A new algorithm for location parameter estimation in DTV ground broadcast network

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Abstract. In the city, terrestrial digital TV network is the most perfect TV network, so the location of terrestrial broadcast signal based on digital TV has become one of the research hotspots in recent years. Because multi-path in DTV wireless channel will cause serious signal fading, it becomes more difficult to detect DTV signal in the process of positioning, which directly affects the accuracy of positioning. Therefore, how to improve the detection accuracy of DTV signal through parameter estimation has become the focus of this paper. Based on the detailed study of DTV system based on wireless transmission channel characteristics and system structure, through the analysis based on linear least square (LS) channel estimation algorithm, the advantages and disadvantages of interference elimination is given based on the data, a new method of channel estimation, the simulation results verify the algorithm presented in this paper can well improve the channel estimation performance.

1. Introduction

In general, channel estimation algorithms can be divided into two categories, one is blind estimation algorithm, the other is based on training sequence (pilot) estimation algorithm. Because dvB-T system inserts training sequences (either in the frequency domain or in the time domain) into the transmitted signal, this paper does not discuss the channel blind estimation algorithm, but only studies the channel estimation algorithm based on pilot training sequence[1]. Based on the introduction and analysis of the existing channel transmission coefficient estimation algorithms of DVB-T system, a channel estimation method is proposed combining with the characteristics of PN frame header of DVB-T system[2].

The channel estimation algorithm based on time domain training sequence usually follows the following ideas: firstly, the channel time domain impulse response (CIR) is obtained by using the known time domain training sequence, and then the CIR is used to process the response (such as interpolation, time-frequency domain transformation, etc.) to recover all the channel response. The matrix inverse estimation algorithm based on linear least squares (LS) is a typical channel estimation algorithm based on time domain training sequence and DVB-T system. LS algorithm and its improved algorithm depends on mathematical principles and the advantages of simple structure, usually on the high signal-to-noise ratio in channel is able to have a better estimation precision, and because the $P_t$ belong to the known data, the rest of the operation is completed after multiplication and the attached is an addition operation, channel interpolation is also very convenient, only need to fill zero in hand line frequency domain transformation[3]. The disadvantage of this algorithm is that the protection interval length is at least twice as long as the longest multipath delay, the frequency band utilization rate is low, and the accuracy of this algorithm is greatly compromised in the case of low SNR because the
influence of noise is not considered. At the same time, the estimation accuracy of LS and its improved algorithm will also be affected when the mutual interference between the received data of frame body data and PN frame header data is relatively large[4].

2. New channel estimation method based on data interference elimination

Due to receive data in the work of the LS algorithm and its improved algorithm in the frame body and head of PN frame data between the problem of mutual interference, this paper presents a channel estimation method based on data interference elimination, is the core of the algorithm to improve the data through the analysis of the frame body is derived with the frame header data interference, on the basis of mathematical expressions, find out the data noise reduction method, Thus a more accurate estimate of the channel is obtained.

After transmission through wireless communication multipath channel, the frame structure of data signal received by DVB-T receiver is shown in Figure 1.

![Figure 1. Structure diagram of data frames received by the system.](image)

As shown in the figure above, it is assumed that the current frame is \( n \), the longest multipath delay of the channel is \( L \) symbols, and the length of PN frame header sequence is \( Ng \) symbols, where \( LN_g \leq \). If the initial position of each frame is calculated according to the \( \hat{h}(0) \) of the first multipath position estimated by the channel after signal frame synchronization, the \( \hat{h}(i), (i = 1, 2, \ldots, L - 1) \) of other \( L - 1 \) multipath positions is backward diameter relative to \( \hat{h}(0) \). It can be seen from Figure 1. Because of the influence of the multipath channel, the first \( n \) frame data frame body part before \( L - 1 \) numerical data by this frame PN frame head part of the delay signal interference, as shown in Figure 1 of part B, and the frame body data after \( L - 1 \) numerical signal delay is mixed with the next frame of PN frame data section head of \( L - 1 \) numerical position before, This is shown in Part C of Figure 1. Data of similar with the frame body, the first \( n \) frame frame body PN data before \( L - 1 \) numerical data received on A frame of data frame body part of the delay signal interference, as shown in Figure 1 in part A, and PN frame header data after \( L - 1 \) numerical signal delay is mixed with the data frame body part of this frame before \( L - 1 \) numerical position, as shown in Figure 1 in part B. Data of similar with the frame body, the first \( n \) frame frame head PN data before \( L - 1 \) numerical data received on A frame of data frame body part of the delay signal interference, as shown in Figure 1 in part A, and PN frame header data after \( L - 1 \) numerical signal delay is mixed with the data frame body part of this frame before \( L - 1 \) numerical position, as shown in Figure 1 in part B. Therefore, in order to obtain accurate frame body data and PN frame head data for channel estimation operation, it is necessary to reconstruct the frame body data part and frame head data part of signal frame, so as to eliminate the interference of part A, B and C data to the frame body and PN frame head data.

