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BERT measurements in systems with Crosstalk

May 2010

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BERT measurements in systems with Crosstalk

- Introduction to crosstalk
 - What is crosstalk?
 - How is crosstalk measured?
 - BER-based crosstalk method
- Centellax BER crosstalk solution
 - Hardware and software for high-speed backplane
 - Measurement capability



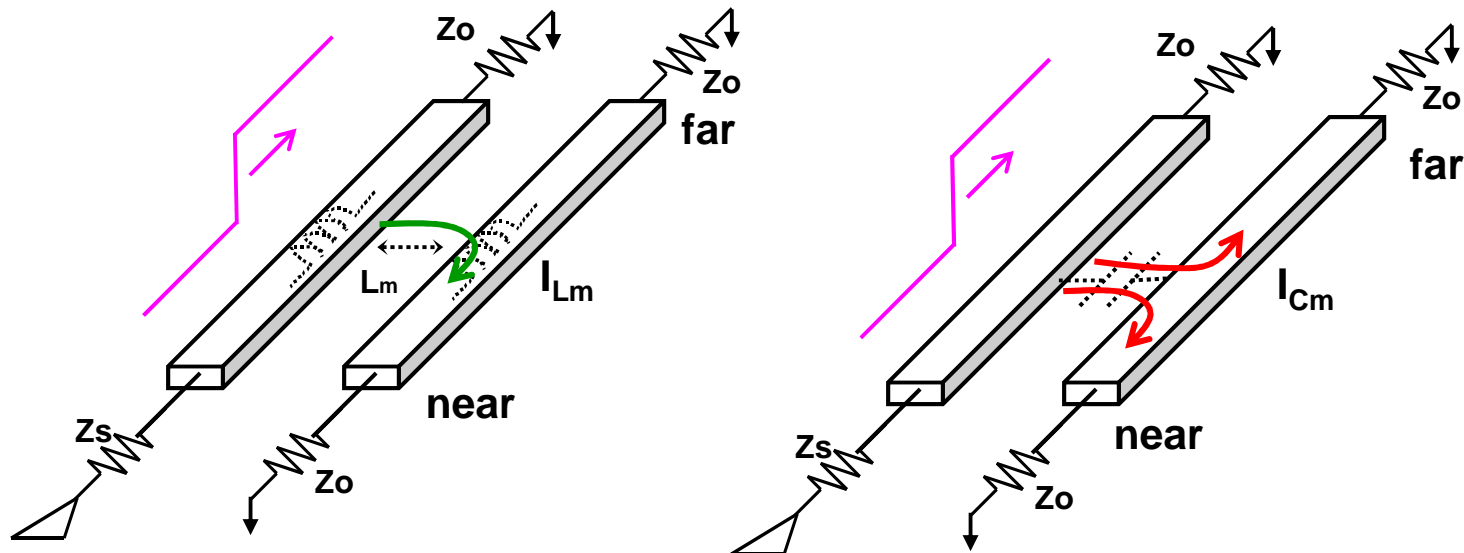
What is crosstalk?

- Crosstalk is the undesired coupling of energy from one transmission line to another
 - Magnetic and electric fields incite mutual fields in adjacent lines (in both forward and reverse directions)
 - Radiating structures (wire bonds, via stubs) couple energy to/from a resonant package or substrate mode
- Crosstalk is a problem for high-speed, high-density signal routing in complex 3D structures



What is crosstalk?

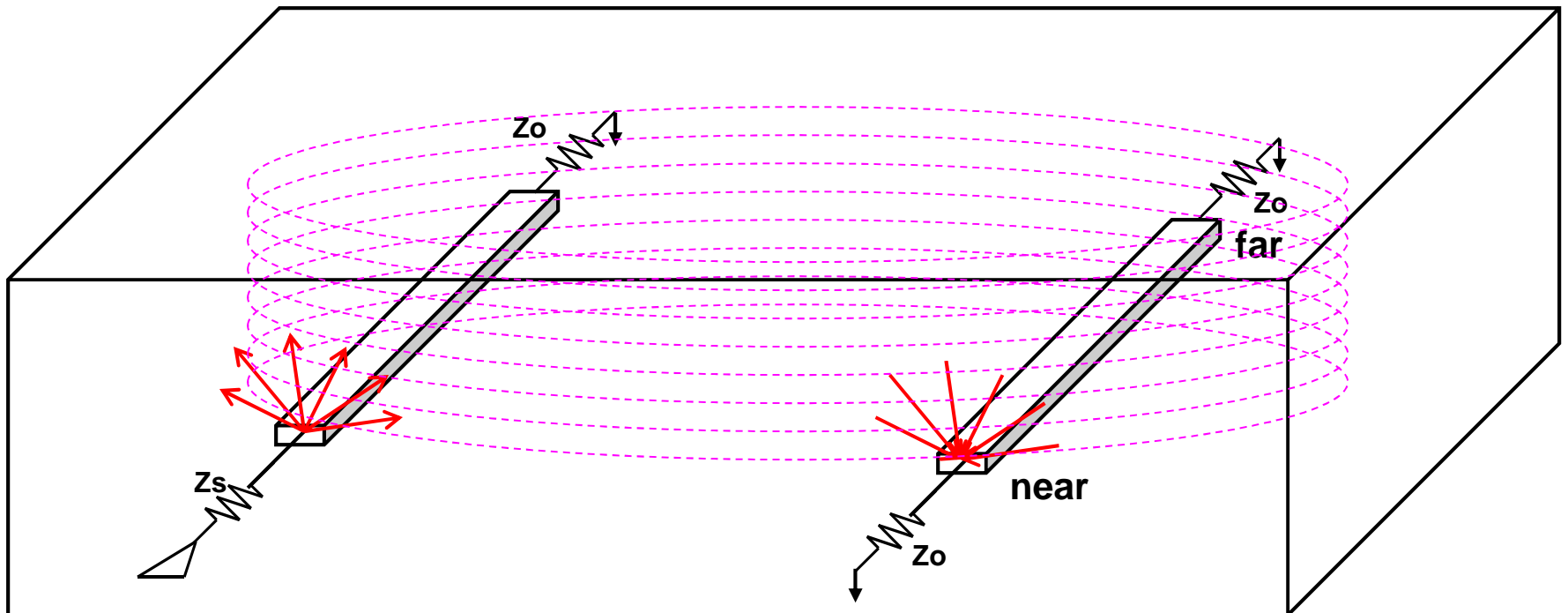
- Magnetic and electric fields incite mutual fields in adjacent lines (in both forward and reverse directions)¹





What is crosstalk?

