Performance Analysis of Parametric and Non-Parametric MIMO-OFDM Channel Estimation Schemes

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***Abstract*:-** A parametric super resolution sparse Multi Input Multi Output (MIMO)-OFDM channel estimation technique in view of the Finite Rate of Innovation (FRI) theory has been proposed, whereby super-resolution assessments of delays in paths with arbitrary values can be accomplished. In the mean time, for wireless MIMO channels both the spatial and temporal correlations are made use of, to enhance the precision of the channel estimation. For outside communication situations, where wireless channels are meager in nature, path delays of distinctive transmit-receive antenna pairs share a similar sparse pattern because of the spatial correlation of MIMO channels. At the same time, the channel sparse pattern is almost unaltered amid several adjacent OFDM symbols because of the temporal correlation of MIMO channels. Exploiting these MIMO channel attributes simultaneously, the proposed technique performs better than existing highly developed techniques. Moreover, by joint processing of signals integrated with distinctive antennas, the pilot overhead can be decreased under the structure of the FRI theory.

***Keywords*:-** *MIMO-OFDM; super-resolution; Finite Rate of Innovation (FRI); spatial correlation; temporal correlation.*

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I. INTRODUCTION

MIMO-OFDM is generally perceived as a key innovation for future wireless communications because of its high spectral efficiency and better robustness to multipath fading channels. For MIMO-OFDM systems, exact channel estimation is vital to ensure the system performance. Normally, there are two classifications of channel estimation scheme for MIMO-OFDM systems. The first one is non-parametric scheme, which embraces orthogonal frequency domain pilots or orthogonal time-domain training sequences to change the channel estimation in MIMO systems to that in single antenna systems [1]. Although, such schemes experiences high pilot overhead at the point when the number of transmit receive antennas increments. The second category is parametric channel estimation scheme, which exploits the sparsity of wireless channels to decrease the pilot overhead. The parametric scheme is more suitable for future wireless systems as it can accomplish higher spectral efficiency. Whereas, path delays of sparse channels are expected to be situated at the integer times of the sampling period [2], which is practically unlikely.

II. METHODOLOGY

A more useful super resolution sparse MIMO-OFDM channel estimation scheme in view of spatial and temporal correlations of sparse wireless MIMO channels is proposed to manage with arbitrary path delays. Initially, the super resolution sparse scheme can accomplish super-resolution estimates of arbitrary path delays, which is practically more appropriate for wireless channels. Second, due to the small scale of the transmit and receive antenna arrays in contrast to the long signal transmission distance in a common MIMO antenna geometry, Channel Impulse Response (CIRs) of distinctive transmit-receive antenna pairs share similar path delays [3], which can be depicted as a common sparse pattern of CIRs because of the spatial correlation of MIMO channels. In the interim, such common sparse pattern is almost unaltered along many nearby OFDM symbols because of the temporal correlation of wireless channels [4]. The proposed scheme uses both spatial and temporal correlations to enhance the channel estimation precision. Third, decrease the pilot overhead by utilizing the FRI theory [5], which can recover the analog sparse signal with very low sampling rate, thus, the average pilot overhead per antenna relies on the channel sparsity level rather than the channel length.

III. MIMO-OFDM

A. OFDM

In Orthogonal Frequency Division Multiplexing (OFDM), a large number of very closely spaced sub-carrier signals with spacing such that each sub carrier is orthogonal to the other, carry data on several parallel data channels. The modulation of each sub-carrier is done with a conventional modulation scheme. Hence, OFDM is a multi-carrier modulation technique which offers high performance characteristics and maximum utilization of bandwidth.

