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Design and Study of an Optical Fiber Digital Transmitter

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Abstract: The optical fiber digital transmitter has been designed for an audible frequency range and parameters like bandwidth, attenuation, intensity and the performance of different components were measured and analyzed. The system performed up to expectations. This paper also gives a basic overview of optical fiber communication system.

Key words: Optical fiber, bandwidth, LED, frequency, density, analog, digital signal

INTRODUCTION

The present century is era of information technology and the communications. The communication systems involve a transmitter, transmitting medium and a receiver. An optical source can be either a Light Emitting Diode (LED) or Solid-state Laser Diode (SLD). Such optical devices can transmit signals having wavelengths of 850, 1300, or 1550 nanometers (Wang *et al*., 2004). The transmitter consists of an analog or digital interface a voltage to frequency converter, a light source and source to fiber optical coupler. The fiber guide is either an ultra pure glass or plastic cable (Kihara and Onishi, 2003). In an optical fiber transmitter, the light source can modulate by a digital or an analogue signal. For analog modulation, the input interface match impedances and limits the input signal amplitude. For digital modulation, the original source may already be in digital form or, if in analog form, it must be converted to a digital pulse stream. For the later case, an analog to digital converter (voltage to frequency converter) must be included in the interface. The voltage to current converter is used to drive the light sources. The amount of light emitted by either an LED or an SLD is proportional to the amount of drive current (Carter, 1988).

The study intends to provide opportunity to understand the optical devices and their role in the optical fiber communication system.

All the signals are continuous in the natural form. The transmission of such signals is called analog communication. The signal in its natural form is the base band signal and becomes carrier signal when base band signal is modulated with a signal of high frequency. Base band can be transmitted over a pair of wires or coaxial cable. Local telephone communication also uses base band communication (Agrawal, 1997). In modern communication technology the analog signals are digitized before transmission. The digital signal may then be encoded into any equivalent desired form.

System embodying the transmission of digitized and coded signals is commonly called pulse code modulation.

It is a method of modulation in which a continuous analog signal is transmitted in an equal digital mode. The large majority of fiber optic communication systems use digital modulation methods for signal transmission. The most important advantage of a digital system over an analog system is; relative freedom from noise and distortion which enhances the quality of the link. In the digital system the laser output jumps between two or more levels. It is usual to operate with two power levels zero and one since with light pulses, photon does not flow backwards (Carter, 1988). The one level is represented by the presence of an optical power pulse and the zero state represents the absence of a pulse. The pulses occur with in predetermine time slots. If the pulse occupies the entire time slot, then the signal is termed a non return zero (NRZ) signal. If on the contrary the pulse occupies only a fraction of the time slot the signal is called return to zero (RZ) signal.

The digital communication system assembled is found suitable for the transmission of Transistor Transistor Logic (TTL) digital signals. The TTL signals modulate the intensity of the light radiation emitted by the LED optical source, mounted on a connector for connection to the fiber. At the receiving end, the fiber is connected to the photo detector. The light source used is a light emitting diode. The light emitted is an invisible infrared signal having wavelength of 1.3 μm. The transmitted information is that of an audio signal (Casimer and De Cusatis, 1998).

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METHODS

The circuit of an optical fiber digital transmitter is shown in Fig. 1.

A brief description of some parts (voltage to frequency converter, driver circuit, transistor as switch in light source) is given in the following paras.

Voltage to frequency converter: Sound waves caused by human speech or some electronic devices are converted to electrical wave. A microphone biased by 12V battery does so, acting as a transducer. The frequency range of the signals used is from 20 Hz to 20 KHz. A 12 V battery is connected at point A through a resistance R_2 and R_3. A capacitor C_1 acts as a blocking capacitor. This DC voltage is mixed with the AC signal to modulate signal in the optical digital transmitter circuit, A voltage to frequency converter, IC LM 331, is ideally suited for use in digital system. At low power supply it can provide low cost analog to digital conversion, precision frequency to voltage conversion, linear frequency, modulation/demodulation and many other functions. The input of an LM 331 is comparator input and its pin no 6 is used as OFF and ON switch. Its frequency range is fixed by using C_3 and R_7 in parallel at 100 KHz. Pin no 3 gives the output frequency.

