Proposed Preamble: Synchronization and Harness Defect Detection

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Outline

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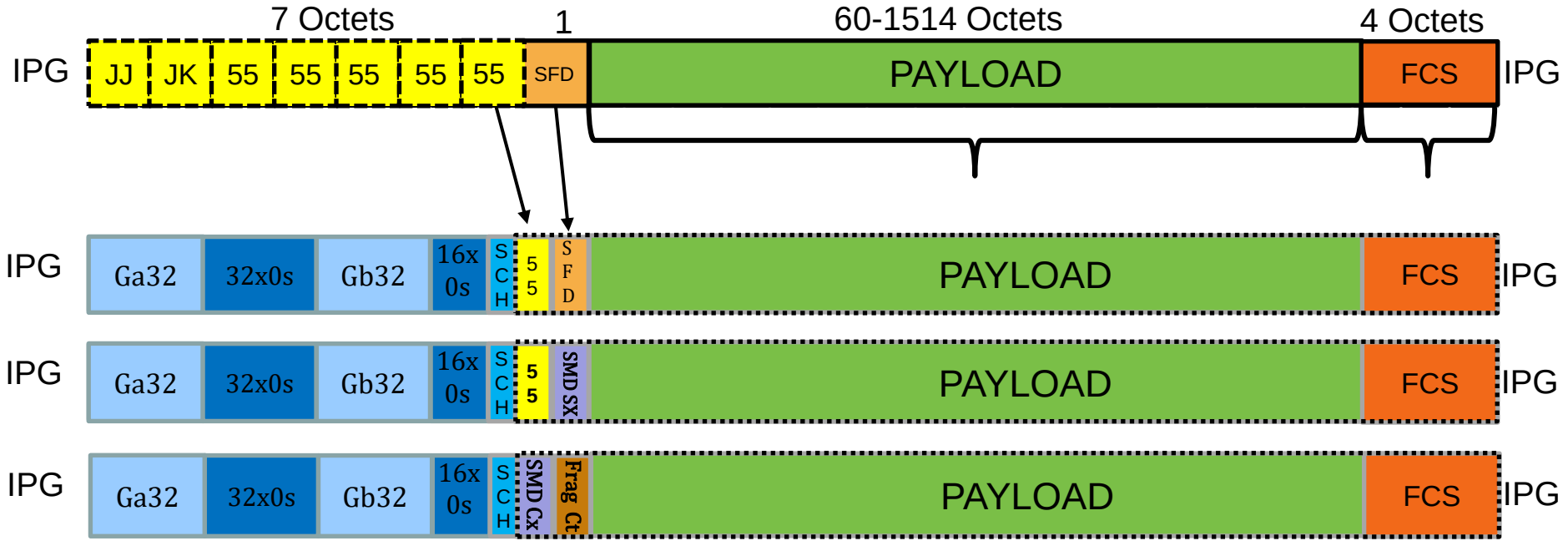
Addressing Concerns Regarding the Proposed Preamble

To address some issues and concerns with preamble proposed in [1] and [2]:

- “Not DC balanced”
  - 802.3 Clause 98 preamble is not DC balanced either (+6). Still works w/DME & PoDL.
- “Preamble not DME encoded”
  - 802.3 Clauses 98 & 73, and 802.5 are DME standards where preamble is not DME.
- “3 level signaling”
  - Clause 147.3.2 already specifies driving BI_DA± at 0V for point-to-point.
- “Requires ADC”
  - Can be detected with comparator more reliably than JJJK.
- “Cannot support preemption”
  - Revised format 7th preamble octet and SFD now 4B5B encoded and DME Modulated.

Current vs. Revised Proposed 10BT-1S Preamble w/802.3br Support



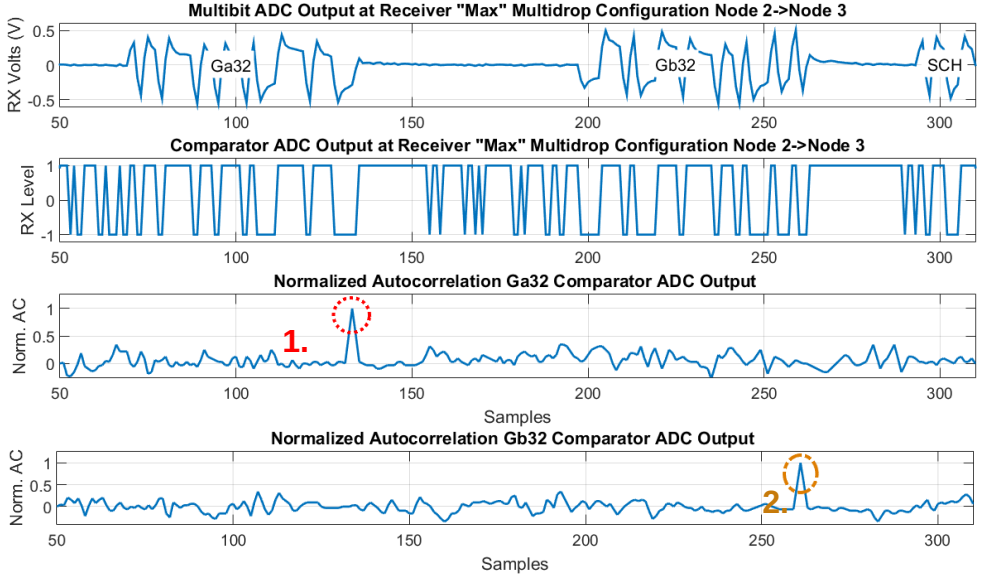
- Current: 4B5B Encoded + DME Modulated Preamble + SFD in 802.3cg D1p1 is 64*($\frac{5}{4}$)=80 symbols (T2) or 160 T3
- Proposed: Ga32, 32 zeros, Gb32, **16** zeros, 4 DME modulated bits (PHY only) for scrambler seed setting + 7th Preamble octet and SFD 4B5B encoded and DME modulated.

