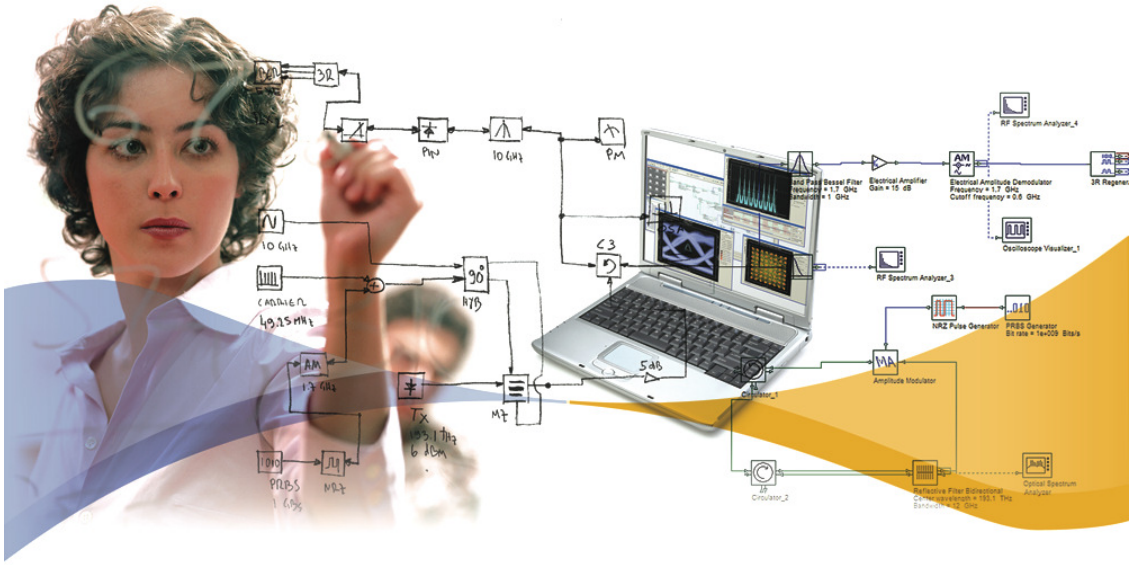

OptiSystem applications:
BER analysis of BPSK with RS encoding

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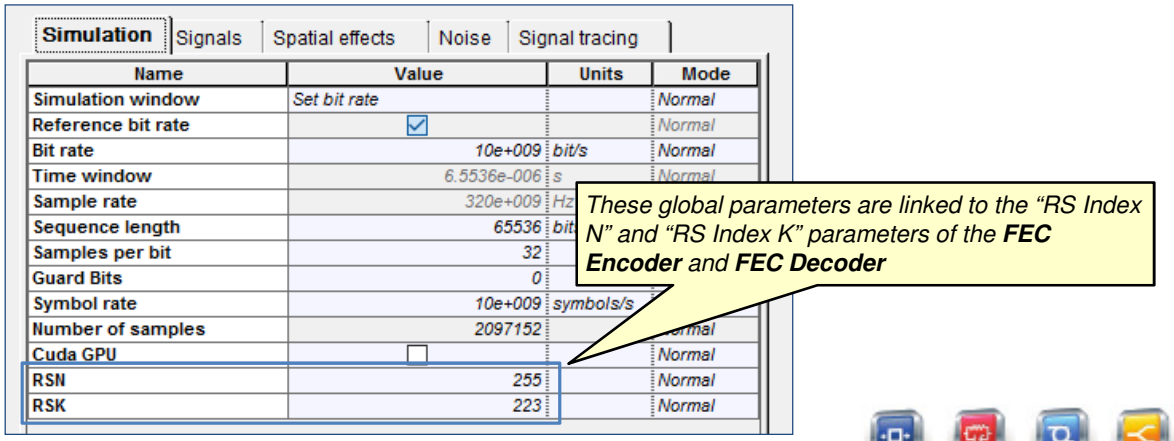
Introduction

