CHANNEL MODELLING FOR UNDERWATER WIRELESS COMMUNICATION SYSTEM

Nilesh Kumar[1], Asst. Prof. Mr.Nikhil Ranjan[2], Dr.Manish Jain[3]
[1]Research Scholar, M.tech (Digital Communication),[3]Head of Department, RKDF IST, Bhopal

Abstract: Now days, underwater wireless communication is getting lot of popularity. Few years before it was related only to military and defense applications. But now it is used in commercial field also.Design of underwater wireless communication is very difficult as behavior of water is completely different than air. We have to take lot of parameters into consideration at the time of design. Also, the losses and noise are comparatively very high in underwater than that of in air. Hence long distance communication is practically very difficult to design. The Electromagnetic waves (EM), Magnetic Induction (MI), Optical waves or acoustic waves are the choices for underwater wireless communication systems. Out of these, acoustics are proven to be best underwater although they are limited with bandwidth due to thermal noise. But still acoustics provide communication at large distance comparing to other due to its special property of low attenuation of sound underwater. The currently favorable technology for underwater communication is upon acoustics. In this paper we present the parameters of acoustic channel, characteristics of acoustics, its mathematics and analysis. Also, we take a look at modulation technique that can be used in transmitter and receiver.

Keyword: Acoustic communications, Channel models, deep water, Shallow water, underwater networking

I. INTRODUCTION

All most 70% of the surface of earth is covered with water. It contains large amount of energy and natural resources and hence for exploring these resources, development of effective underwater wireless communication system became very important. Due to number of applications like scientific marine exploring, pollution controlling, voice and data communications between divers, mine reconnaissance, study of disasters, military projects, etc. the field of underwater wireless communication is rapidly increasing. Also, shipbuilding and offshore engineering is taking lot of interest in it. So, obviously it is one of the important communication media for communication researchers. Underwater wireless communication is an enabling technology for oceanography and its applications. But, development of underwater wireless communication system is not that much easy as it is totally different from terrestrial radio environment both in terms of energy, cost and channel propagation.

1.1 MAJOR CHALLENGES

- The available bandwidth is very limited which causes reduction in transmission range
- The underwater channel is mainly impaired due to multipath and fading
- Propagation delay in underwater wireless communication is five times higher than RF terrestrial channel
- Underwater sensors are very costly. And very high protection is required for these sensors. Also most of the times they fail due to corrosion
- Battery power is very limited and it can't be charged as solar energy can't be exploited.

Out of EM, MI and acoustic waves most of the applications are done by using acoustics as they are proven to be excellent in underwater compare to others as they provide wide range up to 10 km with very small antenna size nearly about 0.1m. Also, power loss in underwater acoustics is very small compare to EM and optical waves in sea environment. The basic problems in front of underwater acoustic communication are limited sound velocity, absorption of a sound in water, multipath propagation, ambient noise, Doppler's spread, etc. Small change in sound velocity also causes lot of effects on underwater communication system. Multipath propagation is due to the surface reflection and bottom reflection and mainly present in shallow water.

1.2 Applications of Underwater wireless acoustic networks

The applications of underwater wireless communication are given in terms of environmental, marine, scientific and military system. Table 1.1 gives applications of UWCN.

Environmental	Marine	Scientific	Military
Pollution	Finding natural resources	Oceanography	Bottom imaging
Finding oil and gas Sources	To study marine life	Geo sciences	Detection of underwater objects
Protection of ships	Finding resources in deep sea	Marine biology	Threat detection
Weather study	Pollution controlling	Seismic study	AUV controlling

Table 1.1 Applications of wireless communication

II. OVERVIEW OF UNDERWATER WIRELESS COMMUNICATIONS

Underwater wireless acoustic communication system is a two way communication system in which digital data is

converted into special underwater sound signals [1]. Then these signals are received by another Transreceiver and then converted back to digital data. This communication is done in multipath propagation of acoustic/sound signal.

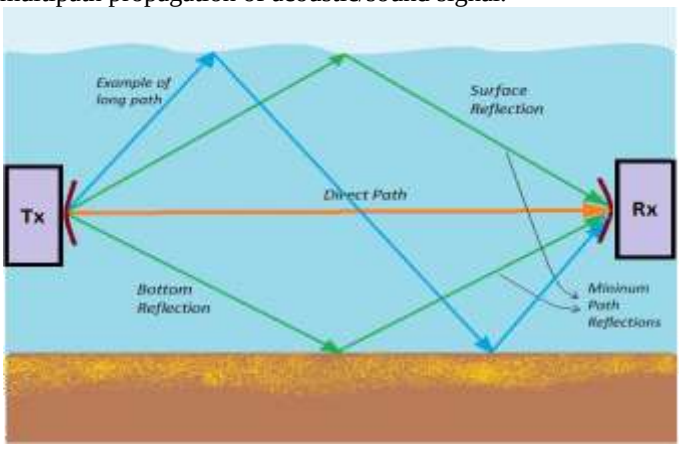

Figure 1.1: Overview of Underwater wireless communication

III. DIFFERENT TYPES OF WAVES

- EM Waves

Electromagnetic radiation is one of the many ways that energy travels through space. The heat from a burning fire, the light from the sun, the X-rays used by your doctor, as well as the energy used to cook food in a microwave are all forms of electromagnetic radiation. While these forms of energy might seem quite different from one another, they are related in that they all exhibit wavelike properties. EM waves are the waves with frequency between 400 MHz to 300 GHz. They are very good for short distances and proven better in shallow water but for deep underwater and salt water it fails.