Driver circuit: The circuit between input of IC 7404 and the anode point "I" is called driver circuit. The output of the voltage to frequency converter is connected to the input of inverter at point "G" when +5 V is applied with pin no 14 of inverter and remaining pins are grounded. The output is a TTL signal. A diode 1N 4148 connected in parallel to C_5, saves the transistor from excessive current through the base emitter junction by keeping the voltage differential between base and ground. Another capacitor is used to suppress the high order harmonics during the switching order. This logic circuit is called an inverter. In this circuit, conversion terminals 5 and 6 are being used as the Input and output terminals, respectively (Casimer and De Cusatis, 1998).

Transistor as a switch: When TTL signal at input of inverter is low and high at output the PNP transistor is in OFF state and all current flows through resistance and then goes to LED and diodes D1 and D2.These diodes completely switch OFF the LED. When current flows through LED, it emits infrared radiation. With input of inverter high and output low, the switching transistor is turned ON by low bias through diode switch short anode of LED to ground which turn it OFF. With transistor ON, LED turns ON and generates infrared light (Kihara and Onishi, 2003).

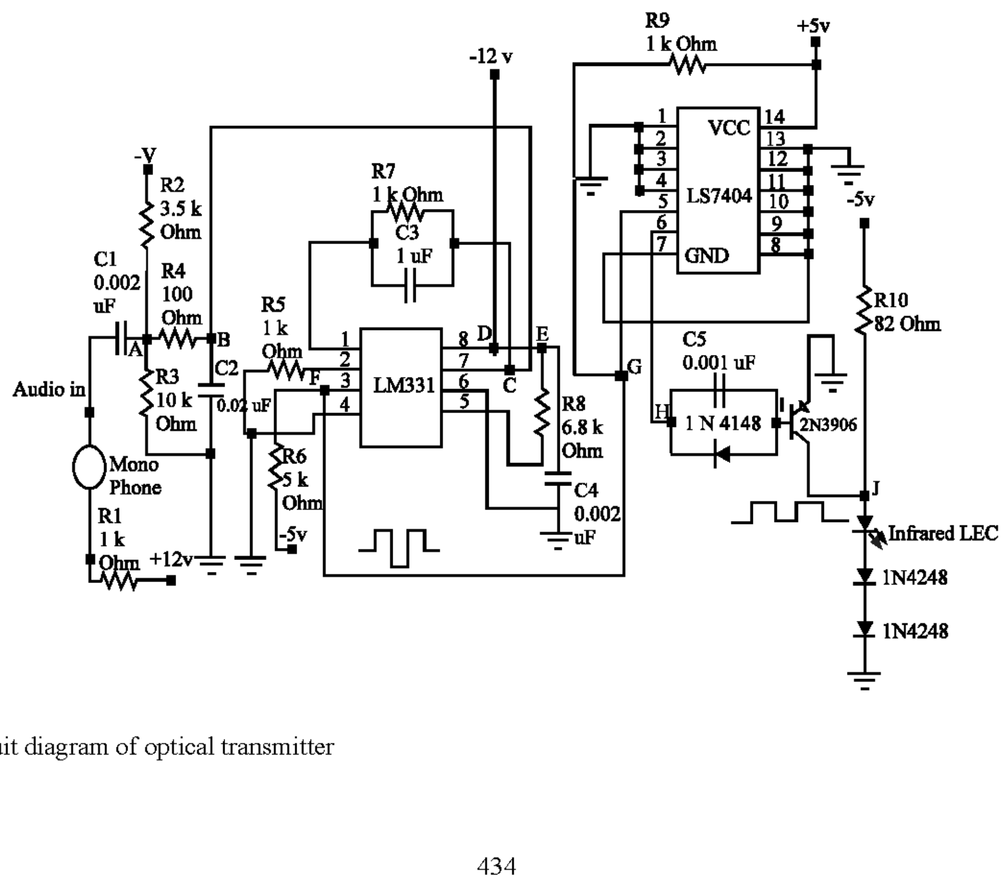

Fig. 1: Circuit diagram of optical transmitter

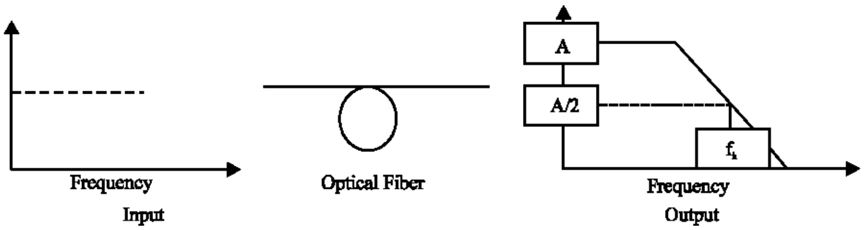

Fig. 2a: Frequency domain

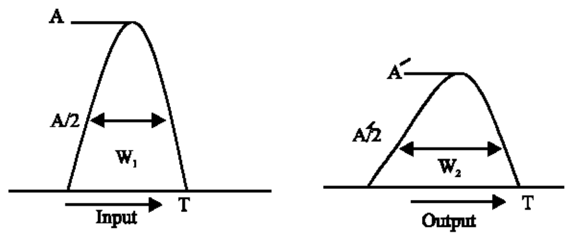

Fig. 2b: Optical Gaussian pulses at input and output

Light Source: Under the ON condition of a transistor the LED generates infrared light under forward bias due to recombination of the carrier, which is injected at the PN junction. The light passes through transmission media (optical fiber) and is detected at photodiode. Contrarily with transistor in OFF state, the LED is also OFF (Kihara and Onishi, 2003).

Optical fiber: The transmission media consist of optical fiber. Optical wave in a fiber is propagated in the core, subjected by the principle of total internal reflection. In such a wave guide structure the optical wave has specific discrete propagation angles, which are determined by the phase relations of the optical wave perpendicular to the cyber axis. In general, the optical wave satisfying the relation is called "Mode" number of modes to be propagated in fiber is deter mined by optical wavelength, refractive index difference between core and clad, refractive index profile in the core and clad dimensions. A fiber supporting only one mode is called single (mono) mode fiber and that supporting plural number of modes is called multi modes fiber (Wang *et al*., 2004; Carter, 1988).