BER Analysis of BPSK with Reed Solomon encoding

OptiSystem
Optical Communication System and Amplifier Design Suite

- This application note demonstrates how to perform the BER testing of a BPSK system with Reed Solomon (RS) encoders and decoders.
- The typical output of a BER analysis is a set of waterfall curves that map a system's BER results against gradually increasing background noise levels, defined as Eb/No (the ratio of energy per bit to noise density). When Reed Solomon encoding is applied, the BER performance can be significantly improved as RS encoding can correct multiple errors per symbol block.
- An OptiSystem project has been built to allow for the automatic creation of BER waterfall curves for different settings of the RS encoder/decoder. The project folder includes three files:
  - The OptiSystem project for the BPSK system analysis (***BER_Calculation_RS_FEC_BPSK.osd***)
  - The Excel output file where the results are exported and plotted (***BER Analysis BPSK FEC - Export Excel.xlsx***)
  - The data tracking file which provides more detailed information on the simulation results (***BER_FEC_Analysis_Tracking.txt***)
- The BER results for three common RS coding schemes (RS4, RS8, RS16) can be seen in the file *BER Analysis BPSK FEC - Export Excel.xlsx*. Prior to running a simulation these coding schemes can be set from the OptiSystem global parameters RSN and RSK. For example for RS16, RSN = 255 and RSK = 223

