-OFDM

Channel prediction is an appealing technique to mitigate the performance degradation due to inevitable feedback delay of the channel state information in modern wireless system. In this, auto regressive model is used to predict channel coefficient. This analysis made on evaluating BER, NMSE & complexity of three predictor algorithms.

In an MIMO-OFDM system, the transmitter modulates the message bit sequence into QAM symbols, performs IFFT on the symbols to convert them into time-domain signals, and sends them out through a (wireless) channel.The received signal is usually distorted by the channel characteristics. In order to recover the transmitted bits, the channel effect must be predicted and compensated in the receiver. The orthogonality allows each subcarrier component of the received signal to be expressed as the product of the transmitted signal and channel frequency response at the subcarrier. Thus, the transmitted signal can be recovered by prediction of the channel response just at each subcarrier. In general, the channel can be predicted by using a preamble or pilot symbols known to both transmitter and receiver, which employ various interpolation techniques to predict the channel response of the subcarriers between pilot tones. In general, data signal as well as training signal, or both, can be used for channel Prediction.

A. MIMO-OFDM PILOT

Depending on the arrangement of pilots, three different types of pilot structures are considered: block type, comb type, and lattice type.

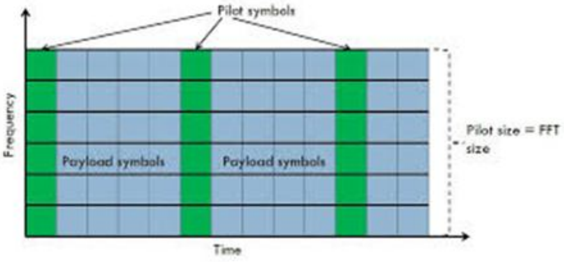

Figure 3(a)

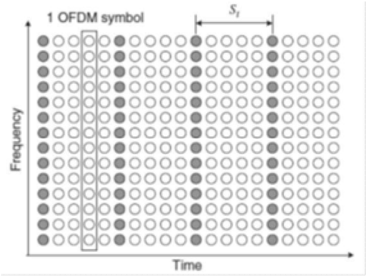

Figure 3(b)

B. TRAINING AND PREDICTION BASED CHANNEL PREDICTION

Training symbols can be used for channel prediction, usually providing a good performance. However, their transmission efficiencies are reduced due to the required overhead of training symbols such as preamble or pilot tones that are transmitted in addition to data symbols.The least-square (LS) and minimum-mean-square-error (MMSE) techniques are widely used for channel Prediction when training symbols are available.

C. DFT-BASED CHANNEL PREDICTION

The DFT-based channel Prediction technique has been derived to improve the performance of LS or MMSE channel Prediction by eliminating the effect of noise outside the maximum channel delay. Note that the maximum channel delay L must be known in advance. This technique is used for noise reduction.

D. SEMI-BLIND CHANNEL PREDICTION

Semi-blind channel predictor is another class of channel predictors that utilize not only that part of signal corresponding to the training symbols but also the part corresponding to data symbols.

E. BLIND CHANNEL PREDICTION

Using the statistical properties of received signals, the channel can be predicted without resorting to the preamble or pilot signals. Obviously, such a blind channel prediction technique has an advantage of not incurring an overhead with training signals. However, it often needs a large number of received symbols to extract statistical properties. Furthermore, their performance is usually worse than that of other conventional channel prediction techniques that employ the training signal. It consists of a filter, zero-memory nonlinear predictor, and adaptive algorithm.

F. PILOT BASED CHANNEL PREDICTOR

In the pilot mode, only few subcarriers are used for the initial prediction process. Depending on the stage, where the prediction is performed, prediction techniques will be considered under time and frequency domains techniques. In frequency domain prediction techniques, as a first step, CFR for the known pilot subcarriers is predicted. These LS predicts are then extrapolated to get the channel at the non-pilot subcarriers. The process of the extrapolation can be denoted as

^H = Q^HLS (8)

Where, Q is the interpolation or extrapolation matrix. The goal of the prediction technique is to obtain Q with lower computational complexity but at the same time is to achieve higher accuracy for a given system. In this subsection, the calculation of matrix Q for simple interpolation techniques will be discussed.

Let, A is the diagonal matrix of pilots as A=diag{ A0 , A1, … , AN) N is the number of pilots in one OFDM symbol, hˆis the impulse response of the pilots of one OFDM symbol, and Z is the Channel noise.

