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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

- *Motivation*
- *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

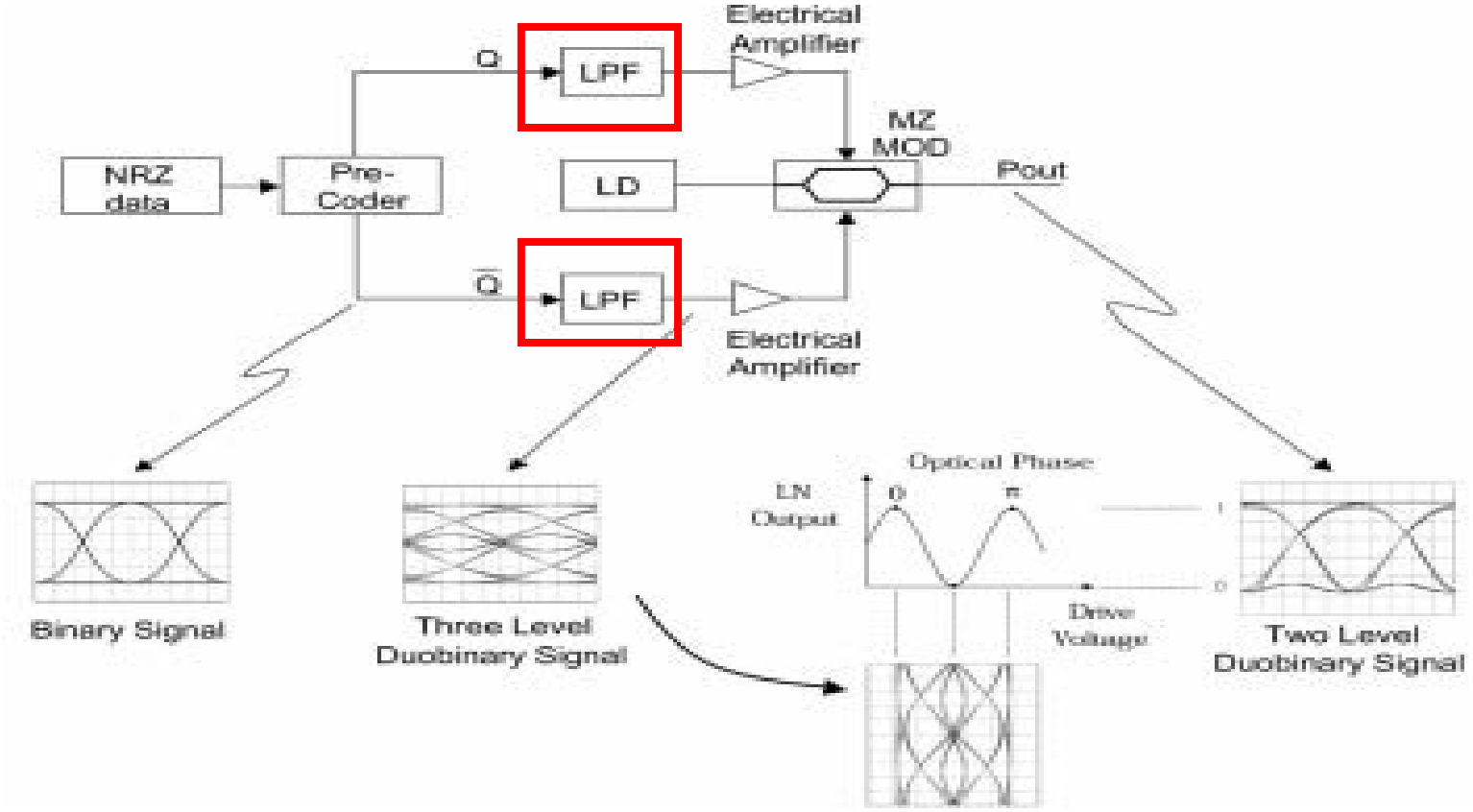
- Today's multimedia rich communication pushes the system data rate to be 40 Gbps (and 100 Gbps in near future)
- Components need to be upgraded to support higher data rate
- For successful deployment of Duobinary modulation format, Bessel low pass filter's bandwidth needs to be increased
- Correct filter 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

