8B/10B Idle EMI Reduction

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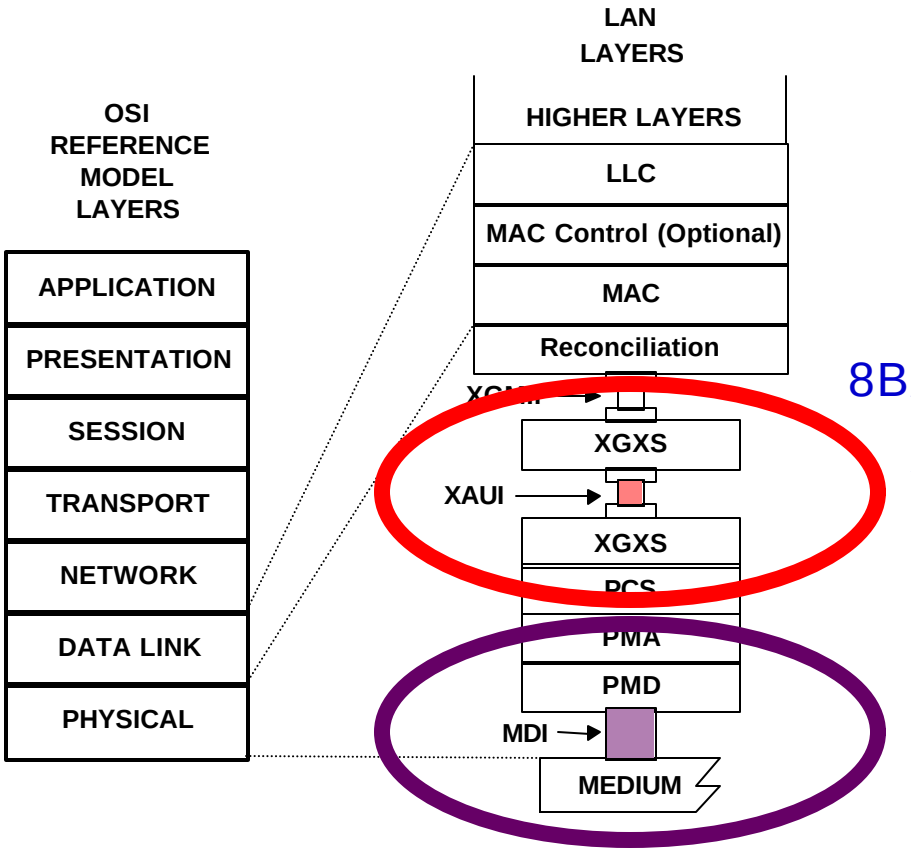
Presentation Purpose

- Address concerns of 8B/10B Idle pattern EMI
- Propose simple “Coding Only” solution
- Propose adding this solution to XAUI/XGXS and WWDM PCS

Location - Layer Model



8B/10B on XAUI

8B/10B on MDI,Medium e.g. WWDM

MDI = Medium Dependent Interface
XGMII = 10 Gigabit Media Independent Interface
XAUI = 10 Gigabit Attachment Unit Interface
PCS = Physical Coding Sublayer

XGXS = XGMII Extender Sublayer
PMA = Physical Medium Attachment
PHY = Physical Layer Device
PMD = Physical Medium Dependent

General EMI Concerns

- EMI has been a serious engineering issue for 1GbE.
- EMI will be a significantly larger problem for 10 GbE.
- Clocks and repetitive signals that are high in frequency and close to the bulkhead are primary EMI sources.
- EMI design objectives include reducing source strength and preventing signals from radiating outside of the enclosure.
- General engineering practice requires cooperative electrical and mechanical design efforts to achieve an optimum EMI design.
- Emission limits are set by agencies such as FCC and VDE
  - EMI testing of “idling” equipment is required.
- “EMI is best dealt with at the design, not on the production line :)”

  - Joel Goergen, Lucent, 3/31/2000, note to HSSG reflector

EMI Issues of 8B/10B Coding

- Clocks and repetitive signals that are high frequency and close to the bulkhead are a primary EMI sources.
  - XAUI is self-timed (i.e. is not accompanied by a clock)
  - XAUI Idle pattern is the only repetitive signal .: primary EMI source
- 8B/10B used on XAUI and PMD (e.g. WWDM Parallel Optics)
  - Each interface is a separate source of EMI
- Once a code is standardized its EMI characteristic and implementation burden is fixed.
- 10 GbE must, by good code design, ease the EMI burden.

