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Analysis of Channel Equalization Techniques of ATSC Main and Mobile Transmission System

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Abstract

After introducing digital HDTVs, smart consumers now require new DTV services. ATSC has adapted 3DTV standard which is ATSC SC-MMH (Service Compatible 3DTV using Main and Mobile Hybrid delivery), and the 3DTV standard uses the ATSC M/H transmission system. Even though an 8-VSB frame has only 0.8% training sequence, an ATSC M/H frame has about 3.9% training sequence when the number of group is 8. So the longer training sequence of ATSC M/H can be used to improve the performance of channel equalization technique. This paper uses LMS-based channel equalization techniques, and compares the equalization performance of ATSC M/H transmission system with ATSC 8-VSB system. By the benefit of longer training sequence of ATSC M/H, the equalizer works well in Ricean channel of K = 0 dB.

Keywords: *SC-MMH, ATSC M/H, LMS-DFE, Channel Equalizer*

1. Introduction

With the advent of digital technology, manufacturing industries of 3D contents and display techniques have been widely researched and developed. Through the efforts of these studies, many tools and devices rendering the 3D contents have been developed in the world. Moreover, smart consumers now require the realistic services such as augmented reality, 3D movie and 3DTV broadcast services. So the interest in providing these services has increased, and standardization of 3D services is now progressing. According to this trend, ATSC (Advanced Television System Committee) has also adapted 3DTV standard entitled "3DTV terrestrial broadcasting" on August 2014 [1].

Part 5 of the standard contains SC-MMH to provide 3DTV broadcasting techniques. The SC-MMH describes that service multiplex and transport system comply with A/53 Part 3 and A/153 Part 3 [2, 3]. By using A/53 transport system and A/153 transport system, 3D contents can be transmitted via two data stream paths. Two data streams are then transmitted in a ATSC M/H transmission system which can provide the main DTV service and the mobile service.

Generally, 3D contents consist of left view and right view. The SC-MMH indicates that the left view can be transmitted by ATSC main service and the right view can be transmitted by ATSC mobile service. This transmission method not only guarantees the backward compatibility, but can also launch the new 3DTV service. Considering that two signals are transmitted in the same channel, frequency spectrum can be used efficiently.

If 3DTV service using SC-MMH is launched, 3DTV and DTV will be broadcasted simultaneously. Considering that ATSC M/H transmission system uses longer and more training sequence than ATSC 8-VSB system, reception performance of the ATSC M/H system is better than that of ATSC 8-VSB system.

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In this paper, we experimented with the performance of conventional system and 3DTV terrestrial broadcasting system. This paper is organized as follows. Section 2 compares ATSC 8-VSB data frame and ATSC M/H frame structure. An equalizer was designed for evaluation of two systems in Section 3. Simulation results are presented in Section 4, which is followed by the conclusion in Section 5.

2. ATSC 8-VSB Data Frame and ATSC M/H Frame

2.1. ATSC 8-VSB Data Frame

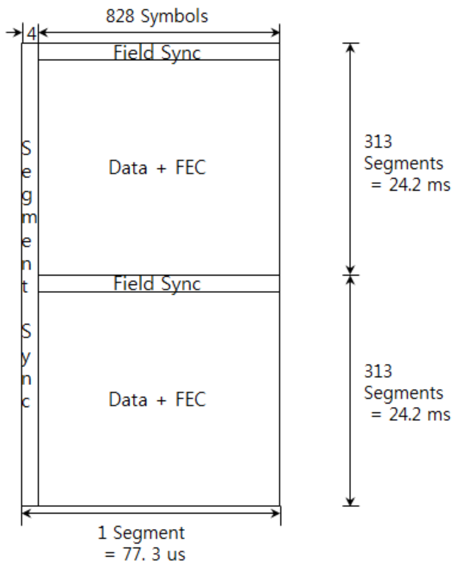

Figure 1. 8-VSB Data Drame

Figure 1 shows ATSC 8-VSB data frame structure [4]. The frame consists of segment sync, field sync, data, and FEC (Forward Error Correction). Data and FEC are the unknown data, so the receiver can't estimate the channel. On the other hand, segment sync and field sync are the known data, so the receiver can estimate the channel to obtain the information of echoes. The echo information consists of amplitude, phase, and delay time.