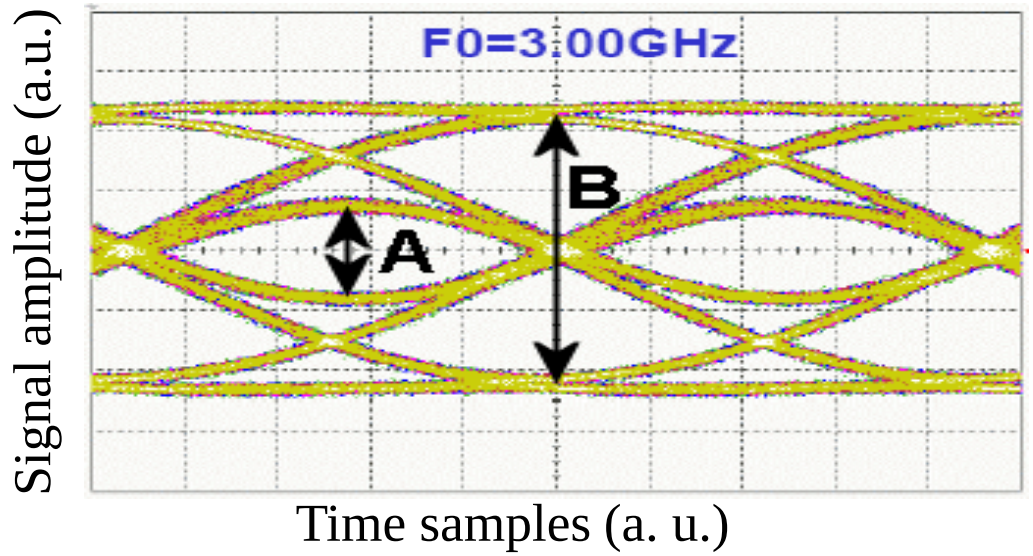
- Transmitter model for duobinary modulation format
- LPF limits the data and generates three level electrical signal



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

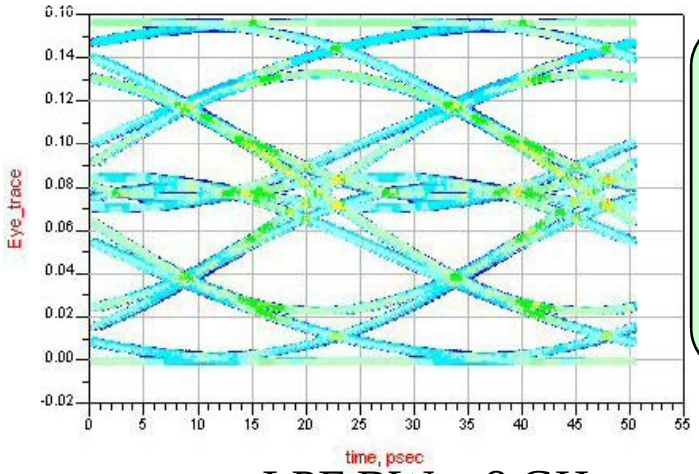


•Observable binary eye amplitude (A) is 45% of signal eye amplitude (B)

Low Pass Filter Bandwidth Optimization

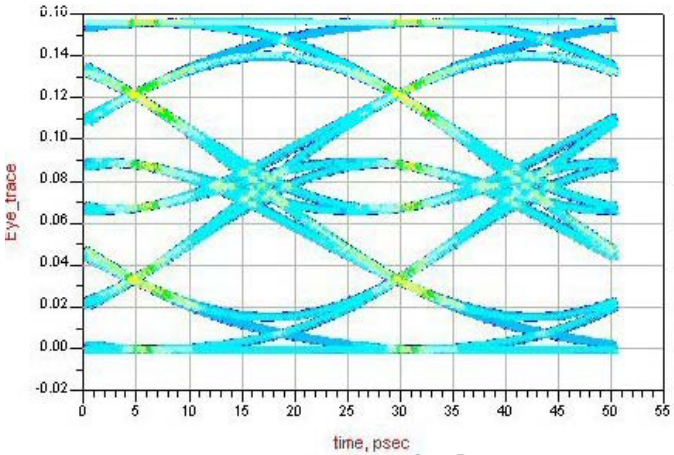
- We simulated duobinary transmitter model for 40 Gbps data rate
- Used ideal Bessel low pass filter for generating three level electrical signal
- Changed filter bandwidth for different signal amplitude
- Used Bessel low pass filter having –3dB bandwidth from 8 GHz to 15 GHz
- Observed electrical binary 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



