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Performance of Pilot-Aided 3D-OFDM Channel Estimation using Different Antenna Configurations

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Abstract

This paper aims, a 3D-Pilot Aided Multi-Input Multi-Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) Channel Estimation (CE) for Digital Video Broadcasting -T2 (DVB-T2) for the 5 different proposed block and comb pilot patterns model and performed on different antenna configuration. The effects of multi-transceiver antenna on channel estimation are addressed with different pilot position in frequency, time and the vertical direction of spatial domain framing. This paper first focus on designing of 5-different proposed spatial correlated pilot pattern model with optimization of pilot overhead. Then it demonstrates the performance comparison of Least Square (LS) & Linear Minimum Mean Square Error (LMMSE), two linear channel estimators for 3D-Pilot Aided patterns on different antenna configurations in terms of Bit Error Rate. The simulation results are shown for Rayleigh fading noise channel environments. Also, 3x4 MIMO configuration is recommended as the most suitable configuration in this noise channel environments.

Keywords*: channel estimation, MIMO, OFDM, LS, LMMSE, Pilot density [Dx, Dy, Dz]*

1. Introduction

In wireless communication system, the combination of multiple input multiple output-orthogonal frequency division multiplexing (MIMO-OFDM) plays an important role as it provides high transmission rate. The channel estimation is performed to get channel state information that is about effect of channel on signal. With comparative to conventional MIMO technique,3D MIMO System have some benefits such as it decrease intercell interference, enhance throughput and spectrum efficiency by exploiting spatial domain in the vertical direction [1]. This paper presents the performance comparison of 3D MIMO-OFDM channel estimation technique such as LS and LMMSE for various antenna configuration.

3D-OFDM (MIMO) communication system uses multiple transmitters and multiple receivers which utilize diversified spatial correlated multiple antennas at the transmitting and receiving ends of the system, to improve the performance of MIMO communication system [2-3]. It utilizes uncoupled parallel sub-channels, where the number of sub-channels is given by the channel characteristics and the number of antennas employed independent path in a scattering environment, which enhance capacity of channel but it may downgrade the high data rate in DVB-T2 system. Thus, in pilot aided, 3D channel estimation system design, pilot patterns play important role along with antenna configuration to trade-off with existing 2D-pilot aided system.

In 3D-OFDM systems, channel estimation is directed using pilot block along data block in frequency, time and the vertical direction of spatial domain framing with parameter constraints pilot interval, pilot number, system overhead, SNR loss. In DVB-T2 System, for bandwidth utilization pilot-data ration is improved in case of worst wireless channelling where number of spectral sub-channels is used using independent localized number of antenna configuration. In 2D-OFDM, many researchers has proved that pilot aided channel estimation can be improved by changing pilot allocation in given pilot-data ration framing without increasing payload of pilot [4-5]. To inline this, in our research we have proposed the 5 different proposed block and comb pilot patterns model and tested with different antenna configuration using Rayleigh fading channel. The proposed 3D-pilot patterns are summarized as follows.

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Proposed Pilot patterns scheme: Based on literature of [5], typically different antenna configuration is used in 2D-analysis which is experimented in similar form for different pilot position based modelling. The summary of different pilot based OFDM 3D-frame modelling is design with suitability of antenna configuration are elucidated in following Table 1.

Table 1. Indicate Pilot Scheme Configuration

Proposed 3-D Pilot Pattern	No. of subscriber Pilot	Pilot Payload	Dx	Dy	Dz	Pattern type
Pilot Scheme-1	1248 Pilots	50%	2	1	416	Block
Pilot Scheme-2	848 Pilots	34%	3	1	416	Comb
Pilot Scheme-3	624 Pilots	25%	4	1	416	Comb
Pilot Scheme-4	524 Pilots	21%	5	1	416	Comb
Pilot Scheme-5	424 Pilots	17%	6	1	416	Comb

