A New Line Code MB810 for 10GbE

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Abstract

We propose a new line code for 10GbE which has the spectrum bounded wit hin the Nyquist band and no DC component. This presentation introduces th e design concept of the new line code, MB810, and compares its characterist ics with the existing 8B/10B code. In addition, experimental results applied t o 10Gbps -fiber transmission system are given, wherein improvements in SN R, fiber-transmission distance, and eye-openings are demonstrated.

CONTENTS

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Line Code Issues for 10GbE

- Bit sequence independence
- Small low frequency content
- Transmission of adequate timing information
- High coding efficiency [2.5G redundancy with 8B10B]
- Low error multiplication
- Low system jitter
- Compatibility with GbE
- In addition
  - Spectral efficiency
  - Error detection and monitoring
  - Special symbols for link initialization and synchronization

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New Line Code MB810 for 10GbE

- Is a Binary code.
- Converts 8bits into 10 bits as 8B/10B does.
- DC-free and of the Minimum (Nyquist) bandwidth.
- Doubles the spectrum efficiency over that of 8B10B.
- Max. run-length 7, ASV 5, DSV 6.
- Decodable state-independently.
- Advantages of saving the spectrum bandwidth results in;
  - **Longer transmission distance in band-limited channels**
  - **SNR improvement with a narrower noise-bandwidth**
  - **Mitigating frequency limits of electronic components**
  - **Lower implement cost**

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New Line Code MB810 for 10GbE(Con't)

Theoretical Description [1][2][3]

System Parameter ASV, DSV

$$ASV \equiv \max_{I,J,\{Yn\}} \left| \sum_{n=I}^{J} (-1)^n Y_n \right|,$$ Finite --> Minimum Bandwidth

$$DSV \equiv \max_{I,J,\{Yn\}} \left| \sum_{n=I}^{J} Y_n \right|,$$ Finite --> DC-Free

where i and j are arbitrary integers
such that $i < j$, and Y_n is the output symbol sequence of the encoder.

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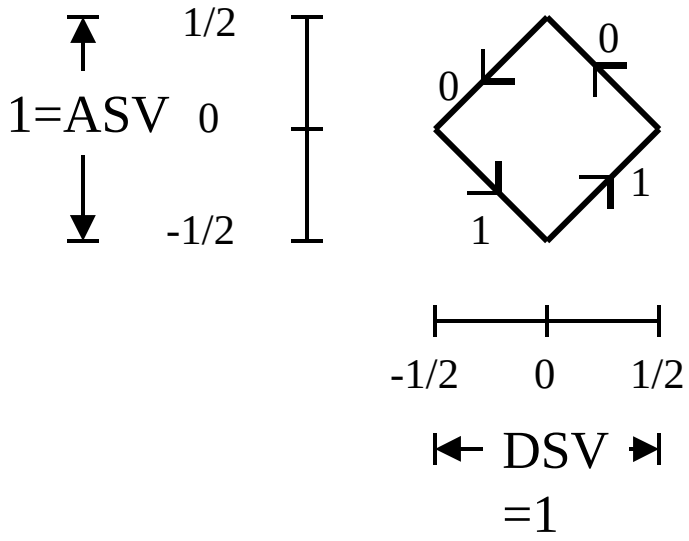
New Line Code MB810 for 10GbE(Con't)

- BUDA(Binary Unit DSV and ASV) Cell Concepts



  - ASV and DSV are '1'
  - Mapping '1' to a shift right, mapping '0' to a shift left
  - '1100' and '' for CCW, '1001' and '0011' for CW.
  - By stacking BUDA cells, MBxy codes can be easily designed.

