# Overview of the modified 8B10B code scheme

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# Objectives of coding scheme

- DC Balance
  - essential for all fiber media and UTP
- Low maximum run length, sufficient transition density for clock recovery
- Spectral properties conducive to FCC class B emissions
- Sufficient control signals for 1394 (+ spare)
- Robust to errors during packets and control
- Low complexity

# Data coding

- The proposed scheme uses exactly the same 8B10B data coding as Fibre Channel and Gigabit Ethernet.
- DC balanced
  - 10 bit characters have disparity of zero or +/- 2
  - running disparity constrained by +/- 3
  - maximum runlength = 5
- Low complexity
  - encoder = 89 gates, 17 flipflops
  - decoder = 79 gates, 9 flipflops*

*A.X. Widmer and P.A. Franaszek, IBM J. Res. Develop., vol. 27, 5, Sept 1983, pp440-451.

# Control coding

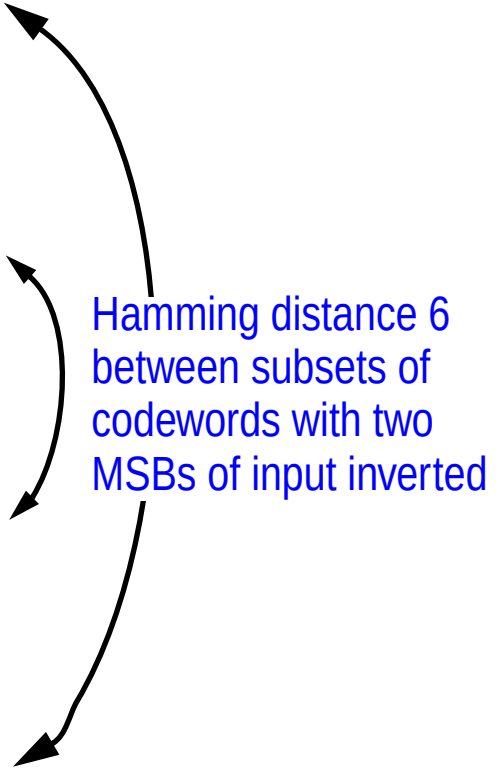
- A new set of 10 bit characters is used for control signaling. These replace the Ordered Sets used in Fibre Channel and Gigabit Ethernet.
  - Shorter than ordered sets
  - Greater Hamming distance from data codewords than ordered sets
  - better spectrum than ordered sets (when used with a scrambler)
- The sixteen new 10 bit control characters have following properties:
  - DC balanced
  - every character has disparity of zero
  - running disparity constrained by +/-6
  - maximum runlength =10
  - all control characters are Hamming distance 2 from any data character, and Hamming distance 2 from each other
- All 1394 control states can be accomodated (plus spare).

# New control codeword set

| scrambled control state input | | | codeword |
|---|---|---|---|
| hex | binary | label | |
| 0 | 0000 | C0 | 0 0 0 0 0 1 1 1 1 1 |
| 1 | 0001 | C1 | 0 0 0 0 1 0 1 1 1 1 |
| 2 | 0010 | C2 | 0 0 0 0 1 1 1 1 1 0 |
| 3 | 0011 | C3 | 0 0 0 1 0 0 1 1 1 1 |
| 4 | 0100 | C4 | 0 0 1 0 0 0 1 1 1 1 |
| 5 | 0101 | C5 | 1 1 0 0 0 0 0 1 1 1 |
| 6 | 0110 | C6 | 0 1 0 0 0 0 1 1 1 1 |
| 7 | 0111 | C7 | 1 0 0 0 0 0 1 1 1 1 |
| 8 | 1000 | C8 | 0 1 1 1 1 1 0 0 0 0 |
| 9 | 1001 | C9 | 1 0 1 1 1 1 0 0 0 0 |
| a | 1010 | C10 | 0 0 1 1 1 1 1 0 0 0 |
| b | 1011 | C11 | 1 1 0 1 1 1 0 0 0 0 |
| c | 1100 | C12 | 1 1 1 0 1 1 0 0 0 0 |
| d | 1101 | C13 | 1 1 1 1 0 0 0 0 0 1 |
| e | 1110 | C14 | 1 1 1 1 0 1 0 0 0 0 |
| f | 1111 | C15 | 1 1 1 1 1 0 0 0 0 0 |

All zero disparity.