- Radiating structures (wirebonds, via stubs) couple energy to/from a resonant package or substrate mode





What is crosstalk?

- **Crosstalk causes signal integrity problems:**
 - Increased noise levels (decreased SNR)
 - Increased jitter on data edges (closed eyes)
 - Reflections of undesired signals (reduced sensitivity)
- **Crosstalk can be mitigated by design changes**
 - Separate traces further apart, use short traces, route on different layers, route traces orthogonally, use differential signaling
 - But lots of long lines close together are hard to avoid!



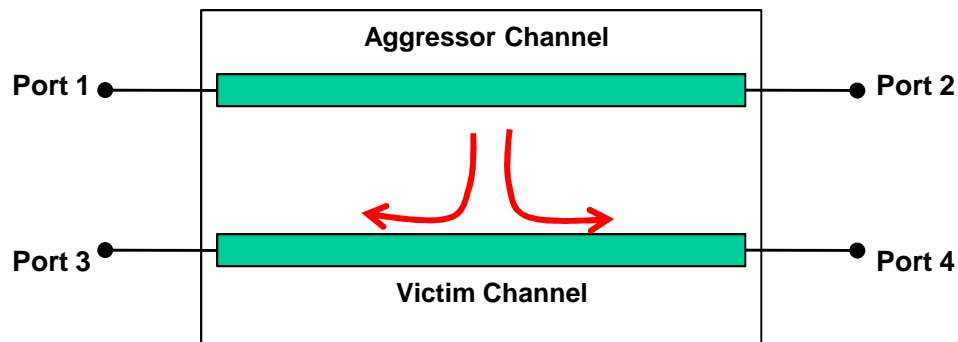
How is crosstalk measured?

- Crosstalk can be measured many different ways
 - Frequency-domain measurement of an induced signal
 - Measures aggressor and victim channel S-parameters
 - Requires a 4-port vector network analyzer
 - Time-domain measurement of an induced signal
 - Measures induced signal amplitude and pulse width
 - Requires a pulse generator and an oscilloscope
 - Time-domain measurement of victim channel jitter
 - Measures the increase of jitter on a victim channel due to aggressor channel traffic
 - Requires pattern generator(s) and oscilloscope/BERT



How is crosstalk measured?

- Frequency-domain measurement of an induced signal
 - Measures multi-port aggressor and victim channel S-parameters
 - Requires a 2+ port vector network analyzer²



Measure S-parameters of
victim channel
(S43, S33, S44 etc)

and

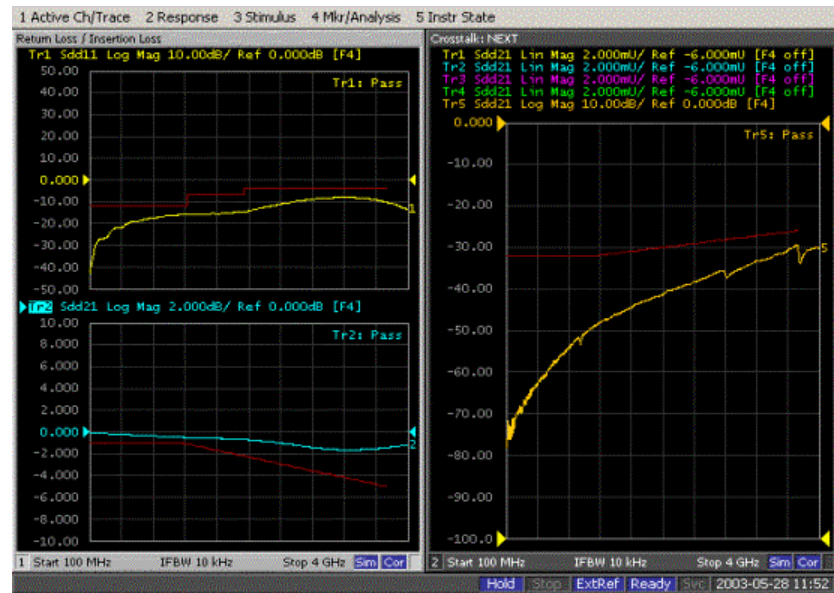
crosstalk from aggressor
channel
(S41, S31, S32, S42 etc)

How is crosstalk measured?

- Frequency-domain measurement of an induced signal
 - Good for analog circuitry, essential for measuring package or substrate resonances, but not useful for high-speed data!



1. This 12-port VNA system makes mixed-mode and balanced differential S-parameter measurements from 40 MHz to 65 GHz.



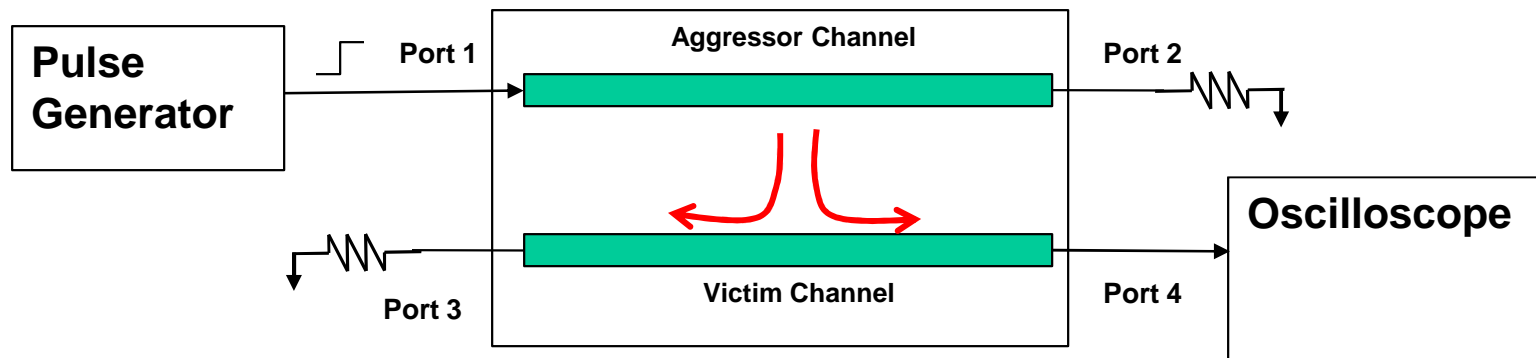
S-parameters are difficult to relate to eye diagrams.

