Laboratory Exercise on Demodulation Of PAM signal

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Abstract

Pulse amplitude modulation (PAM) is used extensively in telecommunications as an intermediate step of other techniques such as phase shift keying (PSK), quadrature amplitude modulation (QAM) and pulse code modulation (PCM)[1]. PAM however is an amplitude modulated (AM) form of a pulse carrier[2], and hence has all the advantages and disadvantages of the purely analog AM, a major disadvantage being noise. PAM can be time-division multiplexed (TDM), as can pulse code modulation (PCM) which is a digital signal. TDM is one of the multiplexing techniques used in telephony (the other is space-division multiplexing). PAM is used as a first step in converting voice signal to PCM in the public switched telephone network (PSTN), and is also used to produce high-level modulation schemes for data modems and digital radio. High-level modulation is done in the output circuit of the radio frequency (RF) power amplifier stage, and is more efficient than low-level modulation. PCM is used for long-distance telecommunications, making PAM an important pulse modulation technique in communications systems.

Introduction

Engineering Technology programs are characterized by hands-on experiential instructional processes that help students to understand the application of the technology. This method of instruction is particularly useful for graduates who seek employment in industries that are service and maintenance oriented. The hands-on experiential approach may not be sufficient in cases where the graduate intends to seek employment in a research establishment. It is generally believed that students preparing for employment in research establishments require a higher level of mathematical utilization than students in technology programs do. It is however, essential that technology students understand all the principles employed in any particular technology that is taught in their program.

The Telecommunications industry has both research, and service and maintenance companies. It can be stated that there are more service and maintenance oriented companies than there are research establishments. As such, the majority of graduates find jobs in the service and maintenance sector which is profit driven, and the more work that is completed, the higher the profits. This creates an environment where service is not taken to the component level where design may be needed, but to the card level where faulty cards are simply replaced. It is therefore essential for the personnel to know how a card in working order should perform and the correct signals to obtain from test points on the card. The personnel should also know how to technically interpret the signals to make correct diagnosis. This paper discusses a laboratory experiment used to supplement a

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lecture on extracting useful information from a pulse amplitude modulated signal. This exercise was used in a telecommunications technology class.

Applications of Pulse Modulation Techniques

Both analog and digital signals can be transmitted over long distances. In transmitting analog signal over a long distance, amplifiers are used at intermediary points. The amplifiers amplify the signal as well as the noise on the signal that arrive at the amplifier. Transmission of digital signal over a long distance employs repeaters which regenerate the signal and transmit it, hence eliminating any noise picked up during transmission. This makes transmission of digital signals more efficient.

Analog signals can be converted to digital once the signal has been sampled. The sampled signal forms pulses, hence pulse modulation. The four common types[1] are pulse width modulation (PWM) which is sometimes called pulse duration modulation (PDM) or pulse length modulation (PLM), pulse position modulation (PPM), pulse amplitude modulation (PAM) and pulse code modulation (PCM). PWM and PPM are used in few instances in communications systems, usually for military purpose. These two are rarely used in commercial multiplexed communications systems[2] because of the large bandwidths needed. Also, the fact that frequency division multiplexing (FDM) must be used with these two makes them unsuitable for commercial communications systems because the equipment needed for FDM is more complex than that needed for TDM, hence more expensive. Again, with PPM, a phase-locked loop needs to be used so as to employ its acquisition circuitry.

However, there are telecommunications applications in which PWM and PPM are employed. PWM is used in high-powered audio amplifiers that are used to modulate amplitude modulated (AM) transmitters[3]. It is also used in telemetry systems. PWM is not sensitive to amplitude changes as a result of noise and distortion. PPM is also applied in telemetry systems.

PAM on the other hand can be multiplexed by TDM as stated above, and the technology that employs TDM is less expensive than that which employs FDM. PAM is used as an intermediate form of modulation with pulse modulation techniques such as pulse shift keying (PSK), quadrature amplitude modulation (QAM), and pulse code modulation (PCM). It is an analog technique in which the amplitude of each pulse is proportional to the amplitude of the signal when it was sampled.

PCM can also be multiplexed by TDM and is extensively used for communication. In particular, it is commonly used in the public switched telephone network (PSTN). A laboratory exercise on PAM signal is therefore useful for beginners in the field of telecommunications technology. The demodulation exercise was used to demonstrate how a signal is reconstructed at the receiver to obtain the original message.

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Experimental Exercise

The experiment was performed with Lab Volt Digital Communications Trainer Model 8085. The experimental circuits of the trainer are designed on cards as modules that can be connected to the power supply and measuring components to form a specified modular arrangements. Experimental procedures are provided with the trainer. These can be modified to suit particular preferences. The experimental set up is shown in Figure 1.

