



StatEye supports MMF

www.StatEye.org

Independent, Non-partisan, Neutral

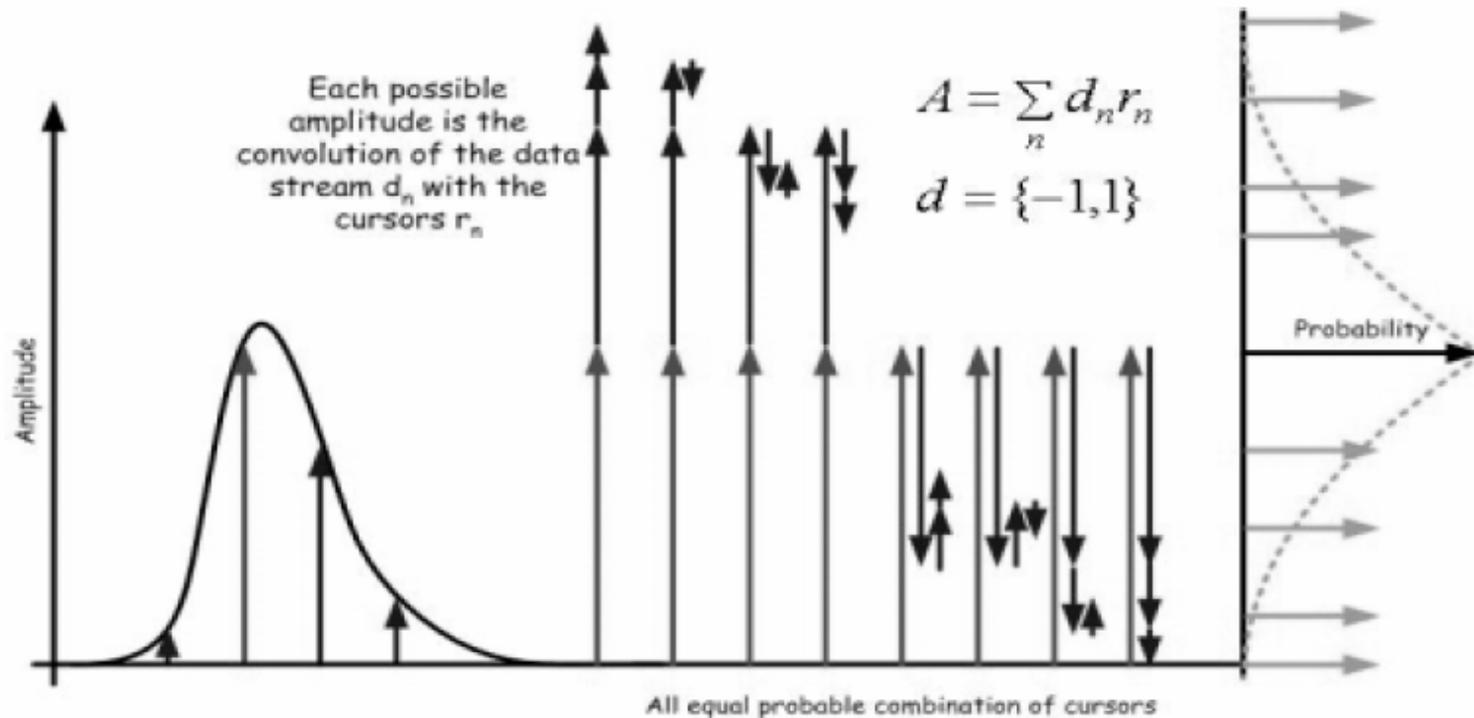


- ◆ StatEye is a physical layer simulation tool, originally developed by Anthony Sanders of Infineon
- ◆ <http://www.StatEye.org/> was launched in April 2004 by all developers
- ◆ StatEye is independent of any commercial company
- ◆ StatEye now being used or considered by 7 different standards organisations
- ◆ StatEye.org is non-partisan, neutral
- ◆ Focus is to get the truth, good or bad, in minutes instead of the months involved in getting same information using SPICE, so we can develop solutions that address the issues and avoid distractions