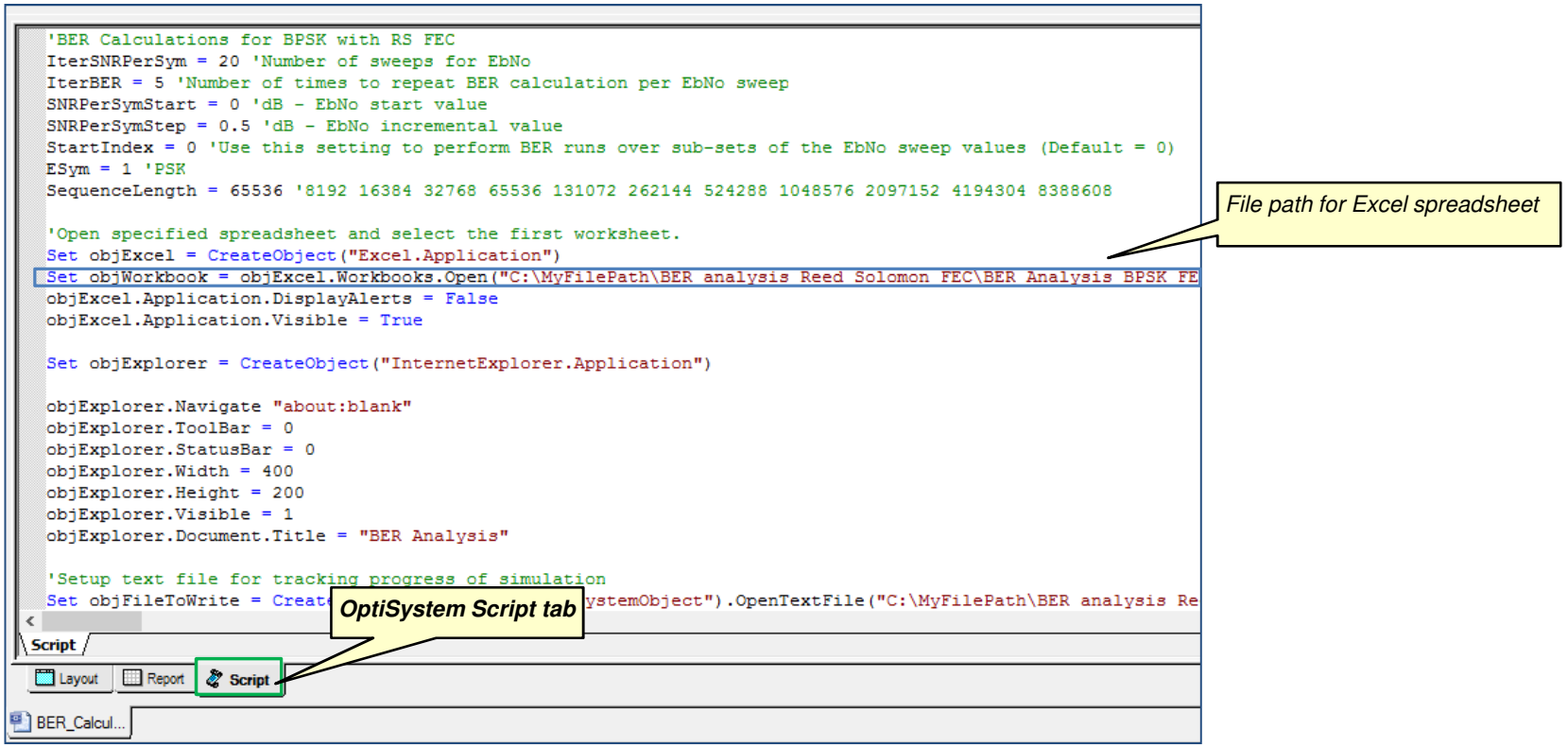


Optiwave

How to run a BER simulation (1)

BER analysis – RS encoding

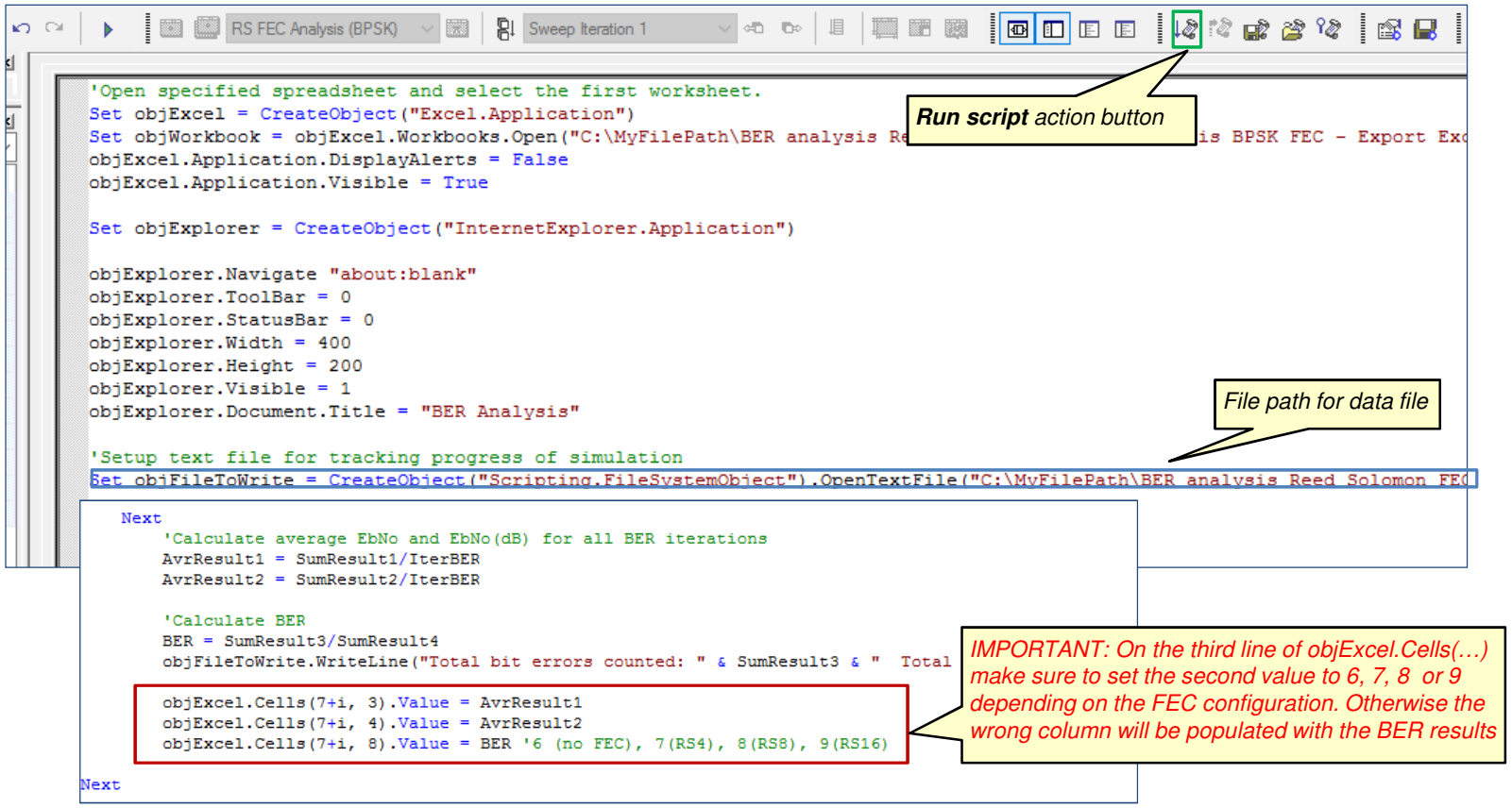
1. Open the OptiSystem project ***BER_Calculation_RS_FEC_BPSK.osd***
2. After determining which RS coding scheme you wish to run (see previous slide for further information), select the tab "Script" (see GREEN box below)
3. Got to the line "Set objWorkbook = objExcel.Workbooks.Open(…)" (see BLUE box below) and set up the file path information such that it matches the location of the Excel export file on your computer. The format should be as follows: *"C:\YourFilepath\BER analysis Reed Solomon\BER Analysis BPSK FEC - Export Excel.xlsx ")*



