A Coded MIMO-OFDM System's Performance Comparison of the Spatial Channel Model and the Onering Channel Model Based on Interpolation Techniques

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Abstract

In this paper, we consider to estimate the channel coefficient in the wideband and frequency selective multi-input multi-output orthogonal frequency division multiplexing (MIMO-OFDM) system. The simulation is based on two channel models, one has been proposed by the 3rd Generation Partnership Project (3GPP) standard - the Spatial Channel Model (SCM) and the other is the Onering channel model, under the LTE Advanced standard for 4G in the suburban macro-cell environment. The obtained results show the symbol error rate (SER) value when using different interpolations (Linear, Sinc or Wiener) with the same input parameters. The Space Frequency Block Coding (SFBC) and minimum mean-squared error (MMSE) equalizer are also used for the simulation of the MIMO 2x2 systems. The SER results in the SCM channel model are lower than that obtained by the Onering channel model when employing the different interpolation methods.

Keywords: MIMO-OFDM, Onering channel model, SCM channel model, SFBC, Wiener interpolation, Sinc interpolation, Linear interpolation

1. Introduction

Channel modelling method is used in the wideband channel model to design and optimize the communication systems. In the stochastic channel model, we use the measurement results to simulate to the statistical features from which are reproduced the channel's probability properties. The geometry-based stochastic models (GBSM) and the parametric stochastic models (PSM) are in the group of stochastic channel model [1].

In the GBSM, the assumptions are given that the scatters are arranged in a geometrical form by using the physical principles of reflections, scattering, and diffractions of electromagnetic waves. The scatter's statistical properties are described by the distribution of angle of arrival (AoA) and the angle of departure (AoD). The Onering channel model of GBSM has been shown for wideband and frequency selective channel model in the Fourth Generation Advanced Long Term Evolution (4G- LTE-A) in [2].

In the PSM, the transmission paths which divide into the sub-paths of the paths, the AoA or AoD are narrated by the channel parameters in the measurement. Therefore, there is huge database for simulating those channel models.

Based on the PSM channel model method, the Third Generation Partnership (3GPP) develops the spatial channel model (SCM) [3]. The SCM has been studied for non-line of sight (NLOS) model for suburban macro, urban macro and urban micro cell.

Authors in [4] have compared the spatial correlation properties of both the SCM and the Onering channel model in suburban macro cell. Coding method SFBC which takes advantages of diversity in frequency selective channel transmission scheme and the equalizer MMSE [5] are combined to investigate the performance of the MIMO-OFDMA system in physic and medium access control (MAC) layer.

By reducing the pilot overhead requirements, the interpolation algorithms are applied to the MIMO-OFDM receiver to estimate the coefficient of the channel. The interpolation techniques in [6]–[12] are based on the training sequence estimation or the pilot estimation.

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In this paper, we study the performance of the symbol error rate (SER) when using different interpolation methods (Linear, SI and Wiener) on those channel models in 2×2 MIMO-OFDM system. The channel models are simulated by using the SCM channel model as well as the Onering channel model under the LTE-A standard in NLOS case. We also combine the SFBC and the MMSE detection to improve the effectiveness of the channel estimation.

The structure of this paper is as follows: Section 2 studies the two channel modelling methods of the Onering and SCM channel by the cross-correlation functions. The interpolation techniques for 2×2 MIMO-OFDM system are introduced in section 3 and 4. Section 5 shows the simulation results and discussions. Conclusions are given in Section 6.

2. The wideband and frequency selective Onering and SCM channel modelling methods

Both of the channel models point out the closed form expression the channel impulse responses which depend on the same condition: the delay power function, the number of transmit and receive antennas.

2.1. The Onering channel modelling approach

In [1-2], authors describer the Onering channel models as the scatters are arranged around the mobile station (MS), from which the scatters are assumed to locate on a ring with the radius R as in Fig.1.

