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Digital Communication-Technology and Advancements

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Abstract

Usage of the benefits of electrical communication has become an inseparable part of our lives now. Through this paper, I have tried to summarize various technologies that are important in the field of digital communication and have also included the recent advancements in the same field. The paper starts with the basic idea about the communication system followed by basic modulation techniques like amplitude, frequency and phase modulation. The paper then explains the analog to digital conversion techniques including the basics about sampling theorem, pulse-code modulation, quantization of signals followed by digital modulation techniques like Amplitude shift keying, Frequency shift keying, Phase shift keying, Binary Phase Shift Keying, Binary Frequency Shift keying, M-ary digital Modulation technique and Quadrature Amplitude Shift Keying . It then covers the problems of occurrence of noise and error in various modulation systems and the methods of reducing it like coding for error detection and correction. Lastly, the various latest advancements in the field of digital communication have been discussed for instance the new graphene technology that has the potential to break the current speed limits in digital communication as demonstrated by the scientists at the University of California, the advancements in underwater acoustic (UWA) digital communication as per the paper published in IEEE in the oceanic engineering and recent developments using Phase Shift Keying on High Frequency.

Keywords: Modulation; pulse code modulation; delta modulation; sampling theorem; quantization; graphene modulator; underwater acoustic communication.

1. Introduction

The basic elements of a digital communication system can be visualized as follows:

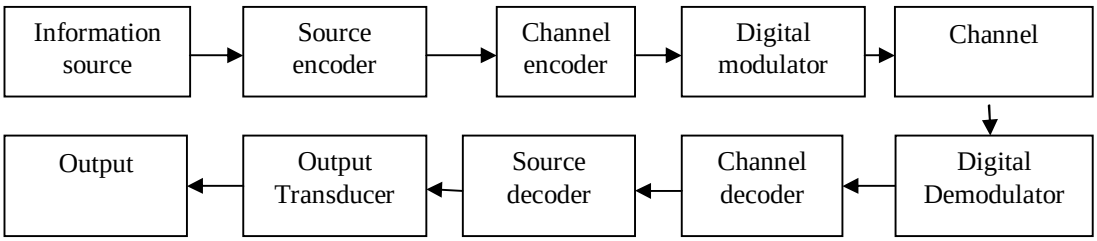

Fig. 1: Elements of digital communication system.

Information source or may be termed as input transducer is the source of information that is to be transmitted. It may have digital (telegraphic signal) information or analog (audio, video signal) information. The source encoder then provides with the efficient conversion of the output of the preceding stage into a sequence of binary digits. Channel encoder then adds the extra bits to the source encoded bits in order to cope with the noise which makes digital communication system more immune towards noise. The digital modulator then performs the task of converting the binary digits into a waveform for the purpose of transmission through the channel which may be wired/ wireless. The digital demodulator then performs the task of regenerating the previous bit pattern from the received waveform. After all of these processes are performed the channel decoder and the source decoder then works in conjunction with the channel encoder and source encoder to perform the decoding technique since the decoding technique would be the same as the encoding technique. The output signal is then converted into a desirable form by using the appropriate transducer and the output is received. Information source, source encoder, channel encoder and the digital modulator forms a part of transmitter section while digital demodulator, channel decoder, source decoder and output transducer forms a part of receiver section.

2. Processes and Techniques

2.1 Sampling Theorem

The most important role of this theorem is to convert continuous-time signal to an equivalent discrete-time signal. The theorem can be explained in two parts: First, If a signal x(t) does not contain any frequency beyond W Hz, then the signal is completely described by its instantaneous uniform samples with sampling interval of $Ts<1/(2W)$ sec. Second, the signal can be reconstructed from the set of uniform instantaneous samples by passing the samples sequentially through an ideal low-pass filter with bandwidth B, where $W \leq B < fs-W$ and $fs=1/T$.

2.2 Analog to Digital Conversion

Before the signal is converted into digital form, its preprocessing is required to be done since most of the A/D convertors quantizes accurately only if the signal is within specific range and most of the signals are random in nature. Only after the signal has been processed to a desired range, it can be converted into its corresponding digital form. Pulse Code Modulation is a technique that is used for the conversion. Following is the block diagram of the process in which the analog input signal is assumed to posses zero mean and suitable variance such that the signal samples at the input of the A/D convertor lie satisfactorily within acceptable signal range.

