A Denoising Autoencoder based wireless channel transfer function estimator for OFDM communication system

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***Abstract*— This paper proposes a channel estimation method for Orthogonal Frequency Division Multiple Access (OFDM) communication system by utilizing a Neural Network (NN) based a Machine Learning (ML). Especially, Autoencoder is utilized to estimate Channel Transfer Function (CTF) and to reduce a noise on the estimate. Japanese Digital TV broadcast system is assumed as target system. Then 8k FFT/IFFT is used and number of sub-carriers are 5617 such as mode3 in Integrated Services Digital Broadcasting-Terrestrial (ISDB-T) spec. 5617 complex CTF points must be estimated by limited number of scattered pilot sub-carriers. Assumed channel condition is 2 wave multipath channel with Additive White Gaussian Noise (AWGN). The multipath parameters are randomly generated. To train the autoencoder, 5000 CTFs are generated and pre-training was performed. System performance was evaluated by measuring Bit Error Rate (BER). The system with conventional frequency-domain interpolator and the system with autoencoder based were compared. According to BER simulation results, the autoencoder based system has shown lower BER than the conventional. At BER=10^{-5}, autoencoder system shows roughly 2dB gain than conventional system.**

Keywords—Neural Network, Machine Learning, Deep Learninig, Autoencoder, OFDM, Channel Estimation, Denoise

I. Introduction

The machine learning (ML) and, in particular, deep learning (DL) applications has growing rapidly in the last decade. The application fields cover almost every industrial areas [1, 2, 3]. Digital communication related applications such as channel coding, channel decoding, detection, MIMO detection, deep learning communication system are also investigated by many researchers [4, 5, 6, 7]. For example, a paper [8] proposed a channel estimation application for OFDM communication system and it shows the advantage of DL systems using 64 sub-carries OFDM system.

In this article, we introduce a channel estimation method utilizing NNs. In order to show the usefulness of NNs, one big real OFDM system is assumed such as Integrated Services Digital Broadcasting-Terrestrial (ISDB-T) system, which is used as Digital TV service in Japan, the Philippines, Latin America. Fig. 1 shows the simple diagram of the OFDM communication system. The upper side is the transmitter side and the lower side is the receiver side. Bit information are mapped to constellations through 64QAM mapper and 5617 constellations with 2575 zeros are 8192 points IFFTed as OFDM modulation [9]. In order to avoid a Inter Symbol Interference (ISI), Guard Interval (GI) is pre-attached at each OFDM symbol as Cyclic prefix (CP) manner. Transmitted radio wave go through multipath channel. Then the receiver basically performs reverse order operation. To mitigate a distortion caused by the multipath channel, channel transfer function (CTF) must be estimated and the FFT outputs are divided by the CTFs. By the scatter pilot (SP), the CTF at SP position can be measured. To estimate all CTF values, Time-domain and Frequency-domain interpolation is required as shown in the figure. The proposed system replaces the frequency-domain interpolator with autoencoder.

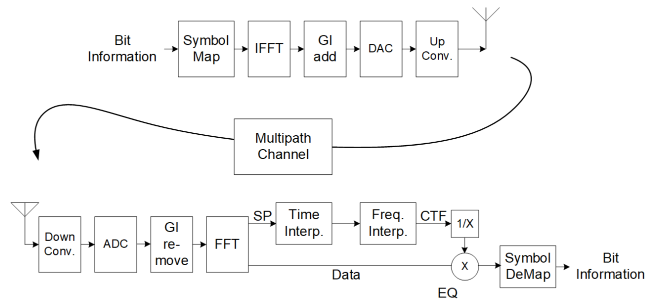

Fig. 1: OFDM communication system.

The section II describes the system architecture including the system block diagram with and without autoencoder. The detail of the system operation will be described. The section III shows computer simulation results. Finally, the summary is concluded in section IV.

