

# Continuous Time PHY for Category 5 UTP



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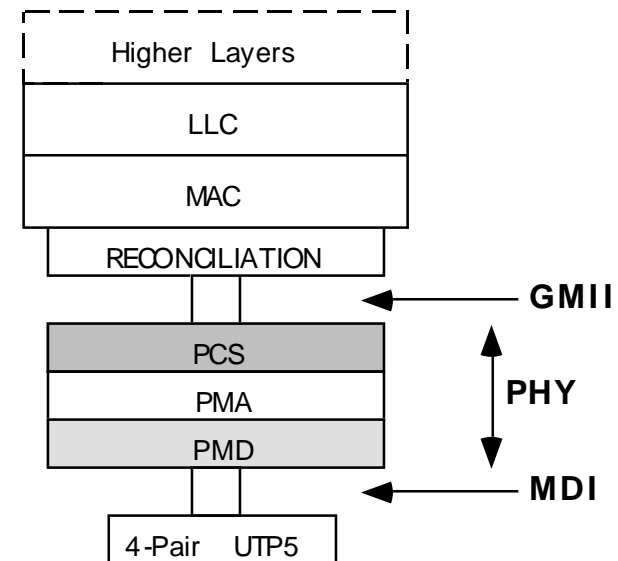
**tel: 604.415.6000**

**The following companies have indicated their support for the concepts outlined in this proposal (in alphabetical order):**

- Cabletron
- Packet Engines

# Continuous Time PHY for Category 5 UTP

- **Gigabit Ethernet PHY interface;**
  - *50 m* short-haul - Full Duplex UTP-5, 4-pair interface
  - *100 m* intermediate - Full Duplex UTP-5, 8-pair interface
- **Basic Concept**
- **Updates from Coeur d'Alene**
- **Future Work**



# Gigabit UTP TTM Work Plan



- Work against plan is complete

No#	Group	Objective	Original View	Current View	Done
A	Modeling				
1		develop PMD Concept	Aug-96		√
2		model cable	Aug-96		√
3		model receiver	Aug-96		√
4		model transmitter	Aug-96		√
5		simulate system	Aug-96		√
B	Standards				
1		refine definition	Oct-96		√
2		define 2 bundle operation	Nov-96		√
3		define GMII ( add tx_clk)	Nov-96		√
4		define PCS ( 1 bundle & 2 bundle)	Nov-96		√
5		define PMA	Nov-96		√
6		define PMD	Nov-96		√
C	Hardware Testing				
1		construct prototype board	Sep-96		√
2		transmission testing	Sep-96		√
2.1		- AT&T Cable	Sep-96		√
2.2		- Belden Cable	Sep-96		√
2.3		- BER measurements @ 50 m	Oct-96		√
2.4		- BER measurements @ 100 m	Dec-96		
3		prep board to address FCC Class B	Oct-96		√
4		test board in an EMC lab	Nov-96		√

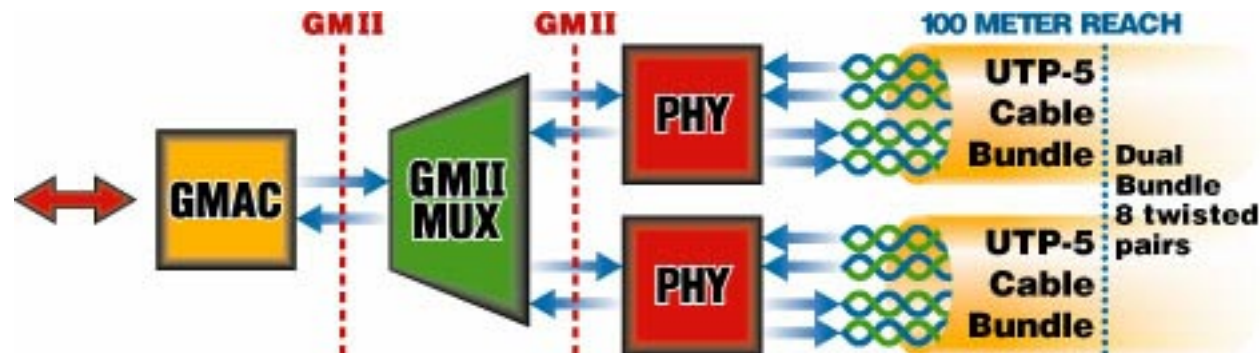
# Short Haul PHY

- *50 m* short-haul - Full Duplex UTP-5, 4-pair interface
- Based on existing technology:
  - Continuous time analog
  - Trade distance for SNR penalty of:
    - » Multi-level code
    - » Reduced symbol period (higher baud rate)
  - NEXT, Return Loss noise effects scale with baud rate

