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The Use of Pulse Frequency Modulation Technique for Optical Video Communication System

K. A. Al-Naimee A. M. Taleb and H. J. Gubashi

Department of Physics, College of Science, University of Baghdad, Baghdad, IRAQ

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Abstract: An optical video communication system is designed and constructed using pulse frequency modulation (PFM) technique. In this work PFM pulses are generated at the transmitter using voltage control oscillator (VCO) of width 50 ns for each pulse. Double frequency, equal width and narrow pulses are produced in the receiver be for demodulation. The use of the frequency doubling technique in such a system results in a narrow transmission bandwidth (25 ns) and high receiver sensitivity.

Introduction

Video transmission using optical technique is an attractive method due to the excellent characteristics of optical fibers, such as low loss, wide bandwidth, low attenuation, low weight, no crosstalk between adjacent fibers, and immunity to electromagnetic interference [1, 2].

The transmission of information in the form of light propagation within an optical fiber requires the construction of an optical communication system. Such system involves two sources electrical and optical, the first contains a source of information which is received by the second subsystem (modulator or encoder) depending on analog or digital message format. In digital systems, a source encoder is used to convert the message signal from an analog in to a stream of bits or pulses [3, 4].

The use of pulse frequency modulation (PFM) is better suited for optical video transmission because of the large output signal to noise ratio and linearity of the pulse frequency modulation system. Such properties enable for transmitting video signal over long distance by using optical fiber cable [5]. The PFM technique, however, has many advantages over the intensity modulation (IM) technique and digital fiber transmission [6].

Experimental Work

In this work the experimental setup of the PFM system contains three major units, the transmitter, optical fiber link and the receiver unit. Fig. (1) Shows a block diagram of such system.

1. The Transmitter Unit

This unit consists of a clamped circuit, second order low pass filter, voltage controlled oscillator, and driver circuit of the light source as shown in Fig. (2).

The Clamped Circuit

The output video signal from the camera, or any source of video signal, has one voltage peak to peak (from -0.4 to + 0.6 V). The 1 Vp.p video signal must be clamped at a precise DC level for feeding the LPF. The signal is then clamped to about zero level by Buffer amplifier (LM324) and diode D.

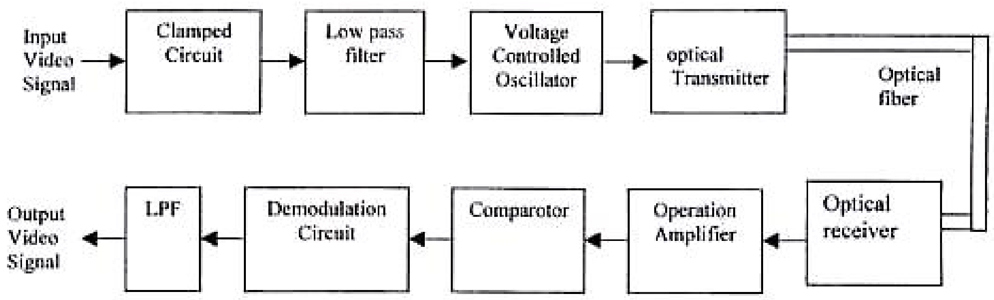

Fig. (1) Block diagram of the PFM system

The Low Pass Filter with Gain Circuit

The second stage in the transmitter and the last stage in the receiver of the PFM systems are low pass filters. The fast operational amplifier (OP-AMP37) is used for this purpose. Second orders LPF Butterworth response filters are used in the transmitter, limits the bandwidth of the modulating signal and prevent the noise form interfering with it. This is assembled by placing a resistor in parallel with feedback capacitor turning the integrator (OP-AMP37) into a low pass filter with gain 2. The cutoff frequency of the video signal is about 4 MHz and is given by

$$f_c = \frac{1}{2\pi \alpha_o R C} \qquad (1)$$

where α_o is a damping factor and for the second order, α_o is 0.707

The Voltage Controlled Oscillator (VCO)

VCO is an oscillator whose frequency of oscillation varies in response to the input voltage. VCO represent how much frequency shift occurs for a given change in the input voltage. An IC 74LS629 is used as VCO; this integrated circuit has two independent voltage controlled oscillators in a single package. The output frequency of VCO is established by using a single external capacitor. The output frequency can be approximated as

$$Fc = 3.6\,(0.87 + Vi) \qquad (2)$$

where Fc is the output frequency in MHz and Vi is the input control.