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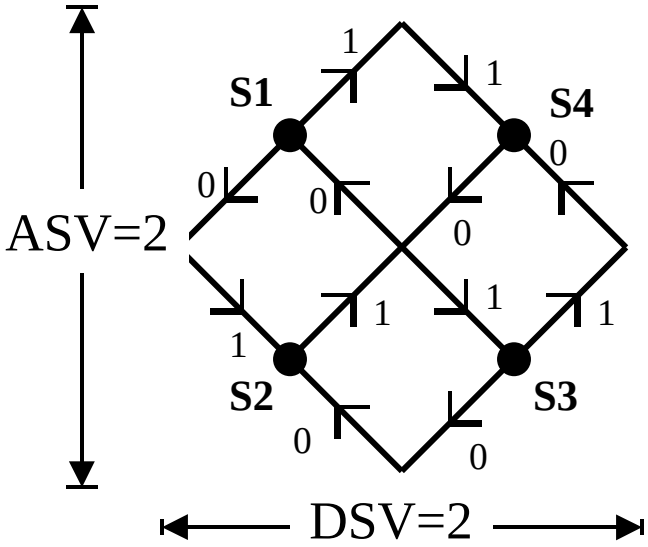
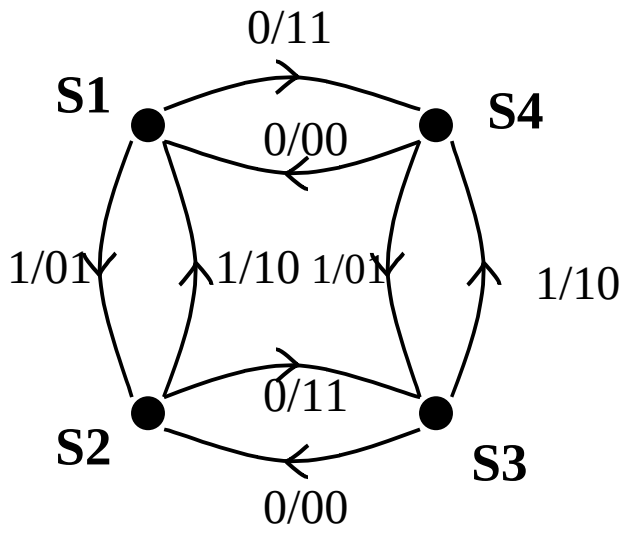
Design Example for MB12





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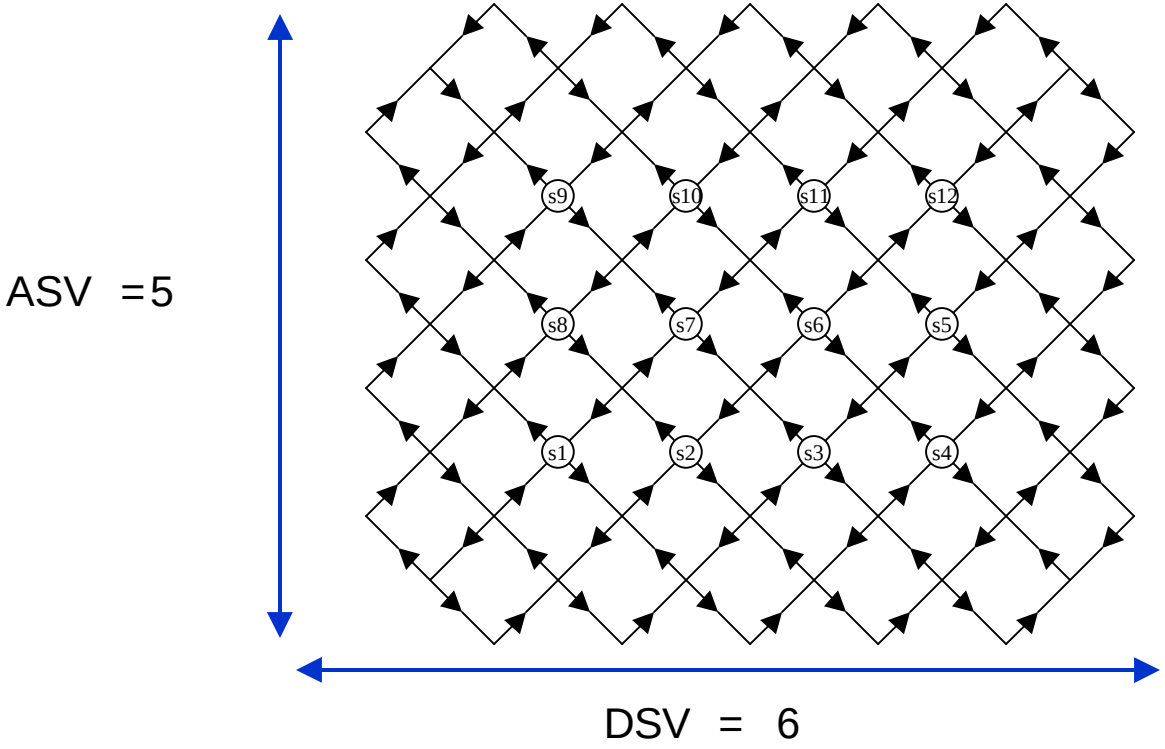
- **BUDA cell stack for MB810**