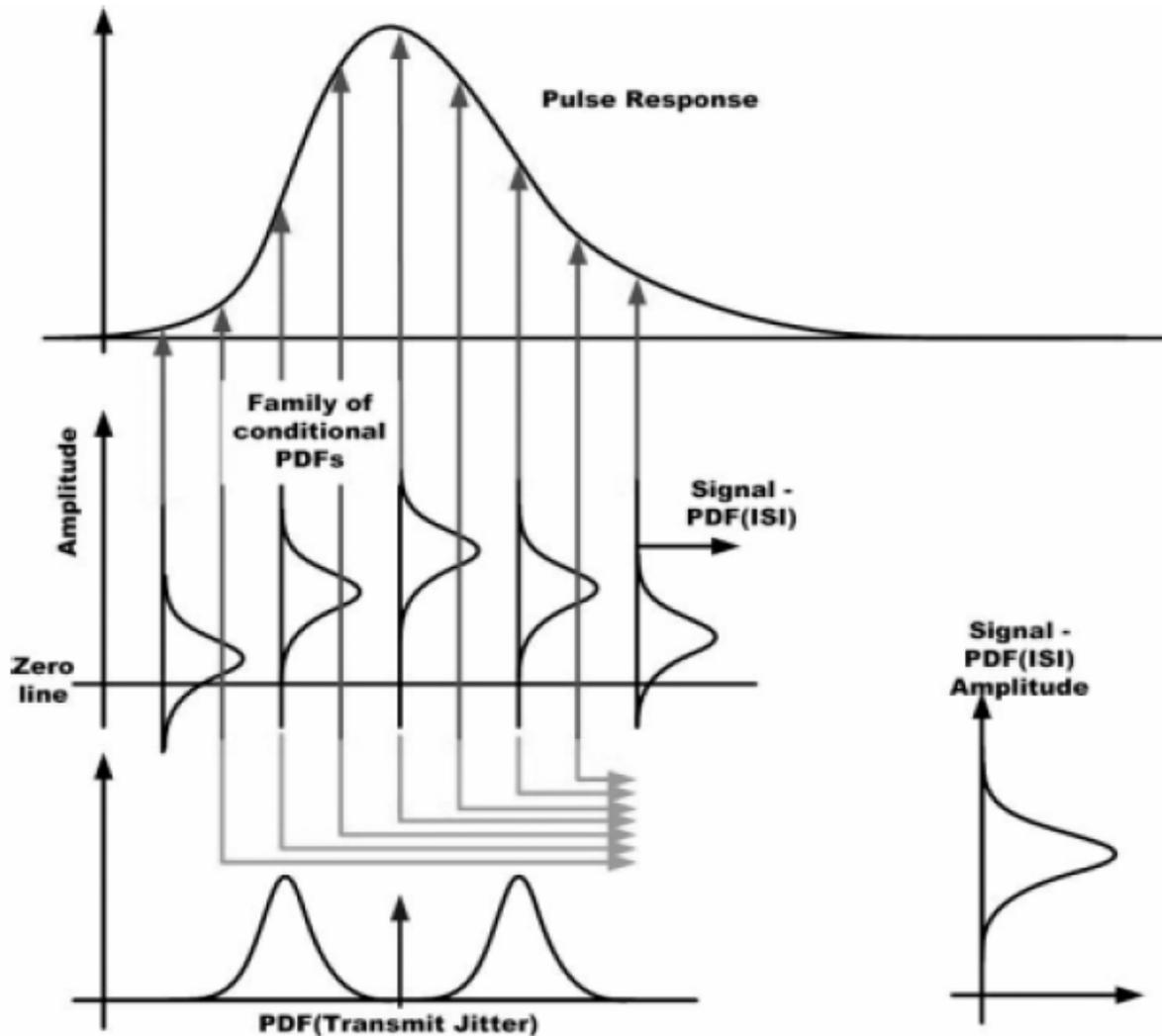
Open Source, Open Forum, Open Box



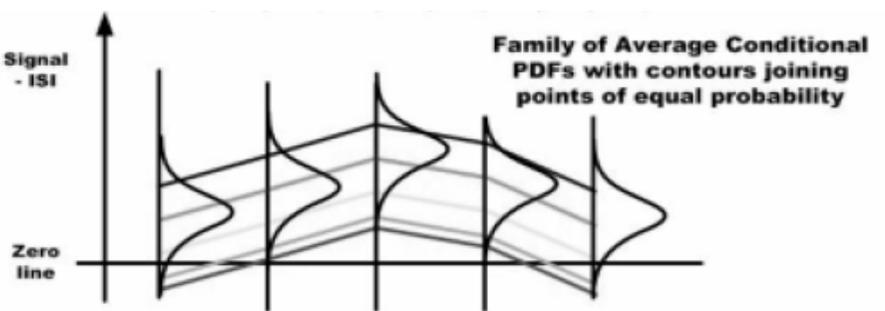
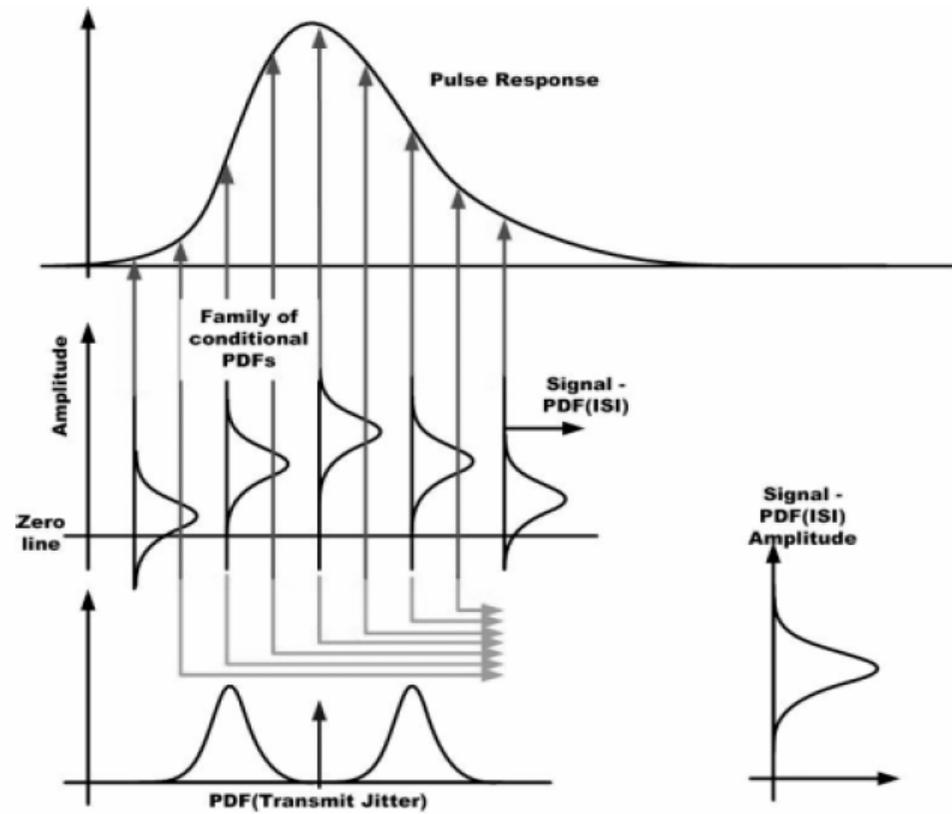
- ◆ StatEye is completely **Open Source**
- ◆ The **Open Forum** mean developers debate improvements, do changes and verify the StatEye completely publicly
- ◆ Documentation pack makes it is easy to see everything inside the box and understand StatEye to the finest technical detail: it is exemplary in being **Open Box**
- ◆ The StatEye **theory is published** under
<http://www.stateye.org/presentation.php>



- ◆ Cursors are derived from system pulse response.
- ◆ Convolution with random data stream gives all equal probable combination of cursors. Each cursor could occur as +1 (logical 1 in data stream) and -1 (logical 0 in data stream)
- ◆ Probability of a given ISI can be calculated, more details see www.stateye.org



- ◆ For each arbitrary sample point within the pulse response a Conditional PDF can be calculated, forming a family of Conditional PDFs
- ◆ Given an arbitrary receiver sampling point with no jitter then the associated PDF sampled is simply the already generated Conditional PDF from the family of PDFs. If the sampling point is jittered with a known distribution then the sampling sees an average conditional PDFs



- ◆ For each sampling point within the pulse response a conditional PDF can be calculated
- ◆ If the sampling point is jittered with a known distribution then the sampling sees an average conditional PDF
- ◆ The points of equal probability can be drawn creating the StatEye. The StatEye shows the probability of receiving a specific amplitude for a given arbitrary receiver sampling point.

- ◆ The StatEye source and documentation is on http://www.stateye.org/released_scripts.php and has a Beta area also.
- ◆ StatEye has Megabytes of comments and diagrams in commented script