SCH Field

- Additive (sidestream) scrambler $1+x^4+x^{15}$ applied after SCH field.
- SCH field is 4 bits DME modulated (not 4B5B encoded) sent LSB First.
- SCH does not pass to MAC and does not need 4B5B encoding.
- Allows descrambler to be initialized with same seed value as scrambler.
- Scrambler can be turned off.

SCH	FUNCTION
4'b0000	Scrambler Disabled
4'b1000	Scrambler Enabled scr_inital_state=15'b001111100110101
4'b1001	Scrambler Enabled scr_inital_state=15'b011111100110101
4'b1010	Scrambler Enabled scr_inital_state=15'b101111100110101
4'b1011	Scrambler Enabled scr_inital_state=15'b111111100110101
4'b1100	Scrambler Enabled scr_inital_state=15'b001010011000001
4'b1101	Scrambler Enabled scr_inital_state=15'b011010011000001
4'b1110	Scrambler Enabled scr_inital_state=15'b101010011000001
4'b1111	Scrambler Enabled scr_inital_state=15'b111010011000001
All others	Reserved

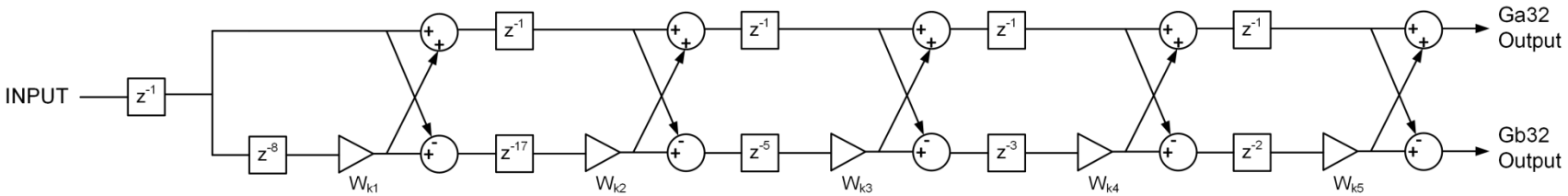
Addressing BEACON Detection Time Concern I



- Use Ga32 for frame preamble→ Shorter than 4b/5b DME modulated JJJK.
  1. Detect Ga32.
  2. Then, (optional) look for Gb32 at 64 T3s from Ga32 for further synchronization and other benefits.

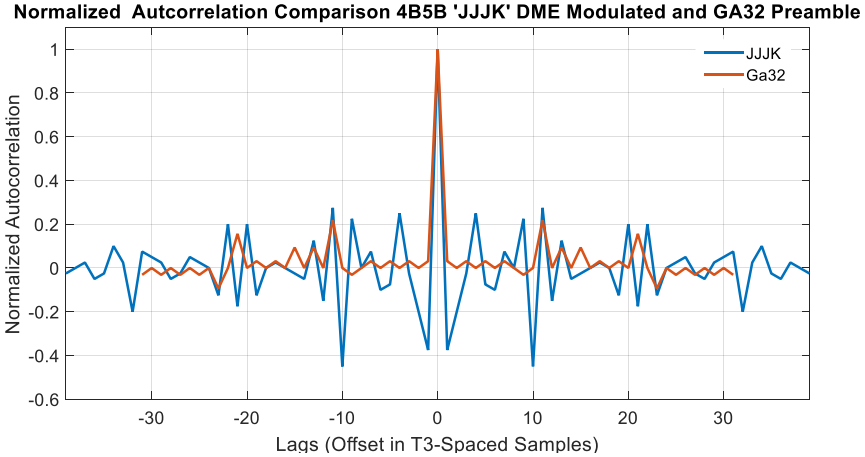
Addressing BEACON Detection Time Concern II

