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WIRELESS OFDM SYSTEM TRANSMISSION CHANNEL MODEL PARAMETER DETECTION

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Abstract:
Using pilot sub-carrier time-frequency phase correlation statistical detection and QAM signal de-mapping decision error statistics, a transmission channel modelling parameter detection scheme, suitable for frequency domain pilot wireless OFDM systems is proposed, including the maximum multipath delay of the channel, Maximum Doppler frequency and signal-to-noise ratio detection. It can effectively solve the traditional OFDM channel estimation algorithm usually designed according to the worst channel condition upper limit, and the channel prior information statistical calculation complexity in the optimal channel estimator based on MMSE criterion. The shortcomings of the simulation results show that the approximate statistical information of the current transmission channel model parameters can be effectively obtained under low complexity conditions.

Keywords: OFDM, Channel Estimation; Multipath Delay, SNR, Doppler Frequency

I. Introduction

A wireless OFDM receiver with excellent performance must be built on the basis of strong adaptation to the transmission channel, which is particularly important for the channel estimator: the traditional channel estimation design first considers the reliability of the system link, usually according to the worst The design of channel conditions will cause the loss of system performance due to channel mismatch errors; and with the improvement of communication transmission quality requirements, the new generation of OFDM systems must have an estimator based on the channel state, which can adaptively select the best Algorithms and parameters, which must be based on good channel information detection. At the same time, multi-user wireless link adaptive modulation, as a powerful technology to improve transmission efficiency under fading channels, has now received more and more attention: if the transmitter can know the current channel conditions, it can adjust the modulation parameters automatically. To adapt to the optimization adjustment, the Shannon capacity of the channel can be obtained [1]. Based on the above two application methods, a transmission channel modeling parameter detection scheme suitable for frequency domain pilot wireless OFDM communication systems is proposed, including maximum multipath delay, maximum Doppler frequency offset and transmission signal-to-noise ratio detection.

II. System Model

In order to facilitate the analysis of the algorithm expression, define the wireless OFDM system digital baseband transmission model [2]: if the i^{th} OFDM symbol subcarrier consists of N QAM symbols $\{X(i,k), 0 \le k \le N-1\}, i \in (-\infty, \infty)$ is the time sequence number of the OFDM symbol, and k is the sub-carrier sequence number within the symbol, assuming that the sub-carrier signals are independent and identically distributed. After IFFT transform and insert G guard interval samples, there are

$$x(i,n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(i,k) e^{j2\pi nk/N}, -G \le n \le N-1 \quad (1)$$

After the transmitter radio frequency modulation, the antenna transmits a continuous signal $x(t)$. Assuming that the continuous form of the impulse response of the wireless fading channel is $h(\tau, t)$, and the complex gain of the multipath is $h_m(t)$, the continuous radio frequency signal received by the receiver antenna can be expressed as

$$y(t) = \sum_m h_m(t) x(t - \tau_m) + n(t) \quad (2)$$

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After OFDM symbol timing synchronization, after removing the guard interval, the frequency domain form of the demodulated data can be obtained through FFT transformation.

$Y(i,k) = H(i,k)X(i,k) + N(i,k), 0 \leq k \leq N-1$(3)

Among them, $N(i,k)$ is Gaussian noise, and $H(i,k)$ is the channel transfer function. It changes dynamically in the two-dimensional time-frequency direction. Different sub-carriers will face different channel characteristics. The influence of fading can be attributed to the fading of the amplitude of each subcarrier and the rotation of the phase. If there is an estimation error σ_{HN}^2 with a variance of $N^H(i,k)$ in the channel estimation, the channel response estimate $\widehat{H}(i,k)$ can be approximately expressed as

$\widehat{H}(i,k) = H(i,k) + N^H(i,k)$(4)

After channel equalization, the estimated value of $X(i,k)$ can be obtained. The last term in equation (4) can be regarded as the noise component introduced by non-ideal channel estimation