How to run a BER simulation (2)

BER analysis – RS encoding

4. Go to the line “Set objFileToWrite = CreateObject("Scripting.FileSystemObject").OpenTextFile(…)” (see GREEN box below) and set up the file path information such that it matches the location of the data export file on your computer. The format should be as follows:
   "C:\YourFilepath\BER analysis Reed Solomon\BER_FEC_Analysis_Tracking.txt",2,true)“
5. Go to the code section where the BER calculations are exported to Excel (see RED box below). Make sure to set the second number in the brackets (objExcel.Cells (7+i, 8)) to align with the configuration for your simulation (no FEC, RS4, RS8, RS16 or 6, 7, 8 or 9; respectively).



How to run a BER simulation (3)

BER analysis – RS encoding

6. On the upper right menu bar, left-click select the “Run Script” action button (see GREEN box previous slide). The simulation will start.
7. The Excel spreadsheet will automatically open. At the end of each BER iteration, the simulation data for the BPSK system will be exported to the associated data columns in the spreadsheet (including **Eb/No**, **Eb/No (dB)** and one of the BER test configurations: **BER (No FEC)**, **BER(RS4)**, **BER(RS8)**, or **BER(RS16)** (see RED boxes)
8. During the simulation a progress box will appear to provide information on the status of the simulation sweeps. Once the message “Simulation complete!” is posted, this dialog box can be closed

