Digital AGC Circuit Design based on FPGA

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Abstract: Users’ demand for broadband wireless and mobile is increasing, making wireless broadband access technology WiMAX, arise at the historic moment, rapid development, has become the focus of attention in the industry these two years. In this paper, based on the WiMAX transmission standard 802.16D, the AGC of channel demodulation in WiMAX receiver is described in detail. Firstly, the basic components and main characteristic indexes of the AUTOMATIC gain control system are introduced, and the output formula of AGC model is obtained through the analysis of a step-type AGC. Then the adc and AGC circuits in THE AGC system in the WiMAX receiver are introduced and analyzed theoretically. In this paper, SPW model is used to analyze the algorithm of the basic structure of AGC circuit. Combined with the simulation results, AGC circuit is explained in detail and parameters are explained. Finally, the verification results based on SPW and FPGA are given. The individual performance test of AGC is carried out through SPW, and combined with the performance test of the simulation system, it shows that AGC can work in cooperation with other modules of the system. In FPGA test, it can be proved that AGC can also work well with Verilog.

1. Introduction
Wireless access technologies are usually divided into mobile access and fixed access [1]. Mobile access and can be divided into two categories, high-speed access and low-speed access [2], high-speed access to the cellular systems, satellite mobile communication systems, is commonly used in cluster system, such as the low speed system available PCN (personal communication) system, such as CDMA (code division multiple access) local loop, APCS (personal access system) communication, PHS (personal handset system) and so on to achieve [3-4]. Fixed access is the wireless access from switching node to fixed user terminal, which is actually the wireless extension of PSTN/ISDN (public switched telephone network/integrated digital service network) [5]. Nowadays, people are no longer limited to the traditional voice communication, but more need to carry out large-capacity data communication, and can communicate anytime and anywhere [6]. Wireless VoIP and wireless video on demand (VOD) are changing people's communication mode, and at the same time, wireless communication is required to have a higher rate and a larger coverage area [7]. At present, optical fiber is widely used in backbone network, so the bandwidth provided by optical fiber is enough to guarantee the current needs of multimedia communication. Using broadband wireless access and improving its transmission rate has become a research hotspot [8].

WiMAX, a wireless man (WMAN) technology, is a new air interface standard for microwave and millimeter-wave frequency bands [9]. The advantage of WiMAX network determines that WiMAX will be an important part of wireless communication network in the future [10]. This paper is part of the design, development and implementation of WiMAX demodulation chip in key laboratory of embedded system. Through theoretical and algorithm analysis, AGC algorithm based on leading sequence is realized. WiMAX currently has some products in the market, but its market share is small
and mostly foreign firms. If the WiMAX chip is successful, it could give China's IC industry a competitive edge in broadband wireless access.

The stepping digital AGC based on pilot frequency is a solution for the GAIN control circuit of WiMAX system. Combined with the transmission mode of WiMAX system, the proposed algorithm has the characteristics of fast locking signal, which can meet the requirements of WiMAX system. At the same time, due to the various key parameters are designed for register matching mode, with good flexibility and higher portability, it can be used as a general digital AGC algorithm.

2. Automatic Gain Control System Application
AGC (Automatic Gain Control, AGC) in the broadcast, communication receiver can use the system, this is because the signal transmission power size, sending and receiving of distance, there will be a significant decline in the transmission medium and other factors, makes the role has changed a lot in receiver signal strength at the input and the ups and downs, deep and remote in receiver devices generally can handle only little change in the amplitude, Automatic Gain Control system can ensure the receiver receives the signal amplitude stable.

2.1. Classification of AGC Technologies
AGC can be divided into RF analog control and ADC front-end digital control. The former works by extracting the analog signal received by the receiver as the control parameter, while the latter extracts the digital signal at the back end of the ADC as the control parameter. After certain algorithm processing, the actual control signal is obtained, which is also the focus of this paper. Analog AGC is generally located after the RF part of the receiver LNA, and its implementation is to obtain the statistical estimation of the received signal in a period of time (which is usually relatively slow), and then use this estimation as the control signal to control the signal in the next period. This paper mainly analyzes the digital AGC system.

AGC systems are of two types: open-loop and closed-loop. In an open-loop AGC system, there is no feedback from output to input. In practical applications, most closed-loop AGC systems are adopted, which can keep the output voltage amplitude of the receiver unchanged with certain accuracy and have moderate fast response. Closed-loop AGC systems can also be classified into delayed or non-delayed types. In the delayed AGC system, gain adjustment occurs only when the input signal amplitude exceeds a certain level, and there is an action threshold in the feedback circuit. In the AGC system without delay, there is no such threshold effect, and it has gain adjustment effect on the signal at any level. This paper mainly analyzes the delayed AGC system.

2.2. Principle of Digital AGC
Digital AGC mainly consists of four parts: signal level estimator, first order CIC filter, comparator and digital control attenuator. After the signal passes through the signal estimator, the signal level is estimated. After the level is averaged by CIC summation, the average level of the signal is obtained. The comparison of the average level with the set highest and lowest level in the comparator determines the direction of gain adjustment. The output of the comparator passes through the digital controlled attenuator to obtain the gain that needs to be adjusted so that the signal can be adjusted to the desired range.

Taking the input signal as spread spectrum signal (DS-BPSK) for example, the expression of ADIN is shown in Formula (1), where A is signal amplitude, d is modulated information, Pn is modulated spread spectrum code and Wn is noise. After coherent demodulation, the carrier (SIN=) and spread spectrum code (PNI=Pn) of the input signal are obtained. SIN and PNI input digital AGC modules are used to extract amplitudes. Signal S1 is obtained, as shown in Equation (2).

\[ ADIN = AdPn \cos(\omega t + \theta) + W_n \] (1)
\[ S_1 = ADIN \times SIN \times PNI = Ad / 2 - Ad / 2 \times \cos(2\omega t + 2\theta) + W_n \times P_n \cos(\omega t + \theta) \] (2)
3. Realization of Automatic Gain Control Circuit

The model of automatic gain control circuit in WiMAX system is shown in Figure 1. It mainly includes power estimation, error processing and AGC state machine.