Current 8B/10B Idle Encoding

- Idle (no data to send) is conveyed by the repeating sequence:

  AKRKRKRKRKRKRKRKAKRKR.... on each of 4 lanes

- /A/ used to deskew and align lanes at receiver
- /K/ contains a comma. The alternating sequence KR contains both running disparity versions of comma (comma+, comma-).
  - Translates to /+K/-R/-K/+R/…
- /R/ selected for its spectral properties when combined with /K/ and sometimes /A/ during Idle. Disparity neutral enabling insertion/removal without affecting lane running disparity.
- /A/, /K/ and /R/ are all a hamming distance of 3 from each other
- EMI looks to be almost as bad as for 1 GbE Idle

Solution: Randomize Idle Pattern

- 8B/10B Idle pattern is already long
  - 32 code-group repeating pattern

+A-K+R+K-R-K+R+K-R-K+R+K-R-K+R+K-A+K-R-K+R+K-R-K+R+K-R-K+R+K-R-K…

(colors indicate same 8B/10B code-groups)

(+/- indicates disparity polarity)

- Periodicity of Idle pattern is still “spikey”
- Two-tier solution preserves Idle protocol functionality

1. Randomize /A/ spacing to 16 min and 32 max
2. Randomize /K/R/ sequence between /A/s by random selection of /K/ and /R/

Random AKR Idle Pattern

- 160 bit minimum Align (/A/) column spacing maintained
- Minimum IPG /A/K/R/ pattern is retained
- PRBS 2^7-1 engine used for test (e.g. loopback, built-in BERT) doubles as random number generator for /A/ spacing and /K/R/ generation
- Example Idle pattern. Worst case /A/ spread (32 columns)