The Optical Fiber Transmitter

The HFBR 1404 optical fiber transmitter contains a 820 nm GaAlAs emitter capable of efficiently launching optical power into four different optical fiber size: 62.5/125 μm, 100/140 μm, 50/125 μm, and 200 nm PCS. An optical transmitter is used to convert the output pulses from VCO in to optical power. The HFBR 1404 transmitter with high coupling efficiency allows the emitter to be driven at low current levels.

High power transmitter optimized for small size fiber is used and typically can launch -14.5 dBm optical power into 50/125 μm fiber. The output optical power of the HFBR 1404 depends only on the driver current IF. A pull up resistor is connected with the LED to provide a driver current 50 mA and to get a 32 μW optical power [7].

2. The Optical Fiber Link

The available optical fiber cable is 50 cm long with core to cladding 50/125 μm and over all cable diameter of 3.2 mm. The cable is multimode fiber SMA connector's type with attenuation factor of 3 dB/km at 820 nm, and bandwidth of 400 MHz.km.

3. The Receiver Unit

The optical video receiver unit consists of an optical fiber receiver (PIN detector and amplifier), operational amplifier, comparator, three Ex-OR gates for demodulation process, and fourth order low pass filter for reconstruction as shown in Fig. (3).

The Optical Fiber Receiver

The optical receiver is a process that converts incident optical power into an equivalent electrical signal. The HFBR 2404 is utilized to operate with the Hewlett-Packard HFBR 1404 optical fiber transmitter and 62.5/125 μm, 100/140 μm, and 50/125 μm optical fiber cable. The receiver output is an analog signal that can be optimized for a variety