At the receiving end signal received is written as

$$B = AF\hat{h} + Z \qquad (9)$$

where B is the vector of output signal after OFDM demodulation as B={B0,B1,…BN-1}T

F is the Fourier transfer matrix as

$$F = \begin{bmatrix} W_N^{00} & \cdots & W_N^{0(N-1)} \\ \vdots & \ddots & \vdots \\ W_N^{(N-1)0} & \cdots & W_N^{(N-1)(N-1)} \end{bmatrix} \tag{10}$$

Where weights of Fourier matrix is

$$W_N^{i,k} = \frac{1}{\sqrt{N}} e^{-j2\pi(\frac{ik}{N})} \tag{11}$$

And the detection function is

$$\begin{aligned} K &= \left| B - AF\hat{h} \right|^2 \\ &= (B - AF\hat{h})^H (B - AF\hat{h}) \\ &= B^H B - B^H AF\hat{h} - A^H B F^H \hat{h}^H + A^H F^H \hat{h}^H AF\hat{h} \end{aligned} \tag{12}$$

For the minimization of K

$$\frac{\partial K}{\partial \hat{h}^H} = 0 \tag{13}$$

$$= -F^H A^H B + F^H A^H AF\hat{h} \tag{14}$$

$$= 0 \tag{15}$$

V. CONCLUSION

A review of different channel prediction techniques has been discussed. Different channel predictors such as pilot based predictor, blind channel predictor and semi-blind channel predictors have been discussed and it is concluded that pilot based channel prediction is far better than others, because blind and semi-blind channel predictor use mathematical information about the transmitted data and become complex. Block type arrangement and comb type arrangement for pilot insertion have been reviewed and compared. Block type arrangement is used for slow fading channel whereas comb type arrangement is used for fast fading channel. In block type arrangement includes algorithms like LSE, MMSE whereas comb type arrangement includes interpolation techniques such as piecewise constant interpolation, linear interpolation, second order interpolation, cubic spline interpolation and time domain interpolation techniques. Ithas been found that the performance of MMSE is much better than LSE but computation is very complex when number of subcarrier of OFDM increases. However, applying the DFT on the predicted output of these algorithms the results can be improved. DFT based channel prediction technique allows the reduction of noise component owing to operation in the transform domainand thus providing higher prediction accuracy.

REFERENCES

1. Ye (Geoffrey) Li, NambirajanSeshadri and SirikiatAriyavisitakul "Channel estimation for ofdm systems with transmission diversity in mobile wireless channels" IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, VOL. 17, NO. 3, MARCH 1999, pp 461-471.
2. Blum.rs, Yan.q, Li.y and winters "Improved techniques for 4-transmit and 4-receive antenna MIMO-OFDM for wireless communications", IEEE VTS VOL.2 53rd 2001, pp 1298-1302 .
3. Geoffrey J. Byers, FambiraiTakawira. "Spatially and temporarly correlated MIMO channels-modeling and capacity analysis" IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, VOL. 53,. 3, MAY 2004, pp 634-643.
4. HongleiMiao, and Markku J. Juntti. "Space time channel estimation and performance analysis for wireless MIMO-OFDM system with spatial correlation" IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, VOL. 54, NO. 6, NOVEMBER 2005, pp 2003-2016.
5. Islam t,Ahmed.I, Malik.s, Alam.f. "Quasi static channel estimation for multiuser STBC-OFDM systems" ICECE 2006 ,pp 68-71.
6. Thomas Savantesson and A.lee and swindle hurst "A performance bound for prediction of mimo channels" IEEE TRANSACTION ON SIGNAL PROCESSING, VOL. 54, NO.2 FEBRUARY 2006, pp 520-529.
7. Hossein, zamiri –jafaria and subbarayanpashupathy. "Robust and improved channel estimation algorithm for MIMO-OFDM systems" IEEE TRANSACTION ON WIRELESS COMMUNICATION, VOL. 6, NO. 6, JUNE 2007, pp 2106-2113.

8. Ian.cwong and brian .l Evans. “Sinusoidal modeling and adaptive channel prediction in mobile OFDM systems” IEEE TRANSACTION ON SIGNAL PROCESSING,VOL 54,NO.4 april 2008, pp 1601-1615.
9. Zhang jie,Liuliang,Lijin. “ Systems performance analysis of space time block code in MIMO-OFDM”, IEEE TRANSACTION ON WIRELESS COMMUNICATION, 2011 PP 13-16.
10. Meili,Xiangwang,kunzhang “comparative study of adaptive filter channel estimation technique in MIMO-OFDM system based on STBC”IEEE TRANSACTION 2014 , pp 680-683.
11. Zhen Gao, Linglong Dai, Zhaohua Lu, Chau Yuen and Zhaocheng Wang. “Super resolution sparse MIMO-OFDM channel estimation based on spatial and temporal correlations” IEEE COMMUNICATION LETTERS, VOL. 18, NO. 7, JULY 2014, pp1266-1269.