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Channel Estimation for 5g Communications using Conjugate Gradient Total Least Square

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Abstract: We proposed Modified Conjugate Gradient Total Least Square (MCGTLS) method to estimate the 5G Communication system. The proposed MCGTLS will increase the system performance by cancelling the Inter symbol Interference and Inter carrier Interference. Here the interferences are not treated as AWGN. The operation of matrix becomes perplexed, thus obtaining accurate simulation results to validate the performance of MCGTLS method. The obtained Results are compared with theoretical analysis under large different normalized Doppler frequencies with different modulation techniques like QAM and MQPSK.

Key words: Channel Estimation, 5G, OFDM, Conjugate Gradient (CG), Total Least Square, Interference

I. INTRODUCTION

The 'n' number of transmitter and receivers are used in MIMO system to reduce the interference as well as to improve the channel performance of the system by using Minimum mean squared error (MMSE) receivers. Conjugate gradient (CG) method is the correct method for time division duplex (TDD) broadcast multi-antenna to solve the TLS problems for large matrices imple mentation [1]. Joint-MMSE receiver is the new approach for generalized frequency division multiplexi ng to get reasonable bit error rate with compromised on com putational complexity [2&3]. A
TLS based receiver [4] is implemented in visible light comm unication system with Optical FDM to achieve reasonable Computational complexity. In application part the Zero-correlation zone is used in MIMO-OFDM vehicular system for better accuracy [5] and less complexity. The Wahba's problem [6] is widely recognized as a least-square problem in three-axis approach estimation from vector measurements. Errors corrupting both observation and reference vectors can be same as to pseudo errors.

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The MMSE receiver technique [7] faces the high computational complexity problem due to an inversion matrix operation. Least Square method with adaptive pilot can be used to achieve less complexity and to increase performance with high SNR. The proposed MCGTLS method and matrix derivations are taken into account to compare conventional CGTLS to prove the efficiency of proposed system.

II. 5G OFDM CHANNEL MODEL

A.Cyclic Prefix-5G OFDM System

The proposed 5G OFDM channel model shown in Fig(1). The input binary data bits from source are converted from serial to parallel (S/P) converter. Now each user allocates a non-oversampling set of sub-carriers based on their Quality of Service (QoS) for a given channel characteristics. Data streams are modulated by MQPSK. After inserting the pilots, the Inverse Fast Fourier transform (IFFT) will change data bit L{U(x)} to time domain signal u(c) and this can be expressed as

$$u(c) = \mathrm{IFFT}\{U(x)\} \quad (1)$$

$$= 1/L\sum_{x=0}^{L-1} U(x) e^{j2\pi xc/L} \quad . C = 0,1\ldots.L-1 \quad (2)$$

Here L is the number of sub-carriers .After getting U(c), to sustain the orthogonality. Among subcarriers, after adding Cyclic Prefix (CP) in every symbol parallel bits are converted to serial bits. Thus the subsequent OFDM symbol expressed as

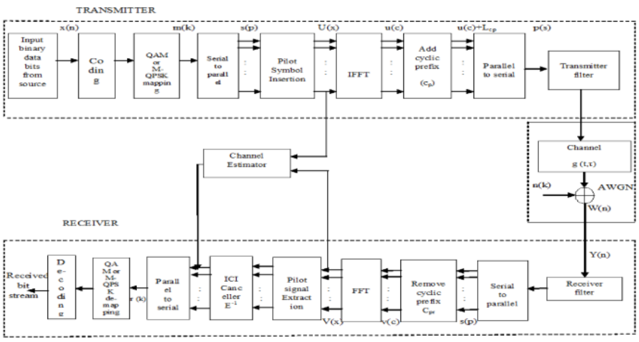

Fig.1 Proposed 5G OFDM system

$$E(i) = \frac{\left(1 - e^{j2\pi f_l(h)}\right)}{\left(1 - e^{j2\pi}\left(i^2 + f_l(h) + e - 13\right)\right)} \quad (3)$$