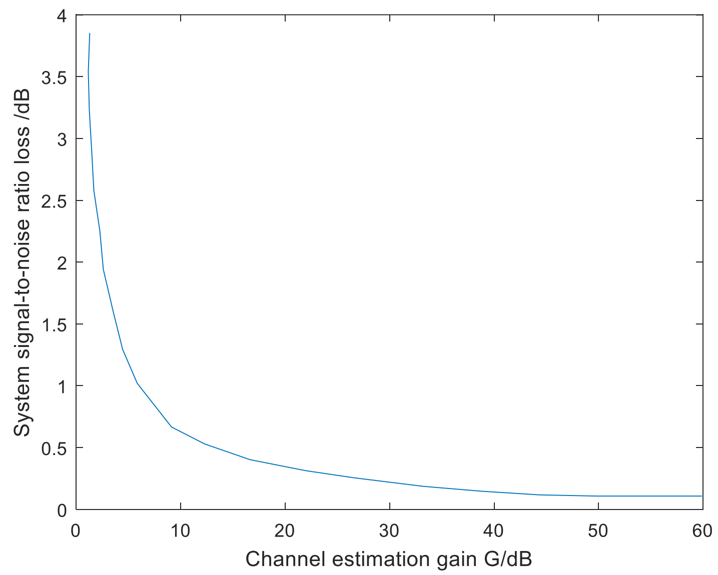

Fig 1: SNR loss of non-ideal channel estimation in OFDM system

$\hat{X}(i,k) = \frac{H(i,k)X(i,k)+N(i,k)}{\widehat{H}(i,k)} = X(i,k) + \frac{N(i,k)}{H(i,k)} + \frac{X(i,k)}{H(i,k)} N^H(i,k)$ (5)

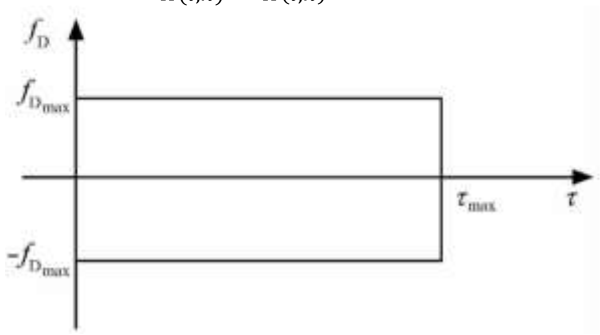

Fig 2: Channel Doppler-Delay Spread Function

Wireless OFDM systems usually use frequency-domain interpolation pilots for channel estimation, and the channel response of the data sub-carrier position can be obtained by interpolating the channel responses of adjacent pilots. Among them, Wiener filter [3] is the optimal linear filter under the minimum mean square error MMSE criterion [4]

$\widehat{H}(i,k) = \sum_{(i',k')\in P} w_{i',k'}^{i,k} \widehat{H}_p(i',k')$ (6)

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where, $\widehat{H}_p(i',k')$ is the channel response estimation of the pilot position. However, the Wiener algorithm is extremely complex, and the filter coefficients $w_{i',k'}^{i,k}$ need to know prior statistical information such as channel correlation matrix and noise variance. In order to simplify processing in implementation, several sets of filters with fixed coefficients are usually constructed according to the possible correlation in the time-frequency direction of the channel. The receiver selects a set of best filter coefficients to complete the interpolation according to the current channel characteristics. Computing resources. However, the traditional channel estimation first considers the security of the system link, and it is often designed according to the worst channel conditions, which will lead to system performance loss due to non-matching with the channel. Assuming OFDM signal average energy E_s, noise unilateral power spectral density N_0, define the gain factor

$$G = \frac{N_0}{E_s'\sigma_{HN}^2} \quad (7)$$

where, $E_s' = \frac{E_s N}{N+G}$ takes into account the part of the signal energy loss brought by the guard interval. The gain factor represents the proportional relationship between the channel estimation error and the channel noise, that is, the channel estimation accuracy. Under ideal synchronization conditions, from equation (5), it can be seen that the equalizer output signal-to-noise ratio is

