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Design and Implementation of Optical Wireless Communication System

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الخلاصة

تم في هذا البحث تصميم وبناء منظومة اتصالات ضوئية رقمية لنقل قناتين صوتية بأتجاهين متعاكسين بوقت واحد بتقنية الإرسال الآني مع تأمين خط النظر تعمل باستخدام أشعة الليزر كوسط ناقل للمعلومات في الفضاء الحر.
ان بناء منظومة الاتصالات الضوئية تضمنت بوردين الكترونيين يحتوي كل بورد على وحدة ارسال واستقبال ، وباستخدام تقنية التضمين النبضي المشفر PCM لنقل قناة صوتية يتراوح ترددها بين 0.3 – 4 kHz ومعدل نقل البيانات الرقمية لهذه المنظومة 100kbps باستخدام تقنية توشير اللاعودة الى الصفر لقد تم تحقيق حلقة اتصال صوتية بوقت واحد وبوضوح عالي الدقة وعلى مديات وصلت الى مسافة 1300 m وتم حساب نسبة الإشارة إلى الضوضاء S/N فوجد انها تساوي (21.1dB) .

Abstract

In this paper, we have designed and constructed an optical communication system to transmit two-voice channel full duplex technique with line of sight, which uses a laser beam as a carrier wave in free space. The constructed system consists of a tranciever (transmitter and receiver) for both sides. The transmitter part includes a laser source and other transmitter accessories as well as a receiver component. Pulse code modulation (PCM) technique has been used to transmit voice signal. High quality sound communication link for a distance reaching about 1300m is achieved with signal to noise ratio (S/N) equal to 21.1 dB.

1. Introduction

Free space laser communications systems provide only interconnection between points that have direct line of sight, an optical through-the-air technique has a very large information handling capacity [1].There are three basic modes of the transmission techniques, simplex-the transmission of information occurred only in one direction, half-duplex the information can travel in both directions by one channel, full-duplex the information can be sent instantaneous through two separate channels[2]. Free space laser communication has many advantages such as; no communication license is required, no cables need to be burial, no complex network of switches and amplifiers are needed, large information capacity and no agreements need to be made with landowners[3]. This "free space" technique requires only a clear line-of-sight path between the transmitter and the distant receiver to form an information link. The valiability of a coherent, monochromatic optical communication which, due to the very high frequency of the carrier (10^{14}Hz), would allow a very large amount of information to be transmitted. Figure (1) shows a block schematic of a typical digital optical communication system, initially the input digital signal from the information source is suitably encoded for optical transmission. The laser drive circuit directly modulates the intensity of semiconductor laser with the encoded digital signal. The photodetector is followed by a preamplifier to provide gain. Finally, the obtained signal is decoded to give the original digital information [4].

2. Expermantal work

The full duplex optical communication system consists of a tranceiver unit which consist mainly of the transmitter unit and receiver unit, The signal could be sent and received in a free space between two termina 1 and 2 as illustrated schematically in figure (2).

2.1 Transmitter Unit

This unit includes the microphone, buffer amplifier LM324, stage amplifier IC741, sampling and hold circuit, analog to digital converter (ADC) AD574A, microcontroller AT89C51, circuit drive NAND Gates (7400) for laser and laser source, figure (3) shows the transmitter circuit. The sound wave will be entered by a microphone, this signal will be amplified and converted to a digital signal by using analog to digital converter (ADC) with sample resolution of 8 bits per sample, the microcontroller used to convert the 8 bits parallel to serial, the serial digital data which comes from the microcontroller can be driven to the laser by using a driver circuit, which applies the needed current to the laser in order to control of the output power of the laser, The properties of the laser diode used through the paper is output power 5mW, wavelength 650nm and angular diverging of beam 0.6 mRad.

2.2 Optical Antenna & Optical Receiver

The output power of the laser transmitter is often collimated by a transmitter optical antenna called a beam expander, which is used to reduce the beam divergence. Since our aim is to send the laser beam to longer distance and reduce the beam divergence, a Keplerian type beam expander was used, which is consists of two positive lenses positioned in front of the laser source [5].

In the receiver antenna, we used one convex lens to collimate the laser beam to the area close to the detection area of the detector. For this purpose, we used lens with diameter 6 cm and focal length 5 cm.

2.3 The Receiver Unit

The receiver unit consists of a PIN Photodetector with large area (100 mm^2) and responsivity 0.4 A/W for wavelength 650 nm, pre-amplifier IC741, microcontroller AT89C51, digital to analog converter (DAC) AD667, audio amplifier, and speaker, figure (4) shows the receiver circuit .