Are the S-params on the left good or bad?
How bad?



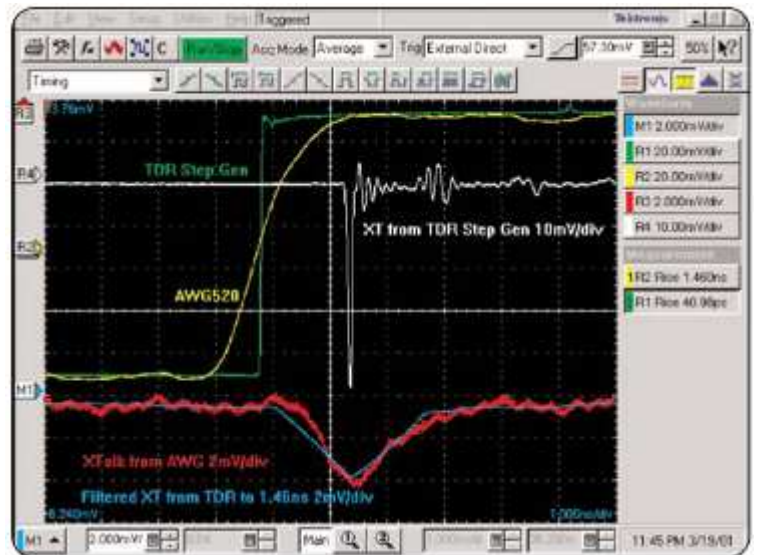
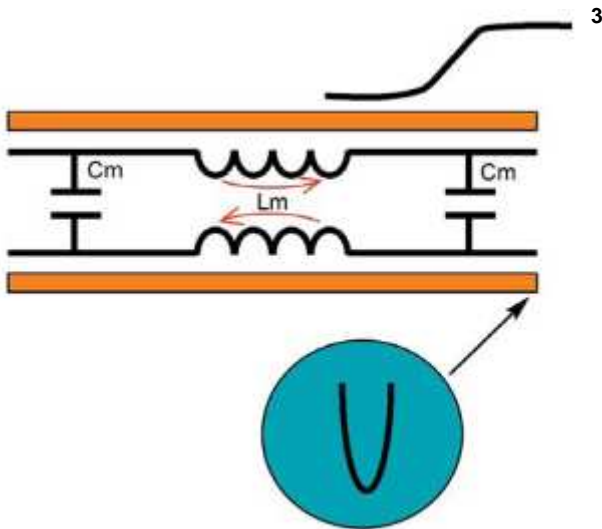
How is crosstalk measured?

- Time-domain measurement of an induced signal
 - Measures induced signal amplitude and pulse width
 - Requires a pulse generator and an oscilloscope³



How is crosstalk measured?

- Time-domain measurement of an induced signal
 - Measures the induced signal from one aggressor, but unclear how this impacts the victim channel eye and does not address high-density layouts with multiple aggressors

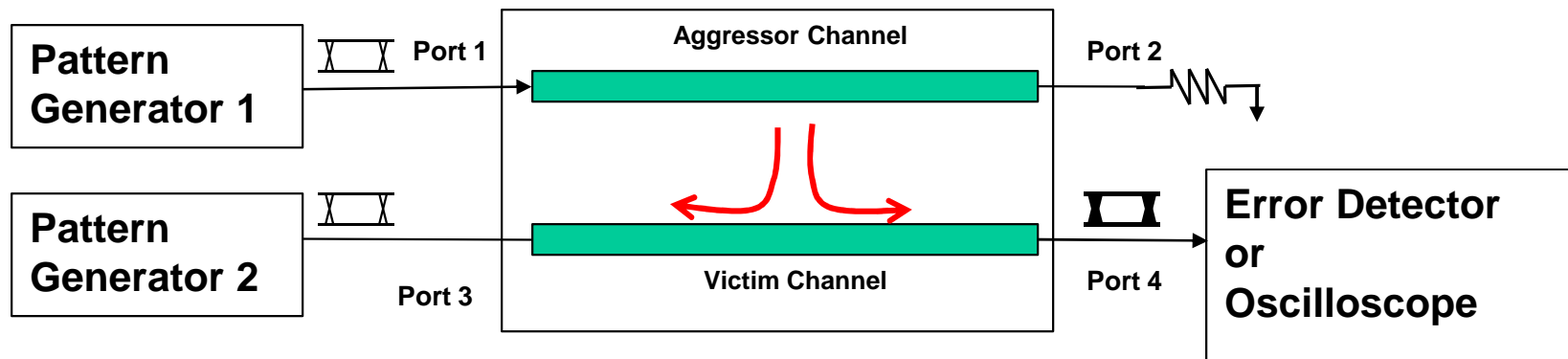


Nice results, but how can this be used to determine the impact of crosstalk on the victim channel?



How is crosstalk measured?