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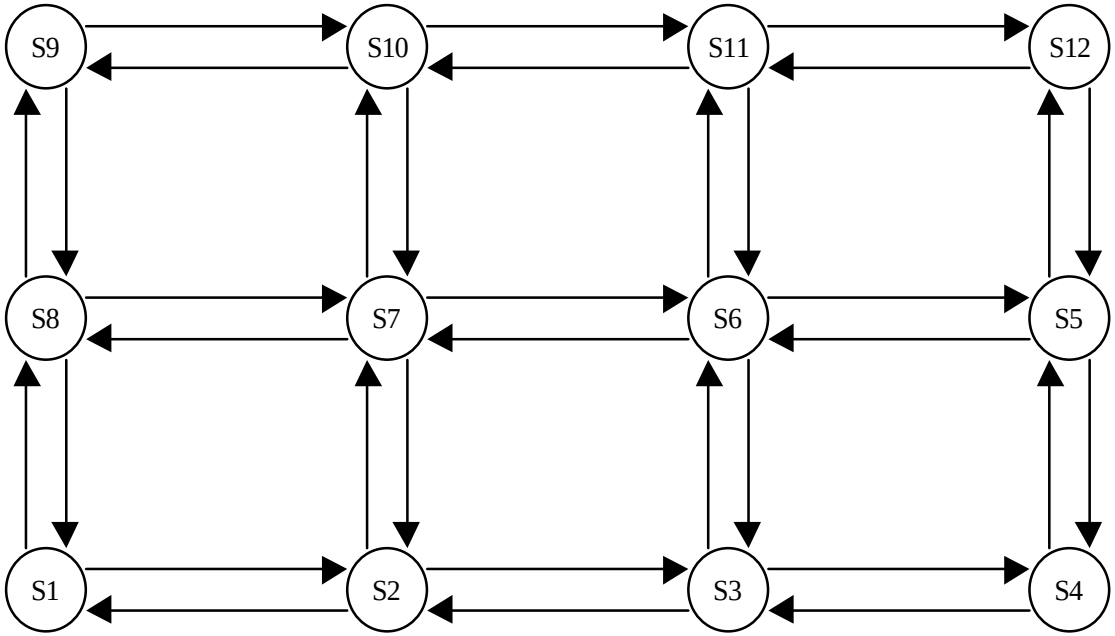
- **MB810 State Transition Diagram**



