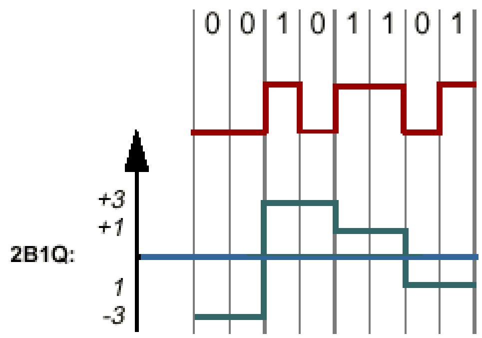
Line code and bit-clock regeneration

Line Codes

The following page gives a rough overview about line coding and data coding techniques. These describe how a certain data channel has access to a physical medium beside other data channels.

Line Coding Basics

Transmission of serial data over any distance, be it a twisted pair, fiber optic link, coaxial cable, etc., requires maintenance of the data as it is transmitted through repeaters, echo chancellors and other electronically equipment. The data integrity must be maintained through data reconstruction, with proper timing, and retransmitted. Line codes were created to facilitate this maintenance. In selecting a particular line coding scheme some considerations must be made, as not all line codes adequately provide the all important synchronization between transmitter and receiver. Other considerations for line code selection are noise and interference levels, error detection and error checking, implementation requirements, and the available bandwidth.



Unipolar Coding

The most basic transmission code is unipolar or unbalanced coding. In this scheme each discrete variable is transmitted with a different assigned level, 0V and for example +2.5V. But this holds a number of disadvantages:

- The average power is two times other bipolar codes
- The coded signal contains DC and low frequency components.
- When long strings of zeros are present, a DC or baseline wander occurs.
- This results in loss of timing and data because a receiver/repeater cannot optimally discriminate ones and zeros.
- Repeaters/receivers require a minimum pulse density for proper timing extraction. Long strings of ones or zeros contain no timing information and lead to timing jitter (when a clock recovery is used) and possible loss of synchronization.
- There is no provision for line error rate monitoring.

Bipolar Coding

With bipolar, or also called balanced coding, the same data may be transmitted more efficiently achieving the same error distance with half the power. This coding is often referred to as Non-Return to Zero (NRZ) coding as the signal level is maintained for the duration of the signal interval. Although bipolar coding is more efficient than unipolar, it still lacks provisions for line error monitoring, and is susceptible to DC wander and timing jitter. This coding scheme provides a number of features which:

- Eliminate DC Wander
- Minimize Timing Jitter
- Provide for Line Error Monitoring

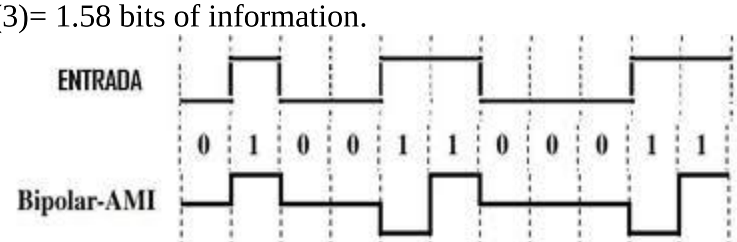
This is accomplished by introducing controlled redundancy in the code through extra coding levels.

Line Coding Techniques

2B1Q
The 2B1Q (two binary, one quaternary) line encoding scheme was intended to be used by the ISDN DSL and SDSL applications. This code is a four-level line code in which two binary bits (2B) represent one quaternary symbol (1Q). The 2B1Q line coding was seen as a major enhancement over the original T1 line coding, because 2B1Q encoded two bits per signal change instead of just one per change.

4B5B 4 Bit / 5 Bit
4B5B uses 5 bit signals for each 4 data bits. The 5 bit sequences are chosen so that there are never more than 3 consecutive zeros in the output stream. When used with NRZI, will have at least 2 signal transitions in every 5 bits.

BAMI Bipolar-Alternate Mark Inversion
BAMI uses 3 signal levels: +V, 0, -V 0 = no signal (0 voltage) 1 = alternating +V and –V BAMI has no DC component because of regularly alternating between +V and -V. Thus it is also able to detect some bit errors between consecutive +V or -V. The problems are a loss of synchronization during long string of 0 bits and the inefficient use of bandwidth. With 3 signal levels BMI you could transmit log2(3)= 1.58 bits of information.