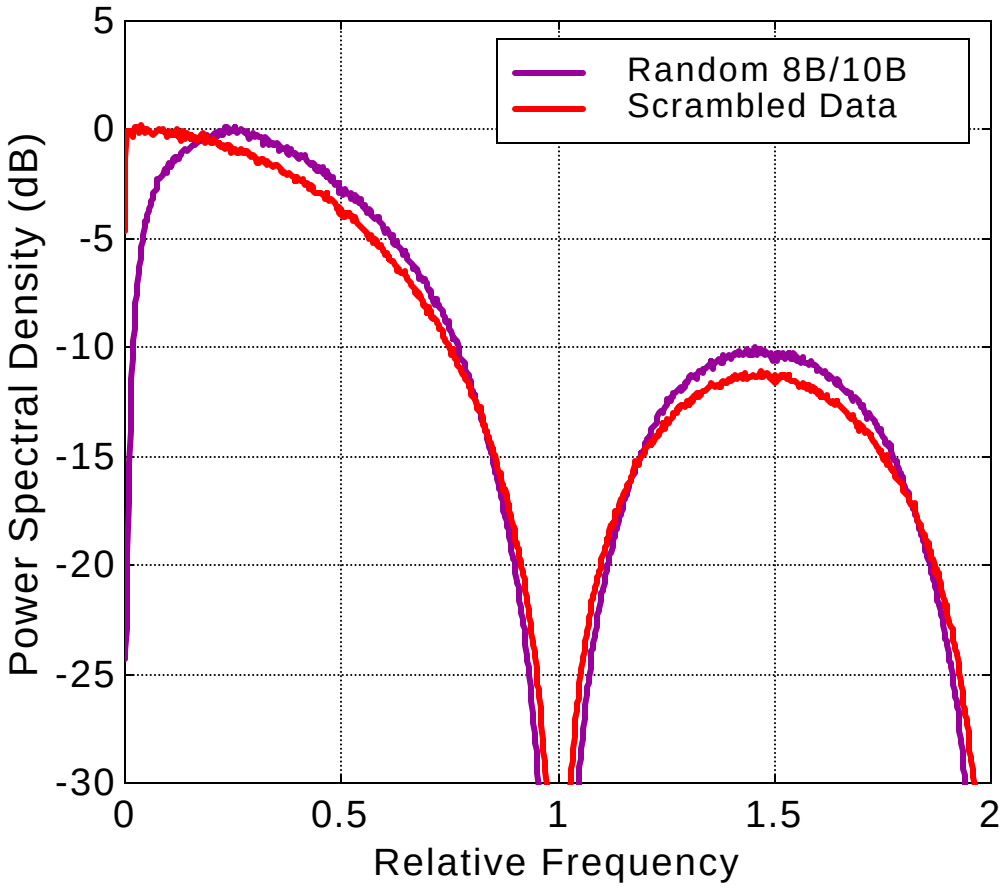
+T-A+K-R-K+R+R+K-R-K+R+K-R-R-K+R+R

+K-R-K+R+K-R-R-K+R+K-R-R-K+R+K-R-A

Simulated Spectra

Scrambled Data & Random 8B/10B

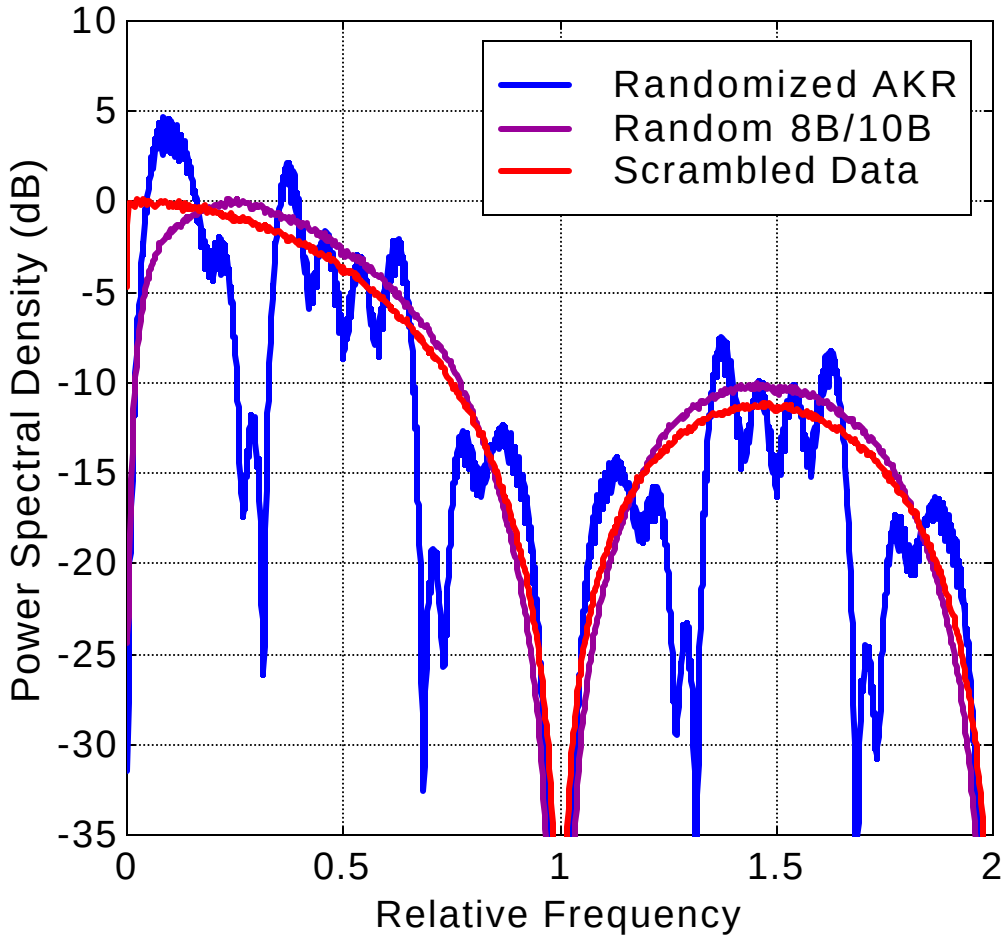
- Reference patterns
- No discrete spectrum
- Null in 8B/10B continuous spectrum at DC
- Slightly more energy in 8B/10B at higher *f* (relative to line rate)