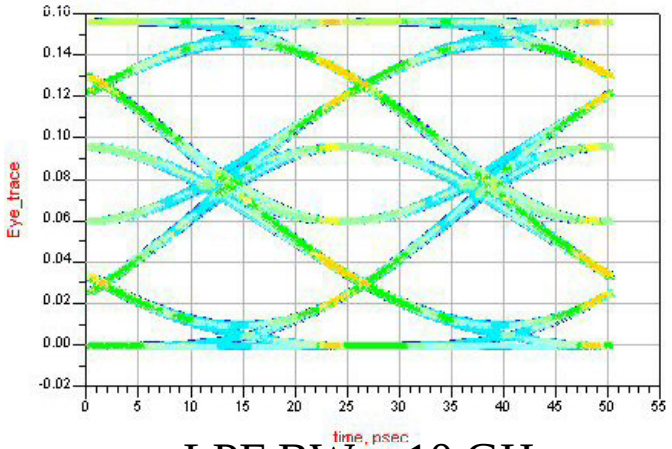
LPF BW = 8 GHz

•binary eye height is 11% of signal eye height



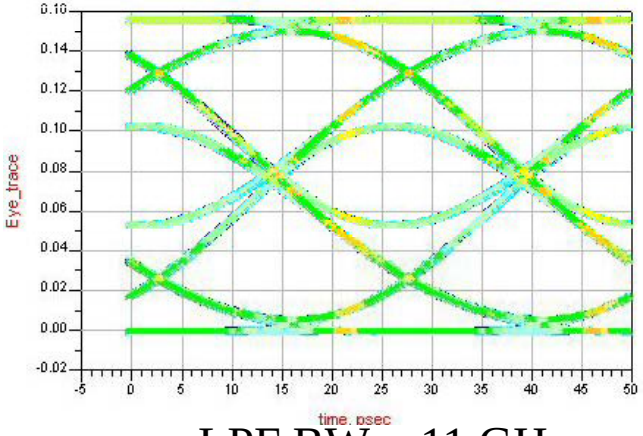
LPF BW = 9 GHz

•binary eye height is 17% of signal eye height



LPF BW = 10 GHz

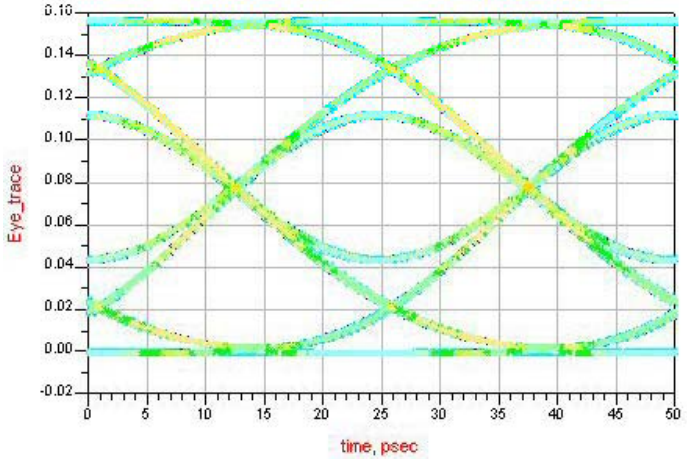
•binary eye height is 26% of signal eye height



LPF BW = 11 GHz

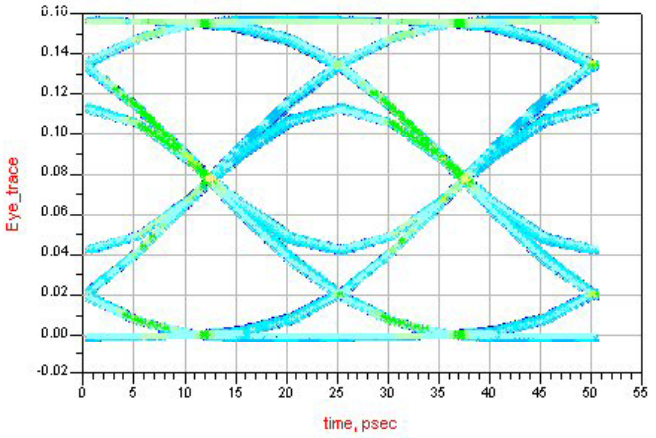
•binary eye height is 39% of signal eye height