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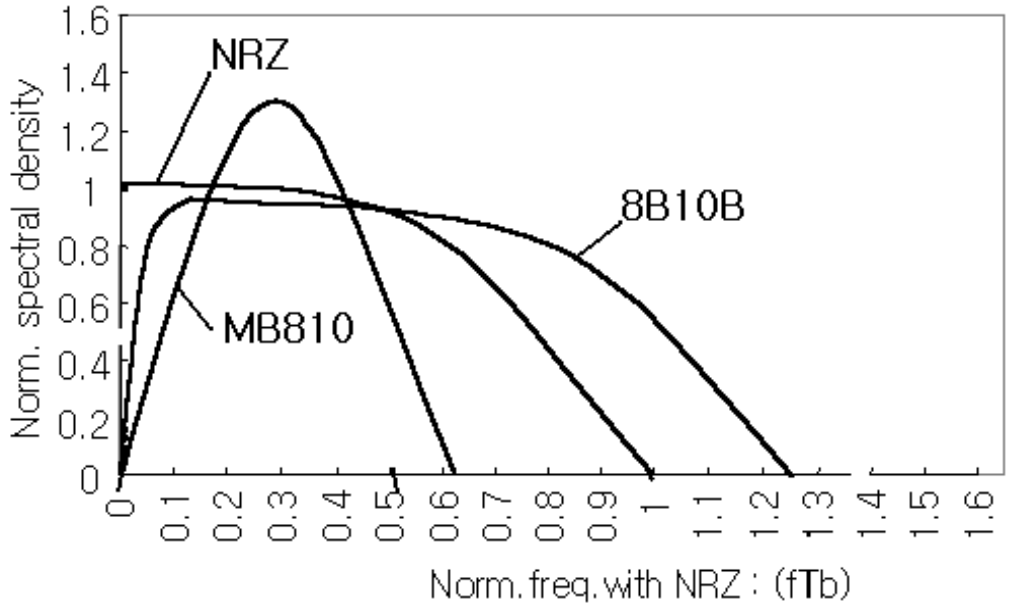
- **Spectrum of MB810**



Tb: Data input duration

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Comparison with 8B/10B

- IBM 8B/10B is a US patent 4486739 [1984.12.4] [5]

	MB810	8B10B	Remarks
Input bits	8	8	
Coded output bits	10	10	
Maximum run-length	7	5	
RAS	2.5	*	*Not limited
RDS	3	3	
ASV	5	*	*Not limited
DSV	6	6	
Spectrum Bandwidth	1/(2T)	1/T	1/T is output bit rate
Implement Method	Hardwire	Hardwire (5B6B +3B4B)	

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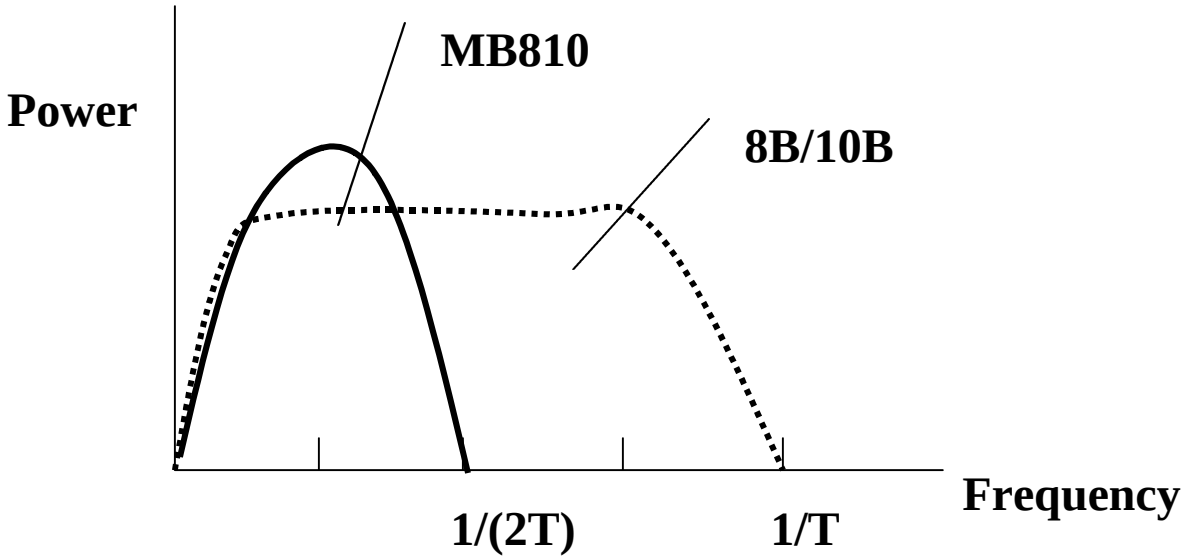
Comparison with 8B/10B(Con't)

