

**Agenda Item:** **6.4**

**Source:** **Nortel**

**Title:** **Turbo Interleaver Performance Comparison**

**Document for:** **Discussion**

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## 1 Introduction

In the TSG RAN WG1 #47, it was agreed that the performance of all other interleaver candidates to be used in the LTE, should be compared to the existing Rel6 interleaver. The interleavers simulated in this contribution include

- Current Release 6 interleaver [1]
- Quadratic permutation polynomial (QPP) interleavers
  - Ericsson (Ericsson-QPP) [2]
  - Motorola (Motorola-QPP) [3]
  - Qualcomm byte-aligned designs (QPP-Q) [4]
- Almost regular permutation (ARP) interleavers
  - Motorola (Motorola-ARP) [3]
  - Broadcom (Broadcom-ARP) [5]
- Quasi-cyclic (QC) interleavers from France Telecomm (FranceTelecom-QC-a and -b) [6]
- Inter-block permutation interleavers from ITRI (ITRI-IBP) [7]
- LRI interleavers from Mitsubishi Electric Corp (Mitsubishi-LRI) [8]

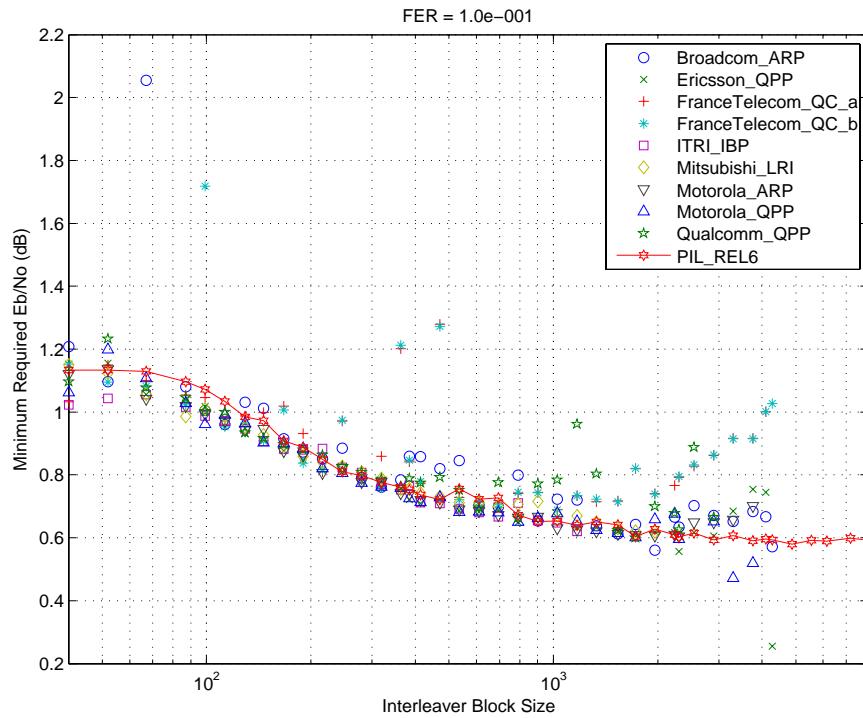
It is agreed that the comparison is to be made over 42 different block sizes distributed over block sizes of 40 to 8192 bits.

In this contribution, we compare all other 9 candidates to the baseline Rel6 interleaver.

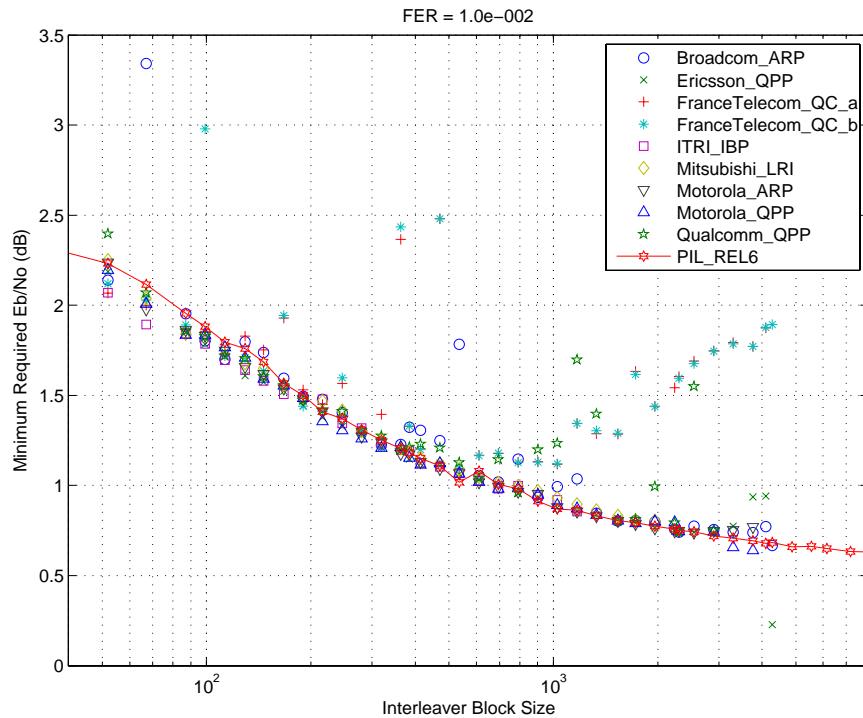
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## 2 Simulation Results Overview

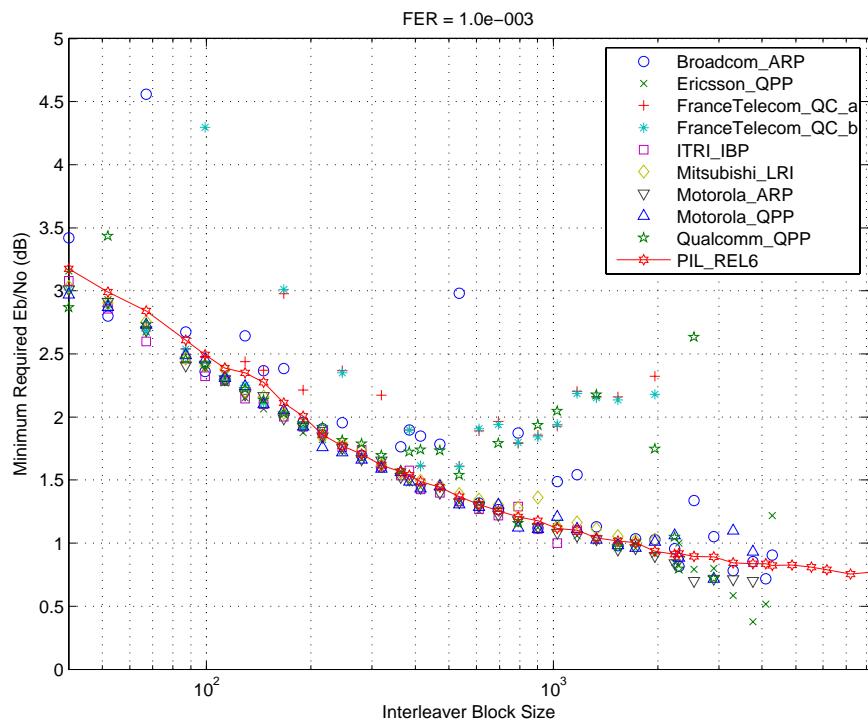
In this contribution, we show the performance of all 10 different interleavers and compare the required SNR (in terms of  $E_b/N_0$ ) for the BLER target of 0.1, 0.01, 0.001, 1e-4 and 1e-5 in Figures 1, 2, 3, 4 and 5, respectively. The channel is AWGN and the modulation is assumed to be BPSK.



