400GbE AMs revised proposal

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Introduction

A set of alignment markers for 400GbE was proposed in anslow_01_1215_logic. The worst case performance of the proposed codes was analysed for 4:1 bit interleaving for 100 Gb/s lanes and found to have a large “shoulder” on the clock content for “all transitions” (page 22).

A revised proposal was analysed in anslow_01_0116_logic with adequate performance, but this proposal had issues with 10-bit symbol boundaries.

A proposal to change the bit positions of the alignment markers was made on page 7 of gustlin_01_0216_logic

This contribution analyses the performance of this further revised proposal.

Baseline wander

Previous NRZ contributions have used a “baseline wander” parameter

This was defined as:

Baseline wander is the instantaneous offset (in %) in the signal generated by AC coupling at the Baud rate / 10,000.

This analysis re-uses this definition unmodified, but it should be noted that for PAM4, the eye height is 1/3 that of NRZ so the effects of a given amount of baseline wander will be greater.

For NRZ contributions see:

P802.3ba anslow_01_0108
P802.3ba anslow_06_1108
P802.3bj anslow_01a_0112

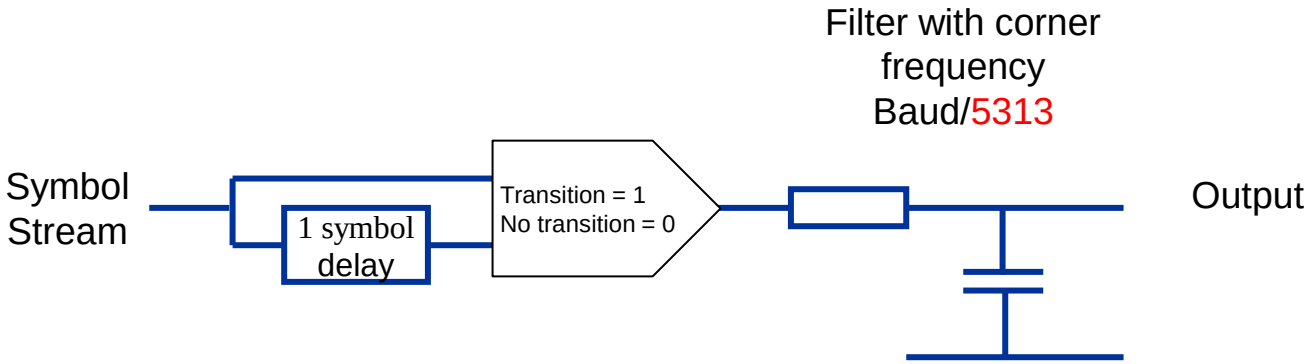
Clock content

The “clock content” parameter is defined here as:

Create a function which is a 1 for a transition and a 0 for no transition and then filter the resulting sequence with a corner frequency of Baud/5313.

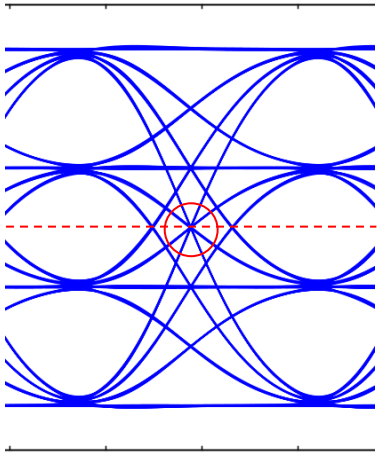
This analysis defines a transition as one of three possibilities (as per healey_3bs_01_1115):

- Symmetrical transitions through the signal average
- Transitions through the signal average
- All transitions

