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Adaptive MIMO-OFDM Channel Estimation of Super Resolution Approach Utilizing Spatial and Temporal Correlation and TTOP

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Abstract-

This paper provide adaptive technique for the channel estimation of MIMO-OFDM. Generally there are a lot of methods for channel estimation of OFDM as well as MIMO OFDM. In this paper I first described about the latest MIMO OFDM channel estimation which is super resolution approach that explores spatial and temporal correlation of MIMO-OFDM. I then designed conventional Time domain training based orthogonal pilot (TTOP). I then compared the performance of two channel estimation schemes i.e. 2 D graph between the SNR vs. BER.I generated the performance graphs for different MIMO OFDM antenna pairs for above two. And finally I propose the combination of two techniques which is used in Adaptive way given much better results than previous channel estimation techniques and it will better utilize resources much efficiently.

Keywords-Adaptive Channel Estimation; Super sparse Resolution; MIMO OFDM channel estimation; TTOP

1. INTRODUCTION

MULTIPLE Input Multiple Output (MIMO) – OFDM is key technology for future wireless communication due to its High spectral efficiency and superior robustness to multipath fading channels.[2].

For MIMO-OFDM systems, better channel estimation is essential for system performance [3]. Generally, there are two categories of channel estimation schemes for MIMO-OFDM systems. The first one is nonparametric approach, which utilizes orthogonal frequency domain pilots or time domain training sequence to convert the channel estimation in MIMO-OFDM system to single antennasystem[3].In this paper I proposed Time domain training based orthogonal pilot (TTOP) for example of this channel estimation approach.

However these sort schemes suffers from high pilot overhead [4][5].when number of transmit antennas increases. The second approach is parametric channel estimation. It utilizes sparsity of wireless channels to reduce the pilot overhead.This is much useful for future advancement since it can achieve better higher spectral efficiency.

However, path delays of sparse channels are assumed to be located at the integer multiples of sampling period, which is unrealistic in practice. In this paper,a more practical sparse MIMO-OFDM channel estimation scheme based on spatial and temporal correlation of

sparse wireless MOMO channelsis proposed to deal with arbitrary path delays.
The proposed scheme can achieve super-resolution estimates of arbitrary path delays, Which is more suitable for wireless channels in practice.

Due to the small scale of the transmit and receive antenna arrays compared to long signal transmission distance in typical MIMO antenna geometry, channel impulse responses (CIR) of different transmit receive antenna pairs share common path delays ,which can be translated to as a common sparse pattern of CIRs due to spatial correlation of MIMO channels.
Due to temporal correlation of such common sparse pattern doesn't change along several adjacent OFDM symbols Previously the MIMO channel estimation schemes were proposed such that they exploit spatial correlation or temporal correlation.

But by exploiting both correlations the estimation accuracy will be increases. In this method we reduce pilot overhead by utilizing Finite Rate Innovation (FRI) theory. This technique can recover the antilog sparse signal with very low sampling rate, as a result channel scarcity level will decide average pilot overhead length per antenna instead of channel length.

2 .SPARSE MIMO CHANNEL MODEL

The MIMO channel is shown in Fig.1 ,its characteristics are

1)Channel Sparsity: In typical outdoor communication scenarios ,due to several significant characteristics CIR is intrinsically sparse..

For an N_t X N_r MIMO system , the CIR $h^{(i,j)}$(t) between the ith transmit antenna and jth receive antenna can be modelled as [1]

$$h^{(i,j)}(t) = \sum_{p=1}^{P} \alpha_p^{(i,j)} \delta(t-\tau_p^{(i,j)}),\ 1 \le i \le N_t,\ 1 \le j \le N_r \qquad (1)$$

Where δ(•) is the Dirac function, P is the total number of resolvable propagation paths , and $\tau_p^{(i,j)}$ and $\alpha_p^{(i,j)}$ denote the path delay and path gain of pth path respectively.