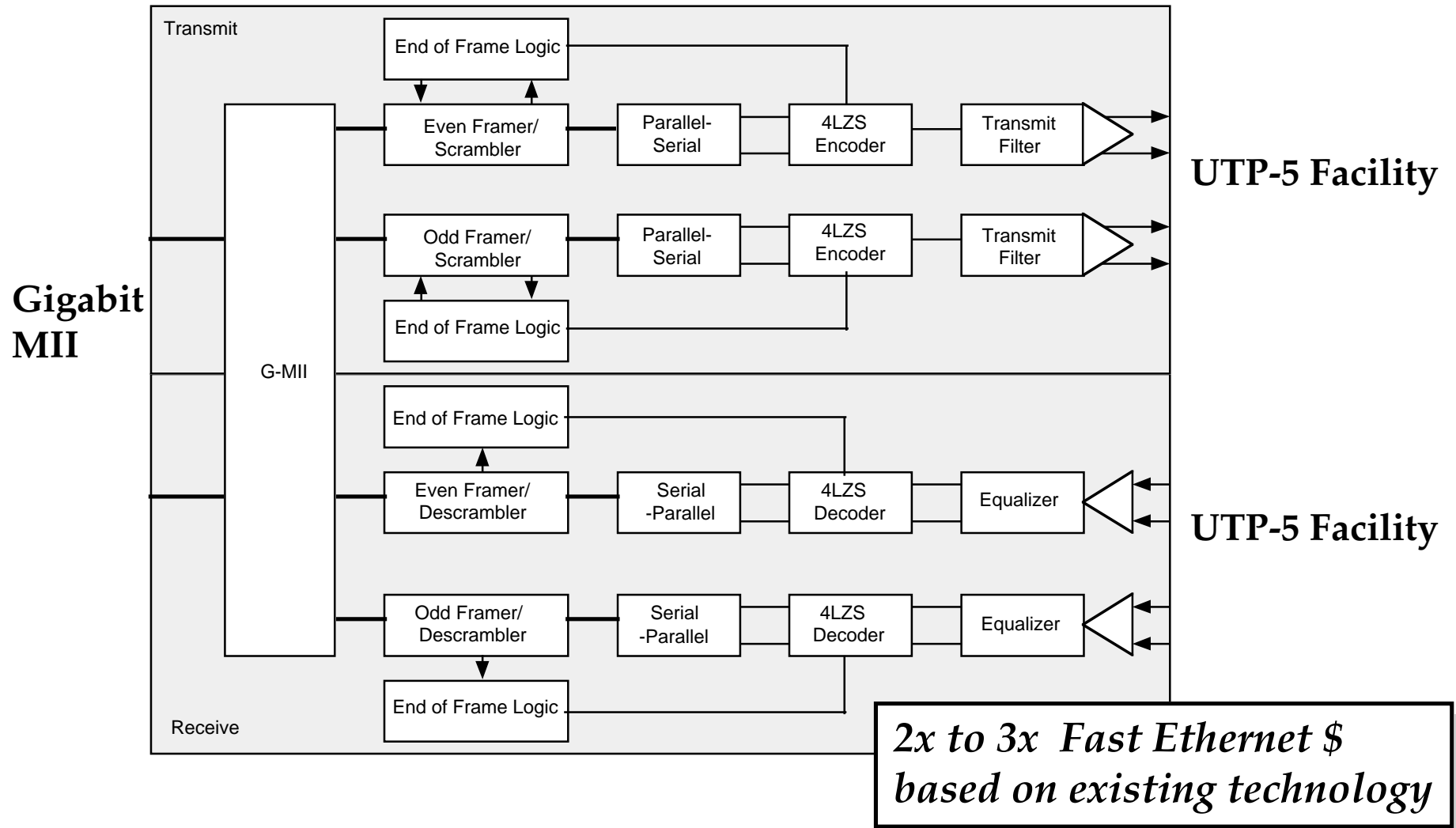


# Long Haul Application

- Two PHY devices running half rate on 8 pairs can reach 100m
- Transparent from the GMII
- Some installations already wired this way