Randomized AKR Idle Spectra

Random AKR Idle

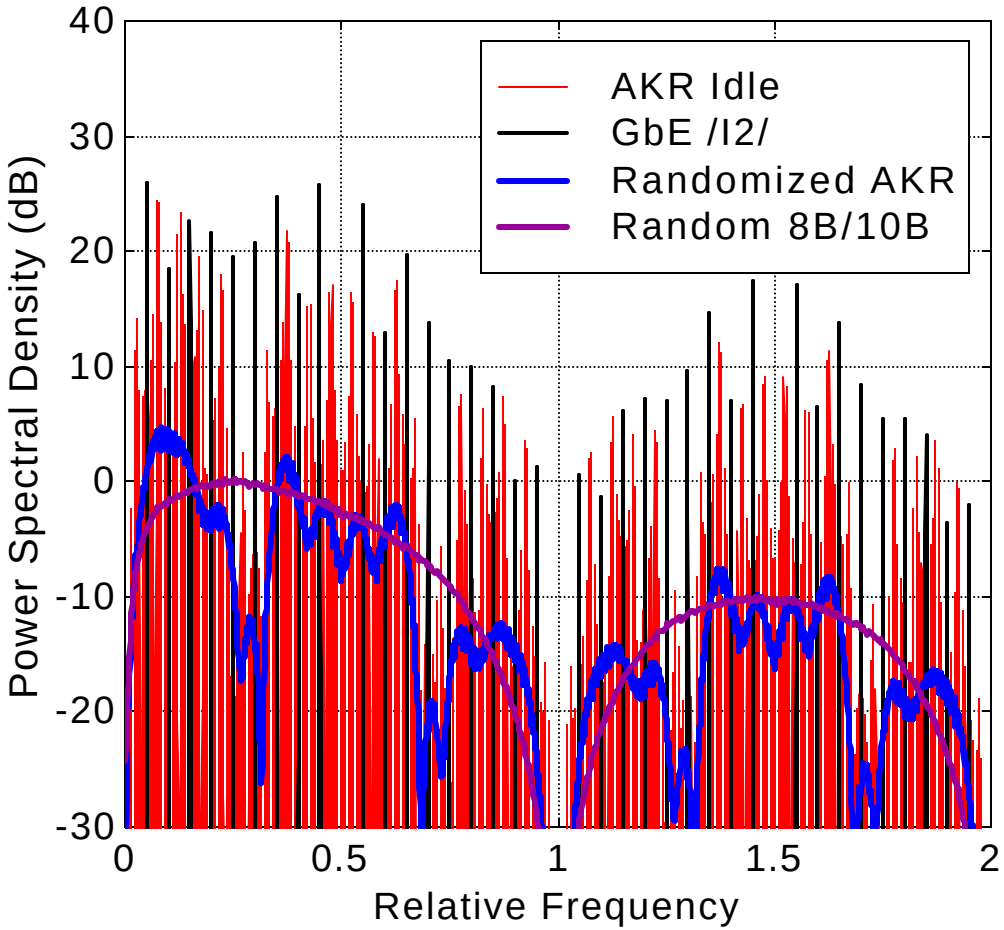
- No discrete spectrum
- Random 8B/10B & scrambled data spectra shown for reference



