Automatic Gain Control in High Adjacent Channel Interference for OFDM Systems

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***Abstract*—In wireless communication systems, the received signal power is highly fluctuated by changing of distance between transmitter and receiver, and by mobility of the receiver. Most of automatic gain controller (AGC) algorithms are developed to make the constant power of received signal. But in high adjacent channel interference (ACI) environment, the conventional algorithms do not work well. The proposed algorithm utilizes a gain splitting on variable gain amplifier (VGA) and fast Fourier transform (FFT) to enhance the receiver demodulation performance in high ACI environment. The proposed algorithm has better bit error rate (BER) performance than the conventional algorithm.**

I. Introduction

In wireless communication systems, the received signal power is highly fluctuated by changing of distance between transmitter and receiver, and by mobility of the receiver even though the transmitted signal has constant power. When the receiver uses this changed signal without power controlling, bit error rate (BER) will be increased due to the unwanted quantization noise and clipping noise on analog-to-digital converter (ADC). Automatic gain controller (AGC) of the receiver minimizes the distortions. The goal of AGC is making the constant signal power by control variable gain controller (VGA) and low noise amplifier (LNA) [1].

If the receiver is in high adjacent channel interference (ACI) environment, the signal quality will be distorted by clipping or quantization when AGC has no protection scheme for high ACI. In this paper, the proposed algorithm uses gain splitting scheme to remove distortion by poor gain control of orthogonal frequency division multiplexing (OFDM).

Simplified system model of OFDM wireless mobile communication systems is illustrated in Fig. 1 Modulated data is mapped to subcarrier and passes through inverse fast Fourier transform (IFFT) and digital-to-analog converter (DAC). The converted analog signal is transmitted through the channel. On the receiver side, ACI and additive white Gaussian noise (AWGN) are added to the received signal. After gain controlling by VGA, the received analog signal is converted to a digital signal by ADC. The digitized received signal is transformed to modulated data by fast Fourier transform (FFT) and subcarrier de-mapper.

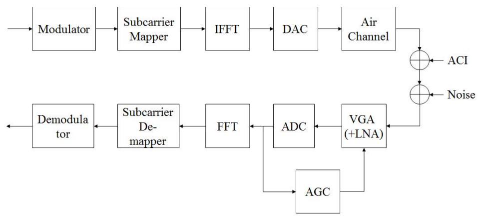

Fig. 1. A simplified system model of OFDM wireless communication system including AGC algorithm 1.

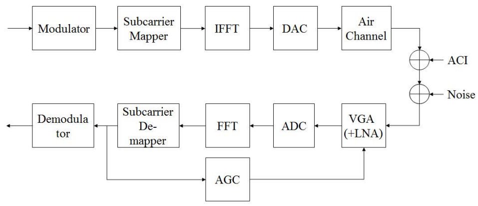

Fig. 2. Structure of AGC algorithm 2.

The rest of the paper is organized as follows. In Section II, the conventional AGC algorithms and their performance degradation due to high ACI are introduced. In Section III, a modified AGC algorithm based on gain splitting method is proposed and a performance assessment of the proposed AGC algorithm in various environments is provided through a numerical analysis. Finally, conclusions are given in Section IV.

II. The Conventional AGC Algorithms

To analysis the performance of AGC, we assume that 12 bit ADC has ideal quantization and clipping. Under this assumption, we found the ideal AGC set point as 2^6 which has less than 0.01dB BER performance degradation on 10^{-5} BER point with 64 quadrature amplitude modulation (QAM) compared to analog simulation.

AGC can make the constant signal for FFT input or output. To make constant FFT input signal power, AGC uses the FFT input signal as shown in Fig. 1. Otherwise, to make constant FFT output signal power, AGC uses the FFT output signal as shown in Fig. 2.

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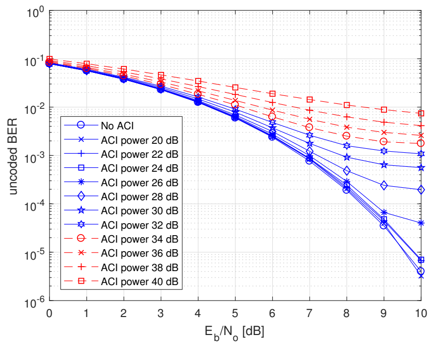

Fig. 3. BER performance of the conventional AGC algorithm 1 with QPSK in AWGN channel.

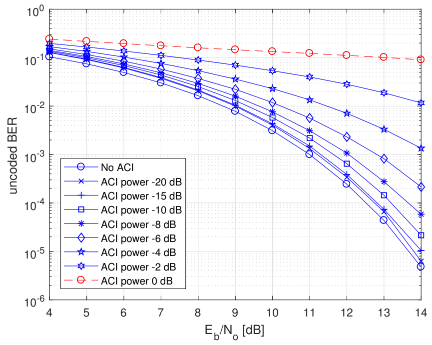

Fig. 4. BER performance of the conventional AGC algorithm 1 with 16QAM in AWGN channel.