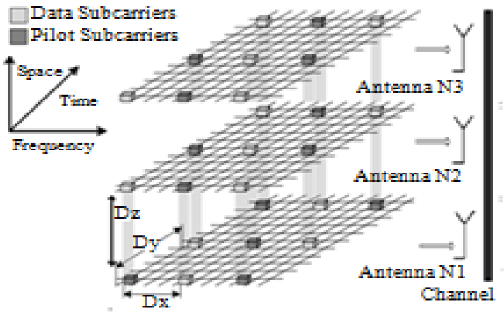

Figure 1. Pilot transmission scheme at transmitter

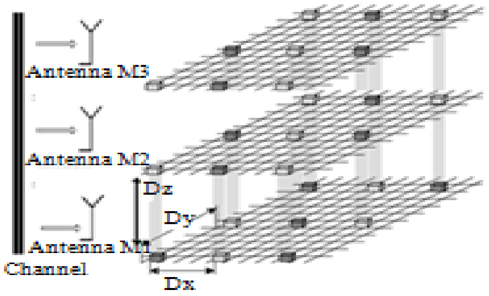

Figure 2. Pilot transmission scheme at receiver

These proposed pilot patterns are re-designed and re-investigated as per consideration of factor such as slow and fast varying channel, sensitive to frequency selectivity and sensitivity domain, requirement of interpolation and guard interval to match desired channel estimation interns of SNR and BER [6-13]. So we proposed and concluded exact pilot pattern scheme to adopt 3D-pilot allocation patterns to improve system performance with differential antenna configuration over existing 2D-OFDM system.

The rest of the paper, Section II explores the 3D-scattered pilot based system model of DVB-T2 & the channel model. In Section III, highlights experimental parameter which support to DVB-T2. In Section IV, simulation results for different antenna configuration for all five proposed pilot pattern are explained, analyzed and compared in depth with test result. Finally, in Section V, establish conclusion of the analyzed result of proposed scheme with the effectiveness of 3D-channel estimator.

2. System Model and Cognitive MIMO Channel Model

Let us define the system includes (24*5=120)120-frame for five plane whereas 26, 34, 39, 41, 43-active subcarrier indices/frame with 26, 17, 13, 11, 9-pilot active subcarriers indices/frame as rectangle pilot shape are provided & retrieves to 16-QAM modulator & de-modulator respectively. As per experimentation done in previous research, the desirable load as Pilot Payload / information 50%, 34%, 25%, 21%, 17% is aligned to establish novel pilot scheme with small estimation loss. This approach is relegated with testing on parametric based Rayleigh fading transmission channel noise mode.

The parameters and distances of subcarriers (data & pilot) forming a periodic pattern in time, frequency & space domains, respectively and in the selection of Dt (Dy), Df (Dx) & Ds (Dz), we have considered of different errors as inter-frame error, intra-frame error & channel error respectively, accordance with adoption channel estimation at receiver side. The reference symbols sequence for proposed 3D-generating pilots and the amplitude of the SP (Scattered pilots) are processed, through 16 QAM modulator. Then, the symbols are modulated onto IFFT of size 64K and the Guard interval (GI) (1/4 length of actual frame) is inserted. Then complete OFDM frame is transmitted over a multipath channel modelled through noise model.

At a receiver, following with the removal of GI to individual sampled signal, the receiver transforms the remaining samples into the frequency domain via a 16 QAM Demodulator and FFT. The output is allocated to estimation techniques (LS, LMMSE) to get channel specific reference signal with minimum error. Then collected signal handover to adder with frame selection & allocation to get required signal. Based on literature [4], a typical antenna configuration is used to verify the capacity of proposed pilot aided frame structure which is modelled through 3D- OFDM. The transmitter side, different Nth antenna structure with same characteristics is used. The spacing of every three adjacent element is Dx to x-axis, Dy to y-axis and Dz to z-axis plane. The receiver configures uniform linear antenna 3D- structure as shown in figure (4) with Mth - no. of antenna with equal spacing as transmitter.