- **Spectrums**



ta rates are assumed to be the same in the transmission channel

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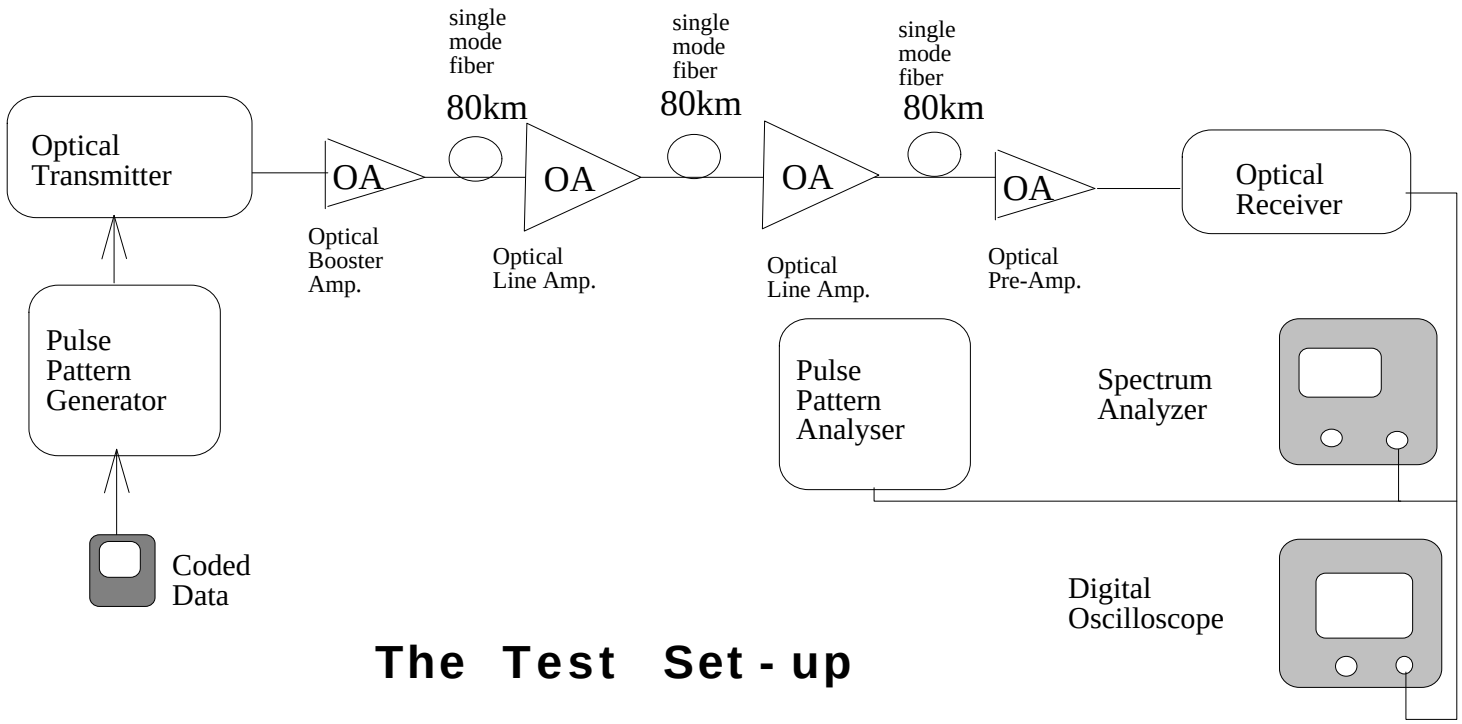
Exemplary Test Results

- **Experimental evaluation of a minimum bandwidth code of a similar kind, MB34, over the 10Gbps optical transmission system. [4]**
- **Test performed over SMF of 240km.**



The Test Set-up

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Exemplary Test Results(Con't)

MEASUREMENT CONDITION

Signal format	NRZ data	Coded data
Data rate	9.95328 – 12 Gb/s	9.95328 – 12 Gb/s
Line code	Scrambled-NRZ	MB34
Sequence period	2^{11} -1	2^{11} -1
Light source	External modulator of lithium niobate	External modulator of lithium niobate
Optical amplifier	EDFA with DCF	EDFA with DCF
Detector	PIN	PIN
Fiber	Single mode fiber 240 km	Single mode fiber 240 km
BER	$<1 \times 10^{-12}$	$<1 \times 10^{-12}$