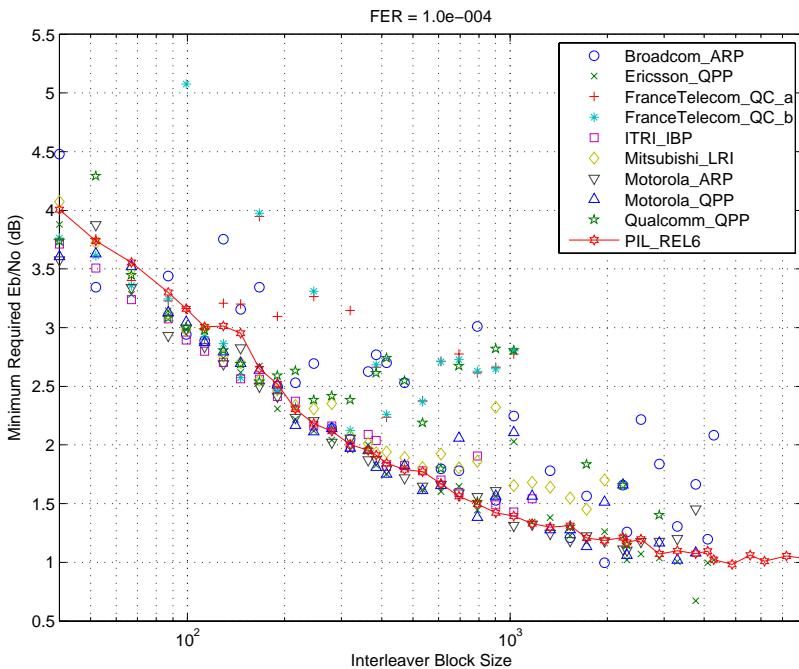
**Figure 1. Required SNR for the BLER target of 0.1**



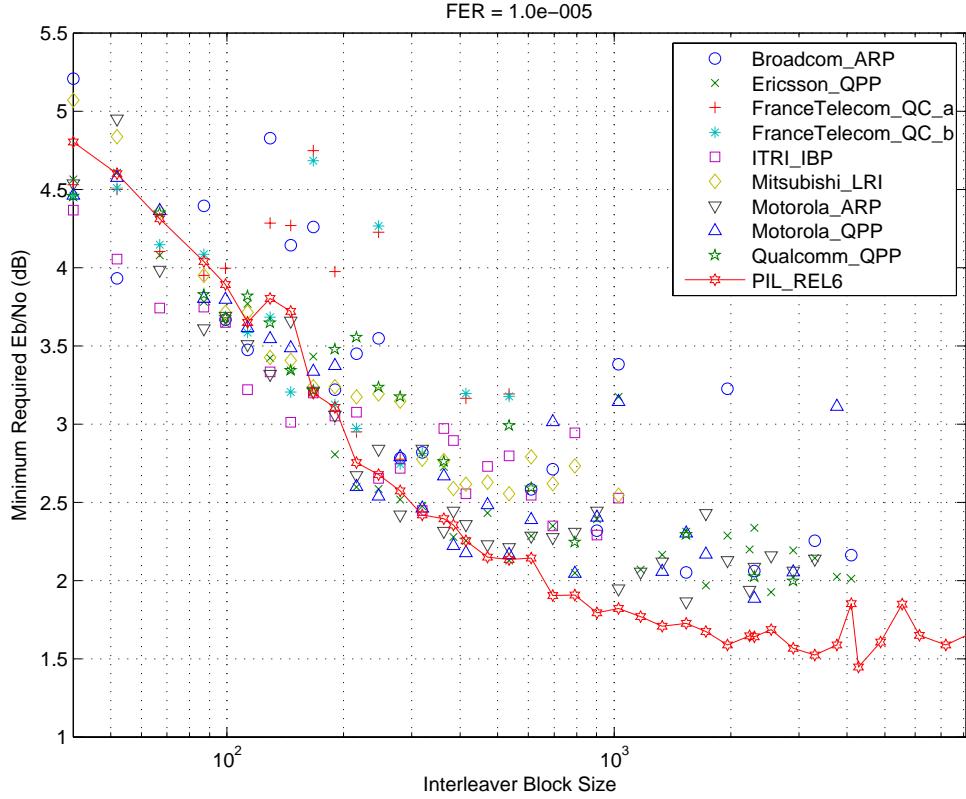
**Figure 2. SNR for the BLER target of 0.01**



**Figure 3. SNR for the BLER target of 0.001**



**Figure 4. SNR for the BLER target of 1e-4**



**Figure 5. SNR for the BLER target of 1e-5**

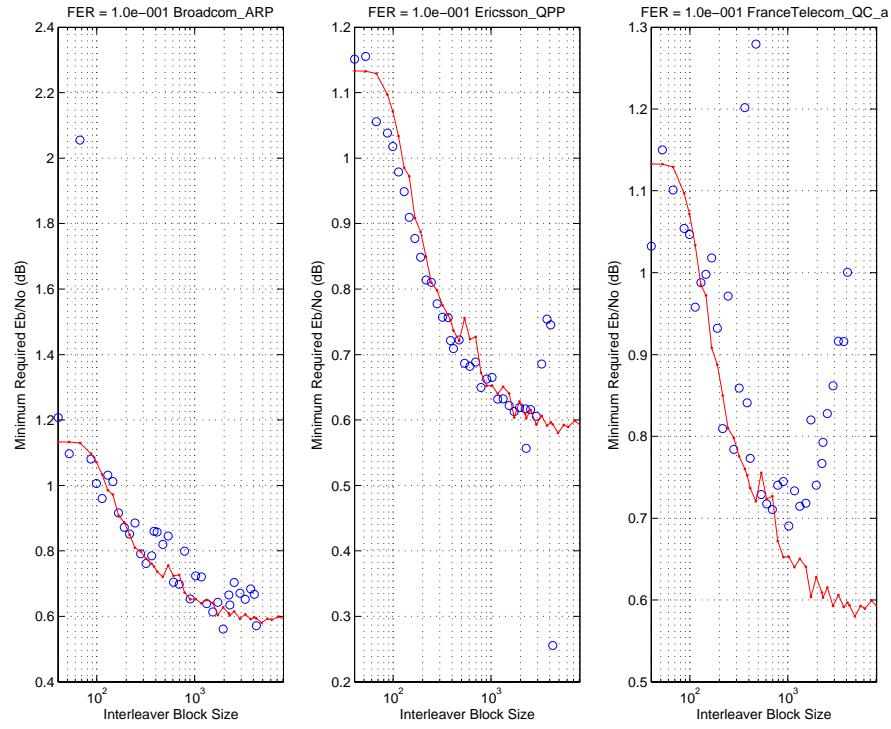
As shown in these five figures, there is no clear evidence that the proposed interleavers outperform the baseline Rel6 interleaver. These Figures also show that the Rel6 interleaver consistently performs very well over the full range of LTE block sizes.