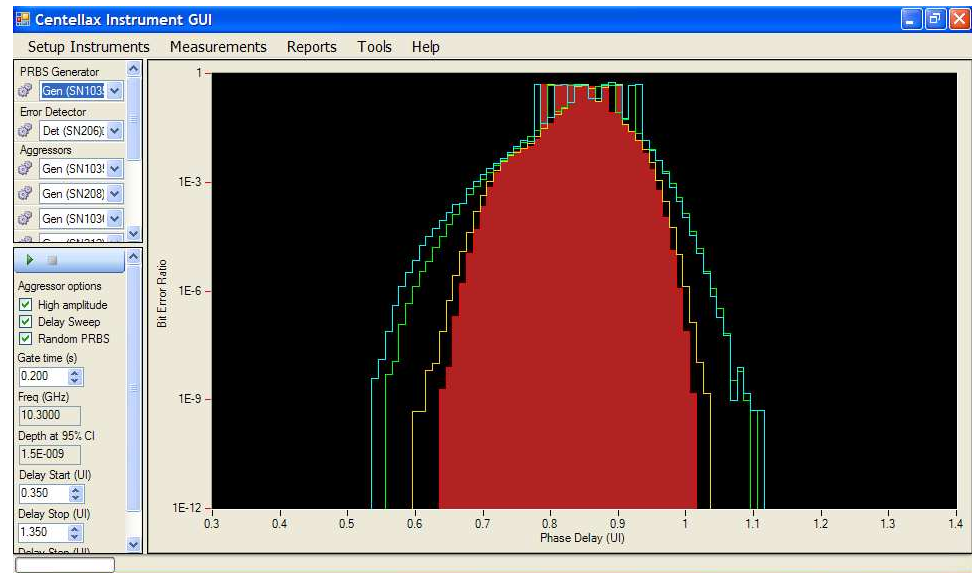
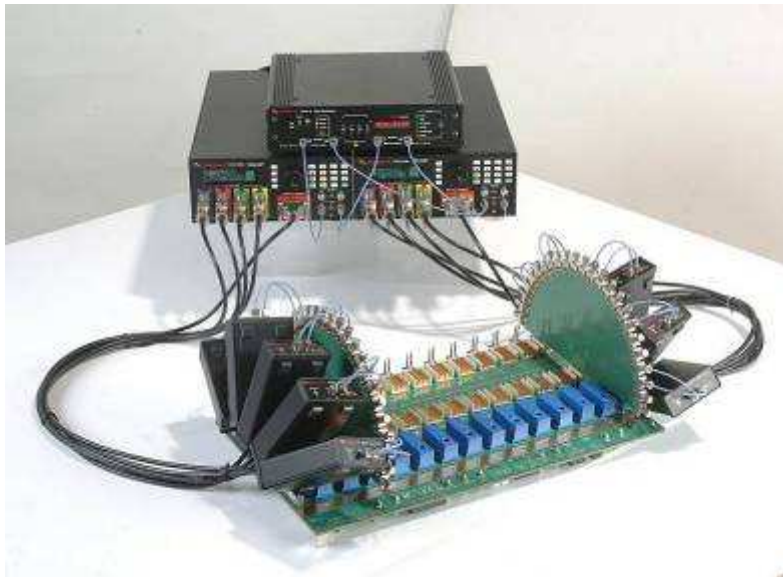
- Time-domain measurement of victim channel jitter
 - Measures the increase of jitter on a victim channel
 - Requires pattern generator(s) and oscilloscope/BERT



How is crosstalk measured?

- Time-domain measurement of victim channel jitter
 - This method accounts for multiple aggressors and measures the most important metric of a datacom link: the eye opening

Direct measurement of TJ (total jitter) with & without aggressors shows effect of crosstalk on eye opening





How is crosstalk measured?

- **Crosstalk measurement methods are different**
 - Methods may be determined by available equipment
 - Different methods measure different things!
 - Results may not be useful for your application
- **So how should I measure crosstalk?**
 - Depends on your application and what you want to do with the results
 - For data signals, victim channel T_j measured in the presence of aggressors yields most useful results



BER-based crosstalk method using a multi channel BERT

- Time domain measurement of victim channel jitter
 - Victim channel is stimulated at the ‘near’ end with a PRBS generator, channel is tested at the ‘far’ end with error detector
 - Neighboring aggressor channels are stimulated at the near or far ends; other end of aggressor channels are terminated in 50ohm loads
 - Aggressor setup for maximum crosstalk effect (worst-case):
 - All neighboring channels stimulated with aggressors (some near-end, some far-end) at full electrical line rate
 - Aggressor edges intentionally skewed relative to victim transmitter edges
 - Complex routings will have unclear relationship between victim channel and aggressor channel edges; swept edges necessary
 - Adjustable amplitude, de-emphasis, PRBS pattern, etc



BER-based crosstalk method using a multi channel BERT

- **Crosstalk measurement: jitter added by aggressors**
 - Total jitter (TJ) measured at a BER depth with 95% confidence interval
 - BER depth of 1E-9 with 95% CI is only a 300ms measurement at 10.3125Gb/s
 - BER tester is the most accurate method of measuring TJ^{4,5,6}
 - Every single bit is measured; no fancy forecasting math is involved
 - BER-based crosstalk measurement:
 1. Measure victim channel TJ with aggressors turned off
 2. Measure victim channel TJ with aggressors turned on (+ adjust settings)
 3. The difference in the victim channel TJ is crosstalk!
 - Adjusting aggressors enables insight into what's causing the crosstalk:
 - NeXT (near-end crosstalk): turn on near-end aggressors, others off
 - FeXT (far-end crosstalk): turn on far-end aggressors, others off
 - Amplitude, de-emphasis, PRBS pattern: adjust aggressor settings
 - Data edges: sweep the delay on each aggressor clock (this is hard!)



Centellax crosstalk solution

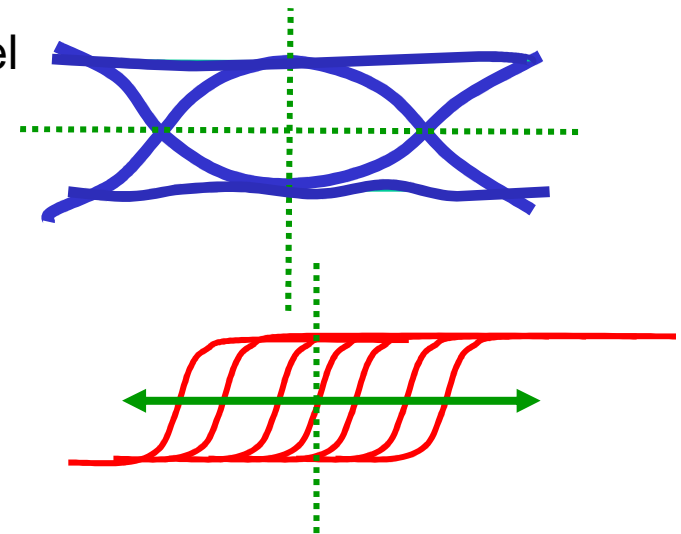
- Based on PCB12500 Parallel Channel BERT
 - Each PCB12500 controls up to five remote heads
 - Remote heads can be PRBS Generator or Error Detector
 - Multi-channel design allows for LOTS of aggressors!
 - Each channel (aggressor or victim) has fully adjustable:
 - Amplitude (0.2 to 2V in 0.005V steps)
 - Offset (-1.8 to +1.8V in 0.005V steps)
 - Crossover (20 to 80%)
 - De-emphasis (0-20dB; two tap – one post cursor)
 - Patterns PRBS 2^N-1 (N=7, 10, 15, 23, 31), and 1010.., 11001100..
 - Channel skew (-1,000 to +1,000UI in 0.001UI steps!)
 - Automatic delay sweep (1, 2, 4UI p-p)