The digital signals are carried on the laser beam in free space, then sent to the receiver, the laser power is converted to a weak electrical signal by the photodetector, this signal was amplified, by a two stage preamplifier, and then converted back to analog signal by using digital to analog converters (DAC) to produce the original transmitted signal.

3. Results & Discussions

3.1 Input and Output Voice Signal

we have observed a small difference between the input analog signal from microphone and the output analog signal from speaker is due to the thermal noise effect as shown in the figure (5).

3.2 The Power Received in Free Space Optical Link we found that the amount of the received power is proportional to the amount of power transmitted and the area of the collection aperture ($A_{receiver}$). It is inversely proportion to the square of the beam divergence (Div) and the square of the link range(R). It is also inversely proportion to the exponential of the product of the atmospheric attenuation coefficient (μ) .The total power of the received signal through the earth's atmosphere can be calculated by[6] :-

$$P_{receiver} = P_{transmit} \times \frac{A_{receiver}}{(Div * Range)^2} \times \exp(-\mu * Range) \quad ....(1)$$

$$A_{receiver} = \pi \times (D^2 / 4) \quad ....(2)$$

where D is the receiver optics diameter.

In the theoretical measurement calculation the power received according to equation (1) at Range = 1300m is $P_{receiver}$ =14.3 µW.

In the experimental field calculation the power received of laser beam by the digital power meter is $P_{receiver}$ =0.9 µW.

The system designed in clear weather, which is the attenuation coefficient equal to 0.1km-1. The differences between the theoretical calculations and the experimentally measured values for the received laser power at long distances are due to the absorption and scattering effect on the divergent laser beam.

3.3 Signal to Noise Ratio Calculations

The total signal to noise ratio (S/N) at the optical detector for the distance (1300m) can be calculated according to the equation[7] :-

S/N in dB=20 log10 (S/N) (using voltage or current ratio).....(3)

the signal to noise ratio of the system could be calculated as follows:-

S/N = 20 log(0.36*1000 nA / 31.4 nA) = 21.1 dB

It is noticed that S/R decreases with the increase of the range between the transmitter and receiver as shown in figure (6).

The Bit Error Rate (BER) may be calculated depending on the SNR value.

Shown the figure (7)

3.4 Power Budget of the PCM System

The power budget is calculated if the transmitted power is P_t and the minimum required receiver power is P_{min} , the power budget is the ratio[8] :-

$$\text{Power budget} = \frac{P_t}{P_{min}} \qquad \text{…................................(4)}$$

Let S/N equal to (1)

$P_{min}= i_s /R$, $P_{min} = 88$ nW

power budget= P_r / P_{min}

Therefore the power budget was equal to 47.4dB

4. Conclusions

From this study, we can conclude the following:-

By using a suitable optical transmitter antenna(beam expander) the beam divergence of the laser beam decreases which leads to increase the communication range for the same laser source, the maximum distance of free space optical link is limited by the output power of the optical source. From the calculations results obtained, it is concluded that the maximum distance of the free space optical link can offer, approximately 1.3 km. Therefore, the maximum distance may be increased either by increasing the transmitter power, or by increasing the gain values of the receiver amplifiers then the minimum required received power would decrease .Also the maximum distance of free space optical link is limited by the noise and atmospheric attenuation. It is noticed that signal to noise ratio (SNR) decreases with the increase of the range and the bit error rate (BER) increases with increase of the range, the power budget increases, as the transmitted optical power increases, however it decreases, as the minimum detectable power increases.

Reference:-

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[7] 12.444/503a Optical Components & Communication, 2001.

[8] J. M. Senior, “Optical Fiber Communications Principles and Practice“, 2nd ed., Prentice Hall, 1996.

Figure captions:-

Figure (1) Schematic block of a typical optical communication system
Figure (2) Main unites of the full duplex system
Figure (3) The transmitter circuit
Figure (4) The receiver circuit
Figure (5) input and output waveform voice signal
Figure (6) The relation between the S/N and range
Figure (7) Bit error rate versus signal to noise ratio