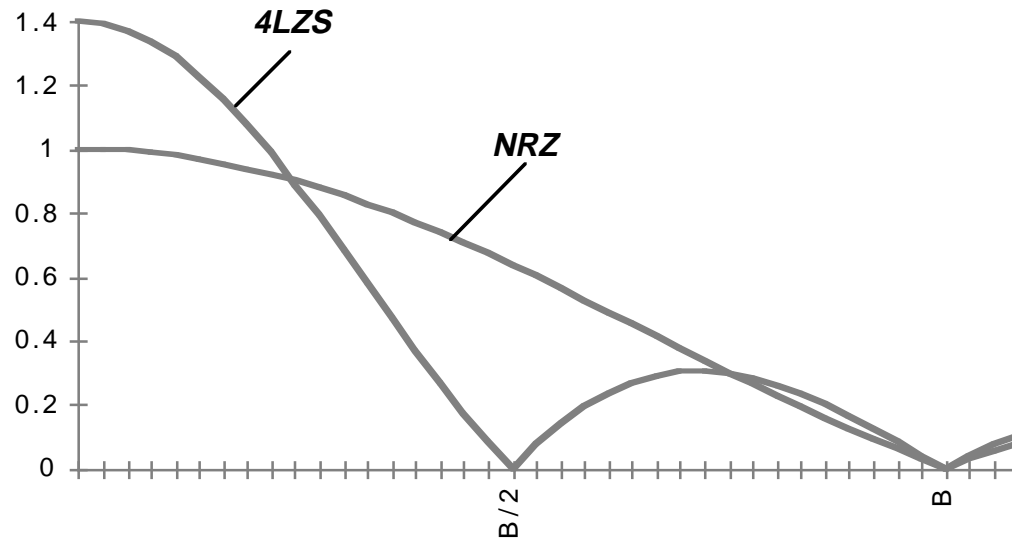
# PHY Block Diagram



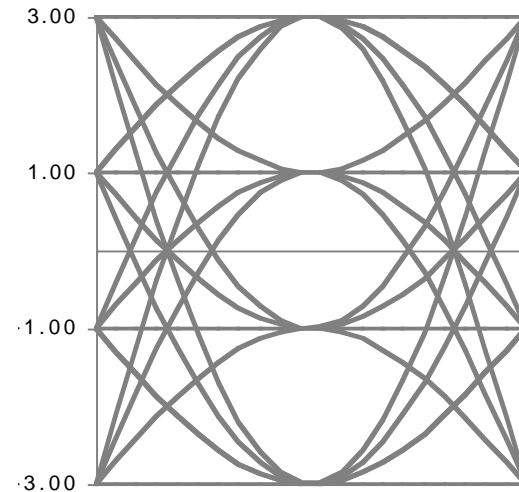
# 4-Level Code

- When coding  $n$  bits per pulse, for a bit rate of  $B$ , the pulse (symbol) rate is  $B/n$
- 4 Level gives 2 bits per symbol
  - 500 Mbits transmits in 250 Mbaud
- One dimensional code - one degree of complexity