The following parameters were studied in locally designed, developed optical fiber digital transmitter.

Bandwidth of optical fiber: There are two methods used to evaluate the bandwidth o f multimode optical fiber (Carter, 1988).

i. Frequency domain (direct)
ii. Time domain (indirect)

Frequency domain: Using frequency domain method, the fiber bandwidth is determined as the -3dB(optical) point of the amplitude/frequency function, corresponding to 50% signal. We found f_B is1.25 kHz from Fig. 2a. This is our bandwidth from frequency domain method.
Also the bands of optical fiber is given by

Bands = frequency/length (Mondal and Sarkar, 1999) .
Where f = 10 kHz = 10^{-2} MHz
L = 3.5 m = 0.0035 km
Therefore,
Bands = 10^{-2} MHz/0.0035 km
= 2.85 MHz km^{-1}

Since the bands of fiber far surpasses that of copper it is suitable for local telecommunication used in one building.

Time domain: In this method, LED output was modulated sinusoidally at different frequencies by using an oscillator (Agrawal, 1997; Gueos *et al*., 1988). The pulses are shown in Fig. 2a,b. The input optical pulse to the fiber is Gaussian at W_1 full width at half maximum (FWHM). The output pulse is Gaussian at W_2 full width half maximum (FWHM) in Fig. 2b.

The total dispersion caused by mode and material is the given as;

$$\Delta t_f = (W_2^2 - W_1^2)^{1/2}$$

Where, W1 and W2 are mode and material dispersion, respectively.

From the oscilloscope screen, the measured values are:

$$W_1 = 0.10\ \mu s \text{ and } W_2 = 0.20\ \mu s\text{; which gives}$$
$$\Delta t_f = 0.22\ \mu s = 0.22\times10^{-6} s$$

This was the total dispersion.
The relation between the bandwidth and dispersion was given

$$BW = 0.44/\ \Delta t_f$$
$$= 2\ \text{MHz}$$

After performing the above calculations, it is discovered that fiber bandwidth is inadequate for transmitting the signal; it is necessary to select a different transmitter (wavelength).

This effort in system of transmission is very useful to finding bandwidth.

Bandwidth of circuit: Bandwidth of circuit is defined as the circuit in which lie between two points on higher side of its resonance curve where current is 0.707 of its maximum value at resonance. Bandwidth is calculated by:

$$BW = f_2 - f_1$$

Where

f_1 = 0.2 kHz (Lower cutoff frequency)
f_2 = 1.4 kHz (Upper cutoff frequency)

So

$$BW = 1.4 - 0.2 = 1.2\ \text{kHz}$$

Bandwidth of circuit, in fact, represents the range of its useful frequencies.
The measured values are shown in Fig. 3.