Transmitter Model Simulation Result



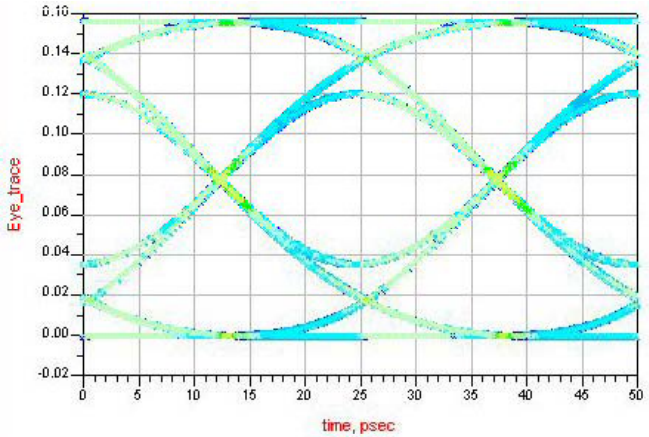
LPF BW = 12 GHz

- *binary eye height is 46% of signal eye height*



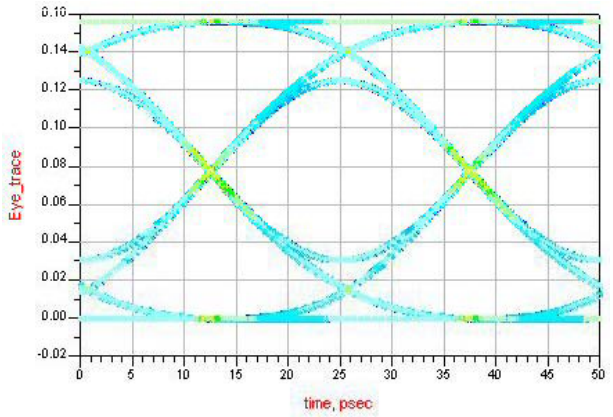
LPF BW = 13 GHz

- *binary eye height is 54% of signal eye height*



LPF BW = 14 GHz

- *binary eye height is 59% of signal eye height*



