디지털 -> 디지털 이더넷
아날로그 -> 디지털 wifi, pc통신, LTE, 5G
디지털-> 아날로그
아날로그 -> 아날로그 라디오

Data Communications

-Digital Transmission (1)-

회선 부호화 : 디지털 데이터를 전송하기 위한 신호로 변환하는 기술

2024. 10. 15

Young Deok Park (박영덕)

Line Coding

회선 부호화

디지털신호를 만드는 기법

1011
1: +5V
0: 0V

- Converting a string of 1's and 0's (digital data) into a sequence of signals that denote the 1's and 0's

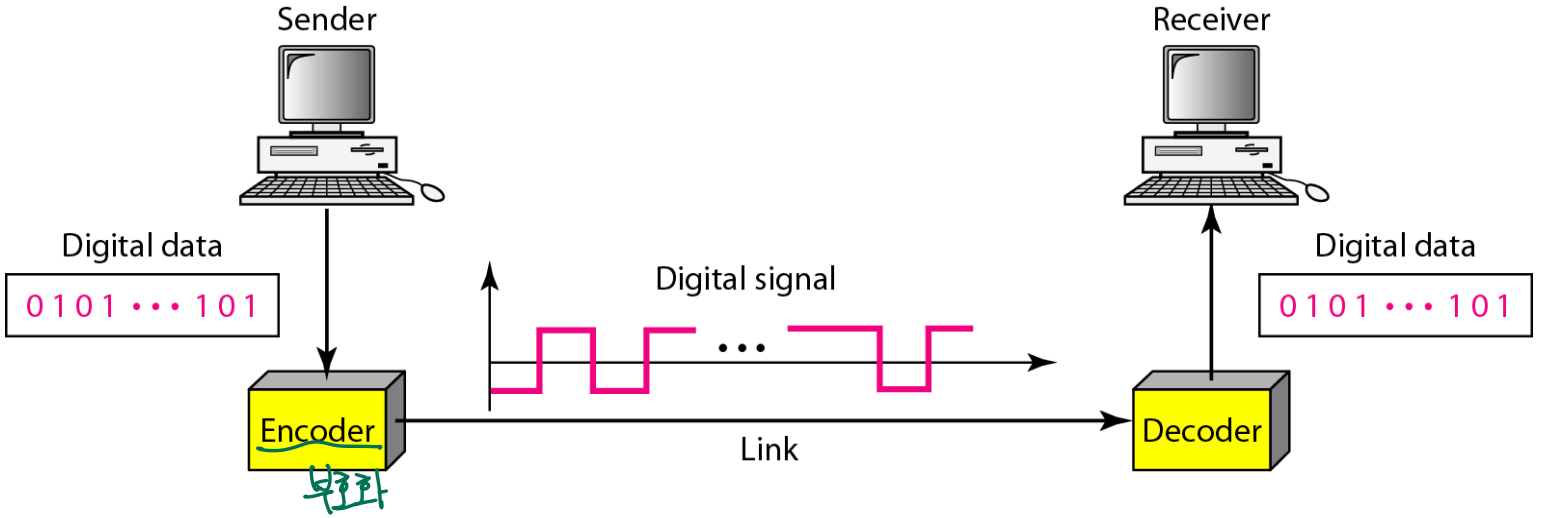
로

나타내는

- Example
  - A high voltage level (+V) could represent a "1" and a low voltage level (0 or -V) could represent a "0"

