Data Coding Schemes

CST 05202: BASICS OF DATA COMMUNICATION NETWORKS

UNIT V

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Introduction to Coding Scheme

A Coding Scheme refers to a standard, rules, or structure that is used to convert data into a different form.

- A computer uses Coding Schemes to convert simple information (Text Based) into Binary digits. Without a Coding Scheme, a computer will be unable to process information.
- For example, Mainframe computers use EBCDIC coding system, which stands for *Extended Binary Coded Decimal Interchange Code*.
- ASCII Coding Scheme which stands for *American Standard Code for Information Interchange* is commonly used in most Microcomputers.

What does Coding Scheme do?

As a Computer needs to convert information from Human readable format to its Language, which is Binary, a Coding Scheme is used in the conversion process.

- During the Encoding process, which is the process of converting information from simple format to the Binary status, Human readable information is represented by Bits, which a computer system can understand.
- Having That said, the process of Encoding is essential for computers and That's why, the importance of a Coding Scheme is undeniable.

What is the uses of Coding Scheme?

- Coding Scheme is used to assign groups of Bits to Human readable characters. So that, the processing of data inside a computer's unit is possible in Binary language.
- Coding Schemes are also helpful when it comes to storing large amount of data inside computers' memory..

Data & Signal

Data & Signal: Introduction

Layer 1 of the OSI model is all about the physical transmission of signals over media. Point-to-point transmission of data across nodes falls in layer 2.

- **Data** are entities that convey meaning
- **Signals** are the electric or electromagnetic encoding of data
- **Computer networks** and **data/voice communication** systems transmit signals
- **Data** and **signals** can be analog or digital

Data & Signal: Analog & Digital

To be transmitted, data must be Note transformed to electromagnetic signals.

The term **analog data** refers to information that is continuous; **digital data** refers to information that has discrete states.

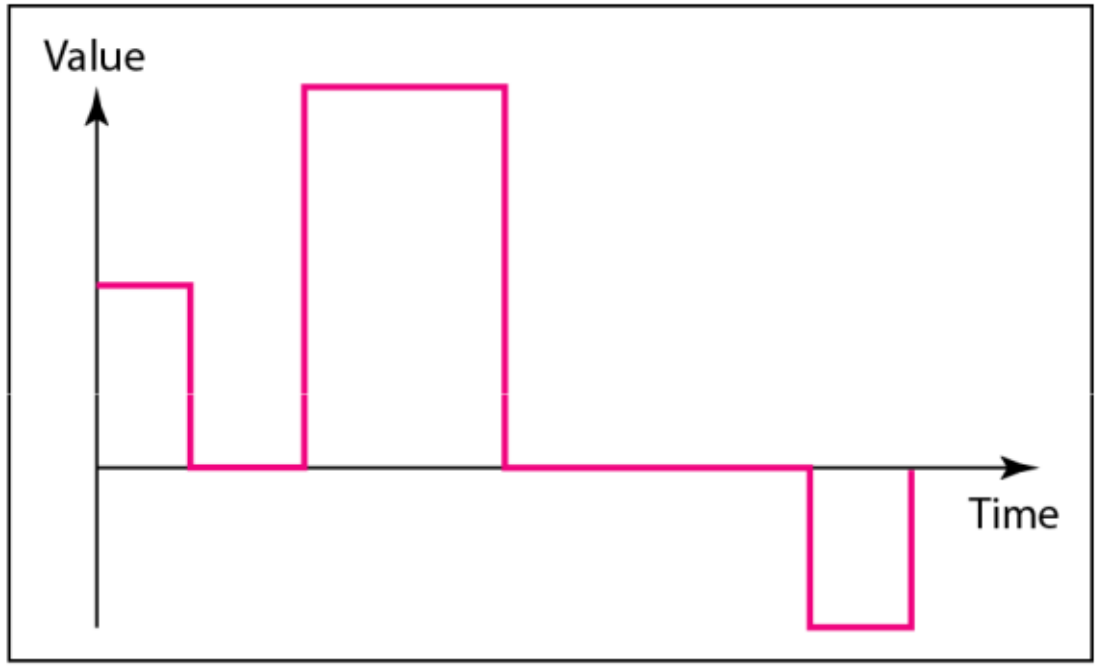
- Analog data, such as the sounds made by a human voice, take on continuous values.
- When someone speaks, an analog wave is created in the air. This can be captured by a microphone and converted to an analog signal and converted to a digital signal.
- Digital data take on discrete values. For example, data are stored in computer memory in the form of Os and Is.

Data & Signal: Analog & Digital

>>> **Wave forms**

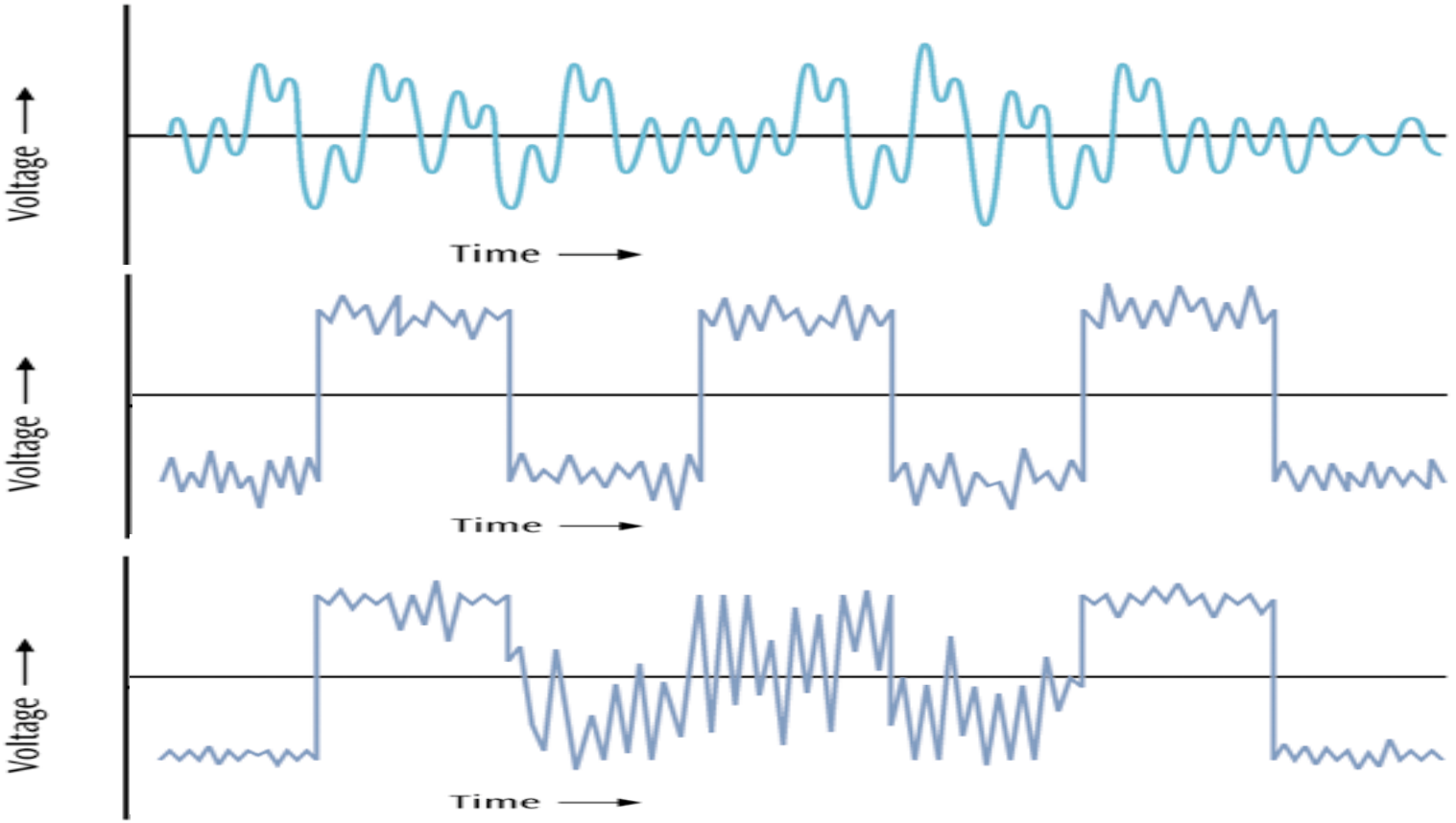


a. Analog signal



b. Digital signal

Data & Signal: Noises



Fundamental of Signal

All signals has four components:

Amplitude: The "height" of the wave above (or below) a central point, often measured in volts (V)