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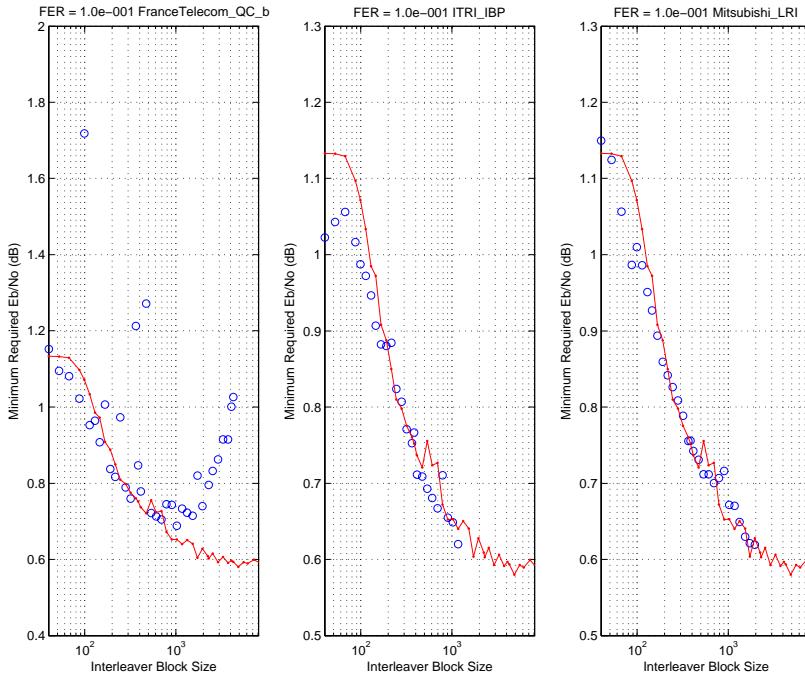
### 3 Detailed Performance Comparison Against Baseline Rel6 Interleaver

In the following Figures, we show pair-wise performance comparison of Rel6 interleaver with other interleaver contenders.

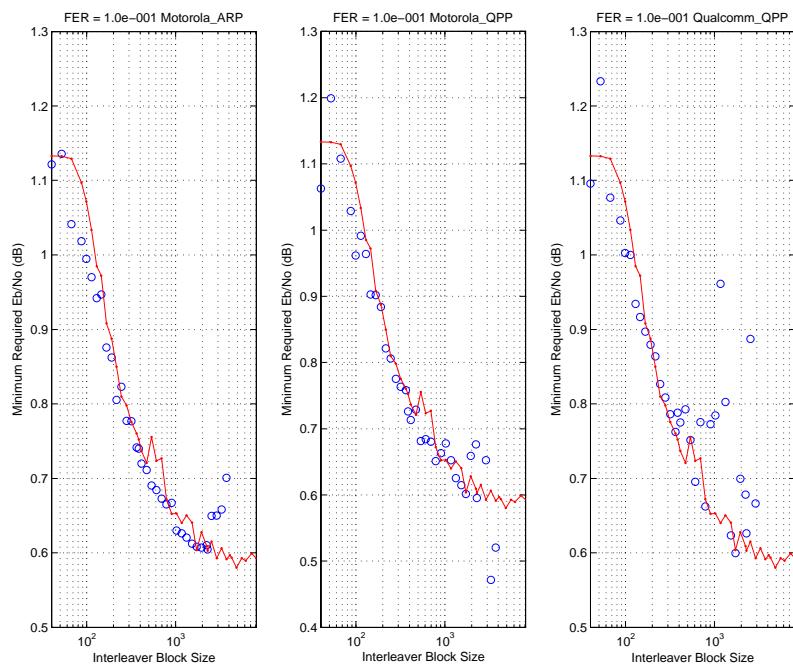
Figure 6 compares the performance of Broadcom-ARP, Ericsson-QPP and FranceTelecom-QC-a with the existing Rel6 interleaver for the BLER target of 0.1. Figure 7 shows this comparison for FranceTelecom-QC-b, ITRI-IBP and Mitsubishi-LRI. Finally, Figure 8 shows this comparison for Motorola-ARP, Motorola-QPP and Qualcomm-QPP for the same BLER target of 0.1.