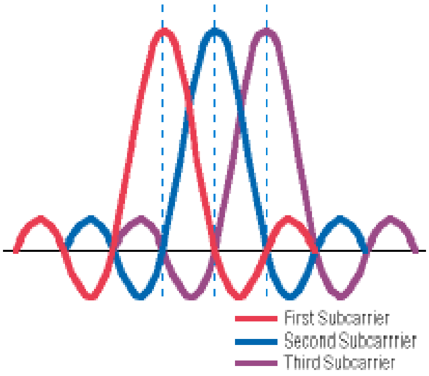

Figure 1: OFDM subcarriers

B. MIMO

In a Multiple Input Multiple Output (MIMO) system, multiple antennas can be used at the transmitter and receiver to take advantage of the spatial diversity that is obtained by spatially separated antennas in a dense multipath scattering environment.

The following characteristics of MIMO are considered:

1) Channel Sparsity: LTE resolves the individual propagation paths from transmitters to receivers which results in a channel impulse response showing only a few peaks and many zeros which can be stated as a sparse signal. In an outdoor environment CIR is normally sparse due to many significant scatterers.

2) Spatial Correlation: As compared to the long signal transmission distance, the scale of the transmit/receive antenna array is impeccably small, therefore channels of various transmit-receive antenna pairs share very similar scatterers. Meanwhile, for many communication systems, the path delay difference from the same scatterer is very much less than the system sampling period. Hence, CIRs of different transmit-receive antenna pairs have a common sparse pattern, even though the corresponding path gains may be quite different.

3) Temporal Correlation: Path delays of CIRs for several adjacent OFDM symbols are almost unchanged which can be equivalently stated as a common sparse pattern of CIRs because of the temporal correlation of MIMO channels. In wireless channels, the path gains vary continuously compared to the path delays. Hence, the channel sparse pattern is almost unchanged for several adjacent OFDM symbols as well as the path gains are also correlated.

C. MIMO-OFDM

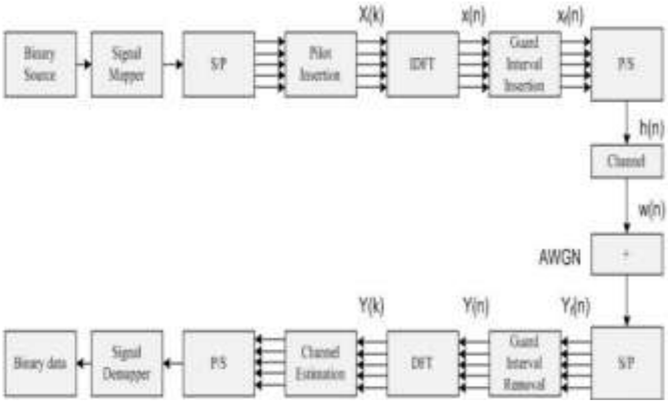

Figure 2. Block diagram of MIMO-OFDM

The binary information is first grouped and mapped according to the modulation in signal mapper as shown in the fig. 2. Serial to parallel conversion of the signal is done at S/P block. Now inserting of pilots is done. To transform the data sequence of length into time domain, IDFT block is used. Following IDFT block, guard time, which is chosen to be larger than the expected delay spread is inserted. This is done to prevent inter-symbol interference. The inter-carrier interference is also eliminated with the help of this guard time. The transmitted signal will pass through the frequency selective time-varying fading channel with additive white Gaussian noise.

At the receiver, the analog signal received gets the guard time removed. The discrete time domain samples are converted to frequency domain by the DFT block. Following DFT block, the pilot signals are extracted and the estimated channel for the data sub-channels is obtained in channel estimation block. Now parallel to serial conversion of signal is done using P/S block. Then the binary information data is obtained back in signal demapper block.

IV. SUPER RESOLUTION SPARSE MIMO-OFDM CHANNEL ESTIMATION

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

A. Pilot Pattern

The pilot pattern used is shown in fig.3, P pilots are spaced equidistant to each other such that there is a pilot interval G between each other. In the meantime, each pilot is assigned with a pilot index I such that 0<I<P-1. Pilot index increases as the subcarrier index increases. To safeguard the orthogonality of the pilots, zero subcarriers are used. Additionally, to differentiate MIMO channels corresponding to different transmit antennas, a unique initial phase of a subcarrier index is used by each transmit antenna.