The received time domain signal suffered from frequency offset and an AWGN this can be written as

$$s(n) = u(c)e^{j2\pi c\varepsilon/L} + w(n) \quad (4)$$

Then the received signals are converted into serial to parallel, and then the cyclic prefixes are removed. We can write the received signal in vector form as

$$\overline{s(n)} = D_i^{\Omega} C_p w^* + \overline{w},$$

(5) where Cp is the Cyclic prefix, w^* is IFFT matrix, D_i^{Ω} is referred as delay-Doppler channel and $\overline{w}$ is the Additive white Gaussian noise, the frequency signal can be

$$V(x) = \sum_{x=0}^{L-1} y_n . e^{-j2\pi cl/L} \quad (6)$$

After adding interference in the system the received symbol V(c) can be

$$V(c) = E_l(k)u(c) + \sum_{d=-l, d\neq l}^{L-1-l} E_d(l)X(l+d) + w(n) \quad (7)$$

Where E_l (k) is gain the channel and E_d (l) is the interference gain.

B. Signal Representation and Channel Estimation for MCGTLS with Polynomial Fitting

Modified CGTLS with polynomial fitting is presented to improve the channel performance of OFDM systems. The received symbol Y can be written as

$$Y_i(k) = x_i(k) + e^{-j2\pi(d-1)n(l)/N}\left(x(d)h(l)R(N-k-d)\right)$$

(8)

where d = 1,2 ,….N; l = 1,2,……..L; k = 1,2,…….N and $x_i(k)$ is the i-th transmitted signal appearing at the k-th subcarrier. Subcarrier can be expressed in matrix form as follows

$$\begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \\ Y_4 \end{bmatrix} = \begin{bmatrix} A_1 & B_1 & C_1^1 ....C_1^Z \\ A_2 & B_2 & C_2^1 ....C_2^Z \\ A_3 & B_3 & C_3^1 ....C_3^Z \\ A_4 & B_4 & C_4^1 ....C_4^z \end{bmatrix} D + \begin{bmatrix} W^1 \\ W^2 \\ W^3 \\ W^4 \end{bmatrix} \quad (9)$$

In which Y_1, Y_2, Y_3 and Y_4 are the received symbols, while D is the polynomial coefficients. Matrices A_1, A_2, A_3, B_1^1, B_2^2, B_3^3, and C_1^z, C_2^z, C_3^z, z = 1,2,…..Z can be raised as follows:

$$A_i(l,k) = X_i(k)e^{-j2\pi(k-1)n(l)/N} \quad (10)$$

where k = 0, 1, ….. N-1;   i=1, 2, 3

$$B_i(l,k) = \sum_{n=0}^{N-1} Xi(n).e^{-j2\pi n(l)/N}\left(-j2\pi(1-w)/N\right)$$

(11)

n = 0,1,….N-1; w = 0,1…..w-1; i = 1,2,3,4,and k = 0, 1, ….. N-1.

C_i (l, k) =

$$\sum_{n=0}^{N-1} Xi(n).e^{-j2\pi n(l)/N}\left(2\pi^2(1-2w/(w-1)/N\right)(1-w)/N)$$

(12)

n = 0,1,….N-1; w = 0,1…..w-1; i = 1,2,3,4 and k = 0, 1, ….. N-1.