II. System Aechitecture

Fig. 2 shows a block diagram of receiver's equalizer. The upper (a) is a conventional method and the lower (b) is the proposed autoencoder channel estimator. Fig.3 show the Time-Frequency representation of OFDM signals. The blue circles are scatter pilots (SPs), which is BPSK modulated, and receiver knows the pilot value. Then receiver can estimated the CTF values at SP positions. In order to estimate all CTF values at all circle points, first time-domain interpolation is performed with 15 tap FIR filter. Then after, by performing frequency-domain interpolation, all CTF values can be estimated.

An autoencoder is a neural network that is trained to attempt to copy its input to its output. In addition, autoencoder has capability of denoising which is reported [10, 11 Chapter14.2.2]. When some inputs are dropout, autoencoder tries to estimate the

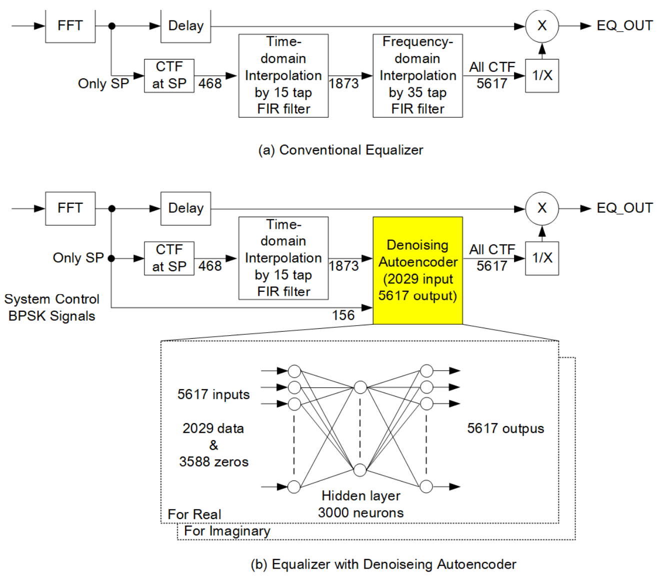

Fig. 2: Block Diagram of receiver equalizer. (a) shows the conventional interpolator method, and (b) shows autoencoder based equalizer.

empty points. As shown in figure 2(b), two sets (the one for real of CTF and the other for imaginary) of denoising autoencoder gets 1873 CTF values from SP and 156 CTF values (totally 2029 values). Since ISDB-T spec has BPSK modulated control data are imbedded as shown in Fig. 3 red circle. Actual name of this control signal TMCC/AC1 such as Transmission and Multiplexing Configuration Control Information / Auxiliary Channel 1 [9]. Since those signals are BPSK modulated and they can be easily demodulated, in our design CTF at red circle are assumed to be usable. Totally, 156 additional CTF values are used to estimate correct all CTF through denoising autoencoder.

Table I shows the system parameters. To train the denoising autoencoder, 5000 CTF sets are generated assuming 2 wave multipath channel with no AWGN. The input and output size of the denoising autoencoder is 5617 and the size of hidden layer

TABLE I : SYSTEM FEATURE

Parameters	Value
FFT size	8k
Number of Sub-carriers	5617
Number of SP	468
Number of BPSK Control Sub-carriers	156
Carrier Modulation	64QAM
Simulated Channel	Randomly generated 2 waves multipath
Neural Net Layers	3 layers Autoencoder
Autoencoder size	Input=Output=5617 Hidden=3000
Activation Function	Rectified Linear Unit