*NRZ vs. 4LZS Spectrum at bit rate 'B'*



*4 Level Eye*

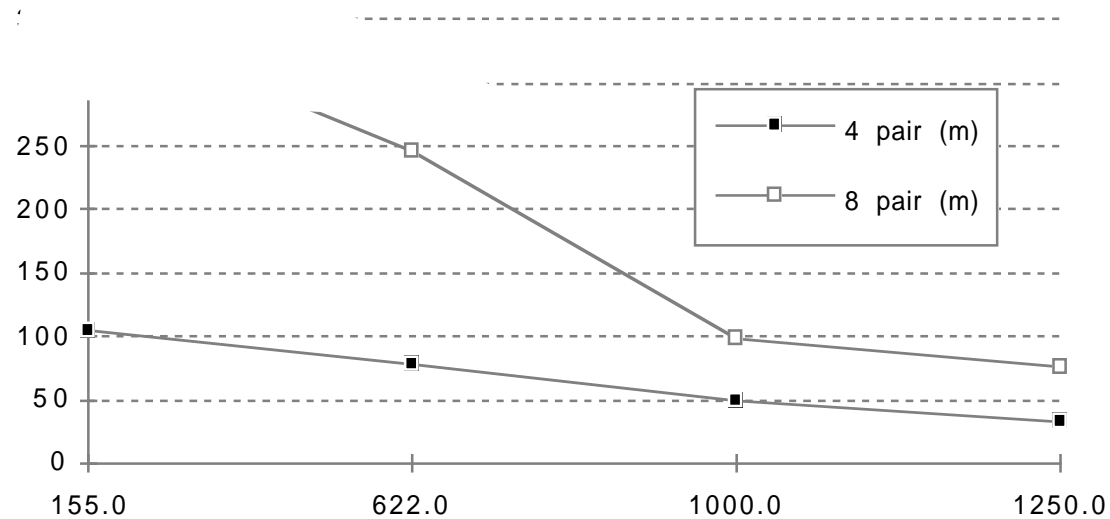


# PHY Comparisons

Capacity (Mb/s)	4 pair (m)	8 pair (m)	Coding Technique
155.0	105		* NRZ 155 UTP
622.0	77	245	4LZS 622 UTP
1000.0	50	99	4LZS 1000BaseT
1250.0	33	76	8B10B 1000BaseT