$$S = \frac{E_s'}{(N_0+E_s'\sigma_{HN}^2)} = \frac{E_s'}{N_0(1+1/G)} \quad (8)$$

Then the signal-to-noise ratio loss caused by the non-ideal channel estimation algorithm is

$$\Delta S(dB) = 10\log(1+1/G) \quad (9)$$

It can be seen that the performance loss of the OFDM receiver caused by the equalizer is completely determined by the channel estimation performance, and the Gain factor is related to the complexity of the channel estimation algorithm used. Figure 1 shows this nonlinear relationship, which shows the signal noise that the receiver can tolerate the specific performance loss is very demanding for channel estimation performance. Therefore, channel estimation with good performance must be based on strong adaptation to the transmission channel, and the selection of the interpolation estimation filter coefficients is expected to be closely integrated with the approximate statistical information of the current transmission channel modelling parameters.

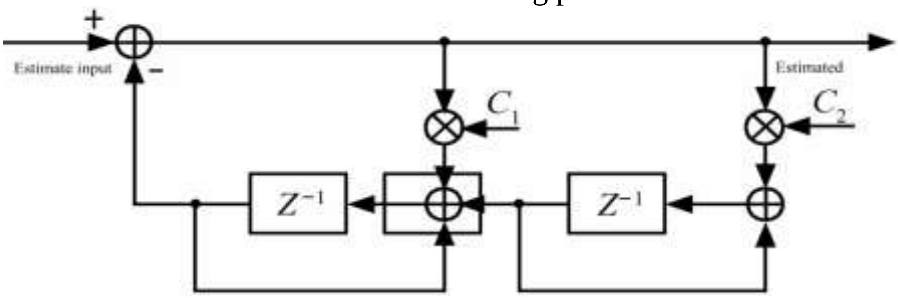

Fig 3: Channel correlation statistical filter adjustment model

III. Discussion on channel characteristics

The generalized stationary uncorrelated scattering WSSUS channel model [5] is recognized as the simplest random process that can represent the delay spread and Doppler spread. Suppose the channel impulse response is $h(\tau,t)$, where t represents the electromagnetic wave propagation time, t represents the electromagnetic wave space propagation time delay, and

$$h(\tau,t) = \frac{1}{\sqrt{M}}\sum_{n=1}^{M} e^{j(\theta_n+2\pi f_{D_n}t-2\pi f\tau_n)} \quad (10)$$

where, $M, \theta_n, f_{D_n}, \tau_n$ respectively represent the number of multipaths, the phase of the nth multipath, Doppler frequency and time delay. The corresponding channel frequency response is

$$R_{HH}(\Delta f;\Delta t)=E\left\{\frac{1}{M}\sum_{m,m'=1}^{M}e^{j(\theta_m-\theta_{m'})}e^{j2\pi(f_{D,m}t-f_{D,m'}(t+\Delta t))}e^{-j2\pi(f\tau_m-(f-\Delta f)\tau_{m'})}\right\} \quad (11)$$

The time difference-frequency difference autocorrelation function of the WSSUS channel can be defined as

$$R_{HH}(\Delta f;\Delta t)=E\{e^{j2\pi f_{D,m}\Delta t}\}E\{e^{-j2\pi\Delta f\tau_m}\}=R_f(\Delta f)R_t(\Delta t) \quad (12)$$

Since each variable in equation (12) is independent, the time-frequency statistical characteristics can be separated

$$S(\tau,f_D)=\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}H(f,t)e^{j2\pi f}e^{-j2\pi f_D t}\,df\,dt \quad (13)$$

It can be seen that the channel time direction correlation is only uniquely related to the Doppler spectrum; while the channel frequency direction correlation is only uniquely related to the multipath delay spectrum, but the specific probability distribution density functions of channel parameters are not known in advance.

