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Efficient RF Transceiver System for Underwater Submarine System

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Abstract: One of the main problems in under water communications is the low data rate available due to the use of low frequencies. Moreover, there are many problems inherent to the medium such as reflections, refraction, energy dispersion, etc., that greatly degrade communication between devices. In some cases, wireless sensors must be placed quite close to each other in order to take more accurate measurements from the water while having high communication bandwidth. In these cases, while most researchers focus their efforts on increasing the data rate for low frequencies, we propose the use of the 2.4 GHz ISM frequency band in these special cases. In this paper, we show our wireless sensor node deployment and its performance obtained from a real scenario and measures taken for different frequencies, modulations and data transfer rates. The performed tests show the maximum distance between sensors, the number of lost packets and the average round trip time. Based on our measurements, we provide some experimental models of underwater communication in fresh water using EM waves in the 2.4 GHz ISM frequency band. Finally, we compare our communication system proposal with the existing systems. Although our proposal provides short communication distances, it provides high data transfer rates. It can be used for precision monitoring.

Key words:

INTRODUCTION

There has been a growing interest in designing distributed underwater wireless sensor networks because of their ability to bring computation and sensing into the physical world. Underwater sensor networks have many potential applications, including seismic monitoring, scientific exploration of the ocean, tactical surveillance, pollution monitoring, offshore exploration and support for underwater robots. For example, underwater sensor networks can provide significant benefits in seismic imaging of undersea oil fields. Today, most seismic imaging tasks for offshore oil fields are carried out by a ship that tows a large array of hydrophones on the surface. The cost of such technology is very high and the seismic survey can only be carried out rarely, for example, once every two to three years. In comparison, sensor network nodes [1] have very low cost and can be permanently deployed on the ocean floor, which allows frequent seismic imaging (e.g., once every three months). Additionally, networks near the bottom are more trawl resistant and covert. However, achieving reliable underwater acoustic communications between sensors deployed on the ocean floor is not an easy task. First, the underwater acoustic (UWA) channel is one of the most challenging communication channels. It suffers large delay spread, leading to strong frequency selectivity and exhibits high temporal and spatial variations. Being both frequency and time selective, UWA channel poses great challenges for high performance and reliable underwater communications. Furthermore, the underwater communications near the ocean floor are even more challenging due to lower signal strength. Finally, near-bottom sensor network nodes [1] may get buried or partially buried (due to movements in the ocean), which introduces additional attenuation in the system and may prevent communication between nodes. To investigate the feasibility of UWA communications between buried or bottom-mounted sensor network nodes [1], we have conducted two experiments: the Naval Research Laboratory (NRL) Acoustic Communications Measurement System (ACOMMS09) experiment and the NRL sediment experiment (SedEx09). During the ACOMMS09 experiment, a portion of the sensors (i.e., hydrophones) were buried in the soft sediment (i.e., mud). The experiment was held near the New Jersey shore in May 2009. On the other hand, during the SedEx09 experiment, the hydrophones were buried in the hard

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sediment (i.e., sand). This experiment was held near Panamam City, FL, in August 2009. All signals analyzed in this paper were transmitted at 17 kHz. Due to its unique strength in handling transmissions over long dispersive channels, we have chosen orthogonal frequency-division multiplexing (OFDM) communications to test UWA communications between buried network nodes. Recently, there has been an increased interest in underwater OFDM communications, e.g., the low-complexity adaptive OFDM [2] receiver, the pilot-tone-based block-by-block OFDM receivers in and the no coherent OFDM receiver based on ON–OFF keying in [3]. However, all these OFDM schemes are designed to achieve high data rate communications in the water column and may not be suited for communications between network nodes placed on

Review of Literature

Feasibility Study of Underwater Acoustic Communications Between Buried and Bottom-Mounted Sensor Network Nodes: This paper presents a feasibility study of underwater communications between buried sensor network nodes. To investigate this problem, two experiments have been conducted:

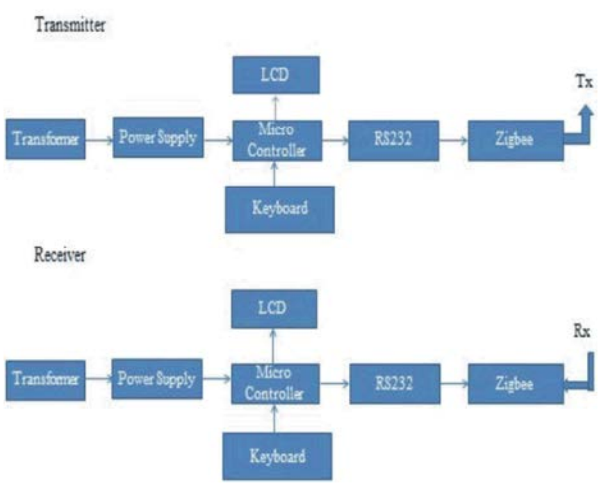
Where some sensor nodes are buried in the sediment and where all sensor nodes are buried in the sediment. The orthogonal frequency-division multiplexing (OFDM) communications have been chosen to test underwater communications because of its unique strength in handling transmissions over long dispersive channels. Since the existing OFDM schemes for underwater communications are designed to achieve high data rate communications within the water column and are not adequate for communications between sensors placed on the ocean floor, a new low-complexity OFDM receiver has been proposed. The proposed receiver performs frame-by-frame channel estimation, residual phase tracking, diversity combining and data demodulation. This approach is adopted because of its effectiveness in applications with very fast varying channels and a large number of propagation paths. It is demonstrated that the error-free performance can be achieved between buried sensors using the proposed OFDM receiver.

MIMO-OFDM for High-Rate Underwater Acoustic Communications: Multiple-input-multiple-output(MIMO) [2] techniques have been actively pursued recently in underwater acoustic communications to increase the data rate over the bandwidth-limited channels. In this communication, we present a MIMO system design, where spatial multiplexing is applied with orthogonal-frequency-division-multiplexing (OFDM) [2] signals. The proposed receiver works on a block-by-block basis, where null subcarriers are used for Doppler compensation, pilot subcarriers are used for channel estimation and a MIMO detector consisting of a hybrid use of successive interference cancellation and soft minimum mean square error (MMSE) equalization is coupled with low-density parity-check (LDPC) channel decoding for iterative detection on each subcarrier. The proposed design has been tested using data recorded from three different experiments. A spectral efficiency of 3.5 b/s/Hz was approached in one experiment, while a data rate of 125.7 kb/s over a bandwidth of 62.5 kHz was achieved in another. These results suggest that MIMO-OFDM [2] is an appealing solution for high-data-rate transmissions over underwater acoustic channels.

Multicarrier Communication over Underwater Acoustic Channels With No uniform Doppler Shifts: Underwater acoustic (UWA) channels are wideband in nature due to the small ratio of the carrier frequency to the signal bandwidth, which introduces frequency-dependent Doppler shifts [4]. In this paper, we treat the channel as having a common Doppler scaling factor on all propagation paths and propose a two-step approach to mitigating the Doppler Effect: 1) nonuniform Doppler compensation via resampling that converts a "wideband" problem into a "narrowband" problem and 2) high-resolution uniform compensation of the residual Doppler. We focus on zero-padded orthogonal frequency-division multiplexing (OFDM) to minimize the transmission power. Null subcarriers are used to facilitate Doppler compensation and pilot subcarriers are used for channel estimation. The receiver is based on block-by-block processing and does not rely on channel dependence across OFDM blocks; thus, it is suitable for fast-varying UWA channels. The data from two shallow-water experiments near Woods Hole, MA, are used to demonstrate the receiver performance. Excellent performance results are obtained even when the transmitter and the receiver are moving at a relative speed of up to 10 km, at which the Doppler shifts [4] are greater than the OFDM subcarrier spacing. These results suggest that OFDM is a viable option for high-rate communications over wideband UWA channels with nonuniform Doppler shifts.

Signal Processing for Underwater Acoustic Communications: The performance and complexity of signal processing systems for underwater acoustic communications has dramatically increased over the last two decades. With its origins in noncoherent modulation and detection for communication at rates under 100 b/s, phase-coherent digital communication systems employing multichannel adaptive equalization with explicit symbol-timing and phase tracking are being deployed in commercial and military systems, enabling rates in excess of 10 kb/s. Research systems have been shown to further dramatically increase performance through the use of spatial multiplexing. Iterative equalization and decoding has also proven to be an enabling technology for dramatically enhancing the robustness of such systems. This article provides a brief overview of signal processing methods and advances in underwater acoustic communications, discussing both single carrier and emerging multicarrier methods, along with iterative decoding and spatial multiplexing methods. Sparse channel estimation [5] for multicarrier underwater acoustic communication from subspace methods to compressed sensing.

BLOCK DIAGRAM



Components used in Project

802.15.4 – ZigBee Physical Layer: ZigBee is a wireless technology developed as an open global standard to address the unique needs of low-cost, low-power wireless M2M networks. The ZigBee standard operates on the IEEE 802.15.4 physical radio specification and operates in unlicensed bands including 2.4 Ghz, 900 MHz and 868 MHz

The ZigBee Advantage: The ZigBee protocol is designed to communicate data through hostile RF environments that are common in commercial and industrial applications.