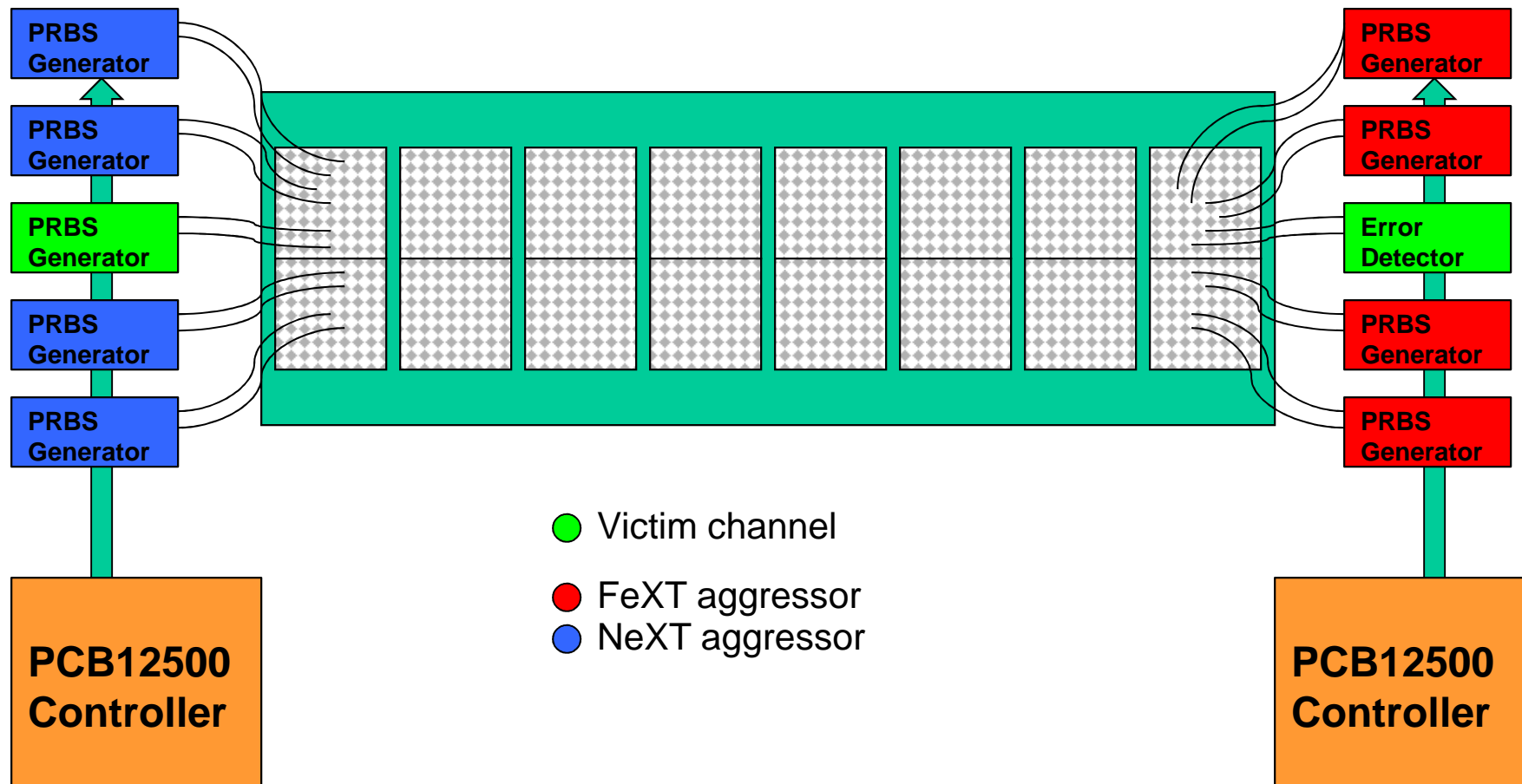


Centellax crosstalk solution

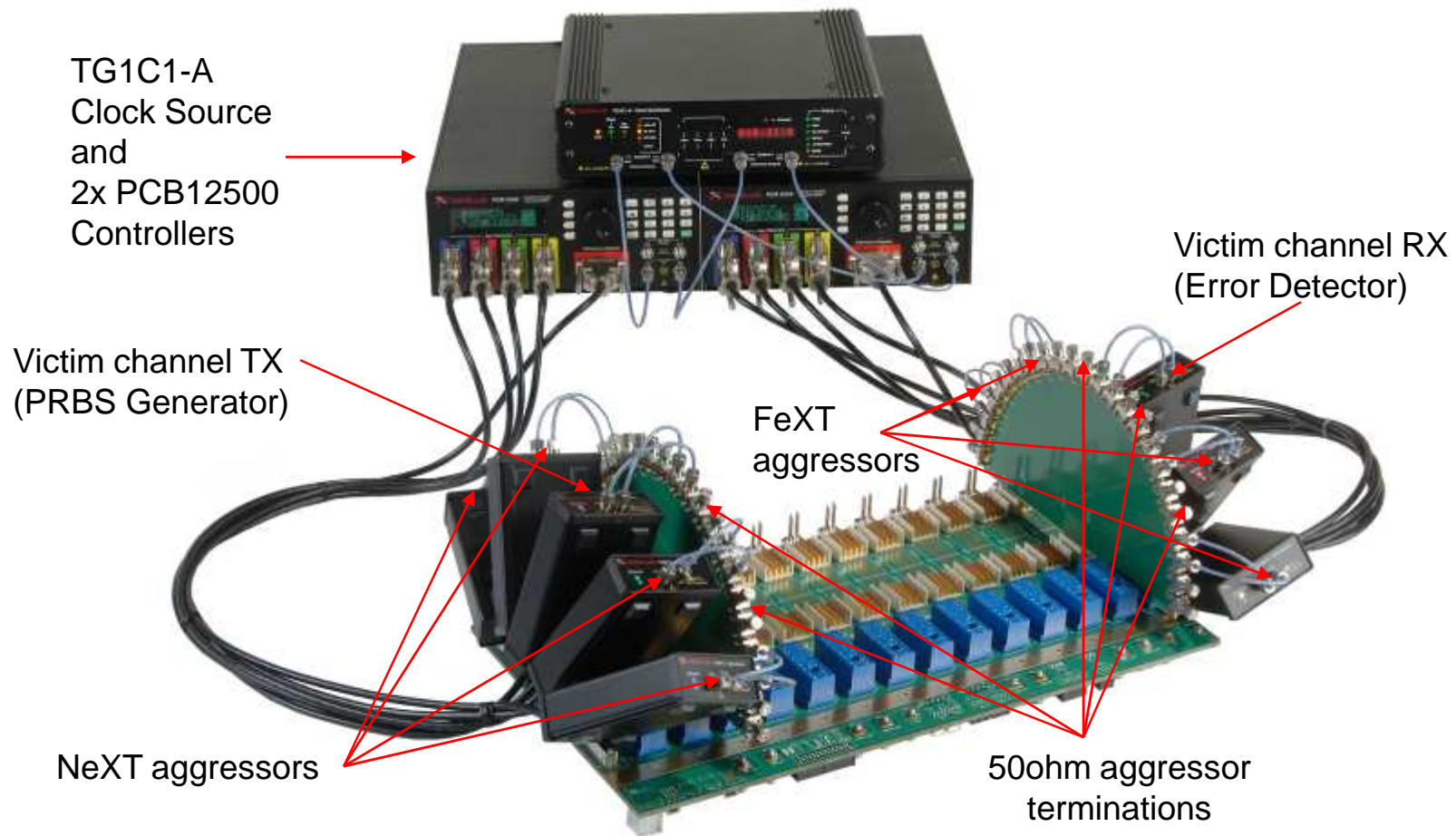
- Automatic Delay Sweep PCB12500
 - Each channel can be configured with automatic delay sweep (0, 1, 2, or 4UI p-p)
 - Victim is most susceptible to crosstalk induced errors at receiver sampling point, near center of eye
 - Effective crosstalk testing requires varying the phase of the aggressors
 - Delay Sweep function sweeps data channel phase relative to clock
 - Triangular modulation, different frequency on each channel (7-19Hz)



