

Automatic gain control in an underwater acoustic receiver

Stoyan Kolev*, Bistra Nenova, Ivan Ivanov

Institute of Metal Science, Equipment and Technology with Hydroaerodynamic Center at Bulgarian Academy of Sciences,
67 Shipchenski Prohod Street, 1574 Sofia, Bulgaria
s_kolev@abv.bg

Abstract: The performance of two automatic gain control circuits is compared in an underwater acoustic receiver: a low-power hardware gain control and a software-controlled gain control that disables the gain change for a predetermined time interval after a valid signal level. Binary digits "0" and "1" are transmitted using bursts of the frequencies 33kHz and 43kHz, respectively, in two modes of operation. In the first mode, each digit is sent as one frequency burst followed by a pause. In the second mode, a frequency burst is transmitted at the beginning of a clock interval. Experiments are conducted in shallow waters. The results show that the hardware gain control circuit is suitable to equal time intervals between the transmitted bursts. The software gain control circuit allows arbitrary time intervals between the transmitted bursts. Increased power consumption of the device is detected as a disadvantage of the software gain control circuit.

Keywords: AUTOMATIC GAIN CONTROL, UNDERWATER ACOUSTIC TRANSMISSION

1. Introduction

Underwater wireless communication is most commonly performed using acoustic waves [1,2,3,6]. The underwater acoustic channel is considered to have some of the harshest communication conditions. Automatic gain control (AGC) is an important component of communication receivers [4,5]. Over a wide dynamic range of the signal at the receiver input, the AGC circuit provides relatively constant signal level to the demodulator input (and the analog-to-digital converter (ADC) input) for optimum operation.

We experimentally compare the performance of two automatic gain control circuits in an underwater acoustic receiver.

2. Acoustic receiver

2.1. Signal modulation

For the purposes of underwater acoustic transmission, the binary digits "0" and "1" (low and high level) are represented using

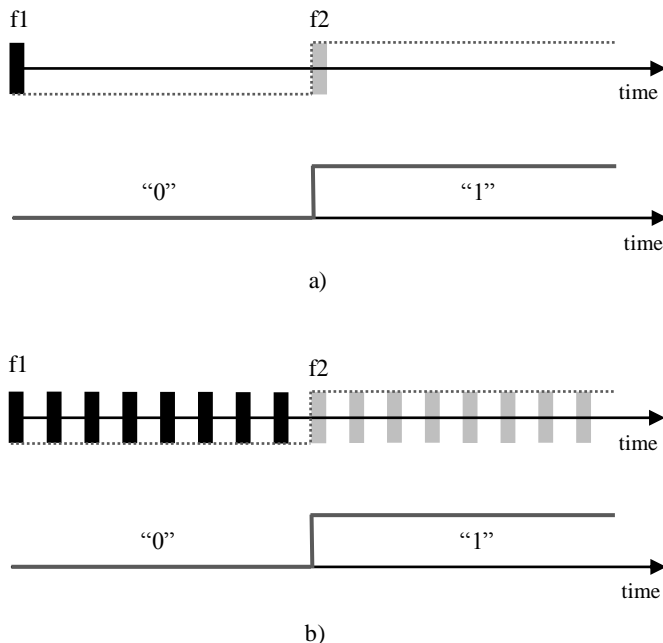


Fig.1. Signal modulation:

- a) one frequency burst with corresponding frequency for digits "0" and "1";
b) multiple frequency bursts with corresponding frequency for digits "0" and "1".

two different frequencies, f_1 and f_2 , respectively. In order to provide greater attenuation of the reflected acoustic signals, short bursts of signal are transmitted at the respective frequencies. Frequency burst transmission allows for conducting experiments in shallow waters. Two modes of operation are implemented. In the first mode, each digit is sent as one burst at the specified frequency, followed by a pause. In the second mode, the durations of digits "0" and "1" are multiples of a clock interval. A corresponding frequency burst is transmitted at the beginning of each clock interval. Fig.1 shows an example of signal modulation in the two modes of operation. The durations of the digits "0" and "1" can be equal or different.

2.2. Automatic gain control

Two typical circuits for automatic gain control are implemented in an underwater acoustic receiver in order to compare their performance: a low-power hardware gain control and a software-controlled gain control.