고전압

저전압



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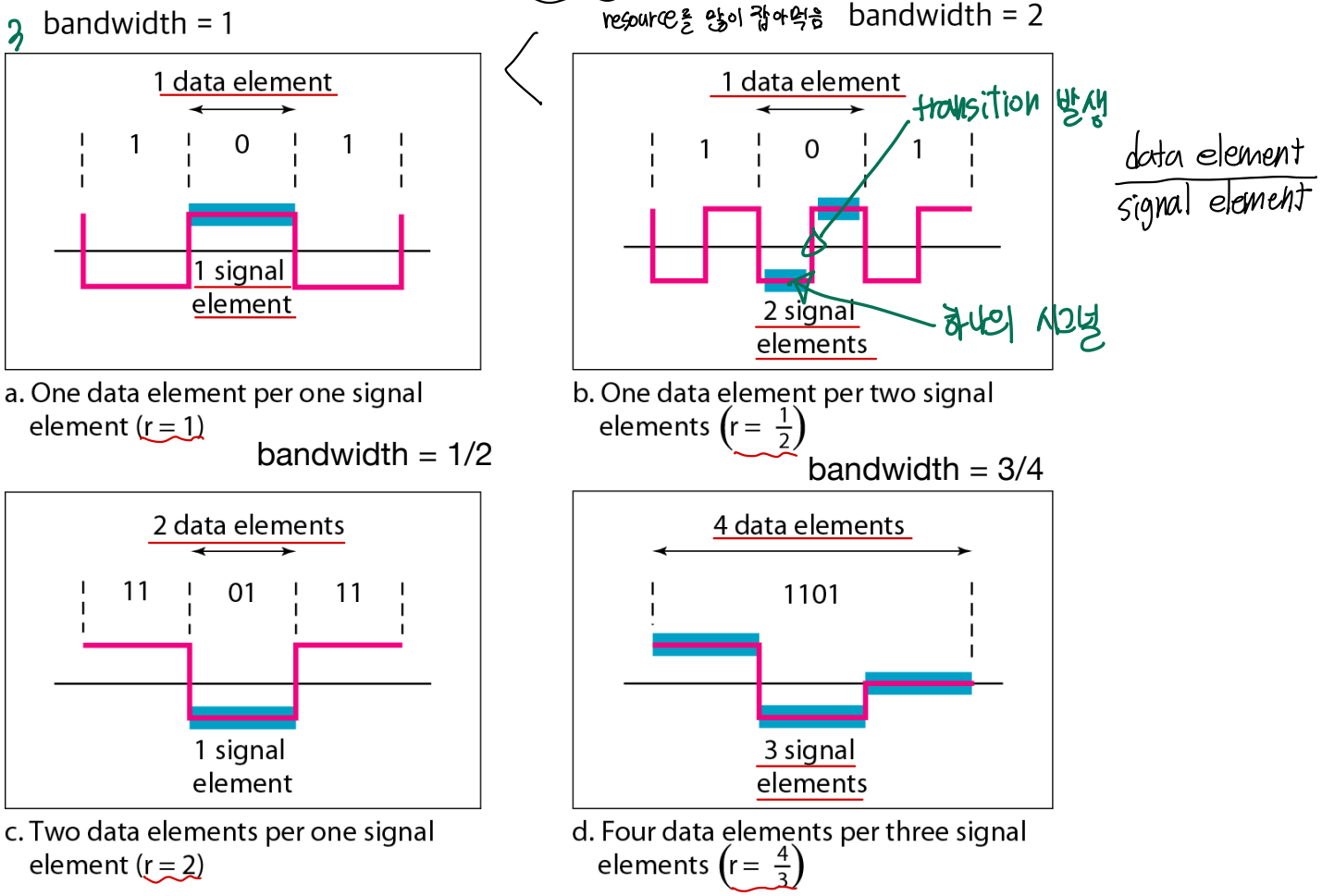
Data Element vs Signal Element

bandwidth, bitrate 비례 관계

transition하는데 bandwidth 2배 더 필요

resource를 많이 잡아먹음



Considerations

고려사항

평균 0 : 양or음으로 편향

평균이 0이 아닐때 존재

: 일정한 전압, 전류

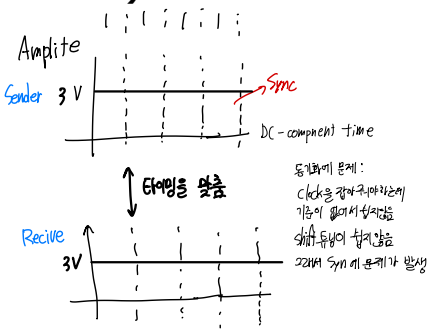
1 : +5V
0 : 0V
평균 2.5V
DC O

1 : 5V
-1 : -5V
평균 0V
DC X

전압이 걸려있지가 되어야함

0V는 전압이 안걸려있기 때문에 X

- DC components 직류성분
  - When the voltage level remains constant for long periods of time, there is an zero frequency of the signal (DC component)
  - Some devices may not support the zero frequency
  - Encoding scheme without DC component is better



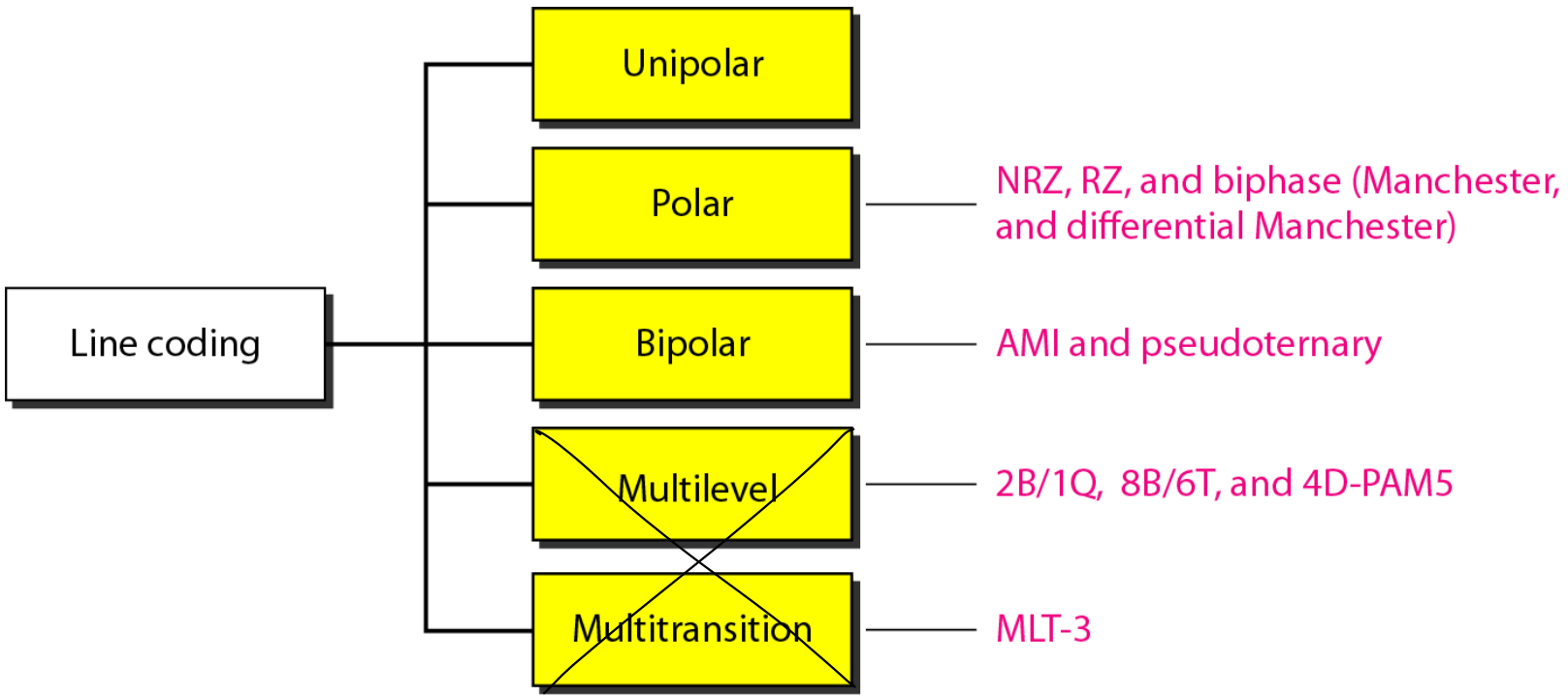
- Synchronization 동기화
  - To correctly interpret the signals received from the sender, the receiver's bit intervals must correspond