Max. run length is 10 (cf. 5 with IBM data codewords)



Hamming distance 6 between subsets of codewords with two MSBs of input inverted

# Control State Mapping

| 1394 state | Binary control state |
|---|---|
| IDLE | 0000 |
| REQUEST / GRANT | 0001 |
| PARENT_NOTIFY | 0010 |
| CHILD_NOTIFY | 0011 |
| SPEED+ (rds +ve) | 0100 |
| DATA_PREFIX- (rds -ve) | 0101 |
| DATA_END- (rds -ve) | 0110 |
| DATA_END+E (Errored packet, rds +ve) | 0111 |

| 1394 state | Binary control state |
|---|---|
| SPEED- (rds -ve) | 1000 |
| DATA_PREFIX+ (rds +ve) | 1001 |
| DATA_END+ (rds +ve) | 1010 |
| DATA_END-E (Errored packet, rds -ve) | 1011 |
| ESCAPE | 1100 |
| spare | 1101 |
| spare | 1110 |
| RESET | 1111 |

- Hamming distance 6 between +ve and -ve rds (disparity) versions of control states.
- Hamming distance 6 between SPEED_SIGNAL and DATA_PREFIX.

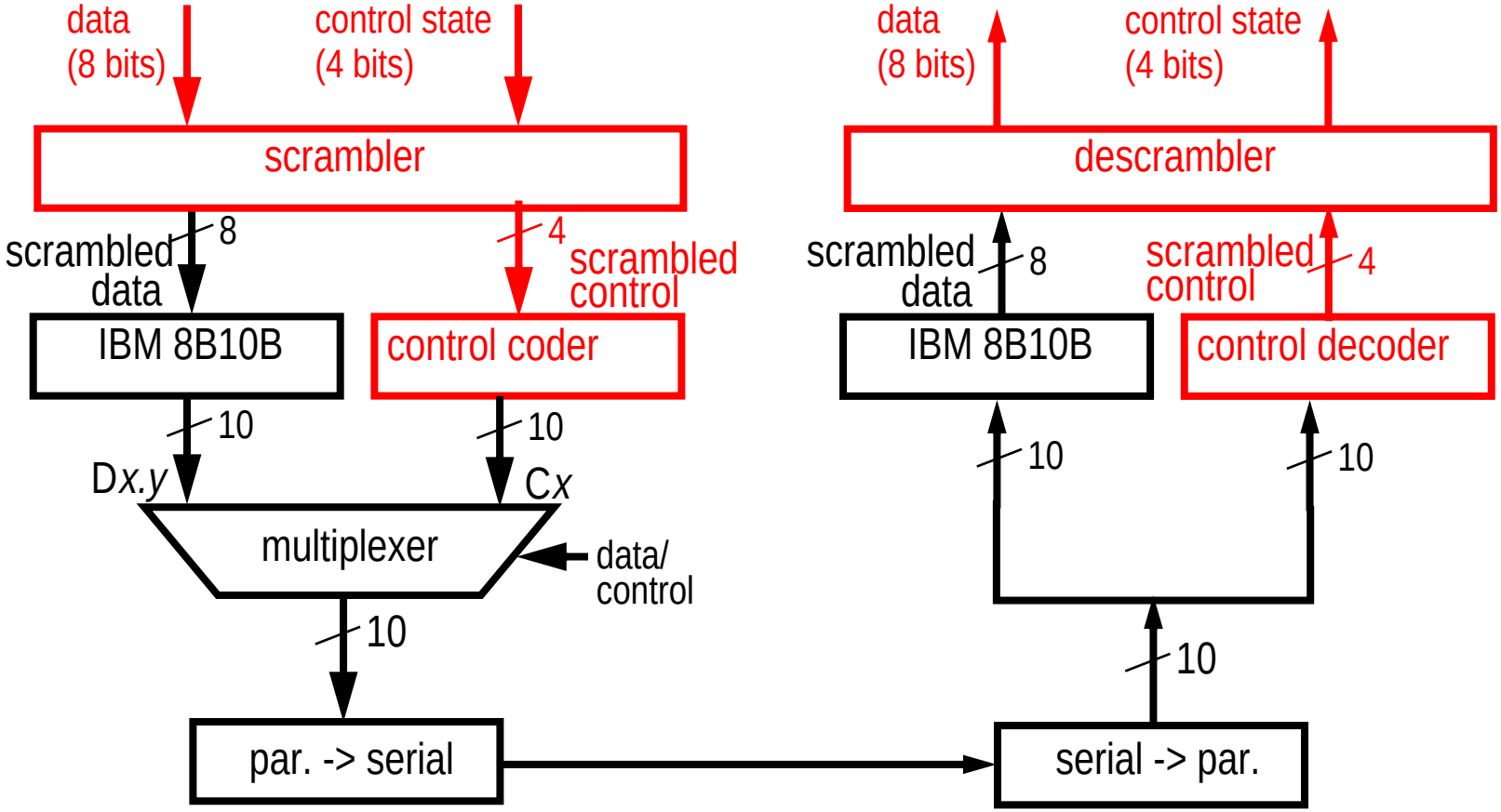
# Scrambling

- The proposed scheme uses a scrambler to aid EMC compliance. The scrambler eliminates patterns that cause discrete spectral lines:
  - repetitive control patterns
  - patterns formed from a small alphabet when padding lower rate packets on higher rate links

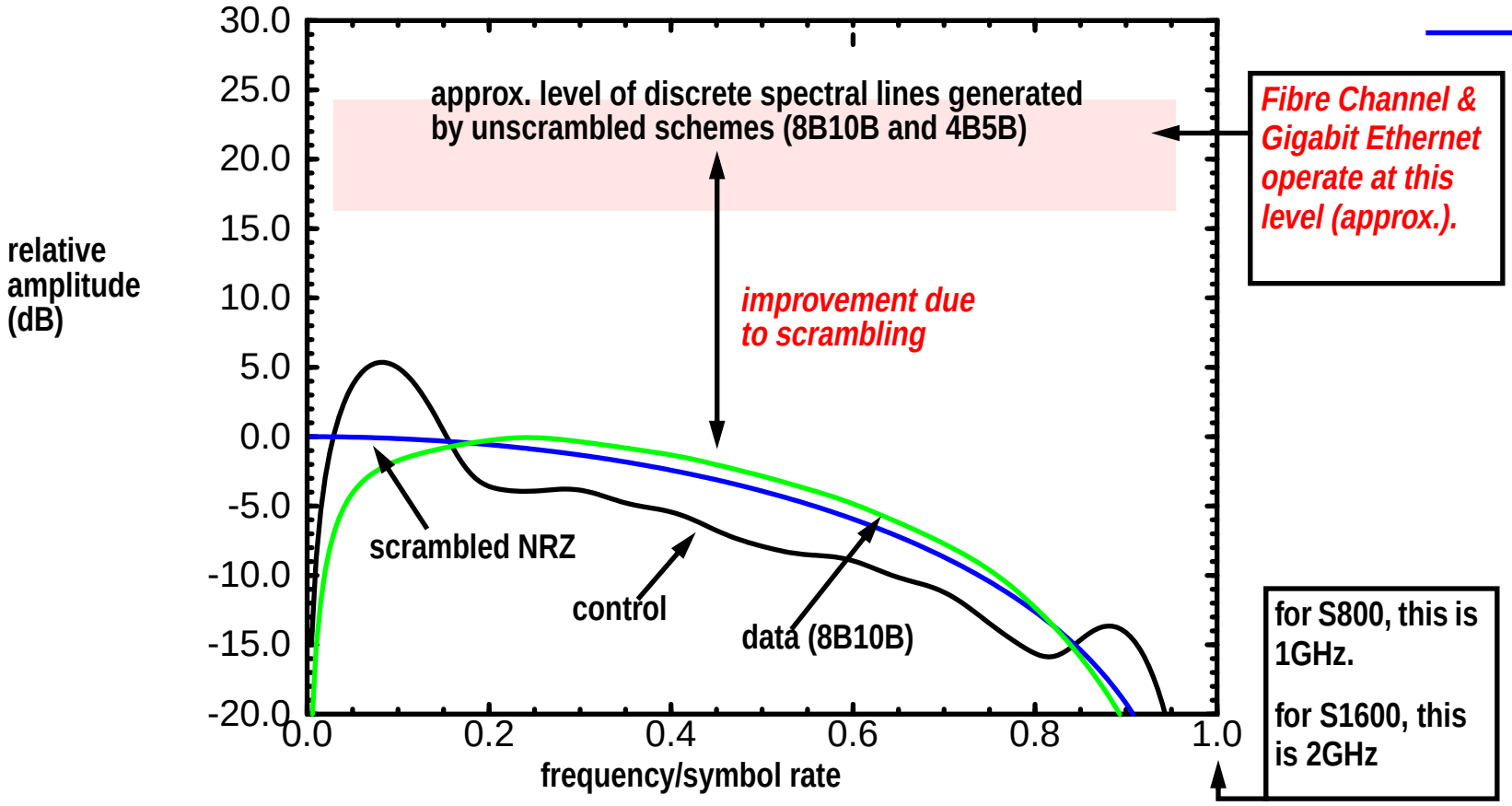
- Scramblers are used in many existing applications:
  - Telecomms
  - FDDI TP-PMD
  - 100Base-TX, -T2, -T4
  - ATM-25, ATM-51, etc.

