TSN: Lecture 20
Multilevel Codes

Topics Covered

- Bipolar C/Cs
- Multilevel Schemes
- Representing Multilevel Codes

Bipolar C/Cs

- It is a better alternative to NRZ.
- Has no DC component or baseline wandering.
- Has no self synchronization because long runs of “0”s results in no signal transitions.
- No error detection.

Multilevel Schemes

- In these schemes we increase the number of data bits per symbol thereby increasing the bit rate.
- Since we are dealing with binary data we only have 2 types of data element a 1 or a 0.
- We can combine the 2 data elements into a pattern of “m” elements to create “2^m” symbols.
- If we have L signal levels, we can use “n” signal elements to create L^n signal elements.

Code C/Cs

- Now we have 2^m symbols and L^n signals.
- If $2^m > L^n$ then we cannot represent the data elements, we don't have enough signals.
- If $2^m = L^n$ then we have an exact mapping of one symbol on one signal.
- If $2^m < L^n$ then we have more signals than symbols and we can choose the signals that are more distinct to represent the symbols and therefore have better noise immunity and error detection as some signals are not valid.

Note

In *m*B*n*L schemes, a pattern of *m* data elements is encoded as a pattern of *n* signal elements in which $2^m \leq L^n$.

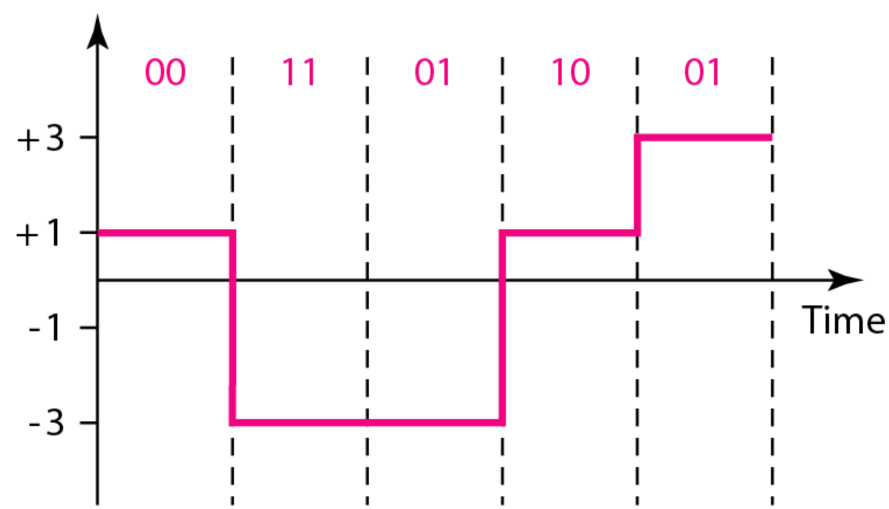
Representing Multilevel Codes

- We use the notation mBnL, where m is the length of the binary pattern, B represents binary data, n represents the length of the signal pattern and L the number of levels.
- L = B binary, L = T for 3 ternary, L = Q for 4 quaternary.

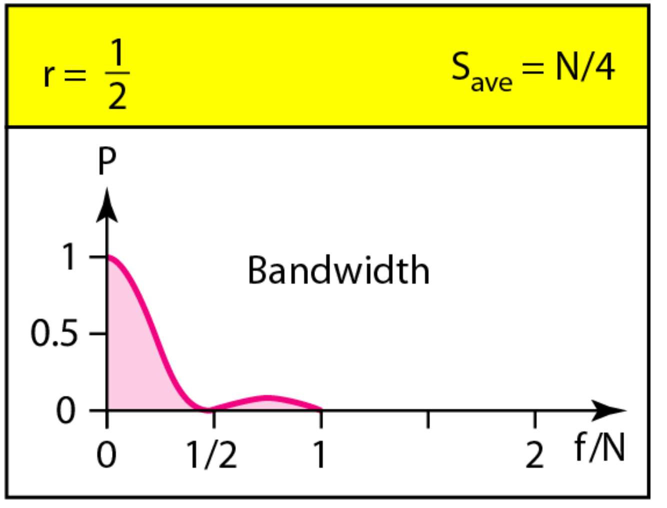
Figure 4.10 *Multilevel: 2B1Q scheme*

Next bits	Next level (Previous level: positive)	Next level (Previous level: negative)
00	+1	-1
01	+3	-3
10	-1	+1
11	-3	+3