**Figure 6. Pair-wise performance comparison for the BLER target of 0.1**

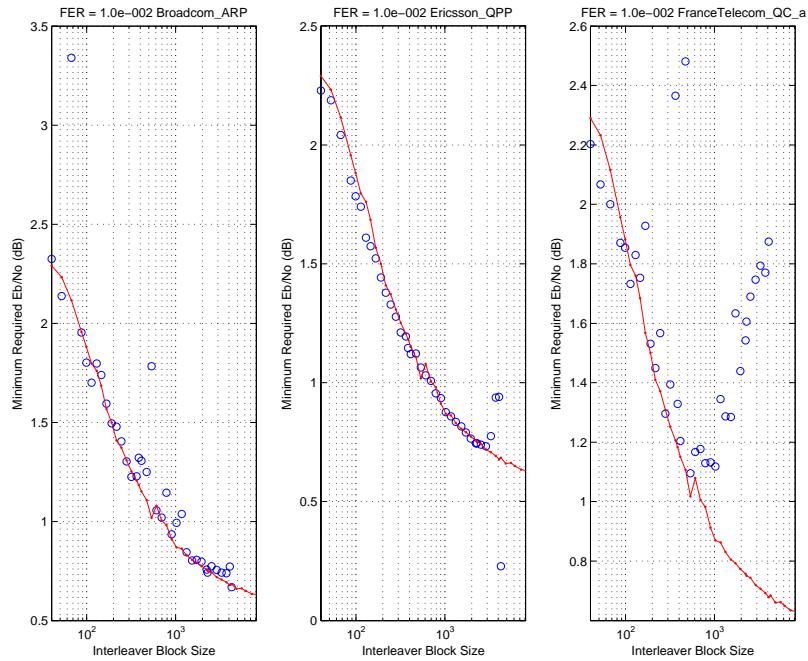


**Figure 7. Pair-wise performance comparison for the BLER target of 0.1**

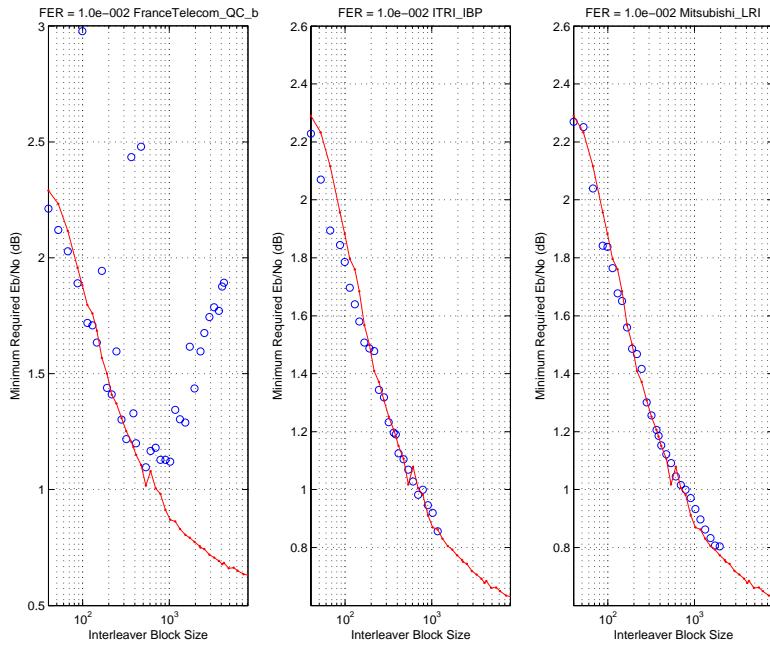


**Figure 8. Pair-wise performance comparison for the BLER target of 0.1**

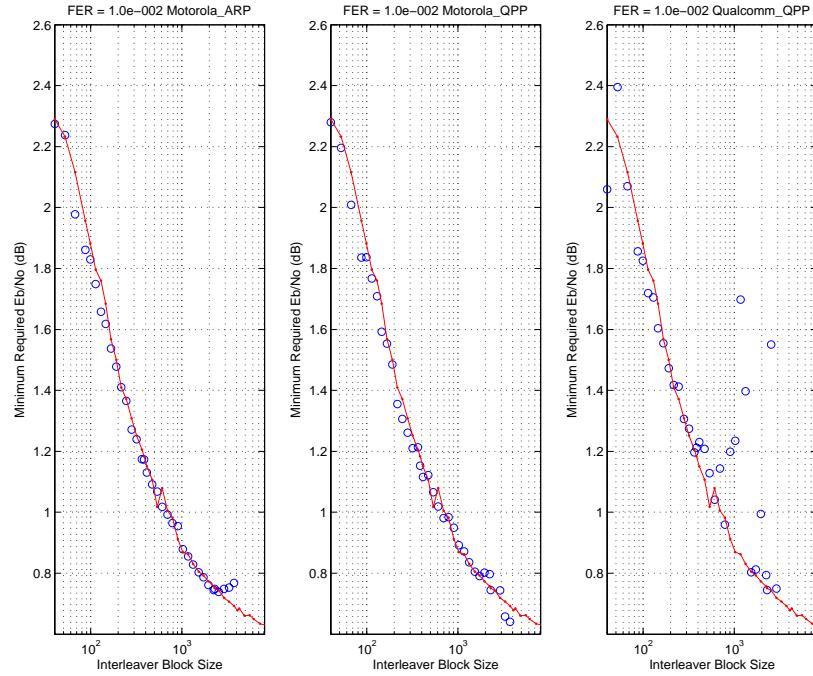
Figures 9 to 11 are the same as Figures 6 to 8 except that the BLER target is 0.01.



