PAM-3 Line Coding/Mapping For 1000 BASE-T1

Xiaofeng Wang, Qualcomm Inc
wangxiao@qti.qualcomm.com

Motivation

- PAM-3 has been identified as a suitable modulation scheme for 1000 base-T1.
- Line coding or mapping between bits and symbols needs to be defined.

Line Coding

- Tradeoff between BW efficiency and other desired properties.
- Desired properties:
  - Small run length of consecutive symbols of the same value.
  - ISI/error propagation control.
  - Finite running digital sum: *unnecessary.*
  - Spectral shaping to fit TX PSD mask: *filtering can also do the job.*
  - Low implementation complexity: *small block length if block mapping.*

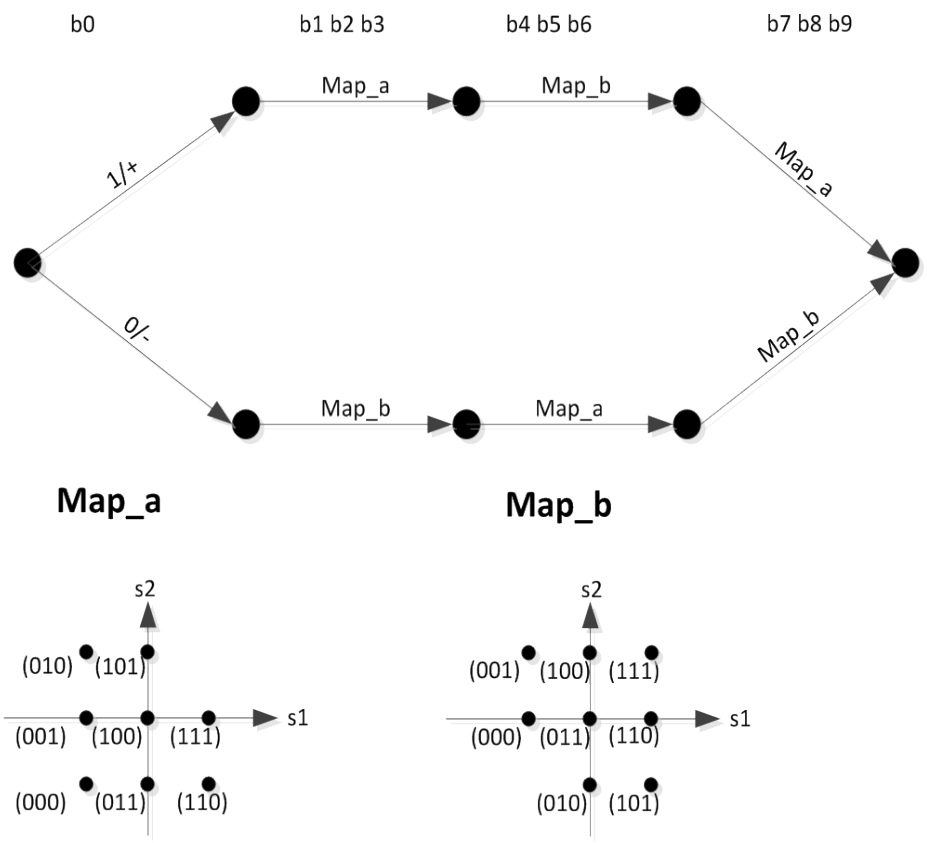
DFE Error Propagation in 1000 Base-T1

- First two DFE feedback taps can be greater than 0.5 [xiaofeng_3bp_01_0114][bliss_3bp_01_1113].
- Severe error propagation will happen with a standard DFE implementation.
- 1+D pre-coding may help but only effective for the Error propagation caused by a dominant first feedback tap.
- Error propagation requires coding protection well beyond the duration of a transient noise and reduces the coding gain in general.