8B10B 8 Bit / 10 Bit
8B10B coding is used in interfaces as PCI Express, Infinity Band, XAUI, Fiber Channel, DVB-ASI, and others. In this applications B10B transmission code provides the following functions:

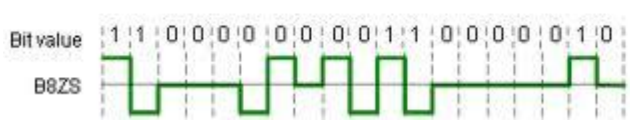
- Improves transmission characteristics
- Enables bit- level clock recovery
- Improves error detection
- Separates data symbols from control symbols
- Derives bit and word synchronization

The data bytes are encoded into 10-bit data characters resulting into 1024 possible characters. 2x256=512 are reserved for the data byte transfers. One character representative has more 1's, the other has more 0's and are selected according to the current disparity (see below). 12 special characters are defined for special signaling. The rest of the 1024-512-12 are not allowed for transmission and indicate transmission errors or unsynchronized status once they are received at the destination. Ordered sets are flexible building blocks which may be used for in-band and or out-of-band protocol functions.
8B10B code recognizes the idea of a Running Disparity (the difference between the number of 1's and 0's transmitted). The sender keeps the running disparity around zero, the receiver checks the data stream according to this rules and is thus able to detect some transmission errors. Other neighboring coding schemes like 64B66B are available and are used in certain applications.

B8ZS Bipolar with 8 Zero Substitution

B8ZS is used commonly in North American T1 (1.544MHz) and T1C (3.152MHz) carriers. For every string of 8 zeros, bipolar code is substituted according to the following rules:

- If the immediate preceding pulse is of (-) polarity, then code each group of 8 zeros as 000-+0+-.
- If the immediate preceding pulse is of (z) polarity, then code each group of 8 zeros as 000+-0-+



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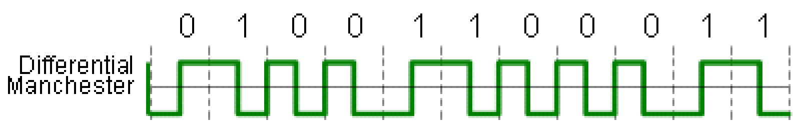
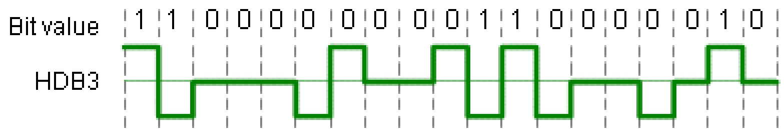
Differential Manchester Encoding
Mid-bit transition is used only for clocking 0 = transition at beginning of bit period (low-to-high or high-to-low, depending on previous output level) 1 = no transition at beginning of bit period This coding is used in IEEE 802.5 (Token Ring) at 4Mbps and 16Mbps. It has the same properties as Manchester encoding, but a better signal detection and clocking in presence of noise. Still there is the inefficient use of bandwidth.



HDB3 High Density Bipolar 3

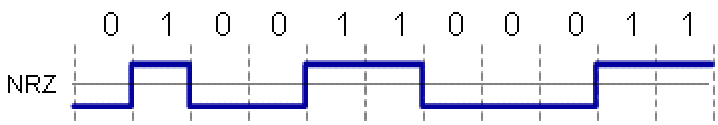
Another coding scheme is HDB3, high density bipolar 3, used primarily in Europe for 2.048MHz (E1) carriers. This code is similar to BNZS in that it substitutes bipolar code for 4 consecutive zeros according to the following rules:

- If the polarity of the immediate preceding pulse is (-) and there have been an odd (even) number of logic 1 pulses since the last substitution, each group of 4 consecutive zeros is coded as 000-(+00+).
- If the polarity of the immediate preceding pulse is (+) then the substitution is 000+(-00-) for odd (even) number of logic 1 pulses since the last substitution.



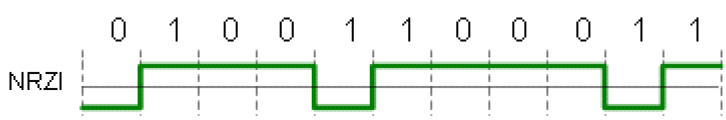
NRZ Non-return to Zero

1 = signal on 0 = signal off (no signal) NRZ is used on low speed links, such as serial ports. Its problems are lack of clock recovery during long string of 0 or 1 bits and it has a DC component resulting in “baseline wander” during long strings of 0 or 1 bits.



NRZI Non-return to Zero Inverted

1 = change of signal level (on-off or off-on) 0 = no change of signal level NRZI is a differential encoding used in 4B/5B on fast Ethernet. It fixes problems in clocking during long strings of 1 bits. The problems are the DC component and the lack of clock recovery during long string of 0 bits.



Pseudoternary

Pseudoternary has the same behavior as Bipolar-AMI except it reverses signaling: 1 = no signal (0 voltage) 0 = alternating +V and –V