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Low Pass Filter Bandwidth Optimization to Generate Electrical Duobinary Signal for 40 Gb/s Optical System’s Duobinary Modulation Format

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Outline

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- Review of Duobinary modulation format for Fiber optics communication system
- Low pass filter bandwidth analysis
- Filter bandwidth optimization
- Low pass Bessel Thomson filter design
- Device fabrication
- Measured results
- Proof of concept
- Summary and conclusion
- Acknowledgement and Future work
Motivation

- Today’s multimedia rich communication pushes the system data rate to be 40 Gbps (and 100 Gbps in near future)
- Components need to be upgraded to support higher data rate
- For successful deployment of Duobinary modulation format, Bessel low pass filter’s bandwidth needs to be increased
- Correct filter bandwidth improves the system performance
- Filter bandwidth needs to be optimized for higher data rate
- Research is done to realize the filter’s bandwidth for the best system performance
Review: Duobinary modulation format for Optical Communication

- Optical duobinary transmission system enjoys higher system performance for optical communication system
- Higher spectral efficiency
- Has narrower spectrum bandwidth
- Excellent tolerance for chromatic and residual dispersion
- Minimum channel spacing allowing DWDM capability

- Optical duobinary modulation format operates as follows
  - Binary signal is converted to three level electrical signal
  - Three level signal (“-1”, “0”, and “+1”) drives the MZM
  - Signal amplitude “-1” and “+1” becomes optical “1” and amplitude “0” becomes optical “0”
Review: Duobinary modulation format for Optical Communication

- Transmitter model for duobinary modulation format
- LPF limits the data and generates three level electrical signal
Low Pass Filter Bandwidth Analysis

- Three level signal amplitude depends on LPF’s bandwidth
- LPF bandwidth needs to be 0.25 to 0.33 of the signal data rate
- TFT’s 3.0 GHz Bessel filter provides excellent 3 level electrical signal for 10 Gbps optical signal

Eye diagram of 3 level electrical signal for 10 Gbps optical Duobinary signal

Observable binary eye amplitude \((A)\) is 45% of signal eye amplitude \((B)\)
Low Pass Filter Bandwidth Optimization

- We simulated duobinary transmitter model for 40 Gbps data rate
- Used ideal Bessel low pass filter for generating three level electrical signal
- Changed filter bandwidth for different signal amplitude
- Used Bessel low pass filter having –3dB bandwidth from 8 GHz to 15 GHz
- Observed electrical binary eye height to signal’s eye height
- By comparing the eye diagram, we chose the filter that produced three level eye diagram where binary eye height is closest to 45% of signal eye height
Transmitter Model Simulation Result

- Binary eye height is 11% of signal eye height
- Binary eye height is 17% of signal eye height
- Binary eye height is 26% of signal eye height
- Binary eye height is 39% of signal eye height

LPF BW = 8 GHz
LPF BW = 9 GHz
LPF BW = 10 GHz
LPF BW = 11 GHz
Transmitter Model Simulation Result

- **LPF BW = 12 GHz**
  - Binary eye height is 46% of signal eye height

- **LPF BW = 13 GHz**
  - Binary eye height is 54% of signal eye height

- **LPF BW = 14 GHz**
  - Binary eye height is 59% of signal eye height

- **LPF BW = 15 GHz**
  - Binary eye height is 69% of signal eye height

CARTS 2010  LPF bandwidth optimization for duobinary modulation
Designed absorptive low pass filter

- 12 GHz Bessel low pass filter provided best three level eye diagram
- Binary eye height is 46% of signal eye height
- Observed jitter is 1.44 ps
- Based on the result, we designed 12 GHz Bessel low pass filter
- For better return loss characteristics we designed absorptive Bessel low pass filter
- We designed 9th order absorptive filter to match characteristics of 5th order ideal Bessel filter
Designed absorptive low pass filter

Insertion Loss result

Return Loss result
We fabricated the 12 GHz absorptive low pass Bessel filter.

Filter is fabricated in Aluminum substrate with 0.63 mm thickness.

Filter size is 2.0 mm X 7.2 mm in BGA package.
Absorptive Low Pass Filter Fabrication

- Filter is housed in evaluation board for measurement procedure
- Evaluation board’s PCB material is Rogers 4350, 10 mil thick, ½ oz. CU.

Evaluation board PCB

Evaluation board with filter
Measured results of fabricated LPF

- Fabricated filter was measured
- Data was compared with simulation results

Insertion Loss results comparison

Return Loss results comparison
Proof of Concept

- We used measured data into the simulated transmitter model
- Three level electrical signal is produced using the model
- Data rate was 40 Gbps
- Eye diagram of the three level signal is observed

Eye diagram of 3 level electrical signal using fabricated 12 GHz Bessel LPF

• Observable binary eye amplitude is 42% of signal eye amplitude
Proof of Concept

- Fabricated absorptive low pass filter was used in 40 Gbps optical duobinary transmission system
- Eye diagram of 3 level electrical and 2 level optical duobinary signal is as follow
Summary and conclusion

- We discussed influence of low pass filter’s bandwidth for duobinary modulation format
- We analyzed LPF’s bandwidth for 10 Gbps system
- We simulated 40 Gbps duobinary transmitter model and used LPF with different bandwidth
- We optimized LPF’s bandwidth for best three level signal’s eye diagram
- Based on the simulation results, we designed 12 GHz absorptive Bessel Thomson LPF
Summary and conclusion

- We fabricated 12 GHz absorptive Bessel Thomson LPF from simulation results.
- Measured data was compared to simulation result.
- We used measured result in model and generated three level eye diagram.
- Measured results eye diagram closely matches simulation results eye diagram.
- We presented some industry system performance result using our fabricated 12 GHz Bessel Thomson Low Pass Filter.
Acknowledgement

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Future Work

- Future work can be done on Low pass filter for 100 Gbps Duobinary modulation format system
- Low pass filter bandwidth can be optimized for receiver system
- LPF’s impact can be studied for other advanced modulation format (ie. DPSK, DQPSK, OOK)
- Other electrical passive device can be studied for advanced modulation format

Thank you!