To estimate the channel precisely, length of known data is very important. The known data for channel equalization is field syncs and segment syncs. The field sync is indicated repeatedly every 24.2 msec and the field sync including the segment sync has 832 symbols. One symbol time is approximately 93 nsec, so the field sync time duration is 77.3 μsec. However, considering that the segment sync has only 4 symbols and the segment sync time duration is 0.372 μsec, the segment sync is too short to be used in an equalizer. So, the channel equalizer can use only field sync data for channel estimation. The rate of training sequence is approximately 0.8 %.

2.2. ATSC M/H Frame Structure

ATSC M/H standard defines the M/H frame structure in order to transmit main and mobile data in the same channel. ATSC M/H frame consists of main TS packets and mobile packets. Main packets and mobile packets of ATSC M/H frame are mixed in a same channel. And the frame structure of M/H data and that of 8-VSB data are very similar to ensure backward compatibility. ATSC M/H frame structure is shown in Figure 2 [5].

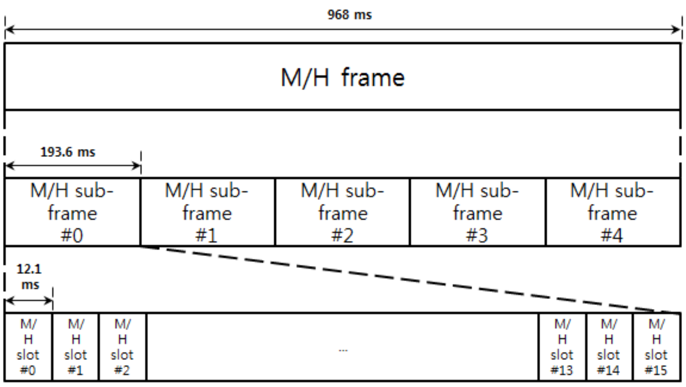

Figure 2. ATSC M/H Frame Structure

An M/H frame consists of 5 consecutive M/H sub-frames, *i.e.* sub-frame 0, 1, 2, 3, 4, respectively. And each M/H sub-frame consists of 16 consecutive M/H slots, i.e. slot 0, 1, 2, …, 15, respectively. Each slot consists of 156 TS packets or equivalently 156 data segments, or equivalently one half of a VSB data field.

The M/H slot is the basic time period for multiplexing of M/H data and main data. M/H data is formatted as an M/H group of 118 consecutive mobile packets which encapsulates the M/H service data. If an M/H group is transmitted during an M/H slot, then the first 118 TS packets in the M/H slot are an M/H group, and the remaining 38 packets are main packets. If there is no M/H group in an M/H slot, the M/H slot consists of 156 main packets. Therefore a particular M/H slot may contain M/H data or may consist of only main data.

Only M/H slots containing M/H groups have the training sequence defined by ATSC M/H. There are two types of ATSC M/H training sequence such as train A and train B. train A has 1424 symbols, and train B has 1060 symbols. So, the time duration of train A is 132.3 μsec and that of train B is 98.6 μsec. ATSC M/H training sequences have the longer time duration than field sync defined by 8-VSB, so the equalizer can converge due to the longer training sequence. Location of each training sequence in M/H slot is shown in Figure 3.