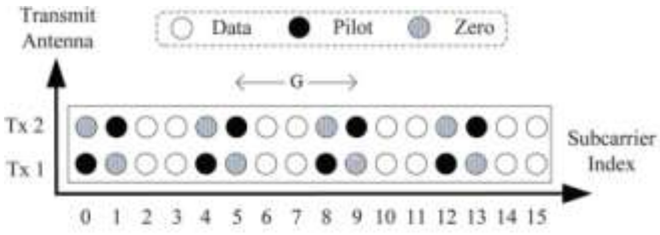

Figure 3: Pilot Pattern

B. Spatial and Temporal Correlation

As the wireless channel is sparse by nature and the small scale of various transmit/receive antennas is negligible with respect to the large signal transmission distance, CIRs of multiple pairs of transmit-receive antennas have the common path delays, which is correspondingly interpreted as a common sparse pattern of CIRs owing to the spatial correlation of the MIMO channels. Hence, by utilizing such spatially common sparse pattern distributed among Mt transmit antennas and Mr receiver antennas pertaining to the ith transmit antenna, the channel frequency response is given by

$$H=VA+N\ldots\ldots\ldots(1)$$

Where V is a Vandermonde matrix of size P*P, A is path gain of size P*Mr and N is additive white Gaussian noise.

Comparing (1) with the traditional direction-of-arrival (DOA) problem [6], its been observed that these two are mathematically equivalent. Explicitly, the classical DOA problem is to commonly estimate the DOAs of the M sources from a group of time-domain quantities, which are acquired from the P sensors outputs at MtMr discrete points in time. On the contrary, the path delays of M multipaths in (1) are estimated from a group of frequency-domain quantities, which are obtained from P pilots of MtMr discrete pairs of antenna. The Total Least Square-Estimating Signal Parameters via Rotational Invariance Techniques (TLS-ESPRIT) algorithm [6] is used to estimate path delays with arbitrary values by applying it to (1).

Additionally, the temporal correlation of wireless channels is also exploited to enhance the precision of the channel estimation. Initially, path delays of CIRs for various adjacent OFDM symbols are almost unaltered [7], [8], which is similarly, made reference to as a common sparse pattern of CIRs because of the temporal correlation of MIMO channels. Furthermore, path gains throughout adjacent OFDM symbols are also correlated pertaining to the temporal continuity of the

CIR. Also various adjacent OFDM symbols are also correlated. Hence, noise is decreased which in turn improves the accuracy of channel estimation.

C. *Pilot Overhead*

Based on the FRI theory [9], it is stipulated that CIRs of MtMr transmit-receive antenna pairs are similar to the MtMr semiperiod sparse subspaces, and the P pilots are similar to the Tp multichannel filters. Hence, with respect to the FRI theory, the least required number of pilots for a transmit antenna is Tp=2Q(i.e., Q is the sparsity level) in a noiseless environment. On the contrary, for the non-parametric channel estimation techniques the necessary number of pilots highly depend upon channel length L, where as the super resolution sparse parametric scheme only requires 2Q pilots where Q<<L.