Assume that time-frequency resources of MIMO OFDM system are divided into same equal block as per pilot structure scheme. Each block contributes K-subscriber, L-OFDM symbol.

At the receiver side, received block can be expressed in Mth antenna as;

$$y\,(t,m)=h\,(t,m)\;x\,(t,m)+s\,(t,m) \qquad (1)$$

Where y (t, m) is the M x1 dimension receiving signal and the dimension of y is LK x M x1; x (t,m) is the transmitted symbol and s(t, m) is the additive Rayleigh fading noise channel is the convolution operation. h(t, m) is MxN channel matrix from transmitter to receiver with s(t,m) is the Mx1 dimension white Gaussian noise for zero mean and variance (δ2). Rayleigh distribution model is a specialized fading model for urban or non-line-of-sight communication between the transmitter and receiver; the objects in the environment attenuate, reflect, refract, and diffract the signal before it arrives at the receiver. If we assume that there is no direct path or line-of sight component, the received signals (t) can be expressed as:

$$s(t)=\sum_{i=1}^{N} a_i\,cos(\omega_c t+\Phi_i) \qquad (2)$$

Where N is the number of paths. The phase ω depends on the varying path lengths.

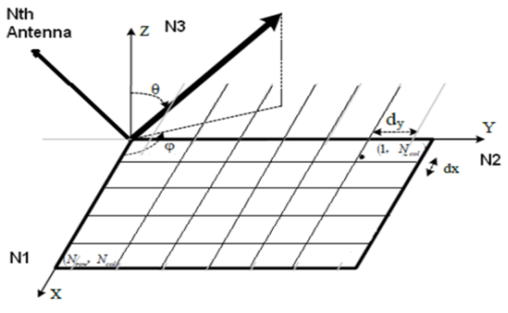

Figure 3. Antenna configuration of the transmitter

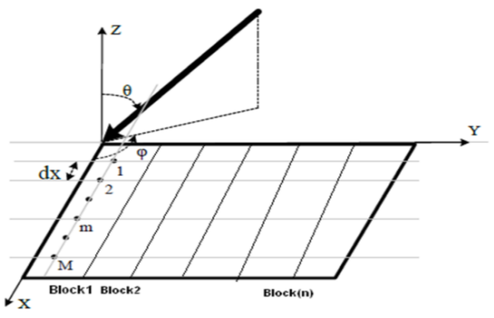

Figure 4. Antenna configuration of the receiver

Assume that $X(p0,\omega 0,t0,r0)$ is the pilot signal transmitted in the $p0^{th}$ OFDM symbols, $\omega 0^{th}$ sub-carrier and the $r0^{th}$ transmitting antennas. The Coefficient Matrix (H) can be estimated by LS algorithm to estimate from the receiving signal in this time-frequency resource and is expressed as:

$$\hat{H}(p0,\omega 0,t0,r0)=\frac{Y(p0,\omega 0,t0,r0)}{X(p0,\omega 0,t0,r0)} \qquad (3)$$

The channel information of other antenna and other time-frequency resources are obtained by the interpolation using Wiener filtering [6]. Wiener interpolation filter achieve the minimum Ĥm, n (p,ω) and desired Hm, n (p,ω). The channel information of every receiving antenna is acquired by formula (1), and the output signal of Wiener filter is written as:

$$\begin{aligned}\hat{H}(p,\omega,t,r) &= W_{opt}\cdot\hat{H}(p0,\omega0,t0,r0)\\ &= R_{dp}R^{-1}{}_{pp}\hat{H}(p0,\omega0,t0,r0) \qquad (4)\end{aligned}$$

The channel correlation matrix Rdp and Rpp are the four-dimensional function for Tx & Rx antenna configuration.