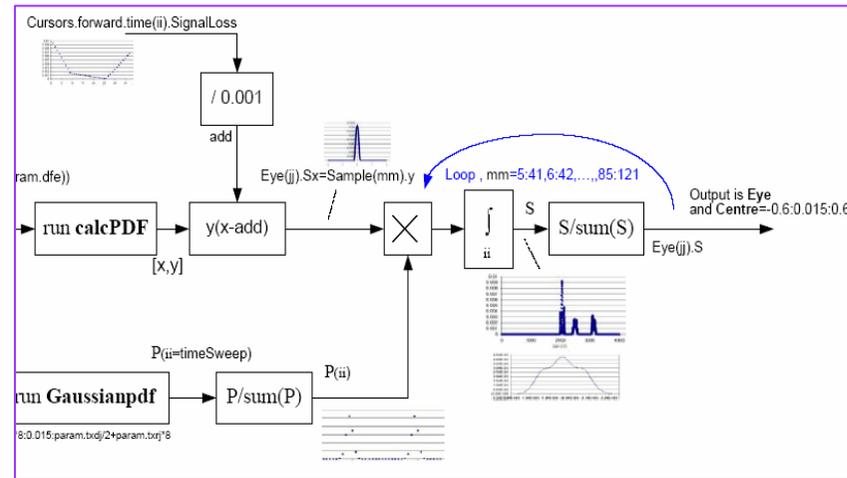
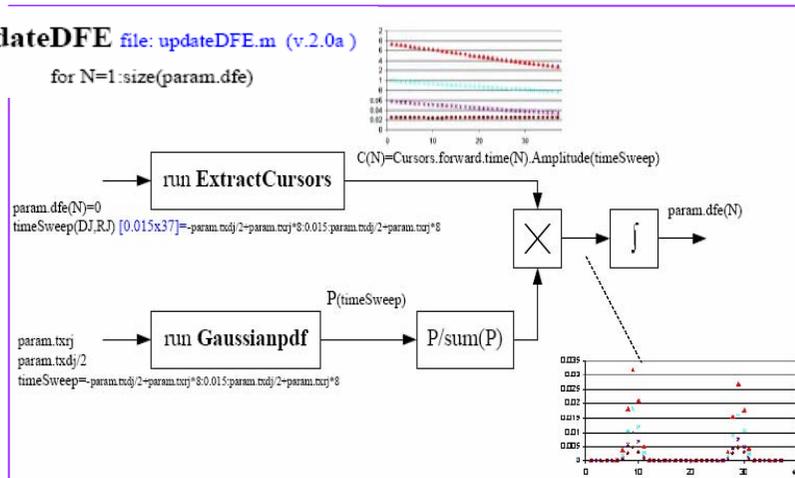
```

Cpad = (320e-15+150e-15)*param.cpad;          Cpad = 3.5250e-013
Rterm = 50+10;
Cg = 100e-15;
Rs = 200;
Z = 1./(data.iw .* Cpad + 1./Rterm + (1 ./ (Rs + 1./Cg ./ data.iw)));    Z(1x401)
                                data.iw = data.f * 2*pi*j    - jw frequency or s
                                data.iw = 0 +3.1416e8i: 0 +3.1416e8i: 0 +1.2598e11i
    
```

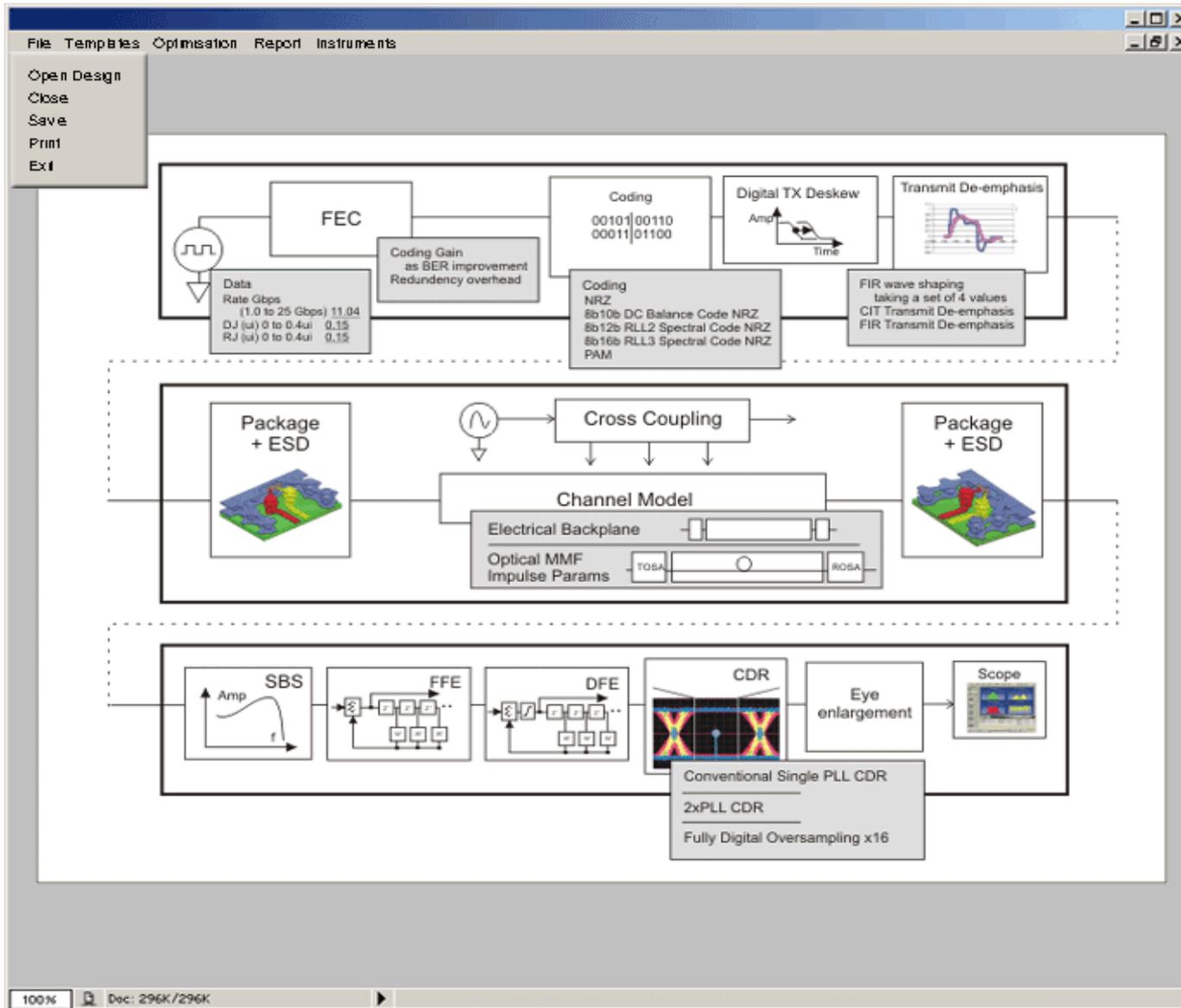
$$Z = \frac{1}{s \times Cpad + \frac{1}{Rterm} + \frac{1}{Rs + \frac{1}{Cg \times s}}} = \frac{Rterm(RsCgS + 1)}{RsRtermCpadCgS^2 + RtermCgS + 1} \text{ where } s = j\omega$$

