Chapter Contents

1.0 Introduction

Modern digital or data communications networks are largely offshoots of the less glamorous telephone system. A notable exception to this is the telegraph system. From its inception, telegraph used a form of digital binary signaling called Morse code, after its inventor. Alphanumeric characters were translated into a series of *dots, dashes,* and *spaces* that were transmitted as current pulses. This ingenious signaling method is still used today on telephone lines.

In the early years, the telegraph system dominated long distance communications while the telephone system addressed more local needs. In time, this too changed as telephony reached out over the miles leaving telegraphy to address a much smaller niche market.

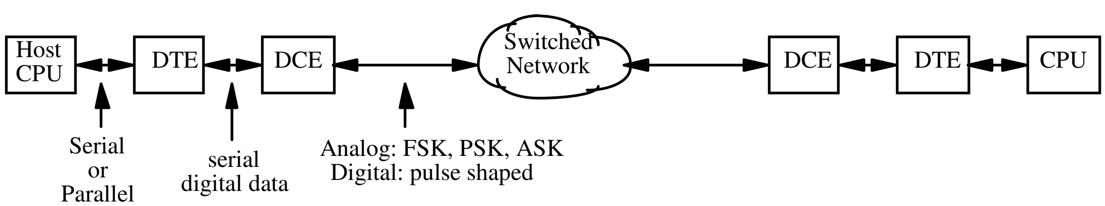
It was only natural when a century later the demands for data service arose, they would be met by the now enormous telephone corporations.

Data communications services offered through the **PSTN**†s needed to make digital signals look like analog voice signals. This was, and still is accomplished through the use of modems. Later, separate all digital data networks were developed by both **Telcos**† and private industry.

A simple data link consists of **DTE**†, **DCE**†, and an interconnecting network. In some cases, the DTE and DCE are incorporated into the same device. The DTE is a data terminal and handles only digital type signals, performs serial and parallel conversions, and may implement some sort of protocol. The DCE is the communications device and performs the physical layer signal conversion. In the case of a modem, it performs the modulation and demodulation functions.

The switched network allows millions of users to connect to each other at will. It is an extremely complex facility, often illustrated by a cloud. An examination of the network is beyond the scope of this course, but is addressed in *Telecommunications Systems.*

Simplified Block Diagram of a Data Communications Link



1.1 Digital vs. Analog

For many years, there has been a sort of ‘friendly feud’ between hardware and software designers. Each blaming the other if there is a malfunction, and yet

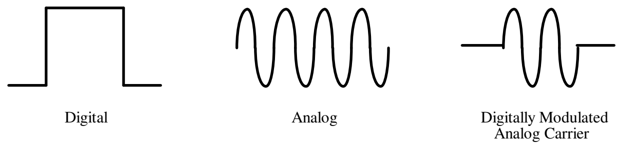
† Public Switched Telephone [Telecommunications] Networks
† Telephone Companies
† Data Terminal Equipment
† Data Communications Equipment

absolutely defending their own essential nature. This debate is largely over, since it is now the software that defines the machines. Software won.

A second area of debate has been the relative merits of analog and digital hardware design. Analog designers often consider themselves an elitist group, seeing infinite shades of gray while digital designers see only simplistic contrasts of ones and zeros, highs and lows, true and false. This type of banter could go on forever were it not for the fact that software operated on digital hardware.

The point of all of this is: the wave of the future is essentially digital.

The boundary between the analog and digital domains is sometimes quite obscure or even nonexistent. It is self evident that binary baseband signals are digital in nature. It is however, not clear that they remain digital if used to modulate an analog carrier, have multiple levels, or are spectrally shaped. If one could invent a word for this type of signal, perhaps we could call it *digilog*, or should it be *digalog?*



Although the bulk of the communications industry uses *all digital* technology, traditional analog technology retains important and powerful analytical tools. For example, in order to determine the maximum capacity of a digital channel, one must resort to analog spectral analysis and consideration of signal to noise ratios.