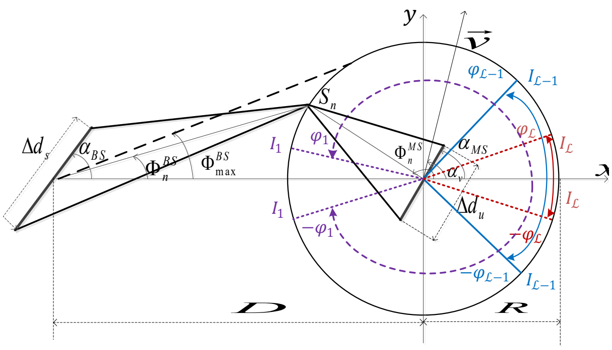

Fig. 1. The scatering Onering model [4]

In the MIMO system with $S\ (s = 1,2,\ldots S)$ transmit antennas and $U\ (u = 1,2,\ldots U)$ receive antennas, d_s and d_u are the distance of base station (BS) and MS antenna elements, respectively, the channel impulse response (CIR) in time domain modelled by the Onering channel method $h_{u,s}^{OR}(\tau,t)$ is given as [1] with the angles α_{BS}, α_{MS} are the angles of the transmit antenna at the BS and of the receive antenna at the MS, respectively.

$$h_{u,s}^{OR}(\tau,t) = \sum_{l=1}^{\mathcal{L}} \frac{c_l}{\sqrt{N_l}} \sum_{n=1}^{N_l} a_{n,s,l} b_{n,u,l}\, e^{j(2\pi f_{n,l}t+\theta_{n,l})} \times \delta(\tau-\tau_l),$$

where:

$$a_{n,s,l} = e^{j\pi(S-2s+1)\frac{d_s}{\lambda}\left[\cos(\alpha_{BS})+\phi_{max}^{BS}\sin(\alpha_{BS})\sin\left(\phi_{n,l}^{MS}\right)\right]},$$

$$b_{n,u,l} = e^{j\pi(U-2u+1)\frac{d_u}{\lambda}\cos\left(\phi_{n,l}^{MS}-\alpha_{MS}\right)},$$

$$f_{n,l} = f_{max}\cos\left(\phi_{n,l}^{MS} - \alpha_v\right). \quad (1)$$

Authors in [4] divide the scatter ring to $\mathcal{L}$ pairs of segments $I_l(l = 1 \ldots . \mathcal{L})$, each pair is considered as a cluster of scatters. The l^{th} pair $(l = 1 \ldots . \mathcal{L})$ consists of N_l scatters, c_l is the attenuation factor of the l^{th} path. The channel transfer function $H_{u,s}^{OR}(f,t)$ is a Fourier transform of $h_{u,s}^{OR}(\tau,t)$ as follows:

$$H_{u,s}^{OR}(f,t) = \sum_{l=1}^{\mathcal{L}} \frac{c_l}{\sqrt{N_l}} \sum_{n=1}^{N_l} a_{n,s,l} b_{n,u,l} \times e^{j[2\pi(f_{n,l}t-\tau_l f)+\theta_{n,l})]}. \quad (2)$$

ϕ_n^{MS} and ϕ_n^{BS} are the arrival and departure angles of the reflection path n, which come from the scatter S_n. ϕ_{max}^{BS} is the maximal departure angle of the transmitting signal. α_v is the angle from the horizontal of the velocity vector of MS.

2.2. The SCM channel modelling approach in NLOS environment

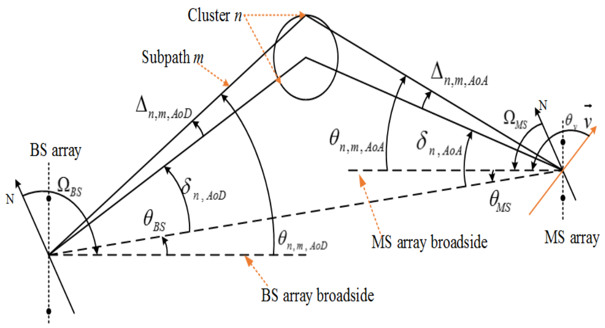

Fig. 2. SCM with one cluster of scatters [3]