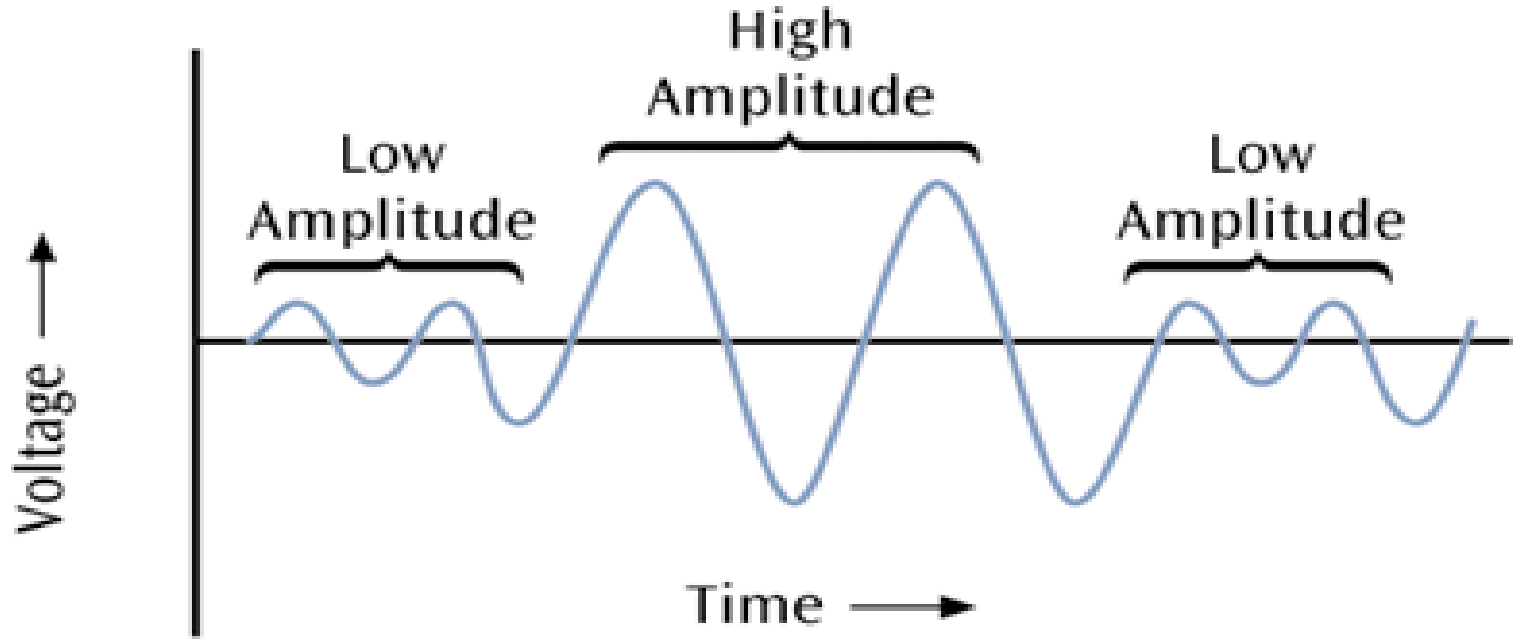
Frequency: The number of waves that pass a given point per second, measured in Hertz (Hz)

Wavelength: The distance from the start to the end of the wave, measured in meters (m)

Phase: Position of the waveform at a given time, measured in degrees of shift (o)

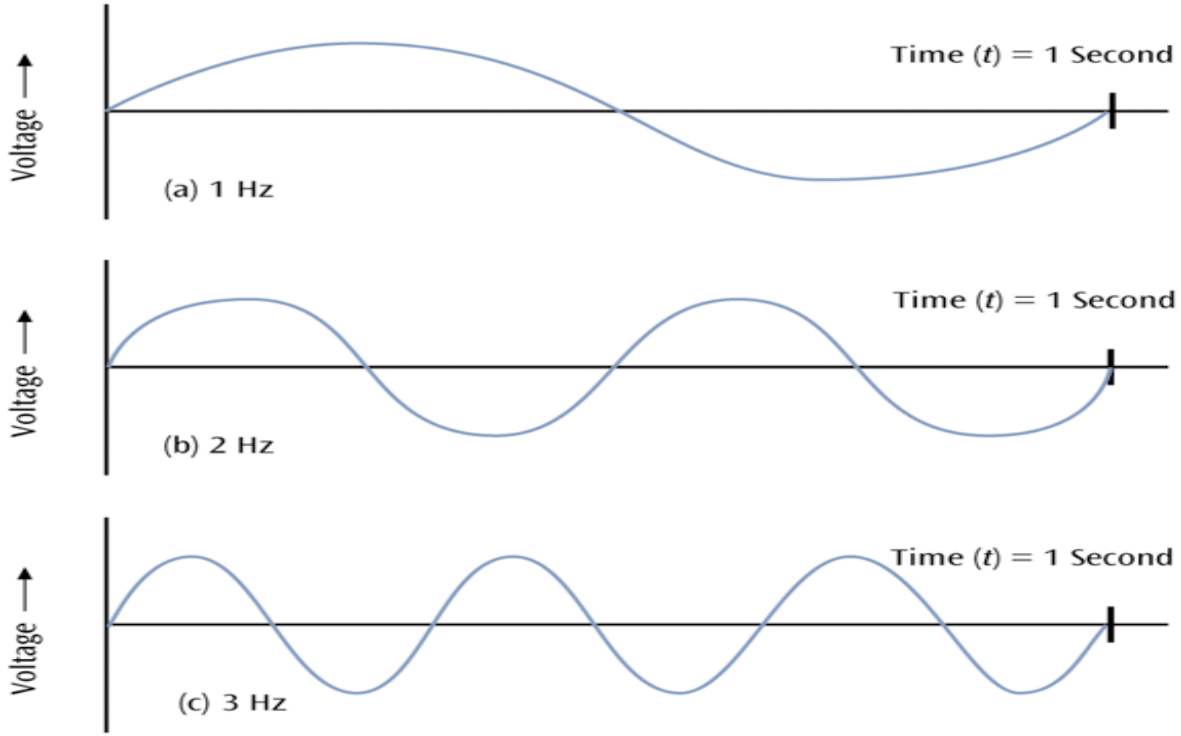
Fundamental of Signal: Amplitude

Amplitude refer to the "height" of the wave above (or below) a central point, often measured in volts (V)



Fundamental of Signal: Frequency

Frequency: The number of waves that pass a given point per second, measured in Hertz (Hz)



Fundamental of Signal: Frequency

The **frequency** is the number of times a signal makes a complete cycle within a given time frame

Spectrum - The range of frequencies that a signal spans from minimum to maximum

Bandwidth - The absolute value of the difference between the lowest and highest frequencies of a signal

For example, consider an average voice:

- The average voice has a frequency range of roughly 300 Hz to 3100 Hz.
- The spectrum would thus be 300 - 3100 Hz
- The bandwidth would be 2800 Hz

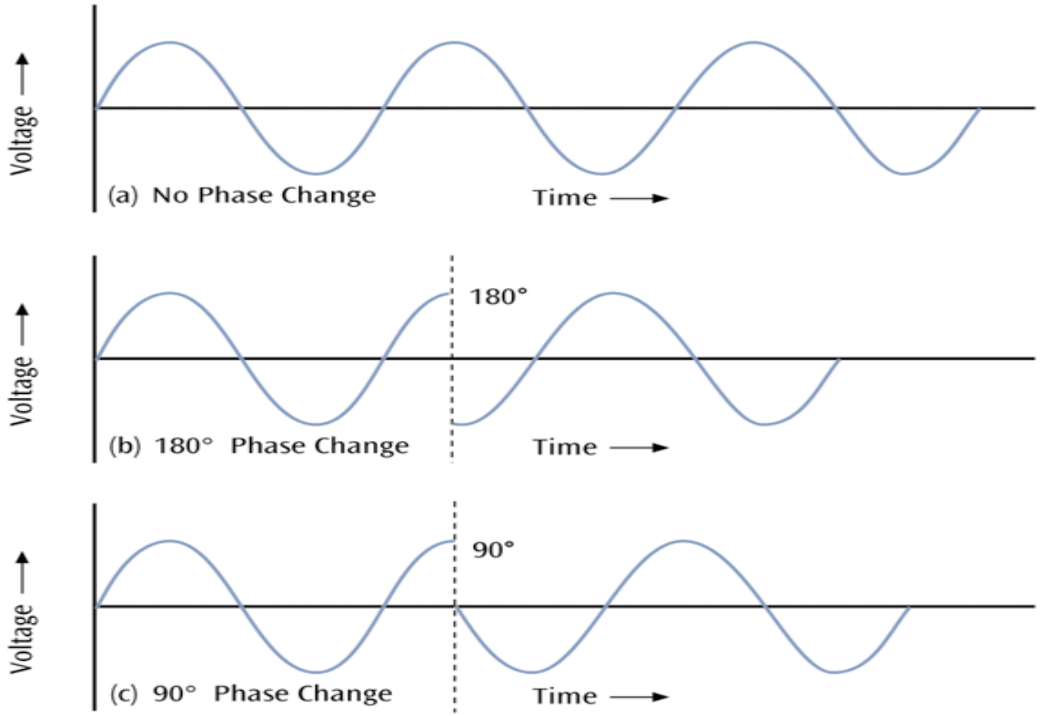
Fundamental of Signal: Phases

Phase: Position of the waveform at a given time, measured in degrees of shift (o)

The phase of a signal is the position of the waveform relative to a given moment of time or relative to time zero

A change in phase can be any number of angles between 0 and 360 degrees

Phase changes often occur on common angles, such as 45, 90, 135, etc.



Signal Strength

All signals experience loss (attenuation)

Attenuation is denoted as a decibel (dB) loss

Decibel losses (and gains) are additive



Spread Spectrum Technology

A secure encoding technique that uses multiple frequencies or codes to transmit data

Two basic spread spectrum technologies:

- Frequency hopping spread spectrum
- Direct sequence spread spectrum

Binary Coding Schemes

Introduction

Binary Coding Schemes

- The alphabetic data, numeric data, alphanumeric data, symbols, sound data and video data, are represented as combination of bits in the computer.
- The bits are grouped in a fixed size, such as 8 bits, 6 bits or 4 bits. A code is made by combining bits of definite size.
- Binary Coding schemes represent the data such as alphabets, digits 0−9, and symbols in a standard code.
- A combination of bits represents a unique symbol in the data.
- The standard code enables any programmer to use the same combination of bits to represent a symbol in the data.

Binary Coding Schemes: Introduction

The binary coding schemes that are most commonly used are—

1. Extended Binary Coded Decimal Interchange Code (EBCDIC)
2. American Standard Code for Information Interchange (ASCII)
3. Unicode

EBCDIC

EBCDIC (extended binary-coded decimal interchange code) data-encoding system, developed by IBM and used mostly on its computers, that uses a unique 8-bit binary code for each number and alphabetic character as well as punctuation marks and accented letters and non-alphabetic characters.

- Since EBCDIC, code is an 8-bit code, this indicates that there are $2^8 = 256$ different methods to represent numerals, alphabets, and other special symbols.