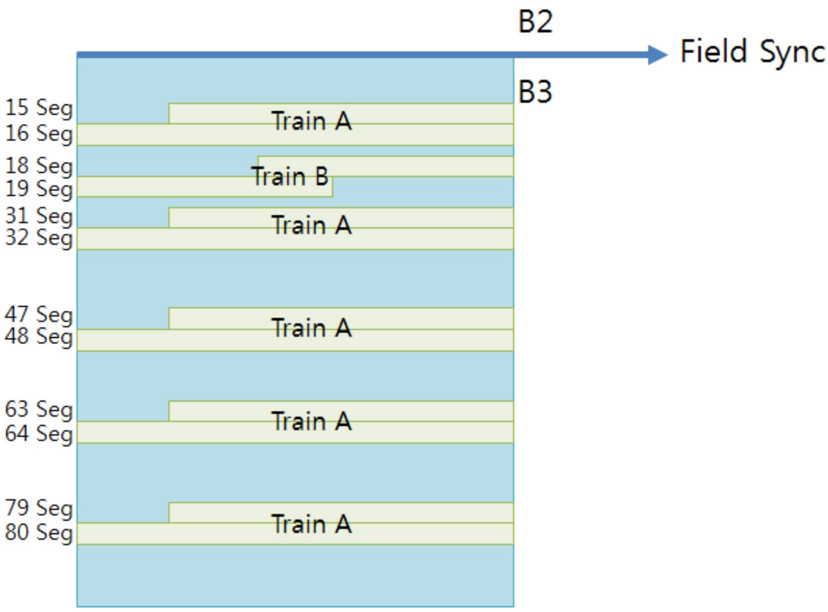

Figure 3. Location of Each Training Sequence in M/H Slot after Interleaving

2.3. Comparison of ATSC 8-VSB Data Frame and M/H Frame

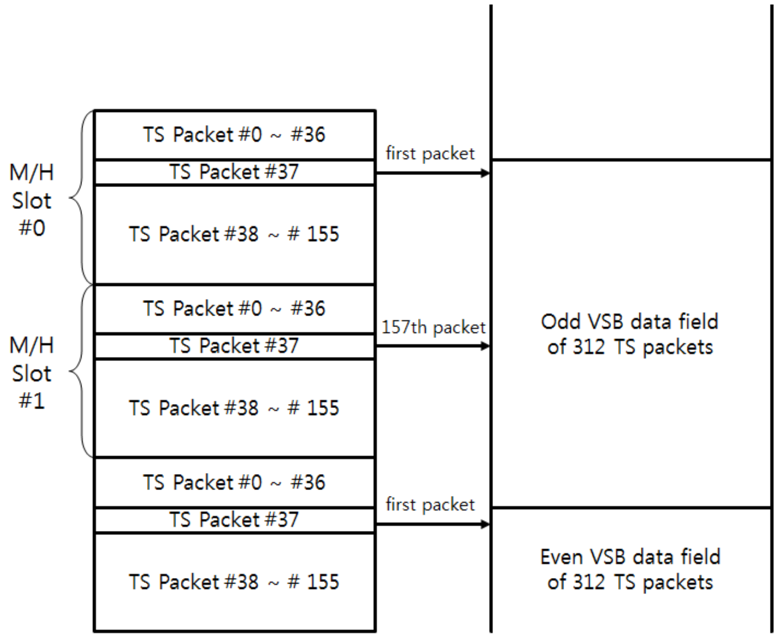

Figure 4. M/H Slot Position with Respect to a VSB Data Frame

Figure 4 shows the relation between ATSC 8-VSB data frame and M/H frame. Odd VSB data field contains packets from TS packet #37 of M/H slot #0 to TS packet #36 of M/H slot #2. And even the VSB data field contains packets in a same way.

In this paper, we assume that the number of M/H parade, which means a collection of M/H groups having the same M/H FEC parameters, is one and NoG (Number of M/H Group) is 8. In this case, training sequence data is approximately 3.9%. The training sequence pattern is shown in Figure 5.

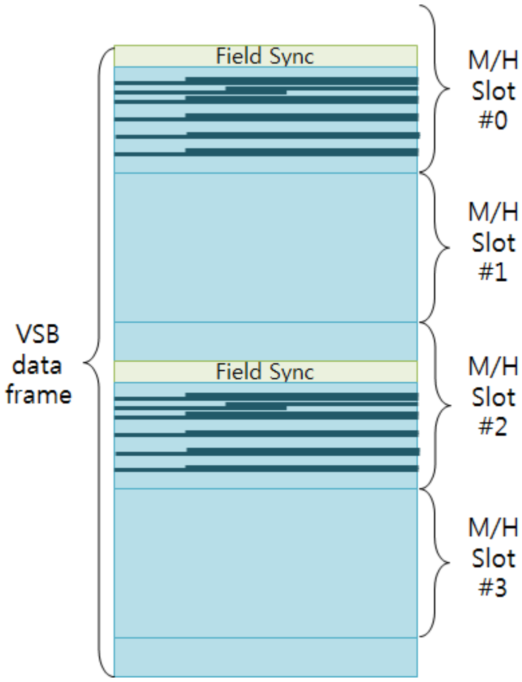

Figure 5. ATSC M/H Frame Represented in 8-VSB Frame

3. Channel Equalizer

The channel equalizer compensates the channel distortion due to multipaths. Generally, the equalizer uses MMSE (Minimizing the Mean Square Error) algorithm. So, in this paper, we use the equalizer based on LMS (Least Mean Square) algorithm. The equalizer consists of a channel estimator, an adaptive feedforward filter, an adaptive feedback filter, a filter coefficient update algorithm, a decision device, and error signal generators, as shown in Figure 6.