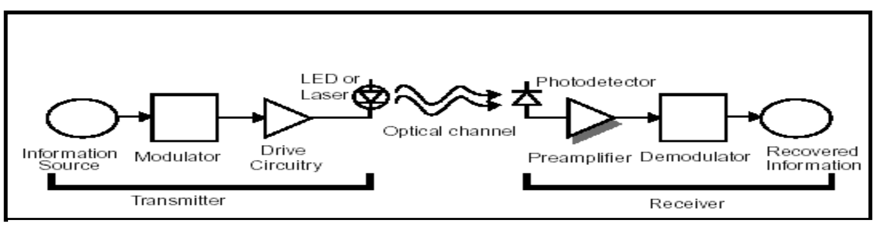
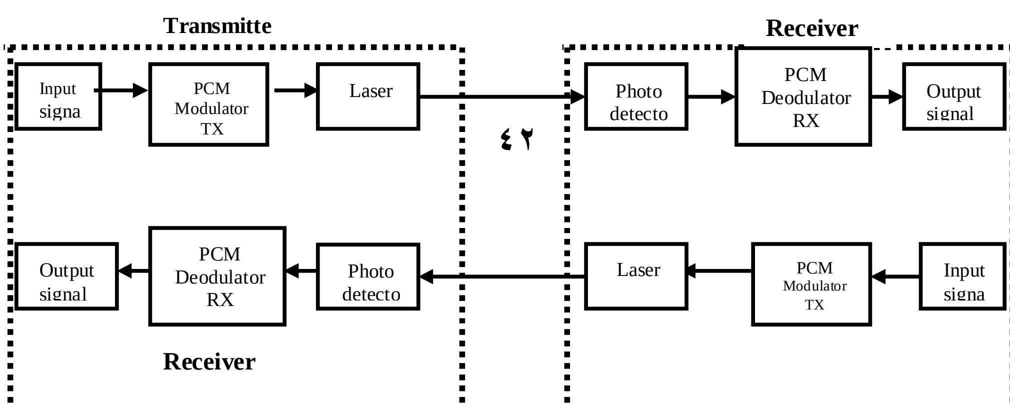


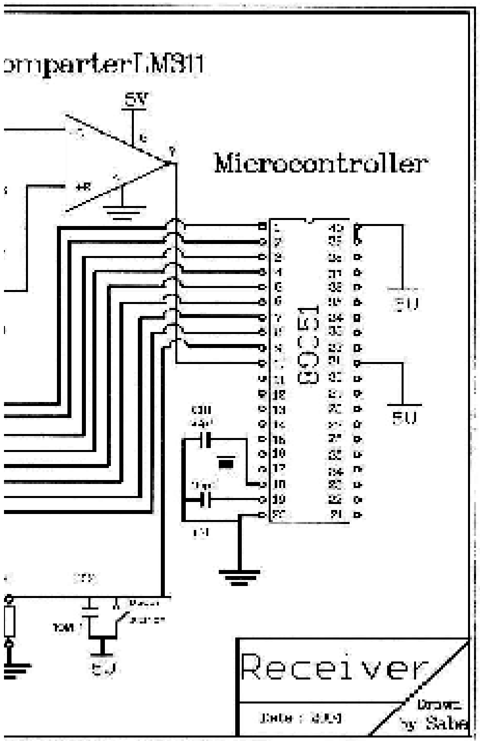
Figure (1)