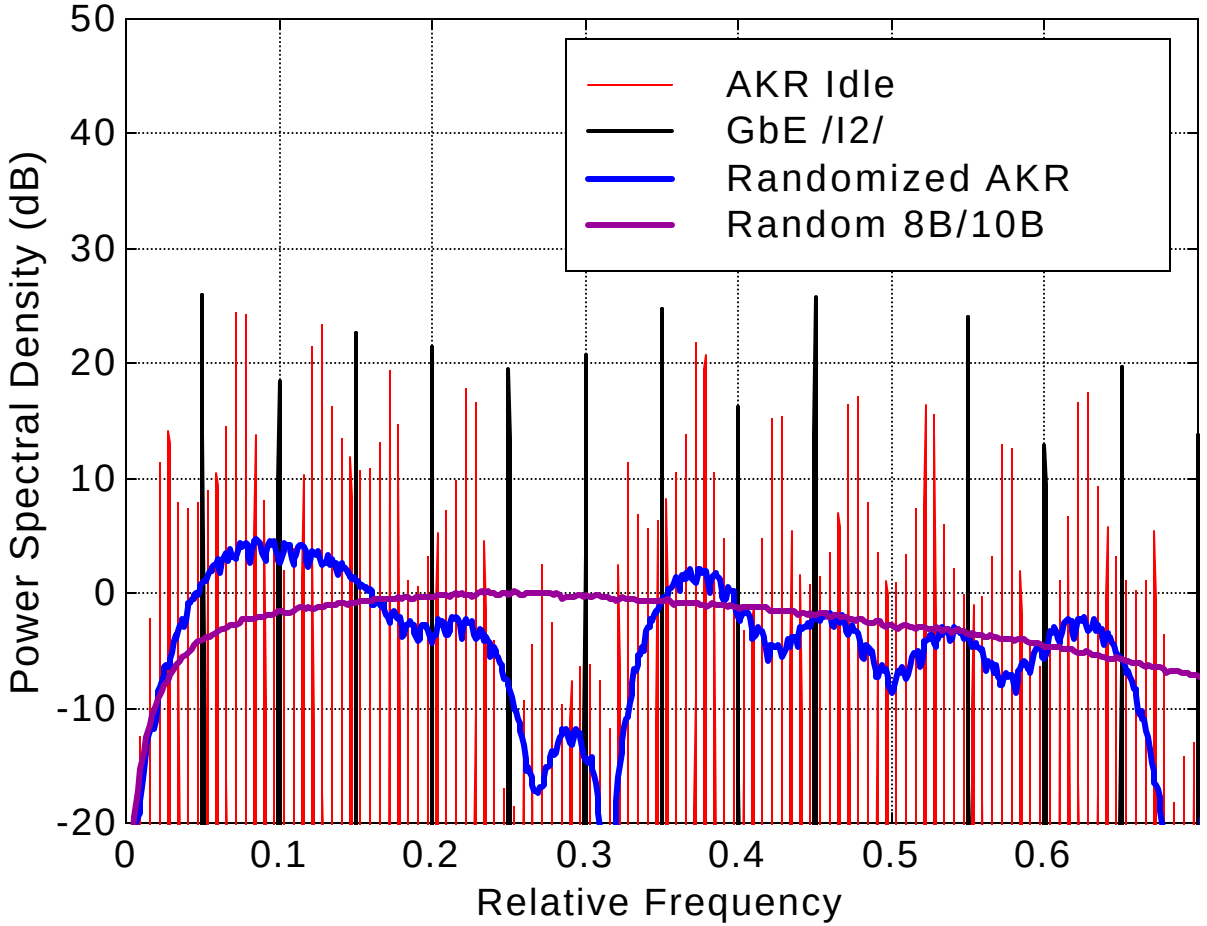
Idle Spectra Comparison

Old vs. New AKR

- Current AKR Idle slightly better than 1 GbE Idle pattern (/I2/)
- Randomized AKR Idle pattern significantly better
  - No discrete spectrum
- Random 8B/10B spectrum shown for reference



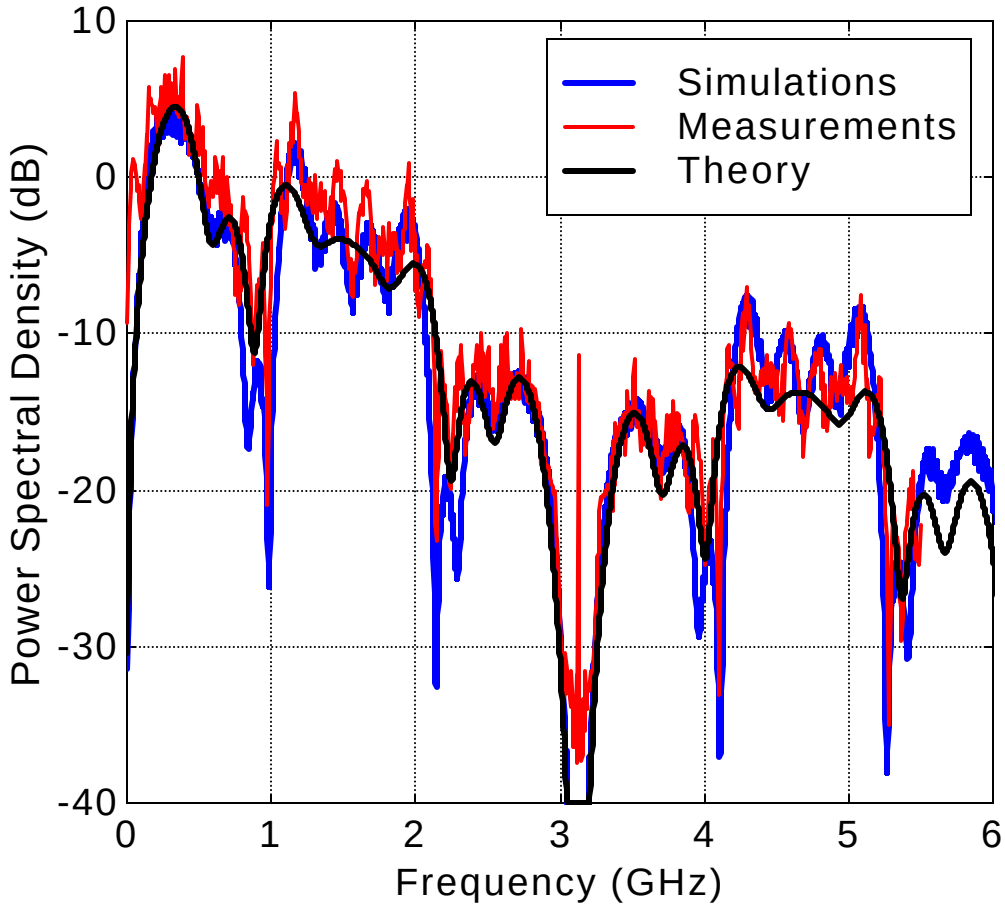
Idle Spectra (expanded)