EBCDIC

The Extended Binary Coded Decimal Interchange Code (EBCDIC) uses 8 bits (4 bits for zone, 4 bits for digit) to represent a symbol in the data.

- EBCDIC allows $2^8 = 256$ combinations of bits.
- 256 unique symbols are represented using EBCDIC code. It represents decimal numbers (0−9), lower case letters (a−z), uppercase letters (A−Z), Special characters, and Control characters (printable and non−printable, e.g., for cursor movement, printer vertical spacing, etc.).
- EBCDIC codes are mainly used in the mainframe computers.

ASCII

The **American Standard Code for Information Interchange (ASCII)** is widely used in computers of all types. ASCII codes are of two types—ASCII−7 and ASCII−8.

- **ASCII-7** is a 7-bit standard ASCII code. In ASCII-7, the first 3 bits are the zone bits and the next 4 bits are for the digits. ASCII-7 allows 2^7 = 128 combinations. 128 unique symbols are represented using ASCII-7. ASCII-7 has been modified by IBM to ASCII-8.
- **ASCII-8** is an extended version of ASCII-7. ASCII-8 is an 8-bit code having 4 bits for zone and 4 bits for the digit. ASCII-8 allows 2^8 = 256 combinations. ASCII-8 represents 256 unique symbols. ASCII is used widely to represent data in computers.

The ASCII-8 code represents 256 symbols.

- » Codes 48 to 57 stand for numeric 0−9.
- » Codes 65 to 90 stand for uppercase letters A−Z.
- » Codes 97 to 122 stand for lowercase letters a−z.
- » Codes 128 to 255 are the extended ASCII codes.

Unicode

Unicode is a universal character encoding standard for the representation of text which includes letters, numbers and symbols in multi−lingual environments. The Unicode Consortium based in California developed the Unicode standard.

- Unicode uses 32 bits to represent a symbol in the data.
- Unicode allows 232 = 4164895296 (~ 4 billion) combinations.
- Unicode can uniquely represent any character or symbol present in any language like Chinese, Japanese, etc. In addition to the letters; mathematical and scientific symbols are also represented in Unicode codes

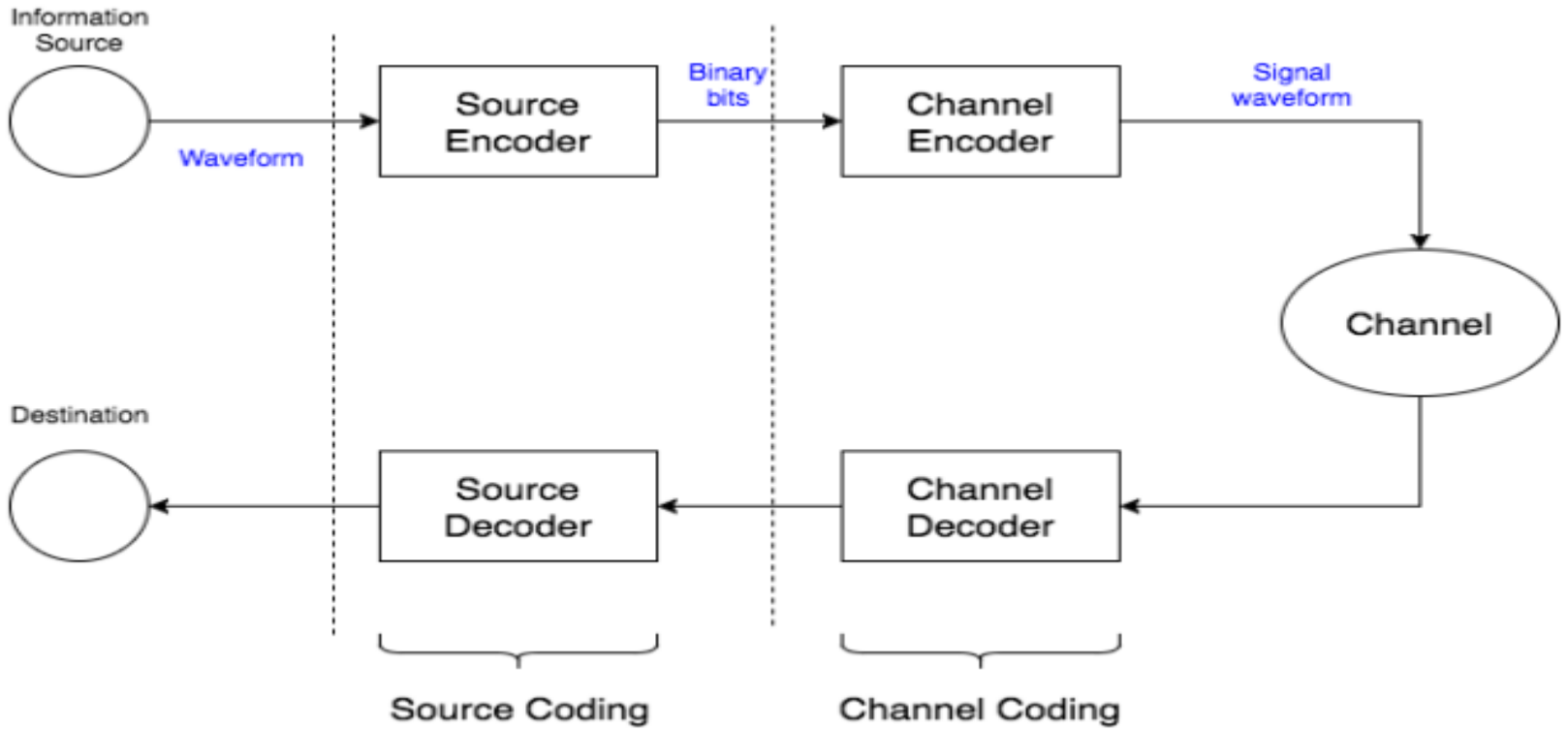
An advantage of Unicode is that it is compatible with the ASCII−8 codes. The first 256 codes in Unicode are identical to the ASCII-8 codes.

- Unicode is implemented by different character encodings. UTF-8 is the most commonly used encoding scheme. UTF stands for Unicode Transformation Format. UTF-8 uses 8 bits to 32 bits per code.

Source & Channel Coding

Introduction

Digital communication systems are communication systems that use digital sequence (typically binary digits, that is, bits) as an interface between the source coding part and the channel coding part.



Source Coding

Source coding: The source encoder converts information waveforms to bits, while the decoder converts bits back to waveforms.

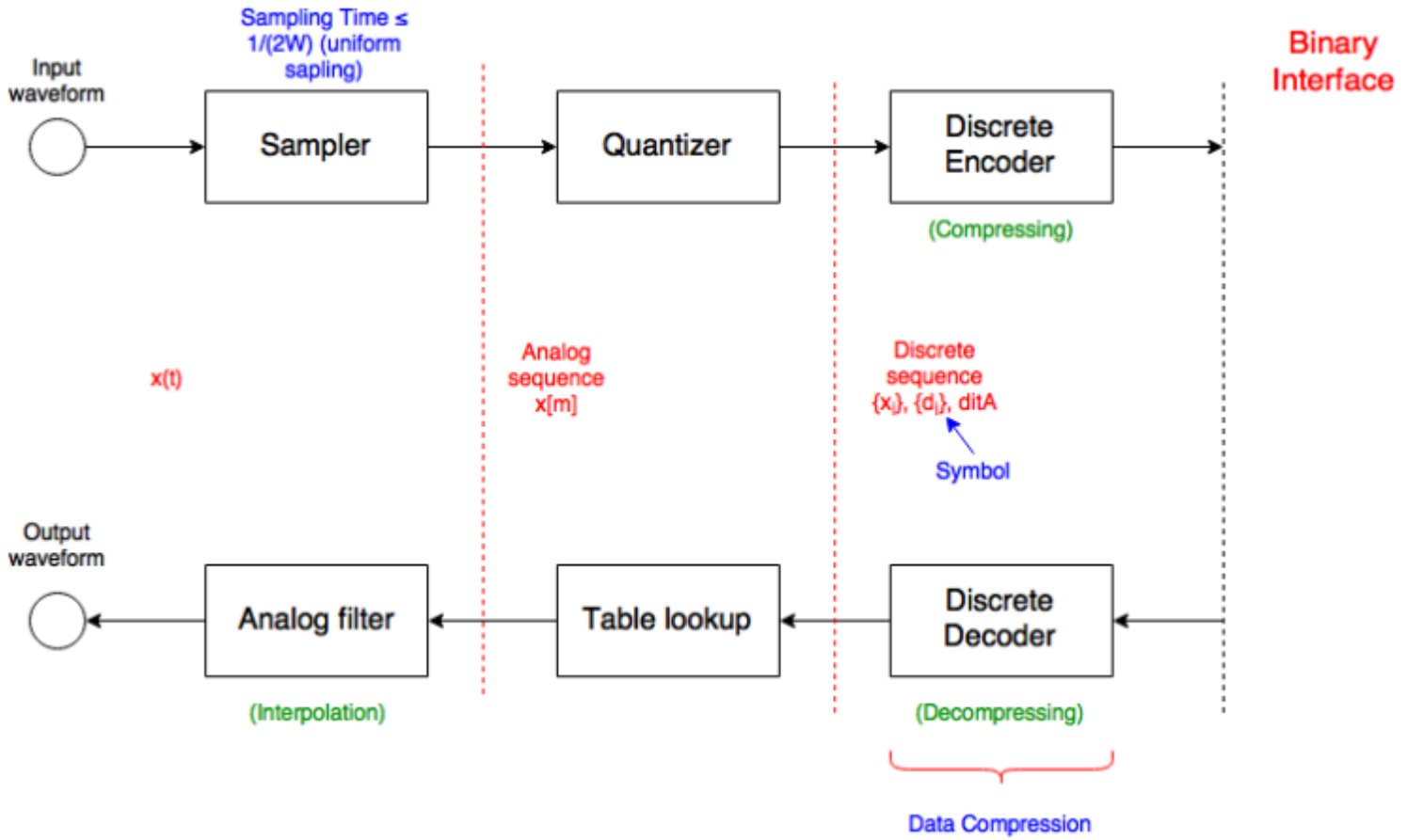
Source *encoding* aims to convert information waveforms (text, audio, image, video, etc.) into bits, the universal currency of information in the digital world.

