ULTRACOMM TECHNOLOGY
IMPLEMENTATION OF CODE DIVISION MULTIPLEXING
FOR UNDERWTER COMMUNICATION

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Abstract:

The primary goal of this project is to setup a Communication system in under sea. Even though the bandwidth available is limited, the proposed system will provide high data rates. This is achieved by using Code Division Multiplexing using Parallel Processing. Even though the real data rate is low, the multiplying factor increases the data rate by many folds (in the range of Mbps). This is equivalent to N different users with different codes, operating at the same frequency, processing data at the same time but all integrated as a single unit. Implementation of Code Division Multiplexing in Ultrasonic communication will make the system compact, power efficient and cost effective. A typical application of this idea could be, a LAN setup between four divers undersea and a boat on the water surface. Each of them can communicate with each other (Transfer of Voice, Video and Data).

Introduction:

Wireless acoustic communication is a rapidly growing field. Growth in new technologies has made underwater communications more fast and reliable. The two main resources of Communication Engineering are the Bandwidth and the Power. For video and other data transfer processes, the bandwidth required is very high when compared to voice. So Code division multiplexing is implemented in order to increase the Bit rate even though the acoustic channels are severely band limited. High rate underwater communications have traditionally relied on equalization methods to overcome the inter-symbol interference (ISI) caused by multipath propagation.

ULTRAsonic COMMunication:

A method of transmitting digital data through water as acoustic signals comprising the steps of separating and feeding successive digits of a serial input, at the transmitter, each into a selected number of channels (given by different codes) such that each digit is fed into a different channel from its preceding digit and such that, after a digit has been fed into one channel, The next successive digit is fed into one or other of two further channels separate from the channel into which the preceding digit is fed, the further channel being selected in accordance with whether the digit is a 1 or0 or whether the digit is the same or different from the preceding digit, and then transmitting the signals in the separate channels as acoustic pulses on same sonic or ultrasonic frequencies (but with different codes), and, at the receiving end, the signals are decoded with the particular set of codes to obtain the digital pulses In the last years, fully coherent modulation techniques, such as phase shift keying (PSK) and quadrature amplitude modulation (QAM), have become practical due to the availability of powerful digital processing.
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Implementation of Direct Sequence Spread spectrum in UltraComm:

Spread spectrum techniques in communication may provide many benefits for acoustic communications. The main principle of spread spectrum communications is that the bandwidth occupancy is much higher than other modulation techniques, resulting in a much lower power spectral density.

This results in several advantages:

The signal thus just looks like noise and interferes minimally with other communication systems or others users. Additional communication systems or users appear as increased Gaussian noise to other users.
The system is also more robust against distortions, multi-path fading and noise (potentially non-Gaussian) due to the larger bandwidth. The system is also much more difficult to jam.
Additionally, spread spectrum communications automatically provides secure communications because it is nearly impossible to recover the transmitted data without knowledge of the spreading code.