V. RESULTS AND ANALYSIS

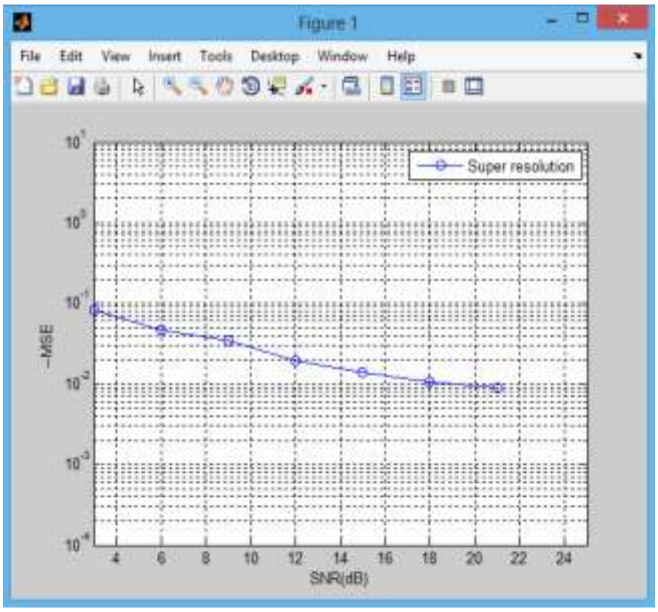

Figure 4: Performance analysis of super resolution sparse scheme in static channel

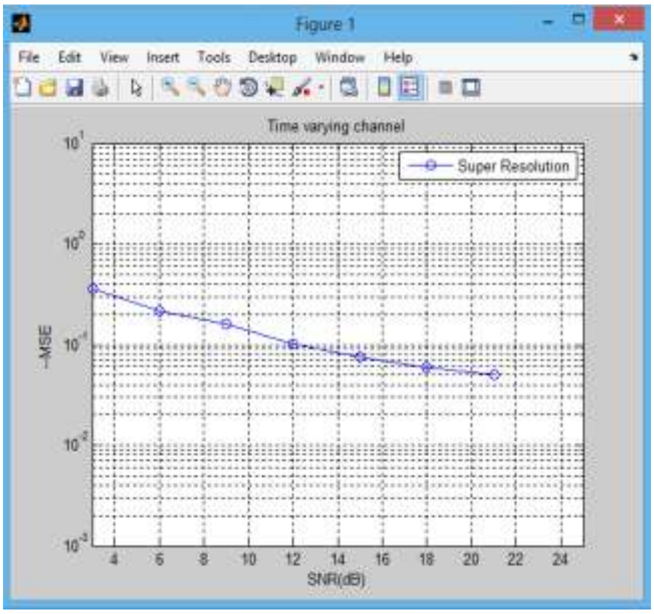

Figure 5: Performance analysis of super resolution sparse scheme in time-varying channel

Fig. 4 and fig. 5 show the performance of super resolution sparse scheme in a static and a time-varying channel respectively. The sparse channel estimation scheme does not work well in time-varying channel as the placement of path delays for practical channels may not be at the integer times of the sampling period.

The non-parametric schemes considered here are comb-type pilot channel estimation scheme [10] and Time-domain Training based Orthogonal Pilot (TTOP) channel estimation schemes [1]. Performance of the non-parametric conventional TTOP scheme and comb-type pilot with the parametric super resolution sparse scheme in an International Telecommunication Union Vehicular B (ITU-VB) channel model is compared. In a MIMO system, the ITU-VB static channel and an ITU-VB time-varying channel with a mobile speed of 90 kmph are considered.

Following are the comparative simulations of performance analysis of the parametric and non-parametric channel estimation schemes.