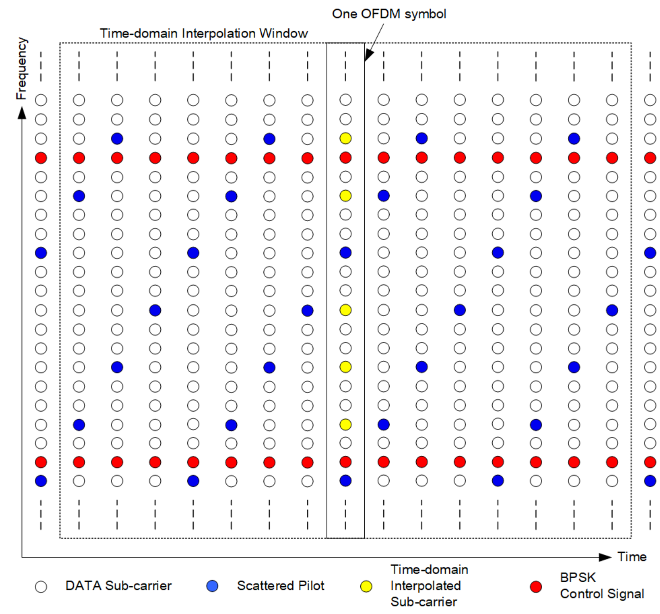

Fig. 3: Time-Frequency representation of OFDM signals. Every four time domain symbol, Scattered Pilots (Blue) are placed and they are used to calculate Channel Transfer Function.

is 3000. Then the 1st layer has 5617X3000 weights and biases and 2nd layer has 3000X5627 weights and biases. The 1st layer outputs go through Rectified Linear Unit.

III. Simulation Results

Fig. 4 shows inputs and outputs of the denoising auto encoder with three Carrier power to Noise power Rasios (CNRs=30dB/20dB/10dB). Black points corresponds to the inputs of the autoencoder. Then many inputs are zeros. Red cross corresponds to the outputs of autoencoder. According to the figures, autoencoder sucsessfully estimates all CTF values. In addition, as shown in Fig 4(c) such as CNR=10dB case, black input points are largely distubed by noise. However, the outputs of autoencoder are not influenced by the noise addtion. Then the proposed denoising autoencoder performs not only estimation of CTF but also CTF noise reduction successfully.

Fig. 5shows the CTF conparison between conventional and the proposed denoising autoencoder with CNR(dB)=30/20/10. Solid black line correponds to conventional and red cross corresponds to the autoencoder. Because of no noise reduction in conventional, solod black lines are influenced by the added noise.

Fig 6. Shows the 64QAM constellations at CNR=30dB. Autoencoder equalizer shows clearer constellation than conventional. Fig 7. Shows the Bit Error Rate (BER) comparizon between conventiona and denoising autoencoder cases. Because of the denoising effect of the autoencoder, the proposed system shows lower BER. At BER=10^{-5}, autoencoder system shows rougly 2dB gain than conventional system.