2) Spatial Correlation:
Because transmitter and receiver antenna array is small compared with the transmitting distance very similar scattering happens in channels of different transmit-receive antenna pairs. Path delays delay difference from the similar scatters is far less than sampling period for most communication systems. Even though the path gains are different CIRs of different transmit-receive antenna pairs share common sparse pattern[6].
3) Temporal Correlation*:* For wireless channels , the path delays are not as fast varying as the path gains. And path gains vary continuously. Thus , the channel sparse pattern is nearly unchanged during several adjacent 0FDM symbols, and the path gains are also correlated[8].

3. TTOP CHANNEL ESTIMATION

Based on the assumptions such as perfect synchronization and block fading, a MIMO-OFDM system is design. In training based channel estimation algorithms, training symbols or pilot tones that are known to the receiver, are multiplexed along with the data stream for channel estimation.
The idea behind these methods is to develop knowledge of transmitted pilot symbols at the receiver to estimate the channel.
For a block fading channel, where the channel is constant over a few OFDM symbols, the pilots are transmitted on all subcarriers in periodic intervals of OFDM blocks. The channel estimates from the pilot subcarriers are interpolated to estimate the channel at the data subcarrierThis type of pilot arrangement, given in Fig.1 is called the block type arrangement

In block-type pilot based channel estimation, OFDM channel estimation symbols are transmitted periodically, in which all subcarriers are used as pilots. If the channel is constant during the block, there will be no channel estimation error since the pilots are sent at all carriers.

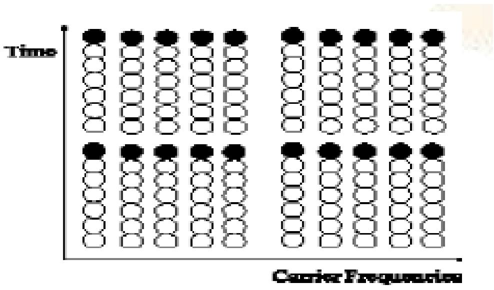

Fig 1 BLOCK TYPE

4. SPARSE MIMO-OFDM CHANNEL ESTIMATION

In this section, the widely used pilot pattern is briefly introduced first, based on which a super-resolution sparse MIMO –OFDM channel estimation method is then applied. Finally, the required number of pilots is discussed under the framework of the FRI theory.

A. pilot Pattern

The pilot pattern widely used in common MIMO –OFDM system is illustrated in Fig 3.

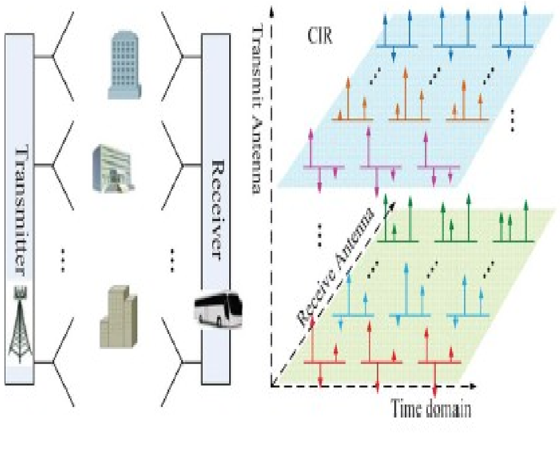

Fig 2. Spatial and temporal correlations of MIMO OFDM channels

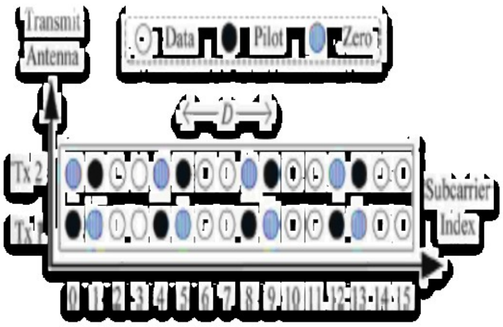

Fig.3 Pilot pattern. Note that the specific N_t =2 , D =4 , N_P =4, and $N_{\text{p\_total}}$ =8are used for illustration purpose.