Centellax crosstalk solution - high-speed backplane example



Centellax crosstalk solution - hardware





Centellax crosstalk solution - software

Instrument finder

Instrument selection

Selected instrument configuration

The screenshot displays the Centellax Instrument GUI with the following components:

- Menu Bar:** Setup Instruments, Measurements, Reports, Tools, Help
- Search Bar:** Find, Query All, Query
- Instrument List (Left Panel):**
 - Enabled Instruments
 - TG1C1-A (SN3005) GPIB0::16
 - PCB12500 (SN112) GPIB0::19
 - Gen (SN1035) CH0 PCB12500 (S)
 - Gen (SN208) CH1 PCB12500 (SN)
 - Gen (SN1036) CH2 PCB12500 (S)
 - Gen (SN212) CH3 PCB12500 (SN)
 - Gen (SN1035) CH4 PCB12500 (S)
 - PCB12500 (SN111) GPIB0::18
 - Gen (SN1023) CH0 PCB12500 (S)
 - Gen (SN221) CH1 PCB12500 (SN)
 - Gen (SN220) CH2 PCB12500 (SN)
 - Gen (SN1034) CH3 PCB12500 (S)
 - Det (SN206) CH4 PCB12500 (SN)
 - Other Instruments

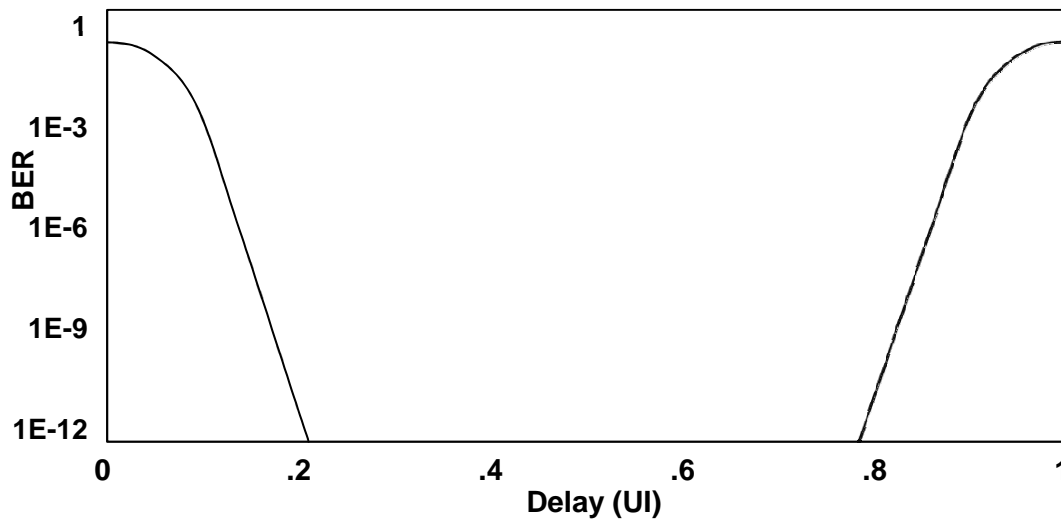
- Configuration Panel (Right):**
- Input:
- Pattern: PRBS7
- Offset (V): 0.000
- Term (V): 0.000
- Auto Threshold:
- Threshold Step (V): 0.020
- 0/1 Threshold (V): 0.000
- Auto Delay:
- Delay Step (UI): 0.020
- Delay (UI): 0.350
- Skew (UI): 0.000
- Auto Align:
- Gate time (ms): 0.010
- 95% BER Depth: 0.0E+000
- Status Bar (Bottom):** CH4 PCB12500 (SN: SN206) Det 4.0-2.0



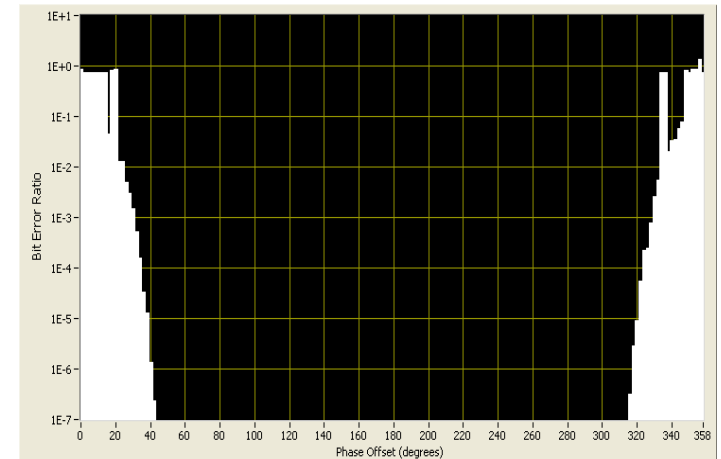
Centellax crosstalk solution – software “bathtub curve”