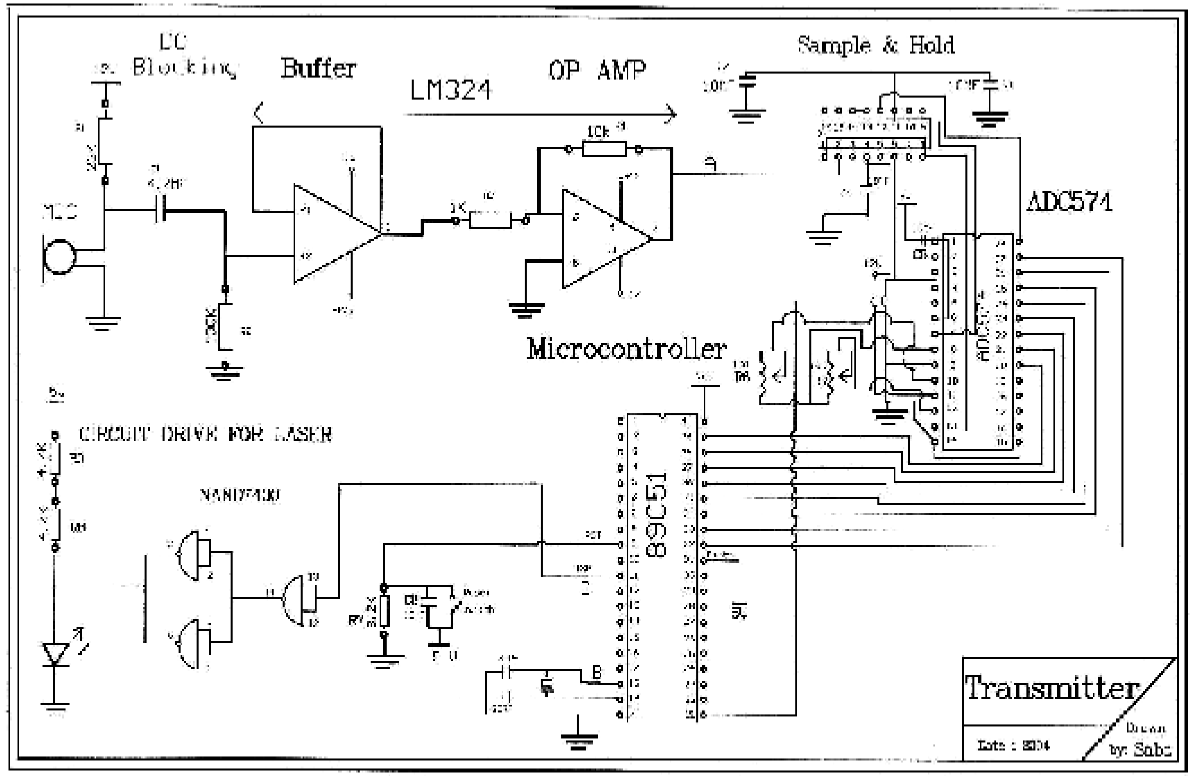


Figure(2)

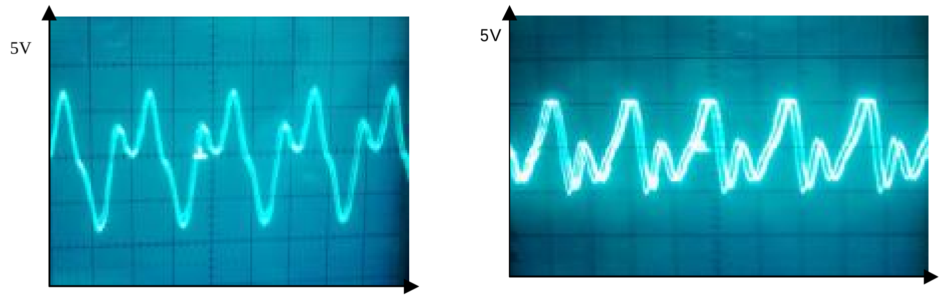
Transmitter

Free space


omparterLM311
5V
Microcontroller
89C51
5V
5V
Receiver
Drawn
by Saba


DC
Blocking
Buffer
LM324
OP AMP
Sample & Hold
ADC574
MIC
4.7nF
100K
10K
1K
Microcontroller
CIRCUIT DRIVE FOR LASER
NAND7400
89C51
B
Transmitter
Drawn
by Saba

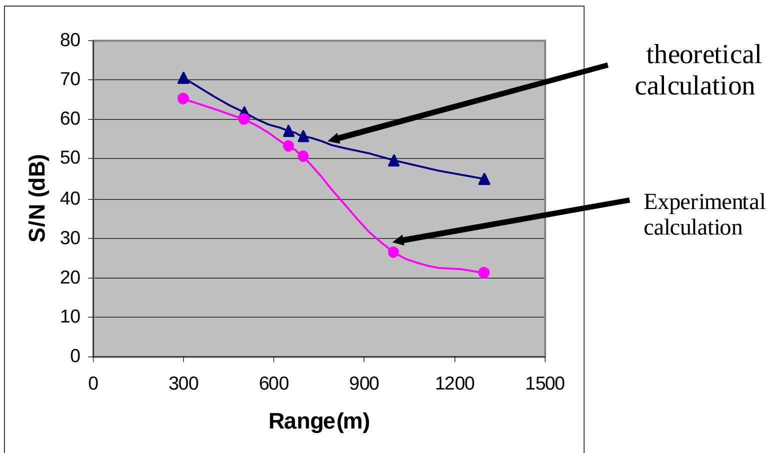
Figure(3)



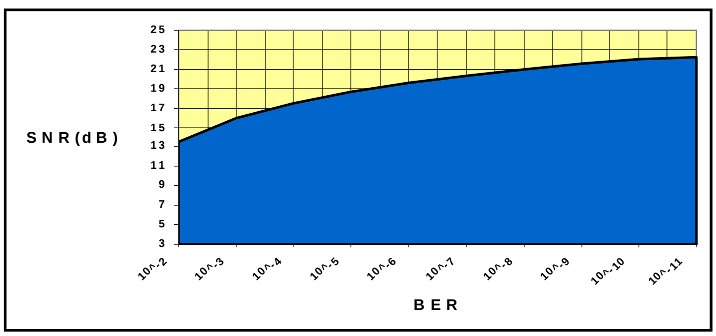
The waveform voice signal after the microphone & amplifier

The waveform of voice analog signal output before the speaker

Figure(5)



Figure(6)



Figure(7)