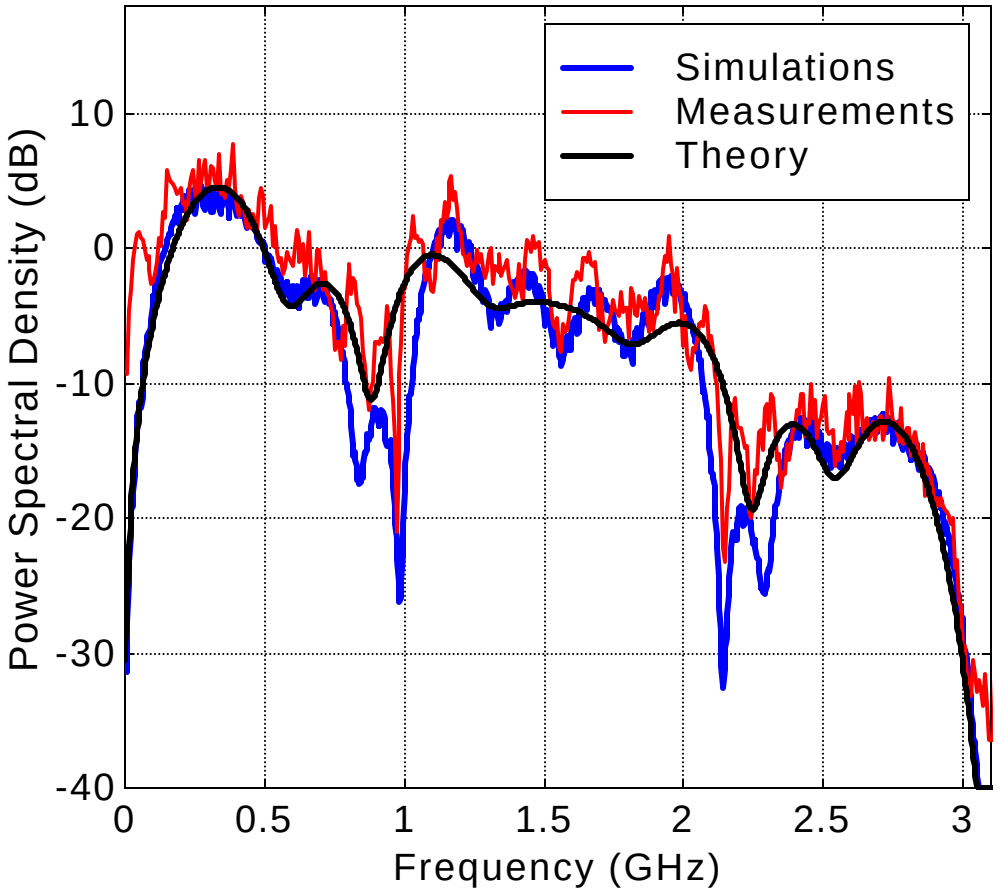
Measurements vs. Simulation

Random AKR Idle

- Simulated/Measured spectra in agreement with Theoretical Calculations
- Data normalized to be consistent with prior slides
  - 0 db at DC for pure random NRZ data.



Sim/Meas/Theory (expanded)