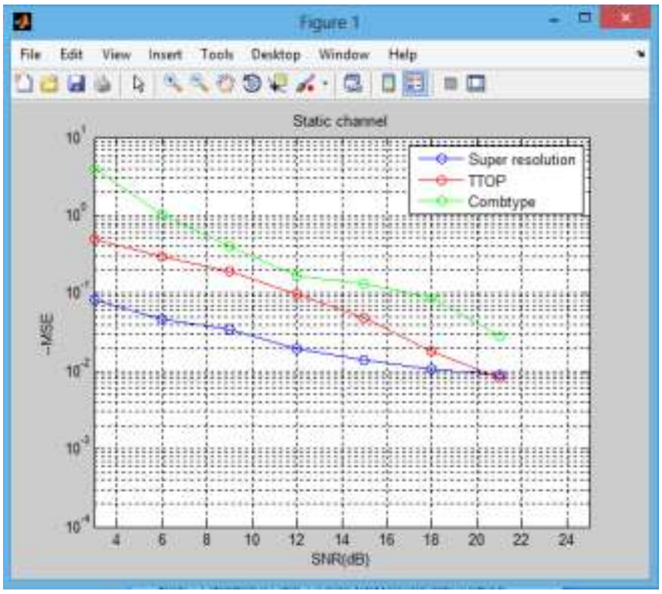

Figure 6: Comparison of comb-type, TTOP and super resolution sparse schemes in a static channel

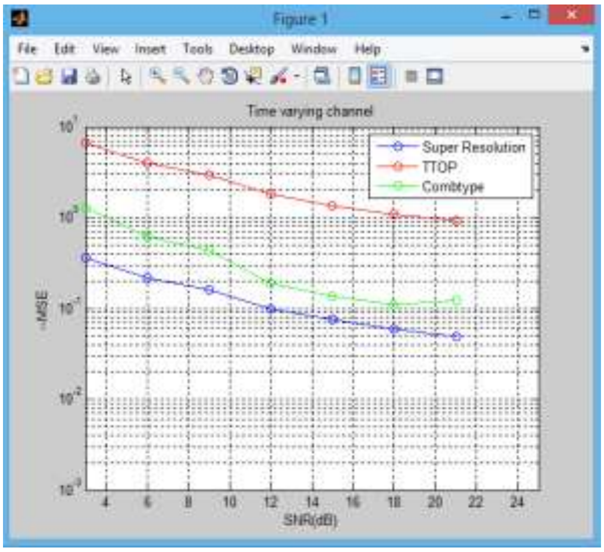

Figure 7: Comparison of comb-type, TTOP and super resolution sparse schemes in a time-varying channel

Parameters	Specification
MIMO system	4*4
Channel	ITU-VB static & time-varying
Modulation	QPSK
Time varying channel speed	90 kmph
No. of pilots in comb-type	256
No. of pilots in TTOP	64
No. of pilots in super resolution sparse scheme	64

Table 1: Simulation Parameters

Name of the technique	Channel	SNR (dB)	MSE
Comb type scheme	Static	6	1.028
	Time varying	6	1.077
TTOP scheme	Static	6	0.2925
	Time varying	6	3.92
Super resolution scheme	Static	6	0.04696
	Time varying	6	0.2178

Table 2: Result analysis of comb-type, TTOP, super resolution schemes in static and time varying channels

Fig. 6 and fig. 7 compare the Mean Square Error (MSE) performance of different channel estimation schemes in static and time-varying channel respectively. The MSE performance of parametric super resolution sparse scheme in the ITU-VB static channel is better than the non-parametric comb-type pilot and TTOP based schemes. Furthermore, the performance of super resolution sparse scheme is superior to the comb-type pilot and TTOP schemes for the ITU-VB time-varying channel. This is due to the fact that non-parametric schemes suffer from higher pilot overhead and also spatial and temporal correlation helps the parametric scheme in better channel estimation. TTOP scheme performance is very poor in the ITU-VB time varying channel compared to its performance in the static ITU-VB channel as it assumes that the nature of channel is static for the adjacent OFDM symbols.

VI. CONCLUSION

The super-resolution sparse MIMO channel estimation scheme exploits the sparsity of wireless MIMO channels as well as their spatial and temporal correlations. It can obtain estimates of path delays with arbitrary values and provides greater channel estimation accuracy than non-parametric comb type and TTOP schemes. Also by utilizing FRI theory, the required number of pilots in the super resolution sparse scheme is significantly less than that in non-parametric comb type and TTOP channel estimation schemes. Henceforth, simulations demonstrate that the performance of the parametric super resolution sparse channel estimation scheme is better than the non-parametric comb-type and TTOP channel estimation schemes.

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