First, eliminate the interference of frame volume data in DVB-T. According to the structural characteristics of received data frame in Figure 1, if the influence of noise is not taken into account, the first \( L - 1 \) values of the \( y_d(l)^{(n)} \) part of frame body data in frame \( n \) can be expressed by the following formula:

\[
y_d(l)^{(n)} = \sum_{i=0}^{L-1} h(i)^{(n)} d(l-i)^{(n)} + \sum_{i=1}^{L-1} h(i)^{(n)} PN_{N_g-1+i}^{(n)}
\]

Where, \( l = 0, 1, \ldots, L-2, d(k)^{(n)} (k = 1, 2, \ldots, 1705) \), The number of valid data subcarriers in 2K mode is 1750) is
the \( n \) frame frame body at the sender to send data. According to the structure in figure 1, it is obvious that:

\[
B = \sum_{i=1}^{L-1} h(i)^{(n)} PN_{N_{N-1}-1}^{(n)}
\]

(2)

The first \( L-1 \) numerical signals of \( y_{PN}(l)^{(n+1)} \) in the immediate PN frame header data of frame \( n+1 \) can be expressed as follows:

\[
y_{PN}(l)^{(n+1)} = \sum_{i=0}^{L-1} h(i)^{(n+1)} d(1705-i+l+1)^{(n)}
\]

Where, \( l = 0,1,\ldots,L-2 \), from the structure of figure 1, it is clear that:

\[
C = \sum_{i=1}^{L} h(i)^{(n+1)} d(1705-i+l+1)^{(n)}
\]

(4)

make

\[
D = \sum_{i=0}^{L} h(i)^{(n+1)} PN_{N_{N-1}}^{(n+1)}
\]

(5)

If the interval channel of two adjacent frames is regarded as quasi-static, \( h(i)^{(n)} \approx h(i)^{(n+1)} \) can be obtained. In this way, if \( h(i)^{(n)} \) is known, \( PN_{N_{N-1}}^{(n)} \) is also known, and \( PN_{N_{N-1}}^{(n+1)} \) is also known, B and D can be obtained by the convolution sum of formula and formula. The C part can be calculated according to the formula, and its expression is as follows:

\[
C = \sum_{i=1}^{L} h(i)^{(n+1)} d(1705-i+l+1)^{(n)} = y_{PN}(l)^{(n+1)} - D
\]

(6)

\[
y_{PN}(l)^{(n+1)} \approx y_{PN}(l)^{(n+1)} - \sum_{i=0}^{L} h(i)^{(n)} PN_{N_{N-1}}^{(n+1)}
\]

Where, \( l = 0,1,\ldots,L-2 \).

In this way, after the above calculation, frame body data \( y_{c}(l)^{(n)} \) of frame 1705 point \( n \) after interference removal can be reconstructed at the receiving end, and its expression is as follows:

When \( l = 0,1,\ldots,L-2 \):

\[
y_{c}(l)^{(n)} = y_{d}(l)^{(n)} = y_{PN}(l)^{(n+1)} - B + C
\]

(7)

\[
y_{d}(l)^{(n)} = y_{d}(l)^{(n)} - \sum_{i=1}^{L} h(i)^{(n)} PN_{N_{N-1}+1}^{(n)} + y_{PN}(l)^{(n+1)} - \sum_{i=0}^{L} h(i)^{(n+1)} PN_{N_{N-1}+1}
\]