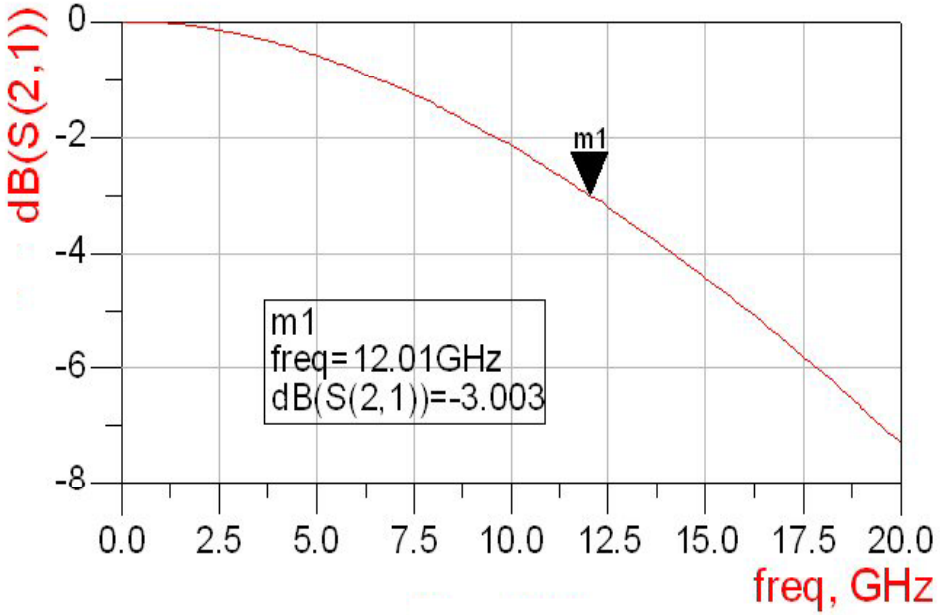
LPF BW = 15 GHz

- *binary eye height is 69% of signal eye height*

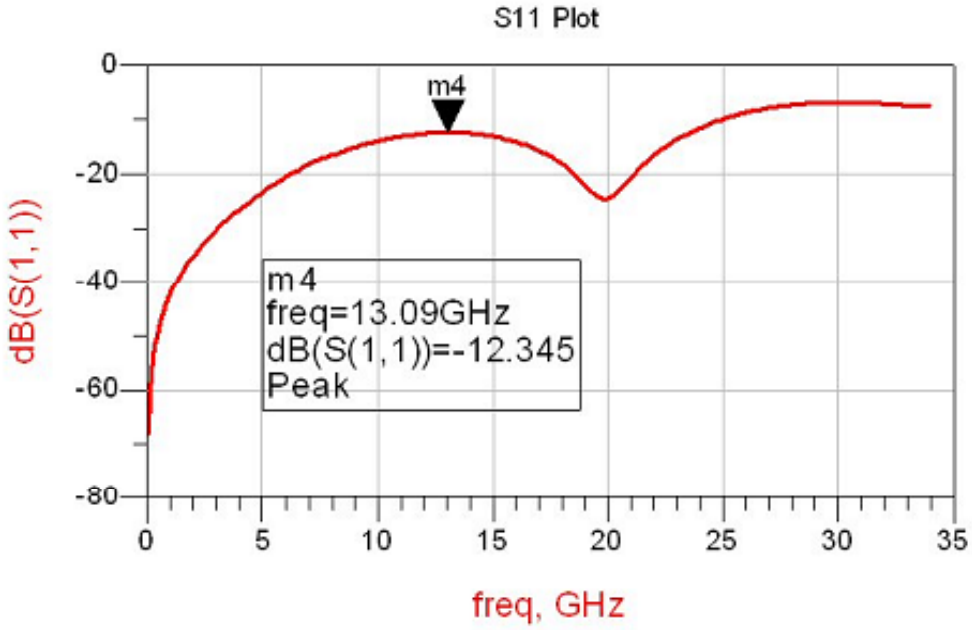
Designed absorptive low pass filter

- 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 9^{th} order absorptive filter to match characteristics of 5^{th} order ideal Bessel filter