Display Unit: To display messages received we are using a 20*4 alphanumeric LCD. If any new message arrives the current one is erased and new one is displayed.

Filter: The Filter is used to remove the pulsated AC. A filter circuit uses capacitor and inductor. The function of the capacitor is to block the DC voltage and bypass the AC voltage. The function of the inductor is to block the AC voltage and bypass the DC voltage.

Transformer: A transformer is an electro-magnetic static device, which transfers electrical energy from one circuit to another, either at the same voltage or at different voltage but at the same frequency.

Rectifier: The function of the rectifier is to convert AC to DC current or voltage. Usually in the rectifier circuit full wave bridge rectifier is used.

POWER SUPPLY

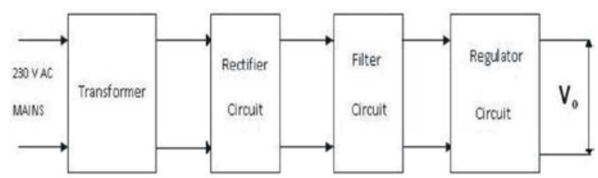


Fig. 3.2 Block diagram of power supply

Voltage Regulator: Voltage regulator constitutes an indispensable part of the power supply section of any electronic systems. The main advantage of the regulator ICs is that it regulates or maintains the output constant, in spite of the variation in the input supply.

8 RS 232: Due to its relative simplicity and low hardware overhead (as compared to parallel interfacing), serial communications is used extensively within the electronics industry. Today, the most popular serial communications standard in use is certainly the EIA/TIA–232–E specification. This standard, which has been developed by the Electronic Industry Association and the Telecommunications Industry Association (EIA/TIA), is more popularly referred to simply as “RS–232” where “RS” stands for “recommended standard”. In recent years, this suffix has been replaced with

"EIA/TIA" to help identify the source of the standard. We use the common notation "RS– 232".

LCD: A liquid crystal display (LCD) is a thin, flat display device made up of any number of color or monochrome pixels arrayed in front of a light source or reflector. Each pixel consists of a column of liquid crystal molecules suspended between two transparent electrodes and two polarizing filters, the axes of polarity of which are perpendicular to each other. Without the liquid crystals between them, light passing through one would be blocked by the other. The liquid crystal twists the polarization of light entering one filter to allow it to pass through the other.

HARDWARE DESCRIPTION

MICROCONTROLLER – ATMEGA8

Features

- High-performance, Low-power AVR® 8-bit Microcontroller
- Advanced RISC Architecture
  - 130 Powerful Instructions – Most Single-clock Cycle Execution
  - Fully Static Operation
    - Up to 16 MIPS Throughput at 16 MHz
  - On-chip 2-cycle Multiplier
  - 8K Bytes of In-System Self-programmable Flash program memory
  - 512 Bytes EEPROM
  - 1K Byte Internal SRAM
  - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
  - Data retention: 20 years at 85°C/100 Years at 25°C.

Acuastic Algorithm: There are many references found on underwater acoustic networks from the perspective of communications people and on properties of underwater acoustic propagation from the perspective of acoustics people. I did not locate a basic primer on the various changes in a transmitted signal as seen by a receiver highlighting the issues impacting contemporary approaches to communications (e.g., wireless network techniques). This report summarizes my own simple analysis of what is happening and should be regarded as an effort by a non-specialist.

CONCLUSION

This paper presented the feasibility study of underwater communications between buried sensor network nodes [1]. To investigate this problem, two experiments were conducted: one where sensor network nodes are buried in the soft sediment and the second one where the sensor network nodes were buried in the hard sediment. The new, low-complexity OFDM receiver was designed to combat a large number of strong propagation paths that are distorting signal near the ocean floor. The proposed receiver performs frame-by-frame channel estimation, residual phase tracking, diversity combining and data demodulation. The presented results show that communication among buried distributed sensors is possible. They also show that using the proposed OFDM [2] receiver, error-free communications can be achieved among buried distributed sensors. Furthermore, the results indicate that the performance of sensor nodes at about 1 and 2 m above the ocean floor have similar both SNR and BER. Finally, the results show that SNR is degraded by about 2 dB by being buried just below the sediment. All presented results indicate that to achieve reliable underwater communications between buried distributed sensors, we need to design a system that has high SNR, can successfully handle the large number of propagation paths and uses multiple hydrophones as receiving elements.

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4. **Missing**
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