The SCM is depicted in Fig.2, there are S element linear BS array and U element linear MS array, the channel impulse respond function is given for the wideband frequency channel as, where τ is the time delay of the channel:

$$h_{u,s,n}^{SCM}(t) = \sqrt{\frac{P_n \sigma_{SF}}{M}} \sum_{m=1}^{M} \left\{ \begin{array}{c} \sqrt{G_{BS}(\theta_{n,m,AoD})}\, exp\left(j\left[kd_s\, sin\left(\theta_{n,m,AoD}\right) + \Phi_{n,m}\right]\right) \\ \times \sqrt{G_{MS}\left(\theta_{n,m,AoA}\right)}\, exp\left(jkd_u\, sin\left(\theta_{n,m,AoA}\right)\right) \\ \times\, exp\left[jk\|v\|\, cos\left(\theta_{n,m,AoA} - \theta_v\right) t\right] \end{array} \right\}. \quad (3)$$

$$h_{u,s,n}^{SCM}(\tau, t) = h_{u,s,n}^{SCM}(t)\delta(\tau - \tau_n)$$

We assumed the lognormal shadow fading and antenna gain of both BS and MS are equal to one. The transfer function H_{usn}^{NLOS} is given as [4]:

$$H_{usn}^{NLOS}(f,t) = \sum_{n=1}^{N} h_{u,s,n}(t) \times \exp(-\mathrm{j}2\pi\tau_n f), \quad (4)$$

Therefore, we have:

$$H_{usn}^{NLOS}(f,t) = \sum_{n=1}^{N} \sqrt{\frac{P_n}{M}} \sum_{m=1}^{M} \left\{ \begin{array}{c} exp\left(j\left[kd_s\, sin\left(\theta_{n,m,AoD}\right) + \Phi_{n,m}\right]\right) \times \\ \exp\left(jkd_u\, \sin\left(\theta_{n,m,AoA}\right)\right) \times \\ \exp\left[jk\|v\|\, \cos\left(\theta_{n,m,AoA} - \theta_v\right)\tau\right] \end{array} \right\} \times \exp(-\mathrm{j}2\pi\tau_n f). \quad (5)$$

whereby, $\theta_{n,m,AoD}$ and $\theta_{n,m,AoA}$ are the AoD and the AoA for the m^{th} sub-path of the n^{th} path; $\Phi_{n,m}$ is the phase of the m^{th} sub-path of the n^{th} path. The SCM method has N paths ($N = 6$), each path has M sub-path ($M = 20$).

3. Cancellation methods for 2×2 MIMO-OFDM system

In this section, the three popular interpolation methods: Linear, Sinc and Wiener interpolation are applied to study the performance of MIMO-OFDM system.

3.1. The Linear Interpolation (LI)

With the assumption of that the interpolation approach is in shift invariant, LI [6]-[9] relies on two consecutive pilot positions in both time and frequency domains.

If the frequency interval of the neighboring pilot subcarrier is L , the index of the non-pilot subcarrier between two adjacent pilots is l, the index of pilot subcarriers is p. The transfer function for non-pilot subcarriers between k^{th} and $(k+1)^{th}$ pilots is described as:

$$\hat{H}(kL + l) = \left(1 - \frac{l}{L}\right)\hat{H}_p(k) + \left(\frac{l}{L}\right)\hat{H}_p(k+1). \quad (6)$$

where $H_p(k)$ is the transfer function of the pilot.