D_i (l, k) =

$$\sum_{n=0}^{N-1} Xi(n).e^{-j2\pi n(l)/N}\left(\begin{matrix} j4\pi^3(N^2(1-w)^2 + \\ 3w(N+1+w+Nw))/3/N^3/(1-w)^3 \end{matrix}\right)$$

(13)

By defining a new matrix

$$E_{pq} = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} = \begin{bmatrix} A_1 & B_1^1 & C_1^1 ....C_1^Z \\ A_2 & B_2^1 & C_2^1 ....C_2^Z \\ A_3 & B_3^1 & C_3^1 ....C_3^Z \\ A_4 & B_4^1 & C_4^1 ....C_4^z \end{bmatrix} \quad (14)$$

Here, the coefficients D can be estimated as $[\hat{a}_{0,0} \ldots \hat{a}_{0,N-1}, \hat{a}_{z,0} \ldots$ N-1$]^T$ =

$$(E^H_{pq} E_{pq})^{-1} E^H_{pq} \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} \quad (15)$$

The solution precision depends on the AWGN noise w (n).

C. Modified- Conjugate Gradient Total Least-Squares:

Total least square (TLS) considers disruption of the vector of perceptions 'v' and of the m × n data matrix 'd', the TLS equation optimization problem is,

$$\min_{q,\Delta E,\Delta e} \| [\Delta E, \Delta e] \|_F \quad (16)$$

Subject to the constraint

(d + E)q = Range (v + e)

Where, E is denoted as perturbation matrix, e is denoted as noise. The most of the TLS problem deal with Singular Value Decomposition (SVD). The SVD of a large matrix is very expansive and it needs higher order multiplications.

The conjugate gradient method requires only lower order multiplication per iterations. Therefore the secular equation approach is more preferable than the SVD approach, this low rank approximation can reduce the computational complexity of OFDM system, and it will initially cause attenuation of system performance. Our aim is to use the scheme for large matrices; here we applied conjugate gradient method to reduce complexity of the system.

Let S (t) can be representing the solution at t^{th} iteration. Modified-CGTLS updates S value by using Successive-approximation method.

$$z(b+1) = z(b) + g(b)\, l(b) \quad (17)$$

Where z (b) and l (b) is the direction of iteration and g (b) is chosen to reduce Rayleigh fading. There are two possibilities to yields the Rayleigh fading, first one is

$g(b) = -A + \sqrt{A^2 - 4BC}\,/\,2B$ and another one is $g(b) = -A - \sqrt{A^2 - 4BC}\,/\,2B$,

we are considering smaller value of Rayleigh fading channel that can be written as

$$z(b) = -A + \sqrt{A^2 - 4BC}\,/\,2B \quad (18)$$

Where, $A = \beta(f)\,\eta(f^1) + \beta(f^1)\,\eta(f)$

$B = \eta(f^1)\,\eta(f)$

$C = \beta(f^1)\,\beta(f) - \eta(f^1)\,\alpha(f) - \alpha(f^1)\,\eta(f)$

$D = -(\alpha(f)\,\beta(f^1) + \beta(f)\,\alpha(f^1))$

Then the coefficients are

$A = P_a(k)\,P_c(k) + P_a(k)\,P_c(k)$

$A = 2\,P_a(k)\,P_c(k)$

Similarly $B = 2P_c(k)$

$C = 2\,[P_a(k) - P_c(k)\,P_b(k)]$

$D = -2\,P_a(k)\,P_b(k)$

The above symbols can be written in conjugate form

Symbol A can be written as

$P_a(k) = G_p(k),G_q(k) + G_p(k),G_q(k)$

$= 2G_p(k),G_p(k)$

Similarly, $P_b(k) = G_p(k),G_q(k)$

$P_c(k) = G_p(k),G_q(k) - 2G_p(k),G_q(k)$

$= -G_p(k),G_q(k)$ and

$P_d(k) = -2G_p(k),G_q(k)$

Complex conjugate gradient symbols in matrix from,

$\alpha(f) = [\alpha(h) - C^H M(k) + (1-\eta)\, f_i(n, l)].A(l)$

Where, $f_i(n, l)$ is the initial value of a matrix with n^{th} row and l^{th} column, $C^H M(k)$ is the conjugate gradient of k-th iteration, η is variables, finally α (f) can be constructed as,