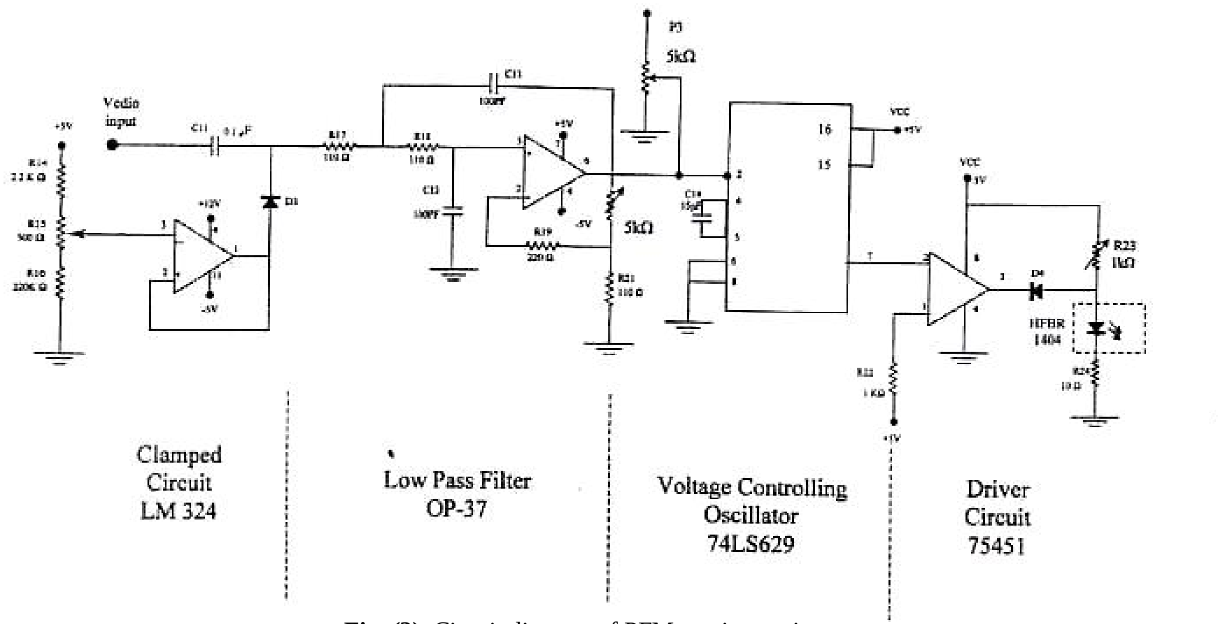

Fig. (3) Circuit diagram of PFM receiver unit

of distance/data rate requirements. The HFBR 2404 receiver contain a PIN photodiode is used in the detection of light at the front end of every optical receiver to generate a photocurrent proportional to the incident light intensity, and low noise transimpedance pre-amplifier integrated circuit with an inverting output. The frequency response is typically from DC to 25 MHz.The HFBR-2404 receiver is operated with a 5 V supply voltage [7]

The Operational Amplifier

The analog output signal from HFBR-2404 receiver must be amplified by using ultra high speed OP-AMP NE5539 and converted to pulses by using comparator OP-AMP37. The signal is applied to non inverting input of the NE5539 and the inverting input is connected through a 75 Ω resistance to ground in order to balance the amplifier input bias current and voltage as shown in Fig. (3). The amplified signal is then passed to a comparator in order to convert it to a pulse. The level of comparison is chosen to be 0.5 V. If the signal is above 0.5 V this gives a high logic level (i.e. 5 V). If the signal is bellow 0.5 the output of the comparator is a low logic level (i.e. 0V).

Demodulation Circuit

Demodulation process can be achieved by generating a baseband replica of the modulation signal for recovery by low pass filter. The baseband replica is generated either by producing constant width pulses or double frequency equal width narrow pulses in the receiver demodulation [8]. The narrower pulse width, the higher the relative power of higher order components. The use of the frequency doubling technique in such a system results in a narrow transmission bandwidth and high receiver sensitivity [1]. This technique is needed to produce a baseband replica by constant width pulse regeneration, and this method offers advantages as good linearity, no setup tuning, cost effectiveness, and low distortion levels.

Frequency doubling and pulse regeneration are performed by X-OR gates IC74S86 as shown in Fig. (3). Each gate has a propagation delay of 10 ns. Three of these gates are used to the demodulation. The first and the second gates are connected in series to generate the width of the new pulse train, which is equal to 10 ns. However one input of the gate number three is connected to the PFM, while the second is connected to the delayed PFM which is available at the output of second gate. the output of an X-OR is logic 1 when the inputs are different state, and 0 when the inputs are the same state. The output signal from the 74S86 is a train of pulses of 20 ns width without any overlap with the baseband.

The design of the four order LPF in the receiver unit is selected so that its attenuation is adequate to save the baseband video signal carrier frequency.

