Modulation and Demodulation of Pulse Position Modulation with Carrier

L. Kirasamuthranon¹, K. Rattanawattanathorn¹, P. Tuwanut², J. Koseeyaporn¹, P. Wardkein¹ ¹Department of Telecommunication Engineering, Faculty of Engineering

²Faculty of Information Technology King Mongkut's Institute of Technology Ladkrabang, Ladkrabang, Bangkok, Thailand 10520 E-mail : s3611423@kmitl.ac.th

Abstract

In this paper, Pulse Position Modulation with Carrier (PPMWC) and its demodulator is presented. The scheme of proposed demodulator is based on the toggle circuit. The Pulse Position Modulation (PPM) signal is generated from the phase locked loop (PLL) circuit whereas the PPMWC signal is generated by summing the PPM signal and the PLL reference signal. In demodulation of the proposed scheme, the PPMWC signal is passed through the toggle circuit, resulting in the Pulse Width Modulation (PWM) signal. The output information is obtained by passing the PWM signal through the low pass filter. The obtained results from simulation and experiment agree well with the mathematical analysis.

Keywords: PPM, PWM, PPMWC, PLL.

1. Introduction

Pulse Position Modulation (PPM) is widely employed in Optical communications [1] and wireless communication [2]. One reason is that PPM signal is a low power consuming signal. Generally, the characteristic of PPM signal is that amplitude and width of pulse are constant, while the pulse position is directly proportional to the amplitude of a message signal, when compared with a reference pulse position of carrier. Currently, there are several techniques to generate a PPM signal [3-5], In [5], it was based on digital process proposed by Che-Fu Liang *et al.* But this circuit is quite complicate which is composed of AND gate, inverter, multiplexer, 10 stage buffers and delay cell.

For information recovery, the message signal contained in a PPM signal is generally obtained by first generating a PWM signal from a PPM signal, and then using a low pass filter to recovery a message signal. However, this classical scheme requires the carrier (clock) signal for synchronizing at the receiver and it is mostly difficult to generate.

In this paper, the technique to generate a PPM signal with carrier (PPMWC) is proposed. The circuit used to generate the PPM signal is based on phase locked loop. The PPMWC signal is obtained by summing the PPM signal and the PLL reference signal. At the receiver, the PWM signal can be easily obtained by passing the received PPMWC through the toggle circuit.

After that, the low pass filter is used to recover the information from the PWM signal. This proposed technique recovers the message signal in asynchronous mode or non coherent detector mode. It does not require the carrier recovery circuit at the receiver.

2. Principle

2.1 Modulation of PPMWC by PLL

In this paper, the proposed technique for generating the PPMWC signal is based on the PLL circuit as depicted in Fig. 1. The advantage of the proposed circuit is that it provides a compact circuit for pulse position modulation. In addition, the carrier signal is easily generated and its frequency can also be easily controlled.



Figure 1. Block diagram of PLL

From Fig. 1, it is found that $v_x(s)$ and $\phi_o(s)$ are

$$k_{x}(s) = k_{d}F(s)\left[\phi_{i}(s) - \phi_{o}(s)\right] + m(s)$$
(1)

$$\phi_o(s) = \frac{B}{s} \left(k_o v_x(s) + \omega_r \right) \tag{2}$$

By substituting (1) into (2), it yields

$$(s) = \frac{B}{s} k_o k_d F(s) \phi_i(s) - \frac{B}{s} k_o k_d F(s) \phi_o(s) + \frac{B}{s} k_o m(s) + \frac{B}{s} \omega_r$$
(3)

Eq.(3) is rewritten by

φ.

$$\phi_o(s) + \frac{B}{s} k_o k_d F(s) \phi_o(s)$$

$$= \frac{B}{s} k_o k_d F(s) \phi_i(s) + \frac{B}{s} k_o m(s) + \frac{B}{s} \omega_r$$
(4)

