International Journal of Sciences and Techniques of Automatic control & computer engineering
IJ-STA, Volume 3, N° 2, December 2009, pp. 1084–1091.

Simulation and Hardware Investigation of the Multi-tone Pulse Amplitude Modulation Using Few Components

Hind B. Bouraoui[1], Amer R. Zerek[2], Mostafa M. Abdalla[3] and Marwa B. Almeheday[4]

1 Assistant Lecturer, Academy of Maritime Studies /Electric and Electronic Engineering Department Tripoli - Libya .
Email Hind_Ali55@hotmail.com
2Associate Professor, Electric and Electronic Engineering Department, Academy of Engineering, Tajura, Libya.
Email ARZ_amer@yahoo.com
3 Assistant Professor, Electric and Electronic Engineering Department, Academy of Engineering, Tajura, Libya.
Email ARZ_amer@yahoo.com
4 Student , communication Engineering Department, High Instutate of Electronics Professions, Tajura, Libya.
Email M_memomory_m@yahoo.com

Abstract- *Despite being known for many years, Pulse Amplitude Modulation (PAM) technique remains of important and widely used in many engineering applications. That technique takes some advantages of the transmitted data as time division multiplexed (TDM) analog pulses with the amplitude of the information channel pulse being the analog-variable parameter.*

In this article multi-tone PAM (MT- PAM) is investigated, simulated and implemented in the laboratory using few components. In these investigations three approaches have been used, theoretical, simulation and experimental. Computer simulations have been carried out using Matlab with Simulink. The use of multiple approaches has enabled very good confirmation of achieved result.

After the over all investigations it is observed that, the obtained theoretical, simulation and experimental results are very close to each other and have very good agreement between them.

Keywords: *Modulation, MT-PAM, Multi-ton, Matlab*

1- Introduction

For the duration of the past several years, the electronic communications industry has undergone some remarkable technological changes. Traditional electronic communications systems that use conventional continuous-wave modulation (CW) techniques are gradually being replaced with more modern types of pulse modulation

This paper was recommended for publication in revised form by the editor Staff.
Edition: CPU of Tunis, Tunisia, ISSN: 1737-7749

(PM) techniques. The PM technique offers two potential advantages over CW modulation. First, the transmitted power can be concentrated into short bursts rather than being delivered continuously. Second, the time intervals between pulses can be filled with sample values from other message.

PAM is one of the main types of analogue pulse modulation techniques, which the amplitude of regularly spaced pulses are varied in proportion to the corresponding samples values of a continuous message signal. The pulses can be of a rectangular form or same other appropriate shape. PAM technique is widely used in numerous engineering applications especially in communication field for transmission of analogue data such as TV transmission and commercial radio. A multi-tone approach is often more preferred in practice than the single tone approach to transmit of signals. A multi-tone frequency modulated signal was developed by Cuccia [4] in 1951. Based on his work, Ghassemlooy and Wilson [5] introduced the idea of the multi-tone single-edge natural pulse width modulation (NPWM) modulated signal, which are used to simulate a TV signal containing both colour and sound sub carrier signals. In addition to that researcher [6] is derived the formula of multi-tone NPWM modulated signal.[1, 2 ,3, 10].

The aim of this paper is to present a formula for a multi-tone PAM (MT-PAM) modulated signal. Also in this paper the computer simulation is carried out to confirm the theoretical analysis of the multi-tone PAM technique. In addition to that it implemented MT-PAM modulator in the laboratory using few components is carried out.

The rest of this paper is organized as follows: Section 2 provides brief descriptions of the MT-PAM modulated signal generation. The derivation and the theoretical analysis of the MT-PAM is presented in Section 3. The results of the computer simulation of the MT-PAM system are given in Section 4. In Sections 5, the experimental results that we carried out on the constructed circuit are shown. Finally, the conclusions are given in Section 6.

.

2- Modulation Method

In MT-PAM, the amplitude of each carrier pulse is proportional to the value of the summing of the two message signals at each sampling instant. A PAM modulated signal is simply generated by multiplying the carrier voltage (sampling signal) by a factor $V(1+m_1(t)+m_2(t))$ as an AM, the MT-PAM modulator is shown in figure (1). [2, 8].

The output of the MT-PAM modulator can be written in mathematical expression as follows.

$$y(t)=\sum_{k=-\infty}^{\infty} V(1+m_1(kT_S)+m_2(kT_S)) * \delta(t-kT_S) \tag{1}$$

Where: $g(t)$ is the pulse shaping which has a maximum amplitude unity.

V is the peak amplitude of the unmodulated train of pulses.

$m_1(t), m_2(t)$ are the modulating signals.