A correlation method is used as a channel estimation technique. We can get the channel transfer function by cross-correlation between the received signal and the training sequence. The received signal is expressed that,

$$\mathrm{y[n]} = \sum_{k=-N_a}^{N_c} h_k x[n-k] + v[n] \tag{1}$$

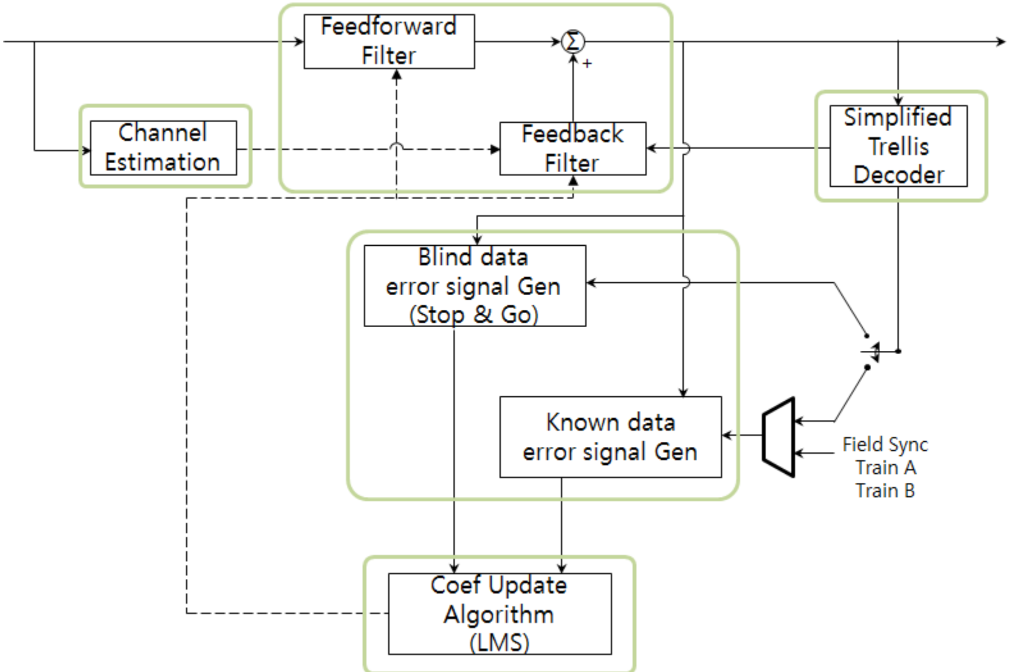

Figure 6. Block Diagram of Equalizer

$y[n]$ is the received signal, h_k is the channel coefficient, $x[n]$ is the message signal, $v[n]$ is the noise, N_c is the maximum delay time of post-echo, and N_a is the maximum delay time of pre-echo. The channel estimation using the correlation method is given as,

$$h_k = E\{\, y[n]a[n+k]\}/E\{a[m]a[m]\} \tag{2}$$

where $a[m]$ is training sequence.

It is simply implemented, but 2 kinds of noises can occur. One is data-dependent noise. It occurs because the autocorrelation of the training sequence is not a perfect delta function. The other is data-independent noise due to channel noise or inter-symbol-interference. These noises are observed at Figure 7 (a). These correlation noises can be reduced by an adaptive threshold algorithm [6] and we use the threshold value of 0.1. So these noises are removed like Figure 7 (b). But, if the amplitude of echo is less than 0.1, the echo is neglected. Therefore, the channel estimation method still needs continuous study for improvement.

Initial coefficients of adaptive feedback filter are loaded by inverse values of the channel estimator. Also, the channel estimation can be used to observe the degree of channel change.