IV. Channel modeling parameter detection algorithm

4.1.Maximum multipath delay detection

The channel multipath time extension is consistent with the channel frequency response amplitude change: under short delay conditions, the channel frequency response amplitude changes slowly, and the correlation bandwidth is wide; while under long delay conditions, the channel response amplitude The changes are dramatic and the correlation bandwidth is narrow. Therefore, the fluctuation range of the adjacent pilot sub-carrier amplitude can be used to approximate the frequency correlation of the channel

$$R_{\Delta f}(N_f)=\left\{\sum_{k=0}^{N_p-2}\left\|\hat{X}_p(i,k)-\hat{X}_p(i,k+1)\right\|/\sum_{k=0}^{N_p-2}\left|\hat{X}_p(i,k)\right|\right\} \quad (14)$$

where, $\hat{X}_p(i,k)$ is the estimated value of the transmission data of the pilot subcarrier position, the denominator is the pilot subcarrier signal power, and the numerator is the accumulation of the power difference of the pilot subcarrier positions corresponding to the adjacent OFDM symbols; where the symbol $\{.\}_i$ represents the average of multiple OFDM symbols in the time direction. It can be seen that the more severe the amplitude change of the channel frequency response, the greater the current channel multipath maximum delay, the greater the statistical value of equation (14).

4.2.Maximum Doppler frequency detection

The time-direction cross-correlation function of the WSSUS channel after separation is defined as

$$R_{\Delta t}(\Delta i)=J_0\left[2\pi f_{D_{max}}\Delta i T_s\right] \quad (15)$$

Among them, Δi is the OFDM symbol sequence number interval, and T_s is the effective duration of the symbol. According to the first kind of m-order modified Bessel function definition

$$J_m(x)=\frac{1}{2\pi}\int_{-\pi}^{\pi}e^{jx\sin\theta}e^{-jm\theta}d\theta \quad (16)$$

From mathematical knowledge, it can be known that the Bessel function $j_m(x)$ has the maximum value at position $x=0$, and there is the first zero-crossing point at position 2.405 x [6]. Let $l=\Delta i$, the maximum Doppler frequency estimation can be simplified to the process of finding the time cross-correlation function $R_{\Delta t}(\Delta i)$ the first zero crossing $\hat{l}_0$ position,

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$f_{D_{max}} = \frac{2.405}{(2\pi \hat{l}_0 T_s)}$ (17)

The performance of the algorithm is independent of channel Gaussian noise, but if only one pilot subcarrier signal is used for correlation calculation, the statistical time will be relatively long and it will be easily affected by co-channel interference CCI. Two improvements are made to it: First, make the estimation based on the parallel averaging of more pilot sub-carriers to reduce the statistical time; second, make filtering adjustments to the estimation results in the time direction. Define the time cross-correlation function statistics as

$$\hat{R}_{\Delta t}(|l|) = \frac{1}{N_r - |l|} \sum_{i=0}^{N_r-1-|l|} \left[\frac{1}{N_p} \sum_{k=0}^{N_p-1} \quad \right] \text{(18)}$$

Among them, N_r is the number of symbols used in related statistics. The estimation steps of the channel maximum Doppler frequency are as follows:

1. Calculate from $l = 0$, search equation (19) to get the value of $\hat{l}$ when the first negative value is obtained.
2. Use the value of $\hat{l}$ obtained in step 1) and its previous value to determine the value of the first zero-crossing point $\hat{l}_0$ through interpolation.
3. Substitute the value of $\hat{l}_0$ into equation (18) to calculate the maximum Doppler frequency of the current channel.
4. Due to the influence factors such as Gaussian noise and ICI interference in the actual OFDM receiver, the correlation estimation fluctuates greatly, and the estimated value should be further adjusted to make it slowly change around a DC value. Then give the filter adjustment model shown in Figure 3, the transfer function is

$$H(Z) = \left(c_2 \times \frac{Z^{-1}}{1-Z^{-1}} + c_1\right) \times \frac{Z^{-1}}{1-Z^{-1}} \qquad \text{(19)}$$

Among them, the filter coefficients c_1 and c_2 can be determined by the sampling frequency of the OFDM system and the required IIR filter attenuation factor.