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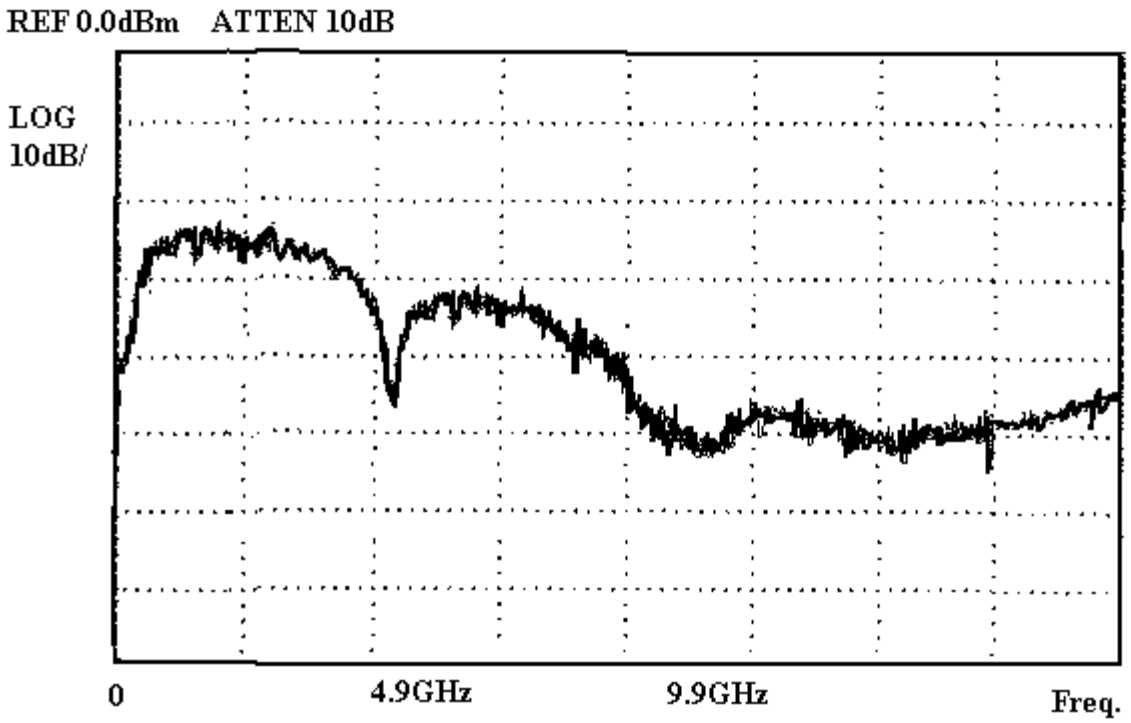
Exemplary Test Results(Con't)

- Measured spectrum



Spectral Null can be seen at 4.9GHz, halfway to 9.95GHz.