\* - Single pair

Distance vs. Bit Rate



**Reach is more sensitive to symbol period than multi-level code**



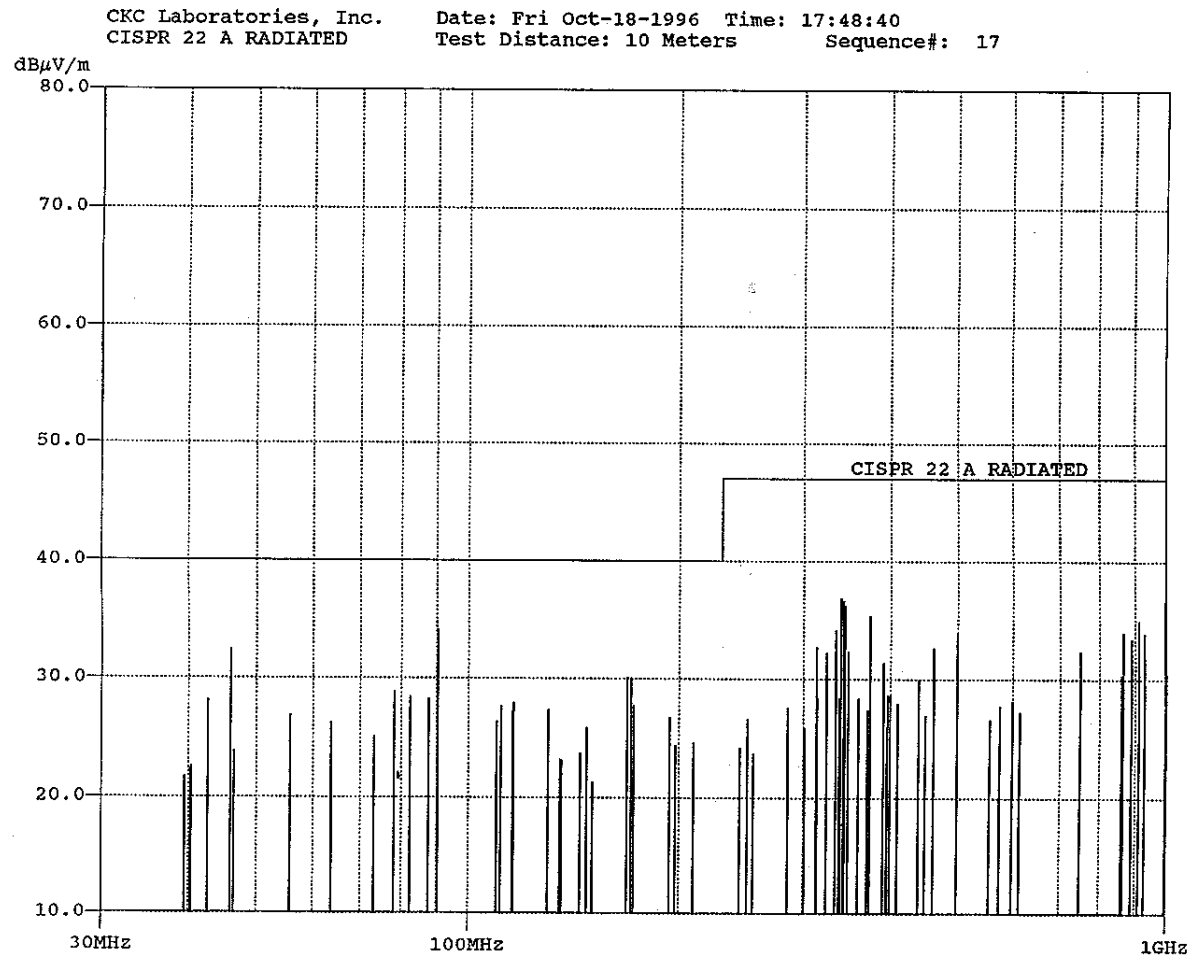
# Open Issues at Coeur d'Alene



- **BER performance over temperature**
- **Confirm spectral and FCC results**
- **'ESCAPE' words required**
  - Error conditions, TSC ?
- **DC balance requirements**
  - Decision feedback at receiver vs. transmitter RDS correction
- **Transmit templates and slicing levels**