**Figure 9. Pair-wise performance comparison for the BLER target of 0.01**

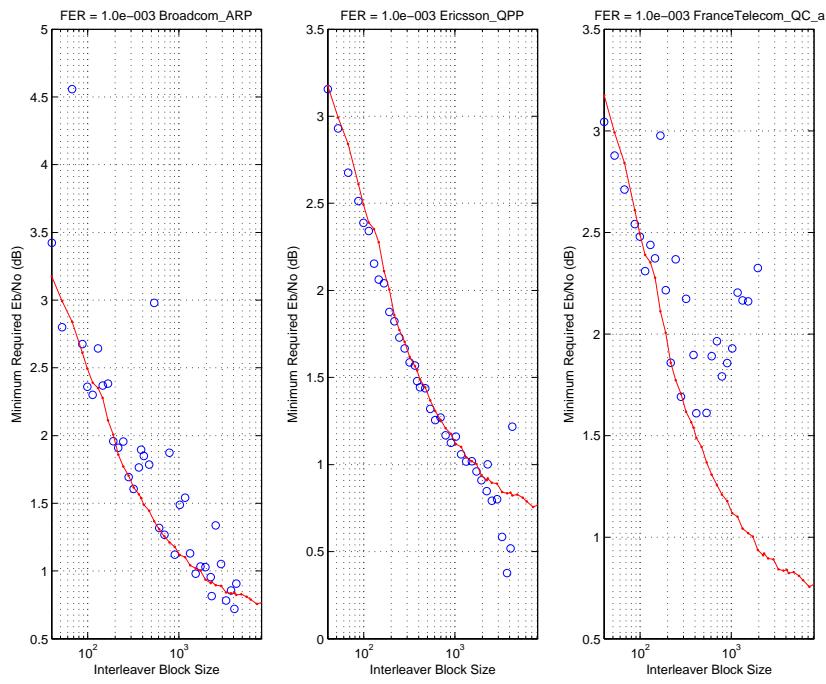


**Figure 10. Pair-wise performance comparison for the BLER target of 0.01**

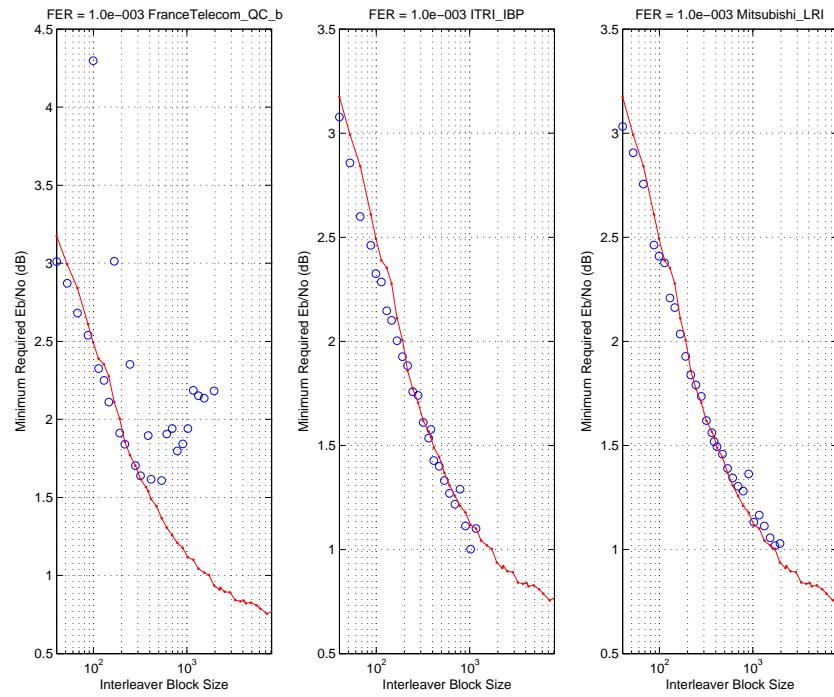


**Figure 11. Pair-wise performance comparison for the BLER target of 0.01**

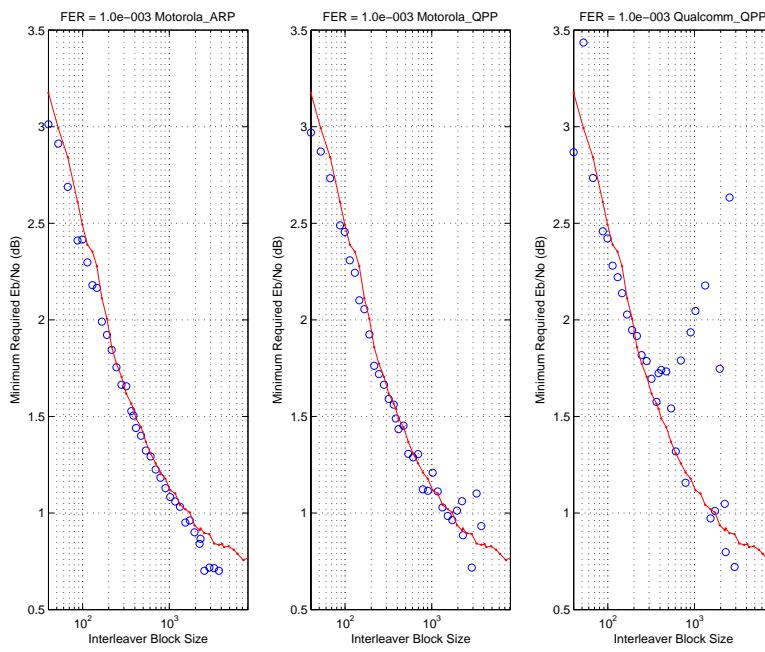
Figures 12 to 14 show the same picture for the BLER target of 0.001.



**Figure 12. Pair-wise performance comparison for the BLER target of 0.001**

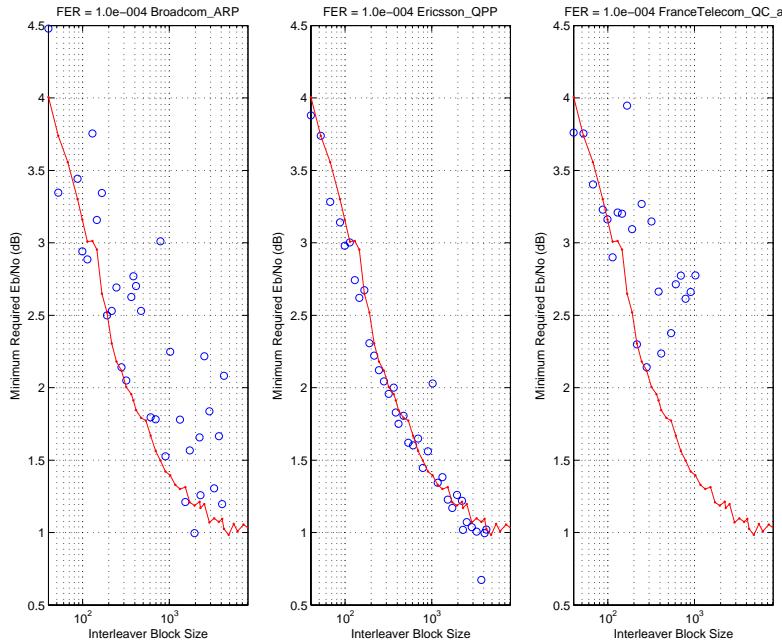


**Figure 13. Pair-wise performance comparison for the BLER target of 0.001**

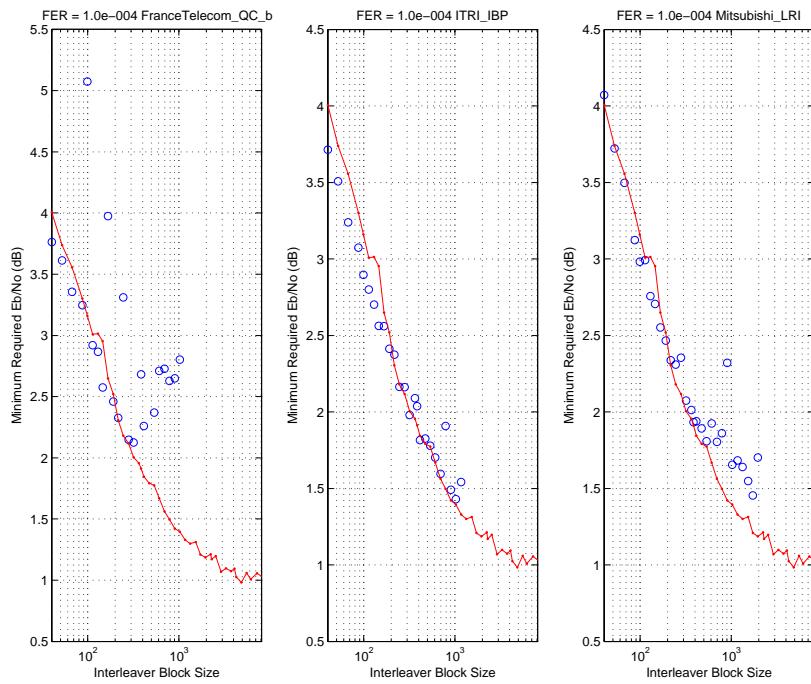


**Figure 14. Pair-wise performance comparison for the BLER target of 0.001**

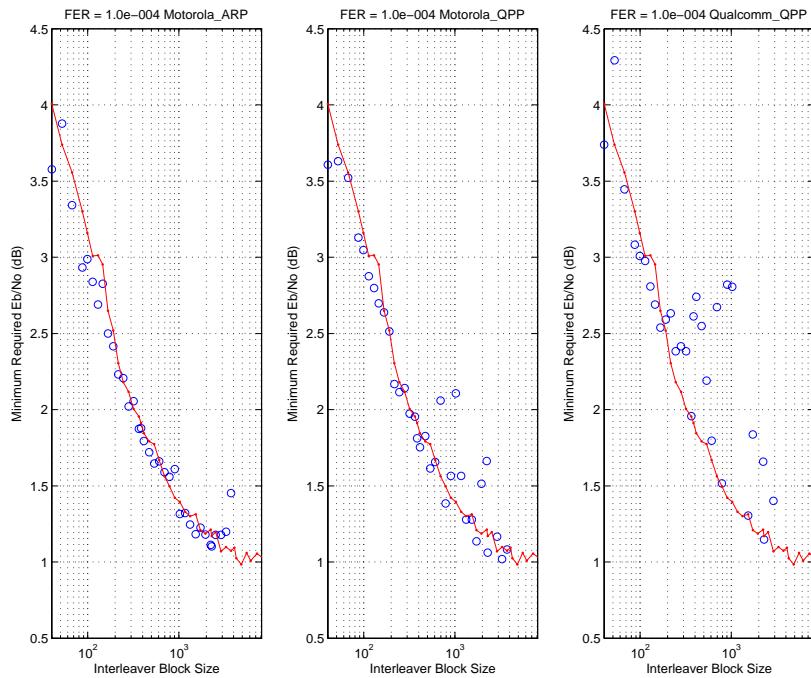
Figures 15 to 17 show the performance comparison for BLER target of 1e-4.