- Bandwidth
  - A encoding scheme requiring less bandwidth is better

데이터를 전송할 수 있는 최대 용량

초당 비트수 , Hz

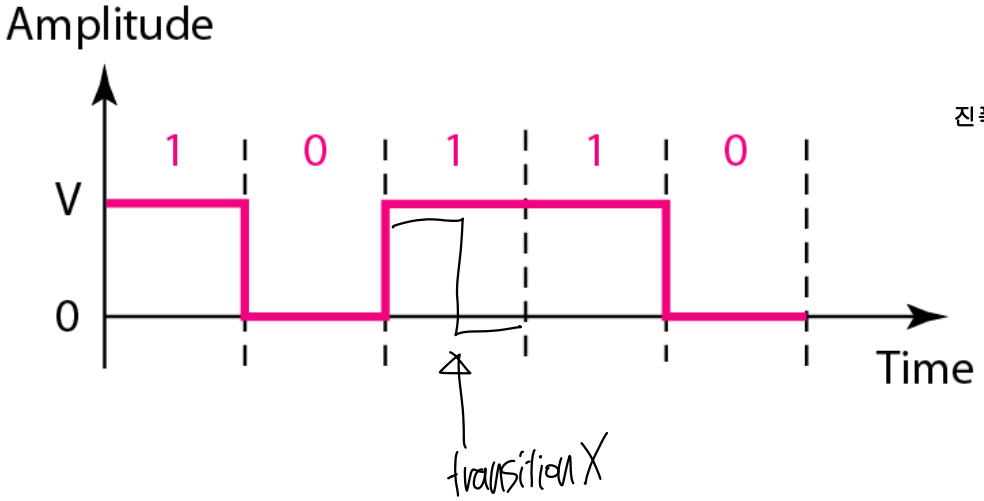
Line Coding Schemes

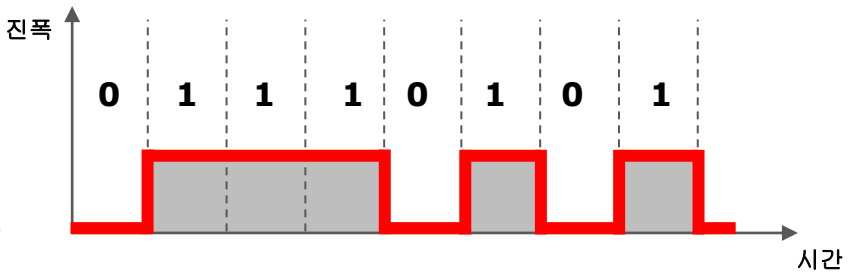


Unipolar

단극형 (+ or - 하나만 사용해서 표현)

DC component O
Synchronization X
Bandwidth ↓





- All signal levels are on one side of the time axis - either above or below
  아래(음수) : 신호의 전압 레벨이 시간 축의 한쪽에서만 나타남 한쪽에 축 위쪽(양수)
- Unipolar scheme has DC component
- It has no synchronization capacity 기능