In frequency domain N_P pilots are uniformly spaced with pilot interval D (e.g. D = 4 in Fig. 3 Meanwhile, every pilot is allocated with a pilot index l for $0 \le l \le N_P - 1$, which is ascending with the increase of the subcarrier index. Each transmit antenna uses

A Aubcarrier index to distingush MIMO channels associated with them.which has initial phase θ_i for $1 \le i \le N_t$ and $(N_t - 1)N_P$ zero subcarriers to ensure the orthogonality of pilot.Therefore for ith transmit antenna , the subcarrier index of the lth pilot is

$$I_{pilot}^{i}(l) = \theta_i + lD, \quad 0 \le l \le N_P - 1 \qquad (2)$$

Consequently , the total overhead per transmit antenna is $N_{\text{p\_total}} = N_t N_P$, and thus , N_P can be also referred as the average pilot overhead per transmit antenna in the letter.

B Super – Resolution Chnnel Estimation

The eqivalent baseband channel frequency response (CFR) H(f) can be expressed at receiver as

$$H(f) = \sum_{p=1}^{P} \alpha_p e^{-j2\Pi f\tau_p}, \ -f_s/2 \le f \le f_s/2 \qquad (3)$$

Where superscript i and j in (1) are omitted for convienience $f_s = 1/T_s$ is the system bandwidth, and Ts is the sampling period. Meanwhile, the N-point discrete Fourier transform (DFT) of the time-domain equivalent baseband channel can be expressed as [5], i.e.,

$$H[k] = H\left(\frac{kf_s}{N}\right), \ 0 \le k \le N-1 \qquad (4)$$

Therfore for (i , j)th transmit-receive antenna pair , according to (2)-(4) , the estimated CFRs over pilots can be written as

$\hat{H}^{(i,j)}$ [l] = H [I^{i}_{pilot} (l)]
= H($\frac{\theta_i + lD}{N}$)

$$= \sum_{p=1}^{P} \alpha_p^{(i,j)} e^{-j2\Pi \frac{(\theta_i + lD)\tau_p^{(i,j)}}{N}} + W^{(I,J)}(l) \qquad (5)$$

where $\hat{H}^{(i,j)}$ [l] for $0 \le l \le N_P - 1$ can be obtained by using the conventional minimum mean square error (MMSE) or least square (LS) method, and$W^{(I,J)}$(l) is the additive white Gaussian noise (AWGN).

Eq. (5) can be also written in a vector form as

$$\hat{H}^{(i,j)}[l] = (V^{(i,j)}[l])^T a^{(i,j)} + W^{(I,J)}(l) \qquad (6)$$

Where $V^{(i,j)}[l]$= [${}^{\prime}\Upsilon^{lD\tau_1^{(i,j)}}$,${}^{\prime}\Upsilon^{lD\tau_2^{(i,j)}}$ … ${}^{\prime}\Upsilon^{lD\tau_P^{(i,j)}}$] $a^{(i,j)}$ = [$\alpha_p^{(i,j)}{}^{\prime}\Upsilon^{\theta_i\tau_1^{(i,j)}}$, $\alpha_p^{(i,j)}{}^{\prime}\Upsilon^{\theta_i\tau_2^{(i,j)}}$ ……. $\alpha_p^{(i,j)}{}^{\prime}\Upsilon^{\theta_i\tau_P^{(i,j)}}$] and ${}^{\prime}\Upsilon = e^{-j2\Pi(\frac{f_s}{N})}$.

Because the wireless channel is inherently sparse and the smallscaleofmultipletransmitorreceiveantennasisnegligible compared to the long signal transmission distance, CIRs of different transmit-receive antenna pairs share common path delays, which is equivalently translated as common sparse patter of CIRs due to the spatial correlation of MIMOchannels i.e. , $\tau_p^{(i,j)}$= $\tau_p V^{(i,j)}[l]$ = v[l] for 1 ≤ p ≤ P,), 1 ≤ i N_P, 1 ≤ j ≤ N_r.Hence , by exploiting such spatially common sparse pattern shared among different receive antennas associated with the ith transmit antenna ,we have