“Simplest” Ternary Line code

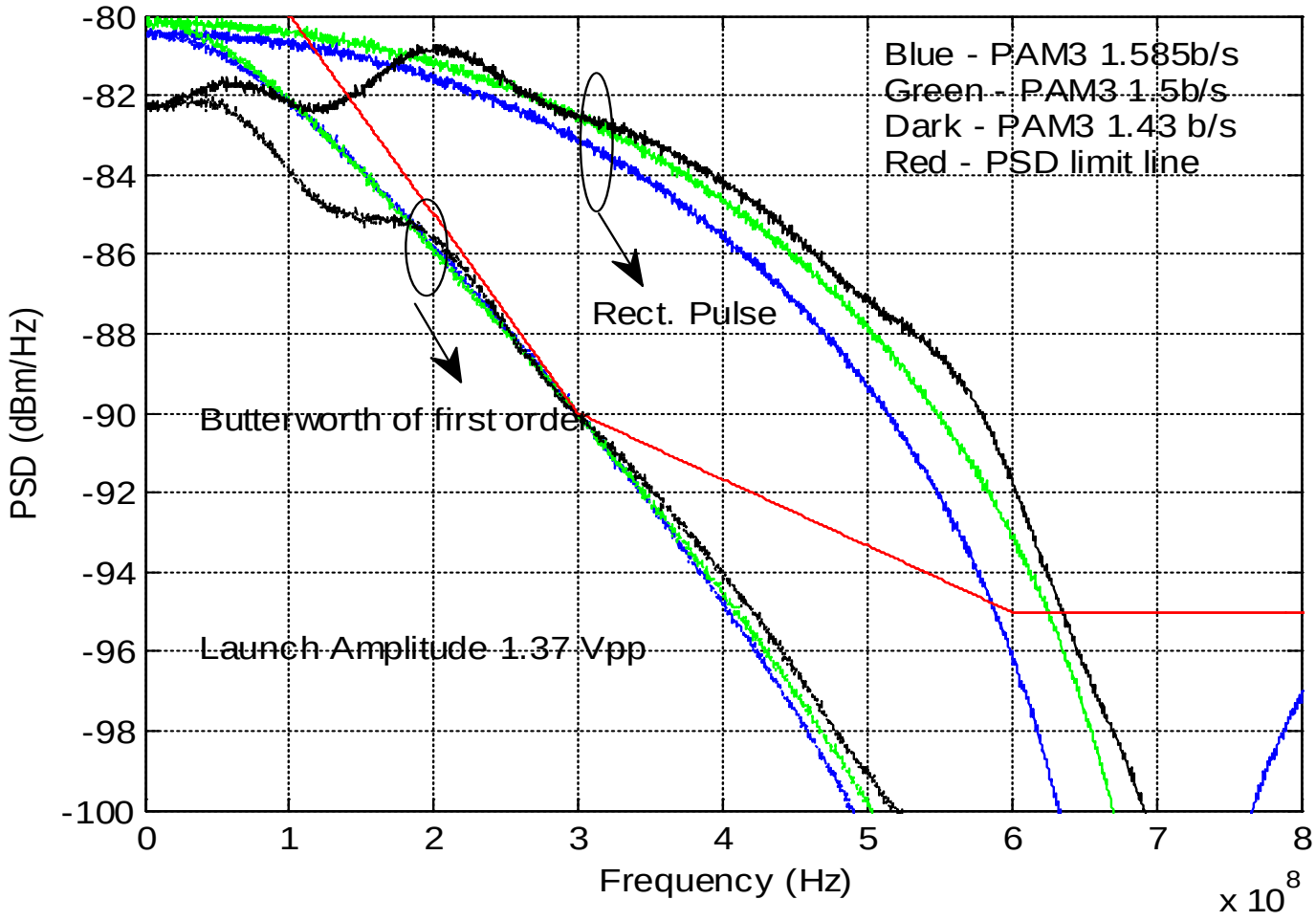
- Map 3 bits into 2 ternary symbols.
  - “00” output is not allowed so that one-to-one mapping can be defined between 8 possible inputs and 8 possible outputs.
- Bandwidth efficiency is 1.5 bits/symbol as compared to full potential of 1.585 bits/symbol.
- No error propagation protection, infinite run length of consecutive ones or negative ones, minimum implementation overhead.

A Ternary Line Code for Error Propagation Control



- Block mapping: 10 bits to 7 symbols, i.e., 1.43 bits/symbol.
- First symbol only takes value + or -, and can tolerate 6db more noise.
- Error propagation is likely limited within one block.
- Maximal run length of consecutive “+” or consecutive “–” is 4 and maximal run length of “0” is 6.
- Match well with RS code over GF(2^{10}).

Transmit PSD



Simulation Results

Table – Finite-length DFE results for 15m channel at room temperature (5.8 mV and 5.1 mV rms quantization noise assumed for full-efficiency mapping and proposed line coding, respectively).

Mapping	Raw Eye Height (mV)	SNR (dB)	SBNR @100 mVpp RFI (dB)
1.585 b/s	224	28.7	19.3
1.43 b/s	202	28.3	18.1

Discussions and Conclusions

- The ternary line coding scheme effectively prevents error propagation and has limited run length for the ease of clock recovery.

- The loss in SNR and eye height are outweighed by its capability of error propagation control and potential saving in check symbols in FEC design.
  - Positive margin remains for 15m channel at room temperature under 100 mVpp RFI.

- Propose to adopt the 10:7 ternary line code and consider RS codes over GF(2^{10}).