Algorithm: Channel Estimation LS & LMMSE

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Step1: Generation of random binary sequence
Step2: Performing 16-QAM modulation.
Step3: Assigning to multiple OFDM symbols adding Cyclic prefix i.e.16
Step4: Convolving each OFDM symbol with a 10-tap Rayleigh fading channel. On each symbol the fading is independent. Compute the frequency response of fading channel on each symbol and stored.
Step5: Concatenation of multiple symbols in order to form a long transmit sequence
Step6: Performing transmission over Rayleigh fading channel.
Step7: The received vector is then grouping into multiple symbols, removing cyclic prefix
Step8: Converting the received symbol from time domain into frequency domain
Step9: The received symbol is then divide with the known frequency response of the channel
Step10: Obtaining the desired subcarriers
Step11: Perform demodulation and conversion to bits
Step12: Measure the number of bit errors
Step13: Repeat the process for multiple values of Eb/No
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3. Simulation Parameters

Performance analysis is performed on the MATLAB simulator having the baseband equivalent system. The following performance parameters can be configured for the DVB-T2 standard:

a) 3D-Pilot Pattern with five tested model with payload is 50%, 34%, 25%, 21 % and 17 %
b) Transmit/Receive Antenna configuration
c) 2x2,2x3,3x3,3x4,4x4,4x5,5x5,5x6 and 6x6
d) OFDM modulation with 16-QAM constellations.
e) OFDM modes are 1k, 2k, 4k, 8k, 16k, and 32k.
f) Guard intervals are of 25% to total frame length.
g) DVB - T2 is specified for 8 MHz channel bandwidth.
h) Alamouti Multi–Antenna (6x6) MIMO OFDM Scheme
i) Number of Subcarrier–1248

4. Simulation Result

The simulated DVB-T2 3D-OFDM system, we considered Alamouti scheme, having differential antennas configuration (maximum 6-transmitters & 6-Receivers antennas) with total 1248 subcarriers are used. Data subcarriers are modulated by the length of the cyclic prefix (CP) is 16, and QAM is adopted with different Pilot density is processed with Guard Interval 1/4.This whole process is modeled through a typical Rayleigh distribution transmission channel noise model. The MSE performance of LS and MMSE algorithms versus SNR with different L (Sample points), N (iteration) =192, 33 are comparatively studied and explained for all five Proposed 3D-pilot Equal Distribution Blocking 3-D Structure scheme.

4.1. Proposed Strucure-1

The data rate (BER) result is presented in Figure 5 for proposed 3-D Pilot Pattern MIMO-OFDM with 2x2, 2x3, 3x3, 3x4, 4x4, 4x5, 5x5, 5x6 and 6x6 antenna configuration with min 1-dB and maximum SNR 30 dB. The MSE Vs SNR performance of LS & LMMSE channel estimation is demonstrated that, in this pilot patterns model, for 3x4 antenna configuration show better performance with i.e. LS (BER)=0.00002604, LMMSE (BER)=0.00004459 over the other antenna configuration for SNR-20dB.It is found that the performance of system get deteriorate onward 25 dB. So 3-D Pilot Pattern is employed with the larger the number of subcarriers and minimum hardware requirement with pilot overload (50%) that affect in performance (MSE, BER) in channel estimation as it shown in Figure 5.

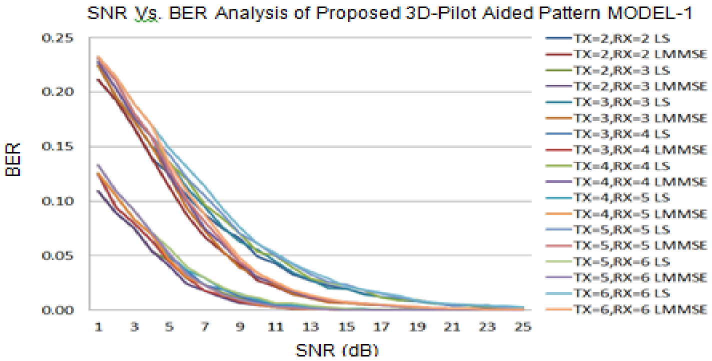

Figure 5. BER analysis of proposed 3-D pilot pattern OFDM model-1 by LS-CE and LMMSE-CE method

