



OptiSystem applications: BER analysis of BPSK with RS encoding



7 Capella Court Nepean, ON, Canada K2E 7X1

+1 (613) 224-4700 www.optiwave.com

Introduction



- 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

Namo	Value	Unit	Modo	1					
Name	value	- Unite	is Mode						
Simulation window	Set bit rate		Normal						
Reference bit rate			Normal						
Bit rate	10e+00	9 bit/s	Normal						
Time window	6.5536e-00	6 s	Normal	11					
Sample rate	320e+00	Hz Th	ana alahal na			linko	d to the	o "RS Ir	day
			iese ulubal ba	rame	ters are	IIIIne	u u u u u	- 110 11	iuex i
Sequence length	6553	6 bit. N"	and "RS Inde	rame vx K"	ters are narame	ters o	f the F	FC	luex
Sequence length Samples per bit	6553	6 bit N"	and "RS Inde	rame x K" =C D	ters are parame	ters o	f the F	EC	luex
Sequence length Samples per bit Guard Bits	6553	6 <i>bit</i> N" 2 En	and "RS Inde coder and Fl	rame x K" EC D	ters are parame ecoder	ters o	f the F	EC	luex
Sequence length Samples per bit Guard Bits Symbol rate	6553 3 10e+00	6 bit N" 2 En 9 symbols	and "RS Inde coder and Fl	rame x K" EC D	parame parame	ters o	f the F	EC	luex
Sequence length Samples per bit Guard Bits Symbol rate Number of samples	6553 3 10e+00 209715	6 bit N" 2 En 9 symbols 2	and "RS Inde coder and Fl	rame x K" EC D	parame parame ecoder	ters o	f the F	EC	IUEX
Sequence length Samples per bit Guard Bits Symbol rate Number of samples Cuda GPU	6553 3 10e+00 209715	6 bit N" 2 En 9 symbols 2	and "RS Inde coder and Fl s/s Normal	rame x K" EC D	parame parame ecoder	ters o	f the F	EC	
Sequence length Samples per bit Guard Bits Symbol rate Number of samples Cuda GPU RSN	6553 3 10e+00 209715 25	6 bit N" 2 En 0 symbols 2 5	and "RS Inde coder and Fl s/s Normal Normal		parame parame ecoder	ters o	f the F	EC	



How to run a BER simulation (1)

- 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 ")

'BER Calculations for BPSK with RS FEC	
IterSNRPerSym = 20 'Number of sweeps for EbNo	
IterBER = 5 'Number of times to repeat BER calculation per EbNo sweep	
SNRPerSymStart = 0 'dB - EbNo start value	
SNRPerSymStep = 0.5 'dB - EbNo incremental value	
StartIndex = 0 'Use this setting to perform BER runs over sub-sets of the EbNo sweep values (Default = 0)	
ESym = 1 'PSK	
SequenceLength = 65536 '8192 16384 32768 65536 131072 262144 524288 1048576 2097152 4194304 8388608	
	File path for Excel spreadsheet
'Open specified spreadsheet and select the first worksheet.	
Set objExcel = CreateObject("Excel.Application")	
Set objWorkbook = objExcel.Workbooks.Open("C:\MyFilePath\BER analysis Reed Solomon FEC\BER Analysis BPSK FE	
objExcel.Application.DisplayAlerts = False	
objExcel.Application.Visible = True	
Set objExplorer = CreateObject("InternetExplorer.Application")	
objExplorer.Navigate "about:blank"	
objExplorer.ToolBar = 0	
objExplorer.StatusBar = 0	
objExplorer.Width = 400	
objExplorer.Height = 200	
objExplorer.Visible = 1	
objExplorer.Document.Title = "BER Analysis"	
'Setup text file for tracking progress of simulation	
Set objFileToWrite = Creat Onic and Covint to ystemObject").OpenTextFile("C:\MyFilePath\BER analysis Re	
Copiisystem Script tab	
Script /	
Layout Report & Script	
BER_Calcul	
	1





How to run a BER simulation (2)

- 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)