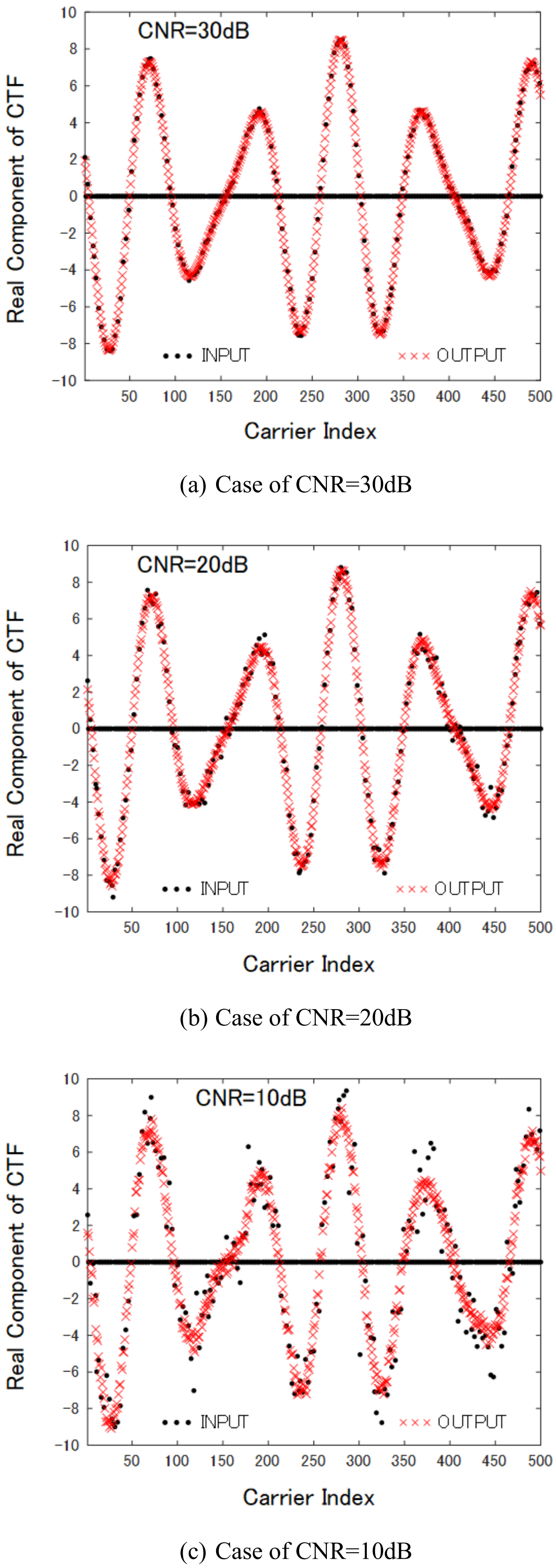

Fig. 4: Inputs and outputs of denoising auto encoder.

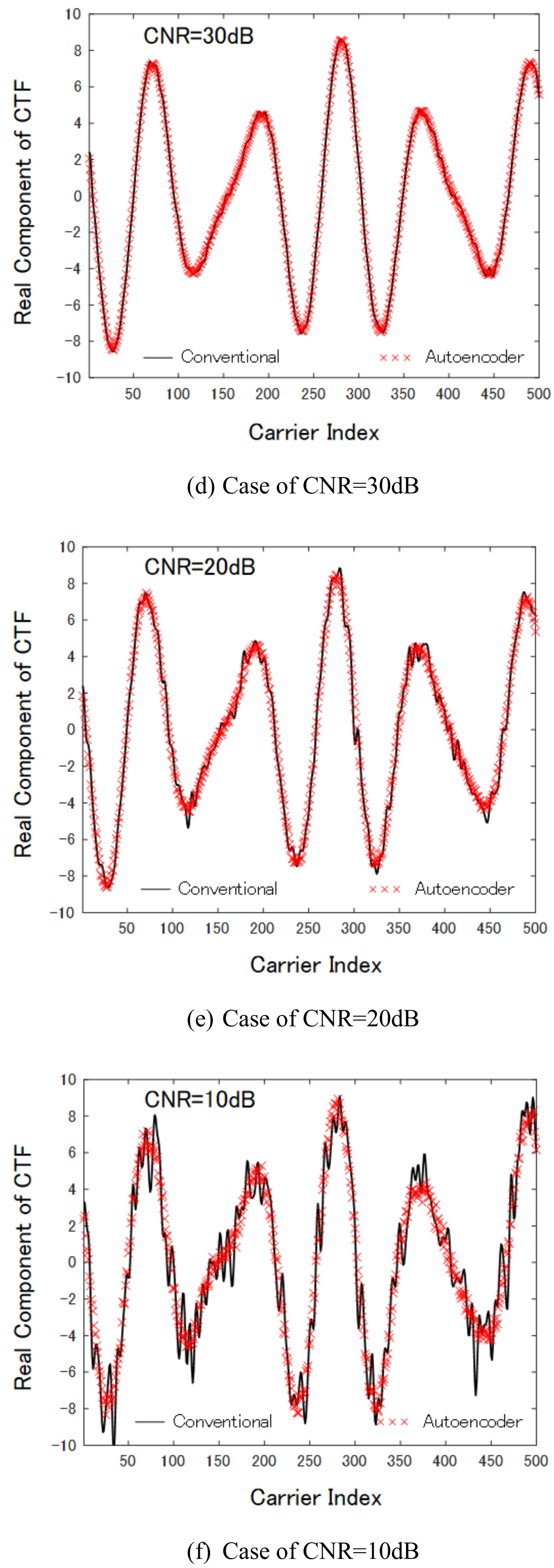

Fig. 5: Outputs of conventional freq.-domain interpolator and Autoencoder .