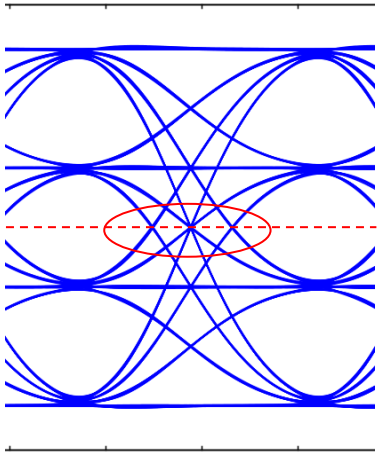


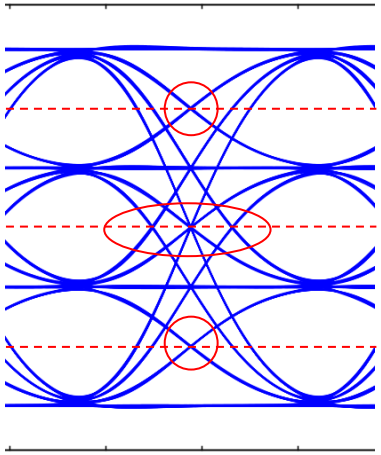
Clock content illustration

Symmetrical transitions through the signal average



Transitions through the signal average





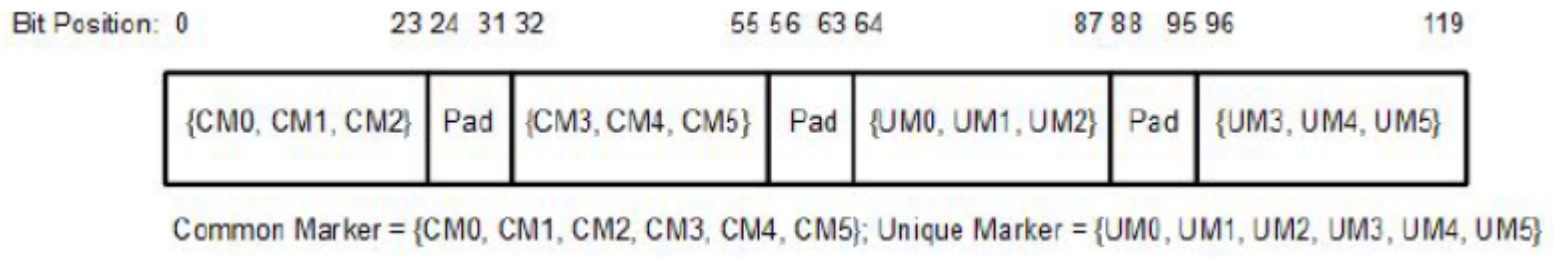
All transitions

Revised alignment markers

This contribution proposes 96-bit alignment markers with a 48-bit common part of “0x9A, 0x4A, 0x26, 0x65, 0xB5, 0xD9” followed by a 48-bit unique part.

The 48-bit unique parts of the alignment markers are composed of the first three bytes of the unique parts in anslow_01_1215_logic followed by their inverse.

The alignment markers include PRBS9 pad bits as per:



(figure courtesy A. Butter)

The proposed markers are shown on the next page and the PRBS9 bit order on the following page.