Data Eye Diagram

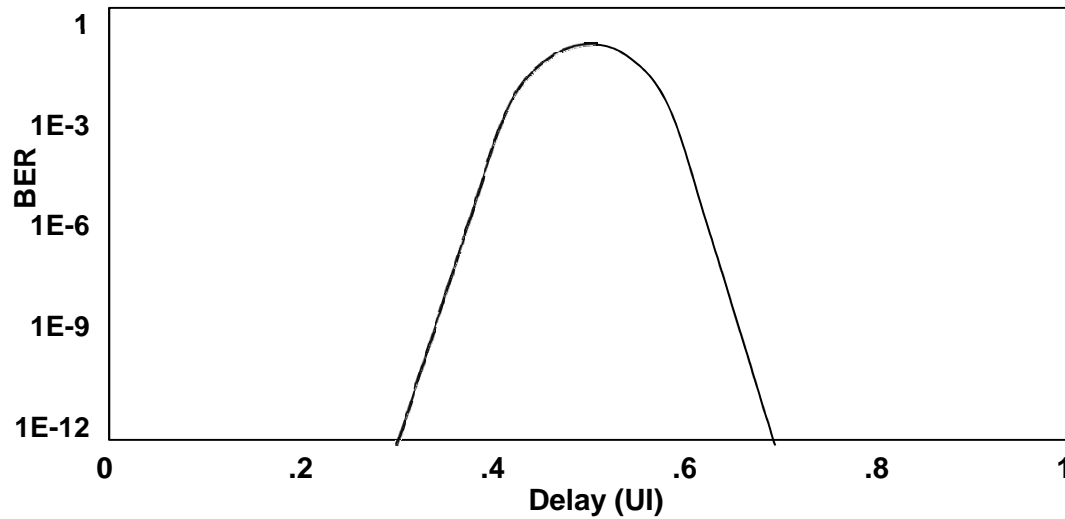


“Bath tub”
Jitter vs Delay
across Data Eye

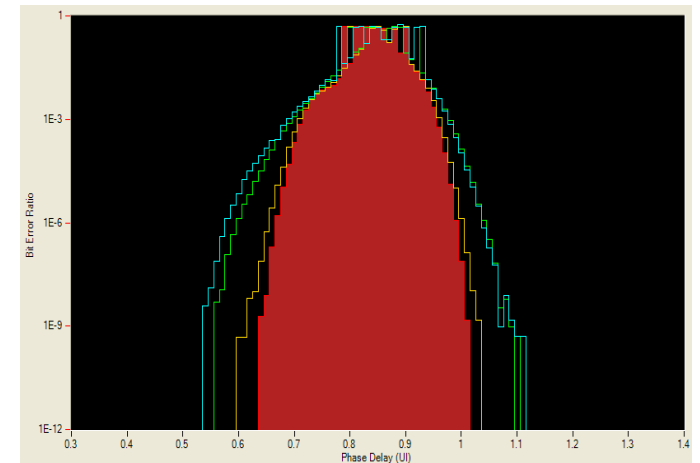




Centellax crosstalk solution – software “alternate bathtub curve”



“Bath tub”
Jitter vs Delay
across Data Eye





Centellax crosstalk solution - software

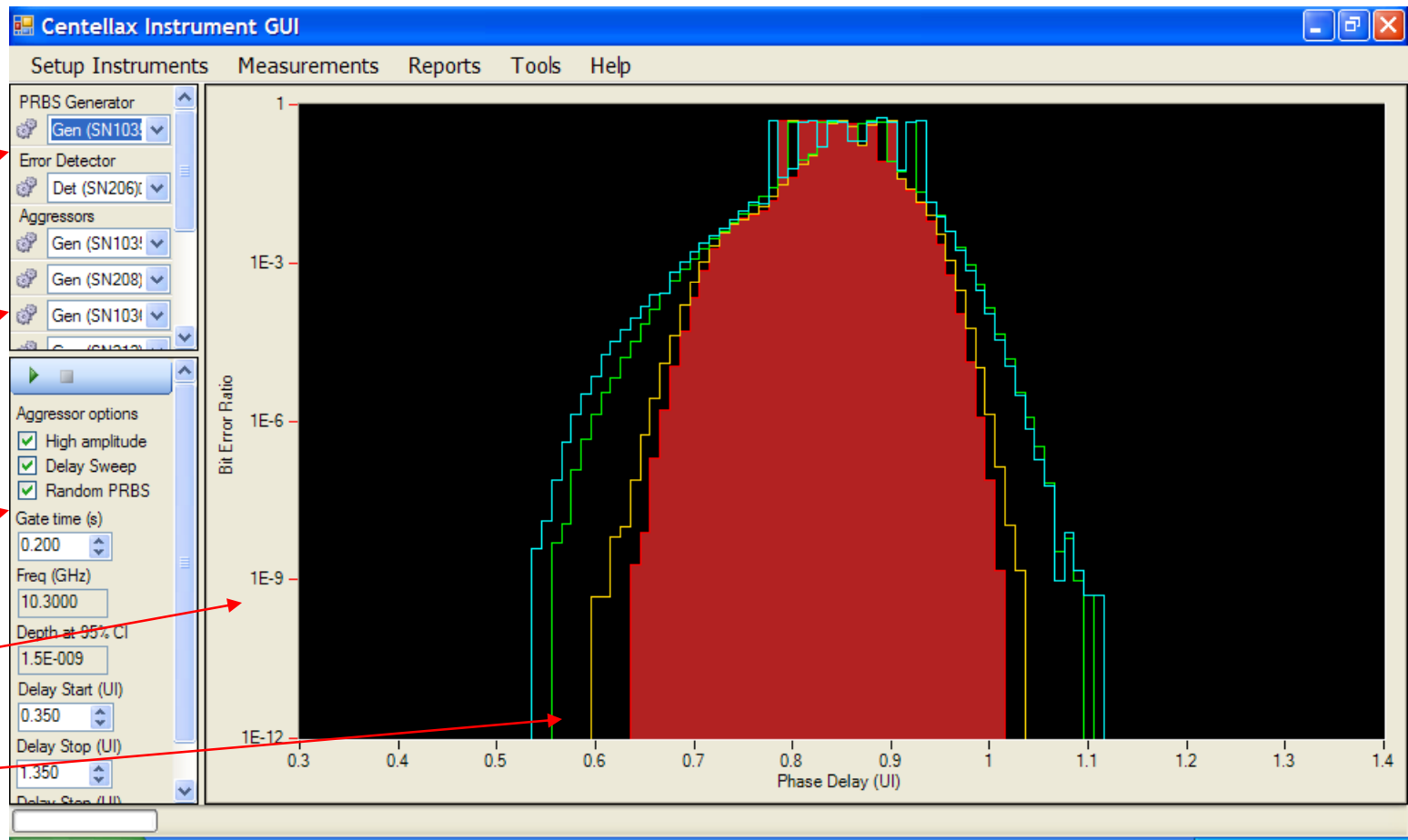
Victim channel selection and setup

Aggressor channel selection and setup

Measurement configuration

Measurement results

Change in TJ based on crosstalk!