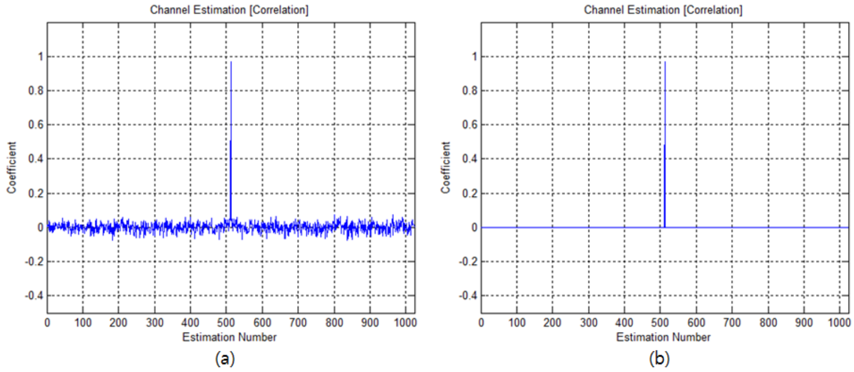

Figure 7. Channel Estimation Using the Correlation Method

The structure of the adaptive filter is decision feedback equalizer (DFE), which consists of feedforward filter and feedback filter. The feedforward filter can reduce pre-echoes and the feedback filter can reduce the post-echoes.

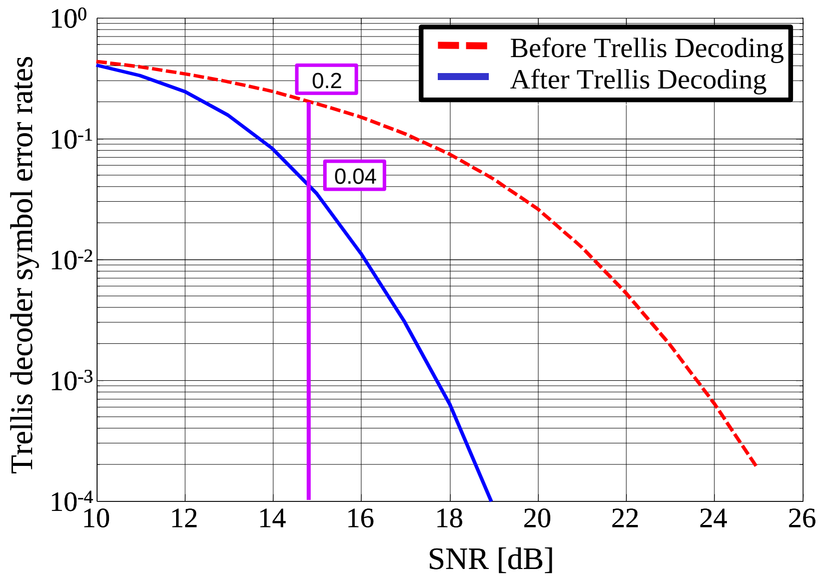

Figure 8. Simplified Trellis Decoder Performance

The decision device in the equalizer is Simplified Trellis Decoder [7]. The output of adaptive filters is sliced by the decision device and the sliced data is used as input value of the feedback filter. The simplified trellis decoder is one of the Viterbi decoder; it uses a method of selecting a survival path which minimizes the accumulated error. Generally, Viterbi decoder requires long delay time. But the decision feedback equalizer should use the decision device with no delay. Because general long delay Viterbi decoder can't be used in the equalizer, we used the simplified trellis decoder with no delay. We designed the simplified trellis decoder using an IIR filter with only one tap and weight factor of 0.9 [7]. The performance of the simplified trellis decoder is shown in Figure 8. If the MSE of the equalizer output is less than -15 dB, the equalizer is assumed to be converged.

The coefficient update algorithm is LMS (Least Mean Square) algorithm. LMS algorithm uses the steepest descent method, which is given by

$$H(n) = H(n-1) + \mu_n \cdot e(n) \cdot X(n), \quad (3)$$
$$e(n) = a(n) - y(n). \quad (4)$$

$H(n)$ is a filter coefficient, μ_n is a step-size, $e(n)$ is an error signal between an equalizer output and a decision value, and $y(n)$ is an equalizer output. LMS algorithm can be easily implemented due to low computational complexity, and it works stably in a static channel or a slow moving channel.