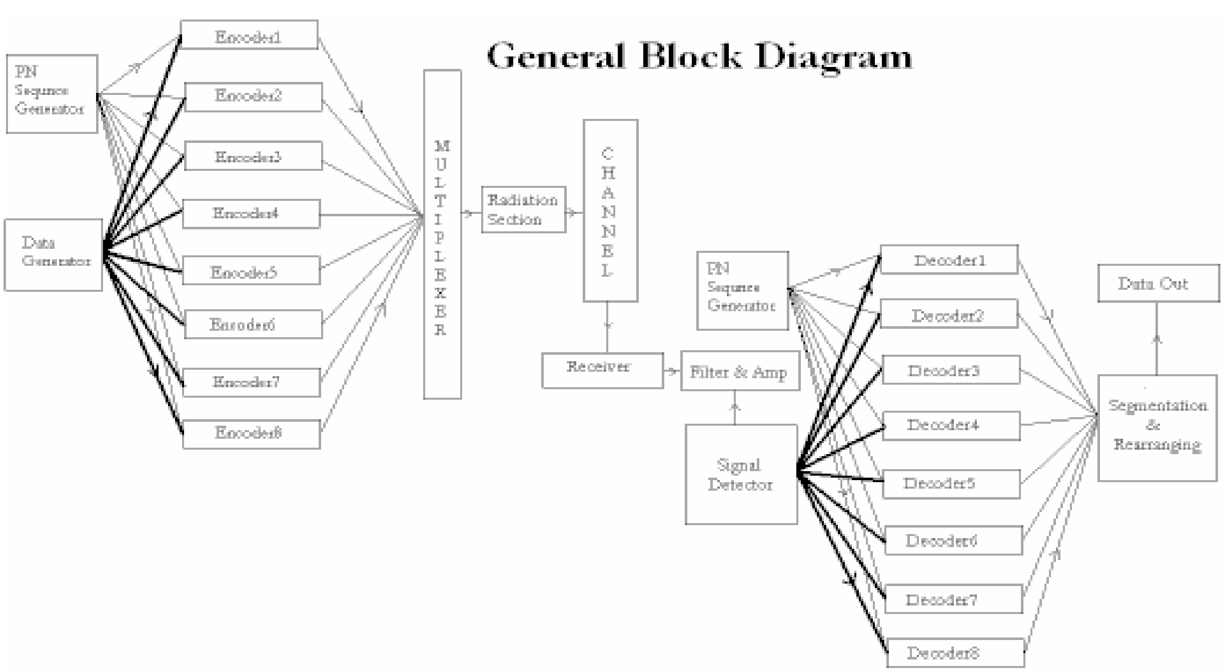
Short PN codes are often used in spread spectrum communications. These codes (typically 10-128 chips in length) are used to modulate each data bit. The codes are then repeated for every data bit. Long PN codes (millions of chips in length) are used in systems that require higher security. As these PN codes are repeated infrequently, they are more difficult to decode.

Medium to long PN codes may be useful in underwater acoustic communications, as they may provide the added benefit of reducing ISI from multi-path propagation. If the PN code has a desirable autocorrelation and a length more than the maximum multi-path delay, the ISI from multi-path propagation can be reduced significantly. This will allow effective acoustic communications which is robust against multi-path effects.

Code Division Multiplexing:

A number of techniques have been investigated for communication over an underwater acoustic link where one end is equipped with a single transmit/receive element and another with an array. To achieve maximal bit rate within a fixed bandwidth, an optimization criterion of maximizing the data detection SNR, while eliminating or minimizing the residual ISI was chosen. Transmit/receive filters were obtained analytically for uplink and downlink transmission, with varying degrees of system complexity. But this system also had a lot of problems. Hence Code Division Multiplexing is deployed. Here also the degree of complexity is more. But the high data rates offered by this technology is the price paid for the hardware complexity.

The figure shown below is the general block diagram for implementation of Code Division Multiplexing In Ultrasonic Communication.



First the Serial data is converted into parallel data using a Serial to Parallel Converter. Then the data is split-up into small data packets (in case of bulk data). There are N number of PN sequence Generators which generate PN sequences of a higher Chip rate. The (N) number of Direct Sequence encoders present in the transmitter spread each packet with a particular PN sequence and transmits them at the fundamental frequency (f). The out put of each individual encoder is a particular data packet encoded with a particular PN sequence. Then the signal is multiplexed so that it can be transmitted in a single channel and in a single frequency.

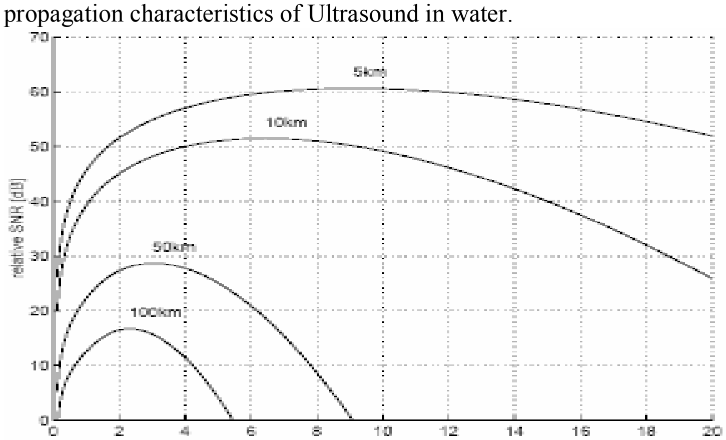
In the block diagram, the radiation section is given a as a general name. In case of Ultrasonic Communication, there are N numbers of radiating Piezo electric crystals which form an array. This Multi-Element Piezo Array is used for transduction (conversion of electrical signal to ultrasound). This conversion is done using the concept of Inverse Piezo Electric effect. Here, each signal is transmitted at a fundamental frequency (f) and it corresponds to a fundamental (real) data rate B. But the Overall/ Virtual speed B' = (N X f) i.e., it is multiplied by a factor N. Hence the Bandwidth offered becomes virtually very high.