Bandwidth ↓

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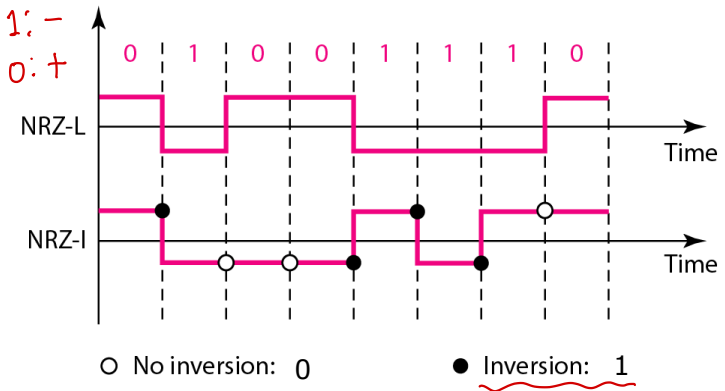
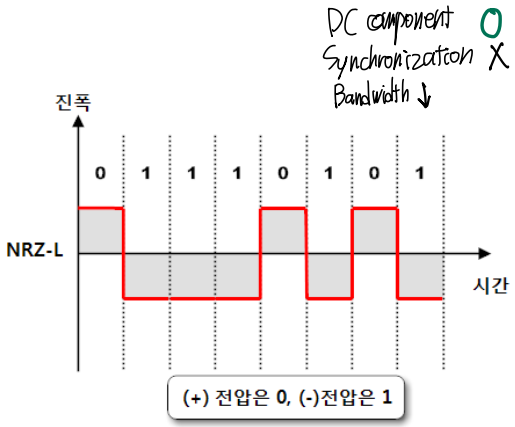
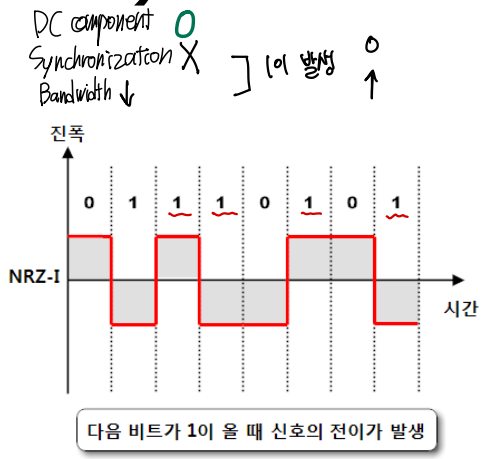
Polar – NRZ (Non-Return to Zero)

극형

항상 1이거나 0일때 발생



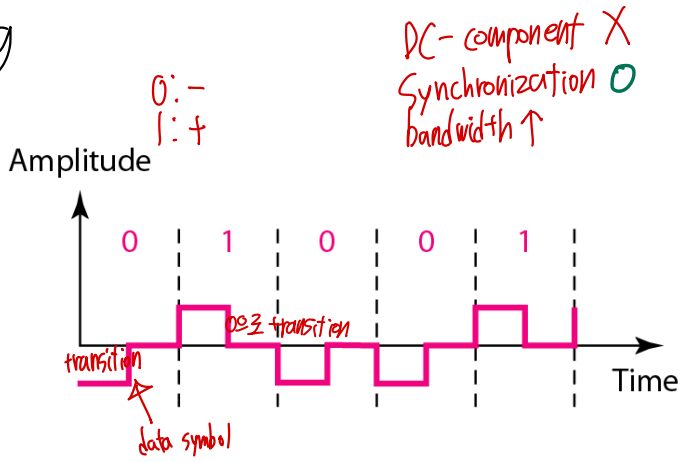


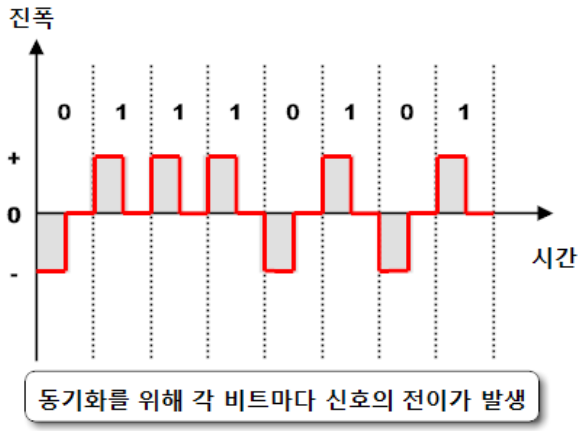


- The voltages are on both sides of the time axis
  전압 양쪽에
- Polar NRZ scheme can be implemented with two voltages
  - E.g. +V for 1 and -V for 0
- Two versions:
  - NRZ - Level (NRZ-L): positive voltage for one symbol and negative for the other
    양전압 위해 기호 음전압
  - NRZ - Inversion (NRZ-I): the change or lack of change in polarity determines the value of a symbol
    변화O 변화X 전압
    - E.g. a "1" symbol inverts the polarity a "0" does not
      반전 전압

Polar – RZ (Return to Zero)

self clocking



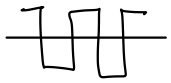


- The Return to Zero (RZ) scheme uses three voltage values. +, 0, -.
- Each symbol has a transition in the middle. Either from high to zero or from low to zero.
- This scheme has more signal transitions (two per data symbol) and therefore requires a wider bandwidth
- No DC component
- Synchronization - transition indicates symbol value.
- More complex as it uses three voltage levels

Polar – Manchester and Differential Manchester

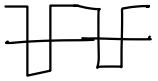
DC component X
Synchronization O
Band Width 수