- ◆ Full block and flow diagrams of all routines

Function **updateDFE** file: **updateDFE.m** (v.2.0a)



Using StatEye



Driven from Matlab 6.5 script with parameters or new GUI (shown)

Generates a 1 UI pulse

Adds RJ and DJ

Shapes pulse for slew rate of silicon

User can apply any combo of techniques shown on diagram

Filters such as DFE can be optimised automatically

Includes non-linear components such as DFE

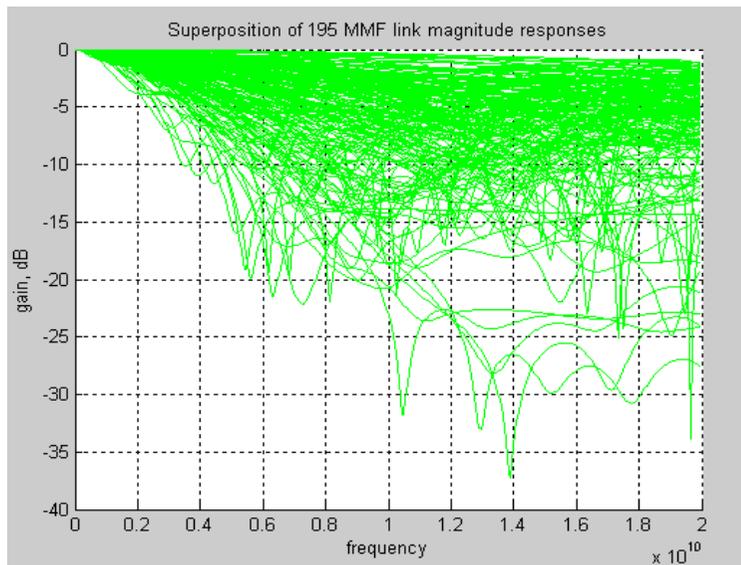
Computes ISI

Shows output pulse, spectrum, bathtub curve and eye diagram for different BERs.

Working with MMF Measurement Data



- ◆ StatEye can use a channel defined by S Parameters, ABCD parameters, Amplitude Frequency Response, or by Fibre Modal Power Factors and provides tools to convert ABCD to S Params and Power Factors to AFR
- ◆ Model Power Factors and AFR are in the same general format as Cambridge 300m MMF data
- ◆ Fibres described by AFR or modal power factors can be modelled in series with TOSA/ROSA defined by S Parameters



Here is the Cambridge AFR data read by the StatEye, for all fibres.

The AFR is a linear approximation of a MMF response.

StatEye Rev 2.1b supports Modal Data in its non-linear fibre model. We are finding the results virtually the same with linear and non-linear models.