4.2. Proposed Strucure-2

In this section, we test the proposed scheme, 3-D Pilot Pattern-2, where the pilot overhead drops from 50% to 37%, whereas the loss of performance is improved in case increasing number of antenna configuration. The MSE performance of LS and LMMSE algorithms as a function of SNR verses BER with different L and N at SNR= 5 dB to 30 dB is presented in figure 6. Experimentally it shows that, MSE of MMSE & LS could be improved in the antenna configuration 4x4 and 4x5, where the result are obtained as LS (BER)=0.0000588, LMMSE (BER)=0.0000104 for 4x5 configuration to get SNR 25dB as against other antenna configuration.

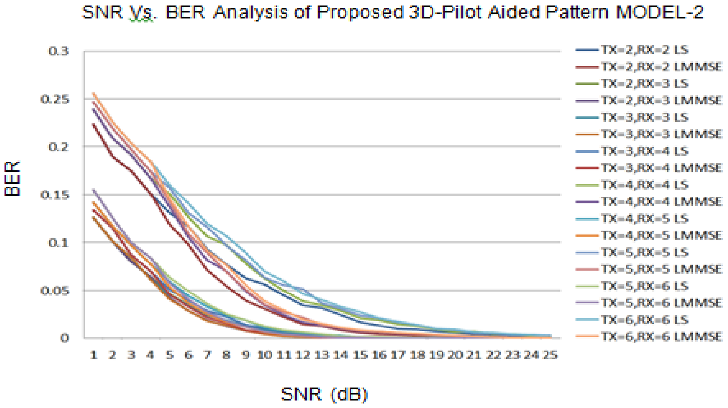

Figure 6. BER analysis of proposed 3-D pilot pattern OFDM model-2 by LS-CE and LMMSE-CE method

4.3. Proposed Strucure-3

Figure 7 shows the MSE performance of LS and LMMSE algorithms versus SNR with different antenna configuration for Proposed 3-D Pilot Pattern OFDM Model-3, as the pilot overhead drops from 50% to 25%, the MSE of LMMSE & LS could be improved with antenna configuration 2x3 where improved results are obtained as LS (BER)=0.000156, LMMSE (BER) =0.000069 for 20 dB SNR.

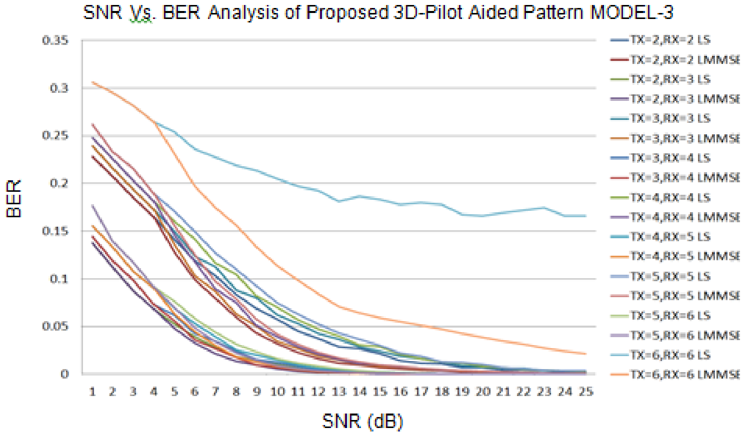

Figure 7. BER analysis of proposed 3-D Pilot pattern OFDM MODEL-3 by LS-CE and LMMSE-CE method

4.4. Proposed Strucure-4

Figure 8 shows the MSE performance of LS and LMMSE algorithms versus SNR for Proposed 3-D Pilot Pattern OFDM Model-4, as the pilot overhead drops from 50% to 21%, the best result could be replicated with antenna configuration 4x5 where improved results are obtained as LMMSE =0.000004 over 25 dB SNR. In this, BER using LMMSE is improved against LS =0.0000245.

