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DESIGN of LASER BASED UNDERWATER COMMUNICATION SYSTEM

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Abstract

In this study, laser based communication system was used as an alternative to the communication executed with wires by underwater teams. Green light was employed as the carrier signal for the reason that it could proceed underwater with lowest refraction apart from the refraction of red and yellow light. Sound signals were transported from one point to another by imposing them on green light, in other words by using modulation process. Communication between two underwater teams was performed reciprocally.

LAZER TABANLI SU ALTI HABERLEŞME SİSTEM TASARIMI

Özetçe

Bu çalışmada, su altı timlerinin telli olarak gerçekleştirdikleri haberleşmeye alternatif olarak lazerin kullanıldığı bir haberleşme sistemi gerçekleştirilmiştir. Yeşil ışık, su altında en fazla kırılmadan ilerleyebildiği için taşıyıcı olarak kullanılmıştır. Ses işaretleri, yeşil ışığın üzerine bindirilerek yani genlik modülasyonu işlemi gerçekleştirilerek bir noktadan diğer bir noktaya iletilmiştir. İki su altı timindeki haberleşme çift taraflı gerçekleştirilmiştir.

Keywords: *Green laser**,** Underwater communication, Optical communication, Amplitude modulation.*
Anahtar Kelimeler: *Yeşil lazer, Su altı haberleşmesi, Optik haberleşme, Genlik modülasyonu.*

1. Introduction

Information is transmitted from one point to another via modulation. Modulation, forming the basis of communication, is the process of transmission of low frequency data signal with high frequency carrier signal. As it could be understood from the description above, we need two signals for modulation process. These are data signal (voice, music, map, video) to transmit and high frequency carrier signal. For three reasons modulation is a necessity. First, low frequency data signal has not that much energy to travel far distances. Second, if low frequency data signal were not imposed on carrier signal, in other words if not modulated, the dimension of the antenna would be inefficiently long. It is because the dimension of the antenna is inversely proportional to frequency. Third, data signal bandwidth is 20 Hz-20 KHz and assuming the frequency range of amplitude modulation is 5-10 KHz, there could be a few stations established. For these causes modulation as basis of communication is a demanding tool needed to be used.

In literature there are some works on underwater communication. M. Sui and his friends have augmented underwater communication quality via pulse-position modulation (PPM) with error control code [1]. M. Chen and his friends have constituted another PPM application [2]. In another work LDPC (Low Density Parity Check) code is applied to PPM communication system [3] and optical communication is implemented in a wireless communication network [4]. N. Farr and his friends have integrated optic and acoustic communication system [5].

Since voice signals could propagate well enough in water, for acoustic systems they provide proper underwater communication. But the depth must not be much deeper than 100 meters. Underwater communication has a very wide bandwidth but it is established in a short range because of the attenuation of propagating light through water channel.

The fundamental idea of underwater optic communication system is to transmit information via light signals. For that reason selected type of light is quite important. Blue light has the most efficient wavelength to travel at deepest level underwater. Because two divers could not stay much distant and could see each other, green light is implemented in the application.

Table 1. Color Spectrum

COLOUR	FREQUENCY	WAVELENGTH
Blue	631-668 THz	450-475 nm
Green	526-606 THz	495-570 nm
Yellow	508-526 THz	570-590 nm
Orange	484-508 THz	590-620 nm
Red	400-484 THz	620-750 nm

In Table 1 some of the color frequencies and wavelengths are given [6]. Because different colors of light are absorbed in different levels underwater, every depth level has a different spectrum characteristic. Above three meter depth spectrum is very near to day light. After 15-20 meter depth blue and purple colors, having the most refraction, cover much more space in the spectrum.

In order to obtain an underwater optic communication system, there are two attenuation parameters to be improved near with propagation of light and background noise. First of these parameters is the attenuation constant of beam of light [7].

$$I_t = I_0 \exp(-\alpha z) \qquad (1)$$

I_0= Original light intensity (watt/m^2),
I_t= Propagating light intensity,
z= Range of light,
α= Beam attenuation constant.

Unit of attenuation constant of beam of light is m^{-1} and used at finding laser attenuation underwater. It is not dependent of wavelength and approximately equal to 0.02 m^{-1} in clear water.

The other attenuation parameter is signified with letter K and it describe propagation of light.

$$I_t = I_0 \, exp(-Kz) \qquad (2)$$

Unit of propagation attenuation constant is m^{-1} and defines attenuation value of light travelling deep into water like sunlight. This parameter is also not dependent of wavelength. K is 0.02 m^{-1} in clear water and 0,8 m^{-1} in shallow water.