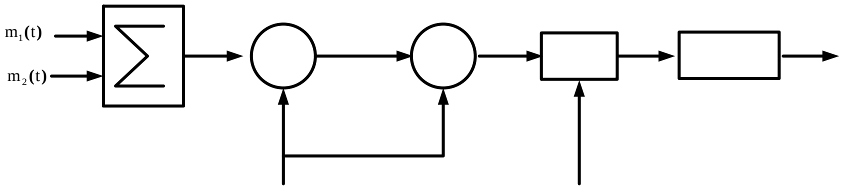


Fig. 1. MT- PAM modulator

3- Theoretical Analysis

Expression of a single tone PAM was derived by many authors including Carlson [2] and the other researchers [8]. In this paper the expression for MT- PAM is derived where the two tones constitutes a cosine wave with relative phase angle θ_m. This spectral prediction formula for two tones is given by.

$$v(t) = k_o + k_o M_1 \cos(\omega_{m2} t + \theta_{m1}) + k_o M_2 \cos(\omega_{m2} t + \theta_{m2}) + \frac{2V}{\pi}\sum_{n=1}^{\infty}\frac{1}{n}\sin\left(\frac{n\pi}{2}\right)\cos(n\omega_0 t) +$$

$$\frac{2V}{\pi}\sum_{n=1}^{\infty}\frac{1}{n}\sin\left(\frac{n\pi}{2}\right)M_1\cos(\omega_{m1}t+\theta_{m1})\cos(n\omega_0 t) + \frac{2V}{\pi}\sum_{n=1}^{\infty}\frac{1}{n}\sin\left(\frac{n\pi}{2}\right)M_2\cos(\omega_{m2}t+\theta_{m1})\cos(n\omega_0 t) \quad \textbf{(2)}$$

Where, $k_o = \frac{V\tau}{T}$ V = height of the pulse, τ = width of the pulse, M_1 *and* M_2 = Modulation indices, ω_{m1} and ω_{m2} = Angular frequencies of the modulating signals, θ_{m1} and θ_{m2} = Relative phase angles of the modulating signals, ω_0 = Angular frequency of the modulated signal (sampling frequency).

The first term of the above equation represents a DC component, the second and third terms correspond to modulating signals f_{m1} and f_{m2}, while the fourth term represents the carrier frequency f_c and its harmonics. The fifth and sixth terms are represents a diminishing side-tone structure for both the modulating signals $m_1(t)$ and $m_2(t)$ respectively and sub-side-tones which are set around the f_o. A typical frequency spectrum of MT-PAM modulated signal produced by two co-sinusoidal modulating signals $m_1(t)$ and $m_2(t)$ is shown in figure (2). The side-tones around the fundamental f_c are repeated around all the odd harmonics of f_c.

In Equation (2) removing one of the modulating signals i.e. M_1=0 or M_2 =0, then the expression is represented a single tone PAM modulated signal which is obtained [2, 8].

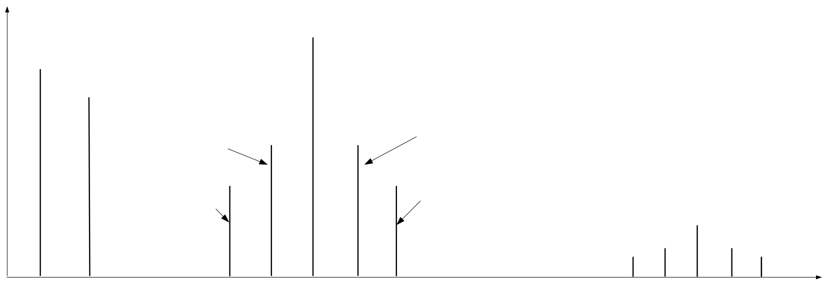


Fig.2. Typical frequency spectrum of MT-PAM modulated signal.

The Fourier spectrum of the MT- PAM modulated signal is given by Equation (2) when both modulating signals are cosines wave. Therefore equation (2) can be expanded for n=1, 2, 3 to obtain the frequency spectrum of the modulated signal. To evaluate the amplitudes of the frequency components of the MT-PAM modulated signal, the typical values were assumed such that the peak amplitude of both modulating signals were M_1= M_2 =30% with modulating frequencies f_{m1} =1kHz, f_{m2}=3f_{m1} , f_o =10kHz and the height of the pulses 1Volt. The theoretical frequency spectrum of the MT-PAM modulated signal is shown in figure (3).

