Timing Recovery Considerations for Differential Manchester Encoded (DME) ACT Upstream Channel

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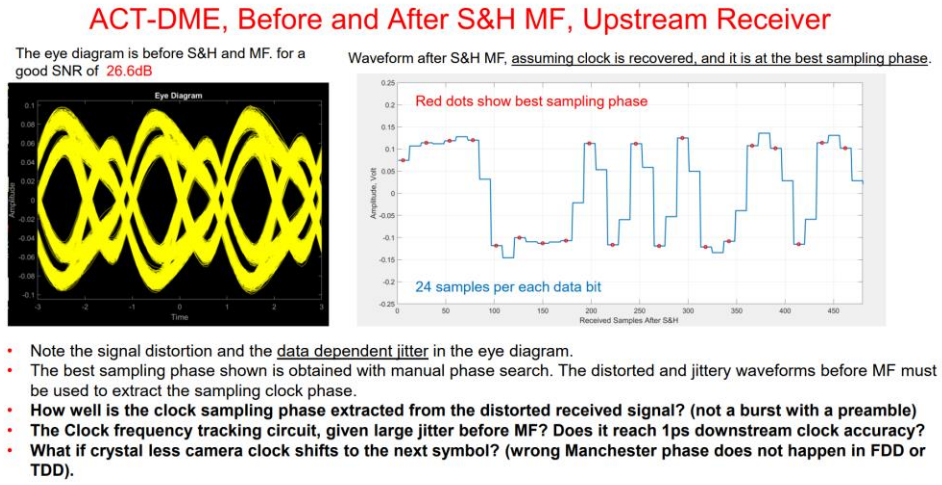
Why DME Timing Recovery Matters

- There has been some confusion on timing recovery with Differential Manchester Encoded (DME) data
- DME or Bi-Phase Encoding has been used in numerous digital communications systems including:
  - IEEE 802.3 Clauses 73, 98, 147
  - 802.5 (Token Ring)
  - AES3
  - SMPTE 12M (with the moniker ‘Biphase Mark Code’)
  - USB PD
  - ARINC 717 (with the moniker ‘Harvard Bi-Phase’)
  - ISO/IEC-7811 (with the moniker ‘Aiken Biphase’)
- This presentation will show robust low-complexity joint data reception and timing recovery for the DME upstream channel for the technology with the moniker ‘ACT’ is feasible without an equalizer

Background

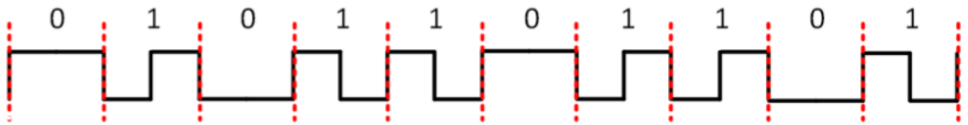
- A. Chini and M. Tazebay's DME presentation [1] raised concerns about:
  - data dependent jitter (DJ)
  - extracting phase with the DME signal without an equalizer or preamble
  - Phase ambiguity/CDR Delay (?) "*What if crystal less [sic] camera clock shifts to the next symbol?*"
- While there is DJ, it is not an issue
  - Due to the characteristics of DME no equalizer is required for any ACT channel for proper reception of symbols and timing recovery
- ACT-DME phase can be extracted and tracked with a comparator receiver without an equalizer or preamble



Differential Manchester Encoding (DME) Overview

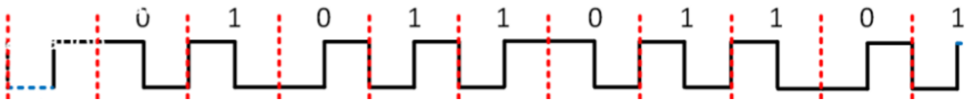
- Differential Manchester Encoding (DME) has been proposed for ACT+GMSLE low speed upstream direction.
  - Robust and used for 802.3 Clause 98, Clause 146, etc.
  - Encoding rule:
    - 0: {1 1 } {-1 -1}
    - 1: {1 -1} {-1 1} (transition mid symbol)
    - Transition at symbol boundary (**self-clocking**)

- Note that unlike NRZ, the maximum run length of symbols without a transition is ‘1’ because there is always a transition at a symbol boundary



Differential Detection

- Instead of symbol-by-symbol detection, shift detection interval by ½ symbol period and differentially detect vs. previous symbol [2]