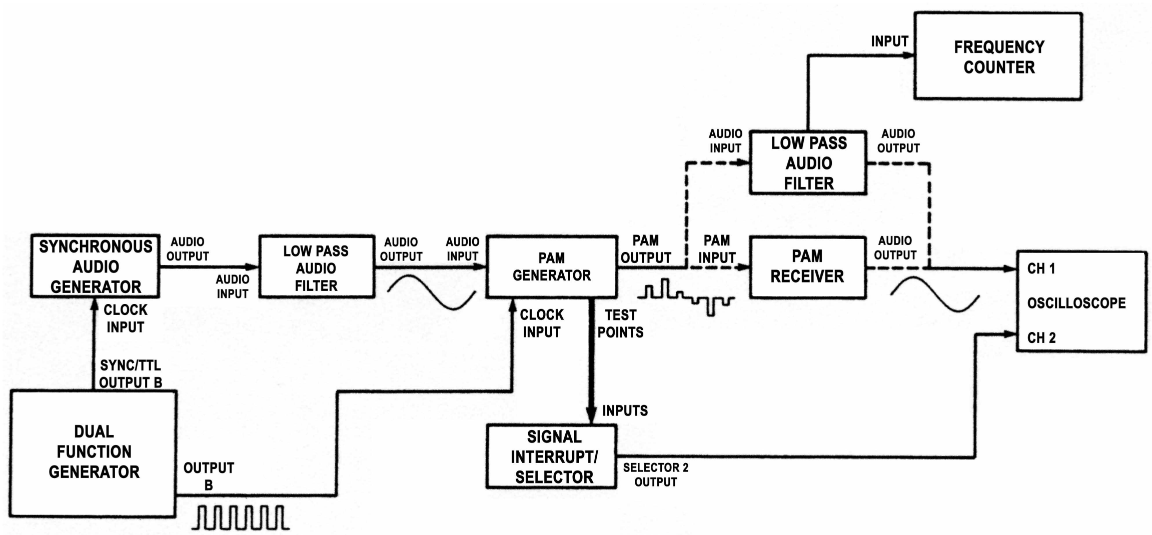

Figure 1. System for PAM signal demodulation

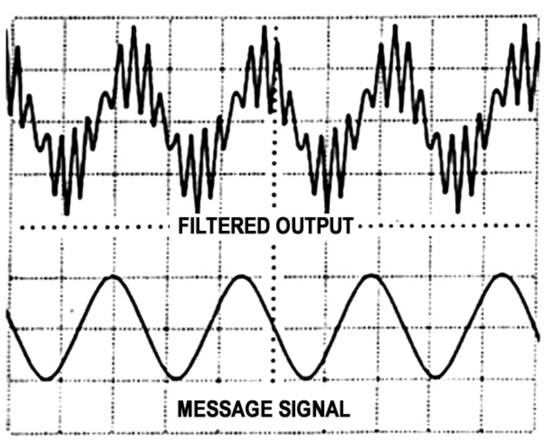

Figure 2. Low Pass Filter Output. Cutoff Frequency at 8 kHz

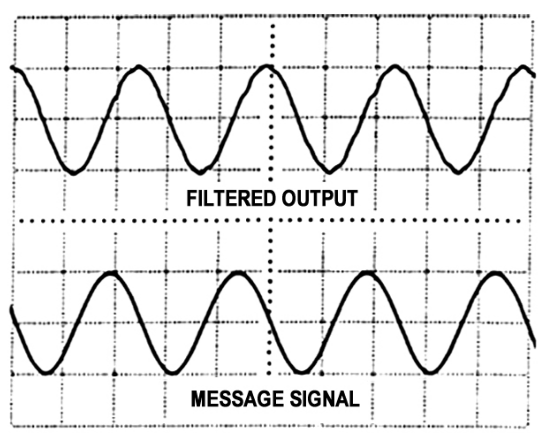

Figure 3. Low Pass Filter Output. Cutoff Frequency at 3.4 kHz

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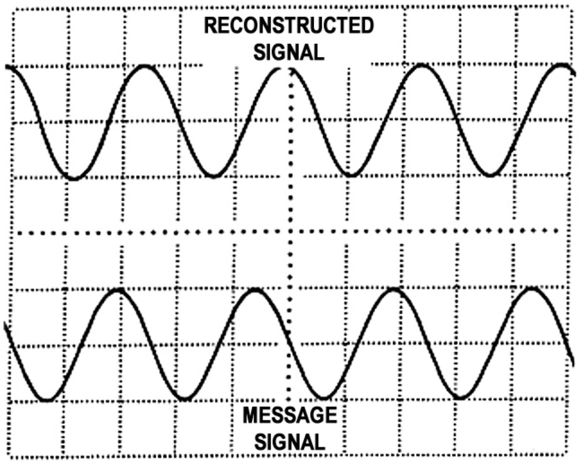