When \( l = L-1,L,\ldots,1705-1 \):

\[
y_{c}(l)^{(n)} = y_{d}(l)^{(n)}
\]

(8)

In this way, after obtaining the reconstructed frame body data, perform FFT transformation on it and signal recovery can be carried out through the following formula:

\[
\hat{X}(n,k) = \frac{Y(n,k)}{\hat{H}(n,k)} = \frac{FFT_{1705} [y_{c}(l)^{(n)}]}{FFT_{1705} [\hat{h}(n,l)]}
\]

(9)

Where, \( \hat{h}(n,l) \) is the estimated time-domain impulse response of the channel, and \( \hat{H}(n,k) \) is the estimated channel frequency domain response of the \( k \) confident channel of frame \( n \).

Now, the interference elimination and data reconstruction of PN frame header data are considered. The method is similar to frame body data reconstruction, and the influence of noise is also not considered. The first \( L-1 \) value of \( y_{PN}(l)^{(n)} \) part of PN frame header data in \( n \) frame is expressed as:

\[
y_{c}(l)^{(n)} = \sum_{i=0}^{L} h(i)^{(n)} PN_{N_{N-1}+1}^{(n)} d(1705-i+l+1)^{(n+1)}
\]

(10)
Where, $l = 0, 1, \cdots, L - 2$, according to the structure in figure 1, there are
\[
A = \sum_{i=1}^{L} h(i)^{(n)} d(1705 - i + l + 1)^{(n-1)}
\]
(11)
is the interference term, and can be obtained from equation and:
\[
B = \sum_{i=1}^{L} h(i)^{(n)} PN_{N_g-i+l+1}^{(n)} = y_d(l)^{(n)} - \sum_{i=0}^{l} h(i)^{(n)} d(l - i)^{(n)}
\]
(12)
Where, $l = 0, 1, \cdots, L - 2$.

In this way, the $n$ frame PN frame header data $y_{pnc}(l)^{(n)}$ after interference removal can be reconstructed at the receiving end, and its expression is as follows:
When $l = 0, 1, \cdots, L - 2$ :
\[
y_{pnc}(l)^{(n)} = y_{PN}(l)^{(n)} - A = y_{PN}(l)^{(n)} - \sum_{i=1}^{L} h(i)^{(n)} d(1705 - i + l + 1)^{(n-1)}
\]
(13)
When $l = L - 1, L, \cdots, N_g$ :
\[
y_{pnc}(l)^{(n)} = y_{pnc}(l)^{(n)}
\]
(14)

As can be seen from the formula, $d(1705 - i + l + 1)^{(n-1)}$ is the data of the previous frame and can be considered as known. Since it is the object requiring solution, $HN$ is unknown due to $y_{pnc}(l)^{(n)}$. However, if the interval channel of the two adjacent frames is still assumed to be quasi-static, $h(i)^{(n)} \approx h(i)^{(n-1)}$ can be approximated, that is, it can be replaced by the estimated channel value obtained in the previous frame. Thus, the PN frame header data can be obtained by eliminating the interference of frame data. It can be seen that the new channel estimation method based on data interference elimination sacrifices the data processing time of a frame in exchange for the elimination of data interference between frame body and frame head, so as to obtain more accurate received data after interference elimination for the estimation operation of various channel estimation algorithms. It can be regarded as an improvement based on PN cycle correlation algorithm. The quasi-static state of the channel between the two adjacent frames is the theoretical basis of the algorithm.

Through the above analysis, specific algorithm implementation steps of the new channel estimation method based on data interference elimination can be obtained as follows:
(1) At $T=0$, $h(i)^{(0)}$ was obtained by PN cycle correlation estimation algorithm, and $d(1705 - i + l + 1)^{(0)}$ was obtained by data balancing.
(2) At $T=1$, $h(i)^{(1)}$ was obtained by PN cycle correlation estimation algorithm, and $d(1705 - i + l + 1)^{(1)}$ was obtained by data balancing.
(3) At $T=2$, $h(i)^{(2)} \approx h(i)^{(1)}$, the data obtained in step (2) are used to substitute $d(1705 - i + l + 1)^{(1)}$ and $h(i)^{(1)}$ into the equation to calculate $y_{pnc}(l)^{(2)}$ after interference elimination, and on this basis, the new $h(i)^{(2)}$ is obtained by using PN cycle correlation estimation algorithm, then $h(i)^{(2)}$ at this time is the estimated value at $T=2$. Let $h(i)^{(3)} = h(i)^{(2)}$, obtain $y_{c}(l)^{(2)}$ after eliminating the interference of PN frame header data before and after the equation, obtain frequency domain data after the equation is balanced, and perform IFFT operation on the balanced data to obtain the latest $d(1705 - i + l + 1)^{(2)}$, which will be used in the next iterative operation.
(4) At $T = 3, 4, \cdots$. Update iteration repeats the work of step (3) until it stops.
3. Performance analysis of channel estimation algorithm

