Duobinary Coding for 10GbE

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Abstract: We propose a new optical coding technique for 10GbE, Duobinary coding. This coding has a spectrum bounded within the Nyquist band, which makes it a minimum bandwidth coding-scheme. This presentation compares duobinary coding with several other possible coding schemes

Duobinary Coding

- Duobinary coding is a partial response signal: certain amount of ISI is not suppressed by the equalizer but rather left for a simple detector to handle.
- Permits noise enhancement to remain small even when amplitude distortion is severe.
- Changes input data sequence a_k, which has a flat spectrum, into a sequence b_k whose spectral characteristics match channel.

Duobinary Coding/Cntd.

- Simple to implement. Output sequence is

$$b_k = a_k + a_{k-1}$$

- A precoder is added to eliminate error propagation in receiver, transfer function becomes:

$$b_k=(a_k+1)d_{k-1}$$

d_{k-1} can not be zero, so estimated ak is:

$$a\_est_k = \begin{cases} -1 & \text{if } b_k = 0 \\ 0 & \text{else} \end{cases}$$

which is just memoryless inverse mapping

Duobinary System Architecture

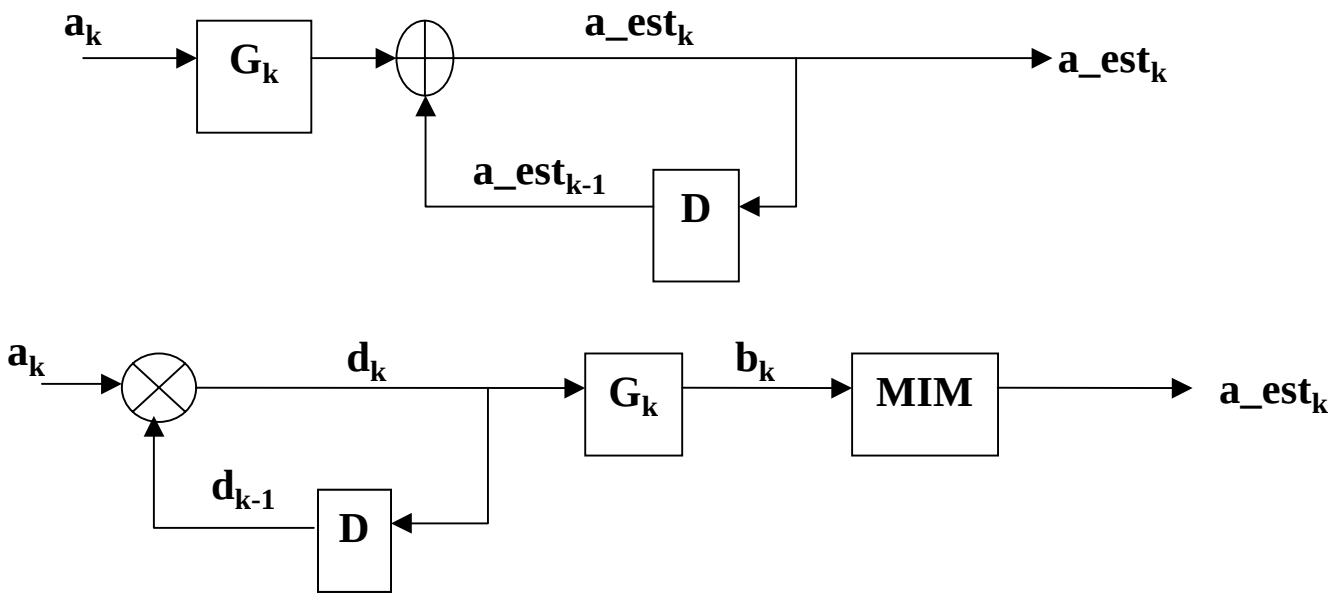


Figure 1: a: A one pole recursive filter transforms b_k into an estimate a_est_k b: To avoid error propogation, the filter is replaced by a precoder and a memoryless inverse mapping (MIM)

Duobinary Performance

- Duobinary gives very robust solutions for many problems in optical channels. It suppresses dispersion and nonlinear effects in optical fiber, waveform distortion and wavelength fluctuation in WDM systems.
- To pack a Terabit/s capacity into the gain bandwidth of WDM systems, spectral efficiency has to be more than 0.23 b/s/Hz, or a channel spacing of 0.7nm. Duobinary signals increased spectral efficiency to 0.6 b/s/Hz.

Duobinary Performance/Cntd.

- High dispersion tolerance, about twice that of IM (intensity modulated) signals.
- Suppresses Four-wave mixing (FWM) in WDM systems.
- Typical setup includes push-pull type LiNbO3 (LN) Mach-Zehnder modulator in transmitter side.
- Can be demodulated into a binary signal with a conventional direct detection type optical receiver.