4.3.Transmission signal-to-noise ratio detection

Ove Edfors proposed a simplified linear LMMSE algorithm [7], which obtains the signal-to-noise ratio estimation through the low-order approximation of single value decomposition SVD. Although matrix inversion calculation is avoided, the complexity of matrix decomposition operation is still very high. The detection algorithm given below is based on the QAM demapping hard decision error statistics. According to equation (5), if the channel estimation value is close to the true channel response, the following approximation holds at the pilot subcarrier position

$\hat{X}_p(i,k) = X_p(i,k) + N_p(i,k)/\hat{H}_p(i,k)$ (20)

Transform the above formula

$$\frac{\hat{H}_p(i,k)}{N_p(i,k)} = \frac{1}{(\hat{X}_p(i,k) - X_p(i,k))} \qquad \text{(21)}$$

According to the definition of signal-to-noise ratio, the statistics of the signal-to-noise ratio at the k-th pilot subcarrier position is

$$S_k = \hat{H}_k^2 / N_0 \qquad \text{(22)}$$

Observing the above two equations, we can see that if equation (22) is averaged in the time-frequency direction, the signal-to-noise ratio of the current transmission channel can be estimated

$$E_{SNR} = 10 \log\left(\frac{1}{N_p} \sum_p \left\{\frac{1}{D_p(i,k)}\right\}_i\right) \qquad \text{(23)}$$

where, $\{\ \}_i$ represents the average of OFDM symbols in the time direction, and the decision credibility measurement distance D_p is defined as

$$D_p(i,k) = \left|\hat{X}_p(i,k) - S_p(i,k)\right|^2 \qquad (24)$$

Among them, $S_p(i,k)$ is the position of the constellation point obtained by making a hard decision on $\hat{X}_p(i,k)$, and its physical meaning is: the OFDM pilot subcarrier data is between a pair of values before and after the hard decision Euclidean distance.