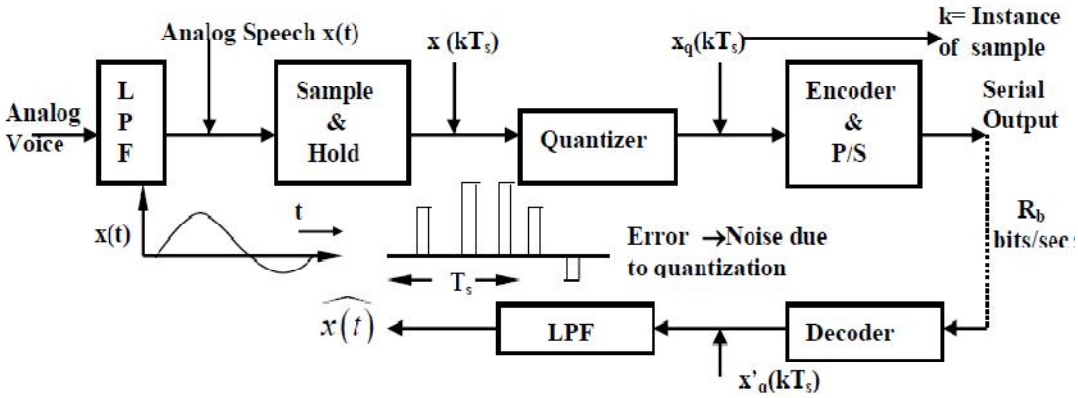

Fig. 2: Schematic diagram of Pulse Code Modulator coder-decoder.

Another such technique is Delta Modulation which is based on the principle that if the signal is sampled at a rate which is much faster than Nyquist sampling rate, the adjacent samples will then have a high correlation. The sample to sample amplitude difference will be very small, so one may even think of 1-bit quantization of the difference signal.

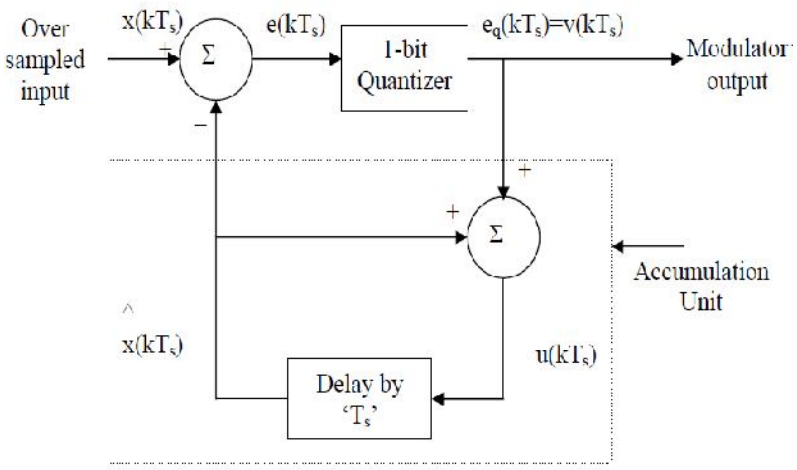

Fig. 3: Block diagram of Delta Modulator.

2.3 Modulation

The very basic process in any communication system is the process of modulation which is performed on the signal to be transmitted in order to enable it to acquire an acceptable form. In the analog domain, modulation refers to the process of changes in the parameters of the carrier signal with respect to the variations in the modulating signal. As per the variations in the parameters the modulation techniques are amplitude modulation, frequency modulation and phase modulation. Similarly, there are various digital modulation techniques as well such as Amplitude Shift Keying, Frequency Shift Keying and Phase Shift Keying. Amplitude Shift Keying is a process of shifting the amplitude of carrier signal between two levels depending on whether 1 or 0 is to be transmitted. Frequency Shift Keying is a process of shifting the frequency of the carrier signal between the two levels depending on whether 1 or 0 is to be transmitted and Phase Shift Keying is defined as the shifting in the phase of the carrier signal depending on whether 1 or 0 is to be transmitted. Apart from the basic techniques, other variants in the form of Binary Amplitude Shift Keying, Binary Frequency Shift Keying and Binary Phase shift Keying is also available. In these types of modulation the amplitude, frequency and phase of the carrier signal can take only two values respectively and that is why the term binary. Another variant to these modulation technique is M-ary Digital Modulation techniques which differ from the binary techniques as in binary techniques the parameters (amplitude or phase or frequency) of the carrier can take only two values while in M-ary modulation techniques the parameters(amplitude or phase or frequency) of the carrier can take M different values. Lastly, the Quadrature Amplitude Modulation technique which is a variant of amplitude modulation to conserve bandwidth in which the two message signals can be transmitted on the same bandwidth using two carriers having same frequency but separated by a phase shift of $\pi/2$.

2.4 Error Control

As mentioned earlier, channel encoding and decoding is performed in order to make the system resistant to noise. The process of error control can be categorized as follows:

2.4.1 *Forward Error Correction (FEC):* Complete process of decoding is applied on the received sequence in order to detect the position of erroneous symbols. However, the process of error detection is not full proof and the decoder may often fail to distinguish the position of erroneous symbols. The various types of forward error correction can be given by the following diagram:

2.4.2 *Auto Repeat Request (ARQ):* In some of the applications, it is important to receive only the error free information even if there is a delay from the usual time. Therefore, in these cases a simple error detection code is applied at the received sequence. In case of any error, it is sent back until the error free sequence is obtained. It is of three types (i) stop and Wait Auto Repeat Request (ii) Continuous Auto Repeat Request (iii) Selective Repeat Auto Repeat Request