Without EDC on Cambridge MMF, BER is gross



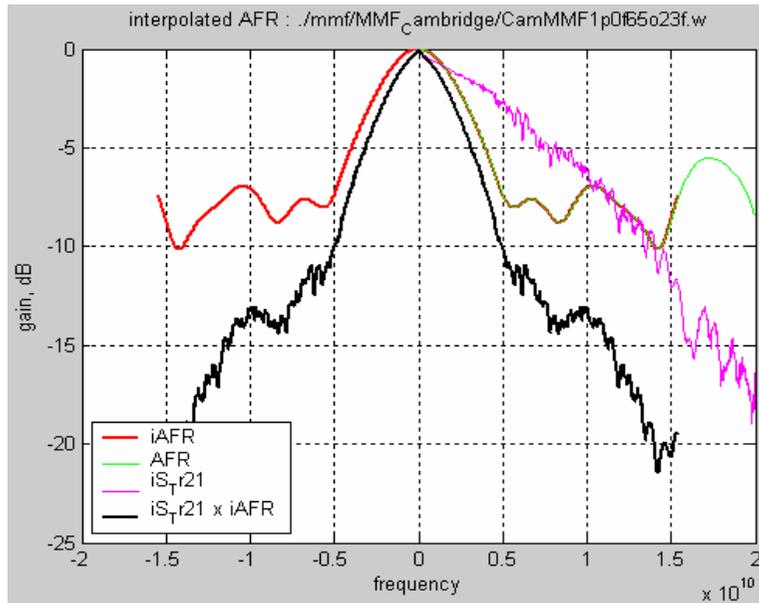
Fibre: CamMMF1p0f65o23f.w

Baud rate: 10.3125Gbps

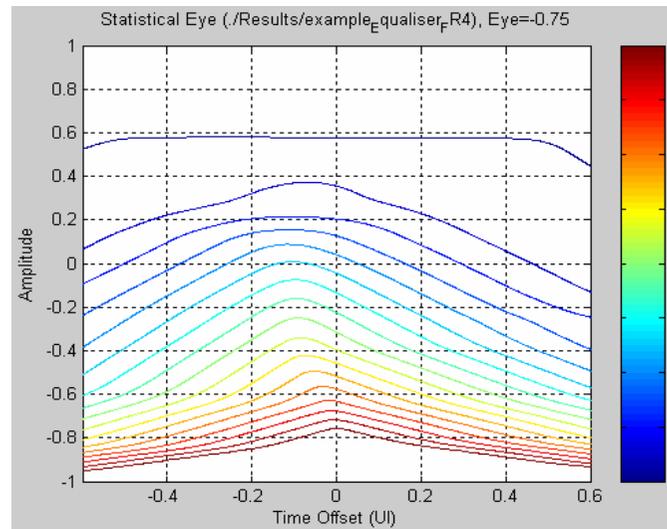
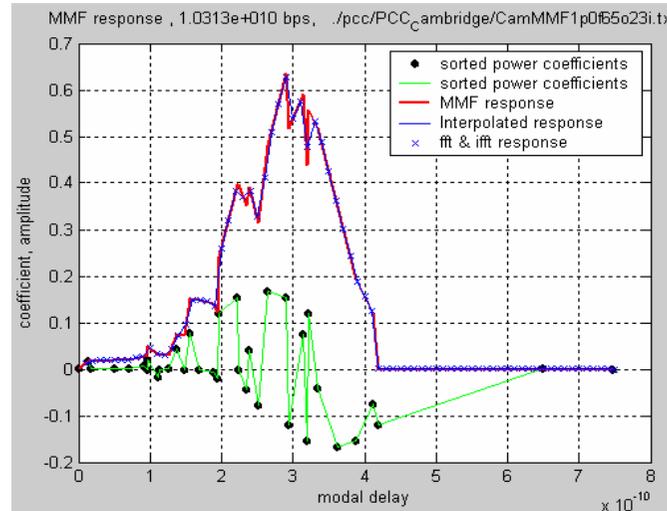
RJ: 0.15UI

DJ: 0.15UI

Raw channel: pre, post, FFE and DFE off



Red, Green is AFR
 Brown is AFR interpolated and truncated to 15GHz
 Pink is the TOSA+ROSA response (S params)
 Black is the combined channel response