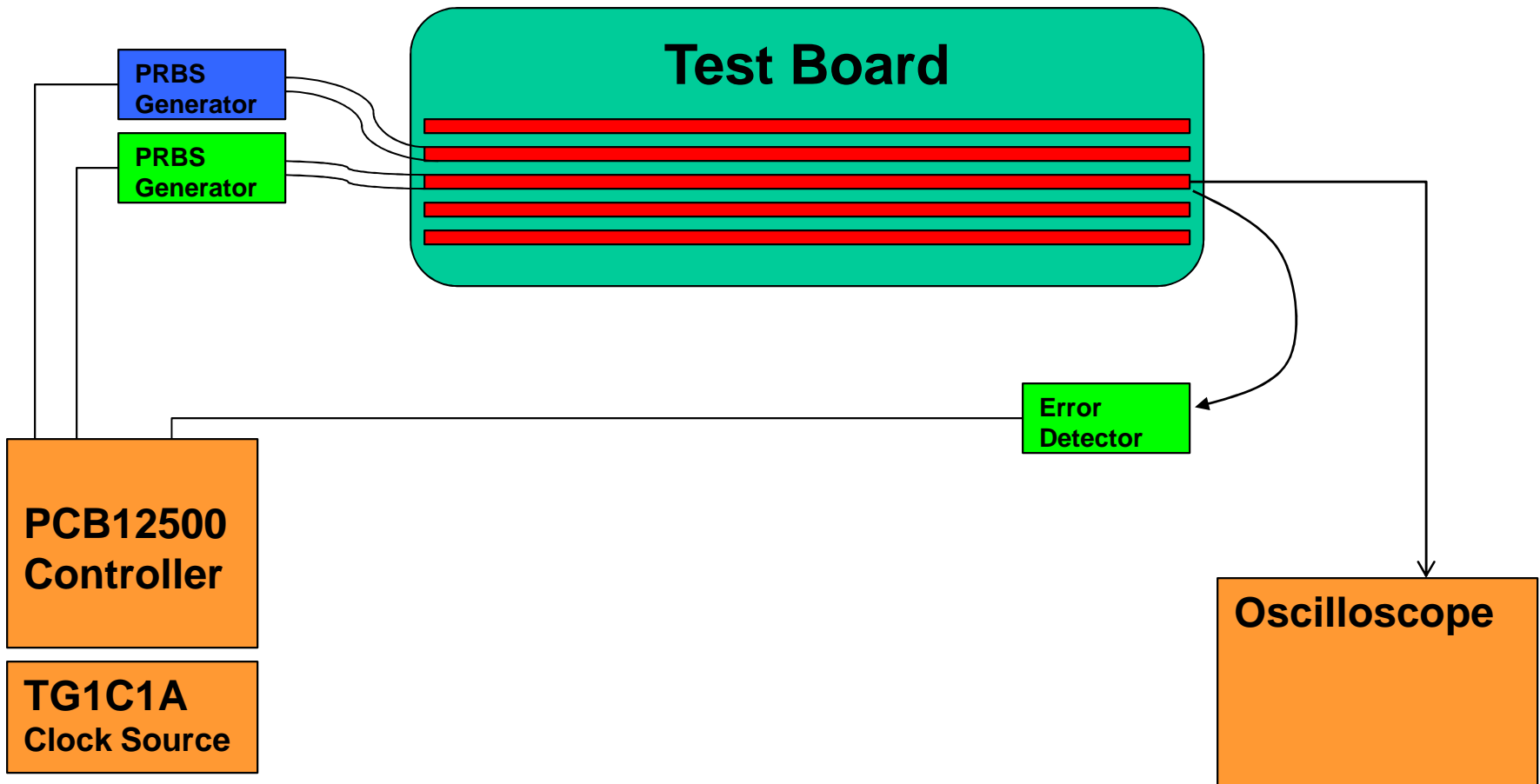


Centellax crosstalk solution – measurement capability

- Crosstalk is measured by TJ(BER) addition
 - Based on BER measurements made by PCB12500 e.g.
 - $TJ(BER)_{no_aggr}$: victim measured with aggressors off
 - $TJ(BER)_{low_ampl_aggr}$: victim measured with 0.5V aggressors
 - $TJ(BER)_{high_ampl_aggr}$: victim measured with 2V aggressors
 - $TJ(BER)_{max_aggr}$: victim measured with 2V aggressors with delay sweep 'interference' feature
 - Crosstalk impairment = $TJ(BER)_{no_aggr} - TJ(BER)_{whichever}$
 - Automated measurement run from control software
 - Report generation capability for use in R&D, characterization, or production test verification



Crosstalk Demo



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SPEED INNOVATION



Questions?

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References

1. Intel Higher Education – ELCT 762, “Signal Integrity for High Speed Integrated Circuits”,
<http://www.intel.com/education/highered/Signal/elct762.htm>
2. Anritsu MWRF T&M article, “12-Port VNA Characterizes Crosstalk on High-Speed Lines”,
<http://www.mwrf.com/Article/ArticleID/18370/18370.html>
3. Tektronix Application Note, “Time Domain Methods for Measuring Crosstalk for PCB Quality Verification”,
<http://www2.tek.com/cmswpt/tidetails.lotr?ct=TI&cs=Application+Note&ci=11499&lc=EN>
4. Texas Instruments Application Report SLLA064, “Measuring Crosstalk in LVDS Systems”
5. Maxim Application Note HFTA-12.0, “Measuring Crosstalk Penalty in High-Speed Bidirectional Serial Communication Modules”,
<http://pdfserv.maxim-ic.com/en/an/AN3766.pdf>
6. Agilent AnalogZone article, “The Rules of Jitter Analysis”,
<http://www.analogzone.com/nett0927.pdf>