BER performances for the conventional AGC algorithm 1 with QPSK, 16QAM, and 64QAM are depicted in Fig. 3, Fig.4, and Fig. 5, respectively. ACI power in the figure is the relative signal power which is compared to the desired signal. ACI power 0dB means that the power of ACI is same as the power of the desired signal. As shown in the figures, BER performance degradation is observed from ACI power 21dB for QPSK, -20dB for 16QAM and 64QAM. When the ACI power is increased, the desired signal power will be decreased. Because AGC tries to make constant received signal power. QPSK is more robust for ACI than 16QAM and 64QAM because 16QAM and 64QAM are demodulated by both of phase and amplitude but QPSK is demodulated by phase only.

BER performances for the conventional AGC algorithm 2 with QPSK, 16QAM, and 64QAM are depicted in Fig. 6, Fig. 7, and Fig. 8, respectively. As shown in the above figures, BER performance degradation is observed from ACI power 22dB for QPSK, 21dB for 16QAM, and 20dB for 64QAM. When the ACI power is increased with constant desired signal power, total power of received signal will be increased. When ACI power is very high compared to the desired signal, the received signal will be clipped. Because of the set point of the desired signal is 2^6 as mentioned before, FFT input signal set point of the 20dB higher ACI is about $2^9 + 2^7$. OFDM signal has high peak-to-average power ratio (PAPR), PAPR is

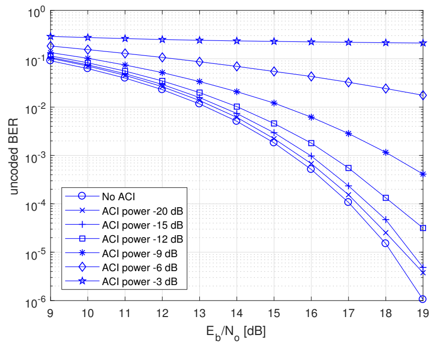

Fig. 5. BER performance of the conventional AGC algorithm 1 with 64QAM in AWGN channel.

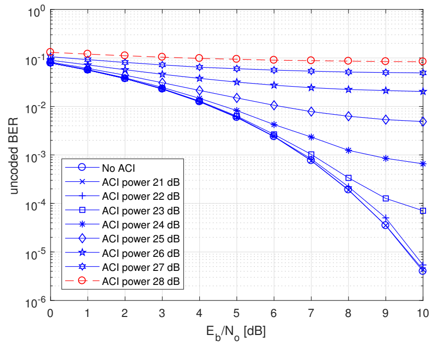

Fig. 6. BER performance of the conventional AGC algorithm 2 with QPSK in AWGN channel.

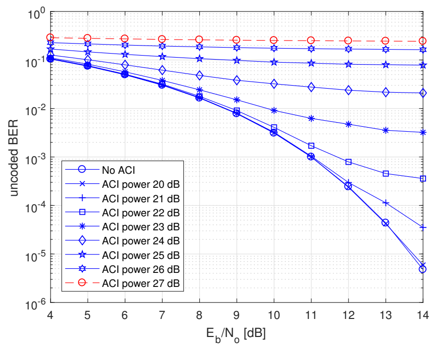

Fig. 7. BER performance of the conventional AGC algorithm 2 with 16QAM in AWGN channel.

about 12dB in 10^{-4} complementary cumulative distribution function (CCDF) point [2]. In this situation, larger than 10^{-4} of received signal is higher than clipping point 2^{11}. This is the reason why the BER performance degradation is observed with 20dB of ACI power.

From the simulation results, we observe the fact that the conventional AGC algorithm 1 is too sensitive to ACI power. We should choose the conventional AGC algorithm 2 to enhance the performance.

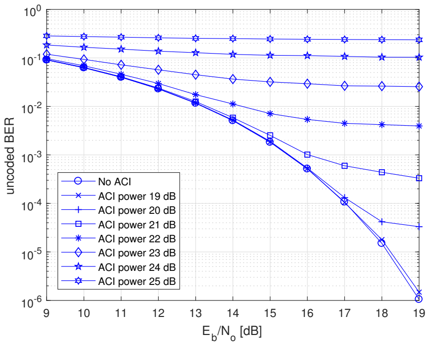

Fig. 8. BER performance of the conventional AGC algorithm 2 with 64QAM in AWGN channel.