Experimental Setup

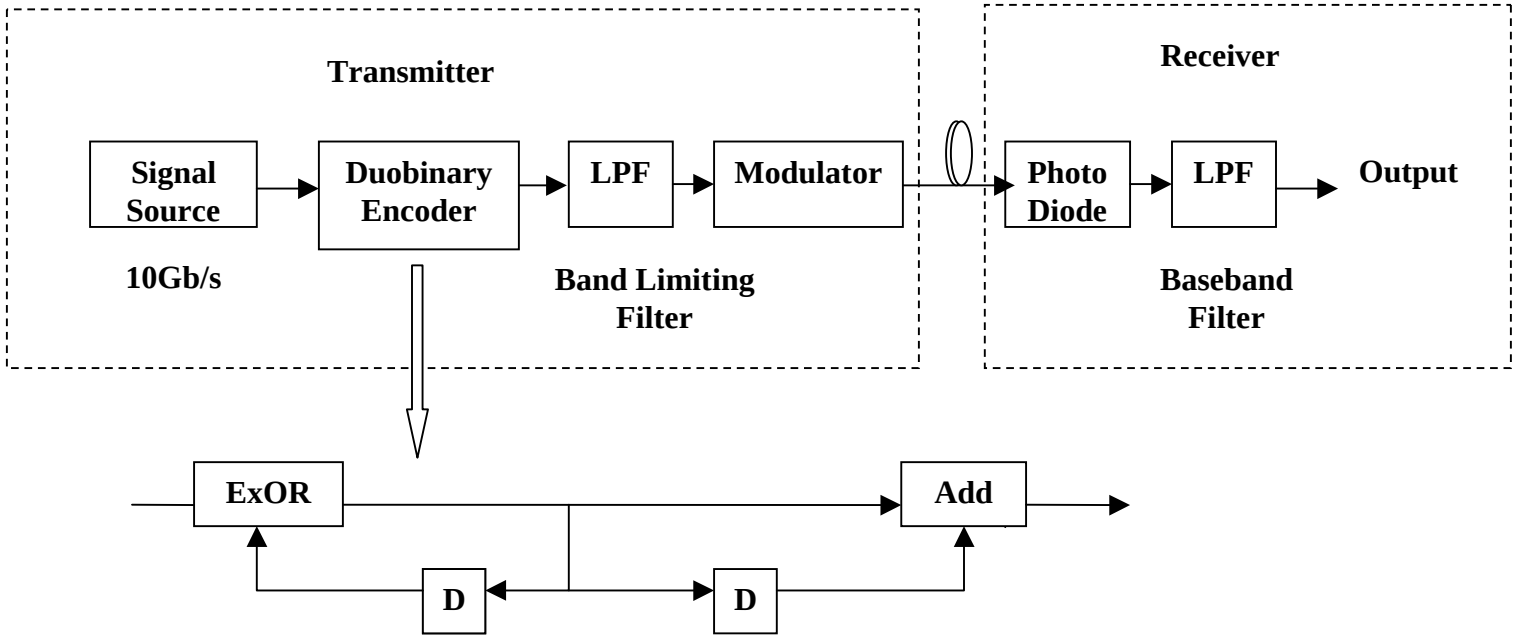
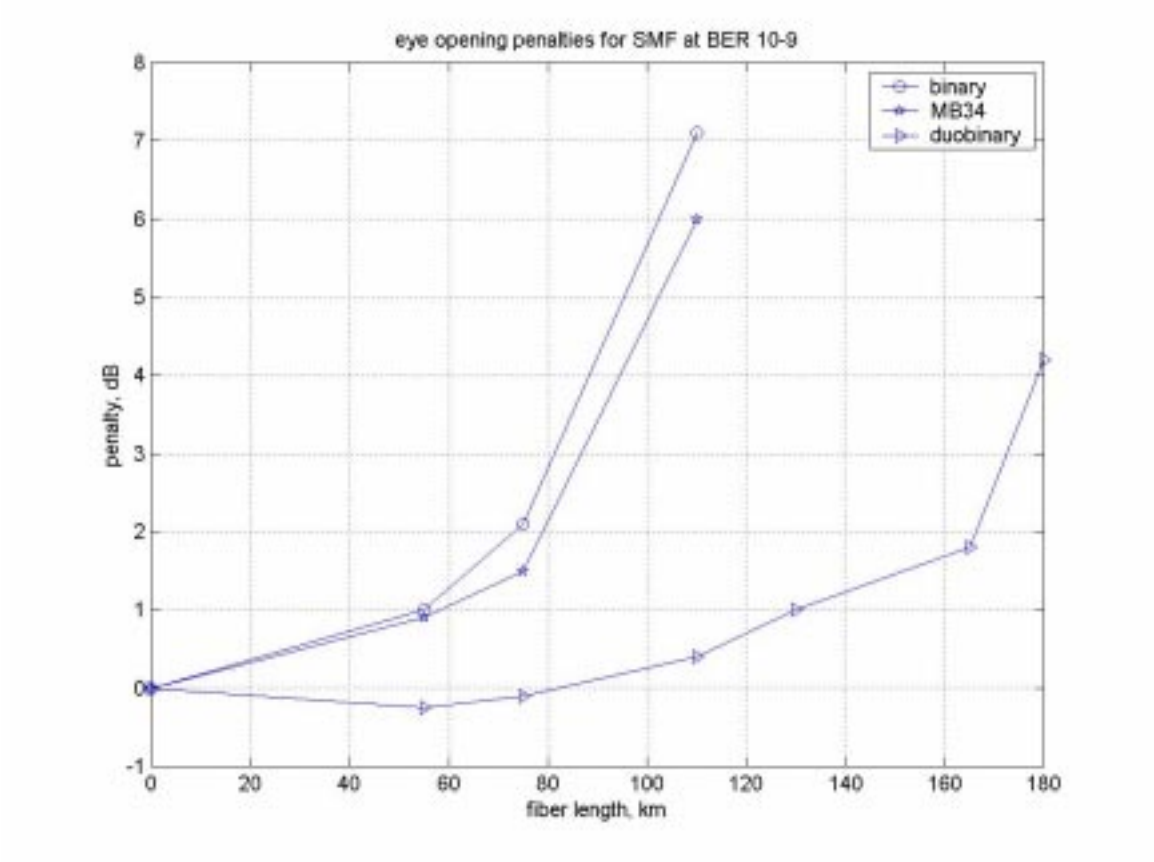