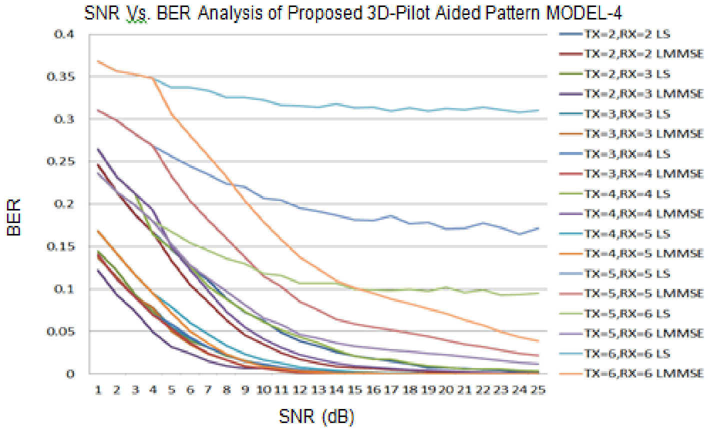

Figure 8. BER analysis of proposed 3-D pilot pattern OFDM model-4 by LS-CE and LMMSE-CE method

4.5. Proposed Strucure-5

The bit error rate (BER) result is presented in Figure 9 for Proposed 3-D Pilot Pattern-5 with 2x2,3x3,4x4, 5x5 and 6x6 antenna configuration with min 1-dB and maximum SNR 30 dB. In this, pilot overhead get minimized to 17%. The BER Vs SNR performance of LS & LMMSE channel estimation is demonstrated that better performance is shown with i.e. LS (BER) =0.0000472, LMMSE (BER)=0.0000651 for antenna configuration 3x4 against other antenna configuration for SNR-25dB.It is found, this pilot provide trade-off between data overload and number of antenna hardware that affect in performance (MSE, BER) in channel estimation as it shown in Figure 9.

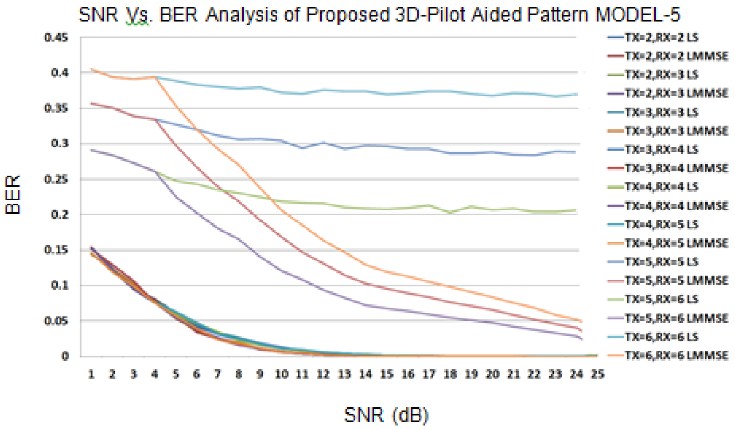

Figure 9. BER analysis of proposed 3-D pilot pattern OFDM model-5 by LS-CE and LMMSE-CE method

Overall summary can be briefed with following result analysis for proposed 3D-Pilot pattern MIMO- OFDM Model.

In this work, we compare all proposed pilot pattern scheme with the DVB-T2 protocol, in our scheme verify trade-off between pilot overhead and system performance, the system overhead drops from 50%to17% with hardware configuration in which the loss of performance is variant around 3dB.Comparisons of channel estimation for different pilot allocation along with support antenna configuration over Rayleigh fading channel is validated and suggested for further research, are illustrated in Table 2.