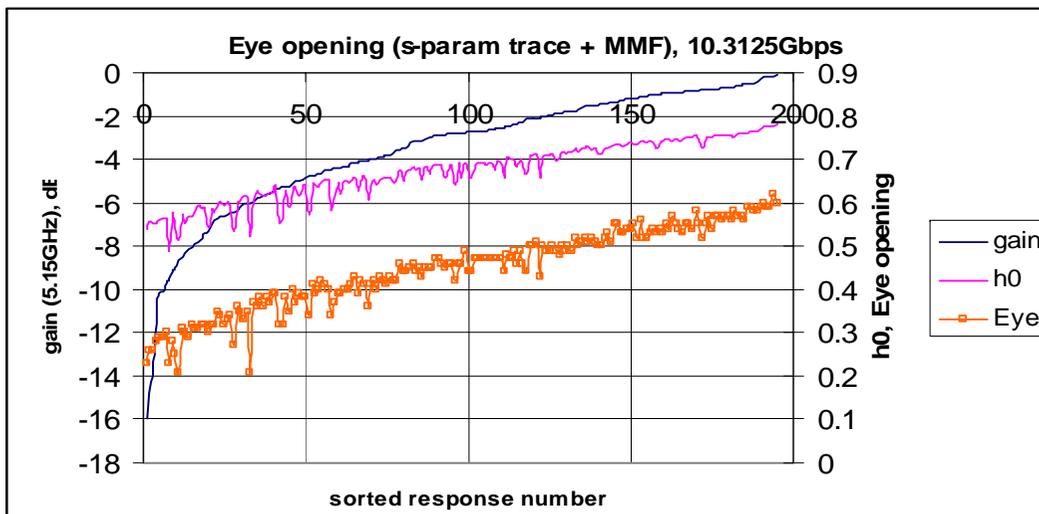
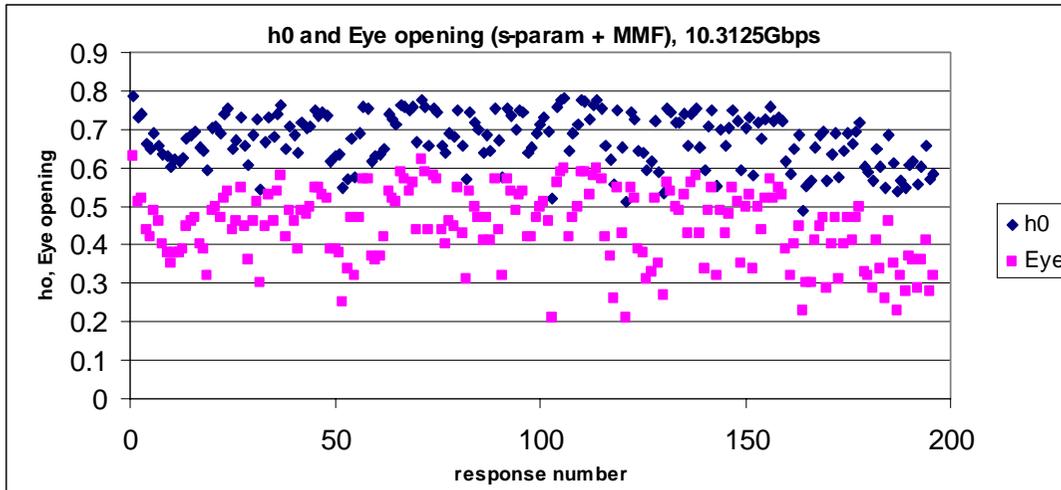
Received pulse is highly distorted in non-linear and linear models.

Modal power coefficients (green) with large amplitude are spread over more than 1 UI

Error from time to frequency transforms and rounding in the StatEye is tiny (red and blue lines)

ISI computed by StatEye results in a BER of $1 \text{ in } 10^{-3}$

With EDC all Cambridge fibres are useable



StatEye Simulation includes a TOSA/ROSA, chip parasitics etc

EDC Comprised:

- Transmit De-emphasis
- DFE, 5 tap
Seed 0.3, 0.1, 0.1, 0.1, 0.1
- Oversampling CDR to remove all random jitter
- Eye too narrow for non-oversampled CDR with this DFE (0.2 UI width in worst case fibre)
- No data coding assumed
- Model is public, on www.StatEye.org Workspace MMF