Figure 2: Typical experimental setup for duobinary transmission system

Simulation and Experimental Results

- Eye opening degrades due to chromatic dispersion as the transmission distance is extended. Eye opening penalty gives the performance:
- Penalty = $-10\log_{10}(B/A * P_0/P_{AVE})$ (dB)
- A: eye-opening of the reference eye diagram
- B: eye-opening of the distorted signal due to chromatic dispersion
- P_0/P_{AVE}: Averaged optical power if band-limiting filter inserted

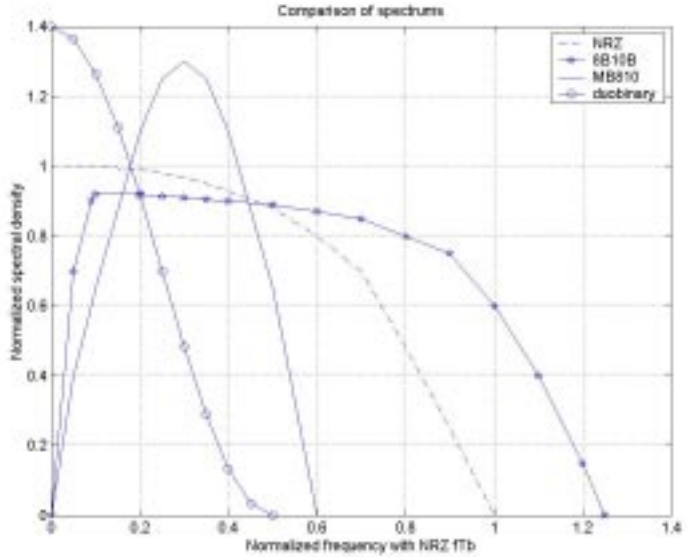
Eye Opening Penalty



Spectrum Comparison

- Duobinary is Minimum-Bandwidth signal, high tolerance to chromatic dispersion, power limitation due to SBS can be relaxed.
- Power Spectrum:

$P(f) = T^2 * \cos^2(\pi f T)$

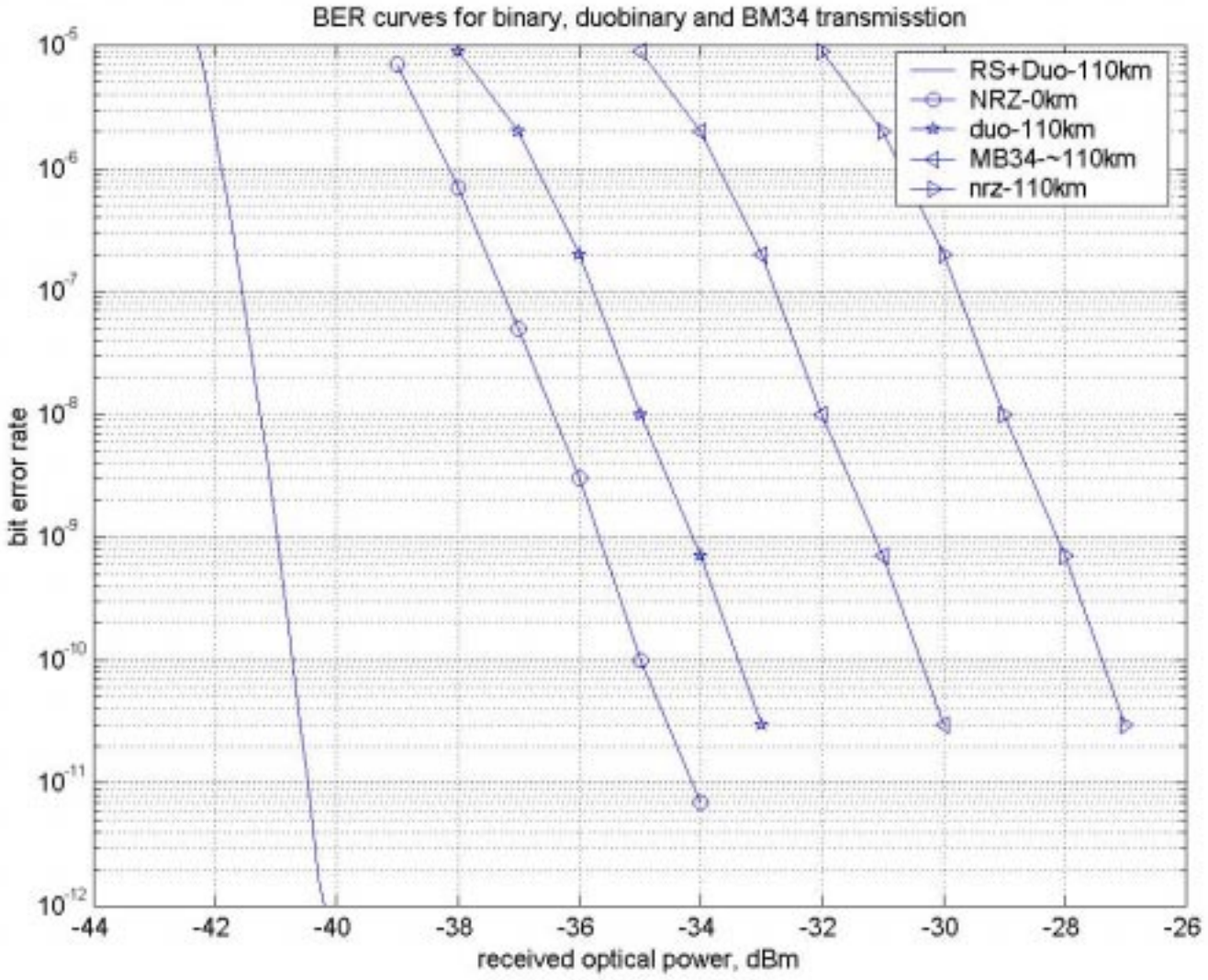


BER and Receiver Sensitivity

- Due to more spectral efficiency attained by duobinary coding, there is less receiver sensitivity compared to other signaling techniques.
- With a powerful FEC scheme added to duobinary signal, very good BER performance can be attained. This opens the possibility of reaching 2-3 times distance in fiber optic cables without any repeaters.

Forward Error Correction

- Reed-Solomon (255, 239) is 8 error correcting FEC scheme. It is ideal for bursty channels like fiber optic, and wireless systems.
- RS(255, 239) is recommended for submarine fiber optic systems by ITU (ITU G.975), and is being considered for other fiber optic systems.
- Following is receiver sensitivity versus BER curves for a SMF at 110 km. There is just 2dB degradation in receiver sensitivity for duobinary signaling. Degradation is 5dB for Mb34 and 8dB for NRZ signaling. For Duobinary and RS concatenated systems, there is 7dB improvement in receiver sensitivity


BER curves for binary, duobinary and BM34 transmisstion
RS+Duo-110km
NRZ-0km
duo-110km
MB34-~110km
nrz-110km
bit error rate
received optical power, dBm
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
10^-12
-44
-42
-40
-38
-36
-34
-32
-30
-28
-26

Remarks and Conclusion

- Duobinary coding is more efficient compared to other signaling techniques.
- Duobinary is MB signal with bandwidth at half the bit rate, and most of the signal power is concentrated in lower frequencies. More channel bandwidth reduction than other techniques.
- 6dB eye opening improvement over NRZ, and 5dB on MB34. Timing recovery constraints are reduced.
- Transmission distance is enhanced, less number of repeaters are needed for optical fiber systems
- Very simple algorithm. No separate complex encoder or decoder needed.

Remarks and Conclusion/Cntd.

- Less receiver sensitivity,and better BER performance. If combined with another FEC algorithm, like Reed-Solomon(255,239), significant error correction improvement is possible. (~12dB)
- Extensive research has been made upon duobinary signaling for high speed fiber optic systems in last 10 years, and very promising results obtained.

References

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