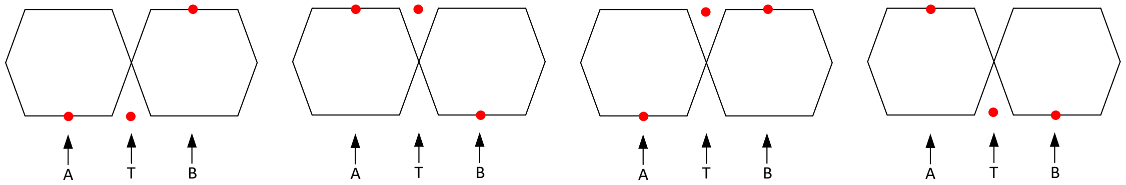
- If current symbol is in phase with previous symbol, detect ‘1’. If out of phase with previous symbol, detect zero.
- Phase ambiguity exists
  - Differential detection rule also works (with less signal margin) with normal offset (1/2 symbol period offset from differential)
- Differential detection symbol distance improves resistance to droop and resistance to noise. Refer to [2] & [3] for more information

Timing Recovery Methods

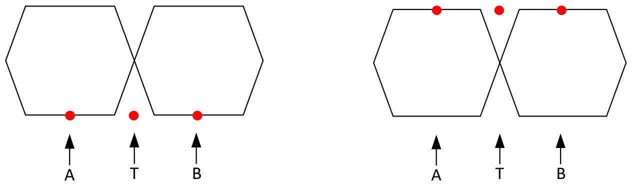
- Timing recovery methods include: [4, p.638]
  - Preamble correlation
    - Golay Sequence in Clause 98 is an example
  - Transition or Zero Crossing Methods
    - Gardner Timing Recovery
    - Quantized Zero Crossing Detection (QZCD) (so-called ‘Bang Bang’ Phase Detector)
  - Maximum Likelihood (ML) approximations
    - Early/Late Matched Filter correlation
    - harris Band Edge
  - Minimum variance methods
- The conceptual timing recovery shown in this presentation is one possible implementation of QZCD for DME

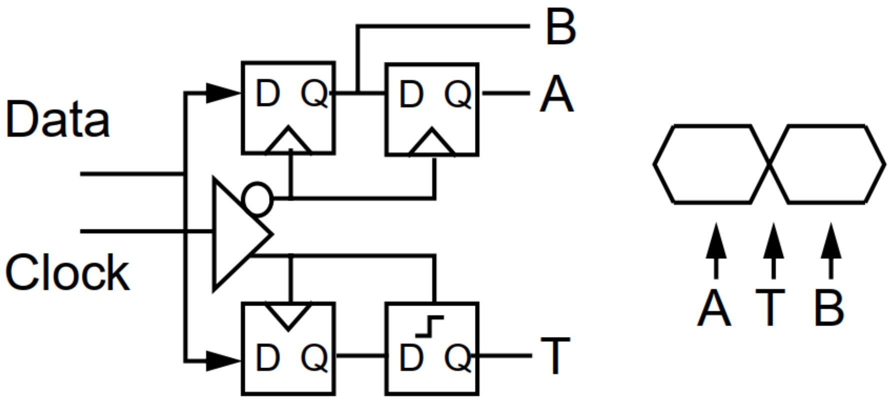
Quantized Zero Crossing (Bang Bang) with NRZ

- The Alexander [5] phase detector is shown at right from Rick Walker's presentation [6].
- The data is 2x oversampled at ½ Unit Intervals (UI). If there is a transition, depending on value of 'T', give a coarse action of 'early' or 'late' to the PI filter which controls the VCO.