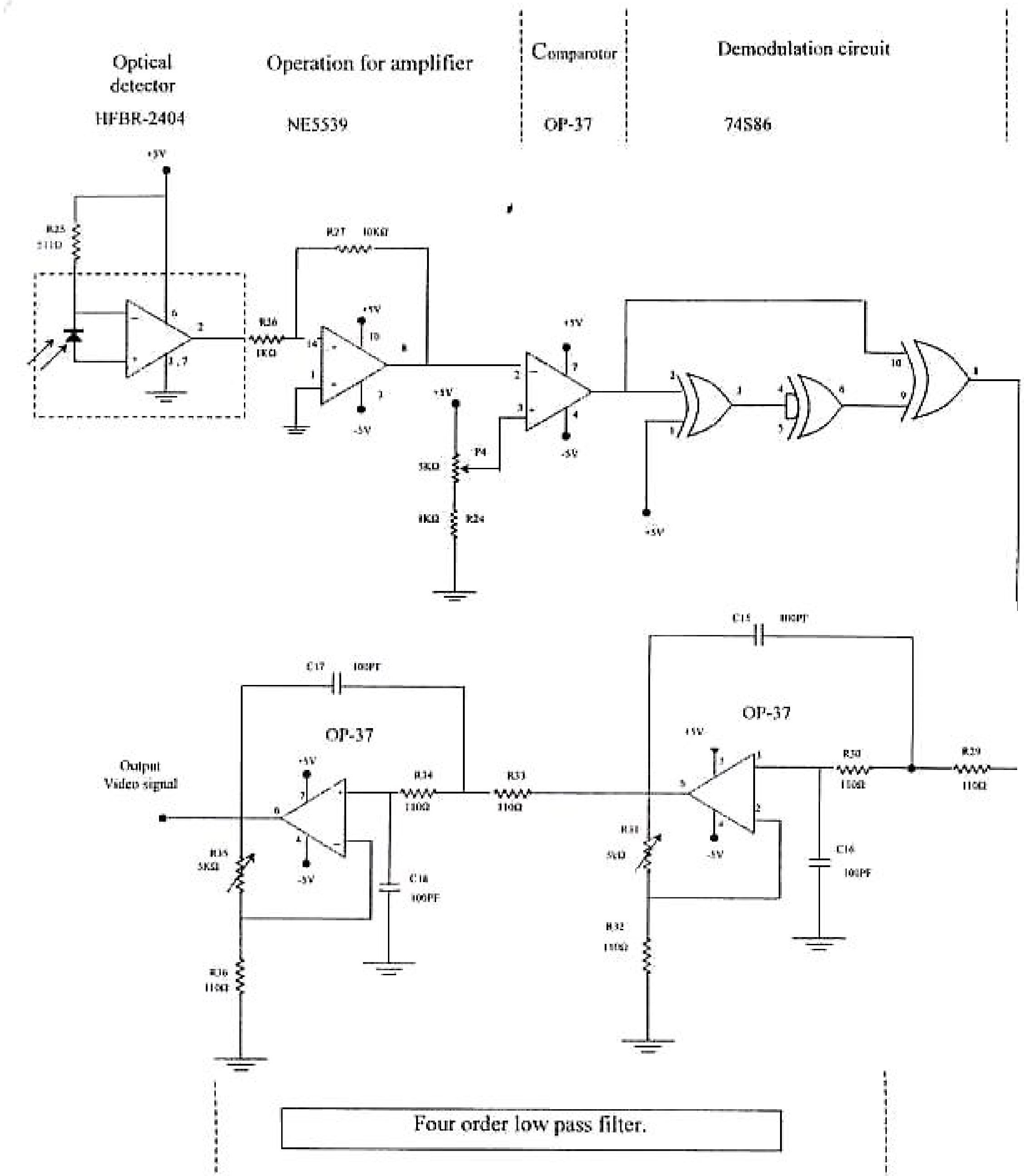

Fig. (3)
Circuit diagram of the PFM receiver unit

Results and Discussion

In the PFM system, a frequency deviation Δf is equal to 4 MHz was determined using oscilloscope device. The carrier frequency is given as f_c= 20 MHz and the modulating frequency of the video signal f_m is 4 MHz. The modulation index β for PFM system is calculated from the relation

$$\beta = \frac{\Delta f}{f_m} \quad (3)$$

It is clear from Eq. (3) that the modulation index is equal to one.

The signal to noise ratio (S/N) for optical video PFM system of the peak- to peak signal power to root mean square (rms) noise power is given by [5]

$$\left(S/N\right)=\frac{12\left(T_D\Delta fMRP_{so}\right)^2}{\left(2pt_rB\right)^2 i_n^2} \quad (4)$$

where $T_D = 1/f_c$ is the normal pulse period, P_{so} is the peak receiver optical power, M is the photodiode multiplication factor, t_r is the pulse rise time at the regenerator circuit input, B is the postdetection or baseband bandwidth, i_n^2 is the receiver mean square noise current, and R is the responsivity.

In our system the normal pulse period is 50 ns (20 MHz), frequency division is 4 MHz, photodiode multiplication factor is 1, peak receiver optical power is 32 μW, baseband bandwidth is 4 MHz, responsivity is 0.1 A/W, the noise originating in the detector has a thermal noise current in generated within the photo detector's load resistor R_L.

The thermal noise current is given by

$$i_n = \sqrt{\frac{4kT\Delta f}{R_L}} \quad (5)$$

where k is the Boltzmann constant, T is the temperature in K, Δf is the signal bandwidth.