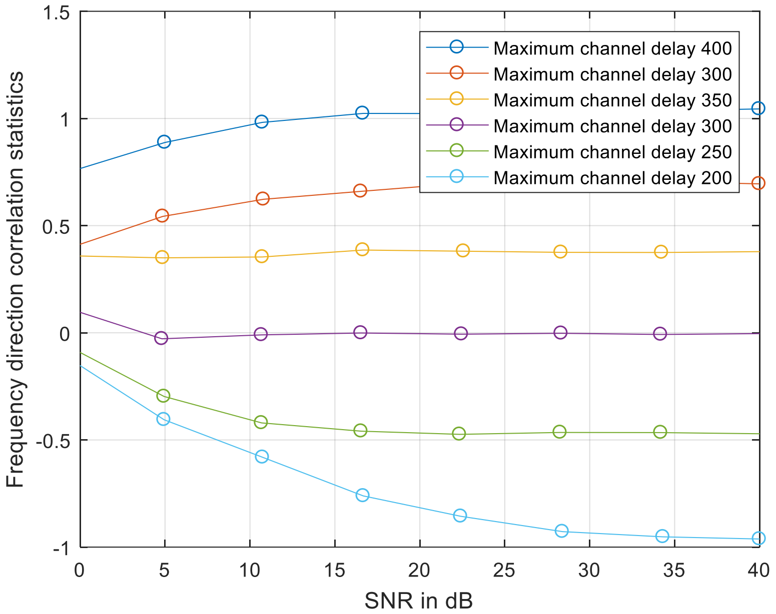

Fig 4: Simulation of Frequency Correlation Estimation between Channel Carriers

V. Algorithm simulation and performance analysis

In order to investigate the performance of the algorithm, the European ETS 300 744 standard 2k mode OFDM system [8] is used for simulation analysis and verification. Figure 4 shows the estimated value of the channel frequency direction correlation function under the condition that the 0dB two-path channel spacing is 0, 50, 100, 150, 200, and 300 time sampling points. Simulation conditions: N=2048, 1/4 guard interval; channel selection is the worst 0dB constant-amplitude two-path channel model for OFDM transmission, and the maximum Doppler frequency is 50Hz. It can be seen that the statistical function of equation (15) is related to both multipath delay and signal-to-noise ratio: the larger the multipath delay, the greater the estimated value, that is, the smaller the frequency correlation; and as the signal-to-noise ratio increases, the estimated value The sensitivity to changes in the signal-to-noise ratio also gradually decreases. According to the step nature of the estimation result interval, the pre-stored look-up table method can be used as the basis for selecting the interpolation filter coefficients. Figure 5 shows the estimated Doppler frequency output by the phase adjustment model when the maximum Doppler frequency is 50, 100, and 150 Hz respectively. The number of OFDM symbols used for statistical average N is 2,000. Simulation conditions: QPSK modulation, 1/4 protection interval; Rayleigh fading channel [8], SNR 20dB, filter adjustment model coefficients are set to: $c_1 = 0.25, c_2 = 0.0625$.

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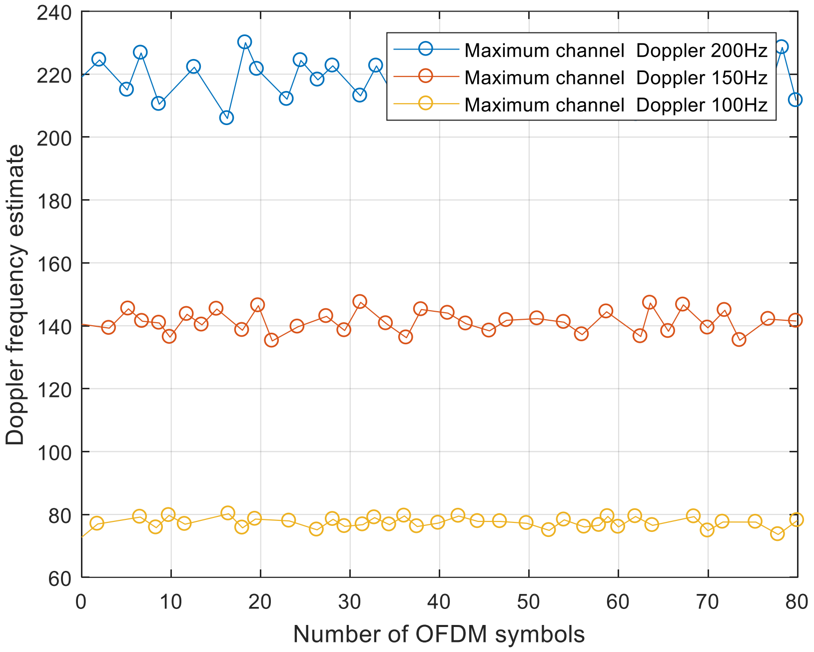

