**Chapter 5 Digital Pulse Modulation System**

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**1. Introduction**

* Basically this chapter of Digital Pulse modulation deals with how an analog signal is converted into digital signal from communication theory point of view
* So at the transmitting side the information bearing signals are converted into digital signals and are ready for transmission. But the channels that exist in the real world are analog and are not suitable to transmit these converted digital signals.
* Hence for efficient transmission of digital signals over the channel ,the Keying techniques like ASK,FSK and PSK are implemented
* So this chapter examines the various A/D conversion methods like PCM,DM and the keying techniques such as ASK,FSK and PSK

**2. Digital Pulse modulation systems**

Digital Pulse modulation is a mechanism or a method that converts the information about the message signal into ‘1’ & ‘0’

The difficulty that we face in this method is that the information about the message signal is basically analog or continuous in nature .But the values which we have to represent are discrete in nature. So how do we represent a signal that has continuously varying amplitude with another signal having discrete set of amplitude?

The answer to the above question is to employ one of the following methods

 (a)PCM-Pulse Code Modulation

 (b) DPCM- Differential PCM

 (c) DM- Delta Modulation

 **(a)PCM-Pulse Code Modulation**

***DEFINITION***: Chang deifnationPulse code modulation (PCM) is essentially analog-to-digital conversion of a special type where the information contained in the instantaneous samples of an analog signal is represented by digital words in a serial bit stream

The PCM signal is generated by carrying out three basic operations:

1. Sampling
2. Quantizing
3. Encoding

SAMPLER

QUANTIZER

ENCODING

1**. Sampling**: The process of generating pulses of zero width and of amplitude equal to the instantaneous amplitude of the analog signal. Note that sampled values obtained should satisfy the Nyquist rate. Hence sampling converts a continuous signal into discrete signals

 2. **Quantization**: Representing the sampled values by a finite set of levels is called quantizing

3. **Encoder**: The encoder represents these quantized levels into bits which are transmitted over the channel.

**(b) DPCM- Differential PCM**

* In PCM system we transmit the encoded sample value of analog signal .The number of bit required to encode the message signal depend on the message peak amplitude.
* If we can decrease the peak amplitude ,then we can reduce the number of bits
* Hence employing such kind of technique to reduce the peak amplitude which in turn reduces the number of bits is known as DIFFERENTIAL PCM SYSTEM.

 **(c) DM- Delta Modulation**

In DM technique we increase the sampling rate ;generally it is 4 times the Nyquist rate .Due to increase in sampling ,correlation between samples increase which result in the improvement of prediction of m[k-1] samples .Since we are making good prediction about m[k-1] the quantization noise decreases.

**3. Companding**

* The quantizer we have discussed so far is of the type known as UNIFORM QUANTIZER . This type of quantizer employs uniform step size.
* Another type of quantizer is called as NON-UNIFORM QUANTIZER which employs non –uniform step size Non uniform quantizer is also referred as compandium; which consists of two word compression and expansion.
* **Compressing** of signal is done at the transmitter and **expansion** is done at the receiver ;hence the name companding

**4. FDM (Frequency Division Multiplexing), TDM (Time Division Multiplexing)**

***What is multiplexing and why its required? What are the different types multiplexing?***

* Simultaneous transmission of multiple messages (more than one message ) over the channel is known as multiplexing. The channel is referred to here as the media of transmission. The channel may be a pair of wires or free space.
* If transmitted without modulation the different message signals over a single channel will interfere with one another. This is because their baseband spectrum is identical or overlapping
* However because of modulation (i.e. frequency translation) ,multiple message signals can be transmitted over the same channel without interference using multiplexing techniques.

**Types of multiplexing techniques**

 (i) FDM (Frequency Division Multiplexing).FDM uses analog modulation systems (AM or FM)

 (ii) TDM (Time Division Multiplexing).TDM uses pulse modulation systems (PCM)

**FDM (Frequency Division Multiplexing)**

* To understand FDM, we try to solve the following problem and analyze a case study on how a telephone system can be implemented using FDM

 Two signals m1(t) and m2(t) both band limited to 4000 rad/s are to be transmitted simultaneously over a channel by the multiplexing scheme shown in the diagram below. The signal at point b is the multiplexed signal which now modulated by a carrier frequency of 25,000 rad/s. The modulated signal at point c is transmitted over a channel.