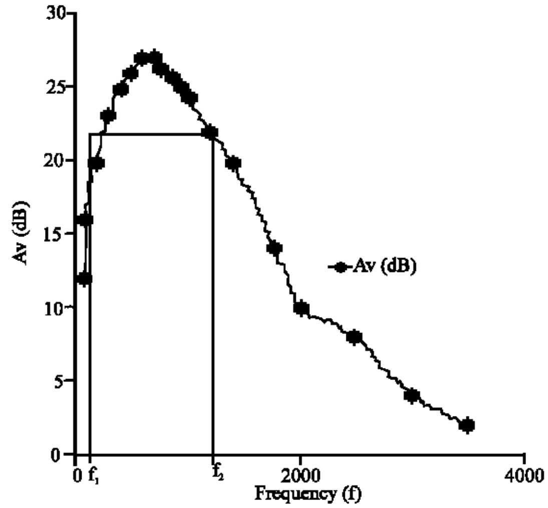

Fig. 3: Graph b/w gain of circuit and frequency

Attenuation Measurements: The attenuation A (λ) at a wavelength (λ) between two cross section and separated by a distance L of fiber is defined as (Carter, 1988; Agrawal, 1997).

$$A(\lambda) = 10 \log (P_{out} / P_{in})$$

An optical signal detected by a photo-detected produce a photo current I which is proportional to the optical signal.

A value of $A_{optical}$ dB is per definition
A [dB optical] $= 10 \log (P_{out} / P_{in})$
$= 10 \log (I_{out} / I_{in})$

From the circuit we measure the input current

$$I_{in} = 10\ \text{mA}$$

Photo current I_{out}= 4.4 mA
Putting these values in above Formula, we get

A [dB optical] $= 10 \log (P_{out} / P_{in})$
$= 10 \log (I_{out} / I_{in})$
$= 10 \log (4.4/10)$
$= -3.56\text{dB}$

Which is the measured attenuation for 3.5 m long fiber optic.

The attenuation per unit length or attenuation coefficient is defined as:

$$\alpha\ (\text{dB/km}) = A(\lambda) / L$$
$$= -3.56/2.5$$
$$= -1.4\text{dB/km}$$

The photo current produced an electrical power P_{el}. The relation between electrical power and optical power is given

$$dB_{el} = 2\times dB_{opt}$$
$$dB_{el} = -7.12\ \text{dB}$$

Here the electrical dB number is twice as large as the optical dB number.

For multimode 2.5 m fiber optic and other fiber optics for power loses (Attenuation) with the help of handy power meter of model OLP-25.
Attenuation is measured and shown in Table. 1.

Table 1: Attenuation measurements

Fiber mode	Length	Wave length	Loss (dB)
Single mode	2.0	1300 (nm)	-54
Multi- mode	3.5	850 (nm)	-65
Multi- mode	10.0	1300 (nm)	-70

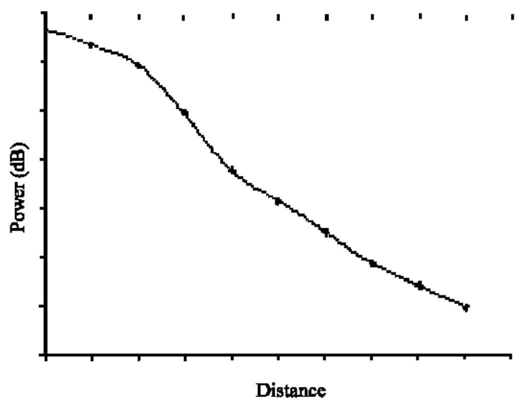

Fig. 4: Graph between output power

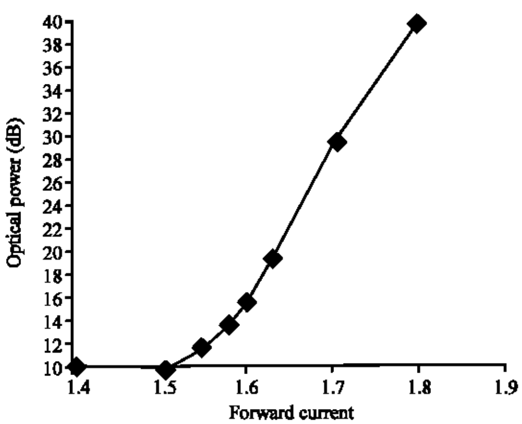

Fig. 5: Optical powers vs. forward current

Performance of optical fiber: The performance of optical fiber (single mode) was conducted at central optical fiber exchange Faisalabad of Pakistan Telecommunication. The apparatus used in Optical Time Domain Reflector meter (OTDR). The apparatus is quite handy and gives losses in dB at its screen as emitted light passes through the fiber. The out power for different lengths of the fiber were measured and plotted as shown in Fig. 4.