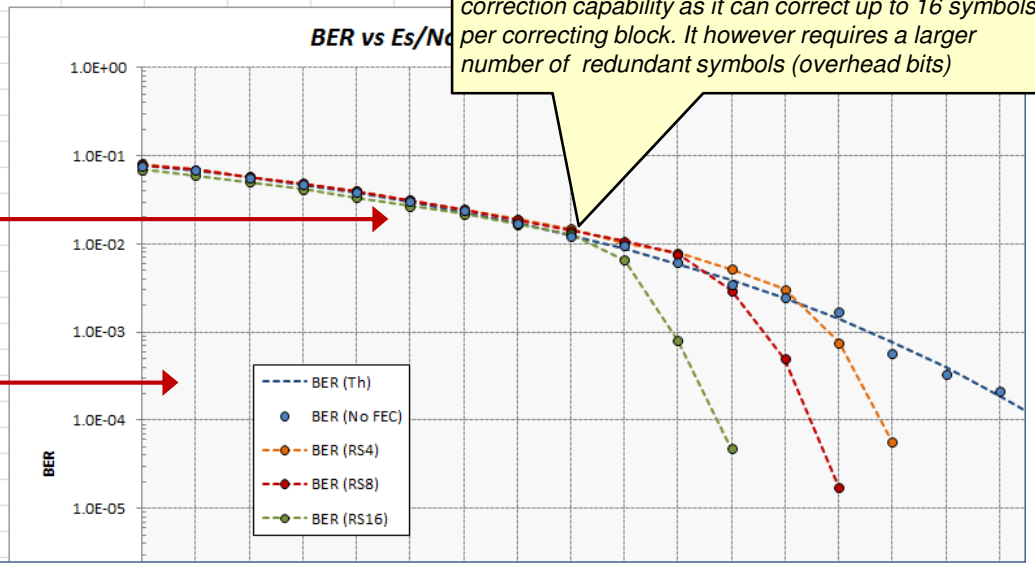
The data for each row is updated after a simulation run of the OptiSystem script

*BER vs Eb/No simulation results are automatically plotted for the specified RS format. Also the associated BER theoretical limit is calculated (obtained from column **BER – Th**).*

As expected, RS16 provides the most powerful error correction capability as it can correct up to 16 symbols per correcting block. It however requires a larger number of redundant symbols (overhead bits)

BER Analysis Reed Solomon Coding

	Eb/No	Eb/No (dB)	BER (Th)	BER (No FEC)	BER (RS4)	BER (RS8)	BER (RS16)
1	1.000205	0.0008886	0.078628313	0.07699585	0.080752461	0.078863755	0.069778442
2	1.121935	0.4996783	0.067072398	0.067962646	0.069296765	0.069180113	0.060112
3	1.2589	0.9999128	0.056283754	0.056732178	0.058073136	0.057971314	0.050460815
4	1.412419	1.4996359	0.046408102	0.046875	0.047925457	0.048438146	0.041984558
5	1.58453	1.9990045	0.03752281	0.038299561	0.039803094	0.0395773	0.033748627
6	1.778759	2.501171	0.029638144	0.030578613	0.03125879	0.031523238	0.02696228
7	1.995393	3.000285	0.022874847	0.024261475	0.024409283	0.024572473	0.021850586
8	2.239771	3.502034	0.017151463	0.01739502	0.019022504	0.01868363	0.016746521
9	2.511759	3.9997793	0.012502658	0.012207031	0.014824191	0.014180803	0.012889862
10	2.817129	4.4980675	0.008806395	0.00970459	0.010246132	0.010746794	0.006585447
11	3.161885	4.999459	0.005956504	0.006195068	0.007890295	0.007654117	0.000795263
12	3.548908	5.5009466	0.003858898	0.003509521	0.005203938	0.002975452	4.72954E-05
13	3.980989	5.9999094	0.002388509	0.002471924	0.003037975	0.000496483	0
14	4.462798	6.496072	0.001406008	0.001678467	0.000752461	1.7239E-05	0
15	5.01161	6.999772	0.000772895	0.000579834	5.62588E-05	0	0
16	5.624698	7.5009915	0.000398245	0.000335693	0	0	0
17	6.304689	7.996635	0.000191908	0.000213623	0	0	
18	7.075203	8.4973884	8.43804E-05	0.000106812	0	0	