3.2. The Sinc Interpolation (SI)

This method has been introduced in [10]-[11]. With the assumption that $h(n); n = 1, 2 \dots N$ is the channel coefficient in the all of OFDM symbols and $h(k); k = 1, 2 \dots N_{pilot}$ is the channel coefficient in the pilot symbols in the time domain, the closed form expression data symbols bases on pilot positions is as following as in equation (7). The effectiveness of the channel estimation in interpolation methods depends on the L step value as the same as the LI.

$$h(n) = \sum_{n=1}^{N} \sum_{k=1}^{N_{pilot}} h(k) \times \frac{\sin\left(\frac{\pi(n - kL)}{L}\right)}{\frac{\pi(n - kL)}{L}}. \quad (7)$$

3.3. The Wiener Interpolation (WI)

This method has been introduced in [12]. With the assumption that $\hat{H}_{i,l}$ is the channel coefficient at i^{th} OFDM symbol and the l^{th} sub-carrier, $\hat{H}_{i\prime,p}$ is the channel coefficient at the p^{th} sub-carrier and the i'^{th} OFDM symbol that contains the pilot data, the input of Wiener filter is described as:

$$\hat{H}_{i,l} = \sum_{i',p} w_{i',p,i,l}\, \hat{H}_{i',p} \ , \quad (8)$$

Set the matrix coefficient of the filter as:

$$W_{i,l}^{T} = \left(w_{1,1,i,l}, \dots, w_{i',p,i,l}, \dots, w_{(\ell_t - 1)D_t + 1, (\ell_f - 1)D_f + 1, i, l}\right), \quad (9)$$

Therefore, we have :

$$\hat{H}_{i,l} = W_{i,l}^{T}\, \hat{H}_{i\prime,p} \ . \quad (10)$$

where ℓ_t, ℓ_f are the number of OFDM symbols that contain pilots in the time and frequency axis, respectively, $w_{i',p,i,l}$ is the filter coefficients. D_f and D_t are distance of pilots in frequency and time domain, respectively.

4. Description the 2 × 2 MIMO-OFDM system

We consider a 2×2 MIMO system as in Fig.3 with the transmitter and receiver. In the transmitter, signal is modulated by QAM-64, then using SFBC to advantage diversity in space and frequency domain.

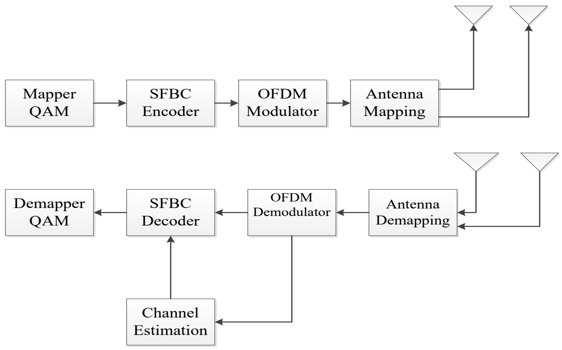

Fig. 3. The 2 × 2 MIMO-OFDM system

The receiver basically do the visa versa of the transmitter but channel estimator is added to increase the system performance by using different interpolation methods. The arrangement of user data, reference signal and zero data in frequency domain obey the rules that on the same i^{th} symbol and the same the k^{th} sub-carrier, the existing reference signal (pilot) in this antenna can be gotten by setting the other to zero and vice versa.

We denote the square matrix F_L with $N_{FFT} \times N_{FFT}$ matrix and the RS can be generated in antenna 1 and 2, respectively as below with N_{FFT} is number of symbol fast fourier transfer:

$$X_{p,1}(k) = e^{-jD_f \pi k^2/N_{FFT}}$$

$$X_{p,2}(k) = e^{-jD_f \pi (k+M)^2/N_{FFT}} \tag{11}$$

$$M = N_{FFT}/D_f$$

The channel coefficients at the pilot possitions is as:

$$H_p(k) = (Q^H Q)^{-1} Q^H Y_r \tag{12}$$

$$Q = \left[diag\left(X_{p,1}(k)\right) \times F_L, diag\left(X_{p,2}(k)\right) \times F_L\right]$$

Table 1. Simualtion parameters for channel modelling methods

Parameters	Value
Bandwidth	5 MHz
Maximum access delay	$\tau_{max} = 2473.96$ ns
Antenna array distance BS	$\Delta d_s = 10\lambda$
Antenna array distance MS	$\Delta d_u = 0.5\lambda$
No of OFDM symbols	11
Number of sub-carrier	300
Length of guard interval (GI)	128
Number of IFFT	512
Frequency sampling	$T_s = 130.21\ ns$

