Using ENRZ for CEI-56G-LR and CNRZ-5 for CEI-56G-USR

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OIF CEI Application Space

- **3D Stack**
- **2.5D Chip-to-OE**
- **Optics**
- **Chip**
- **Chip to Nearby OE**
- **Chip-to-Module**
- **Pluggable Optics**
- **Chip-to-Chip & Midplane Applications**
- **Chip**
- **Chip**
- **CEI-56G-USR**
- **CEI-56G-XSR**
- **CEI-56G-VSR**
- **CEI-56G-MR**
- **CEI-56G-LR**

Backplane or Passive Copper Cable
ENRZ – Is a good choice

- ENRZ is a the 4-wire version of NRZ
  - Delivers 3 bits over 4 wires using the 8 codes of the form:
    - +/{-1, -1/3, -1/3, -1/3}
    - These are the orthogonal linear combination of three NRZ signals
    - Three joint detectors compare the average of two sets of two wires
  - ENRZ uses the line termination power of one differential pair
    - Lowers the baud rate by 1/3 as compared to NRZ links and is compatible with binary DFEs
  - ENRZ works better than PAM-4
    - Needs more balance than NRZ & works well with two correlated pairs

- Delivers 112 Gb/s over two pairs, running at 37.3 GBaud
  - For 100 Gb/s, runs at 33.3 GBaud
  - ENRZ has much better ISI performance than PAM-4 and thus has a much better eye shape
    - ENRZ’s ratio of the largest to the smallest signal at the slicer is 1
    - PAM-4’s equivalent ratio is 3. It interferes with itself.
CEI-112G Generation: ENRZ plus PAM-3 gives a solution

• ENRZ can be combined with PAM-3 and a digital coding layer to provide an additional generation over the same four wires
• Delivers 3x3x3 = 27 codewords per symbol or 4.75 bits/symbol
  – Gives 224 Gb/s over 4 wires at 47.1 GBAud
  – Small digital coder allows the use of the full capability of the code and can be combined with other framing needs
• The eye shape will be better than PAM-4 and worse than plain ENRZ
  – Ternary DFEs are required
• Few other options exist for the CEI-112 generation (112 Gb/s per pair)
CNRZ-5 is the 6-wire version of NRZ

- Delivers 5 bits over 6 wires (5b6w) using a low complexity code
  - Five joint detectors deliver NRZ shaped eyes
  - Five 28 Gb/s channels can be carried over 6 wires
    - Almost equivalent throughput to NRZ at 56 Gb/s
    - Works well with a forwarded clock, which can be shared

- Uses the line termination power of 1.67 differential pairs
  - Forwarded clock pair can be amortized over multiple links

- NRZ is overkill for the USR application
  - Signal integrity is not the limiting factor
  - NRZ is not pin-efficient

- CNRZ-5 is a better choice than NRZ
Alternate CEI solution

- **CEI-56G-USR**: 3D Stack or 2.5D Chip-to-OE
- **CEI-56G-XSR**: Chip to Nearby OE
- **CEI-56G-VSR**: Chip-to-Module
- **CEI-56G-MR**: Chip-to-Chip & Midplane Applications
- **CEI-56G-LR**: Backplane or Passive Copper Cable

**Key Points**
- ENRZ can support Long Reach at 37.3 Gbaud.
- Repeater device can convert from PAM-4 or NRZ.
- Can last at least two generations through the use of ENRZ-PAM-3 224.