$\alpha(f) = [\alpha(h) - \eta^2 [(C^H (\alpha(h^1) / \beta(h^1))]]. A(l)$

$\beta(f) = [\eta\, C^H M(k) + (1-\eta) f_i(n, l)]. B(l)$

Finally conjugate gradient symbol β (f) and η (f) can be written as,

$$\beta(f) = [\eta^2\, [C^H (\alpha(h^1) / \beta(h^1))]]. B(l) \quad (19)$$

$$\eta(f) = [\eta\, [C^H M(k) + (1-\eta) f_i(n, l)]]. C(l)$$

$$\eta(f) = [\eta^2\, [C^H (\alpha(h^1) / \beta(h^1))]]. C(l) \quad (20)$$

$$\theta(f) = \eta\, C^H M(k) + (1-\eta) f_i(n, l)\, D(l) \quad (21)$$

Finally complex conjugate gradient symbol θ(f) can be written as,

$$\theta(f) = [\eta^2\, [C^H (\alpha(h^1) / \beta(h^1))]]. D(l) \quad (22)$$

α(f), β (f), η (f), θ (f) Modified-CGTLS channel estimation coefficients, other search direction initiated as

$$p(b+1) = r(b+1) + \beta(b)\, p(b) \quad (23)$$

q(b+1) = r (b+1) + β (b) q(b), where β (b) is vector, then 'r' can be written as

$r =, \sqrt{p}$, Where, p = [A B C D]

Here the initial value of the vector is set to '0' except last value from estimation channel.

III. RESULTS AND DISCUSSION

Fig.2 illustrates SNR and BER performance of the channel; here number of subcarrier considered as 600, Cyclic Prefix length 64 and high modulation techniques (QAM) considered for evaluating the channel. The simulation result shows the performance of proposed estimation method for Doppler frequency $f_dT = 0.5$, and Fig.3 shows MQPSK channel estimation for $f_dT = 0.1$.