In the receiver, with the help of the same kind of N' Multi-Element Piezo Array (operating at the same fundamental frequency f), the signal is detected. The signal is then amplified and given to the N Code Division Decoders which decode the signals into the corresponding data with same set of PN sequences. Then, the original video data is obtained by Segmentation And Reassembling.

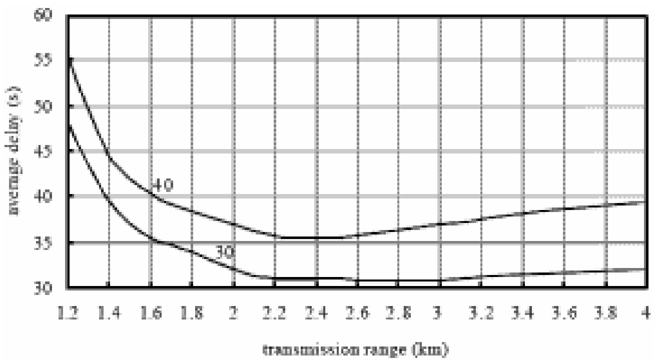
The ambient noise in shallow water tends to be non-Gaussian. Standard techniques such as match filtering used in communication schemes is often tuned for Gaussian environments. Knowing the statistical characteristics of the noise allows better detectors and communication schemes to be Doppler correction. As electromagnetic radiation travels much faster than any mobile station, Doppler shift does not play an important part in wireless communication. However, Doppler shift due to movement of the communicating modem or due to water currents can easily be significant in the ocean due to the fact that the sound speed in seawater is much lower. Uncorrected Doppler shift may easily cause significant degradation in communication. So Doppler shift is also considered as an important parameter

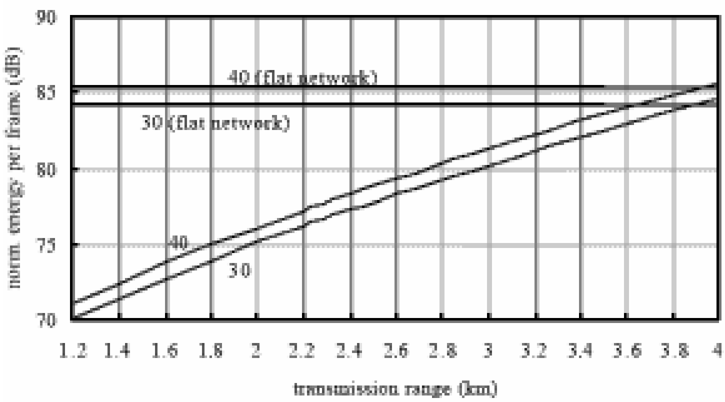
In communication schemes where the synchronization signal is sent over the communication channel, the Doppler shift may automatically be corrected if the synchronization signal Doppler shift automatically compensates for the data signal Doppler shift. This, however, depends on the way the synchronization signal is encoded. In general, the acoustic modem should allow for Doppler correction by monitoring multiple shifted frequencies. A Kalman filter is used for tracking the Doppler shift of a peer modem in real-time for cases.

Here are some of the simulation results which give various information about the channel Conditions and the propagation characteristics of Ultrasound in water.



The simulation result shown below gives the Average time delay and Normalized energy per frame as a function of transmission range.





Conclusions:

High Data rate is achieved by processing the data in a parallel fashion and then transmitting it in a parallel way, receiving it in a parallel way and again processing it in a parallel fashion. Thus, Implementation of Code Division Multiplexing in Ultrasonic communication will make Communication systems perform better by increasing the BER and the Coverage area. Though this leads to increase in hardware complexity, the data rate offered is very high. Hence, there is a trade off between the Speed and Hardware Complexity.

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