The three major steps are:

- Sampling: convert the continuous-time analog waveform to discrete-time sequence (but still continuous-valued).
- Quantization: convert each continuous-valued symbol to discrete-valued representatives.
- Data compression: remove the redundancy in the data and generate uniformly distributed bits.

Source decoding does the reverse of encoding.

Basic Diagram of Source Coding



Channel Coding

Channel coding: The channel encoder converts bits to signal waveform, while the decoder converts received waveform back to bits. Channel encoding aims to convert information bits into passband wave forms bits, the universal currency of information in the digital world.

The four major steps are:

- **Error correcting codes:** introduce redundancy into the information bits and produce longer coded bits.

  Remark Example of "error correction":

  – Repetition code: each bit repeat *N* times

  Channel noise: flip the bit *n.p. p, w.p.(1 − p)* remain the same.

  Bit Error happens when there are more than $\frac{N}{2}$ bit flips

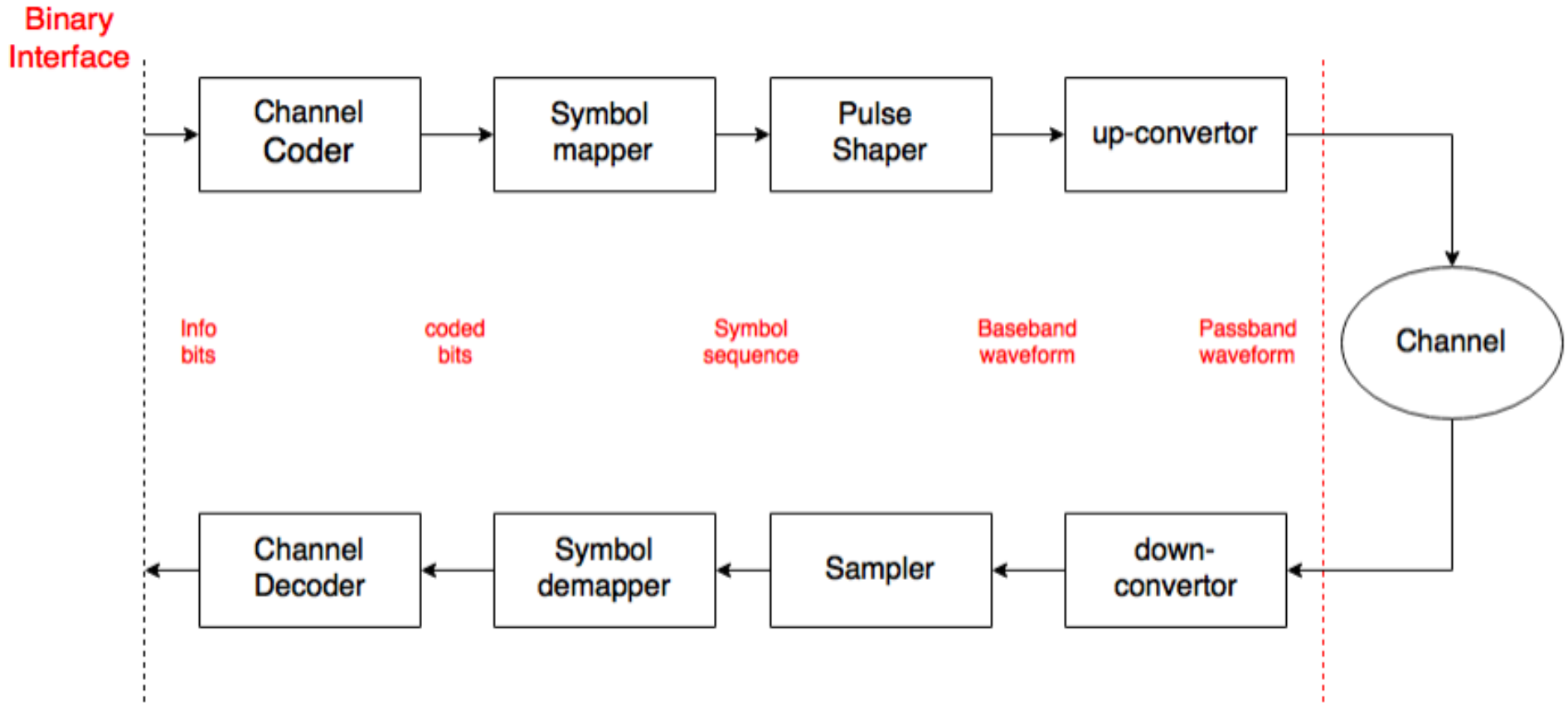
$$\Pr\{\text{error}\} = 1 - \sum_{i=0}^{\lfloor \frac{N}{2} \rfloor} \binom{N}{i} p^i (1-p)^{n-i}$$

Channel Coding: Steps cont…

- **Symbol mapping:** map the coded bits to constellation points, each of which is a complex symbol.
- **Pulse shaping:** modulate the symbol to suitable baseband waveforms. There are some specific conditions needed to be satisfied, which will be discussed in later lectures.
- **Up conversion:** convert the baseband waveform to passband waveform, so that the effective frequency band follows the constraints from the physical world.

Channel decoding does the reverse of encoding.

Basic Diagram of Channel Coding



Signal Coding Scheme

Signal Coding: Introduction

Signal coding is the process of representing an information signal in a way that realizes a desired communications objective such as

- analog-to-digital conversion,
- Digital-to-digital conversion,
- low bit rate transmission, or message encryption.

Signal Coding: Digital Transmission

Data can be represented either in analog or digital form.

The computers used the digital form to store the information. Therefore, the data needs to be converted in digital form so that it can be used by a computer.

Digital Transmission: Digital-to-Digital Conversion

In this section, we see how we can represent digital data by using digital signals.

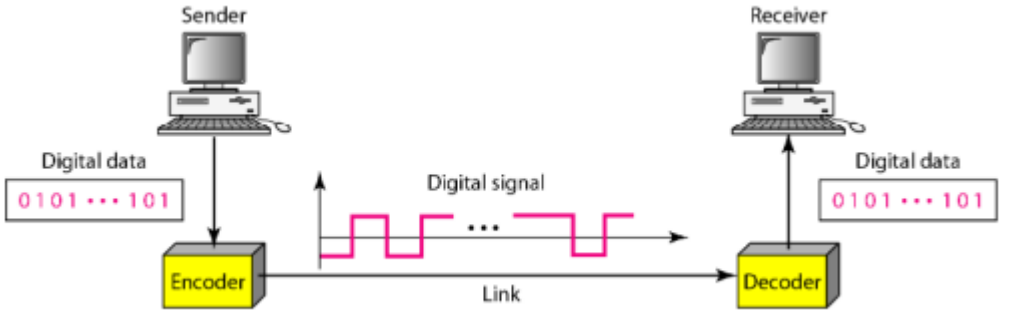
The conversion involves three techniques: *line coding, block coding, and scrambling.*

***Line coding is always needed; block coding and scrambling mayor may not be needed.

Digital-to-Digital Conversion: Line Coding

Line coding is the process of converting digital data to digital signals.

- We assume that data, in the form of text, numbers, graphical images, audio, or video, are stored in computer memory as sequences of bits.
- Line coding converts a sequence of bits to a digital signal.



Digital-to-Digital Conversion: Line Coding

Signal Element Versus Data Element

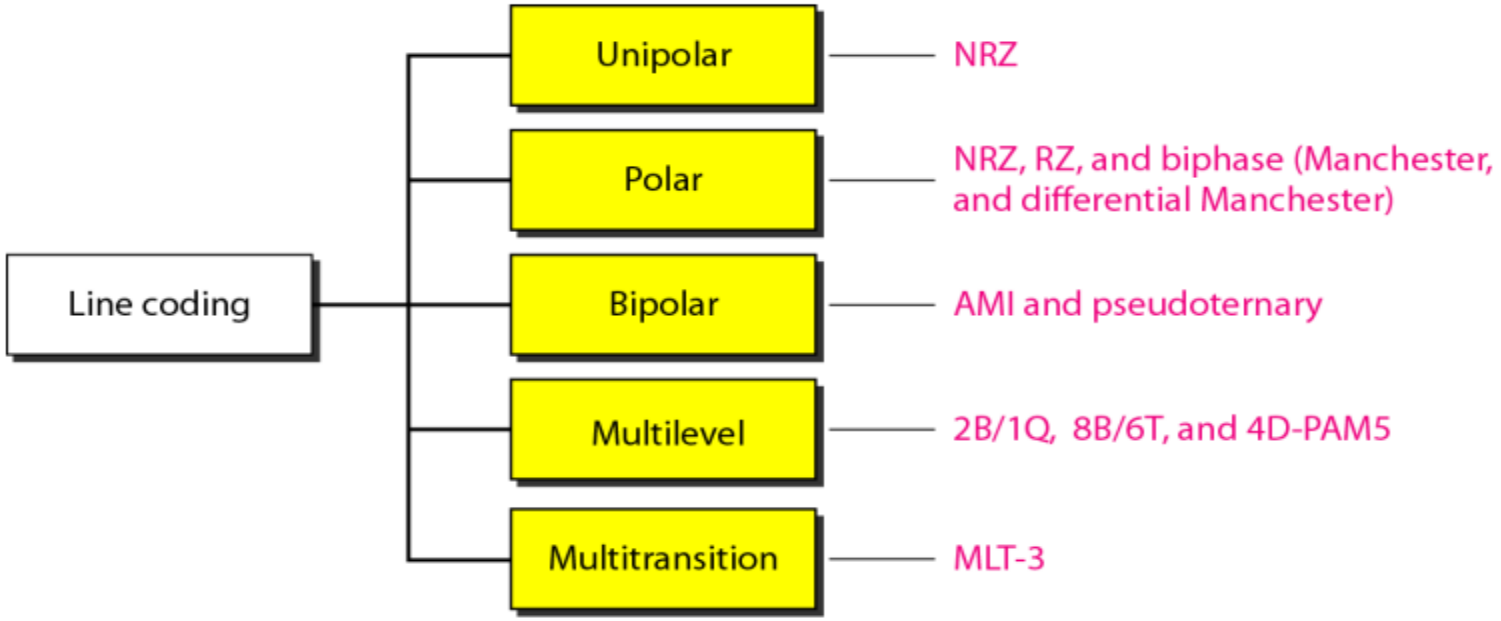
In data communications, our goal is to send data elements.