IV. Conclusion

This paper proposed a denoising autoencoder based channel estimation method for Orthogonal Frequency Division Multiple Access (OFDM) communication system. Japanese Digital TV broadcast system is assumed as target system. Assumed channel condition is 2 wave multipath channel with Additive White Gaussian Noise (AWGN). The multipath parameters are randomly generated 5000 CTF sets to train the autoencoder. System performance was evaluated by measuring Bit Error Rate (BER). According to BER simulation results, the autoencoder based system has shown lower BER than the conventional. At BER=10^{-5}, autoencoder system shows roughly 2dB gain than conventional system.

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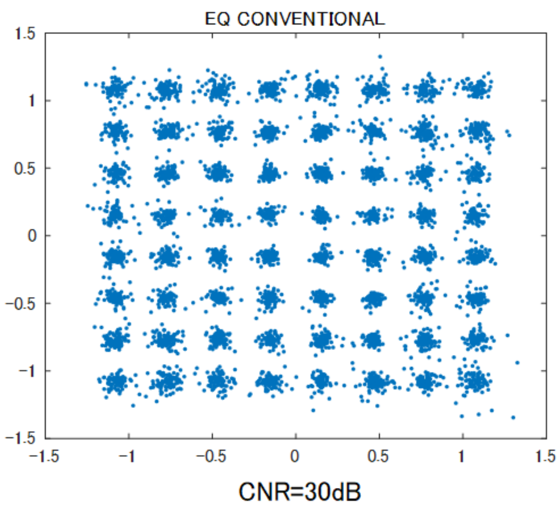
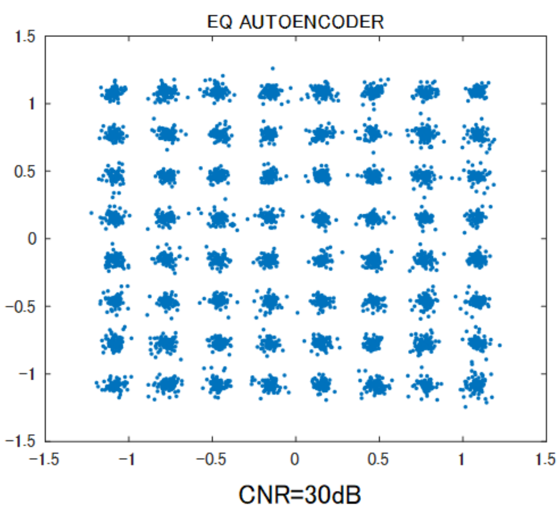


(a) Conventional



(b) Denoising Autoencoder

Fig. 6: 64QAM constellation of conventional and autoencoder.

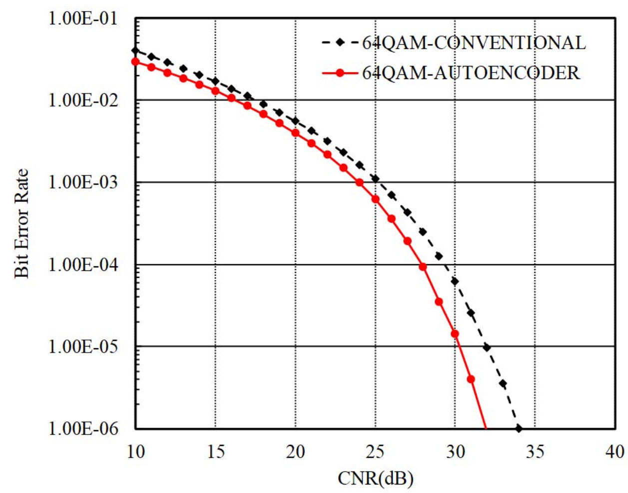


Fig. 7: BER comparison between conventional and autoencoder.

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