It is assumed that a LPF circuit is the first order passive circuit whose transfer function is $F(s) = \frac{\omega_L}{s + \omega_L}$. Eq.(4) is rewritten as follows

$$\phi_o(s) + \frac{K\omega_L\phi_o(s)}{s(s+\omega_L)} = \frac{K\omega_L\phi_i(s)}{s(s+\omega_L)} + \frac{B}{s}k_om(s) + \frac{B}{s}\omega_r$$
(5)

where *K* is $Bk_o k_d$. Later, by multiplying $s(s + \omega_L)$ throughout (5) and rearranging the equation, it results in

$$\phi_{o}(s) \lfloor s(s + \omega_{L}) \rfloor + K\omega_{L}\phi_{o}(s)$$

$$= K\omega_{L}\phi_{I}(s) + Bk_{o}m(s)(s + \omega_{L})$$

$$+ B\omega_{r}(s + \omega_{L})$$
(6)

$$s^{2}\phi_{o}(s) + s\phi_{o}(s)\omega_{L} + K\omega_{L}\phi_{o}(s)$$

$$= K\omega_{L}\phi_{i}(s) + sBk_{o}m(s)$$

$$+ Bk_{o}m(s)\omega_{L} + sB\omega_{r} + B\omega_{r}\omega_{L}$$
(7)

By taking inverse Laplace transform of (7), hence

$$\frac{d^{2}\phi_{o}(t)}{dt^{2}} + \omega_{L}\frac{d\phi_{o}(t)}{dt} + K\omega_{L}\phi_{o}(t)$$

$$= K\omega_{L}\phi_{i}(t) + Bk_{o}\frac{dm(t)}{dt}$$

$$+ Bk_{o}m(t)\omega_{L} + B\frac{d\omega_{r}}{dt} + B\omega_{r}\omega_{L}$$
(8)

where m(t) is an information signal. It is assumed that m(t) is slowly varying with respect to time and ω_r is constant. Therefore, the influence of first-order derivatives of $\frac{dm(t)}{dt}$ and $\frac{d\omega_r}{dt}$ can be neglected. So, (8) is rewritten as follows

$$\frac{d^2\phi_o(t)}{dt^2} + \omega_L \frac{d\phi_o(t)}{dt} + K\omega_L\phi_o(t)$$

$$= K\omega_L\phi_i(t) + Bk_om(t)\omega_L + B\omega_r\omega_L$$
(9)

Let $\phi_i(t) = \omega_i t + \theta_i$ then $\phi_o(t) = at + b$ be supposed and by substituting them into (9) which is

$$\frac{d^{2}(at+b)}{dt^{2}} + \omega_{L}\frac{d(at+b)}{dt} + K\omega_{L}(at+b)$$

$$= K\omega_{L}(\omega_{i}t+\theta_{i}) + Bk_{o}m(t)\omega_{L} + B\omega_{r}\omega_{L}$$
(10)

The terms on left-hand and right-hand sides of (10) are compared to determine *a* and *b*. It is found that $\phi_o(t)$ can be defined by

$$\phi_o(t) = \omega_i t + \theta_i + \frac{Bk_o m(t)}{K} + \frac{B\omega_r}{K\omega_L} - \frac{\omega_i}{K}$$
(11)

where the phase difference $\phi_d(t) = \phi_i(t) - \phi_o(t)$ is found to be

$$\phi_d(t) = -\frac{Bk_o m(t)}{K} - \frac{B\omega_r}{K\omega_l} + \frac{\omega_i}{K} \quad ; K = Bk_o k_d \tag{12}$$

From (12), it can be concluded that $\phi_d(t)$ is proportional to -m(t). From Fig. 1., it can be realized in block diagram of circuits as shown in Fig. 2. The phase detector part is of using RS flip-flop and monostable multivibrator. In Fig. 2, $\phi_d(t)$ is a PWM, $u_o(t)$ is a PPM and $u_i(t)$ is a reference signal. The PPMWC signal is generated by the summation between $u_a(t)$ and $u_i(t)$.