Transition table



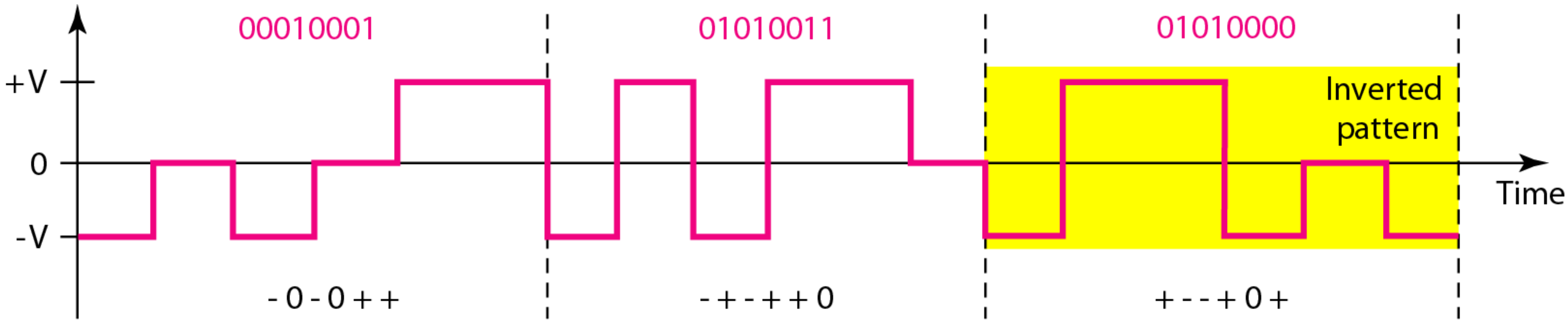
Assuming positive original level



Redundancy

- In the 2B1Q scheme we have no redundancy and we see that a DC component is present.
- If we use a code with redundancy we can decide to use only "o" or "+" weighted codes (more +'s than -'s in the signal element) and invert any code that would create a DC component. E.g. '+oo++-' -> '-oo--+'
- Receiver will know when it receives a "-" weighted code that it should invert it as it doesn't represent any valid symbol.