- Scrambler implementation and synchronization is simple (see separate presentation).

# Block diagram

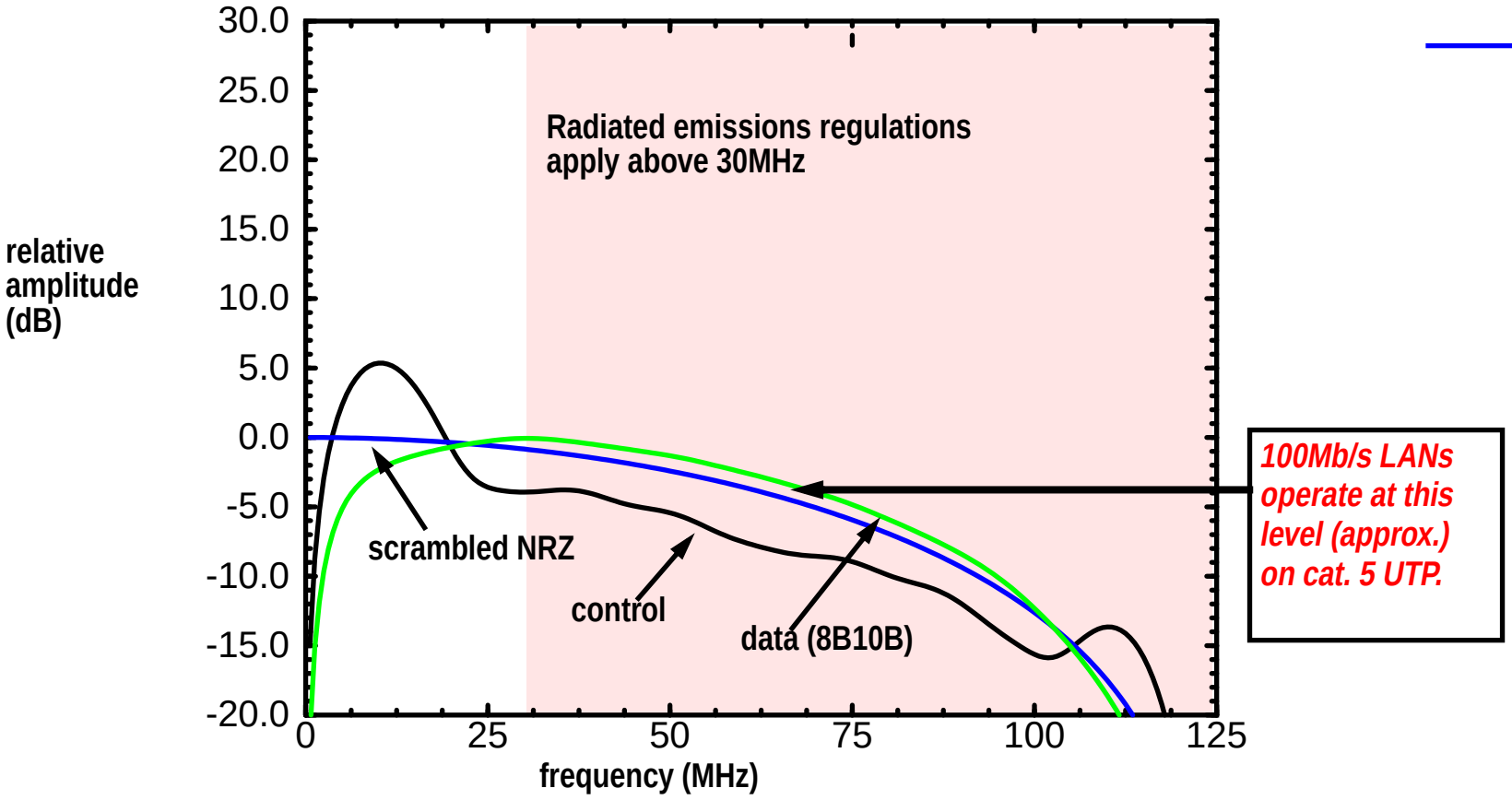


# Spectral properties




- Differences between scrambled data and control spectra should not be significant given reduction provided by scrambler. (Clearly this should be checked by EMC tests.)