- Manchester encoding
  - Combining the NRZ-L and RZ schemes
  - Every symbol has a level transition in the middle: from high to low or low to high (similar to RZ)
  - Uses only two voltage levels (similar to NRZ-L)



- Differential Manchester encoding
  - Combining the NRZ-I and RZ schemes
  - Every symbol has a level transition in the middle (similar to RZ)
  - But the level at the beginning of the symbol is determined by the symbol value./One symbol causes a level change the other does not (similar to NRZ-I)

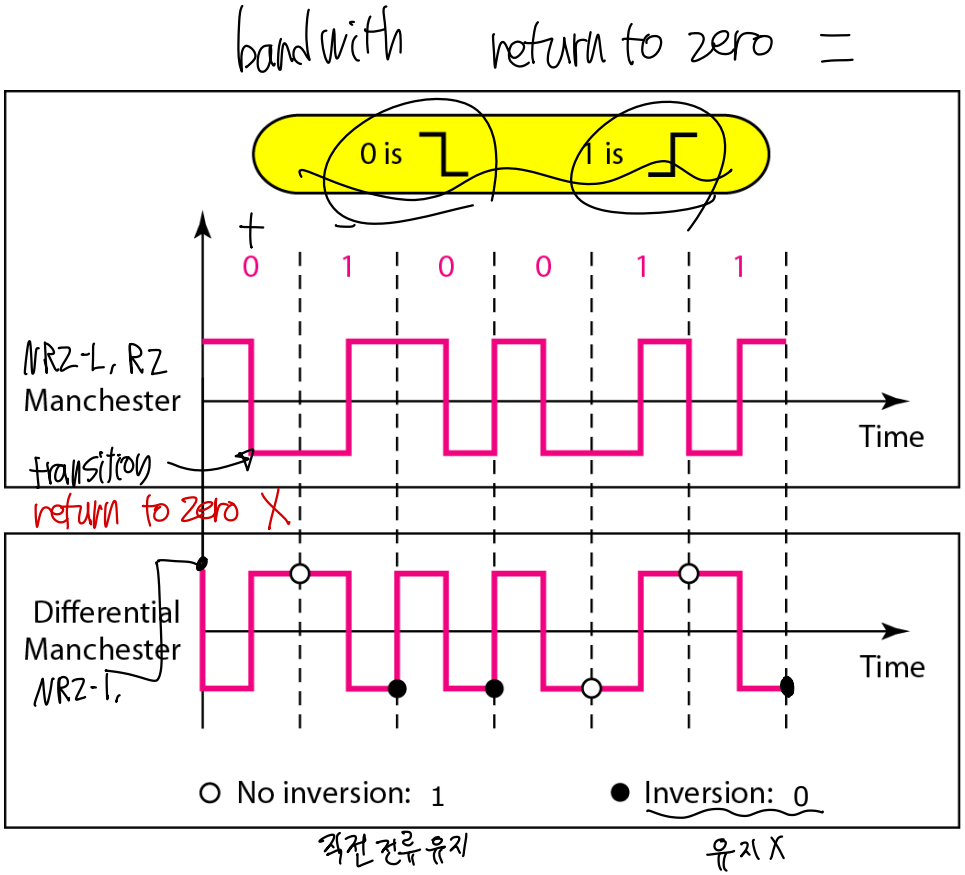
1일 때 비트 시작 부분에서 전압이 변화, 0일 때 시작 부분에서 전압 유지

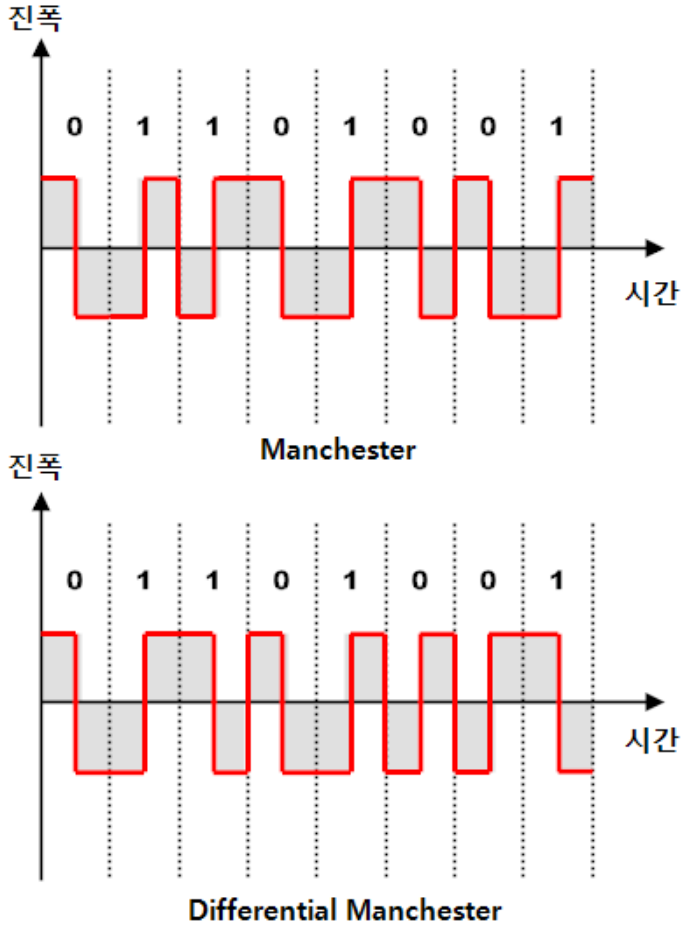


- Manchester/Differential Manchester have more signal transitions (two per symbol) and therefore require a wider bandwidth than NRZ
- No DC component
- Synchronization - transition indicates symbol value