$$\hat{H}^{i} = VA^{i} + W^{I}, \quad 1 \le i \le N_t \qquad (7)$$

where $N_P \; x \; N_r$ measurement matrix $\hat{H}^{i}$ is

$$\hat{H}^{i} = \begin{bmatrix} \hat{\mathcal{H}}^{(i,1)}[0] & \hat{\mathcal{H}}^{(i,2)}[0] & \cdots & \hat{\mathcal{H}}^{(i,N_r)}[0] \\ \hat{\mathcal{H}}^{(i,1)}[1] & \hat{\mathcal{H}}^{(i,2)}[1] & \cdots & \hat{\mathcal{H}}^{(i,N_r)}[1] \\ \vdots & \vdots & \ddots & \vdots \\ \hat{\mathcal{H}}^{(i,1)}[N_p-1] & \hat{\mathcal{H}}^{(i,2)}[N_p-1] & \cdots & \hat{\mathcal{H}}^{(i,N_r)}[N_p-1] \end{bmatrix}$$

V = [v[0], v[1], v[2], , v[$N_P - 1$]]^T is a vandermonde matrix of size $N_P \; x \; N_r$,A^i = [$a^{(i,1)}$, $a^{(i,2)}$, …..$a^{(i,N_t)}$] $of\ size$ $N_P \; x \; N_r$ and W^I is an $N_P \; x \; N_r$ matrix with $W^{(I,J)}$(l) in its jth column and the (l+1)th row.

When all N_t transmit antennas are considered based on (7), wehave

$$\hat{H} = VA + W \qquad (8)$$

Where $\hat{H}$ = [$\hat{H}^1$, $\hat{H}^2$, ……,$\hat{H}^{N_t}$] of size $N_P \; x \; N_t N_r$, A = [A^1 , A^2,……….A^{N_t}], and W =[W^1 , W^2,……….W^{N_t}] .

By Comparing the formulated problem and the classical direction-of-arrival (DOA) problem , I find out that they are mathematically equivalent. Traditional DOA problem is to estimate the DOAs of the P sources from a set of time-domain measurements, which are obtained from the N_P sensors outputs at $N_t N_r$distinct time instants (time-domain samples).

In this case, we try to estimate the path delays of P multipaths from a set of frequency-domain measurements, which are acquired from N_P pilotsof $N_t N_r$distinctantennapairs(antenna-domain samples).To efficiently estimate path delays with arbitrary valuesit has been verified by the total least square estimating signal parameters via rotational invariance techniques (TLS-ESPRIT) algorithm can be applied to (8).

we can obtain superresolution estimates of path delays, i.e., $\widetilde{\tau_p}$ for1 ≤ p ≤ P, by using the TLS-ESPRIT algorithmand thus, $\check{V}$can be obtained accordingly. Then, path gains can be acquired by the LS method , i.e.,

$$\hat{\mathbf{A}} = \hat{\mathbf{V}}^{\dagger}\hat{\mathbf{H}} = (\hat{\mathbf{V}}^{H}\hat{\mathbf{V}})^{-1}\hat{\mathbf{V}}^{H}\hat{\mathbf{H}}.$$

For certain entry of $\hat{A}$, i.e.($\alpha_p^{(i,j)}$)^${}^{\prime}\Upsilon^{\theta_i\widetilde{\tau_p}}$, because θ_i is known at the receiver and $\widetilde{\tau_p}$ has been estimated after applying the TLS-ESPRIT algorithm ,we can easily obtain the estimation of the path gain.($\alpha_p^{(i,j)}$)^ for 1 ≤ p ≤ P, 1 ≤ i ≤N_t, 1 ≤ j ≤ N_r Finally, the complete CFR estimation over all OFDM subcarriers can be obtained based on (3) and (4).

Furthermore,to improve the accuracy of the channel estimation we can also exploit the temporal correlation of wireless channels. First, path delays of CIRs during several adjacent OFDM symbols are nearly unchanged which is equivalently referred as a common sparse pattern of CIRs due to the temporal correlation of MIMO channels.

Thus, the Vandermonde matrix V in (8) remains unchanged across several adjacent OFDM symbols. Moreover, path gains during adjacentOFDMsymbolsarealsocorrelatedduetothetemporal continuity of the CIR, so As in (8) for several adjacent OFDM symbols are also correlated. Therefore, when estimating CIRs of the qth OFDM symbol, we can jointly exploit$\hat{H}$s of several adjacent OFDM symbols based on (8) ,i.e.,

$$\frac{\sum_{P=q-R}^{q+R}\hat{H}_{\rho}}{2r+1} = V_q \frac{\sum_{P=q-R}^{q+R} A_{\rho}}{2r+1} + \frac{\sum_{P=q-R}^{q+R} W_{\rho}}{2r+1}$$

where the subscript ρ is used to denote the index of the OFDM symbol, and the common sparse pattern of CIRs is assumed in 2R +1adjacent OFDM symbols, Hence effective noise can be reduced, so the improved channel estimation accuracy is expected.