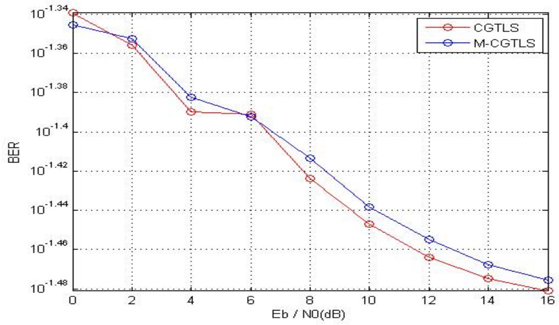

Fig.2. Comparison of channel Estimation with CGTLS and MCGTLS for $f_dT = 0.5$

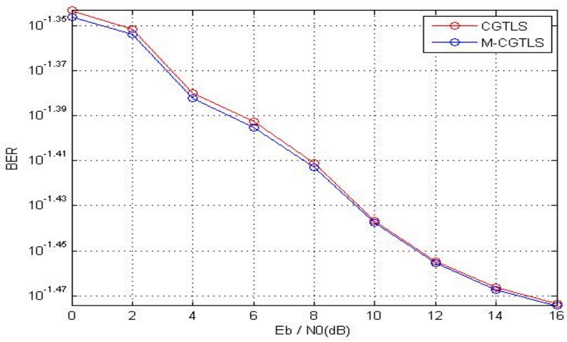

Fig.3. Comparison of channel Estimation with CGTLS and MCGTLS for $f_dT = 0.1$

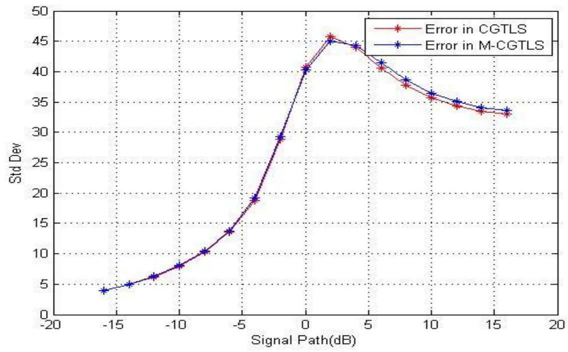

Fig.4 Comparison of Error Calculation with CGTLS and MCGTLS for $f_d T = 0.5$

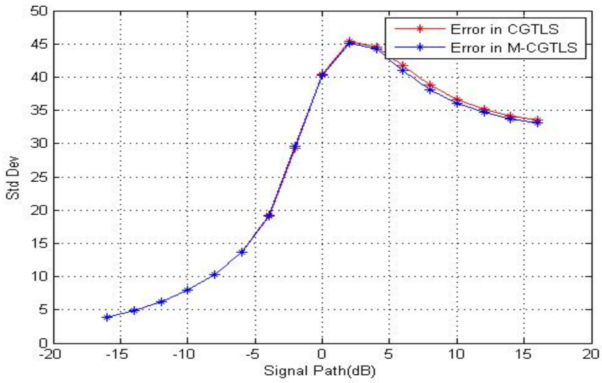

Fig.5. Comparison of Error Calculation with CGTLS and MCGTLS for $f_d T = 0.1$

Error is estimated by signal path and standard deviation of the channel. Fig.4 &Fig. 5 shows the error calculation of OFDM system and this proposed method can reach outstanding result for a high Doppler frequency value. Fig.6 & 7 illustrate the performance evaluation of channel with actual value for different Doppler frequency.

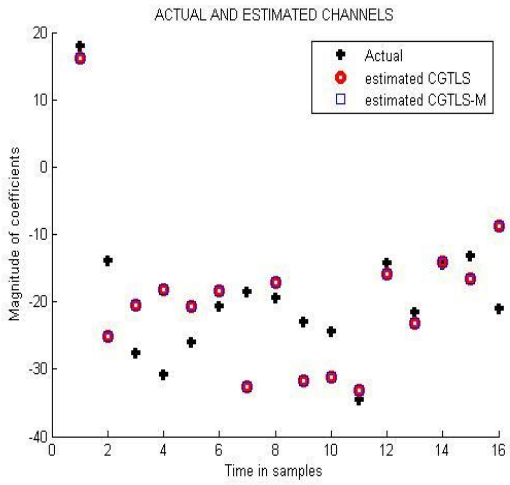

Fig.6 Comparison of channel Estimation with actual value for $f_d T = 0.1$

IV. CONCLUSION

Inter symbol Interference and Inter carrier Interference are cancelled and the presented method uses the MCGTLS receiver with polynomial fitting to improve the channel estimation for 5G OFDM system. Proposed method achieves less computational complexity when compare with conventional method for different Doppler frequency. The results are compared with
theoretical analysis and achieved good performance.

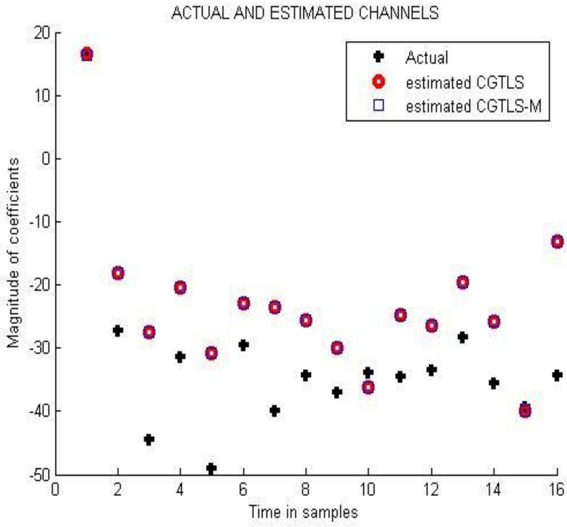

Fig.7 Comparison of channel Estimation with actual value for $f_d T = 0.5$

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