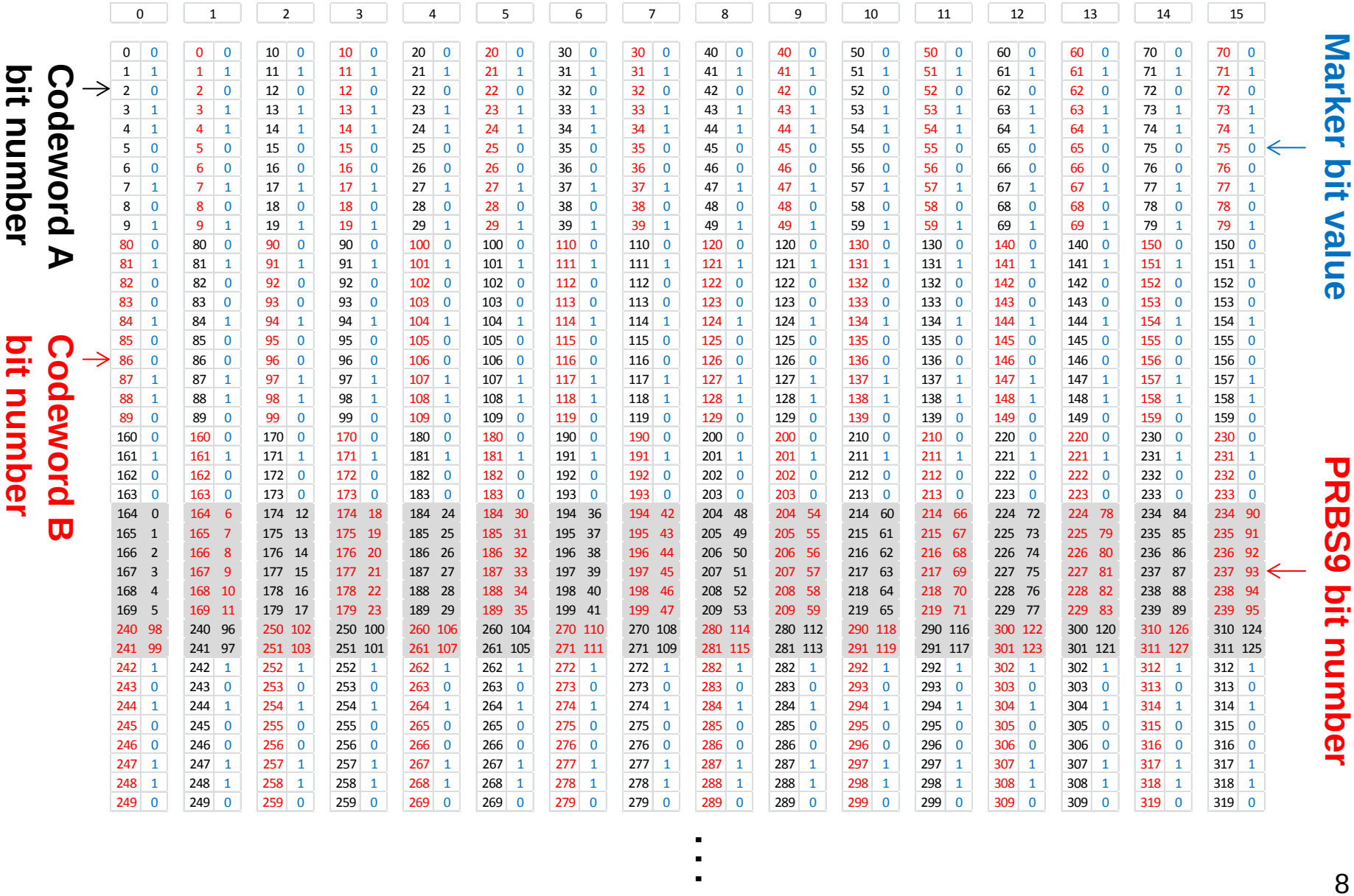
Revised alignment marker proposal

Table 119–1—400GBASE-R Alignment marker encodings

PCS lane number	Encoding[a] {CM_0, CM_1, CM_2, CM_3, CM_4, CM_5, UM_0, UM_1, UM_2, UM_3, UM_4, UM_5}
0	0x9A, 0x4A, 0x26, 0x65, 0xB5, 0xD9, 0x9E, 0xEB, 0x27, 0x61, 0x14, 0xD8
1	0x9A, 0x4A, 0x26, 0x65, 0xB5, 0xD9, 0x50, 0x74, 0x88, 0xAF, 0x8B, 0x77
2	0x9A, 0x4A, 0x26, 0x65, 0xB5, 0xD9, 0xB4, 0xB7, 0xEA, 0x4B, 0x48, 0x15
3	0x9A, 0x4A, 0x26, 0x65, 0xB5, 0xD9, 0xE4, 0xFB, 0xF1, 0x1B, 0x04, 0x0E
4	0x9A, 0x4A, 0x26, 0x65, 0xB5, 0xD9, 0xDC, 0x58, 0xEE, 0x23, 0xA7, 0x11
5	0x9A, 0x4A, 0x26, 0x65, 0xB5, 0xD9, 0xBD, 0xA9, 0xBF, 0x42, 0x56, 0x40
6	0x9A, 0x4A, 0x26, 0x65, 0xB5, 0xD9, 0x97, 0x67, 0x77, 0x68, 0x98, 0x88
7	0x9A, 0x4A, 0x26, 0x65, 0xB5, 0xD9, 0x24, 0x35, 0xA5, 0xDB, 0xCA, 0x5A
8	0x9A, 0x4A, 0x26, 0x65, 0xB5, 0xD9, 0x57, 0x64, 0x51, 0xA8, 0x9B, 0xAE
9	0x9A, 0x4A, 0x26, 0x65, 0xB5, 0xD9, 0x28, 0xF9, 0x3E, 0xD7, 0x06, 0xC1
10	0x9A, 0x4A, 0x26, 0x65, 0xB5, 0xD9, 0xCB, 0xD1, 0xAD, 0x34, 0x2E, 0x52
11	0x9A, 0x4A, 0x26, 0x65, 0xB5, 0xD9, 0x5E, 0x1E, 0x38, 0xA1, 0xE1, 0xC7
12	0x9A, 0x4A, 0x26, 0x65, 0xB5, 0xD9, 0x19, 0x98, 0xF9, 0xE6, 0x67, 0x06
13	0x9A, 0x4A, 0x26, 0x65, 0xB5, 0xD9, 0x84, 0xEC, 0x20, 0x7B, 0x13, 0xDF
14	0x9A, 0x4A, 0x26, 0x65, 0xB5, 0xD9, 0x13, 0xA4, 0xED, 0xEC, 0x5B, 0x12
15	0x9A, 0x4A, 0x26, 0x65, 0xB5, 0xD9, 0x3F, 0x8A, 0xBE, 0xC0, 0x75, 0x41

[a]Each octet is transmitted LSB to MSB.