**Figure 15. Pair-wise performance comparison for the BLER target of 1e-4**

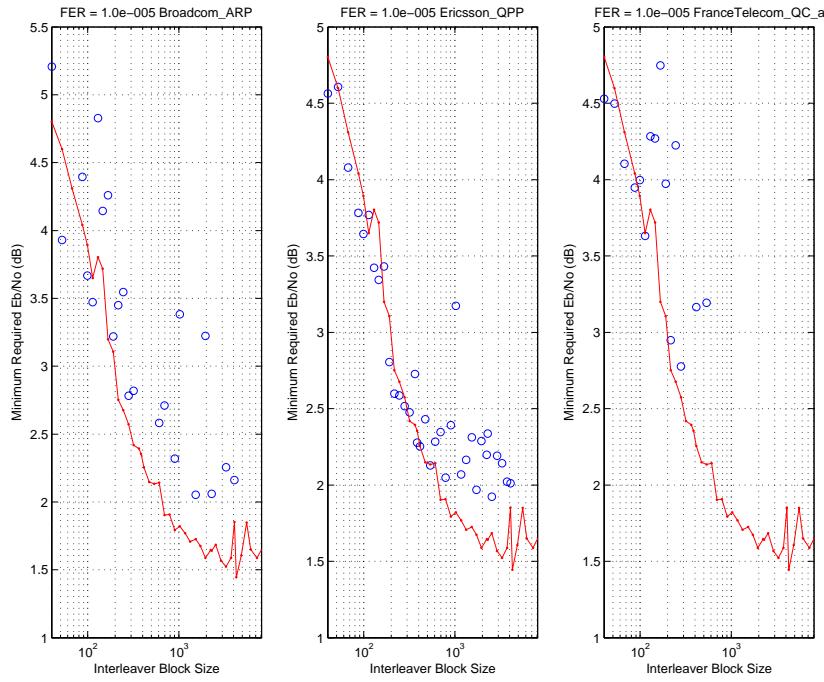


**Figure 16. Pair-wise performance comparison for the BLER target of 1e-4**

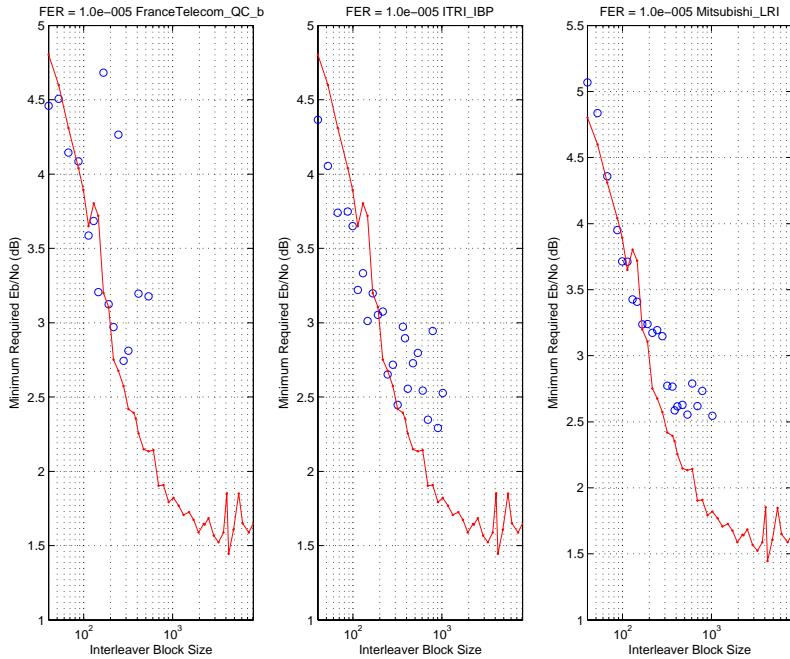


**Figure 17. Pair-wise performance comparison for the BLER target of 1e-4**

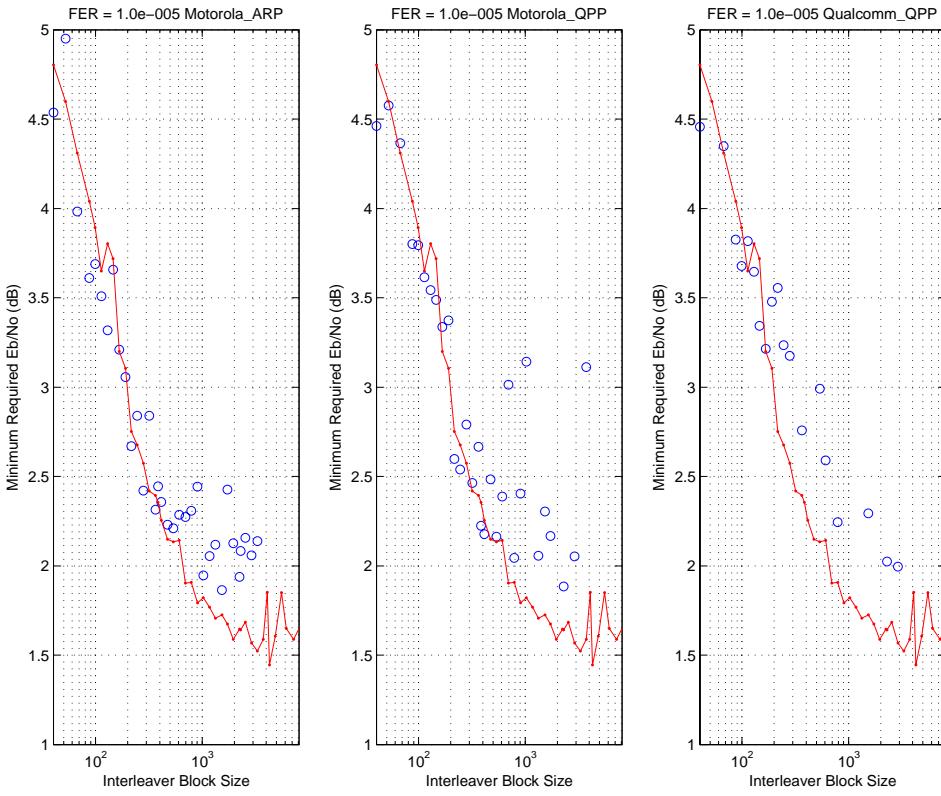
In the following Figures, we compare the performance of all these interleavers at the BLER target of 1e-5.



**Figure 18. Pair-wise performance comparison for the BLER target of 1e-5**



**Figure 19. Pair-wise performance comparison for the BLER target of 1e-5**



**Figure 20. Pair-wise performance comparison for the BLER target of 1e-5**

Tables 1 to 5 show the SNR values for different target BLER values. Tables 6 to 10 compare the SNR value required for those BLER targets compared to those of the baseline PIL-Rel6 interleaver.