# Spectrum at S100




- UTP is only feasible at S100 (unless complex coding is used).
- Major differences in spectra are below 30 MHz: no problem.
- Modified 8B10B is suitable for UTP (and POF) at S100.

# Error detection properties (1)

- Two single bit errors within an 8B10B coded packet:
  - When decoded, these result in two errored bytes.
  - With the IBM 8B10B code, ***all combinations of two errors are detected by CRC32.***

- Three single bit errors within an 8B10B coded packet:
  - Three error events will always cause a disparity error.
  - Disparity is checked using packet delimiters (similar to Fibre channel). Disparity at start of packet is indicated by sending either DATA_PREFIX+ or DATA_PREFIX-. Disparity at end of packet is checked by sending either DATA_END+ or DATA_END-.
  - ***All combinations of three errors are detected by the disparity check.***

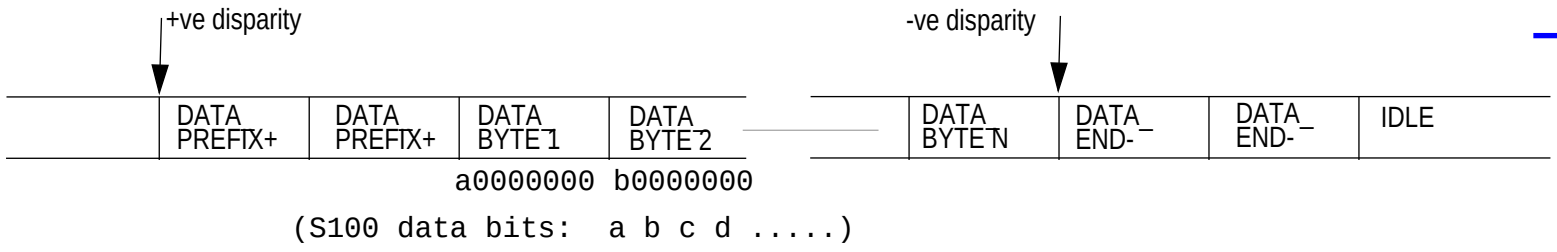
- Burst Errors
  - CRC32 will detect bursts up to 32 bits long in uncoded data. This translates to bursts up to 35 bits long in coded data.

# Error detection properties (2)

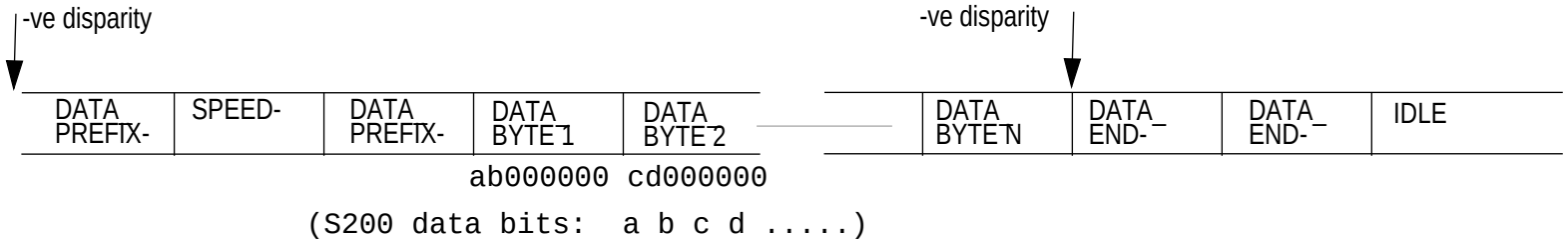
- Error propagation in forwarded packets
  - Many error combinations that CRC32 may not detect will be detected by code violations (invalid codeword received).
  - These errors can be masked when a packet is decoded, forwarded and then coded (correctly).
  - Code violation error detection is preserved in modified 8B10B scheme by using “errored packet” delimiters.
  - If any error is detected in a packet, the DATA_END+/- signal is replaced with a DATA_END+/-E(rrored) signal.

- Errors during control signals
  - In general, at least two errors in a single control codeword (2 errors in 10 bits) are needed to change a control signal to another valid control signal.
  - Particular control signals can be separated by Hamming distance 6 (6 errors in 10 bits needed to change to other valid control signal).
  - At least two errors needed to change a control signal to valid data.