PRBS9 bit order



0		1		2		3		4		5		6		7		8		9		10		11		12		13		14		15	
0	0	0	0	10	0	10	0	20	0	20	0	30	0	30	0	40	0	40	0	50	0	50	0	60	0	60	0	70	0	70	0
1	1	1	1	11	1	11	1	21	1	21	1	31	1	31	1	41	1	41	1	51	1	51	1	61	1	61	1	71	1	71	1
2	0	2	0	12	0	12	0	22	0	22	0	32	0	32	0	42	0	42	0	52	0	52	0	62	0	62	0	72	0	72	0
3	1	3	1	13	1	13	1	23	1	23	1	33	1	33	1	43	1	43	1	53	1	53	1	63	1	63	1	73	1	73	1
4	1	4	1	14	1	14	1	24	1	24	1	34	1	34	1	44	1	44	1	54	1	54	1	64	1	64	1	74	1	74	1
5	0	5	0	15	0	15	0	25	0	25	0	35	0	35	0	45	0	45	0	55	0	55	0	65	0	65	0	75	0	75	0
6	0	6	0	16	0	16	0	26	0	26	0	36	0	36	0	46	0	46	0	56	0	56	0	66	0	66	0	76	0	76	0
7	1	7	1	17	1	17	1	27	1	27	1	37	1	37	1	47	1	47	1	57	1	57	1	67	1	67	1	77	1	77	1
8	0	8	0	18	0	18	0	28	0	28	0	38	0	38	0	48	0	48	0	58	0	58	0	68	0	68	0	78	0	78	0
9	1	9	1	19	1	19	1	29	1	29	1	39	1	39	1	49	1	49	1	59	1	59	1	69	1	69	1	79	1	79	1
80	0	80	0	90	0	90	0	100	0	100	0	110	0	110	0	120	0	120	0	130	0	130	0	140	0	140	0	150	0	150	0
81	1	81	1	91	1	91	1	101	1	101	1	111	1	111	1	121	1	121	1	131	1	131	1	141	1	141	1	151	1	151	1
82	0	82	0	92	0	92	0	102	0	102	0	112	0	112	0	122	0	122	0	132	0	132	0	142	0	142	0	152	0	152	0
83	0	83	0	93	0	93	0	103	0	103	0	113	0	113	0	123	0	123	0	133	0	133	0	143	0	143	0	153	0	153	0
84	1	84	1	94	1	94	1	104	1	104	1	114	1	114	1	124	1	124	1	134	1	134	1	144	1	144	1	154	1	154	1
85	0	85	0	95	0	95	0	105	0	105	0	115	0	115	0	125	0	125	0	135	0	135	0	145	0	145	0	155	0	155	0
86	0	86	0	96	0	96	0	106	0	106	0	116	0	116	0	126	0	126	0	136	0	136	0	146	0	146	0	156	0	156	0
87	1	87	1	97	1	97	1	107	1	107	1	117	1	117	1	127	1	127	1	137	1	137	1	147	1	147	1	157	1	157	1
88	1	88	1	98	1	98	1	108	1	108	1	118	1	118	1	128	1	128	1	138	1	138	1	148	1	148	1	158	1	158	1
89	0	89	0	99	0	99	0	109	0	109	0	119	0	119	0	129	0	129	0	139	0	139	0	149	0	149	0	159	0	159	0
160	0	160	0	170	0	170	0	180	0	180	0	190	0	190	0	200	0	200	0	210	0	210	0	220	0	220	0	230	0	230	0
161	1	161	1	171	1	171	1	181	1	181	1	191	1	191	1	201	1	201	1	211	1	211	1	221	1	221	1	231	1	231	1
162	0	162	0	172	0	172	0	182	0	182	0	192	0	192	0	202	0	202	0	212	0	212	0	222	0	222	0	232	0	232	0
163	0	163	0	173	0	173	0	183	0	183	0	193	0	193	0	203	0	203	0	213	0	213	0	223	0	223	0	233	0	233	0
164	0	164	6	174	12	174	18	184	24	184	30	194	36	194	42	204	48	204	54	214	60	214	66	224	72	224	78	234	84	234	90
165	1	165	7	175	13	175	19	185	25	185	31	195	37	195	43	205	49	205	55	215	61	215	67	225	73	225	79	235	85	235	91
166	2	166	8	176	14	176	20	186	26	186	32	196	38	196	44	206	50	206	56	216	62	216	68	226	74	226	80	236	86	236	92
167	3	167	9	177	15	177	21	187	27	187	33	197	39	197	45	207	51	207	57	217	63	217	69	227	75	227	81	237	87	237	93
168	4	168	10	178	16	178	22	188	28	188	34	198	40	198	46	208	52	208	58	218	64	218	70	228	76	228	82	238	88	238	94
169	5	169	11	179	17	179	23	189	29	189	35	199	41	199	47	209	53	209	59	219	65	219	71	229	77	229	83	239	89	239	95
240	98	240	96	250	102	250	100	260	106	260	104	270	110	270	108	280	114	280	112	290	118	290	116	300	122	300	120	310	126	310	124
241	99	241	97	251	103	251	101	261	107	261	105	271	111	271	109	281	115	281	113	291	119	291	117	301	123	301	121	311	127	311	125
242	1	242	1	252	1	252	1	262	1	262	1	272	1	272	1	282	1	282	1	292	1	292	1	302	1	302	1	312	1	312	1
243	0	243	0	253	0	253	0	263	0	263	0	273	0	273	0	283	0	283	0	293	0	293	0	303	0	303	0	313	0	313	0
244	1	244	1	254	1	254	1	264	1	264	1	274	1	274	1	284	1	284	1	294	1	294	1	304	1	304	1	314	1	314	1
245	0	245	0	255	0	255	0	265	0	265	0	275	0	275	0	285	0	285	0	295	0	295	0	305	0	305	0	315	0	315	0
246	0	246	0	256	0	256	0	266	0	266	0	276	0	276	0	286	0	286	0	296	0	296	0	306	0	306	0	316	0	316	0
247	1	247	1	257	1	257	1	267	1	267	1	277	1	277	1	287	1	287	1	297	1	297	1	307	1	307	1	317	1	317	1
248	1	248	1	258	1	258	1	268	1	268	1	278	1	278	1	288	1	288	1	298	1	298	1	308	1	308	1	318	1	318	1
249	0	249	0	259	0	259	0	269	0	269	0	279	0	279	0	289	0	289	0	299	0	299	0	309	0	309	0	319	0	319	0