5. Simulation results and discussions

Under the simulated condition of the Vehicle A model C with the speed of $30km/h$ at $2GHz$, the channel is independent in time domain and the channel profile delay is described by LTE-A. The parameters for simulation for channel modelling and the MIMO-OFMD system can be given as in Table 1 with number IFFT is number of symbol inverse fast Fourier transfer. Fig.4 - Fig.9 are the results of the comparing the two channel modelling methods when using Linear, SI and Wiener interpolations, respectively in time domain with the window step L from 2 to 4.

In Fig.4 and Fig.5 the effectiveness of the Linear cancelation methods of the MIMO 2x2 is compared in the Onering and the SCM. The Onering has the SERs higher than the SCM with the same window step of LI are from $L = 2$ to $L = 4$, respectively. With the increasing of step window L, the higher of the SERs, because of the more decrease of the exactitude results.

Fig.6 and Fig.7 are the SERs comparison of SI in two channel modellings. As one can see the SERs of SCM is lower than of the Onering. One can see the smaller of L, the better of the performance's system.

Fig.8 and Fig.9 are the SERs comparison of Wiener interpolation which have the same conclusions as the LI and SI. The SCM has better performance than the Onering with each L and the SERs are lower at the L=2.

Also,we can get the results of each window step L, the SERs of the LI are higher than the SI, the SERs of the WI are lowest of the three interpolation methods. We can see that if the step L is increased the system performance is decreased. In Onering channel model, the SER results are higher than those obtained in the SCM as can be seen in Table 2 in the case of $SNR = 14\ dB$.

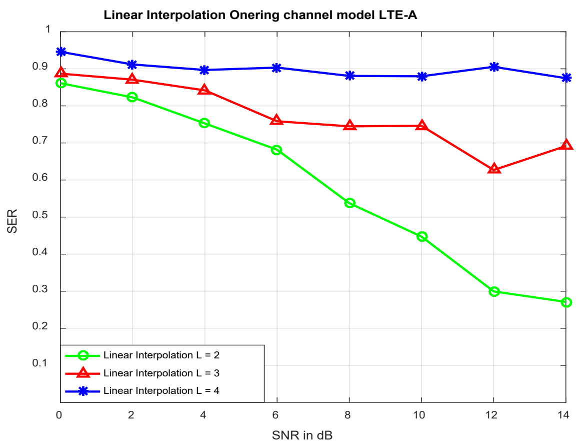

Fig. 4. SER of LI of ORM

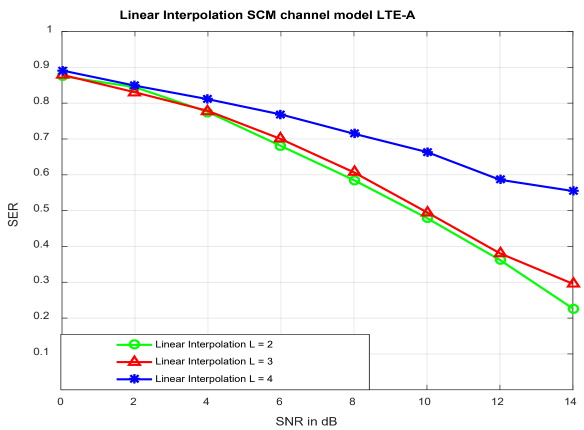

Fig. 5. SER of LI of SCM

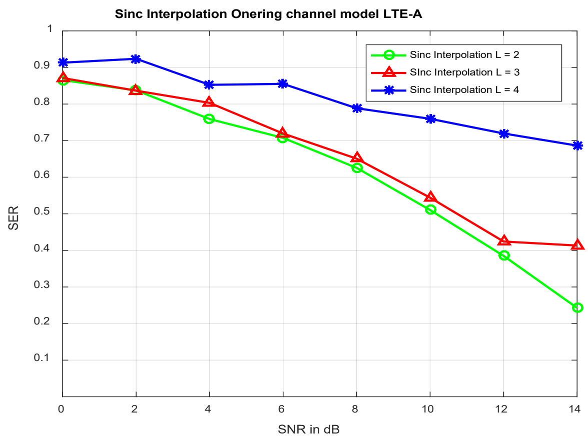

Fig. 6. SER of SI of ORM

Table 2. SERs of interpolation methods, $SNR = 14$ dB when window step $L = 2$ to $L = 4$