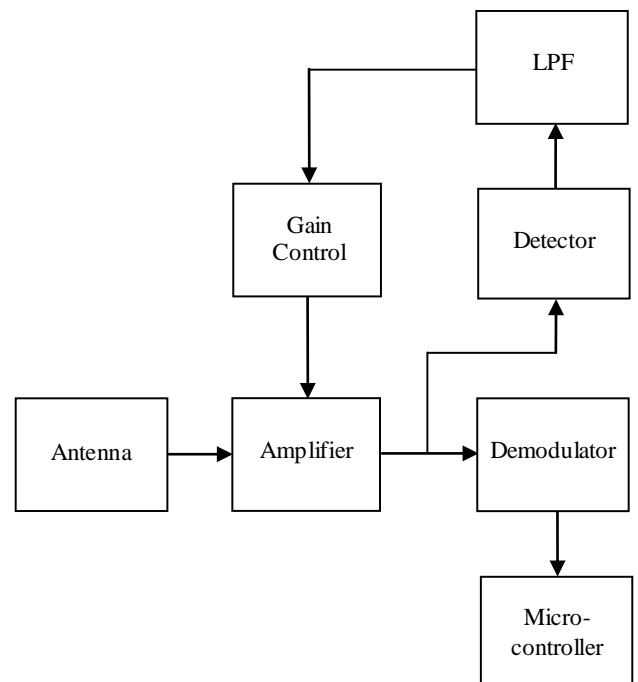


Fig.2. Low-power hardware automatic gain control. Block diagram of the acoustic receiver.

2.2.1. Low-power hardware gain control

A block diagram of an acoustic receiver using a low-power hardware gain control circuit is shown in Fig.2. The signal from the acoustic antenna goes to a variable gain amplifier where it is amplified to a level suitable for the selected demodulator. The demodulated signal is fed to a microcontroller for processing and recognition. Automatic gain control is needed to obtain an appropriate signal level at the demodulator input. For this purpose, the signal at the output of the variable gain amplifier passes through a detector and a low-pass filter (LPF). The detector and the low-pass filter are designed so that the voltage at the input of the Gain Control block to depend mainly on the peak values of the modulated signal. With this voltage, the Gain Control block adjusts the gain of the amplifier, so that the voltage, formed at the amplifier's output, does not change over a wide range. Since the microcontroller only decodes the demodulated signal, a basic low-power microcontroller operating at a low clock frequency can be used.

2.2.2. Software gain control

The acoustic receiver from the block diagram in Fig.3 uses a software-controlled gain control circuit. The signal received from the antenna is amplified, demodulated, and fed to an analog-to-digital converter (ADC) of a microcontroller for digital conversion. The microcontroller then decodes the signal.

The microcontroller controls the gain of a variable gain amplifier by means of a digital potentiometer so as to maintain appropriate signal amplitude at the amplifier's output and, accordingly, at the ADC input. The software control allows the gain change to be disabled for a specified time interval after detecting a valid signal level. Using an external demodulator reduces the power consumption of the microcontroller and therefore of the receiver. Due to the more complex software and the built-in ADC, the microcontroller here generally consumes more power than the one in the receiver using hardware gain control.

3. Experiments and results

The acoustic receivers are experimentally tested in shallow waters with a constant temperature, about 10m deep, at a transmitter-receiver distance of 200m. 8-digit binary sequences are transmitted multiple times underwater. The digits "0" and "1" are transmitted using signal bursts at frequencies 33kHz and 43kHz, respectively.

3.1. Transmission of one frequency burst for each digit

A) *The durations of digits "0" and "1" are equal and vary in the range from 5ms to 50ms.*

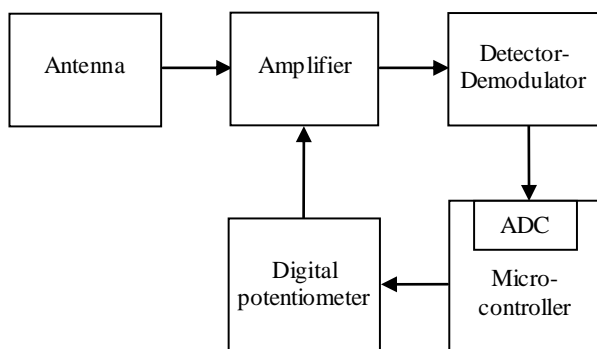


Fig.3. Software automatic gain control. Block diagram of the acoustic receiver.