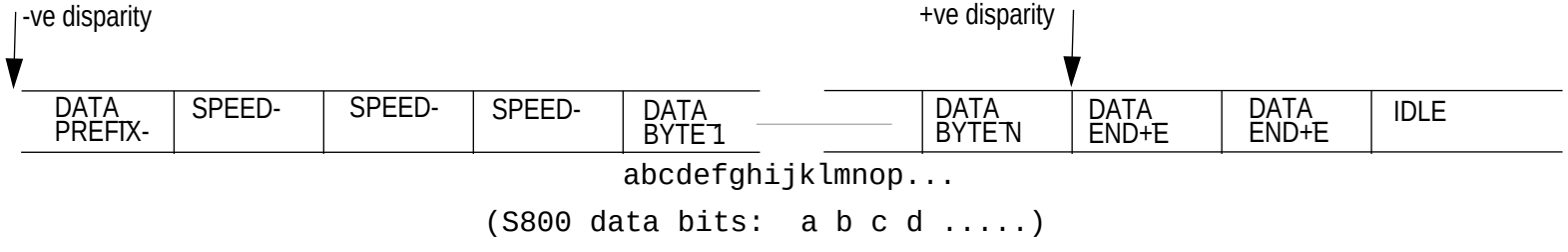
# Example packet structures




**S100 packet transported on S800 1394B link**




**S200 packet transported on S800 1394B link**




**Errored S800 packet forwarded on S800 1394B link**

# Example of coding

| 1394-1995 state | REQUEST | DATA_PREFIX | | | | data.... | |
|---|---|---|---|---|---|---|---|
| 1394-1995 data | | | | | | 01110101 | 00110111 |
| rds | + | + | + | + | + | + | + |
| control | REQUEST | DAT_PREF+ | SPEED+ | SPEED+ | SPEED+ | | |
| control state | 0 0 0 1 | 0 1 0 1 | 0 1 0 0 | 0 1 0 0 | 0 1 0 0 | | |
| scrambler | 00000100 | 00000010 | 10000001 | 00010000 | 10101010 | 01000000 | 01101000 |
| scram cntrl | 0 0 0 1 | 0 1 0 0 | 1 1 0 0 | 0 1 0 0 | 1 0 1 1 | | |
| scram data | | | | | | 00110101 | 01011111 |
| codeword | C1 | C4 | C12 | C4 | C11 | D21.1 | D31.2 |
| coded output | 0000101111 | 0010001111 | 1110110000 | 0010001111 | 1101110000 | 1010101001 | 0101000101 |

| 1394-1995 state | ....data | | DATA_END | | | IDLE | |
|---|---|---|---|---|---|---|---|
| 1394-1995 data | .... | 00111001 | | | | | |
| rds | .... | - | - | - | - | - | - |
| control | .... | | DATA_END- | DATA_END- | DATA_END- | IDLE | |
| control state | .... | | 0 1 1 0 | 0 1 1 0 | 0 1 1 0 | 0 0 0 0 | 0 0 0 0 |
| scrambler | .... | 00111001 | 00011011 | 10101110 | 10100010 | 10000101 | 00010010 |
| scram cntrl | .... | | 0 1 0 1 | 1 0 0 1 | 1 0 1 1 | 1 0 0 0 | 0 0 0 1 |
| scram data | .... | 00000000 | | | | | |
| codeword | .... | D0.0 | C5 | C9 | C11 | C8 | C1 |
| coded output | .... | 1001110100 | 1100000111 | 1011110000 | 1101110000 | 0111110000 | 0000101111 |

# Summary

- Modified 8B10B scheme leverages existing well-proven 8B10B code for data.
  - Already used for Fibre Channel and Gigabit Ethernet.
  - Excellent dc balance, low complexity implementation.
- New control scheme has better spectrum for EMC, is more robust and faster than Ordered Sets.
- Modified 8B10B scheme is suitable for 1394B at all speeds (S100 through S3200) on all media (UTP, POF, Glass fiber, shielded cables).

- Reference material: (All available from http://hplbwww.hpl.hp.com/people/ed/)

"Coding schemes for 1394B", Alistair Coles, presentation to 1394B, June 10/11, 1997.
"Spectral measurements and use of a scrambler", Eric Deliot, presentation to 1394B, June 10/11, 1997.
"Start up with modified 8B10B scheme", Alistair Coles, presentation to 1394B, August 6-8, 1997.
"S100 1394B and UTP", Alistair Coles, presentation to 1394B, August 6-8, 1997.