# Spectrum Management

**PMC** *PMC-Sierra, Inc.*

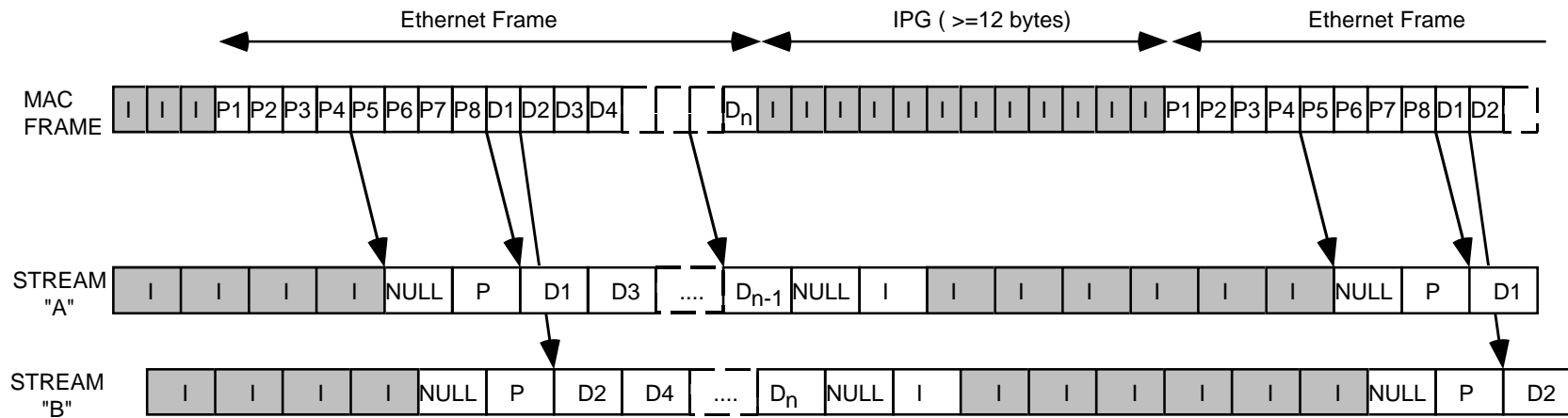


# PCS functions

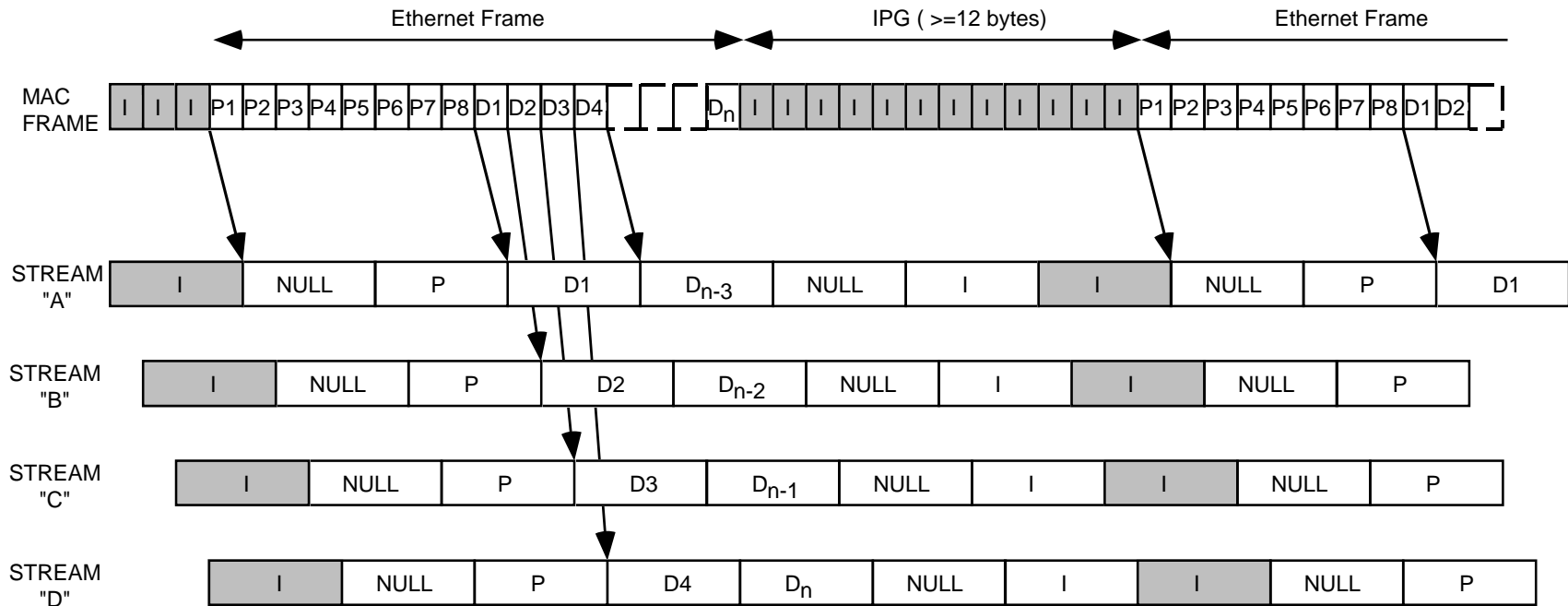


- **Bytes from GMII word byte multiplexed on different pairs**
- **Zero State signalling delimits change of state**
  - EOF turns off transmitter for one byte (4 quats)
  - Receiver requires quiescent detection comparators and digital decoding
- **Functionally identical to 8B10B**
  - transparent services to MAC
- **Configuration, Idle, Start of Packet Data, Carrier Extension, etc. as delimited states**
- **IPG used for IDLE codes and Zero State**
  - minimum IPG > 96 bits = 12 bytes
  - in 8 pair system - 3 bytes per Tx pair - 1 ZS & 2 IPG Bytes