2. Laser's Modulation

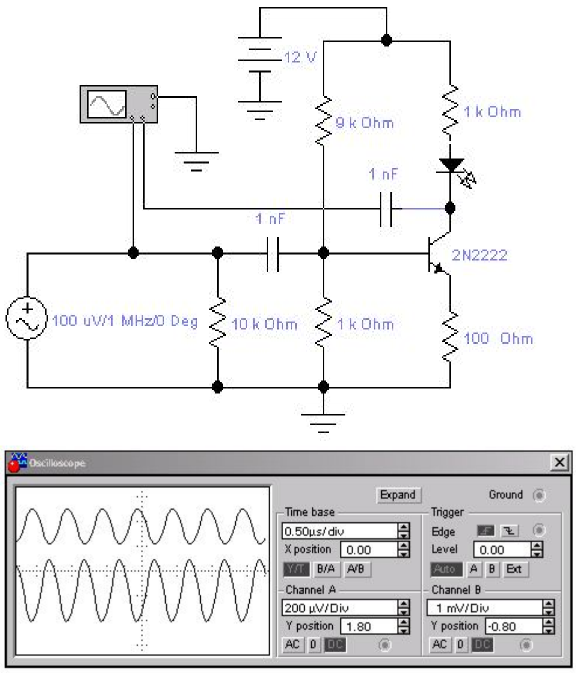

Figure 1. Laser driver circuit

Laser driver circuit is shown in Figure 1. Voice signal which modulate the laser connected to collector of the transistor, is represented as a sinusoidal signal [8].

Because the change of amplitude of the green laser light is controlled by voice, output signal at the transmitting level is an amplitude modulation signal. According to amplitude modulation, amplitude of carrier signal changes expediently with data signal. Carrier signal could be described as below [9]:

$$e_c(t) = E_c \cos(\varpi_c t + \phi) \tag{3}$$

E_c= Carrier signal's peak amplitude (volt),
ϖ_c= Carrier signal's frequency (rad/s),
ϕ= Phase angle.

Phase angle could be omitted because it may have any value. Modulated voice signal data could also be stated as below.

$$e_m(t) = E_m \cos(\varpi_m t) \tag{4}$$

E_m= Modulating signal's peak amplitude (volt),
ϖ_m= Modulating signal's frequency (rad/s) dır.

When $e_m(t)$ has modulated E_c, equation (3) changes to equation (5):

$$e_{AM}(t) = (E_c + E_m \cos\varpi_m t)\cos\varpi_c t \tag{5}$$

When Ec has put in parenthesis and all terms are multiplied by $\cos\varpi_c t$ equation (5) could be rewritten as below:

$$e_{AM}(t) = E_c\left(1 + \frac{E_m}{E_c}\cos\varpi_m t\right)\cos\varpi_c t \tag{6}$$

Em/Ec is the rank of amplitude modulation and represented with letter "m". Generally it is expected to take a value lower than one.

$$e_{AM}(t) = E_c \cos \varpi_c t + m\frac{E_c}{2}\cos(\varpi_c + \varpi_m)t + m\frac{E_c}{2}\cos(\varpi_c - \varpi_m)t \qquad (7)$$

In this equation the first term represents the carrier signal, the second term represents upper side band and the last term represents lower side band. When an amplitude modulation has been implemented with a single frequency voice signal, upper and lower sides of the signal form an upper side band and lower side band.

3. Design and Implementation of the System

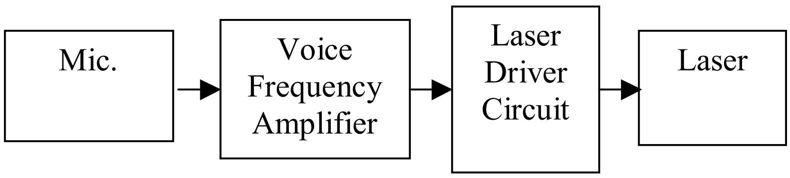

Figure 2. Transmitter circuit

In Figure 2 transmitter circuit is shown. Voice signals are turned into electric signals. Voice frequency amplifier consists of two stages. The first amplifier stage is BC 548 Transistor and the other stage is 741 Opamp. Laser light intensity is changed by the voice signal which is amplified enough via laser driver circuit. 532 nm wavelength, less than 50 mW output power is occupied by green laser. At the transmitter stage green laser is employed as the carrier and voice signal is employed as modulating signal. Voice signal amplified at voice frequency amplifier stage, modulates laser's light. Because the laser's light intensity is changed by the voice signal, the output is an amplitude modulation signal.

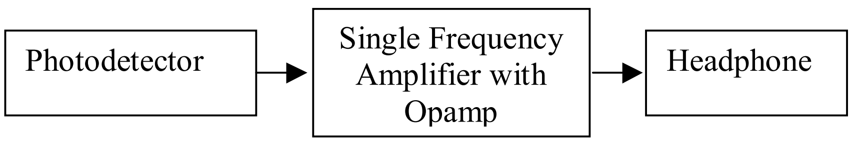

Figure 3. Receiver circuit

In Figure 3 the receiver circuit is shown. Laser light of which the light intensity changes at the transmitting stage according to the voice signal is sent to the photodetector positioned at receiver circuit. Light intensity changes at the transmitting stage parallel to voice signal's amplitude and could be detected by the photodetector. At the receiver stage FPT 100 phototransistor is used. Phototransistor's current is changed by the intensity of light. Incoming light intensity causes a voltage and the signal caused by the change of that voltage is applied to the input of Opamp via coupling capacitor. From now on amplified voice signal can be heard by headphones.