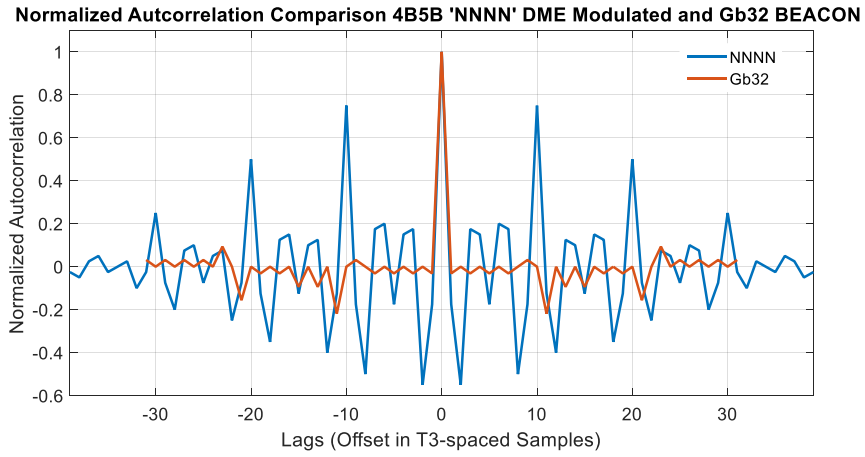
- Use Gb32 for BEACON instead of 4B5B ‘NNNN’
- Budišin structure can be used to detect both BEACON and preamble.
  - Select largest when peak above threshold.
  - Balanced D Flip-Flops added to structure after every adder.
    - Helps close timing in older processes.
    - Still allows detection of BEACON or preamble in <20 bit times/40T3.



Modified Budišin Structure for Preamble/BEACON Detection

Current Preamble & Beacon vs. Proposed Sequences

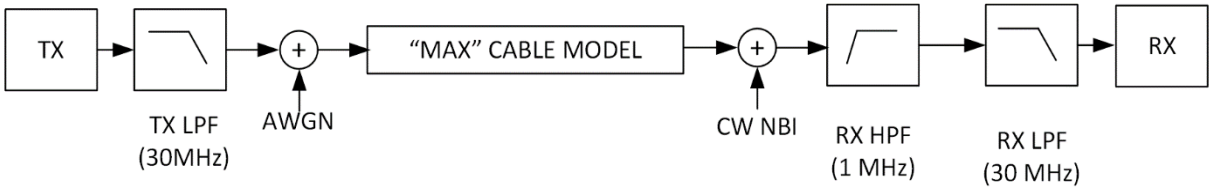




- Sequences normalized for comparison purposes of energy in main peak vs. sidelobes.
- Ga32 has more energy concentrated in main peak than current ‘JJJK’.
- Gb32 has more energy concentrated in main peak than current ‘NNNN’.

→Ga32 and Gb32 are better sequences for detection of preamble and BEACON.

Simulation Setup



- Preamble: Current vs. Proposed
- BEACON: Current vs. Proposed
- TX Voltage: 1V pk-pk=500mV$_{RMS}$
- TX filtering: 2nd order Butterworth
  - fc of 30MHz
- White noise: -30dBc added
- H(t) "Max" Cable model.
  - Built & measured w/100BASE-T1 cables
  - Node 2->Node3 presented.

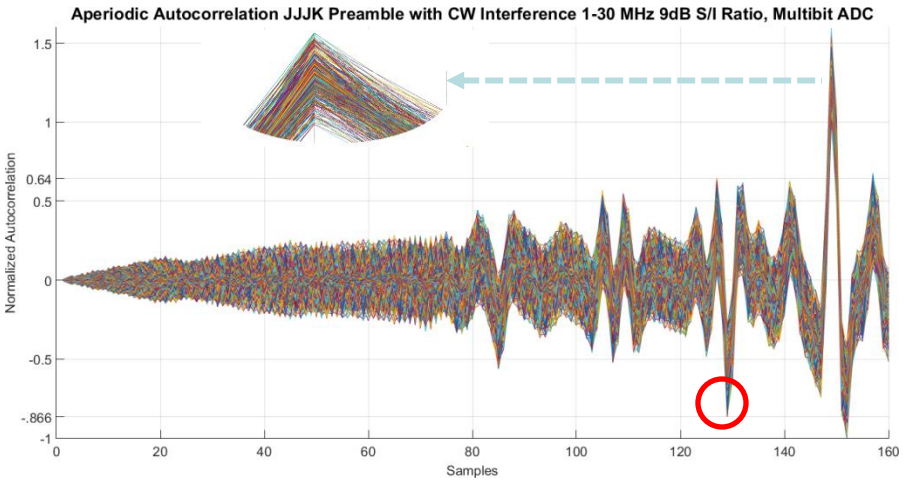
- CW interference: 178mV$_{RMS}$ from 1-30MHz from [3] in 500kHz freq. steps, $\frac{\pi}{4}$ phase steps.