Fig 5: Channel maximum Doppler frequency estimation simulation

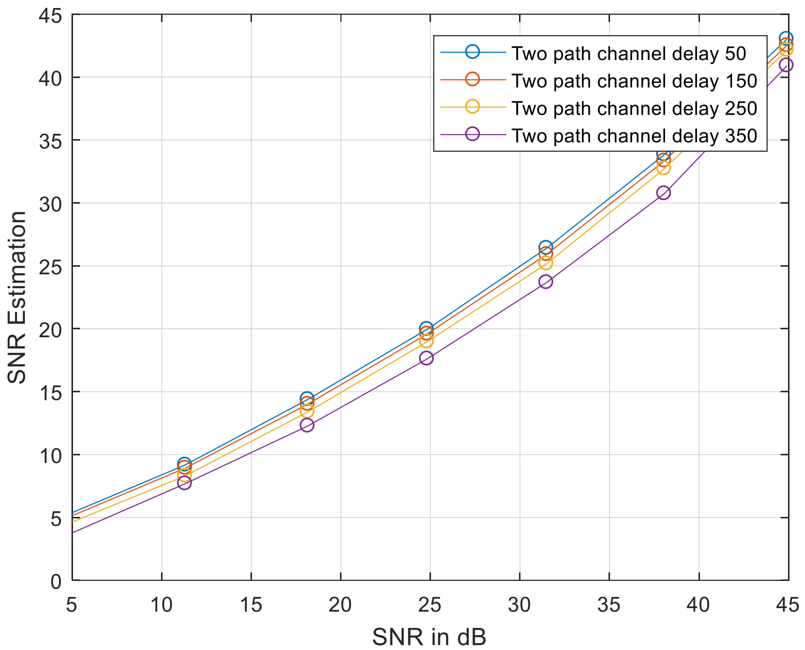

Fig 6: Simulation of Estimation of SNR of OFDM System Transmission

It can be seen that after a large number of symbol pilot correlation statistics and filter model adjustments, the estimated value more accurately reflects the maximum Doppler frequency shift of the current channel; and the smaller the Doppler frequency, the more accurate the corresponding estimated value. Figure 6 shows the estimated value of the signal-to-noise ratio function under the conditions of 0dB two-path channel spacing: 0, 100, 200, and 300 sampling points. The number of symbols used for statistical averaging is 200. The other simulation conditions are the same。 In Figure 4, it can be seen that the estimated value is not sensitive to multipath delay. The difference between it and the actual value is mainly due to the guard interval power and time-frequency domain transformation. Once the guard interval is determined, the relationship between the two is basically maintained.

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VI. Conclusion

In the actual wireless communication OFDM receiver, if the design according to the worst channel condition upper limit will bring about the loss of receiver performance and the complexity of channel prior information statistics restricts the application of Wiener filtering, the proposed channel model the chemical parameter detection scheme effectively solves this defect. This scheme is adopted in the BDB-T transmission standard prototype of the national digital high-definition television group (HDTV TEEG). Through selective statistical detection of pilot sub-carriers in time and frequency directions, dynamic tracking The changing characteristics of the current transmission channel, adaptive selection of the current receiver's optimal algorithm and parameters, under low complexity conditions, can effectively reduce the mismatch error between the channel estimation model and the transmission channel; the algorithm is also suitable for multi-user OFDM Wireless link adaptive modulation system.

References:

[1] Goldsmith, Andrea J., and Pravin P. Varaiya. "Capacity of fading channels with channel side information." *IEEE transactions on information theory* 43.6 (1997): 1986-1992.
[2] Speth, Michael, et al. "Optimum receiver design for wireless broad-band systems using OFDM. I." *IEEE Transactions on communications* 47.11 (1999): 1668-1677.
[3] Moon, Jae Kyoung, and Song In Choi. "Performance of channel estimation methods for OFDM systems in a multipath fading channels." *IEEE Transactions on Consumer Electronics* 46.1 (2000): 161-170.
[4] Sanzi, Frieder, and Joachim Speidel. "An adaptive two-dimensional channel estimator for wireless OFDM with application to mobile DVB-T." *IEEE transactions on broadcasting* 46.2 (2000): 128-133.
[5] Hoeher, Peter. "A statistical discrete-time model for the WSSUS multipath channel." *IEEE Transactions on vehicular technology* 41.4 (1992): 461-468.
[6] Haykin, Simon S. *Digital communications*. New York: Wiley, 1988.
[7] Edfors, Ove, et al. "OFDM channel estimation by singular value decomposition." *IEEE Transactions on communications* 46.7 (1998): 931-939.
[8] ETSI Normalization Committee. "Digital broadcasting systems for television, sound and data services; framing structure, channel coding and modulation for digital terrestrial television." *Norme ETSI, Sophia-Antipolis, France, Doc. pr ETS* 300 (1996): 744.