Polar – Manchester and Differential Manchester

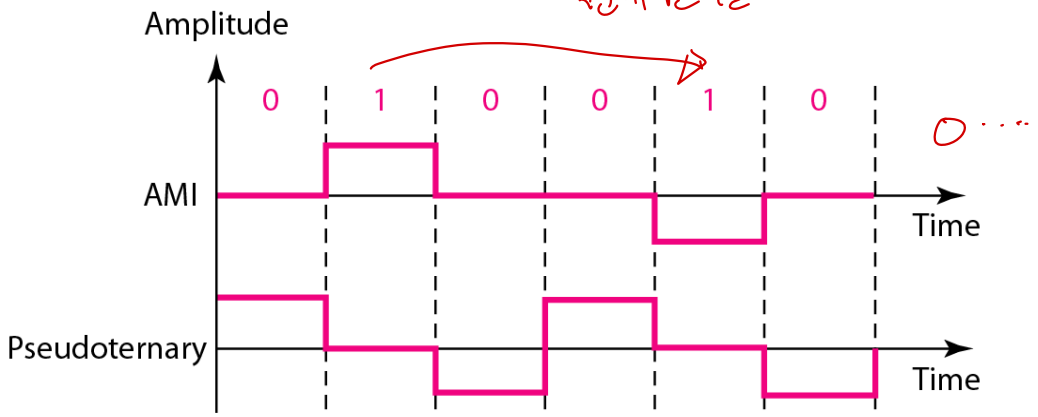
DC X 항상 전위





Bipolar – AMI and Pseudoternary

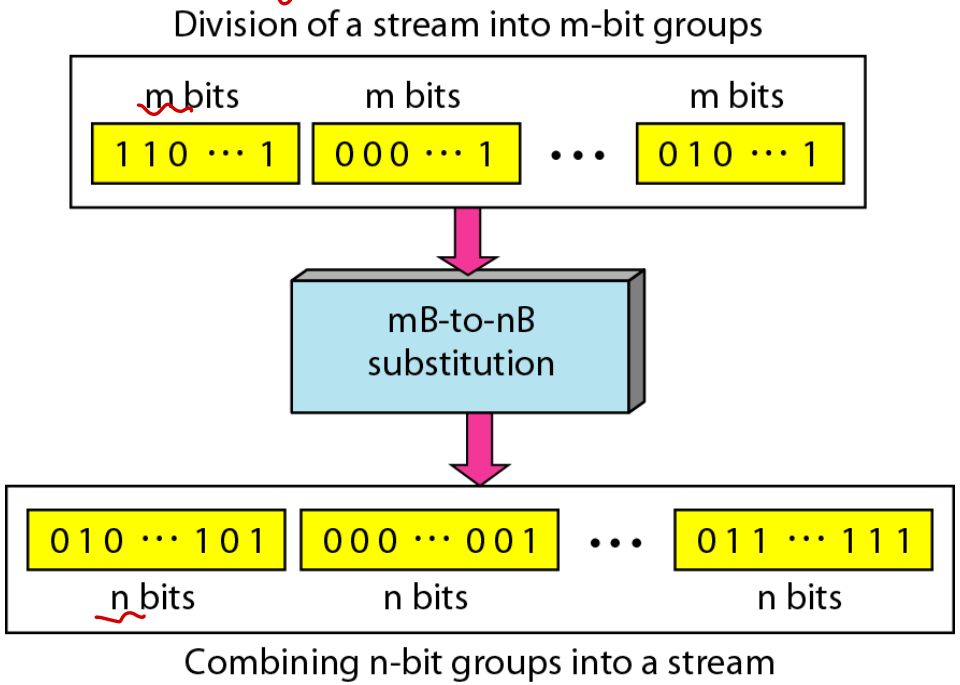
- Code uses 3 voltage levels: +, 0, -, to represent the symbols (not transitions to zero as in RZ)
- Voltage level for one symbol is at "0", and the other alternates between + & -
- Alternate Mark Inversion (AMI) - the "0" symbol is represented by zero voltage and the "1" symbol alternates between +V and -V
- Pseudoternary is the reverse of AMI



- DC component?
- Synchronization?