Designed absorptive low pass filter



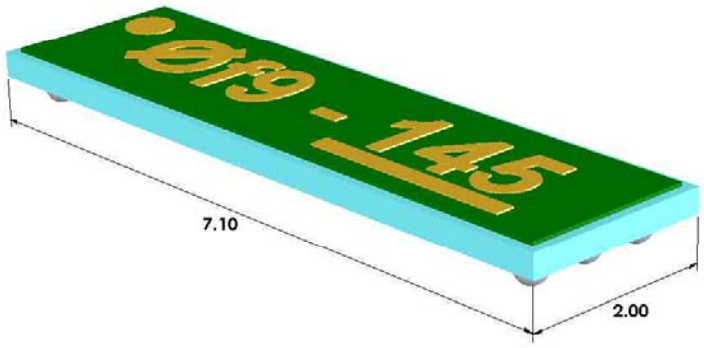
Insertion Loss result



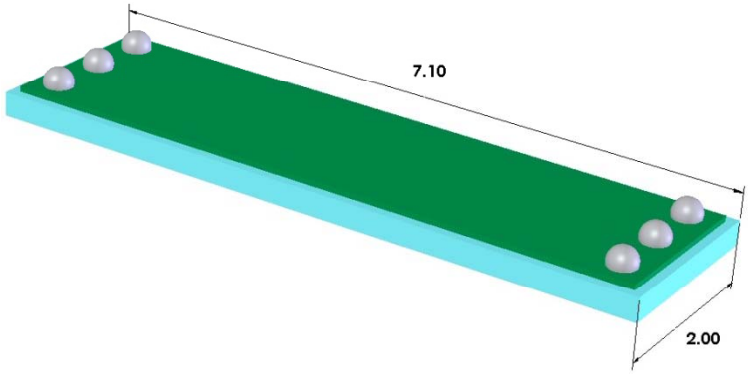
Return Loss result

Absorptive Low Pass Filter Fabrication

- 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



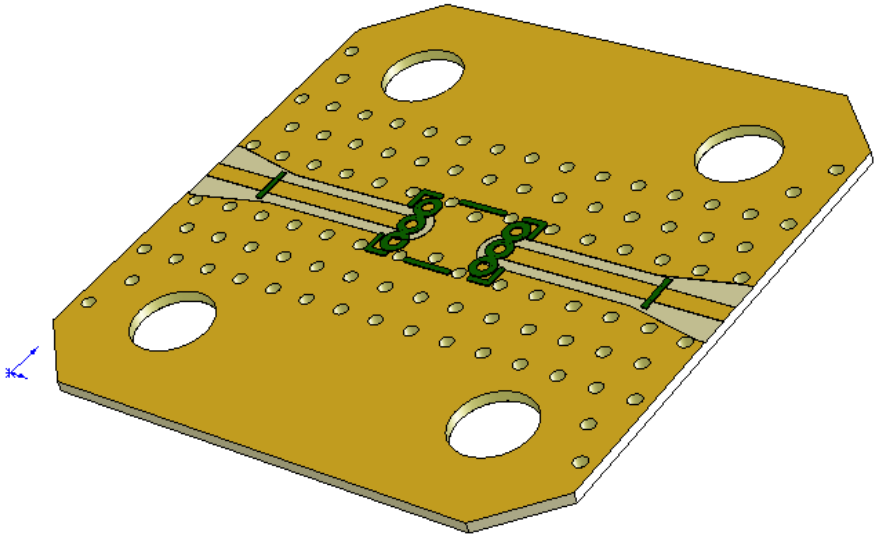
Top view of the filter



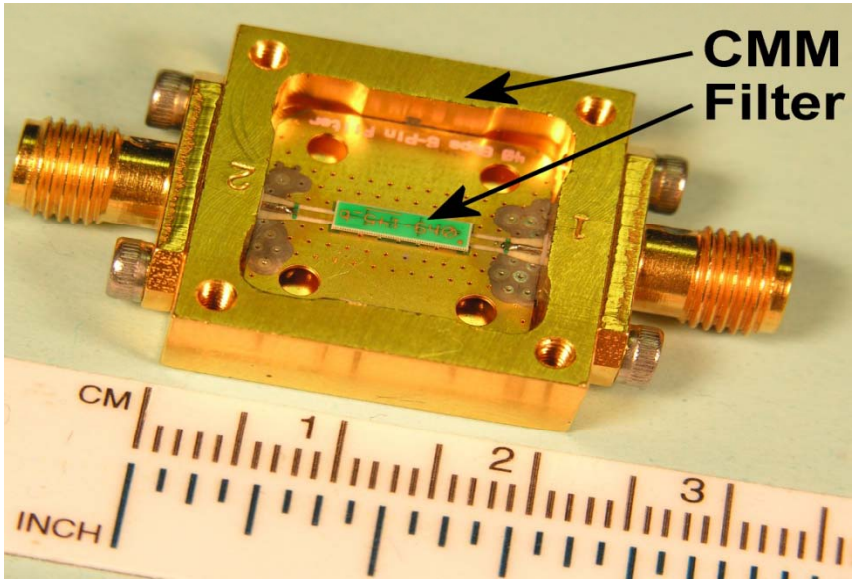
Bottom view of the filter

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.