The bandwidth Δf is 20 MHz, load resistor R_L of the photodiode detector is 511 Ω, and the temperature is 300K. By substituting these values in Eq. (5), the thermal noise current is 25.45 nA.

The pulse rise time at the regenerator circuit would equal to the system rise time for an optimum system. Thus [9]

$$T_{system} = 1.1\sqrt{T^2_{source} + T^2_{modal} + T^2_{material} + T^2_{detector}} \quad (6)$$

when the T_{system} represented the pulse rise time and T_{sourse}, T_{modal}, $T_{matertial}$, $T_{detector}$ are the source, modal, material and detector rise time respectively. However, T_{modal} and $T_{tnaterial}$ are equal to zero because of the short length of the fiber is used. Then

$$T_{system} = 1.1\sqrt{T^2_{source} + T^2_{detec}} \quad (7)$$

Since the rise time of the optical transmitter is 4 ns and the rise time of the optical receiver is 14 ns, then the rise time of the system is equal to 16.01 ns. By substituting these values in Eq. (5), then the signal to noise ratio (S/N) of the PFM system is 46.72 dB.

The relationship between the frequency deviation, carrier frequency and the output signal to noise ratio is shown in Fig. (4). Table (1) presents signal to noise ratio variation as a function of frequency deviation change, while Table (2) gives signal to noise ratio variation as a function of carrier frequency.

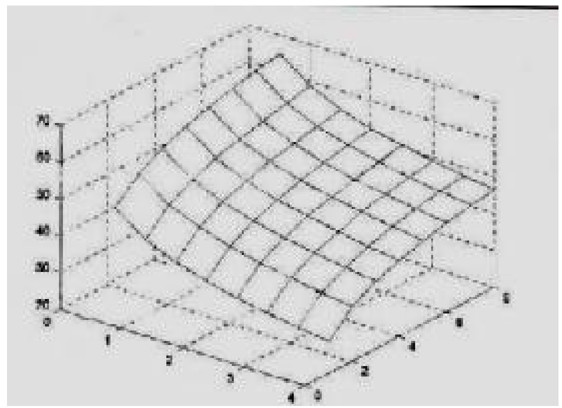

Fig. (4) Relationship between S/N, frequency deviation and carrier frequency

It can be observed from Fig. (4) that S/N is directly proportional with frequency deviation and in the mean time it is inversely proportional with frequency carrier. Also it can be seen that frequency carrier and frequency deviation are directly proportional.

Table (1) Signal to noise ratio versus frequency division at a fixed frequency carrier

Frequency deviation (MHz)	S/N ratio (dB)
1	34.67
2	40.71
3	44.23
4	46.73
5	48.76
6	50.23
7	51.57
8	52.70

Table (2) Signal to noise ratio versus carrier frequency at a fixed frequency deviation

Carrier Frequency (MHz)	S/N ratio (dB)
5	58.75
10	52.73
15	49.12
20	46.71
25	44.77
30	43.18
35	41.50
40	40.60

Conclusion

The results show that increasing of the frequency carrier happened on the expense of the frequency division at certain S/N value. It also shows that optimized value of frequency division is in the range between 3-5 MHz and frequency carrier at 1.5- 2.5 MHz range. This would allow a wide selected frequency range in this region to obtain a good quality signal and less noise.

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استخدام تقنية تضمين التردد النبضي في منظومة الاتصال الفديوي الضوئي

قيس عبد الستار النعيمي　　عبد المهدي طالب رحمة الله　　هاني جاسم كباشي

قسم الفيزياء / كلية العلوم / جامعة بغداد – بغداد - العراق

الخلاصة

في هذا البحث تم تصميم وبناء منظومة اتصال فديوي ضوئي باستخدام تقنية تضمين التردد النبضي في هذه المنظومة تولد النبضات في مرحلة الاستلام يتم توليد نبضات بتردد مضاعف الى تردد النبضات المرسلة لعملية فك التضمين باستخدام مرشح الترددات الواطئة وقد أمكن الحصول على نتائج بعرض حزمة نقل ضيقة جداً (25 ns) وحساسية استلام عالية باستخدام تقنية مضاعفة التردد .