- A data element is the smallest entity that can represent a piece of information: this is the bit. In digital data communications, a signal element carries data elements.
- A signal element is the shortest unit (time wise) of a digital signal. In other words, *data elements are what we need to send*; *signal elements are what we can send*.

Digital-to-Digital Conversion: Line Coding

Line Coding Scheme:

We can roughly divide line coding schemes into five broad categories:



Line Coding Scheme: Unipolar Scheme

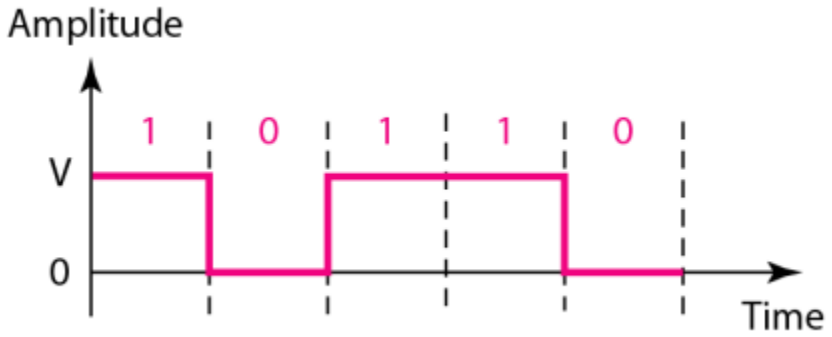
In a unipolar scheme, all the signal levels are on one side of the time axis, either above or below.

NRZ (Non-Return-to-Zero):

- A unipolar scheme was designed as a non-return-to-zero (NRZ) scheme in which the positive voltage defines bit 1 and the zero voltage defines bit 0.
- It is called NRZ because the signal does not return to zero at the middle of the bit. The Figure shows a unipolar NRZ scheme.

Line Coding Scheme: Unipolar Scheme

Compared with its polar counterpart, this scheme is very costly. The normalized power (power needed to send 1 bit per unit line resistance) is double that for polar NRZ. For this reason, this scheme is normally not used in data communications today.



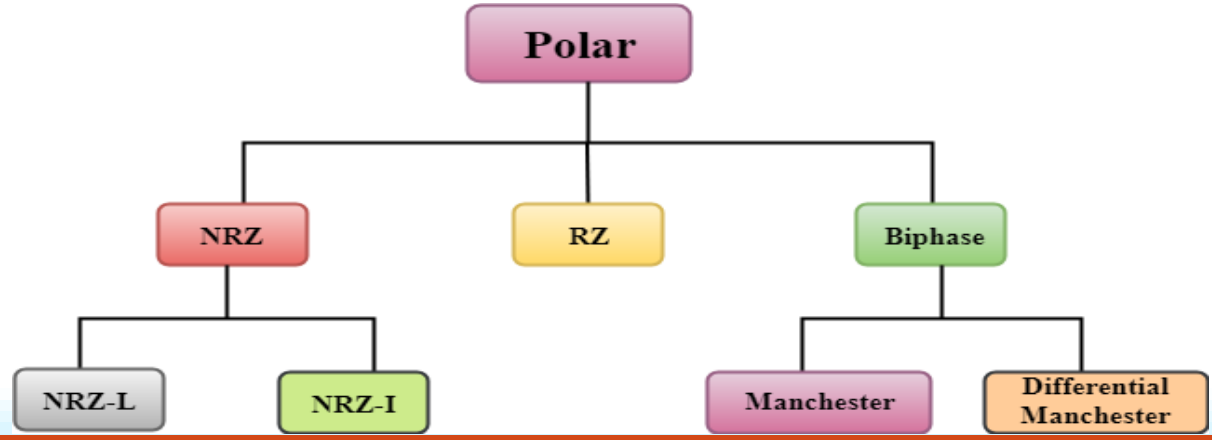
$$\frac{1}{2}V^2 + \frac{1}{2}(0)^2 = \frac{1}{2}V^2$$

Normalized power

Line Coding Scheme: Polar Scheme

In polar schemes, the voltages are on the both sides of the time axis.

- Polar encoding is an encoding scheme that uses two voltage levels: one is positive, and another is negative.
- By using two voltage levels, an average voltage level is reduced, and the DC component problem of unipolar encoding scheme is alleviated.



Polar Scheme: Non-Return-to-Zero (NRZ)

The two most common methods used in NRZ are:

NRZ-L: In NRZ-L encoding, the level of the signal depends on the type of the bit that it represents.

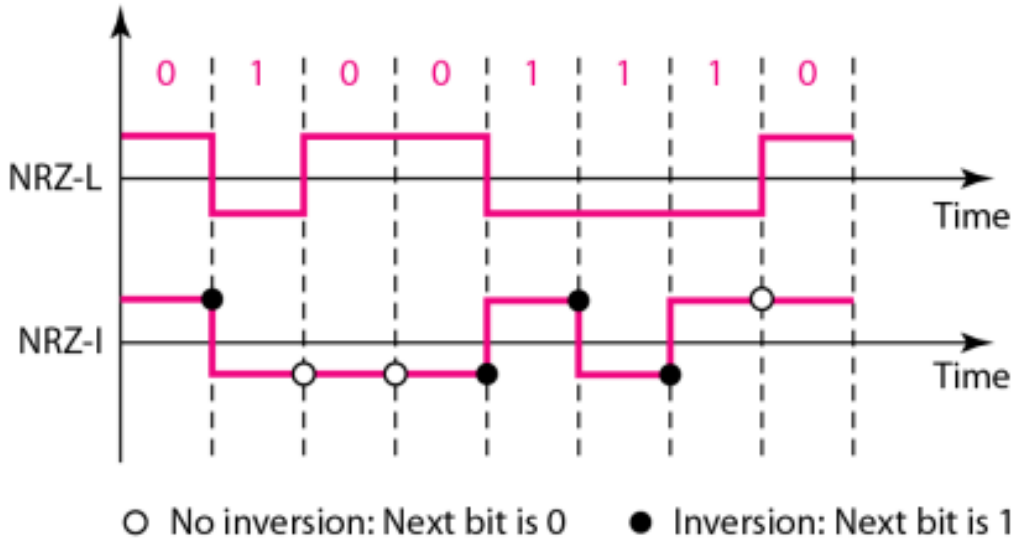
- If a bit is 0 or 1, then their voltages will be positive and negative respectively.
- Therefore, we can say that the level of the signal is dependent on the state of the bit.

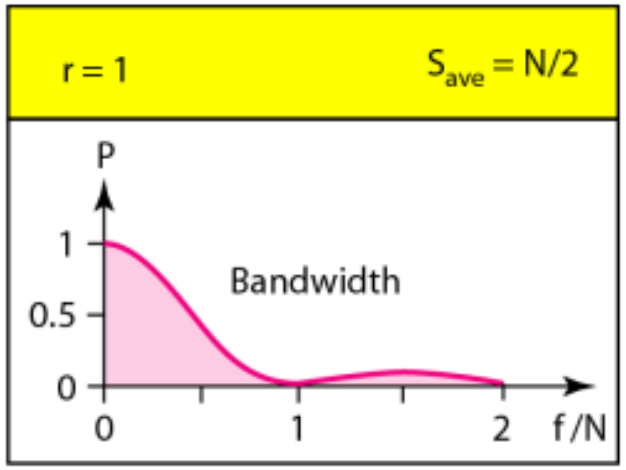
NRZ-I: NRZ-I is an inversion of the voltage level that represents 1 bit.

- In the NRZ-I encoding scheme, a transition occurs between the positive and negative voltage that represents 1 bit.
- In this scheme, 0 bit represents no change and 1 bit represents a change in voltage level.

Polar Scheme: Non-Return-to-Zero (NRZ)

In polar schemes, the voltages are on the both sides of the time axis.