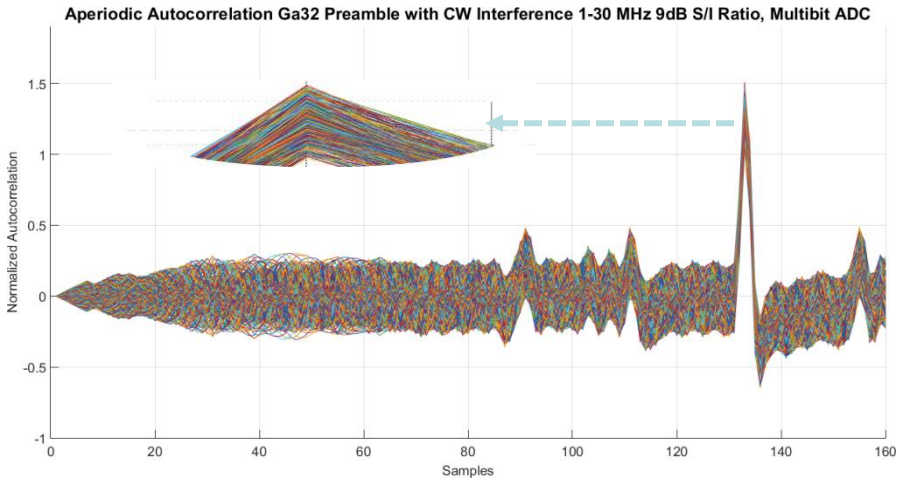
$$178mV_{RMS} = 500mV_{pk\text{-}pk} = 20\log10\left(\frac{500mV_{TX\_RMS}}{178mV_{CW\_NBI\_RMS}}\right)$$

$$= 9dB\ S/I\ Ratio$$

  - RX Filtering:
  - 1st order HPF fc of 1 MHz.
  - 2nd order Butterworth RX LPF fc 30MHz.
- RX: with appropriate preamble, compare
  - Matched filters (MF) for current preamble & BEACON.
  - MF for proposed preamble & BEACON.

Preamble Synchronization with CW Noise, Multibit ADC

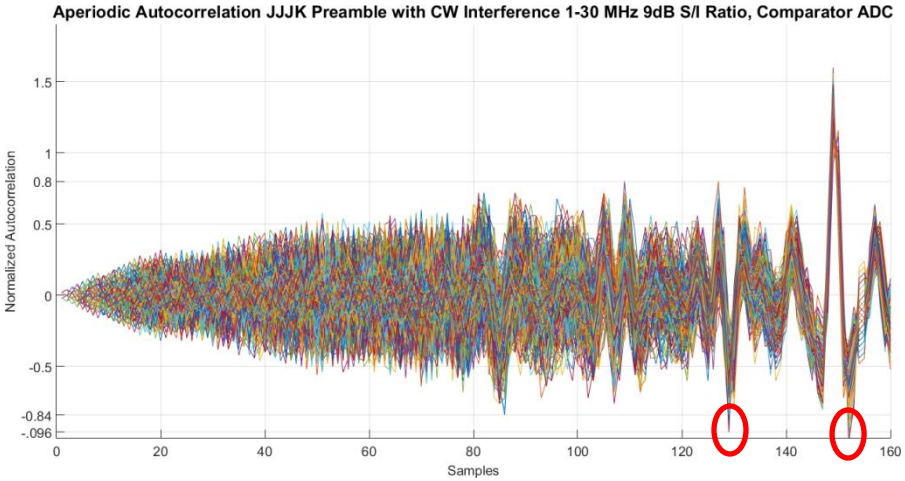


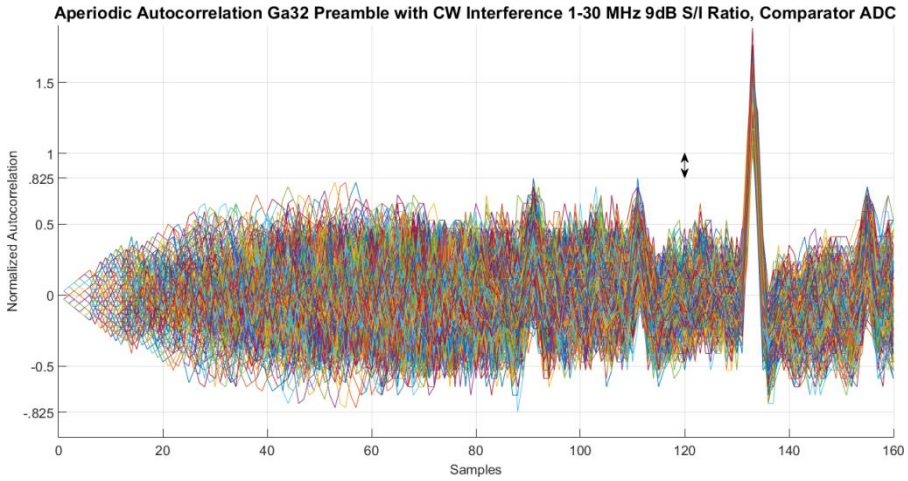


- Correlation normalized so smallest peak in main lobe is ‘1’.
- Evaluate peak sidelobe height vs. main peak.
- Both detectible, JJJK has a max absolute sidelobe peak of 0.866.
- Ga32 has more margin (max absolute sidelobe peak of 0.48)

→ Ga32 is the superior preamble for detection of preamble with multibit ADCs.