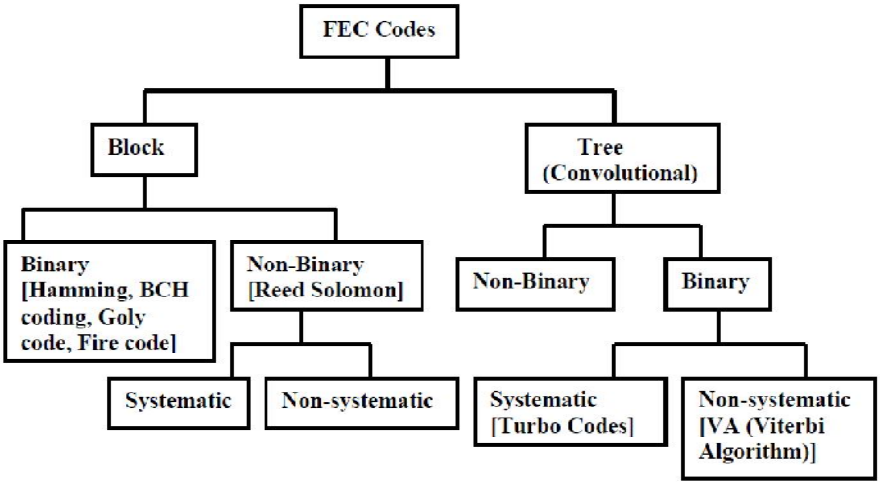

Fig. 4: Classification of Forward Error Code.

2.4.3 *Hybrid Auto Repeat Request:* It combines the feature of both the above coding i.e. the delay in the Auto Repeat request process can be decreased if proper type of Forward Error Correction is applied to the Auto Repeat Request. Application of a Forward Error Code and a judicious choice of the code parameters are based on the parameters such as (i) Nature of communication channel (ii) Available channel bandwidth (iii) Hardware complexity cost and delay and (iv) The coding gain.

3. Recent Advancements

3.1 Use of Graphene Modulators to enhance the speed of Digital Communication

Scientists at the University of California, Berkeley have demonstrated a new technology that could break the current speed limits in digital communication. A team of researchers led by Professor Xiang Zhang built a tiny optical device that uses graphene, a one atom thick layer of crystallized carbon, to switch light on and off. This switching ability is the fundamental characteristic of a network modulator, which controls the speed at which data packets are transmitted. The faster the data pulses are sent out, the greater the volume of information that can be sent. According to Professor Xiang, graphene enables us to make incredibly compact modulators that potentially perform at the speed up to ten times faster than the current technology. Also, the researchers were able to tune the graphene electrically to absorb light in wavelengths used in data communication which adds another advantage to graphene. Graphene based modulators not only provide increased modulation speed but also enable greater amounts of data packets and hence "instead of broadband we will have 'extremeband', as quoted by Professor Xiang.

3.2 Advances in Underwater Acoustic Communication

In recent years, underwater acoustic (UWA) communications have received much attention as their applications have begun to shift from military towards commercial.

Digital communications through UWA channels differ substantially from those in other media, such as radio channels, due to severe signal degradation caused by multipath propagation and high temporal and spatial variability of the channel condition. The design of underwater acoustic communication system has until relied on the use of non-coherent modulation techniques. However to achieve high data rates on the severely band-limited UWA channels, bandwidth-efficient modulation techniques must be considered. The new generation of underwater communication systems, employing phase coherent modulation techniques, has the potential of achieving at least an order of magnitude increase in data throughput. Current research focuses on development of efficient signal processing algorithms, multiuser communications in the presence of interference and design of efficient modulation and coding schemes.

3.3 Developments using Phase Shift Keying on High Frequency

It is difficult to understand that true coherent demodulation of Phase Shift Keying could ever be achieved in any non-cabled system since random phase changes would introduce uncontrolled phase ambiguities. Presently, we have the technology to match and track carrier frequencies exactly; however tracking carrier phase is another matter. As a matter of practicality thus, we must revert to differentially coherent phase demodulation. Another practical matter concerns that of symbol, or baud rate; conventional RTTY runs at 45.45 baud. This relatively long symbol time have been favored as being resistant to HF multipath effects and thus attributed to its robustness. Symbol rate also plays an important role in spectral occupancy. In case of a 45.45 baud RTTY waveform, the expected spectral occupancy is some 91Hz for each of the two data tones. For a two tone Frequency Shift Keying signaling system of continuous-phase frequency shift keying paced at 170Hz, this system would occupy approximately 261Hz.

4. Conclusions

To conclude, it may not be an overstatement that 'information highways' are considered as the essential ingredients of national infrastructure in the march of modern society. Communication has occupied an important part of our lives without which information exchange cannot be imagined. Though analog communication system is much easier to implement but digital communication system is considered to be far better than its analog counterpart. It has gained so much of popularity that almost all the communication processes in today's era is performed in digital domain. It is much more immune towards erroneous signals, noise and the other stray signals that have the potential to infect the useful information. Talking about the past as well, the first of all the communication system was also a digital one which is a telegraph system in 1830's. Since it is so important a system, rigorous research is being carried out and various technologies have also been invented in order to increase its efficiency.

5. Acknowledgements

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