# Line Data

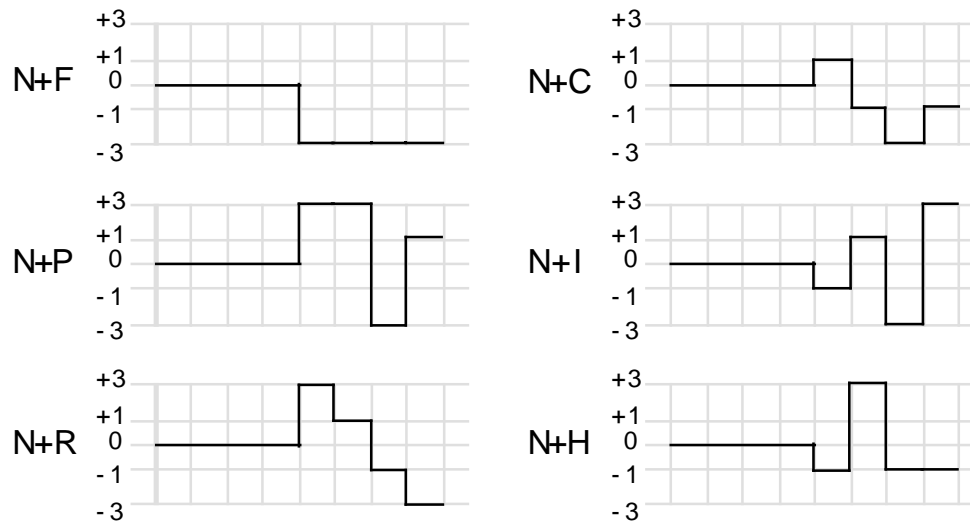


# Line Data - 8 Pair



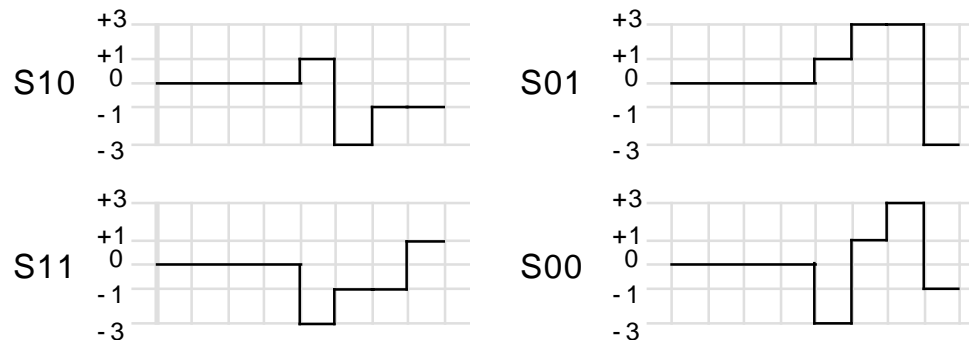
# Escape Codes

- Meets 802 Hamming Distance (4) Requirement
- Word and byte sync maintained



# Scrambling

- **Frame synchronous scrambler for spectrum management**
  - spreading components reduces emissions
  - self-synchronous cannot meet error propagation
  - TP-PMD  $x^{11}+x^9$  scrambler analyzed
- **DC runs eliminated with code substitution**
  - prevents ‘killer packets’
  - probability of two back-back substitutions ~once/100 years



# Proof of Concept



- **Cable measurements used to create simulation model**
  - 20th order 3 spline model
  - sensitivity comparisons and magnetic requirements
- **Discrete transceiver built**
  - FCC emissions
    - » Tx Levels
  - Baseline Wander
    - » Magnetics
  - Equalization
  - BER



# Results of Concept Test



- 50 meters on 4 pair agrees with theory
- 100 meters on 4 pair more risk & more than twice the work
- 4 LZS simple; 8B4P possible
- FCC - difficult but Class B possible
- Implementation issues effecting standards
  - Baseline wander, equalization

# Future Work

- **Successful proof of concept completed**
- **Ubiquitous copper >2 years behind fiber**
- **Smaller niches viable in near term**
  - <100m for equipment rooms, closet jumpers  
UTP preferred technology
  - Leading edge can use 8 pair for 100m
- **Spec should address both short and long-haul applications:**
  - **ø1: 50 m x 4 pair & 100 m x 8 pair**
  - **2+ years: work out requirements to extend design**
    - » **NEXT & Echo cancellers, Rxvr technology improvement**
  - **ø2: 100m x 4 pair**
    - » **backwards compatibility with ø1 spec**

## Supplementary Material

### Frequently Asked Question (FAQ) List

White Papers:           Application Drivers  
                                  Technical Proposal

Analytical Papers:      Scrambler Run Length  
                                  PCS Robustness

Web:                        <http://www.pmc-sierra.com>

## Demonstration Hardware and Refreshments:

**Hotel Vancouver  
Room 235  
Tuesday, November 12th  
6 - 9 PM**