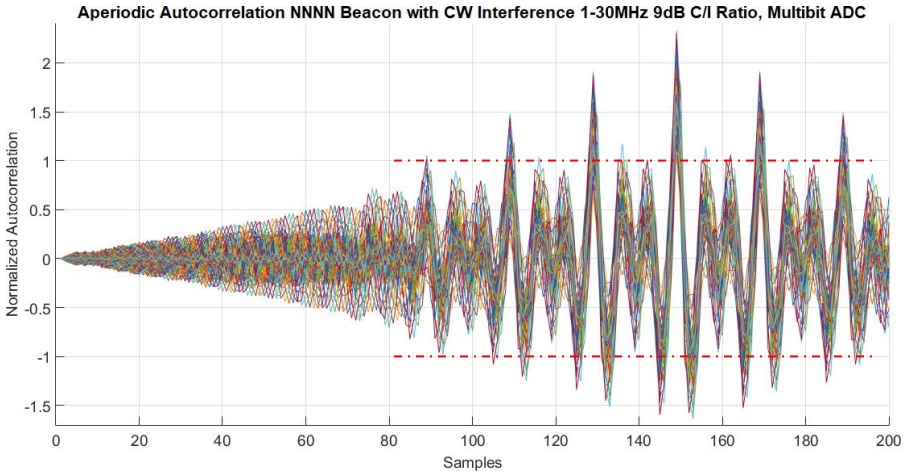
Preamble Synchronization with CW Noise, Comparator

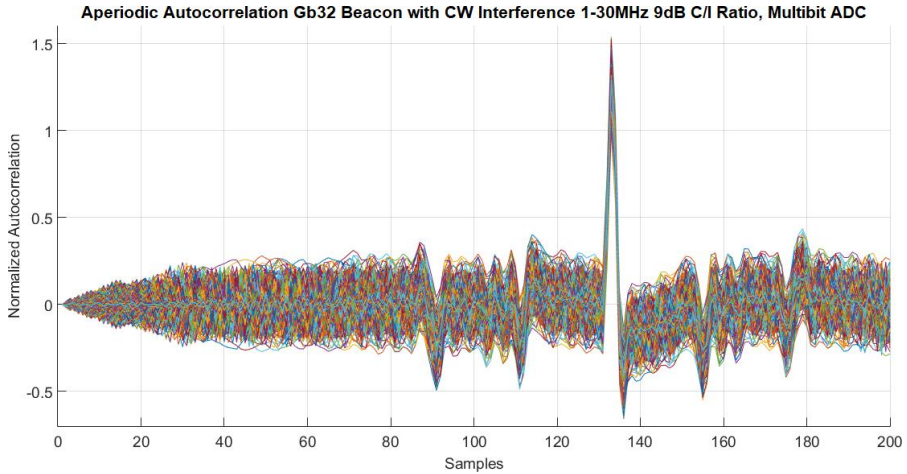




- Absolute height of JJJK peak sidelobe (0.96) is almost height of main peak minimum.
- If detector misses main peak, likely to mis-detect later.
- Ga32 has lower sidelobe peaks (0.825) and is still detectible with simple threshold detector.
  → Ga32 is the superior preamble for operation.

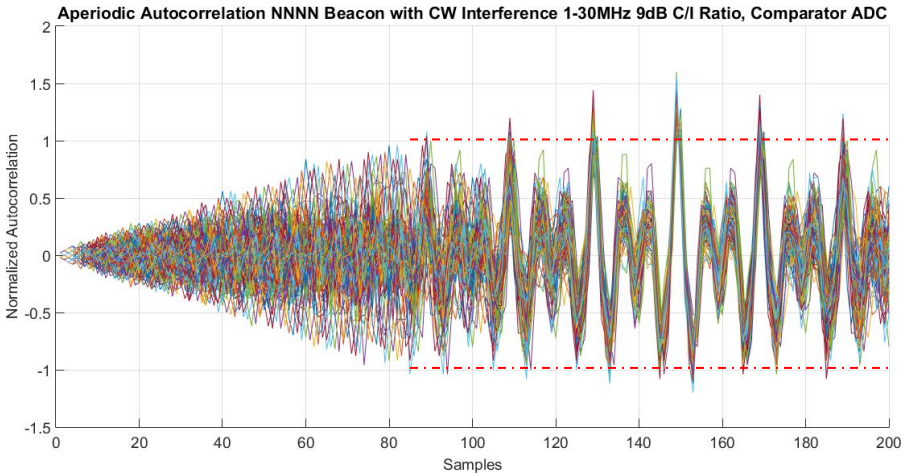
BEACON Synchronization and Detection with CW Noise, Multibit ADC