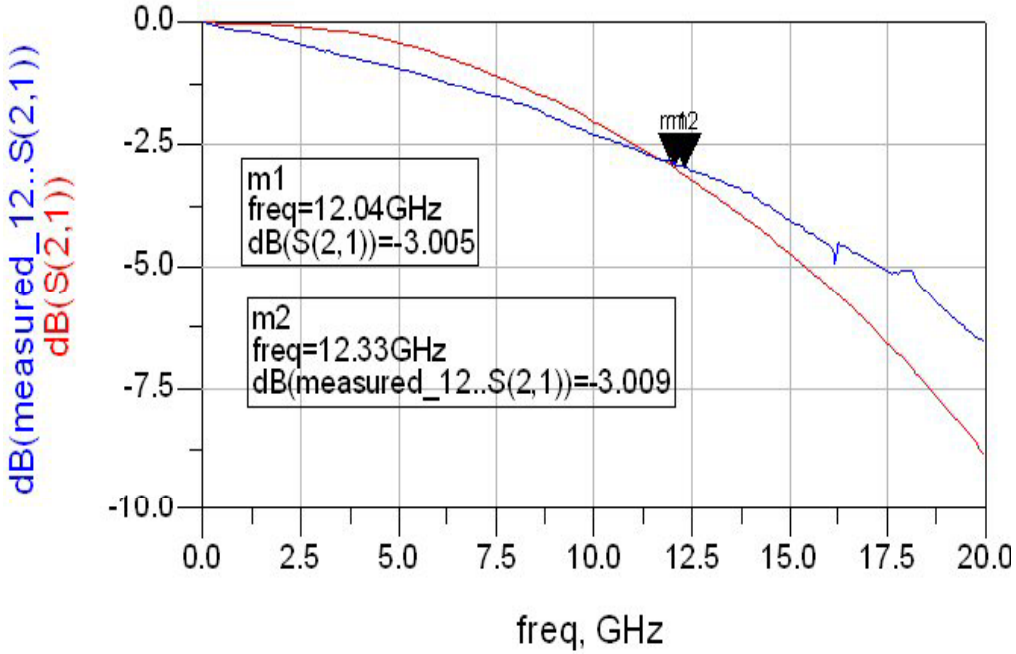
Evaluation board PCB



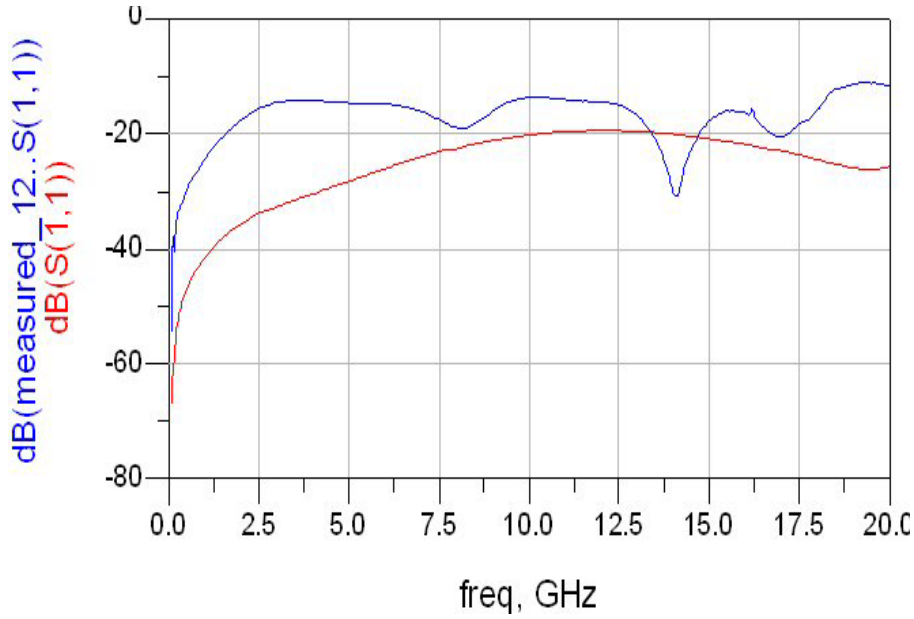
Evaluation board with filter

Measured results of fabricated LPF

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



Insertion Loss results comparison

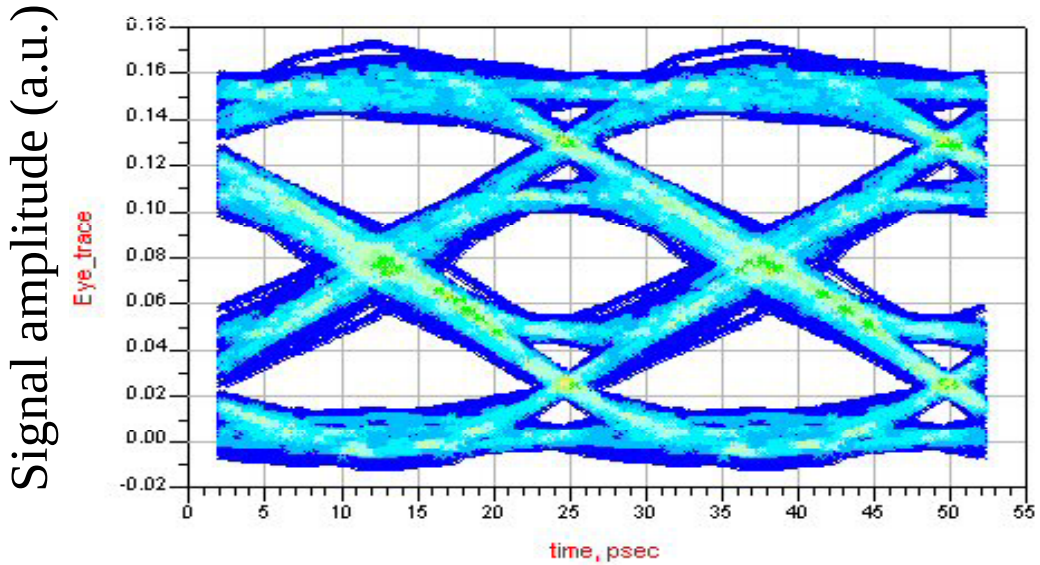


Return Loss results comparison

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

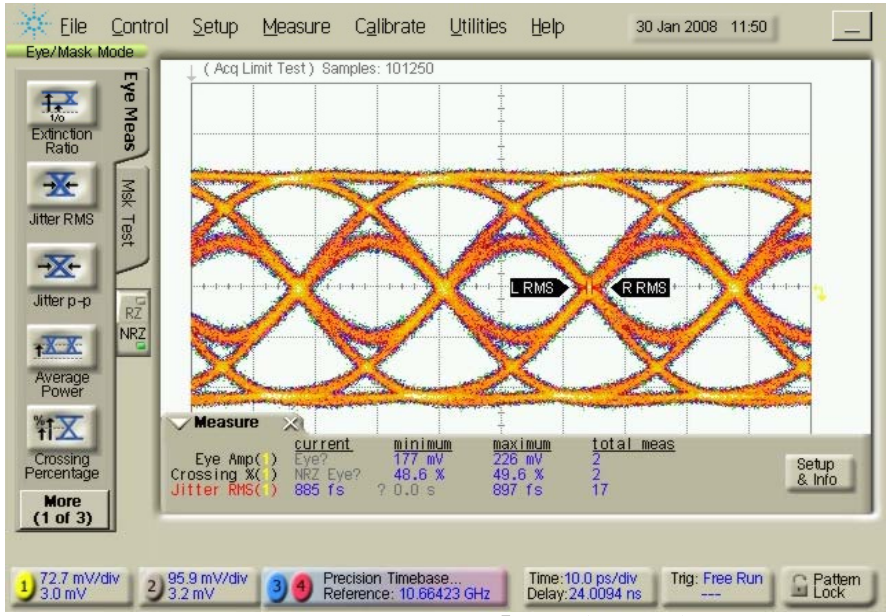


•Observable binary eye amplitude is 42% of signal eye amplitude

Proof of Concept

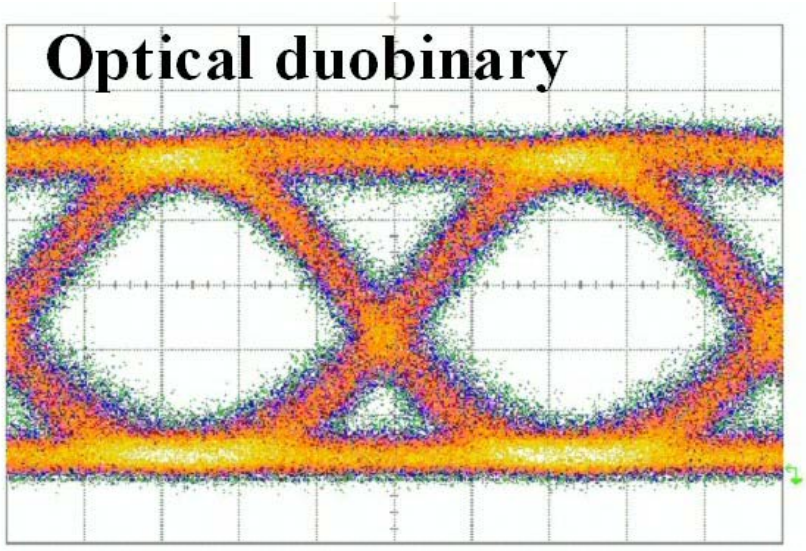
- Fabricated absorptive low pass filter was used in 40 Gbps optical duobinary transmission system
- Eye diagram of 3 level electrical and 2 level optical duobinary signal is as follow

Signal amplitude (a.u.)



Time samples (a. u.)

Signal amplitude (a.u.)



Time samples (a. u.)

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

- We would like to thank Mr. Kano and Mr. Ryo Shimizu from Sumitomo Osaka Cement Company for sharing data of 10 Gbps duobinary system using our LPF
- We would like to thank Dr. Michael Vitalli from University College London (UCL) for discussion on LPF and its bandwidth impact on successful duobinary modulation format deployment
- We would like to thank Mr. Eric Darvin from Narda L3 Communication for sharing data of 40 Gbps duobinary system using our LPF, also for various important discussion

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!