- Magnetic Induction (MI) waves

Electromagnetic or magnetic induction is the production of an electromotive force (i.e., voltage) across an electrical conductor in a changing magnetic field. Michael Faraday is generally credited with the discovery of induction in 1831, and James Clerk Maxwell mathematically described it as Faraday's law of induction. Lenz's law describes the direction of the induced field. Faraday's law was later generalized to become the Maxwell–Faraday equation, one of the four Maxwell's equations in James Clerk Maxwell's theory of electromagnetism. Electromagnetic induction has found many applications in technology, including electrical components such as inductors and transformers, and devices such as electric motors and generators. MI waves came into a picture of underwater wireless communication design to reduce a path loss. Basically, MI waves are tolerant to losses and they usually don't impact on marine life. Even they are very immune to acoustic noise which is a better property of MI waves. It can't be affected by multipath propagation or fading. Also Magnetic Induction waves provide superior bit error rate in fresh water. Magnetic induction can give important applications like diver-to-diver communication, voice and text telecommunication, real time data transfer between AUV's. Telemetry and remote control from underwater or surface equipment is also possible.

- Acoustic Waves

Acoustic waves are proven and now a days mostly preferable technology due to its long transmission capability at small frequencies. It can travel up to 200 Km. They provide stable characteristic properties at long distance. Also Acoustics have excellent proven characteristics for both transmitter and receiver as in terms of transmission the results through acoustics under saltwater are far better than EM waves.

IV. CHARACTERISTICS OF OCEAN ACOUSTICS

4.1 Acoustic waves underwater

The frequencies between 0 KHz to 100 KHz are generally chosen for underwater acoustic communication. In case of acoustics we have to consider attenuation, absorption and ambient noise which are key parameters for characterization and Modelling of channel. The main problem during design of a channel is, all these parameters increase with increase in frequency and affect communication system badly. Hence, proper selection of a frequency for underwater is a key thing for good system design.

4.2 Attenuation due to bottom reflection

This parameter is also very important in terms of attenuation. Attenuation due to bottom reflection mainly depends upon bottom type or sand type lie very fine slit sand, fine sand, coarse sand or medium sand.

4.3 Ambient Noise

Ambient noise is one of the most important characteristics to be considered while channel Modelling. There are different types of noises like noise due to heavy traffic of ships, noise due to rain, noise due to wind, noise due to earthquake or breaking of waves, etc.

V. MODULATION TECHNIQUES OF COMMUNICATION

- **What is modulation?**

Generally, the transmission of a message signal over a low frequency must be converted into higher frequency range, and then it reduces the antenna size. And after successful transmission we can shift it back to original frequency range after reception. Consider one example, suppose we have frequency of 1 KHz. Hence, wavelength can be given as, that is λ = 300 Km. Design of an antenna for wavelength of 300 Km is practically impossible. Hence to reduceλ we have to increase the frequency. For this modulation technique is used. In short we can say modulation is defined as the process in which "carrier signal is varied in accordance with message signal". Generally, in modulation technique, the baseband signal is a "modulating signal" while the carrier signal is a high frequency sinusoidal signal.

- **What is Demodulation?**

After the message is successfully received, it must be converted into its original format. This process is done by demodulation of a signal which is exactly inverse of modulation process.

5.1 Different modulation techniques

There are three basic modulation techniques also known as

keying technique. These three techniques are based on three different parameters namely amplitude, frequency and phase. According to these parameters system performance can be analyzed. Each technique has its own advantages and disadvantages. They are as follows

- **Amplitude Shift Keying (ASK)**

Amplitude shift keying is a technique in which the digital bit '1' is represented in the form of amplitude. If a transmitted signal transmits bit '1' then carrier is transmitted otherwise '0' is transmitted. The demodulator at output side recovers the data in the form of amplitude keeping frequency and phase constant. Generally ASK is used to transmit data through optical fiber.

Advantages
- Significant reduction in transmission energy
- Simplicity
- Easy to generate and detect

Disadvantages
- Easily influenced to noise interference
- It is used at very low data bit rates (usually 100 b/s)

- **Frequency shift keying (FSK)**

In frequency shift keying, sine wave is shifted in accordance with change in frequency. Bits '1' and '0' shows compression and expansion of a signal at output. The higher frequency given to bit '1' known as Mark Frequency where the frequency representing '0' known as Space Frequency. A modem converts binary data into FSK signal for transmission through telephone lines or wireless media. It is in a format of low and high state which is known by system. Generally at the transmission input signal given is a NRZ signal.

Advantages
- Reduction in noise as amplitude is constant
- High data rate and greater signal strength

Disadvantages
- Requires very high bandwidth
- High complexity in circuitry

- ***Phase shift keying (PSK)***

Phase shift keying is a technique in which phase of a message signal is varied while transmission of a signal. The simplest technique of phase shifting in digital communication is Binary phase shift keying which is dependent on two phase angles 0 degree and 180 degree. The digital transmission signal is divided into two parts and next bit is determined by taking a reference of a previous bit. For 0 degree the transmission of a bit is normal but when phase changes from 0 degree to 180 degree, transmission also changes from '0' to '1' or '1' to '0'.

Advantages of PSK
- High power efficiency
- Simple design
- Work very effectively at low transmission frequencies

Disadvantages of PSK
- Very low speed communication
- Low bandwidth efficiency
- Very low transmission power

VI. CONCLUSION

Thus, we say channel modulation for underwater wireless communication is extremely difficult as it mainly depends upon multipath propagation. The channel variation causes degradation in bit error rate. Also, we don't have too much flexibility to change signal frequency range too high because most of the underwater parameters are dependent on frequency.

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