Digital Advantages

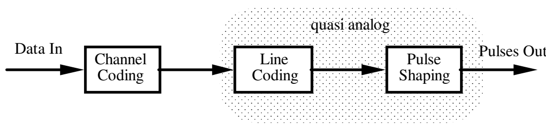
- Can be compressed
- Noise does not accumulate as system length increases
- Less susceptible to external noise or interference
- More compatible with computer systems
- Microprocessors support software reconfigurable hardware
- More easily encrypted than analog signals
- Circuits are readily integrated in silicon
- Powerful simulation tools exist
- Current **PCM**† costs are less than for equivalent **FDM**†

Analog Advantages

- Analog is more bandwidth efficient than uncompressed digital
- Easier to analyze mathematically
- FDM standards exist but PCM standards are not universal
- Most communications systems still use significant analog technologies

Digital signals must undergo several processes before being transmitted through a switching network:

† Pulse Code Modulation
† Frequency Division Multiplexing



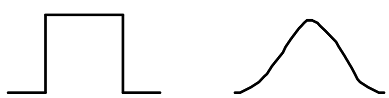
Channel coding is mainly concerned with data integrity and may incorporate error correction coding to compensate for the noise characteristics of the transmission channel. Conventional digital transmission over copper wire requires many overhead bits in order to maintain acceptable error rates. Fiber networks on the other hand, are not as susceptible to interference and require substantially less error-correcting overhead.

Line coding converts the sequence of data bits into a series of impulses. There is a wide range of variables to choose from when selecting line coding

Variables	Examples
Pulse Levels	Binary, ternary, quaternary
Polarity	Unipolar, bipolar, AMI
Duty Cycle	RZ, NRZ
Encoding	Differential, viterbi

In actual practice, the line coding function is performed in the same unit that does the pulse shaping. As a result, many texts do not distinguish between the two.

Pulse shaping constitutes a very important field of study, since the spectral content of the pulse must fit the frequency band of the transmission channel. In other words, the shape of the pulse must match the impulse response of the channel.



Unshaped Digital Pulse   Spectrally Shaped Pulse

1.2 Digital Modulation of Analog Carriers

Many communications media do not convey purely digital signals very well. Radio based systems such as microwaves, satellites, and cell phones rely upon RF carriers and frequency division multiplexing as the basic transport and access method. Using digital modulation in these types of applications can offer significant advantages:

- Increased capacity
- Reduced error rate
- Increased service offering

There are many variations on digital modulation. Many of these are examined in an excellent applications note by hp (required reading):

Digital Modulation in Digital Communications Systems by Hewlett-Packard

Modulation	Application
MSK, GMSK	GSM, CDPD
BPSK	Deep space telemetry, cable modems
QPSK, π/4 DQPSK	Satellites, CDMA, NADC, TERA, PHS, PDC, LMDS, DVB-S, cable modems, TFTS
OQPSK	CDMA, satellite
FSK, GFSK	DECT, paging, RAM mobile data, AMPS, CT2, ERMES, land mobile, public safety
8, 16 VSB	North American ATV, broadcast, cable
8PSK	Satellite, aircraft
n QAM	Digital microwave, satellite, DVB-C, DBV-T, MMDS
OFDM	ADSL, cable modems

The factors that determine the modulation scheme most suitable for any particular application include:

Bandwidth efficiency

Power consumption

Complexity

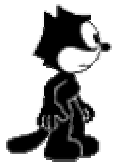
These factors are interdependent. Improving one generally has a negative impact on the others.

Large backbone service providers are very concerned with bandwidth efficiency. To them, bandwidth is a very limited resource. Generally, the increased power consumption and cost associated with increasing complexity can be distributed among the increased customer base.

End-users are often more concerned with power consumption, particularly in portable battery powered devices. Complexity can also be an issue since it is often directly related to the purchase cost.

Notes

Assignment Questions



Composition Questions

1. Identify some areas where analog communications techniques are used, and explain why they are preferred in certain applications.
2. Explain where and why digital communications techniques dominate.
3. Explain why some communications facilities require a hybrid combination of analog and digital methods.
4. Explain the importance of I/Q (vector) modulation.