Optical power output v/s forward current characteristics: Connected the optical fiber to the designed transmitter and receiver. Microvltmeter also connected across the terminals labeled V_f and I_f of the receiver. The voltage measured across one-kilo ohm resistor in series with potential difference inside the receiver. The results of

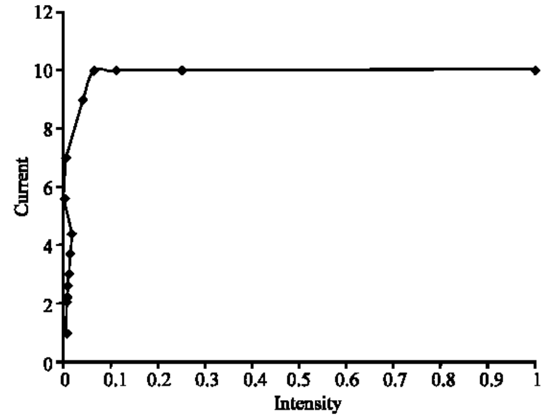

Fig. 6: Intensity meaurement

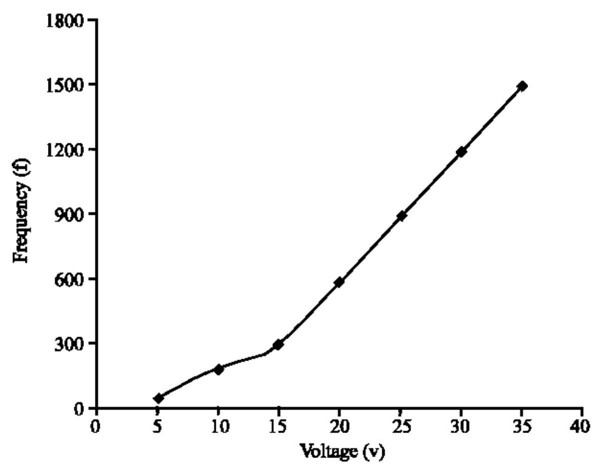

Fig. 7: Performance of voltage to frequency converter

measurements showed an increase in the current, which is the forward bias voltage a graph depicted as in Fig. 5.

This result indicates that these levels are sufficient to switch ON the receiver. We noticed that a voltage of some volts is displayed on meters corresponding to some mA photodiode current. The results of measurements visualized by drawing the graph between voltage and optical powers and current. Ideally the relationship between current and power be linear.

Intensity Measurement: The intensity of light holds inverse square law ($I\alpha 1/D^2$) (Carter, 1988), here "I" is intensity and D is the distance from the source. The intensity was measured by measuring currents and voltages at various distances.

A graph was drawn between different measured currents and intensity levels and is shown in Fig. 6.

Performance of voltage to fequency converter: In order to assess the performance of voltage to frequency converter (LM 331) a power supply was connected to the input terminal. By changing voltage from 5 to 35 V, the output frequency was measured with the help of an oscilloscope. The results of the measurements are shown in Fig. 7.

The designed optical fiber digital transmitter shown in Fig. 1 is suitable to convert analog signal (speech) to digital signal. It was noticed that speech quality transmitted through designed circuit is quite good as the message is clearly distinguishable and understandable. The salient features of the project are that the designed optical fiber transmitter is low power, low cost, more accurate and easy to handle. It is portable and its efficiency is sufficient.

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REFERENCES

Agrawal, G., 1997. Fiber-Optic Communication Systems Kai-chang Series, 2nd Edn., pp: 72-80.

Carter, A., 1988. Advance structures of semiconductor optoelectronics devices for telecommunications. Winter College on Laser Physics, (ICTP) Italy.

Casimer, M. and DeCusatis, 1998. Optical data communication: Fundamentals and future directions. Optical Engineering, 37: 3082-3099.

Gueos, G. and M. Blaser, 1988. Fiber optic experimental digital transmission system. 2nd Workshop on Optical Fiber Communications (ICTP) Italy.

Kihara, M. and M. Onishi, 2003. NTT Access Network Service Syst. Lab., Tsukuba-city, Japan. Influence of wavelength and temperature changes on optical performance of fiber joints. Optical Fiber Communications Conference, OFC, IEEE, 1: 13-14.

Mondal, K.S. and S. Sarkar, 1999. Coupling of a laser diode to single-mode fiber with an upside-down taped lens end. Applied Optics, 38: 6272-6276.

Wang, Q., R. Ahrens and N.K. Dutta, 2004. Optical gain of single mode short Er/Yb doped. Optic Express, 12: 6192-6197.