Table 2. Comparison Table for Pilot Pattern OFDM Model

Proposed 3-D Pilot Scheme	LS Estimation Method (optimum Result)	LMMSE Estimation Method (optimum Result)
Pilot Scheme-1	Antenna Configuration (Tx=3 & Rx=4) with Optimized Result BER (Min=0.00002604 for 20 dB. Max=0.12479 for 1dB)	Antenna Configuration (Tx=3 & Rx=4) support Optimized BER (Min=0.00004459 for 20 dB. Max 0.12479 for 1dB)
Pilot Scheme -2	Antenna Configuration (Tx=3 & Rx=3) with Optimized Result BER (Min=0.0000882 for 20 dB, Max=0.1265 for 1 dB)	Antenna Configuration (Tx=4 & Rx=4) support Optimized BER (Min=0.000057 for 20 dB, Max=0.1265 for 1 dB)
Pilot Scheme -3	Antenna Configuration (Tx=2 & Rx=3) with Optimized Result BER (Min=0.000156 for 20 dB, Max=0.1372 for 1 dB)	Antenna Configuration (Tx=2 & Rx=3) support Optimized BER (Min=0.000069 for 20 dB, Max=0.1372 for 1 dB)
Pilot Scheme -4	Antenna Configuration (Tx=2 & Rx=3) with Optimized Result BER (Min=0.00015 for 20 dB, Max=0.14436 for 1 dB)	Antenna Configuration (Tx=2 & Rx=3) support Optimized BER (Min=0.000015 for 20 dB, Max=0.1218 for 1 dB)
Pilot Scheme -5	Antenna Configuration (Tx=3 & Rx=4) with Optimized Result BER (Min=0.0000472 for 20 dB, Max=0.15116 for 1 dB)	Antenna Configuration (Tx=4 & Rx=4) support Optimized BER (Min=0.0000651 for 20 dB, Max=0.15116 for 1dB)

5. Conclusion

In this paper, simulation results obtained have validated the effectiveness of the proposed 3D-pilot pattern scheme over 2-D OFDM, in which 3D-OFDM system with 2x2, 2x3, 3x3, 3x4, 4x4, 4x5, 5x5, 5x6 and 6x6 antenna configurations over Rayleigh fading channel has been evaluated using SNR versus BER for LS & LMMSE channel estimation.

The multi-dimensional 3D-channel estimation algorithm configures five pilot transmission-reception schemes. From the results obtained, it is clear that as SNR increases, the data rate also increases for 2x3 or 3x4 or 4x5 or 5x6 MIMO antenna configuration for 25 dB in pilot pattern model-1 against the other antenna configuration 2x2, 3x3, 4x4, 5x5, and 6x6 but lag in pilot overhead. Practically, proposed model-5 balanced trade-off between pilots overhead with hardware antenna configuration as 3x4 against other antenna configuration for SNR-20dB in the Rayleigh fading channel environment.

In the simulation, we used 1/2 convolutional code and 16 QAM modulation. Best pilot transmission scheme is determined by the characteristics of 3D-channel estimation algorithm for pilot overhead is 50% in LS & LMMSE. The throughput of the proposed algorithm is optimal and much higher than the 2D-pilot scheme over all existing estimation algorithm. At low SNR, the proposed algorithm (pilot scheme-I) with the equal pilot scheme get higher throughput than 2D-scheme, and as the SNR increasing, the quality of channel estimation is improved and pilot overhead determines throughput of the proposed algorithm is optimal and much higher than the 2D-pilot scheme over all existing estimation algorithm. In future, in order to obtain optimized result in terms of Bit Error Rate as well as for trade off between system performance and pilot overhead, we may go for LS & LMMSE algorithm based hybrid algorithm such as Particle Swarm Optimization (PSO) Algorithm. Using PSO variant meant for solving more sophisticated multimodal problems would produce better results.

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