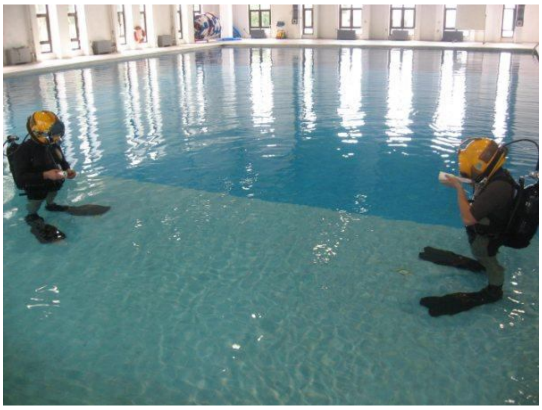

Figure 4. Implementation of the system

As shown in Figure 4 both the transmitter and receiver circuits are arranged as waterproof and modified to a diver's suit. Diver's cap is equipped with a microphone and a headphone. As shown in Figure 5 inside the waterproof bag both the receiver and transmitter circuit is located.

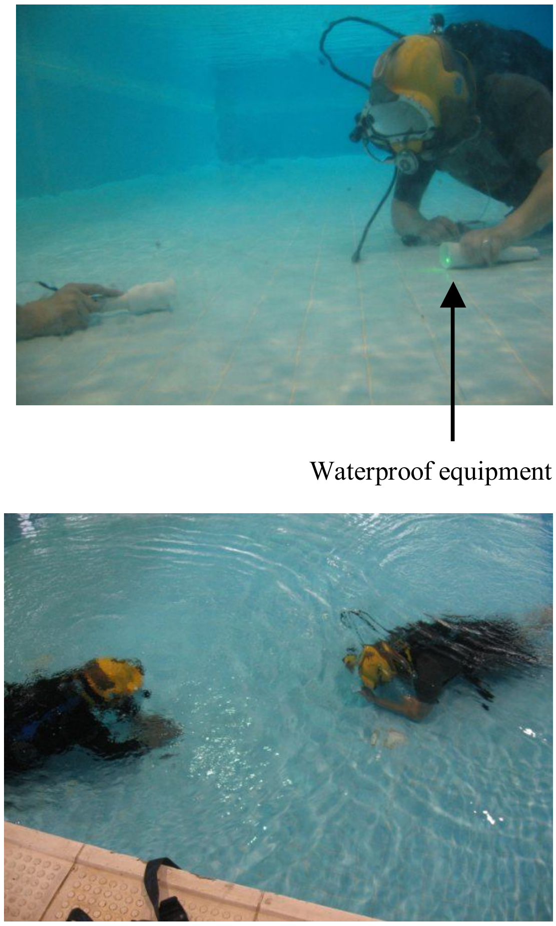

Figure 5. Implementation of the system

4. Conclusion and Evaluation

Optoelectronics play the most important role at transferring data in a secure way as the information occupies an important position nowadays. Whoever store more information and whoever transfer it in a more secure way, could be powerful and effective that much.

As an alternative way to the communication through wire which is used by divers and underwater teams, laser communication system has achieved to communicate underwater without wire in a 12 meter swimming pool.

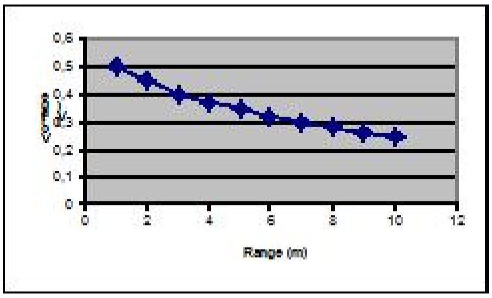

Figure 6. The change of potential difference according to distance

In Figure 6 voltage induced on photodetector by means of laser light reaching to its surface is given. The reason for degrading slope in the chart, is the decreasing light intensity inversely proportional to range. After all communication was established from 12 meters which is the maximum range of the swimming pool. In addition to that if power supply of the laser is increased, the range of communication would also be increased.

When amplitude modulated laser light arrived to the surface of photodetector with 0° view angle, the most affective voice detecting achieved. Here, phototransistor's receiving power is directly proportional to the cosine of view angle. With an arrival angle greater than 60°-70°, laser light could not touch the sensitive surface of the detector and prevent to obtain a clear communication.

Laser based underwater communication system has been tested between two divers successfully. In case of increased power output of laser light, the range of communication will expand to allow submarines' voice communication. Also the system could be arranged for exploration purposes in unmanned navy vehicles and autonomous underwater vehicles.

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