Simulations

Using these alignment codes, all possible combinations of PCS lanes for 4:1 bit interleaving for 100 Gb/s lanes were then analysed to find the worst cases for Baseline Wander (BW) and Clock Content (CC) after Gray coding to PAM4 symbols. These searches included lane delays of -20 to +20 as per the previous analysis for the 4:1 case.

The worst case PCS lane combinations and delays were then used to generate the worst case PDFs for 400 GbE scrambled idle 100 Gb/s lanes.

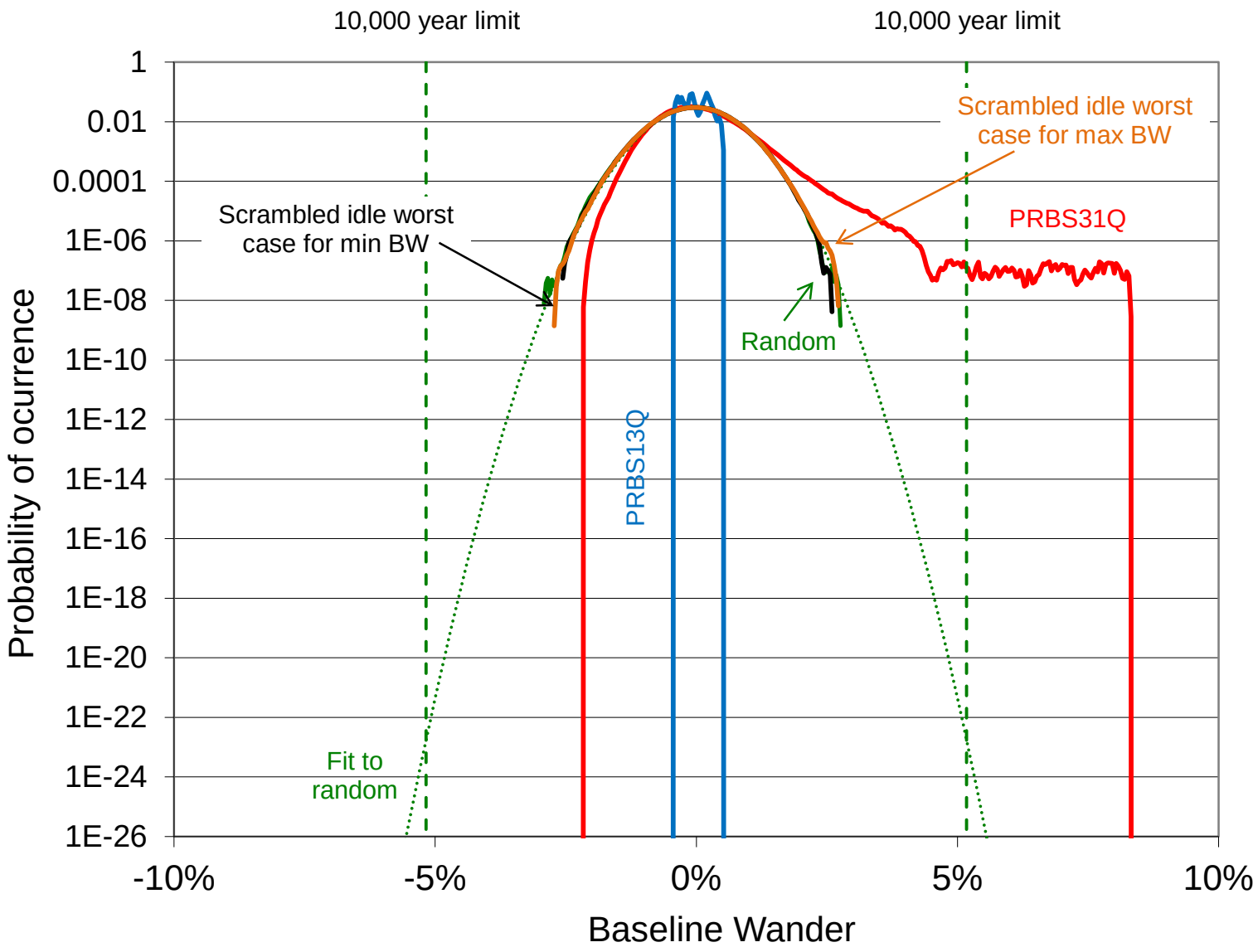
Scrambled idle construction