SERs	LI			SI			WI		
L	2	3	4	2	3	4	2	3	4
ORM	.28	.7	.89	.24	.41	.69	.18	.19	.22
SCM	.22	.3	.56	.17	.19	.25	.17	.18	.21

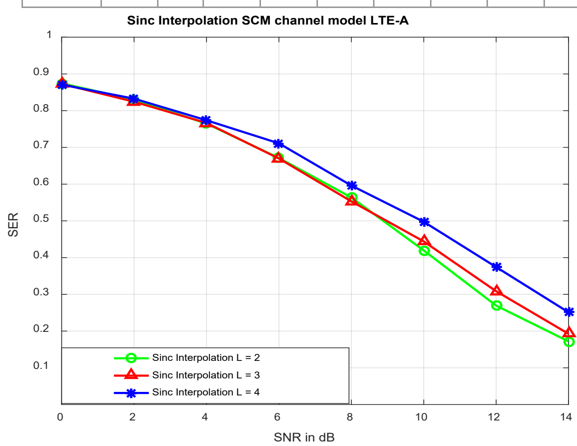

Fig. 7. SER of SI of SCM

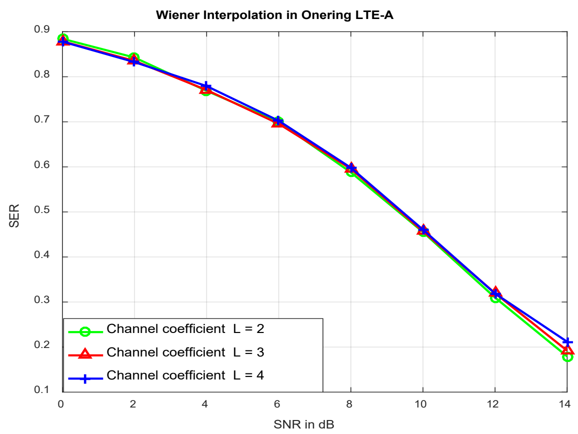

Fig. 8. SER of WI of ORM

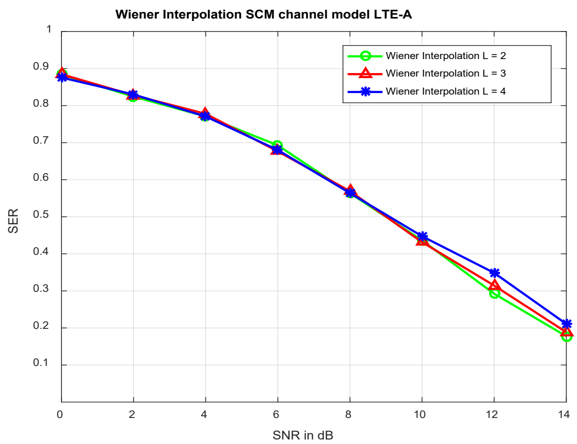

Fig. 9. SER of WI of SCM

6. Conclusions

Our paper studies interpolation methods applied to estimate the channel coefficients of MIMO 2x2 systems in both channel modelling methods: the SCM and the Onering channel model in the suburban macro-cell. From the SER results, of the three interpolation methods, the WI has the best result, the following is the SI in the same above characteristic of the channel. The SER results depend on the pilot positions by the step L in the rule of the higher of the L step, the worse of the performance system can get. As mention above, in the case of NLOS, the system performance of MIMO channel is researched in two channel modelling, the effectiveness of the cancellation methods in the SCM is better than in the Onering channel model.

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