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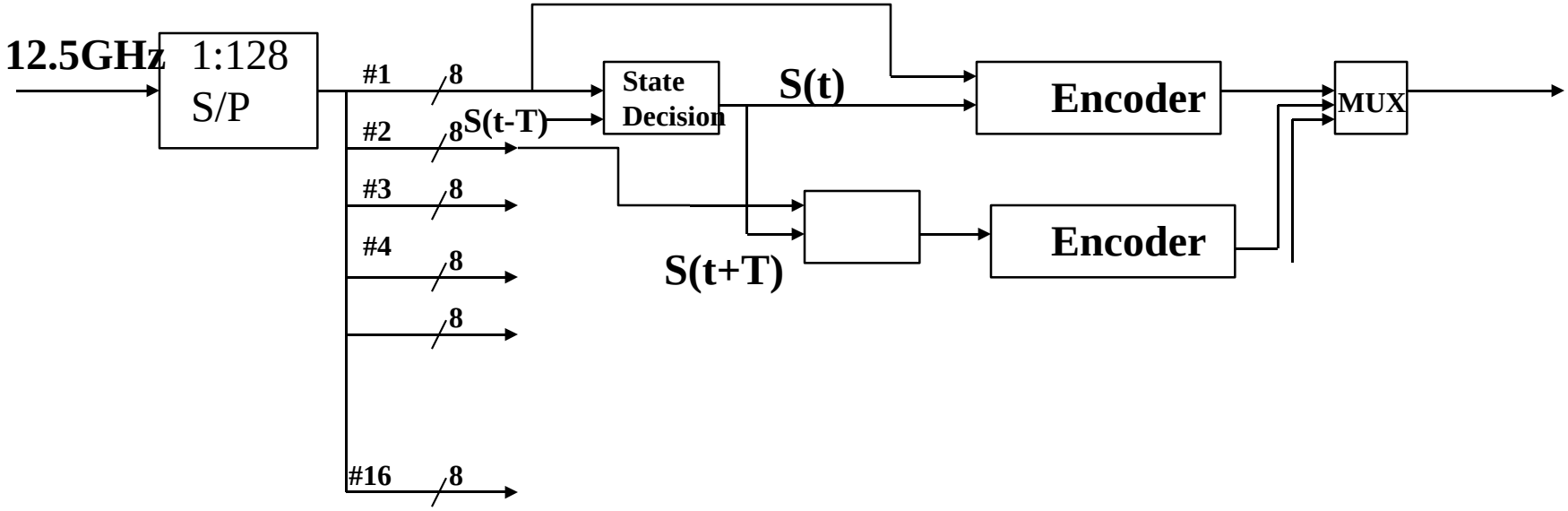
Exemplary Test Results(Con't)

- Measurement results

Items	Scrambled NRZ	MB34 code	Differences
Spectral zero freq.	9.95GHz	4.9GHz	4.9GHz
S/N	8.5dB	11.7dB	3.2dB
DC component	- 20dBm	-50dBm	30dB
Eye Opening @ PIN/preamp	11.1mV	14.6mV	3.5mV
Eye Width	65ps	77ps	12ps
Optical spectral line width	0.404 nm	0.404 nm	0
Receiver sensitivity	-20.4dBm	-21.7dBm	1.3dB
Optical output power	-3dBm	-3dBm	0

The clock SNR was 120dB with the conventional 10G clock recovery circuit

Chip ...



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Conclusion and Suggestion

- MB810 is Binary, DC-free, and of the Minimum Bandwidth.
- State-dependent encoding, yet with state-independent decoding.
- Approx. 50% bandwidth reduction over 8B/10B.
- Approx. 40% bandwidth reduction over Scrambled NRZ.
- Approx. 20% more bandwidth than that of MAS which, however, is of five levels with considerable SNR penalty.
- Chip being designed.
- Wish group support.

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[1] D. Y. Kim, and J. -k. Kim, “A condition for stable minimum-bandwidth line codes,” *IEEE Trans. Commun.*, vol. COM-33, no. 2, pp. 152-157, Feb. 1985.

[2] D.Y.Kim, J.I.Baek, J.-k. Kim, S.K.Hyun, and Y.K.Park, “Run-Length-Limited Variants of Duobinary and Modified Duobinary,” *IEEE Trans. on Commun.*, vol. COM-33, No.2, pp.142-150, Feb. 1987.

[3] D. Y. Kim, “Lower-bound eye widths of minimum-bandwidth systems,” *IEEE Trans. on Commun.*, vol. 43, no. 2/3/4, pp. 1235-1249, Feb./Mar./Apr., 1995.

[4] C. G. Lee, D. I. Lee, and D. Y. Kim, "An evaluation for high speed optical line code : Minimum Bandwidth(MB) Line code MB34,”proc.of ICT'98, porto Carras, Greece, June. 22-25, 1998.

[5] Widmer AX and Franaszek PA, “A DC-balanced, partioned block, 8B/10B transmission code,” IBM Journal of Research and Development, Vol.27, no. 5, pp.440-451, Sept.,1983.