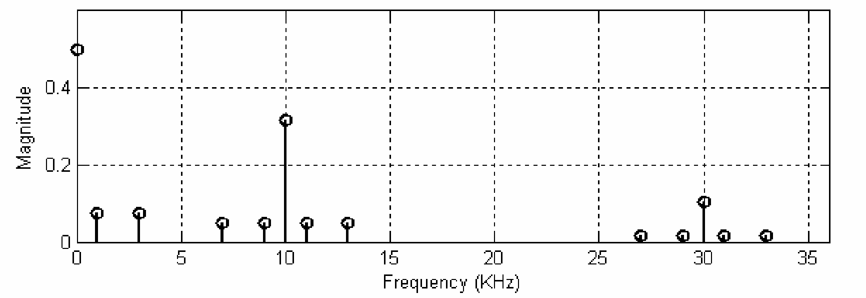


Fig.3. Theoretical frequency spectrum of the MT- PAM modulated signal

4- Computer Simulation

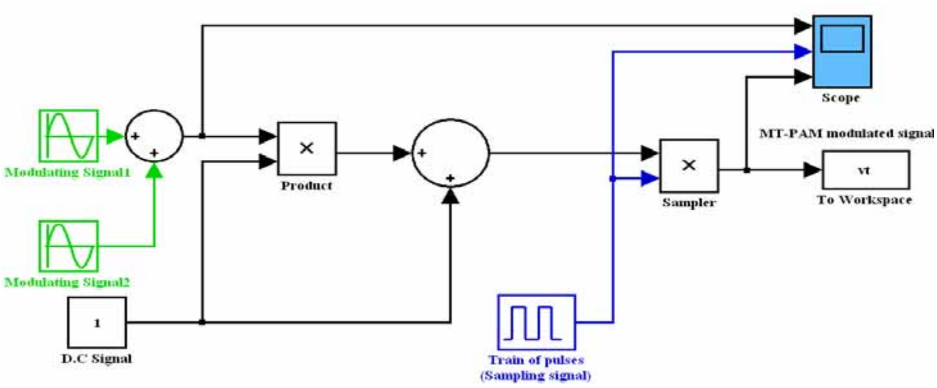
Magnitude

To confirm the predictions of Equation (2), a PAM modulator is simulated by using MatLab with Simulink as shown in Figure (4). The simulated result in both time and frequency domains of the MNT-PAM modulated signal are achieved, where the modulating signals have the same peak amplitudes of 0.3 Volt and

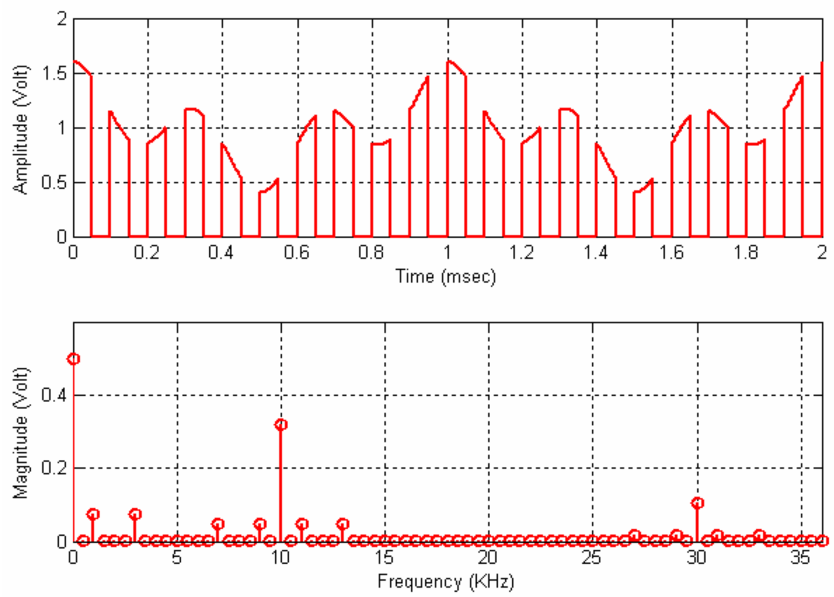
$M_1(f)$

$M_2(f)$

modulating frequencies 1kHz and 3kHz as well as the train of pulse with height of 1Volt and f_o =10kHz as shown in figure (4). [7, 8, 9].



(a)



(b)

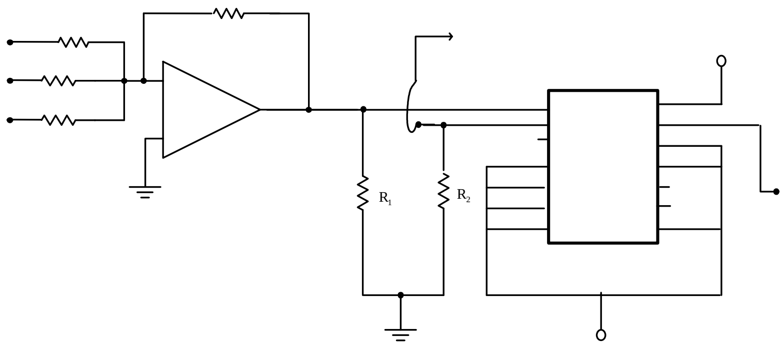
Fig. 4. MT-Pulse Amplitude Modulation

(a) Simulation circuit diagram
(b) MT- PAM modulated signal in time and frequency domains