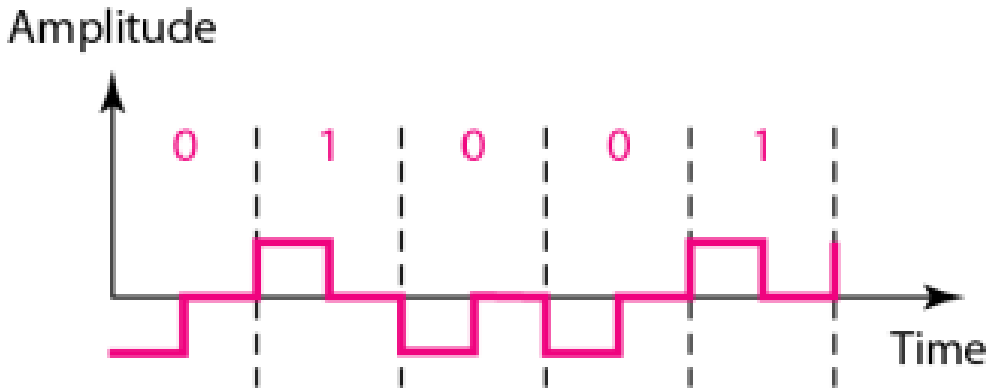


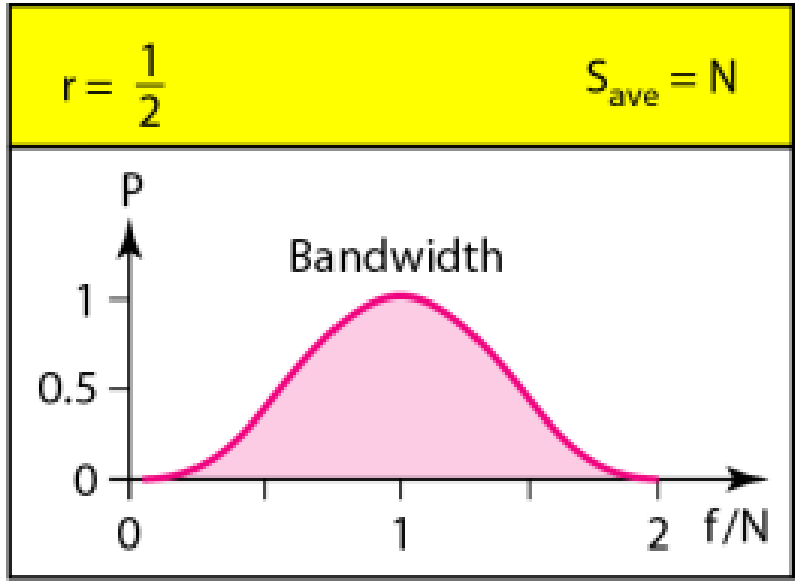
Polar Scheme: Return-to-Zero (RZ)

RZ stands for Return to zero.

- There must be a signal change for each bit to achieve synchronization. However, to change with every bit, we need to have three values: positive, negative and zero.
- RZ is an encoding scheme that provides three values, positive voltage represents 1, the negative voltage represents 0, and zero voltage represents none.
- In the RZ scheme, halfway through each interval, the signal returns to zero.
- In RZ scheme, 1 bit is represented by positive-to-zero and 0 bit is represented by negative-to-zero.

Polar Scheme: Return-to-Zero (RZ)





Polar Scheme: Biphase

Biphase is an encoding scheme in which signal changes at the middle of the bit interval but does not return to zero.

Biphase encoding is implemented in two different ways:

1. Manchester
2. Differential Manchester

Polar Scheme: Biphase

Manchester:

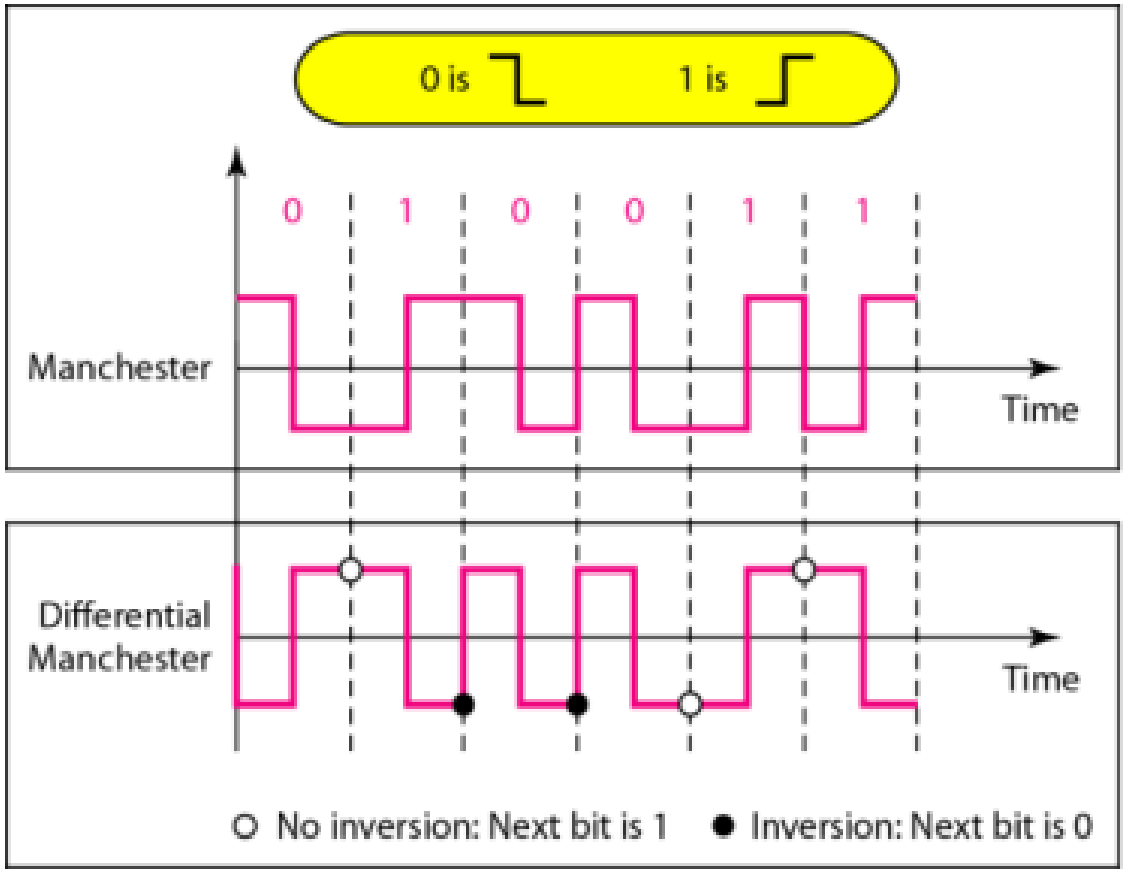
- It changes the signal at the middle of the bit interval but does not return to zero for synchronization.
- In Manchester encoding, a negative-to-positive transition represents binary 1, and positive-to-negative transition represents 0.
- Manchester has the same level of synchronization as RZ scheme except that it has two levels of amplitude.

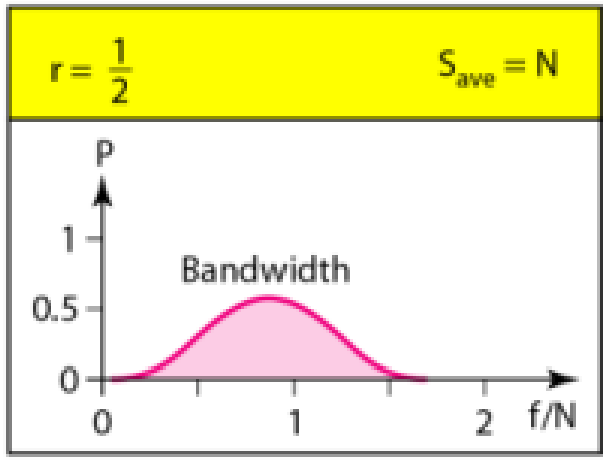
Polar Scheme: Biphase

Differential Manchester:

- It changes the signal at the middle of the bit interval for synchronization, but the presence or absence of the transition at the beginning of the interval determines the bit. A transition means binary 0 and no transition means binary 1.
- In Manchester Encoding scheme, two signal changes represent 0 and one signal change represent 1.