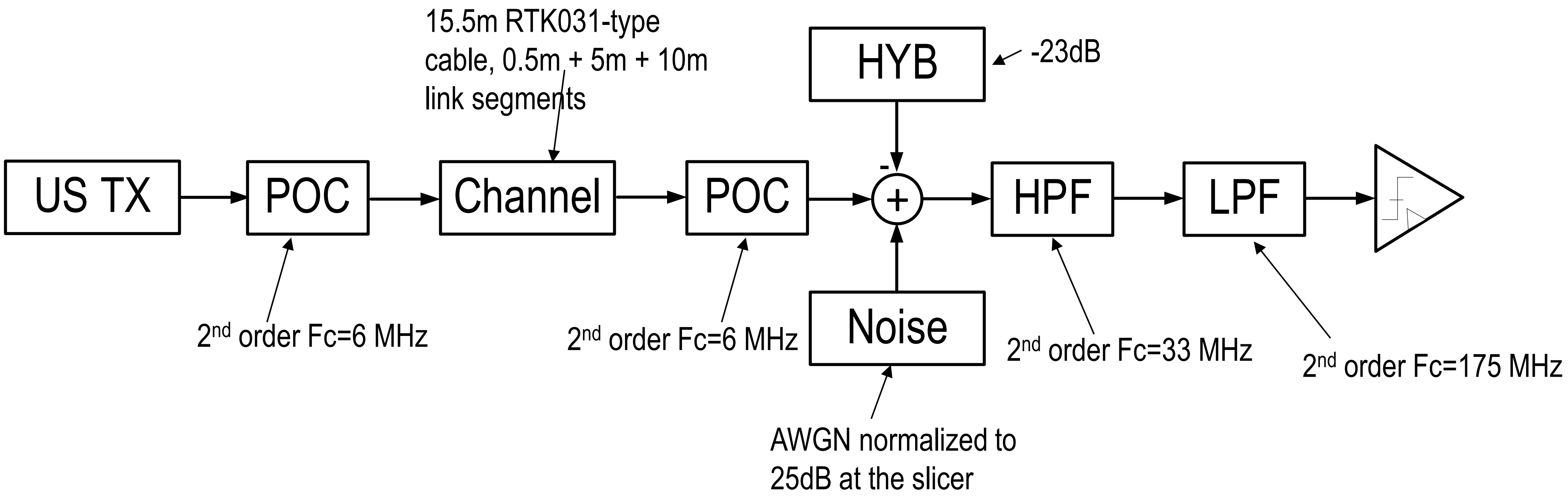
- Note that if there are long strings of ones or zeros, which will occur without a line coding with guaranteed transitions, a 'hold' signal to the VCO is required when there are long sequences of no transitions





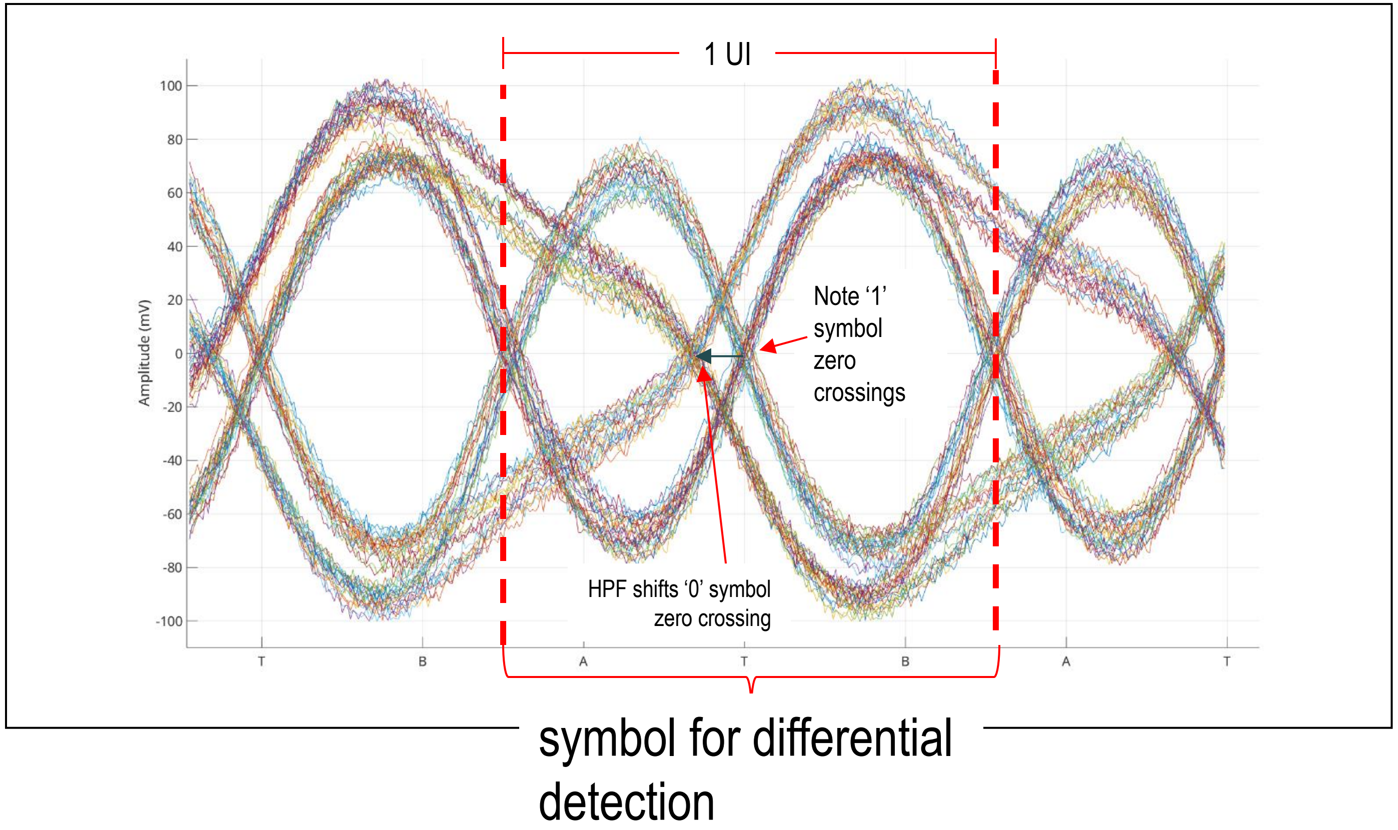
St	A	T	B	UP	DWN	Action
0	0	0	0	0	0	Hold
1	0	0	1	0	1	Early
2	0	1	0	1	1	Hold/Err
3	0	1	1	1	0	Late
4	1	0	0	1	0	Late
5	1	0	1	1	1	Hold/Err
6	1	1	0	0	1	Early
7	1	1	1	0	0	Hold