The scrambled idle symbol streams generated for this analysis were:

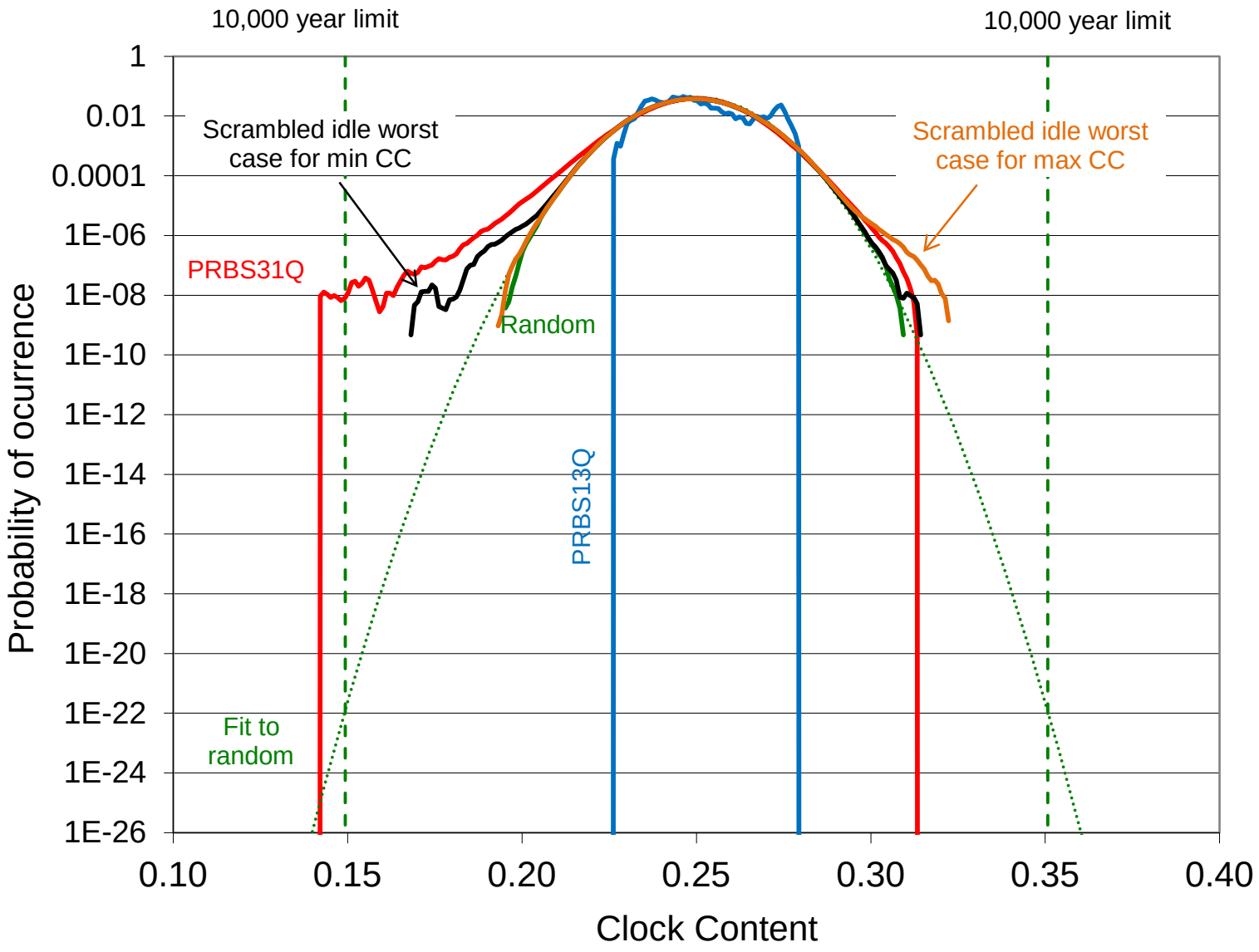
- Idle control characters
- 256B/257B transcoded
- Scrambled
- Distributed 10 bits at a time to two FEC codewords which start with alignment markers PRBS9 one in every 8192 code words
- 300 bits of RS(544,514) FEC parity added
- Interleaved 10 bits at a time to form PCS lanes (option 8a)
- Bit interleaved with worst case PCS lane combinations and delays

The results for baseline wander and clock content are in the following slides.