(a) Sketch signal spectra at points a, b and c **. 4pts**

(b) What must be the bandwidth of the channel? **1pt**

(c) Design a receiver (only functional blocks) to recover signals m1(t) and m2(t) from the modulated signal at point c. **2pts**





**CASE STUDY ON HOW A TELEPHONE SYSTEM CAN BE IMPLEMENTED USING FDM**

* Imagine that at transmitter side message signals are transmitted simultaneously over the common channel without multiplexing, they will interfere with each other and no useful information will be produced at the receiver end.
* However they can be transmitted without interference if they are multiplexed .In frequency division multiplexing, each message signal is frequency translated by analog modulation (amplitude modulation or angle modulation) to different carrier frequencies.
* Each modulated signal is separated from the adjacent one by at least 2fm.Then the modulated signals are multiplexed (added) .Hence the multiplexed signals can be transmitted over a common channel without interference and can be separated at receiver by suitable band pass filter
* At the receiver end the multiplexing is done ,that is various carrier frequencies are selected using band pass filters tuned to appropriate carrier frequencies and the message signals are detected (recovered) by separate demodulators

FDM AT TRANSMITTER SIDE



m3 (t)

m2 (t)

m1 (t)

DEMULTIPLEXING AT RECEIVER END SIDE



m3 (t)

m2 (t)

m1 (t)

**TDM (Time Division Multiplexing)**

* TDM is a digital process that allows several connections to share the bandwidth of a link(connection)
* Instead of sharing a portion of the bandwidth as in FDM, time is shared
* Message signal is passed through LPF. After that signal is fed to the commutator .Here the commutator is a fast electronic switch works as a sampler
* Therefore commutator take sample of each N message signals at a rate higher than the Nyquist Rate
* After the commutator process, the message signals are multiplexed. These multiplexed signals are passed to the pulse modulator. The pulse modulator can be a **PCM system**. So the modulator will transmit the multiplexed signals through the communication channel.
* At the receiver end the reverse process takes place as shown in the diagram



Block Diagram of TDM system

**5 Keying techniques**

* The output of a PCM system is a string of 1’s and 0’s.If they are to be transmitted over copper wires, they can be transmitted as appropriate voltage levels using a line code.(to explain the concept of line code ;it is beyond the scope of the chapter.)
* But if they are to be transmitted through space using antenna for longer distance, some mechanism of modulation has to be implemented. Hence for efficient transmission of the digital signals we use the different Keying techniques like ASK,FSK and PSK.(Keying techniques are also known as Binary Signaling Technique)

**(a)ASK-Amplitude Shift Keying**

* Amplitude-shift keying (ASK) is a form of modulation that represents digital data as variations in the amplitude of a carrier wave.
* The amplitude of an analog carrier signal varies in accordance with the bit stream (modulating signal), keeping frequency and phase constant.
* The level of amplitude can be used to represent binary logic 0s and 1s.
* In the modulated signal, logic 0 is represented by the absence of a carrier, thus giving OFF and ON keying operation and hence the name ON-OFF keying (OOK) given.
* In the diagram given below the bit stream to be transmitted is 10110.Notice that whenever logic ‘0’ has to be transmitted it is represented by the absence of the carrier.



**(b) FSK- Frequency Shift Keying**

In FSK 2 sinusoidal carrier signals of same amplitude with different carrier frequencies are used to represent 1 and 0.

So to represent bit 1 the frequency of carrier wave is increased and for bit 0 the frequency is decreased as shown in the diagram. The variation in frequency is controlled by an electronic device called as voltage controlled oscillator

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**(c) PSK –Phase shift Keying**

In PSK, the phase of the carrier is varied to represent two different signal elements i.e 1 and 0. Both peak amplitude and frequency remain constant as the phase changes. Today, PSK is more common than ASK or FSK.

PSK is as simple as binary ASK with one big advantage it is less vulnerable to noise. In ASK, the criterion for bit detection is the amplitude of the signal; in PSK, it is the phase. Noise can change the amplitude easier than it can change the phase. In other words, PSK is less vulnerable to noise than ASK. Also PSK is superior than FSK since we do need to use 2 carrier signals as inFSK.

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**Extra points on digital transmission and principal advantage**

* The concept of digital transmission is entirely different from its analog counterpart. With an analog signal there is **continuity**, as contrasted with a digital signal that is concerned with **discrete** states.
* The information content of an analog signal is conveyed by the value or magnitude of some characteristic(s) of the signal such as amplitude, frequency, or phase of a voltage; the amplitude or duration of a pulse;
* The information content of a digital signal is concerned with discrete states of the signal, such as the presence or absence of a voltage
* The process of making the signals discrete results in digital signals which are binary. So with a binary signal (a bit), the signal can only take on one of two states 0 or 1. Hence with a binary system, we can utilize the number base2 and apply binary arithmetic, if need be. The other good reason is that we can use a decision circuit where there can only two possible conditions. We call those conditions a 1 and a 0.
* Key to the principal advantage of digital transmission is the employment of such simple decision circuits. We call them **regenerators**. A corrupted digital signal enters on one side, and a good, clean, nearly perfect square-wave digital signal comes out the other side. Accumulated noise on the corrupted signal stops at the regenerator. This is the principal disadvantage of analog transmission: noise accumulates. Not so with digital transmission.
* It is compatible with the integrated circuits (ICs) such as LSI, VLSI, and VHSIC. PCs are digital. A digital signal is more tolerant of noise than its analog counterpart.