DME System Conditions



- The system conditions are shown, above
- Represent expected values for one ACT implementation
- Exact values are not critical for the operation of the CDR

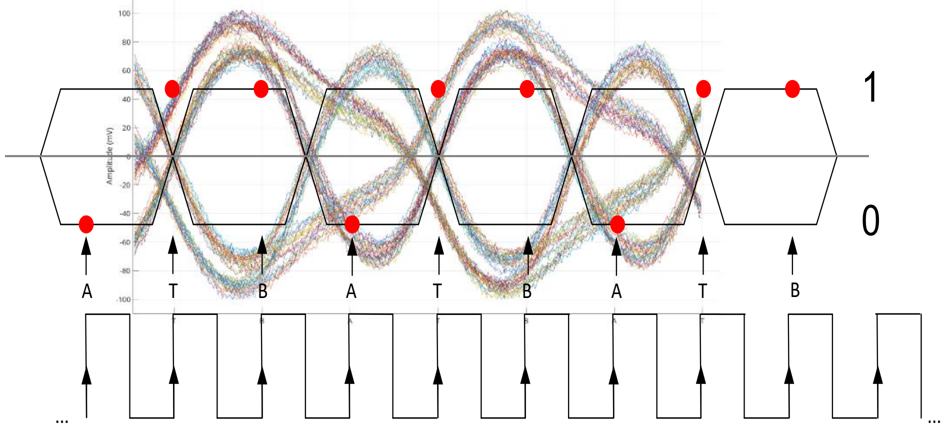
DME Received Waveform



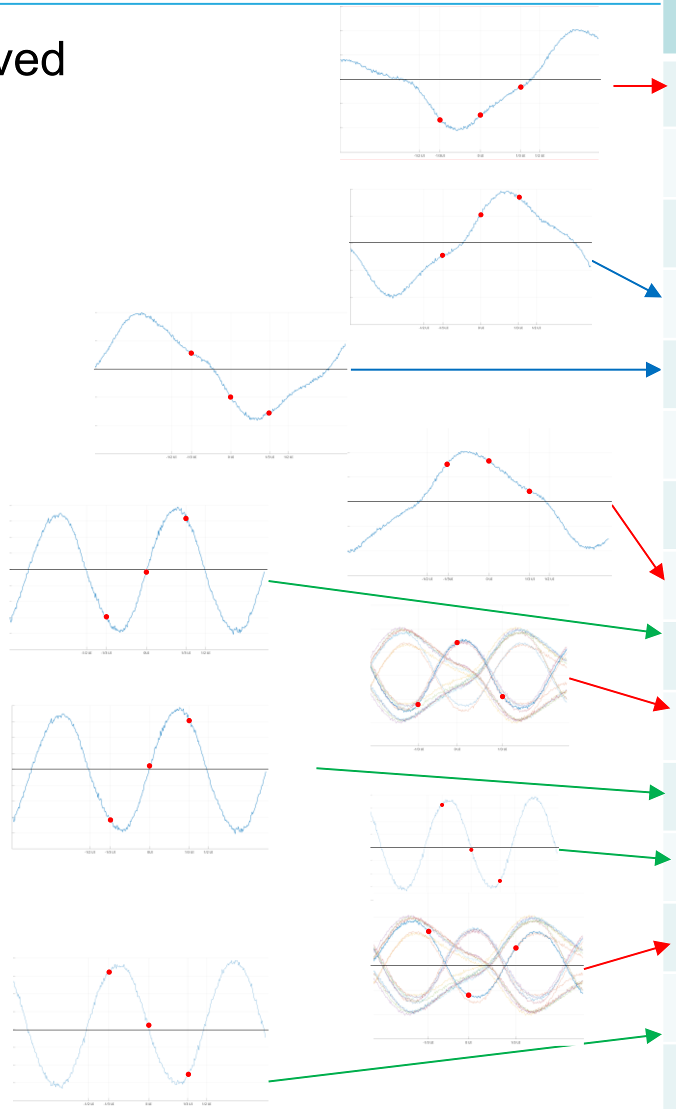
- Differentially decoded '1' shows clean zero crossing in middle of symbol
- Differentially decoded '0' shows significant zero crossing distortion (DJ)

DME Quantized Zero Crossing Dection

- From the Alexander PD, a DME QZCD PD can be derived



- Sample at 1/3 UI (3x oversample the 8.533ns symbol interval)
  - Timing decision and symbol detection from 3 samples
  - 1.5x OSR is also possible, but not shown
- Pattern match to filter which transitions are used to update control loop to remove DJ from timing decisions
  - Differential symbol == ‘1’, update
  - Differential symbol == ‘0’, hold
- Pattern match to filter the absence of transitions in a UI to detect and correct for ½ symbol period offset
- Pattern match to detect and correct ¼ symbol period offset



Sym	A	T	B	Output
0	0	0	0	Misalign
0	0	0	1	Hold
0	0	1	0	Error/Hold
0	0	1	1	Hold
0	1	0	0	Hold
0	1	0	1	Error/Hold
0	1	1	0	Hold
0	1	1	1	Misalign
1	0	0	1	Early
1	0	1	0	Misalign
1	0	1	1	Late
1	1	0	0	Late
1	1	0	1	Misalign
1	1	1	0	Early
1	1	1	1	Error/hold

Summary

- A conceptual implementation of a particular quantized zerocrossing phase detector for DME for the ACT channel was introduced