- Hardware gain control

With the hardware gain control, at duration of the digits of more than 30ms, amplitude changes at the input of the demodulator are observed at a constant level at the input of the acoustic receiver. The hardware gain control circuit performs stably up to 30ms duration of "0" and "1".

- Software gain control

With the software gain control, when the duration of the digits changes from 5ms to 50ms, the signal amplitude at the demodulator input remains stable at a constant level at the input of the receiver. The software gain control circuit performs well at all tested durations in the 5ms to 50ms range.

B) *The durations of digits "0" and "1" are different*

- Hardware gain control

With the hardware gain control, increasing the difference between the durations of "0" and "1" increases the difference in the amplifier gain. This leads to changes in the input signal of the demodulator and, as a consequence, to incorrect decoding by the microcontroller. Therefore, the hardware gain control circuit is not applicable.

- Software gain control

The software gain control performs well at different durations of digits "0" and "1". The output amplitude of the amplifier does not depend on the difference in the durations of digits "0" and "1".

3.2. Transmission of multiple frequency bursts with the respective frequency for each digit

The selected clock interval for burst transmission is equal to 20ms.

A) *Transmission at longer durations of "0" and "1", equal to 160ms.*

With both gain control circuits, no difference in the gain of the amplifier is observed at a constant level of the input signal.

B) *Transmission at different from each other durations of "0" and "1" (multiples of the clock interval).*

With both gain control circuits, no difference in the gain of the amplifier is observed at a constant level of the input signal.

In the mode of transmission of multiple bursts, both the hardware and software gain controls perform well. The hardware gain control is stable even at longer or different durations of digits "0" and "1".

4. Conclusion

The performance of two automatic gain control circuits is compared in an underwater acoustic receiver: a low-power hardware gain control and a software-controlled gain control. Digits "0" and "1" are transmitted using bursts of the frequencies 33kHz and 43kHz, respectively, in two modes of operation. In the first mode, each digit is sent as one frequency burst followed by a pause. In the second mode, a frequency burst is transmitted at the beginning of a clock interval.

The transmission of one frequency burst for each digit and at equal durations of "0" and "1", up to 30ms long, allows for the use of the low-power hardware gain control circuit. In this mode, the software gain control circuit performs well at all tested durations in the 5ms to 50ms range.

With transmission of one frequency burst for each digit and at different durations of digits "0" and "1", the software gain control performs well. The hardware gain control circuit operates at only small differences in the durations.

With transmission of multiple frequency bursts at the respective frequency for each digit, both the hardware and software gain controls perform well. The hardware gain control is stable even at longer or different durations of digits "0" and "1".

Increased power consumption of the acoustic receiver is detected as a disadvantage of the software gain control circuit.

The experimental results show that the hardware gain control circuit is suitable to equal time intervals between the transmitted bursts. The software gain control circuit allows arbitrary time intervals between the transmitted bursts.

Acknowledgement

This work was supported by the European Regional Development Fund within the OP "Science and Education for Smart Growth 2014 - 2020", Project CoE "National center of mechatronics and clean technologies", № BG05M2OP001-1.001-0008-C08.

References

1. L. Liu, S. Zhou, J.-H. Cui, Prospects and Problems of Wireless Communication for Underwater Sensor Networks, *Wireless Communications and Mobile Computing*, **8** (8), 977-994 (2008)
2. M. Stojanovic, J. Preisig, Underwater Acoustic Communication Channels: Propagation Models and Statistical Characterization, *IEEE Communications Magazine*, **47** (1), 84-89 (2009)
3. J. Partan, A Survey of Practical Issues in Underwater Networks, Computer Science Department Faculty Publication Series, 133 (2006)
4. C. Sayre, *Complete Wireless Design*, McGraw-Hill (2008)
5. U.Rohde, J.Whitaker, H.Zahnd, *Communications Receivers*, McGraw-Hill (2017)
6. Н. Георгиев, А. Коларов, В. Пехливански, Тенденции в развитието на безжичните подводни комуникации, *Инженерни науки*, год. LVI, 2, 19-30 (2019)