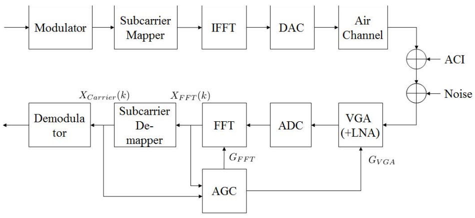

Fig. 9. The proposed AGC algorithm.

III. The Proposed AGC Algorithm

To enhance the performance of AGC in high ACI environment, the receiver should monitor the ACI power. The ACI power P_{ACI} is calculated by power difference between FFT output signal X_{FFT} and subcarrier de-mapper output signal X_{Car} as

$$P_{ACI} = \frac{1}{N_{FFT}} \left\{ \sum_{k=0}^{N_{FFT}-1} X_{FFT}^2(k) - \sum_{k=0}^{N_{Car}-1} X_{Car}^2(k) \right\} \tag{1}$$

where N_{FFT} is FFT size and N_{Car} is the number of used carrier.

When the ACI power is high, the receiver separates the total gain G_{AGC} to G_{VGA} and G_{FFT} as

$$G_{AGC} = G_{VGA} + G_{FFT}. \tag{2}$$

If G_{FFT} is changed by 6dB, we can change the FFT output signal amplitude by bitwise because one bit left shift is the same as boosting 6.02dB. The overall structure of the proposed AGC algorithm is illustrated in Fig. 9. For example, when the high ACI is detected, AGC will split the total gain G_{AGC} 50dB into G_{VGA} 32dB and G_{FFT} 18dB. From this setting, the desired signal power in FFT input is 18dB lower than AGC set point with clipping noise reduction. After three bit left shift in FFT, the desired signal power will be aligned to the original AGC set point.

BER performances for the proposed AGC algorithm with QPSK, 16QAM, and 64QAM are depicted in Fig. 10, Fig. 11, and Fig. 12, respectively. To observe the effect of gain splitting, we set G_{FFT} as 0, 6, 12, 18, and 24dB with ACI power 30dB. From the results, BER performance is improved as G_{FFT} increasing. As VGA gain is decreased by gain splitting, clipping in ADC is also decreased. But if we set too high VGA gain, quantization noise will be increased. This is the reason why G_{FFT} = 24dB has worse BER performance than G_{FFT} = 18dB. From the simulation results, the proposed AGC algorithm improves BER performance than that of conventional algorithms.

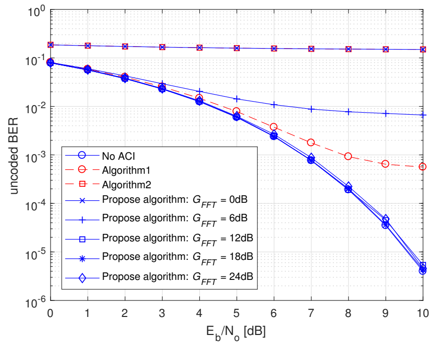

Fig. 10. BER performance of the proposed AGC algorithm with QPSK in AWGN channel.

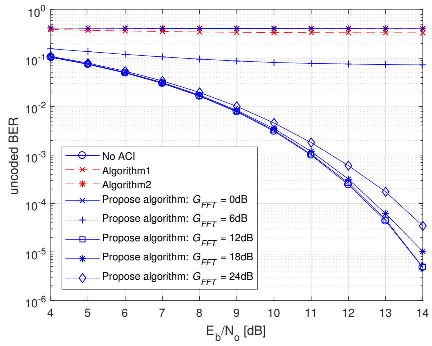

Fig. 11. BER performance of the proposed AGC algorithm with 16QAM in AWGN channel.

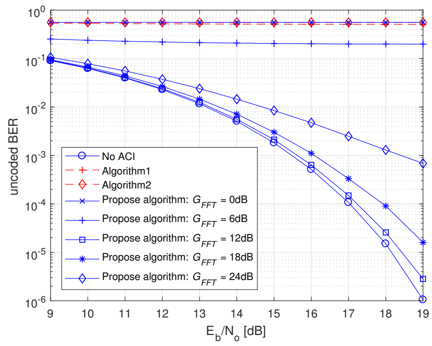

Fig. 12. BER performance of the proposed AGC algorithm with 64QAM in AWGN channel.

IV. Conclusion

In this paper, we found that AGC for constant power of FFT output signal is more stable than AGC for constant power of FFT input signal for OFDM mobile wireless communication system from the numerical analysis.

We propose a new AGC algorithm by splitting the total gain into VGA gain and FFT gain, which is determined by monitoring the ACI power. The proposed AGC algorithm can enhance the BER performance in high ACI environment by reducing the clipping noise.

Our future work will develop the overall scenario for ACI detection and AGC switching mechanism. Firstly, we should evaluate the ACI power monitoring accuracy to do this. Secondly, we evaluate the BER performance under the scenario.

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