**6. Self evaluation quiz-II**

1. Which of the following modulation is digital in nature ?

(a)PAM (b) PPM (c) DM (d) None of the above

2. Which of the following modulation is analog in nature?

(a)PCM (b)DPCM (c)DM (d)None of the above

3. The main advantage of PCM is

(a) less bandwidth (b)less power (c)better performance of noise (d)possibility of multiplexing

4. The main disadvantage of PCM is

(a) Large bandwidth (b) large power (c)complex circuitry (d)quantization noise

5. The number of bits per sample in a PCM system is increased from 8 to 16.The bandwidth of the system will increase

(a) 8 times (b) 2 times (c)1/2 times (d)28 times

6. The standard data rate of a PCM voice channel is

(a)8 kbps (b)8bps (c)16bps (d)64kbps

7. In PCM systems , the quantizing noise depends on

(a) the number of quantizing levels (b)the sampling rate (c ) both the number of quantizing levels & the sampling rate

8. Quantizing noise is produced in

(a) all pulse modulation systems (b) PCM (c) all modulation system

9. For an efficient communication in PCM system number of samples per second must be at least equal to twice the highest modulating frequency

(a) true (b)false

10. In FDM the following modulation technique is implemented

(a)AM and FM (b) Digital Pulse modulation (c)both a and b

11. In TDM the following technique is implemented

(a)AM and FM (b) Phase modulation (c) PCM

12. ASK is called as OOK

(a)true (b)false

13. In the keying technique the carrier signal is

(a) sinusoidal (b)train of pulse (c)binary digits

14.If we want to transmit digital signals over free space we use

(a) line coding (b)any one of the Keying techniques (c)coaxial wire

Answers for Self evaluation Quiz -II

1. (c) 2.(d) 3.(c) 4.(a) 5.(b) 6.(d) 7.(a)

8. (b) 9.(a) 10(a) 11(c) 12(a) 13(a) 14(b)

Problems

1. Consider the signal m(t) shown below. This analog signal is converted into digital signal with help of a PCM system and the quantization level is L=8.

(a) Sketch the signal at point a , b and c

(b) Calculate the bit rate and bandwidth required to transmit if the maximum frequency of m(t)=1000Hz.

2. A compact disc (CD) records audio signal digitally by using PCM. Assume the audio signal bandwidth is 15 kHz.

(a) What is the sampling rate

(b) If the samples are quantized into L=65,536 levels and then binary coded , determine the number of binary digits required to encode a sample

(c) Determine the number of binary digits per second (bit/s) required to encode the audio signal.

(d) For practical reasons signals are sampled at rate well above the sampling rate given in (a).Hence practical CDs use 44,100 samples per second. If L =65,536 determine the number of bits per second required to encode the signal

3. A television signal has a bandwidth of 4.5 MHz ;this signal is sampled quantized and binary coded to obtain a PCM signal.

(a) Determine the sampling rate if the signal is to be sampled at a rate 20% above the Nyquist rate.

(b) If the samples are quantized into 1024 levels,determine the number of binary pulses required to encode each sample.

(c) Determine the binary pulse rate (bit rate ) of the PCM signal and the minimum bandwidth required to transmit this signal.

4. Five telemetry signals each of bandwidth 1 kHz , are to be transmitted simultaneousli by binary PCM.the maximum tolerable error in sample amplitudes is 0.2% of the peak signal amplitude .The signals must be sampled at least 20% above the Nyquist rate. Framing and synchronizing requires an additonal 0.5%.Determine the minimum possible bit rate that must be transmitted and the minimum bandwidth requires to transmit this signal.

5. It is desired to set up a central station for simultaneous monitoring of the electrocardiograms (ECGs) of 10 hospital patients .The data from the rooms of the 10 patients are brought to a processing center over wires and are sampled ,quantized ,binary coded and multiplexed. The multiplexed data are now transmitted to the monitoring station as shown in the diagram. Consider the ECG signal bandwidth is 100 Hz. The maximum acceptable error in sample amplitude is 0.25% of the peak signal amplitude. The sampling rate must be at least twice the Nyquist rate. Determine the minimum cable bandwidth needed to transmit these data.