Ourproposedschemeexploitsthesparsityas well as the spatial and temporal correlations of wireless MIMO channels to first acquire estimations of channel parameters,
including path delays and gains, and then obtain the estimation of CFR, which is contrast to non parametric schemes which estimatesthechannelbyinterpolatingorpredictingbasedonCFRs over pilots ,

C. *Discussion on Pilot Overhead*

Compared with the model of the multiple filters bank based on the FRI theory , it can be found out that CIRs of $N_t N_r$ transmit-receiveantennapairsareequivalenttothe $N_t N_r$ semiperiod sparse subspaces, and the Np pilots are equivalent to the Np multichannel filters. Therefore, by using the FRI theory, the smallest required number of pilots for each transmit antenna is Np =2P in a noiseless scenario. For practical channels with the maximum delay spreadτ_{max} , although the normalized channel length L =τ_{max} /T_s is usually very large, the sparsity level P is small, i.e., P <<L
Consequently, in contrast to the nonparametric channel estimation method where the required number of pilots heavily depends on L, our proposed parametric scheme only needs 2P pilots in theory. Note that the number of pilots in practice is larger than 2P to improve the accuracy of the channel estimation due to AWGN.

5. SIMMULATION RESULTS

In this we first kept Number of subcarriers (N_{sc}) as 64 and we kept cyclic prefix length (N_g) as 16 and delay spread as 5 and we took different SNR values ranges from 0 to 40 and we perform the channel estimation of MIMO – OFDM by using MMSE channel estimation technique . In this we adopt FFT for performing channel estimation.

We get the channel response as below

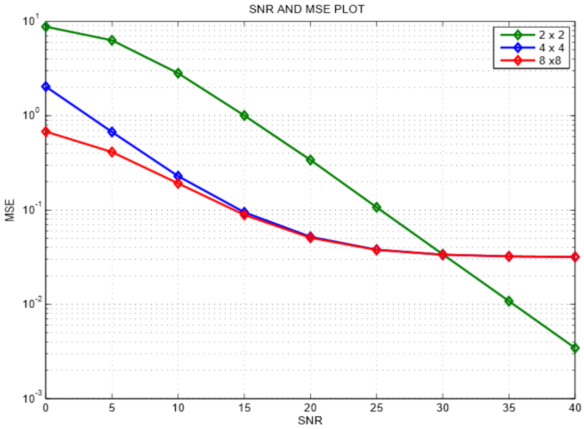

Fig. 4 SNR vs MSE Plot Of TTOP Channel Estimation

We also performed the channel estimation of MIMO - OFDM for static channel for different techniques and we get channel response as below From this response it is clear that for static channels proposed scheme and TTOP channel estimation gives same behaviour compared to other parametric and non parametric approaches.

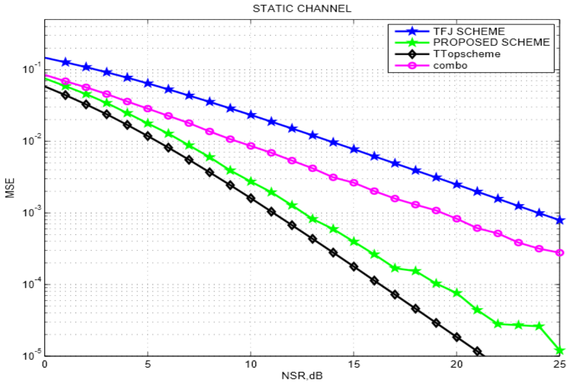

Fig. 5 SNR vs MSE Plot Of Static Proposed Channel

Estimation

We also performed the channel estimation for time varying channel was done and we obtain channel responses for different parametric and non parametric approaches as below