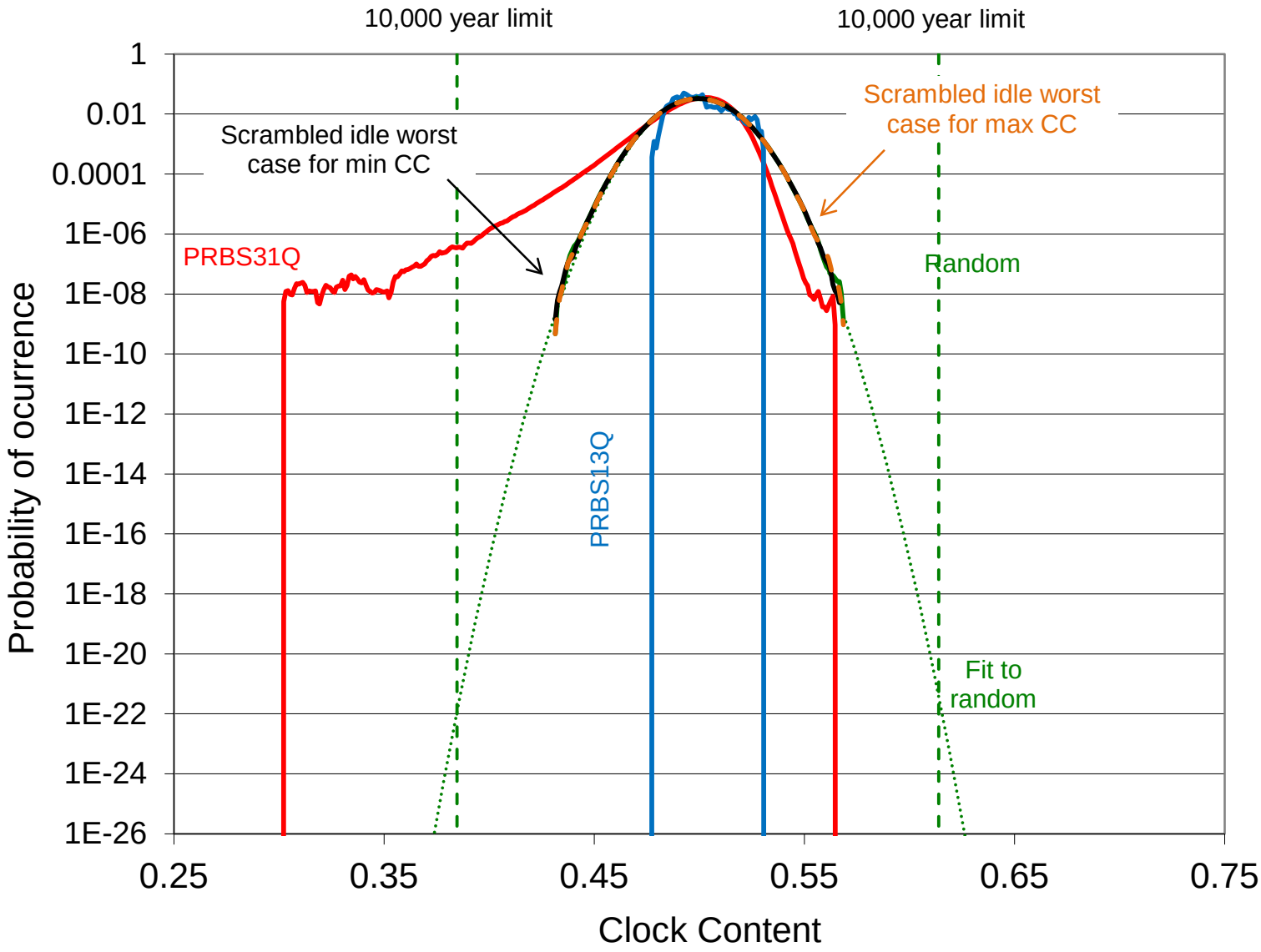
Baseline wander, 100G lanes



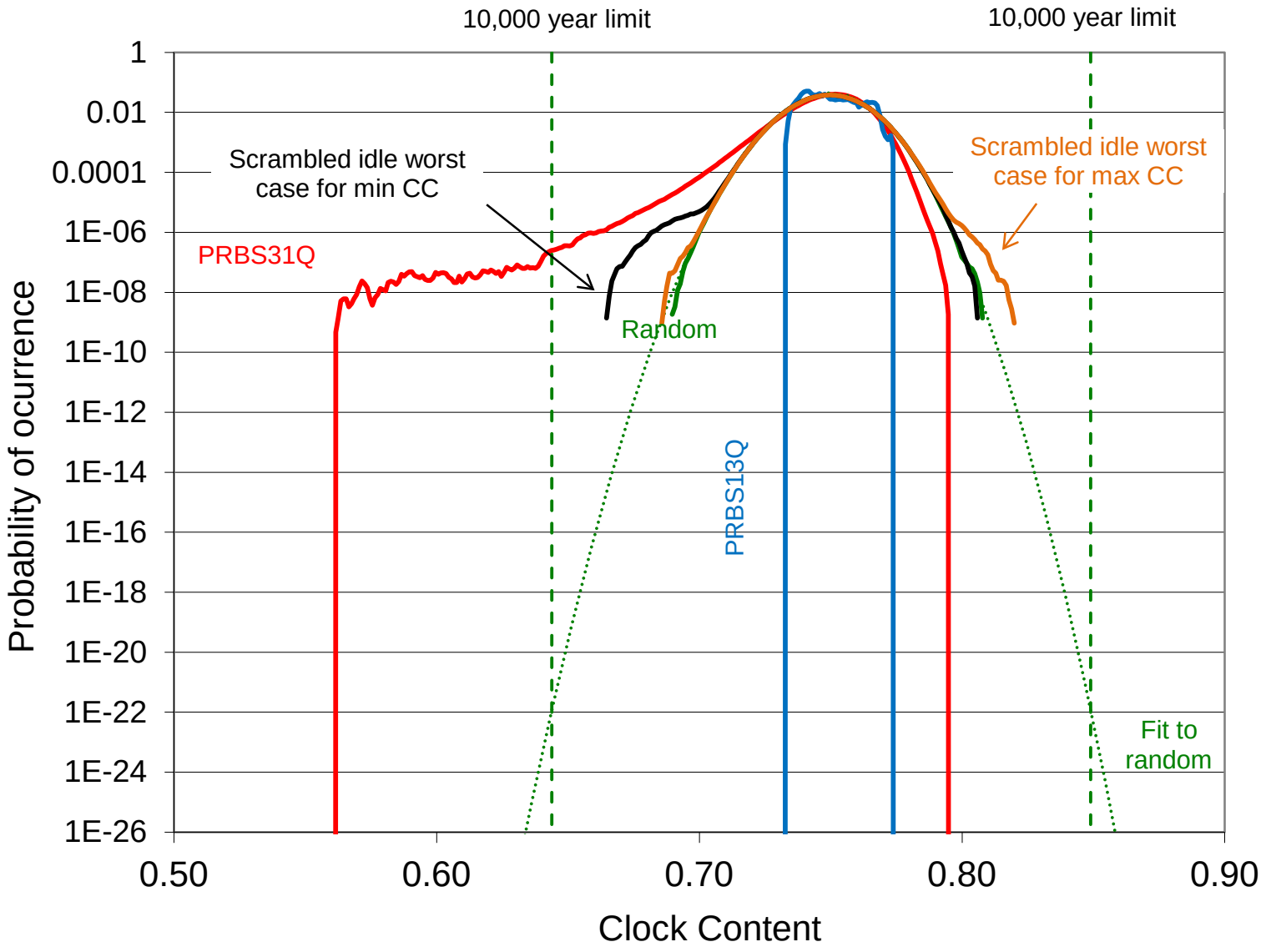
Clock, sym trans through ave, 100G lanes



Clock, trans through ave, 100G lanes



Clock, all transitions, 100G lanes



Conclusion

The baseline wander and clock content for the revised alignment marker proposal still show a “shoulder”, but they remain within the baseline wander and clock content for the PRBS31Q test pattern.

It is therefore proposed to use this alignment marker scheme for 400 Gb/s Ethernet.

Backup

Worst case lane combinations revised proposal

4:1 bit interleaving for 100 Gb/s lanes

	First lane	Second lane	Third lane	Fourth lane	First lane delay	Second lane delay	Third lane delay	Fourth lane delay
wander_max	5	15	8	6	0	0	20	20
wander_min	5	13	6	0	0	-1	20	-12
clock25_max	5	6	13	0	0	2	-2	1
clock25_min	0	13	5	15	0	0	0	0
clock50_max	1	0	3	2	0	-1	-6	12
clock50_min	5	0	15	1	0	15	0	17
clock75_max	1	4	15	10	0	-1	-2	0
clock75_min	0	12	6	11	0	0	0	0

Thanks!