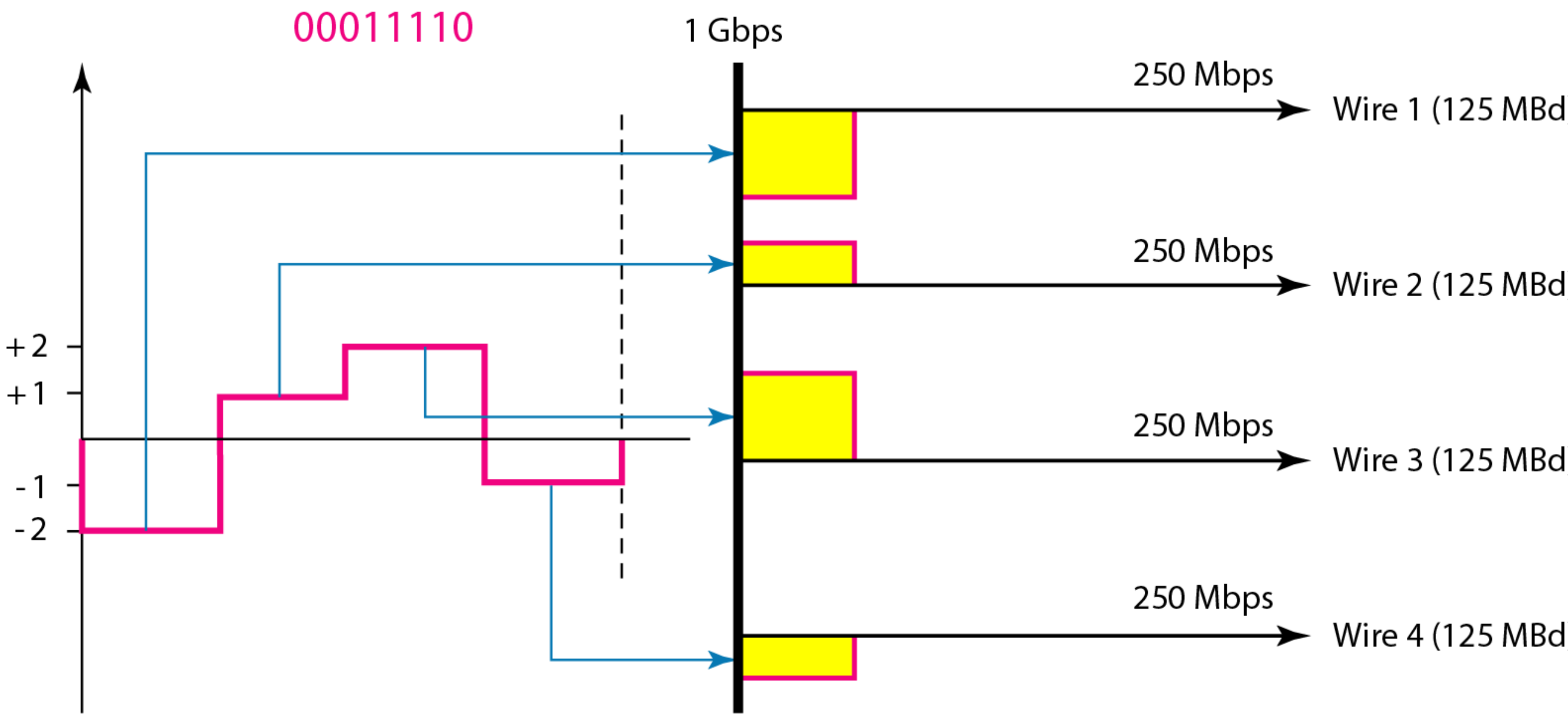
Figure 4.11 *Multilevel: 8B6T scheme*



Multilevel using multiple channels

- In some cases, we split the signal transmission up and distribute it over several links.
- The separate segments are transmitted simultaneously. This reduces the signalling rate per link -> lower bandwidth.
- This requires all bits for a code to be stored.
- xD: means that we use ‘x’ links
- YYYz: We use ‘z’ levels of modulation where YYY represents the type of modulation (e.g. pulse ampl. mod. PAM).
- Codes are represented as: xD-YYYz

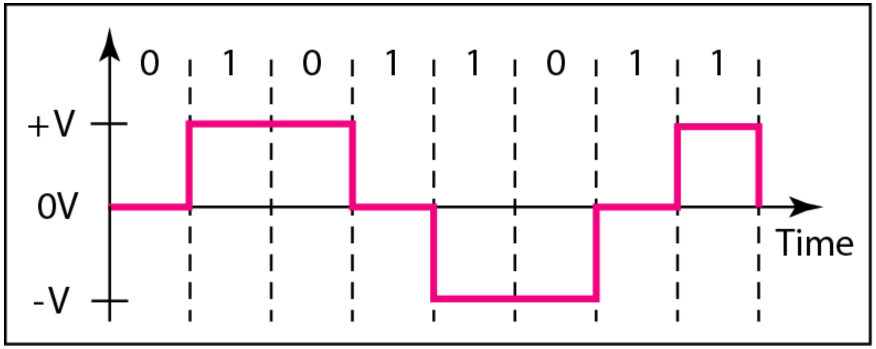
Figure 4.12 *Multilevel: 4D-PAM5 scheme*