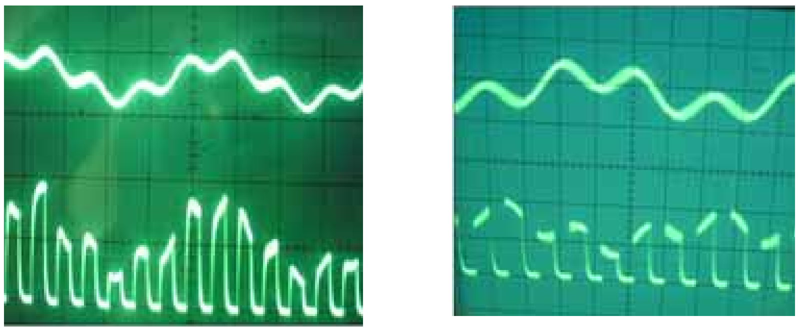
5- Experimental Verification

To confirm the achieved Equation (2) and the simulated results, a MT-PAM modulator is designed and constructed. As shown in figure (5a) by using a few components such as Chip CD4016 is operating as switching, from knowledge this chip constructed from four switching, but in this aim, it needs only one switch. Also, use IC741 chip, which is used as a summer to add a DC signal into the both of the modulating signals. Figure (5a) is illustrated the practical PAM circuit. [11, 12].

The particular frequencies of $m_1(t)$ and $m_2(t)$ were chosen to be 1KHz and 3KHz respectively while both of them having the same peak amplitudes i.e. 3Volt as well as the train of pulse with height of 5Volt and $f_0 = 10kHz$ to enable accurate comparison with the theoretical and simulation results. Also an other test carried out while the modulating frequency of the $m_1(t)$ is doubled and other parameters remain the same as the first test. Figure (5b) represented the measured result in time domain



(a)



(b)

MT-Pulse Amplitude Modulation **Fig. 5.**

(a) Practical circuit diagram
(b) Measured MT- PAM modulated signals

6- Conclusions

In this paper the behavior of MT-PAM technique has been studies via an analytical approach and simulations. Three methods are used to investigate MT-PAM signal such as theoretical evaluation, computer simulation using Matlab with Simulink and experimental verification using few components

From the overall investigation, it is conclude that:

- MT-PAM formula is derived where the two tones constitutes a cosine wave with relative phase angle θ_m.
- The MT-PAM modulator technique has been implemented in the laboratory with simple inexpensive integrated circuits.
- The achieved theoretical, simulation, experimental results of PAM system has very good agreement and very close to each other just view different i.e. 0.1% between the Theoretical and simulation results that due to the performance of the software package in use.

References

1. Ziemer, R., and Tranter, W. H. : Principles of communications, system modulation and noise., John Wiley & Sons, INC..2002
2. Carlson, B.A. :Communication Systems: an Introduction to Signal and Noise in Electrical Communication, McGraw-Hall, Newyork, 4th ` Edition., 2002.
3. Jerry D. G.: The Communications Handbook", 2nd Edition, Southern, Methodist University, Dallas, Texas. 2002.
4. Cuccia, C. L. :Harmonics, Sidebands and Transients in Communication Engineering, McGraw-Hill, USA, 1952.
5. Wilson, B and Ghassemlooy, Z., 'Spectral Structure of Multitone Pulse Width Modulation', Electron. Lett, Vol. 27 No. 9 pp. 702-704, April 1991.
6. Zerek, A. R., : Lower Sidetone Reduction in Pulse Width Modulation', PhD Thesis, University of Wales, College of Cardiff, November 1995.
7. Michel C. J., Philip B. and Sam Shanmugan K.: Simulation of communication systems, Kluwer Academics Publishers New York,2nd Edition., 2002.
8. Zerek A. R., Bouraoui , H. B. and Ali E. F., Computer simulation and hardware investigation of pulse amplitude modulation using few components, International Conference on Modelling and simulation AMSE08 Port Said (Egypt), April, 2008
9. Zerek, A. R. , Meftah M. Almrabet M. M. and ., Bouraoui , H. B. : Application of Matlab with Simulink for teaching the principles of modulation techniques International Conference on Modelling and Simulation (MS’08 JORDAN) (MS’08 JORDAN), PETRA (Jordan), November, 2008.

10. Fitz M. P. :Fundamental of communication systems, McGraw Hill companies, 2007

11. Coughlin, R.F. and Driscoil, F. F. :Operational Amplifiers and Linear Integrated Circuits, Prentice, Hall., 1991

12. Chen W. K. :The electrical engineering handbook, Elsevier Inc., 2004.