Summary

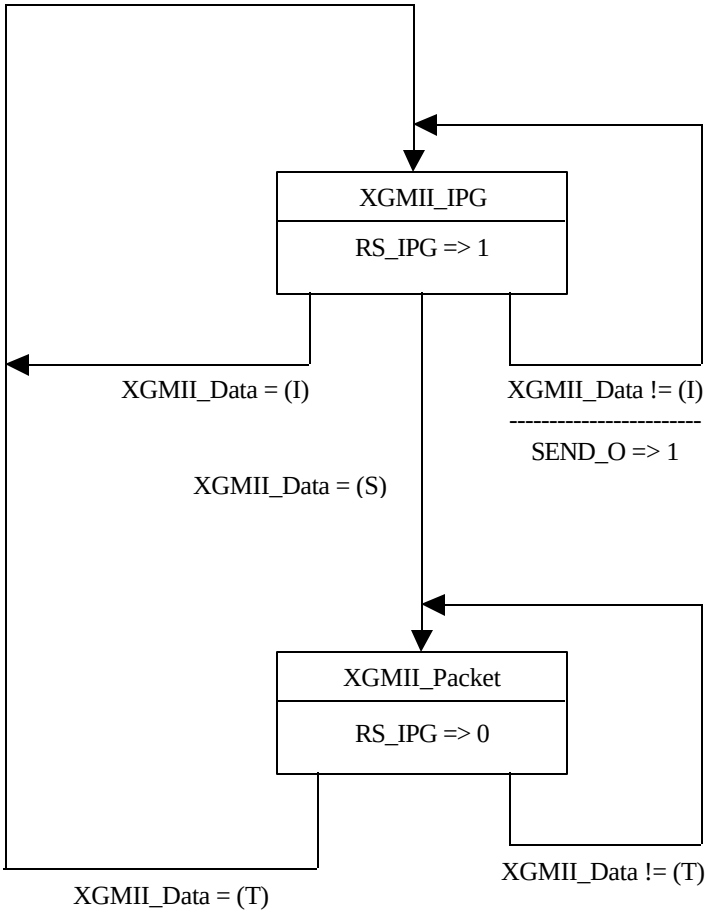
- Concerns of 8B/10B Idle pattern EMI addressed
- “Coding Only” simple solution
  - Minimal added complexity isolated to XGXS Tx state machine
- Retain all benefits of 8B/10B coding
- Retain all benefits of XAUI/XGXS protocol
  - No additional burden on receiver
- Benefits applicable to PCB traces & MultiChannel PMDs
  - WWDM & Parallel Optics
- Propose enhancing Idle EMI characteristics of XAUI/XGXS and WWDM PCS with Random AKR Idle pattern

Supplementary Slides

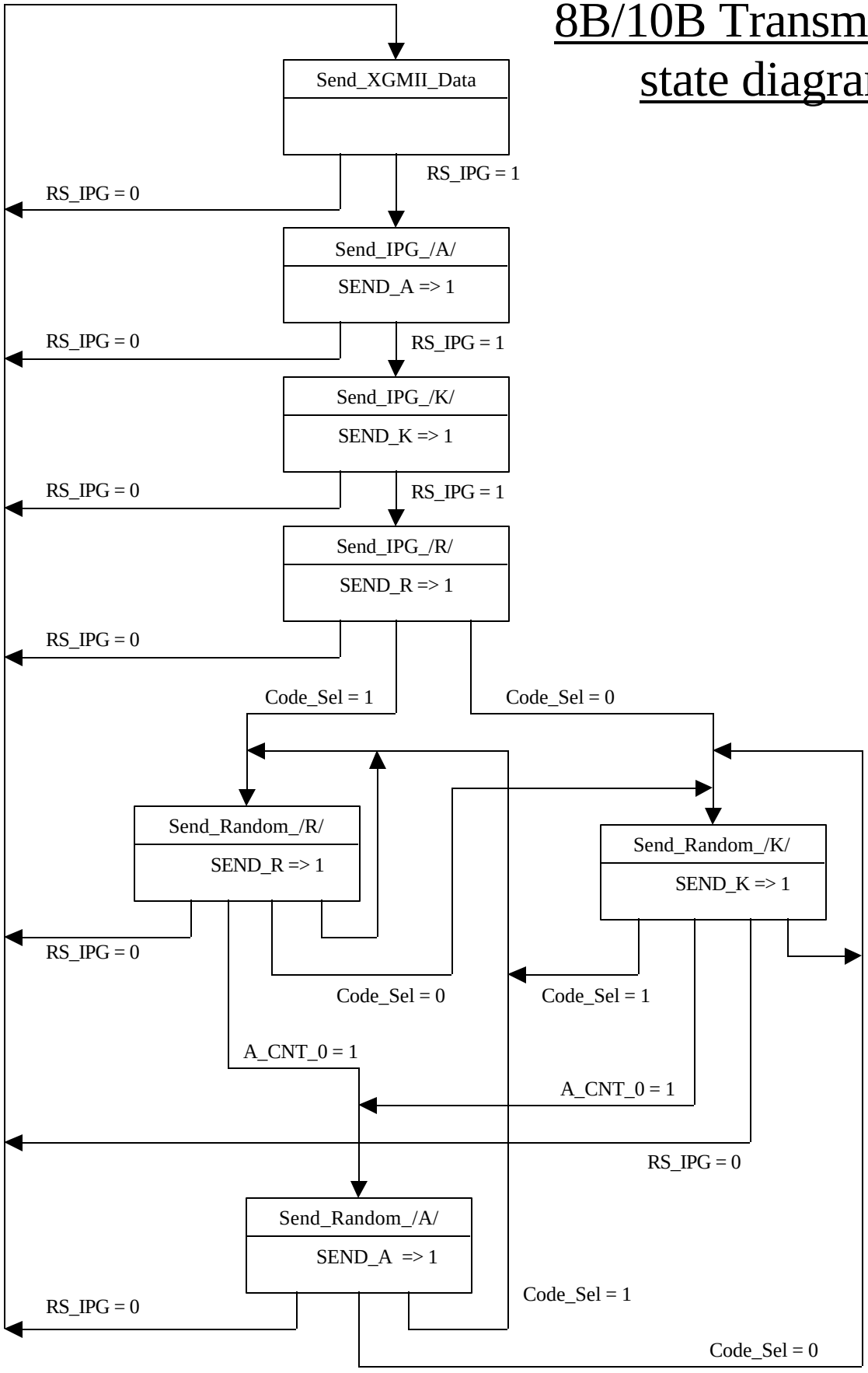
Intended for those that REALLY want to know how this stuff works