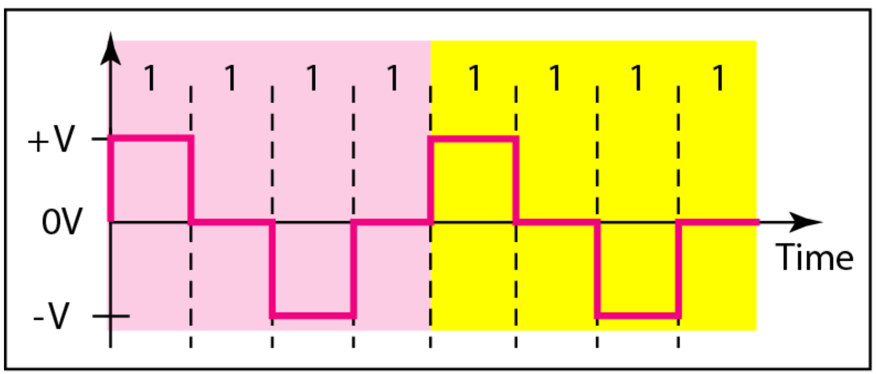
Multitransition Coding

- Because of synchronization requirements we force transitions. This can result in very high bandwidth requirements -> more transitions than are bits (e.g. mid bit transition with inversion).
- Codes can be created that are differential at the bit level forcing transitions at bit boundaries. This results in a bandwidth requirement that is equivalent to the bit rate.
- In some instances, the bandwidth requirement may even be lower, due to repetitive patterns resulting in a periodic signal.

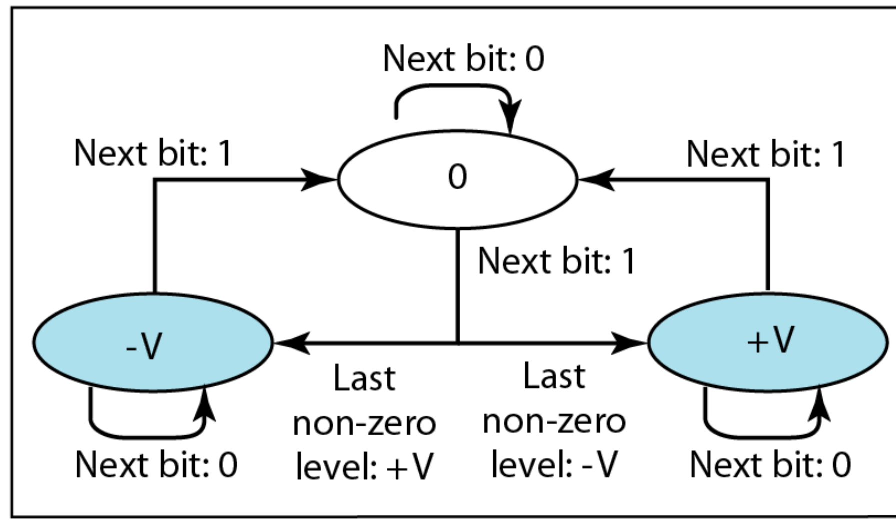
Figure 4.13 *Multitransition: MLT-3 scheme*



a. Typical case



b. Worse case



c. Transition states

MLT-3

- Signal rate is same as NRZ-I
- But because of the resulting bit pattern, we have a periodic signal for worst case bit pattern: 1111
- This can be approximated as an analog signal a frequency 1/4 the bit rate!

Table 4.1 *Summary of line coding schemes*

Category	*Scheme*	*Bandwidth (average)*	*Characteristics*
Unipolar	NRZ	$B = N/2$	Costly, no self-synchronization if long 0s or 1s, DC
Unipolar	NRZ-L	$B = N/2$	No self-synchronization if long 0s or 1s, DC
	NRZ-I	$B = N/2$	No self-synchronization for long 0s, DC
	Biphase	$B = N$	Self-synchronization, no DC, high bandwidth
Bipolar	AMI	$B = N/2$	No self-synchronization for long 0s, DC
Multilevel	2B1Q	$B = N/4$	No self-synchronization for long same double bits
	8B6T	$B = 3N/4$	Self-synchronization, no DC
	4D-PAM5	$B = N/8$	Self-synchronization, no DC
Multiline	MLT-3	$B = N/3$	No self-synchronization for long 0s