- This implementation is low complexity, requiring only 4 flip-flops and is not affected by ACT channel data dependent jitter
- The conceptual implementation extracts the phase of the received DME symbols without an equalizer or preamble
- Phase ambiguity present in decoding DME is detected and resolved
- This is only one conceptual implementation; it may be further optimized by an implementer, or a different implementation or timing recovery method may be used
- DME is a robust self-clocking modulation technique and can be used for ACT Upstream channel without an equalizer or a preamble

References

[1] “DME Receiver Performance and EMC Comparison for ACT versus TDD” A. Chini, M. Tazebay DME Receiver Performance and EMC Comparison for ACT versus TDD

[2] “Proposed Preamble: Synchronization and Harness Defect Detection” J. Cordaro, pp 19-21 https://www.ieee802.org/3/cg/public/adhoc/cordaro_3cg_06_0418.pdf

[3] “IEEE 802.3da – RX Model Proposal” P. Beruto https://www.ieee802.org/3/da/public/0722/beruto_3da_20220711_rx_model.pdf

[4] B. Sklar and f. harris, “Digital Communications”, 3rd ed. Upper Saddle River, NJ, USA: Pearson, p. 637, 2021.

[5] Alexander, “Clock recovery from random binary signals,” Electronics Letters, vol. 11, no. 22, pp. 541–542, October 1975

[6] Walker, R. C.: Designing Bang-Bang PLLs for Clock and Data Recovery in Serial Data Transmission Systems, “Phase-Locking in High-Performance Systems”, edited by: Razavi, B., IEEE Press, Wiley-Interscience, pp. 34–45, 2003