Polar Scheme: Biphase



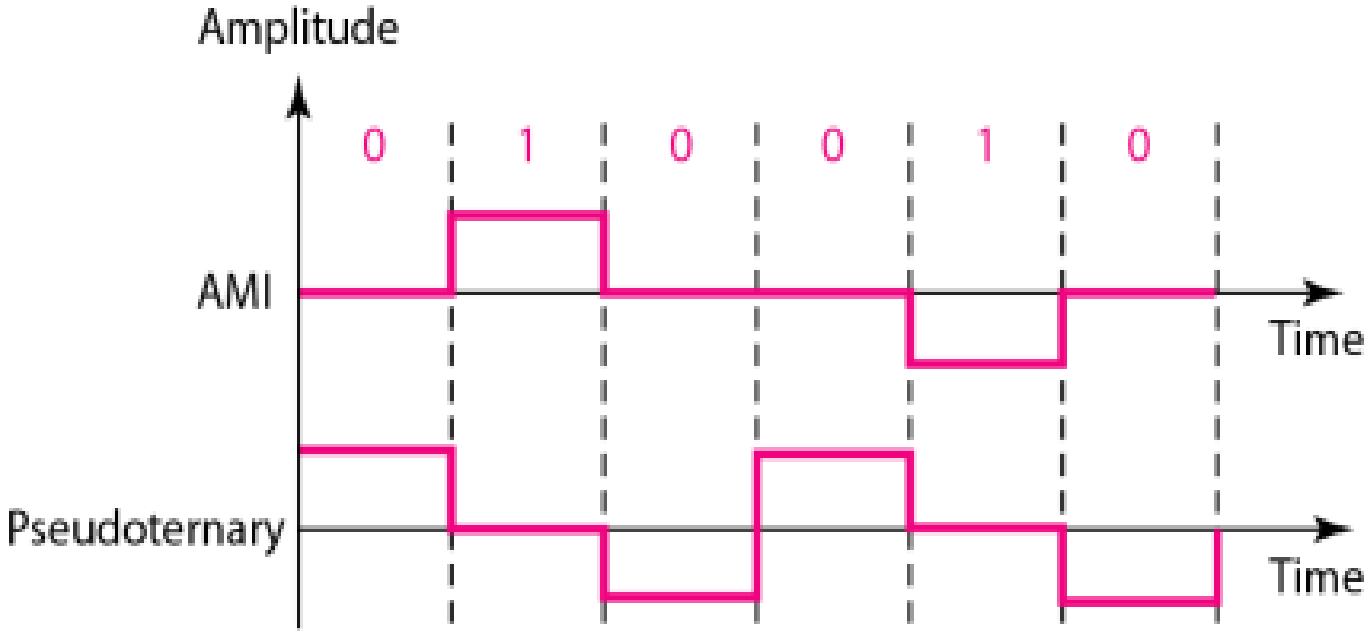


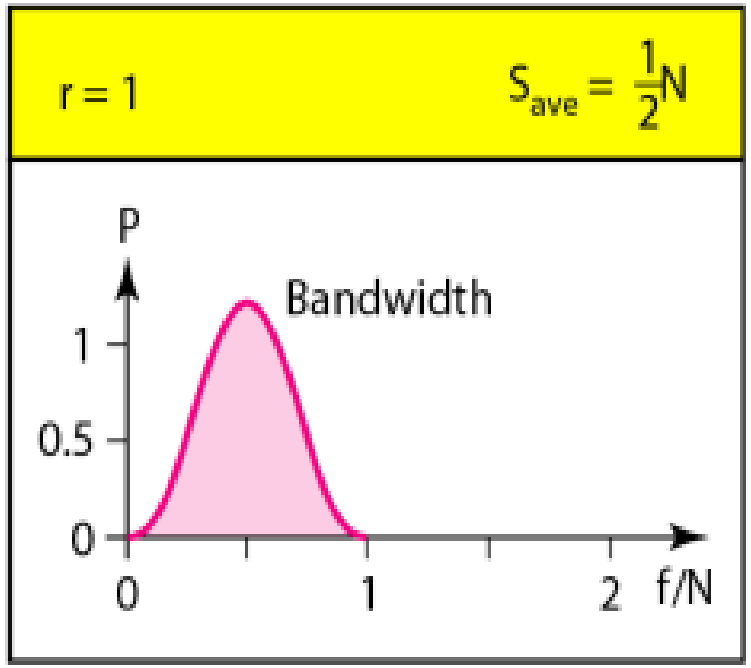
Line Coding Scheme: Bipolar

Bipolar encoding scheme represents three voltage levels: positive, negative, and zero.

- In Bipolar encoding scheme, zero level represents binary 0, and binary 1 is represented by alternating positive and negative voltages.
- If the first 1 bit is represented by positive amplitude, then the second 1 bit is represented by negative voltage, third 1 bit is represented by the positive amplitude and so on. This alternation can also occur even when the 1bits are not consecutive.

Line Coding Scheme: Bipolar





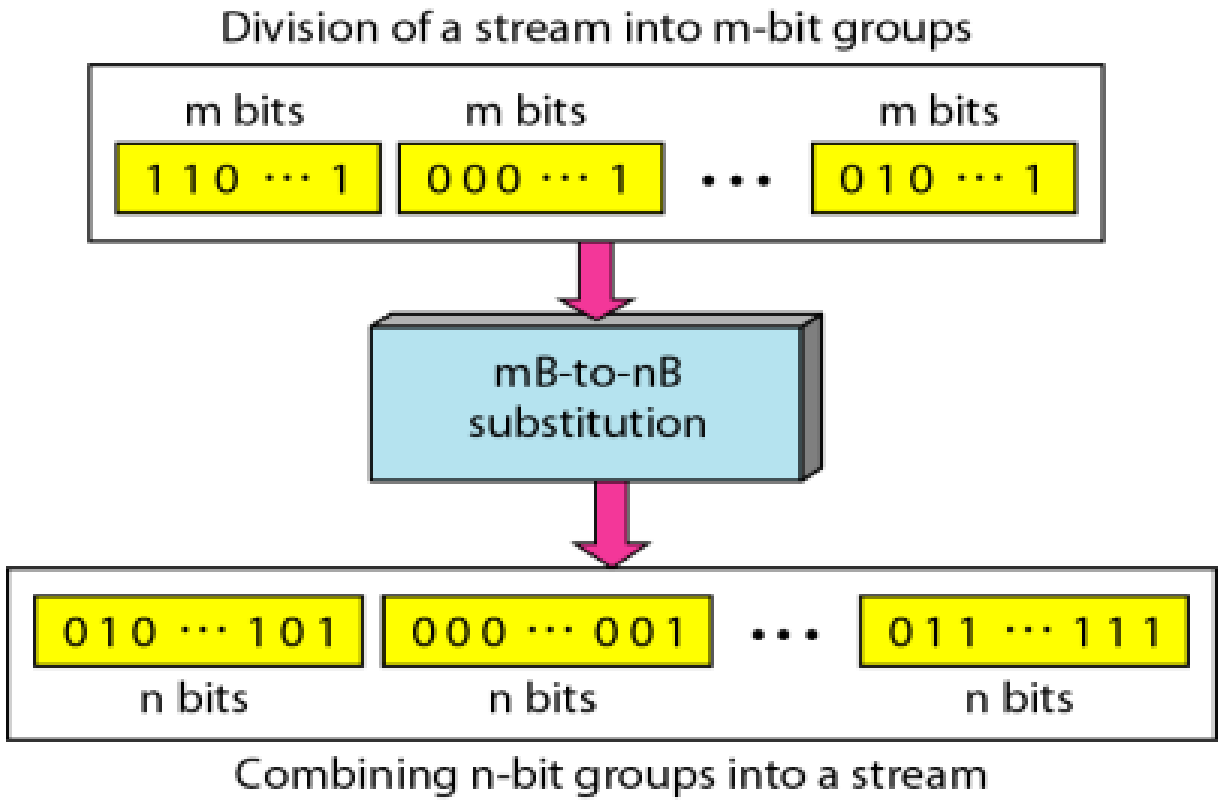
Line Coding Scheme: Bipolar cont…

- If we have a long sequence of 1s, the voltage level alternates between positive and negative; it is not constant.
- Therefore, there is no DC component. For a long sequence of 0s, the voltage remains constant, but its amplitude is zero, which is the same as having no DC component.
- AMI is commonly used for long-distance communication, but it has a synchronization problem when a long sequence of 0s is present in the data.

Digital-to-Digital Conversion: Block Coding

- We need redundancy to ensure synchronization and to provide some kind of inherent error detecting.
- Block coding can give us this redundancy and improve the performance of line coding.
- In general, block coding changes a block of m bits into a block of n bits, where n is larger than m. Block coding is referred to as an mB/nB encoding technique

Digital-to-Digital Conversion: Block Coding



Signal Coding: Analog-to-Digital conversion

When an analog signal is digitalized, this is called an analog-to-digital conversion.

- Suppose human sends a voice in the form of an analog signal, we need to digitalize the analog signal which is less prone to noise.
- It requires a reduction in the number of values in an analog message so that they can be represented in the digital stream.
- In analog-to-digital conversion, the information contained in a continuous wave form is converted in digital pulses.

Signal Coding: Analog-to-Digital conversion

In this section we describe two techniques:

1. Pulse Code Modulation (PCM)
2. pulse amplitude modulation (PAM)

Analog-to-Digital conversion Techniques

1. Pulse Code Modulation (PCM)

- PCM technique is used to modify the pulses created by PAM to form a digital signal.
- To achieve this, PCM quantizes PAM pulses. Quantization is a process of assigning integral values in a specific range to sampled instances.
- PCM is made of four separate processes: PAM, quantization, binary encoding, and digital-to-digital encoding.

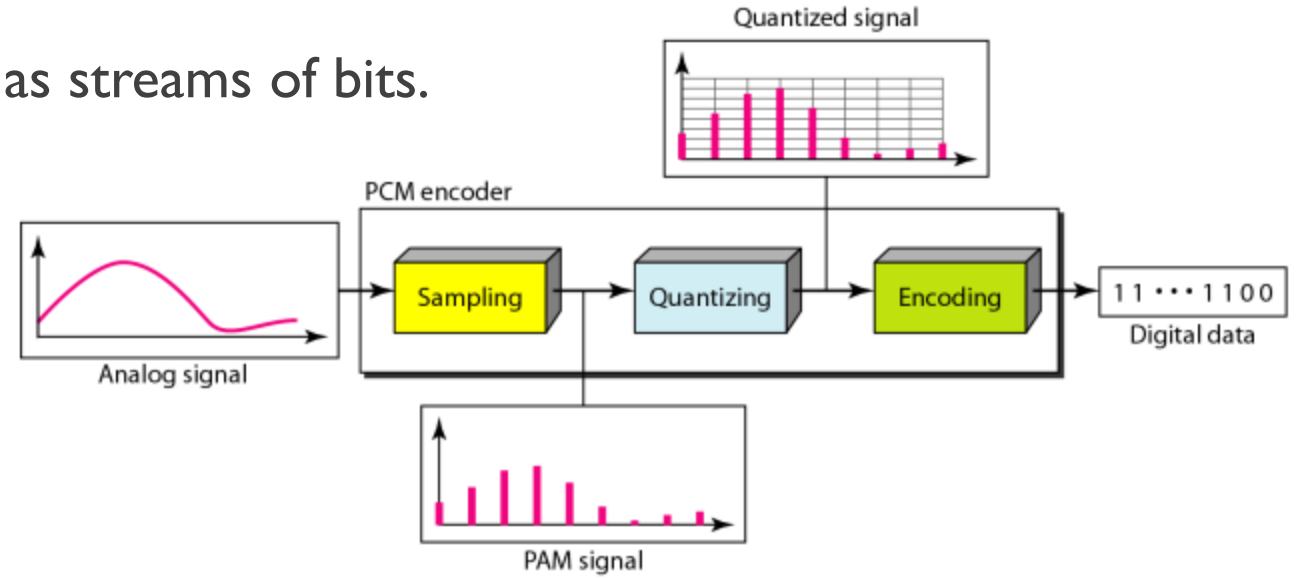
Analog-to-Digital conversion Techniques: PCM

A PCM encoder has three processes, as shown in the Figure:

i. The analog signal is sampled.

ii. The sampled signal is quantized.

iii. The quantized values are encoded as streams of bits.