The mean square error (MSE) of channel estimation is one of the important measures of channel estimation algorithm performance. MSE can be expressed as:

\[ MSE = \frac{1}{N} \sum_{k=0}^{N-1} \left[ H(k) - \hat{H}(k) \right]^* \left[ H(k) - \hat{H}(k) \right] \]  

Equation (15)

Where, \( N \) represents the length of the impact response \( H(k) \) in the frequency domain of the desired channel, \( \hat{H}(k) \) is the estimated value of \( H(k) \), and \( [\cdot]^* \) represents taking conjugate.

Simulation parameter selection: 2k mode, \( N=2048 \) subcarrier, signal 16QAM modulation, PN420 frame header mode as the time domain frame header. Channel parameters are multipath channel parameters as shown in Table 1 and China 8 multipath channel parameters as shown in Table 2.

| \( i \) | \( \rho(dB) \) | \( \tau(us) \) |
|---|---|---|
| 1 | -10.71 | 1.002 |
| 2 | -24.32 | 5.421 |
| 3 | -10.60 | 0.519 |
| 4 | -8.91 | 2.750 |
| 5 | -9.33 | 0.152 |
| 6 | -17.61 | 3.325 |

Table 1. Parameters of DVB-T multipath channel

| \( i \) | \( \rho(dB) \) | \( \tau(us) \) |
|---|---|---|
| 1 | -18.0 | 0.00 |
| 2 | 0.0 | 1.81 |
| 3 | -20.0 | 1.94 |
| 4 | -20.0 | 3.62 |
| 5 | -10.0 | 7.51 |
| 6 | -0.0 | 31.82 |

Table 2. China 8 channel parameters

By the figure 2 shows, in DVB-T multipath channel, in the low SNR region, PN cyclic correlation method and the method MSE performance are slightly better than that of the LS algorithm, with the improvement of input SNR, LS gradually improved algorithm shows a better performance, while the other two algorithms performance difference is not big, but in these two kinds of algorithm of the method with good performance. The reason why the performance of the proposed method is not significantly different from that of PN cycle correlation method in figure 2 is that in dvB-T multipath channel, the maximum delay of multipath does not exceed the cycle protection interval of PN frame head, so a complete PN cycle sequence still exists to obtain better channel estimation performance. This reason is well verified in the curve obtained by simulation based on China 8 channel parameters (figure 3).

Figure 2. MSE comparison of DVB-T channel estimation algorithms

Figure 3. MSE comparison of China 8 channel calculation methods
As can be seen from figure 3, compared with the improved LS algorithm and PN cyclic correlation method, the MSE performance of the proposed method is significantly improved. This is because the maximum delay of multipath under the parameters of China 8 channel is large, which damages the protection interval of PN frame header cyclic data and the integrity of frame body data. As a result, the MSE performance of the IMPROVED LS algorithm and the PN cycle correlation estimation algorithm deteriorates. As for the improved method presented in this paper, the interference elimination of received data (including PN frame header and frame body data) is added on the basis of the PN cyclic correlation channel estimation method, so that the improved data after interference elimination can be used for channel estimation, thus improving the channel estimation performance.

4. Conclusion

Based on DVB-T channel transmission coefficient estimation (i.e., channel estimation) algorithm, namely the LS and its improved algorithm and PN of limit cycle related to channel estimation algorithm, through the derivation of multipath signals and the data frame body frame head frame head interference specific mathematical expressions, this paper proposes a channel estimation method based on data interference elimination. The simulation and verification results of DVB-T channel estimation show that this algorithm can improve the performance of channel estimation.

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