2.2 Demodulation of PPMWC

In the demodulation process, it is accomplished by passing the PPMWC signal through the toggle circuit. The toggle circuit is constructed with the T-flip flop circuit as shown in Fig. 3. The output signal obtained from the toggle circuit is a PWM signal. By feeding the PWM signal into the proper LPF, the information signal can be recovered.

3. Simulation and Experimental Results

The proposed principle for modulation and demodulation of the PPMWC is examined by using computer simulation. The employed information signal is a cosine signal whose frequency is 300Hz and the carrier frequency is 100kHz. Fig. 4 shows the obtained PPMWC signal in the bottom trace whereas the top and the middle traces are the reference carrier and the PPM signal, respectively. When the PPMWC signal is passed through the toggle circuit and the out signal thus is the PWM signal as depicted in Fig. 5. Fig. 6(a) (b) and (c) illustrate the original information signal (top) compared with the recovered signal (bottom) from the PPMWC signals when sinusoidal, triangle and square waves are information signals, respectively.



Figure 2. Block diagram of PPMWC



Figure 3. Demodulation of PPMWC



Figure 4. Illustrations of the reference carrier (top), the PPM signal (middle) and the PPMWC signal (bottom) from computer simulation



Figure 5. Illustrations of the PPMWC signal (top) and the PWM signal (bottom) from computer simulation



Figure 6. Comparison of the original signal (top) and the recovered signal (bottom) where the information signal is (a) sinusoidal wave, (b) triangle wave and (c) square wave, respectively

In addition, the proposed technique is laboratory experimented where IC HD74LS73AP is used for the T flip-flop circuit. The obtained PPMWC signal is demonstrated in the bottom trace of Fig. 7 whereas the top and the middle traces are the reference carrier and the PPM signal, respectively.



Figure 7. Illustrations of the reference carrier (top), the PPM signal (middle) and the PPMWC signal (bottom) from experiment

Moreover, the comparison of the original signal (top) and the recovered signal (bottom) from the experiment where the information signal is (a) sinusoidal wave, (b) triangle wave are given in Fig. 8.



Figure 8. Comparison from experiment of the original signal (top) and the recovered signal (bottom) where the information signal is (a) sinusoidal wave and (b) triangle wave, respectively

Conclusions

This paper presents the modulation and demodulation of pulse position modulation with carrier. The PPMWC signal is generated by summing the PPM signal and the PLL reference signal. The proposed scheme is examined by using computer simulation and experiment. The obtained simulation and experimental results confirm well with the given analysis. The proposed circuit is simple and small. Although, the PPMWC signal consumes more power compared with the PPM without carrier. But with the demodulation using the toggle circuit and the low pass filter, the information signal can be easily recovered.

References

- B. Wilson and Z. Ghassemiooy, "Pulse time modulation techniques for optical communications: a review", *IEE Proc.-J Optoelectronics*, Vol.140, No.6, Dec. 1993, pp 347-357
- [2] R. Saeed, S. Khatun, B.M. Ali, M.K. Abduallah, "Ultra Wide Band (UWB) Ad-hoc Networks: Review and Trends", J. Comp. Sci., 1 (1), 2005, pp 35-39
- [3] P. Wisartpong, J. Koseeyaporn, and P. Wardkein, "Pulse width modulation based on phase locked loop", *ECTI-CON2008*, Vol.2, 14-17 May 2008, pp 697-700.
- [4] W.G.M. Straver, E.H. Nordholt, H.C. Nauta, "A Synchronous Phase-Lock Loop Detector for Integrated AM Radio", *IEEE J. Solid-State Circuits*, Vol.SC-19, Aug. 1984, pp 539-541
- [5] Che-Fu Liang, Shih-Tsai Liu, Shen-Iuan Liu, "A Calibrated Pulse Generator for Impulse-Radio UWB Applications" *IEEE J. Solid-State Circuits*, Vol.41, No. 11, Nov. 2006, pp 2401-2407