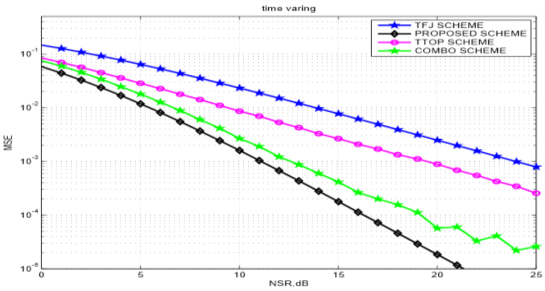

Fig. 6 SNR vs MSE Plot Of Time Varying Proposed Channel Estimation

We also performed channel estimation of MIMO-OFDM with different transmit receive antenna pairs i. e .(4 x 4, 8 x 8, 12 x 12) and obtain channel responses as below.

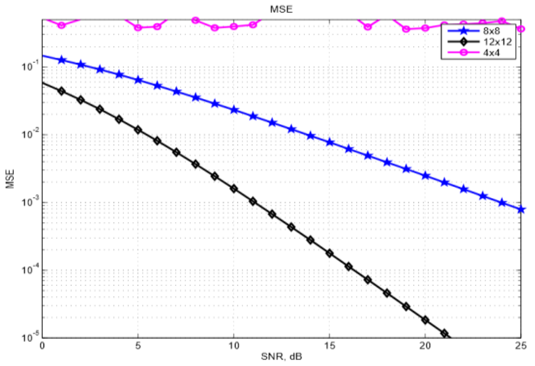

Fig. 7 SNR vs MSE Plot For Different Antenna Pairs

In this channel estimation techniques we use spatial and temporal correlations of hannel which results in better results of this technique even in time varying channels.

The tabular representation of the channel performance of static channel estimation of Time domain Training based Orthogonal Pilot is as below by using MMSE channel estimation

TTOP Channel Estimation For Static Channel

SNR(dB)\MSE	2 X 2	4 X 4	8 X 8
2	9	2	$5x10^{-1}$
5	6	$6x10^{-1}$	$3x10^{-1}$
10	2	$3x10^{-1}$	$2x10^{-1}$
15	1	$1x10^{-1}$	$1x10^{-1}$
20	$3x10^{-1}$	$5x10^{-2}$	$4x10^{-2}$
25	$1x10^{-1}$	$4x10^{-2}$	$3x10^{-2}$

In similar fashion the static channel estimation channel performance of proposed scheme in tabulation is as below

Proposed Channel Estimation for Static Channel

SNR(dB)\MSE	2 X 2	4 X 4	8 X 8
2	$5x10^{-1}$	$3x10^{-1}$	$3x10^{-1}$
5	$4x10^{-1}$	$2x10^{-1}$	$2x10^{-1}$
10	$3x10^{-1}$	$1x10^{-1}$	$9x10^{-2}$
15	$2x10^{-1}$	$8x10^{-2}$	$7x10^{-2}$
20	$1x10^{-1}$	$3x10^{-2}$	$5x10^{-2}$
25	$7x10^{-2}$	$2x10^{-2}$	$4x10^{-2}$

6. CONCLUSION

In this paper we first proposed basic MIMO – OFDM channel model and basic approach to estimate the channel. We also proposed the Time domain Training based Orthogonal Pilot (TTOP) channel estimation technique. We also presented brief overview of the super sparse resolution MIMO OFDM channel estimation by using spatial and temporal correlation. We performed the channel estimation of TTOP by using Minimum Mean Square Error (MMSE) channel estimation technique and we obtain the SNR vs MSE plot for this .In similar way we performed the proposed channel estimation and we obtain performance plot for static and time varying channels.

At last we tabulate static channel estimation of proposed scheme and TTOP for comparison. From that table we came to conclusion that static channel estimation of TTOP scheme gives almost same performance of proposed scheme. Hence we conclude that if we utilize TTOP estimation for static MIMO OFDM requirements then we can get better results with least resource. Hence we propose adaptive MIMO OFDM channel estimation which uses TTOP for static channels and proposed scheme for time varying channels will give better results with maximum utilization of resources.

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