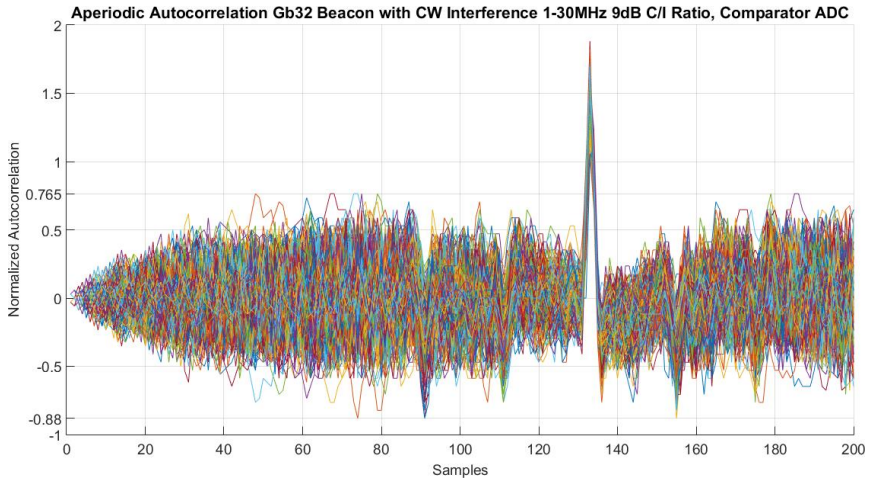




- Correlation normalized for both sequences so smallest peak in main lobe is ‘1’.
- NNNN BEACON has normalized sidelobe height well in excess of minimum of main peak.
  - Makes reliable detection very difficult
- Gb32 normalized absolute sidelobe height of .48.
  - Proposed Gb32 is superior for BEACON in presence of CW noise.

BEACON Synchronization and Detection with CW Noise, Comparator





- Normalized absolute Gb32 sidelobe height of 0.88 versus 1.4 for NNNN.
- Proposed Gb32 is superior for BEACON detection and synchronization with comparator ADC input in the presence of CW noise.

Relative Complexity Analysis

	Multi-bit Clause 98 Correlator	JJJK & NNNN Correlators w/ comparator input[1]	Optimized correlator, proposed preamble & BEACON w/ comparator[2] input
NAND Gates	100%	52%	<20%

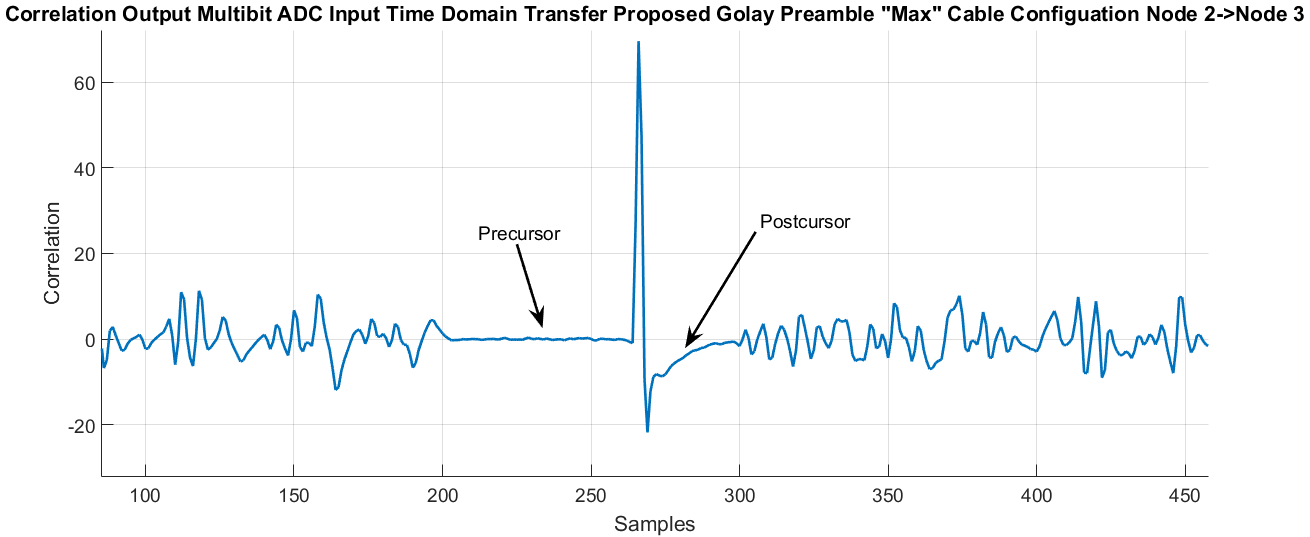
1 Direct-Form I comparator ADC input
2 Optimized proposed correlator using Budišin architecture.

- If using correlator for preamble/BEACON detection, need two correlator structures with current versus one with proposed.

Harness Defect Detection (HDD)

- Correlator driven by multibit ADC with proposed preamble allows low-complexity Harness Defect Detection (HDD)
  - Time Domain Transfer
  - Time Domain Reflectometry
- No extra hardware/logic required.
- Not necessary to perform in real time. Can store and calculate offline.
- Superior Dynamic Range vs. standard TDR.