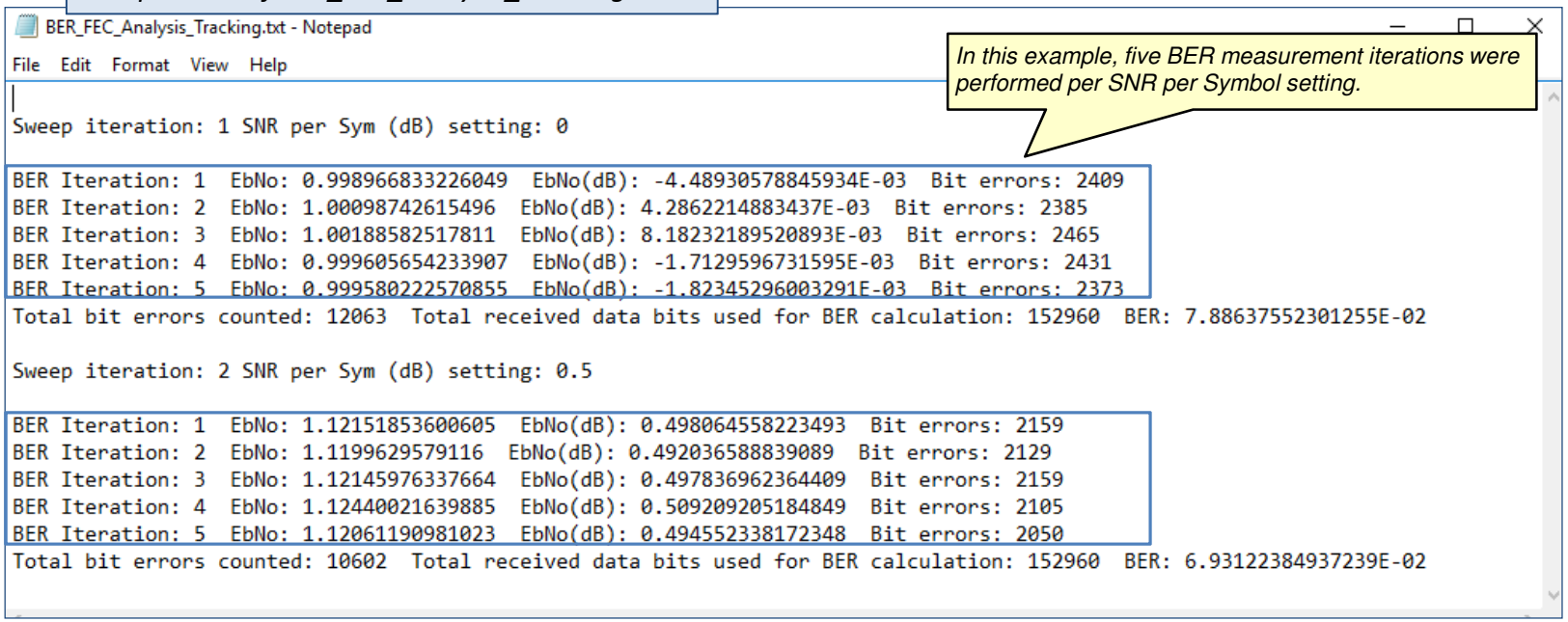


How to run a BER simulation (4)

BER analysis – RS encoding

9. In addition to the Excel spreadsheet analysis tool kit, a data file is also created during the simulation. An example view of the data file content (from *BER_FEC_Analysis_Tracking.txt*) is shown below. The content of this file can be modified as required by using the *objFileToWrite.WriteLine("…")* command in the simulation script