With EDC, 0 errors can be achieved



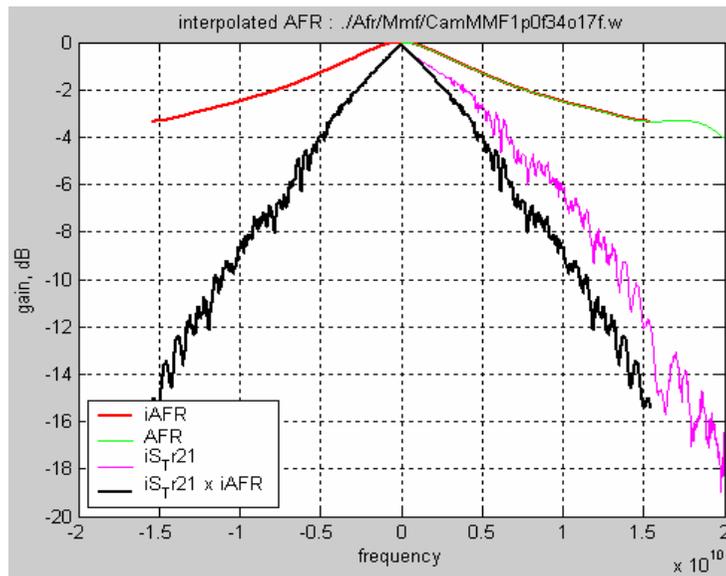
Fibre: CamMMF1p0f34o17f.w

Baud rate: 10.3125Gbps

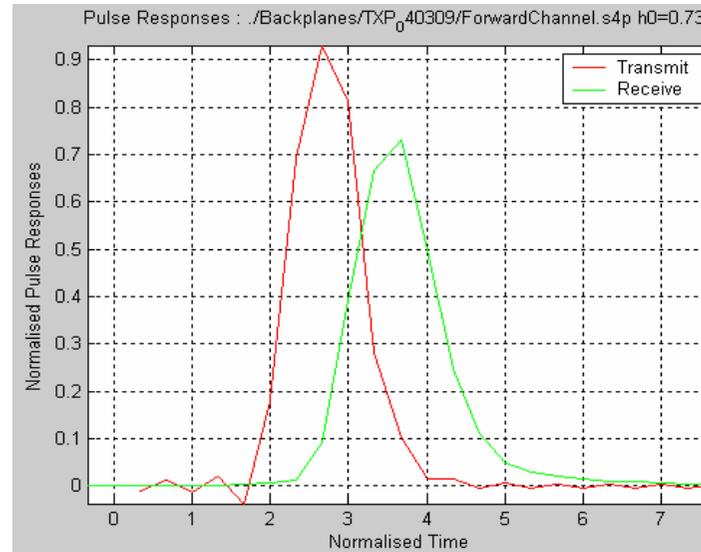
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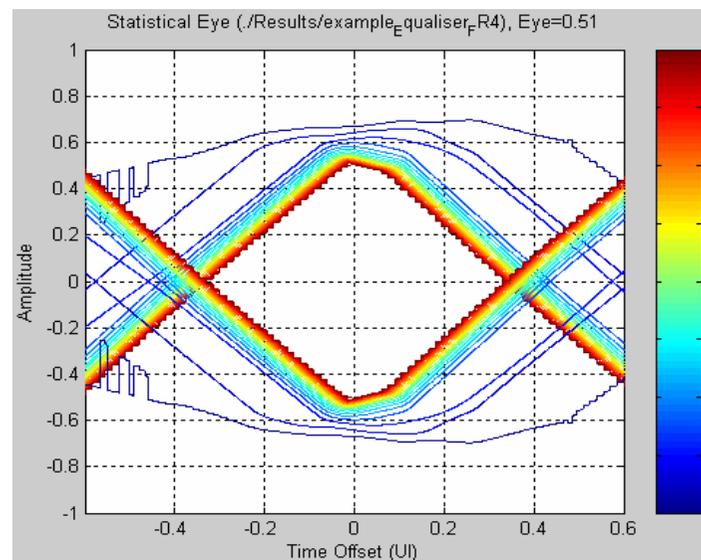


Red, Green is AFR
 Brown is AFR interpolated and truncated to 15GHz
 Pink is the TOSA+ROSA response (S params)
 Black is the combined channel response
 On this particular fibre, TOSA and ROSA is dominant



DFE is removing the ISI effectively

Result is received pulse has low distortion.



ISI computed by StatEye results in a wide eye with BER of 0.

StatEye vs Convolution with Impulse



- ◆ StatEye sends a positive and a negative transition down the channel, transitions spaced 1 UI apart
- ◆ StatEye models all components in system, including low probability ISI events, to generate a BER eye diagram: Pure convolution models only fibre
- ◆ StatEye can include TOSA/ROSA or other system components
- ◆ StatEye includes models for non-linear components such as DFE
- ◆ StatEye has been publically debugged and verified

Summary



- ◆ StatEye is the ideal tool for developing and comparing proposals for EDC
- ◆ StatEye provides highly accurate modelling once data set is available, from AFR or Fibre Modal Power Factors
- ◆ Cambridge MMF AFR data is entirely linear
- ◆ Cambridge Modal Data in a non-linear model is producing the same answers as the AFR, but it seems Modal Data is rounded or smoothed slightly
- ◆ StatEye forum includes full Excel analysis of Cambridge data using StatEye
- ◆ Recommend adopting the StatEye as the tool to verify EDC proposals for optical channels
- ◆ There also exists the possibility to define EDC standards using StatEye performance