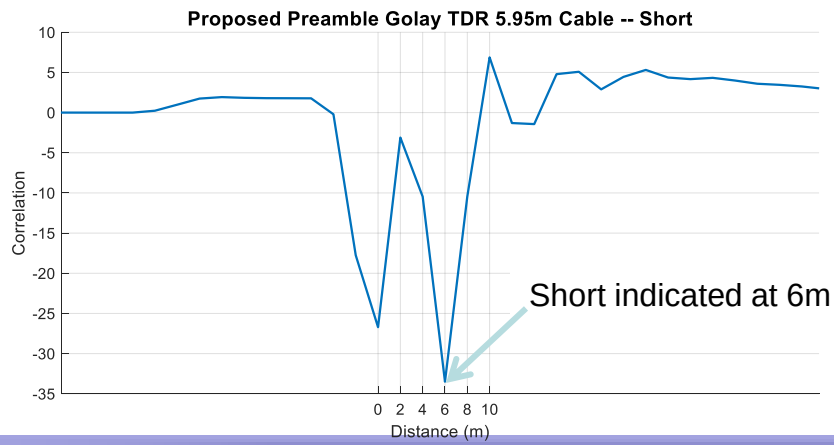
Time Domain Transfer (TDT)

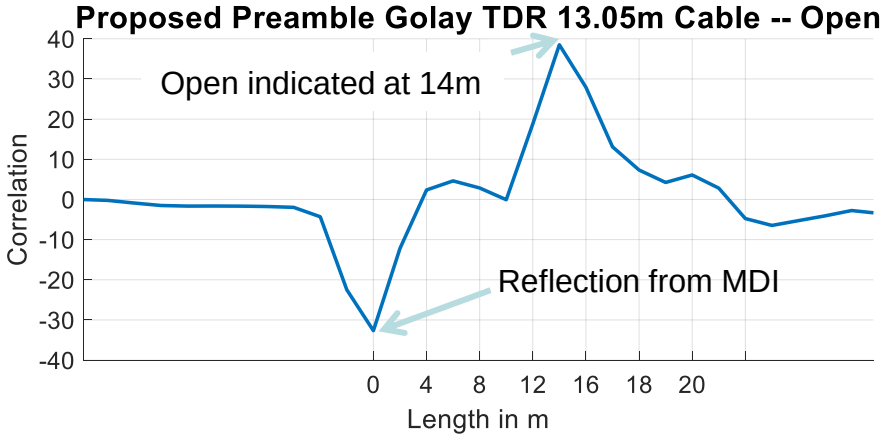


- Sum of Ga32 and Gb32 gives TDT – the impulse response from TX to RX.
- Not necessary for synchronization. Can compute offline periodically.
- TDT Indicates maximum possible quality of link – more information than SQI/MSE.
- Measuring TDT over time can measure aging of components (CMC, harness)

Golay Time Domain Reflectometry (TDR)

- Operating RX correlator while transmitting preamble gives TDR
- Useful for debugging harness defects
  - Cable Short and Location.
  - Cable Open and location.
  - One wire in cable pair open and location.





DME Encoding and Detection

- DME Alphabets defined in 802.3 Clauses 73, 98, 147 as:
  - ‘1’ {[1 -1], [-1 1]}
  - ‘0’ {[1 1], [-1 -1]}
- Alphabets are orthogonal with distance $\sqrt{2E}$ between symbols from different alphabets.
- Symbols in same alphabet are distance $2\sqrt{E}$. See [4] & [5]

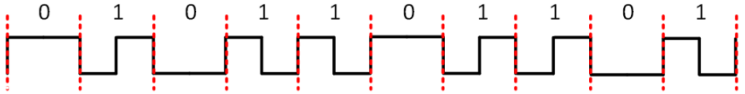


Figure showing 4B5B Encoded “C” and “A” decoded using Orthogonal Detection

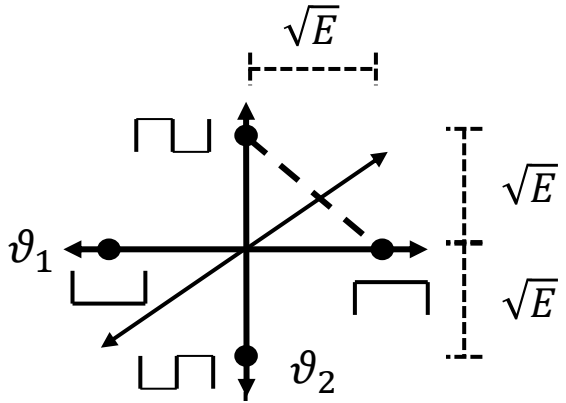


Figure showing Orthogonal Detection Symbol Distance

Note: signal constellation in vector space.
See [4] Example 6.4

Differential Detection of DME

- Shift Detection interval by one T3.
- If symbol phase is equal to previous symbol phase, decode ‘1’.
- If phase is shifted by $180°$, decode ‘0’
- Makes detection antipodal with distance $2\sqrt{E}$ between symbols.