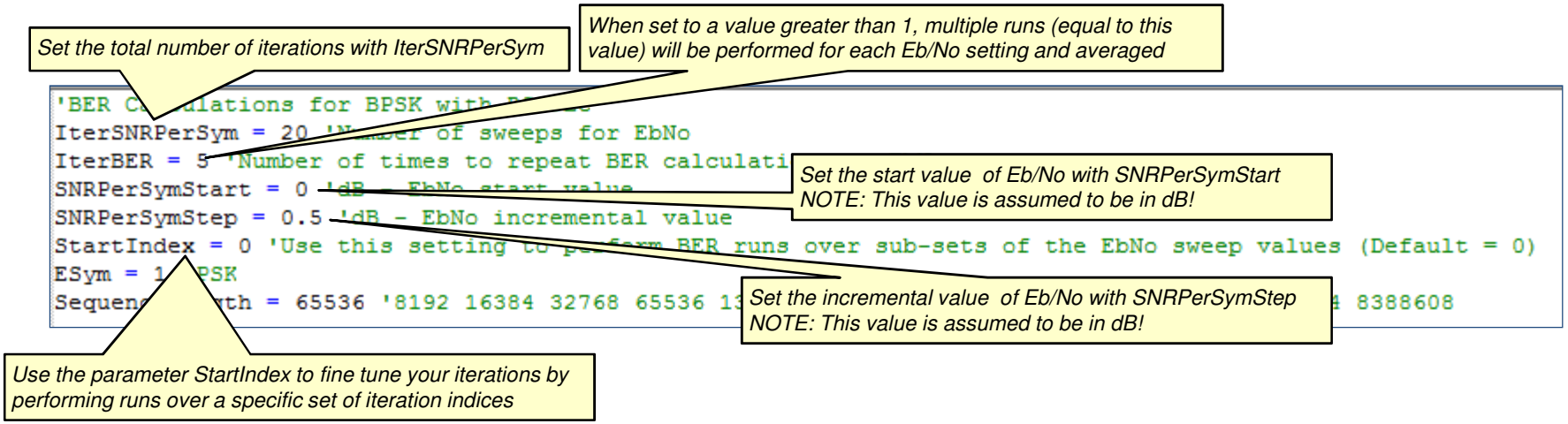
Sample view of BER_FEC_Analysis_Tracking.txt



Notes on BER & FEC analysis (1)

BER analysis – RS encoding

- To create a waterfall curve for a specified modulation format, the VBScripting feature of OptiSystem is used to set up the test conditions, create an instance of OptiSystem, run the simulation and retrieve results from the components and visualizers (thus all simulation runs must start from the **Scripts** tab). If you wish to run a standalone simulation, to verify for example the system setup, start the simulation from the **Layout** tab (in this case the script will be ignored)
- For each simulation run, the parameter Eb/No is configured based on settings in the script and in turn applied to a white noise source in the project layout (specifically the *Noise power* setting for the **AWGN I** noise source)
- To set the number of iterations in your simulation, the start value for Eb/No, and the level of change of Eb/No per iteration use the parameters *IterSNRPerSym*, *SNRPerSymStart* and *SNRPerSymStep* (see below)
- Also if you would like to run a reduced number of iterations over a specific sub-set of the sweep indices, use the parameter *StartIndex* to define at which index point you would like to start your iterations.