Error signal generator calculates $e(n)$ which will be used in the LMS block. While the known training sequence data is transmitted, $a(n)$ is the training sequence. However, while the random information data is transmitted, $e(n)$ is defined by the blind alogirhtm. There are many kinds of blind algorithms, but stop and go algorithm is used in this ATSC transmission system. Stop and go algorithm proposed by Pichi and Prati determines whether the adaptive filter coefficient is updated or not by checking the match of sign of error between decision direct algorithm and Sato algorithm. Coefficient update algorithm of the stop and go is given by

$$C_{k+1} = C_k - \mu \cdot e_{SAG}(k) \cdot X^*(k), \quad (5)$$
$$e_{SAG} = \mathrm{f(k)} \cdot e_{DD}(k), \quad (6)$$

where $e_{DD}(\mathrm{k}) = \widehat{I_k} - \widetilde{I_k}$. And Sato error for $f(k)$ is

$$e_s(\mathrm{k}) = y_k - \alpha \cdot \mathrm{sgn}(y_k), \quad (7)$$

where $\alpha = \mathrm{E}\{{\alpha_k}^2\}/E\{|\alpha_k|\}$. α is 5.25 in VSB.

At equation (6), $f(k)$ is defined as follows,

$$f(k) = \begin{cases} 0 & \text{if } \mathrm{sgn}(e_{DD}) \neq \mathrm{sgn}(e_s) \\ 1 & \text{if } \mathrm{sgn}(e_{DD}) = \mathrm{sgn}(e_s) \end{cases}. \quad (8)$$

4. Analysis of Performance

Considering 3DTV service using SC-MMH, computer simulations were performed in order to analyze the performance of the ATSC M/H transmission system and ATSC 8-VSB system. Channel model of the simulator is the Ricean channel defined by DVB-T [8]. The Ricean channel profile consists of a direct path of line of sight and reflected multi paths. And the Ricean factor K is given as

$$K = \frac{{\rho_0}^2}{\sum_{i=1}^{N} {\rho_i}^2}$$

It is a ratio of the power of the main path and the summed power of reflected multi paths. K of 0, 2, 5, 10 dB are used in the simulation, and their impulse responses are shown in Figure 9, respectively.

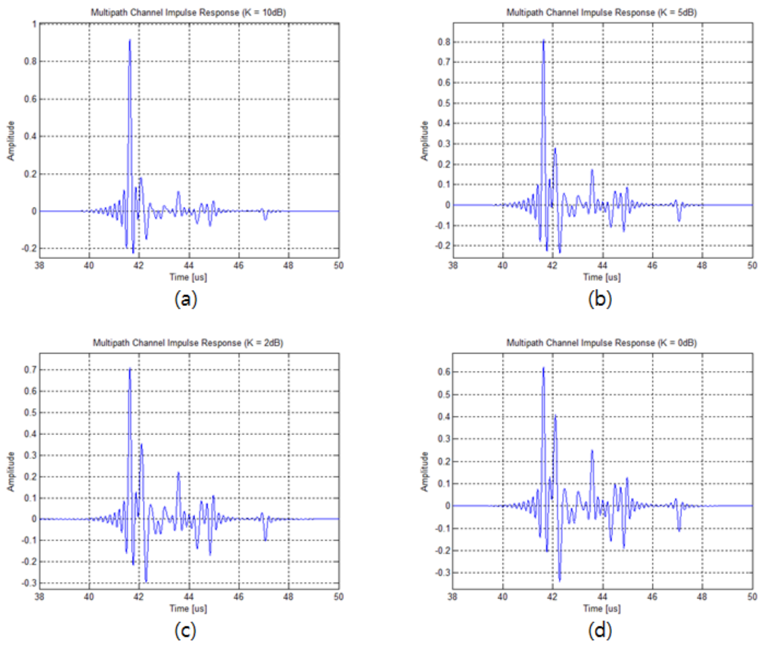

Figure 9. Ricean Channel Impulse Responses with *K* of 10 dB (a), 5 dB (b), 2 dB (c), 0 dB (d)

In this paper, we assumed that SNR (CNR) is 30 dB and observed the mean square error of the equalizer output for performance comparison. In K = 10, and 5 dB channel, performance of the ATSC M/H system and ATSC 8-VSB system is similar. In K = 2 dB channel, the ATSC M/H system converges more quickly than ATSC 8-VSB system. In K = 0 dB channel, ATSC 8-VSB system doesn't converge but ATSC M/H system does converge.