**Table 1. SNR for BLER = 0.1**

Info size	Required SNR									
	Brcm	Ericss	Fr_a	Fr_b	ITRI	Mit	Mot_A	Mot_Q	Qual	PIL-Rel6
40	1.207683	1.151301	1.032292	1.152276	1.022548	1.149625	1.121354	1.062735	1.095723	1.133073
52	1.096764	1.155452	1.150202	1.094714	1.042937	1.124299	1.135853	1.198873	1.233119	1.132549
67	2.054481	1.055329	1.101053	1.081384	1.055971	1.056531	1.041433	1.107783	1.076745	1.129342
87	1.079988	1.038219	1.053796	1.022104	1.016373	0.986399	1.018344	1.028702	1.046374	1.096999
99	1.005386	1.017528	1.046561	1.718319	0.987351	1.009716	0.994773	0.961737	1.002441	1.071412
113	0.960319	0.978674	0.957996	0.952881	0.972258	0.986127	0.970297	0.991451	1.000185	1.033398
129	1.031148	0.948929	0.987929	0.964097	0.946248	0.951109	0.941744	0.963979	0.934268	0.985027
146	1.011558	0.909413	0.997839	0.907697	0.906658	0.926958	0.946764	0.902868	0.916558	0.972233
167	0.915541	0.877126	1.018067	1.006517	0.882336	0.893603	0.875749	0.90173	0.896742	0.908103
190	0.872342	0.848476	0.93205	0.837588	0.880076	0.859322	0.862184	0.883868	0.879371	0.887526
216	0.851072	0.813963	0.809585	0.816961	0.884215	0.841627	0.805354	0.821388	0.863918	0.849716
246	0.88482	0.810151	0.971487	0.973015	0.82372	0.826338	0.822898	0.805993	0.826725	0.809775

280	0.790806	0.77761	0.784061	0.789089	0.806785	0.808527	0.777023	0.775277	0.808697	0.798043
319	0.761482	0.757202	0.858836	0.759872	0.77112	0.788546	0.776777	0.763052	0.786293	0.775373
363	0.784783	0.756488	1.201831	1.212433	0.752507	0.755306	0.741716	0.758043	0.76229	0.7604
384	0.859102	0.721	0.840882	0.847203	0.766574	0.75567	0.73982	0.726151	0.787978	0.752337
414	0.857372	0.709164	0.772981	0.778241	0.711385	0.742204	0.71997	0.712984	0.775153	0.736609
471	0.820078	0.722476	1.279217	1.271717	0.708676	0.73077	0.711418	0.72858	0.792705	0.720801
536	0.844903	0.686466	0.728744	0.721944	0.692984	0.711591	0.690423	0.681268	0.751294	0.755238
611	0.704075	0.681745	0.717397	0.713178	0.68075	0.711758	0.68425	0.683908	0.69549	0.723424
695	0.697847	0.688696	0.710575	0.704904	0.667217	0.700077	0.672866	0.680542	0.775637	0.726767
792	0.799167	0.649847	0.740288	0.744589	0.710548	0.706887	0.664835	0.650916	0.662204	0.672184
902	0.653331	0.662241	0.744679	0.743271	0.654726	0.716171	0.667255	0.663189	0.77249	0.652428
1027	0.72341	0.665227	0.690196	0.688685	0.648525	0.671483	0.629909	0.677875	0.784259	0.652669
1169	0.720463	0.631832	0.733149	0.733425	0.620025	0.670343	0.626289	0.652406	0.961135	0.640159
1331	0.638441	0.632439	0.714392	0.722709		0.649104	0.620576	0.625068	0.802615	0.650488
1536	0.613076	0.621796	0.718005	0.714572		0.629665	0.612386	0.614478	0.623178	0.640612
1725	0.642789	0.612948	0.820074	0.820443		0.621231	0.608071	0.601494	0.599647	0.603772
1965	0.560681	0.619036	0.74022	0.739633		0.619381	0.606823	0.658795	0.699205	0.627954
2237	0.665007	0.616913	0.767067				0.61013	0.676367	0.678002	0.609062
2304	0.634583	0.55676	0.792438	0.795411			0.604534	0.595489	0.625985	0.602802
2547	0.702807	0.615841	0.828002	0.832512			0.649651		0.887301	0.615273
2900	0.670739	0.605556	0.86168	0.862589			0.6497	0.652158	0.666201	0.592716
3302	0.651573	0.685285	0.91618	0.915006			0.657933	0.471759		0.60632
3760	0.683632	0.753709	0.915864	0.914958			0.700722	0.52033		0.591234
4096	0.667155	0.745169	1.00041	1.000473						0.596563
4281	0.571263	0.255418		1.026577						0.593265
4874										0.580106
5550										0.592526
6144										0.589334
7195										0.599027
8192										0.591697

Table 2. SNR for BLER = 0.01

Info size	Required SNR									
	Brcm	Ericss	Fr_a	Fr_b	ITRI	Mit	Mot_A	Mot_Q	Qual	PIL-Re6
67	3.34025	2.0421	2.000802	2.028365	1.893481	2.038997	1.977579	2.008269	2.070233	2.115726
87	1.953588	1.850285	1.870607	1.889776	1.843697	1.841423	1.86168	1.835825	1.856396	1.955892
99	1.801592	1.784235	1.854129	2.978109	1.785545	1.837694	1.829975	1.836775	1.825582	1.881572
113	1.700841	1.73984	1.732914	1.718868	1.696307	1.76458	1.748419	1.767366	1.719589	1.796193
129	1.796883	1.610009	1.829903	1.709074	1.639824	1.677548	1.658073	1.70888	1.704781	1.760212
146	1.739097	1.57438	1.753181	1.634686	1.579861	1.650234	1.618236	1.591994	1.603618	1.684835
167	1.594038	1.523349	1.928189	1.943239	1.507313	1.55984	1.536777	1.553626	1.554902	1.567331
190	1.495335	1.442361	1.53133	1.439267	1.487424	1.485997	1.477429	1.484776	1.473089	1.499952
216	1.478336	1.37847	1.44927	1.41125	1.477443	1.467573	1.410604	1.355518	1.417406	1.409173

246	1.404561	1.32825	1.566808	1.59629	1.343641	1.416522	1.365715	1.305777	1.41201	1.371632
280	1.302657	1.277085	1.296106	1.302469	1.318093	1.300719	1.27124	1.261189	1.306398	1.308563
319	1.224105	1.211152	1.393728	1.217547	1.2327	1.256383	1.23995	1.209597	1.274359	1.251894
363	1.228375	1.193867	2.365125	2.433964	1.196543	1.206225	1.174334	1.21337	1.196151	1.206081
384	1.322039	1.14613	1.328096	1.329248	1.190854	1.185012	1.17311	1.152598	1.21223	1.182827
414	1.30628	1.120652	1.203644	1.199714	1.1251	1.152534	1.130057	1.115354	1.230101	1.150474
471	1.248925	1.122722	2.480861	2.479466	1.104517	1.122024	1.091475	1.12184	1.207856	1.107039
536	1.783067	1.063524	1.095045	1.095661	1.068613	1.091552	1.067448	1.065331	1.128154	1.017548
611	1.055481	1.030237	1.167241	1.166395	1.02828	1.045231	1.017587	1.018837	1.041018	1.079144
695	1.019282	1.007169	1.177105	1.180359	0.982401	1.015948	0.991909	0.981272	1.14378	1.005821
792	1.145383	0.955521	1.128756	1.128428	0.999136	0.999653	0.964489	0.984187	0.959131	0.981441
902	0.935183	0.934713	1.132402	1.128762	0.946265	0.970576	0.954245	0.949085	1.19863	0.911876
1027	0.99287	0.876002	1.11791	1.120899	0.919686	0.93252	0.878384	0.891776	1.234142	0.869487
1169	1.036856	0.858362	1.344388	1.344595	0.856045	0.897008	0.855037	0.871664	1.697687	0.862596
1331	0.844618	0.835438	1.286988	1.30378		0.862059	0.828644	0.835295	1.396725	0.830735
1536	0.80289	0.816351	1.284659	1.289118		0.832224	0.803127	0.804698	0.803023	0.805426
1725	0.80588	0.790379	1.632841	1.616178		0.806869	0.786824	0.791131	0.811889	0.792401
1965	0.797401	0.764366	1.439061	1.436849		0.804144	0.761387	0.801572	0.994246	0.773706
2237	0.756384	0.744908	1.541767				0.744553	0.796539	0.793444	0.756525
2304	0.741007	0.746321	1.605377	1.595685			0.74831	0.744402	0.74419	0.750442
2547	0.774344	0.73998	1.689214	1.674915			0.738377		1.55068	0.743191
2900	0.754988	0.732601	1.74644	1.744638			0.748513	0.743638	0.750037	0.71889
3302	0.741522	0.775181	1.794098	1.786792			0.752781	0.657993		0.706836
3760	0.738824	0.937059	1.770286	1.771644			0.768556	0.640806		0.692699
4096	0.772565	0.940653	1.874443	1.875753						0.678458
4281	0.667657	0.228319		1.89298						0.684011
4874										0.660348
5550										0.662327
6144										0.649773
7195										0.634231
8192										0.630562