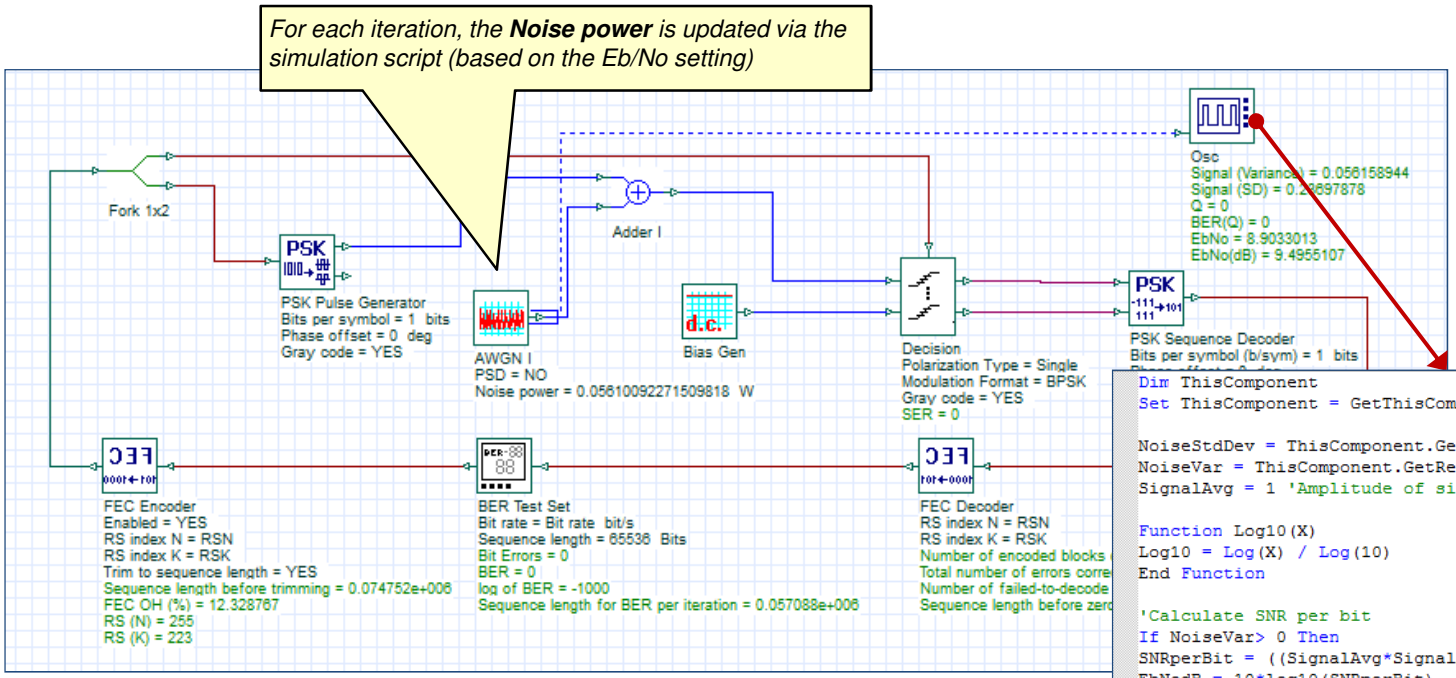


TIP: *To improve the accuracy of BER results under low noise conditions (where the symbol/bit error counts may be quite low) or when a strong FEC encoding is used, it is recommended to increase the Sequence length setting. Also you can increase the parameter IterBER to a value greater than 1 (when this is done, the simulation will perform extra runs for each noise level and take the average of the results)*

Notes on BER & FEC analysis (2)

BER analysis – RS encoding

- To verify that the noise settings are being properly applied to the I channel, the Eb/No parameter is re-calculated in OptiSystem through a Component script procedure written in the Oscilloscope Visualizer (this Visualizer includes a calculation result for ***Noise (Variance)*** which is applied to the calculation for Eb/No)
- The results Eb/No are in turn exported to the Excel analysis spreadsheet and used for plotting of the BER waterfall curves
- The *Bit Errors* (and the associated *Sequence length for BER per iteration*) are obtained from the BER Test Set



Component script for Osc Visualizer

Notes on BER & FEC analysis (3)

BER analysis – RS encoding

- The FEC Encoder works by adding redundant bits (n-k) to information blocks of length k. The bit sequence at the output of the FEC Encoder will thus be longer than the input. When performing tests on higher order modulation systems, the parameter ***Trim to sequence length*** should be enabled. This will ensure that the Decision component correctly recovers all information and redundant (error correcting) symbols that cover the length of the original sequence length.
- At the FEC Decoder, the redundant symbols will then be removed and thus the output of the Decoder will have a shorter sequence than the original sequence from the BER Test Set. This is not a problem as the BER Test Set automatically checks for this condition and only applies error counting against the shorter sequence length (this can be confirmed by viewing the result *Sequence length for BER per iteration* which is equal to 57088; equal in value to the output sequence of the FEC Decoder)