Figure 4. PAM receiver

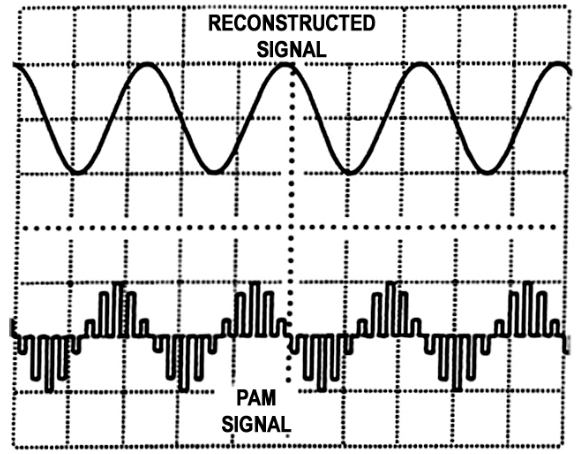

Figure 5. PAM signal

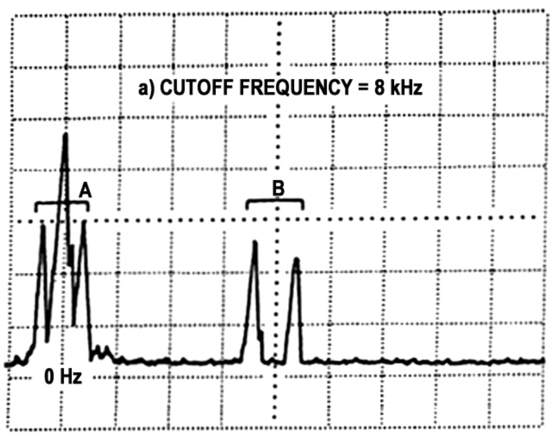

Figure 6. Frequency Spectrum at 8 kHz

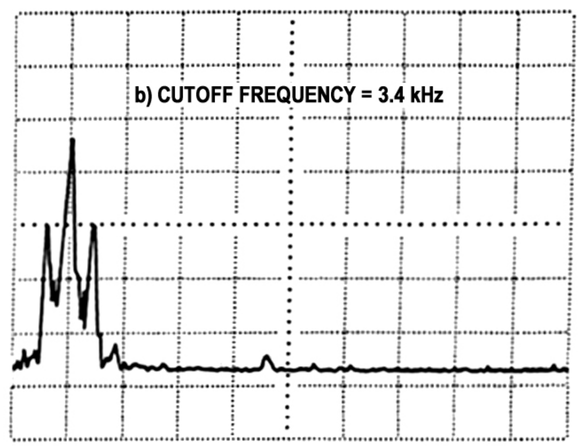

Figure 7. Frequency Spectrum at 3.4 kHz

The PAM signal was demodulated by two methods, one method was by using a low pass audio filter and the other method was by using a PAM receiver which is fixed at 3.4 kHz to allow good reception of the International Telecommunications Union (ITU) standard bandwidth signal. The PAM receiver has a low pass filter incorporated. Measurements were taken at 8 kHz, and at 3.4 kHz in both time and frequency domains.

The PAM generator was first set to message signal, and the output was connected to the low pass filter with the cutoff frequency set at 8 kHz. The output and the message signals are shown in Figure 2. The noise observed in the output is greatly reduced when the cutoff frequency of the low pass filter is reduced to 3.4 kHz. This is shown in Figure 3. Figure 4 shows the output of the PAM receiver when the signal from the PAM generator

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is subsequently connected to the PAM receiver. The PAM generator was then set to PAM signal and this is displayed in Figure 5. A spectrum analyzer was then connected between the low pass filter/PAM receiver and the oscilloscope. The output was first observed from the low pass filter at 8 kHz, then at 3.4 kHz. The responses are shown in Figures 6 and 7 respectively. The spectrum observed from the output of the PAM receiver is similar to Figure 7.

Discussion

By setting the cutoff frequency of the low pass filter at 8 kHz, the bandwidth for the signal was set at that frequency and the response as observed in Figure 2 was very noisy. In real life situation, the noise can be from both external and internal (unwanted frequencies generated by the system) sources. Reducing the cutoff frequency to the ITU recommended standard of 3.4 kHz removed (or reduced) a lot of the noise as the filter smoothed out the PAM signal. The output was still not as smooth as the message signal These are observed in Figure 3. The PAM receiver, which is more sophisticated in construction than a simple low pass filter showed a response which was an exact replica of the message signal. In all these figures, it is observed that the output signal and the input signal were out of phase. This is due to delay of the signal as it passes through the system. The effect of the delay will not be noticeable at the output. Sampling rates above the Nyquist rate are used to avoid aliasing. By varying the duty cycle shown in Figure 5, aperture distortion can be observed, and compensating networks have to be used for a duty cycle of more than 10 %. Figure 6 shows the frequency spectrum of the message plus higher frequencies of the message which will manifest as noise on the channel. Reducing the cutoff frequency to the recommended standard removed these unwanted frequencies.

Conclusion

The experiment showed how a low pass filter is used to smooth out a PAM signal and reconstructs samples of the PAM signal to reproduce an original message signal. With regards to removing unwanted higher frequencies, a high order filter with a sharp rolloff may be used. This is done in commercial components. Selection of a duty cycle of 10 % or less is useful in avoiding aperture distortion. Also, Nyquist theorem needs to be adhered to reproduce a signal with no distortion. As stated above, PAM is very useful as a first step in voice/PCM conversion, and considering the fact that PCM is used extensively in the PSTN, PAM is considered very useful. Its usefulness is emphasized by the research still going on such as on error probabilities for QAM systems[4], and communication systems with cascaded sequences and PAM/QAM signal sets[5].

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