- Transmit state diagram
  - Transmit IPG, SOP, EOP or Other
- Transmit Idle state diagram
  - Generate IPG/Random AKR Idle
- Transmit Idle logic diagram
  - AKR Randomizer
- Transmit Data multiplexer diagram
  - XGXS multiplexes XGMII input and Random AKR Idle

8B/10B Transmit state diagram



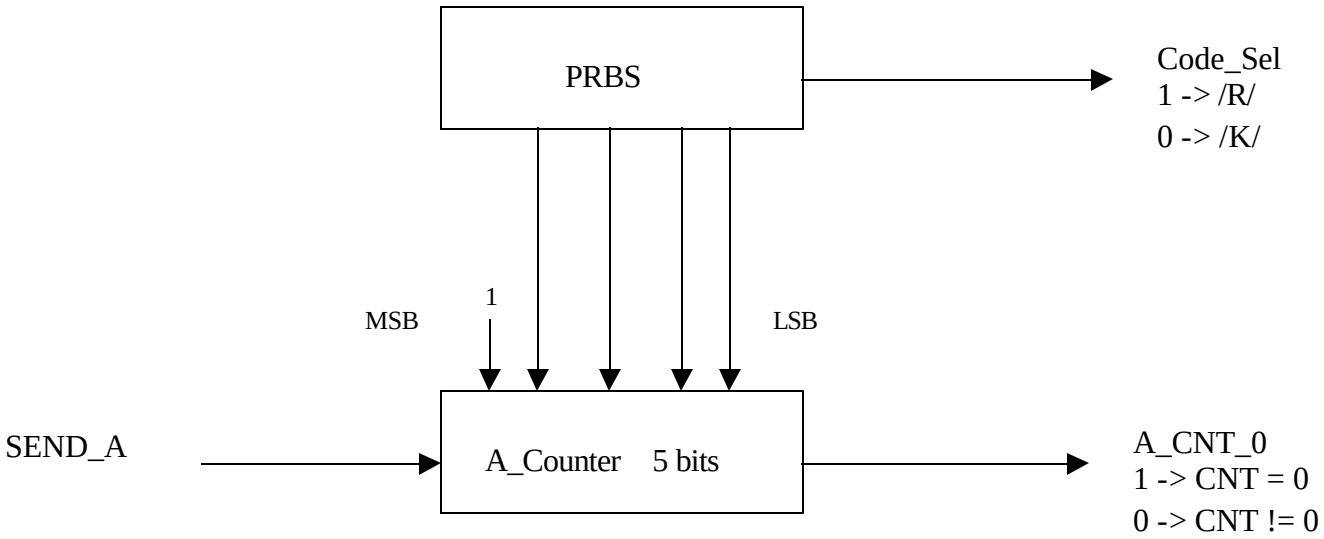
8B/10B Transmit Idle state diagram



8B/10B Transmit Idle logic diagram

The polynomial for the Pseudo-Random Bit Sequencer (PRBS) which has been simulated and tested in the lab is X^7 + X^3 + 1.

Note: it runs serially (one data bit shift per clock) at the byte clock rate.



The A_Counter counts down to zero and is parallel loaded with a random 4-bit pattern from four of the PRBS stages. The MSB is always loaded with a 1 to give the random count between /A/ codes of 16 to 31. It is loaded by the SM when an /A/ code is sent and signals a zero count back to the SM.

8B/10B Transmit Data multiplexer diagram

The data multiplexer selects either the XGMII 32-bit data & 4-bit control or one of the special codes. If none of the SEND_x signals are active, then the XGMII data & control is selected. The SEND_O signal has priority over the other SEND_x signals and will select the XGMII data & control.