- 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 day simulat	ta for each ion run of tl	row is upd ne OptiSys	lated after a stem script	1		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).
BE	R Analysis I	Reed Solom	on Coding						As expected, RS16 provides the most powerful error
1 C2	? C3	C4		C6	С7	C8	С9		correction capability as it can correct up to 16 symbols BER vs Es/Nc per correcting block. It however requires a larger
	Eb/No	Eb/No (dB)	BER (Th)	BER (No FEC)	BER (RS4)	BER (RS8)	BER (RS16)	1.0E+00	number of redundant symbols (overnead bits)
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	1.0E-01	
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	1.0E-02	
	1.995393	3.000285	0.022874847	0.024261475	0.024409283	0.024572473	0.021850586		
2	2.239//1	3.502034	0.01/151463	0.01739502	0.019022504	0.01868363	0.016746521		
1	2.511/59	3.9997793	0.012502658	0.002207031	0.010246132	0.014180803	0.005585447	1.0E-03	
10	2.61/129	4.4960675	0.005055504	0.00970459	0.010246152	0.010746794	0.000365447		
13	3.548908	5 5009466	0.00395858898	0.008193088	0.007890295	0.007634117	4 729545-05		BER (Th)
13	3 980989	5 9999094	0.002388509	0.002471924	0.003037975	0.000496483	0	1.05.04	BER (No FEC)
14	4 462798	6 496072	0.001406008	0.001678467	0.000752461	1 7239F-05	0	1.02-04	
15	5.01161	6.999772	0.000772895	0.000579834	5.62588E-05	0	0	Ш.	•BER (RS4)
16	5.624698	7.5009915	0.000398245	0.000335693	0	0	0		
17	6.304689	7.996635	0.000191908	0.000213623	0	0		1.0E-05	
18	7.075203	8.4973884	8.43804E-05	0.000106812	0	0			



How to run a BER simulation (4)

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							
BER_FEC_Analysis_Tracking.txt - Notepad	X						
File Edit Format View Help	In this example, five BER measurement iterations were performed per SNR per Symbol setting.						
 Sweep iteration: 1 SNR per Sym (dB) setting: 0							
BER Iteration: 1 EbNo: 0.998966833226049 EbNo(dB): -4.489305788	45934E-03 Bit errors: 2409						
BER Iteration: 2 EbNo: 1.00098742615496 EbNo(dB): 4.28622148834	37E-03 Bit errors: 2385						
BER Iteration: 3 EbNo: 1.00188582517811 EbNo(dB): 8.18232189520893E-03 Bit errors: 2465							
BER Iteration: 4 EbNo: 0.999605654233907 EbNo(dB): -1.7129596731595E-03 Bit errors: 2431							
BER Iteration: 5 EbNo: 0.999580222570855 EbNo(dB): -1.823452966	03291E-03 Bit errors: 2373						
Total bit errors counted: 12063 Total received data bits used for BER calculation: 152960 BER: 7.88637552301255E-02							
Sweep iteration: 2 SNR per Sym (dB) setting: 0.5							
BER Iteration: 1 EbNo: 1.12151853600605 EbNo(dB): 0.49806455822	3493 Bit errors: 2159						
BER Iteration: 2 EbNo: 1.1199629579116 EbNo(dB): 0.492036588839	1089 Bit errors: 2129						
BER Iteration: 3 EbNo: 1.12145976337664 EbNo(dB): 0.49783696236	4409 Bit errors: 2159						
BER Iteration: 4 EbNo: 1.12440021639885 EbNo(dB): 0.50920920518	4849 Bit errors: 2105						
BER Iteration: 5 EbNo: 1.12061190981023 EbNo(dB): 0.49455233817	2348 Bit errors: 2050						
Total bit errors counted: 10602 Total received data bits used for	r BER calculation: 152960 BER: 6.93122384937239E-02						
	· · · · · · · · · · · · · · · · · · ·						





Notes on BER & FEC analysis (1)

- 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 <u>IterBER</u> 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)

- 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



Notes on BER & FEC analysis (3)

- 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)



9