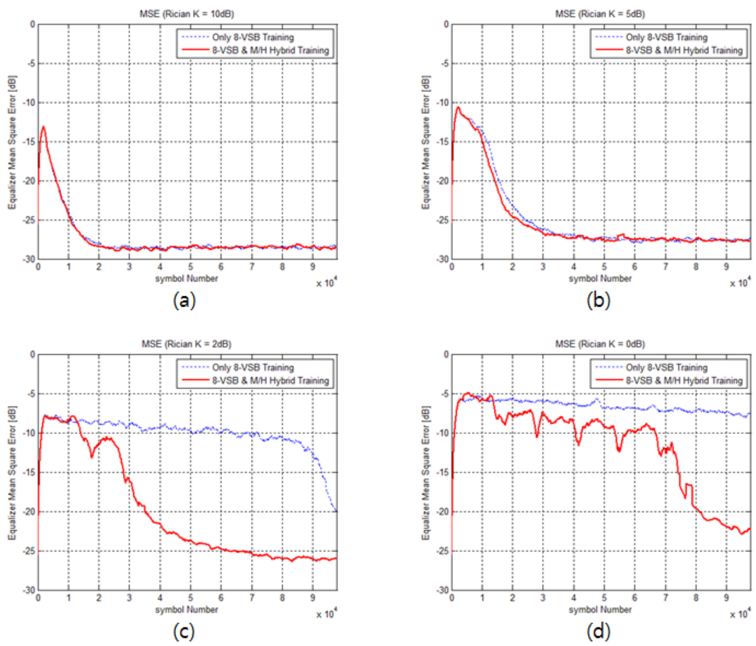

Figure 10. Comparison of MSE of the Equalizer Output with 4 Channel Models of K = 10 dB (a), 5 dB (b), 2 dB (c), 0 dB (d).

5. Conclusion

By analysis of the ATSC M/H frame structure and the ATSC 8-VSB data frame, an equalizer is designed based on the least mean square algorithm and a channel estimator. Simulations were done to compare the performance of the ATSC M/H system and ATSC 8-VSB system. Simulation results show that the performance of ATSC M/H system is enhanced in the severe channel such as Ricean channel of $K = 0$, and 2 dB. If 3DTV is broadcasted by using the SC-MMH, backward compatibility is guaranteed as well as reception performance is improved.

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References

[1] ATSC, Editor, Doc. A/104 "ATSC Standard: 3D-TV Terrestrial Broadcasting, Part 1", Advanced Television Systems Committee, Washington (**2014**).

[2] ATSC, Editor, Doc. A/104 "ATSC Standard: 3D-TV Terrestrial Broadcasting, Part5-Service compatible 3D-TV using Main and Mobile Hybrid Delivery", Advanced Television Systems Committee, Washington (**2014**).

[3] ATSC, Editor, Doc. A/153 "ATSC Mobile DTV Standard: A/153 Part 3, service Multiplex and Transport Subsystem Characteristics", Advanced Television Systems Committee, Washington (**2013**).

[4] ATSC, Editor, Doc. A/53 "ATSC Digital Television Standard – Part 2: RF/Transmission System Characteristics", Advanced Television Systems Committee, Washington (**2011**).

[5] ATSC, Editor, Doc. A/153 "ATSC Mobile DTV Standard: Part 2-RF/Transmission System Characteristics", Advanced Television Systems Committee, Washington (**2011**).

[6] T. Xu, H. Sun and K. Wang, "Channel Estimation Algorithm Analysis of ATSC-M/H DTV System", Internation jounal of Advancements in Computing Technology (IJACT), vol. 3, no. 0, (**2011**), pp. 98-105.

[7] Y. H. Oh, K. W. Lee and D. J. Kim, "A recursive Trellis Decoder to Approach The Shannon capacity in ATSC DTV Receivers", Proceedings of International Conference on Consumer Electronics (ICCE), (**2008**) January 9-13; Las Vegas, United State of America

[8] ETSI, Editor, ETSI EN 300 744 "Digital Video Broadcasting (DVB) : Framing Structure, Channel Coding and Modulation for Digital Terrestrial Television", Digital Video Broadcasting, Sophia Antipolis (**2004**).

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