**Table 3. SNR for BLER = 0.001**

Info size	Required SNR									
	Brcm	Ericss	Fr_a	Fr_b	ITRI	Mit	Mot_A	Mot_Q	Qual	PIL-Re16
52	2.799851	2.930434	2.877588	2.872013	2.856806	2.905241	2.91253	2.871044	3.434105	2.991982
67	4.556985	2.675192	2.710612	2.680624	2.599628	2.755094	2.687932	2.732407	2.733141	2.840941
87	2.67446	2.513235	2.541251	2.538337	2.461456	2.461676	2.409616	2.48816	2.457879	2.609726
99	2.360413	2.387685	2.48005	4.295678	2.324033	2.409073	2.415562	2.455057	2.421334	2.493387
113	2.29943	2.340992	2.308492	2.326115	2.285251	2.376085	2.297379	2.308257	2.279592	2.388826
129	2.643035	2.15385	2.43836	2.250251	2.146441	2.208444	2.178591	2.243807	2.220202	2.351339
146	2.368589	2.062327	2.371515	2.110545	2.099804	2.162475	2.164281	2.100186	2.137006	2.276471

167	2.383166	2.041329	2.976849	3.01288	2.002876	2.033853	1.989323	2.054499	2.026351	2.110547
190	1.956879	1.876301	2.214996	1.911567	1.925316	1.927745	1.92028	1.923672	1.947554	2.004748
216	1.90849	1.823131	1.857587	1.839598	1.882267	1.838498	1.844445	1.761283	1.915748	1.85768
246	1.956074	1.72872	2.367669	2.350824	1.75887	1.789878	1.753544	1.718367	1.816	1.771801
280	1.693959	1.666507	1.690545	1.702907	1.739281	1.735247	1.663461	1.66275	1.786573	1.704475
319	1.604737	1.585713	2.171869	1.638617	1.609162	1.61856	1.655791	1.589898	1.694369	1.617695
363	1.764374	1.569145			1.534528	1.560641	1.526643	1.561197	1.574164	1.565454
384	1.895239	1.478932	1.89573	1.896384	1.576645	1.517904	1.504076	1.488373	1.723536	1.539696
414	1.849788	1.442772	1.609894	1.614771	1.426566	1.493668	1.439156	1.432897	1.739672	1.488007
471	1.78403	1.437678			1.399416	1.457323	1.39929	1.451165	1.732389	1.443443
536	2.979471	1.319391	1.611682	1.607372	1.33053	1.388206	1.322623	1.306504	1.54006	1.367283
611	1.316984	1.25511	1.890547	1.90525	1.269866	1.343317	1.292491	1.28777	1.318377	1.30764
695	1.267073	1.269146	1.964468	1.941063	1.216936	1.302741	1.224248	1.304335	1.789427	1.256664
792	1.872601	1.167055	1.791347	1.79683	1.288712	1.279894	1.1814	1.121757	1.155784	1.208786
902	1.119478	1.123969	1.856551	1.843417	1.113417	1.363018	1.127471	1.114509	1.935068	1.176526
1027	1.488922	1.160633	1.928396	1.941182	1.000745	1.130817	1.081749	1.208466	2.045168	1.117136
1169	1.540564	1.058712	2.203688	2.18572	1.10114	1.164774	1.05847	1.111202		1.100927
1331	1.129758	1.017765	2.16425	2.151742		1.11287	1.030846	1.028928	2.177771	1.042617
1536	0.98079	1.019421	2.160616	2.134196		1.05639	0.94992	0.984547	0.972265	1.018983
1725	1.033279	0.959641				1.018057	0.960211	0.962474	1.009755	1.002866
1965	1.027058	0.91048	2.323665	2.181273		1.02902	0.899151	1.011716	1.746383	0.935905
2237	0.95491	0.84807					0.840228	1.060486	1.047398	0.91031
2304	0.814623	1.000886					0.866465	0.88405	0.796735	0.92013
2547	1.336749	0.79216					0.700342		2.633431	0.895317
2900	1.051421	0.800621					0.717683	0.717424	0.720075	0.891071
3302	0.781402	0.584296					0.713425	1.100032		0.84196
3760	0.854587	0.376848					0.699708	0.931093		0.835358
4096	0.718811	0.517456								0.838118
4281	0.905913	1.217105								0.822762
4874										0.827149
5550										0.809425
6144										0.787833
7195										0.755429
8192										0.769295

**Table 4. SNR for BLER = 0.0001**

Info size	Required SNR									
	Brcm	Ericss	Fr_a	Fr_b	ITRI	Mit	Mot_A	Mot_Q	Qual	PIL-Rel6
52	3.345572	3.738706	3.755126	3.612983	3.506202	3.721757	3.876931	3.629856	4.292267	3.738435
67		3.281509	3.403816	3.356786	3.239307	3.497616	3.342285	3.52049	3.445887	3.557016
87	3.440799	3.141455	3.230046	3.246123	3.073927	3.122698	2.932025	3.129347	3.082408	3.301393
99	2.940679	2.97891	3.16197	5.074436	2.895274	2.981467	2.988099	3.04713	3.008292	3.159722



**Table 5. SNR for BLER = 0.00001**

**Table 6.** SNR difference for BLER = 0.1

**Table 7.** SNR difference for BLER = 0.01

**Table 8. SNR difference for BLER = 0.001**

**Table 9. SNR difference for BLER = 0.0001**

**Table 10. SNR difference for BLER = 0.00001**

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## 4 Conclusion

Based on the simulation results provided in this document, the current Rel6 interleaver consistently performs very well over a wide range of information block sizes from 40 to 8192 bits.

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## References

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## Appendix

In the following Figures, we show the performance of different interleavers and compare it to the Rel6 interleaver for all 42 different block sizes.