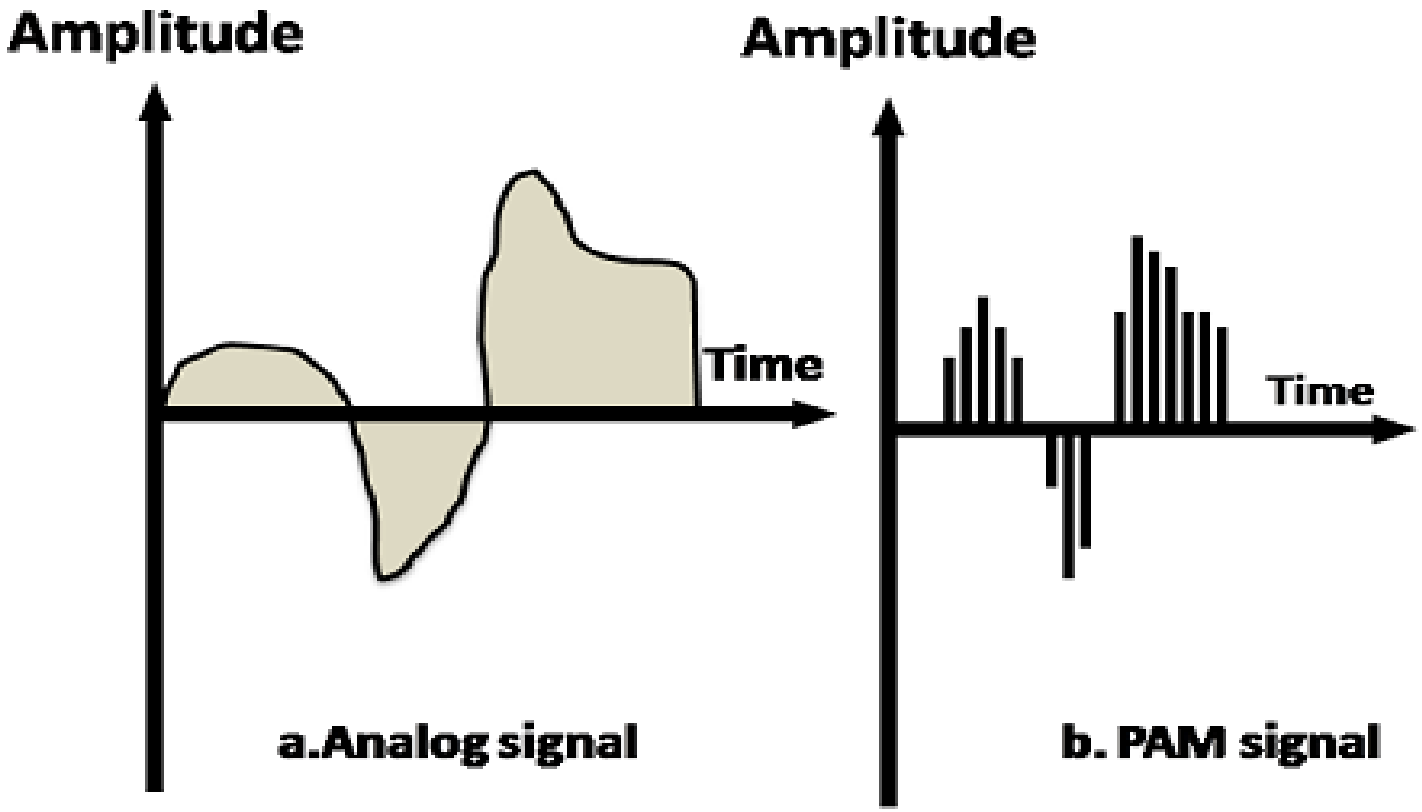


Analog-to-Digital conversion Techniques: PAM

PAM stands for **pulse amplitude modulation**.

- PAM is a technique used in analog-to-digital conversion.
- PAM technique takes an analog signal, samples it, and generates a series of digital pulses based on the result of sampling where sampling means measuring the amplitude of a signal at equal intervals.
- PAM technique is not useful in data communication as it translates the original wave form into pulses, but these pulses are not digital. To make them digital, PAM technique is modified to PCM technique.

Analog-to-Digital conversion Techniques: PAM



Multiple Access Schemes

Multiple Access Schemes: Introduction

Multiple access schemes are used to allow many mobile users to share simultaneously a finite amount of radio spectrum.

Multiple access techniques are used to allow a large number of mobile users to share the allocated spectrum in the most efficient manner. OR

Multiplexing is a technique by which different analog and digital streams of transmission can be simultaneously processed over a shared link. Multiplexing divides the high capacity medium into low capacity logical medium which is then shared by different streams

Multiple Access Schemes Techniques

A cellular system divides any given area into cells where a mobile unit in each cell communicates with a base station.

The main aim in the cellular system design **is to be able to increase the capacity of the channel** i.e. to handle as many calls as possible in a given bandwidth with a sufficient level of quality of service.

There are several different ways to allow access to the channel :

- Frequency division multiple-access (FDMA)
- Time division multiple-access (TDMA)
- Code division multiple-access (CDMA)
- Space Division Multiple access (SDMA)

Multiple Access Techniques: FDMA

Frequency Division Multiple Access (FDMA) is the basic technology for advanced mobile phone services.

The features of FDMA are as follows.

- FDMA allots a different sub-band of frequency to each different user to access the network.
- If FDMA is not in use, the channel is left idle instead of allotting to the other users.
- FDMA is implemented in Narrowband systems and it is less complex than TDMA.
- Tight filtering is done here to reduce adjacent channel interference.
- The base station BS and mobile station MS, transmit and receive simultaneously and continuously in FDMA.

Multiple Access Techniques: TDMA

Time Division Multiple Access (TDMA)

In the cases where continuous transmission is not required, there TDMA is used instead of FDMA. The features of TDMA include the following.

- TDMA shares a single carrier frequency with several users where each users makes use of non-overlapping time slots.
- Data transmission in TDMA is not continuous, but occurs in bursts. Hence handsoff process is simpler.
- TDMA uses different time slots for transmission and reception thus duplexers are not required.
- TDMA has an advantage that is possible to allocate different numbers of time slots per frame to different users.
- Bandwidth can be supplied on demand to different users by concatenating or reassigning time slot based on priority.

Multiple Access Techniques: CDMA

Code Division Multiple Access (CDMA)

Code division multiple access technique is an example of multiple access where several transmitters use a single channel to send information simultaneously. Its features are as follows:

- In CDMA every user uses the full available spectrum instead of getting allotted by separate frequency.
- CDMA is much recommended for voice and data communications.
- While multiple codes occupy the same channel in CDMA, the users having same code can communicate with each other.
- CDMA offers more air-space capacity than TDMA.
- The hands-off between base stations is very well handled by CDMA.

Multiple Access Techniques: SDMA

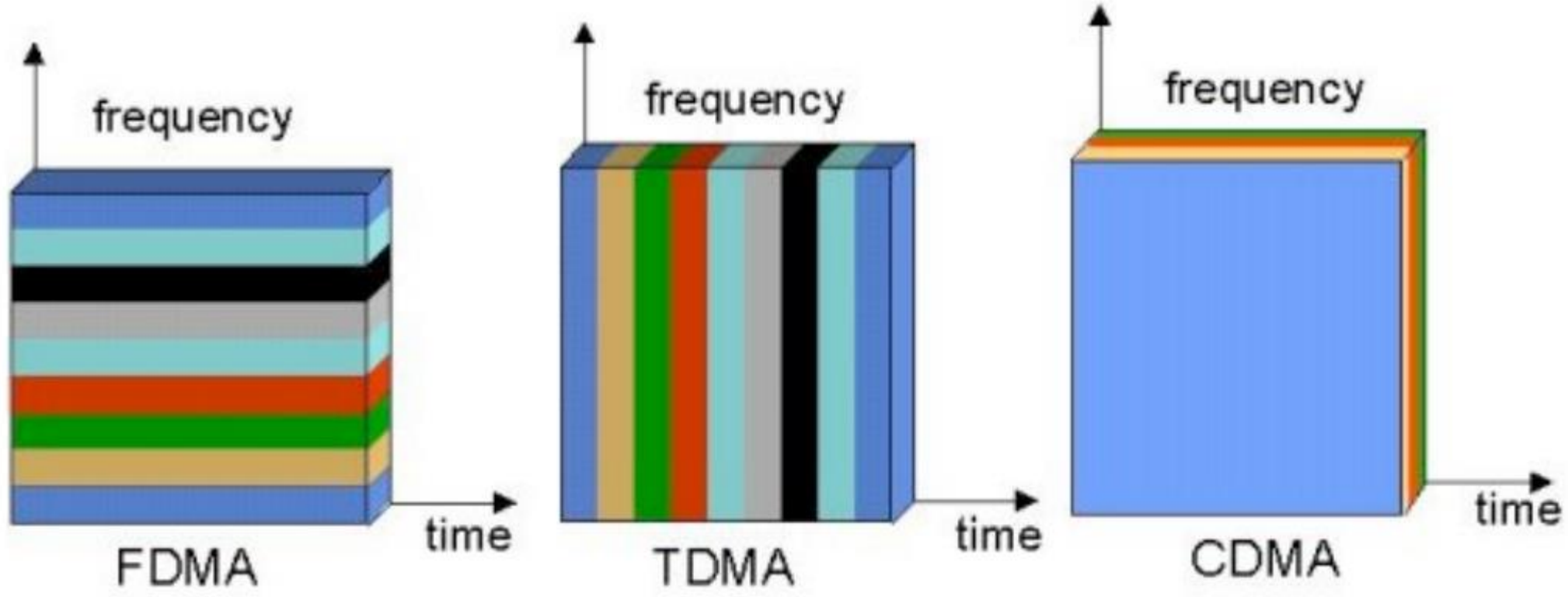
Space Division Multiple Access (SDMA)

SDMA or spatial division multiple access is a technique which is MIMO (multiple-input multiple-output) architecture and used mostly in wireless and satellite communication.

It has the following features:

- All users can communicate at the same time using the same channel.
- SDMA is completely free from interference.
- A single satellite can communicate with more satellites receivers of the same frequency.
- The directional spot-beam antennas are used and hence the base station in SDMA, can track a moving user.
- Controls the radiated energy for each user in space.

Multiple Access Techniques



Thank you!

For listen