![AGC System Model](image)

Pulse width modulation (PWM) and Delta-Sigma modulation. Their common feature is to change a 1-bit digital signal into an analog signal. However, WiMAX system requires fast locking of signals, so it adopts the way of converting multi-bit digital signals into analog signals. The advantages of multi-bit versus L-bit lie in high dynamic tracking capability and high dynamic range. Here, 7bits signal is fed back to A D/A, and D/A is directly used to convert digital signal into analog signal. The adjustment range of AGC implemented in this paper is 0~60dB, and 7bits can represent 0~127, so the adjustment accuracy can reach 0.5dB.

As an ASIC chip, flexibility is very important. Therefore, the requirement of flexibility was fully considered in the design. Each threshold value and gain value were designed to be matched by registers, and many parts were also selected by registers. According to the simulation results of SPW, this paper sets a set of parameters for AGC, as shown in Table 1.

| Register | Set Point       |
|----------|----------------|
| P        | $39.185399219517$ |
| LGC      | 0.25           |
| LGF      | 70             |
| Gmax     | 10             |
| Gmin     | 9              |
| Ed-thresh| 5              |

4. Verification of Dynamic Gain Control System

4.1. SPW Test Analysis

In order to test the performance of AGC, this paper combines the SPW model of WiMAX system for testing. The system model includes the signal source, the channel and the baseband part of the receiver. The channel includes AWGN and SUI, the signal source is responsible for sending data conforming to 802.16D protocol, while the channel is for testing the necessary links, the baseband part of the receiver (including AGC) is responsible for demodulation, and finally the PERFORMANCE of AGC is verified by BER.
According to the requirements of the protocol, 7MHz channel bandwidth and 8MHz symbol transmission rate were used in the performance of AGC tested, and the ratio of cyclic prefix to OFDM length was 1/8, that is, 32. In other words, the interval of the sub-carrier of the system is 31.25khz, the data length in OFDM is 32 s, the protection interval length is 41 s, and the whole OFDM symbol length is 36 s. The data length utilized by AGC is 20 s. So AGC needs to lock the signal within 20 s. Using the simple case of the AWGN only signal, compare the input and output signals first. In the case of an ideal channel, when the energy of the transmitted signal is -56dbm ~ 4dBm, THE AGC can lock the signal well within the specified time, and through the system test, BER is 0-1. This indicates that the actual adjustment range of AGC is 60dB, which is exactly consistent with the designed amplification factor.

Working conditions of AGC were tested under four conditions, respectively ideal channel, AWGN channel, Fading channel and Multipath channel. Due to the influence of multipath, the energy of the input signal is no longer roughly constant, which will seriously affect the performance of AGC, making AGC unable to lock the signal well within the specified time. Finally, combined with the whole system, the work of AGC is illustrated through the test of the whole system. The simulation performance diagram of SPW is shown in Figure 2.

As can be seen from the performance diagram above, when soft decision is adopted, the performance of the whole system is about 4dB better than that required by the protocol, and when hard decision is adopted, the performance of the system is about 2dB better than that required by the protocol.

4.2. FPGA Test and Analysis
FPGA verification is an indispensable link in digital integrated circuit design. Only after complete and strict verification and testing can the correctness of the implemented algorithm and designed circuit be guaranteed. The AGC system verification platform mainly includes tuner, ADC, DAC and FPGA development board. According to the requirements of the protocol, the standard signal sent by SFU adopts the channel bandwidth of 7MHz and the symbol transmission rate of 8MHz. According to the sampling law, the minimum sampling frequency of ADC is 16MHz. 32MHz oversampling was used in the test.

The verification platform includes signal source SFU, tuner, ADC9218, DAC2900 and FPGA. This platform actually constitutes the AGC part of the WiMAX transmitting and receiving systems. The baseband signals obtained by ADC sampling without AGC loop can be seen that the signal amplitude is very small and cannot meet the requirements of system demodulation at all. Through through the
ADC sampling AGC loop of baseband signal can be seen, you can see at the time of received signal to amplify the signal to the largest, is useful in judging the received signal to adjust the signal magnification when, after a period of adjustment, when the signal energy to achieve the set reference signal lock, no longer to adjust signal amplitude. The signal at this point makes full use of the ADC’s dynamic range. This indicates that THE AGC is working normally.

5. Conclusion
Automatic gain control system (AGC) is an essential link in wireless communication. It ensures that the output power of the receiver can be kept constant even when the signal received is very strong and weak, so that the subsequent modems and signal processing units can operate stably without saturation or low level. The main performance indexes of AGC circuit are to establish time and dynamic range. In high-speed burst wireless communication, such as wireless man, the requirement of AGC circuit is stricter and its implementation is more difficult. The establishment time is particularly important for high-speed burst communication, which is related to the loop filter (low pass) bandwidth and loop amplification factor. The wider the bandwidth, the shorter the establishment time; conversely, the narrower the bandwidth, the longer the establishment time. For loop filters, the useful signals should be filtered out and the bandwidth should be large enough to shorten the establishment time. In this paper, we present a step-by-step digital AGC based on pilot. The loop filter contains two gain parameters: coarse loop gain and fine loop gain. Coarse loop gain guarantees the convergence time of AGC and fine loop gain guarantees the convergence accuracy of AGC. The test of SPW and FPGA shows that AGC can work well with other modules of the system.

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