Block Coding

- Block coding is normally referred to as mB/nB coding
- It replaces each m-bit group with an n-bit group
- 4B/5B encoding: resolve synchronization issue of NRZ-I (long 0s)



Block Coding

10100

- 4B/5B mapping codes

장점

동기화 유지 : 추가된 비트 패턴
1과 0의 전환

DC 성분 제거 : 0, 1 패턴 조정
평균전압 0
→ DC 성분 해결

단점

대역폭 비효율 : 추가되는 비트로 인해
대역폭 증가

복잡한 변환 과정 : 원본 데이터를 변환 할 때
복잡한 연산

0이 연속되는 횟수는 최대 3번 → sync

0연속 크게 문제X

채움

데이터 비트 (4비트)	코드 비트 (5비트)	NRZI
0000	11110	
0001	01001	
0010	10100	
0011	10101	
0100	01010	
0101	01011	
0110	01110	
0111	01111	
1000	10010	
1001	10011	
1010	10110	
1011	10111	
1100	11010	
1101	11011	
1110	11100	
1111	11101	

동기화가 완화되는 이유

동기화 문제는 연속된 동일한 비트 패턴으로 인해 발생

block coding은 전환이 없는 연속적인 패턴을 피하도록 설계

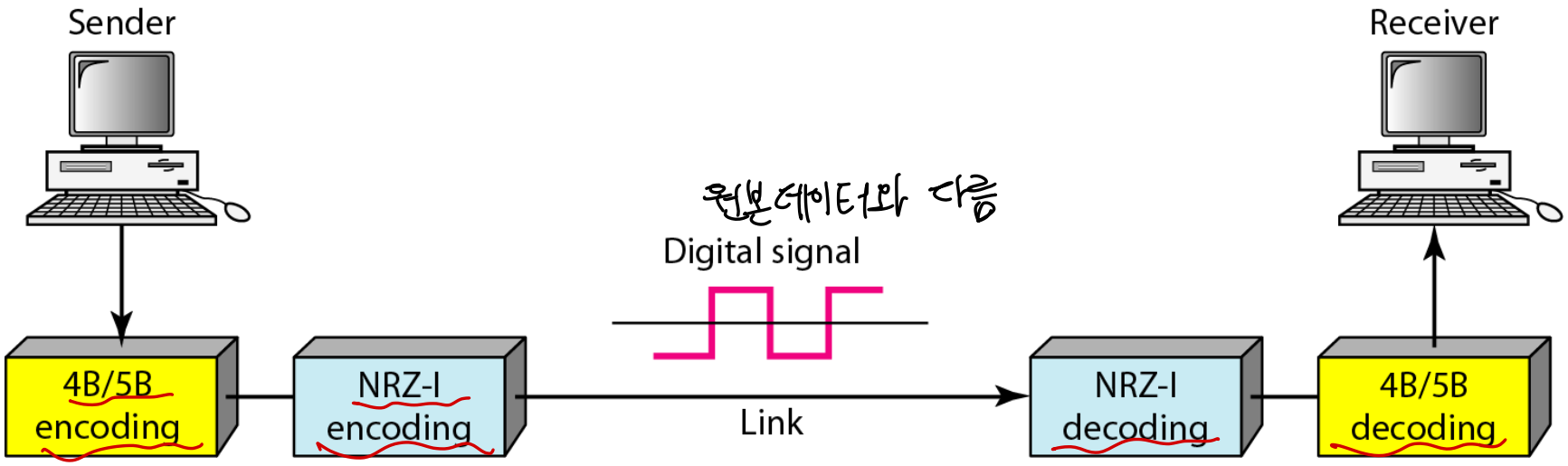
연속된 0 or 동일한 비트 패턴이 길게 이어지지 X

DC-component 해결X

0000 → 11110

0000 → 1110

Block Coding

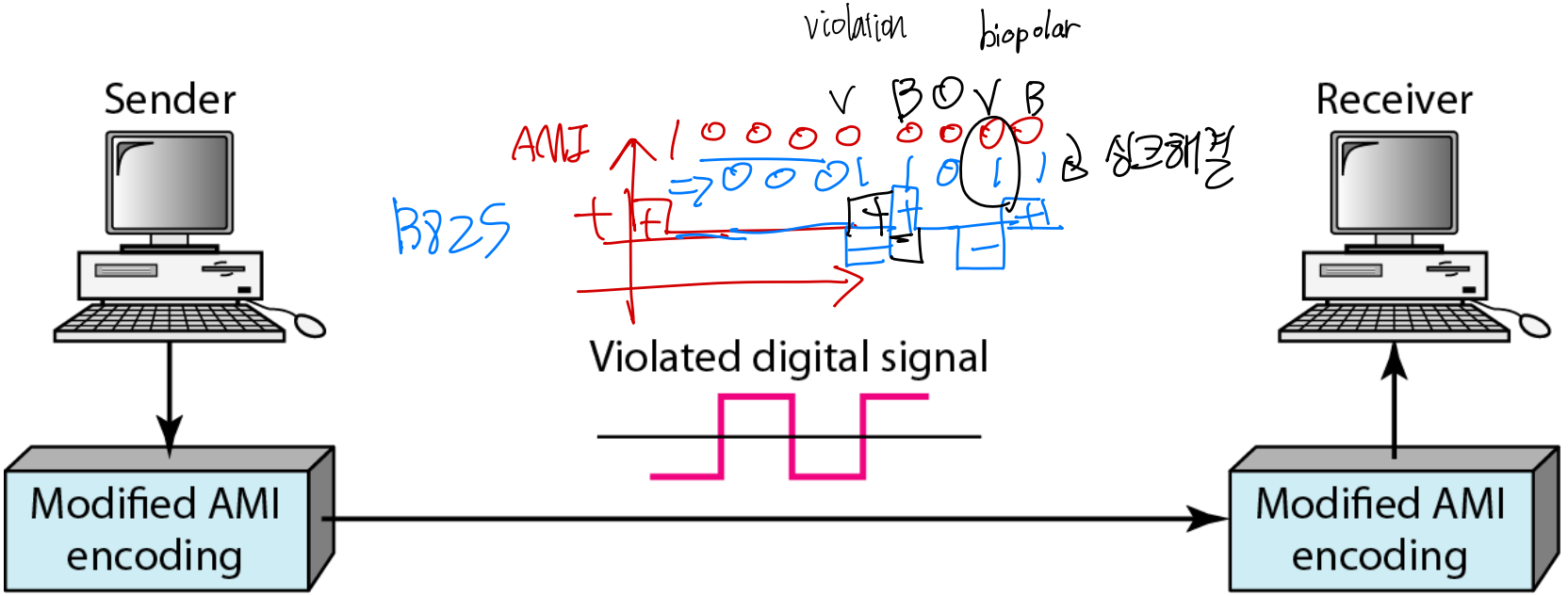


NRZ-I (0 연속일 때)
동기화 완화, 단점 보안

Scrambling