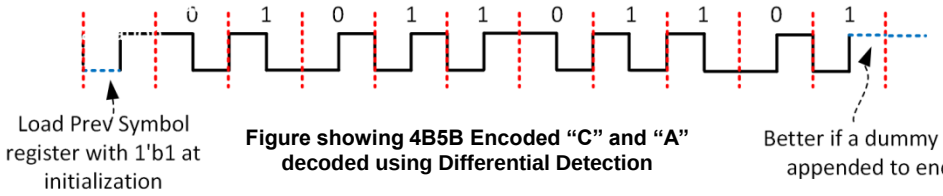


Figure showing 4B5B Encoded “C” and “A” decoded using Differential Detection

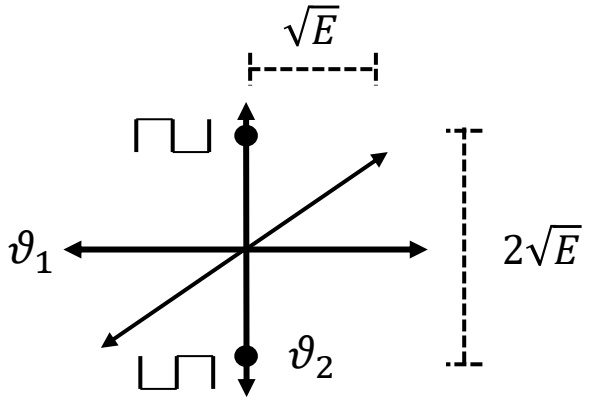
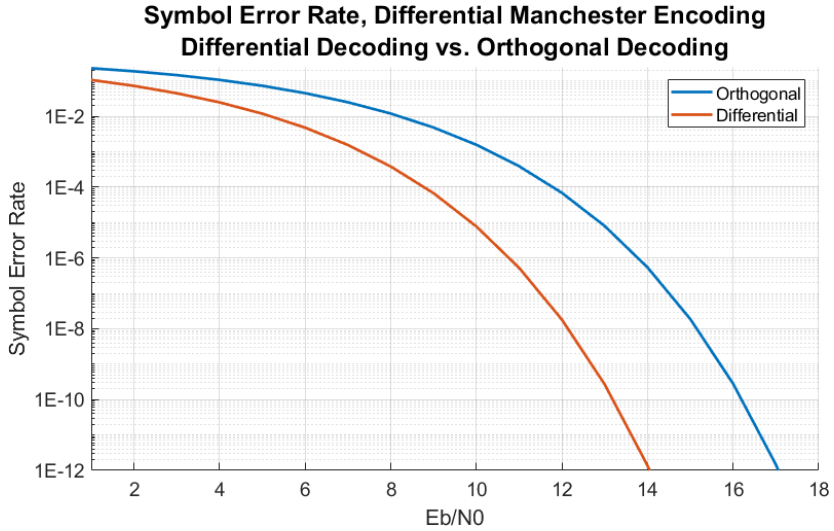


Figure showing Differential Detection Symbol Distance

- As current symbol is detected by difference in phase with previous, 1 decoded error usually becomes 2, however errors become much fewer.

Differential Detection Performance Improvement



- Differential detection improves performance by 3dB in AWGN.
- Increased signal distance improves performance in any type of noise.
- DME is reliably detectible with > 500mVpk-pk of CW Noise added.
- A separate preamble detector makes differential detection straightforward.

Summary

- Ga32 & Gb32 have superior synchronization properties vs. 4B5B-encoded JJJK & NNNN, and showed to operate with noise in excess of 500mV$_{pk-pk}$.
- Differential detection of DME increases performance by 3dB.
- Proposed preamble with multi-bit ADC provides Harness Detect Detection for TDT and TDR without additional hardware.
- Propose to:
  1. Use Ga32/Gb32 for preamble and harness defect detection.
  2. Use Gb32 by itself for BEACON.
  3. Transmit dummy zero for differential detection after ESDERR and ESDOK
     Add to 147.3.2.2 Variables and add dummy zero to Figure 147-5
  4. Use SCH field & proposed scrambler for peak emissions reduction.

References

[1] “New Preamble Proposal for 10BASE-T1S” J. Cordaro
http://www.ieee802.org/3/cg/public/adhoc/cordaro_8023cg_short_reach_new_preamble_proposal_1220.pdf

[2] “Follow-up to New Preamble Proposal for 10BASE-T1S” J. Cordaro, A. Chini, M. Tazebay
http://www.ieee802.org/3/cg/public/adhoc/cordaro_8023cg_01_0118_v2.pdf

[3] “Follow-up to 10BASE-T1S Immunity Measurements” J. Cordaro
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[4] J. R. Barry, E. A. Lee, and D. G. Messerschmitt, *Digital communication*, *3rd Edition*. New York: Springer Science Business Media, LLC, 2004 pp. 212-213,253-256

[5] D. Divsalar, M.K. Simon, “Some interesting observations for certain line codes with application to RFID”, IEEE Transactions on Communications (Volume: 54, Issue: 4, April 2006) pp 583 - 586