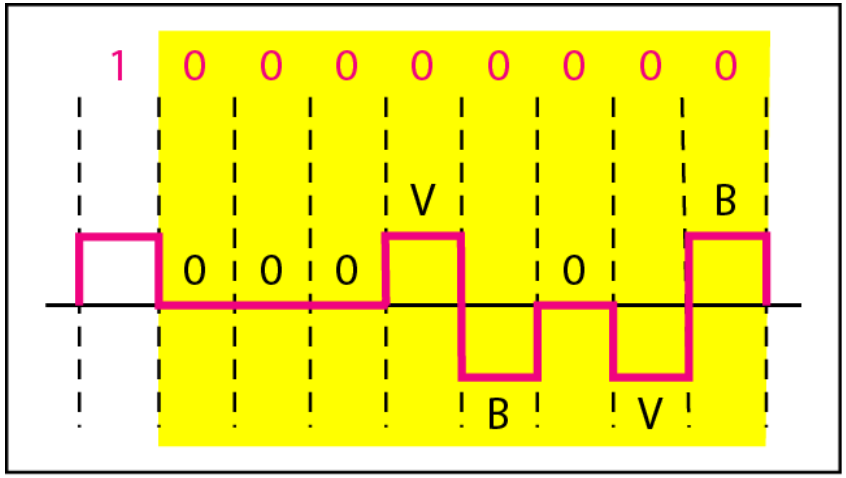
- The best code is one that does not increase the bandwidth for synchronization and has no DC components

- Scrambling is a technique used to create a sequence of bits that has the required features - synchronization, no DC components, no wide bandwidth

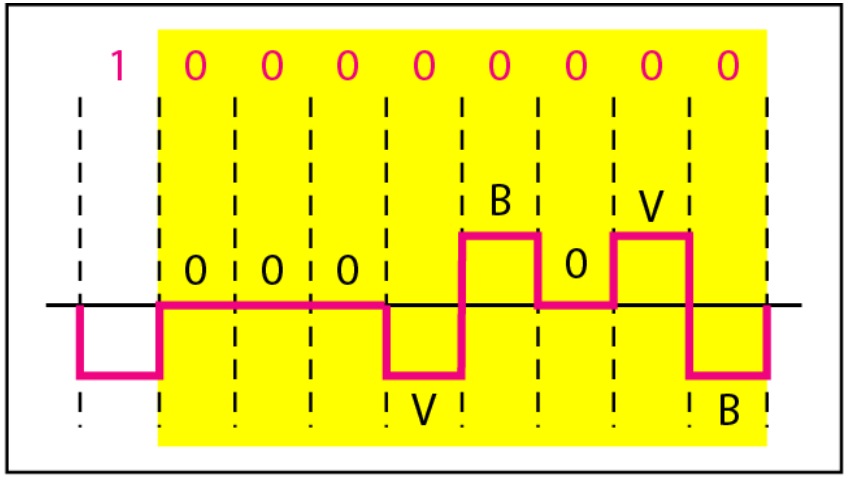


Scrambling – B8ZS (보미) AMI 단점 보완

- Bipolar with 8-zero substitution
  - Eight consecutive zero-level voltages are replaced by the sequence 000VB0VB
    - V: violation 위반
      - ✓ Non-zero voltage that breaks an AMI rule of encoding (opposite polarity from the previous)
    - B: bipolar 양극성
      - ✓ Non-zero voltage in accordance with the AMI rule



a. Previous level is positive.



b. Previous level is negative.

장점 : 동기화 문제 해결, 전압 변화를 인위적으로 삽입 → 동기화 문제 해결
DC성분제거
대역폭 증가X
연속된 특정 패턴방지
기준신호 변경X, 특정 패턴 나올때만 전압 변화 추가

단점 : 오류 감지 기능 부족
복잡한 수신처리
비트패턴 왜곡
전압 변화만큼 삽입
Scrambling 패턴을복원하는 과정이 복잡
원래 데이터 패턴 왜곡

Yeungnam University